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Navigating through this document:

- Clicking in the table of contents takes you to the relevant page / section
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Printing the document: Note: **This is a 356-page document. Insertion of acknowledgments, correct positioning of blank pages (for right-facing pages) as appropriate, final copy-editing, and formatting will be done for the final version, along with links to Appendixes B and C.**

UASSC 20-001, Working Draft dated 4/1/20

Standardization Roadmap for Unmanned Aircraft Systems

Version 2.0

By the

ANSI Unmanned Aircraft Systems Standardization Collaborative (UASSC)

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Acknowledgments

Note: This section will be filled in during June 2020

Sincere thanks are extended to all of the individuals and organizations listed below for providing technical input and/or other support associated with the development of this roadmap. It is because of their involvement and contributions over the last year and a half that this document has been made possible.

The roadmap is based on a consensus of those who actively participated in its development and does not necessarily reflect the views of the individuals or organizations listed below. The employment status and organizational affiliation of participants may have changed during the course of this project.

Organization	Name of Individual(s)

[1] UASSC Co-Chair

[2] UASSC Working Group Co-Chair

[3] UASSC Steering Committee Member

[4] Contributing Author / Editor - Special Recognition

[5] Public Review Comment Submitter

Parentheses following a name signify participation also on behalf of another organization.

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Executive Summary

In September 2017, the American National Standards Institute (ANSI) launched the Unmanned Aircraft Systems Standardization Collaborative (UASSC). The UASSC was established to coordinate and accelerate the development of the standards and conformity assessment programs needed to facilitate the safe integration of unmanned aircraft systems (UAS) into the national airspace system (NAS) of the United States, with international coordination and adaptability. The UASSC was not chartered to write standards.

Founded in 1918, ANSI serves as the administrator and coordinator of the United States private-sector voluntary standardization system. As a neutral facilitator, the Institute has a successful track record of convening stakeholders from the public and private sectors to define standardization needs for emerging technologies and to address national and global priorities, in areas as diverse as homeland security, electric vehicles, energy efficiency in the built environment, and additive manufacturing.

The purpose of the UASSC is to foster coordination and collaboration among industry, standards developing organizations (SDOs), regulatory authorities, and others on UAS standardization issues, including pre-standardization research and development (R&D). A primary goal is to clarify the current and desired future UAS standardization landscape to enable stakeholders to better focus standards participation resources. A third objective is to provide a basis for coherent and coordinated U.S. policy and technical input to regional and international audiences on UAS standardization. Ultimately, the aim is to support the growth of the UAS market with emphasis on civil, commercial, and public safety applications.

This *Standardization Roadmap for Unmanned Aircraft Systems, Version 2.0* ("roadmap") is an update to version 1.0 of this document published in December 2018. It identifies existing standards and standards in development, assesses gaps, and makes recommendations for priority areas where there is a perceived need for additional standardization and/or pre-standardization R&D.

The roadmap has examined **78** issue areas, identified a total of **71** open gaps and corresponding recommendations across the topical areas of airworthiness; flight operations (both general concerns and application-specific ones including critical infrastructure inspections, commercial services, and public safety operations); and personnel training, qualifications, and certification. Of that total, **48** gaps/recommendations have been identified as high priority, **20** as medium priority, and **3** as low priority. A "gap" means no *published* standard or specification exists that covers the particular issue in question. In **45** cases, additional R&D is needed.

As with the earlier version of this document, the hope is that the roadmap will be broadly adopted by the standards community and that it will facilitate a more coherent and coordinated approach to the future development of standards for UAS. To that end, it is envisioned that the roadmap will continue to be promoted in the coming year. It is also envisioned that a mechanism may be established to assess progress on its implementation.

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Summary of Major Changes from Version 1.0

High-Level Structural and Content Changes

- Updates were made to all sub-sections of the Introduction
- Generally speaking, updates were made to the overviews in Chapters 2 through 5
- This Summary of Major Changes from Version 1.0 was added along with a Breakdown of the High, Medium, and Low Priority Gaps

Renamed/Repositioned Roadmap Chapters/Sections/Subsections ***(18)***

- Section 4.7, European Organization for Civil Aviation Equipment (previously 5.6)
- Section 6.2, UAS System Safety
- Section 6.4.1, Command and Control (C2) Link and Communications
- Section 6.4.3, Systems Performing Detect and Avoid (DAA) Functions
- Section 6.4.4, Software Considerations and Approval
- Section 6.4.5, Voice and Data Recorder Systems for UAS
- Section 7.8, UAS Remoted Identification (UAS Remote ID)
- Chapter 8, Flight Operations Standards: Infrastructure Inspections, Environmental Applications, Commercial Services, Workplace Safety – WG3
- Section 8.1.1, Power Plants and Industrial Process Plants
- Section 8.2.3, Power Transmission Lines, Structures, and Environs
- Section 8.3, Environmental Applications
- Section 8.4, Commercial Services
- Section 8.4.1, Commercial Package Delivery via UAS (previously 8.4)
- Section 8.5, Workplace Safety
- Section 9.6.1, sUAS IR Camera Sensor Capabilities
- Section 9.6.2, sUAS Automated Missions during Emergency Response
- Section 9.8, Public Safety Tactical Operations
- Section 9.9, Counter-UAS (C-UAS): Detection and Mitigation

Substantially Revised Roadmap Sections/Subsections ***(20)***

- Section 6.4.1, Command and Control (C2) Link and Communications
- Section 6.4.2, Navigation Systems
- Section 6.4.3, Systems Performing Detect and Avoid (DAA) Functions
- Section 6.4.4, Software Considerations and Approval
- Section 6.4.5, Voice and Data Recorder Systems for UAS
- Section 6.8, Mitigation Systems for Various Hazards to UAS
- Section 7.1, Privacy
- Section 7.3, Beyond Visual Line of Sight (BVLOS)
- Section 7.7, UAS Traffic Management (UTM)

- Section 7.8, UAS Remoted Identification (UAS Remote ID)
- Section 8.1.1, Power Plants and Industrial Process Plants
- Section 8.2.1, Bridges
- Section 8.2.2, Railroads
- Section 8.3.2, Pesticide Application
- Section 8.4.1, Commercial Package Delivery via UAS
- Section 8.5, Workplace Safety
- Section 9.1, sUAS for Public Safety Operations
- Section 9.6.2, sUAS Automated Missions during Emergency Response
- Section 9.8, Public Safety Tactical Operations
- Section 9.9, Counter-UAS (C-UAS): Detection and Mitigation

New Roadmap Sections/Subsections ***(23)***

- Section 2.4.1, International Civil Aviation Organization (ICAO)
- Section 2.4.2, Joint Authorities for Rulemaking on Unmanned Systems (JARUS)
- Section 4.10, NACE International (NACE)
- Section 5.1, Academy of Model Aeronautics (AMA)
- Section 5.2, Aerospace Industries Association (AIA)
- Section 5.6, Aviators Code Initiative (ACI)
- Section 5.7, AW-Drones
- Section 5.10, General Aviation Manufacturers Association (GAMA)
- Section 5.12, Helicopter Association International (HAI)
- Section 5.18, Vertical Flight Society (VFS)
- Section 7.10, Recreational Operations
- Section 7.11, Vertiports
- Section 8.2.4, Implementing UAS for Hydrocarbon Pipeline Inspections
- Section 8.2.5, Implementing UAS in Airport Operations
- Section 8.4.2, Commercial Cargo Transport via UAS
- Section 8.4.3, Urban Air Mobility (UAM, short-haul flights carrying few passengers)
- Section 8.4.4, Commercial Passenger Transport via UAS (long-haul flights carrying many passengers)
- Section 8.4.5, Commercial Sensing Services
- Section 8.4.6, Use of sUAS for News Gathering
- Section 9.9.1: Counter-UAS (C-UAS): Detection
- Section 9.9.2: Counter-UAS (C-UAS): Mitigation
- Section 9.10, UAS for Emergency Management and Disasters
- Section 9.11, Standardization of Data Formatting for sUAS Public Safety Operations

Gap Analysis Changes

- **60** gaps were identified in roadmap version 1.0. Using a traffic light analogy, the status of progress on these is:

    - **41** are Green (moving forward)
    - **4** are Yellow (delayed)
    - **0** are Red (at a standstill)
    - **4** are Not Started
    - **7** are Unknown
    - **3** are Closed
    - **1** has been Withdrawn
- **16** version 1.0 gaps have been substantially revised in roadmap version 2.0
- **15** new gaps are identified in roadmap version 2.0
- **71** gaps are open. Of these:
    - **48** are High priority (should be addressed in 0-2 years)
    - **20** are Medium priority (should be addressed in 2-5 years)
    - **3** are Low priority (should be addressed in 5+ years)
- **45** open gaps require research and development

*Closed Gaps **(3)***

- Gap S1: Use of sUAS for Public Safety Operations (High priority, Tier 2)
- Gap P1: Terminology (High priority, Tier 3)
- Gap P6: Compliance and Audit Programs (High priority, Tier 3)

*Withdrawn Gaps **(1)***

- Gap A5: Command and Control (C2)/Command, Control and Communications (C3) Link Performance Requirements

*Substantially Revised Gaps **(16)***

- Gap A2: UAS System Safety
- Gap A6: Alignment in Standards Between Aviation and Cellular Communities
- Gap A7: UAS Navigation Systems
- Gap A11: Voice and Data Recorder Systems for UAS
- Gap A16: Mitigation Systems for Various Hazards to UAS
- Gap O1: Privacy
- Gap O3: Beyond Visual Line of Sight (BVLOS)
- Gap O7: UTM Services Performance Standards
- Gap I1: UAS Inspections of Power Plant and Industrial Process Plant Assets
- Gap I5: Bridge Inspections
- Gap I6: Railroad Inspections: Rolling Stock Inspection for Transport of Hazardous Materials (HAZMAT)
- Gap I7: Railroad Inspections: BVLOS Operations
- Gap I9: Inspection of Power Transmission Lines, Structures, and Environs Using UAS
- Gap I11: Commercial Package Delivery via UAS

- Gap I12: Occupational Safety Requirements for UAS Operated in Workplaces
- Gap S7: Need for Command and Control Software Specifications for Automated Missions during Emergency Response

New Gaps ***(15)***

- New Gap A20: Unlicensed Spectrum Interference Predictability
- New Gap A21: Unlicensed Spectrum Security
- New Gap O12: Design and Operation of Vertiports
- New Gap I13: Inspection of Pipelines and Operating Facilities - BVLOS Operations
- New Gap I14: Inspection of Pipelines and Operating Facilities – Sensor Validation & Use
- New Gap I15: UAS in Airport Operations
- New Gap I16: Commercial Cargo Transport via UAS
- New Gap I17: Urban Air Mobility (UAM, short-haul flights carrying few passengers and/or cargo)
- New Gap I18: Commercial Passenger Transport via UAS (long-haul flights carrying many passengers)
- New Gap I19: Commercial Sensing Services
- New Gap I20: Use of sUAS for Newsgathering
- New Gap S10: Use of Tethered UAS for Public Safety Operations
- New Gap S11: Counter-UAS (C-UAS) Operations: Detection
- New Gap S12: Integration of UAS into FEMA ICS Operations Section, Air Operations Branch
- New Gap S13: Data Format for Public Safety sUAS Operations

Breakdown of the High, Medium, and Low Priority Gaps

In roadmap version 1, 40 of the 60 gaps identified were ranked high priority.[1] Following publication of version 1, and with a view toward further refinement of the priorities, a survey was taken of the UASSC Steering Committee to rank the 40 high priority gaps as either: Tier 1 (most critical), Tier 2 (critical), or Tier 3 (least critical). In this version 2, some gaps from version 1 have been modified and some new gaps have been introduced, including some high priority gaps where the Tier has yet to be determined (TBD). Following further working group delibrations, the Steering Committee will be asked to review this list prior to publication of version 2.

Note: The order in which the gaps are listed below within each priority level and tier is simply the order in which the gaps appear in sequence in roadmap chapters 6 through 10. It does not represent a hierarchy within each priority level and tier.

High Priority Gaps (51)

High (Tier 1) (Most Critical) (15)

- Gap A1: UAS Design and Construction (D&C) Standards
- Gap A2: UAS System Safety
- Gap A7: UAS Navigational Systems
- Gap A8: Protection from Global Navigation Satellite Signals (GNSS) Interference Including Spoofing and Jamming
- Gap A9: Detect and Avoid (DAA) Capabilities
- Gap A10: Software Considerations and Approval
- Gap A12: UAS Cybersecurity
- Gap O2: Operational Risk Assessment and Risk Mitigation
- Gap O3: Beyond Visual Line of Sight (BVLOS)
- Gap O4: UAS Operations Over People (OOP)
- Gap O8: Remote ID and Tracking: Direct Broadcast
- Gap O9: Remote ID and Tracking: Network Publishing
- New Gap S11: Counter-UAS (C-UAS) Operations: Detection
- Gap S9: Counter-UAS (C-UAS) Operations: Mitigation.
- Gap P8: Flight Control Automation and System Failures

High (Tier 2) (Critical) (16)

- Gap A4: Avionics and Subsystems

[1] The criteria for initial prioritization of gaps as high, medium, or low is described in section 1.3. The full text of the gaps can be found in the summary table that follows this section and in chapters 6 through 10.

- Gap A6: Alignment in Standards Between Aviation and Cellular Communities
- Gap A16: Mitigation Systems for Various Hazards to UAS
- Gap A18: Maintenance and Inspection (M&I) of UAS
- Gap A19: Enterprise Operations: Levels of Automation/ Autonomy/ Artificial Intelligence (AI)
- Gap O5: UAS Operations and Weather
- Gap O7: UTM Services Performance Standards
- Gap O10: Geo-fence Exchange
- New Gap I20: Use of sUAS for Newsgathering
- Gap I12: Occupational Safety Requirements for UAS Operated in Workplaces
- Gap S1: Use of sUAS for Public Safety Operations
- New Gap S13: Data Format for Public Safety sUAS Operations
- Gap P2: Manuals (tie tier 2/3)
- Gap P3: Instructors and Functional Area Qualification
- Gap P5: UAS Maintenance Technicians
- Gap P9: Crew-Composition, Selection, and Training (tie tier 2/3)

High (Tier 3) (Least Critical) (13)

- Gap A13: Electrical Systems
- Gap A14: Power Sources and Propulsion Systems
- Gap A15: Noise, Emissions, and Fuel Venting
- Gap A17: Parachute or Drag Chute as a Hazard Mitigation System in UAS Operations over People (OOP)
- Gap I1: UAS Inspections of Power Plant and Industrial Process Plant Assets
- Gap I9: Inspection of Power Transmission Lines, Structures, and Environs Using UAS
- Gap I10: Pesticide Application Using UAS
- Gap I11: Commercial Package Delivery via UAS
- Gap S3: Transport and Post-Crash Procedures Involving Biohazards
- Gap S5: Payload Interface and Control for Public Safety Operations
- Gap P1: Terminology
- Gap P6: Compliance and Audit Programs
- Gap P7: Displays and Controls

High (Tier TBD) (7)

- New Gap A20: Unlicensed Spectrum Interference Predictability
- New Gap O12: Design and Operation of Vertiports
- Gap I7: Railroad Inspections: BVLOS Operations
- New Gap I16: Commercial Cargo Transport via UAS
- New Gap I17: Urban Air Mobility (UAM, short-haul flights carrying few passengers and/or cargo)
- New Gap I18: Commercial Passenger Transport via UAS (long-haul flights carrying many passengers)

- New Gap I19: Commercial Sensing Services

Medium Priority Gaps (20)

- Gap A3: Quality Assurance/Quality Control of UAS
- New Gap A21: Unlicensed Spectrum Security
- Gap A11: Voice and Data Recorder Systems for UAS
- Gap O1: Privacy
- Gap O6: UAS Data Handling and Processing
- Gap O11: Geo-fence Provisioning and Handling
- Gap I2: Crane Inspections
- Gap I3: Inspection of Building Facades using Drones
- Gap I4: Low-Rise Residential and Commercial Building Inspections Using UAS
- Gap I5: Bridge Inspections
- New Gap I13: Inspection of Pipelines and Operating Facilities - BVLOS Operations
- New Gap I14: Inspection of Pipelines and Operating Facilities – Sensor Validation & Use
- New Gap I15: UAS in Airport Operations
- Gap S2: Hazardous Materials Response and Transport Using a UAS
- Gap S4: Forensic Investigations Photogrammetry
- Gap S6: sUAS Forward-Looking Infrared (IR) Camera Sensor Capabilities
- Gap S8: UAS Response Robots
- New Gap S10: Use of Tethered UAS for Public Safety Operations
- New Gap S12: Integration of UAS into FEMA ICS Operations Section, Air Operations Branch
- Gap P4: Training and Certification of UAS Flight Crew Members Other Than the Remote Pilot

Low Priority Gaps (3)

- Gap I6: Railroad Inspections: Rolling Stock Inspection for Transport of Hazardous Materials (HAZMAT)
- Gap I8: Railroad Inspections: Nighttime Operations
- Gap S7: Need for Command and Control Software Specifications for Automated Missions during Emergency Response

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Summary Table of Gaps and Recommendations

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			Chapter 6. Airworthiness Standards – WG1					
1.	6.1	Design and Construction	**Gap A1: UAS Design and Construction (D&C) Standards**. There are numerous standards applicable to the D&C of manned aircraft which are scalable in application to UASCS. However, these standards fail to address the critical and novel aspects essential to the safety of unmanned operations (i.e., DAA, software, BVLOS, C2, CS, Highly Integrated System, etc.). Lacking any regulatory certifications/publications/guidance (type certificate (TC)/ supplemental type certificate (STC)/Technical Standard Order (TSO)/AC), manufacturers and/or operators require applicable industry standards capable of establishing an acceptable baseline of D&C for these safety-critical fight operation elements such as CS to support current regulatory flight operations and those authorized by waiver and or grants of exemption. Since the CS is one of the most critical parts and functions of the UAS needed to command and control UA remotely, the standards applicable to traditional manned aviation's airborne electronics (software, hardware, integration, spectrum, etc.) may need to be considered for the UAS as well either in the same manner and level or higher than that of the manned aviation aircraft to provide the acceptable level of safety. Some industry standards such as RTCA DO-278 may be applicable to the software aspects of the CS. However, there are currently no known industry standards that support the D&C of UAS CS, other than ASTM F3002-14a for sUAS under Part 107.	No	1) Complete work on in-development standards. 2) Develop D&C standards for UA and CS, and consider operations beyond the scope of regular Part 107 operations such as flight altitudes over 400 feet AGL, and any future technological needs. 3) Develop D&C standards for UA weighing more than 19,000 pounds and develop standards for accompanying CS. **Update**: The gap has been updated to include a specific call for standards for UA weighing more than 19,000 pounds and for control stations.	High (Tier 1)	ASTM, SAE, ISO, EUROCAE, others?	Green
2.	6.2	UAS System Safety	**Gap A2: UAS System Safety**. Numerous UAS airworthiness standards, appropriate regulations, operational risk assessment (ORA) methodologies, and system safety processes already exist. Any gaps that exist in standards applicable to specific vehicle classes and weight are being addressed. While the applicant or regulator will ultimately determine which standard is used, a potential gap is the lack of an aerospace information report ("meta-standard") in which the various existing airworthiness and safety analyses	Maybe or No	Develop an aerospace information report or standard(s) in which the various existing airworthiness and safety analyses methods are mapped to the sizes and types of UAS to which they are most relevant, and the UAS system safety and development assurance are addressed. **Update**: As noted in the text of the gap statement.	High (Tier 1)	SAE, RTCA, IEEE, American Institute of Aeronautics and Astronautics (AIAA), ASTM, DOD, NASA, FAA	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			methods are mapped to the sizes and types of UAS (remotely controlled, optionally piloted, autonomous) to which they are most relevant. Such a report should address design, production, and operational approval safety aspects. Recently SAE's technical committees SAE S-18, AS-4, G-32, G-34 and EUROCAE WG-105 and WG-114 have initiated liaison activities between these technical committees to address UAS system safety and development assurances. SAE S-18 started a new standard "SAE AIR7121, Applicability of existing development assurance and system safety practices to unmanned aircraft systems" on 10/10/2019 to describe how to apply ARP4754 and ARP4761 to UAS system safety and development assurance.					
3.	6.3	Quality Assurance / Quality Control	**Gap A3: Quality Assurance/Quality Control of UAS.** Although there are numerous published QA/QC standards applicable to aviation/aerospace systems (primarily manned), there is only one known published QA/QC standard that is specific to UAS and it covers sUAS: ASTM F3003-14, Standard Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS). A QA/QC standard in development for manufacturers of aircraft systems is ASTM WK51467, New Specification for Quality Assurance for Manufacturers of Aircraft Systems but it is not UAS-specific. There appears to be a need for a QA/QC standard applicable to UAS over 55 pounds.	No	Develop a QA/QC standard applicable to UAS over 55 pounds, taking into account relevant general aviation standards. **Update**: The ASTM F38 Executive Committee gap analysis indicated that this is a low priority, that a near term action would be to revise ASTM F3003-14 Standard Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS), while a long-term action would be to create a new standard.	Medium	ASTM, ISO, SAE, FAA, DOD	Not Started
4.	6.4	Avionics and Subsystems	**Gap A4: Avionics and Subsystems**. Existing avionics standards are proven and suitable for UAS. However, they become unacceptable for the following scenarios: 1) As the size of UAS scales down, airborne equipment designed to existing avionics standards are too heavy, large, and/or power hungry. Therefore, new standards may be necessary to achieve an acceptable level of performance for smaller, lighter, more efficient, more economical systems. For example, it is unclear how to apply some of the major avionics subsystems such as TCAS II, automatic dependent surveillance-broadcast (ADS-B) (IN and OUT). This has implications on existing NAS infrastructures (Air Traffic Radar, SATCOM, etc.), ACAS, etc.	Yes	1) One approach is to recommend that existing standards be revised to include provisions that address the points listed above. The UAS community should get involved on the committees that write the existing avionics standards. Collaboration around a common technological subject is more beneficial than segregating the workforce by manned vs. unmanned occupancy. The standards should address any differing (manned/unmanned) requirements that may occur. 2) Another approach is to recommend new standards that will enable entirely new capabilities. 3) Complete work on the standards of ICAO, ASTM, SAE, and DOD listed above in the "In-Development Standards" section. 4) Review existing and in-development avionics standards for UAS considerations.	High (Tier 2)	For Avionics Issues: RTCA, SAE, SAE-ITC ARINC, IEEE, AIAA, ASTM, DOD, NASA, FAA, ICAO. For Spectrum Issues: FAA, FCC, NTIA, International Telecommunication Union (ITU)	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			2) As the quantity of UAS scales up based on the high demand of UAS operations into the NAS, the new standards are required to handle the traffic congestion. 3) Many UAS introduce new capabilities – new capabilities may not be mature (not statistically proven or widely used) and/or they may be proprietary, therefore industry standards do not exist yet. Avionics are becoming highly integrated with more automation compared to traditional avionics instruments and equipment that were found in manned aviation aircraft a few decades ago. UAS will decreasingly rely on human confirmations, human commands, human monitoring, human control settings, and human control inputs. A time is approaching when the UAS conveys the bare minimum information about its critical systems and mission to the human, that is, a message that conveys, "Everything is OK." Standards to get there are different from those that created the cockpits in use today. Some of the major areas of concern include the reliability and cybersecurity of the command and control (C2) data link, use of DOD spectrum (and non-aviation) on civil aircraft operations, and enterprise architecture to enable UTM, swarm operations, autonomous flights, etc. Cybersecurity, in particular, shall be an important consideration in the development of avionics systems. Cybersecurity is further discussed in section 6.4.6.		5) Create a framework for UAS avionics spanning both airborne and terrestrial based systems. **Update**: SAE AS-4JAUS published AS8024, JAUS Autonomous Capabilities Service Set in June 2019. A new standard in development in SAE G-34 is SAE AS6983, Process Standard for Qualification of Aeronautical Systems Implementing AI: Development Standard. ASTM F3298-19, Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS), was also published.			
5.	6.4.1	Avionics and Subsystems: Command and Control (C2) Link and Communications	**Gap A6: Alignment in Standards Between Aviation and Cellular Communities**. A gap exists in alignment between the aviation and cellular SDO communities, even when sufficient SDO efforts exist within each community. The telecommunications industry has already taken a number of steps to develop standards, particularly in 3GPP, to prepare networks for UAV applications. However, it is expected that fully addressing all KPIs of the C2 link will require further standardization activities.	Yes. The FAA also has worked with CTIA to develop testing principles for use of the commercial wireless networks to support UAS and is considering the outcome of those tests in conjunction with the IPPs and other testing.	Collaboration between the UAS industry and communications industry is required to ensure feasibility of implementation. The aviation and cellular communities should coordinate more closely to achieve greater alignment in architecture and standards between the two communities. Specifically, advance existing work in 3GPP and ensure C2 requirements are communicated to that group. In addition, architectures and standards could be developed for predicting or guaranteeing C2 link performance for a specific flight that is about to be undertaken. **Update**: As noted in the text, standards are in development.	High (Tier 2)	3GPP, GSMA/GUTMA ACJA, ASRI	Green
6.	6.4.1	Avionics and Subsystems:	**New Gap A20: Unlicensed Spectrum Interference Predictability**. Performance in	Yes	Additional R&D could include statistical characterization of congestion in various	High, especiall	FAA is investigating	N/A

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
		Command and Control (C2) Link and Communications	the unlicensed spectrum bands is inherently unpredictable to some extent. There are approaches to enhance modeling and prediction, but there has been little work towards doing so.		environments (urban, rural, etc.), and study of interference caused by aerial radios.	y in evaluating Remote ID broadcast range (Tier TBD)	university research through the ASSURE program to quantify Remote ID broadcast range. This work could be extended to C2 link issues as well.	
7.	6.4.1	Avionics and Subsystems: Command and Control (C2) Link and Communications	**New Gap A21: Unlicensed Spectrum Security**. The protocols used in unlicensed band are typically not highly secure, and may be susceptible to intrusion from another transmitter.	Yes	Further work could be done to increase the robustness of security for unlicensed systems	Medium	FAA is already actively working on this in the context of Remote ID. This foundation could be extended to C2 link as well.	N/A
8.	6.4.2	Avionics and Subsystems: Navigation Systems	**Gap A7: UAS Navigation Systems**. There are a lack of standards specifically for UAS navigation. There are a lack of navigation standards in novel environments where aircraft typically do not operate such as in “urban canyons.” Challenging environments may invoke capabilities such as vision-based navigation. Otherwise, UAS could use existing ground infrastructure such as very high frequency (VHF) omni-directional range (VOR), non-directional beacons (NDB), instrument landing systems (ILS), and satellite infrastructure (GPS), which has vast coverage, and make use of the new enhanced, long-range navigation (eLORAN) standards in development. UAS navigation can leverage many of the same standards used for manned aircraft, but at a smaller scale and lower altitudes. UAS stakeholders should evaluate their PNT performance requirements (precision, accuracy, timing, robustness, etc.) for their flight profiles. SAE6857 can be used as a point of reference.	Yes. A specific R&D effort geared towards applying tracking innovations in satellite navigation for UAS is needed. Additional R&D effort is needed to further mature, test, and validate vision-based navigation systems.	Depending on the operating environments, apply existing navigation standards for manned aviation to UAS navigation and/or develop UAS navigation standards for smaller scale operations and at lower altitudes. Refer to R&D needed. Furthermore, existing navigation practices used by connected/automated vehicle technology should be leveraged to develop integrated feature-based/object-oriented navigation standards to orient the UAS platform in GNSS-deficient areas. **Update**: The text and list of non-UAS specific published and in-development standards has been substantially modified from roadmap version 1. A number of non-UAS specific, but potentially relevant manned aviation standards are in-development, as noted in the text.	High (Tier 1)	SAE, FAA, NASA, DOT	Green
9.	6.4.2	Avionics and Subsystems: Navigation Systems	**Gap A8: Protection from Global Navigation Satellite Signals (GNSS) Interference Including Spoofing and Jamming**. There are standards in place for spoofing and jamming mitigation for manned aircraft. However, these standards are currently being updated to reflect	Yes. An evaluation of the specific characteristics of current aircraft navigation equipment is needed including technical, cost, size, availability, etc. Higher performance	There are likely insignificant differences in navigation system protection measures between manned aircraft and UAS, but it is recommended that this be evaluated and documented. Based on this evaluation, standards and/or policy may be needed to enable UAS platforms to be equipped	High (Tier 1)	SAE, FAA, DOD, NASA, DOT	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			increasing demands on GNSS systems, ongoing efforts to improve mitigation measures/operational needs, and heightened awareness of nefarious activities using spoofing and jamming technologies. Given the fact that manned aircraft standards are being updated/improved, there is a significant gap with how these standards may be applied to UAS platforms. See the command and control section for related discussion.	spoofing/jamming mitigations should be developed.	with appropriate anti-spoofing and anti-jamming technologies. Also, operational mitigations are recommended including updating pilot and traffic control training materials to address interference and spoofing. **Update**: The text and list of non-UAS specific published and in-development standards has been substantially modified from roadmap version 1. A number of non-UAS specific, but potentially relevant manned aviation standards are in-development, as noted in the text.			
10.	6.4.3	Avionics and Subsystems: Systems Performing Detect and Avoid (DAA) Functions	**Gap A9: Detect and Avoid (DAA) Capabilities**. No published standards have been identified that address systems that provide a DAA capability for UAS that do not have the size, weight, and power (SWAP) available as required by the current DAA TSOs (TSO-211, TSO-212 and TSO-213). In addition, a lack of activity in the design, manufacture, and installation of low SWAP systems to provide a DAA capability impairs the FAA's ability to establish a TSO for those systems.	Yes	1) Complete the above listed in-development standards. 2) Encourage the development of standards to address and accommodate systems to provide a DAA capability for UAS that cannot accommodate the current SWAP requirements. This is a necessary first step toward approval for smaller or limited performance systems for DAA and full and complete integration of UAS into the NAS. **Update**: As noted, work is in progress on a number of standards in development.	High (Tier 1)	RTCA, SAE, SAE-ITC-ARINC, AIAA, ASTM, DOD, NASA, 3GPP	Green
11.	6.4.4	Avionics and Subsystems: Software Considerations and Approval	**Gap A10: Software Considerations and Approval**. Standards are needed to address software considerations for UAS operations outside of Part 107, control stations, and associated equipment. The majority of the current resources from manned aviation (standards, regulations, ACs, orders, etc.) are targeted at traditional aircraft and do not address the system of systems engineering used in UAS operations comprising man, machine, the NAS, and integration. UAS standards related to software dependability must properly account for all the unknown risks and potential safety issues (e.g., DAA, cybersecurity) during the software design, development, and assurance processes.	Yes, on assurance methods	1) Complete in-development standards work of SAE. 2) Develop standards to address software dependability for UAS operating outside of Part 107, control stations, and associated equipment. **Update**: ASTM F3298-19, Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS) has been published. As noted in the text, other standards are in development.	High (Tier 1)	ASTM, EUROCAE, RTCA, SAE	Green
12.	6.4.5	Avionics and Subsystems: Voice and Data Recorder Systems for UAS	**Gap A11: Voice and Data Recorder Systems for UAS**. Standards are needed for crash protected voice and data recorder systems for UAS.	Yes. Research should be conducted to determine the proper: 1) Size requirements, based on the class of UAS, class of airspace, performance characteristics of the aircraft, and other relevant factors. 2) Test procedures for crash survival based on the class of UAS and performance characteristics, including, but not limited to:	Revise an existing standard and/or draft a new standard, similar to ED-112A, for a voice and data recorder systems for UAS. **Update**: As noted in the text, EUROCAE WG-118 has been established. ASTM WK62670 is also in development and it will cover this gap to some extent for large UAS.	Medium	SAE, RTCA, ASTM, IEEE, EUROCAE	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
				impact shock, shear and tensile force, penetration resistance, static crush, high temperature fire, low temperature fire, deep sea pressure and water immersion, and fluid immersion. 3) Method(s) for recording data both on the aircraft and in the CS.				
13.	6.4.6	Avionics and Subsystems: Cybersecurity	**Gap A12: UAS Cybersecurity**. Cybersecurity needs to be considered in all phases of UAS design, construction, operation, maintenance, and training of personnel (pilots, crews, others).	Yes	Since there exists such a wide spectrum in UAS designs, CONOPS, and operator capabilities, a risk-based process during which appropriate cybersecurity measures are identified is recommended. One way that this could be accomplished is for an SDO to develop a standard using a process similar to the way the JARUS Specific ORA assigns Operational Safety Objectives. **Update**: As noted in the text, a number of standards are in development.	High (Tier 1)	RTCA, SAE, ASTM, JARUS, AIA	Green
14.	6.5	Electrical Systems	**Gap A13: Electrical Systems**. The existing manned aviation published industry standards are not adequate in addressing the highly demanding needs of the UAS industry regarding electrical systems, wiring, EWIS, electrical load analysis, aircraft lighting, etc. These areas (electrical systems, wiring, EWIS, etc.) are also not covered for control stations (CSs), auxiliary systems, etc.	Yes	1) Complete work on in-development standards. 2) Encourage the development of standards to address electrical systems, wiring, EWIS, electrical load analysis, aircraft lighting, etc., for UA, CS, and auxiliary system(s). **Update**: As noted in the text, standards are in development.	High (Tier 3)	ICAO, RTCA, SAE, AIAA, ASTM, DOD, NASA, UL, IEC, IEEE	Green
15.	6.6	Power Sources and Propulsion Systems	**Gap A14: Power Sources and Propulsion Systems**. Standards are needed for UAS power sources and propulsion systems.	Yes	1) Complete work on in-development standards. 2) Encourage the development of standards to address UAS power sources and propulsion systems. **Update**: As noted in the text a number of standards are in development.	High (Tier 3)	ICAO, RTCA, SAE, AIAA, ASTM, DOD, NASA, UL, IEC, IEEE	Green
16.	6.7	Noise, Emissions, and Fuel Venting	**Gap A15: Noise, Emissions, and Fuel Venting**. No published standards have been identified that address UAS-specific noise, emissions, and fuel venting standards and requirements.	Yes. Data would be helpful.	1) Complete in-development standards. 2) Encourage the development of standards to address noise, emissions, and fuel venting issues for UAS. This is a necessary first step toward UAS rulemaking relating to these topics. **Update**: This is a low priority for ASTM F38 until there is further guidance/data available on noise levels for drones both large and small. Industry is likely collecting data in relation to this which is a first step before a standard can be written.	High (Tier 3)	ICAO, EPA, FAA, RTCA, SAE, AIAA, ASTM, DOD, NASA	Not Started
17.	6.8	Mitigation Systems for Various Hazards to UAS	**Gap A16: Mitigation Systems for Various Hazards to UAS**. There are no UAS-specific standards in the areas of hazard mitigation systems for bird strikes on UAS, engine ingestion, hail damage, water ingestion,	Maybe	1) Complete in-development standards. 2) Create new standards to include hazard mitigation systems for bird strikes on UAS, engine ingestion, icing, and lightning.	High (Tier 2)	Various SAE Committees	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			lightning, electrical wiring, support towers, etc.		**Update**: SAE has a number of standards in development as noted in the text.			
18.	6.9	Parachutes for Small Unmanned Aircraft	**Gap A17: Parachute or Drag Chute as a Hazard Mitigation System in UAS Operations over People (OOP)**. Standards are needed to address parachutes or drag chutes as a hazard mitigation system in UAS operations, particularly OOP, from the perspectives of FAA Type Certification (TC), Production Certificates (PC) and Airworthiness Certificates (AC).	No	Complete work on ASTM WK65042, New Specification for Operation Over People and ASTM WK56338, New Test Method for Assessing the Safety of Small Unmanned Aircraft Impacts. **Update**: As noted, ASTM F38 has published F3322 for sUAS and it has two work items in development. ASTM F38 has no plans at present to address parachutes for UAS over 55 pounds.	High (Tier 3)	ASTM, AIAA, SAE, PIA, DOD, NASA	Green
19.	6.10	Maintenance and Inspection	**Gap A18: Maintenance and Inspection (M&I) of UAS**. M&I standards for UAS are needed.	No	Complete work on standards in development to address M&I for all UAS. **Update**: ASTM F2909-14 has been superseded by ASFM F2909-19 (previously WK63991). ASTM F3366-19 has been published (previously WK62743). ISO 21384-3 has also been published.	High (Tier 2)	ASTM, ISO, SAE	Green
20.	6.11	Enterprise Operations: Level of Automation/ Autonomy/ Artificial Intelligence (AI)	**Gap A19: Enterprise Operations: Level of Automation/Autonomy/Artificial Intelligence (AI)**. Neither the current regulatory framework nor existing standards support fully autonomous flights at this time.	Yes	1) Develop standards and guidelines for the safety, performance, and interoperability of fully autonomous flights, taking into account all relevant factors needed to support the seamless integration of UAS into the NAS. These include: type of aircraft/UA, operators/pilots/crew, air traffic controllers, airspace service suppliers/providers, lost link procedures, human factors/human-machine interactions as well as levels of human intervention, etc. 2) Encourage the development of standards to address fully autonomous flights, per the FAA Reauthorization Act of 2018 and the needs of the UAS industry and end users. 3) Encourage the development of consistent, uniform, harmonized, standardized, and aviation field- acceptable definitions of terms like autonomy, automation, autonomous, AI, machine learning, deep learning, etc. This will lay a foundation for identification of correct and incorrect definitions/ terminologies. **Update**: ASTM ACC 377 has published TR1-EB, Autonomy Design and Operations in Aviation: Terminology and Requirements Framework. As noted, ACC 377 has two other technical reports in development. SAE G-34 (jointly with EUROCAE WG-114), G-32, AS-4 and S-18 are addressing this gap. UL also has a standard in development.	High (Tier 2)	SAE, SAE-ITC-ARINC, RTCA, AIAA, ASTM, DOD, NASA, FCC, Aerospace Vehicle Systems Institute (AVSI), UL	Green
			Chapter 7. Flight Operations Standards: General Concerns – WG2					

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
21.	7.1	Privacy	**Gap O1: Privacy**. UAS-specific privacy regulations are needed as well as standards to enable the privacy framework. Privacy law and rulemaking related to UAS, including topics such as remote ID and tracking, are yet to be clearly defined.	No	Develop UAS-specific privacy standards as needed and appropriate in response to the evolving policy landscape. Monitor the ongoing policy discussion. **Update**: The text has been updated to emphasize protecting the privacy and security of the UAS operator in accordance with applicable laws. Information on FAA's ADS-B PIA program has been noted. ISO 21384-3 has also been published. The gap statement has been tweaked to note that regulations are needed as well as standards to enable the privacy framework. The recommendation also has been tweaked.	Medium	Lawmakers, FAA, ISO/IEC JTC1/SC 27, ISO/TC 20/SC 16, APSAC, IACP	Yellow
22.	7.2	Operational Risk Assessment (ORA)	**Gap O2: Operational Risk Assessment and Risk Mitigation**. The existing risk framework of standards and regulations address small UAS. There are additional considerations for medium and large UAS that are not addressed in the existing small UAS framework. Traditional manned aviation analysis techniques may be applied effectively; however, the standards do not address all risks.	Yes	As use cases evolve, specific risks and associated risk mitigation strategies should be addressed in standards and/or policy including risks associated with property, privacy, security, and the environment. **Update**: JARUS SORA 2.0 was published in 2019. Standards in development are noted in the text.	High (Tier 1)	Standards bodies publishing UAS standards and/or regulators	Green
23.	7.3	Beyond Visual Line of Sight (BVLOS)	**Gap O3: Beyond Visual Line of Sight (BVLOS)**. Although there is an existing BVLOS standard with supplemental revisions in the works and a best practices document, robust BVLOS operations will require a comprehensive DAA solution, Remote ID, and UTM infrastructure to be completely effective. Additional safety measures must be considered such as reduced limits on energy transfer; weight; speed; altitude; stand-off and redundant systems for power; collision avoidance; positioning; loss-of-control automatic soft landing; and methods for two-way communications between the competent operator and worker supervisor(s) or workers to ensure safety of BVLOS operations. These standards should be addressed in a collaborative fashion. In addition, pilot competency and training is especially critical for BVLOS operations. It is anticipated that appendices for BVLOS will be added to ASTM F3266-18, Standard Guide for Training Remote Pilots in Command of Unmanned Aircraft Systems (UAS) Endorsement.	Yes	Complete work on aforementioned BVLOS standards and related documents in development and address for future consideration UAS including payloads larger than 55 pounds as defined in Part 107. Research is also required but more to the point connectivity is needed to ensure interoperability or compatibility between standards for BVLOS/DAA/Remote ID/UTM. **Update**: As noted in the text.	High (Tier 1)	ASTM	Green
24.	7.4	Operations Over People (OOP)	**Gap O4: UAS Operations Over People (OOP)**. There are no published standards for UAS OOP.	No	Complete work on ASTM WK56338, New Test Method for Assessing the Safety of Small Unmanned Aircraft Impacts and ASTM WK65042, New Specification for Operation Over People.	High (Tier 1)	ASTM	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
					Update: As noted in the text, ASTM F38 has two work items in development.			
25.	7.5	Weather	**Gap O5: UAS Operations and Weather**. No published or in-development standards have been identified that adequately fill the need for flight planning, forecasting, and operating UAS (including data link and cockpit/flight deck displays), particularly in low altitude and/or boundary layer airspace. Gaps have been identified related to two different facets of weather, and the related acquisition and dissemination of weather-related data, especially as it relates to BVLOS operations: 1) Weather requirements for flight operations of UAS. For example, to operate in airspace BVLOS, the aircraft must meet certain standards for weather robustness and resiliency, e.g., wind, icing, instrument meteorological conditions (IMC), etc. 2) Weather data standards themselves. Currently, published weather data standards by National Oceanic and Atmospheric Administration (NOAA), World Meteorological Organization (WMO), ICAO, and others do not have sufficient resolution (spatial and/or temporal) for certain types of UAS operations and have gaps in low altitude and boundary layer airspaces. Other standardized delivery mechanisms for weather data exist, but the considerations must be made with respect to the computational processing power required on the aircraft or controller to use such data. Additionally, standards for cockpit displays, data link, avionics, and voice protocols that involve, transmit, or display weather will need to be amended to apply to UAS (e.g., the 'cockpit display' in a UAS CS).	Yes. Research should be conducted to determine the following: 1) For a given UAS CONOPS, what spatial and temporal resolution is required to adequately detect weather hazards to UAS in real-time and to forecast and flight plan the operation? 2) What are the applicable ways to replicate the capability of a 'flight deck display' in UAS C2 systems for the purpose of displaying meteorological information (and related data link communications with ATC)? 3) To what extent can boundary layer conditions be represented in existing binary data formats? 4) To what extent can current meteorological data acquisition infrastructure (e.g., ground-based weather radar) capture data relevant to UAS operations, particularly in low altitude airspace? 5) What weather data and data link connectivity would be required to support fully autonomous UAS operations with no human operator in the loop? 6) What is the highest temporal resolution currently possible with existing or proposed meteorological measurement infrastructure? 7) To what extent do operators need to consider that weather systems have different natural scales in both space and time, depending on whether the weather systems occur in polar, mid-latitude, or tropical conditions?	Encourage relevant research, amending of existing standards, and drafting of new standards (where applicable). **Update**: NASA UTM Weather Advisory Group is conducting a bottom-up review of weather capabilities, gaps and research needs that may address R&D needs identified, or new ones not yet identified. ASTM F38 is moving forward with a recommendation to the board to consider the addition of a Weather Sub-Group to address amending of existing standards and drafting of new standards.	High (Tier 2)	RTCA, SAE, NOAA, WMO, NASA, universities, National Science Foundation (NSF) National Center for Atmospheric Research (NCAR), ASTM	Yellow
26.	7.6	Data Handling and Processing	**Gap O6: UAS Data Handling and Processing**. Given the myriad of UAS "observation" missions in support of public safety, law enforcement, urban planning, construction, and a range of other applications, and given the diversity of standards applicable to the UAS lifecycle, a compilation of best practices is	No R&D should be required, as community examples already exist. However, interoperability piloting of recommended architectures with the user community based on priority use cases/scenarios is recommended.	Develop an informative technical report to provide architectural guidance for data handling and processing to assist with different UAS operations. **Update**: As noted in the text, the OGC GeoTIFF standard was adopted as an OGC standard in 2019,	Medium	OGC, ISO TC/211	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			needed to identify standards-based "architectural guidance" for different UAS operations.		and best practices are in development in OGC UxS DWG.			
27.	7.7	UAS Traffic Management (UTM)	**Gap O7: UTM Services Performance Standards**. UTM service performance standards are needed.	Yes. Considerable work remains to develop the various USS services listed as well as testing to quantify the level of mitigation they provide. Only after some level of flight testing to define the "realm of the possible" can the community of interest write performance-based standards that are both achievable and effective in mitigating operational risk.	There is quite a lot of work for any one SDO. A significant challenge is finding individuals with the technical competence and flight experience needed to fully address the subject. What is needed is direction to adopt the performance standards and associated interoperability standards evolving from the research/flight demonstrations being performed by the research community (e.g., NASA/FAA RTT, FAA UTM Pilot Project, UAS Test Sites, GUTMA, etc.). Given a draft standard developed by the experts in the field (i.e., the ones actively engaged in doing the research), SDOs can apply their expertise in defining testable and relevant interoperability and performance-based requirements and thus quickly converge to published standards. **Update**: As noted above, new activity is underway in ASTM, IEEE, ISO, EUROCAE, and JARUS.	High (Tier 2)	NASA, FAA, ASTM, ISO, IEEE, EUROCAE, JARUS	Green
28.	7.8	UAS Remote Identification (UAS Remote ID)	**Gap O8: Remote ID and Tracking: Direct Broadcast**. Standards are needed for transmitting UAS ID and tracking data with no specific destination or recipient, and not dependent on a communications network to carry the data. Current direct broadcast standards for aviation and telecommunications applications do not specifically address UAS operations, including secure UAS ID, authentication, and tracking capabilities, and specifically when UAS operations are conducted outside ATC.	No	1) Revise published ASTM Remote ID standard once UAS Remote ID Rule is finalized. 2) Continue development of the Open Source implementations and enablement. 3) Continue development of 3GPP specs and ATIS standards to support direct communication broadcast of UAS ID and tracking data with or without the presence of a 4G or 5G cellular network. **Update**: As noted in the text, ASTM F3411 has been published. It addresses the specific concerns outlined in the gap statement. It will be revised as needed once the FAA final rule on remote ID is issued. Other standards are in development as noted in the text.	High (Tier 1)	ASTM, 3GPP, ATIS	Green
29.	7.8	UAS Remote Identification (UAS Remote ID)	**Gap O9: Remote ID and Tracking: Network Publishing**. Standards are needed for secure UAS ID, authentication, and tracking data transmitted over a secure communications network (e.g., cellular, satellite, other) to a specific destination or recipient. Current manned aviation standards do not extend to the notion of transmitting UAS ID and tracking data over an established secure communications network to an internet service or group of services, specifically the cellular and satellite networks and cloud-based services. Nor do they describe how that data is received by and/or accessed from an FAA-approved internet-based database.	Yes	1) Revise the published ASTM Remote ID standard and other applicable standards once UAS Remote ID Rule is finalized. 2) Continue the "FAA cohort" implementation efforts to stand up initial remote ID system with appropriate data exchanges between the Remote ID Federation and the FAA. 3) Continue development of 3GPP specs and ATIS standards related to remote ID of UAS and UTM support over cellular or satellite networks. **Update**: As noted in the text, ASTM F3411 has been published. It includes network remote ID that covers most of the issues raised in the gap statement	High (Tier 1)	ASTM, FAA, 3GPP, ATIS	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
					(except FAA access). Other standards are in development as noted in the text.			
30.	7.9	Geo-fencing	**Gap O10: Geo-fence Exchange**. Standards have been developed (or are in development) to provide a consistent description of the limits of a geo-fence. Standards also exist to define and encode the geometry for a geo-fence. However, a new standard or a profile of an existing standard is needed to exchange geo-fence data. This standard must encode the attributes of a geo-fence necessary for UAS operators or autonomous systems to respond to the proximity of a geo-fence.	Minimal. The encoding mechanism should reply upon existing standards. Minimal investigation is needed to identify which attributes should be included to handle geo-fence interaction.	A draft conceptual model should be developed that identifies allowed geometries in 2D, 3D, as well as temporal considerations and which articulates the necessary attributes. Critical to this model is a definition of terminology that is consistent with or maps to other UAS operational standards. The model should consider “active” vs. “passive” geo-fences, the former being geo-fences where a third party intervenes in the aircraft operation, and the latter being geo-fences where the UAS or operator is expected to respond to proximity/intersection. The model should also define geo-fences with respect to the aircraft operational limits, either: 1) the aircraft operates inside a geo-fence and an action occurs when the aircraft leaves that geo-fence, or 2) the aircraft operates outside a geo-fence and an action occurs when the aircraft intersects the geo-fence boundary. The conceptual model can be used to develop one or more standard encodings so that equipment manufacturers can select the ideal format for their hardware (e.g., XML, JSON, binary). Industry has taken the lead on proposing geo-fencing solutions improving safety on current UAS operations but guidelines from the UAS community (industry+regulator) are needed to harmonize this functionality. The geo-fence exchange standard must be machine-readable to take advantage of existing geospatial processing code and ensure consistent application of rules against the geo-fence. **Update**: As noted in the text, standards are in development.	High (Tier 2)	OGC, ISO/TC 20/SC 16, EUROCAE, UAST, ICANN	Green
31.	7.9	Geo-fencing	**Gap O11: Geo-fence Provisioning and Handling**. There is a need for a best practices document to inform manufacturers of the purpose, handling, and provisioning requirements of geo-fences.	Minimal. The proposed geo-fence exchange standard discussed earlier will suffice for the geo-fence content. There are many existing methods to deploy such data to hardware.	Create a best practices document on geo-fence provisioning and handling in standards for autonomous and remote pilot behavior. This document should include specific guidance on how an aircraft must behave when approaching or crossing a passive geo-fence boundary based on the attributes contained in the geo-fence data, such as: not entering restricted airspace, notifying the operator to turn off a camera, changing flight altitude, etc. For active geo-fences, the document should detail the types of third party interventions. These best practices may not need to be expressed in a separate document, but rather could be provided as content for other documents for control of aircraft operations, such as UTM.	Medium	OGC, ASTM, RTCA, EUROCAE	Not Started

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
					Update: Some best practices are emerging but nothing has been documented at this time. This is a low priority for ASTM F38 and no action is planned at this time.			
32.	7.10	Recreational Operations	No Gap	N/A	N/A	N/A	N/A	N/A
33.	7.11	Vertiports	**New Gap O12: Design and Operation of Vertiports**. There are no published standards for the design and operation of vertiports. There is also no traffic pattern standard for existing airport facilities.	Yes	Complete work on standards in development	High (Tier TBD)	ASTM, ISO	N/A
			Chapter 8. Flight Operations Standards: Infrastructure Inspections, Environmental Applications, Commercial Services, Workplace Safety – WG3					
34.	8.1.1	Vertical Infrastructure Inspections: Power Plants and Industrial Process Plants	**Gap I1: UAS Inspections of Power Plant and Industrial Process Plant Assets**. No published standards have been identified for inspections of power plant and industrial process plant assets using UAS.	No	Develop standards for power plant inspections using UAS **Update**: As noted in the text, ASME is developing a standard on the use of UAS to perform inspections of power plant and industrial process plant assets.	High (Tier 3)	ASME BPV Committee on Nondestructive Examination (V) and ASME Mobile Unmanned Systems (MUS) Standards Committee	Green
35.	8.1.2	Vertical Infrastructure Inspections: Cranes	**Gap I2: Crane Inspections**. Standards are needed to establish requirements for the use of UAS in the inspection, testing, maintenance, and operation of cranes and other material handling equipment covered within the scope of ASME's B30 volumes.	No	Complete work on draft B30.32-20XX, Unmanned Aircraft Systems (UAS) used in Inspection, Testing, Maintenance, and Lifting Operations to address crane inspections using UAS. **Update**: Work continues on development of the draft B30.32 standard.	Medium	ASME	Green
36.	8.1.3	Vertical Infrastructure Inspections: Building Facades	**Gap I3: Inspection of Building Facades using Drones**. There are no known published standards for vertical inspections of building facades and their associated envelopes using a drone. A standard is needed to provide building professionals and drone pilots with a methodology for documenting facade conditions utilizing a sensor mounted to a drone. This should include best practices for the operation of the drone and establish an approach to sensing a building facade, preserving the data, and utilizing data recorded for reporting purposes. The standard should consider the safe operating distance from a building, which may vary depending on the construction material of the facade, and the size and height of the	Yes, for navigation systems to mitigate potential GPS reception loss while operating in close proximity of structures that might obstruct GPS transmission signals.	Expand work on ASTM WK58243, Visual Inspection of Building Facade using Drone to include non-visual sensors, such as radar and thermal. **Update**: As noted, standards are in development.	Medium	ASTM	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			building. It should also take into account FAA requirements that apply to operational navigation (visual and beyond line of sight) and OOP. In addition, the standard should consider the relationship between the licensed design professional and the remote pilot if they are not one-in-the-same. For example, the local jurisdiction authority may stipulate that only a licensed design professional may qualify the inspection results. The remote pilot may help document the inspection findings, but might not be qualified to provide analysis.					
37.	8.1.4	Vertical Infrastructure Inspections: Low-Rise Residential and Commercial Buildings	**Gap I4: Low-Rise Residential and Commercial Building Inspections Using UAS**. There is a need for a set of best practices or a standard operating procedure (SOP) to inform industry practitioners how to conduct low-rise residential and commercial inspections using UAS.	No	Develop a guide or SOP for low-rise residential and commercial inspections using UAS. The document should consider safe operating distance from the building, which may vary depending on the construction material of the facade, and the size and height of the building. It should also take into account FAA requirements that apply to operational navigation (visual and beyond line of sight whether day or night), and OOP. **Update**: No update provided at this time.	Medium	ASHI, ASTM	Unknown
38.	8.1.5	Vertical Infrastructure Inspections: Communications Towers	No Gap	N/A	N/A	N/A	N/A	N/A
39.	8.2.1	Linear Infrastructure Inspections: Bridges	**Gap I5: Bridge Inspections**. Standards are needed for conducting bridge inspections using a UAS to provide state Department of Transportation agencies and bridge owners with a methodology for documenting bridge conditions utilizing sensors mounted to a UAS. This should include best practices for the operation of the UAS and establish an approach to sensing a bridge structure, preserving the data, and utilizing data recorded for reporting and modeling purposes. All bridge types should be considered, including rail, road, and pedestrian. The role of UAS in assisting with fracture critical inspections, which usually require an inspector to be able to touch the fracture critical element, should be considered. The standards should address safety and operator training. They should also take into account FAA requirements that apply to	Yes, for navigation systems to mitigate potential GPS reception loss while operating in close proximity to structures that might obstruct GPS transmission signals, including the role of collision avoidance systems. Also, for evaluating and documenting UAS-mounted sensor capabilities to meet bridge inspection data needs in light of state and federal reporting requirements.	Develop standards for bridge inspections using a UAS **Update**: The FHWA NPRM of November 2019 is noted. Updated references, for example projects on implementing UAS for bridge inspections, have been noted. The gap statement has been tweaked slightly.	Medium	AASHTO, ASTM, FHWA, state DOTs	Yellow

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			operational navigation (visual and beyond line of sight) and OOP (to include vehicular traffic), including short-term travel over people and traffic. In addition, the standards should consider the relationship between the qualified bridge inspector and the remote pilot if they are not one-and-the-same. The remote pilot may help document the inspection findings, but might not be qualified to provide an analysis. Recommendations on how to coordinate their work to maximize the value of UAS-enabled inspections should be part of new standards.					
40.	8.2.2	Linear Infrastructure Inspections: Railroads	**Gap I6: Railroad Inspections: Rolling Stock Inspection for Transport of Hazardous Materials (HAZMAT)**. Standards are needed to address rolling stock inspections for regulatory compliance of transporting HAZMAT. Considerations for BVLOS and nighttime operations are critical. OSHA standards (29 C.F.R. 1910) related to personal protective equipment (PPE) need to be factored in. SDOs should consult/engage with the rail industry in the development of such standards.	Yes. Current inspection procedures are likely more hands-on when in close proximity of HAZMAT containers, so using UAS to reduce the inspector's exposure is similar to other inspection use cases. There are many on-going R&D activities for UAS inspection applications.	It is recommended that guidance be developed for performing inspections of HAZMAT rolling stock that incorporates OSHA and FRA requirements. **Update**: No update provided at this time.	Low	FRA, FAA, SAE, OSHA, PHMSA, ASME	Unknown
41.	8.2.2	Linear Infrastructure Inspections: Railroads	**Gap I7: Railroad Inspections: BVLOS Operations**. Standards are needed to address BVLOS operations for railroad inspection. While there are current integration activities ongoing with the FAA Focus Area Pathfinder program, the results of BVLOS operations for rail system infrastructure inspections are not currently available. Thus, there remains a gap in standards for operating BVLOS. See section 7.3 on BVLOS.	Yes	It is recommended that standards be developed that define a framework for operating UAS BVLOS for rail system infrastructure inspection. This may include the need to identify spectrum used for BVLOS railroad inspections. **Update**: BNSF working with FAA on a framework for BVLOS. FRA is doing research to develop underlying technologies for BVLOS at low altitudes. ASTM AC-478 is looking at BVLOS generally but not specific to railroad inspections. The priority level was changed from medium to high.	High (Tier TBD)	FRA, FAA, SAE, ASTM AC-478 BLOS, American Public Transportation Association (APTA), American Railroad Engineering and Maintenance-of-Way Association (AREMA), ASME	Green
42.	8.2.2	Linear Infrastructure Inspections: Railroads	**Gap I8: Railroad Inspections: Nighttime Operations**. Standards are needed to address nighttime operations for railroad inspections. Railroads operate 24/7, which poses significant hurdles for leveraging UAS technology for rail system infrastructure inspections. The majority of inspections occur during daytime, but incident inspections can occur at any time of day or under poor visibility conditions and, hence, may have OSH considerations.	Maybe. Current R&D activities for operating UAS at night are unknown. Exposing UAS technology and operators to nighttime operations is necessary to encourage the maturation of the technology and processes.	It is recommended that standards be developed that define a framework for operating UAS at night. **Update**: No update provided at this time. AC-478 is looking at BVLOS generally but not specific to nighttime operations or railroad inspections. The priority level was changed from medium to low.	Low	FAA, SAE, ASTM AC-478 BLOS, APTA, AREMA	Unknown
43.	8.2.3	Linear Infrastructure Inspections: Power	**Gap I9: Inspection of Power Transmission Lines, Structures, and Environs Using UAS**. No standards have been identified that specifically address the qualifications of UAS	Yes. There is a need to study acceptable methods of airspace deconfliction around electrical equipment and	Develop standards related to inspections of power transmission lines, structures, and environs using UAS. Review and consider relevant standards from other organizations to determine manufacturer	High (Tier 3)	SAE, IEEE, Department of Energy (DOE), North American	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
		Transmission Lines, Structures, and Environs	pilots to operate near energized equipment to meet Federal Energy Regulatory Commission (FERC) physical and cyber security requirements. Nor have any standards been identified that specifically address the qualifications of UAS pilots to operate around transmission and distribution equipment. This equipment may include telephone, fiber, and cable assets, as well as natural gas and pipeline assets. A standard is needed to address these issues as well as operational best practices and training in how to conduct a safe inspection of power transmission lines, structures, and environs using drones. See also section 10.3 on UAS flight crew.	infrastructure. Identifying appropriate data to collect and study relevant airspace activity around electrical equipment is recommended. Understanding the impact of electromagnetic interference around different types of high voltage lines can help identify what mitigation techniques are needed. Further study should be undertaken regarding the effects of magnetic field interference on UAS C2 signals and communications when in the proximity of energized high voltage electrical transmission, distribution, or substation equipment. Acceptable C2 link methods for BVLOS operation exist, but establishing the equipment and techniques for managing autonomous operations during disruptions in connectivity can help spur further acceptable BVLOS practices. Different DAA techniques exist internationally and in the U.S. Studying their effectiveness in the U.S. NAS is needed.	requirements. As part of the standard, include guidelines on size of aircraft and safe flight operations in proximity to energized equipment, for example, to avoid a scenario where arcing occurs between the drone and physical infrastructure. **Update**: As noted, ASME has some relevant work and SAE is contemplating future work. The ASTM F38 Executive Committee gap analysis viewed this as a low priority for F38, with no action at this time.		Electric Reliability Corporation (NERC), FERC, ORNL, ASTM, ASME	
44.	8.2.4	Linear Infrastructure Inspections: Implementing UAS for Hydrocarbon Pipeline Inspections	**New Gap I13: Inspection of Pipelines and Operating Facilities - BVLOS Operations**. Standards are needed to address BVLOS operations for pipeline inspection. While there have been past research activities provided to the FAA through Pipeline Research Council International (PRCI) research, the standard guidance of BVLOS operations for pipeline infrastructure inspections are not currently available. Thus, there remains a gap in standards for operating BVLOS.	No. Current FAA and industry research program activities will likely address R&D considerations although detect and avoid demonstrations may be required for FAA data collection.	Develop standards that define a framework for operating UAS BVLOS for pipeline inspection as well as standards that describe best practices and use cases for the pipeline industry. Request API to review their portfolio of pipeline inspection standards to determine if revisions to enable inspections performed by UAS could be incorporated. Complete NACE TG 552 on monitoring of pipeline integrity threats.	Medium	FAA, API, NACE, PHMSA (R&D), PRCI (R&D), California Energy Commission (R&D), ASME	N/A
45.	8.2.4	Linear Infrastructure Inspections: Implementing UAS for Hydrocarbon Pipeline Inspections	**New Gap I14: Inspection of Pipelines and Operating Facilities – Sensor Validation & Use**. Standards are needed for minimum testing to validate sensors on UAS platforms at varying flight altitudes utilized for pipeline inspections. Standards are needed to provide Department of Transportation agencies and operators with a methodology for documenting pipeline conditions utilizing sensors mounted to a UAS. This should include	Yes, for validation of sensor quality and accuracy on varying platforms (long-range and short-range UAVs) for risks associated with: • Environmental changes (i.e., ground movement, water saturation, slip / subsidence / sinkhole / erosion) • Third-party threats	Develop standards for validating sensor quality and accuracy on UAS platforms utilized for pipeline inspections. Request API to review their portfolio of pipeline inspection standards to determine if revisions to enable inspections performed by UAS could be incorporated. Complete NACE TG 552 and TG 587 documents.	Medium	API, NACE, PHMSA (R&D), PRCI (R&D), California Energy Commission (R&D), FAA, ASME	N/A

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			best practices for the operation of the UAS and establish an approach to sense and avoid surrounding infrastructure within facilities, safeguarding the data, and utilizing data recorded for reporting and modeling purposes. The standards should address safety and operator training. They should also consider FAA requirements that apply to operational navigation (visual and beyond line of sight).	• Active loading on pipelines (i.e., equipment crossing right of way (ROW), equipment on ROW, material on ROW) • Waterways (i.e., boat anchorage, dredging, levee construction / maintenance) • Structures (i.e., building construction, fence installation, non-permanent structure on ROW) • Pipeline monitoring (i.e., exposure (pipe), pipeline construction / maintenance, possible leak / lost gas, slip / subsidence / sinkhole / erosion • Earthwork (i.e., clearing, drainage, excavation, mining activity) • Forestry (i.e., logging activity, portable sawmill operations)				
46.	8.2.5	Linear Infrastructure Inspections: Implementing UAS in Airport Operations	**New Gap I15: UAS in Airport Operations**. No published or in development standards have been identified for UAS usage in airport operations.	Yes	Develop standards for the application of UAS in airport operations	Medium	Standards bodies publishing UAS standards and/or regulators	N/A
47.	8.3.1	Environmental Applications: Environmental Monitoring	No Gap	N/A	N/A	N/A	N/A	N/A
48.	8.3.2	Environmental Applications: Pesticide Application	**Gap I10: Pesticide Application Using UAS**. Standards are needed to address pesticide application using UAS. Issues to be addressed include communication and automated ID, treatment efficacy (treatment effectiveness), operational safety, environmental protection, equipment reliability, and integration into the national air space, as further described below. • Communication. As pesticide application occurs in near-ground air space, it is also the domain of manned aerial application aircraft. Automated ID and location communication is critical in this increasingly crowded, near surface airspace. • Treatment Efficacy. Assumptions that spraying patterns and efficacy are similar to heavier, existing manned aircraft are incorrect for lighter, multi-rotor UAS. Equipment standards for differing size and rotor configurations may be needed.	Yes. Mostly engineering development and demonstration. There is some indication that treatment efficacy does not meet expectations in some scenarios.	Develop standards for pesticide application using UAS. Organizations such as NAAA, USDA Aerial Application Technology Research Unit (AATRU), ASABE, and ASSURE should be consulted in conjunction with such standards development activities. **Update**: As noted in the text, standards development is underway by ISO and CEN with respect to aerial application by manned aircraft that has potential relevance to UAS.	High (Tier 3)	ISO/TC 23/SC 6, CEN/TC 144, ASABE, FAA	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			• Operational Safety and Environmental Protection. Safety to operators, the general public, and the environment are critical. Transporting hazardous substances raises further safety and environmental concerns. As noted, UAS operate in low altitude air space with various surface hazards including humans and livestock. Standards for safety need to be developed based on the FAA's models of risk as a function of kinetic energy. See also section 9.2 on HAZMAT transport. • Equipment Reliability. Aviation depends on reliability of the equipment involved. Failure at height often results in catastrophic damage and represents a serious safety hazard. Reliability of equipment and specific parts may also follow the FAA's risk curve, though catastrophic failure and damage of expensive equipment that is not high kinetic energy (precision sprayers, cameras, etc.) may require higher standards of reliability due to the potential for large economic loss due to failure. • Airspace Integration. This is tied to automated ID and location communication so that other aircraft can sense the spraying UAS and avoid collisions. Detailed flight plans are probably not necessary and controlled airspace restrictions are already in place.					
49.	8.3.3	Environmental Applications: Livestock Monitoring and Pasture Management	No Gap	N/A	N/A	N/A	N/A	N/A
50.	8.4.1	Commercial Services: Commercial Package Delivery via UAS	**Gap I11: Commercial Package Delivery via UAS**. Standards are needed to enable UAS commercial package delivery operations.	Yes	1) Complete work on ASTM WK62344 and SAE AIR7121. Review small UAS oriented standards for scaling into larger UAVs (those that exceed Part 107 and have Part 135 applicability). 2) Write new standards to address commercial package delivery UAS and its operations. **Update**: Relevant standards in development are noted above.	High (Tier 3)	ASTM, SAE, RTCA, EUROCAE, SAE ARINC	Green
51.	8.4.2	Commercial Services: Commercial	**New Gap I16: Commercial Cargo Transport via UAS**. Additional standards may be needed to enable UAS commercial cargo transport and operations.	Yes. Review existing standards used for traditional commercial cargo transport and determine gaps that are unique to UAS.	Complete work on in-development standards. Engage with industry to determine intent for future services (e.g., replace short haul rail and road freight	High (Tier TBD)	SAE, RTCA, EUROCAE, SAE, ARINC, ASME	N/A

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
		Cargo Transport via UAS			with small general aviation aircraft cargo operations).			
52.	8.4.3	Commercial Services: Urban Air Mobility (UAM, short-haul flights carrying few passengers)	**New Gap I17: Urban Air Mobility (UAM, short-haul flights carrying few passengers and/or cargo)**. Standards are needed to support UAM covering the areas such as vertiports, vertiport security, ground infrastructures, aircraft automation, charging stations, passenger cabin interiors and furnishings, safety equipment and survival, etc. Standards are needed for remotely piloted and eventually highly automated UAS (that may or may not be implemented with and using non-deterministic algorithms and techniques) flying in urban environments and also carrying passengers and/or cargo.	Yes	1) Complete work on in-development standards. Complete work on use of AI and non-deterministic techniques on autonomous, non-piloted UAS. Develop safety and operations standards applicable to non-piloted UAS carrying passengers. 2) Consult the NASA UAM ConOps and write standards to address UAM	High (Tier TBD)	ASTM, RTCA, SAE, EUROCAE	N/A
53.	8.4.4	Commercial Services: Commercial Passenger Transport via UAS (long-haul flights carrying many passengers)	**New Gap I18: Commercial Passenger Transport via UAS (long-haul flights carrying many passengers)**. Standards are needed to support commercial passenger transport via UAS and its operations.	Yes	Complete work on in-development standards to support commercial passenger transport via UAS and its operations. Industry and SDOs should work together to develop standards to enable this type of operation.	High (Tier TBD)	RTCA, SAE, EUROCAE, SAE ARINC	N/A
54.	8.4.5	Commercial Services: Commercial Sensing Services	**New Gap I19: Commercial Sensing Services**. Standards are needed to enable the provision of commercial sensing services by UAS operators. Such standards should address the integrity and security of the information collected, transmitted, and stored by the service provider on behalf of the client.	Yes	Develop standards to enable commercial sensing services. Industry groups should be consulted to determine if additional and/or higher level standards are required for UAS sensor operations conducted by outsourced service providers.	High (Tier TBD)	ASME, NACE, ASTM	N/A
55.	8.4.6	Commercial Services: Use of sUAS for News Gathering	**New Gap I20: Use of sUAS for Newsgathering**. Standards (including best practices) are needed on the use of drones by newsgathering organizations whether the drone controllers are stationary or mobile. sUAS use for newsgathering operations should also include safety and health considerations for participating crew and the public from the NIOSH and OSHA aspects.	No	Develop operational best practices or standards on the use of UAS by newsgathering organizations	High (Tier 2)	companies, industry trade associations	N/A
56.	8.5	Workplace Safety	**Gap I12: Occupational Safety Requirements for UAS Operated in Workplaces**. There is a need for occupational safety standards for operating UAS in workplaces. In addition to collision avoidance and awareness systems that are required to be installed on critical infrastructure, at construction sites, and on buildings, such standards should address: 1) Hazard identification, risk characterization, and mitigation to ensure the safe operation of UAS in workplaces.	Yes. Collecting and analyzing objective data about negative safety outcomes is a key to identifying causes of injuries. This includes investigating: 1) navigation and collision avoidance systems in the design of commercial UAS so as to proactively address workplace safety.	1) Develop proactive approach-based occupational safety standards/recommended best practices for UAS operations in workplace environments. Such work should be done in collaboration and consultation with diverse groups (governmental and non-governmental), to help integrate UAS operations in construction and other industries while ensuring the safety and health of workers and others in close proximity to the UAS. 2) Develop educational outreach materials for non-participating people in workplaces, including	High (Tier 2)	SAE, ASTM, ASSP, BLS, OSHA, NIOSH, CPWR, ISO/TC 20/SC 16, FAA, NTSB, etc.	Yellow

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			This includes incorporating hazard prevention through safety design features/concepts such as frangible UAS, lightweight manipulators, passive compliant systems, safe actuators, passive robotic systems, operating warning devices (audio/visual), two-way communications between the operator and worker supervisor(s) or workers, etc. It also includes the deployment of Personal Protective Equipment (PPE) such as helmets and other equipment and gears. 2) Training, especially in relation to: a) the competency, experience and qualification of UAS operators; b) operator, bystander, and worker safety; c) identification of potential hazards to equipment such as cranes, elevators, fork lifts, etc.; and, d) corrective actions, procedures, and protocols that are needed to mitigate safety hazards. (See also section 10.3 on UAS Flight Crew.)	2) the effects of stiffness and pliability in structural designs of UAS in relation to UAS collisions with critical infrastructure. 3) the severity of UAS collisions with workers wearing and not wearing helmets and other protective devices. 4) potential safety risks of drones in the workplace such as anti-collision lights distracting workers, increasing noise levels, psychological effects. 5) potential mitigation methods that follow the hierarchy of controls to reduce risks of drones to workers. See also section 7.4 on Operations Over People and section 9.2 on HAZMAT (e.g operations at a chemical manufacturing plant).	construction sites where UAS operations are taking place. Occupational safety and health professional organizations should invite speakers on UAS workplace applications to further increase awareness among their members. 3) Encourage the voluntary reporting of events, incidents, and accidents involving UAS in workplace environments. 4) Encourage BLS to modify the SOII and CFOI databases to facilitate search capability that would identify injuries caused by UAS. **Update**: These recommendations require community efforts. It is believed that work is underway by NIOSH in regard to recommendations 1 and 2.			
			Chapter 9. Flight Operations Standards: Public Safety – WG4					
57.	9.1	sUAS for Public Safety Operations	**Gap S1: Use of sUAS for Public Safety Operations**. The roadmap version 1 gap stated that "Standards are needed on the use of drones by the public safety community."	No	The roadmap version 1 recommendation stated "With the publication of NFPA® 2400, Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations, complete work on the development of use cases by the ASTM/NFPA JWG." As noted above, the JWG is now inactive. **Update**: Between the APSAC standards, ASTM F3379, and NFPA® 2400, the group is of the view that this gap is closed. The current edition of NFPA® 2400 will undergo a normal revision cycle. No further work is being done at this time by the ASTM/NFPA JWG. NFPA 1500TM and ASTM F3379 have been added to the list of published standards.	High (Tier 2)	NFPA, ASTM	Closed
58.	9.2	Hazardous Materials Incident Response and Transport	**Gap S2: Hazardous Materials Response and Transport Using a UAS**. Standards are needed to address the transportation of known or suspected HAZMAT by UAS and UAS being exposed to HAZMAT in a response environment.	Yes. Research to assist policy makers and practitioners in determining the feasibility of using UAS in emergency response situations.	Create a standard(s) for UAS HAZMAT emergency response use, addressing the following issues: • The transport of HAZMAT when using UAS for detection and sample analysis • The design and manufacturing of ingress protection (IP) ratings when dealing with HAZMAT • The method of decontamination of a UAS that has been exposed to HAZMAT **Update**: The ASTM F38 Executive Committee gap analysis characterized this as a low priority for F38 that could potentially be addressed by a new	Medium	ASTM, NFPA, OSHA, U.S. Army, DOT, FAA	Not Started

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
					standard but F38 has no plans to develop one at this time.			
59.	9.3	Transport and Post-Crash Procedures Involving Biohazards	**Gap S3: Transport and Post-Crash Procedures Involving Biohazards**. No published or in-development standards have been identified that address UAS transport of biohazards and associated post-crash procedures and precautions.	Yes	1) Write standards to address UAS transportation of biohazards and post-crash procedures and containments 2) Encourage the development of standards to address and accommodate transport of biohazards and post-crash procedures and containments that cannot meet the current regulatory requirements and standards of manned aviation **Update**: None provided at this time.	High (Tier 3)	UN, PHMSA, FAA, WHO, ICAO, DOD, DHS, CDC, USDA, NIH, NFPA, SAE	Unknown
60.	9.4	Forensic Investigations Photogrammetry	**Gap S4: Forensic Investigations Photogrammetry**. Standards are needed for UAS sensors used to collect digital media evidence. The equipment used to capture data needs to be able to survive legal scrutiny. Standards are also needed for computer programs performing post-processing of digital media evidence. Processing of the data is also crucial to introducing evidence into trial.	Yes. R&D will be needed to develop the technical standards to meet legal requirements for the admissibility of digital media evidence into court proceedings.	Develop standards for UAS sensors used to collect digital media evidence and for computer programs performing post-processing of digital media evidence. These standards should take into account data, security and accountability. **Update**: As noted in the text, the OGC GeoTIFF standard was adopted as an OGC standard in 2019, and best practices are in development in OGC UxS DWG.	Medium	OGC	Green
61.	9.5	Payload Interface and Control for Public Safety Operations	**Gap S5: Payload Interface and Control for Public Safety Operations**. Standards are needed for public safety UAS payload interfaces including: • Hardware • Electrical connections (power and communications) • Software communications protocols Additional standards development may be required to define location, archiving, and broadcast of information which will grow in need as data analytics plays a larger role in public safety missions. There currently are no published standards that define the expected capabilities, performance, or control of sUAS payload drop mechanisms.	Yes. Need to examine available options in universal payload mounting as well as electrical connections and communications. Stakeholders including end users and manufacturers of drones should be engaged to contribute to the process of defining acceptable standards. Existing payload drop and control systems should be researched with attention to weight, degree of operator control, and interoperability considered in defining standards that are useful for both public safety and commercial operators.	Develop standards for the UAS-to-payload interface, which includes hardware mounting, electrical connections, and software message sets. Develop a standard for a UAS payload drop control mechanism that includes weight, control, safety and risk metrics, and remote status reporting. **Update**: As noted in the text.	High (Tier 3)	ASTM, DOJ, NFPA, DHS, NIST, IEEE	Green
62.	9.6.1	Search and Rescue: sUAS IR Camera Sensor Capabilities	**Gap S6: sUAS Forward-Looking Infrared (IR) Camera Sensor Capabilities**. UAS standards are needed for IR camera sensor capabilities. A single standard could be developed to ensure IR technology meets the needs of public safety missions, which would be efficient and would ensure an organization purchases a single camera to meet operational objectives.	Yes. R&D (validation/testing) is needed to identify IR camera sensor sensitivity, radiometric capabilities, zoom, and clarity of imagery for identification of a person/object for use in public safety/SAR missions.	Complete work on standards in development related to IR camera sensor specifications for use in public safety and SAR missions. **Update:** As noted in the text.	Medium	NIST, NFPA, ASTM	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
63.	9.6.2	Search and Rescue: sUAS Automated Missions during Emergency Response	**Gap S7: Need for Command and Control Software Specifications for Automated Missions during Emergency Response**. While standards exist for software specifications to complete automated missions, there remains a need to encourage the user community to purchase professional grade equipment that is compliant with these standards, rather than using low-cost, consumer grade equipment.	No	Encourage UAS OEMs to adopt existing standards. Encourage public safety agencies to consider equipment that is compliant with industry standards, and NIST/FEMA guidelines, prior to acquiring UAS. See section 7.6 on data handling and processing. **Update**: Standards exist for software specifications to complete automated missions. Other standards are under development.	Low	NIST, NFPA, ASTM, OGC, UAS OEMs, public safety agencies/organizations	Green
64.	9.7	Response Robots	**Gap S8: UAS Response Robots**. There is a need for standardized test methods and performance metrics to quantify key capabilities of sUAS robots used in emergency response operations and remote pilot proficiencies.	Yes	Complete work on UAS response robot standards in development in ASTM E54.09 and reference them in NFPA® 2400, Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations **Update**: Standards in development are noted in the text.	Medium	NIST, ASTM E54.09, NFPA, DHS	Green
65.	9.8	Public Safety Tactical Operations	**New Gap S10: Use of Tethered UAS for Public Safety Operations**. Training and operational standards are needed on the use of Actively Tethered sUAS by public safety agencies.	Yes	Develop standards for Actively Tethered Public Safety sUAS operations	Medium	NFPA, APSAC, FAA, ASTM	N/A
66.	9.9.1	Counter-UAS (C-UAS): Detection	**New Gap S11: Counter-UAS (C-UAS) Operations: Detection**. No standards exist for the performance of UAS detection systems that might be used by operators of critical infrastructure or public safety agencies. Given the importance of drone detection capabilities, standards must be developed for user identification, design, performance, safety, and operations. User identification insures accountability and provides a necessary tool to public safety officials and operators of critical infrastructure. Design, performance, and safety standards can ensure that risk management decisions are based on reliable and valid data. A comprehensive evaluation template for testing UAS detection systems is needed to: (1) identify current capabilities and anticipated advancement for C-UAS technologies and (2) forecast trends in the C-UAS burgeoning market. The test and evaluation (T&E) community must have clear guidance and a framework to test and evaluate the needs of the end user.	Yes	Encourage the development of detection standards addressing user identification, design, performance, safety, operational aspects, and various available technological methods for detecting UAS. For example, RF detection based systems will follow a different standards protocol than electro-optical or infra-red based systems.	High (Tier 1)	DOD, DHS, DOJ, DOE, FCC, NTIA, FAA, EUROCAE, RTCA	N/A
67.	9.9.2	Counter-UAS (C-UAS): Mitigation	**Gap S9: Counter-UAS (C-UAS) Operations: Mitigation**. Given the imperative that C-UAS technologies be available for use by the proper authorities, user identification, design, performance, safety, and operational	Yes	Encourage the development of Counter-UAS standards addressing user identification, design, performance, safety, operational aspects, and various available technological methods for C-UAS. For example, laser-based systems will follow a	High (Tier 1)	DOD, DHS, DOJ, DOE, FCC, NTIA, FAA, EUROCAE, RTCA	Green

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			standards are needed. User identification insures accountability and provides a necessary tool to public safety officials. Design, performance, and safety standards can reduce the likelihood of harming or disrupting innocent or lawful communications and operations. A comprehensive evaluation template for testing C-UAS systems is needed. Today's C-UAS technologies are often the result of an immediate need for a life-saving measure that was neither originally anticipated, nor given time to mature. The test and evaluation (T&E) community must have clear guidance on what to look for in order to test and evaluate to the needs of the end user. Put another way, clearly defined metrics and standards require foundational criteria upon which to build.		different standards protocol than a kinetic, acoustic, or RF-based solution. **Update**: As noted in the text, standards development work is underway.			
68.	9.10	UAS for Emergency Management and Disasters	**New Gap S12: Integration of UAS into FEMA ICS Operations Section, Air Operations Branch**. The FEMA NIMS does not fully address UAS operations. FEMA's ICS does not presently contain official guidance surrounding the use of UAS within the Operation Section, Air Operations Branch.	Limited	The NIMS should be revised to integrate the use of UA of all types as part of the ICS. Specific recommendations include: 1) Air Operations Summary (ICS 220) should be updated to incorporate UAS as an aviation resource. 2) FEMA, Resource Typing Definition for Response, NIMS 509, should be expanded to include such positions as UAS Coordinator and UAS Base Manager, or similar positions necessary to manage UAS operations under the Air Operations Branch. 3) Update FEMA, National Training and Education Division, Course Number AWR-345, "Unmanned Aircraft Systems in Disaster Management."	Medium	FEMA	N/A
69.	9.11	Standardization of Data Formatting for sUAS Public Safety Operations	**New Gap S13: Data Format for Public Safety sUAS Operations**. Standards are needed for the formatting and storage of UAS data for the public safety community, especially to foster inter-agency cooperation and interoperability, and to help guide industry product development.	No	Develop standards for accepted format of live video and still imagery and associated GIS data for use in sUAS public safety operations.	High (Tier 2)	NFPA, ASTM, Airborne Public Safety Association (APSA), DRONERESPONDERS, AIRT, OGC	N/A
			Chapter 10. Personnel Training, Qualifications, and Certification Standards: General – WG2					
70.	10.1	Terminology	**Gap P1: Terminology**. The roadmap version 1 gap stated "There is an available aviation standard, but no UAS specific standard has been identified. Several are in development and will satisfy the market need for consumer and commercial UAS terminology"	No	The roadmap version 1 recommendation was to "Complete work on terminology standards in development." **Update:** With the publication of ASTM F3341/F3341M-20, *Standard Terminology for Unmanned Aircraft Systems* (previously WK42416), and ISO 21895:2020, *Categorization and*	High (Tier 3)	ASTM, IEEE, ISO, RTCA	Closed

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
					classification of civil unmanned aircraft systems, this gap is deemed closed.			
71.	10.2	Manuals	**Gap P2: Manuals**. Several published UAS standards have been identified for various manuals. Several more are in development and will satisfy the market need for civil and public operators.	No	Complete existing work on manual standards in development **Update**: The ASTM F38 Executive Committee gap analysis characterized this as a high priority for F38. ASTM F2909-14 has been superseded by ASFM F2909-19 (previously WK63991). ASTM F3366-19 has been published (previously WK62743). ASTM WK29229 is no longer an active work item.	High (Tier 2)	ASTM, JARUS, NPTSC, NFPA	Green
72.	10.3	UAS Flight Crew	**Gap P3: Instructors and Functional Area Qualification**. Several published UAS standards have been identified for various crewmember roles. Several are in development and will satisfy the market need for remote pilot instructors and functional area qualification.	No	Complete work on UAS standards currently in development **Update**: ASTM F3330-18 and ASTM F3379 (previously WK61764) have been added to the list of published standards. The other ASTM work items listed (WK61763, and WK62741) are out for ballot. WK61763 may be published before the roadmap is finalized.	High (Tier 2)	SAE, ASTM, AUVSI, PPA	Green
73.	10.4	Additional Crew Members	**Gap P4: Training and Certification of UAS Flight Crew Members Other Than the Remote Pilot**. There is a standards gap with respect to the training and/or certification of aircrew other than the RPIC specifically around the following: • Functional duties of the crew member • Crew resource management principles • Human factors • General airmanship and situational awareness, and • Emergency procedures	No	1) Develop a framework to classify additional UAS crew members around common flight activities identifying in particular those who directly or indirectly influence safety-of-flight. 2) Develop a standard(s) around training, evaluation, and best practices for the relevant UAS crew members other than the RPIC for UAS >55Lbs for activities affecting safety-of-flight. 3) Consider the possibility of recommending – through best practices or a standard – that all flight crew members actively participating in flight activities on UAS > 55Lbs meet the minimum training of a remote pilot for the applicable UA. **Update**: ASTM F3330-18 and ASTM F3379 (previously WK61764) have been added to the list of published standards. The other ASTM work items listed (WK61763, and WK62741) are out for ballot and expected to be published before the roadmap is published.	Medium	SAE, ASTM, AUVSI, JARUS	Green
74.	10.5	Maintenance Technicians	**Gap P5: UAS Maintenance Technicians**. Standards are needed for UAS maintenance technicians. ASTM is developing one and it will satisfy the market need.	No	Complete work on UAS maintenance technician standards currently in development **Update**: As noted in the text, ASTM WK60659 is in development. It will be part of a standard in ASTM F46 and is likely to be published before the roadmap is finalized at which time the gap will be closed.	High (Tier 2)	ASTM	Green
75.	10.6	Compliance / Audit Programs	**Gap P6: Compliance and Audit Programs**. The version 1.0 gap stated "No published UAS standards have been identified for UAS-specific compliance/audit programs. However,	No	The version 1.0 recommendation stated "Complete work on compliance and audit program standards currently in development."	High (Tier 3)	ASTM, AUVSI	Closed

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
			several are in development and will satisfy the market need."		**Update**: With the publication in 2019 of ASTM F3364-19, Standard Practice for Independent Audit Program for Unmanned Aircraft Operators and ASTM F3365-19, Standard Practice for Compliance Audits to ASTM Standards on Unmanned Aircraft Systems, this gap is now closed.			
76.	10.7	Human Factors in UAS Operations	**Gap P7: Displays and Controls**.[2] Standards are needed for the suite of displays, controls, and onboard sensors that provide the UAS operator with the range of sensory cues considered necessary for safe unmanned flight in the national airspace. The UAS operator is deprived of a range of sensory cues that are available to the pilot of a manned aircraft. Rather than receiving direct sensory input from the environment in which his/her vehicle is operating, a UAS operator receives only that sensory information provided by onboard sensors via datalink. Hence, compared to the pilot of a manned aircraft, a UAS operator must perform in relative "sensory isolation" from the vehicle under his/her control. Of particular interest are recent developments in the use of augmented reality and/or synthetic vision systems (SVS) to supplement sensor input. Such augmented reality displays can improve UAS flight control by reducing the cognitive demands on the UAS operator. The quality of visual sensor information presented to the UAS operator will also be constrained by the bandwidth of the communications link between the aircraft and its CS. Data link bandwidth limits, for example, will limit the temporal resolution, spatial resolution, color capabilities and field of view of visual displays, and data transmission delays will delay feedback in response to operator control inputs.	Yes	1) Develop, with substantial validation and testing support, Minimum Operational Performance Standards for the suite of displays, controls, and onboard sensors that provide the UAS operator with the range of sensory cues considered necessary for safe unmanned flight in the national airspace. 2) Conduct further research and development in several areas, specifically, to:[3] a. Identify specific ways in which this sensory isolation affects UAS operator performance in various tasks and stages of flight. b. Explore advanced display designs which might compensate for the lack of direct sensory input from the environment. c. Examine the costs and benefits of multimodal displays in countering UAV operators' sensory isolation, and to determine the optimal design of such displays. d. Address the value of multimodal displays for offloading visual information processing demands. A related point is that multimodal operator controls (e.g., speech commands) may also help to distribute workload across sensory and response channels, and should be explored. e. Determine the effects of lowered spatial and/or temporal resolution and of restricted field of view on other aspects of UAS and payload sensor control (e.g., flight control during takeoff and landing, traffic detection). 3) Examine the design of displays to circumvent such difficulties, and the circumstances that may dictate levels of tradeoffs between the different display aspects (e.g., when can a longer time delay be accepted if it provides higher image resolution). Research has found, not surprisingly, that a UAV operators' ability to track a target with a payload camera is impaired by low	High (Tier 3)	RTCA, NASA, others?	Unknown

[2] Adapted from McCarley, J. & Wickens, C. (2005): pp1-3
[3] Ibid

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
					temporal update rates and long transmission delays **Update**: The ASTM F38 Executive Committee gap analysis characterized this as a low priority for F38. ASTM F3002-14a notionally addresses this gap. Some aspects will be covered in design and construction standards for large UAS (e.g., WK62670). No further action is anticipated by F38 at this time.			
77.	10.7	Human Factors in UAS Operations	**Gap P8: Flight Control Automation and System Failures**.[4] Standards are needed for the various forms of flight control automation, the conditions for which they are optimized, and the appropriate aircraft and operator response in the event of system failures. UAS operations differ dramatically in the degree to which flight control is automated. In some cases, the aircraft is guided manually using stick and rudder controls, with the operator receiving visual imagery from a forward looking camera mounted on the vehicle. In other cases, control is partially automated, such that the operator selects the desired parameters through an interface in the CS. In still other cases, control is fully automated, such that an autopilot maintains flight control using preprogrammed fly-to coordinates. Furthermore, the form of flight control used during takeoff and landing may differ from that used en route. The relative merits of each form of flight control may differ as a function of the time delays in communication between the operator and the UAS, as well as the quality of visual imagery and other sensory information provided to the operator from the UAS.	Yes	1) Develop standards and guidelines for the various forms of flight control automation, the conditions for which they are optimized, and the appropriate aircraft and operator response in the event of system failures. 2) Conduct further research and development to establish and optimize procedures for responding to automation or other system failures. For example, it is important for the UAS operator and air traffic controllers to have clear expectations as to how the UAS will behave in the event that communication with the vehicle is lost. Specific areas of R&D should include but not be limited to the following:[5] a. Determine the circumstances (e.g., low time delay vs. high time delay, normal operations vs. conflict avoidance and/or system failure modes) under which each form of UAS control is optimal. Of particular importance will be research to determine the optimal method of UAS control during takeoff and landing, as military data indicate that a disproportionate number of the accidents for which human error is a contributing factor occur during these phases of flight. b. Examine the interaction of human operators and automated systems in UAS flight. For example, allocation of flight control to an autopilot may improve the UAS operator's performance on concurrent visual mission and system fault detection tasks. c. Determine which of the UAS operator's tasks (e.g., flight control, traffic detection, system failure detection, etc.) should be automated and	High (Tier 1)	SAE A-6, S-18, ASTM, RTCA, others?	Unknown

[4] Adapted from McCarley, J. & Wickens, C. (2005): p3
[5] Ibid

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
					what levels of automation are optimal. The benefits of automation will depend on the level at which automation operates. For example, in a simulated UAS supervisory monitoring task, it can be reasonably expected that there will be different benefits for automation managed by consent (i.e., automation which recommends a course of action but does not carry it out until the operator gives approval) compared to automation managed by exception (i.e., automation which carries out a recommended course of action unless commanded otherwise by the operator). **Update**: ASTM F3002-14a notionally addresses this gap. Some aspects will be covered in design and construction standards for large UAS (e.g., WK62670). No further action is anticipated by ASTM F38 on human factors at this time. No other updates provided at this time.			
78.	10.7	Human Factors in UAS Operations	**Gap P9: Crew Composition, Selection, and Training**.[6] Standards are needed for human factors-related issues in the composition, selection, and training of UAS flight crews. UAS flight crews for BVLOS operations (whether short or long endurance, and/or low or high altitude) will typically comprise a minimum of two operators: one responsible for airframe control, and the other for payload sensor control. This and other multi-crew structures are based on research findings that the assignment of airframe and payload control to a single operator with conventional UAS displays can substantially degrade performance. Data also suggest, however, that appropriately designed displays and automation may help to mitigate the costs of assigning UAV and payload control to a single operator. It may even be possible for a single UAS operator to monitor and supervise multiple semi-autonomous vehicles simultaneously.	Yes	1) Develop standards and guidelines for human factors-related issues in the composition, selection, and training of UAS flight crews. 2) Conduct further research to:[7] a. Determine the crew size and structure necessary for various categories of UAS missions in the NAS, and to explore display designs and automated aids that might reduce crew demands and potentially allow a single pilot to operate multiple UASs simultaneously. b. Develop techniques to better understand and facilitate crew communications, with particular focus on inter-crew coordination during the hand off of UAS control from one team of operators to another. c. Examine standards for selecting and training UAS operators. There are currently no uniform standards for UAS pilot selection and training. While data indicate significant positive skills transfer from manned flight experience to UAS control, research is needed to determine whether such experience should be required of UAS operators, especially those engaged in conducting BVLOS operations. Research is also	High (Tier 2)	RTCA, NFPA, MITRE, NASA, ICAO others?	Unknown

[6] Adapted from McCarley, J. & Wickens, C. (2005): pp3-4
[7] Ibid

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)	Status of Progress
					necessary to determine the core content of ground school training for UAS operators, and to explore flight simulation techniques for training UAS pilots to safely conduct BVLOS operations in the NAS. **Update**: None provided at this time.			

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1. Introduction

1.1. Situational Assessment for UAS

While unmanned aircraft systems (UAS, aka "drones") have been around and used for military purposes for quite some time, their use in civil and public safety applications goes back a little over a decade ago. It is only within the last seven years that interest in commercial uses has emerged. Today, visions of a future where passenger-carrying "flying taxis" are part of the urban landscape is the subject of discussion at industry conferences and has begun to capture the popular imagination. Still, there remain many complex issues to be addressed in order for the potential of drone technology to be fully realized, most of which are centered around non-interference with manned aviation and ensuring the safety of the flying public and persons and property on the ground.

FAA Order 8130.34, Airworthiness Certification of Unmanned Aircraft Systems, dated 03/27/2008, enabled the first airworthiness certification of UAS. Section 332, Integration of Civil Unmanned Aircraft Systems into National Airspace System, of the FAA Modernization and Reform Act of 2012 (FMRA 2012) enabled 14 CFR part 107 rulemaking effort. A July 2018 Federal Aviation Administration (FAA) report on integrating UAS into the National Airspace System (NAS) reviews recent accomplishments and regulatory developments, collaborative relationships, public policy and technological challenges still to be overcome, ongoing work, and next steps.[8] Technology challenges are described as including: detect and avoid (DAA) methods to maintain a safe distance between UAS and other aircraft, especially with respect to minimum performance requirements for operations beyond visual line of sight (BVLOS) of the pilot; the command and control (C2) link between a UAS and its pilot; management of radio frequency (RF) spectrum for UAS operations; standards development; and airspace management. Public policy challenges include: continued educational efforts to promote safe UAS operations, physical security in relation to individuals operating with or without ill intent, cybersecurity, privacy, and adequate funding.

UAS are being deployed in a wide variety of sectors including construction, mining, agriculture, surveying, real estate, insurance, public safety, infrastructure, media, and entertainment. Market forecasts tend to vary depending on the segment evaluated and research methodology used. A 2019 market analysis by BIS Research found that "the global UAV market generated $25.59 billion in 2018 and is estimated to grow at a CAGR of 8.45% during the forecast period, 2019-2029."[9] Research and Markets reported in 2019 that "the global drone market will grow from $14 billion in 2018 to over $43 billion in 2024 at a CAGR of 20.5%."[10]

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[8] Federal Aviation Administration. Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap, Second Edition, July 2018.
[9] Global Unmanned Aerial Vehicle (UAV) Market - Analysis and Forecast 2019-2029 (accessed March 25, 2020)
[10] The Drone Delivery Report 2019-2024 (accessed March 25, 2020)

Clearly, there is considerable interest in UAS technology. Developing solutions in a consensus-based environment with the involvement of all interested and affected parties will result in the strongest possible solutions and help to realize the market's full potential.

1.2. Roadmap Background, Objectives, and Audience

During 2016-17, the American National Standards Institute (ANSI) had discussions with numerous stakeholders on standardization related to UAS and the potential need for coordination via an ANSI standardization collaborative. For one hundred years, ANSI has served as the administrator and coordinator of the United States private-sector voluntary standardization system. As a neutral facilitator, the Institute has a long track record of bringing public and private sectors together through its collaborative process to identify standardization needs for emerging technologies and to address national and global priorities in areas as diverse as: homeland security, electric vehicles, energy efficiency in the built environment, and additive manufacturing.

On May 19, 2017, ANSI convened a standardization collaboration meeting in Washington, DC involving close to seventy representatives from industry, trade associations, SDOs, federal agencies, coalitions, academia, et al. Presentations on UAS priorities were given by federal agencies, a representative of the Joint Authorities for Rulemaking on Unmanned Systems (JARUS), SDOs, and industry. The landscape of current known standardization activities was reviewed and it was clear that many participants were unaware of the breadth of activity taking place. The ANSI collaborative process was explained along with different options for its format. A draft mission statement, objectives, and deliverables were discussed. The outcome of the meeting was broad-based support for ANSI to establish the Unmanned Aircraft Systems Standardization Collaborative (UASSC) and undertake to develop a standardization roadmap for UAS. Details are provided in the May 19, 2017 meeting report.

ANSI formally announced the establishment of the UASSC on May 30, 2017. Because the primary focus of the effort was on the integration of drones in the U.S. NAS and was so closely tied to the U.S. regulatory environment, participation was open to UAS stakeholders that have operations in the United States. Broad participation was sought from all affected parties. ANSI membership was not a prerequisite to engagement in the collaborative and there was no fee to participate.

On September 28, 2017, the UASSC kick-off meeting was held in Washington, DC. Over eighty representatives from close to sixty organizations attended, including representatives of industry, trade associations, SDOs, government, and others. At the meeting, the following mission statement, deliverable, and objectives were approved:

> **Mission:** To coordinate and accelerate the development of the standards and conformity assessment programs needed to facilitate the safe integration of UAS into the NAS of the United States, with international coordination and adaptability
>
> **Deliverable:** A comprehensive roadmap developed over the course of a year describing the current and desired standardization landscape for UAS

Objectives:

- To foster coordination and collaboration among industry, standards developing organizations, regulatory authorities, and others on UAS standardization issues, including pre-standardization research and development (R&D)
- To clarify the current and future UAS standardization landscape and enable stakeholders to better focus standards participation resources
- To provide a basis for coherent and coordinated U.S. policy and technical input to regional and international audiences on UAS standardization
- To support the growth of the UAS market with emphasis on civil, commercial, and public safety applications

Much of the balance of the kick-off meeting was centered around how the UASSC would be organized to develop the roadmap (e.g., on airspace "use cases," on a risk-based regulatory approach, or on topical areas). An FAA representative gave a presentation on the current thinking regarding a classification scheme for airworthiness requirements and a risk-based operational integration strategy. During the ensuing discussion, four primary topical areas were identified: credentialing, airworthiness, operations/procedures, and airspace/infrastructure. It was agreed that level of risk and relevant concepts of operations (CONOPS)/uses cases would need to be considered. Breakout groups brainstormed on the most pressing issues requiring standardization in the topical areas. Details are provided in the September 28, 2017 kick-off meeting report.

The UASSC adopted the following working group (WG) structure, with the four WGs holding virtual meetings twice a month to develop the roadmap:

- **WG1 – Airworthiness Standards (Roadmap Chapter 6)**
  - Covers aircraft systems and communications with the control station (CS)
- **WG2 – Flight Operations Standards: General Concerns and Personnel Qualifications (Roadmap Chapters 7 and 10)**
  - Covers general flight planning and operational concerns, plus personnel training, qualifications, and certification
- **WG3 – Flight Operations Standards: Infrastructure Inspections, Environmental Applications, Commercial Services, and Workplace Safety (Roadmap Chapter 8)**
  - Covers application-specific operational concerns for vertical and linear infrastructure inspections, environmental applications, commercial services, and workplace safety
- **WG4 – Flight Operations Standards: Public Safety (Roadmap Chapter 9)**
  - Covers application-specific operational concerns for conducting public safety operations

On September 20, 2018, the UASSC held its second face-to-face meeting to review a first draft of the roadmap. Details are provided in the September 20, 2018 meeting report. Following a review and comment period, the WGs further refined the document and finalized it for publication.

The *Standardization Roadmap for Unmanned Aircraft Systems, Version 1.0*, was published in December 2018, representing the culmination of the UASSC's initial phase of work. The roadmap subsequently was promoted at industry events.

Throughout the process, the project was guided by a Steering Committee which typically met virtually on a monthly basis. In the lead-up to and following publication of the roadmap version 1.0, the Steering Committee discussed further developing the document and feedback on it. The Steering Committee also undertook a survey to rank the high priority gaps. Goals for a version 2.0 update were identified:

- Expand the topics covered (e.g., spectrum, recreational operations, urban air mobility, etc.)
- Bring in subject matter experts not previously involved
- Identify potentially overlooked issues and gaps
- Track progress to address the roadmap recommendations, including new or completed work
- Review priorities, noting the Steering Committee rankings of high priority gaps
- Incorporate participant feedback and update the document as appropriate

A kickoff meeting to launch this version 2.0 update of the roadmap was held on September 12, 2019. Details are provided in the September 12, 2019 meeting report. From October 2019 through March 2020, the working groups met virtually to update the document. The draft version 2.0 roadmap was released for public comment on April 1, 2020. Following the review of submitted comments by the working groups, the document was finalized for publication.

Ultimately, the goal of this roadmap is to coordinate and accelerate the development of UAS standards and specifications, consistent with stakeholder needs. The intent is to facilitate UAS integration into the NAS and to foster the growth of the UAS industry with emphasis on civil, commercial, and public safety applications.

The roadmap can thus be viewed as a tool designed to help focus resources in terms of participation by stakeholders in the planning and development of industry-wide standards and related R&D activities to the extent R&D needs are identified. It can also provide a basis for policy and technical discussions relating to alignment and harmonization internationally.

There are many potential audiences for this report including standards bodies (both U.S. based and others), certification bodies, trade associations, professional societies, manufacturers and suppliers, service providers, academia, Executive agency personnel, even Congressional members and their staff. It is generally assumed that those reading the document are directly affected stakeholders who have a basic understanding of UAS technologies.

The operation of UAS in indoor environments is outside the scope of this roadmap, as are policy recommendations.

1.3. Roadmap Structure

A summary of major changes from the roadmap version 1.0 can be found immediately following the Executive Summary in this document. That is followed by a breakdown of the identified gaps. Following that is a table summarizing the gaps and recommendations.

Chapter 2 of this document provides introductory context from FAA's perspective as regulator with information on intergovernmental cooperation with ICAO and JARUS.

Chapters 3-5 provide overviews of UAS activities from selected U.S. federal government agencies, private-sector SDOs, and industry stakeholders, respectively.

The gap analysis of standards and specifications is set forth in Chapters 6-10 of this document and maps to the WG structure noted above as follows: Chapter 6-WG1; Chapters 7 & 10-WG2; Chapter 8-WG3; Chapter 9-WG4. For each topic that is addressed, there is a description of the issue(s), identification of relevant published standards (and in a number of cases related regulatory requirements or guidance materials), as well as standards in development.

A "gap" is defined to mean that no *published* standard, specification, etc. exists that covers the particular issue in question. Where gaps are identified and described, they include an indication whether additional pre-standardization R&D is needed, a recommendation for what should be done to fill the gap, the priority for addressing the gap, and an organization(s) – for example, an SDO or research organization – that potentially could carry out the R&D and/or standards development based on its current scope of activity. Where more than one organization is listed, there is no significance to the order in which the organizations are listed.

Carryover gaps from roadmap version 1.0 retain their original numbering and now include a descriptor of the status of progress since the release of version 1.0 in December 2018. The status of progress is described as: Closed (completed) or, using a traffic light analogy, Green (moving forward), Yellow (delayed), Red (at a standstill), Not Started, Withdrawn, or Unknown. Any significant changes from version 1.0 are also summarized in a narrative update statement. New gaps for version 2.0 are identified as such, starting with the next number in sequence from version 1.0 for a particular section.

Each gap has been assessed and ranked using the criteria described in Table 1 below as being high, medium, or low priority. In terms of taking action to address the priorities, the desired timeframes for having a published standard available are as follows: high priority (0-2 years), medium (2-5 years), and low (5 + years).

Table 1: UASSC Prioritization Matrix (provided by ANSI)

Criteria (Make the C-A-S-E for the Priority Level)	Scoring Values
Criticality (Safety/Quality Implications). How important is the project? How urgently is a standard or guidance needed? What would be the consequences if the project were not completed or undertaken? A high score means the project is more critical.	3 - critical 2 - somewhat critical 1 - not critical
Achievability (Time to Complete). Does it make sense to do this project now, especially when considered in relation to other projects? Is the project already underway or is it a new project? A high score means there's a good probability of completing the project soon.	3 - project near completion 2 - project underway 1 - new project
Scope (Investment of Resources). Will the project require a significant investment of time/work/money? Can it be completed with the information/tools/ resources currently available? Is pre-standardization research required? A high score means the project can be completed without a significant additional investment of resources.	3 - low resource requirement 2 - medium resource requirement 1 - resource intensive
Effect (Return on Investment). What impact will the completed project have on the industry? A high score means there are significant gains for the industry by completing the project.	3 - high return 2 - medium return 1 - low return
Score Rankings **High** Priority (a score of 10-12) **Medium** Priority (a score of 7-9) **Low** Priority (a score of 4-6)	

Chapter 11 briefly describes next steps.

This roadmap is supplemented by the *UASSC Standards Landscape*, a list of standards directly or peripherally related to the issues described in the roadmap. Some though not all of the documents listed in this roadmap are included there and vice versa. Some documents apply to multiple sections. For sections 6.4, 6.4.3, and 9.3, the roadmap is supplemented by a list of additional published and in-development standards and related materials in the *UASSC Reference Document*.

1.4. Definitions

The regulatory authority for civil aviation in the United States is the FAA, part of the U.S. Department of Transportation (DOT). Some definitions that are relevant to this roadmap are defined in 14 CFR § 1.1 (except where noted):

Aircraft means a device that is used or intended to be used for flight in the air.

Unmanned aircraft means an aircraft operated without the possibility of direct human intervention from within or on the aircraft.

Unmanned aircraft system means an unmanned aircraft and associated elements (including communication links and the components that control the unmanned aircraft) that are required for the operator to operate safely and efficiently in the national airspace system. [49 USC § 44801(12)]

Small unmanned aircraft means an unmanned aircraft weighing less than 55 pounds on takeoff, including everything that is on board or otherwise attached to the aircraft.

Small unmanned aircraft system (small UAS) means a small unmanned aircraft and its associated elements (including communication links and the components that control the small unmanned aircraft) that are required for the safe and efficient operation of the small unmanned aircraft in the national airspace system.

Model aircraft means an unmanned aircraft that is:

(1) Capable of sustained flight in the atmosphere;

(2) Flown within visual line of sight of the person operating the aircraft; and

(3) Flown for hobby or recreational purposes.

According to the International Civil Aviation Organization (ICAO), in the 2003-04 timeframe, the term unmanned aerial vehicle (UAV) came to be used to describe “a pilotless aircraft, in the sense of Article 8 of the Convention on International Civil Aviation, which is flown without a pilot in-command on-board and is either remotely and fully controlled from another place (ground, another aircraft, space) or programmed and fully autonomous.”[11] In 2007, ICAO agreed to adopt the term “unmanned aircraft systems (UAS)” for consistency with technical specifications being developed within and coordinated between RTCA Inc. and the European Organisation for Civil Aviation Equipment (EUROCAE). An ICAO UAS Study Group (UASSG) was formed as a focal point to ensure global harmonization and interoperability. In 2009, the UASSG decided to focus its efforts on “remotely piloted aircraft systems (RPAS),” being of the view “that only unmanned aircraft that are remotely piloted could be integrated alongside manned aircraft in non-segregated airspace and at aerodromes.” In 2014, an RPAS Panel was established to continue the work begun by the UASSG. The term unmanned aircraft (UA) may refer to a remotely piloted aircraft, an autonomous aircraft, or a model aircraft. As used within this roadmap,

[11] International Civil Aviation Organization. *Manual on Remotely Piloted Aircraft Systems (RPAS).* Doc 10019, First Edition-2015.

unless otherwise specified, UA, UAV, and UAS are synonymous with remotely piloted aircraft and RPAS, respectively.

As used in this document, the term “standards” refers to voluntary consensus standards developed in accordance with the principles outlined in the World Trade Organization’s Technical Barriers to Trade Agreement, the National Technology Transfer and Advancement Act of 1995, OMB Circular A-119, and ANSI’s *Essential Requirements: Due process requirements for American National Standards*. These principles provide that the process for standards development must be consensus-based, open, have balanced participation, and include all the other elements that are the hallmarks of the U.S. standards system.

2. Federal Aviation Administration (FAA) and Intergovernmental Cooperation

2.1. Introduction

The mission of the Federal Aviation Administration (FAA) is to provide the safest, most efficient aerospace system in the world. The National Airspace System (NAS) is a complex national asset providing essential capabilities for the United States along with a critical medium for aviation, the traveling public, commerce, and national security.

The emergence of UAS technology triggered a broad range of applications in government, industry, academia, and recreational endeavors. The rapid growth of the UAS industry has created the need to ensure this new technology is safely integrated into the NAS. As with any rapidly advancing technology, successful integration of UAS into the NAS provides opportunities for innovation and growth, but also presents many challenges.

One such challenge is the standardization of UAS integration into the NAS. Standards are necessary, not only to enable FAA rulemaking efforts, but also to enhance the entire industry's ability to advance safely and efficiently while supporting FAA's Global Leadership roles and international capabilities. These UAS standards ensure a level playing field to support global fair trade and provide consumers the quality and safety they expect while supporting innovation and growth.

2.2. Operating Rules to Enable Current UAS Operations

The Small UAS Rule (Part 107) became effective on August 29, 2016. This was the first comprehensive regulation to enable routine small UAS operations in the NAS. Table 2 below represents the public, civil, and hobbyist options currently available for UAS and its operations and describes parameters associated with each method.

There are three baseline airspace related operating rules (Parts 91, 101 and 107) for UAS operations as of now that are needed to access the airspace/NAS. Depending on the type of UAS operations and missions, additional operating rules such as Parts 133, 135, 137, 121, etc. may also apply to UAS operations.

Table 2: Options for Current UAS Operation (provided by FAA)

Section/Part	Aircraft Requirements	Pilot Requirements	Airspace Requirements	Types of Operation
Part 107	UAS < 55 lbs.	Part 107 remote pilot certificate with small UAS rating	Airspace waiver or authorization for Class B, C, D, E airspace	VLOS, daytime, Class G, 400 ft., not over people (some regulations subject to waiver)
§44807 (was Section 333) (Part 91)	As specified in exemption	Part 61airman certificate	Blanket COA or Standard COA for specific airspace	UAS > 55 lbs.
Experimental Aircraft (Part 91)	Experimental Special Airworthiness Certificate	Part 61airman certificate	Standard COA for specific airspace	Research and development, crew training, market survey, showing compliance with regulations, and exhibition
Type Certificated Aircraft (Part 91)	Restricted type or special class certification	Part 61airman certificate	Part 91 airspace requirements	Specified in operating authorization
Public Aircraft (Part 91/107)	Self-certification by public agency	Self-certification by public agency	Blanket COA or Standard COA for specific airspace	Public Aircraft Operations (AC 00-1.1A); UAS Test Site operations
Section 336[12] Model Aircraft (Part 101)	UAS < 55 lbs.	See footnotes	See footnotes	See footnotes

Note: All UAS greater than 0.55 pounds aircraft must be registered (see part 47 and part 48 requirements).

The Small UAS Rule includes the option to apply for a certificate of waiver, allowing a small UAS operation to deviate from specific operating rules if the FAA determines the proposed operation may be

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More details found at https://www.faa.gov/uas/recreational_fliers/

Section 336 is superseded by FAA Reauthorization Act of 2018 (FAARA 2018; P.L. 115-254).

performed safely. During FY 2017 through FY 2020, thousands of requests for UAS waivers, airspace authorizations, and exemptions were received and processed.

2.3. The Movement Toward Full and Complete UAS Integration

The operational expansion of UAS envisioned by the FAA is illustrated in Figure 1 below, with the incremental UAS operational phases shown on the right, and associated airspace access and support capabilities shown on the left. Seven test sites collect and analyze operational and technical data to support safe UAS integration into the NAS.

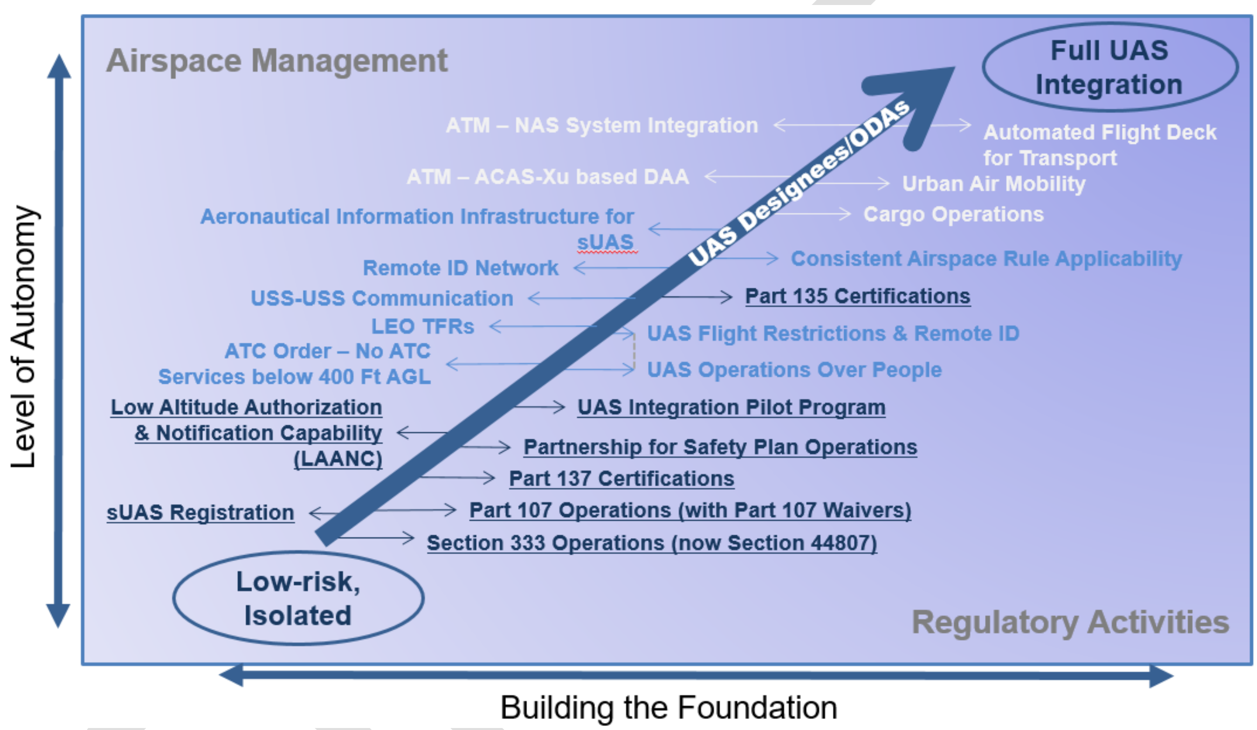

Figure 1: The Path to Full UAS Integration (provided by FAA)

2.4. International Outreach and Engagement

The integration of UAS into the existing aviation operational environment requires the development and introduction of new requirements to promote continued safety and efficiency around the world. Many countries (e.g., Switzerland, India, China, etc.) are currently confronting the challenge of developing a regulatory framework, supported by effective program implementation and oversight, for the safe integration of UAS into their respective domestic aviation systems. Collaboration with the international aviation community will guide the development of interoperable and harmonized UAS standards, policies, and regulations, support more seamless operations of UAS across national boundaries, and facilitate the cross-border movement of new products.

The FAA continually develops relationships with other Civil Aviation Authorities (CAAs) and international organizations to encourage global cooperation and information sharing. Additionally the FAA has conducted, and continues to conduct global outreach to communicate information on the FAA's UAS integration strategies and activities, and to acquire knowledge about other countries' UAS regulatory systems. International relationships will enable the FAA to develop and implement bilateral agreements and other cooperation mechanisms, encouraging harmonization of UAS certification, airworthiness, production and operational standards and oversight.

The two primary UAS-focused international bodies that the FAA participates in are the ICAO RPAS Panel and the JARUS. The ICAO RPAS Panel is composed of experts nominated by ICAO member states and international organizations. Among other things, the panel coordinates and develops ICAO standards and recommended practices for RPAS (UAS) integration. Similarly, JARUS is a group of international experts gathered to recommend requirements for use by civil aviation authorities around the world.

2.4.1. International Civil Aviation Organization (ICAO)

At the global level, States collaborate through the International Civil Aviation Organization (ICAO) to secure the highest practicable degree of uniformity in regulations, standards, procedures and organization in relation to aircraft, including unmanned aircraft, in all matters in which such uniformity will facilitate and improve air navigation.

ICAO works with its 193 Member States and industry groups to reach consensus on Standards and Recommended Practices (SARPs) for aviation, manned and unmanned. The SARPs developed by ICAO's Remotely Piloted Aircraft Systems Panel (RPASP) support IFR operations in controlled airspace and at controlled aerodromes.

The current focus of the RPASP is on airworthiness, operations, operator certification, air traffic management, C2 Link, detect and avoid (DAA), safety management and security. The Panel's work will also provide a context within which simplified regulations can be developed for less demanding national operations. Other aspects of international aviation regulation will also need to be addressed at the ICAO level to cater for unmanned aviation activities, including environmental protection, facilitation, economic regulation, as well as infrastructure funding and financing.

Every year, through its DRONE ENABLE symposia, ICAO brings together key stakeholders from government, industry, academia, and international organizations active in the unmanned aviation sector to exchange research, best practices, lessons learned and respective challenges.

2.4.2. Joint Authorities for Rulemaking on Unmanned Systems (JARUS)

JARUS is a group of experts gathering regulatory expertise from all continents of the world. At present, 61 countries, as well as the European Aviation Safety Agency (EASA) and EUROCONTROL, are contributing to the development of JARUS work products.

At the end of 2015, the Stakeholder Consultation Body (SCB), representing all industry communities of interest, was established to allow stakeholders the opportunity to support JARUS activities. SCB members representing aircraft manufacturers (e.g., AIA and ASD), the unmanned system Industry (e.g. AUVSI, UVSI and small UAV Coalition), ANSPs (e.g., CANSO and COCESNA), standardization bodies (e.g. ISO, EUROCAE and RTCA), airlines (e.g., IATA), and aviation associations (e.g., IAOPA, IBAC, IFALPA and IFATCA) joined the JARUS Plenary meeting for the first time in April of 2016.

Participation in JARUS is open to all regulatory authorities having expertise in unmanned aircraft systems (remotely piloted aircraft systems include). Industry participation in the SCB is also welcome.

The purpose of JARUS, as stated in its Terms of Reference, is to recommend a single set of technical, safety, and operational requirements for all aspects linked to the safe operation of the unmanned aircraft systems (remotely piloted aircraft systems include, UAS for short). This requires review and consideration of existing regulations and other material applicable to manned aircraft, the analysis of the specific tasks linked to UAS, and the drafting of material to cover the unique features of UAS. The JARUS publications aim to facilitate each authority to draft their own requirements and to avoid duplicated efforts.

In 2020, JARUS will consider a new work structure with the following program areas: 1) Automation Concept, 2) Operations and Organizations, 3) Airworthiness, and 4) Safety and Risk Management. The programs, if approved by the plenary, will be led by Working Group Leaders who coordinate the timing and execution of all interrelated work tasks they manage. Three major new work areas with tasks under one or more programs are Autonomy/Automation, UTM/U-Space, and Flight Rules.

The documents drafting and review process for deliverable products is described in the JARUS Terms of Reference under "JARUS deliverables development and approval process." JARUS conducts internal consultation to refine draft work products and make them ready for an external consultation from all interested parties. The external consultation is conducted on the JARUS website at: http://www.jarus-rpas.org/external-consultations. Final JARUS deliverables may be found at: http://www.jarus-rpas.org/publications.

JARUS is open on a voluntary basis to all national aviation authorities and industry stakeholders to make recommendations on operational, technical, and certification requirements. JARUS Working Group Leaders may also accept external advisors nominated by the SCB to provide the technical expertise required for each deliverable. This is a joint effort to share knowledge and provide harmonized requirements that help members establish their national/regional regulatory frameworks.

JARUS needs the support of experienced aviation experts and is committed to limiting travel by holding virtual meetings using IT tools such as Webex, teleconferencing, SharePoint, etc. However, the bi-annual JARUS plenary meetings are intended to be face-to-face. Other face-to-face meetings within work programs may occur when the tasked Working Group has agreed it is necessary to make progress in the development of the assigned activity.

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3. Overviews of Other Selected U.S. Federal Government Agency Activities

3.1. Department of Homeland Security (DHS)

Unmanned aircraft systems (UAS), commonly known as drones, continue to change and challenge the homeland security landscape. There have been significant changes in the policy, use, testing and other aspects related to UAS use in the past year. Department of Homeland Security (DHS) operational components—such as the U.S. Coast Guard, the Federal Emergency Management Agency (FEMA), and others—employ UAS for several purposes. UAS allow operators to monitor remote locations, improve situational awareness, and are a critical tool in emergency response such as search and rescue. However, UAS can also be used for illegal activities. The Department of Homeland Security and the DHS Science and Technology Directorate (S&T) are tackling these challenges by researching ways to protect against UAS-based threats and ways to make UAS more usable for the Homeland Security Enterprise. Through this multifaceted approach, DHS is helping to protect against nefarious UAS use while researching operational use for homeland security officials.

One major development, the Preventing Emerging Threats Act of 2018, grants DHS statutory authority to counter credible threats from UAS to the safety or security of a covered facility or asset. This authority is paramount to the Department's mission to protect and secure the Homeland from evolving threats. The Department is in the process of coordinating with Components and stakeholders regarding the need for additional counter-UAS authorities. More information on DHS counter UAS efforts can be found at https://www.dhs.gov/sites/default/files/publications/dhs_cuas-legal-authorities_fact-sheet_190506-508.pdf and at https://www.dhs.gov/sites/default/files/publications/Counter%20UAS%20Factsheet.pdf .

DHS is actively participating in several interagency UAS activities, ranging from developing policy and guidance for the procurement and use of UAS, to cybersecurity issues and concerns, and UAS and critical infrastructure. The DHS Cybersecurity and Infrastructure Security Agency (CISA) is taking a lead in many of these activities, more information can be found at https://www.cisa.gov/publication/uas-fact-sheets . Additionally, DHS S&T is working closely with NASA, FAA and other agencies to develop a capability to manage national airspace UAS traffic in the future, called the Unmanned Aircraft Systems (UAS) Traffic Management (UTM) infrastructure. More information on the UTM can be found at https://www.dhs.gov/science-and-technology/news/2019/02/12/snapshot-working-nasa-secure-drone-traffic .

DHS Science and Technology Directorate (S&T) established test sites to support UAS demonstrations, operational testing, and training. The site at Camp Shelby, Mississippi includes outdoor space and building facilities for land-based testing and training with UAS and robots. The facility at Singing River Island, Pascagoula, Mississippi is used for maritime-based UAS and related operations. The National

Urban Security Technology Laboratory (NUSTL) in New York, conducts tests, evaluations, and operational assessments of homeland security technologies, including UAS, for the national first responder community. The NUSTL First Responder Robotic Operations System Test (FRROST) program conducts assessments of UAS in various operational scenarios. Details on the FRROST program is at https://www.dhs.gov/science-and-technology/saver/st-small-unmanned-aircraft-systems-search-and-rescue-frrost

DHS S&T is continuing the development of a suite of standardized test methods, designed to evaluate and measure key UAS performance parameters through research and test method development at the National Institute of Standards and Technology (NIST). The standards are published and promulgated through ASTM, International. The standard test methods are used to quantifiably measure robot maneuvering, mobility, sensors, energy, radio communication, dexterity, durability, reliability, logistics, safety, autonomy, and operator proficiency. These standard tests use tangible, repeatable measurements to ensure operator confidence in the capability of the system, while building operator familiarity and skill. These test methods are adopted by numerous organizations around the world and have informed over $100 million in response robot procurements. These test methods also support the training of UAS and response robot operators, are incorporated and adopted by several organizations as part of their UAS operator training and certification programs. More information on the standardized test methods can be found at https://www.dhs.gov/publication/st-can-your-response-robot-really-do-fact-sheet-and-video .

This very short summary just touches on few areas of DHS engagement in UAS-related activities. For more information on S&T activities, please visit https://www.dhs.gov/science-and-technology/unmanned-aerial-systems. For information on DHS UAS activities, visit https://www.dhs.gov/publication/uas-fact-sheets or go to https://www.dhs.gov/publications and search for "UAS" to access other documents.

3.2. Department of the Interior (DOI)

The U.S. Department of the Interior (DOI) is a Cabinet-level agency that manages America's vast natural and cultural resources. The department employs some 70,000 people, including expert scientists and resource-management professionals, in nine technical Bureaus:

- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Ocean Energy Management
- Bureau of Reclamation
- Bureau of Safety and Environmental Enforcement
- National Park Service
- Office of Surface Mining Reclamation and Enforcement
- U.S. Fish and Wildlife Service
- U.S. Geological Survey

DOI manages nearly 20% of the land in the United States and has nearly every use case for UAS in its portfolio. The department has an extensive need for remote sensing data for those use cases. Beginning in 2009, in conjunction with the Bureaus, the DOI Office of Aviation Services began its programmatic planning for the use of UAS for DOI missions. In 2010, DOI acquired over $20M in excess U.S. Department of Defense (DOD) equipment to begin testing and evaluation of whether or not they would support the DOI mission. Over the next several years, DOI operated the excess military equipment on a variety of missions. In the testing of the excess DOD equipment, it became clear that DOI needed more and different sensors than were available on the DOD aircraft. This led the Department to search for commercial off-the-shelf (COTS) solutions that would allow for the development of many different payloads. In 2016, DOI awarded its first contract for drone operations and today has a fleet of nearly 400 small UAS nationwide. In addition, DOI operates a vertical take-off and landing (VTOL) fixed wing aircraft and has contracts with several vendors for the support of emergency missions. Since the inception of the DOI UAS program there have been over 17,000 flights and in FY18 alone DOI conducted over 10,000 flights across the U.S. The goal of the DOI UAS program is to maintain standardization of UAS platforms while building a variety of payloads. DOI has developed or used over 30 different payloads on the four models of fleet aircraft it currently operates. The roadmap for DOI over the next several years will be to increase the availability of low cost UAS solutions for the Bureaus, increase availability of contractor provided services and continue to find new and innovative ways to conduct the many missions of the Department.

3.3. International Trade Administration (ITA)

The International Trade Administration (ITA) strengthens the competitiveness of U.S. industry, promotes trade and investment, and ensures fair trade through rigorous enforcement of trade laws and agreements. ITA has more than 1,500 employees assisting U.S. exporters in 108 U.S. locations and in 78 markets worldwide. More information is available on ITA's website.

I&A UAS-Related Equities

The Industry & Analysis Aerospace Team has roles in both domestic and international development of the Unmanned Aircraft System market. To begin with, I&A serves as a gateway for industry to interact with relevant USG agencies (such as FAA, TSA, and NASA) as well as the parts of Commerce directly involved in the development of UAS policies, procedures, operations, and standards (such as NIST and NTIA).

Moreover, the Director of the I&A Office of Transportation and Machinery regularly represents ITA/Commerce on the UAS Executive Committee (EXCOM), an interagency body hosted by the FAA to coordinate UAS policies across the USG. The UAS EXCOM membership consists of representatives of the FAA, DOD, Commerce, Justice, DHS, Interior, and NASA. The EXCOM oversees rulemaking, addresses specific issues such as Counter-UAS threats and solutions, and identifies research gaps. ITA is working with the interagency on strengthening the industrial base for UAS through EXCOM discussions and multiple other avenues.

On a regular basis, I&A addresses factors that affect the competitiveness of U.S. products, including export control issues. For instance, the U.S. is a member of the Missile Technology Control Regime (MTCR), which seeks to limit the risks of proliferation of weapons of mass destruction by controlling transfers that could contribute to delivery systems for such weapons (other than manned aircraft). As currently written, MTCR regards larger UAS (with a range exceeding 300km and/or a payload exceeding 500kg) as part of Category I. Category I items face a strong presumption of denial of export to anyone except allies.

In discussions with officials from the Bureau of Industry and Security (BIS), I&A determined that certain UAS have the possibility of being reclassified to allow for freer exports. BIS has indicated that they are working with their international partners on providing Category II treatment for a certain subset of UAS with a yet-to-be-determined maximum speed value (as well as associated parts and components).

U.S. export controls reflect the reality of MTCR such that a great number UAS components and complete systems require licensing in order to export (either the more restrictive International Traffic in Arms Regulations (ITAR) process governed by State or the less onerous process for products on the Commerce Control List or designated as falling under the Export Administration Regulations (EAR). Continued movement of UAS-related products from ITAR to the CCL/EAR will be dependent on changes to MTCR that allow governments to shift more UAS out of Category I.

3.4. National Aeronautics and Space Administration (NASA)

UAS Traffic Management (UTM)

NASA’s Ames Research Center in California’s Silicon Valley has set out to create a research platform that will help manage drones flying at low altitude (e.g. below 400 ft.) along with other airspace users. Known as UAS Traffic Management (UTM), the goal is to create a system that can integrate drones safely and efficiently into air traffic that is already flying in low-altitude airspace. That way, package delivery and recreational flights won’t interfere with helicopters, nearby airports, or even public safety drones being flown by first responders helping to save lives.

The system will be a bit different than the air traffic control system used by the FAA for today’s commercial airplanes. UTM will be based on digital sharing of each user's planned flight details. Each user will have the same situational awareness of airspace, unlike what happens in today’s air traffic control. The multi-year UTM project continues NASA’s long-standing relationship with the FAA. Throughout the collaboration, NASA Ames has provided research and testing to the agency, which will ultimately put this knowledge to use in the real world. NASA leads the UTM project along with dozens of partners across various industries and academia who are committed to researching and developing a safe platform.

How does the research work?

UTM research is broken down into four phases called TCLs, technology capability levels, each with specific technical goals that help build up the system as the research progresses.

TCL1: Successfully completed in August 2015 and serving as the starting point of the platform, researchers conducted field tests addressing how drones can be used in agriculture, firefighting, and infrastructure monitoring. The researchers also worked to incorporate different technologies to help with flying the drones safely such as scheduling and geofencing, which is an invisible flight zone assigned to each small aircraft.

TCL2: Successfully completed in October 2016 and focused on monitoring drones that are flown in sparsely populated areas where an operator can't actually see the drones they're flying. Researchers tested technologies for on-the-fly adjustment of areas that drones can be flown in and clearing airspace due to search-and-rescue (SAR) or for loss of communications with a small aircraft.

TCL3: Successfully completed in 2018 with flight demonstration tests conducted at six test sites between May and June. These sites were in Alaska, Nevada, New York, North Dakota, Texas, and Virginia. Approximately 40 partners participated, completing shakedowns and flight tests. All sites connected to the UTM system and testing was coordinated from the Airspace Operations Lab at NASA Ames Research Center.

TCL4: Successfully completed In August 2019 when NASA successfully concluded simulaneous flight operations of multiple small UAS over complex urban environments. TCL4 flight demonstration tests were carried out with 35 partner organizations, from May through August, at Reno, Nevada, and Corpus Christi, Texas.

FAA's operational Low Altitude Authorization and Notification Capability (LAANC) system for enabling small UAS operations expanded to 21 industry service suppliers and approximately 600 airports in 2019. The Notice of Proposed Rulemaking governing the remote identificaiton of small UAS was also published in 2019.

After the research is completed and the results are compiled, NASA will then transfer the findings to the FAA for implementation. This partnership between research and regulatory agencies, along with the input of thousands of experts and users will set the stage for a future of a well-connected sky. Drones will offer many benefits by performing jobs too dangerous, dirty, or dull for humans to do, and NASA is helping to navigate to that future.

More information about the UTM program is available at https://utm.arc.nasa.gov/index.shtml

UAS Integration in the NAS (UAS-NAS)

To address UAS-NAS integration technical challenges, NASA initiated the UAS integration in the NAS (UAS-NAS) Project within the Integrated Aviation Systems Program of the Aeronautics Research Mission Directorate in 2010. The UAS-NAS Project approach was to contribute research findings to reduce technical barriers related to the safety and operational challenges associated with enabling routine UAS access to the NAS in technology areas aligned with current NASA expertise and capabilities. Unlike the research activity of UTM, the goal of UAS-NAS is to develop and test specific technologies leading to the operational integration of UAS into the NAS and providing specific research findings to inform the RTCA-developed Minimum Operational Performance Standards (MOPS) for flights above 500 feet. The technology development is coordinated with the FAA through a Research Transition Team. The Project consists of two phases, with Phase 1 having a Part 1 from FY11 – FY13, and a Part 2 from FY14 - FY16. Phase 2 of the Project was initiated in FY17 and will run through the end of calendar year 2020. By the end of the project, NASA will have invested nearly $300M in support of technology and standards development.

How does the research work?

Phase 1 - Part 1 included development and integration of system-level key concepts, technologies, and procedures based on UAS stakeholder and community needs collected during UAS-NAS Project formulation. This phase also included refinement of those needs as part of defining the specifics of the Phase 1 - Part 2 research portfolio. Phase 1 - Part 1 research activities were continued in Phase 1 - Part 2 and modified as necessary based on the research portfolio. Phase 1 - Part 2 of the Project included demonstration of the integrated technologies in operationally-relevant environments. The technology areas selected for Phase 1 - Part 2 included Detect and Avoid (DAA), Command and Control (C2), Human Systems Integration (HSI), and Integrated Test and Evaluation (IT&E) for Live, Virtual, Constructive - Distributed Environment (LVC-DE) development. By using a rigorous research selection process, the contribution of the Project Phase 1 - Part 2 research activities to the development of RTCA SC-228 Phase 1 DAA and C2 MOPS, as well as providing foundational research associated with full integration of UAS into the NAS, was maximized.

Phase 2 of the Project was formulated simultaneously with the final year of execution for Phase 1 - Part 2. The technology areas selected for Phase 2 include DAA, C2, and Systems Integration and Operationalization (SIO). The DAA and C2 research findings will inform RTCA SC-228 Phase 2 MOPS, and the SIO activity will culminate in an operational demonstration with numerous operational concepts in the summer of 2020. The research findings from the SIO demonstration will be coordinated with the FAA with the intent of informing an accelerated UAS type-certification process.

<u>Resilient Autonomy (RA)</u>

Resilient Autonomy (RA) is an activity initiated at Armstrong Flight Research Center several years ago which was recently jointly funded under a DOD Joint Capabilities Technology Demonstration (JCTD) with investments from NASA, DOD, and industry. The goal of RA is to provide improved autonomous safety capabilities for a range of UAS. RA has a very close connection with the FAA and is structured to establish an FAA certification process for increasing levels of autonomy on UAS. Standards work is being coordinated through both the FAA and ASTM. RA will continue through the summer of 2021 with final deliverables including an Expandable Variable-Autonomy Architecture (EVAA), EVAA software, flight-test artifacts to support safe integration of increasingly automated UAS, and a plan which informs certification strategies and architecture best practices for increasingly automated aircraft (both manned and unmanned).

How does the research work?

RA will take a stepwise approach to informing the UAS certification process by first looking at a Part 23 vehicle with increasing levels of autonomy during FY19. Flight-test artifacts will be infused into the Part 23 certification process to assess the impact of increased levels of autonomy. During FY20, collections of flight-test artifacts will be used to develop a crosswalk between Part 23 and an improved certification process for increasing levels of autonomy on a UAS. RA will culminate in an operational demonstration of a mission using high levels of automation conducted in the NAS during the fall of 2021. RA will deliver a certification guide for increasingly automated aircraft, and a gap analysis of additional work needed by NASA, FAA, and industry to enable routine access for fully automated aircraft into the NAS.

3.5. National Institute for Occupational Safety and Health (NIOSH)

The National Institute for Occupational Safety and Health (NIOSH) is a research agency focused on the study of worker safety and health, and empowering employers and workers to create safe and healthy workplaces. NIOSH is part of the U.S. Centers for Disease Control and Prevention, in the U.S. Department of Health and Human Services. It has the mandate to assure “every man and woman in the Nation safe and healthful working conditions and to preserve our human resources.”

NIOSH established the Center for Occupational Robotics Research (CORR) in September 2017 to provide scientific leadership to guide the development and use of occupational robots that enhance worker safety, health, and well-being. The Center includes multidisciplinary scientists from across NIOSH.

The Center works in partnership with academic researchers, trade associations, robotics manufacturers, employers using robotics technology, labor organizations, and other federal agencies. The Center focuses on:

- the potential of robotics technology to prevent worker injuries and musculoskeletal disorders. The Center addresses traditional robots and emerging technologies such as collaborative robots, mobile robots, exoskeletons, and remotely controlled or autonomous vehicles and drones.
- increasing understanding of human and robot interactions to ensure human worker safety.
- improving the ability to identify and track injuries involving robotics technologies.
- providing guidance on working safely with robotics technologies.

Unmanned aircraft systems (UAS) have the potential to reduce rates of injury and death in the workplace. However, as is the case with other emerging technologies, occupational safety assessments of UAS lag behind technological advancements. UAS may create new workplace hazards that need to be evaluated and managed to ensure their safe operation near workers. A 2017 paper from the NIOSH in the American Journal of Industrial Medicine *UAVs in Construction and Worker Safety* describes the four major uses of UAS (military, public, recreational and commercial), the potential risks of their use to workers, approaches for risk mitigation, and the important role that safety and health professionals can play in ensuring safe approaches to their occupational use. NIOSH has set the stage for future research by incorporating research needs related to drones into its Strategic Plan and a contract to develop and test autonomous drone navigation in dark underground mining environments. See also section 8.5 of this roadmap on Occupational, Safety and Health.

3.6. National Institute of Standards and Technology (NIST)

NIST promotes U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve the quality of life. NIST is a non-regulatory agency of the U.S. Department of Commerce. More information is available on NIST's website.

Standard Test Methods for UASs in the Public Safety Sector (Ongoing)
NIST is developing the measurement and standards infrastructure necessary to evaluate robotic capabilities for emergency responders and military organizations addressing critical national security challenges. This includes leading the development of a comprehensive suite of *ASTM International Standard Test Methods for Response Robots*. The aerial suite includes 20 draft standard test methods for evaluating small UAS with the initial emphasis on vertical take-off and landing (VTOL) systems and small hand-launched fixed wing systems. For the VTOL systems, testing and practice starts within netted aviaries indoors and outdoors to avoid issues of flying in the national airspace. The test methods measure essential capabilities of robots and operator proficiency for hazardous missions defined by emergency responders and soldiers.

These test methods and performance metrics developed by NIST will allow small unmanned aircraft systems (sUAS) and aerial system pilots to get comprehensively evaluated and quantitatively compared prior to deploying into more operationally significant scenarios involving mock villages and cities with scripted scenarios. Embedded standard test apparatuses within the scenarios enable the periodic measurement of performance to capture degradations that may occur due to environmental variables such as shadows, smoke, etc. In addition, these tests include those for navigating hallways within buildings, searching and mapping wide areas, and avoiding situations that may interfere with radio communications.

NIST's test methods and performance metrics are contributing to a new strategic collaboration between the National Fire Protection Association (NFPA) and ASTM International. ASTM will standardize the underlying test methods. NFPA will select various combinations of those test methods representing essential mission capabilities to define sUAS equipment standards for public safety operations. Specifically, the new standard NFPA® 2400, Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations includes a suite of 10 aerial test methods developed by NIST that quantitively measure both the system capabilities of the drove and the proficiency of the pilot in carrying out five basic maneuvers, including accurate landing, vertical climbing, and straight and level flying. There also are five functionality test methods, including circular orbits to identify objects from afar and spiral maneuvers to conduct close-range inspections.

Additional information is available on the NIST Intelligent Systems Division, Standard Test Methods for Response Robots, Aerial Systems webpage.

NIST Grants (Use of UAVs/UASs in Emergency Situations)

In addition to the investment in the development of test methods for UAS, NIST has invested research funding into improvements and the use of UAS for applications in the public safety sector. NIST has also used UAS to collect data, such as during wildland fire research. The following are examples of grants released by NIST specific to the application of UAS.

2018 UAS Flight and Payload Challenge

NIST designed a competition to support field operations of UASs for first responders. One of the barriers for UAS used in a public safety realm is payload versus flight time. VTOL of a UAS provides many different mission capabilities, but their flight time is limited. The payload capacity, energy source, and flight time are linked through design trade-offs that can be optimized for efficiency and flexibility. With these parameters in mind, this challenge was designed to help public safety operations by keeping a UAS and its payload airborne for the longest time possible with vertical and hovering accuracy. Additionally, at a cost of less than $20,000 per UAS, this challenge shows first responders that there may someday be an affordable drone in their toolkit to carry wireless networks for search and rescue (SAR) operations. Additional information can be found on the 2018 UAS Flight and Payload Challenge webpage.

Improving Disaster Resilience through Scientific Data Collection with UAV Swarms

The University of California, San Diego (San Diego, California), received a grant for $749,924 from NIST to develop a method by which a "swarm" of UAVs can be used to collect field data on the health of structures and infrastructure lifelines (such as water, electrical, and gas) before, during, and after a natural disaster. This grant was part of NIST's Disaster Resilience Research Grants Program and noted along with other funded projects in an August 2, 2017 NIST news item.

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4. Overviews of Private-Sector Standards Development Organization Activities

4.1. 3rd Generation Partnership Project (3GPP)

The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations: Association of Radio Industries and Businesses (ARIB), Alliance for Telecommunications Industry Solutions (ATIS), China Communications Standards Association (CCSA), European Telecommunications Standards Institute (ETSI), Telecommunications Standards Development Society India (TSDSI), Telecommunications Technology Association (TTA), and Telecommunication Technology Committee (TTC). These are known as “Organizational Partners” and 3GPP provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies.

The original scope of 3GPP (1998) was to produce Technical Specifications and Technical Reports for a 3G Mobile System based on evolved Global System for Mobile (GSM) core networks and the radio access technologies that they support (i.e., Universal Terrestrial Radio Access (UTRA) both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes).

This scope was then expanded to include the maintenance and development of the GSM communications Technical Specifications and Technical Reports including evolved radio access technologies (e.g., General Packet Radio Service (GPRS) and Enhanced Data rates for GSM Evolution (EDGE)).

The 3GPP's scope was subsequently amended to include the specification of 4G Mobile System (aka LTE or EPS) and then 5G, which is the bulk of current 3GPP activities.

The project covers cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities – including work on codecs, security, quality of service (QoS) – and thus provides complete system specifications. The specifications also provide hooks for non-radio access to the core network, and for interworking with Wi-Fi networks.

3GPP specifications and studies are contribution-driven by member companies. The 3GPP structure consists of sixteen Working Groups (WGs), each one covering a dedicated topic (e.g., Radio Layer 1, codecs). These WGs have one to two meetings per quarter. Once per quarter the WGs officials meet and report to three Technical Specification Groups (TSG) where their work is presented for information, discussion, and approval.

The three TSGs in 3GPP are: Radio Access Networks (RAN), Services & Systems Aspects (SA), and Core Network & Terminals (CT).

Each TSG has a particular area of responsibility for the Reports and Specifications within its own Terms of Reference (details available in the Specification Groups pages). The last meeting of the cycle of plenary meetings is TSG SA, which also has responsibility for the overall coordination of work and for the monitoring of its progress.

The 3GPP technologies from these groups are constantly evolving through Generations of commercial cellular / mobile systems. Since the completion of the first LTE and the Evolved Packet Core specifications, 3GPP has become the focal point for mobile systems beyond 3G.

Although these Generations have become an adequate descriptor for the type of network under discussion, real progress on 3GPP standards is measured by the milestones achieved in particular Releases. New features are ’functionality frozen’ and are ready for implementation when a Release is completed. 3GPP works on a number of Releases in parallel, starting future work well in advance of the completion of the current Release. Although this adds some complexity to the work of the groups, such a way of working ensures that progress is continuous and stable.

Normative work related to UAS is targeted for Release 17, to be published by the second half of 2021. Previous Releases 15 and 16 covered preliminary studies.

The following standards, technical reports, and other documents related to unmanned systems are in development or published from 3GPP:

Published Documents:
• 3GPP TR 36.777, Study on Enhanced LTE Support for Aerial Vehicles (V15.0.0, Release 15)
• 3GPP TR 22.825, Study on Remote Identification of Unmanned Aerial Systems (V16.0.0, Release 16)
• 3GPP TS 22.125, Unmanned Aerial System (UAS) support in 3GPP (V16.3.0, Release 16 and V17.1.0, Release 17)

In-Development Documents:
• SP-181252 Rel-17 Work Item “Study on application layer support for Unmanned Aerial System (UAS)” (FS_UASAPP)
• SP-181114 Rel-17 Work Item “Study on supporting Unmanned Aerial Systems Connectivity, Identification, and Tracking” (FS_ID_UAS_SA2)

4.2. Airborne Public Safety Accreditation Commission (APSAC)

The Airborne Public Safety Accreditation Commission (APSAC, formerly the Public Safety Aviation Accreditation Commission) was created in 2004 to establish standards for manned law enforcement aviation programs. Standards for fire and SAR aviation programs have been added to the original law enforcement standards. The National Transportation Safety Board (NTSB) recognizes the APSAC standards for manned aviation as the industry standards for public safety aviation.

The Airborne Public Safety Association (APSA, formerly the Airborne Law Enforcement Association) sponsored the development of sUAS standards to be added to existing manned aviation standards . A committee of experienced law enforcement and fire safety personnel held their first meeting in December 2016. Unlike manned aviation standards, UAS standards also address the legal and ethical use of the technology. The final version of the standards was released in October of 2017.

The standards contain five sections:

1) Administrative Matters
2) Operational Procedures
3) Safety
4) Training
5) Maintenance and Minimum System Requirements

More information is available on the APSAC website.

4.3. American Society of Mechanical Engineers (ASME)

ASME helps the global engineering community develop solutions to real world challenges. Founded in 1880 as the American Society of Mechanical Engineers, ASME is a not-for-profit professional organization that enables collaboration, knowledge sharing, and skill development across all engineering disciplines, while promoting the vital role of the engineer in society. ASME codes and standards, publications, conferences, continuing education, and professional development programs provide a foundation for advancing technical knowledge and a safer world. More information is available on ASME's website.

Use of UAS for Inspection

ASME has formed the Use of UAS for Inspection Subcommittee under the Mobile Unmanned Systems (MUS) Standards Committee tasked to develop a standard that provides the requirements for utilization of UAS to safely and reliably perform visual inspection of fixed equipment including pressure vessels, tanks, piping systems, and other components considered part of the critical infrastructure to obtain quality data and repeatable results. The intent of this standard, regardless of the industry, is not to re-define the inspection acceptance criteria but to define the requirements to use a UAS to perform the inspection in accordance to the acceptance criteria selected by the user. This standard is intended for pilot-operated UAS applications for VLOS and BVLOS.

The standard consists of the following table of contents sections: scope, general definitions, purpose of inspection, preparation for inspection, equipment for inspection, duties and responsibilities, conducting inspections, and documentation. The committee membership consists of 24 subject matter experts in nondestructive testing (NDT) and UAS/UAV, with more than 40 interested party individuals. The committee meets four times per year in-person at the ASME Boiler and Pressure Vessel Code Week and holds 2-3 teleconferences in-between meetings.

This standard provides the basis of using a UAS safety and reliably and can be applied for inspection of most (if not all) critical infrastructure, e.g., pipelines, wind turbines, solar arrays, hydro dams, etc.

There is a similar effort ongoing with the B30 committee on cranes and derricks for the use of UAS for inspections of cranes. The UAS content will be added to the B30 Standard as a separate volume ASME B30.32-20XX, *Unmanned Aircraft Systems (UAS) used in Inspection, Testing, Maintenance and Material Lifting Operations*. This new standard will provide requirements and recommendations that address the use of UAS to support inspecting, maintaining, and operating cranes, and other material handling equipment of the ASME B30 Series of Standards.

The ASME B30.32 subcommittee that was established to develop the standard consists of 16 subject matter experts and reports to the ASME B30 Standards Committee, which has many volunteer experts from the crane and material handling industry. The subcommittee currently plans to meet 6-8 times over the next year.

4.4. American Society of Safety Professionals (ASSP)

The American Society of Safety Professionals (ASSP), formerly known as ASSE, is a global association for occupational safety and health professionals. For more than 100 years, ASSP has supported occupational safety and health (OSH) professionals in their efforts to prevent workplace injuries, illnesses, and fatalities. ASSP provides education, advocacy, standards development, and a professional community to their members in order to advance their careers and the OSH profession as a whole.

ASSP, as secretariat for the ANSI Accredited A10 Committee for Construction and Demolition Operations, continues to receive requests for information addressing the use of drones. From the secretariat perspective most of the drones used for safety related purposes appear to involve construction and demolition operations and/or mining and natural resources. Accordingly, the A10 Committee approved the creation of an ASSP A10 ASC Technical Report (to be registered with ANSI) addressing practices for the safe use of drones for construction and demolition operations. The report is expected to be published in the summer of 2019.

4.5. ASTM International (ASTM)

ASTM International (ASTM) is a globally recognized leader in the development of voluntary consensus standards. Today, over 12,000 ASTM standards are used around the world to improve product quality, enhance safety, strengthen market access and trade, and build consumer confidence. ASTM welcomes and encourages participation from around the world.

ASTM’s leadership in international standards development is driven by the contributions of its members: more than 30,000 of the world’s top technical experts and business professionals representing 140 countries. Working in an open and transparent process and using ASTM’s advanced information technology (IT) infrastructure, ASTM members create the tools that support industries and governments worldwide.

ASTM's 150 technical standards-writing committees serve a broad range of industries: aerospace, infrastructure, public safety personnel, consumer products, and many more. When new industries — such as nanotechnology, additive manufacturing, and robotics — look to advance the growth of cutting-edge technologies through standardization, many of them come to ASTM International.

Beyond standards development, ASTM offers certification and declaration through its subsidiary, the Safety Equipment Institute, as well as technical training programs and proficiency testing. All of ASTM's programs complement its standards development activities and provide enterprise solutions for companies, government agencies, researchers, and laboratories worldwide.

ASTM UAS Portfolio

ASTM International's portfolio of UAS standardization activities extends from the platform and software needs, operational and use, personnel and maintenance, all the way to user community applications. With ASTM's broad sector reach, industry has the ability to leverage UAS expertise and integrate it into long-standing and accepted procedures.

ASTM's manned aircraft committees offer a wide selection of standards that can serve as demonstrated means of compliance to the increasing risk-based regulatory approach of global civil aviation authorities. Depending on the aircraft category or risk class, ASTM standards offer a selection of resources to meet user needs.

At the same time, ASTM standards can help users meet local to international codes, insurance policies or even contractual needs. ASTM standards have commonly been referenced by various regulations and voluntary programs worldwide. With ASTM standards as the baseline of these various programs and regulations, industry can rely on one set of procedures across the NAS.

A detailed roadmap listing specific UAS related standards is maintained on the ASTM F38 website.

ASTM UAS Related Activities

F38 Unmanned Aircraft Systems

This Committee addresses issues related to design, performance, quality acceptance tests, operational applications, personnel, and safety monitoring for UAS. Stakeholders include manufacturers of UAS and their components, federal agencies, design and maintenance professionals, commercial services providers, trade associations, financial organizations, and academia. Three subcommittees support F38.

A *Full Listing of Standards and Work Items* is on the F38 website; its subcommittees are as follows:

- F38.01 Airworthiness: *Product related – platform, system, hardware, software, devices, components*
- F38.02 Flight Operations: *Operations related – overall & specific operations, situational considerations, scenario based*

- F38.03 Personnel Training, Qualification and Certification: *Personnel related – Operators, maintenance, instructors, terminology*

E54 Homeland Security Applications

This Committee addresses issues related to standards and guidance materials for homeland security applications with a specific focus on infrastructure protection, decontamination, personal protective equipment (PPE), security controls, threat and vulnerability assessment, operational equipment and chemical, biological, radiological and nuclear (CBRNE) sensors and detectors. The work of E54 supports public safety personnel through a memorandum of understanding (MOU) agreement with the National Institute of Justice (NIJ). E54's primary UAS standards work is in subcommittee E54.09 on Response Robots. A *Full List of Standards and Work Items* is on the E54 website. A high-level description of E54.09 is as follows:

- E54.09 Response Robots: *Standards for aerial, aquatic and ground response robotic systems with test methods on platform and personnel performance*

F37 Light Sport Aircraft

This Committee addresses issues related to design, performance, quality acceptance tests, and safety monitoring for light sport aircraft (LSA). LSA includes the two categories of aircraft created by the Certification of Aircraft and Airmen for the Operation of Light Sport Aircraft Notice of Proposed Rulemaking (NPRM): (1) special light-sport aircraft (used for personal flight and flight training), or (2) rental and experimental light-sport kit aircraft (any level of kit from zero to 95-percent prebuilt). F37 LSA standards related to structures, systems, and powerplants can be used for UAS requirements depending on the risk class. A *Full List of Standards and Work Items* is on their website.

F39 Aircraft Systems

This committee addresses the design, inspection, alteration, and maintenance of aircraft systems. F39 was formed in response to the FAA's Small Airplane Directorate request for a voluntary consensus standards effort to develop standards addressing general aviation electrical wiring systems. A *Full List of Standards and Work Items* is found on their website. Depending on the UAS risk class, Committee F39 subcommittee structure develops global standards for:

- F39.01 Design, Alteration, and Certification of Electrical Systems
- F39.02 Inspection, Alteration, Maintenance, and Repair
- F39.03 Design of Avionics Systems
- F39.04 Aircraft Systems
- F39.05 Design, Alteration, and Certification of Electric Propulsion Systems

F44 General Aviation Aircraft

This Committee addresses issues related to the design and construction (D&C), systems and performance, quality acceptance tests, and safety monitoring for general aviation aircraft. F44 was formed in response to the recommendation of the Part 23 Aviation Rulemaking Committee (ARC). A *Full*

List of Standards and Work Items is found on their website. Committee F44 is designed to develop global standards for:

- F44.10 General
- F44.20 Flight
- F44.30 Structures
- F44.40 Powerplant
- F44.50 Systems and Equipment
- F44.91 Terminology

F46 Aerospace Personnel

This Committee addresses issues related to the development and maintenance of internationally accepted standards and guidance materials for aerospace personnel education, qualification, testing, certification requirements, and continued education concurrent with technological advancements. The work of this committee includes but is not limited to maintenance. F46's primary UAS standards work is in subcommittee F46.06 on Autonomous and Electric Aircraft Maintenance Personnel. A *Full List of Standards and Work Items* is on the F46 website. A high-level description of F46.06 is as follows:

- F46.06 Autonomous and Electric Aircraft Maintenance Personnel: *Standards for the education, training and certification of aerospace personnel working in UAS and electric powered and electric propulsion aircraft (eVTOL)*

F32 Search and Rescue

This Committee addresses issues related to equipment, testing and maintenance, management and operations as well as personnel training and education for SAR activities. Historically, F32 efforts have been focused on wilderness applications, including land, water, ice, and underwater SAR as well as canine use. A *Full List of Standards and Work Items* can be found on their website.

E06 Performance of Buildings

This Committee address issues relating to the performance of buildings, their elements, components, and the description, measurement, prediction, improvement, and management of the overall performance of buildings and building-related facilities. E06 has 18 technical subcommittees that maintain jurisdiction of over 275 standards. The primary subcommittee that addresses UAS operations related to infrastructure needs is E06.55 Performance of Building Enclosures. A *Full List of Standards and Work Items* can be found on their website.

E57 3D Imaging Systems

This Committee addresses issues related to 3D imaging systems, which include, but are not limited to laser scanners and optical range cameras (also known as flash LADAR or 3D range cameras). UAS using LIDAR technologies may benefit from E57 methods. Stakeholders include manufacturers, federal agencies, design professionals, trade associations, and academia. A *Full List of Standards and Work Items* can be found on their website.

F15 Consumer Products

This Committee addresses issues related to standards for several different consumer product categories, including toy safety. Developed by a unique mixture of representatives from industry, government, testing laboratories, retailers, and the ultimate consumer, the F15 standards have and continue to play a preeminent role in reducing the number of injuries and deaths associated with the use and performance of consumer products based on identified hazards. A *Full List of Standards and Work Items* can be found on their website; however, F15.22 on Toy Safety develops standards for toy, hobby, or model UAS needs, such as micro-UAS.

4.6. Consumer Technology Association (CTA)

As a catalyst to the dynamic technology industry, the Consumer Technology Association (CTA)™ accelerates growth and progress for the fast-paced economy. With leading market research, CTA educates members, and by establishing standards, CTA shapes the industry at large.

A proponent of innovation, CTA advocates for the entrepreneurs, technologists, and innovators who mold the future of the consumer technology industry. CTA provides a platform that unites technology leaders to connect and collaborate, and it avidly supports members who push the boundaries to propel consumer technology forward.

CTA initiated standards work associated with drones in May of 2016, with the involvement of a variety of stakeholders, including the FAA. R6 WG 23, Unmanned Aerial Systems, began with a standard addressing serial numbers for sUAS. ANSI/CTA-2063-A, *Small Unmanned Aerial Systems Serial Numbers,* (now freely available via CTA.tech) was published in September 2019. The standard provides manufacturers with the structure for the creation of a physical serial number. Additionally, ANSI/CTA-2063-A outlines the maintenance and management of the four-digit manufacturer code that is used to identify the manufacturer of the sUAS. ANSI/CTA-2063-A has been adopted as the definitive standard for UAS serial numbers in both pending US and European regulation.

CTA's R14 WG 3, Cybersecurity for Small UAS, was established in September 2019 to develop a baseline set of requirements and recommendations for small UAS cybersecurity. ANSI/CTA-2088.1 will build upon the baseline cybersecurity requirements in CTA-2088, *Baseline Cybersecurity Standard for Devices and Device Systems*, to address the cybersecurity requirements and recommendations relevant to the unique capabilities, uses, and applications of small UAS.

4.7. European Organisation for Civil Aviation Equipment (EUROCAE)

EUROCAE is a non-profit organisation, created in 1963 as the "European Organisation for Civil Aviation Electronics," with the objective to develop standards for European civil aviation. EUROCAE currently has over 240 members, including industry, service providers, regulators, research institutes, and international organizations. EUROCAE has become the European leader in the development of worldwide recognized industry standards for aviation. EUROCAE membership is open to organisations and industries worldwide. EUROCAE, in the interest of its stakeholders, develops technical specifications for the industry and in support of regulations, aiming to increase safety and market potential, facilitate interoperability, and encourage technological development. The development of EUROCAE documents is governed by a well-proven core process promoting teamwork, excellence, industry buy-in, and consensus while ensuring safety. EUROCAE has extended its activity from airborne equipment to complex air traffic management (ATM), and communications, navigation, and surveillance systems (CNS). To date, EUROCAE has published more than 200 EUROCAE documents (EDs), which are recognised worldwide as high quality and state-of-the-art standards. EUROCAE's headquarters are located in the Paris region, Saint-Denis, France.

WG-105 UAS

WG-105 is tasked to develop the necessary standards to enable the safe integration of UAS, or RPAS when controlled and monitored from a Remote Pilot Station (RPS), into all classes of airspace, with due consideration of the emerging European regulatory proportionate risk-based approach, of the related categories of operations (Open, Specific, and Certified), and of the industry requirements. WG-105 is also tasked, in cooperation with the Technical Advisory Committee (TAC), to develop proposals for future activities (to be reflected in the Technical Work Programme (TWP)). WG-105 is specifically tasked to develop standards focussed on the following Focus Areas (FA):

- DAA
- Command, Control, Communication, Spectrum, and Security
- UTM
- Design & Airworthiness (D&AW) Standards
- Enhanced RPAS Automation (ERA)
- Specific Operation Risk Assessment (SORA)

Focus Area 1: Detect and Avoid

The objective of the work on DAA is to develop standards related to conflict management for all conditions of operation, for all UAS categories of operation, and in all airspace classes, to support the performance-based regulation. It is recognized that under DAA, the ICAO RPAS Manual covers a range of different hazards: conflicting traffic, terrain and obstacles, hazardous meteorological conditions, ground operations, and other airborne hazards.

In the current phase, the scope of this FA is limited to conflicting traffic for the work related to VFR and IFR flight. The scope for Very Low-Level operations (VLL) is still to be determined, in relation with the U-space definition.

Focus Area 2: Command, Control and Communication, Spectrum, and Security

The objective of the work on Command, Control, and Communication, Spectrum, and Security (C3&S) is to maximise the relevance of its outputs to all classes of UAS and achieve alignment with regulatory directions and operational needs. The main technical deliverables (MASPS and MOPS) tactically address the needs of Certified RPAS for the C2 Link, Spectrum Management, and Security. A series of technical reports will provide complementary guidance on communications, spectrum management, and cybersecurity applicable to the other UAS categories.

Focus Area 3: UAS Traffic Management

The objective of the work on UTM is to develop standards related to the operation of UAS while under U-space. Following the analysis of regulations and guidance related to the emerging UTM and VLL operations, two specific areas have been identified for the development of such standards:

- E-Identification, i.e., the capability to identify a flying UA without direct physical access
- Geo-fencing, i.e., providing the remote pilot (RP) with information related to the UA position and its airspace environment, and limiting the access of the UA to certain areas

Focus Area 4: Design & Airworthiness Standards

The objective of the work on D&AW is to develop Acceptable Means of Compliance and supporting standards in the framework of the European Aviation Safety Agency's (EASA) UAS-certified category on topics such as Automatic Recovery, Flight Termination system, RPS, and Human factors. Pending availability of the emerging EASA RPAS Certification Specifications, two activities have been currently identified:

- Support to the development of AMC 1309 on UAS System Safety Assessment Objectives and Criteria, based upon recommendations of the JARUS EUROCAE WG-73 conciliation team report
- Standardization of RPS, with a focus on key enablers for Air Traffic Integration of RPAS, such as communications and information exchanges with ATC

Focus Area 5: Enhanced RPAS Automation

The objective of the work on ERA is to develop Minimum Aviation System Performance Standards (MASPS) related to Automatic Take-Off and Landing (ATOL), Automatic Taxiing (AutoTaxi), and Automation and Emergency Recovery (A&ER), in the context of fixed-wing RPAS in the certified category and their integration in non-segregated airspace.

Focus Area 6: Specific Operational Risk Assessment (SORA)

The objective of the work on SORA methodology, as envisaged in EASA NPA 2017-05, is to analyse the related risk mitigation measures (design or/and operational) currently proposed by JARUS. A Work Plan will be subsequently derived to identify the standards that may support these risk mitigation measures and that EUROCAE WG-105 may prepare in a second stage.

The detailed Work Programme of the WG-105 can be found on the EUROCAE website.

<u>EUSCG Initiative</u>

The EUSCG is a joint coordination and advisory group established to coordinate the UAS-related standardisation activities across Europe, essentially stemming from the EU regulations and EASA rulemaking initiatives. The EUSCG provides a bridge between the European activities and those at the international level. The secretariat of EUSCG is provided by EUROCAE.

The tasks of the EUSCG shall be to:

- develop, monitor, and maintain an overarching **European UAS Standardisation Rolling Development Plan** (RDP), based on the standardisation roadmap developed by EASA and other organisations and inputs from the EUSCG members (including the military), and where needed other key actors in the aviation domain
- facilitate the sharing of work among the regulators and SDOs thus avoiding the risk of overlapping developments and gaps
- monitor all relevant processes, resource availability, and other related risks and issues
- provide a forum to manage specific issues and resolution of conflict
- advise the EC and other organisations on standardisation matters

In order to fulfil its tasks, the EUSCG will need to:

- facilitate the participation of various member organisations, in order to develop a comprehensive set of industry standards needed to cover the whole spectrum of UAS and their operations including U-space
- identify and share a common recognition of the fields of competencies of the various contributors in order to avoid the risk of overlapping activities
- establish and maintain a continuous information flow between stakeholders to ensure that changes, delays, and new developments can be taken into account
- maintain awareness of the status of upstream rationale and progress associated with identified needs for standardisation activities

The main deliverable of the EUSCG will be the RDP as described above. The RDP is progressively updated to reflect the current situation. It also provides a method for the identification and discussion of overlaps and gaps, and as a basis for feedback to contributing organisations, to improve overall coordination of standards developments. The process should also identify the technical input from other sources (such as ICAO) into the standards plan. The Work Programme of the WG-105 is reflected in the RDP as well.

Further information on EUSCG and RDP can be accessed on the EUSCG website. It includes a subscription feature to be notified when a new RDP version is being published.

4.8. Institute for Electrical and Electronics Engineers (IEEE)

IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity. Through its highly cited publications, conferences, technology standards, and professional and educational activities, IEEE is the trusted voice in a wide variety of areas ranging from aerospace systems, computers, and telecommunications to biomedical engineering, electric power, and consumer electronics. More information is available on IEEE's website.

IEEE WG on Management of Existing Overhead Lines

The scope of the IEEE WG on Management of Existing Overhead Lines includes providing a forum for exchanging and discussing information on existing technologies and technology needs for inspection, assessment, management, and utilization of overhead lines. It also includes developing papers, guides, and/or standards to present methods for assessing and extending the life expectancy and optimizing the use of the components of existing overhead lines. Organizationally, the WG falls within the Overhead Lines Subcommittee, of the Transmission and Distribution Committee of the IEEE Power and Energy Society.

Sometime during 2014, several members of the WG expressed interest in exploring topics related to UAS. In response, in mid-2015 the WG voted to form a Task Force (TF) on the Application of Unmanned Aerial Systems to Overhead Line Inspection, Assessment, and Maintenance. (Note: The term Unmanned Aerial Systems was chosen rather than Unmanned Aircraft Systems because the group desired to leave leeway to also address various types of line suspended robots.) The mission of the TF is to foster adoption, advancement, and safe and cost-effective use of unmanned aerial systems for overhead line inspection, assessment, and maintenance. The initial intention was to emphasize issues related to transmission lines, however, it soon became apparent that overhead distribution lines and substations were not being addressed elsewhere within IEEE, therefore, the scope was broadened to include these other types of electric utility infrastructure. The TF is comprised of the following four teams, each of which is active to varying degrees:

- Applications/Case Studies of UAS for Overhead Lines and Substations
- FAA and Other Relevant Rules and Regulations
- UAS Technology (aircraft, sensors and related tools)
- Data Management Needs, Processes, and Technologies

Because so much is changing so fast in this arena, the membership determined that the near-term deliverables of the TF should focus on presentations/papers/updates with a view toward fostering and facilitating adoption of UAS technology. The TF also acknowledged that in the foreseeable future they may elect to begin work on deliverables such as suggested practices, application guidelines, and/or standards on topics including selection of aircraft and ground station features, sensor requirements for specific inspection functions, flying in the wires environment, crew member training/background, mission planning, etc.

The WG within which the UAS TF resides has two face-to-face meetings per year. In addition, some of the TF teams connect one or more times via web meetings and conference calls between the regularly scheduled WG meetings.

4.9. International Organization for Standardization (ISO)

ISO is an independent, non-governmental international organization with a membership of 162 national standards bodies. Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market relevant, International Standards that support innovation and provide solutions to global challenges. Its Central Secretariat is located in Geneva, Switzerland. More information is available on the ISO's structure and governance webpage.

ISO Technical Committee 20 Subcommittee (SC) 16, Unmanned Aircraft Systems, was formed in 2014 and has the following scope: "Standardization in the field of unmanned aircraft systems (UAS) including, but not limited to, classification, design, manufacture, operation (including maintenance) and safety management of UAS operations." The chair of SC 16 is Mr. John Walker, The Padina Group. The manager is Chris Carnahan, Aerospace Industries Association (AIA). 29 countries are currently members of SC 16, with the United States, specifically the AIA, serving as secretariat. The list of member countries can be found on the SC 16 Member's webpage. SC 16 has liaison relationships with a number of ISO and IEC committees, and 6 external organizations.

SC 16 currently has six WGs:

WG 1, General

• Scope: This WG specifies general requirements for UAS for civil applications in support of other standards created within ISO/TC 20/SC 16.

• Work items:

- ISO/CD 21384-1, *Unmanned aircraft systems -- Part 1: General specification* (under development)
- ISO/FDIS 21384-4, *Terms and Definitions* (under development)
- ISO 21895, *Categorization and classification of civil unmanned aircraft systems* (published)

WG 2, Product Manufacturing and Maintenance

• Scope: This WG specifies the quality and safety requirements for components of UAS to influence the design and manufacturing process. This group focuses on the individual components that comprise a UAS to further operational safety. The standards will include information regarding components associated with the UA, any associated remote control station(s), the command and control links, any other required data links (e.g. payload, traffic management information, vehicle identification) and any other system elements as may be required.

• Work items:

- ISO/CD 21384-2, *Unmanned aircraft systems -- Part 2: Product systems* (under development)
- ISO/WD 24356, *General requirements for tethered unmanned aircraft system* (under development)

WG 3, Operations & Procedures

• Scope: This WG details the requirements for safe commercial UA operations and applies to all types, categories, classes, sizes, and modes of operation of UA.

• Work items:

- ISO/DIS 21384-3, Unmanned aircraft systems -- Part 3: Operational procedures (published)
- ISO/DIS 23665, *Unmanned Aircraft Systems -- Training of Operators* (under development)

- ISO/NP 5015-1, Unmanned aircraft systems — Part 1: Operational procedures for passenger-carrying UAS (proposed)
- ISO/NP 5015-2, Unmanned aircraft systems — Part 2: Operation of vertiports for unmanned aircraft (UA) (proposed)

WG 4, UAS Traffic Management

• Scope: To establish international standards and guidelines in the area of Unmanned Aircraft Systems Traffic Management (UTM). The standards and guidelines are to be developed aligned with the rules and guidance provided by aviation authorities.

• Work items:

- ISO TR 23629-1, *UAS Traffic Management (UTM) -- Part 1: General requirements for UTM -- Survey results on UTM* (published)
- ISO/WD 23629-5, UAS traffic management (UTM) — Part 5: UTM functional structure (under development)
- ISO/CD 23629-7, UAS traffic management (UTM) — Part 7: Data model for spatial data (under development)
- ISO/PWI 23629-8, UAS Traffic Management (UTM) — Part 8: Remote identification (proposed)
- ISO/WD 23629-12, UAS traffic management (UTM) — Part 12: Requirements for UTM services and service providers (under development)

WG 5, Testing and Evaluation

• Scope: Testing and evaluation of UAS for safety and quality of product.

• Work items:

- ISO/NP 5110, Test method for flight stability of multi-copter UA under wind and rain conditions (proposed)
- ISO/NP 5109, Evaluation method for the resonance frequency of multi-copter UAV by measurement of rotor and body frequencies (proposed)
- ISO/PWI 4594, UA Wind Gust Test (proposed)
- ISO/PWI 4595, Suggestion for improvement in the guideline for UA testing classification (proposed)
- ISO/PWI 4584, Improvement in the guideline for UA testing/design of accelerated lifecycle testing (ALT) for UAS/Sub-system/components (proposed)
- ISO/WD 4358, Test methods for civil multi-rotor unmanned aircraft system (under development)

WG 6, UAS Subsystems

• Scope: Development of standards for UAS subsystems

• Work items:

- ISO/WD 24355, General requirements of flight control system for civil small and light multirotor UAS (under development)
- ISO/WD 24354, General requirements for civil small and light UAS payload interface (under development)
- ISO/WD 24352, Technical requirements for light and small unmanned aircraft electric energy system (under development)

4.10. NACE International (NACE)

NACE International is an ANSI-accredited standards development organization which has been publishing corrosion control and mitigation industry consensus standards for fifty years, since 1969. As the premier authority for corrosion control solutions, NACE's Standards Program is utilized by both private industry and government agencies to ensure safety and integrity of assets through design as well as maintenance and inspection standards. NACE's IMPACT program released a study in 2016 revealing that the global cost of corrosion is US$2.5 trillion, equating to 3.4% of a country's GDP.

NACE International's standards portfolio includes over 175 standards and 70 technical reports. More than 300 technical committees comprised of 4300 subject matter experts from over 20 countries lend their expertise to develop best practices that help preserve the longevity of assets. Utilizing an established framework accredited by ANSI, NACE standards committees develop and maintain standard practices, material requirements, test methods and technical reports which support the needs of numerous industries impacted by corrosion including oil and gas, transportation infrastructure, electrical and utilities, water and wastewater, maritime, and chemical processing.

Use of UAS for Infrastructure Inspection

Several Task Groups were initiated in 2019 to develop standard practices related to the utilization of unmanned aircraft systems for pipeline inspections: Task Group 552 *Drone-Based Condition Monitoring of Below and Above Ground Pipeline Integrity Threats* and Task Group 587 *Large Standoff Magnetometry (LSM) Inspection of Pipelines.* While the latter LSM document primarily addresses sensor technology used as an above ground, non-intrusive screening tool to identify stress concentration in pipelines, it is likely that the platform utilized to conduct such screening will be UAS.

There is interest in UAS applications from other industries that NACE serves, and it is anticipated that additional standards development for infrastructure corrosion and coatings inspections and measurements will be initiated in the near future.

4.11. National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical, and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach, and advocacy; and by partnering with others who share an interest in furthering the NFPA mission. More information can be found on NFPA's website. All NFPA codes and standards can be viewed online at NFPA's Free Access webpage.

NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*, has been developed by representatives from all types of public safety departments that are using UAS, including the fire service, law enforcement, and EMS. Released on November 25, 2018, NFPA® 2400 acts as an all-encompassing standard providing a foundation for sUAS integration into the public safety community. It breaks sUAS integration down into three main elements amongst three core chapters. Chapter 4, *Organizational Deployment and Considerations for sUAS,* provides requirements on program development, program assessment, deployment, general operations, and multiple aircraft operations. A key element of Chapter 4 is the identification of the need for a risk assessment and consideration of mission objectives. Chapter 5, *Professional Qualifications for sUAS Public Safety Personnel,* identifies the minimum JPRs a remote pilot in command (RPIC) and visual observer are required to perform. In essence, it covers the essential job tasks that can be evaluated and tested. Finally, Chapter 6, *Maintenance of sUAS,* provides requirements aimed at identifying the maintenance needs within a sUAS program. It stipulates the need for record keeping, cleaning, and decontamination protocols. Combined, these three chapters form the core of NFPA® 2400 and provide a roadmap for public safety entities to begin to develop and integrate sUAS into their daily operations. NFPA® 2400 is the foundation from which public safety departments can develop sUAS programs, and do so based on the most current industry knowledge and backing of ANSI accreditation. A revision to NFPA® is open for public input until June 30, 2020. The next edition will be 2022 and published late in 2021. More information and free access to the document can be found on the NFPA® 2400 webpage.

4.12. Open Geospatial Consortium (OGC)

The Open Geospatial Consortium (OGC) is an international not-for-profit organization committed to making quality open standards for the global geospatial community. These standards are made through a consensus process and are freely available for anyone to use to improve the sharing of the world's geospatial data.

OGC standards are used in a wide variety of domains including: Geosciences & Environment; Aviation; Defense & Intelligence; Smart & Resilient Cities, including the Internet of Things (IoT) & Sensor Webs, mobile tech, and the 3D & Built Environment; Emergency Response & Disaster Management; Energy & Utilities; and many more.

OGC's 500+ member organizations come from across government, commercial organizations, non-governmental organizations (NGOs), academia, and research institutes.

OGC standards development occurs in its Technical Committee (TC). This group represents all member organizations. The TC includes a large number of WGs, divided into Domain Working Groups (DWGs) and Standards Working Groups (SWGs). A DWG is where discussion occurs on use cases and requirements for standards, as well as application standards to activities in that domain. DWGs are, by default, open to the public and often include domain experts who are not members of OGC. A SWG is where the actual standards writing and review occurs. Many DWGs actively initiate new SWGs.

The OGC has an Unmanned Systems (UxS) DWG. The UxS DWG was established in 2017 and holds sessions at each of OGC's quarterly TC Meetings. While the scope of the UxS DWG broadly encompasses all unmanned vehicles and the sensors or equipment on those vehicles, and the broader systems that support them, most of the conversation in the DWG at this time is focused on the tasking, observations, processing, and usage of aircraft and mounted sensors. However, it is important to note that the UxS DWG does include in its membership experts on autonomous submersibles and automobiles, with the former providing some very relevant expertise to the aircraft community due to its maturity with respect to the use of standards. Participants in the UxS DWG include government organizations with long histories in developing and operating large UASs (e.g., Global Hawk, Predator, etc.), such as NASA, the U.S. Army Geospatial Center, the U.S. National Geospatial-Intelligence Agency, Harris Corporation, Lockheed Martin Corporation, Unifly, and others.

OGC also has an Aviation DWG to cover more general aviation topics. This DWG is currently chaired by the FAA and Eurocontrol and has focused mostly on aviation information, air traffic control (ATC), and meteorology standardizations topics. The Aviation and UxS DWGs regularly collaborate and held a joint coordination Workshop at the June 2018 TC meeting in Fort Collins, Colorado.

OGC has a long history of supporting the aviation community. The Aeronautical and Flight Information Exchange Models (AIXM, FIXM) and Weather Information Exchange Model (WXXM) rely heavily upon OGC standards to describe geospatial parameters and geometries. These standards (such as Geography Markup Language (GML), Web Map Service (WMS), Web Coverage Service (WCS), Observations and Measurements) are developed in dedicated OGC Standards WGs, often with use cases drawn from the Aviation and UxS DWGs and their respective membership.

OGC plans and conducts numerous interoperability testbeds, pilots, and experiments with aviation requirements. These initiatives are focused on joining industry and users in a rapid prototyping / engineering environment to test, validate, and demonstrate potential new standards and related best practices. A large number of Engineering Reports have been delivered from these efforts. These can be found by searching for "aviation" on the OGC Engineering Reports webpage.

4.13. RTCA, Inc. (RTCA)

RTCA is a private, not-for-profit association founded in 1935 as the Radio Technical Commission for Aeronautics, now referred to simply as "RTCA." RTCA has provided the foundation for virtually every modern technical advance in aviation. Its products serve as the basis for government certification of equipment used by the tens of thousands of aircraft flying daily through the world's airspace.

A standards development organization (SDO), RTCA works with the FAA to develop comprehensive, industry-vetted, and endorsed standards that can be used as a means of compliance with FAA regulations. RTCA deliberations are open to the public and its products are developed by aviation community volunteers functioning in a consensus-based, collaborative, peer-reviewed environment.

While RTCA's documents and committees cover a wide range of aviation technology, the **UAS Steering Committee** is identifying those standards that are involved in the UAS technology space. The committees that are developing standards specifically for this area include:

- SC-228, Minimum Operational Performance Standards (MOPS) for UAS, established May 20, 2013, is working to develop the MOPS for DAA equipment and a C2 Data Link MOPS establishing L-Band and C-Band solutions. The initial phase of standards development focused on civil UAS equipped to operate in Class A airspace under instrument flight rules (IFR). The Operational Environment for the MOPS is the transitioning of a UAS to and from Class A or special use airspace, traversing Class D and E, and perhaps Class G airspace. The committee published the first of the Phase 1 documents in September 2016 with the release of DO-362, *C2 Data Link MOPS (Terrestrial)*, and followed that with *Detect and Avoid Standards* (DO-365) and the accompanying *Air-to-Air RADAR MOPS* (DO-366). Phase 2 of MOPS development is underway to specify DAA equipment to support extended UAS operations in Class D, E, and G airspace, transit operations in B and C airspace, and C2 Link MASPS, and MASPS for Satellite-based C2.

- SC-147, Traffic Alert & Collision Avoidance System (TCAS), established November 1, 1980, has defined and updated the TCAS and TCAS II performance standards, thereby contributing to one of the most significant advances in aviation safety in the past twenty years. They continue their work with the addition of Airborne Collision Avoidance System (ACAS) Xa, ACAS Xo, and ACAS Xu. ACAS Xu will provide the minimum performance standards for the interaction of an ACAS system specifically designed for UAS to interact with other ACAS Xu and Xa/Xo systems (compatible with Xo/Xa).

- While not a committee in the same sense as a typical RTCA Special Committee, the Forum on Aeronautical Software (FAS) has been established to provide a forum for those involved in the development of aeronautical software to share experiences and good practices and to provide a platform for the exchange of information regarding subjects addressed in the "software document suite," new and emerging technologies, development methodologies, interesting use cases, and other topics related to aeronautical software and related technologies.

  The FAS is a joint RTCA/EUROCAE User Group that holds discussions and develops Information Papers (IPs) relating to aeronautical software topics in efforts to harmonize these informational papers. Topics typically addressed by the FAS will relate to aeronautical software, including topics covered by the following set of RTCA/EUROCAE published documents (referred to as the "software document suite"):

  - DO-178C - Software Considerations in Airborne Systems and Equipment Certification
  - DO-278A - Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems
  - DO-248C - Supporting Information
  - DO-330 - Software Tool Qualification Considerations
  - DO-331 - Model Based Development & Verification Supplement
  - DO-332 - Object Oriented Technology and Related Techniques Supplement
  - DO-333 - Formal Methods Supplement

The FAS is currently reviewing a subset of these documents to determine their applicability with respect to UAS.

4.14. SAE International (SAE)

SAE International is a global body of scientists, engineers, and practitioners that advances self-propelled vehicle and system knowledge in a neutral forum for the benefit of humanity. It is a not-for-profit, non-lobbying technical organization and membership association with 138,000 members in over 100 countries. It is the largest non-government mobility standards developing organization in the world. The first aerospace standard was published in 1917, and today there exist over 8900 active aerospace standards and over 21000 historical standards in circulation. SAE International's core competencies are life-long learning and voluntary consensus standards development.

SAE staff or committee representatives are working with a number of external agencies/programs including ICAO, FAA, NASA, DoD, EASA, MoD, Transport Canada, JAXA, CAAC, AUVSI, ANSI, and others to provide a holistic approach to standardization. Hundreds of SAE International standards are accepted as means of compliance to regulations across the globe.

Over 250 SAE International aerospace technical committees & subcommittees have developed many existing standards that can be applied to unmanned aerial systems (UAS), and going forward, new and revised standards are including provisions and special considerations for UAS. Furthermore, some SAE International committees are focused solely on UAS. Participation in the SAE Technical Committees includes global representation from OEMs, suppliers, robotics and UAS integration companies, consulting firms, government, think tanks, academic institutions, and others across the unmanned systems industry. **Error! Reference source not found.** displays a non-exhaustive variety of SAE International Aerospace Technical Committees.

- Learn about SAE International standards development and the standards developing process
- Complete list of all SAE International Aerospace Technical Committees
- View the SAE International Aerospace Technical Committee Meeting Schedule
- Join an SAE technical standards committee
- Make a recommendation for standards development

UAS Committees

S-18UAS Autonomy Working Group

To support Type Certification of UAS, S-18UAS is currently identifying the specific gaps in both ARP4754 and ARP4761 processes that affect UAS development, the domains where the gaps should be filled, and would provide a common understanding of necessary guidance needed to support development assurance and system safety of UAS for both developers and regulators.

SAE S-18/EUROCAE WG-63 Aircraft and System Development and Safety Assessment Committee

The S-18/WG-63 committee brings together qualified specialists for the advancement of aerospace safety and to support effective safety management. It provides a resource for other committees and organizations with common interests in safety and development processes. The committee develops Aerospace vehicle and system:

- Safety assessment processes
- Development assurance processes
- Practices for accomplishing in-service safety assessments

SAE G-34/EUROCAE WG-114 Artificial Intelligence in Aviation

The G-34/WG-114, Artificial Intelligence in Aviation, Committee is a joint committee with EUROCAE, responsible for creating and maintaining SAE/EUROCAE Technical Reports (i.e., Aerospace Information Reports, Aerospace Recommended Practices, and Aerospace Standards) on the implementation and certification aspects relate to AI technologies inclusive of any on or off-board system for the safe operation of aerospace systems and aerospace vehicles.

A-6 Aerospace Actuation, Control and Fluid Power Systems

The SAE A-6 Aerospace Actuation, Control and Fluid Power Systems committee addresses all aspects of aerospace flight and utility actuation and control systems as well as fluid power systems. The committee is comprised of three subcommittees: System/Subsystem Integration, Actuation and Control, and Fluid Power Generation and Distribution. The subcommittees work together to assure compatibility and integration of the various types of actuation systems (electrohydraulic, electromechanical and electrohydrostatic) with the entire functioning flight and utility control systems and the fluid power systems.

G-32 Cyber Physical Systems Security (CPSS) Committee

The SAE G-32 shall utilize and coordinate the knowledge, experience, and skills of technical experts in the field of CPSS to:

- Characterize and address the risk to CPSS, assess vulnerabilities, and recommend System Engineering focused mitigation actions.
- Share the knowledge of how vulnerabilities are introduced and exploited in cyber physical systems and document best practices for addressing areas of concern utilizing existing processes, procedures, and standards.
- Develop a taxonomy for CPSS.
- Establish standard methods for identifying vulnerabilities in cyber physical systems introduced at any point in the CPSS life cycle and mitigating impacts.

- Develop validation and verification methods to ensure requirements are addressed.

AS-4JAUS Joint Architecture for Unmanned Systems Committee

AS-4 was formed as a result of the Joint Architecture for Unmanned Systems Working Group (JAUS WG) migration to SAE International. The JAUS WG was chartered by the Deputy Director, Office of the Undersecretary of Defense, Acquisition, Technology, and Logistics, Strategic & Tactical Systems/Land Warfare. The objective is to define and sustain a joint architecture for the domain of unmanned systems. JAUS is a message-based architecture that defines data formats and methods of communication among computing nodes. The architecture defines messages and component behaviours that are independent of technology, computer hardware, operator use, communications equipment, and vehicle platforms. The JAUS documents serve as the basis for SAE Aerospace Standards.

AS-4UCS Unmanned Systems (UxS) Control Segment Architecture

Responsibility for the UCS Architecture transitioned from the Office of the Secretary of Defense (OSD) to SAE International in April 2015. It was republished as SAE AS6512 in December 2016. The AS6512 Revision A is a Service-Oriented Architecture (SOA) and Data Model (DM) that includes 250+ services for the control and exploitation of heterogeneous unmanned systems, including unmanned aircraft (UAS), ground vehicles, and surface/subsurface maritime vehicles. The SOA/DM is expressed as a UML model from which interface software can be automatically generated for a chosen middleware technology. The architecture is scalable from a handheld device for small robots, to a fixed facility with intercontinental control of theater assets. AS6512 supports an Open Business Model (OBM) for the development and reuse of UxS application software. Government adoption of AS6512 (and its OSD precursor) includes several branches of the military. Peer interest in UCS includes the National Information Exchange Model (NIEM) MilOps Domain and the NATO Multi-Domain Vehicle Control architecture.

AS6523 is the Data Dictionary for Quantities Used in Unmanned Systems. It provides a mathematically-coherent substrate from which data modelers can develop their own UxS datatypes based on shared and unambiguous semantics.

E-39 Unmanned Aircraft Propulsion Committee

SAE E-39, Unmanned Aircraft Propulsion Systems Committee, is a technical committee in SAE's Aerospace Propulsion Systems Group with the responsibility to develop and maintain standards for all facets of unmanned aircraft propulsion systems. Both chemical (internal combustion) and electrical propulsion and the supporting systems will be addressed. The UAS industry benefits by understanding well-defined categories and system types, familiarization of accepted test methods and measurements, and building upon industry best practices and specifications.

G-30 UAS Operator Qualifications Committee & G-10U Unmanned Aerospace Vehicle Committee

The Unmanned Aircraft Systems Operator Qualifications Committee, will develop and maintain supplementary qualification standards beyond the existing regulatory requirements of UAS operators, instructors, and remote pilots, for a variety of unmanned aircraft system types, sizes, operations, and missions. The Committee also will look to qualifications of the organizations that engage UAS.

A-20 Aircraft Lighting Committee

The SAE A-20 Aircraft Lighting committee addresses all facets of aircraft lighting equipment– design, manufacture, operation, maintenance, and in-service experience. It is responsible for standards pertaining to aircraft lighting and lighting emission sources which will fulfil the needs and requirements of operational control and utility, including all lighting on and in an aircraft and under its control. The group is comprised of three committees – A-20A Crew Station Lighting, A-20B Exterior Lighting, and A-20C Interior Lighting – dedicated to creating, preparing, and maintaining all relevant specifications, standards, and requirements for aircraft lighting systems.

AC-9C Aircraft Icing Technology Committee

AC-9C is a professional technical committee working in the field of aircraft inflight icing under the auspices of the SAE. The committee is charged with the responsibility of developing and continually updating standards, recommended practices, and information reports which contribute to the operational capability and safety of civil and military aircraft. In many instances, these objectives are achieved through an international exchange of ideas, data and experience. The scope of the committee includes all facets of aircraft inflight icing including ice protection and detection technologies and systems design, meteorological and operational environments, maintenance, regulation, certification, and in-service experience.

PNT Position, Navigation, and Timing Committee

The PNT Committee develops standards that define architectures, sensors, interfaces, training, and certification recommended practices, so that the commercial marketplace can continue to develop products and capabilities to provide robust and resilient PNT solutions for consumers. These standards will provide governments, managers, engineers, technicians, and educators with the tools they need to develop a robust and reliable critical infrastructure.

AE-7 Aerospace Electrical Power and Equipment Committee

The AE-7 Aerospace Electrical Power and Equipment Committee is dedicated to developing standards and specifications relative to the generation and control, storage, conversion, charging, distribution, load management and utilization of electric power for aerospace vehicles. The Committee also provides a forum for gathering and disseminating electrical power and technical equipment information between users and suppliers. Currently, AE-7’s newest initiative involves developing standards for high voltage.

AE-8A Elec Wiring and Fiber Optic Interconnect Sys Install Committee

The SAE AE-8A committee addresses all facets of aerospace electrical/electronic distribution systems installation—design, test, maintenance, and in-service experience. It provides a forum for gathering and disseminating technical information on electrical and fiber optic interconnect systems in aerospace vehicles and equipment. The group is dedicated to creating, preparing, and maintaining all relevant specifications, standards, and requirements for the installation of these system types.

G-28 Simulants for Impact and Ingestion Testing

SAE G-28, Simulants for Impact and Ingestion Testing, is a technical committee in SAE’s General Projects Systems Group with the responsibility to develop and maintain standards for simulating objects utilized in the development and certification of structures and engines for impact or ingestion. The committee works in conjunction with defense agencies and regulatory authorities to ensure that the standards developed meet regulatory requirements for certification testing. The initial project will focus on the requirements for the manufacture of artificial birds of varying size utilized in development and certification testing. If requirements for the certification of structures for drone or FOD impact/ingestion are necessary, the committee is prepared to help develop artificial simulant standards.

Electric Aircraft Steering Group

Established in 2015, the Electric Aircraft Steering Group (EASG) of SAE International strategically identifies, landscapes, and coordinates the various standardization activities necessary to support full-electric and more-electric aircraft applications at system, subsystem, and component levels. All aircraft featuring either hybrid or totally electric solutions for propulsion and systems are target applications. Aircraft segments addressed encompass general aviation, business aviation, UAM, VTOL, and regional and transport category aircraft.

For those segments, the EASG has tracked the progress made to date by standardization activities as a whole, and the group has also put into perspective the gaps that need to be addressed by new standards. The EASG then delegates to relevant SAE Technical Committees the required development and/or updates of standards. When deemed necessary, the EASG recommends the creation of ad hoc standardization committees. Three new committees have been recently created:

- E-40 Electrified Propulsion
- AE-7D Aircraft Energy Storage and Charging
- AE-9 Electrical Materials

Wherever appropriate, in order to avoid duplication, collaboration with other SDOs can be part of EASG recommendations. Prioritization of standards development for targeted aircraft segments is one of the core missions of the EASG. The EASG is developing a report on the current status of standardization with special emphasis on gaps and the means to address them.

4.15. Telecommunications Industry Association (TIA)

The Telecommunications Industry Association (TIA) represents manufacturers and suppliers of global communications networks through standards development, policy and advocacy, business opportunities, market intelligence, events, and networking. TIA enhances the business environment for broadband, mobile wireless, information technology, networks, cable, satellite and unified communications. Members' products and services empower communications in every industry and market, including healthcare, education, security, public safety, transportation, government, the military, the environment, and entertainment. TIA is accredited by the American National Standards Institute (ANSI) as a standards developing organization (SDO).

Engineering Committee TR-14 is responsible for the ANSI/TIA-222, *Structural Steel Standards for Steel Antenna Towers and Supporting Structures* and ANSI/TIA-322, *Loading, Analysis, and Design Criteria Related to the Installation, Alteration and Maintenance of Communication Structures* standards. TR-14 is launching a new UAS working group to draft a telecom specific document for use case scenarios on workflow enhancement and best practices on data management. This includes the configuration of telecommunications towers and management of structural data as well as carrier audits.

Engineering Committee TR-34 is responsible for standards and studies related to satellite communications systems, including both the space and earth segments. The committee focuses on standards for space-borne and terrestrial hardware; interfaces on standards for satellite and terrestrial systems; and the efficient use of spectrum and orbital resources, including sharing between satellite and terrestrial services. TIA convenes the LEO Roundtable forum for discussing and consensus building around LEO specific issues and objectives including LEO satellite communication between unmanned systems and satellites at all altitudes.

Engineering Committee TR-8 formulates and maintains standards for private radio communications systems and equipment for both voice and data applications. TR-8 addresses all technical matters for systems and services, including definitions, interoperability, compatibility and compliance requirements. The types of systems addressed by these standards include business and industrial dispatch applications, as well as public safety (such as police, ambulance and firefighting) applications.

Much of the work of the committee relates to the formulation of TIA-102 Series standards for APCO Project 25 (PDF). These are standards sponsored by the Association of Public-Safety Officials International (APCO), the National Association of State Telecommunications Directors (NASTD) and agencies of the federal government. Project 25 standards are developed to provide digital voice and data communications systems suited for public-safety and first-responder applications.

The communications and information exchange that TIA-102 Series standards covers are for use in tactical situations and to ensure interoperable communication (human to human) in tactical situations.

4.16. Underwriters Laboratories, Inc. (UL)

For more than 100 years, Underwriters Laboratories (UL) has been a leader in facilitating the safe introduction of new technologies through hazard-based safety engineering, research, and testing. UL Standards are the culmination of a broad stakeholder collaboration drawing from the very best in scientific methodology, testing expertise, and input from diverse stakeholders – from industry to academia, regulatory to retail, manufacturers to end-users – via UL's consensus-based standards development process.

UL Standards development encompasses more than product standards; it also includes standards covering systems and services. With more than 1,700 standards and over 400 technical panels, UL is able to gain insight, knowledge, and expertise, from stakeholders from around the globe. Through this work, UL is able to develop standards that address not only safety, but also performance, environmental health, and sustainability.

UL's Standard Technical Panel (STP) 3030, Unmanned Aircraft Systems, developed UL 3030, *Standard for Unmanned Aircraft Systems*, through stakeholder collaboration. The First Edition of ANSI/CAN/UL 3030 was published on September 18, 2018. UL 3030 covers the electrical system of UASs, as defined in the standard, used inflight for commercial applications or flight incidental to business applications. The requirements in UL 3030 are intended to cover a UAS that is operated by certified UAS pilots as identified in the Federal Regulations, where the unmanned aircraft is less than 25 kg (55 lbs). The UAS covered by UL 3030 is intended to be provided with an internal lithium ion battery that is charged from an external source.

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5. Overviews of Selected UAS Industry Stakeholder Activities

5.1. Academy of Model Aeronautics (AMA)

The Academy of Model Aeronautics (AMA) is a nationwide, community-based organization of nearly 180,000 model aviation enthusiasts. Since 1936, AMA has successfully managed the recreational UAS community by providing robust safety guidelines and training programs. In addition to safety programming, AMA provides its members with the benefit of a $2.5 million dollar liability insurance policy.

AMA's recreational safety programing focuses on creating a safe environment to protect bystanders, surrounding property, and the national airspace.

AMA Safety Code: https://www.modelaircraft.org/sites/default/files/105.pdf

In addition to the general safety guidelines, AMA members must also be diligent in actions to avoid collisions between all aircraft flying within the National Airspace System (NAS). This practice is known as "See and Avoid." Vigilance must be maintained by each person operating any aircraft to "see and avoid" other aircraft.

See and Avoid Practices:
https://www.modelaircraft.org/system/files/documents/Safety%20%26%20Member%20Benefits%20-%20540-D.pdf

In addition to the AMA Safety Code, First-Person View (FPV) operators must also abide by another set of safety and operational guidelines. FPV aircraft are RC UAS that are equipped with a video transmitter to send real-time video images from an onboard camera to a ground-based receiver for display on a pilot's video monitor/goggles. All recreational UAS operations must stay within line-of-sight of the operator or person co-located with the UAS operator.

FPV operations: https://www.modelaircraft.org/sites/default/files/550.pdf

AMA is the voice of its membership, providing liaison with the Federal Aviation Administration, the Federal Communications Commission, and all levels of government agencies. AMA works with local governments, zoning boards, and parks departments to promote the interests of local chartered clubs. These model clubs host events throughout the year, with many of these benefiting local and national charities.

AMA manages approximately 2400 clubs, most of which manage at least one flying site. Each club sets their own rules for operations at their flying site, but all who fly there must abide by the AMA Safety Program. AMA provides clubs with guidelines in order to assist them in creating a flying site that is safe and promotes the enjoyment of model flying.

Flying Site Specifications:
https://www.modelaircraft.org/sites/default/files/documents/Suggested%20Flying%20Site%20Specifications.pdf

AMA provides $2,500,000 in general liability coverage to members, clubs, and site owners. In addition to general liability insurance, members receive accident/medical coverage and fire/theft/vandalism coverage.

One of the main purposes of the AMA is to is to promote the advancement of model aviation into the future. AMA does this through educational programming and youth outreach. Model aviation is an effective tool for inspiring young people to explore careers in aviation STEM-related fields. Building and flying model airplanes have long been a gateway to aviation for aviators and engineers. Building and flying model aircraft are “hands-on” experiences to motivate and inspire a future generation of problem solvers and inventors, opening doors to careers in aviation and engineering.

AMA Education: http://amaflightschool.org/

5.2. Aerospace Industries Association (AIA)

The Aerospace Industries Association (AIA) is the voice of the American aerospace and defense industry, representing more than 300 leading aerospace and defense manufacturers and suppliers, supporting over 2.5 million jobs and over $151 billion in annual exports. Its members are on the cutting edge of innovation and are leading the industry on developing emerging technologies such as UAS that will revolutionize the way in which goods are moved, services are performed, and people connect.

To do this, AIA has an Emerging Technologies Committee that is comprised of a UAS Subcommittee, UAM Subcommittee, Spectrum Subcommittee and Airspace Integration Working Group that work in tandem with the FAA, NASA, and other government entities. AIA also houses the National Aerospace Standards, and has been actively writing standards for the aerospace and defense industry since 1941, including standards on emerging technologies and UAS cybersecurity.

All of these groups work together by looking at the entirety of the aviation ecosystem and how these new technologies, whether small, large, manned or unmanned will eventually become a part of it at all altitudes. AIA and its members work with a mature focus towards developing high level policies that will enable the regulatory framework to allow technologies into the airspace.

5.3. Alliance for Drone Innovation (ADI)

The [Alliance for Drone Innovation (ADI)] is a leading policy voice for manufacturers, suppliers, and software developers of recreational and commercial drones. Headquartered in Washington, D.C., ADI proudly supports policies that encourage the growth of the unmanned aircraft industry for personal, professional, educational, and governmental use. ADI members are the nation's industry leaders and corporate visionaries who are responsible for creating the vibrant drone ecosystem of today, and who will lead us to the future applications of tomorrow.

The mission of the Alliance for Drone Innovation is to promote stakeholder awareness and advance public policies that encourage a safety culture while enabling innovation and growth of the unmanned aircraft industry for both professional and personal use in the United States.

Drone manufacturers and those who use their technologies have specific insights and priorities that compel their voices to be heard. Among other things, ADI members have a strong interest in:

- Crafting a framework for professional and personal use of drones in a broad range of innovative applications for today and tomorrow
- Ensuring safety by maintaining user liability for operations and personal and corporate compliance with regulations during drone flight
- Advocating for objective, scientific risk assessments over arbitrary hardware or software mandates
- Harmonizing product requirements
- Partnering with the Congress and federal regulators in creating sound policies that promote unmanned aircraft manufacturing, and sensible standards and operations
- Protecting data privacy through technology-neutral policies; and
- Providing a respected resource for media inquiries and proactive public affairs efforts that represent the recreational and commercial industry leaders.

5.4. Alliance for Telecommunications Industry Solutions (ATIS)

Background

As a leading technology and solutions development organization, the Alliance for Telecommunications Industry Solutions, brings together the top global ICT companies to advance the industry's business priorities. ATIS membership includes North American network operators as well as some of the most innovative mobile equipment vendors. Increasingly, ATIS also collaborates with vertical industries and government agencies that utilize mobile technology. Member companies are currently working to address 5G, network-enabled artificial intelligence, distributed ledger technology/blockchain, network functions virtualization, emergency communications, IoT, cybersecurity, network evolution, quality of service, operations, and much more. All projects follow a fast-track development lifecycle – from design and innovation through standards, specifications, requirements, business use cases, software toolkits, open source solutions, and interoperability testing.

As the North American partner in 3GPP, ATIS is responsible for guiding 3GPP developments to ensure they meet market and regulatory requirements in the region and publishing regional standards that encapsulate 3GPP specifications.

Overview

In 2017, ATIS launched its Unmanned Aerial Vehicle (UAV) initiative to apply ATIS members' expertise in mobile cellular and other communications networking technologies to better understanding the interaction of UAVs and communication technologies.

A focus of the UAV group is to advance the use of mobile cellular networks (especially 3GPP specified technology) to support the communication needs of UAVs. This includes monitoring and advancing the development of 3GPP specifications to address UAV-related requirements. The group helps align member strategies and contributions in 3GPP.

The group also considers how UAVs can provide benefits to mobile network operators – for example in helping restore cellular communications in emergency situations.

The group has published the following reports:

- *Use of Cellular Communications to Support Unmanned Aerial Vehicle (UAV) Flight Operations* (August 2019)
- *Use of UAVs for Restoring Communications in Emergency Situations* (December 2018)
- *Support for UAV Communications in 3GPP Cellular Standards* (October 2018)
- *Unmanned Aerial Vehicle Utilization of Cellular Services* (September 2017)

While much of the work to advance understanding of UAVs and communications technologies takes place in ATIS' UAV Initiative, ATIS also recognizes how its UAV findings are increasingly relevant to other work taking place in the organization. For example, ATIS's initiative to characterize the communications needs for Internet of Things (IoT) applications addresses several UAV-based services such as package delivery, aerial survey, and video production. It is this synergistic, cross-sector view that ATIS believes is critical to advancing how UAVs and communications technology can best work together.

5.5. Association for Unmanned Vehicle Systems International (AUVSI)

The Association for Unmanned Vehicle Systems International (AUVSI), the world's largest nonprofit organization dedicated to the advancement of UxS and robotics, represents corporations and professionals from more than 60 countries involved in industry, government, and academia. AUVSI members work in the defense, civil, and commercial markets.

AUVSI members who are participating in the development of the ANSI UAS roadmap view it as a vital activity that is needed to identify standards that will support the safe integration of UAS operations into society. Much of the effort involved with developing the ANSI UAS standards roadmap has taken place in conjunction with the AUVSI Trusted Operator Program™ (TOP), which was launched on November, 1, 2018.

There is positive synergy between the ANSI UAS roadmap and the AUVSI TOP. The ANSI roadmap, once completed, will point to the existing and future formal UAS standards, while TOP provides a practical industry solution to an industry problem now. TOP tests the veracity of commercial UAS operators, while supporting industry unification on best practices and protocols to be compliant with these emerging standards. TOP focuses heavily on safety, reliability, and professionalism in remote pilot training and operator certification, pointing to recognized standards and safety 'behaviors' including: industry best practice, codes of conduct, and in some cases new association standards, such as the AUVSI AIRBOSS supplement and Airmanship Principles as contained in the TOP Protocols Certification Manual.

There is no doubt that as the industry continues to evolve so will the need to refine existing standards and develop new standards where more '*gaps*' become apparent. In the meantime, the TOP provides a practical certification program that supports future standardization.

5.6. Aviators Code Initiative (ACI)

The Aviators Code Initiative (ACI) provides original tools to advance aviation safety and professionalism, and to provide a vision of excellence for aviators. With aviation experience totaling more than 500 years, the Permanent Editorial Board builds upon the ACI's 18-year foundation of creating a family of guidance materials for pilots of manned and unmanned aircraft, instructors, maintenance technicians and others. Its UAS guidance includes:

- Unmanned Aircraft Systems Pilots Code (UAS Pilots Code)
- Improving Cockpit Awareness of Unmanned Aircraft Systems Near Airports (whitepaper)
- Flight Safety in the *Drone Age* (for manned aircraft pilots operating near drones)

Other ACI resources that have contributed to the development of UAS practices and safety include:

- Aviation Maintenance Technicians Model Code of Conduct
- Aviators Model Code of Conduct
- Flight Instructors Model Code of Conduct
- Glider Aviators Model Code of Conduct
- Helicopter Pilots Model Code of Conduct
- Light Sport Aviators Model Code of Conduct
- Seaplane Pilots Model Code of Conduct
- Student Pilots Model Code of Conduct
- Teaching the AMCC to Kids

ACI has also produces extensive commentary, supporting materials, and code of conduct language translations, all of which are available at www.secureav.com. For more information, contact its Permanent Editorial Board peb@secureav.com.

5.7. AW-Drones

AW-Drones is a 36 months (2019-2021) project co-funded by the European Commission in the framework of Horizon 2020, the biggest EU Research and Innovation programme. The project supports the on-going EU regulatory process for the definition of technical rules, standards, and procedures for civilian drones to enable safe, environmentally sound and reliable operations in the EU. This objective is met through four main strands of activity:

- **Collect** information on on-going and planned work with regards to technical rules, procedures and standards developed for mass-market drones worldwide;
- Carry out a critical **assessment/benchmarking** of all collected data to identify **best practices, gaps and bottlenecks**;
- **Propose and validate a well-reasoned set of technical standards** for each category of drone operations;
- **Engage with key stakeholders and end-users**, i.e., representatives of the whole drone value chain.

EC and EASA, together with the project consortium, considered the current regulatory needs at EU level and decided to give priority to the following areas:

- Year 1: Analysis of standards required to support effectively the Specific Operations Risk Assessment (SORA) methodology. In particular, AW-Drones will look at the mitigations strategies proposed by SORA in its Annexes B and E and identify to what extent supporting standards to implement those mitigations are available or need to be developed. The identification of these standards will initially focus on technical ones, but those that are more related to operations and procedures will be considered as well.
- Year 2: Analysis of standards supporting the development of U-Space in Europe. In particular, all standards required to support the technical implementation of U-Space services in both U1, U2 and U3 phases will be addressed.
- Year 3: Towards its end, AW-Drones will focus on standards needed to support the operation of highly automated UAS and to ensure that they can be operated safely in a variety of applications. Standards and principles needed for Autonomous UAS certification will be investigated.

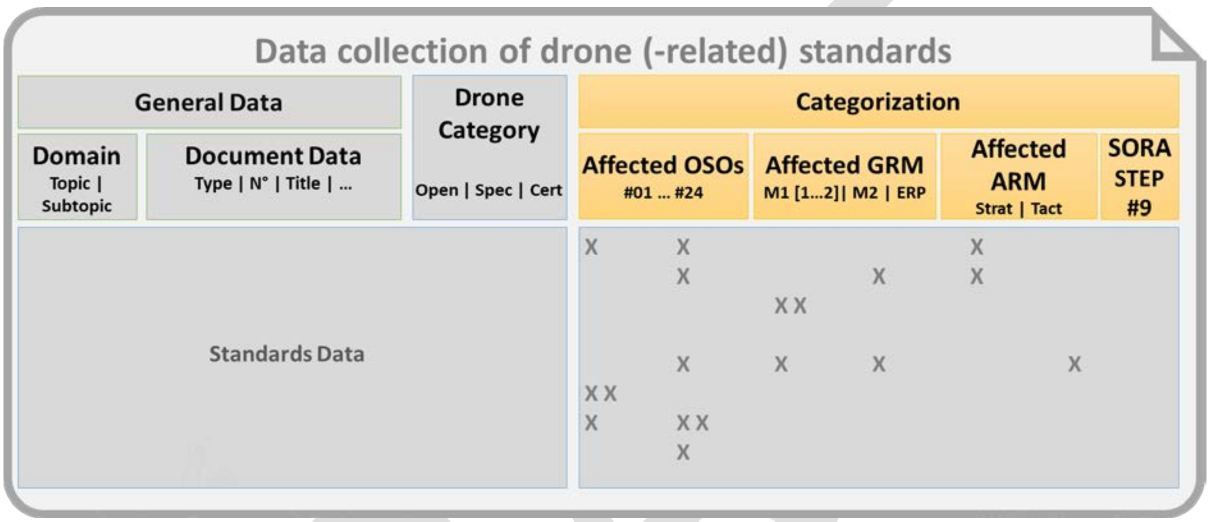
Collection of UAS standards

The starting point for the collection of data has been the EUSCG Rolling Development Plan as it provides an overview of a large number of standards related to UAS. However, this source has been complemented with other data, e.g., ANSI roadmap and other literature studies. Special importance has been placed on the collection of UAS related standards from ANSI and

ASTM, as they cover a huge amount of documents and are obviously very much complete about the standards by these Standards Development Organizations (SDOs).

The collected standards are linked to the SORA Operational Safety Objectives (OSOs), ground/air risk mitigations (GRM/ARM), and Step #9 (Adjacent Area/Airspace Considerations). This is a first step for the assessment of a standard as a possible Acceptable Means of Compliance (AMC) to one or more OSO/mitigation. The final outcome of the data collection is organized as shown in Table 3:

Table 3: Data collection of drone (-related) standards (Source: AW-Drones)



Standards assessment

During the first year (2019), the AW-Drones project focused on the collection and assessment of standards potentially suitable to support the demonstration of compliance to the requirements set in the Specific Operations Risk Assessment methodology (SORA). This methodology is officially recommended by EASA as AMC to Article 11 of EU Regulation 947/2019, but at the moment lacks clear guidance on which technical standards the UAS operators should use.

AW-Drones is in charge of the assessment of the standards collected as described in the previous section. In line with the iterative approach of the AW-Drones project, this work will be updated regularly in the next years to include updates related to the standards assessed and inputs from relevant UAS industry stakeholders (e.g. EASA, Standard Making Bodies, Operators, etc.).

According to the assessment methodology defined by the project, the assessment is focused on the following cases:

- CASE 1: one or more standards that are potentially suitable to comply with a given requirement have been identified;
- CASE 2: there is no standard fully covering a given requirement, thus a gap is identified.

For each SORA requirement AW-Drones is therefore able to present:

- A list of standards that are covering in part or fully the requirement, ranked by a global score obtained by assessing each standard according to the methodology;
- A list of gaps identifying aspects that are not adequately covered by existing standards. Gaps are also given a score based on the criteria identified by the methodology;
- Recommendations about the preferred standards and suggested strategies to fill the identified gaps based on their score.

The aforementioned assessment was carried out for all the requirements stemming from the SORA methodology, including:

- Ground Risk Mitigations
- Tactical Mitigations Performance Requirements (TMPR)
- Operational Safety Objectives
- Adjacent Area/Airspace requirements

With respect to the standards considered in the analysis, the scope was limited considering the following aspects:

- In general, no standards in the planning phase were considered, with few exceptions related to standards for which the first draft was already available.
- The maturity of the standards (i.e., their phase of development) was determined in September 2019, so there could be recent updates which are not yet included in this document
- AW-Drones partners did not have full access to all standards at the time of the assessment. A complete assessment is provided only for the standards with full access. For the others, AW-Drones provides a preliminary assessment based on the publicly available information.

Finally, it is worth mentioning that the assessment did not address the technical quality of the individual standards. AW-Drones assumed that each standard was adequate to fulfil the scope for which it was developed, and focused the assessment only on the evaluation of its capability to address the requirements.

Results presentation

The AW-Drones open repository is an online platform where users will be able to easily identify relevant information from the AW-Drones database of standards and regulations.

In the year 2019, the main requirements of the AW-Drones open repository have been produced and are detailed. The AW-Drones open repository is an online platform that will provide a single point of access to relevant information about:

- rules, procedures and technical standards developed for civilian drones;
- best practices, gaps and bottlenecks;
- technical standard for each category of drone operations;

Apart from an open platform that will be used as information exchange (access, mine, exploit, reproduce, disseminate data), the AW-Drones repository will also include collaboration features (commenting, rating, adding and editing content, reviewing, etc.) that will enhance its use and purpose and will further support its sustainability even after the end of the AW-Drones project.

The AW-Drones repository will store the following information for each standard: Domain (Domain and Subtopic); Type of Standard (Whether it is Standard/Specification, Best Practice or Information/Guidance); Document info (Document No, Title, Organization, Status, Description); Safety requirements (including affected SORA OSO, Technical requirements, Operational requirements, Remote crew training, Safe design, Deterioration of external systems supporting UAS operation, Human Error, Adverse Operating Conditions); Ground Risk Mitigations (M1 Generic, M2 Effects on ground impact, ERP); and Collision Risk/Air Risk (Strategic Mitigation, Tactical Mitigation).

Four types of users have been identified: Administrator, Editor, Acknowledged user and Basic user. Different functionalities will be offered for each type of user. The AW-Drones open repository will be ready in June 2020 and will be linked by the project website: https://www.aw-drones.eu/.

Engagement with main stakeholders

The AW-Drones project is built upon a solid and structured communication with stakeholders external to the consortium. The project identified three main categories of stakeholders, with different levels of involvement and means of consultation:

1. Institutional bodies:
    a. EU and EC: DG-INEA, DG-MOVE (EASA and the European Commission represent the main targets of the project, to be updated constantly on progress, findings and results);
    b. European Joint Undertakings (e.g. SESAR, Clean-Sky);
    c. Regulatory and safety agencies: ICAO, EASA and National CAAs, JARUS;
    d. Standard making bodies: EUSCG, ISO, EUROCAE, ASTM, RTCA, ASD-STAN;
    e. National bodies: National Ministries of Transport, National Agencies.
2. Specialised audience:
    a. AW-Drones Advisory Board
    b. Research community
        i. R&I institutes;
        ii. Universities;
        iii. Private research companies;
    c. Industry
        i. Drones manufacturers and maintainers;
        ii. Drones operators;
        iii. Drones Pilots
        iv. ANSPs;
        v. UTM/U-Space Service Providers
        vi. Industrial associations;

        d. Training Institutes.
    3. General stakeholders:
        a. General public;
        b. Media.

Contacts

- AW-Drones Project Coordinator: Damiano Taurino, Deep Blue (damiano.taurino@dblue.it)
- AW-Drones Communication manager: Vera Ferraiuolo, Deep Blue (vera.ferraiuolo@dblue.it)
- AW-Drones Project website
- AW-Drones Project LinkedIn Page

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- JARUS, Specific Operations Risk Assessment (SORA)
- EASA, AMC and GM to Commission Implementing Regulation (EU) No 2019/947
- EUSCG (EUROCAE): European UAS Standardization Rolling Development Plan
- ANSI: Standardization Roadmap – For Unmanned Aircraft Systems, Version 1.0
- ASTM: Unmanned Aircraft Systems – A comprehensive solution

5.8. Commercial Drone Alliance

The Commercial Drone Alliance is an industry-led non-profit association representing commercial drone end users and the broader commercial drone ecosystem. The Alliance's members include key leaders in the commercial drone industry, including manufacturers, service providers, software developers, and end users in vertical markets such as oil and gas, precision agriculture, construction, security, communications technology, infrastructure, newsgathering, filmmaking, and more.

The goals of the Alliance are to reduce barriers to enable the emergence of drone technology, and to work with the federal government and other stakeholders to facilitate drone integration into the National Airspace System (NAS) in a way that is safe and secure. The Alliance is actively engaged in drone security issues. The Alliance is also dedicated to supporting commercial drone industry market growth, enhancing value for commercial enterprise drone end users, educating the public on the benefits of commercial drones, and merging policy with innovation to create relevant rules for operation. To this end, the Alliance regularly engages with federal regulators, policymakers, and industry stakeholders, and actively participates in rulemaking initiatives, aviation rulemaking committees, the development of legislation, and public debate about drones.

In 2017 and 2018, the Alliance's activities included, among others:

- Strongly urged the federal government to propose and finalize "expanded operations" rulemakings, including those that will enable drone operations over people (OOP), BVLOS, and at night.

- Actively supported public-private partnerships such as the NASA/FAA UTM program, the FAA's Unmanned Aircraft Safety Team, and the FAA's waiver improvement efforts.
- Hosted the first-ever Domestic Drone Security Series to facilitate discussions between industry and federal policymakers around drone security and counter-drone issues. Participating organizations have included the White House Office of Science and Technology Policy (OSTP) and National Security Council (NSC), the National Aviation Intelligence Integration Office (NAI2O), DOD, DOJ, Federal Bureau of Investigation (FBI), DHS, NASA, FAA, DOI, U.S. Congress, state and local government representatives, and more.
- Worked with Congress to protect drone industry priorities in the FAA Reauthorization Bill and Infrastructure Bill.
- Participated in the UAS Identification and Tracking ARC and filed a dissent to certain aspects of the ARC's final report, which was joined by a number of other ARC members. The dissent focused on disagreements over a carve-out for model aircraft and the proposal for a narrow capabilities-based threshold for the applicability of the remote ID and tracking requirements, which inhibits the growth of innovation.
- Met with the White House's Office of Information and Regulatory Affairs (OIRA) to discuss and offer comments on the FAA's proposed rulemaking on "Operations of Small Unmanned Aircraft Over People." The Alliance advocated for a rule with a broad-based risk analysis that considers overall levels of safety, including safety outside of the aviation system. It also advocated for the incorporation of a "consent" element to the rule that allows more flexibility for OOP who are aware of and have consented to the drone operation.
- Met with the OIRA to discuss and offer comments on the FAA's proposed rulemaking on "Safe and Secure Operations of Small Unmanned Aircraft Systems." The Alliance advocated for basic rules of the road applicable to all drones in order to promote innovation, including requirements for registration, remote ID, and tracking of all drones in the sky over a certain weight threshold, enabling technology solutions to policy problems, and the establishment of a comprehensive drone remote ID and tracking framework.
- Advocated for the elimination (or, at least, significant amendment) of Section 336 of the FAA Modernization and Reform Act of 2012, seeking to enable the FAA to regulate all drones for safety and security as appropriate.
- Opposed the Uniform Law Commission's draft Tort Law regarding Drones, with a particular focus on objections to the creation of a strict liability per se aerial trespass claim for drones operated below 200 feet above ground level (AGL) or any structure on the land.
- Advocated a creative solution to industry's problem posed by the White House Office of Management and Budget (OMB) "2-for-1" regulatory Executive Order, titled "Reducing Regulation and Controlling Regulatory Costs." Specifically, the Alliance urged OMB to promulgate additional guidance to the FAA clarifying that every new regulation issued that further integrates drones into the NAS qualifies as a "deregulatory action" for purposes of implementing the Executive Order.

- Participated in a House of Representatives Transportation and Infrastructure Committee Roundtable on Counter-drone issues, making the case for Congress to enable safe, selective, and surgical drone security solutions in a way that is appropriately tailored.
- Was the lead sponsor developing the content for and planning the Commercial UAV Expo, a leading commercial drone industry trade show.

For the remainder of 2018 and early 2019, the Alliance will remain focused on growing the commercial drone industry by enabling timely and safe integration of drone technology into the NAS. This will include, among other things, collaborating with industry policymakers to authorize expanded drone operations beyond the current scope of Part 107 (e.g., BVLOS, over people, at night, etc.) and to establish comprehensive drone remote ID and tracking requirements.

5.9. CTIA

CTIA® represents the U.S. wireless communications industry and the companies throughout the mobile ecosystem that enable Americans to lead a 21st century connected life. The association's members include wireless carriers, device manufacturers, suppliers, as well as app and content companies. CTIA vigorously advocates at all levels of government for policies that foster continued wireless innovation and investment. The association also coordinates the industry's voluntary best practices, hosts educational events that promote the wireless industry, and co-produces a leading wireless industry tradeshow. CTIA was founded in 1984 and is based in Washington, D.C.

CTIA engages with policymakers at regulatory agencies, in Congress, and in the Administration to address how commercial wireless technology (sometimes referred to as "networked cellular") can support UAS communications functions. For example, CTIA responded to UAS spectrum inquiries from the Federal Aviation Administration and the Federal Communications Commission to explain the critical role of networked cellular in robust, reliable and secure UAS communications, and to address how wireless carriers are addressing interference and mobility issues CTIA advocates for flexible policies and standards related to spectrum and wireless infrastructure that will enable the growing UAS industry to flourish. CTIA also commented in the FAA's Safe and Secure Operation of Small UAS proceeding on the role of wireless networks and devices in small UAS operational evolution. Additionally, CTIA monitors UAS discussions in SDOs such as 3GPP, which is developing specifications for 5G wireless technology, and ASTM's UAS Remote ID Working Group. Through its UAS Working Group, CTIA provides a forum for wireless carriers and suppliers, UAS and urban air mobility operators, and researchers from organizations such as NASA to explore concepts of UAS integration and communications needs. In 2019, the FAA and CTIA established common data testing principles across all FAA UAS Integration Pilot Program (IPP) to allow FAA to assess the wireless industry's readiness to address key UAS communications needs.

5.10. General Aviation Manufacturers Association (GAMA)

The General Aviation Manufacturers Association (GAMA) is an international aviation industry trade association representing over 120 of the world's leading manufacturers of general aviation airplanes and rotorcraft, engines, avionics, components, and related service providers. GAMA exists to foster and advance the general welfare, safety, interests and activities of the global business and general aviation industry. This includes promoting a better understanding of general aviation manufacturing, maintenance, repair, and overhaul and the important role these industry segments play in economic growth and opportunity, and in serving the critical transportation needs of communities, companies and individuals worldwide.

GAMA works certification issues for passenger or cargo carrying Part 23 to Part 29 aircraft (and equivalent aircraft categories of the global authorities) through a collection of standing committees. GAMA Standing Committees evaluate common issues around design and safety, licensing and training, maintenance and operations as well as airspace integration to streamline where improvements can be made but also advocate on areas which impact the general and business aviation community. GAMA's electric propulsion & innovation committee (EPIC) also provides a forum to companies introducing new and innovative concepts to explore best pathways for certification and integration into the national airspace. Since 2015, EPIC has been working with over 80 global stakeholders to support hybrid and electric propulsion systems, eVTOL aircraft, autonomous systems, and urban air mobility operations concepts.

Publications and Resources

GAMA produces important technical publications and specifications, which guide the industry in standards for development and maintenance of general aviation aircraft. Readers can also access numerous studies detailing general aviation's significant economic impact globally, as well as documents highlighting the industry's work on the environment and other issues. GAMA is well-known and respected for its close tracking of the industry's shipment and billing numbers, issuing new results each quarter. The association also publishes an annual report, which not only includes historical aircraft delivery data, but also fleet and flight activity data from around the globe and critical statistics about aviation safety.

The GAMA has developed an "Aerospace Standards Applicability and Acceptance" database including industry consensus standards which support the aviation industry. It includes all the standards approved or in development by the primary standards development organizations (SDOs) supporting the general and business aviation industries. With the safety continuum in mind, GAMA's database addresses manned, unmanned, and cargo aircraft, as well as related systems and technologies, including major components. At this time, it does not include all materials, testing or chemicals but if needed can be expanded at a later date. The database is intended as a tool where companies may identify standards by categories, applicability, regulation, organization and more.

GAMA's database includes applicability and acceptance tables. The applicability tables highlight the standards' relationship to various EASA and FAA rules. For example, if a standard is intended for Light Sport Aircraft (LSA) but is also helpful to UAS, or intended for Level 1 Part 23 but helpful to LSA or Level

2, the user can sort to identify which standards they may want to review for applicability to their project. The acceptance tables denote where and if each standard has been accepted by the CAAs, including references to the published policy calling out its acceptance. Currently, cross reference tables to Part 23 and EASA's special condition vertical takeoff and landing (SC-VTOL) are also included.

Alongside the Aerospace Standards Portfolio and Matrices is a partnering website which addresses the various SDOs, available educational resources, and FAQs about how to participate in standards development as well as how to use the standards. Additionally, it will reference other industry roadmaps that the GAMA's Aerospace Standards Database does not address, such as UAS and additive manufacturing (ANSI UASSC and AMSC[13] offerings). The GAMA's Aerospace Standards Database will be maintained on the public GAMA standards website and is expected to launch in April 2020.

The GAMA Aerospace Standards Database aims to provide industry more visibility into the existing work available in order to save time and resources, both in terms of locating standards and so as not to create unnecessary new standards. It does not aim to identify gaps in standards, research and regulation as those areas are worked within the GAMA committees and with the appropriate outside organizations leading those initiatives. Other standards organizations have developed gap analyses that are relevant for standards needs for urban air mobility (UAM) aircraft and supporting technologies. The manned aviation community is looking to the unmanned aircraft community for needed airspace integration standards, such as Remote ID and Detect and Avoid (DAA). The ANSI UASSC roadmap already includes those gaps.

The general aviation industry is a significant economic contributor to the global economy, as seen in reports published by GAMA and others, and available here. GAMA also provides guidance to manufacturers in addressing technical issues and meeting product certification standards. Furthermore, GAMA periodically publishes documents on other topics of interest to the general aviation industry, such as business aviation's commitment on climate change.

Related GAMA Technical Publications

- GAMA Specification No. 1: Specification for Pilot's Operating Handbook (Version 2.0)
- GAMA Specification No. 7: Specification for Continuing Airworthiness Program (CAP) (Version 1.0)
- GAMA Publication No. 16: Hybrid and Electric Propulsion Performance Measurement (Version 1.0)
- Interim Procedure on Noise Certification for Emerging VTOL Aircraft Version1.0 (Oct2019)

[13] The America Makes & ANSI Additive Manufacturing Standardization Collaborative (AMSC) has developed a *Standardization Roadmap for Additive Manufacturing (Version 2.0, June 2018)*. Additional information is available at www.ansi.org/amsc.

- A Rationale Construct for Simplified Vehicle Operations (SVO); Whitepaper Version 1.0 (May2019)

Related Certification Publications

- The FAA and Industry Guide to Product Certification (2017)
- Implementing a Safety Management System for Design, Manufacturing and Maintenance Providers (SM-001)

Questions regarding the GAMA's standards strategies and the database can be directed to Christine DeJong Bernat at cdejong@gama.aero.

5.11. Global UTM Association (GUTMA)

The Global UTM Association (GUTMA) is a non-profit consortium of worldwide Unmanned Aircraft Systems Traffic Management (UTM) stakeholders. Its purpose is to foster the safe, secure and efficient integration of drones in national airspace systems. Its mission is to support and accelerate the transparent implementation of globally interoperable UTM systems.

Since its establishment in 2016, the association has grown to over 70 members, representing 28 countries worldwide. As UTM systems and services are taking shape in pilot programs and demonstrations around the globe, various new actors apply to join the emerging industry. The diversity can be tackled in the current composition of GUTMA community: civil aviation authorities and air navigation service providers share their views with telecommunication companies, UAS manufacturers, drone operators and UTM service providers to identify the new solutions, roles and responsibilities in the UTM ecosystem.

All GUTMA protocols are open source, publicly available, and have a process of engagement, updates, reviews, and tests.

Flight Declaration Protocol	The Flight Declaration Protocol is targeted at drone operators. It provides a way to share interoperable flight and mission plans digitally.
Flight Logging Protocol	The Flight Logging Protocol is targeted at drone manufacturers and UAS service suppliers (USSs). It offers an interoperable interface to access post-flight data. It is in the process of being expanded to enable access to inflight telemetry data.
Air Traffic Data Protocol	The Air Traffic Data Protocol aims to standardize how sensor data are transmitted to the apps and services used during drone operations.
Drone Registry Database Schema	This is a GUTMA sandbox for working on an interoperable drone registry. It has three main things to work with: Registry Landscape Whitepaper, Interoperable API Specification and a working API.

Database Brokerage API specification	GUTMA's drone registry broker sandbox has three things to work with: Registry Broker Whitepaper, two working registries with sample data and operating test system with IDs, tokens and status and results.
Aerial Connectivity Working Group	This Working Group addresses the need for better and more formal coordination between aviation stakeholders with bodies representing the commercial/cellular communication industries.
GUTMA is also addressing harmonized concepts and standards for remote ID, geo-awareness, inter-USS communications and "open FIMS".	

5.12. Helicopter Association International (HAI)

Since its founding in 1948, the mission of Helicopter Association International (HAI) has been to provide its members with services that directly benefit their operations, and to advance the international rotorcraft community by providing programs that enhance safety, encourage professionalism and economic viability, and promote the unique contributions vertical flight offers society. Today, HAI members in more than 70 nations annually operate more than 5,000 aircraft some 2.3 million flight hours while carrying out nearly 50 different operational missions.

HAI supports safety, operational, regulatory, and legislative initiatives to improve and promote the rotorcraft industry. Unique among aviation associations, it represents the interests of rotorcraft operators, manufacturers, and service providers. HAI also holds the world's largest rotorcraft trade show, providing a platform where the international vertical flight community comes together to connect, conduct business, and address industry issues.

In 1948, when HAI was founded, the civil helicopter industry was only two years old, and the association grew and matured with the industry. Decades later, HAI is a leader in welcoming a new sector to the rotorcraft industry: unmanned aircraft systems (UAS).

Besides sharing vertical-lift technology, both manned and unmanned rotorcraft share the low-altitude airspace to perform many of the same missions. Unmanned rotorcraft, in a number of configurations, including quadcopters, tiltrotors, and traditional main/tail rotor designs, today execute a wide variety of operations that formerly required helicopters. Today, everything from small UAS weighing only a few pounds performing aerial photography and surveillance to full production–size unmanned aircraft conducting aerial firefighting and heavy construction missions fits within the continuum of modern rotorcraft aviation.

First and foremost, HAI supports the safe, efficient integration of UAS into the airspace. To ensure that integration, HAI staff have been foundational participants on a number of important UAS-related advisory groups, including aviation rulemaking committees, working groups, panels, the FAA Pathfinder program, and the FAA Drone Advisory Committee.

HAI has also welcomed UAS members into the association, launching in 2016 a new membership category for UAS operators and creating an Unmanned Aircraft Systems Working Group. HAI's 12 working groups provide the Board of Directors with industry perspectives and insight to a variety of topics. The UAS Working Group promotes cooperative communication among all sectors of rotorcraft aviation, helps HAI members incorporate unmanned systems into their operations, and develops best practices to enhance the safety and efficiency of both manned and unmanned aviation in shared airspace.

As technology evolves, unmanned rotorcraft will fill an increasing number of missions, eventually to include the movement of people and goods. The number of rotorcraft missions being performed is also expanding as consumers and businesses come to understand the capabilities and advantages provided by these new aircraft. Insurance adjusters, for example, now commonly use UAS to perform aerial inspection of property damage.

Each year, more traditional helicopter operators incorporate the use of unmanned aircraft in their business models. These companies have decades of experience in low-altitude rotorcraft operations, aviation regulatory compliance, and safety management and risk mitigation. As such, their UAS learning curve is more about incorporating a new aircraft into their fleet as opposed to a drone company trying to learn the complexities of aviation operations.

HAI will continue to be a leader in the integration of unmanned rotorcraft into global aviation. As has been the case since 1948, HAI will do so with a focus on safety and professionalism, while promoting the economic and social benefits of this latest addition to the rotorcraft industry.

You can learn more about HAI at www.rotor.org.

5.13. National Agricultural Aviation Association (NAAA)

The National Agricultural Aviation Association (NAAA), founded in 1966, represents approximately 1,900 members in 46 states. NAAA supports the interests of small business owners and pilots licensed as professional commercial aerial applicators who use aircraft to enhance food, fiber and biofuel production, protect forestry, and control health-threatening pests. NAAA works with its partner organization, the National Agricultural Aviation Research & Education Foundation (NAAREF), to provide research and educational programs focused on enhancing the efficacy, security, and safety of aerial application.

NAAA largely agrees with the gaps identified in the ANSI UAS roadmap. For example, NAAA strongly agrees with the roadmap’s assessment that gaps exist in the communication, treatment efficacy, operational safety, equipment reliability, and airspace integration of unmanned aircraft used for aerial application compared to their manned counterparts, and that extensive research and development should be required to prove their safe use. Efficacy, drift potential, and ability to comply with the aerial application requirements on EPA pesticide labels are key areas UAVs need to comply with before certification for pesticide application use. The drift characteristics and efficacy of applications made by UAVs are largely unknown and require extensive research and development to ensure environmental and human safety.

Currently, USDA's AgDRIFT model is the regulatory and industry standard for calculating drift risk for ag aircraft, ground sprayers, and air blasters. This model has been developed over the years through extensive research and smaller unmanned aircraft do not fit properly into the AgDRIFT model. NAAA has provided data to the EPA explaining why the agency needs to develop a committee to accurately study the drift characteristics of applications made by UAVs, so this data could be incorporated into the AgDRIFT model. NAAA also requested that until this research is conducted and evaluated, the EPA clarify the rules regarding how UAS can make aerial applications under existing law.

Additionally, NAAA strongly agrees that more research and development is needed to develop detect and avoid systems and that it should be a high priority for the aviation industry, if not the highest priority. Furthermore, NAAA believes detect and avoid systems should be standard on all unmanned aircraft, requiring unmanned aircraft to land autonomously when a manned aircraft is detected close by. Research shows pilots cannot reliably detect UAVs, so the burden of avoidance lies with the UAV operator. The Colorado Agricultural Aviation Association conducted a study on the visibility of UAVs at low levels and only one of five manned aircraft were able to positively identify a moving UAS, albeit briefly.

NAAA supports the safe integration of UAS into the NAS, provided they provide an equivalent level of safety to having a pilot on board. This includes installation of an Automatic Dependent Surveillance Broadcast (ADS-B) like technology aboard that grounds the UAS when approaching an unsafe distance to a manned aircraft, strobe lighting, aviation orange and white marking to promote visibility, requiring line of sight operation and other measures to ensure proper operation, and awareness by manned low-level aviation operations. NAAA has met with the FAA UAS integration office and numerous members of Congress to communicate these safety concerns and promote a safety minded approach to UAV integration.

5.14. National Council on Public Safety UAS (NCPSU)

The National Council on Public Safety UAS (NCPSU), a federation of national public safety organizations, is continuing its mission of advancing the safe and effective use of UAS in the public safety community. This is being accomplished in a number of ways. First, to collect and share best practices, lessons learned, UAS successes, and policies/procedures. Next, to increase the awareness about public safety UAS by partnering and participating with organizations such as AUVSI to provide public safety forums. The National Council is in the process of reaching out to public safety organizations in Canada and Europe to create an international collaboration to share thoughts and ideas.

Presently, the NCPSU is promoting and facilitating the development of state public safety UAS councils for the simple purpose of identifying public safety UAS programs/resources within the state, UAS capabilities, and points of contact toward the goal of a statewide database that will also combine into a nationwide network of public safety UAS Programs. This is designed to enhance communication, coordination, and collaboration with and between public safety agencies. It will also serve as a way to identify UAS trends and issues. Agencies that are exploring a UAS program of their own can also learn how nearby agencies operate and access their policies and procedures. These state councils may be existing committees and are not designed to replace other WGs. 18 states are currently in the process of organizing a state public safety UAS council.

The NCPSU also stays abreast of technology and legislation related to counter-UAS (C-UAS) as this is a critical component to public safety and the communities they serve to address the clueless, the careless, and the criminal UAS operations.

The NCPSU submits articles, provides public safety speakers, works on and promotes UAS standards development, organizes a 2-day Public Safety UAS Forum at AUVSI's national XPONENTIAL Conference (in Chicago in 2019), supports the AUVSI Trusted Operator Program™ (TOP), promotes regional public safety UAS training, and more.

5.15. National Public Safety Telecommunications Council (NPSTC)

The National Public Safety Telecommunications Council (NPSTC) is a federation of organizations whose mission is to improve public safety communications through collaborative leadership.

Public safety communications are comprised of voice and data. Data includes digital voice, images, video, and information from sensors. This includes the data/information that may be transmitted by UASs. NPSTC is represented on the governing board of the NCPSU.

NPSTC has an Unmanned Aircraft System Working Group which has produced three reports:

- Using UAS for Communications Support (May 30, 2018)
- UAS Communications Spectrum and Technology Considerations (May 30, 2018)
- Guidelines for Creating a UAS Program (April 18, 2017)

The purpose of this UAS WG is to:

1) Review the work being done by other groups and organizations to better understand the current landscape.
2) Create a list of use cases that document public safety use of these devices by law enforcement, fire/rescue, and EMS.
3) Review the current regulatory environment including issues that impact research, affect public safety use, and concern appropriate management of commercial and hobby devices.
4) Provide input on pending rule-making actions which will impact public safety operations (either directly or via regulation of commercial and hobby operations).
5) Consider the need for additional spectrum to communicate with Public Safety UAS and coordinate with the NPSTC Spectrum Management Committee.
6) Develop outreach statements which will help to educate the public safety community of the current state of UAS and robotic usage.

7) Examine the need for best practices in the use of UAS and robotic systems.

On January 27, 2020, NPSTC filed Comments to the Federal Communications Commission (FCC) supporting the use of 960-1164 MHz and 5030-5091 MHz bands for UAS and reiterating previous recommendations filed with the FCC to authorize both manned and unmanned airborne public safety operations on the lower 10 MHz of the 4.9 GHz band.

Currently, NPSTC is not engaged in further UAS discussions or studies unless there is a new issue or need for updating current reports.

5.16. Security Industry Association (SIA)

SIA is an international trade association representing manufacturers and integrators of physical security equipment, cyber security technologies, and life safety solutions. Its membership ranges from large global technology companies to locally owned and operated security industry participants that develop, manufacture, install, or service security products. These products include alarm systems, access control, video surveillance, data analytics, and identity management solutions, as well as security-related unmanned systems, robotics, and a range of other cutting-edge security solutions that help keep streets, schools, critical infrastructure, and businesses safe. SIA is the primary sponsor of the largest security trade show in North America, ISC West, which attracts over 30,000 attendees annually. In 2017, ISC West unveiled its inaugural *Unmanned Security Expo* featuring SIA member companies showcasing several UAS, counter-UAS, and robotic technologies utilized in a security setting.

UAS technologies and ground-based robotics have diversified the security industry's technology portfolio. As a result, SIA has become actively involved in UAS and counter-UAS policy development, and was recently cited as a supporter of federal legislation creating a framework for agency use of counter-UAS technology during a congressional hearing. In 2018, SIA created the *Autonomous Security Robotics Working Group* (ASRWG), which is comprised of member volunteers advising SIA on UAS/robotic initiatives benefiting the security industry. SIA and ASRWG recently released a regulatory guide entitled, *UAS FAQ for the Security Industry* to assist members in comprehending the legal and regulatory landscapes governing UAS technology. Concurrently, the ASRWG assisted in the development of market research addressing how robotics are expanding and augmenting the capabilities of security personnel.

5.17. Small UAV Coalition

Industry leaders established the Small UAV Coalition to provide a unified voice advocating for changes to law and policy that will allow unfettered commercial, civil, and philanthropic UAS operations in the United States and abroad. The Coalition provides lawmakers and regulators with technical expertise needed to develop a progressive, forward-leaning regulatory framework that will allow businesses to seize the benefits of UAS technology in the near term.

The current pace of regulatory and policy development, particularly in the United States, is impeding UAS development, sales, services, and consumer and public benefits in the near term. Thus, the Coalition seeks to expedite testing and operation of UAS in the United States and abroad by spurring and shaping acceptable UAS regulations and policies that will allow businesses to begin to fully realize the potential of UAS technology in order to maximize revenue.

Specifically, the Coalition aims to:

- promote the safe commercial, civil, and philanthropic use of UAS;
- demonstrate the important economic, environmental, and public safety benefits of UAS;
- develop a sensible, efficient, and open regulatory process to ensure the timely introduction and operation of UAS; and
- support American competitiveness and exports in the UAS industry.

The Coalition’s top priority is to promote safe and responsible commercial and civil use of UAS in the near term. The Coalition is working with Congress, the Federal Aviation Administration, DOT, the White House, the Federal Communications Commission, NASA, and the Departments of Commerce, Homeland Security, and Justice, and third party stakeholders to encourage coordination and to meet its key goals. The Coalition also works on other policy issues including privacy, spectrum use, public interest concerns, the roles and responsibilities of the Federal, State, and local governments, international trade, and international collaboration on UAS regulations.

Coalition members have participated in all FAA UAS initiatives to date, including the Aircraft Registration Task Force, the Drone Advisory Committee, the Micro Unmanned Aircraft Systems Aviation Rulemaking Committee, the UAS Identification and Tracking Aviation Rulemaking Committee, the Unmanned Aircraft Safety Team, the UAS Integration Pilot Program, and the UTM System Pilot Program. The Coalition also participates in the Joint Authorities for Rulemaking of Unmanned Systems (JARUS) through its Stakeholder Consultation Body.

In addition to its advocacy work, the Coalition serves as a meeting ground for the best and brightest minds in the UAS industry. Current Board and Associate members include Amazon Prime Air, Intel, PrecisionHawk, Verizon/Skyward, Wing (formerly Google X Project Wing), Aeronyde, Airmap, Dominion Energy, Dronecourse.com, Iris Automation, OneSky, Percepto, T-Mobile, and Yamaha Motor Ventures.

5.18. Vertical Flight Society (VFS)

The Vertical Flight Society (VFS) is the world’s oldest and largest technical society dedicated to enhancing the understanding of vertical flight technology. Originally known as the American Helicopter Society (AHS), VFS is a non-profit charitable education and technical organization. Since it was founded in 1943 — just as the first US helicopter was being put into service — the Society has been the primary forum for interchange of information on vertical flight technology. According to the Society Bylaws, the purpose of the Society is to "advance the theory and practices of the science of vertical flight aircraft."

Each year, the Society organizes or co-sponsors several regional and international conferences that facilitate the advancement of the theory and practices of helicopter and other VTOL aircraft technology, and publishes their proceedings. The Society publishes the premier vertical flight technology bi-monthly magazine, Vertiflite, as well as the world's only peer-reviewed vertical flight technical publication, The Journal of the AHS (JAHS). VFS also maintains the eVTOL.news site, which has the complete encyclopedia of electric vertical take-off and landing (eVTOL) aircraft and companies.

Society members participate in twenty-two technical committees to advance the industry's collective knowledge from acoustics and aerodynamics to test and evaluation and unmanned VTOL. While VFS is not a standards development organization, members are very active in industry standards development, participating on committees from SAE, ANSI, ASTM, ASME, ASD-Stan, AIA and others.

The Society advocates on behalf of rotorcraft technology to the public and to government bodies, awards some two dozen annual engineering scholarships, and sponsors an annual student design competition and other challenges for undergraduate and graduate student teams. In addition, it presents two dozen annual awards to members of the vertical flight technical community for scientific and technical accomplishments, inspiring rescues and promoting the goals of the Society.

6. Airworthiness Standards – WG1

6.1. Design and Construction

Scalable, consensus-based, and acceptable design and construction (D&C) standards for UAS are critical to full integration of UAS into the NAS. Such standards are needed to expand upon the current 14 CFR part 107 and any applicable waivers and exemptions approved by the FAA. Full integration of UAS will require standards that support Design (Type) and Production Approvals as the foundational requirements before additional standards for Operational Approval -- such as operations over people (OOP), beyond visual line of sight (BVLOS), and other operations -- can be issued and accepted. Such standards will support reliability and provide a minimum level of confidence/assurance that is not currently required for sUAS operating under Part 107. Prudence dictates D&C acceptance criteria as a basis for further standards and regulatory development, just as it is for manned aircraft. This is not limited to sUAS standards and it will allow expansion beyond sUAS low altitude use cases for aircraft in excess of 55lbs. Additionally, a standard developed for a larger UAS may not be practical for a sUAS less than 55lbs (25kg). Therefore, in some cases, D&C standards should be scaled and scoped to the size of the aircraft, risk, airspace, and complexity of the operations, and focus on the needed system of systems and mission to support applications for waiver, exemptions, or airworthiness.

Published Standards:[14]

- ASTM F2910-14, *Standard Specification for Design and Construction of a Small Unmanned Aircraft System (sUAS)*
- ASTM F2911-14e1, *Standard Practice for Production Acceptance of Small Unmanned Aircraft System (sUAS)*
- ASTM F3002-14a, *Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)*
- ASTM F3003-14, *Standard Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS)*
- ASTM F3298-19, *Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS)*
- JARUS CS-LUAS, *Recommendations for Certification Specification for Light Unmanned Aeroplane Systems*

[14] While not specific to UAS, ASTM Committee F42, ISO/TC 261, SAE, ASME, and others have published standards and are developing standards related to additive manufacturing, an emerging technology being used by the aerospace sector. America Makes and ANSI have published a *Standardization Roadmap for Additive Manufacturing (version 2.0, June 2018)* and an on-line gaps portal to track progress against the roadmap recommendations. Both are freely available at www.ansi.org/amsc.

- JARUS CS-LURS, *Certification Specification for Light Unmanned Rotorcraft Systems (CS-LURS)*
- JARUS AMC RPAS 1309, *Safety Assessment of Remotely Piloted Aircraft Systems (package)*
- JARUS CS-UAS, *Recommendations for Certification for Unmanned Aircraft Systems*
- EUROCAE ER-019, UAS System Safety Assessment Objectives and Criteria Inputs to "AMC RPAS.1309"
- SAE AS6969, *Data Dictionary for Quantities Used in Cyber Physical Systems*
- STANAG 4671, *UAV System Airworthiness Requirements (USAR)* (Fix wing UAV, 150Kg <MTOW<20,000lbs)
- STANAG 4702, *Rotary Wing Unmanned Aerial Systems Airworthiness Requirements* (Rotorcraft UAV, 150Kg<MTOW< 3125Kg
- STANAG 4703, *Light Unmanned Aircraft Systems Airworthiness Requirements* (Fix wing UAV, <150KgMTOW)
- STANAG 4746, *Unmanned Aerial Vehicle System Airworthiness Requirements for Light Vertical Take Off and Landing Aircraft*

In-Development Standards:

- ASTM WK49440, *Revision of F3002 - 14a Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)*
- ASTM WK59101*, New Specification for Structures, Design and Construction* (Light Sport Aircraft)
- ASTM WK61232, *New Practice for Low Stress Airframe Structure* (Light Sport Aircraft)
- ASTM WK62670, *New Specification for Large UAS Design and Construction* (for aircraft <19,000lbs)
- ASTM WK70877*, New Practice for Showing Durability and Reliability Means of Compliance for Unmanned Aircraft Systems*
- ASD-STAN D1WG4, *UAS Product requirements to develop European standards specifying the means of compliance to the regulatory requirements defined in Appendix I.1 to I.5 of EASA-NPA 2017-05(A)* (defines the design, construction, and test requirements for CE marking conformity)
- ISO/CD 21384-2, *Unmanned aircraft systems -- Part 2: Product systems*EUROCAE Applicability of safe design standards for UAS in Specific Operations category;
- EUROCAE Guidelines on the Automatic protection of the flight envelope from human errors for UAS;
- EUROCAE Generic Functional Hazard Assessment (FHA) for RPAS
- EUROCAE Draft ED-272, Minimum Aviation Systems Performance Specification for Remote Pilot Stations supporting IFR operations into non-segregated airspaceRTCA DO-3XX, Environmental Conditions and Test Procedures for Ground Based Equipment
- SAE AIR7121**,** *Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems*
- SAE JA7496, *Cyber Physical Systems Security Engineering Plan (CPSSEP)*
- SAE AS6983, *Process Standard for Qualification of Aeronautical Systems Implementing AI: Development Standard*

- SAE JA6678, *Cyber Physical Systems Security Software Assurance*
- SAE AS6969A, Data Dictionary for Quantities Used in Cyber Physical Systems

Relevant Published General Industry Standards: Published standards and committees that have developed relevant standards include:

- ASTM F2245-16c, *Standard Specification for Design and Performance of a Light Sport Airplane*
- ASTM 3082/F3082M-17, *Standard Specification for Weights and Centers of Gravity of Aircraft*
- ASTM F3180/F3180M-18, *Standard Specification for Low-Speed Flight Characteristics of Aircraft*
- ASTM F3115/F3115M-15, *Standard Specification for Structural Durability for Small Airplanes*
- ASTM F3116/F3116M-15, *Standard Specification for Design Loads and Conditions*
- ASTM F963-17, *Standard Consumer Safety Specification for Toy Safety*
- ASTM F2563-16, *Standard Practice for Kit Assembly Instructions of Aircraft Intended Primarily for Recreation*
- ASTM F2930-16e1, *Standard Guide for Compliance with Light Sport Aircraft Standards*
- ASTM F3264-18, *Standard Specification for Normal Category Aeroplanes Certification*
- ASTM F2972-15, *Standard Specification for Light Sport Aircraft Manufacturer's Quality Assurance System*
- SAE AE-2 Lightning Committee
- SAE AE-4 Electromagnetic Compatibility (EMC) Committee
- SAE A-6 Aerospace Actuation, Control and Fluid Power Systems
- SAE A-6A1 Commercial Aircraft Committee
- SAE A-6A3 Flight Control and Vehicle Management Systems Committee
- SAE A-6B3 Electro-Mechanical Actuation Committee
- SAE A-20B Exterior Lighting Committee
- SAE A-20C Interior Lighting
- SAE A-22 Fire Protection and Flammability Testing Committee
- SAE A-4 EFIS Electronic Flight Instrument System Display
- SAE A-5 Aerospace Landing Gear Systems Committee
- SAE A-5A Wheels, Brakes and Skid Controls Committee
- SAE A-5B Gears, Struts and Couplings Committee
- SAE A-5C Aircraft Tires Committee
- SAE AE-7A Generators and Controls Motors and Magnetic Devices
- SAE AE-7B Power Management, Distribution and Storage
- SAE AE-7C Systems
- SAE AE-7D Aircraft Energy Storage and Charging Committee
- SAE AE-7M Aerospace Model Based Engineering
- SAE AE-7P Protective and Control Devices
- SAE AE-8A Elec Wiring and Fiber Optic Interconnect Sys Install
- SAE AE-8C1 Connectors Committee
- SAE AE-8C2 Terminating Devices and Tooling Committee
- SAE AE-8D Wire and Cable Committee

- SAE E-36 Electronic Engine Controls Committee
- SAE E-40 Electrified Propulsion Committee
- SAE EG-1 Aerospace Propulsion Systems Support Equipment
- SAE EG-1A Balancing Committee
- SAE EG-1B Hand Tools Committee
- SAE EG-1B1 Power Tools - Productivity, Ergonomics and Safety
- SAE EG-1E Gas Turbine Test Facilities and Equipment
- SAE S-18 Aircraft and Sys Dev and Safety Assessment Committee
- SAE G-3, Aerospace Couplings, Fittings, Hose, Tubing Assemblies
- SAE ACBG Plain Bearing Committee
- SAE ACBG Rolling Element Bearing Committee
- SAE G-11 Probabilistic Methods Committee
- SAE G-25, Avionics and Electronics Corrosion Committee
- SAE G-41 Reliability
- SAE G-47 Systems Engineering
- SAE AS-4JAUS Joint Architecture for Unmanned Systems Committee
- SAE AS-4UCS Unmanned Systems Control Segment Architecture

Relevant In-Development General Industry Standards: In-development standards and committees that are developing relevant standards include:

- ASTM WK51467, *New Specification for Quality Assurance for Manufacturers of Aircraft Systems*
- SAE AE-2 Lightning Committee
- SAE AE-4 Electromagnetic Compatibility (EMC) Committee
- SAE A-6 Aerospace Actuation, Control and Fluid Power Systems
- SAE A-6A1 Commercial Aircraft Committee
- SAE A-6A3 Flight Control and Vehicle Management Systems Committee
- SAE A-6B3 Electro-Mechanical Actuation Committee
- SAE A-20B Exterior Lighting Committee
- SAE A-20C Interior Lighting
- SAE A-22 Fire Protection and Flammability Testing Committee
- SAE A-5 Aerospace Landing Gear Systems Committee
- SAE A-5A Wheels, Brakes and Skid Controls Committee
- SAE A-5B Gears, Struts and Couplings Committee
- SAE A-5C Aircraft Tires Committee
- SAE AE-7A Generators and Controls Motors and Magnetic Devices
- SAE AE-7B Power Management, Distribution and Storage
- SAE AE-7C Systems
- SAE AE-7D Aircraft Energy Storage and Charging Committee
- SAE AE-7M Aerospace Model Based Engineering
- SAE AE-7P Protective and Control Devices
- SAE AE-8A Elec Wiring and Fiber Optic Interconnect Sys Install

- SAE AE-8C1 Connectors Committee
- SAE AE-8C2 Terminating Devices and Tooling Committee
- SAE AE-8D Wire and Cable Committee
- SAE E-36 Electronic Engine Controls Committee
- SAE E-40 Electrified Propulsion Committee
- SAE EG-1A Balancing Committee
- SAE EG-1B Hand Tools Committee
- SAE EG-1B1 Power Tools - Productivity, Ergonomics and Safety
- SAE EG-1E Gas Turbine Test Facilities and Equipment
- SAE S-18 Aircraft and Sys Dev and Safety Assessment Committee
- SAE S-18UAS Autonomy Working Group
- SAE G-3, Aerospace Couplings, Fittings, Hose, Tubing Assemblies
- SAE ACBG Plain Bearing Committee
- SAE ACBG Rolling Element Bearing Committee
- SAE G-41 Reliability
- SAE G-47 Systems Engineering
- SAE AS-4JAUS Joint Architecture for Unmanned Systems Committee
- SAE AS-4UCS Unmanned Systems Control Segment Architecture

Gap A1: UAS Design and Construction (D&C) Standards. There are numerous standards applicable to the D&C of manned aircraft which are scalable in application to UASCS. However, these standards fail to address the critical and novel aspects essential to the safety of unmanned operations (i.e., DAA, software, BVLOS, C2, CS, Highly Integrated System, etc.). Lacking any regulatory certifications/publications/guidance (type certificate (TC)/ supplemental type certificate (STC)/Technical Standard Order (TSO)/AC), manufacturers and/or operators require applicable industry standards capable of establishing an acceptable baseline of D&C for these safety-critical fight operation elements such as CS to support current regulatory flight operations and those authorized by waiver and or grants of exemption. Since the CS is one of the most critical parts and functions of the UAS needed to command and control UA remotely, the standards applicable to traditional manned aviation's airborne electronics (software, hardware, integration, spectrum, etc.) may need to be considered for the UAS as well either in the same manner and level or higher than that of the manned aviation aircraft to provide the acceptable level of safety. Some industry standards such as RTCA DO-278 may be applicable to the software aspects of the CS. However, there are currently no known industry standards that support the D&C of UAS CS, other than ASTM F3002-14a for sUAS under Part 107.

R&D Needed: No

Recommendation:

1) Complete work on in-development standards.
2) Develop D&C standards for UA and CS, and consider operations beyond the scope of regular Part 107 operations such as flight altitudes over 400 feet AGL, and any future technological needs.

3) Develop D&C standards for UA weighing more than 19,000 pounds and develop standards for accompanying CS.

Priority: High (Tier 1)

Organization(s): ASTM, SAE, ISO, EUROCAE, others?

Status of Progress: Green

Update: The gap has been updated to include a specific call for standards for UA weighing more than 19,000 pounds and for control stations.

6.2. UAS System Safety

Airworthiness safety and risk management are critical to integration of UAS into the U.S. airspace. The aviation safety process, which is well established, includes the design and operation of UAS (discussed elsewhere in this roadmap) in accordance with FAA rules and regulations. Safety is based on acceptable risks and appropriate mitigations as they pertain to people and property damage.. Aircraft must be operated within the environmental and performance parameters defined by the manufacturer and must be maintained in accordance with established instructions for continued airworthiness.

Published Regulations, Standards, and Related Documents Include but Are Not Limited to:

FAA: (see also the FAA Data & Research Safety webpage)

- 14 CFR SUBCHAPTER C—AIRCRAFT
- Part 21 Certification procedures for products and articles
- Part 23 Airworthiness standards: Normal category airplanes
- Part 25 Airworthiness standards: Transport category airplanes
- Part 26 Continued airworthiness and safety improvements for transport category airplanes
- Part 27 Airworthiness standards: Normal category rotorcraft
- Part 29 Airworthiness standards: Transport category rotorcraft
- Part 31 Airworthiness standards: Manned free balloons
- Part 33 Airworthiness standards: Aircraft engines
- Part 34 Fuel venting and exhaust emission requirements for turbine engine powered airplanes
- Part 35 Airworthiness standards: Propellers
- Part 36 Noise standards: Aircraft type and airworthiness certification
- Part 39 Airworthiness directives
- 14 CFR §107 Operation small Unmanned Aircraft systems
- 14 CFR §107.51, Operating limitations for small unmanned aircraft
- TSO-C213, Unmanned Aircraft Systems Control and Non-Payload Communications Terrestrial Link System Radios, September 3, 2018

- TSO-C213, Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment, September 16, 2013
- TSO-C154c, Universal Access Transceiver (UAT) Automatic Dependent Surveillance-Broadcast (ADS-B) Equipment, December 2, 2009
- TSO-C166b, Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information, December 2, 2009
- TSO-C195b, Avionics Supporting Automatic Dependent Surveillance – Broadcast (ADS-B) Aircraft Surveillance, September 29, 2014
- FAA Advisory Circular, AC 107-2, Small UAS (sUAS), 6/21/2016
- FAA Order 8040.6, Unmanned Aircraft Systems Safety Risk Management Policy, 10/4/2019
- UAS Traffic Management (UTM) Concept of Operations, FAA, May 18, 2018
- FAA Advisory Circular, AC 20–170, Integrated Modular Avionics Development, Verification, Integration, and Approval Using RTCA/DO-297 and Technical Standard Order-C153, November 21, 2013
- FAA Advisory Circular, AC 23.1309-1E, System Safety Analysis and Assessment for Part 23 Airplanes
- FAA Advisory Circular, AC 20-174, Development of Civil Aircraft and Systems
- FAA Advisory Circular, AC 27-1B, Certification of Normal Category Rotorcraft
- FAA Advisory Circular, AC 29-2C, Certification of Transport Category Rotorcraft

ASTM:

- ASTM F2909-19, *Standard Specification for Continued Airworthiness of Lightweight Unmanned Aircraft Systems*
- ASTM F3178-16, *Standard Practice for Operational Risk Assessment of Small Unmanned Aircraft Systems (sUAS)*
- ASTM F3269-17, *Standard Practice for Methods to Safely Bound Flight Behavior of Unmanned Aircraft Systems Containing Complex Functions*
- ASTM F3298-19, *Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS)*

RTCA:

- RTCA/DO-362, *with Errata - Command and Control (C2) Data Link Minimum Operational Performance Standards (MOPS) (Terrestrial)*, September 22, 2016

SAE:

- AS6969, *Data Dictionary for Quantities Used in Cyber Physical Systems*
- ARP4754A, *Guidelines for Development of Civil Aircraft and Systems*
- ARP4761, *Guidelines And Methods For Conducting The Safety Assessment Process On Civil Airborne Systems And Equipment*
- AIR6219, *Development of Atmospheric Neutron Single Event Effects Analysis for Use in Safety Assessments*

- AIR6110, *Contiguous Aircraft/System Development Process Example*
- AIR6218, *Constructing Development Assurance Plan for Integrated Systems*
- ARP5150A, *Safety Assessment of Transport Airplanes in Commercial Service*
- ARP5151A, *Safety Assessment of General Aviation Airplanes and Rotorcraft in Commercial Service*
- GEIASTD0010A, *Standard Best Practices for System Safety Program Development and Execution*

DOD:
- DOD Policy Memorandum 15-002, Guidance for the Domestic Use of Unmanned Aircraft Systems, February 17, 2015
- DOD-NATO, STANAG 4671, Unmanned Aerial Vehicles Systems Airworthiness Requirements
- DOD-NATO, STANAG 4702, Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements
- DOD-NATO, STANAG 4703, Light Unmanned Aircraft Systems Airworthiness Requirements
- 07-1-003 Unmanned Aircraft Systems (UAS) Sensor and Targeting, July 27, 2010
- DOD-NATO, Guidance For The Training Of Unmanned Aircraft Systems (UAS) Operators, April 22, 2014
- 07-2-032 Unmanned Aircraft Systems (UAS) Navigation System Test, US Army, July 27, 2010
- DOD-NATO, Interoperable Command And Control Data Link For Unmanned Systems (IC2DL) – Operational Physical Layer / Signal In Space Description, November 14, 2016

NASA:
- Small Unmanned Aircraft Electromagnetic Interference (EMI) Initial Assessment, Jung, Jaewoo, et. al., ICNS 2018, April 10-12, 2018

In-Development Standards and Other Documents Include:

ICAO:
- Annex 2 to the Convention on International Civil Aviation – Rules of the Air, Q1 2018
- Annex 3 to the Convention on International Civil Aviation – Meteorological Service for International Air Navigation, Q1 2021
- Annex 6 to the Convention on International Civil Aviation – Part IV – International Operations – RPAS, Q1 2020
- Annex 8 to the Convention on International Civil Aviation – Airworthiness of Aircraft, Q1 2018
- Annex 10 to the Convention on International Civil Aviation – Volume IV, Part II – Detect and Avoid Systems, Q1 2020
- Annex 11 to the Convention on International Civil Aviation – Air Traffic Services, Q1 2020
- Annex 14 to the Convention on International Civil Aviation – Aerodromes, Q1 2021
- Annex 19 to the Convention on International Civil Aviation – Safety Management, Q1 2020
- Manual on RPAS (Doc 10019), Q1 2021
- Procedures for Air Navigation Services – Air Traffic Management (Doc 4444), Q1 2021

- Procedures for Air Navigation Services – Aircraft Operations – Vol I – Flight Procedures (Doc 8168), Q1 2021

SAE:

SAE S-18, *Aircraft and Sys Dev and Safety Assessment Committee*

- AIR7121, Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems
- AS7209, *Development Assurance Objectives for Aerospace Vehicles and Systems*
- ARP4754B, *Guidelines for Development of Civil Aircraft and Systems*
- ARP4761A, *Guidelines And Methods For Conducting The Safety Assessment Process On Civil Airborne Systems And Equipment*
- AIR6913, *Using STPA During Development and Safety Assessment of Civil Aircraft*
- AIR6276, *Use of Modeling and Tools for Aircraft Systems Development - A Strategy for Development Assurance Aspects with Examples*
- GEIASTD0010B, *Standard Best Practices for System Safety Program Development and Execution*
- SAE1003, *Glossary of System Safety Engineering and Management*
- SAE1005, *Model Based Functional Safety*

SAE G-32, Cyber Physical Systems Security Committee

- SAE JA7496, *Cyber Physical Systems Security Engineering Plan (CPSSEP)*
- *SAE JA6678 Cyber Physical Systems Security Software Assurance*

SAE G-34, Artificial Intelligence in Aviation Committee

- SAE AS6983, *Process Standard for Qualification of Aeronautical Systems Implementing AI: Development Standard*

DOD:

- DOD Unmanned Aircraft Systems (UAS) Airspace Integration, May 28, 2014
- Systems Engineering of SAA Systems, US Army Unmanned Aircraft Systems, US Army 2015b
- DOD-NATO Standard, AEP-80, Rotary Wing Unmanned Aerial Systems Airworthiness Requirements, 2014

ASTM:

F38.01 on Airworthiness

- ASTM WK65056, *Revision of F3269 - 17 Standard Practice for Methods to Safely Bound Flight Behavior of Unmanned Aircraft Systems Containing Complex Functions*

F38.03 on Personnel Training, Qualification and Certification

- ASTM WK62744, *New Practice for General Operations Manual for Professional Operator of Light Unmanned Aircraft Systems (UAS)*

F44.50 on Systems and Equipment

- ASTM WK56374, *New Practice for Aircraft Systems Information Security Protection*

Gap A2: UAS System Safety. Numerous UAS airworthiness standards, appropriate regulations, operational risk assessment (ORA) methodologies, and system safety processes already exist. Any gaps that exist in standards applicable to specific vehicle classes and weight are being addressed. While the applicant or regulator will ultimately determine which standard is used, a potential gap is the lack of an aerospace information report ("meta-standard") in which the various existing airworthiness and safety analyses methods are mapped to the sizes and types of UAS (remotely controlled, optionally piloted, autonomous) to which they are most relevant. Such a report should address design, production, and operational approval safety aspects.

Recently SAE's technical committees SAE S-18, AS-4, G-32, G-34 and EUROCAE WG-105 and WG-114 have initiated liaison activities between these technical committees to address UAS system safety and development assurances. SAE S-18 started a new standard "SAE AIR7121, *Applicability of existing development assurance and system safety practices to unmanned aircraft systems*" on 10/10/2019 to describe how to apply ARP4754 and ARP4761 to UAS system safety and development assurance.

R&D Needed: Maybe or No

Recommendation: Develop an aerospace information report or standard(s) in which the various existing airworthiness and safety analyses methods are mapped to the sizes and types of UAS to which they are most relevant, and the UAS system safety and development assurance are addressed.

Priority: High (Tier 1)

Organization(s): SAE, RTCA, IEEE, American Institute of Aeronautics and Astronautics (AIAA), ASTM, DOD, NASA, FAA

Status of Progress: Green

Update: As noted in the text of the gap statement.

6.3. Quality Assurance/Quality Control

An established quality assurance (QA)/quality control (QC) program is critical in establishing processes and procedures that support airworthiness and reliability essential to safe operations of UAS in the NAS. The current regulatory environment requires that all things associated with manned airborne operations be controlled by a QA program. However, this requirement has not been defined, established, or verified for current unmanned operations in the NAS beyond what is listed below under published standards.

Published Standards, Regulations, and Other Documents: The only identified published QA/QC standard for UAS is:

- ASTM F3003-14, *Standard Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS)*, developed by ASTM F38.01

Other published QA/QC aviation/aerospace standards include those listed below.

ASTM:

- F2972-15, *Standard Specification for Light Sport Aircraft Manufacturer's Quality Assurance System*, developed by ASTM F37.70

SAE:

- AS9100 is the globally recognized de facto quality assurance document used in the aerospace industry. AS9100 is not just one document, however. It is part of a family of over 30 quality-related standards with the 9,000 designation. A list of published documents can be found here: https://saemobilus.sae.org/search/?op=doFacetSearch&ft_cc=TEAG14. These include:
- AS9100, *Quality Systems - Aerospace - Model for Quality Assurance in Design, Development, Production, Installation and Servicing*
- AS9100D, *Aerospace Quality Management Systems – Requirement for Aviation, Space, and Defense Organizations*
- AS9103A, *Aerospace Series – Quality Management Systems – Variation Management of Key Characteristics*

Also related to UxS is:

- SAE AS6522, *Unmanned Systems (UxS) Control Segment (UCS) Architecture: Architecture Technical Governance*

The SAE G-19 Counterfeit Electronic Parts Committees address aspects of preventing, detecting, responding to, and counteracting the threat of counterfeit electronic components. As of March 2020, G-19 had published 21 documents and 19 are in development.

The SAE G-21 Counterfeit Materiel Committee addresses aspects of preventing, detecting, responding to, and counteracting the threat of counterfeit materiel. The objective of the SAE G-21 committee is to develop standards suitable for use in high performance/high reliability applications to mitigate the risks of counterfeit materiel. In this regard, the standard will document recognized best practices in materiel management, supplier management, procurement, inspection, test/evaluation methods, and response strategies when suspect or confirmed counterfeit materiel is detected. As of March 2020, G-21 had published 2 documents and 3 are in development.

The SAE S-18 Aircraft and Systems Development and Safety Assessment Committee brings together qualified specialists for the advancement of aerospace safety and to support effective safety management. It provides a resource for other committees and organizations with common interests in safety and development assurance processes. As of March 2020, S-18 had published 9 documents and 8 are in development. The SAE S-18 Committee is active in the development of guidelines, including processes, methods and tools, to accomplish safety assessment of airplanes and related systems and equipment.

The committee develops aerospace vehicle and system standards on:

- Safety assessment processes
- Development assurance processes
- Practices for accomplishing in-service safety assessments

Other SAE standards[15] include:

- AS9006A, *Deliverable Aerospace Software Supplement for AS9100A, Quality Management Systems - Aerospace - Requirements for Software (based on AS9100A)*
- ARP9134A, *Supply Chain Risk Management Guideline*
- ARP9090A, *Requirements for Industry Standard e-Tool to Collaborate Quality Assurance Activities Among Customers and Suppliers*
- ARP9034A, *A Process Standard for the Storage, Retrieval and Use of Three-Dimensional Type Design Data*
- ARP9009A, *Aerospace Contract Clauses*
- ARP9005A, *Aerospace Guidance for Non-Deliverable Software*
- AS9133A, *Qualification Procedure for Aerospace Standard Products*
- AS9132B, *Data Matrix Quality Requirements for Parts Marking*
- AS9131C, *Aerospace Series - Quality Management Systems - Nonconformance Data Definition and Documentation*
- AS9120B, *Quality Management Systems – Requirements for Aviation, Space, and Defense Distributors*
- AS9115A, *Quality Management Systems - Requirements for Aviation, Space, and Defense Organizations - Deliverable Software (Supplement to 9100:2016)*
- AS9110C, *Quality Management Systems – Requirements for Aviation Maintenance Organizations*
- AS9104/2A, *Requirements for Oversight of Aerospace Quality Management System Registration/Certification Programs*
- AS9102B, *Aerospace First Article Inspection Requirement*
- AS9101F, *Quality Management Systems - Audit Requirements for Aviation, Space, and Defense Organizations*
- AS9003A, *Inspection and Test Quality Systems, Requirements for Aviation, Space, and Defense Organizations*
- ARP9114A, *Direct Ship Guidance for Aerospace Companies*

[15] See also search results for SAE Quality Assurance standards.

- ARP9107A, *Direct Delivery Authorization Guidance for Aerospace Companies*
- AS9017, *Control of Aviation Critical Safety Items*
- AS9162, *Aerospace Operator Self-Verification Programs*
- AS9146, *Foreign Object Damage (FOD) Prevention Program - Requirements for Aviation, Space, and Defense Organizations*
- AS9145, *Aerospace Series – Requirements for Advanced Product Quality Planning and Production Part Approval Process*
- AS9138, *Aerospace Series - Quality Management Systems Statistical Product Acceptance Requirements*
- AS9117, *Delegated Product Release Verification*
- AS9116, *Aerospace Series - Notice of Change (NOC) Requirements*
- AS9104/3, *Requirements for Aerospace Auditor Competency and Training Courses*
- AS9104/1, *Requirements for Aviation, Space, and Defense Quality Management System Certification Programs*
- ARP9137, *Guidance for the Application of AQAP 2110 within a 9100 Quality Management System*
- ARP9136, *Aerospace Series - Root Cause Analysis and Problem Solving (9S Methodology)*
- AS6171/1, *Suspect/Counterfeit Test Evaluation Method*
- AS6171/10, *Techniques for Suspect/Counterfeit EEE Parts Detection by Thermogravimetric Analysis (TGA) Test Methods*
- AS6171/11, *Techniques for Suspect/Counterfeit EEE Parts Detection by Design Recovery Test Methods*
- AS6171/2A, *Techniques for Suspect/Counterfeit EEE Parts Detection by External Visual Inspection, Remarking and Resurfacing, and Surface Texture Analysis Using SEM Test Methods*
- AS6171/3, *Techniques for Suspect/Counterfeit EEE Parts Detection by X-ray Fluorescence Test Methods*
- AS6171/4, *Techniques for Suspect/Counterfeit EEE Parts Detection by Delid/Decapsulation Physical Analysis Test Methods*
- AS6171/5, *Techniques for Suspect/Counterfeit EEE Parts Detection by Radiological Test Methods*
- AS6171/6, *Techniques for Suspect/Counterfeit EEE Parts Detection by Acoustic Microscopy (AM) Test Methods*
- AS6171/7, *Techniques for Suspect/Counterfeit EEE Parts Detection by Electrical Test Methods*
- AS6171/8, *Techniques for Suspect/Counterfeit EEE Parts Detection by Raman Spectroscopy Test Methods*
- AS6171/9, *Techniques for Suspect/Counterfeit EEE Parts Detection by Fourier Transform Infrared Spectroscopy (FTIR) Test Methods*
- AS6171A, *Test Methods Standard; General Requirements, Suspect/Counterfeit, Electrical, Electronic, and Electromechanical Parts*
- AS6810, *Requirements for Accreditation Bodies when Accrediting Test Laboratories Performing Detection of Suspect/Counterfeit in Accordance with AS6171 General Requirements and the Associated Test Methods*

- AS6496, *Fraudulent/Counterfeit Electronic Parts: Avoidance, Detection, Mitigation, and Disposition - Authorized/Franchised Distribution*
- AS6301, *Compliance Verification Criterion Standard for SAE AS6081, Fraudulent/Counterfeit Electronic Parts: Avoidance, Detection, Mitigation, and Disposition – Distributors*
- AS6462A, AS5553A, *Fraudulent/Counterfeit Electronic Parts; Avoidance, Detection, Mitigation, and Disposition Verification Criteria*
- ARP6328, *Guideline for Development of Counterfeit Electronic Parts; Avoidance, Detection, Mitigation, and Disposition Systems*
- AS5553B, *Counterfeit Electrical, Electronic, and Electromechanical (EEE) Parts; Avoidance, Detection, Mitigation, and Disposition*
- AS6081, *Fraudulent/Counterfeit Electronic Parts: Avoidance, Detection, Mitigation, and Disposition – Distributors Counterfeit Electronic Parts; Avoidance Protocol, Distributors*
- ARP6178, *Fraudulent/Counterfeit Electronic Parts; Tool for Risk Assessment of Distributors*
- AIR6860, *Use of AS5553 for Implementation of Defense Federal Acquisition Regulation Supplement 252-246-7007*
- AS6174/1, *Compliance Verification Matrix (VM) Slash Sheet for SAE AS6174A, Counterfeit Materiel; Assuring Acquisition of Authentic and Conforming Materiel*
- AS6174A, *Counterfeit Materiel; Assuring Acquisition of Authentic and Conforming Materiel*
- AIR6110, *Contiguous Aircraft/System Development Process Example*
- AIR6218, *Constructing Development Assurance Plan for Integrated Systems*
- ARP1834B, *Fault/Failure Analysis for Digital Systems and Equipment*
- ARP4754A, *Guidelines for Development of Civil Aircraft and Systems*
- ARP4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*
- ARP5150, *Safety Assessment of Transport Airplanes in Commercial Service*
- ARP5151, *Safety Assessment of General Aviation Airplanes and Rotorcraft in Commercial Service*
- ARP926C, *Fault/Failure Analysis Procedure*

FAA:

Advisory Circulars (AC):

- AC 33.15-1 Manufacturing Process of Premium Quality Titanium Alloy Rotating Engine Components
- AC 21-26A Quality System for the Manufacture of Composite Structures
- AC 145-9A Guide for Developing and Evaluating Repair Station and Quality Control Manuals
- AC 21-31A Quality Control for the Manufacture of Non-Metallic Compartment Interior Components
- AC 33.15-2 Manufacturing Processes for Premium Quality Nickel Alloy for Engine Rotating Parts
- AC 23-20 Acceptance Guidance on Material Procurement and Process Specifications for Polymer Matrix Composite Systems
- AC 33.4-2 Instructions for Continued Airworthiness: In-Service Inspection of Safety Critical Turbine Engine Parts at Piece-Part Opportunity

- AC 150/5370-12A Quality Control of Construction for Airport Grant Projects
- AC 00-41B FAA Quality Control System Certification Program
- AC 20-88A Guidelines on the Marking of Aircraft
- AC 91-33A Use of Alternate Grades of Aviation Gasoline for Grade 80/87, and Use of Automotive Gasoline
- AC 135-17 Pilot Guide - Small Aircraft Ground Deicing (pocket)
- AC 120-59A Air Carrier Internal Evaluation Programs
- AC 33.28-1 Compliance Criteria for 14 CFR §33.28, Aircraft Engines, Electrical and Electronic Engine Control Systems[16]
- AC 145-5 Repair Station Internal Evaluation Programs
- AC 25.939-1 Evaluating Turbine Engine Operating Characteristics
- AC 20-156 Aviation Databus Assurance[17]
- AC 25.783-1A Fuselage Doors and Hatches
- AC 150/5100-13A Development of State Standards for Non-Primary Airports
- AC 23-1523 Minimum Flight Crew
- AC 150/5300-16A General Guidance and Specifications for Aeronautical Surveys: Establishment of Geodetic Control and Submission to the National Geodetic Survey
- AC 150/5320-6D CHG 1 Change 1 to Airport Pavement Design and Evaluation
- AC 150/5210-19 Driver's Enhanced Vision System (DEVS)
- AC 25-19A Certification Maintenance Requirements
- AC 20-146 Methodology for Dynamic Seat Certification by Analysis for Use in Part 23, 25, 27, and 29 Airplanes and Rotorcraft[18]
- AC 91-36D Visual Flight Rules (VFR) Flight Near Noise-Sensitive Areas
- AC 150/5300-9A Predesign, Prebid, and Preconstruction Conferences for Airport Grant Projects
- AC 150/5220-21B Guide Specification for Devices Used to Board Airline Passengers with Mobility Impairments[19]
- AC 150/5220-17A CHG 1 Change 1 to Design Standards for an Aircraft Rescue and Firefighting Training Facility[20]

Regulations:

- §13.401 - Flight Operational Quality Assurance (FOQA) program
- §21.137 - Quality System (Subpart G-PC)

[16] AC 33.28-1 references the following SAE International documents: SAE ARP1834A; SAE ARP4754; SAE ARP4761; SAE ARP5107; SAE ARP926B.
[17] AC 20-156 references the following SAE International documents: SAE ARP4754; SAE ARINC429.
[18] AC 20-146 references the following SAE International documents: SAE AS8049A; SAE J211/1; SAE J211/2.
[19] AC 150/5220-21B references the following SAE International documents: SAE ARP1247.
[20] AC 150/220-17A references the following SAE International document: SAE J551.

- §21.138 - Quality Manual (Subpart G)
- §21.150 - Changes to Quality System (Subpart G)
- §21.307 - Quality System (Subpart K-PMA)
- §21.308 - Quality Manual (Subpart K)
- §21.320 - Chg. to Quality System (Subpart K)
- §21.607 - Quality System (Subpart O-TSO)
- §21.608 - Quality Manual (Subpart O)
- §21.620 - Chg. to Quality System (Subpart O)
- §414.19 - Technical criteria for reviewing a safety approval application.

DOD[21]:

- MIL-HDBK-516C – Airworthiness Certification Criteria (Ref. 4.4.4, p. 56)
- Note: DOD relies on contractors showing evidence of ISO9001 standards

Other published QA/QC standards for general industry include:

ISO:

- ISO 9001:2015, *Quality management systems – Requirements*
- ISO/IEC/IEEE 90003:2018, *Software engineering – Guidelines for the application of ISO 9001:2015 to computer software*
- ISO 9004:2018, *Quality management – Quality of an organization – Guidance to achieve sustained success*

ASTM:

Editorial/Terminology:

- E456-13A(2017)e2, *Standard Terminology Relating to Quality and Statistics*

Reliability:

- E2555-07(2018), *Standard Practice for Factors and Procedures for Applying the MIL-STD-105 Plans in Life and Reliability Inspection*
- E2696-09(2013), *Standard Practice for Life and Reliability Testing Based on the Exponential Distribution*
- E3159-18, *Standard Guide for General Reliability*

Sampling / Statistics:

- E105-16, *Standard Practice for Probability Sampling of Materials*

[21] Additional DOD Quality Control/Assurance standards can be identified on the DOD Assist-Quick Search webpage by searching on "QCIC" in the FSC/Area drop down menu.

- E122-17, *Standard Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process*
- E141-10(2018), *Standard Practice for Acceptance of Evidence Based on the Results of Probability Sampling*
- E178-16a, *Standard Practice for Dealing With Outlying Observations*
- E1325-16, *Standard Terminology Relating to Design of Experiments*
- E1402-13, *Standard Guide for Sampling Design*
- E2586-18, *Standard Practice for Calculating and Using Basic Statistics*
- E3080-17, *Standard Practice for Regression Analysis*

Standards:

- SI10-16, *IEEE/ASTM SI 10 American National Standard for Metric Practice*

Statistical QC:

- E29-13, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*
- E1994-09(2018), *Standard Practice for Use of Process Oriented AOQL and LTPD Sampling Plans*
- E2234-09(2013), *Standard Practice for Sampling a Stream of Product by Attributes Indexed by AQL*
- E2281-15, *Standard Practice for Process Capability and Performance Measurement*
- E2334-09(2018), *Standard Practice for Setting an Upper Confidence Bound For a Fraction or Number of Non-Conforming items, or a Rate of Occurrence for Non-conformities, Using Attribute Data, When There is a Zero Response in the Sample*
- E2587-16, *Standard Practice for Use of Control Charts in Statistical Process Control*
- E2762-10(2014), *Standard Practice for Sampling a Stream of Product by Variables Indexed by AQL*
- E2819-11(2015), *Standard Practice for Single- and Multi-Level Continuous Sampling of a Stream of Product by Attributes Indexed by AQL*
- E2910-12(2018), *Standard Guide for Preferred Methods for Acceptance of Product*

Test Method Evaluation and QC:

- E177-14, *Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods*
- E691-18, *Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method*
- E1169-18, *Standard Practice for Conducting Ruggedness Tests*
- E1323-15, *Standard Guide for Evaluating Laboratory Measurement Practices and the Statistical Analysis of the Resulting Data*
- E1488-12(2018), *Standard Guide for Statistical Procedures to Use in Developing and Applying Test Methods*
- E2282-14, *Standard Guide for Defining the Test Result of a Test Method*

- E2489-16, *Standard Practice for Statistical Analysis of One-Sample and Two-Sample Interlaboratory Proficiency Testing Programs*
- E2554-18, *Standard Practice for Estimating and Monitoring the Uncertainty of Test Results of a Test Method Using Control Chart Techniques*
- E2655-14, *Standard Guide for Reporting Uncertainty of Test Results and Use of the Term Measurement Uncertainty in ASTM Test Methods*
- E2709-14e1, *Standard Practice for Demonstrating Capability to Comply with an Acceptance Procedure*
- E2782-17, *Standard Guide for Measurement Systems Analysis (MSA)*
- E2935-17, *Standard Practice for Conducting Equivalence Testing in Laboratory Applications*

In-Development Standards:

- ASTM WK67357, *New Specification for Light Unmanned Aircraft System Manufacturers Quality Assurance System*, under ASTM F38.03
- ASTM WK51467, *New Specification for Quality Assurance for Manufacturers of Aircraft Systems*, under ASTM F39.04

Gap A3: Quality Assurance/Quality Control of UAS. Although there are numerous published QA/QC standards applicable to aviation/aerospace systems (primarily manned), there is only one known published QA/QC standard that is specific to UAS and it covers sUAS: ASTM F3003-14, *Standard Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS)*. A QA/QC standard in development for manufacturers of aircraft systems is ASTM WK51467, *New Specification for Quality Assurance for Manufacturers of Aircraft Systems* but it is not UAS-specific. There appears to be a need for a QA/QC standard applicable to UAS over 55 pounds.

R&D Needed: No

Recommendation: Develop a QA/QC standard applicable to UAS over 55 pounds, taking into account relevant general aviation standards.

Priority: Medium

Organization(s): ASTM, ISO, SAE, FAA, DOD

Status of Progress: Not Started

Update: The ASTM F38 Executive Committee gap analysis indicated that this is a low priority, that a near term action would be to revise ASTM F3003-14 *Standard Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS)*, while a long-term action would be to create a new standard.

6.4. Avionics and Subsystems

Avionics are the electronic systems used on an aircraft (or UA) and/or control station (CS) to perform and manage various functions including but not limited to communications, navigation, display, and control of the aircraft. The aircraft cockpit (or avionics bay of a UA) or CS is the typical location for such equipment. Aircraft or CS cost, size, weight, and power (CSWaP) are factors that determine the avionics equipment needed. Payload is generally not considered part of avionics.

Published Regulations, Standards, and Guidance: Existing regulations, policies, standards, and guidance, including for manned aviation avionics and subsystems that may apply to UAS, are listed below. A more complete list can be found in the *UASSC Reference Document*.

FAA:

Of the numerous airborne avionics TSOs, TSO-embedded standards and regulations, the following may apply to UAS:

- 14 CFR Chapter I, Subchater C (Aircraft), Subchapter F (General Operating Rules)
- TSO-C88b, Automatic Pressure Altitude Reporting Code-Generating Equipment, 2-06-07
- TSO-C112e, ATCRBS/Mode S Airborne Equipment, 9-16-13
- TCAS/TCAS I/ TCAS II (TSO-C118, C118a, C119d, C119e)
- TSO-C124c, Flight Data Recorder Equipment, 12-19-13
- TSO-C151c, -C151d, Terrain Awareness and Warning System (TAWS)
- TSO-C154c, Universal Access Transceiver (UAT) ADS-B Equipment, 12-02-09
- TSO-C177a, Data Link Recorder Equipment, 12-19-13
- TSO-C195b, Avionics Supporting ADS-B Aircraft Surveillance, 9-29-14
- TSO-C211, Detect and Avoid (DAA) Systems, 9-25-17
- TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance, 9-22-17
- TSO-C213, UAS CNPC Terrestrial Link System Radios, 9-3-18

RTCA:

In addition to RTCA airborne avionics standards, the following may apply to UAS:

- DO-362 with Errata, Command and Control (C2) Data Link MOPS (Terrestrial), 9-22-16
- DO-365, MOPS for Detect and Avoid (DAA) Systems, 5-31-17
- DO-366, MOPS for Air-to-Air Radar for Traffic Surveillance, 5-31-17

IEEE:

- Various Aerospace Electronics Standards

ICAO:

In addition to ICAO airborne avionics standards, the following may apply to UAS:

- Annex 8 – Airworthiness of Aircraft
- Annex 10 Vol 1 - Radio Navigation Aids, Vol 2 - Com Procedures, Vol 3 - Communication Systems, Vol 4 - Surveillance and Collision Avoidance Systems
- Doc 9684 Manual for SSR Systems
- Doc 9871 Technical Provisions for Mode S Services and Extended Squitter

SAE:

In addition to SAE airborne avionics standards, the following may apply to UAS:

- AS8034C, *Minimum Performance Standard for Airborne Multipurpose Electronic Displays*, 7-30-18
- ARINC718A-4, *Mark 4 Air Traffic Control Transponder (ATCRBS/Mode S)*
- ARINC735B-2, *Traffic Computer TCAS and ADS-B Functionality*
- AS6254A, *Minimum Performance Standard for Low Frequency Underwater Locating Devices (Acoustic) (Self-Powered)*
- AS8045A, *Minimum Performance Standard for Underwater Locating Devices (Acoustic) (Self-Powered)*
- ARINC677, *Installation Standards for Low Frequency Underwater Locator Beacon (LF-ULB)*
- *Multi-Sensor Data Fusion Techniques for RPAS Detect, Track and Avoid*, 9-15-15
- ARP4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*, 12-01-96
- ARP5621, *Electronic Display of Aeronautical Information (Charts)*
- AS6296, *Electronic Flight Instrument System (EFIS) Displays*, 3-16-16
- AS8024, *JAUS Autonomous Capabilities Service Set*

For avionic networks, subsystems, embedded computing, and fiber optics and applied photonics, the following aerospace standards committee's documents may apply:

- AS-1A Avionic Networks Committee
- AS-1B Aircraft Store Integration Committee
- AS-1C Avionic Subsystems Committee
- AS-2 Embedded Computing Systems Committee
- AS-2C Architecture Analysis and Design Language
- AS-2D1 Time-Triggered Fieldbus
- AS-2D2 Deterministic Ethernet and Unified Networking
- AS-3 Fiber Optics and Applied Photonics Committee

DOD:

In addition to DOD airborne avionics standards, the following may apply to UAS:

- Transponder and Electronic ID System (AIMS 03-1000B ATCRBS/IFF/MARK XIIA, AIMS 03-1101/2/3B Mark XIIA and Mode S, AIMS 03-1201/2/3 Mark XIIA and Mode S)
- MIL-STD-1796A-Avionics Integrity Program, 10-13-11
- Others

NASA:

- Various NASA Documents on Avionics

ASTM:

In addition to ASTM airborne avionics standards, the following may apply to UAS:

- F3153-15, *Standard Specification for Verification of Avionics Systems*
- F3269-17, *Standard Practice for Methods to Safely Bound Flight Behavior of Unmanned Aircraft Systems Containing Complex Functions*
- F3298-19, *Standard Specification for Design, Construction, and Verification of Fixed-Wing Unmanned Aircraft Systems (UAS)*

FCC:

- Code of Federal Regulations, Title 47, Telecommunications, Chapter I

AIAA:

- ANSI/AIAA S-102.2.4-2015, *Performance-Based Product Failure Mode, Effects and Criticality Analysis (FMECA) Requirements*
- ANSI/AIAA S-102.2.18-2009, *Performance-Based Fault Tree Analysis Requirements*
- Various AIAA Standards

In-Development Standards (see also the *UASSC Reference Document*)**:**

ICAO:

- Annex 8 – Airworthiness of Aircraft, Q1 2018
- Annex 10 – Volume IV, Part II – Detect and Avoid Systems, Q1 2020
- Manual on RPAS (Doc 10019), Q1 2021

JARUS:

- JARUS WG4 - Detect & Avoid, JARUS Detect and Avoid
- JARUS WG4 - Detect & Avoid, JARUS Detect and Avoid CONOPS for VLL operations

DOD:

- Sense and Avoid (SAA) and Ground Based Sense and Avoid System (GBSAA)

ASTM:

- WK62668, *New Specification for Detect and Avoid Performance Requirements*
- WK62669, *New Test Method for Detect and Avoid*
- WK65041, *New Practice for UAS Remote ID and Tracking*
- WK65056, *Revision of F3269 - 17 Standard Practice for Methods to Safely Bound Flight Behavior of Unmanned Aircraft Systems Containing Complex Functions*

SAE:

- AS6983, *Process Standard for Qualification of Aeronautical Systems Implementing AI: Development Standard*

For avionic networks, subsystems, embedded computing, and fiber optics and applied photonics, the following aerospace standards committee's works in progress may apply:

- AS-1A Avionic Networks Committee

- AS-1B Aircraft Store Integration Committee
- AS-2D1 Time-Triggered Fieldbus
- AS-3 Fiber Optics and Applied Photonics Committee

Gap A4: Avionics and Subsystems. Existing avionics standards are proven and suitable for UAS. However, they become unacceptable for the following scenarios:

1) As the size of UAS scales down, airborne equipment designed to existing avionics standards are too heavy, large, and/or power hungry. Therefore, new standards may be necessary to achieve an acceptable level of performance for smaller, lighter, more efficient, more economical systems. For example, it is unclear how to apply some of the major avionics subsystems such as TCAS II, automatic dependent surveillance-broadcast (ADS-B) (IN and OUT). This has implications on existing NAS infrastructures (Air Traffic Radar, SATCOM, etc.), ACAS, etc.
2) As the quantity of UAS scales up based on the high demand of UAS operations into the NAS, the new standards are required to handle the traffic congestion.
3) Many UAS introduce new capabilities – new capabilities may not be mature (not statistically proven or widely used) and/or they may be proprietary, therefore industry standards do not exist yet.

Avionics are becoming highly integrated with more automation compared to traditional avionics instruments and equipment that were found in manned aviation aircraft a few decades ago. UAS will decreasingly rely on human confirmations, human commands, human monitoring, human control settings, and human control inputs. A time is approaching when the UAS conveys the bare minimum information about its critical systems and mission to the human, that is, a message that conveys, "Everything is OK." Standards to get there are different from those that created the cockpits in use today.

Some of the major areas of concern include the reliability and cybersecurity of the command and control (C2) data link, use of DOD spectrum (and non-aviation) on civil aircraft operations, and enterprise architecture to enable UTM, swarm operations, autonomous flights, etc. Cybersecurity, in particular, shall be an important consideration in the development of avionics systems. Cybersecurity is further discussed in section 6.4.6.

R&D Needed: Yes

Recommendation:

1) One approach is to recommend that existing standards be revised to include provisions that address the points listed above. The UAS community should get involved on the committees that write the existing avionics standards. Collaboration around a common technological subject is more beneficial than segregating the workforce by manned vs. unmanned occupancy. The standards should address any differing (manned/unmanned) requirements that may occur.
2) Another approach is to recommend new standards that will enable entirely new capabilities.

3) Complete work on the standards of ICAO, ASTM, SAE, and DOD listed above in the "In-Development Standards" section.
4) Review existing and in-development avionics standards for UAS considerations.
5) Create a framework for UAS avionics spanning both airborne and terrestrial based systems.

Priority: High (Tier 2)

Organization(s): For Avionics Issues: RTCA, SAE, SAE-ITC ARINC, IEEE, AIAA, ASTM, DOD, NASA, FAA, ICAO. **For Spectrum Issues:** FAA, FCC, NTIA, International Telecommunication Union (ITU)

Status of Progress: Green

Update: SAE AS-4JAUS published AS8024, *JAUS Autonomous Capabilities Service Set* in June 2019. A new standard in development in SAE G-34 is SAE AS6983, *Process Standard for Qualification of Aeronautical Systems Implementing AI: Development Standard*. ASTM F3298-19, *Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS)*, was also published.

6.4.1. Command and Control (C2) Link and Communications

UAS involve an aircraft, either remotely piloted or autonomous, and a secure and reliable communications link to relay telemetry, tracking, systems, and other information for aircraft awareness to some external entity, often, but not always, on the ground. FFor example, the link could be used in a primary control function, reporting function, or backup function. Still others have begun to call this capability the Command, Control, and Communications (C3) link. For purposes of this standards roadmap document, the most commonly used term "C2 link" is used, but the intent is certainly to cover all cases cited above.

1. Applicable Rules and Regulations

The following framing points are provided with respect to the scope of FCC rules, and the relationship between FCC and FAA rules.

FCC rules generally address radio specific rules and regulations, with an eye toward limiting harmful interference. The FAA is focused on aviation safety, thus its rules address issues such as radio link reliability, and aeronautical equipment (including radio equipment and relevant industry standards associated with various aviation radio equipment) and aviation/airspace operating rules and regulations.

FCC rules are partitioned into various radio services (e.g., aviation, maritime, broadcast, satellite, public mobile, amateur, various unlicensed frequency bands, etc.) and some rule parts that may be common to many types of radio services, such as 47 CFR Part 2, frequency allocations, treaty matters, and general rules (e.g., equipment authorization procedures).

As a general matter, some FCC radio service rules specifically address aeronautical mobile use, either allowing it (e.g., in the aviation services, satellite services – Earth Stations Aboard Aircraft (ESAA), and some other radio services); or prohibiting such use (e.g., in the 47 CFR Part 2 table of frequency allocations, mobile except aeronautical mobile) and/or prohibiting specific radio service rules (e.g., 47 CFR Section 22.925 – cellular radiotelephone service). Other FCC rules do not expressly allow or prohibit aeronautical mobile use (e.g., some, but not all, of the 47 CFR Part 27 Miscellaneous Wireless Communications Services) and UAS operations in such instances must be considered on a case-by-case basis, as aeronautical uses were not considered when service rules were developed.

Operation under most radio service rules expressly requires an FCC-issued station/operator license. Some radio services may not expressly require an end-user station/operator license within their service rules, e.g., those found in 47 CFR Part 95. Operation in certain bands may occur without a license or registration in accordance with 47 CFR Part 15, provided no interference is caused, without any presumption of reliability or protection from interference.

In all instances, operation under any FCC rule part requires compliance with specific requirements beyond power level and allocated service. For example, the 47 CFR Part 97 Amateur Radio Service is expressly for the purpose of non-commercial personal aim and operation may not be in the pursuit of any pecuniary interest. Generally, each service has specific licensing rules and policies governing the assignment of frequencies, along with specific station operating requirements including operating procedures, prohibited uses, interstation communication, station identification, control requirements, and record keeping. Given such requirements, along with the inherent time involved in any application process, consideration of appropriate FCC rules should be an early step in any UAS implementation process.

Spectrum is a valuable and finite resource that is shared by many services. Demand for spectrum continues to grow rapidly as wireless communications become more and more ubiquitous and essential. Thus UAS implementation planning should also address the impact on reliable C2 links arising from potential changes in spectrum allocation driven by this demand. Aviation systems lifecycles are typically much longer than those for commercial systems, thus there is a need to address frequency flexibility in the early stages of the UAS system development.

2. Categories of Spectrum

Potential datalinks for providing C2 to UAS include:

Aviation Bands

Existing aviation spectrum for AM(R)S was also recommended for allocation to UAS C2 links by the ITU, in the 5030-5091 MHz band (C-Band) and the 960-1164 MHz band (L-Band). Both of these bands were subsequently allocated by the FCC for this purpose. The aerospace industry has developed standards and equipment for UAS C2 links using these bands, and extensive testing, focusing on the C-Band, has been conducted with NASA support. For the L-Band, various research efforts are being conducted into L-Band communications, such as the L-Band Digital Aeronautical Communications System (LDACS), but the band has many incumbent users for other AM(R)S applications and military airborne datalinks, limiting its availability for UAS C2 Links. Routine (non-experimental) use of these bands for UAS C2 has not yet occurred, awaiting the development and publication of service rules by the FCC.

Aviation spectrum is also used for voice communications with ATC and with other nearby aircraft, when operating in controlled airspace. UAS use the same VHF band (118-137 MHz) and channels as manned aircraft for voice communications. For UAS operations conducted under instrument rules, such as those with a flight plan in controlled airspace, there is a requirement for the remote pilot to maintain voice communication with Air Traffic Control (ATC) and other local airspace users. At present, this can only be done using 2-way VHF radios tuned to the frequency of the applicable ATC tower or center. In cases where the VHF radio must be installed on the aircraft, to remain within radio range of ATC ground antennas and other aircraft in the vicinity, the audio is relayed between the pilot and the aircraft's radio over the C2 link. This requirement for relaying ATC voice communications places unique latency and reliability requirements on the C2 link.

Regulations:

- 47 CFR Part 87 – Aviation Services
- ICAO Annex 10

Organizations:

- RTCA SC-228, Minimum Performance Standards for Unmanned Aircraft Systems, Working Group 2, Command and Control Links
- Aviation Spectrum Resources, Inc. (ASRI)

Published Standards and Related Documents:

- RTCA DO-377, *Minimum Aviation System Performance Standards for C2 Link Systems Supporting Operations of Unmanned Aircraft Systems in U.S. Airspace*, March 2019
- RTCA DO-362 with Errata, *Command and Control (C2) Data Link Minimum Operational Performance Standard (MOPS) (Terrestrial)*, September 2016
- TSO-C213 Unmanned Aircraft Systems Control and Non-Payload Communications Terrestrial Link System Radios, September 2018
- TSO-C169a VHF Radio Communications Transceiver Equipment Operating Within Radio Frequency Range 117.975 To 137.000 Megahertz, September 2007
- AC 90-50D, Requirements for 760-Channel VHF Aeronautical Operations
- AC 90-117,_Data Link Communications -- dated 2017
- ARINC 619-5, *ACARS Protocols for Avionic End Systems*
- ARINC 620-9, *Datalink Ground System Standard and Interface Specification (DGSS/IS)*
- ARINC 622-5, *ATS Data Link Applications Over ACARS Air-Ground Network*
- ARINC 623-3, *Character-Oriented Air Traffic Service (ATS) Applications*
- ARINC 753-3 HF Data Link System
- ARINC761-5 Second Generation Aviation Satellite Communication System, Aircraft Installation Provisions
- ARINC781-7 Mark 3 Aviation Satellite Communication Systems

- ARINC791P1-3 Mark I Aviation Ku-Band and Ka-Band Satellite Communication System, Part 1, Physical Installation and Aircraft Interfaces
- ARINC791P2-1 Mark I Aviation Ku-Band and Ka-Band Satellite Communication System, Part 2, Electrical Interfaces and Functional Equipment Description
- ARINC792 Second-Generation Ku-Band and Ka-Band Satellite Communication System
- ICAO, Performance-Based Communications and Surveillance (PBCS) Manual Doc 9869, June 2017.
- ICAO, Global Operational Data Link Document (GOLD), SecondEdition, April 26, 2013.
- RTCA AWP-2, *Command and Control (C2) Data Link White Paper*, Mar 2014
- RTCA AWP-4, *Command and Control (C2) Data Link White Paper Phase 2*, Sep 2017
- JARUS, *RPAS C2 Link, Required Communication Performance (C2 link RCP) Concept*, Oct 2014
- JARUS, *RPAS "Required C2 Performance" (RLP) Concept*, May 2016
- JARUS, *Recommendations on the Use of Controller Pilot Data Link Communications (CPDLC) in the RPAS Communications Context*, Jun 2016

In-Development Standards and Related Documents:

- RTCA DO-377A
- RTCA DO-362A
- EUROCAE WG-105 SG-21, RPAS C2 Datalink, *Minimum Operational Performance Specification (MOPS) for RPAS Command and Control Data Link (Terrestrial)*
- EUROCAE WG-105 SG-21, RPAS C2 Datalink, *MOPS for RPAS Command and Control Data Link (C-Band Satellite)*
- EUROCAE WG-105 SG-21, RPAS C2 Datalink, *MASPS for RPAS Command and Control Data Link*
- EUROCAE WG-105 SG-22, Spectrum, *MASPS for management of the C-Band Spectrum in support of RPAS C2 Link services*
- EUROCAE WG-105 SG-22, Spectrum, *Guidance on Spectrum Access, Use and Management for UAS*
- EUROCAE WG-105 SG-23, Security, *MASPS on RPAS C3 Security*
- EUROCAE WG-105 SG-23, Security, *Guidance on UAS C3 Security*
- JARUS, *RPAS C2 Link CONOPS*

Summary of Aviation/Satellite Band Spectrum Allocation

Safety communications requiring high integrity and rapid response such as those used for 1) safety-related communications carried out by the air traffic services (ATS) for air traffic control (ATC), flight information and alerting; and 2) communications carried out by aircraft operators, which also affect air transport safety, regularity and efficiency (aeronautical operational communications (AOC)), or command and control by UAS operators require radio frequency spectrum allocated to aviation safety, such as the aeronautical mobile (route) and aeronautical mobile satellite (route) services.

Currently, aviation communications and data between aircraft and ground stations, with priority 1 to 6 as defined in the international radio regulations RR No. 44.1, use radio frequency spectrum allocated to aviation safety, such as the AM(R)S and AMS(R)S services.

Table 4 below identifies 1) spectrum that has been allocated in the United States, including the status of the operational service rules, or 2) spectrum that is actively under consideration internationally that could be domestically implemented to support UAS C2 or payload communications. Table 4 does not include commercial mobile radio, amateur, or unlicensed spectrum.

Table 4: Aviation/Satellite Band Spectrum Allocation

Frequency Range	Spectrum Summary and Status
117.975-137.0 MHz	Allocated for civil air/ground voice and data communications. Pilots and air traffic controllers use these frequencies to communicate their intentions, instructions, and clearances.
960-1164 MHz	Allocated for terrestrial-based communications relating to safety and regularity of flight (AM(R)S), primarily along national or international civil air routes. Use of this band by the aeronautical mobile (R) service is limited to systems that operate in accordance with recognized international aeronautical standards. Such use shall be in accordance with Resolution **417 (Rev. WRC-12)**. This frequency band is heavily used by civil aviation to provide critical aircraft separation, identification and landing functions, including traffic collision avoidance systems, automatic dependent surveillance – broadcast (ADS-B) and distance measuring functions are example systems using this frequency band. Operational service rules for UAS C2 have not been initiated at FCC.
1610-1626.5 MHz space-to-Earth: 1545-1559 MHz Earth-to-space: 1646.5-1660.5 MHz	Allocated and available for satellite-based communications relating to safety and regularity of flights (AMS(R)S), primarily along national or international civil air routes (can be considered for UAS C2). In the 1545-1559 MHz and 1646.5-1660.5 MHz bands, certain AMS(R)S communications also have priority and immediate access over any other mobile-satellite communication operating within a network in these bands
5030-5091 MHz	Allocated for terrestrial-based (AM(R)S) and satellite-based (AMS(R)S) communications relating to safety and regularity of flight, primarily along national or international civil air routes. A petition for rulemaking for terrestrial-based UAS C2 operational service rules is pending with the FCC. Satellite-based operational service rules for UAS C2 have not been initiated at FCC.
Space-to-Earth 4000-4200 MHz	Allocated for commercial use of Space to Earth Fixed Satellite communications. Potentially, could be made available for shared use for satellite-based UAS C2

  Earth-to-Space 6225-6425 MHz	link (currently 500 MHz is allocated, from which 3700-4000 MHz is being re-allocated for terrestrial 5G communications) Allocated for commercial use of Earth to Space Satellite communications. Potentially, could be made available for UAS C2 link (paired spectrum with above 4000-4200 MHz downlink)
space-to-Earth: 10.95-11.2 GHz 11.45-11.7 GHz 11.7-12.2 GHz 19.7-20.2 GHz Earth-to-space: 14-14.47 GHz 29.5-30.0 GHz	Internationally being studied to revise and finalize Resolution 155 (Rev. WRC-19) that enables regulations for UAS C2 use by GSO Fixed-Satellite Service (FSS) satellites. These allocations to allow UAS C2 use have not been allocated (nor have any operational service rules been adopted or initiated) within the United States by the FCC. ICAO is finalizing Standards and Recommended Practices (SARPS) to enable the FSS to be used in these frequency bands for UAS C2.
space-to-Earth: 10.95-11.2 GHz 11.45-11.7 GHz 11.7-12.2 GHz 18.3–18.8 GHz 19.7–20.2 GHz Earth-to-space: 14.0-14.5 GHz 28.35–28.6 GHz 29.25–30.0 GHz	Allocated and operational service rules adopted for Earth Stations in Motion (ESIMs) for Earth Stations Aboard Aircraft (ESAA) using GSO FSS Satellites that can be used for UAS payload communications. This spectrum could also be considered for UAS C2 using GSO FSS satellites in airspace that does not have equipage requirements. Pending FCC rulemaking that would permit these bands except the 18.6-18.8 GHz and 29.25–29.5 GHz using Non-Geostationary Fixed Satellite (NGSO) for Earth Stations in Motion (ESIMs). NOTE: Internationally, AMSS is allocated in the 14.0-14.5 GHz band and ESIMs may operate in allocations in the 17.7-20.2 GHz and 27.5-30 GHz bands

Satellite

Spectrum for UAS communications can be provided via satellite communications on both geostationary and non-geostationary platforms with Aeronautical Mobile Service (AMSS), Mobile Satellite Service (MSS), and Aeronautical Mobile Satellite on Route Service (AMS(R)S) designations in portions of frequency bands below 3 GHz. Additionally, AMSS in portions of the Ku-band and earth stations in motion (ESIMs) in portions of the Ka frequency band can be used for UAS payload communications and considered for C2 in airspace that does not have equipage requirements.

Satellite communications networks provide a variety of services to traditional aviation including mobile broadband access, broadcast television/radio/weather, and critical safety services. Generally, the spectrum and services most appropriate for C2 operations are those approved for and utilized for safety services - that is to say cockpit to ground voice and data communications. Satellite communications are utilized in commercial transport to augment/supplement traditional ground based networks, and are particularly important for trans-oceanic flights where traditional ground based infrastructure does not exist or has limitations in range (horizon, altitude, interference). The spectrum bands specified and utilized for AMS(R)S for safety and regularity of flight that are defined as protected and prioritized by ICAO and ITU are 1545-1555 MHz, 1610-1626.5 MHz, and 1646.5-1656.5 MHz, and in the United States

1555-1559 MHz and 1656.5-1660.5 MHz. These frequencies fall within the L-Band range, and are less prone to rain/weather fade and rotor noise than other satellite communications bands like Ka/Ku.

In 2012, the ITU made the 5030-5091 MHz band available for AMS(R)S to support satellite command and control of UAS. In 2015, the ITU adopted Resolution 155 which identified Fixed-Satellite Service (FSS) spectrum in the 10.95-11.2 GHz (space-to-Earth), 11.45-11.7 GHz (space-to-Earth), 11.7-12.2 GHz (space-to-Earth) in Region 2, 12.2-12.5 GHz (space-to-Earth) in Region 3, 12.5-12.75 GHz (space-to-Earth) in Regions 1 and 3 and 19.7-20.2 GHz (space-to-Earth), and in the frequency bands 14-14.47 GHz (Earth-to-space) and 29.5-30.0 GHz (Earth-to-space) bands for satellite command and control of UAS in non-segregated airspace with the objective to finalize the regulations in 2023. The ITU is studying these provisions to ensure spectrum compatibility with other services operating in the frequency bands and developing technical characteristics of UAS. ICAO is developing the standards and recommended practices (SARPs) for FSS C2 Links.

Regulations:

- ITU-R Res 155, for which final implementation has not yet been adopted and is in the process of being finalized to provide additional satellite bands
- ITU-R ESIMs in 17.7-19.7 GHz, 19.7-20.2GHz, 27.5-29.5 GHz, and 29.5-30 GHz
- FCC Part 25
- ITU Radio Regulations (specifically 5.357A)

Organizations:

- RTCA SC-228, Minimum Performance Standards for Unmanned Aircraft Systems, Working Group 2, Command and Control Links
- RTCA SC-222, AMS(R)S
- ICAO
- ITU
- ETSI
- FCC
- SAE-ITC ARINC

Published Standards and Related Documents:

- ETSI EN 301 473, *Satellite Earth Stations and Systems (SES); Harmonized Standard for Aircraft Earth Stations (AES) providing Aeronautical Mobile Satellite Service (AMSS)/Mobile Satellite Service (MSS) and/or the Aeronautical Mobile Satellite on Route Service (AMS(R)S/Mobile Satellite Service (MSS), operating in the frequency band below 3 GHz covering the essential requirements of article 3.2 of the Directive 2014/53/EU*
- ETSI ETR 270, *Satellite Earth Stations and Systems (SES); Survey on the need for an ETS for Aircraft Earth Stations (AES) in the Aeronautical Mobile Satellite Service (AMSS)*

- RTCA DO-262E, *Minimum Operating Performance Standards for Avionics supporting Next Generation Satellite Systems*
- RTCA DO-343C, *Minimum Aviation System Performance Standard for AMS(R)S Data and Voice Communications Supporting Required Communications Performance (RCP) and Required Surveillance Performance (RSP)*

In-Development Standards and Related Documents:

- RTCA DO-377A, Minimum Aviation System Performance Standard for UAS C2 Links
- RTCA SC-222 revisions in draft
- NGSO ESIMs in Ka bandGaps

<u>Commercially licensed spectrum</u>

Use of commercial terrestrial wireless spectrum and networks to enable UAS is a topic that has been under discussion by the FCC and FAA for many years. Industry has been studying this new use of the commercial wireless networks, including as part of the Integration Pilot Programs in North Carolina, San Diego and other locations. The recently released FAA notice of proposed rulemaking (NPRM) related to remote identification of UAS mentions a number of times the intent to connect UAS to the Internet over the cellular networks.

The FCC's Technological Advisory Council ("TAC") UAS Working Group[22] validated use of commercial wireless technology for UAS communications, finding that "3GPP[23] technology satisfies the expected communications requirements for low altitude UAVs."[24] The TAC UAS Working Group identified advantages of 3GPP technologies, including leveraging existing infrastructure, readily-available commercial hardware, flexibility to meet varying flight operations, and extensive security and privacy support. The TAC did not consider the interference effects of UAS communications on commercial wireless networks.

An absence of expressed restrictions on Aeronautical Service in the Table of Allocations (ToA) or in the FCC's service rules for a band of spectrum, including commercial wireless spectrum, does not mean that the FCC has contemplated or analyzed aeronautical or UAS operations for that band. That analysis is ongoing. The FAA also has been supportive of exploring use of the commercial wireless networks for UAS. As government sponsored and industry working groups have noted, licensed commercial wireless

[22] The TAC, which provides technical advice to the Commission on a variety of emerging technologies, has included a sub-group specifically tasked to analyze the communications needs (including spectrum) for UAS applications. Information released by the TAC does not represent an official determination of the FCC.
[23] 3GPP is the 3rd Generation Partnership Project, a partnership between seven major standards development organizations from around the world that work to develop technical specifications for mobile systems.
[24] Presentation by the Communication Strategies for UAS Working Group at the FCC's March 26, 2019 TAC Meeting.

networks provide the coverage, authentication and security, quality of service, reliability and redundancy, latency, and global interoperability required for safe UAS control links. See, for example, the FAA's Drone Advisory Committee,[25] the FAA's Remote ID Aviation Rulemaking Committee,[26] Qualcomm,[27] and the FCC Technology Advisory Council.[28] **Regulations:** The FCC issues technical and service rules for terrestrial commercial wireless spectrum that can be found in 47 CFR of the FCC Rules.

Organizations: CTIA, GUTMA, ASRI, GSMA, ACJA

The Global UTM Association (GUTMA) in conjunction with GSMA have formed the Aerial Connectivity Joint Activity (ACJA) to promote interchange between the aviation and cellular communities, and to synchronize contributions between the existing SDOs of each community in order to avoid incompatibilities between them.

3GPP is developing specifications for use of the long-term evolution (LTE) and emerging 5G networks to support UAS communications links. It has already completed Release 15 and is now working on Release 16 and planning for Release 17. The objectives of releases 16 and 17 are as follows:

- System requirements for UAS-related requirements;
- Key Performance Indicators (KPIs) for command and control traffic;
- Developing the architecture requirements and solution recommendations to enable application layer support for UAS over 3GPP networks;
- Radio architecture network frameworks for UAS payload communications for 5G which includes a proposal for the same functionality enabled in Release 15 for LTE, with additional aspects;
- System architecture work related to: identification and tracking of both drones and drone controllers, including studying the extent to which the 3GPP system is involved; authorization and identification of drones and drone controllers by UAS Traffic Management ("UTM"); and the role of the 3GPP system, if any, in authorization and/or authentication of the drone controller;
- Drone to controller communications, and drone to drone communications, including: identifying the impacts on UAS operations of lack of/revocation of authorization while considering the need for the system to keep track of and control drones; enhancements to existing mechanisms for connectivity between drone controllers; drones and the UTM, considering both line of sight

[25] RTCA, *Drone Advisory Committee Report* (November 8, 2017). The DAC report (p. 66) highlighted reasons why using commercial wireless networks is the right approach for safe and secure UAS operations. The DAC also cited the reliability of wireless networks as a positive factor in supporting beyond visual line-of-sight missions (p. 67, "Network Coverage/Reliability").
[26] FAA *Remote ID and Tracking ARC Report* (Dec. 19, 2017)
[27] Qualcomm, *LTE Unmanned Aircraft Systems, Trial Report* (May 12, 2017)
[28] FCC Technological Advisory Council, 2016 Recommendations (December 2016)

connectivity and non-line of sight connectivity; and detection and reporting of unauthorized drones towards UTM.

Published Standards and Related Documents:

- 3GPP TR 36.777 V15.0.0 (2017-12), *Study on Enhanced LTE Support for Aerial Vehicles; Release 15*, Dec 2017. This technical report gives a broad overview, including simulation and test results, of aerial LTE connectivity quality, handover, and interference issues. Release 15 normative specification changes were more limited in scope, and focused on: height reporting when a drone crosses a network-configured reference altitude, interference detection and mitigation, UAS-dedicated radio measurement reporting, signaling of flight path information from drone to LTE network, location information reporting including a drone's horizontal and vertical velocity, and subscription-based aerial drone remote identification and authorization.
- 3GPP TS 22.125 V16.3.0 (2019-09), *UAS Support in 3GPP; Stage 1; Release 16*, Sep. 2019
- 3GPP TS 22.281 V16.0.0 (2018-09), *Mission Critical Video Services; Release 16 (includes UAV-related mission critical video requirements)*, Sep. 2018
- 3GPP TS 22.282 V16.4.0 (2018-12), *Mission Critical Data Services; Release 16 (includes UAV-related mission critical data requirements),* Dec. 2018
- 3GPP TS 22.825 V16.0.0 (2018-09), *Remote ID of UAS; Stage 1; Release 16*, Sep. 2018

In-Development Standards and Related Documents:

- 3GPP Study Item Enhancements for UAS (FS EAV)
- 3GPP TS 22.125 V 17.0.0 (2019-09), *UAS Support in 3GPP; Stage 1; Release 17* (Note: KPI values negotiated by cellular/aviation communites are being worked for addition to this spec.)
- 3GPP TS 22.261 V17.0.1 (2019-10), *Service Requirements for the 5G System; Stage 1; Release 17*
- 3GPP TR 23.754 *Study on supporting Unmanned Aerial Systems (UAS) connectivity, Identification and tracking; Release 1*7 (anticipated completion at Stage 2 Architecture level by December 2020, with possible Stage 3 Protocol work to be done afterward)
- Proposed RTCA DO-377 revision. DO-377 will rely heavily on the Satcom information coming from SC-222. The Satcom discussion in SC-228 are largely ancillary to SC-222 and are relying on the MASPS and MOPS for traditionally piloted aircraft to make up the majority of the details for UAS/RPAS. Revisions to documents are in draft, and expected to be puglished 2020. DO-262E(MOPS) and DO-343C(MASPS) will generally be the guidelines for SC-228 and the Satcom performance stadnards. In the meantime, the current versions of SC-222 DO-262/343 can be utilized for reference to Satcom MOPS/MASPS.

Gap A6: Alignment in Standards Between Aviation and Cellular Communities. A gap exists in alignment between the aviation and cellular SDO communities, even when sufficient SDO efforts exist within each community. The telecommunications industry has already taken a number of steps to develop standards, particularly in 3GPP, to prepare networks for UAV applications. However, it is expected that fully addressing all KPIs of the C2 link will require further standardization activities.

R&D Needed: Yes. The FAA also has worked with CTIA to develop testing principles for use of the commercial wireless networks to support UAS and is considering the outcome of those tests in conjunction with the IPPs and other testing.

Recommendation: Collaboration between the UAS industry and communications industry is required to ensure feasibility of implementation. The aviation and cellular communities should coordinate more closely to achieve greater alignment in architecture and standards between the two communities. Specifically, advance existing work in 3GPP and ensure C2 requirements are communicated to that group. In addition, architectures and standards could be developed for predicting or guaranteeing C2 link performance for a specific flight that is about to be undertaken.

Organization: 3GPP, GSMA/GUTMA ACJA, ASRI

Priority: High (Tier 2)

Status of Progress: Green

Update: As noted in the text, standards are in development.

Unlicensed spectrum

Using unlicensed spectrum for communication is attractive for many UAV makers and operators because no FCC license is required for the operator. Because these bands are used for a wide variety of purposes, there exists a healthy ecosystem of radio transceiver parts and modems that can be leveraged to create cost-effective solutions. These are deployed by manufacturers with varying degrees of customization specific to the UAV use case. It is important to consider that such operations only occur on a “non-interfering basis.” That is, users may not cause interferference and, likewise, their operations are not protected from interference. Each user operating in an unlicensed band is required to comply with the pertinent FCC rules (generally 47 CFR Part 15), which specify maximum transmit power and other parameters. Some bands also require additional operating procedures, such as Listen Before Talk (LBT), that are intended to minimize interference. These bands are commonly used for both C2 and payload (such as video).

In the USA, unlicensed bands available for UAVs are:

- 915MHz (902Mhz-928Mhz); 2.4GHz (2400MHz-2483.5MHz); and 5.8GHz (5725-5850Mhz). These three bands are typically governed by 47 CFR Section 15.247, which, among other things requires frequency hopping or wideband digital modulation. (Alternatively, 47 CFR Section 15.249 provides other lower power limits for usage not meeting these conditions.) The maximum transmitter power depends on parameters of modulation, but can generally be up to 1 watt total and 4 watt effective isotropic radiated power (EIRP) in the direction of highest gain. Note that fixed point-to-point usage can use much higher EIRP, per 15.247(c)(1), which increases the potential for interference to UAV communications. In many countries, the 5GHz band requires LBT, but the USA is not among these.

- 27MHz (6 channels from 26.995 MHZ to 27.255 MHz). The primary usage of these bands for RC aircraft falls under 47 CFR Section 15.227, which allows only 30uW EIRP (10000uv/m at 3m). These frequencies are also part of the RCRS (Radio Control Radio Service) and are allocated for both surface and aerial vehicles. RCRS is governed by 47 CFR Part 95, which allows much higher powers (4 to 25 watts). But usage under Part 95 is relatively rare compared to usage in small low-cost toys under Section Part 15.227. This band is shared with the CB radio service (26.960 MHz to 27.410 MHz) and the industrial, scientific, and medical (ISM) radio band (26.957 MHz to 27.283 MHz).
- 49MHz (49.82-49.9 MHz). These are governed by 47 CFR Section 15.235 when used for RC aircraft. The power limit and usage is similar to the 27MHz usage under 15.227.
- 72MHz (72.0-73.0MHz). These are designated as RCRS and governed by Part 95 when used for model aircraft. This stipulates a limit of 0.75W (and thus the usage for larger model aircraft, versus 27MHz and 49MHz).
- Equipment in 27 MHz, 49 MHz, and 72 MHz generally relies on the operator to select an available frequency, and simply does not function if two users of the same channel are collocated. Places where RC modelers congregate may have a “flag” or “board” system for 72 MHz, to check out a frequency, to ensure that two users are not using the same frequency.

In other countries other bands may be used for RC aircraft. For example 35Mhz is a common band in aero models in the EU (although similar to 72MHz in USA, it is largely replaced by 2.4GHz equipment).

Organizations: Among the organizations creating standards applicable to the usage of unlicensed bands for UAVs are:

- Bluetooth SIG
- IEEE 802.11 and Wifi Alliance
- IEEE 802.15.4
- ISO (18000-7)
- ITU-T (G.9959)

Published Standards: It is common for UAV manufacturers to modify drivers and upper layer software to introduce proprietary features, while still taking advantage of the ecosystem of standards-based integrated circuits and modules. All transmitters operated by non-federal users are subject to the FCC’s equipment authorization rules found in 47 CFR Part 2, Subpart J. Compliant devices will include a valid FCC ID number. Any modification to parameters associated with the FCC ID number must satisfy the FCC requirements before the device is marketed or operated.

General purpose standards leveraged for UAVs include:

- Wifi (802.11, various versions). Typically, this operates in 2.4 GHz and 5.8 GHz, except 802.11ah (Wifi HaLow) which operates in the 915 MHz band.
- Bluetooth. LAN/PAN standard operating in the 2.4 GHz band, defined by the Bluetooth SIG.

- Z-wave. This operates in the 915 MHz band in the USA, and other nearby bands in other countries. The physical layer is defined by ITU-T G.9959.
- Dash7. An IOT Protocol in the 433, 868, and 915MHz unlicensed bands based on ISO/IEC 18000-7.
- 802.15.4. This is the physical layer foundation for Zigbee, ISA100.11a, WirelessHART, MiWi, 6LoWPAN, thread and SNAP, each of which defines upper layers not defined in 802.15.4.

Some common UAV-specific protocols are:

- Spektrum DSM, DSM2 and DSMX
- JR DMSS, originally based on Spektrum DSM but with proprietary modifications
- Futaba FASST
- FrSky D8, D16, and LR12
- Hitec A-FHSS

In many cases, these protocols leverage chipset from the above standards. There is also a large selection of RF transceiver chips with proprietary protocols available for these bands.

Gaps in the use of unlicensed bands for UAVs include the following:

New Gap A20: Unlicensed Spectrum Interference Predictability. Performance in the unlicensed spectrum bands is inherently unpredictable to some extent. There are approaches to enhance modeling and prediction, but there has been little work towards doing so.

R&D Needed: Yes.

Recommendation: Additional R&D could include statistical characterization of congestion in various environments (urban, rural, etc.), and study of interference caused by aerial radios.

Priority: High, especially in evaluating Remote ID broadcast range (Tier TBD)

Organization(s): FAA is investigating university research through the ASSURE program to quantify Remote ID broadcast range. This work could be extended to C2 link issues as well.

New Gap A21: **Unlicensed Spectrum Security.** The protocols used in unlicensed band are typically not highly secure, and may be susceptible to intrusion from another transmitter.

R&D Needed: Yes.

Recommendation: Further work could be done to increase the robustness of security for unlicensed systems

Priority: Medium

Organization(s): FAA is already actively working on this in the context of Remote ID. This foundation could be extended to C2 link as well.

Amateur bands

Drone first person view (FPV) video transmitters use amateur bands, which require operators to maintain an amateur radio (HAM) license. The following amateur (non-commercial) bands are used for C2: 50MHz, 53MHz, and 433MHz for UAS.

Regulations: 47 CFR Part 97, Amateur Radio Service which provides that any use of amateur bands must be for personal use, without any pecuniary or commercial interest.

Organizations: American Radio Relay League (ARRL)

3. Spectrum-Agnostic IEEE In-Development Standards and Documents

IEEE P1920.1, Aerial Communications and Networking Standards. IEEE P1920.1 defines air-to-air communications over self-organized aerial ad hoc networks and describes the reference architecture for aerial networks, where aircraft can form a network to share information with one another with or without any supporting infrastructure, such as satellite or cellular communications. It is primarily intended for small UASs used for civilian and commercial applications. This standard is still under development and is expected to be released in early 2021.

IEEE P1920.2, Standard for Vehicle to Vehicle Communications for Unmanned Aircraft Systems. IEEE P1920.2 defines a Vehicle to Vehicle Communications (V2V) standard for UASs. It is primarily focused on the protocol for exchanging information between the vehicles. The information exchange will facilitate beyond line of sight (BLOS) and beyond radio line of sight (BRLOS) communications. The information exchanged between the aircraft may be for the purpose of command, control, and navigation, or for any application specific purpose.

4. Conclusions

Much work remains to be done with respect to spectrum options for UAS C2 in order to complete any required regulatory actions, and confirm which options are optimal or necessary for each category of UAS (small or large), in view of varying altitudes of operation and concepts of use. All of the spectrum options discussed above, aviation-protected bands, commercial licensed bands (cellular and satellite), and unlicensed bands are viable for UAS C2 and ultimately may be used in concert for certain UAS operations. Until work on these spectrum options is concluded by the regulators and industry, many commercial UAS operations are relying on unlicensed bands, commercial wireless and satellite bands (with the licensee's authorization), and experimental licenses issued by the FCC to satisfy the UAS C2 function.

6.4.2. Navigation Systems

Radio frequency navigation requirements on UAS platforms are highly dependent on the platform and application. Satellite (including augmentation systems) navigation uses global navigation satellite signals (GNSS) to determine the position of the aircraft. Processing these signals into navigation solutions is dependent on the GNSS receiver's capability (e.g., mulit-frequency (L1/L2/L5), multi-constellation (GPS, Galileo, GLONASS, etc.), ionospheric correction, multipath mitigation, Real-Time Kinematic Corrections, etc.), integration with other sensors/components on the platform, forecasting GNSS coverage, and integrity monitoring of the system. The operations of UAS are changing. Initially small UAS had the pilot operate the UAS remotely using visual contact with the assistance of a control station (small device, smartphone, tablet, or laptop). In this mode of operation, the control station maintains a communications link with the UAS for manual and automated navigation using a GNSS receiver in the UAS, or for very basic manual control there maybe GNSS at the ground station or none at all. (Note, regulatory requirements may mandate position information at the ground station or in the UAS). As operations of UAS become increasingly automated and beyond visual line of sight (BVLOS) positioning, navigation, and time (typically derived from GNSS) will become critical to successful flights, safe, and efficient operation of the UAS. Furthermore, a UAS platform equipped with a transponder allows its broadcasted position to be known/tracked by other UAS, ground observers, UTM, ATC, etc. (See the section on remote ID and tracking.) It is even possible that the navigational performance of the UAS may impact the efficiency of the Unmanned Traffic Management (UTM) by making the volume of airspace allocated to each UAS dependent (in part) on the accuracy, reliability, and integrity of the navigation system.

Flight control algorithms ensure that system sensors/components (e.g., GNSS, inertial measurement unit (IMU)/inertial navigation systems (INS), magnetometer/compass, pressure altimeter, etc.) are providing reliable navigational accuracy. In certain situations, a magnetometer/compass may be adversely affected (e.g., operating in close proximity to ferrous materials or proximity to power transmission lines). Likewise, operating a UAS in close proximity to buildings, structures, vegetation, and in canyons creates multipath and obscuration of GNSS signals that may degrade navigational performance.

GNSS frequencies are highly regulated by the FCC; however, recent advancements in ground-based communication signal transmission technologies have shown some interference with GNSS signals even though their authorized frequencies are adjacent to the GNSS frequency bands. Currently, communication networks using these interfering frequencies have not been deployed, but this highlights how sensitive GNSS signals can be with technologies using GNSS frequencies.

For manned aviation, the FAA has signaled a transition from radar and VHF navigational aids to precise tracking using GNSS satellite signals by requiring ADS-B technology since January 2020. The improved accuracy, integrity, and reliability of satellite signals over radar means controllers will eventually be able to safely reduce the minimum separation distance between aircrafts and increase capacity in the nation's skies. Relying on satellites instead of ground navigational aids will enable aircraft to fly more directly from point A to B. Also, ground control displays could accurately identify hazardous weather and terrains, and provide pilots important flight information, such as temporary flight restrictions, which would improve navigation for UAS operations BVLOS. The difference in GNSS navigation reliability & integrity for manned, unmanned, manual, and automated flight systems must be considered to ensure safe and efficient operation in nominal as well as degraded conditions for the flight environments.

The above methods of navigation use terrestrial or satellite radio navigations systems, which are external to the aircraft. UAS augment those systems with self-reliant navigation functionality such as machine/computer vision-based navigation using sensors such as optical cameras or LIDAR. Computer vision-based systems operate similarly to the way human pilots navigate by using visual cues and landmarks for VFR flight. Vision based systems perform aircraft localization corrections to inertial measurement unit (IMU) predictions. Upon successful detection and association of a landmark using a vision-based system, the pixel coordinates of the detected landmark are measured. Because the global coordinates of the landmarks are known, the absolute location of the aircraft can be estimated based on the location of the landmark’s projected image in the airborne 2D image plane with the aid of existing onboard aircraft instrumentation (e.g. IMU, altimeter, airspeed indicator). Vision-based navigation systems increase self-reliance and can be self-contained on the aircraft; therefore, they are not susceptible to signal interferences, which are discussed in the later section. Vision system are however impacted by environmental effects like rain, fog, snow and low light, and are limited by the line of sight from the sensor to the environment detected. Moreover, matching of the landmarks detected by the system to a map requires that the area be surveyed and updated periodically, and that the area have enough landmarks to yield a high confidence in the derived position. For UAS the use of multiple position, navigation, and time technologies like GNSS and vision systems can greatly increase the reliability and safety of the system. There currently exists no industry standards for computer vision-based navigation systems.

Published Standards: While not specific to UAS, relevant published standards include:

- FAA Advisory Circular 20-165B - Airworthiness Approval of Automatic Dependent Surveillance - Broadcast OUT Systems
- FAA TSO-C154c, Universal Access Transceiver (UAT) Automatic Dependent Surveillance-Broadcast (ADS-B) Equipment Operating on Frequency of 978 MHz
- FAA TSO-C166b, Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information Service - Broadcast (TIS-B) Equipment Operating on the Radio Frequency of 1090 Megahertz (MHz)
- FAA TSO-C145e, Airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Satellite Based Augmentation System (SBAS)
- FAA TSO-C146e, Stand-Alone Airborne Navigation Equipment Using the Global Positioning System Augmented (GPS) by the Satellite Based Augmentation System (SBAS)
- FAA TSO-C196b, Airborne Supplemental Navigation Sensors for Global Positioning System (GPS) Equipment using Aircraft-Based Augmentation
- FAA TSO-C204a, Circuit Card Assembly Functional Sensors using Satellite-Based Augmentation System (SBAS) for Navigation and Non-Navigation Position/Velocity/Time Output.
- FAA TSO-C205a, Circuit Card Assembly Functional Class Delta Equipment Using the Satellite-Based Augmentation System for Navigation Applications

- FAA TSO-C213 Unmanned Aircraft Systems Control and Non-Payload Communications Terrestrial Link System Radios
- ARINC660B CNS/ATM Avionics Architectures Supporting NextGen/SESAR Concepts
- ARINC743A-6 GNSS Sensor
- ARINC743B-1 GNSS Landing System Sensor Unit (GLSSU)
- ARINC743C GNSS Landing System Sensor Unit (GLSSU) with VHF Data Broadcast (VDB) Receiver
- ARINC755-5 Multi-Mode Receiver (MMR) – Digital
- ARINC756-3 GNSS Navigation and Landing Unit (GNLU)
- ARNC760-1 GNSS Navigation Unit (GNU)
- RTCA DO-229, *MOPS for Global Positioning System/Wide Area Augmentation System Airborne Equipment*
- RTCA DO-316, *MOPS for Global Positioning System/Aircraft Base Augmentation System*
- SAE1002 U.S. National Grid Standard
- SAE6857 Requirements for a Terrestrial Based Positioning, Navigation, and Timing (PNT) System to Improve Navigation Solutions and Ensure Critical Infrastructure Security
- SAE9990 Transmitted Enhanced Loran (eLoran) Signal Standard
- SAE9990/1 Transmitted Enhanced Loran (eLoran) Signal Standard for Tri-State Pulse Position Modulation
- SAE9990/2 Transmitted Enhanced Loran (eLoran) Signal Standard for 9th Pulse Modulation
- ANSI/TIA-5041, future Advanced SATCOM Technologies (FAST) Open Standard Digital – If Interface (OSDI) for SATCOM Systems
- TIA-1008, IP over Satellite (IPoS)
- TIA-1073.000 Satellite Network Modem System (SNMS) General Requirements
- TIA-1073.001 Satellite Network Modem System (SNMS) Network Layer Standard
- TIA-1073.002 Satellite Network Modem System (SNMS) Encryption

In-Development Standards: While not specific to UAS, relevant in-development standards include:

- SAE1004 Raw Measurements from Global Navigation Satellite System (GNSS) Receivers
- SAE1012 Global eLoran User Equipment Interface Standard
- SAE1012/1 Global eLoran User Equipment Interface Standard for Timing
- SAE1012/2 Loran or Enhanced Loran (e)Loran Position, Navigation, and Timing (PNT) Interface Specification for the Embedded Global Positioning System and Inertial Navigation System (EGI)
- SAE1013 Guidelines for Resilient GNSS Receivers
- SAE1014 Standard for Interfacing Resilient GNSS Receivers
- SAE1015 Improving the Accuracy, Availability, Integrity, Continuity, or Coverage of Positioning, Navigation, and/or Timing Solutions Using Raw Measurements from Global Navigation Satellite System (GNSS) Receivers
- SAE1016 Security and Resilience Recommendations for Positioning, Navigation, and Timing (PNT) Users
- SAE4572 Open System Architecture Interface to Enable Simulator Laboratory Testing of Embedded Global Navigation Satellite System and Inertial Navigation System (EGI) Equipment
- SAE9980 Specification of The Transmitted Loran-C Signal
- SAE9991 Receiver Standard for the Transmitted eLoran Signal

- SAE9992 Introduction to the Operation and Use of the Transmitted Enhanced Loran (eLoran) Signal
- SAE9993 A Guideline for Using the Transmitted Enhanced Loran (eLoran) Signal for Timing, Phase, and Frequency

Gap A7: UAS Navigation Systems. There are a lack of standards specifically for UAS navigation. There are a lack of navigation standards in novel environments where aircraft typically do not operate such as in "urban canyons." Challenging environments may invoke capabilities such as vision-based navigation. Otherwise, UAS could use existing ground infrastructure such as very high frequency (VHF) omni-directional range (VOR), non-directional beacons (NDB), instrument landing systems (ILS), and satellite infrastructure (GPS), which has vast coverage, and make use of the new enhanced, long-range navigation (eLORAN) standards in development. UAS navigation can leverage many of the same standards used for manned aircraft, but at a smaller scale and lower altitudes.

UAS stakeholders should evaluate their PNT performance requirements (precision, accuracy, timing, robustness, etc.) for their flight profiles. SAE6857 can be used as a point of reference.

R&D Needed: Yes. A specific R&D effort geared towards applying tracking innovations in satellite navigation for UAS is needed. Additional R&D effort is needed to further mature, test, and validate vision-based navigation systems.

Recommendation: Depending on the operating environments, apply existing navigation standards for manned aviation to UAS navigation and/or develop UAS navigation standards for smaller scale operations and at lower altitudes. Refer to R&D needed. Furthermore, existing navigation practices used by connected/automated vehicle technology should be leveraged to develop integrated feature-based/object-oriented navigation standards to orient the UAS platform in GNSS-deficient areas.

Priority: High (Tier 1)

Organization(s): SAE, FAA, NASA, DOT

Status of Progress: Green

Update: The text and list of non-UAS specific published and in-development standards has been substantially modified from roadmap version 1. A number of non-UAS specific, but potentially relevant manned aviation standards are in-development, as noted in the text.

Protection from GNSS Signal Interference Including Spoofing and Jamming

Every GNSS provides position and timing signals to a GNSS receiver such as those equipped on UAS platforms. There continues to be significant concerns that GNSS satellite signals, like any other navigational signals, are subject to interference, whether intentional or unintentional.

The GNSS receiver measures the time delay for the signal to reach the receiver from the satellite. One type of interference impacting GNSS is multipath of the signals. As the signals from the satellites travel down to earth they can be reflected off buildings, structures, and other objects and then be received by the GNSS receiver. Due to the reflection of the signal it will take longer to reach the receiver than the straight line that is intended. This additional time, delay, caused by environmental interference leads to positioning inaccuracy.

Interference by spoofing degrades the integrity of the GNSS signals by falsifying positions or timing offsets. Interference by jamming (intentional or unintentional) blocks or degrades the GNSS signals; thus making the signals more difficult for the receiver to receive or process, degrading or eliminating the ability to navigate using GNSS alone. The FAA is actively working with other U.S. Federal Agencies to detect and mitigate these effects and make sure that the GNSS and any related augmentation systems are available for safe manned aviation operations. With the proliferation of UAS, the industry and SDOs are encouraged to develop needed standards to address similar approach or fold in specific UAS-related considerations.

As described below, there are several actions that UAS manufacturers and operators can take to protect against interference (multipath, spoofing and jamming)..

Interference countermeasures include:

- Ensuring that GNSS receivers simultaneously track multiple constellations (e.g., GPS and Galileo) and track multiple frequencies (L1, L2, & L5). To completely spoof a GNSS receiver, an adversary would have to produce and transmit all possible GNSS signals simultaneously. Multiple GNSS signals also enable better accuracy and mitigation of multipath.
- Filtering out-of-band radio frequencies. This is only effective with signals outside of GNSS frequency bands.
- Using an adaptive antenna array such as a controlled reception pattern antenna (CRPA). CRPAs are very effective at nulling multiple, high-powered jammers and are used by military platforms and weapons that operate in highly-jammed environments.
- Incorporate an IMU. IMUs are impervious to radio-frequency interference. Spoofing an IMU would require fabricating the Earth's gravitational field or vehicle dynamics to cause the IMU to think that it has moved in a way that it has not, which is not likely. However, the system needs to ensure that an IMU is not fed spoofed data taking it off course. An IMU can bridge GNSS positioning gaps for short or long periods depending on the design.
- Networking the GNSS receiver and UAS to services that can alert them of spoofing, jamming, and other interference in their area and report spoofing when/if detected.
- Using forecasting and planning tools to avoid areas of environmental interference or change the mode of operation (speed, altitude, alert limits, air corridor width, etc.) based on the forecasting GNSS performance.

Lower altitude flights may pose a higher risk of GNSS signal interference from magnetic fields or near frequency emissions. Lower altitude flights will experience more interference from multipath.

Published and In-Development Standards: See list in preceding section.

Gap A8: Protection from Global Navigation Satellite Signals (GNSS) Interference Including Spoofing and Jamming. There are standards in place for spoofing and jamming mitigation for manned aircraft. However, these standards are currently being updated to reflect increasing demands on GNSS systems, ongoing efforts to improve mitigation measures/operational needs, and heightened awareness of nefarious activities using spoofing and jamming technologies. Given the fact that manned aircraft standards are being updated/improved, there is a significant gap with how these standards may be applied to UAS platforms. See the command and control section for related discussion.

R&D Needed: Yes. An evaluation of the specific characteristics of current aircraft navigation equipment is needed including technical, cost, size, availability, etc. Higher performance spoofing/jamming mitigations should be developed.

Recommendation: There are likely insignificant differences in navigation system protection measures between manned aircraft and UAS, but it is recommended that this be evaluated and documented. Based on this evaluation, standards and/or policy may be needed to enable UAS platforms to be equipped with appropriate anti-spoofing and anti-jamming technologies. Also, operational mitigations are recommended including updating pilot and traffic control training materials to address interference and spoofing.

Priority: High (Tier 1)

Organization(s): SAE, FAA, DOD, NASA, DOT

Status of Progress: Green

Update: The text and list of non-UAS specific published and in-development standards has been substantially modified from roadmap version 1. A number of non-UAS specific, but potentially relevant manned aviation standards are in-development, as noted in the text.

6.4.3. Systems Performing Detect and Avoid (DAA) Functions

The cost and scale of current technology for the design, manufacture, installation, and operation of systems to provide a DAA capability for UAS has created a gap in approvals for civil UAS operations. Additionally, small and medium UAS may have size, weight, and/or power (SWAP) limitations that prevent implementation of on-board systems to provide a DAA capability as defined by the FAA TSOs (TSO-C211, TSO-C212 and TSO-C213). While large UAS may have traffic alert and collision avoidance systems (TCAS II), advanced collision and avoidance systems (ACAS), ADS-B, and radar systems that are typical on commercial aircraft, additional DAA technology is required to meet current regulatory guidance. This challenge of developing an on-board system for DAA for any sized UAS, especially those with SWAP challenges, contributes to a lack of verification, validation, reliability, and confidence in the operations of an installed system for DAA on a UAS.

The FAA TSOs (TSO-211, TSO-212 and TSO-213) and companion RTCA documents (DO-362, DO-365 and DO-366) reference additional equipage requirements to meet the DAA performance requirements, such as ADS-B, TCAS II, etc. These systems are currently required for commercial aircraft and will likely be required for UAS operating in the same airspace (TCAS is not yet approved for use on a UAS). These TSOs and RTCA documents do not sufficiently address the requirements for a DAA capability by UAS operating at low altitudes. Likewise, they are not applicable to the Visual Flight Rules (VFR) traffic pattern of an airport. Further revisions of these documents are expected to address other operational scenarios and sensors better suited to meet smaller aircraft needs, as well as other DAA architectures, including ground-based sensors. In addition, the TSO Authorization (TSOA) does not address TSOA Installation Approval which is a separate approval required to install the TSO compliant article/equipment in an aircraft. For purpose of discussion, if a UAS holds no Type Certification (TC) then approval for installation of a TSO'd system providing a DAA capability would require no further approval.

Table 5: DAA Classes and Articles (ref. FAA TSO-C211, pages 2-3)

Class	Equipment[1]	Criticality		DAA Article Designation[2&3]	DAA Equipment Article Name	Function
		Loss of Function	Misleading Information			
1	**DAA – Basic**	Major	Major	A	Active Surveillance	Air Traffic Control Radar Beacon System (ATCRBS)/Mode S Intruder Detection, TCAS II Mode data, Collision Avoidance coordination data
				B	Unmanned Aircraft (UA) DAA Processor	Track Processing, DAA Alerting[2] and Guidance[2]
				C	Control Station (CS) DAA Processor	DAA Alerting[2] and Guidance[2]
				D	CS DAA Control Panel	DAA Mode Control
				E	CS DAA Traffic Display	Display of Traffic, Alerting, and Guidance Information
2	**DAA with TCAS II**	Major	Hazardous/ Severe Major (See 3.b.(2)(b))	A	TCAS II, Version 7.1	ATCRBS/Mode S Intruder Detection, TCAS II Resolution Advisories (RA)Status and coordination data, Collision Avoidance System Logic, Hybrid Surveillance
				B	UA DAA Processor	Track Processing, DAA Alerting[2] and Guidance[2]
				C	CS DAA Processor	DAA Alerting[2] and Guidance[2] with TCAS II Integration
				D	CS DAA Control Panel	DAA Mode Control with TCAS II Integration
				E	CS DAA Traffic Display	Display of Traffic, Alerting, Guidance, and RA Information

Notes (ref. FAA TSO-C211, pages 2-3):

1) In addition to the articles listed in Table 5, in order for the DAA system to function according to TSO-C211, both Class 1 and Class 2 Equipment will require the integration of an Air-to-Air Radar

for Traffic Surveillance (ATAR) to detect non-cooperative aircraft and an Automatic Dependent Surveillance-Broadcast (ADS-B) In system to receive ADS-B messages. TSO-C212 provides the minimum performance standards (MPS) for ATAR equipment. TSO-C166b provides MPS for ADS-B In equipment for DAA systems. TSO-C166b equipment used with DAA systems must be Class A, 1090 MHz with receive capability. TSO-C154c equipment may also be used in addition to TSO-C166b Class A equipment. However, TSO-C154c equipment may not be used in place of TSO-C166b Class A equipment because TSO-C154c equipment by itself does not meet the ADS-B detection performance requirements for a DAA system.

2) Articles can be designated both Class 1 and 2 equipment. Articles A and B are installed on aircraft. Articles C, D, and E contain functions that operate remotely on the ground or in a CS, or, for manned aircraft, may be located in the aircraft. Articles B and C contain DAA alerting and guidance functions that are interchangeable on an unmanned aircraft system platform. They may reside either in the UA or in the CS. See Section 5.a.(3) for installation limitations associated with interchangeability and class designations.

3) The requirements for the individual articles are identified in RTCA/DO-365, Appendix O.

Even though the DOD has been using ground-based systems to provide a DAA capability in the NAS that may benefit operations at lower altitudes (below Class A), much of the DOD's UAS DAA technologies are not affordable for widespread public and commercial applications.

With assistance from the DOD, NASA, and the UAS community, integration of systems and technologies for DAA has made some headway, but not enough for full integration.

Published Standards and Related Materials: Published UAS DAA standards, as well as U.S. Federal government and inter-governmental materials (for civil, military, and space applications) relevant to this issue include but are not limited to those listed below. A more complete list can be found in the *UASSC Reference Document*.

FAA:

- 14 CFR §91.111, Operating near other aircraft
- §91.113, Right-of-way rules: Except water operations
- §91.115, Right-of-way rules: Water operations
- §91.123, Compliance with ATC clearances and instructions
- §91.181(b), Course to be flown
- Other Rules (§§91.205, 91.209, 91.215, 91.217, 91.219, 91.223, 91.225, 91.227, 91.411, 91.413)
- §107.37, Operation near aircraft; right of way rules
- §107.51, Operating limitations for small unmanned aircraft
- Other sUAS Regulations (§§107.15, 107.23, 107.25, 107.29, 107.31, 107.33, 107.35, 107.39, 107.41)
- Technical Standard Order (TSO), TSO-C74d, Air Traffic Control Radar Beacon System (ATCRBS) Airborne Equipment, December 17, 2008
- TSO-C211, DAA Systems, September 25, 2017

- TSO-C212, Air-to-Air Radar (ATAR) for Traffic Surveillance, September 22, 2017
- TSO-C213, UASs Control and Non-Payload Communications Terrestrial Link System Radios, September 3, 2018
- TSO-C112e, Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment, September 16, 2013
- TSO-C118, TCAS Airborne Equipment, TCAS I, August 5, 1988
- TSO-C118a, TCAS Airborne Equipment, TCAS I, October 27, 2014
- TSO-C119d, TCAS Airborne Equipment, TCAS II with Hybrid Surveillance, September 5, 2013
- TSO-C119e, TCAS Airborne Equipment, TCAS II with Hybrid Surveillance, June 30, 2016
- TSO-C151d, Terrain Awareness and Warning Systems (TAWS), August 31, 2017
- TSO-C154c, Universal Access Transceiver (UAT) ADS-B Equipment, December 2, 2009
- TSO-C166b, Extended Squitter ADS-B and Traffic Information, December 2, 2009
- TSO-C195b, Avionics Supporting ADS-B Aircraft Surveillance, September 29, 2014
- Advisory Circular, AC 107-2, Small UAS (sUAS), June 21, 2016
- UAS Traffic Management (UTM) Concept of Operations, FAA, May 18, 2018

RTCA:

- DO-181E, *MOPS for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment*, Section 2 as amended by Appendix 2 of the TSO-112e dated September 16, 2013
- DO-254, *Design Assurance Guidance for Airborne Electronic Hardware (AEH)*
- DO-289, *MASPS for Aircraft Surveillance Applications*, December 13, 2006
- DO-362, *with Errata - Command and Control (C2) Data Link MOPS (Terrestrial)*, September 22, 2016
- DO-365, *Minimum Operational Performance Standards (MOPS) for DAA Systems*, May 31, 2017
- DO-366, *MOPS for Air-to-Air Radar for Traffic Surveillance*, May 31, 2017
- DO-367, *Minimum Operational Performance Standards (MOPS) for Terrain Awareness and Warning Systems (TAWS) Airborne Equipment*

ICAO:

- Annex 1 – Personnel Licensing, Q1 2016
- Annex 2 – Rules of the Air, Q1 2018
- Annex 8 – Airworthiness of Aircraft, Q1 2018

AIAA:

- AIAA R-103-2004, *Terminology for Unmanned Aerial Vehicles and Remotely Operated Aircraft*
- ANSI/AIAA G-043B-2018, *Guide to the Preparation of Operational Concept Documents*
- AIAA G-118-2006, *Guide: Managing the Use of Commercial Off the Shelf (COTS) Software Components for Mission-Critical Systems*
- AIAA G-010-1993, *Guide: Reusable Software: Assessment Criteria for Aerospace Applications*
- AIAA S-117A-2016, *Space Systems Verification Program and Management Process*

- ANSI/AIAA S-102.1.4-2009, *Performance-Based Failure Reporting, Analysis & Corrective Action System Requirements*
- ANSI/AIAA S-102.1.5-2009, *Performance-Based Failure Review Board (FRB) Requirements*
- ANSI/AIAA S-102.2.2-2009, *Performance-Based System Reliability Modeling Requirements*
- ANSI/AIAA S-102.2.4-2015, *Performance-Based Product Failure Mode, Effects and Criticality Analysis Requirements*
- AIAA S-102.2.5-2009, *Performance-Based Sneak Circuit Analysis (SCA) Requirements*
- ANSI/AIAA S-102.2.11-2009, *Performance-Based Anomaly Detection and Response Analysis*
- ANSI/AIAA S-102.2.18-2009, *Performance-Based Fault Tree Analysis Requirements*
- Various Documents and Publications

SAE:

- J2735_201603, *Dedicated Short Range Communications (DSRC) Message Set Dictionary*
- AIR6514, *UxS Control Segment (UCS) Architecture: Interface Control Document (ICD)*
- ARP5707, *Pilot Training Recommendations for Unmanned Aircraft Systems (UAS) Civil Operations*
- ARP6012A, *JAUS Compliance and Interoperability Policy*
- AIR5645A, *JAUS Transport Considerations*
- AS5669A, *JAUS/SDP Transport Specification*
- AS6091, *JAUS Unmanned Ground Vehicle Service Set*
- AS8024, *JAUS Autonomous Capabilities Service Set*
- ARP6128, *Unmanned Systems Terminology Based on the ALFUS Framework*
- AIR5665B, *Architecture Framework for Unmanned Systems*
- ARP94910, *Aerospace - Vehicle Management Systems - Flight Control Design, Installation and Test of, Military Unmanned Aircraft, Specification Guide For*
- AIR5664A, *JAUS History and Domain Model*
- AS6522, *Unmanned Systems (UxS) Control Segment (UCS) Architecture: Architecture Technical Governance*
- AS6969, *Data Dictionary for Quantities Used in Cyber Physical Systems*
- AS6062A, *JAUS Mission Spooling Service Set*
- ARP5007A, *Development Process - Aerospace Fly-By-Wire Actuation System*
- J2958, *Report on Unmanned Ground Vehicle Reliability*
- J2940_201111, *Use of Model Verification and Validation in Product Reliability and Confidence Assessments*
- J3016_201806, *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*
- J3018_201503, *Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems (ADS)*
- ARINC 400 Series describes guidelines for installation, wiring, data buses, and databases.
- ARINC 500 Series describes older analog avionics equipment used on early jet aircraft such as the Boeing 727, Douglas DC-9, DC-10, Boeing 737 and 747, and Airbus A300.

- ARINC 600 Series are reference standards for avionics equipment specified by the SAE ARINC 700 Series.
- ARINC 700 Series describes the form, fit, and function of avionics equipment installed predominately on transport category aircraft.
- ARINC 800 Series comprises a set of aviation standards for aircraft, including fiber optics used in high-speed data buses.
- ARINC 762-1 Terrain Awareness and Warning System (TAWS)

The ground vehicle community has developed standards through the following committees:

- Active Safety Systems Standards Committee
- Driving Automation Systems Committee
- Advanced Driver Assistance Systems (ADAS) Committee
- On-Road Automated Driving (ORAD) committee
- Truck and Bus Active Safety Systems Committee
- Driver Vehicle Interface (DVI) Committee

DOD:

- DOD Policy Memo 15-002, Guidance for the Domestic Use of UASs, February 17, 2015
- DOD-NATO, STANAG 4671, UAVs Systems Airworthiness Requirements
- DOD-NATO, STANAG 4702, Rotary Wing UAS Airworthiness Requirements
- DOD-NATO, STANAG 4703, Light UAS Airworthiness Requirements
- 07-1-003 UAS Sensor and Targeting, July 27, 2010
- DOD-NATO, Guidance For The Training Of UAS Operators, April 22, 2014
- 07-2-032 UAS Navigation System Test, US Army, July 27, 2010
- DOD-NATO, Interoperable C2 Data Link For Unmanned Systems (IC2DL) – Operational Physical Layer/Signal In Space Description, November 14, 2016
- DOD-NATO Standard, STANREC AEP-101 Guidance on Sense and Avoid (SAA) for UASs, February 2017
- DOD-NATO, AEP-80, Rotary Wing UASs Airworthiness Requirements, 2014
- Investigation of Alerting and Prioritization Criteria for SAA, US Army, October 2013
- Top Level SAA Performance Requirements Based on SAA Efficacy, US Army, 2015
- Systems Engineering of SAA Systems, US Army, 2015
- DOD UAS Airspace Integration, May 28, 2014

NASA:

- ADS-B Mixed sUAS and NAS System Capacity Analysis and DAA Performance, April 2018
- An Evaluation of DAA Displays for UAS: The Effect of Information Level and Display Location on Pilot Performance, 2015
- Implicitly Coordinated DAA Capability for Safe Autonomous Operation of Small UAS, 17th AIAA Aviation Technology, Integration, and Operations Conference, June 5-9, 2017

- Safety Considerations for UAS Ground-based DAA, SGT/NASA, IEEE-DASC 2016, September 26-29, 2016
- Various DAA Systems Documents

EUROCAE:
- ED-258 Operational Services and Environment Description for Detect & Avoid [Traffic] in Class D-G airspaces under VFR/IFR

In-Development Standards:

ICAO:
- Annex 2 – Rules of the Air, Q1 2018
- Annex 3 – Meteorological Service for International Air Navigation, Q1 2021
- Annex 6 – Part IV – International Operations – RPAS, Q1 2020
- Annex 8 – Airworthiness of Aircraft, Q1 2018
- Annex 10 – Volume IV, Part II – DAA Systems, Q1 2020
- Annex 11 – Air Traffic Services, Q1 2020
- Annex 14 – Aerodromes, Q1 2021
- Annex 19 – Safety Management, Q1 2020
- Manual on RPAS (Doc 10019), Q1 2021
- Procedures for Air Navigation Services – Air Traffic Management (Doc 4444), Q1 2021
- Procedures for Air Navigation Services – Aircraft Operations – Vol I – Flight Procedures (Doc 8168), Q1 2021

IEEE:
- IEEE P1920.2, *Standard for Vehicle to Vehicle Communications for Unmanned Aircraft Systems*

DOD:
- US Army Ground Based Sense and Avoid System (GBSAA)
- GBSAA: Enabling Local Area Integration of UASs into the National Airspace System, US Army

ASTM:
- ASTM WK62668, *Specification for Detect and Avoid Performance Requirements*
- ASTM WK62669, *Test Method for Detect and Avoid*

JARUS:
- WG4 - Detect & Avoid, JARUS Detect and Avoid
- WG4 - Detect & Avoid, JARUS DAA CONOPS for VLL operations

RTCA:
- MOPS for Airborne Collision Avoidance System sXu (ACAS sXu) being developed under RTCA SC-147, Traffic Alert & Collision Avoidance System (TCAS). Designed specifically to support

unmanned aircraft, it will be assigned a number once it is approved by the Program Management Committee, scheduled for September 2020.

SAE:

- AS7209, *Development Assurance Objectives for Aerospace Vehicles and Systems*
- AIR7121, Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems
- ARP4754B, *Guidelines for Development of Civil Aircraft and Systems*
- ARP4761A, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*
- JA7496, *Cyber Physical Systems Security Engineering Plan (CPSSEP)*
- JA6678, *Cyber Physical Systems Security Software Assurance*
- AS6983, *Process Standard for Qualification of Aeronautical Systems Implementing AI: Development Standard*
- AS6111, *JAUS Unmanned Maritime Vehicle Service Set*
- J2924, *Engineering Probabilistic Methods - Basic Concepts, Models and Approximate Methods for Probabilistic Engineering Analysis*
- J2925, *System Reliability and Integration*
- J2945/2, *DSRC Requirements for V2V Safety Awareness*
- J2945/3, *Requirements for V2I Weather Applications*
- J2945/4, *DSRC Messages for Traveler Information and Basic Information Delivery*
- J2945/5, *Service Specific Permissions and Security Guidelines for Connected Vehicle Applications*
- J2945/6, *Performance Requirements for Cooperative Adaptive Cruise Control and Platooning*
- J2945/10, *Recommended Practices for MAP/SPaT Message Development*
- J2945/11, *Recommended Practices for Signal Preemption Message Development*
- J2945/12, *Traffic Probe Use and Operation*
- J3092, *Dynamic Test Procedures for Verification & Validation of Automated Driving Systems (ADS)*
- J3131, *Automated Driving Reference Architecture*
- J3164, *Taxonomy and Definitions for Terms Related to Automated Driving System Behaviors and Maneuvers for On-Road Motor Vehicles*
- Various documents

The ground vehicle community has developed standards through the following committees:

- Active Safety Systems Standards Committee
- Driving Automation Systems Committee
- Advanced Driver Assistance Systems (ADAS) Committee
- On-Road Automated Driving (ORAD) committee
- Truck and Bus Active Safety Systems Committee
- Driver Vehicle Interface (DVI) Committee

EUROCAE:

- MASPS for Detect & Avoid [Traffic] in Class A-C airspaces under IFR;
- MASPS for Detect & Avoid [Traffic] in Class A-C airspaces under IFR
- MASPS for Detect & Avoid [Traffic] under VFR/IFR
- MOPS for Detect & Avoid [Traffic] under VFR/IFR
- Operational Services and Environment Description for Detect & Avoid in Very Low Level Operations
- MOPS for Detect & Avoid in Very Low Level Operations
- EUROCAE Guidelines on the use of multi GNSS for UAS

3GPP:

- Remote Identification of Unmanned Aerial Systems (ID_UAS) – Release 16

Gap A9: Detect and Avoid (DAA) Capabilities. No published standards have been identified that address systems that provide a DAA capability for UAS that do not have the size, weight, and power (SWAP) available as required by the current DAA TSOs (TSO-211, TSO-212 and TSO-213). In addition, a lack of activity in the design, manufacture, and installation of low SWAP systems to provide a DAA capability impairs the FAA's ability to establish a TSO for those systems.

R&D Needed: Yes

Recommendation:

1) Complete the above listed in-development standards.
2) Encourage the development of standards to address and accommodate systems to provide a DAA capability for UAS that cannot accommodate the current SWAP requirements. This is a necessary first step toward approval for smaller or limited performance systems for DAA and full and complete integration of UAS into the NAS.

Priority: High (Tier 1)

Organization(s): RTCA, SAE, SAE-ITC-ARINC, AIAA, ASTM, DOD, NASA, 3GPP

Status of Progress: Green

Update: As noted, work is in progress on a number of standards in development.

6.4.4. Software Considerations and Approval[29]

[29] The highly integrated nature of the UAS and its advanced avionics systems and the inseparable interactions and interfaces amongst software, hardware, integrations, human factors, spectrum, etc. are discussed in detail in

The FAA and the aviation industry have established resources and frameworks (regulations, standards, orders, advisory circulars (ACs), etc.) related to software dependability and approval (in some cases referred to as certification) for manned aviation. Many of the existing aerospace software resources apply to unmanned aircraft; however, current standards and regulations related to software considerations and approval do not address control stations and associated equipment. Additionally, COTS software may not meet the "process-specific" intent of FAA regulations, which base approval on how the software development and sustainment processes are documented and if they meet an SDO's standards or not. Proprietary or closed COTS software may also not allow users to make necessary changes to bring the software into compliance.

Furthermore, aerospace software standards currently expect that software development processes controls, coding standards, and software design provide full traceability of requirements to the software implementation to provide the highest levels of assurance for safety-critical systems. New approaches to aircraft control and decision-making may incorporate machine-learning and/or artificial intelligence technologies that are not well suited to existing assurance methodologies.

Published Standards:

FAA:

- Advisory Circular (AC), AC 20-171 Alternatives to RTCA/DO-178B for Software in Airborne Systems and Equipment, 1-19-11
- AC 119-1 Airworthiness and Operational Authorization of Aircraft Network Security Program (ANSP), 9-30-15
- AC 20-115D, *Airborne Software Development Assurance Using EUROCAE ED-12( ) and RTCA DO-178( )*, 7-21-17
- AC 00-69, Best Practices for Airborne Software Development Assurance Using EUROCAE ED-12( ) and RTCA DO-178( ), 7-21-17
- Order 8110.49A, Software Approval Guidelines, 3-29-18
- AC 20-156, Aviation DataBus Assurance, 8-4-06
- AC 43-216 Software Management During Aircraft Maintenance, 12-20-17
- AC 20-148 Reusable Software Components, 12-7-04
- Various Software related Exemption Grants
- Various Software related Special Conditions
- Various Software related Policy Statements

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roadmap section 6.11 on Enterprise Operations: Level of Automation/Autonomy/Artificial Intelligence (AI). The Enterprise Operations section also addresses "System, Software and Hardware Assurance" from the perspectives of the broader assurance topic and inclusive of software." Software dependability as discussed in this section 6.4.4 is a component of the overall development assurance.

ASTM:

- ASTM F3201-16, *Standard Practice for Ensuring Dependability of Software Used in Unmanned Aircraft Systems (UAS)*
- ASTM F3269-17, *Standard Practice for Methods to Safely Bound Flight Behavior of Unmanned Aircraft Systems Containing Complex Functions*
- ASTM F3298-19, *Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS)*

RTCA:

- DO-178C, *Software Considerations in Airborne Systems and Equipment Certification*, 12-13-11
- DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*, 4-19-00
- DO-248C, *Supporting Information for DO-178C and DO-278A*, 12-13-11
- DO-330, *Software Tool Qualification Considerations*, 12-13-11
- DO-331, *Model-Based Development and Verification Supplement to DO-178C and DO-278A*, 12-13-11
- DO-332, *Object Oriented Technology and Related Techniques Supplement to DO-178C and DO-278A*, 12-13-11
- DO-333, *Formal Methods Supplement to DO-178C and DO-278A*, 12-13-11

SAE:

- ARINC667-2, *Guidance for the Management of Field Loadable Software*, 7-1-17
- ARINC675, *Guidance for the Management of Aircraft Support Data*, 6-26-17

- AS-4UCS Unmanned Systems Control Segment Architecture
    - AIR6514, *UxS Control Segment (UCS) Architecture: Interface Control Document (ICD)*
    - AS6518, *Unmanned Systems (UxS) Control Segment (UCS) Architecture: UCS Architecture Model*
    - AS6522, *Unmanned Systems (UxS) Control Segment (UCS) Architecture: Architecture Technical Governance*

- E-32 Aerospace Propulsion Systems Health Management Committee
    - (29 documents as of March 2020)

- E-36 Electronic Engine Controls Committee
  For example: AIR4250C, *Electronic Engine Control Specifications and Standards*

- HM-1 *Integrated Vehicle Health Management Committee*

- SAE S-18, *Aircraft and Sys Dev and Safety Assessment Committee*
    - ARP4754A, *Guidelines for Development of Civil Aircraft and Systems*, 12-21-10
    - ARP4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*, 12-1-96

DOD:

- MIL-STD-882E, *System Safety Standard Practice, Appendix-B: Software System Safety Engineering and Analysis*, 5-11-12
- DOD-STD-2168, *Defense System Software Quality Program*
- MIL-S-52779, *Software Quality Assurance Program Requirements*

ISO:

- ISO/IEC/IEEE 90003:2018, *Software engineering – Guidelines for the application of ISO 9001:2015 to computer software*

Related In-Development Standards Include:

RTCA SC-240/EUROCAE WG-117, Topics on Software Advancement[30]:

- DO-xx/ED-xx, Process Standard for Software Considerations in Low Risk Applications, Equipment Certifications and Approvals, expected June 2021
- DO-xx/ED-xx, Process Standard for the Integration of COTS, Open Source and Service History into Software, expected September 2021.

ASTM:

- ASTM WK65056, *Revision of F3269 - 17 Standard Practice for Methods to Safely Bound Flight Behavior of Unmanned Aircraft Systems Containing Complex Functions*
- ASTM WK68098, *Standard Practice for Ensuring Dependability of Software Used in Unmanned Aircraft Systems (UAS)*, is a work item revision to existing standard F3201-16.

SAE:

G-31 Electronic Transactions for Aerospace Committee

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[30] Per EUROCAE, while the certified UAS category is aligned with the ED-12C / DO-178C document suite for development, and the open category does not have a software development standard needed for use and deployment, the specific category does not currently have a comprehensive compliant development standard identified to provide assurance as to the safe operations of the UAS. The continued release of information on UAS development and UAS operations by EASA provides a need but also an opportunity for a new software development process standard that will be specific to low risk UAS applications and the specific category defined by EASA. Moreover, it is considered that certain applications e.g. by the general aviation (GA) community might benefit from a simplified software development methodology.

In addition, the FAS Ad Hoc UAS report recommended the creation of supplemental guidance in the areas of COTS, Open Source and Service History, which could be used as well by other stakeholders performing low-risk operations. EUROCAE WG-117 and RTCA SC-240 will work jointly on this.

- AIR7501, Digital Data Standards in Aircraft Life Cycle
- ARP6823, Electronic Transactions for Aerospace Systems; An Overview
- ARP6984, Determination of Cost Benefits from Implementing a Blockchain Solution

G-32 Cyber Physical Systems Security Committee

- JA6678, *Cyber Physical Systems Security Software Assurance*
- JA7496, *Cyber Physical Systems Security Engineering Plan (CPSSEP)*

G-34, Artificial Intelligence in Aviation

- AS6983, *Process Standard for Development and Certification/Approval of Aeronautical Safety-Related Products Implementing AI*
- AIR6987, *Artificial Intelligence in Aeronautical Systems: Taxonomy*
- AIR6988, *Artificial Intelligence in Aeronautical Systems: Statement of Concerns*

S-18UAS Autonomy Working Group

- AIR7121, *Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems*

S-18 Aircraft and Sys Dev and Safety Assessment Committee

- AS7209, Development Assurance Objectives for Aerospace Vehicles and Systems
- ARP4761A Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
- ARP4754B Guidelines for Development of Civil Aircraft and Systems
- AIR6913 Using STPA During Development and Safety Assessment of Civil Aircraft
- AIR6276 USE OF MODELING AND TOOLS FOR AIRCRAFT SYSTEMS DEVELOPMENT – A STRATEGY FOR DEVELOPMENT ASSURANCE ASPECTS WITH EXAMPLES

APMC Avionics Process Management

HM-1 Integrated Vehicle Health Management Committee:

- AIR6900, *Applicable Integrated Vehicle Health Monitoring (IVHM) Regulations, Policy, and Guidance Documents*
- AIR6904, *Data Interoperability for IVHM*
- AIR6915, *Implementation of IVHM, Human Factors and Safety Implications*
- AIR8012, *Prognostics and Health Management Guidelines for Electro-Mechanical Actuators*
- ARP6290, *Guidelines for the Development of Architectures for IVHM Systems*
- ARP6407, *Integrated Vehicle Health Management Design Guidelines*
- ARP6883, *Guidelines for writing IVHM requirements for aerospace systems*
- ARP6887, *Verification & Validation of IVHM Systems and Software*

Gap A10: Software Considerations and Approval. Standards are needed to address software considerations for UAS operations outside of Part 107, control stations, and associated equipment. The majority of the current resources from manned aviation (standards, regulations, ACs, orders, etc.) are targeted at traditional aircraft and do not address the system of systems engineering used in UAS operations comprising man, machine, the NAS, and integration. UAS standards related to software dependability must properly account for all the unknown risks and potential safety issues (e.g., DAA, cybersecurity) during the software design, development, and assurance processes.

R&D Needed: Yes, on assurance methods

Recommendation:

1) Complete in-development standards work of SAE.
2) Develop standards to address software dependability for UAS operating outside of Part 107, control stations, and associated equipment.

Priority: High (Tier 1)

Organization(s): ASTM, EUROCAE, RTCA, SAE

Status of Progress: Green

Update: ASTM F3298-19, *Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS)* has been published. As noted in the text, other standards are in development.

6.4.5. Voice and Data Recorder Systems for UAS

Voice and data recorder systems encompass flight data recorders (FDR) as well as cockpit voice recorders (CVR).

FDR, or 'black boxes,' are a critical piece of safety avionics that are used in the event of a crash, major system failure, and/or other catastrophic event to investigate the root cause of an event. FDR include recordings of voice, data link, and other aircraft data including but not limited to video.

A cockpit voice record (CVR) system records the aural environment of the cockpit and communications to, from, and between flightcrew members, and in some cases required ATC to pilot text-based messages to assist investigations of accidents and incidents. The objective is met by complying with the current requirements in parts 23, 25, 27, 29, 91, 121, 125, 129, and 135.

There are a number of aspects unique to the UAS environment. For example, in the UAS context, flight / telemetry data is available on the control station, there is a data link, etc. In addition to the installation of a FDR or CVR on a UA, there may be operational requirements that necessitate the installation of a CVR on or in the CS.

Published Standards, Regulations and Other Documents for Manned Aviation:

- FAA AC 20-141B - Airworthiness and Operational Approval of Digital Flight Data Recorder Systems (dated 8/17/10, initiated by AIR-130) provides information on certification (design and installation) and continued airworthiness of digital flight data recorder systems (DFDRS). DFDRS provide information for an investigative authority—the National Transportation Safety Board (NTSB) in the United States—to conduct more thorough investigations of accidents and incidents. The data recorded is also used by operators to enable the prediction of trends that may be useful in determining modifications needed to avoid accidents and incidents. The purpose of a DFDRS is to collect accurate data to assist investigations of accidents and incidents. The objective is met by complying with the current requirements in 14 CFR parts 91, 121, 125, 129, and 135.

The primary international standard for manned aircraft voice and data recorders is EUROCAE ED-112A, *MOPS for Crash Protected Airborne Recorder Systems* (CPARS), dated Sept 2013. This document is cited in the U.S. by FAA:

- Technical Standard Order TSO-C123c (*Cockpit Voice Recorder Equipment,* Dec 2013)
- TSO-C124c (*Flight Data Recorder Equipment*, Dec 2013)
- Advisory Circular AC 20-186 (*Airworthiness and Operational Approval of Cockpit Voice Recorder Systems,* July 2016)
- AC 20-160A (*Onboard Recording of Controller Pilot Data Link Communication (CPDLC) in Crash Survivable Memory,* Aug 2016).
- Additionally, AC-20-141B (*Airworthiness and Operational Approval of Digital Flight Data Recorder Systems,* Aug 2010) and EUROCAE ED-155, *MOPS for Lightweight Flight Recording Systems* (July 2009) are referenced in ED-112A. EUROCAE ED-155 may be more applicable for some classes of UAS, but still shares some deficiencies with ED-112A described below.

SAE standards include:

- SAE AS8039A, *Minimum Performance Standard General Aviation Flight Recorder*, is a performance standard for general aviation flight recorders. It does not prescribe weight or size limits. The standard defines three basic types of flight recorders: voice recorder, flight data recorder, and voice/flight data recorder combination. It specifies requirements for all recorder types except where noted. It covers fixed wing and rotorcraft, ejectable and nonejectable recorders. SAE AS8039 is due for review/revision, which offers an opportunity to make this standard applicable to UAS. Topics covered include:
  - General Requirements
  - Design Considerations
  - Minimum Performance Standards in Ambient Environment
  - Minimum Performance Standards in Severe Environments
  - Crash Survivability

There are also SAE ARINC standards:

- SAE ARINC767-1, *Enhanced Airborne Flight Recorder*, published 2017-05-29
- SAE ARINC647A-1, *Flight Recorder Electronic Documentation (FRED)*, published 2009-07-01
- SAE ARINC757-6, *Cockpit Voice Recorder (CVR)*, published 2015-08-01

There also exists the three-part J1698 series of standards used on ground vehicles:

- SAE J1698_201703, *Event Data Recorder*, published 2017-03-17

By way of further analysis, EUROCAE ED-112A describes:

- A *minimum* size for the CPARS, such that it can be located in a crash site, that is inconsistent with the size and weight of many classes of UAS (i.e., too large/heavy to be feasibly carried), and unnecessary due to the reduced size of wreckage that would be caused by many classes of UAS.
- ED-112A recommends redundancy (cockpit and aft) in CPARS that may not be necessary for many classes of UAS.
- ED-112A requires certain testing for penetration, shock, shear force, tensile force, crush, and others that are unnecessary and inconsistent with the scenarios many classes of UAS will experience in the event of a catastrophic crash (e.g., 6000lbs of shear force; immersion testing of fluids not present on board a UAS (e.g., formaldehyde-based toilet fluids)).
- None of the above referenced standards capture the unique, distributed nature of UAS operations, given that some data will exist on board the aircraft and some will reside in the CS. This suggests that a CPARS for UAS should reside on the aircraft, and a non-crash-protected data recorder system should reside in the CS. An example of this is CVRs.
- CPDLC may apply to some classes of UAS, particularly large UAS flying in oceanic airspace, but is unnecessary for many classes of UAS.
- MOPS should explicitly state CAA equipage requirements for UAS based on size, weight, CONOPS, airspace access, and/or an ORA.

Published Standards, Regulations and Other Documents for UAS: Standards are needed for UAS-specific voice and data recorder systems. The only documents identified in the UAS operational context are:

- TSO-C213, Unmanned Aircraft Systems Control and Non-Payload Communications Terrestrial Link System Radios
- ASTM F3298-19, *Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS)*, includes a basic overview of a digital flight data recorder system for lightweight UAS. The standard calls for the equipage of a digital flight recorder system but fails to specify performance criteria or metrics by which such a system should be evaluated or certified. For example, ED-112A provides specific test metrics that a digital flight data recorder system can be evaluated on for crash survivability. Additionally, F3298-19 does not include the recording of voice communication between a remote pilot and (a) additional crew members (e.g., a sensor operator), or (b) ATC or other air navigation service provider (ANSP) personnel.

- STANAG 4671, *UAS Systems Airworthiness Requirements (USAR)* is another published standard.

In-Development Standards:

- ASTM WK62670, New Specification for Large UAS Design and Construction
- EUROCAE WG-118, Crash-protected and Lightweight Flight Recorders: This WG shall maintain and enhance the MOPS for airborne flight recorders mandated by operational regulations and ICAO Annex 6 requirements aiming to provide the necessary data for accident investigation and prevention. The WG will develop ED-112B MOPS for Crash Protected Airborne Recorder Systems, expected mid-2022.

Gap A11: Voice and Data Recorder Systems for UAS. Standards are needed for crash protected voice and data recorder systems for UAS.

R&D Needed: Yes. Research should be conducted to determine the proper:

1) Size requirements, based on the class of UAS, class of airspace, performance characteristics of the aircraft, and other relevant factors.
2) Test procedures for crash survival based on the class of UAS and performance characteristics, including, but not limited to: impact shock, shear and tensile force, penetration resistance, static crush, high temperature fire, low temperature fire, deep sea pressure and water immersion, and fluid immersion.
3) Method(s) for recording data both on the aircraft and in the CS.

Recommendation: Revise an existing standard and/or draft a new standard, similar to ED-112A, for a voice and data recorder systems for UAS.

Priority: Medium

Organization(s): SAE, RTCA, ASTM, IEEE, EUROCAE

Status of Progress: Green

Update: As noted in the text, EUROCAE WG-118 has been established. ASTM WK62670 is also in development and it will cover this gap to some extent for large UAS.

6.4.6. Cybersecurity

Cybersecurity is a critical safety concern that must be addressed in the design, construction, and operation of UAS. It is being addressed by various groups as noted below.

The ICAO Working Group on Airworthiness is focused on four primary areas of airworthiness:

- Initial design considerations (i.e., secure-by-design)
- Cybersecurity in production considerations

- Modifications to in-service aircraft
- Aircraft maintenance (with a specific focus on field-loadable software).

RPAS are also within the scope of work, including the C2 link between the RPS and the aircraft. The scope of work may change and be reconsidered as the cyber threat landscape continues to evolve.

The ICAO Working Group on Current and Future Air Navigation Systems is focused on (among other areas):

- Airport interactions with air navigation systems
- Initial ATM system design considerations (i.e., secure-by-design)
- Modifications to in-service ATM systems
- ATM system maintenance (with a specific focus on remote maintenance or administration)
- System-wide information management (SWIM) global interoperability
- Air-ground, air-air, and ground-ground links through all appropriate connection means

The scope of work may change and be reconsidered as the cyber threat landscape continues to evolve.

JARUS is currently working on an addendum to the Specific Operations Risk Assessment that augments existing guidance on Operational Safety Objectives and Mitigations to provide appropriate, risk-proportionate cyber safety requirements for various levels of robustness. This work is focused on cyber threats to flight safety and thus is not directly addressing threats to data security and loss of personal identifying information.

RTCA SC216 is also addressing cybersecurity as well as air navigation systems as further described below.

The Aerospace Industries Association (AIA) National Aerospace Standards is currently writing a UAS Cybersecurity standard that will focus on data privacy and ownership for “high” category users such as the federal government. In order to accomplish this task, AIA set up a working group within its Emerging Technology Committee which is made up of AIA members, subject matter experts and federal government partners to write a performance based standard that will ensure that sensitive location, video and other forms of data is both protected and secure.

The SAE International G-32 Cyber Physical Systems Security Committee is developing technical reports (Standards, Recommended Practices and Information Reports) covering a systems engineering approach to cyber physical systems security that includes analysis of the system operating environment defined by the operational, functional, and architectural systems engineering elements.

Published Regulations, Standards, and Other Documents Include:

FAA:

- 14 CFR §107 Operation small Unmanned Aircraft systems
- 14 CFR §107.51, Operating limitations for small unmanned aircraft

- TSO-C213, Unmanned Aircraft Systems Control and Non-Payload Communications Terrestrial Link System Radios, September 3, 2018
- TSO-C213, Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment, September 16, 2013
- TSO-C154c, Universal Access Transceiver (UAT) Automatic Dependent Surveillance-Broadcast (ADS-B) Equipment, December 2, 2009
- TSO-C166b, Extended Squitter Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information, December 2, 2009
- TSO-C195b, Avionics Supporting Automatic Dependent Surveillance – Broadcast (ADS-B) Aircraft Surveillance, September 29, 2014
- Advisory Circular, AC 107-2, Small UAS (sUAS), 6/21/2016
- UAS Traffic Management (UTM) Concept of Operations, FAA, May 18, 2018
- Advisory Circular, AC 20–170, Integrated Modular Avionics Development, Verification, Integration, and Approval Using RTCA/DO-297 and Technical Standard Order-C153, November 21, 2013

RTCA:

- RTCA DO-178C, *Software Considerations in Airborne Systems and Equipment Certification*
- RTCA DO-254, *Design Assurance Guidance for Airborne Electronic Hardware (AEH)*
- RTCA DO-326, *Airworthiness Security Process Specification*
- RTCA DO-355, *Information Security Guidance for Continued Airworthiness*
- RTCA DO-356, *Airworthiness Security Methods and Considerations*
- RTCA DO-362, *with Errata - Command and Control (C2) Data Link Minimum Operational Performance Standards (MOPS) (Terrestrial)*, September 22, 2016

ASTM:

- ASTM F3002-14a, *Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)*

SAE:

- SAE AS6969, *Data Dictionary for Quantities Used in Cyber Physical Systems*
- SAE J3061_201601, *Cybersecurity Guidebook for Cyber-Physical Vehicle Systems*

DOD:

- DOD Policy Memorandum 15-002, Guidance for the Domestic Use of Unmanned Aircraft Systems, February 17, 2015
- DOD-NATO, STANAG 4671, Unmanned Aerial Vehicles Systems Airworthiness Requirements
- DOD-NATO, STANAG 4702, Rotary Wing Unmanned Aircraft Systems Airworthiness Requirements
- DOD-NATO, STANAG 4703, Light Unmanned Aircraft Systems Airworthiness Requirements
- 07-1-003 Unmanned Aircraft Systems (UAS) Sensor and Targeting, July 27, 2010

- DOD-NATO, Guidance For The Training Of Unmanned Aircraft Systems (UAS) Operators, April 22, 2014
- 07-2-032 Unmanned Aircraft Systems (UAS) Navigation System Test, US Army, July 27, 2010
- DOD-NATO, Interoperable Command And Control Data Link For Unmanned Systems (IC2DL) – Operational Physical Layer / Signal In Space Description, November 14, 2016

NASA:
- Small Unmanned Aircraft Electromagnetic Interference (EMI) Initial Assessment, Jung, Jaewoo, et. al., ICNS 2018, April 10-12, 2018

NIST:
- NIST 800-53, *Security and Privacy Controls for Federal Information Systems and Organizations*
- NIST Cybersecurity (CSF), *Framework for Improving Critical Infrastructure Cybersecurity*

ISO:
- ISO 80001, *Application of risk management for IT-networks incorporating medical devices*

International Electrotechnical Commission (IEC):
- IEC 62443, Industrial Automation and Control Systems Security

UL:
- UL 2900-1, *Software Cybersecurity for Network Connectable Products, Part 1: General Requirements*

In-Development Standards and Other Documents Include:

ICAO:
- Annex 6 to the Convention on International Civil Aviation – Part IV – International Operations – RPAS, Q1 2020
- Annex 8 to the Convention on International Civil Aviation – Airworthiness of Aircraft, Q1 2018
- Annex 10 to the Convention on International Civil Aviation – Volume IV, Part II – Detect and Avoid Systems, Q1 2020
- Annex 11 to the Convention on International Civil Aviation – Air Traffic Services, Q1 2020
- Annex 19 to the Convention on International Civil Aviation – Safety Management, Q1 2020
- Manual on RPAS (Doc 10019), Q1 2021
- Procedures for Air Navigation Services – Air Traffic Management (Doc 4444), Q1 2021
- Procedures for Air Navigation Services – Aircraft Operations – Vol I – Flight Procedures (Doc 8168), Q1 2021

JARUS: As noted above, work is underway on a cyber SORA.

DOD:

- DOD Unmanned Aircraft Systems (UAS) Airspace Integration, May 28, 2014
- *Systems Engineering of SAA Systems, US Army Unmanned Aircraft Systems*, US Army Unmanned Aircraft Systems Common Systems Integration Product Office, Hendrickson, A., 2015b
- DOD-NATO Standard, AEP-80, Rotary Wing Unmanned Aerial Systems Airworthiness Requirements, 2014

AIA: As noted above.

ASTM:

- ASTM WK49440, *Revision of F3002 - 14a Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)*
- ASTM WK65041, *New Practice for UAS Remote ID and Tracking*
- ASTM WK56374, New Practice for Aircraft Systems Information Security Protection

SAE International:

- JA6678, *Cyber Physical Systems Security Software Assurance*
- AS6983, *Process Standard for Qualification of Aeronautical Systems Implementing AI: Development Standard*
- AIR7121**,** *Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems*
- JA7496, *Cyber Physical Systems Security Engineering Plan (CPSSEP)*
- SAE Committee G-32 is working on a software security standard targeted for completion within two years.

Gap A12: UAS Cybersecurity. Cybersecurity needs to be considered in all phases of UAS design, construction, operation, maintenance, and training of personnel (pilots, crews, others).

R&D Needed: Yes

Recommendation: Since there exists such a wide spectrum in UAS designs, CONOPS, and operator capabilities, a risk-based process during which appropriate cybersecurity measures are identified is recommended. One way that this could be accomplished is for an SDO to develop a standard using a process similar to the way the JARUS Specific ORA assigns Operational Safety Objectives.

Priority: High (Tier 1)

Organization(s): RTCA, SAE, ASTM, JARUS, AIA

Status of Progress: Green

Update: As noted in the text, a number of standards are in development.

6.5. Electrical Systems

The satisfactory performance of any modern aircraft depends to a high degree on the continuing reliability of electrical systems and subsystems. Improperly or carelessly installed or maintained wiring can be a source of both immediate and potential danger. The continued proper performance of electrical systems including but not limited to wiring, electrical load analysis, etc., depends on the knowledge and technique of the mechanic who installs, inspects, and maintains the electrical system's wires and cables. Regardless of whether an aircraft is manned or unmanned, important electrical considerations still apply. Therefore, existing best practices and electromagnetic interference testing can be used. Aircraft light colors have also been standardized and are well understood for operation in the NAS.

Published Standards and Related Materials: As noted below, there are few published electrical system standards specific to UAS. The UAS industry has been using existing manned aviation standards and applicable TSOs and regulations for UAS approvals including but not limited to certifications, section-333 exemption (section 44807) petitions, Part 107 waivers, etc., due to a lack of UAS-specific industry standards. Currently, there are no aviation standards for control stations in the areas of electrical systems, wiring, electrical load analysis, lighting, etc.

Published standards, as well as U.S. Federal government and inter-governmental materials relevant to this issue, include but are not limited to those listed below.

<u>FAA Regulations/Documents:</u>
The following FAA TSOs may contain companion industry standards:

- TSO-C16b, Electrically Heated Pitot and Pitot-Static Tubes, 1/27/2017
- TSO-C20A-1, Amendment-1, Combustion Heaters, 4/16/1951
- TSO-C20a, Combustion Heaters and Accessories, 1/12/2017
- TSO-C30c, Aircraft Position Lights, 5/12/1989
- TSO-C49b, Electric Tachometer: Magnetic Drag (Indicator and Generator), 5/30/1995
- TSO-C56b, Engine Driven Direct Current Generator / Starter Generators, 6/1/2006
- TSO-C59b, Airborne Selective Calling (SELCAL) Equipment, 6/27/2016
- TSO-C71, Airborne Static ("DC TO DC") Electrical Power Converter (For Air Carrier Aircraft), 6/15/1961
- TSO-C73, Static Electrical Power Inverter, 12/18/1963
- TSO-C77b, Gas Turbine Auxiliary Power Units, 12/20/2000
- TSO-C85b, Survivor Locator Lights, 10/22/2007
- TSO-C88b, Automatic Pressure Altitude Reporting Code-Generating Equipment, 2/6/2007
- TSO-C96a, Anticollision Light Systems, 4/7/1989
- TSO-C104, Microwave Landing System (MLS) Airborne Receiving Equipment, 6/22/1982
- TSO-C141, Aircraft Fluorescent Lighting Ballast/Fixture Equipment, 8/17/1999
- TSO-C142a, Non-Rechargeable Lithium Cells and Batteries, 8/7/2006

- TSO-C142b, Non-Rechargeable Lithium Cells and Batteries, 3/26/2018
- TSO-C178, Single Phase 115 VAC, 400 Hz Arc Fault Circuit Breakers, 3/3/2006
- TSO-C179a, Permanently Installed Rechargeable Lithium Cells, Batteries and Battery Systems, 4/19/2011
- TSO-C179b, Rechargeable Lithium Batteries and Battery Systems, 3/23/2018
- TSO-C184, Airplane Galley Insert Equipment, Electrical/Pressurized, 9/30/2011

Aircraft Electrical Load Analysis and Power Source Capacity:

- AC 21-99, Aircraft wiring and bonding
- AC 91.U-04, Airworthiness requirements for performance based navigation
- 71 FR 12771, Volume 71 US Federal Register page 12771 - Aircraft Electrical Load and Power Source Capacity Analysis
- AC 43.13-1B, Acceptable Methods, Techniques, and Practices - Aircraft Inspection and Repair
- AC 43.13-2B, Acceptable Methods, Techniques, and Practices – Aircraft Alterations
- AC 21-16G, RTCA Document DO-160 versions D, E, F, and G, Environmental Conditions and Test Procedures for Airborne Equipment
- AC 23.1309-1E, System Safety Analysis and Assessment for Part 23 Airplanes
- AC 25-16, Electrical Fault and Fire Prevention and Protection
- AC 25.1309-1A, System Design and Analysis
- AC 20-184, Guidance on Testing and Installation of Rechargeable Lithium Battery and Battery Systems on Aircraft
- Other regulations, ACs, Orders, Policy Statements, and Special Conditions are at FAA's Regulatory and Guidance Library website

Aircraft Lighting Regulations:

- Regulations: §§23.2530, 25.812, 25.1381, 25.1383, 25.1385, 25.1387, 25.1389, 25.1391, 25.1393, 25.1395, 25.1397, 25.1399, 25.1401, 25.1403, 27.1381, 27.1383, 27.1385, 27.1387, 27.1389, 27.1391, 27.1393, 27.1395, 27.1397, 27.1399, 27.1401
- ACs: AC 25-17A, AC 25.812-1A, AC 25.812-2, AC 20-131A, AC 25-8, AC 25-12, AC 25-15, AC 25-23, AC 20-30B, AC 20-74, AC 25.1419-1A, AC 20-73A, AC 27-1B, AC 29-2C
- Policies: ANM-111-06-001, PS-ACE-100-2010-003, PS-ANM100-01-03A, PS-ANM111-1999-99-2

Electrical Systems:

- Regulations: §§23.2500, 23.2515, 23.2520, 23.2525, 25.581, 25.899, 25.1301, 25.1309, 25.1316, 25.1317, 25.1351, 25.1353, 25.1355, 25.1357, 25.1362, 25.1363, 25.1365, 25.1715, 26.11, 27.1301, 27.1309, 27.1316, 27.1317, 27.1351, 27.1353, 27.1357, 27.1361, 27.1365, 27.1367, and other Part 29 regulations
- ACs: AC 20-136B, AC 20-158A, AC 20-173, AC 25-11B, AC 25-8, AC 25-12, AC 25-15, AC 25-16, AC 25-21, AC 25-23, AC 25.981-1C, AC 20-131A, AC 25.672-1, AC 25.899-1, AC 25.1353-1A, AC 25.1357-1A, AC 1362-1, AC 25.1365-1, AC 25. 1701-1, AC 27-1B, AC 29-2C

- Policies: ANM-111-05-004, AIR-100-12-110-001, PS-ANM100-1993-00054, AIR-100-12-110-001, AIR-100-2011-02-23, PS-ACE100-2010-001, ANM-01-04, ANM-01-111-165, PS-ANM100-2000-00105, PS-ANM100-2001-00113, PS-ANM100-2001-00114, PS-ANM-25-13, PS-AIR-100-May-4-2010 EAPAS FTS
- FAA Handbook, Chapter 9, Aircraft Electrical System

Electrical Wiring Interconnection System (EWIS):

- Regulations: §§25.1701, 25.1703, 25.1705, 25.1707, 25.1709, 25.1711, 25.1713, 25.1715, 25.1717, 25.1719, 25.1721, 25.1723, 25.1725, 25.1727, 25.1729, 25.1731, 25.1733, 26.11
- ACs: AC 25-27A, AC 26-1, AC 120-102A, AC 120-94, AC 25.1701-1, FAA EWIS Job Aid
- Policies: AIR-100-EWIS-4-6-10, ANM-08-113-001, PS-AIR-100-2007-12-27B, PS-AIR-100-May-4-2010 EAPAS FTS

ISO:

- ISO 1540:2006, *Aerospace - Characteristics of aircraft electrical systems*
- Other ISO documents

DOD:

- MIL-E-7016F, Analysis of Aircraft Electric Load and Power Source Capacity
- MIL-STD-704F, Aircraft Electric Power Characteristics, 2004
- MIL-STD-7080, Selection and Installation of Aircraft Electric Equipment
- JSSG-2009, DOD Joint Services Specification Guide, Air Vehicle Subsystems, 1998
- MIL-HDBK-516C, Electrical System, 2014
- STANAG 3456, Aircraft Electrical System Characteristics
- Various DOD technical manuals and documents

AIAA:

- Aircraft Electrical System
- Wiring: Design, Inspection, Maintenance
- Electrical wiring design
- EWIS
- Electric Propulsion Units

IEEE:

- Various IEEE documents

SAE:

AE-7 Aerospace Electrical Power and Equipment Committee:

- AS35091A, *Receptacles, Electric, Aircraft Storage Battery*
- AS81099A, *Electric Devices, Simple, General Specification for*

AE-7A Generators and Controls Motors and Magnetic Devices:

- AIR34B, *Penalties in Performance of Three-Phase, Four-Wire, 400-Cycle Motors Causes By the Opening of One Phase*
- AIR857A, *Speed Variation of D-C Motors*
- ARP4255A, *Electrical Actuation Systems for Aerospace and Other Applications*
- ARP497B, *Precision Control Motors - 400 Cycles*
- ARP826A, *Electrical Computing Resolvers*
- AS20708/131B, *Synchro, Control Transmitter, Type 15CX4F*
- AS20708/139B, *SYNCHRO CONTROL TRANSMITTER, TYPE 31CX6a*
- AS20708/14B, *Synchro, Control Transmitter, Type 15CX4D*
- AS20708/15B, *Synchro, Control Transformer, Type 15CT4C*
- AS20708/16B, *Synchro, Control Differential Transmitter, Type 15CDX4D*
- AS20708/17B, *Synchro, Torque Differential Transmitter, Type 15TDX4C*
- AS20708/19B, *Synchro, Torque Receiver Transmitter, Type 15TRX4A*
- AS20708/1B, *Synchro, Control Transformer, Type 11CT4E*
- AS20708/20B, *Synchro, Control Transmitter, Type 15CDX6C*
- AS20708/21B, *Synchro, Control Transformer, Type 15CT6D*
- AS20708/22B, *Synchro, Control Differential Transmitter, Type 15CDX6C*
- AS20708/23B, *Synchro, Torque Receiver Transmitter, Type 15TRX6A*
- AS20708/25B, *Synchro, Control Transformer, Type 16CTB4B*
- AS20708/28B, *Synchro, Control Transmitter, Type 18CX4D*
- AS20708/29B, *Synchro, Control Transformer, Type 18CT4C*
- AS20708/2B, *Synchro, Control Transmitter, Type 11CX4E*
- AS20708/30B, *Synchro, Control Differential Transmitter, Type 18CDX4C*
- AS20708/31B, *Synchro, Torque Differential Transmitter, Type 18TDX4C*
- AS20708/32B, *Synchro, Torque Receiver Transmitter, Type 18TRX4A*
- AS20708/33B, *Synchro, Control Transmitter, Type 18CX6C*
- AS20708/34B, *Synchro, Control Transformer, Type 18CT6D*
- AS20708/35B, *Synchro, Torque Receiver Transmitter, Type 18TRX6B*
- AS20708/36B, *Synchro, Control Differential Transmitter, Type 18CDX6D*
- AS20708/39C, *Synchro, Control Transformer, Type 19CTB4B*
- AS20708/3B, *Synchro, Torque Receiver, Type 11TR4C*
- AS20708/45B, *Synchro, Control Transmitter, Type 23CX4D*
- AS20708/46B, *Synchro, Control Transformer, Type 23CT4C*
- AS20708/47B, *Synchro, Control Differential Transmitter, Type 23CDX4C*
- AS20708/48B, *Synchro, Torque Differential Transmitter, Type 23TDX4C*
- AS20708/49B, *Synchro, Differential Receiver, Type 23TDR4B*
- AS20708/4B, *Synchro, Torque Transmitter, Type 11TX4C*
- AS20708/500B, *Synchro, Torque Receiver, Type 26V-10TR4*
- AS20708/50B, *Synchro, Torque Receiver Transmitter, Type 23TRX4A*
- AS20708/52B, *Synchro, Control Transmitter, Type 23CX6D*

- AS20708/53B, *Synchro, Control Transformer, Type 23CT6D*
- AS20708/54B, *Synchro, Control Differential Transmitter, Type 23CDX6C*
- AS20708/55B, *Synchro, Torque Differential Transmitter, Type 23TDX6C*
- AS20708/56B, *Synchro, Torque Receiver Transmitter, Type 23TRX6B*
- AS20708/5B, *Synchro, Torque Receiver, Type 26V-11TR4C*
- AS20708/62B, *Synchro, Torque Receiver Transmitter, Type 31TRX4A*
- AS20708/66B, *Synchro, Torque Receiver Transmitter, Type 31TRX6A*
- AS20708/67B, *Synchro, Torque Differential Receiver, Type 31TDR6B*
- AS20708/68B, *Synchro, Torque Differential Transmitter, Type 31TDX6C*
- AS20708/6B, *Synchro, Torque Transmitter, Type 26V-11TX4C*
- AS20708/70B, *Synchro, Torque Receiver Transmitter, Type 37TRX4A*
- AS20708/74B, *Synchro, Torque Receiver Transmitter, Type 37TRX6A*
- AS20708/76B, *Synchro, Torque Differential Transmitter, Type 37TDX6A*
- AS20708/78B, *Synchro, Control Transmitter, Type 26V-08CX4C*
- AS20708/79B, *Synchro, Control Transformer, Type 26V-08CT4C*
- AS20708/7B, *Synchro, Control Transformer, Type 26V-11CT4D*
- AS20708/80B, *Synchro, Torque Receiver Transmitter, Type 26V-08CDX4C*
- AS20708/81B, *Synchro, Control Differential Transmitter, Type 11CDX4B*
- AS20708/8B, *Synchro, Control Transmitter, Type 26V-11CX4C*
- AS20708/94C, *Synchro, 60 and 400 Hz, Size 23*
- AS20708/9B, *Synchro, Control Differential Transmitter, Type 26V-11CDX4C*
- AS20708C, *Synchros, General Specification For*
- AS8020, *Minimum Performance Standards for Engine Driven D.C. Generators/Starter-Generators and Associated Voltage Regulators*

SAE EUROCAE Fuel Cell Task Group

- AIR6464, *EUROCAE/SAE WG80/AE-7AFC Hydrogen Fuel Cells Aircraft Fuel Cell Safety Guidelines*
- AIR7765, *Considerations for Hydrogen Fuel Cells in Airborne Applications*
- AS6858, *Installation of Fuel Cell Systems in Large Civil Aircraft*

AE-7B Power Management, Distribution and Storage:

- AIR5561, *Lithium Battery Powered Portable Electronic Devices*
- AIR5709A, *SAE AE-7 High Temperature Components Survey, 2005*
- ARP5584, *Document for Electric Power Management*
- AS4805, *Solid State Power Controller, General Standard For*
- AS5625A, *Minimum Performance Standards for Static Electric Power Frequency Converters*
- AS6349, *Minimum Performance Standard (MPS) for an Airborne AC to AC Converter*
- AS8033, *Nickel Cadmium Vented Rechargeable Aircraft Batteries (Non-Sealed, Maintainable Type)*

AE-7C Systems:

- AIR6540A, *Fundamentals in Wire Selection and Sizing for Aerospace Applications*
- AIR1213A, *Radioisotope Power Systems*
- AIR6127, *Managing Higher Voltages in Aerospace Electrical Systems*
- AIR6139, *Ways of Dealing with Power Regeneration onto an Aircraft Electrical Power System Bus*
- AIR999A, *Cryogenically Fueled Dynamic Power Systems*
- ARP4729A, *Document for 270 Voltage Direct Current (270 V DC) System*
- AS1212A, *Electric Power, Aircraft, Characteristics and Utilization of*
- AS1831A, *Electrical Power, 270 V DC, Aircraft, Characteristics and Utilization of*
- AS5698A, *Space Power Standard*

AE-7D Aircraft Energy Storage and Charging Committee:

- AIR6343, Design and Development of Rechargeable Lithium Battery Systems for Aerospace Applications

AE-7M Aerospace Model Based Engineering:

- AIR6326, *Aircraft Electrical Power Systems, Modeling and Simulation, Definitions*
- ARP6538, *Dynamic Modeling of Aerospace Systems (DyMAS)*

AE-8A Elec Wiring and Fiber Optic Interconnect Sys Install:

- AS50881G, *Wiring Aerospace Vehicle* [Note: It applies to UAS too.]
- ARP4404C, *Aircraft Electrical Installations*
- AIR6820, *Electrical Wiring Fuel Compatibility*
- ARP6881, *Guidelines for the Use and Installation of Bonded Cable Harness Supports*
- AIR4465A, *Design and Handling Guide Radio Frequency Absorptive Type Wire and Cables (Filter Line, AS85485)*
- AIR5468B, *Ultraviolet (UV) Lasers for Aerospace Wire Marking*
- AIR5558, *Ultraviolet (UV) Laser Marking Performance of Aerospace Wire Constructions*
- AIR5575A, *Hot Stamp Wire Marking Concerns for Aerospace Vehicle Applications*
- AIR5717, *Mitigating Wire Insulation Damage During Processing and Handling*
- ARP5062A, *Recommended Test Fluids for Electrical Components Used on Aircraft Exterior or for Ground Support Near Aircraft*
- ARP5369B, *Guidelines for Wire Identification Marking Using the Hot Stamp Process*
- ARP5607A, *Legibility of Print on Aerospace Wires and Cables*
- ARP5614, *Guidelines for Harness Critical Clamp Locator Marker Installation on Electrical Cable Assemblies*
- ARP6167, *Etching of Fluoropolymer Insulations*
- ARP6216, *EWIS Wiring Insulation Breakdown Testing*
- ARP81490A, *Transmission Lines, Transverse Electromagnetic Mode*
- AS21378A, *Plugs And Cable Assemblies, External Power, Aircraft, 230/400 VOLT, 400 Hertz*
- AS24122A, *Wiring Harness - External Power, 115 Volt AC, Single Phase*

- AS24208A, *Cable and Plug Assembly, External Power 115/200 VOLTS 3 Phase, Single Point Refueling*
- AS25019A, *Cable Assembly, External Electric Power, Aircraft, 28 VOLT DC, Jet Starting*
- AS25064A, *Conduit, Flexible, Radio Frequency Shielding*
- AS25065A, *Ferrule, Flexible Conduit, Radio Frequency Shielding*
- AS25066, *Conduit Assembly, Nut, Flexible, Radio Frequency Shielding*
- AS25067A, *Conduit Assembly, Flexible, Radio Frequency Shielding*
- AS4461C, *Assembly and Soldering Criteria for High Quality/High Reliability Soldering Wire and Cable Termination in Aerospace Vehicles*
- AS5649A, *Wire and Cable Marking Process, UV Laser*
- AS5942, *Marking of Electrical Insulating Materials*
- AS7974/2A, *Cable Assembly, External Power, Aircraft 115/200 VOLT, 400 Hertz Power Distribution Flight Line (for A/E 24A-166A)*
- AS7974/4A, *Cable Assembly, External Electric Power, Aircraft, Single-Jacketed 115/200 VOLT, 400 Hertz*
- AS7974/5A, *Cable Assembly, External Electric Power, Aircraft, Single-Jacketed 270 VDC, 90 KW*
- AS7974A, *Cable Assemblies and Attachable Plugs, External Electrical Power, Aircraft, General Specification for*
- AS90328A, *Cable Assembly, External Electric Power, Aircraft 115/200 VOLT, 400 Hertz*
- AS90347A, *Cable Assembly, External Electric Power, Aircraft 28 VOLT DC, Operating Power*

AE-8C1 Connectors Committee

- (466 documents as of March 2020)

AE-8C2 Terminating Devices and Tooling Committee

- (218 documents as of March 2020)

AE-8D Wire and Cable Committee

- (234 documents as of March 2020)

A-20B Exterior Lighting Committee:

- ARP6336, *Lighting Applications for Unmanned Aircraft Systems (UAS) – specific to UAS*
- ARP6621, *Predicting Photometric Degradation of Exterior Aircraft Lights*
- AIR1276B, *Aircraft Flashtube Anticollision Lighting Systems*
- AIR1106B, *Some Factors Affecting Visibility of Aircraft Navigation and Anticollision Lights*
- ARP693E, *Landing and Taxiing Lights - Design Criteria for Installation*
- ARP991C, *Position and Anticollision Lights - Fixed-Wing Aircraft*
- ARP5637A, *Design and Maintenance Considerations for Aircraft Exterior Lighting Plastic Lenses*
- AS8017D, *Minimum Performance Standard for Anticollision Light Systems*
- AS25050B, *Colors, Aeronautical Lights and Lighting Equipment, General Requirements For*
- ARP6402A, *LED Landing, Taxiing, Runway Turnoff, and Recognition Lights*

- ARP4392, *Lighting, Aircraft Exterior, Night Vision Imaging System (NVIS) Compatible*
- ARP5825A, *Design Requirements and Test Procedures for Dual Mode Exterior Lights*
- AIR5689B, *Light Transmitting Glass Covers for Exterior Aircraft Lighting*
- ARP694C, *Aerial Refueling Lights - Design Criteria*
- ARP5647A, *High Intensity Discharge Light Sources*
- ARP5029B, *Measurement Procedures for Short Pulse Width Strobe Anticollision Lights*
- AS8037C, *Minimum Performance Standard for Aircraft Position Lights*
- ARP4087C, *Wing Inspection Lights - Design Criteria*

Under the SAE Electronics and Electrical Systems Group are:
AE-2 Lightning Committee:

- ARP5672, *Aircraft Precipitation Static Certification*
- ARP5412B, *Aircraft Lightning Environment and Related Test Waveforms*
- ARP5416A, *Aircraft Lightning Test Methods*
- ARP5414B, *Aircraft Lightning Zoning*
- ARP5577, *Aircraft Lightning Direct Effects Certification*
- ARP5415B, *User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning*

AE-4 Electromagnetic Environmental Effects (E3) Committee:

- ARP60493, *Guide to Civil Aircraft Electromagnetic Compatibility (EMC)*
- ARP1705C, *Coaxial Test Procedure to Measure the RF Shielding Characteristics of EMI Gasket Materials*
- AIR6236A, *In-House Verification of EMI Test Equipment*
- ARP6248, *Stripline Test Method to Characterize the Shielding Effectiveness of Conductive EMI Gaskets up to 40 GHz*
- AS6451A, *Shields, Protective, Aircraft and Missiles*
- ARP936B, *Capacitor, 10 Microfarad for EMI Measurements*
- ARP935B, *Control Plan/Technical Construction File*
- ARP4242A, *Electromagnetic Compatibility Control Requirements Systems*
- ARP1173A, *Test Procedure to Measure the R.F. Shielding Characteristics of E.M.I. Gaskets*
- ARP1267, *Electromagnetic Interference Measurement Impulse Generators; Standard Calibration Requirements and Techniques*
- AIR1221, *Electromagnetic Compatibility (EMC) System Design Checklist*
- AIR1147A, *Electromagnetic Interference on Aircraft from Jet Engine Charging*
- ARP4244A, *Recommended Insertion Loss Test Methods for EMI Power Line Filters*
- ARP1972A, *Recommended Measurement Practices and Procedures for EMC Testing*
- ARP1870A, *Aerospace Systems Electrical Bonding and Grounding for Electromagnetic Compatibility and Safety*
- ARP5583A, *Guide to Certification of Aircraft in a High-Intensity Radiated Field (HIRF) Environment*

- AIR1700A, *Upper Frequency Measurement Boundary for Evaluation of Shielding Effectiveness in Cylindrical Systems*
- AIR1425A, *Methods of Achieving Electromagnetic Compatibility of Gas Turbine Engine Accessories, for Self-Propelled Vehicles*
- AIR1404, *DC Resistivity Vs RF Impedance of EMI Gaskets*
- AIR1394A, *Cabling Guidelines for Electromagnetic Compatibility*
- AIR1255, *Spectrum Analyzers for Electromagnetic Interference Measurements*
- ARP5889, *Alternative (Ecological) Method for Measuring Electronic Product Immunity to External Electromagnetic Fields*
- AIR1423, *Electromagnetic Compatibility on Gas Turbine Engines for Aircraft Propulsion*
- ARP1481A, *Corrosion Control and Electrical Conductivity in Enclosure Design*
- AIR1209, *Construction and Calibration of Parallel Plate Transmission Line for Electromagnetic Interference Susceptibility Testing*
- ARP958D, *Electromagnetic Interference Measurement Antennas; Standard Calibration Method*
- ARP1172, *Filters, Conventional, Electromagnetic Interference Reduction, General Specification For*

Other SAE documents:

Other Electric Aircraft Steering Group (EASG) TC Liaisons:

- Electrical Power & Equipment – AE-7
- Electrical Distribution Systems – AE-8
- Electrical Materials Committee – AE-9
- Aerospace Behavioral Engineering Technology – G-10
- Vertical Flight Committee – G-10V
- Landing Gears – A-5
- Flight Control & Actuation Systems – A-6
- Aircraft Instruments – A-4
- Aircraft Environmental Systems – AC-9
- Aircraft Icing Technology – AC-9C
- Lightning – AE-2
- Electromagnetic Environmental Effects – AE-4
- Aircraft Lighting – A-20
- Electronic Engine Controls – E-36
- Integrated Vehicle Health Management – HM-1
- Aerospace Propulsion Systems Health Management – E-32
- Aircraft Systems & Systems Integration – AS-1
- Embedded Computing Systems – AS-2
- Fiber Optics and Applied Photonics – AS-3
- Aircraft Ground Support Equipment – AGE-3
- Aircraft & Systems Development and Safety Assessment – S-18

- Avionics Process Management – APMC
- Aerospace Fuel, Inerting & Lubrication Systems – AE-5A
- ARINC AEEC

ASTM:

F37.20 Airplane:

- F2840-14, *Standard Practice for Design and Manufacture of Electric Propulsion Units for Light Sport Aircraft*
- F2245-16c, *Standard Specification for Design and Performance of a Light Sport Airplane* [NOTE: electrical systems are covered in this document although the title does not mention it.]

F38.01 Airworthiness:

- F3005-14a, *Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)* – specific to UAS
- F3201-16, *Standard Practice for Ensuring Dependability of Software Used in Unmanned Aircraft Systems (UAS)* – specific to UAS

F39.01 Design, Alteration, and Certification of Electrical Systems:

- F2490-05(2013), *Standard Guide for Aircraft Electrical Load and Power Source Capacity Analysis*
- F2639-15, *Standard Practice for Design, Alteration, and Certification of Aircraft Electrical Wiring Systems*

F39.02 Inspection, Alteration, Maintenance, and Repair:

- F2696-14(2019), *Standard Practice for Inspection of Aircraft Electrical Wiring Systems*
- F2799-14, *Standard Practice for Maintenance of Aircraft Electrical Wiring Systems*

F39.04 Aircraft Systems:

- F3238-17, *Standard Specification for Design and Installation of an Infrared (IR) Searchlight System (USA)*

F44.50 Systems and Equipment:

- F3061/F3061M-17, *Standard Specification for Systems and Equipment in Small Aircraft*
- F3227/F3227M-17, *Standard Specification for Environmental Systems in Small Aircraft*
- F3228-17, *Standard Specification for Flight Data and Voice Recording in Small Aircraft*
- F3229/F3229M-17, *Standard Practice for Static Pressure System Tests in Small Aircraft*
- F3230-17, *Standard Practice for Safety Assessment of Systems and Equipment in Small Aircraft*
- F3231/F3231M-17, *Standard Specification for Electrical Systems in Small Aircraft*
- F3232/F3232M-17, *Standard Specification for Flight Controls in Small Aircraft*
- F3233/F3233M-17, *Standard Specification for Instrumentation in Small Aircraft*
- F3234/F3234M-17, *Standard Specification for Exterior Lighting in Small Aircraft*
- F3235-17a, *Standard Specification for Aircraft Storage Batteries*

- F3236-17, *Standard Specification for High Intensity Radiated Field (HIRF) Protection in Small Aircraft*
- F3309/F3309M-18, *Standard Practice for Simplified Safety Assessment of Systems and Equipment in Small Aircraft*
- F3316/F3316M-18, *Standard Specification for Electrical Systems for Aircraft with Electric or Hybrid-Electric Propulsion*

NASA Documents:

- Electrical Systems
- Wiring
- Electrical Load Analysis
- Electric Propulsion Units
- Various NASA documents

UL:

- UL 3030, *Standard for Unmanned Aircraft Systems* – specific to UAS

In-Development Standards: The following manned aviation standards may be applicable to UAS. As noted, there are a few standards specific to UAS.

ASTM:

F38.01 Airworthiness:

- WK60937, *New Specification for Design of Fuel Cells for Use in UASs*
- WK66135, *Revision of F3005 - 14a Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)* – specific to UAS
- WK68098, *Standard Practice for Ensuring Dependability of Software Used in Unmanned Aircraft Systems (UAS)* is a work item revision to existing standard F3201-16

F39.02 Inspection, Alteration, Maintenance, and Repair:

- WK55298, *Classifying Alterations for In-Service Aircraft under FAA Authority Oversight*

F39.04 Aircraft Systems:

- WK44921, *New Practice for Continued Airworthiness of IR Filter System Installation*
- WK44922, *New Practice for the Operational Use of IR Filter Systems*
- WK51467, *New Specification for Quality Assurance for Manufacturers of Aircraft Systems*

F39.05 Design, Alteration, and Certification of Electric Propulsion Systems:

- WK47374, *New Specification for Design and Manufacture of Electric Propulsion Units for General Aviation Aircraft (Aeroplanes)*
- WK56255, *Design of Electric Propulsion Energy Storage Systems for General Aviation Aircraft*

F44.50 Systems and Equipment:

- WK58700, *Electrical Systems for Aircraft with Electric or Hybrid-Electric Propulsion*

- WK61550, *Simplified High Intensity Radiated Field (HIRF) Protection in Level 1, Level 2, and Level 3 Aircraft*
- WK60748, *Application of Systems-Theoretic Process Analysis to Aircraft*
- WK56374, *Aircraft Systems Information Security Protection*
- WK52829, *Simplified Safety Analysis of Systems & Equipment in Small Aircraft*
- WK62762, *System Level Verification of Software and Airborne Electronic Hardware on Small Aircraft*
- WK55940, *Boundary layer control systems in aerial vehicles*
- WK61549, *Indirect Flight Control Systems in Aircraft*
- WK63976, *Establishing the Net Safety Benefit of Aircraft Systems*

SAE:

AE-7 Aerospace Electrical Power and Equipment Committee:

- AIR6511, *Safety Consideration for a 48/60 VDC Aircraft distribution system*

AE-7A Generators and Controls Motors and Magnetic Devices:

- ARP6505, *Electrical Load Characterization and ELA Standardization*
- AS8441, *Minimum Performance Standard for Permanent-Magnet Propulsion Motors and Associated Variable-Speed Drives*

AE-7B Power Management, Distribution and Storage:

- AS4805A, *Solid State Power Controller, General Standard For*
- AS6087, *ARC Fault Interrupter, 270 VDC*

AE-7C Systems:

- AIR6198, *Considerations for future more electric aircraft electric power systems*
- AIR7497, *Advanced methods for Wire Selection and Sizing for Aerospace applications*
- AIR7502, *Aerospace Electrical Voltage Level definitions*
- AIR8445, *Aerospace Electrical Power System Stability*
- AS7499, *Aircraft High Voltage DC Power Quality Standard*

AE-7D Aircraft Energy Storage and Charging Committee:

- AIR6897, *Battery Management Systems for Rechargeable Lithium Batteries Used in Aerospace Applications*
- AS6968, *Connection Set of Conductive Charging for Electric Aircraft*

AE-7M Aerospace Model Based Engineering:

- AIR6387, *Aircraft electrical power systems. Modeling and simulation. Validation and verification methods.*

AE-8A Elec Wiring and Fiber Optic Interconnect Sys Install:

- AIR6808, *Aerospace Vehicle Wiring, Lessons Learned*

- ARP5607B, *Legibility of Print on Aerospace Wires and Cables*
- AS6136A, *Conduit, Electrical, Flexible, Shielded, Aluminum Alloy for Aircraft Installations*
- AS10380A, *Coupling Installations, Standard Conduit, Electrical*
- AS10051A, *Hubs, Conduit Connection, Standard Dimensions*
- AIR6982, *Arc Damage Assessment of Arc Plume and Physical Damage*
- AS7974B, *Cable Assemblies and Attachable Plugs, External Electrical Power, Aircraft, General Specification For*
- AS4461D, *Assembly and Soldering Criteria for High Quality/High Reliability Soldering Wire and Cable Termination in Aerospace Vehicles*

AE-8C1 Connectors Committee:

- (22 works in progress as of March 2020)

AE-8C2 Terminating Devices and Tooling Committee:

- (40 works in progress as of March 2020)

AE-8D Wire and Cable Committee:

- (23 works in progress as of March 2020)

AE-9 Electrical Materials Committee:

- AIR6674, *Electrical Insulation Materials in Hybrid Aerospace*
- AIR7219, *Degradation in electrical materials*

A-20B Exterior Lighting:

- AS8037D, *Minimum Performance Standard for Aircraft Position Lights*
- ARP4087D, *Wing Inspection Lights - Design Criteria*

AE-2 Lightning Committee:

- ARP5416B, *Aircraft Lightning Test Methods*
- ARP6205, *Transport Airplane Fuel Tank and Systems Lightning Protection*

AE-4 Electromagnetic Compatibility (EMC) Committee:

- ARP5583B, *Guide to Certification of Aircraft in a High-Intensity Radiated Field (HIRF)*
- AIR1209A, *Construction and Calibration of Parallel Plate Transmission Line for Electromagnetic Interference Susceptibility Testing*
- ARP958E, *Electromagnetic Interference Measurement Antennas; Standard Calibration Method*

Gap A13: Electrical Systems. The existing manned aviation published industry standards are not adequate in addressing the highly demanding needs of the UAS industry regarding electrical systems, wiring, EWIS, electrical load analysis, aircraft lighting, etc. These areas (electrical systems, wiring, EWIS, etc.) are also not covered for control stations (CSs), auxiliary systems, etc.

R&D Needed: Yes

Recommendation:

1) Complete work on in-development standards.
2) Encourage the development of standards to address electrical systems, wiring, EWIS, electrical load analysis, aircraft lighting, etc., for UA, CS, and auxiliary system(s).

Priority: High (Tier 3)

Organization(s): ICAO, RTCA, SAE, AIAA, ASTM, DOD, NASA, UL, IEC, IEEE

Status of Progress: Green

Update: As noted in the text, standards are in development.

6.6. Power Sources and Propulsion Systems

Drones are typically battery-powered. Alternative power sources are emerging for use in some platforms, though standardization is at a nascent stage.

Published Standards and Related Materials: The following manned aviation standards and related materials may be applicable to UAS. As noted below, there are few standards specific to UAS.

FAA:

- TSO-C11e, Powerplant Fire Detection Instruments (Thermal and Flame Contact Types), 10/17/1991
- TSO-C56b, Engine Driven Direct Current Generator / Starter Generators, 6/1/2006
- TSO-C71, Airborne Static ("DC TO DC") Electrical Power Converter (For Air Carrier Aircraft), 6/15/1961
- TSO-C73, Static Electrical Power Inverter, 12/18/1963
- TSO-C77b, Gas Turbine Auxiliary Power Units, 12/20/2000
- TSO-C142a, Non-Rechargeable Lithium Cells and Batteries, 8/7/2006
- TSO-C142b, Non-Rechargeable Lithium Cells and Batteries, 3/26/2018
- TSO-C155a, Recorder Independent Power Supply, 06/09/2010
- TSO-C155b, Recorder Independent Power Supply (RIPS), 04/21/2015
- TSO-C173a, Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid Batteries, 03/15/2013
- TSO-C174, Battery Based Emergency Power Unit (BEPU), 07/25/2005
- TSO-C179a, Permanently Installed Rechargeable Lithium Cells, Batteries and Battery Systems, 4/19/2011
- TSO-C179b, Rechargeable Lithium Batteries and Battery Systems, 3/23/2018

- TSO-C200a, Airframe Low Frequency Underwater Locating Device (Acoustic) (Self-Powered), 05/03/2016

Aircraft Electrical Load Analysis and Power Source Capacity

- 71 FR 12771, Volume 71 US Federal Register page 12771 - Aircraft Electrical Load and Power Source Capacity Analysis
- AC 20-184, Guidance on Testing and Installation of Rechargeable Lithium Battery and Battery Systems on Aircraft

FAA Technical Center Documents on Lithium Batteries
FAA Technical Center Documents on Fuel Cells

Open Source Documents:

- Beam-powered propulsion systems are Laser, Microwave, Electric, Direct Impulse, etc.

Royal Aeronautical Society:

- Fly by Light

NASA:

- Fuel Cells
- Electric Aircraft
- Propulsion Systems
- Power Systems
- Power Sources
- Solar Powered Aircraft
- GaAs/Ge Solar Powered Aircraft, NASA/TM-1998-208652
- A Preliminary Study of Solar Powered Aircraft and Associated Power Trains, 1983
- Structural Sizing of a Solar Powered Aircraft, 1984
- Laser Power Sources
- Beamed Laser Power for UAVs
- The Effect of Power System Technology and Mission Requirements on High Altitude Long Endurance Aircraft, NASA CR 194455, 1994
- Airborne Reconnaissance in the Civilian Sector: Agricultural Monitoring from High-Altitude Powered Platforms, 1983
- Scientific Application of Remotely Piloted Aircraft Measurements of Radiation, Water Vapor, and Trace gases to Climate Studies, 1991
- Other NASA documents

IEEE:

- Solar-powered unmanned aerial vehicles, IECEC 96. Proceedings of the 31st Intersociety Energy Conversion Engineering Conference, 1996
- Solar Powered Aircraft

- Fuel Cells Powered Aircraft
- Laser Powered Systems on Aircraft
- Batteries for Aircraft
- Power Sources for Aircraft
- Propulsion Systems for Aircraft
- Other IEEE Documents

DOD:

- MIL-E-7016F, Analysis of Aircraft Electric Load and Power Source Capacity
- MIL-STD-704F, Aircraft Electric Power Characteristics, 2004
- MIL-STD-7080, Selection and Installation of Aircraft Electric Equipment
- MIL-HDBK-516C, Electrical System, 2014
- STANAG 3456, Aircraft Electrical System Characteristics
- Other DOD Documents

AIAA:

- Design of Long-Endurance Unmanned Airplanes incorporating Solar and Fuel Cell Propulsion," AIAA 84-1430, 1984
- Solar-Powered Airplane Design for, Long-Endurance, High-Altitude Flight," AIAA Paper 82-0811, 1982
- Electric Propulsion Units

SAE:

E-25 General Standards for Aerospace and Propulsion Systems

- (960 documents as of March 2020)

E-30 Propulsion Ignition Systems Committee

- (50 documents as of March 2020)

E-32 Aerospace Propulsion Systems Health Management

- (29 documents as of March 2020)

E-33 In Flight Propulsion Measurement Committee

- (10 documents as of March 2020)

E-34 Propulsion Lubricants Committee

- (20 documents as of March 2020)

E-36 Electronic Engine Controls Committee

- (11 documents as of March 2020)

E-38 Aviation Piston Engine Fuels and Lubricants

- (3 documents as of March 2020)

AE-6 Starting Systems and Auxiliary Power Committee

- (28 documents as of March 2020)

EG-1 Aerospace Propulsion Systems Support Equipment

- (5 documents as of March 2020)

EG-1A Balancing Committee

- (13 documents as of March 2020)

EG-1B Hand Tools Committee

- (20 documents as of March 2020)

EG-1B1 Power Tools - Productivity, Ergonomics and Safety

- (1 document as of March 2020)

EG-1E Gas Turbine Test Facilities and Equipment

- (28 documents as of March 2020)

AE-7A Generators and Controls Motors and Magnetic Devices:

- AIR857A, *Speed Variation of D-C Motors*
- AS8020, *Minimum Performance Standards for Engine Driven D.C. Generators/Starter-Generators and Associated Voltage Regulators*
- AIR34B, *Penalties in Performance of Three-Phase, Four-Wire, 400-Cycle Motors Causes By the Opening of One Phase*
- ARP4255A, *Electrical Actuation Systems for Aerospace and Other Applications*

AE-7B Power Management, Distribution and Storage:

- AIR5561, Lithium Battery Powered Portable Electronic Devices
- ARP5584, Document for Electric Power Management
- AS4805, Solid State Power Controller, General Standard For
- AS5625A, Minimum Performance Standards for Static Electric Power Frequency Converters
- AS6349, Minimum Performance Standard (MPS) for an Airborne AC to AC Converter
- AS8033, Nickel Cadmium Vented Rechargeable Aircraft Batteries (Non-Sealed, Maintainable Type)
- AIR5709A, *SAE AE-7 High Temperature Components Survey, 2005*

AE-7C Systems:

- AIR6540A, *Fundamentals in Wire Selection and Sizing for Aerospace Applications*

- AIR1213A, *Radioisotope Power Systems*
- AIR6127, *Managing Higher Voltages in Aerospace Electrical Systems*
- AIR6139, Ways of Dealing with Power Regeneration onto an Aircraft Electrical Power System Bus
- AIR999A, *Cryogenically Fueled Dynamic Power Systems*
- ARP4729A, Document for 270 Voltage Direct Current (270 V DC) System
- AS1212A, Electric Power, Aircraft, Characteristics and Utilization of
- AS1831A, *Electrical Power, 270 V DC, Aircraft, Characteristics and Utilization of*
- AS5698A, *Space Power Standard*

AE-7D Aircraft Energy Storage and Charging Committee:
- AIR6343, Design and Development of Rechargeable Lithium Battery Systems for Aerospace Applications

AE-8A Elec Wiring and Fiber Optic Interconnect Sys Install:
- AS50881G, *Wiring Aerospace Vehicle* [Note: It applies to UAS too.]
- AS21378A, Plugs And Cable Assemblies, External Power, Aircraft, 230/400 VOLT, 400 Hertz
- AS24122A, Wiring Harness – External Power, 115 Volt AC, Single Phase
- AS24208A, Cable And Plug Assembly, External Power 115/200 VOLTS 3 Phase, Single Point Refueling
- AS25019A, Cable Assembly, External Electric Power, Aircraft, 28 VOLT DC, Jet Starting
- AS7974/2A, Cable Assembly, External Power, Aircraft 115/200 VOLT, 400 Hertz Power Distribution Flight Line (For A/E 24A-166A)
- AS7974/4A, Cable Assembly, External Electric Power, Aircraft, Single-Jacketed 115/200 VOLT, 400 Hertz
- AS7974/5A, Cable Assembly, External Electric Power, Aircraft, Single-Jacketed 270 VDC, 90 KW
- AS7974A, Cable Assemblies and Attachable Plugs, External Electrical Power, Aircraft, General Specification For
- AS90328A, Cable Assembly, External Electric Power, Aircraft 115/200 VOLT, 400 Hertz
- AS90347A, Cable Assembly, External Electric Power, Aircraft 28 VOLT DC, Operating Power

A-6C4 Power Sources:
- AIR744C, Aerospace Auxiliary Power Sources

S-18: Aircraft and Systems Development and Safety Assessment:
- ARP4754A, Guidelines for Development of Civil Aircraft and Systems
- ARP4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

Other Electric Aircraft Steering Group (EASG) TC Liaisons:
- Aerospace Propulsion Systems Health Management - E-32
- Aircraft Ground Support Equipment AGE-3

SAE EUROCAE Fuel Cell Task Group

- AIR6464, *EUROCAE/SAE WG80/AE-7AFC Hydrogen Fuel Cells Aircraft Fuel Cell Safety Guidelines*
- AS6858, *Installation of Fuel Cell Systems in Large Civil Aircraft*

AS8028, *Powerplant Fire Detection Instruments Thermal & Flame Contact Types (Reciprocating and Turbine Engine Powered Aircraft)*

ASTM:

F37.20 Airplane:

- F2840-14, *Standard Practice for Design and Manufacture of Electric Propulsion Units for Light Sport Aircraft*

F37.70 Cross-Cutting:

- F2538-07a(2010), *Standard Practice for Design and Manufacture of Reciprocating Compression Ignition Engines for Light Sport Aircraft*
- F2506-13, *Standard Specification for Design and Testing of Light Sport Aircraft Propellers*

F38.01 Airworthiness:

- F3005-14a, *Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)* – specific to UAS

F39.01 Design, Alteration, and Certification of Electrical Systems:

- F2490-05(2013), *Standard Guide for Aircraft Electrical Load and Power Source Capacity Analysis*

F44.50 Systems and Equipment:

- F3235-17a, *Standard Specification for Aircraft Storage Batteries*
- F3316/F3316M-18, *Standard Specification for Electrical Systems for Aircraft with Electric or Hybrid-Electric Propulsion*

NASA Documents:

- Electric Propulsion Units
- Various NASA documents

UL:

- UL 1642, *Standard for Safety for Lithium Batteries*
- UL 2271, *Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications*
- UL 2580, *Standard for Batteries in Use in Electric Vehicles*
- UL 2743, *Standard for Safety for Portable Power Packs*
- UL 3030, *Standard for Unmanned Aircraft Systems* – specific to UAS
- UL 62133, *Standard for Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes - Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications*

In-Development Standards and Related Materials: The following manned aviation standards may be applicable to UAS. There are a few standards specific to UAS.

ASTM:

F38.01 Airworthiness:

- WK60937, *New Specification for Design of Fuel Cells for Use in Unmanned Aircraft Systems (UAS)* – specific to UAS
- WK66135, *Revision of F3005 - 14a Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)* – specific to UAS

F44.50 Systems and Equipment:

- WK58700, *Electrical Systems for Aircraft with Electric or Hybrid-Electric Propulsion*

F39.05 Design, Alteration, and Certification of Electric Propulsion Systems:

- WK47374, *New Specification for Design and Manufacture of Electric Propulsion Units for General Aviation Aircraft (Aeroplanes)*
- WK56255, *Design of Electric Propulsion Energy Storage Systems for General Aviation Aircraft*

IEC

IEC/TC 105 (Fuel Cell Technologies)

- New Work Item Proposal(s) are coming from China on FCs for unmanned aircraft systems (possibly one for Performance, and one for Safety)

SAE:

E-39 Unmanned Aircraft Propulsion Committee:

- AS6971, *Test Protocol for UAS Reciprocating (Intermittent) Engines as Primary Thrust Mechanism* – specific to UAS. SAE E-39 has some future work planned for propeller hubs, propeller information report, UAS propulsion system categorization, and ground support equipment.

E-40 Electrified Propulsion Committee

- AIR8678, Architecture Examples for Electrified Propulsion Aircraft
- ARP8676, Nomenclature & Definitions for Electrified Propulsion Aircraft
- ARP8677, Safety Considerations for Electrified Propulsion Aircraft

E-25 General Standards for Aerospace and Propulsion Systems

- (60 works in progress as of March 2020)

E-32 Aerospace Propulsion Systems Health Management

- (7 works in progress as of March 2020)

E-33 In Flight Propulsion Measurement Committee

- (3 works in progress as of March 2020)

E-34 Propulsion Lubricants Committee
- (13 works in progress as of March 2020)

E-36 Electronic Engine Controls Committee
- (4 works in progress as of March 2020)

EG-1A Balancing Committee
- (15 works in progress as of March 2020)

EG-1B Hand Tools Committee
- (8 works in progress as of March 2020)

EG-1B1 Power Tools – Productivity, Ergonomics and Safety
- (2 works in progress as of March 2020)

EG-1E Gas Turbine Test Facilities and Equipment
- (2 works in progress as of March 2020)

AE-7 Aerospace Electrical Power and Equipment Committee:
- AIR6511, *Safety Consideration for a 48/60 VDC Aircraft distribution system*

AE-7A Generators and Controls Motors and Magnetic Devices:
- AS8441, *Minimum Performance Standard for Permanent-Magnet Propulsion Motors and Associated Variable-Speed Drives*

AE-7B Power Management, Distribution and Storage:
- AS4805A, *Solid State Power Controller, General Standard For*
- AS6087, *ARC Fault Interrupter, 270 VDC*

AE-7C Systems:
- AIR6198, *Considerations for future more electric aircraft electric power systems*
- AIR7497, *Advanced methods for Wire Selection and Sizing for Aerospace applications*
- AIR7502, *Aerospace Electrical Voltage Level definitions*
- AIR8445, *Aerospace Electrical Power System Stability*
- AS7499, *Aircraft High Voltage DC Power Quality Standard*

AE-7D Aircraft Energy Storage and Charging Committee:
- AIR6897, *Battery Management Systems for Rechargeable Lithium Batteries Used in Aerospace Applications*
- AS6968, *Connection Set of Conductive Charging for Electric Aircraft*

AE-7M Aerospace Model Based Engineering:

- AIR6387, *Aircraft electrical power systems. Modeling and simulation. Validation and verification methods.*

AE-8A Elec Wiring and Fiber Optic Interconnect Sys Install

- AS7974B*, Cable Assemblies and Attachable Plugs, External Electrical Power, Aircraft, General Specification For*

Gap A14: Power Sources and Propulsion Systems. Standards are needed for UAS power sources and propulsion systems.

R&D Needed: Yes

Recommendation:

1) Complete work on in-development standards.
2) Encourage the development of standards to address UAS power sources and propulsion systems.

Priority: High (Tier 3)

Organization(s): ICAO, RTCA, SAE, AIAA, ASTM, DOD, NASA, UL, IEC, IEEE

Status of Progress: Green

Update: As noted in the text a number of standards are in development.

6.7. Noise, Emissions, and Fuel Venting

Design, manufacturing, and operational approvals for manned aviation include requirements relating to noise, emissions, and fuel venting. Such requirements are not currently required for sUAS operating under Part 107 but are nonetheless desirable from a safety perspective. For example, the machines and equipment in a UAS produce noise levels that are not totally addressed by aviation standards and/or regulations. While the operating situation and environment of a UAS are admittedly different from a flight deck or cockpit, there are similar safety concerns.

Published Standards and Related Materials: There are no standards for noise, emissions, and fuel venting requirements specific to UAS.

Published noise, emissions, and fuel venting standards, as well as U.S. Federal government and inter-governmental materials relevant to this issue include but are not limited to those listed below.

FAA:

- 14 CFR §21.93(b)(c), Classification of Changes in Type Design

- Part 34, Fuel Venting and Exhaust Emission Requirements for Turbine Engine Powered Airplanes
- Part 36 - Noise Standards: Aircraft Type and Airworthiness Certification
- Part 150, Airport Noise Compatibility Planning
- Part 161 - Notice and Approval of Airport Noise and Access Restrictions
- SFAR 27-5, Fuel venting and exhaust emission requirements for turbine engine powered airplanes
- SFAR 88, Fuel Tank System Fault Tolerance Evaluation Requirements
- Advisory Circular (AC), AC 20-133, Cockpit Noise and Speech Interference Between Crewmember
- AC 34-1B, Fuel Venting and Exhaust Emission Requirements for Turbine Engine Powered Airplanes
- AC 36-2C, Measured or Estimated (Uncertificated) Airplane Noise Levels
- AC 36-4C, Noise Standards: Aircraft Type and Airworthiness Certification
- AC 91-36D, Visual Flight Rules (VFR) Flight Near Noise-Sensitive Areas
- AC 150/5020-2, Guidance on the Balanced Approach to Noise Management
- AC 91-35, Noise, Hearing Damage, and Fatigue in General Aviation Pilots
- AC 150/5020-1, Noise Control and Compatibility Planning for Airports
- AC 91-66, Noise Abatement for Helicopters
- AC 91-53A, Noise Abatement Departure Profile
- AC 91-86, Guidance on Carrying Noise Certification Documents On Board Aircraft Operating Outside the United States
- AC 93-2, Noise Levels for Aircraft used for Commercial Operations in Grand Canyon National Park Special Flight Rules Area
- Order 1050.1F, Environmental Impacts: Policies and Procedures
- Order 1100.128, Implementation of Noise Type Certification Standards
- Order 8110.35B, Aircraft Noise Certification Historical Database (RIS 8110.1)
- Order, 1100.128, Implementation of Noise Type Certification Standards
- Order 8110.4C, Type Certification
- Other regulations, ACs, Orders, Policy Statements, Special Conditions are available on the FAA's Regulatory and Guidance Library website.

ICAO:

- Annex 2 – Rules of the Air
- Annex 8 – Airworthiness of Aircraft
- Annex 16, Environmental Protection
- Annex 16, Vol II: Engine Emissions Standards cover HC, CO, NOx and Smoke
- Doc 9501 AN/929, Environmental Technical Manual, Volume I, Procedures for the Noise Certification of Aircraft, 2015
- Doc 9501 AN/929, Environmental Technical Manual, Volume II, Procedures for the Emissions Certification of Aircraft Engines, 2014
- Annex 18, Safe Transport of Dangerous Goods by Air

- Aircraft Engine Emissions
- ICAO's Balanced Approach to Aircraft Noise Management
- ICAO Current initiatives on Aircraft Noise
    - Noise Reduction Technology
    - Community engagement for aviation environmental management
    - Supersonic Aircraft Noise Standards Development
    - Future ICAO work

AIAA:

- Aircraft noise
- Emissions
- Fuel venting
- Other documents

SAE:

- ARP1256D, *Procedure for the Continuous Sampling and Measurement of Gaseous, Emissions from Aircraft Turbine Engines*
- ARP1801A, *Measurement of Exterior Sound Level of Specialized Aircraft Ground Support Equipment*
- ARP1846A, Measurement of Far Field Noise from Gas Turbine Engines During Static Operation
- ARP4721/2, *Monitoring Aircraft Noise and Operations in the Vicinity of Airports: System Validation*
- ARP4721/1, *Monitoring Aircraft Noise and Operations in the Vicinity of Airports: System Description, Acquisition, and Operation*
- AIR5662, *Method for Predicting Lateral Attenuation of Airplane Noise*
- ARP4055, *Ground-Plane Microphone Configuration for Propeller-Driven Light-Aircraft Noise Measurement*
- ARP1279, *Standard Indoor Method of Collection and Presentation of the Bare Turboshaft Engine Noise Data for Use in Helicopter Installations*
- AIR1935, *Methods of Controlling Distortion of Inlet Airflow During Static Acoustical Tests of Turbofan Engines and Fan Rigs*
- AIR1672B, *Practical Methods to Obtain Free-Field Sound Pressure Levels from Acoustical Measurements Over Ground Surfaces*
- AIR1081, *House Noise-Reduction Measurements for Use in Studies of Aircraft Flyover Noise*
- AIR1905A, *Gas Turbine Coaxial Exhaust Flow Noise Prediction*
- ARP876F, *Gas Turbine Jet Exhaust Noise Prediction*
- AIR4068B, *Gas Turbine Emission Probe Factors*
- ARP1179D, *Aircraft Gas Turbine Engine Exhaust Smoke Measurement*
- ARP1533C, *Procedure for the Calculation of Gaseous Emissions from Aircraft Turbine Engines*
- Other documents

A-21 Aircraft Noise Measurement Aviation Emission Modeling
- (37 documents as of March 2020)

E-31B Bleed Air Committee
- (2 documents as of March 2020)

E-31G Gaseous Committee
- (5 documents as of March 2020)

E-31P Particulate Matter Committee
- (6 documents as of March 2020)

AE-5A Aerospace Fuel, Inerting and Lubrication Sys Committee
- (32 documents as of March 2020)

AE-5B Aircraft and Engine Fuel and Lubricant Sys Components
- (22 documents as of March 2020)

AE-5C Aviation Ground Fueling Systems Committee
- (7 documents as of March 2020)

AE-5D Fuel Tank Flammability Reduction Systems Committee
- (3 documents as of March 2020)

DOD:
- MIL-V-81356B(AS), Valve, Fuel System Pressurization and Vent, 1992
- Aircraft noise
- Other documents

NASA:
- Noise
- Emission
- Fuel venting

In-Development Standards:

ICAO:
- Future ICAO work on Aircraft Noise
- Annex 2 – Rules of the Air, Q1 2018
- Annex 8 – Airworthiness of Aircraft

SAE:

A-21 Aircraft Noise Measurement Aviation Emission Modeling

- ARP4055A, Ground-Plane Microphone Configuration for Propeller-Driven Light-Aircraft Noise Measurement
- ARP1846B, Measurement of Far Field Noise from Gas Turbine Engines During Static Operation
- AIR1935A, Methods of Controlling Distortion of Inlet Airflow During Static Acoustical Tests of Turbofan Engines and Fan Rigs
- AIR1672C, Practical Methods to Obtain Free-Field Sound Pressure Levels From Acoustical Measurements Over Ground Surfaces
- AIR1081A, House Noise-Reduction Measurements for Use in Studies of Aircraft Flyover Noise
- ARP4721/2A, Monitoring Aircraft Noise and Operations in the Vicinity of Airports: System Validation
- ARP4721/1A, Monitoring Aircraft Noise and Operations in the Vicinity of Airports: System Description, Acquisition, and Operation
- ARP6973, Aircraft Noise Level Reduction Measurement of Building Facades
- AIR5715A, Procedure for the Calculation of Aircraft Emissions
- ARP1307C, Measurement of Exterior Noise Produced by Aircraft Auxiliary Power Units (APUs) and Associated Aircraft Systems During Ground Operation
- AIR6183, Procedures for the calculation of airplane fuel consumption
- AIR5766, Using Aircraft Position Data to Estimate Aircraft Thrust

E-31B Bleed Air Committee

- (1 work in progress as of March 2020)

E-31G Gaseous Committee

- (3 works in progress as of March 2020)

E-31P Particulate Matter Committee

- (3 works in progress as of March 2020)

AE-5A Aerospace Fuel, Inerting and Lubrication Sys Committee

- (15 works in progress as of March 2020)

AE-5B Aircraft and Engine Fuel and Lubricant Sys Components

- (7 works in progress as of March 2020)

AE-5C Aviation Ground Fueling Systems Committee

- (3 works in progress as of March 2020)

AE-5D Fuel Tank Flammability Reduction Systems Committee

- (4 works in progress as of March 2020)

Gap A15: Noise, Emissions, and Fuel Venting. No published standards have been identified that address UAS-specific noise, emissions, and fuel venting standards and requirements.

R&D Needed: Yes. Data would be helpful.

Recommendation:

1) Complete in-development standards.
2) Encourage the development of standards to address noise, emissions, and fuel venting issues for UAS. This is a necessary first step toward UAS rulemaking relating to these topics.

Priority: High (Tier 3)

Organization(s): ICAO, EPA, FAA, RTCA, SAE, AIAA, ASTM, DOD, NASA

Status of Progress: Not Started

Update: This is a low priority for ASTM F38 until there is further guidance/data available on noise levels for drones both large and small. Industry is likely collecting data in relation to this which is a first step before a standard can be written.

6.8. Mitigation Systems for Various Hazards to UAS

Potential hazards that UAS may encounter during operations include: prop/rotor strike, foreign object debris (FOD), bird strikes and ingestion on UAS, icing, hail damage, lightning, power lines, masts, towers, and guy-wires, etc. Standards have a role to play in mitigating potential adverse outcomes associated with these hazards. Prior to UAS operations, standards also have a role to play in mitigating foreign object damage for organizations that design, develop, and provide aviation, space, and defense products and services; and by organizations providing post-delivery support, including the provision of maintenance, spare parts, or materials for their own products and services. Avoidance of airborne collision with other users of the NAS and/or with persons and property on the ground is covered in section 6.4.3 of this roadmap. In addition, some of the hazards associated with UAS will have to be mitigated through CONOPS and Aircraft and System Development Assurance and Safety Assessment. Separation and avoidance are the absolute requirements for any aircraft (manned or unmanned) operating in the NAS.

Most hazards to manned aircraft can occur to unmanned aircraft. Therefore many standards will fall back to the design and construction. There are operational considerations for UAS, though, and there may not be standards or procedures to point back to. Hazardous conditions are affected by SWAP limitations of the aircraft and the CONOPS.

Published Standards and Related Materials:

<u>Hazard Mitigation Systems for Bird Strikes, Bird Ingestion, Rain, Hail, Foreign Object Ingestion</u>

- Bird Strikes are covered under 14 CFR §§ 25.631, 25.571(e), 23.2320(b), 29.631, 29.573(c)(3)(d)(1)(iv), 35.36, Advisory Circulars: AC 33.76-1A, AC 150/5200-32B, Policies: PS-ANE-2001-35.31-R0, PS-AIR-33.76-01.

- Bird Ingestions are covered under § 33.76.
- Rain and hail ingestions are covered under § 33.78, AC 20-124.
- Foreign object ingestion – ice is covered under § 33.77.
- Foreign object debris (FOD)
- Bird Strike exemptions
- Bird and Wildlife Strikes, Aircraft Owners and Pilots Association
- Wildlife Strike Database and Reporting, FAA Wildlife Strike Database
- Fact Sheet – FAA Wildlife Hazard Mitigation Program
- UAS Airborne Collision Severity Evaluation, National Institute for Aviation Research (NIAR), FAA Center of Excellence (COE) for UAS Research[31]
- UAS Ground Collision Severity Evaluation, NIAR, FAA Center of Excellence for UAS Research[32]

The SAE International S-12 Powered Lift Propulsion Committee develops and maintains aerospace standards, recommended practices and other SAE technical reports related to the design, performance, installation and operation of propulsion systems for powered-lift aircraft. This committee also includes, but is not limited to, vertical powered lift aircraft as well as the propulsion system/aircraft interface.

- AIR4096 Helicopter Engine Foreign Object Damage

The SAE International G-14 Americas Aerospace Quality Standards Committee (AAQSC) addresses all facets of aerospace quality-design, maintenance, and in-service experience. A longer list of G-14 standards can be found chapter 6.3. Quality Assurance/Quality Control.

- AS9146 Foreign Object Damage (FOD) Prevention Program - Requirements for Aviation, Space, and Defense Organizations

Hazard Mitigation Systems for Icing

Ice protection is covered under 14 CFR §§ 25.773, 25.929, 25.1093, 25.1323, 25.1324, 25.1325, 25.1403, 25.1419, 25.1420, O25.1, 23.2165, 23.2540, 27.1093, 29.1093, 29.1419, C29.1, 33.68, B33.1, D33.1.

ACs: AC 25-25A, AC 135-9, AC 120-60B, AC 135-16, AC 120-89, AC 121.321-1, AC 23.1419-2D, AC 20-113, AC 91-74B, AC 120-112, AC 25-28, AC 20-73A, AC 20-147A, AC 20-117, AC 20-29B, AC 20-95B, AC 23.1419-2D

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[31] The reports embedded in this hyperlink discuss hazard mitigation systems for bird and/or UAS strikes on UAS, UAS strikes on manned aviation including but not limited to persons, property and other users of the national airspace system (NAS), engine ingestion, etc.
[32] The reports embedded in this hyperlink are specific to UAS ground collision severity.

Policies: PS-ANM-25-10, PS-ACE-23-05, PS-ANE-2003-35-1-R0

The SAE International AC-9C Aircraft Icing Technology Committee, deals with all facets of aircraft inflight icing including ice protection and detection technologies and systems design, meteorological and operational environments, maintenance, regulation, certification, and in-service experience. It has a number of published standards for the manned aviation environment that may be relevant as listed below.

- AIR1168/4B SAE Aerospace Applied Thermodynamics Manual, Ice, Rain, Fog, and Frost Protection
- AIR1667A Rotor Blade Electrothermal Ice Protection Design Considerations
- AIR4015D Icing Technology Bibliography
- AIR4367A Aircraft Inflight Ice Detectors and Icing Rate Measuring Instruments
- AIR4906 Droplet Sizing Instrumentation Used in Icing Facilities
- AIR5320A Summary of Icing Simulation Test Facilities
- AIR5396A Characterizations of Aircraft Icing Conditions
- AIR5666A Icing Wind Tunnel Interfacility Comparison Tests
- ARP5624 Aircraft Inflight Icing Terminology
- ARP5903 Droplet Impingement and Ice Accretion Computer Codes
- ARP5904 Airborne Icing Tankers
- ARP5905 Calibration and Acceptance of Icing Wind Tunnels
- AS5498A Minimum Operational Performance Specification for Inflight Icing Detection Systems
- AS5562 Ice and Rain Minimum Qualification Standards for Pitot and Pitot-static Probes

Hazard Mitigation Systems for Lightning

Lightning is covered under 14 CFR §§ 25.581, 25.954, 25.1316, 25.1317, 23.2335, 23.2515, 23.2520, 27.610, 27.954, 27.1316, 27.1317, D27.1, 29.954, 29.1316, 29.1317, E29.1, 35.38.

ACs: AC 33.4-3, AC 20-53B, AC 20-136B, AC 20-155A, AC 20-158A

Policies: ANM-111-05-004, PS-ANM100-1993-00054, PS-ANM-25.981-02, PS-ANE-2001-35.31-R0, PS-ACE-23-10, ANM-112-08-002, AIR-100-12-110-001

The scope of the SAE International AE-2 Lightning Committee covers:

- The natural lightning environment and related environment standards
- Protection of aerospace vehicles from the effects of lightning and other atmospheric electrical environments
- Means of verifying the adequacy of protection measures, and
- Standardized and other atmospheric electrical environments for lightning simulation and test methods

Potentially relevant published standards for manned aviation are listed below:

- ARP5412B Aircraft Lightning Environment and Related Test Waveforms
- ARP5414B Aircraft Lightning Zoning
- ARP5415B User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning
- ARP5416A Aircraft Lightning Test Methods
- ARP5577 Aircraft Lightning Direct Effects Certification
- ARP5672 Aircraft Precipitation Static Certification

In-Development Standards/Documents:

Hazard Mitigation Systems for Foreign Object Ingestion

The S-12 Committee has launched the following standards relating to mitigating foreign object powerplant ingestion:

- AIR4096A Helicopter Engine Foreign Object Damage
- AIR6980 General Considerations for Rotorcraft Inlet Barrier Filter Installations
- ARP6912 Substantiation of Power Available and Inlet Distortion Compliance for Rotorcraft Inlet Barrier Filter Installations

Hazard Mitigation Systems for Bird and UAS Strikes

The G-28 Simulants for Impact and Ingestion Testing Committee has the responsibility to develop and maintain standards for simulating objects utilized in the development and certification of structures and engines for impact or ingestion. The committee works in conjunction with defense agencies and regulatory authorities to ensure that the standards developed meet regulatory requirements for certification testing. The initial project will focus on the requirements for the manufacture of artificial birds of varying size utilized in development and certification testing. In the event that requirements for the certification of structures for drone or foreign object debris (FOD) impact/ingestion are necessary, the committee is prepared to help develop artificial simulant standards." Relevant standards in development include:

- ARP6924 Tests Recommended for Qualifying an Artificial Bird for Aircraft Certification Testing
- AS6940 Standard Test Method for Measuring Forces During Impact of a Soft Projectile on a Rigid Flat Surface

Hazard Mitigation Systems for Icing

In terms of UAS-specific standards, SAE AIR6962, *Ice Protection for Unmanned Aerial Vehicles,* is in development within SAE AC-9C. SAE AC-9C has a number of other potentially relevant in-development standards for manned aviation as listed below.

- AIR1667B Rotor Blade Electrothermal Ice Protection Design Considerations
- AIR4367B Aircraft Inflight Ice Detectors and Icing Rate Measuring Instruments
- AIR4906A Particle Sizing Instrumentation for Icing Cloud Characterization
- AIR6247 Guidance on Selecting a Ground-based Icing Simulation Facility
- AIR6341 SLD capabilities of icing wind tunnels
- AIR6440 Icing Tunnel Tests for Thermal Ice Protection Systems
- AIR6962 Ice Protection for Unmanned Aerial Vehicles
- AIR6974 Ice Crystal and Mixed Phase Icing Tunnel Testing of Air Data Probes
- AIR6977 Instrumentation for Liquid, Ice and Total Water Content Measurements
- ARP5624A Aircraft Inflight Icing Terminology
- ARP5905A Calibration and Acceptance of Icing Wind Tunnels
- ARP6455 Ice Shape Test Matrix Development for Unprotected Surfaces
- ARP6901 Consideration for passive rotorcraft engine/APU induction system ice protection

Hazard Mitigation Systems for Lightning

Potentially relevant in-development standards for manned aviation within SAE AE-2 are listed below.

- ARP5414B Aircraft Lightning Zoning
- ARP5415B User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning
- ARP6205 Transport Airplane Fuel Tank and Systems Lightning Protection

Gap A16: Mitigation Systems for Various Hazards to UAS. There are no UAS-specific standards in the areas of hazard mitigation systems for bird strikes on UAS, engine ingestion, hail damage, water ingestion, lightning, electrical wiring, support towers, etc.

R&D Needed: Maybe.

Recommendation:

1) Complete in-development standards.
2) Create new standards to include hazard mitigation systems for bird strikes on UAS, engine ingestion, icing, and lightning.

Priority: High (Tier 2)

Organization(s): Various SAE Committees

Status of Progress: Green

Update: SAE has a number of standards in development as noted in the text.

6.9. Parachutes for Small Unmanned Aircraft

Both the DOD and NASA have used parachute systems as a safety mitigation system for safe recovery of mission critical systems such as drones, airdrop systems (personnel, food, equipment, emergency, etc.), military aircraft, etc. The reliability and performance of parachutes installed on aircraft as a hazard mitigation system has been proven by extensive use and can be applied to civil aviation as a safety enhancement to enable UAS OOP.

The only available FAA regulations, "14 CFR part 105, Parachute Operations" and associated documents (AC 105-2E and TSO-C23f), address sport/personnel parachuting and do not address the design and manufacturing aspects of the parachute installed on an aircraft as a hazard mitigation system. The design and manufacturing approvals of the parachute or drag chute installed in an aircraft as a hazard mitigation system have been accomplished through the FAA's Special Conditions provision in Type Certification.

Parachute or drag chute (drogue parachute) as a normal landing and/or hazard mitigation system in UAS OOP must properly account for anticipated risks and potential safety issues using systems engineering during the design, development, manufacturing, and assurance processes. It should also focus on integration with other users of the NAS.

Published Standards and Related Materials: The vast majority of the currently available parachute-related resources (standards, regulations, ACs, orders, etc.) from manned aviation, military, space, and satellite applications do not address the system of systems engineering used in UAS operations comprising man, machine, the NAS, and integration. Recently published is ASTM F3322-18, *Standard Specification for Small Unmanned Aircraft System (sUAS) Parachutes*.

Published parachute approval standards and regulatory materials that are not specific to UAS (including military and space applications) include the following:

FAA:

- 14 CFR §91.307, Parachutes and parachuting
- Part 105, Parachute Operations
- TSO-C23f, Personnel Parachute Assemblies and Components
- AC 105-2E, Sport Parachuting
- Powered Parachute Flying HDBK, FAA-H-8083-29, 2007
- Various FAA Special Conditions for Type Certification (parachutes as safety mitigation)

SAE:

- AS8015B, *Minimum Performance Standard for Parachute Assemblies and Components, Personnel*, July 7, 1992
- Parachute material standards (AMS Standards) see AMS P Polymeric Materials Committee and AMS P-17 Polymer Matrix Composites Committee

- Various Parachute related Standards

Technical Publications:

- Selection and Qualification of a Parachute Recovery System for Your UAV, 2007-01-3928
- Simulation of Dropping of Cargo with Parachutes, TBMG-1688, 2006-05-01
- Decelerator System Simulation (DSS), TBMG-23905, 2016-02-01

Parachute Industry Association (PIA):

- TS135v1.4 Performance Standards for Personnel Parachute Assemblies and Components, 2010
- Other PIA Documentation

ASTM:

- ASTM F2241-14, *Standard Specification for Continued Airworthiness System for powered Parachute Aircraft*
- ASTM F2242-05(2013), *Standard Specification for Production Acceptance Testing System for Powered Parachute Aircraft*
- ASTM F2243-11(2013), *Standard Specification for Required Product Information to be Provided with Powered Parachute Aircraft*
- ASTM F2244-14, *Standard Specification for Design and Performance Requirements for Powered Parachute Aircraft*
- ASTM F2316-12(2014), *Standard Specification for Airframe Emergency Parachutes*
- ASTM F2426-13, *Standard Guide on Wing Interface Documentation for Powered Parachute Aircraft*

DOD:

- US Navy, Parachute Recovery Systems Design Manual, March 1991
- USAF Parachute HDBK, December 1956
- UASF Recovery Systems Design Guide, December 1978
- USAF Performance of and Design Criteria for Deployable Aerodynamic Decelerators, December 1963
- USAF Parachute HDBK, ATI No. 35532, March 1951
- USAF JSSG-2010-12, Crew Systems Deployable Aerodynamic Decelerator Systems HDBK, October 30, 1998
- US Army, MIL-DTL-7567, Parachutes, Personnel, Detail Manufacturing Instructions For, October 30, 2010
- Other DOD documents related to parachutes

NASA:

- Small Business Innovation Research contracts and deliverables, "NASA Helps Create A Parachute To Save Lives, Planes," November 20, 2002
- NASA Parachute Recovery System for a Recorder Capsule, February 7, 1966

- Design and Drop Testing of the Capsule Parachute Assembly System Sub-Scale Drop Main Parachute, June 2017
- Orbiter Drag Chute Stability Test in the NASA/Ames 80x120 Foot Wind Tunnel, Sandia National Laboratories, SAND93- 2544, February 1994
- Aerodynamic stability and performance of next-generation parachutes for Mars descent, NASA, March 26, 2013
- Various Parachute Recovery Systems used in Space Applications and their documentation

AIAA:

- AIAA 2007-2512, *Design and Testing of the BQM-167A Parachute Recovery System*, May 2007
- AIAA 2013-1358, *Aerodynamic Characterization of New Parachute Configurations for Low-Density Deceleration*, March 2013
- AIAA 2013-1356, *Aerodynamic Stability and Performance of Next- Generation Parachutes for Mars Descent*
- ANSI/AIAA S-017B-2015, *Aerodynamic Decelerator and Parachute Drawings*, 2015

In-Development Standards:

ASTM:

- ASTM WK65042, *New Specification for Operation Over People*
- ASTM WK56338, *New Test Method for Assessing the Safety of Small Unmanned Aircraft Impacts*

Gap A17: Parachute or Drag Chute as a Hazard Mitigation System in UAS Operations over People (OOP). Standards are needed to address parachutes or drag chutes as a hazard mitigation system in UAS operations, particularly OOP, from the perspectives of FAA Type Certification (TC), Production Certificates (PC) and Airworthiness Certificates (AC).

R&D Needed: No

Recommendation: Complete work on ASTM WK65042, *New Specification for Operation Over People* and ASTM WK56338, *New Test Method for Assessing the Safety of Small Unmanned Aircraft Impacts*.

Priority: High (Tier 3)

Organization(s): ASTM, AIAA, SAE, PIA, DOD, NASA

Status of Progress: Green

Update: As noted, ASTM F38 has published F3322 for sUAS and it has two work items in development. ASTM F38 has no plans at present to address parachutes for UAS over 55 pounds.

6.10. Maintenance and Inspection

Maintenance of an aircraft or its associated equipment is essential to ensuring that which is being maintained is in an equal-to or greater-than condition for which it was originally intended and/or manufactured. Failure to maintain UAS to their originally designed conditions could invariably cause unintended harm and/or risk to the operator, NAS, and or people/property. The lack of definitive maintenance and inspection (M&I) standards for UAS introduces unnecessary risks to the NAS, operator(s), and/or people/property on the ground.

Published Standards and Related Materials: In terms of UAS-specific standards and related reports, there are:

- ASTM F2909-19, *Standard Specification for Continued Airworthiness of Lightweight Unmanned Aircraft Systems*
- ASTM F3366-19, *Standard Specification for General Maintenance Manual (GMM) for a small Unmanned Aircraft System (sUAS)*
- ASSURE, *A.5 UAS Maintenance, Modification, Repair, Inspection, Training, and Certification Considerations Task 4: Draft Technical Report of UAS Maintenance Technician Training Criteria and Draft Certification Requirements, 6 Nov 2017, Final Report*
- ISO 21384-3:2019, *Unmanned Aircraft Systems – Part 3: Operational Procedures*

In terms of general aviation standards, there are in ASTM F39.02:

- F2696-14(2019), *Standard Practice for Inspection of Aircraft Electrical Wiring Systems*
- F2799-14, *Standard Practice for Maintenance of Aircraft Electrical Wiring Systems*

In ASTM F46.02:

- F3245-17, *Standard Guide for Aircraft Electronics Technician Personal Certification*

Standards under SAE's HM-1 Integrated Vehicle Health Management Committee include:

- AIR6212, *Use of Health Monitoring Systems to Detect Aircraft Exposure to Volcanic Events*
- ARD6888, *Functional Specification of Miniature Connectors for Health Monitoring Purposes*
- ARP5783, *Health and Usage Monitoring Metrics, Monitoring the Monitor*
- ARP6275, *Determination of Cost Benefits from Implementing an Integrated Vehicle Health Management System*
- ARP6803, *IVHM Concepts, Technology and Implementation Overview*
- AS4831A, *Software Interfaces for Ground-Based Monitoring Systems*
- AS5391A, *Helicopter Health and Usage Monitoring System Accelerometer Interface Specification*
- AS5392, *Health and Usage Monitoring System, Rotational System Indexing Sensor Specification*
- AS5393, *Health and Usage Monitoring System, Blade Tracker Interface Specification*
- AS5394, *Health and Usage Monitoring System, Advanced Multipoint Interface Specification*
- AS5395, *Health and Usage Monitoring System Data Interchange Specification*
- JA6268_201804, *Design & Run-Time Information Exchange for Health-Ready Components*

Standards under the G-11M Maintainability, Supportability and Logistics Committee include:

- AIR4276A, *Survey results: Computerization of Reliability, Maintainability and Supportability (RM&S) in Design*
- JA1010/1_201105, *Maintainability Program Standard Implementation Guide*
- JA1010_201108, *Maintainability Program Standard*
- JA1011_200908, *Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes*
- JA1012_201108, *A Guide to the Reliability-Centered Maintenance (Rcm) Standard*

In-Development Standards: In terms of UAS-specific standards in development, there are:

- WK60659, *New Guide for Lightweight UAS Maintenance Technician Qualification*
- WK62734, *New Specification for Specification for the Development of Maintenance Manual for Lightweight UAS*

In terms of general aviation standards, there are:

- WK30359, *New Specification for Light Sport Aircraft Manufacturers Continued Operational Safety (COS) Monitoring Program*, under ASTM F37.70
- WK55298, *New Guide for Classifying Alterations for In-Service Aircraft under FAA Authority Oversight*, under ASTM F39.02

Aerospace standards under SAE's HM-1 Integrated Vehicle Health Management Committee include:

- AIR6334, *A Power Usage Metric for Rotorcraft Power Train Transmissions*
- AIR6900, *Applicable Integrated Vehicle Health Monitoring (IVHM) Regulations, Policy, and Guidance Documents*
- AIR6904, *Data Interoperability for IVHM*
- AIR6915, Implementation of IVHM, Human Factors and Safety Implications
- AIR8012, *Prognostics and Health Management Guidelines for Electro-Mechanical Actuators*
- ARP6290, *Guidelines for the Development of Architectures for Integrated Vehicle Health Management Systems*
- ARP6407, *Integrated Vehicle Health Management Design Guidelines*
- ARP6883, *Guidelines for Writing IVHM Requirements for Aerospace Systems*
- ARP6887, *Verification & Validation of Integrated Vehicle Health Management Systems and Software*

Gap A18: Maintenance and Inspection (M&I) of UAS. M&I standards for UAS are needed.

R&D Needed: No

Recommendation: Complete work on standards in development to address M&I for all UAS.

Priority: High (Tier 2)

Organization(s): ASTM, ISO, SAE

Status of Progress: Green

Update: ASTM F2909-14 has been superseded by ASFM F2909-19 (previously WK63991). ASTM F3366-19 has been published (previously WK62743). ISO 21384-3 has also been published.

6.11. Enterprise Operations: Level of Automation/ Autonomy/ Artificial Intelligence (AI)

One of the most challenging issues in manned and unmanned aviation is the incorporation of fully autonomous flights of an enterprise or fleet of aircraft/UAS within the scope of airworthiness approvals such as Type Certificate (TC), Production Certificate (PC), and Airworthiness Certificate (AC). Observability, predictability, and intervention, when required, are the main factors in trusting and accepting fully autonomous flights. There is a lack of consensus on a certification process and a significant research gap in the area of enterprise level automation.

Until the existing regulatory framework [i.e., Parts 25, 27 and 29, Equipment Function and installation (XX.1301, 23.2505) - Equipment, systems, and installations (XX.1309, 23.2510)] is validated for its sufficiency and applicability to enable fully autonomous flights, the UAS community comprising the U.S. government, aviation industry, and other end users must use the existing regulatory framework for certification of the enterprise operations of aircraft/UA.

The scope of this section is to describe enterprise level automation as it relates to the technological and regulatory gaps in the ANSI UASSC Roadmap. It does not address technical terminologies and definitions of words such as autonomous, autonomy, AI, automation. Those terms are or will be covered in the SDOs' standards and various publicly available documents. However, it must be clarified that there are significant differences between "fully autonomous" and "fully automated" systems. Within those technical definitions, there are implications on pilot priorities and tasking that is beyond the scope of this discussion. It is important for UAS standards development that a consensus be reached on standard, uniform, consistent, harmonized/aligned definitions.

It is unclear if current standards on system safety and software such as MIL-STD-882E, SAE ARP4761, SAE ARP4754A, SAE ARP5150, D0-178C, etc. are sufficient to address fully autonomous flights of an enterprise or fleet of UAS from airborne, land and sea launches. Therefore, the S-18UAS Autonomy Working Group is developing AIR7121 *Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems*. Questions remain whether the existing regulatory framework (XX.1301/1309, 23.2505/2510) needs to be changed or new regulations need to be added to accommodate fully autonomous flights.

The following are some of the challenges/issues related to fully autonomous flights:

- Self-separation/deconfliction between cooperative and non-cooperative aircraft
- Right of way operations/yielding to manned aviation, or least maneuverable flight systems
- ATC management with respect to integration of manned aviation and emergency operations (MEDVAC, distressed aircraft/operators, aerial firefighting, etc.) involving UAS
- Lost link procedures during emergency operations
- Environmental and privacy considerations
- Charting activities such as updating and/or creating new aeronautical charts
- Major airport routings/re-routings especially in Class B/C airspace in close proximity to dense urban areas
- Air routes (existing vs. new ones)
- Mass volume of UAS operations requiring separation, safety, and efficiency in the NAS
- Air traffic flow control (safeguards to not allow aircraft to run out of fuel)
- Will air traffic controllers become the "manager of ATC systems" in the future state of fully autonomous flights of enterprises/fleets of UAS?
- What will be the role of Low Altitude Authorization and Notification Capability (LAANC) in the future state? The current role is limited to Part 107 operations within controlled airspace such as Class-D, C, B, and surface-E.
- Can this technology be also implemented/installed in the manned aviation environment, keeping manned aviation pilots as OPA[33] pilots? Will this incur change in ATC management?
- Short-, intermediate-, and long-term strategies for the integration of autonomous operations based on the development and deployment of technology solutions and community acceptance
- Autonomous UAS will require fail-safe systems to insure safe operations in all of the approved environmental conditions.
- Autonomous UAS flights present an operational risk for other UAS and manned aircraft operations. Will the existing Operational Risk Assessment method and procedures work for fully automated flights of UAS?

Published Standards and Related Materials. The below standards and regulations from the U.S. government and other sources can be the starting point for introducing fully autonomous flights.

FAA Regulations/Documents:

- 14 CFR §23.2505, Function and installation; §23.2510, Equipment, systems, and installations§XX.1301, Function and installation (14 CFR parts 25, 27, 29)
- §XX.1309, Equipment, systems, and installations (14 CFR parts 25, 27, 29)

[33] Per FAA Order 8130.34D, an Optionally Piloted Aircraft (OPA) is a manned aircraft that can be flown or controlled by the onboard pilot in command or by another individual from a location not onboard the aircraft.

- §25.1302, Installed systems and equipment for use by the flightcrew
- §23.2500, Airplane level systems requirements; §23.2600, Flightcrew interface
- §21.17(b), Designation of applicable regulations for Special Classes of Aircraft§107.35, Operation of multiple small UA; §107.205(e), List of regulations subject to waiver
- §§91.111, 91.113, 91.115, 107.37, 107.51
- TSO-C211, TSO-C212, TSO-C213
- LAANC; UAS Traffic Management (UTM); NextGen/Modernization of the U.S. NAS
- FAA Reauthorization Act of 2018 – 5 Year (2018-2023)

Defense Advanced Research Projects Agency (DARPA) Documents:

- Fast Lightweight Autonomy (FLA) Program
- Launch and Recover Multiple Reusable Drones from a C-130
- OFFensive Swarm-Enabled Tactics (OFFSET)

DOD Documents:

- Autonomous UAS: A Partial Solution To America's Future Airpower Needs, Air University, USAF, 2010
- US Air Force wants autonomous air-to-air collision avoidance system on F-35, 2018
- Autonomy: The Future of Aerial Combat, 2017
- Air Force looking at autonomous systems to aid war fighters, 2016
- US Navy MQ-25 (Design and Make by Boeing) for Persistent, Sea-Based Aerial Refueling UAS
- Human and computer control of undersea teleoperators, Navy, 1978

EASA Documents:

- *Artificial Intelligence Roadmap: A human centric approach to AI in aviation* (February 2020, version 1.0)
- *Concepts of Design Assurance for Neural Networks (CoDANN)* (March 31, 2020, version 1.0)

AIAA Documents:

- Standards for space automation and robotics, Space Programs and Technologies Conference, AIAA SPACE Forum, 1992
- System Automation of a DA42 General Aviation Aircraft (AIAA 2018-3984)
- Various Documents and Publications

ASTM International Documents:

- TR1-EB, *Autonomy Design and Operations in Aviation: Terminology and Requirements Framework* was published in June 2019. This technical report was prepared by Technical Committees F37 on Light Sport Aircraft, F38 on Unmanned Aircraft Systems, F39 on Aircraft Systems, and F44 on General Aviation Aircraft. This work is coordinated by ASTM Task Group AC377 on Autonomy Design and Operations in Aviation.

SAE International Documents:

S-18, Aircraft and Systems Development and Safety Assessment Committee

- ARP4754A, Guidelines for Development of Civil Aircraft and Systems
- ARP4761, Guidelines And Methods For Conducting The Safety Assessment Process On Civil Airborne Systems And Equipment
- ARP5150, Safety Assessment of Transport Airplanes in Commercial Service

AS-4JAUS, Joint Architecture for Unmanned Systems Committee

- AS8024, *JAUS Autonomous Capabilities Service Set*
- AIR5665B, *Architecture Framework for Unmanned Systems*
- ARP6128, *Unmanned Systems Terminology Based on the ALFUS Framework*
- AIR5645A, AIR5664A, , ARP6012A, , ARP6227, AS5669A, AS5684B, AS5710A, AS6009A, AS6040, AS6057A, AS6060, AS6062A, AS6091,

AS-4UCS, Unmanned Systems Control Segment Architecture

- AIR6514, AIR6515, AIR6516, AIR6517, AIR6519, AIR6520, AIR6521, AS6512, AS6513, AS6518, AS6522, AS6969, AS6969_DA

A-6A3 Flight Control and Vehicle Management Systems Cmt

- ARP94910, Aerospace - Vehicle Management Systems - Flight Control Design, Installation and Test of, Military Unmanned Aircraft, Specification Guide For

Systems Management Council

- CRB1, Managing the Development of Artificial Intelligence Software

Driver Vehicle Interface (DVI) Committee

- J3077_201512, Definitions and Data Sources for the Driver Vehicle Interface (DVI)

Driving Automation Systems Committee

- J3114_201612, Human Factors Definitions for Automated Driving and Related Research Topics

G-10U Unmanned Aerospace Vehicle Committee

- ARP5707, Pilot Training Recommendations for Unmanned Aircraft Systems (UAS) Civil Operations

On-Road Automated Driving (ORAD) committee

- J3016_201806, Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles, 2018

SAE-ITC (ARINC)

- ARINC 400, ARINC 500, ARINC 600, ARINC 700, ARINC 800 Series

NASA Documents:

- Safe Autonomous Flight Environment for the Notional Last "50 ft" of Operation of "55 lb" Class of UAS, 2017
- Towards A Computational Framework for Autonomous Decision-Making in UAVs, 2017

- NASA And MTSI To Develop Framework For Autonomous Aircraft That Can Be Used To Achieve FAA Certification, October 16, 2018
- Certification Considerations for Adaptive Systems. NASA/CR–2015-218702, NASA
- Various NASA Documents

Boeing Documents:

- Autonomous Systems - The Future in Aerospace, Boeing Defense, Space & Security, 2017
- Boeing's MQ-25 brings the combination of refueling, autonomy and seamless carrier deck integration
- Aurora Flight Sciences activities – UAS Sector - Autonomy
- Boeing HorizonX activities

Lockheed Martin Documents:

- Anatomy of an Autonomous Mission
- Autonomous and Unmanned Systems

Northrop Grumman Documents:

- Northrop Grumman's autonomous helicopter
- Autonomous Systems

IEEE Documents:

- Intelligent control for near-autonomous aircraft missions, 2001
- Autonomous aircraft operations to managed airspace transfer management tool (T-MAT)
- Intelligent systems for autonomous aircraft, 2000
- A model for types and levels of human interaction with automation, 2000
- Various IEEE Documents

Various Other Documents:

- Federal automated vehicles policy, National Highway Traffic Safety Administration, 2016
- Developing Safety-Critical Software: A Practical Guide for Aviation Software and DO-178C Compliance, CRC Press, 2013
- RTCADO-344 Volume 2-Appendices F & G - Operational and Functional Requirements and Safety Objectives for UAS Standards, 2013

In-Development Standards

SAE International Activities/Documents:

S-18, Aircraft and Systems Development and Safety Assessment Committee

- AIR7121, Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems

G-32, Cyber Physical Systems Security Committee

- JA7496, Cyber Physical Systems Security Engineering Plan (CPSSEP)
- JA6678, Cyber Physical Systems Security Software Assurance

G-34, Artificial Intelligence in Aviation

- G-34 is addressing AI in line with Executive Order on Maintaining American Leadership in Artificial Intelligence.
- AIR6987, *Artificial Intelligence in Aeronautical Systems: Taxonomy*
- AIR6988, *Artificial Intelligence in Aeronautical Systems: Statement of Concerns*
- AS6983, *Process Standard for Development and Certification/Approval of Aeronautical Safety-Related Products Implementing AI*

AS-4JAUS Joint Architecture for Unmanned Systems Committee

- AS5710B, *JAUS Core Service Set*
- AS6060A, *JAUS Environment Sensing Service Set*
- AS6111, *JAUS Unmanned Maritime Vehicle Service Set*

AS-4UCS Unmanned Systems Control Segment Architecture

- AS6513A, Unmanned Systems (UxS) Control Segment (UCS) Architecture: Conformance Specification
- AS6512A, Unmanned Systems (UxS) Control Segment (UCS) Architecture: Architecture Description
- AS6518A, UxS Control Segment (UCS) Architecture: UCS Architecture Model
- AIR6520A, Unmanned Systems (UxS) Control Segment (UCS) Architecture: Version Description Document
- AS6522A, UxS Control Segment (UCS) Architecture: Architecture Technical Governance
- AS6969A, Data Dictionary for Quantities Used in Cyber Physical Systems

A-6A3 Flight Control and Vehicle Management Systems Cmt

- ARP94910A, *Aerospace - Vehicle Management Systems - Flight Control Design, Installation and Test of, Military Unmanned Aircraft, Specification Guide For*

ASTM International Documents:

- WK63418, New Specification for Service provided under UTM Is being developed by ASTM F38.02
- AC377 Autonomy Design and Operations in Aviation has 2 technical reports in development:
  - *Pillars for the Development of Increased Automation for Aviation Systems* is expected to be published in early 2020.
  - *Regulatory Barriers to Autonomy in Aviation,* is expected to reach publication in Q4 2020.

Underwriters Laboratories, Inc. Documents:

- UL 4600, *Standard for Safety for the Evaluation of Autonomous Products*

Gap A19: Enterprise Operations: Level of Automation/Autonomy/Artificial Intelligence (AI). Neither the current regulatory framework nor existing standards support fully autonomous flights at this time.

R&D Needed: Yes

Recommendation:

1) Develop standards and guidelines for the safety, performance, and interoperability of fully autonomous flights, taking into account all relevant factors needed to support the seamless integration of UAS into the NAS. These include: type of aircraft/UA, operators/pilots/crew, air traffic controllers, airspace service suppliers/providers, lost link procedures, human factors/human-machine interactions as well as levels of human intervention, etc.
2) Encourage the development of standards to address fully autonomous flights, per the FAA Reauthorization Act of 2018 and the needs of the UAS industry and end users.
3) Encourage the development of consistent, uniform, harmonized, standardized, and aviation field-acceptable definitions of terms like autonomy, automation, autonomous, AI, machine learning, deep learning, etc. This will lay a foundation for identification of correct and incorrect definitions/ terminologies.

Priority: High (Tier 2)

Organization(s): SAE, SAE-ITC-ARINC, RTCA, AIAA, ASTM, DOD, NASA, FCC, Aerospace Vehicle Systems Institute (AVSI), UL

Status of Progress: Green

Update: ASTM ACC 377 has published TR1-EB, *Autonomy Design and Operations in Aviation: Terminology and Requirements Framework*. As noted, ACC 377 has two other technical reports in development. SAE G-34 (jointly with EUROCAE WG-114), G-32, AS-4 and S-18 are addressing this gap. UL also has a standard in development.

7. Flight Operations Standards: General Concerns – WG2

7.1. Privacy

Drone operations and data collection capabilities give rise to a number of concerns related to the protection of personally identifiable information (PII) and privacy for drone operators and/or the general public[34] including:

- Location tracking (license plate readers, thermal imaging, facial recognition) and data profiling
- Government surveillance
- Drones "spying" on/recording people at home or in their yard without their consent
- Unauthorized individuals illegally employing C-UAS measures because of privacy concerns
- Data collection/data management related to tracking UAS operations
- Protecting the privacy and security of the UAS operator in accordance with applicable laws

A February 15, 2015, *Presidential Memorandum: Promoting Economic Competitiveness While Safeguarding Privacy, Civil Rights, and Civil Liberties in Domestic Use of Unmanned Aircraft Systems* mandated that "information must be collected, used, retained, and disseminated consistent with the Constitution, Federal law, and other applicable regulations and policies," including compliance with the Privacy Act of 1974. It further specified that, prior to deploying new UAS technology and at least every three years, U.S. federal government agencies must "examine their existing UAS policies and procedures relating to the collection, use, retention, and dissemination of information obtained by UAS, to ensure that privacy, civil rights, and civil liberties are protected." As needed, agencies were directed to update their policies and procedures or issue new ones in accordance with requirements spelled out in the memorandum. The memorandum also required that "state, local, tribal, and territorial government recipients of Federal grant funding for the purchase or use of UAS for their own operations" have in place such policies and procedures prior to expending such funds. Agencies were directed to make publicly available an annual summary of their UAS operations.

A separate component in the aforementioned Presidential Memorandum was the establishment of "a multi-stakeholder engagement process to develop and communicate best practices for privacy, accountability, and transparency issues regarding commercial and private UAS use in the NAS." NTIA was directed to lead this effort in consultation with other agencies and the private sector. The result of this process, *Voluntary Best Practices for UAS Privacy, Transparency, and Accountability: Consensus, Stakeholder-Drafted Best Practices Created in the NTIA-Convened Multistakeholder Process (May 18, 2016)*, is an informative reference on this topic. It is not intended to replace or take precedence over

[34] Kaminski, Margot E. "Enough With the 'Sunbathing Teenager' Gambit," *Slate*. May 17, 2016.

any local, state, or federal law or regulation; or take precedence over contractual obligations; or serve as a basis for future statutory or regulatory obligations.

At the state and local level, a range of positions on privacy policy exist in jurisdictions around the nation.[35] At the federal level, there is legislation being considered within the U.S. Congress (S.631 - Drone Aircraft Privacy and Transparency Act of 2017), but it appears that it may not have drone industry support.[36] Developments such as the General Data Protection Regulation (GDPR) in Europe may impact the policy discussion. On the judicial front, the D.C. Circuit ruled in June 2018 that the Electronic Privacy Information Center lacked standing to compel the FAA to establish privacy rules for drones.[37]

In its 2017 final report, the FAA's UAS Identification and Tracking (UAS ID) ARC recommended (pp. 47-48) that "the United States government be the sole keeper of any PII collected or submitted in connection with new UAS ID and tracking requirements." It went on to state that "[t]he privacy of all individuals (including operators and customers) should be addressed, and privacy should be a consideration during the rulemaking for remote ID and tracking."

Recognizing the desire of some operators to limit the availability of real-time ADS-B position and identification information for specific aircraft, the FAA initiated the Privacy ICAO Address (PIA) program to improve the privacy of certain eligible aircraft beginning in 2020.

The FAA's December 31, 2019 NPRM on Remote ID includes a privacy impact assessment.[38] Sections with privacy implications include: "the registration of the UAS with the FAA, the transmission of data from the UAS to Remote ID USS [UAS Service Suppliers], the broadcast of data from standard remote identification UAS to any person capable of receiving broadcasts, the use of PII in the manufacturer's declaration of compliance, and the use of PII in applications to establish FAA-recognized identification areas for UAS flying (NPRM, page 272)." Privacy concerns would be addressed through mitigation strategies and contractual agreements. Security for PII protection is also heavily emphasized (see, e.g., privacy impact assessment, p. 15).

Published Standards and Related Materials: The Airborne Public Safety Accreditation Commission's (APSAC) *Standards for Public Safety Small Unmanned Aircraft Systems Programs* dated 10/14/17 include brief discussions of privacy, data collection minimization, management of digital media evidence, and retention of PII. The International Association of Chiefs of Police (IACP) Aviation Committee

[35] Smith, Max. "Fairfax Co. delays drones for first responders over privacy concerns," *Fairfax County News.* August 1, 2018.
Frank, Michael. "Drone Privacy: Is Anyone in Charge," *Consumer Reports.* Last Updated: February 10, 2016.
[36] "Commercial Drone Alliance Opposes Aircraft Privacy and Transparency Act of 2017," Commercialdronealliance.org. March 29, 2017.
[37] "DC Circuit Denies EPIC's Petition, Will Not Mandate Privacy Rules for Drones," *Epic.org*. June 19, 2018.
[38] Privacy Impact Assessment for Remote Identification of Unmanned Aircraft Systems NPRM.

Recommended Guidelines for the Use of Unmanned Aircraft also touch on privacy. The FAA Reauthorization Act of 2018 also contains several privacy-related provisions.

In November 2019, ISO/TC 20/SC 16/WG 3 published ISO 21384-3:2019, *Unmanned Aircraft Systems – Part 3: Operational Procedures*. It includes brief discussions of data protection and privacy etiquette.

While not UAS-specific, there are a number of international standards related to information security management and the protection of PII that have been developed within ISO/IEC JTC1/SC 27, *IT Security techniques*. Work tends to focus on privacy enhancing technologies and data protection since "privacy" gets into cultural and social norms which differ around the world. WG5 on *Identity Management and Privacy Technologies* is the home for such work within SC27.

In-Development Standards: None have been identified.

Gap O1: Privacy. UAS-specific privacy regulations are needed as well as standards to enable the privacy framework. Privacy law and rulemaking related to UAS, including topics such as remote ID and tracking, are yet to be clearly defined.

R&D Needed: No

Recommendation: Develop UAS-specific privacy standards as needed and appropriate in response to the evolving policy landscape. Monitor the ongoing policy discussion.

Priority: Medium

Organization(s): Lawmakers, FAA, ISO/IEC JTC1/SC 27, ISO/TC 20/SC 16, APSAC, IACP

Status of Progress: Yellow

Update: The text has been updated to emphasize protecting the privacy and security of the UAS operator in accordance with applicable laws. Information on FAA's ADS-B PIA program has been noted. ISO 21384-3 has also been published. The gap statement has been tweaked to note that regulations are needed as well as standards to enable the privacy framework. The recommendation also has been tweaked.

7.2. Operational Risk Assessment (ORA)

Operational Risk Assessment (ORA) is applicable to all phases of aviation/aerospace life cycle management (pre-certification, during-certification, and post-certification or Continued Operational Safety). Managing risk in UAS operations is essential for airspace and public safety. There are multiple published documents related to airspace risk with varying levels of detail and UAS application. Published small UAS risk guidance is provided by ASTM, JARUS, and FAA CFR Title 14 Part 107. Various other published documents address risk associated with manned aircraft and airspace operations. This includes 14 CFR part 5, Safety Management Systems even though Part 5 addresses only Part 119 operators.

The risk framework for small UAS provided in current regulations and published standards is reasonably sufficient; however, there are three recommendations:

1) Existing standards and materials provide a framework for carrying out an ORA. As the industry evolves, UAS use cases and operations are introduced with specific associated airspace risks. The current standards provide a generic framework for addressing risk but the documents do not address all possible risks.

   Standards are being developed for use cases and operations such as beyond line of sight and standards associated with critical infrastructure. It is recommended that each new standard contains a section on risk that identifies the specific risks and risk mitigation steps associated with the use cases and operations. The risk section should be viewed as a supplement to the existing risk framework standards. Periodically, standards should be reviewed for commonality of risks. Risks that are common across use cases and operations standards should be reviewed for inclusion in the framework standards.

2) Existing framework standards provide risk mitigation not associated with safety risks[39] and are considered "other risks" in the JARUS WG-7 *RPAS Operational Categorization* document. As further described below, these are property, privacy, security, and environmental risks that should be addressed by supplementing existing standards and/or through policy.

   a. **Property** - To encourage UAS operators to follow proper rules for operations, authorities can implement measures such as restricting operations over private property and/or requiring some form of insurance to operate a UAS over property.
   b. **Privacy** - A common feature of small UAS is a camera or video recorder payload with either on-board storage or the ability to stream the content to the operator or third party. This means of surveillance is a disrupting factor to any real or perceived sense of privacy. This risk to privacy from UAS operations can be managed by regulations via operational limitations, limitations on design, or, in extreme instances, outright bans on UAS usage.
   c. **Security** - These are risks associated with motives of deliberate, malicious actors. In direct involvement, a remote pilot can purposefully fly a UA with the intention of causing harm to persons or property by controlled flight crash landing, through deliberate interference/distraction (e.g., distraction of motor vehicle operators), or

[39] Safety risks are addressed in documents such as JARUS WG-6 SORA, ASTM F3178-16, FAA – CFR Title 14 Part 107, Small UAS.

through carriage and dispatch of harmful items (e.g., munitions, chemicals). Indirect involvement includes instances of third-party takeover of a UAS (e.g., cyber threats) where control of the UA is either temporarily or permanently taken from the remote pilot. A routine outcome to this event would be loss of the UA. There is also additional risk that a UA that was overtaken could be used purposefully to crash into people/property on the ground, and other aircraft and airspace users.

d. **Environmental** - Nations may desire to protect sensitive and/or fragile local settings (e.g., national parks, housing developments) from ambient noise or other emissions created by UAS operations. National environmental strategies may also look to protect against ambient noise or emissions, but instead target comprehensive national outputs. These environmental risks may be managed by airspace restrictions and/or design requirements to contain noise or emissions.

Published Regulations, Standards, and Guidance Material:

UAS Risk Standards and Guidance Materials

- ACI UAS Pilots Code
- ACI Flight Safety in the Drone Age
- ASTM F3178-16, *Standard Practice for Operational Risk Assessment of Small Unmanned Aircraft Systems (sUAS)*
- FAA – CFR Title 14 Part 107, *Small Unmanned Aircraft Systems*
- FAA Order 8040.6 UAS Safety Risk Management Policy
- IEEE P1936.1, Standard for Drone Applications Framework
- JARUS *Recommendations for Unmanned Aircraft Systems (UAS) Category A & Category B Operations* JAR-DEL-WG2-D.04, 10/28/19
- JARUS *Guidelines on Specific Operations Risk Assessment (SORA)*, Edition 2.0, 30 Jan 2019, JAR-DEL-WG6-D.04
- NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*, calls for risk assessment on an operational basis.
- RTCA DO-320, *Operational Services and Environmental Definition (OSED) for Unmanned Aircraft Systems,* assesses and establishes operational, safety, performance, and interoperability requirements for UAS operations in the U.S. NAS.

Aviation Aircraft Risk Documents (will also apply to UAS)

- FAA – Order 8040-4B - *Safety Risk Management Policy, 5/2/2017*
- Air Traffic Organization (SMS) - *Safety Management System Manual, 7/2017*
- ASA – *Risk Management Handbook* – related to manned aircraft
- Small Airplane Risk Analysis (SARA) Handbook, 9/30/2010
- Transport Airplane Risk Assessment Methodology (TARAM) Handbook, 11/4/2011
- Monitor Safety/Analyze Data (MSAD) Order 8110.107
- Rotorcraft Risk Analysis Handbook, 6/15/2012

- Engine and Propeller Directorate Continued Airworthiness Assessment Process Handbook, 9/23/2010
- Continued Airworthiness Assessments Of Powerplant And Auxiliary Power Unit Installations Of Transport Category Airplanes, 9/8/2003
- Order 4040.26, Aircraft Certification Service Flight Test Risk Management Program, 1/31/2012
- Order 8110.54, Instructions for Continued Airworthiness Responsibilities, Requirements, and Contents, 10/23/2010
- SAE ARP4754A, *Guidelines for Development of Civil Aircraft and Systems*

In-Development Regulations, Standards, and Guidance Material: EUROCAE WG 105 is currently evaluating industry standards to support SORA objectives. In addition, the following work is underway:

- ASTM WK69335, *New Guide for Framework for Using ASTM Standards for UAS*. A commercial operator may, at their discretion, use this guide to aid their applications for regulatory approval; for example, when submitting a safety case as part of a Specific Operations Risk Assessment (SORA).
- SAE S-18 UAS WG is addressing Operational Risk Assessment and Mitigations as applicable to ARP4754 & ARP4761.

Gap O2: Operational Risk Assessment and Risk Mitigation. The existing risk framework of standards and regulations address small UAS. There are additional considerations for medium and large UAS that are not addressed in the existing small UAS framework. Traditional manned aviation analysis techniques may be applied effectively; however, the standards do not address all risks.

R&D Needed: Yes.

Recommendation: As use cases evolve, specific risks and associated risk mitigation strategies should be addressed in standards and/or policy including risks associated with property, privacy, security, and the environment.

Priority: High (Tier 1)

Organization(s): Standards bodies publishing UAS standards and/or regulators

Status of Progress: Green

Update: JARUS SORA 2.0 was published in 2019. Standards in development are noted in the text.

7.3. Beyond Visual Line of Sight (BVLOS)

Beyond visual line of sight (BVLOS) is required before the full capability of UAS can be realized by the drone industry. BVLOS operations are performed beyond the pilot's line of sight (as opposed to visual line of sight, or VLOS flights, which are performed within the pilot's line of sight). FAA's Part 107 does not currently allow for BVLOS operations. BVLOS or BVLOS (E), meaning extended visual line of sight operations, requires visual observers to track the UAS when it's not in direct visual range of the pilot operator.

Potential applications that would benefit from BVLOS operations are:

- Package Delivery
- Railroad/Pipeline/Power-line Inspections
- Critical Infrastructure Inspection
- Windmill Inspections
- Agriculture
- Remote Sensing/Mapping/Surveying
- Government/Public Applications
- Search & Rescue
- Firefighting/Public Safety

Published Standards: Despite the importance of BVLOS operations, there is only one published standard and a Best Practices Document (*Unmanned Systems Canada Small RPAS Beyond Visual Line of Sight (BVLOS) Best Practice*.

- ASTM F3196-18, *Standard Practice for Seeking Approval for Beyond Visual Line of Sight (BVLOS) Small Unmanned Aircraft System (sUAS) Operations*

In-Development Standards and Related Documents:

- ASTM has established AC 478 which is developing a BVLOS Strategic Plan for true BVLOS (i.e., those operations requiring a waiver for CFR 91.113) to be published as a Technical Report. The intent is to deconstruct/break down components standards and technologies required for BVLOS.
- ASTM WK62344, Revision of F3196 - 17 Standard Practice for Seeking Approval for Extended Visual Line of Sight (EVLOS) or Beyond Visual Line of Sight (BVLOS) Small Unmanned Aircraft System (sUAS) Operations
- ASTM WK63418, *New Specification for Service provided under UAS Traffic Management (UTM)*
- ASTM WK65041, *New Specification for UAS Remote ID and Tracking*

See also discussion of airworthiness considerations discussed in Chapter 6.

Gap O3: Beyond Visual Line of Sight (BVLOS). Although there is an existing BVLOS standard with supplemental revisions in the works and a best practices document, robust BVLOS operations will require a comprehensive DAA solution, Remote ID, and UTM infrastructure to be completely effective. Additional safety measures must be considered such as reduced limits on energy transfer; weight; speed; altitude; stand-off and redundant systems for power; collision avoidance; positioning; loss-of-control automatic soft landing; and methods for two-way communications between the competent operator and worker supervisor(s) or workers to ensure safety of BVLOS operations.

These standards should be addressed in a collaborative fashion. In addition, pilot competency and training is especially critical for BVLOS operations. It is anticipated that appendices for BVLOS will be added to ASTM F3266-18, *Standard Guide for Training Remote Pilots in Command of Unmanned Aircraft Systems (UAS) Endorsement*.

R&D Needed: Yes.

Recommendation: Complete work on aforementioned BVLOS standards and related documents in development and address for future consideration UAS including payloads larger than 55 pounds as defined in Part 107. Research is also required but more to the point connectivity is needed to ensure interoperability or compatibility between standards for BVLOS/DAA/Remote ID/UTM.

Priority: High (Tier 1)

Organization(s): ASTM

Status of Progress: Green

Update: As noted in the text.

7.4. Operations Over People (OOP)

Manned aircraft routinely fly over people since they comply with a standard airworthiness certification or a special airworthiness certificate (limited, restricted, experimental, etc.). Generally, UAS do not routinely receive certification at this time and require additional mitigations to gain approval for operations over people (OOP). Small UAS may require additional mitigations such as parachutes, risk assessments, and operational procedures.

There are a range of items that a manufacturer or operator of a UAS should take into account when trying to achieve OOP including aircraft design, construction, and risk mitigation devices. Combining safe operations with these considerations will increase the likelihood of achieving approval for OOP from a CAA to accommodate a wide variety of uses.

The recommended mitigations for OOP should vary according to the level and type of risk imposed on the public, which is affected by a wide variety of factors. These include population density under the route of flight, whether the UAS will operate in an access-controlled and protected area, or whether or not the people being flown over are participants in the mission or are non-participants. See also section 8.5 of this roadmap on workplace safety.

In determining the overall level of risk for flights over people, the totality of the circumstances should be considered, as opposed to a transmitted kinetic-energy-only based risk analysis. The totality of the circumstances includes: an operator's safe history of operations; enhanced pilot training and meeting current qualification requirements; a detailed CONOPS and ORA; the reliability of the vehicle; safety/design features of the vehicle; and a low probability of serious injury based on an analysis of relevant factors.

As confidence in the reliability of UAS platforms increases, the issues surrounding OOP will become as routine as manned aircraft OOP. See also the Design and Construction section of this document.

Published Standards and Related Documents: Despite the significance of operating over people there are currently no standards published that specifically address this topic.

Related published standards include:

- ASTM F3178-16, *Standard Practice for Operational Risk Assessment of Small Unmanned Aircraft Systems (sUAS)*
- ASTM F3322-18, *Standard Specification for Small Unmanned Aircraft System (sUAS) Parachutes*
- *JARUS Specific Operations Risk Assessment (SORA)*

In-Development Standards: Within ASTM F38.01, the following standards are being developed:

- ASTM WK56338, *New Test Method for Assessing the Safety of Small Unmanned Aircraft Impacts.* This is a test method to measure the potential for injury when a small unmanned aircraft hits a person on the ground using data from the ASSURE UAS Ground Collision Severity Evaluation Final Report
- ASTM WK65042, *New Specification for Operation Over People*, which deals with additional operational considerations when flying over people or populated areas.

Gap O4: UAS Operations Over People (OOP). There are no published standards for UAS OOP.

R&D Needed: No

Recommendation: Complete work on ASTM WK56338, *New Test Method for Assessing the Safety of Small Unmanned Aircraft Impacts* and ASTM WK65042, *New Specification for Operation Over People*.

Priority: High (Tier 1)

Organization(s): ASTM

Status of Progress: Green

Update: As noted in the text, ASTM F38 has two work items in development.

7.5. Weather

Meteorological weather data is critical to the safe and efficient use of the NAS. Weather data is an important component for flight planning, forecasting, ATM, data link, and overall aircraft operations. Improving the resiliency of the NAS to adverse weather conditions is a near term FAA NextGen objective. However, many UAS CONOPS are unlikely to be adequately covered by existing meteorological data acquisition, reporting, or forecasting methods. See also section 10.3 on UAS flight crew training.

Published Standards and Related Materials:

- SAE ARP5740, *Cockpit Display of Data Linked Weather Information* (2015)
- Advisory Circular AC 00-45H, Aviation Weather Services (2016)
- Advisory Circular AC 00-24C, Thunderstorms (2013)
- FMH-1, Surface Weather Observations and Reporting (2005)
- Advisory Circular 23.1419-2D, Certification of Part 23 Airplanes for Flight in Icing Conditions (2007)
- FAA Order JO 7930.2N, Notice to Airmen (2013)
- National Weather Service Policy Directive 10-8 (2016)
- FAA Order JO 7110.0Z, Flight Services (2018)
- ICAO Annex 3, Meteorological Services for International Air Navigation Part I and II (2016)
- World Meteorological Organization (WMO), GRIB-2
- RTCA DO-369, *Guidance for the Usage of Data Linked Forecast and Current Wind Information in Air Traffic Management (ATM) Operations*
- RTCA DO28-364, *Minimum Aviation System Performance Standards (MASPS) for Aeronautical Information/Meteorological Data Link Services*
  - RTCA DO-358A, *Minimum Operational Performance Standards (MOPS) for Flight Information Services - Broadcast (FIS-B) with Universal Access Transceiver (UAT)* was published 6/27/2019. It considers an equipment configuration consisting of the airborne processing and cockpit display of aeronautical and meteorological data known as FIS-B provided by the FAA. It does not address UAS or UAM.
- OGC 15-045r7 OGC MetOcean Application profile for WCS2.1: Part 0 - MetOcean Metadata (2020)
- OGC 15-108r3 OGC MetOcean Application profile for WCS2.1: Part 1 - MetOcean GetCorridor Extension (2020)
- OGC 17-086r3 OGC MetOcean Application profile for WCS2.1: Part 2 - MetOcean GetPolygon Extension (2020)
- OGC 17-089r1 OGC Web Coverage Service (WCS) Interface Standard – Core, version 2.1 (2018)
- EUROCONTROL, FAA, and UCAR, Weather Information Exchange Model (WXXM), version 2.1 (2015)
- AUVSI Trusted Operator Program™ (TOP) training protocols for remote pilots and training organizations

In-Development Standards: None have been identified.

Gap O5: UAS Operations and Weather. No published or in-development standards have been identified that adequately fill the need for flight planning, forecasting, and operating UAS (including data link and cockpit/flight deck displays), particularly in low altitude and/or boundary layer airspace.

Gaps have been identified related to two different facets of weather, and the related acquisition and dissemination of weather-related data, especially as it relates to BVLOS operations:

1) Weather requirements for flight operations of UAS. For example, to operate in airspace BVLOS, the aircraft must meet certain standards for weather robustness and resiliency, e.g., wind, icing, instrument meteorological conditions (IMC), etc.
2) Weather data standards themselves. Currently, published weather data standards by National Oceanic and Atmospheric Administration (NOAA), World Meteorological Organization (WMO), ICAO, and others do not have sufficient resolution (spatial and/or temporal) for certain types of UAS operations and have gaps in low altitude and boundary layer airspaces.

Other standardized delivery mechanisms for weather data exist, but the considerations must be made with respect to the computational processing power required on the aircraft or controller to use such data.

Additionally, standards for cockpit displays, data link, avionics, and voice protocols that involve, transmit, or display weather will need to be amended to apply to UAS (e.g., the 'cockpit display' in a UAS CS).

R&D Needed: Yes. Research should be conducted to determine the following:

1) For a given UAS CONOPS, what spatial and temporal resolution is required to adequately detect weather hazards to UAS in real-time and to forecast and flight plan the operation?
2) What are the applicable ways to replicate the capability of a 'flight deck display' in UAS C2 systems for the purpose of displaying meteorological information (and related data link communications with ATC)?
3) To what extent can boundary layer conditions be represented in existing binary data formats?
4) To what extent can current meteorological data acquisition infrastructure (e.g., ground-based weather radar) capture data relevant to UAS operations, particularly in low altitude airspace?
5) What weather data and data link connectivity would be required to support fully autonomous UAS operations with no human operator in the loop?
6) What is the highest temporal resolution currently possible with existing or proposed meteorological measurement infrastructure?
7) To what extent do operators need to consider that weather systems have different natural scales in both space and time, depending on whether the weather systems occur in polar, mid-latitude, or tropical conditions?

Recommendation: Encourage relevant research, amending of existing standards, and drafting of new standards (where applicable).

Priority: High (Tier 2)

Organization(s): RTCA, SAE, NOAA, WMO, NASA, universities, National Science Foundation (NSF) National Center for Atmospheric Research (NCAR), ASTM

Status of Progress: Yellow

Update: NASA UTM Weather Advisory Group is conducting a bottom-up review of weather capabilities, gaps and research needs that may address R&D needs identified, or new ones not yet identified. ASTM F38 is moving forward with a recommendation to the board to consider the addition of a Weather Sub-Group to address amending of existing standards and drafting of new standards.

7.6. Data Handling and Processing

UAS operations involve the use of a range of different sensors to conduct real-time observations to support a variety of operational scenarios/use cases including traffic incident response, wildfire management, pipeline/utilities infrastructure inspection, volcanic ash monitoring, wildlife tracking, and urban planning. All of this information is inherently location-based. Ample standards exist to support collection, processing, communication/distribution, and application of location-based observations captured from UASs via a variety of sensors; however, varying standards "architectures" will be required to support efficient UAS operations. Further, the ability to capture and process UAS telemetry with sensor observations is critically important to assure proper location referencing of observations.

Published Standards: The following data handing and processing standards are relevant:

- OGC Web Processing Service (WPS) 2.0 Interface Standard – allows the insertion of processing algorithms on board the UAS or anywhere in a workflow to support the processing of sensor observations to support the end user, or the next application in a workflow
- OGC LAS Specification 1.4, OGC Community Standard – represents a standardized file format for the interchange of 3-dimensional point cloud data between data users
- OGC GML in JPEG 2000 for Geographic Imagery Encoding Standard – defines the use of OGC GML in encoding imagery in JPEG 2000 format
- OGC Wide Area Motion Imagery (WAMI) Best Practice – recommends a set of Web service interfaces for the dissemination of Wide Area Motion Imagery (WAMI) products
- WXXM – Weather Information Exchange Model (WXXM)
- OGC 12-000, *OGC Sensor Model Language (SensorML):Model and XML Encoding Standard (v2)*
- OGC 12-006, *OGC Sensor Observation Service Interface Standard (v2)*
- OGC 09-000, *OGC Sensor Planning Service Implementation (v2)*
- OGC 10-025r1, *Observations and Measurements - XML Implementation (v2)*

- OGC 15-078r6, *OGC SensorThings API Part 1: Sensing (v1)*
- OGC 06-103r4, *OpenGIS Implementation Standard for Geographic information - Simple feature access - Part 1: Common architecture (v1.2.1)* (also ISO 19125-1:2004)
- OGC 07-036r1, *OGC Geography Markup Language (GML) — Extended schemas and encoding rules (v3.2)* (also ISO 19136:2007)
- OGC 12-007r2, *KML 2.3 (v1)*
- OGC 06-042, *OpenGIS Web Map Server Implementation Specification (v1.3)* (also ISO 19128:2005)
- OGC 07-057r7, *OpenGIS Web Map Tile Service Implementation Standard (v1)*
- OGC 09-110r3, *OGC Web Coverage Service (WCS) 2.0 Interface Standard - Core (v2)*
- OGC 09-11or4, *OGC Web Coverage Service (WCS) 2.0 Interface Standard- Core: Corrigendum (v2.0.1)*
- OGC 09-146r6, *OGC Coverage Implementation Schema (v1.1)*
- OGC GeoTIFF (v1.1). Geostationary Earth Orbit Tagged Image File Format (GeoTIFF) is used throughout the geospatial and earth science communities to share geographic image data. GeoTIFF was adopted as an OGC standard in 2019.

In-Development Standards:

- OGC is advancing best practices through its UxS DWG and through a series of ongoing interoperability pilot activities.
- IEEE P1937.3, *Protocol for the Flight Data Transmission of Civil Unmanned Aerial Vehicle Based on BeiDou Short Message*

Gap O6: UAS Data Handling and Processing. Given the myriad of UAS “observation” missions in support of public safety, law enforcement, urban planning, construction, and a range of other applications, and given the diversity of standards applicable to the UAS lifecycle, a compilation of best practices is needed to identify standards-based “architectural guidance” for different UAS operations.

R&D Needed: No R&D should be required, as community examples already exist. However, interoperability piloting of recommended architectures with the user community based on priority use cases/scenarios is recommended.

Recommendation: Develop an informative technical report to provide architectural guidance for data handling and processing to assist with different UAS operations.

Priority: Medium

Organization(s): OGC, ISO TC/211

Status of Progress: Green

Update: As noted in the text, the OGC GeoTIFF standard was adopted as an OGC standard in 2019, and best practices are in development in OGC UxS DWG.

7.7. UAS Traffic Management (UTM)

The term "UTM" refers to a set of federated services and an all-encompassing framework for managing multiple UAS operations. In Europe, the idea of 'U-space' extends the UTM services to include manned aircraft and new concepts in air mobility. These services are separate, but complementary to those provided by the ATM system, and are based primarily on the sharing of information between operators on flight intent and airspace constraints. UTM can offer services for flight planning, communications, separation, and weather, among others.

UTM is a community-based traffic management system, where the operators and UAS Service Suppliers are responsible for the coordination, execution, and management of all UAS flights, within the regulatory and procedural guidelines established by FAA. This federated set of services enables the management of simultaneous operations by multiple UAS operators, facilitated by third-party support providers through networked information exchanges.

The FAA UTM ConOps V2.0 is focused on UTM operations below 400 feet above ground level (AGL), but introduces increasingly more complex operations within both uncontrolled (Class G) and controlled (Classes B, C, D, E) airspace environments. ConOps V2.0 updates and expands the following:

- operational scenarios, describing more complex operations in denser airspace, including beyond visual line of sight (BVLOS) operations in controlled airspace;
- descriptions of/approaches to several UTM components, including UAS volume reservations (previously referred to as dynamic restrictions), performance authorizations, data archiving and access, USS service categories, UTM/ATM contingency notification, and security aspects associated with UTM operations; and
- new topics including airspace authorization for BVLOS flight within controlled airspace, UTM architecture support to remote identification of UAS operators, and standards development efforts with industry as an integral part of enabling UTM operations.

FAA UTM ConOps V2 describes essential conceptual and operational elements associated with UTM to inform the development of solutions necessary to implement UTM. The ConOps also supports a spiral development approach – maturing the concept through analysis of more complex airspace environments, tested and validated by field demonstrations, including National Aeronautics and Space

Administration (NASA) Technology Capability Level (TCL), FAA UTM Pilot Program (UPP), and UAS Integration Pilot Program (IPP) demonstrations.[40]

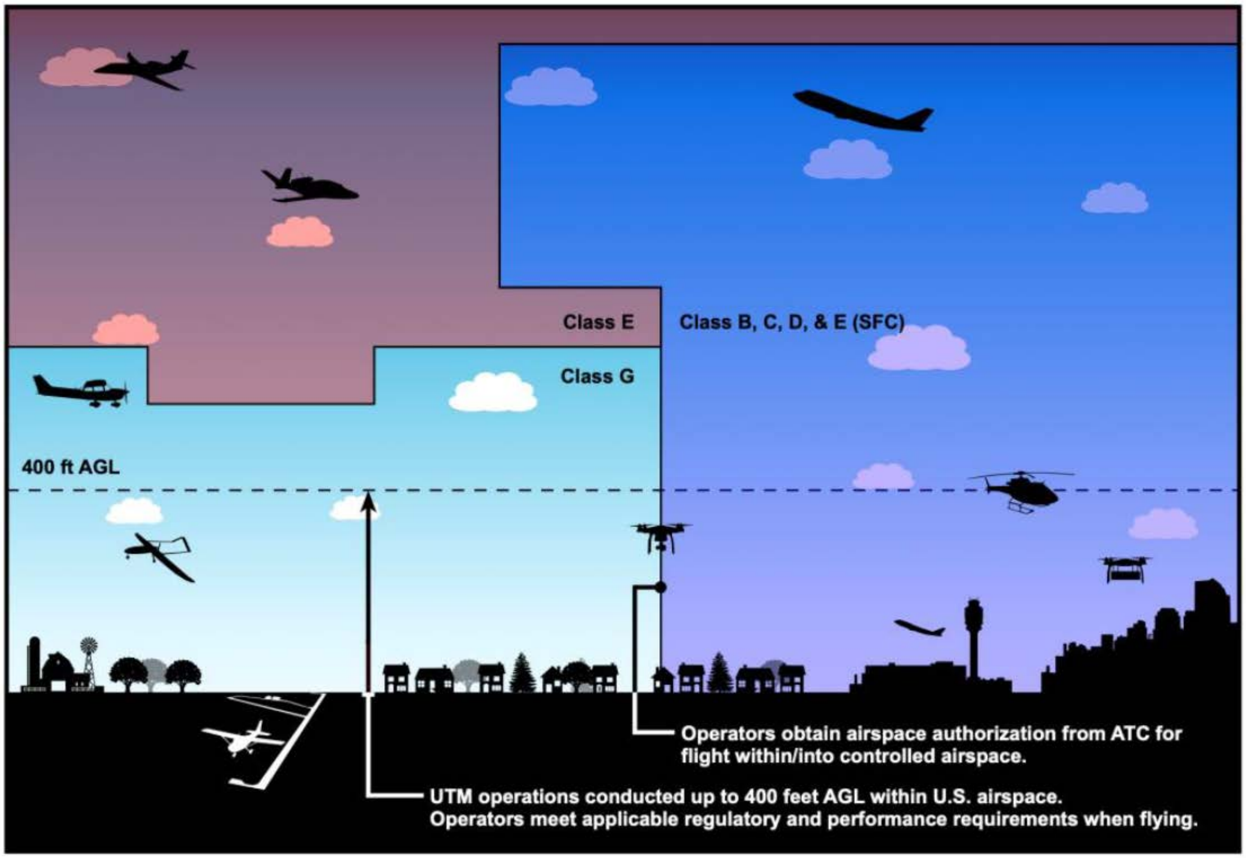


Figure 2: UTM Operations in Context of Airspace Classes[41]

[40] Source: FAA's UTM ConOps v2 dated 2 March 2020, Executive Summary, page xi
[41] Source: FAA's UTM ConOps v2 dated 2 March 2020, page 5

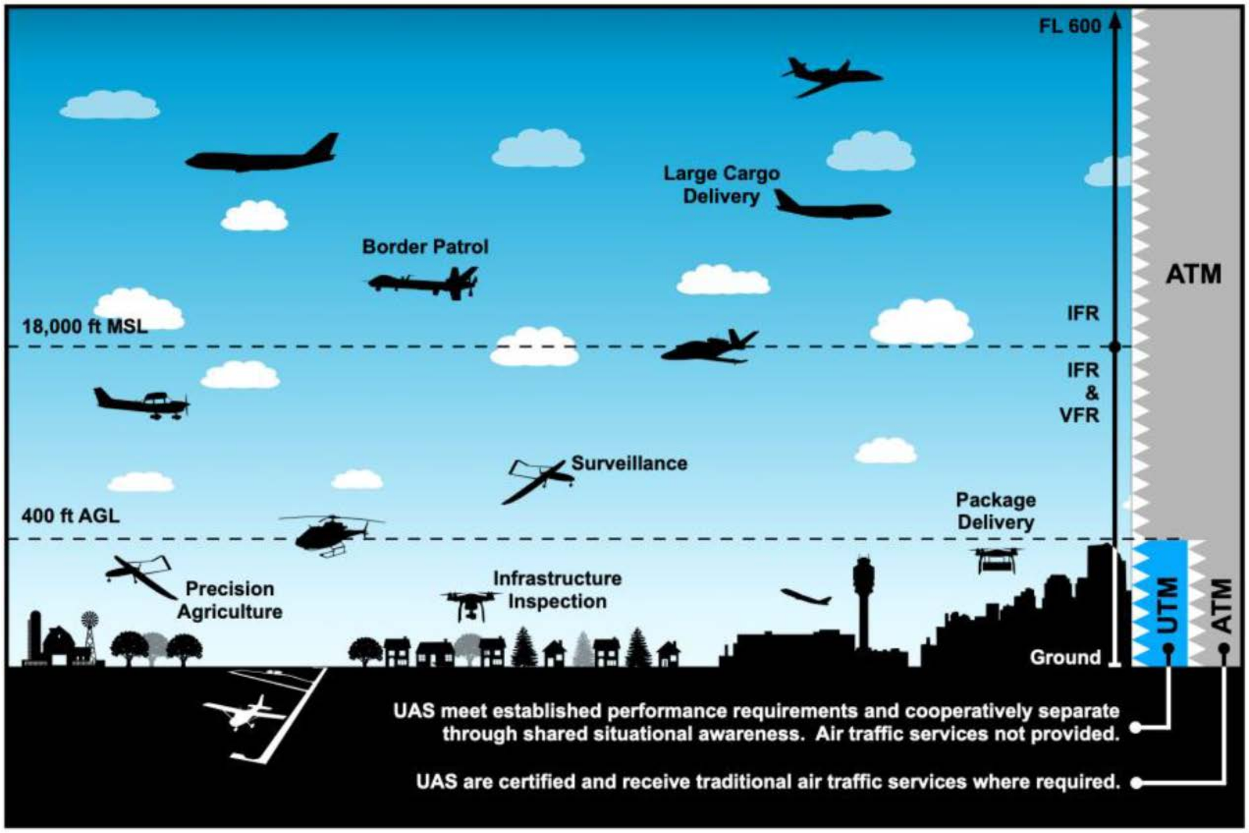


Figure 3: Operational Context of UTM Services[42]

Figure 4 depicts a notional UTM architecture that visually identifies at a high level, the various actors and components, their contextual relationships, as well as high level functions and information flows.

[42] Source: FAA's UTM ConOps v2 dated 2 March 2020, page 13

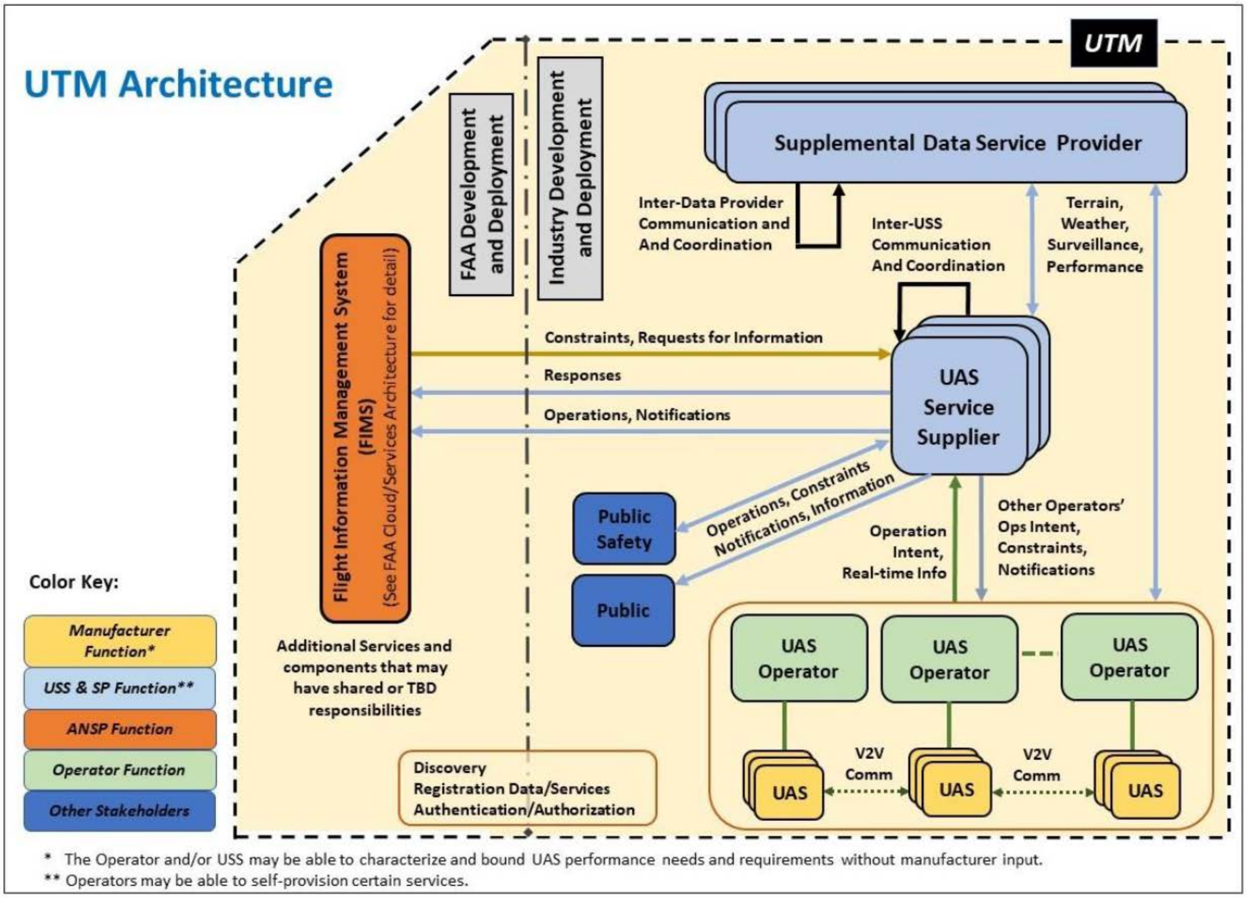


Figure 4: Notional UTM Architecture[43]

Allocation of Responsibilities

Table 6 summarizes roles and responsibilities of the UAS Operator, USS, and FAA associated with a UTM operation.

[43] Source: FAA's UTM ConOps v2 dated 2 March 2020, page 9

Table 4: Allocation of Responsibilities for UTM Actors/Entities[44]

Function		Actors/Entities (✓ = Primary responsibility; S = Support)		
		UAS Operator	USS	FAA
Separation	UAS from UAS (VLOS and BVLOS)	✓	S	
Separation	VLOS UAS from Low-Altitude Manned Aircraft	✓	S	
Separation	BVLOS UAS from Low-Altitude Manned Aircraft [1]	✓	S	
Hazard/ Terrain Avoidance	Weather Avoidance	✓	S	
Hazard/ Terrain Avoidance	Terrain Avoidance	✓	S	
Hazard/ Terrain Avoidance	Obstacle Avoidance	✓	S	
Status	UTM Operations Status	S	✓	
Status	Flight Information Archive	✓	S	
Status	Flight Information Status	✓	S	
Advisories	Weather Information	✓	S	
Advisories	Alerts to Affected Airspace Users of UAS Hazard	✓	S	
Advisories	Hazard Information (e.g., obstacles, terrain)	✓	S	
Advisories	UAS-Specific Hazard Information (e.g., Power-Lines, No-UAS Zones)	✓	S	
Planning, Intent & Authorization	Operation Plan Development	✓	S	
Planning, Intent & Authorization	Operation Intent Sharing (pre-flight)	✓	S	
Planning, Intent & Authorization	Operation Intent Sharing (in-flight)	✓	S	
Planning, Intent & Authorization	Operation Intent Negotiation	✓	S	
Planning, Intent & Authorization	Controlled Airspace Authorization		S	✓
Planning, Intent & Authorization	Control of Flight	✓		
Planning, Intent & Authorization	Airspace Allocation & Constraints Definition		S	✓

[1] Manned aircraft pilots share some responsibility for separation with UAS BVLOS operations (see Section 2.7.1.2).

A UAS Service Supplier (USS) acts as a communications bridge between UAS operators and the local air navigation service provider (ANSP), i.e., air traffic management system. When necessary, a collection of USSs can form a USS Network to collaboratively manage UTM airspace by sharing data and adhering to a

[44] [44] Source: FAA's UTM ConOps v2 dated 2 March 2020, page 20

standard or set of standards required to participate in a USS Network. The ConOps Appendix D – UTM Services, Table D-1, provides a list of UTM services that have been addressed or identified in this document. This list is not exhaustive. Additional services may be developed as required.[45]

In addition to the USS services listed in Appendix D of FAA UTM ConOps v2.0, there are some foundational UTM requirements that include registration and identification of UAS prior to them being eligible/allowed to participate in UTM and use USS services.

The [Federal Aviation Administration (FAA) Extension, Safety and Security Act of 2016](https://www.faa.gov) (PDF) established the UTM Pilot Program (UPP) to define an initial set of industry and FAA capabilities required to support UTM operations.[46]

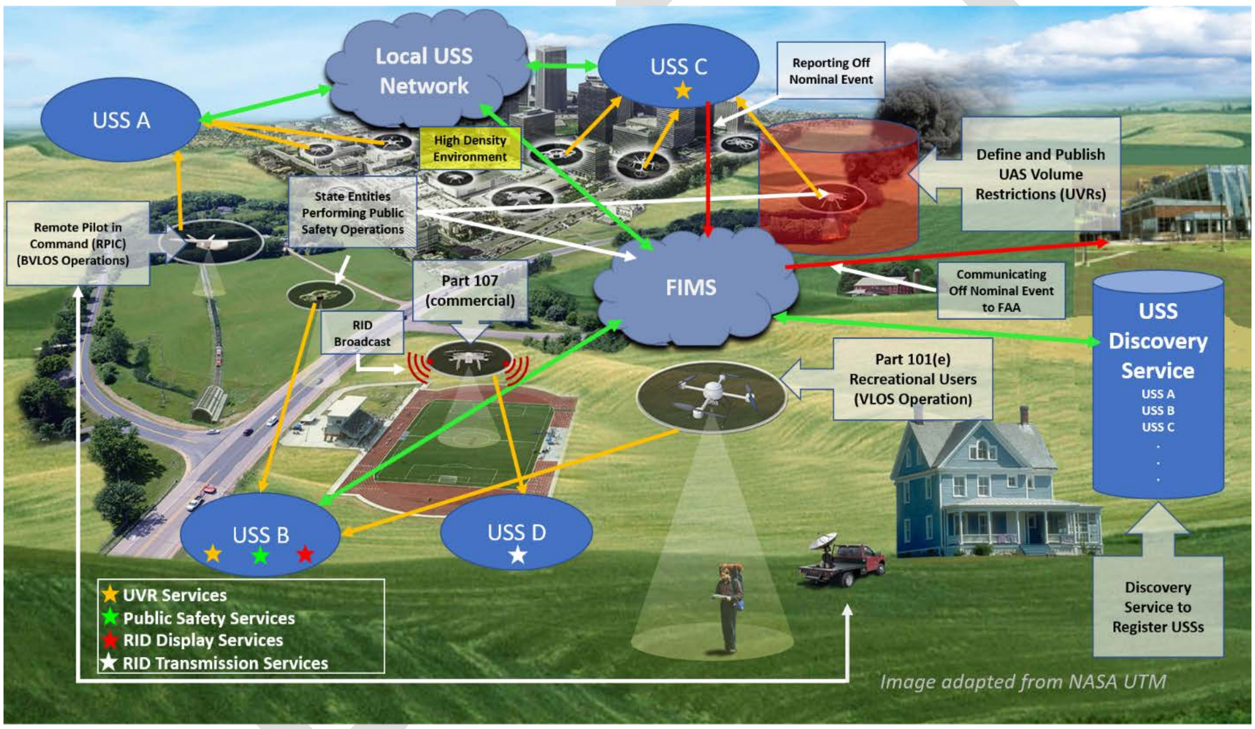


Figure 5: UPP High-Level Operational Concept[47]

NASA is leading the development of a UTM system in the United States, while the Single European Sky ATM Research Joint Undertaking (SESAR JU) is advancing the comparable U-space initiative in Europe. It is the desire of CAAs around the world to be able to use UTM/U-space services as mitigations to the risks inherent in UAS operations. However, without standards that define the level to which these services

[45] Appendix D – UTM Services, FAA UTM ConOps V2.0 dated 2 March 2020, pages 65-66
[46] Source: https://www.faa.gov/uas/research_development/traffic_management/utm_pilot_program/
[47] Source: https://www.faa.gov/uas/research_development/traffic_management/utm_pilot_program/

are effective, it is impossible to quantify the amount of risk mitigation an operator can claim when using a UTM/U-space service.

Published Standards: Despite a large number of top-level strategic discussions on the topic of what UTM and U-space are intended to provide, there are no published standards that define the expected level of performance for any of the services in the proposed ecosystem. That said, there are published data exchange formats (interoperability standards) for limited UTM services such as remote identification and strategic separation that enable the federated UTM ecosystem which have been successfully demonstrated in numerous flight tests events around the world. While interoperability standards, such as a data interface control document (ICD) or application programming interface (API), are necessary standards, additionally the industry needs performance standards. Both interoperability standards and performance standards are needed for each UTM service or function listed in Table 6.

In-Development Standards:

ASTM: Work includes:

- ASTM WK63418, *New Specification for Service provided under UAS Traffic Management (UTM)*
- ASTM WK69690, *Specification for Surveillance UTM Supplemental Data Service Provider (SDSP) Performance*

IEEE: Work includes:

- IEEE P1939.1, *Standard for a Framework for Structuring Low Altitude Airspace for Unmanned Aerial Vehicle (UAV) Operations*

ISO: ISO/TC 20/SC 16/WG 4 on UAS Traffic Management has been created. Work includes:

- ISO/CD TR 23629-1, *UAS Traffic Management (UTM) -- Part 1: General requirements for UTM -- Survey results on UTM.*
- ISO/NP 23629-5, *UAS traffic management (UTM) — Part 5: UTM functional structure*
- ISO/CD 23629-7, *UAS traffic management (UTM) – Part 7: Data model for spatial data*
- ISO/PWI 23629-8, *UAS Traffic Management (UTM) — Part 8: Remote identification*
- ISO/NP 23629-12, *UAS traffic management (UTM) — Part 12: Requirements for UTM services and service providers*

EUROCAE: A WG has been established to support UTM standards. The Geofence/GeoCage group released minimum operational performance requirements to an Open Consultation (closed 18 January, 2020).

RTCA: There is no activity.

SAE:

- G-31 Electronic Transactions for Aerospace Committee
  - AIR7501, Digital Data Standards in Aircraft Life Cycle
  - ARP6823, Electronic Transactions for Aerospace Systems; An Overview
  - ARP6984, Determination of Cost Benefits from Implementing a Blockchain Solution

GUTMA, while not an SDO, has been active in defining the data exchange formats and thus has been contributing to standards in some regards.

While the activity in this area from traditional SDOs has been minimal, there is growing awareness among regulators and JARUS that a performance standard void exists. NASA and the FAA have a Research Transition Team in place and they are also aware that performance-based standards require development. JARUS is taking up a more active role in identifying standards and regulatory gaps associated with UTM/ATM integration in 2020.

Gap O7: UTM Services Performance Standards. UTM service performance standards are needed.

R&D Needed: Yes. Considerable work remains to develop the various USS services listed as well as testing to quantify the level of mitigation they provide. Only after some level of flight testing to define the "realm of the possible" can the community of interest write performance-based standards that are both achievable and effective in mitigating operational risk.

Recommendation: There is quite a lot of work for any one SDO. A significant challenge is finding individuals with the technical competence and flight experience needed to fully address the subject. What is needed is direction to adopt the performance standards and associated interoperability standards evolving from the research/flight demonstrations being performed by the research community (e.g., NASA/FAA RTT, FAA UTM Pilot Project, UAS Test Sites, GUTMA, etc.). Given a draft standard developed by the experts in the field (i.e., the ones actively engaged in doing the research), SDOs can apply their expertise in defining testable and relevant interoperability and performance-based requirements and thus quickly converge to published standards.

Priority: High (Tier 2)

Organization(s): NASA, FAA, ASTM, ISO, IEEE, EUROCAE, JARUS

Status of Progress: Green

Update: As noted above, new activity is underway in ASTM, IEEE, ISO, EUROCAE, and JARUS.

7.8. UAS Remote Identification (UAS Remote ID)

The FAA maintains a website that outlines requirements for UAS Remote Identification. It describes how the agency is working with stakeholders regarding UAS Remote Identification as follows below:

UAS Remote Identification

Drones or unmanned aircraft systems (UAS) are fundamentally changing aviation, and the FAA is committed to working to fully integrate drones or UAS into the National Airspace System (NAS). Safety and security are top priorities for the FAA and Remote Identification (Remote ID) of UAS is crucial to our integration efforts.

What is Remote ID?
Remote ID is the ability of a UAS in flight to provide identification information that can be received by other parties.

Why Do We Need Remote ID?
Remote ID would assist the FAA, law enforcement, and Federal security agencies when a UAS appears to be flying in an unsafe manner or where the drone is not allowed to fly.

The development of Remote ID builds on the framework established by the small UAS registration rule (PDF) and the LAANC capability to lay the foundation of an Unmanned Aircraft System Traffic Management System (UTM) that is scalable to the national airspace.

Notice of Proposed Rule Making:
The Remote Identification proposed rule provides a framework for remote identification of all UAS operating in the airspace of the United States. The rule would facilitate the collection and storage of certain data such as identity, location, and altitude regarding an unmanned aircraft and its control station.

The comment period for FAA's published the notice of proposed rulemaking on remote identification closed on March 2, 2020. The docket number on https://www.regulations.gov is **FAA-2019-1100**.

Remote ID Cohort:
The goal of the FAA Remote ID Cohort is to develop the technology requirements applicable to FAA qualified remote ID UAS service suppliers.

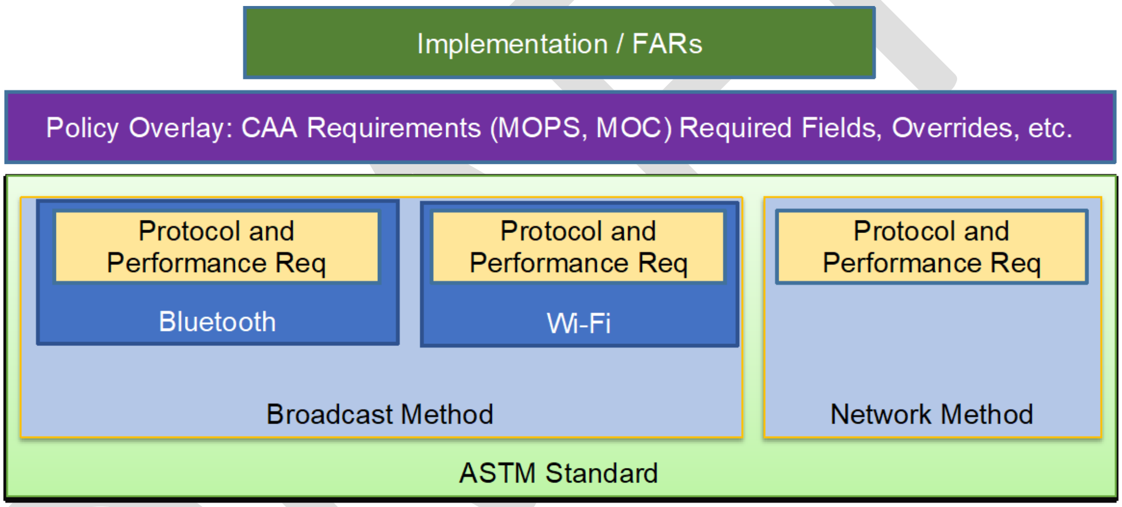
What's next?
Remote ID is the next step to enable safe, routine drone operations across our nation. This capability will enhance safety and security by allowing the FAA, law enforcement, and Federal security agencies to identify drones flying in their jurisdiction.

What has the FAA done?
In December 2018, the FAA issued a Request for Information (RFI) to establish an industry cohort to explore potential technological solutions for Remote ID.

The UAS Identification and Tracking Aviation Rulemaking Committee (ARC), chartered by the FAA in June 2017, submitted its report and recommendations (PDF) to the agency on technologies available to identify and track drones in flight and other associated issues.[48]

Published Standards and Related Materials:

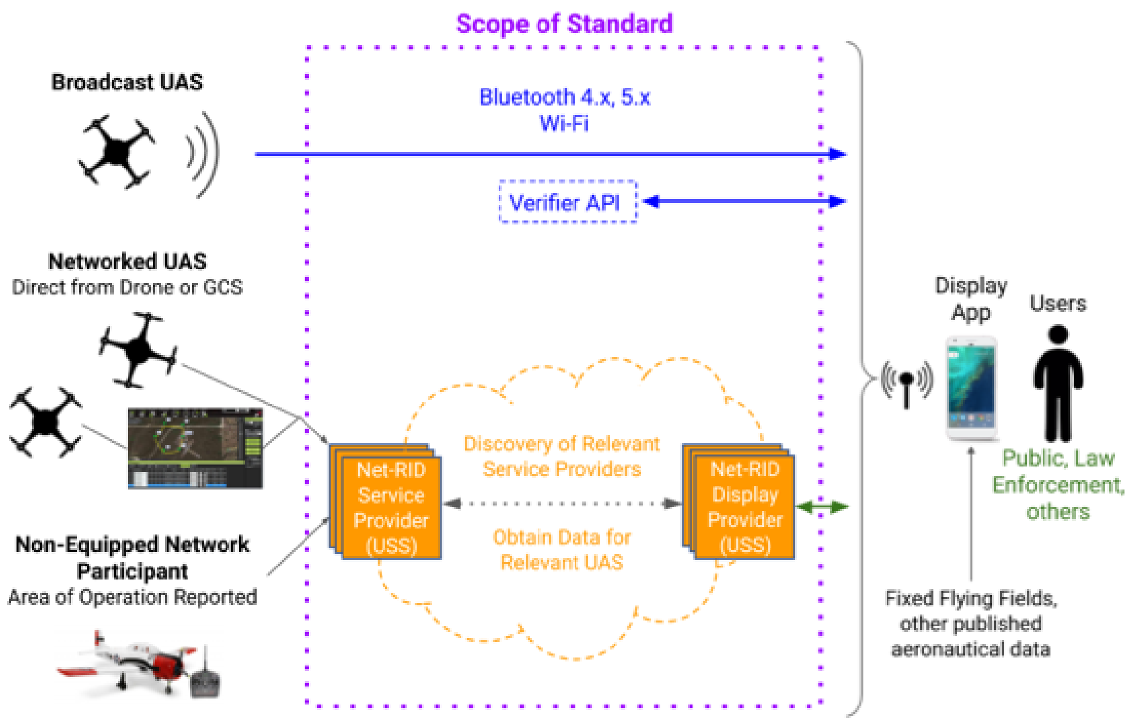
- ASTM F3411-19, *Standard Specification for Remote ID and Tracking*, published February 2020.
  ASTM Remote ID Standard Overview: The ASTM Remote ID Standard is comprehensive of both broadcast and network remote ID methods. It provides a series of technical options from which regulators can choose and provide an "overlay' (MOC, MOPS, AC, etc.) of options that the regulator would like to be required.



This standard was created with inputs from the FAA UAS ID and Tracking ARC report, and many industry, academic, and public stakeholders.

The scope of the standard is focused on interoperability between broadcasters and receivers and participants in the network remote ID federation.

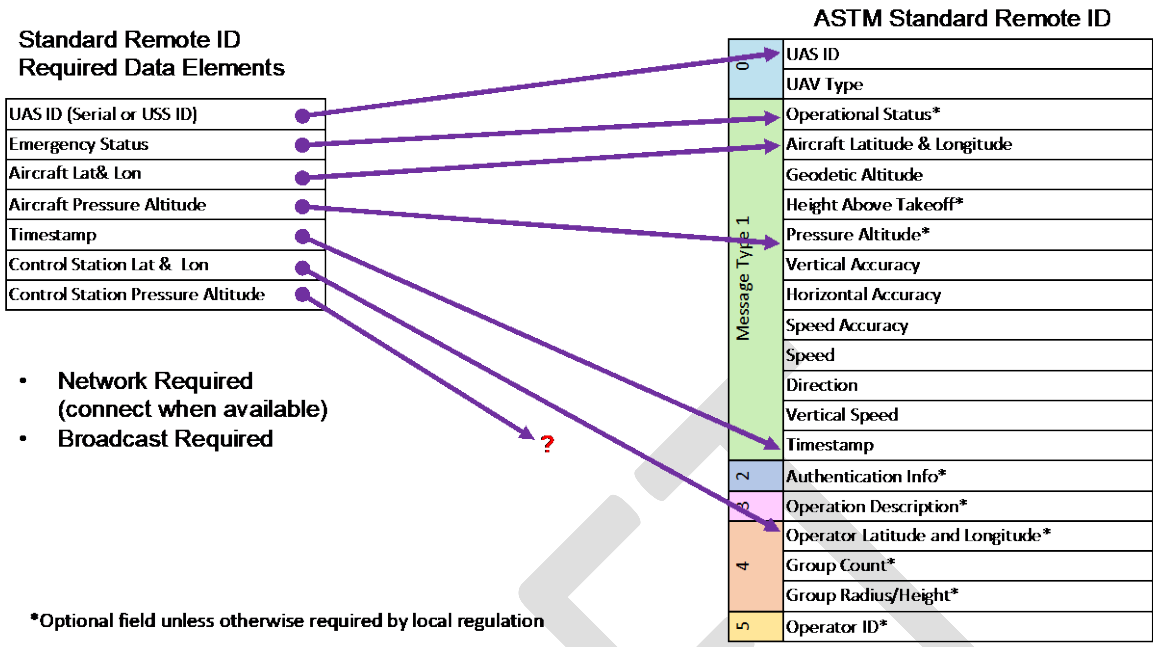
[48] Preceding text taken from FAA UAS Remote Identification webpage https://www.faa.gov/uas/research_development/remote_id/), accessed March 19, 2020



The standard has the following points of alignment with the NPRM:

- Made to be compatible with Handheld Devices
- Network and Broadcast are specified
- Broadcast uses unlicensed spectrum
- Superset of *most* data elements required by the FAA
- NPRM updates registration requirements to go from 1:Many to 1:1
- The ANSI/CTA 2063-A S/N becomes the “primary key” linking to registration record.
- USS ID option to link to registration info.

The following field mappings illustrate the NPRM synergy with the fields pointed out in the standard.



- Open Source Enablement of the ASTM Remote ID Standard**:**
    - The Open Drone ID project has evolved to primarily be open source repository and information for implementations of the ASTM Remote ID Standard (including broadcast implementations).
      https://www.opendroneid.org
      https://github.com/opendroneid
    - The Interuss project provides open source network remote ID implementations of the ASTM Remote ID standard:
      https://github.com/interuss/dss
- ATIS-I-0000060, *Unmanned Aerial Vehicle (UAV) Utilization of Cellular Services – Enabling Scalable and Safe Operation (white paper)*
- ATIS-I-0000069, *Support for UAV Communications in 3GPP Cellular Standards (technical report).*
- 3GPP UAS Remote ID: The normative 3GPP service requirements for “UAS ID” from the North American market were defined by 3GPP SA1 in release 16, and the 3GPP technical solutions will be defined in release 17.
- ANSI/CTA-2063-A, *Small Unmanned Aerial Systems Serial Numbers,* September 2019 The ASTM Remote ID Standard uses this standard for encoding serial numbers and this standard has been referenced by the FAA NPRM as well as the EU delegated act.

In-Development Standards and Related Materials:

- ASTM F3411-19, *Standard Specification for Remote ID and Tracking*:
    - The standard generally applies to aircraft typically operating at lower altitudes.
    - The standard will be revise as needed to align with the final rule.

  - There are minor differences with the NPRM, but the standard will not be updated until issuance of the final rule.

- 3GPP WI810049 Release 16, *Feasibility Study and Work Item on Remote Identification of Unmanned Aerial Systems*. Ubiquitous coverage, high reliability and QoS, robust security, and seamless mobility are critical factors in supporting UAS C2 functions. 3GPP SA1 has completed a feasibility study with potential requirements and use cases for remote ID and the services that can be offered based on remote ID. A normative work item to implement these requirements has been approved. The next steps in 3GPP are to complete requirements and protocol specifications to support remote ID of UAS. The ongoing Release 17 3GPP specification work is applicable to both 4G and 5G systems.
- EUROCAE - Minimum Operational Performance Specification (MOPS) for UAS e-identification
- ASD-STAN – Developing the CE mark standard for Remote ID. ASTM is currently working with them.

Gap O8: Remote ID and Tracking: Direct Broadcast. Standards are needed for transmitting UAS ID and tracking data with no specific destination or recipient, and not dependent on a communications network to carry the data. Current direct broadcast standards for aviation and telecommunications applications do not specifically address UAS operations, including secure UAS ID, authentication, and tracking capabilities, and specifically when UAS operations are conducted outside ATC.

R&D Needed: No

Recommendation:

1) Revise published ASTM Remote ID standard once UAS Remote ID Rule is finalized.
2) Continue development of the Open Source implementations and enablement.
3) Continue development of 3GPP specs and ATIS standards to support direct communication broadcast of UAS ID and tracking data with or without the presence of a 4G or 5G cellular network.

Priority: High (Tier 1)

Organization(s): ASTM, 3GPP, ATIS

Status of Progress: Green

Update: As noted in the text, ASTM F3411 has been published. It addresses the specific concerns outlined in the gap statement. It will be revised as needed once the FAA final rule on remote ID is issued. Other standards are in development as noted in the text.

Gap O9: Remote ID and Tracking: Network Publishing. Standards are needed for secure UAS ID, authentication, and tracking data transmitted over a secure communications network (e.g., cellular, satellite, other) to a specific destination or recipient. Current manned aviation standards do not extend to the notion of transmitting UAS ID and tracking data over an established secure communications network to an internet service or group of services, specifically the cellular and satellite networks and cloud-based services. Nor do they describe how that data is received by and/or accessed from an FAA-approved internet-based database.

R&D Needed: Yes

Recommendation:

1) Revise the published ASTM Remote ID standard and other applicable standards once UAS Remote ID Rule is finalized.
2) Continue the "FAA cohort" implementation efforts to stand up initial remote ID system with appropriate data exchanges between the Remote ID Federation and the FAA.
3) Continue development of 3GPP specs and ATIS standards related to remote ID of UAS and UTM support over cellular or satellite networks.

Priority: High (Tier 1)

Organization(s): ASTM, FAA, 3GPP, ATIS

Status of Progress: Green

Update: As noted in the text, ASTM F3411 has been published. It includes network remote ID that covers most of the issues raised in the gap statement (except FAA access). Other standards are in development as noted in the text.

7.9. Geo-fencing

This section describes geo-fencing and the exchange of geo-fence data and actions to be taken by an aircraft and/or operator upon approaching or intersecting a geo-fence. Note that various standardizing bodies have variable terminology for geo-fence, geo-fence, geo-limit, geographical limitation, etc., and consider the "geo-awareness" of the UAS in the context of the terminology.

Operation of UA includes consideration of actions or policies related to boundaries referenced to the Earth. For instance, no-fly zones are typically mapped to specific boundaries relative to the ground and often by altitude above the ground surface. These boundaries are commonly referred to as "geo-fences" and describe a threshold over which an aircraft must take an action (including not to cross that threshold). Geo-fences may be described in a number of ways ranging from a sequence of coordinates to a text description of an outline to a digital representation of geographic information. For UAS operations, the geo-fence should be represented in a consistent and standardized fashion as digital data, which the aircraft and/or operational controls can reference and against which the aircraft location can be inspected.

Geo-fences can be static, time-limited, and/or move/reshape with time. For instance, no-fly zones may be permanent and fixed (such as around a military installation) or defined for a specific amount of time (such as when a dignitary is at a location). Further, a geo-fence may also be established around a moving object (such as an aircraft or a motorcade transporting a dignitary).

Geo-fencing has long been a core function of geographic information systems and is commonly used in the logistics and transportation industries. Geo-fencing is also used (albeit with different nomenclature) in ATC. However, with autonomous UAS or UAS operators often ignorant of restricted airspaces, geo-fences need to be provisioned to the aircraft or control systems and the aircraft or operator should receive appropriate guidance when approaching or crossing a geo-fence.

Geo-fences, particularly as no-fly zones, have long been defined by aviation authorities. Existing FAA, Eurocontrol, and defense standards allow for the defining of some types of geo-fences. EUROCAE WG-105 (Unmanned Aircraft Systems) is also accessing standardization targets for geo-caging.

Published Standards: The following geospatial standards are relevant for defining, disseminating, and interacting with geo-fences:

- OGC 06-103r4, *OpenGIS® Implementation Standard for Geographic* information *- Simple feature access - Part 1: Common architecture v. 1.2.1* (also ISO 19125) - Describes a common model for describing geographic features in encodings and databases
- OGC 07-036r1, *OpenGIS® Geography Markup Language (GML) Encoding Standard v. 3.2.2* - An XML encoding of geographic features, including 3D features
- OGC 12-007r2, *OGC KML v. 2.3* - A simple and widely-implemented encoding of geographic features
- IETF 7946, *The GeoJSON Format* - Another simple and widely-implemented encoding of geographic features
- OGC 09-025r1, *OpenGIS Web Feature Service (WFS) 2.0 Interface Standard* (also ISO 19142) - A service for web-provision of feature data, primarily as GML. Note that OGC has issued a corrigendum (OGC 09-025r2) and that the previous version of WFS (OGC 04-094r1) is more widely implemented.
- OGC 15-078r6, *OGC SensorThings API Part 1: Sensing* – A very simple interface to sensor observations
- OGC 12-006, *OGC® Sensor Observation Service Interface Standard* - Web service of interoperable sensor observations
- OGC 16-120r3, *OGC Moving Features Access* - Methods for retrieving information regarding moving features, including attributes and trajectory. Other related moving features encoding standards (OGC 14-083r2 and OGC 14-084r2) are also relevant.

- OGC 17-069r3, *OGC API – Features – Part 1: Core* – most current OGC standard for serving feature data through a Web API.
- ISO 21384-3:2019, *Unmanned Aircraft Systems – Part 3: Operational Procedures*

In-Development Standards:

- EUROCAE: Minimum Operational Performance Standard for UAS geo- caging
- EUROCAE: Draft ED 269, Minimum Operational Performance Specification for UAS geo-fencing

Gap O10: Geo-fence Exchange. Standards have been developed (or are in development) to provide a consistent description of the limits of a geo-fence. Standards also exist to define and encode the geometry for a geo-fence. However, a new standard or a profile of an existing standard is needed to exchange geo-fence data. This standard must encode the attributes of a geo-fence necessary for UAS operators or autonomous systems to respond to the proximity of a geo-fence.

R&D Needed: Minimal. The encoding mechanism should reply upon existing standards. Minimal investigation is needed to identify which attributes should be included to handle geo-fence interaction.

Recommendation: A draft conceptual model should be developed that identifies allowed geometries in 2D, 3D, as well as temporal considerations and which articulates the necessary attributes. Critical to this model is a definition of terminology that is consistent with or maps to other UAS operational standards. The model should consider "active" vs. "passive" geo-fences, the former being geo-fences where a third party intervenes in the aircraft operation, and the latter being geo-fences where the UAS or operator is expected to respond to proximity/intersection. The model should also define geo-fences with respect to the aircraft operational limits, either: 1) the aircraft operates inside a geo-fence and an action occurs when the aircraft leaves that geo-fence, or 2) the aircraft operates outside a geo-fence and an action occurs when the aircraft intersects the geo-fence boundary. The conceptual model can be used to develop one or more standard encodings so that equipment manufacturers can select the ideal format for their hardware (e.g., XML, JSON, binary).

Industry has taken the lead on proposing geo-fencing solutions improving safety on current UAS operations but guidelines from the UAS community (industry+regulator) are needed to harmonize this functionality.

The geo-fence exchange standard must be machine-readable to take advantage of existing geospatial processing code and ensure consistent application of rules against the geo-fence.

Priority: High (Tier 2)

Organization(s): OGC, ISO/TC 20/SC 16, EUROCAE, UAST, ICANN

Status of Progress: Green

Update: As noted in the text, standards are in development.

Gap O11: Geo-fence Provisioning and Handling. There is a need for a best practices document to inform manufacturers of the purpose, handling, and provisioning requirements of geo-fences.

R&D Needed: Minimal. The proposed geo-fence exchange standard discussed earlier will suffice for the geo-fence content. There are many existing methods to deploy such data to hardware.

Recommendation: Create a best practices document on geo-fence provisioning and handling in standards for autonomous and remote pilot behavior. This document should include specific guidance on how an aircraft must behave when approaching or crossing a passive geo-fence boundary based on the attributes contained in the geo-fence data, such as: not entering restricted airspace, notifying the operator to turn off a camera, changing flight altitude, etc. For active geo-fences, the document should detail the types of third party interventions. These best practices may not need to be expressed in a separate document, but rather could be provided as content for other documents for control of aircraft operations, such as UTM.

Priority: Medium

Organization(s): OGC, ASTM, RTCA, EUROCAE

Status of Progress: Not Started

Update: Some best practices are emerging but nothing has been documented at this time. This is a low priority for ASTM F38 and no action is planned at this time.

7.10. Recreational Operations

The FAA Reauthorization Act of 2018 established the Exception for Limited Recreational Operations of Unmanned Aircraft (49 U.S.C. 44809). The FAA refers to individuals operating under that statutory exception as “recreational flyers.”

The FAA maintains a website that outlines safety requirements for recreational flyers and modeler community-based organizations. It describes how the agency is working with stakeholders to develop test administration requirements for online aeronautical knowledge and safety tests.

Published Regulations, Standards, and Related Documents Include but Are Not Limited to:

- 49 U.S. Code § 44809 *Exception for limited recreational operations of unmanned aircraft*
- FAA AC 91-57B - *Exception for Limited Recreational Operations of Unmanned Aircraft* (May 31, 2019)
- 14 CFR part 107 *Small Unmanned Aircraft Systems*

- 47 CFR part 97 *Amateur Radio Service*. Provides standards and needed qualifications for pilots/operators using remote control or FPV transmission frequencies requiring a FCC Technician License.
- Academy of Model Aeronautics Doc # 105, Academy of Model Aeronautics National Model Aircraft Safety Code
- Academy of Model Aeronautics Doc # 510-A, B, C, I, D, F, Q. All relate to the waiver process, operation, design, construction, and operation of turbine and pulse jet engines in model aircraft.
- Academy of Model Aeronautics Doc # 520-A, AMA Large Model Airplane Program (over 55 lbs.) Requirements and Inspector Information
- Academy of Model Aeronautics Doc # 535-A, Guidelines for Bylaws for Chartered Clubs. Outlines a club grievance procedure that provides a mechanism to enforce existing safety rules by providing a progressive disciplinary system when needed. Multiple grievances against a member can lead to suspension of flying privileges, and ultimately expulsion from the club. Safety grievances are recorded in club records.
- Academy of Model Aeronautics Doc # 535-B, Flying Site Safety and Operational Rules. Provides generic sample of a set of rules designed to supplement the required current Official AMA National Model Aircraft Safety Code.
- Academy of Model Aeronautics Doc # 540-D, "See and Avoid" Guidance. Includes reporting instructions for near miss incidents involving manned aircraft.
- Academy of Model Aeronautics Doc # 550, Unmanned Aircraft Operation Utilizing First-Person View. Outlines FPV operations, requirements, limitations, and privacy protection safeguards.
- Academy of Model Aeronautics Doc # 551, Radio Controlled Model Aircraft Operation Utilizing "First Person View" Systems for Indoor Flying of Ultra-Micro and Micro-Aircraft
- Academy of Model Aeronautics Doc # 560, Radio-Controlled small/micro Unmanned Aircraft Systems/Model Aircraft (m/sUAS) Operations Utilizing Failsafe, Stabilization, Autopilot, Ground-Station, Cameras/Sensors
- Academy of Model Aeronautics Doc # 590, FCC Requirements for Model Aircraft Operations
- Academy of Model Aeronautics Doc # 903, Suggested Duties for Club Officers. Recommends duties for a Safety Coordinator, to include, safety audits, establishing a club emergency action plan to handle serious accidents/incidents, reviews emergency procedures annually with club members, and serves as a mentor.
- Academy of Model Aeronautics Doc # 921, AMA Guide for Introductory Pilot Instructor Selection Criteria and Flight Proficiency Demonstration. Includes a checklist of proficiencies introductory AMA pilots must be able to demonstrate.
- Academy of Model Aeronautics Membership Manual 2018

In-Development Regulations, Standards and Other Documents: As set forth in FAA AC 91-57B - *Exception for Limited Recreational Operations of Unmanned Aircraft* (May 31, 2019), "Upcoming Guidance" includes the following:

7.2.1 CBO Requirements and Procedures. The FAA intends to provide further information on how organizations can be recognized by the FAA as official CBOs.

7.2.2 Basic Aeronautical Training and Test (BATT). The FAA is developing a training module with an accompanying test to provide basic aeronautical education to all recreational flyers and enhance the safety of the NAS through greater education and awareness. The training and test will be developed in consultation with stakeholders. The FAA expects to provide the training module and test to recognized CBOs for online administration to their members and also to the general public.

No voluntary standards gaps has been identified at this time.

7.11. Vertiports

UAS will rely heavily on a broad ecosystem of passenger accommodation facilities, skilled personnel, and ground support equipment and services in order to create an efficient system able to realize the full potential. Similar requirements exist for the emerging optionally-piloted aircraft (OPA) and “flying taxis” of urban air mobility.

In the legacy world of aviation, airport operations are well understood. Once the daily activity exceeds 10 operations per day, exceeds thirty days in duration, or occurs more than three days in a week, 14 CFR Part 157 requires 90-day notice for an airport. For UAS, the role is not clear.

The FAA National Airspace Forecast 2019-2039 discussed a forecast of 835,000 UAS in 2023. The National Plan of Integrated Airport Systems 2019-2023 discussed UAS over two paragraphs within sixty pages, by way of a brief overview and summary.

FAA does not recognize UAS activity as “aeronautical activity” on airports, and UAS do not count towards the number of based aircraft. The FAA Reauthorization Act of 2018 Sec. 341 established definitions for “permanent areas,”[49] but did not include UAS. Airports are categorized by the number of passenger boardings or by tonnage of cargo. This metric does not work with the current limitations of UAS operations.

There are no acceptable standards for traffic patterns for any size UAS. The FAA cancelled AC 150/5390-3 - Vertiport Design, the one document that provided guidance to planners and communities interested in developing a civil vertiport or vertistop, in July 2010.

Published Standards: No published standards have been identified.

[49] The term `permanent areas' means areas on land or water that provide for launch, recovery, and operation of small unmanned aircraft.

In-Development Standards:

- ASTM WK59317, *New Specification for Vertiport Design*
- ISO/NP 5015-2, Unmanned aircraft systems — Part 2: Operation of vertiports for unmanned aircraft (UA) (proposed in ISO/TC20/SC16)

New Gap O12: Design and Operation of Vertiports. There are no published standards for the design and operation of vertiports. There is also no traffic pattern standard for existing airport facilities.

R&D Needed: Yes

Recommendation: Complete work on standards in development

Priority: High (Tier TBD)

Organization: ASTM, ISO

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8. Flight Operations Standards: Infrastructure Inspections, Environmental Applications, Commercial Services, Workplace Safety – WG3[50]

8.1. Vertical Infrastructure Inspections

8.1.1. Power Plants and Industrial Process Plants

Owner operators are utilizing sUAS to perform inspections of assets with power plant assets and industrial process plants. Industrial process plants can consist of refineries, chemical plants, pharmaceutical, food, and other bulk production facilities.

Published Standards: No published UAS standards have been identified.

In-Development Standards: The ASME Mobile Unmanned Systems (MUS) Standards Committee is currently developing a standard that would provide requirements for the safe and reliable use of UAS to perform inspections of various assets within power plants and industrial process plants. UAS can be used for internal and external inspection as well as both VLOS and BVLOS scenarios. The standard will provide guidelines on how to perform UAS visual inspections that perform as good or better than conducting a manual visual inspection and achieves quality data and repeatable results. The goal of the committee is to address operation of a UAS using other NDE methods, e.g., infrared, ultrasonic, gas detection, radiographic, lidar etc.,

Five case studies are being developed in conjunction with the ASME standard, two of which are external inspection case studies: visual inspection of a nuclear containment dome and a stack. Renewable energy inspection case studies, e.g., solar, wind, and hydropower, are being considered. The guidelines being developed in this standard provides the basis of using a UAS safely and reliably and can be applied to inspect most critical assets, e.g., piping, pipelines, railroads, transmission lines etc. The inspection criteria will differ depending upon the asset being inspected.

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[50] In addition to the topics listed below, ASSP is looking at the use of drones for construction and demolition operations (see 4.4).

Gap I1: UAS Inspections of Power Plant and Industrial Process Plant Assets. No published standards have been identified for inspections of power plant and industrial process plant assets using UAS.

R&D Needed: No.

Recommendation: Develop standards for power plant inspections using UAS

Priority: High (Tier 3)

Organization(s): ASME BPV Committee on Nondestructive Examination (V) and ASME Mobile Unmanned Systems (MUS) Standards Committee

Status of Progress: Green

Update: As noted in the text, ASME is developing a standard on the use of UAS to perform inspections of power plant and industrial process plant assets.

8.1.2. Cranes

UAS can be used to safely conduct certain "at height" crane inspections, reducing hazards to crane personnel and saving time and money as compared to traditional means. Some of the issues that will come into play include: regulatory body requirements, the location of the crane (e.g., on the ground, on top of a building, in a waterway), inspection operation proximity to fixed structures and electrical power distribution systems, and the necessary flight paths of the drone to accomplish the inspections.

Published Standards: No published standards for crane inspections using UAS have been identified. The ASME B30 Standards Committee maintains safety standards for the crane industry.

In-Development Standards: The ASME B30.32 subcommittee is developing ASME B30.32-20XX, *Unmanned Aircraft Systems (UAS) used in Inspection, Testing, Maintenance, and Lifting Operations*. The standard will provide requirements and recommendations that address the safety relevant to UAS to support inspecting, maintaining, and operating cranes, and other material handling equipment. It will also provide UAS and material handling equipment designers, owners, and operators a clear and consistent set of recommendations to help prevent accidents and injuries.

Gap I2: Crane Inspections. Standards are needed to establish requirements for the use of UAS in the inspection, testing, maintenance, and operation of cranes and other material handling equipment covered within the scope of ASME's B30 volumes.

R&D Needed: No

Recommendation: Complete work on draft B30.32-20XX, *Unmanned Aircraft Systems (UAS) used in Inspection, Testing, Maintenance, and Lifting Operations* to address crane inspections using UAS.

Priority: Medium

Organization(s): ASME

Status of Progress: Green

Update: Work continues on development of the draft B30.32 standard.

8.1.3. Building Facades

In the U.S., there are 12 cities with facade ordinances requiring periodic inspection of building facades or their appurtenances. This amounts to approximately 30,000 buildings requiring periodic inspection. UAS are being applied in many areas for construction, building, and architecture for pre-project, in progress, and post-project activity. Use cases include the following:

- Inspections conducted in dense urban environments: wind and navigation challenges
- Inspections using thermal sensors for leak detection
- Inspections using penetrating radar for deterioration, cavity detection
- Collection of data for building information modeling
- Inspections for change detection of building facade conditions
- Documentation of deficiencies such as, cracking, spalls, and member deflection. Deterioration mechanisms that result in possible changes in material properties, such as corrosion of steel reinforcement, thermal damage, and concrete reactions like alkali-aggregate.

Published Standards: There are no known published standards for vertical inspections of building facades with a drone. However, there are published standards for building inspections, including:

- ASTM E1825-17, *Standard Guide for Evaluation of Exterior Building Wall Materials, Products, and Systems*. This guide may be used by design professionals and others in the building construction industry to provide factual support for professional judgment of materials, products, or systems during the design development of new and remedial exterior building wall construction.
- ASTM E2128-17, *Standard Guide for Evaluating Water Leakage of Building Walls*. This guide describes methods for determining and evaluating causes of water leakage of exterior walls.
- ASTM E2270-14, *Standard Practice for Periodic Inspection of Building Facades for Unsafe Conditions*. This standard practice is intended to establish the minimum requirements for conducting periodic inspections of building facades to identify unsafe conditions that could cause harm to persons and property.
- ASTM E2947-16a, *Standard Guide for Building Enclosure Commissioning*. This guide provides recommendations for the enclosure commissioning process from its project planning through design, construction, occupancy, and operation phases.

- ASTM E3036-15, *Standard Guide for Notating Facade Conditions in the Field*. This guide consists of symbols and notations pertaining to documenting deficient conditions observed during facade inspections.
- ACI 562-16, *Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary*. This code provides minimum requirements for assessment, repair, and rehabilitation of existing structural concrete buildings, members, systems, and where applicable, non-building structures.
- ACI 201.1R-08, *Guide for Conducting a Visual Inspection of Concrete in Service*. This guide provides terminology to perform and report on the visual condition of concrete in service. It includes a checklist of the many details that may be considered in making a report and descriptions for various concrete conditions associated with the durability of concrete.

In-Development Standards: There's one known standard in development for vertical visual (i.e., optical) inspections with a drone. There are no standards being developed for other sensors that do not use the visible light spectrum, such as radar or thermal.

- ASTM WK58243, *Visual Inspection of Building Facade using Drone*, developed by Committee E06 on Performance of Buildings, Subcommittee E06.55, Performance of Building Enclosures. This standard consists of guidelines for utilizing drones with cameras to document facade conditions with video and still photography. The purpose of this standard is to establish procedures and methodologies for conducting visual inspections of building facades via drone, and documenting such inspections. Work on this standard was initiated in March 2017.

Related building inspection standards in development include the following:

- ASTM WK43980, *New Guide for Assessing Building or Structure Designs for Sliding or Falling Ice and Snow Hazard Potential*. The guide is intended to establish procedures and methodologies for the review and assessment of building or structure designs, with respect to their anticipated performance when exposed to winter weather; and the potential for danger to people or property due to ice and snow accretion that can release from the building or structure surface.
- ASTM WK62463, *New Practice for Protection of Public and Property During High-rise Construction*. The intent of this practice is to provide protection for public and property exposed to falling debris materials, etc. during construction of high-rise building over 15 stories.

Gap I3: Inspection of Building Facades using Drones. There are no known published standards for vertical inspections of building facades and their associated envelopes using a drone.

A standard is needed to provide building professionals and drone pilots with a methodology for documenting facade conditions utilizing a sensor mounted to a drone. This should include best practices for the operation of the drone and establish an approach to sensing a building facade, preserving the data, and utilizing data recorded for reporting purposes.

The standard should consider the safe operating distance from a building, which may vary depending on the construction material of the facade, and the size and height of the building. It should also take into account FAA requirements that apply to operational navigation (visual and beyond line of sight) and OOP.

In addition, the standard should consider the relationship between the licensed design professional and the remote pilot if they are not one-in-the-same. For example, the local jurisdiction authority may stipulate that only a licensed design professional may qualify the inspection results. The remote pilot may help document the inspection findings, but might not be qualified to provide analysis.

R&D Needed: Yes, for navigation systems to mitigate potential GPS reception loss while operating in close proximity of structures that might obstruct GPS transmission signals.

Recommendation: Expand work on ASTM WK58243, *Visual Inspection of Building Facade using Drone* to include non-visual sensors, such as radar and thermal.

Priority: Medium

Organization(s): ASTM

Status of Progress: Green

Update: As noted, standards are in development.

8.1.4. Low-Rise Residential and Commercial Buildings

UAS inspections of single-family homes, duplexes, and 3-4 story condos, as well as one- and two-story commercial buildings, are becoming more common. This is in part because of the need to inspect areas difficult to access in a safe manner. Drones provide inspectors a safe and accessible means of evaluating issues relating to grading, drainage, septic systems, site lines, roofing, HVAC systems, etc., in both hot and cold environments. Selecting the appropriate aircraft and software and determining the means by which data is delivered to the client are key considerations for these missions.

Almost all of these inspections are done in VLOS in a confined space within the property boundaries whether it be residential or commercial. The drone is typically operating at about 100-150 feet above the structure. Alerting neighbors of the imminent inspection is a standard practice.

Published Standards: None identified specific to conducting inspections of low-rise residential and commercial buildings. See the section on building facade inspections for other potentially relevant published and in-development work not specific to the use of drones.

In-Development Standards: The American Society of Home Inspectors (ASHI) is considering the development of a document addressing both residential and commercial inspections using UAS.

Potentially relevant in-development standards include [ASTM WK58243, *New Guide for* Visual Inspection of Building Facade using Drone](#).

Gap I4: Low-Rise Residential and Commercial Building Inspections Using UAS. There is a need for a set of best practices or a standard operating procedure (SOP) to inform industry practitioners how to conduct low-rise residential and commercial inspections using UAS.

R&D Needed: No

Recommendation: Develop a guide or SOP for low-rise residential and commercial inspections using UAS. The document should consider safe operating distance from the building, which may vary depending on the construction material of the facade, and the size and height of the building. It should also take into account FAA requirements that apply to operational navigation (visual and beyond line of sight whether day or night), and OOP.

Priority: Medium

Organization(s): ASHI, ASTM

Status of Progress: Unknown

Update: No update provided at this time.

8.1.5. Communications Towers

Inspections of communications towers using UAS are needed to improve safety for tower technicians, ground personnel, and the general public with respect to flight operations of UAS in the NAS surrounding these vertical structures.

Published Standards and Regulations: NATE, The Communications Infrastructure Contractors Association, has published a best practices document entitled *sUAS Operations Best Practices Advisory* and a UAS Operations Resource Document titled *Unmanned Aerial Systems Operations around Vertical Communications Infrastructure (2nd Edition, January 2017)* which are freely available to the public on their website's UAS Operations Portal.

The intended focus of these documents are on UAS operations around wireless infrastructure, cellular towers, broadcast towers, and utility structures. These documents intend to improve UAS operations by suggesting additional items to consider above and beyond the established FAA, federal, state, and local requirements as well as provide a resource to help standardize training requirements and operator processes. The operational suggestions in these documents are in support of all FAA regulations in this arena.

Other related standards and regulations include:

- ANSI/TIA-222-H Structural Standard For Antenna Supporting Structures, Antennas and Small Wind Turbine Support Structures
- ANSI/TIA-322 Loading, Analysis, and Design Criteria Related to the Installation, Alteration and Maintenance of Communication Structures
- TIA satellite standards
- FCC Tower and Antenna Siting – FCC regulations on antenna structure registration, marking and lighting requirements
  - Antenna Structure Painting and Lighting Requirements

In-Development Standards: No in-development standards have been identified.

More research is needed to determine the nature and schedule for the development of such standards and what, if any, gaps are to be identified. More research is also needed to determine if other SDOs are working on standards in this arena.

The Telecommunications Industry Association (TIA) TR-14 UAS working group is looking to augment the legacy processes for tower work performed with UAS. Rationales include:

New Construction/Asset Modification

- Establish a baseline configuration for future asset management
- Leverage real time data acquisition to enhance field services and streamline work flows
- Improve planning with better data

Damage Assessments/Downtime Reduction

- Utilizing UAS increases safety and efficiency which reduces downtime. It also dramatically reduces time on site as compared to using traditional climbing methods.

Field Services and Enhanced Safety

- Establish the use of enhanced 3D modeling, versus traditional 2D drawing deliverables
- Provide more complete datasets resulting in faster project cycles
- Improve planning with better data
- Perform climb path assessment (safety climb cable, climb obstructions)

8.2. Linear Infrastructure Inspections

8.2.1. Bridges

Historically, bridge inspections have been performed primarily with visual inspection by walking around the bridge, or using an aerial work platform (AWP), an under-bridge “snooper” bucket, ladders, or ropes. The choice of apparatus used depends on the bridge type, size, and location, the access needed, and whether there is traffic that needs to be diverted. Implementation of non-destructive evaluation (NDE) techniques by bridge inspectors has helped meet some data needs. UAS are proving to offer a safer, faster, more cost-effective alternative for performing bridge inspections.[51] They are being applied in many areas as a tool for collecting data to assess bridge conditions. Use cases include the following:

- Documentation of deficiencies during initial, routine, in-depth, fracture critical member inspections, including: delamination, crack detection and propagation, spalls, and member deflection
- Imaging difficult-to-reach areas that would ordinarily require specialized equipment
- Collection of data for building information modeling (BIM) for bridges
- Inspections for detecting changes in material conditions
- Documentation of deterioration mechanisms that contribute to changes in material properties, such as corrosion of steel reinforcement, thermal damage, and concrete reactions (e.g., alkali-aggregate)
- Assessing movement of bridge components due to hazards such as bridge scour

Published Standards, Regulations, and Related Materials: There are no known published standards for conducting bridge inspections with a UAS. However, there are published standards for general bridge inspections.

- Title 23, Code of Federal Regulations, part 650*,* Subpart C, *National Bridge Inspections Standards.* These regulations set the national standards for the safety inspection and evaluation of all highway bridges. They include regulations for definitions, bridge inspection organization, personnel qualifications, inspection frequency, and inspection procedures.
- American Association of State Highway and Transportation Officials (AASHTO), *Manual for Condition Evaluation of Bridges*. Per 23 CFR Part 650.317, bridges are to be inspected using these procedures. The manual offers assistance to bridge owners at all phases of bridge inspection and evaluation.
- Federal Highway Administration's (FHWA), *Bridge Inspector's Reference Manual (BIRM).* The BIRM is a comprehensive manual on programs, procedures, and techniques for inspecting and evaluating a variety of in-service highway bridges.
- FHWA, *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*. This publication provides more thorough and detailed guidance in evaluating and coding specific bridge data.

[51] - Wells, J. and Lovelace, B., 2018. Improving the Quality of Bridge Inspections Using Unmanned Aircraft Systems (UAS) (No. MN/RC 2018-26). Minnesota Department of Transportation, Report No. MN/RC 2018-26. 345 pgs.
- Brooks, Colin and Cook, Steven J. 2018. Unmanned aerial vehicles assess highways and bridges faster with reduced cost and risk. Michigan Department of Transportation Research Spotlight SPR-1674.
- 2019 AASHTO UAS/Drone Survey of All 50 State DOTs.

- AASHTO, *Load and Resistance Factor Design (LRFD) Bridge Design Specifications.* The provisions of these specifications are intended for the design, evaluation, and rehabilitation of both fixed and movable highway bridges.
- AASHTO*, Guide Manual for Bridge Element Inspection.* The goal of this manual is to completely capture the condition of bridges in a simple way that can be standardized across the nation while providing the flexibility to be adapted to both large and small agency settings.
- Additionally, most states have a local bridge inspection manual, with updates for element-level inspection. For example, Michigan DOT has the *Michigan Bridge Element Inspection Manual*, revised in 2017, and New York DOT has the *Bridge Inspection Manual*, revised in January 2016.

In-Development Standards and Related Activity: In-development standards and related activity include:

- ASTM WK58243, *Visual Inspection of Building Facade using UAS*. Developed by Committee E06 on Performance of Buildings, Subcommittee E06.55, Performance of Building Enclosures. Work on this standard was initiated in March 2017.
- The Steel Bridge Research, Inspection, Training, and Engineering Center at Purdue University has started the development of a UAS Validation Center that will include testing that UAS-collected data has sufficient resolution to meet infrastructure inspection needs, including for bridges.
- The FHWA has established a program in its Office of Infrastructure under the Every Day Counts (EDC) program to help understand and share the benefits of UAS for highway, bridge, and construction inspection.
- On November 12, 2019, the FHWA released a notice of proposed rulemaking (NPRM) proposing to update the National Bridge Inspection Standards (NBIS) to address Moving Ahead for Progress in the 21st Century Act (MAP-21) requirements, incorporate technological advancements including the use of unmanned aerial systems, and address ambiguities identified since the last update to the regulation in 2009.

Gap I5: Bridge Inspections. Standards are needed for conducting bridge inspections using a UAS to provide state Department of Transportation agencies and bridge owners with a methodology for documenting bridge conditions utilizing sensors mounted to a UAS. This should include best practices for the operation of the UAS and establish an approach to sensing a bridge structure, preserving the data, and utilizing data recorded for reporting and modeling purposes. All bridge types should be considered, including rail, road, and pedestrian. The role of UAS in assisting with fracture critical inspections, which usually require an inspector to be able to touch the fracture critical element, should be considered.

The standards should address safety and operator training. They should also take into account FAA requirements that apply to operational navigation (visual and beyond line of sight) and OOP (to include vehicular traffic), including short-term travel over people and traffic. In addition, the standards should consider the relationship between the qualified bridge inspector and the remote pilot if they are not one-and-the-same. The remote pilot may help document the inspection findings, but might not be qualified to provide an analysis. Recommendations on how to coordinate their work to maximize the value of UAS-enabled inspections should be part of new standards.

R&D Needed: Yes, for navigation systems to mitigate potential GPS reception loss while operating in close proximity to structures that might obstruct GPS transmission signals, including the role of collision avoidance systems. Also, for evaluating and documenting UAS-mounted sensor capabilities to meet bridge inspection data needs in light of state and federal reporting requirements.

Recommendation: Develop standards for bridge inspections using a UAS

Priority: Medium

Organization(s): AASHTO, ASTM, FHWA, state DOTs

Status of Progress: Yellow

Update: The FHWA NPRM of November 2019 is noted. Updated references, for example projects on implementing UAS for bridge inspections, have been noted. The gap statement has been tweaked slightly.

8.2.2. Railroads

Rail transport is essential to the movement of passengers (traditional, high-speed, and light transit) and freight across the country over short and long distances. Rail transport is arguably the most dependable mode of transport given the minimal service impact from weather conditions and the fixed routes and reliable schedules.

Railroads perform regular inspections of their track, rolling stock, signals, and other systems to ensure safe and efficient operations. The industry employs manual, automated, and autonomous technologies for inspection tasks, and is generally eager to advance the state-of-the-art of inspection technology to improve performance. The Federal Railroad Administration (FRA), Office of Research, Development, and Technology (RD&T) actively supports the development of new technologies to improve the effectiveness, efficiency, and safety of the rail industry and UAS is an emerging technology that may have a significant, positive, impact on the quality, safety, and efficiency of railroad operations. The rail industry and FRA, in collaboration with FAA, are exploring use cases for UAS technology to advance rail safety. These use cases extended beyond systems inspection and include the use of UAS for safety and security activities, including trespasser detection, rail property and asset mapping, natural and man-made disaster response, and civil construction projects.

Published Standards: There are no known published standards concerning the specific application of UAS for railroad inspections.

In-Development Standards: SAE is planning a future work item. ASME is developing requirements for using UAS for inspection – see section 8.1.1.

Gap I6: Railroad Inspections: Rolling Stock Inspection for Transport of Hazardous Materials (HAZMAT). Standards are needed to address rolling stock inspections for regulatory compliance of transporting HAZMAT. Considerations for BVLOS and nighttime operations are critical. OSHA standards (29 C.F.R. 1910) related to personal protective equipment (PPE) need to be factored in. SDOs should consult/engage with the rail industry in the development of such standards.

R&D Needed: Yes. Current inspection procedures are likely more hands-on when in close proximity of HAZMAT containers, so using UAS to reduce the inspector's exposure is similar to other inspection use cases. There are many on-going R&D activities for UAS inspection applications.

Recommendation: It is recommended that guidance be developed for performing inspections of HAZMAT rolling stock that incorporates OSHA and FRA requirements.

Priority: Low

Organization(s): FRA, FAA, SAE, OSHA, PHMSA, ASME

Status of Progress: Unknown

Update: No update provided at this time.

Gap I7: Railroad Inspections: BVLOS Operations. Standards are needed to address BVLOS operations for railroad inspection. While there are current integration activities ongoing with the FAA Focus Area Pathfinder program, the results of BVLOS operations for rail system infrastructure inspections are not currently available. Thus, there remains a gap in standards for operating BVLOS. See section 7.3 on BVLOS.

R&D Needed: Yes.

Recommendation: It is recommended that standards be developed that define a framework for operating UAS BVLOS for rail system infrastructure inspection. This may include the need to identify spectrum used for BVLOS railroad inspections.

Priority: High (Tier TBD)

Organization(s): FRA, FAA, SAE, ASTM AC-478 BLOS, American Public Transportation Association (APTA), American Railroad Engineering and Maintenance-of-Way Association (AREMA), ASME

Status of Progress: Green

Update: BNSF working with FAA on a framework for BVLOS. FRA is doing research to develop underlying technologies for BVLOS at low altitudes. ASTM AC-478 is looking at BVLOS generally but not specific to railroad inspections. The priority level was changed from medium to high.

Gap I8: Railroad Inspections: Nighttime Operations. Standards are needed to address nighttime operations for railroad inspections. Railroads operate 24/7, which poses significant hurdles for leveraging UAS technology for rail system infrastructure inspections. The majority of inspections occur during daytime, but incident inspections can occur at any time of day or under poor visibility conditions and, hence, may have OSH considerations.

R&D Needed: Maybe. Current R&D activities for operating UAS at night are unknown. Exposing UAS technology and operators to nighttime operations is necessary to encourage the maturation of the technology and processes.

Recommendation: It is recommended that standards be developed that define a framework for operating UAS at night.

Priority: Low

Organization(s): FAA, SAE, ASTM AC-478 BLOS, APTA, AREMA

Status of Progress: Unknown

Update: No update provided at this time. AC-478 is looking at BVLOS generally but not specific to nighttime operations or railroad inspections. The priority level was changed from medium to low.

8.2.3. Power Transmission Lines, Structures, and Environs

UAS performing inspections of power transmission lines, structures, and environs operate in a high-risk environment due to the close proximity to high voltage assets along with the potential for electromagnetic interference issues to UAS craft control signals. Contact with energized equipment could result in catastrophic failure of the UAS and/or the asset it contacts. NERC CIP-14-01 from the North American Electric Reliability Corporation (NERC) has requirements for protecting national critical infrastructure, though UAS are not covered. A variety of power and telecommunication assets are shared in these transmission corridors, including: transmission power assets, distribution power assets, telephone assets, fiber assets, and cable assets.

Published Standards: No published voluntary consensus standards for UAS have been identified for this topic. However, Oak Ridge National Laboratory (ORNL) has published An Early Survey of Best Practices for the Use of Small Unmanned Aerial Systems by the Electric Utility Industry which may be relevant to future standards work. The report notes that vegetation encroachment is a leading cause of power interruption.

Relevant Standards and Regulations for General Industry Include: NERC CIP -14-01, Physical Security. "This Reliability Standard addresses the directives from the [Federal Energy Regulatory Commission] FERC order issued March 7, 2014, Reliability Standards for Physical Security Measures, 146 FERC ¶ 61,166 (2014), which required NERC to develop a physical security reliability standard(s) to identify and protect facilities that if rendered inoperable or damaged could result in widespread instability, uncontrolled separation, or cascading within an interconnection." OSHA provides clearance distance limits within which anyone who is not a trained lineman is not supposed to enter.

In-Development Standards: No in-development voluntary consensus standards for UAS have been identified for this topic. However, SAE G-30 UAS Operator Qualifications & G-10U Unmanned Aerospace Vehicle has identified this subject for possible future work. ASME is developing requirements for using UAS for inspection – see section 8.1.1.

- IEEE P2821, *Guide for Unmanned Aerial Vehicle-based Patrol Inspection System for Transmission Lines*

Gap I9: Inspection of Power Transmission Lines, Structures, and Environs Using UAS. No standards have been identified that specifically address the qualifications of UAS pilots to operate near energized equipment to meet Federal Energy Regulatory Commission (FERC) physical and cyber security requirements. Nor have any standards been identified that specifically address the qualifications of UAS pilots to operate around transmission and distribution equipment. This equipment may include telephone, fiber, and cable assets, as well as natural gas and pipeline assets. A standard is needed to address these issues as well as operational best practices and training in how to conduct a safe inspection of power transmission lines, structures, and environs using drones. See also section 10.3 on UAS flight crew.

R&D Needed: Yes. There is a need to study acceptable methods of airspace deconfliction around electrical equipment and infrastructure. Identifying appropriate data to collect and study relevant airspace activity around electrical equipment is recommended.

Understanding the impact of electromagnetic interference around different types of high voltage lines can help identify what mitigation techniques are needed. Further study should be undertaken regarding the effects of magnetic field interference on UAS C2 signals and communications when in the proximity of energized high voltage electrical transmission, distribution, or substation equipment.

Acceptable C2 link methods for BVLOS operation exist, but establishing the equipment and techniques for managing autonomous operations during disruptions in connectivity can help spur further acceptable BVLOS practices.

Different DAA techniques exist internationally and in the U.S. Studying their effectiveness in the U.S. NAS is needed.

Recommendation: Develop standards related to inspections of power transmission lines, structures, and environs using UAS. Review and consider relevant standards from other organizations to determine manufacturer requirements. As part of the standard, include guidelines on size of aircraft and safe flight operations in proximity to energized equipment, for example, to avoid a scenario where arcing occurs between the drone and physical infrastructure.

Priority: High (Tier 3)

Organization(s): SAE, IEEE, Department of Energy (DOE), North American Electric Reliability Corporation (NERC), FERC, ORNL, ASTM, ASME

Status of Progress: Green

Update: As noted, ASME has some relevant work and SAE is contemplating future work. The ASTM F38 Executive Committee gap analysis viewed this as a low priority for F38, with no action at this time.

8.2.4. Implementing UAS for Hydrocarbon Pipeline Inspections

Unmanned aircraft systems present an opportunity for pipeline operators to more frequently and safely inspect hydrocarbon infrastructure. Currently, operators use manned fixed wing, rotary aircraft, or other methods to perform required routine regulatory pipeline inspection. In the U.S., the Pipeline and Hazardous Materials Safety Administration (PHMSA) of the Department of Transportation mandates inspection intervals in 49CFR §192.705, 192.706 – Natural Gas Transmission Pipelines and §195.412 – Hazardous Liquids Pipelines.

The National Petroleum Council, a federally chartered advisory committee to the U.S Secretary of Energy, recently released a draft analysis of the current hydrocarbon transportation infrastructure entitled Dynamic Delivery – America's Evolving Oil and Natural Gas Transportation Infrastructure. The report notes how the emergence of remote sensing technologies and geospatial analytics will assist the oil and gas industry in the management of pipeline asset integrity. The use of UAS will enable monitors to cover larger areas more cost effectively and improve the response time and response quality mitigation.

Unmanned systems could perform routine automated flights to collect data and detect issues that a pilot or observer may have difficulty evaluating via a simple visual inspection such as leak/ emissions detection, third party encroachment, geohazard monitoring and management, changes in population density, and changes in landscape canopy or elevation over time which may indicate shifts in pipelines. Additionally, more frequent data collection at lower altitudes could help with advanced engineering decisions, change with respect to pipeline class and High Consequence Area (HCA) locations, as well as with record keeping for aging infrastructure. Other areas for which UAVs could be applied for the industry are in safety and security of pipelines and associated facilities, as well as coordination of emergency response and shutdown during natural or manmade hazardous events.

While this section primarily focuses on the use of UAV for hydrocarbon infrastructure inspection to meet regulatory requirements, the concepts may also be applicable for UAS inspections conducted for underground and aboveground pipelines that transport other materials such as water and sewage.

Published Standards: There are no published standards related to the utilization of UAS for pipeline inspections. However, the American Petroleum Institute (API) has published numerous pipeline inspection standards which do not currently incorporate the usage of UAS. There may be an opportunity to revise these documents to enable inspections to be performed by UAS. In addition, API has published the API Guide to Developing an Unmanned Aircraft Systems Program which provides guidance and considerations for the oil and natural gas industry to assist organizations in the development of internal UAS programs.

In-Development Standards: API currently does not have any formal standards under development for UAS to be used in pipeline inspections. However, anyone is permitted to submit a Request for Interpretation to ask if UAS can be used to meet the criteria of any existing API standards.

NACE International has initiated two Task Groups (TG) developing standard practices: Task Group 552 *Drone-Based Condition Monitoring of Below and Above Ground Pipeline Integrity Threats* and Task Group 587 *Large Standoff Magnetometry (LSM) Inspection of Pipelines*. While the LSM document primarily addresses the sensor technology utilized as an above ground, non-intrusive screening tool to identify stress concentration in pipelines, it is likely that the screening inspection will be conducted via a UAS platform.

ASME is developing requirements for using UAS for inspection – see section 8.1.1.

New Gap I13: Inspection of Pipelines and Operating Facilities - BVLOS Operations. Standards are needed to address BVLOS operations for pipeline inspection. While there have been past research activities provided to the FAA through Pipeline Research Council International (PRCI) research, the standard guidance of BVLOS operations for pipeline infrastructure inspections are not currently available. Thus, there remains a gap in standards for operating BVLOS.

R&D Needed: No. Current FAA and industry research program activities will likely address R&D considerations although detect and avoid demonstrations may be required for FAA data collection.

Recommendation: Develop standards that define a framework for operating UAS BVLOS for pipeline inspection as well as standards that describe best practices and use cases for the pipeline industry. Request API to review their portfolio of pipeline inspection standards to determine if revisions to enable inspections performed by UAS could be incorporated. Complete NACE TG 552 on monitoring of pipeline integrity threats.

Priority: Medium

Organization(s): FAA, API, NACE, PHMSA (R&D), PRCI (R&D), California Energy Commission (R&D), ASME

New Gap I14: Inspection of Pipelines and Operating Facilities – Sensor Validation & Use. Standards are needed for minimum testing to validate sensors on UAS platforms at varying flight altitudes utilized for pipeline inspections. Standards are needed to provide Department of Transportation agencies and operators with a methodology for documenting pipeline conditions utilizing sensors mounted to a UAS. This should include best practices for the operation of the UAS and establish an approach to sense and avoid surrounding infrastructure within facilities, safeguarding the data, and utilizing data recorded for reporting and modeling purposes. The standards should address safety and operator training. They should also consider FAA requirements that apply to operational navigation (visual and beyond line of sight).

R&D Needed: Yes, for validation of sensor quality and accuracy on varying platforms (long-range and short-range UAVs) for risks associated with:

- Environmental changes (i.e., ground movement, water saturation, slip / subsidence / sinkhole / erosion)
- Third-party threats
- Active loading on pipelines (i.e., equipment crossing right of way (ROW), equipment on ROW, material on ROW)
- Waterways (i.e., boat anchorage, dredging, levee construction / maintenance)
- Structures (i.e., building construction, fence installation, non-permanent structure on ROW)
- Pipeline monitoring (i.e., exposure (pipe), pipeline construction / maintenance, possible leak / lost gas, slip / subsidence / sinkhole / erosion
- Earthwork (i.e., clearing, drainage, excavation, mining activity)
- Forestry (i.e., logging activity, portable sawmill operations)

Recommendation: Develop standards for validating sensor quality and accuracy on UAS platforms utilized for pipeline inspections. Request API to review their portfolio of pipeline inspection standards to determine if revisions to enable inspections performed by UAS could be incorporated. Complete NACE TG 552 and TG 587 documents.

Priority: Medium

Organization(s): API, NACE, PHMSA (R&D), PRCI (R&D), California Energy Commission (R&D), FAA, ASME

8.2.5. Implementing UAS in Airport Operations

UAS usage in legitimate airport operations encompass multiple potential tasks. The tasks are in various stages of development. The potential use of drones in airport operations covers several maintenance tasks resulting in time and labor savings. At the same time, a primary risk in the usage of UAS in airport operations is proximity to operating aircraft and the lack of coordination with other airport activities.

"As the drone industry and its enabling technologies mature, more and more legitimate drones will find their way on to airports in roles that offer similar operational and cost benefits. Commercial package delivery capabilities can be used to move spare parts from off-site warehouses to maintenance hangars. Transport asset tracking and management capabilities can be used for security monitoring and management of the large fleet of vehicles used to service aircraft and move materials."[52]

Potential UAS usage in Airport Operations

- Red green blue (RGB) and thermal inspection of aircraft to inspect for structural damage, assess paint quality, marking, and signs of lightning strikes. This could take place at the gate or, in the case of more comprehensive maintenance inspections, at a maintenance hardstand on the tarmac or in the hangar.
- Bird or other wildlife control and monitoring
- Runway, taxiway, and apron inspection
- Navigational aids, approach lighting systems, and antennae structures inspections
- Aerodrome structures inspection utilizing RGB and thermal technology
- Runway Integrity Surveys. Drones could be used to provide 3D maps of runways in a very short space of time for routine maintenance to a very high accuracy level. Detecting problems with runway integrity at an early stage will lead to efficiency savings in the long term.
- Perimeter Security. Drones can be used to provide support to manned guarding via a control center to react to threats quickly and act as a visual deterrent. Tethered drones can stay in the air for extended periods.
- Foreign Object Detection. Drones can be used to provide aerial detection of foreign objects, alleviating the need to shut down a runway as currently happens if this is done by eye and freeing up valuable runway slots.
- Weather measurements above ground level. Zurich Airport is testing a configuration of multiple weather instrumented drones around Zurich Airport to improve short range forecasts around the airport. Results thus far are showing added value.

Published Regulations, Standards, and Guidance Material:

- CFR Part 14 Section 107.43 Operation in the vicinity of airports
- DOT/FAA/CT-94/11 Emerging Nondestructive Inspection for Aging Aircraft October 1994
- FAA Advisory Circular 107-2, Small Unmanned Aircraft Systems (sUAS)

[52] Future Airport – Winter 2019 Issue, Editorial 'thought leadership' article by Philip Hall, President, RelmaTech Inc. (USA)

In-Development Regulations, Standards, and Guidance Material: No standards in development have been identified.

New Gap I15: UAS in Airport Operations. No published or in development standards have been identified for UAS usage in airport operations.

R&D Needed: Yes.

Recommendation: Develop standards for the application of UAS in airport operations

Priority: Medium

Organization(s): Standards bodies publishing UAS standards and/or regulators

8.3. Environmental Applications

8.3.1. Environmental Monitoring

UAS offer significant potential to assist researchers and resource managers in monitoring and protecting the air, ocean and coastal environments, terrestrial habitats, land and water resources, and variety of fauna and flora species.

UAS are emerging as an effective tool for environmental monitoring[53] and enforcement because of their ability to reach areas that would otherwise be inaccessible or cost-prohibitive. Additionally, they have the potential to supplement or replace current conventional means by their ability to collect data via a variety of onboard sensors, upload data from terrestrial sensor arrays, and enable near real time data processing capabilities. For example, UAS are proposed as a viable alternative to manned aircraft for some aerial wildlife surveys.

Environmental monitoring at local, regional, national, and global levels plays a central role in diagnosing weather, climate, and management impacts on natural and agricultural systems, enhancing the understanding of hydrological processes, optimizing the allocation and distribution of land and water resources, and assessing, forecasting and even preventing natural disasters. Environmental monitoring applications include:

[53] Source: Wikipedia Environmental Monitoring page.

- **Weather monitoring** – including collecting wind, temperature, and moisture readings/data to improve micro-weather detection and to improve micro-weather predictions. See also the section of this document dealing with weather in chapter seven.
- **Air quality monitoring** – including sampling, detection, and monitoring programs for air contamination
- **Soil quality monitoring** – including sampling and monitoring programs for soil contamination, erosion, and salinity
- **Water quality monitoring** – including sampling, detection, and monitoring programs for water contamination, where impact parameters include chemical, biological, radiological, and microbiological populations
- **Fauna monitoring** – including monitoring programs for species population, health, movement, and poaching activity
- **Flora monitoring** – including sampling and monitoring programs for species population, health, and location

The wide range of technically capable and inexpensive COTS UAS and sensor accessories currently available are already enabling the advanced design of environmental monitoring programs that can utilize a wide range of environmental monitoring data management systems and environmental sampling methods, including[54]:

- Judgmental sampling
- Simple random sampling
- Stratified sampling
- Systematic and grid sampling
- Adaptive cluster sampling
- Grab samples
- Semi-continuous monitoring and continuous
- Passive sampling
- Remote surveillance
- Remote sensing
- Bio-monitoring

At the same time as COTS UAS become more prevalent and user-friendly, they pose a unique challenge to the environment and its inhabitants. Mitigating adverse impacts of UAS uses in environmental monitoring through policy, regulation, and best practices/guidelines will protect the environment and improve society's perceptions of the industry. Through the thoughtful exercise of responsible practices,

[54] See https://en.wikipedia.org/wiki/Environmental_monitoring#Sampling_methods for a definition of each method.

most environmental issues are manageable. However, the policy and regulatory framework continues to lag behind the rapidly expanding use of the technology.

Published Standards and Related Materials: No published standards have been identified specifically related to the use of UAS for environmental monitoring applications. However, substantial best practice guidance exists, for example:

- Baxter, Robert A. and Bush, David H. "Use of Small Unmanned Aerial Vehicles for Air Quality and Meteorological Measurements," Proceedings of the 2014 National Ambient Air Monitoring Conference.
- Hodgson, Jarrod C. and Koh, Lian Pin. "Best practice for minimising unmanned aerial vehicle disturbance to wildlife in biological field research," *Current Biology Magazine*. 23 May 2016. R404-R405.
- Manfreda, Salvatore, et al. "On the Use of Unmanned Aerial Systems for Environmental Monitoring," *Remote Sens.* 10, No. 4, 641, 20 April 2018.
- Oceans Unmanned Eco-Drone Best Practices Portal
- OFCM Exploratory Mini-Workshop Summary Report FCM-R32-2011 "Utilization of Unmanned Aircraft Systems for Environmental Monitoring," Office of the Federal Coordinator for Meteorological Services and Supporting Research, Washington, DC. May 2011.
- Quevenco, Rodolfo. "Using Unmanned Aerial Vehicles for Environmental Monitoring," International Atomic Energy Agency (IAEA), Division of Public Information; Development as Part of IAEA Action Plan on Nuclear Safety, 17 May 2013.
- Simpson, Joanna, et al. "Drones and Environmental Monitoring," Environmental Law Reporter, Issue 2-2017: 47 ELR10101, Environmental Law Institute, Washington, DC.
- "Unmanned aerial vehicles for environmental applications," *International Journal of Remote Sensing*, 38:8-10, 2029-2036. Published online: 17 March 2017.
- Villa, Tommaso Francesco et al. "An Overview of Small Unmanned Aerial Vehicles for Air Quality Measurements: Present Applications and Future Prospectives." Ed. Assefa M. Melesse. *Sensors (Basel, Switzerland)* 16.7 (2016): 1072. *PMC*. Web. 30 Aug. 2018.
- Watts, Adam C., et al. "Small Unmanned Aircraft Systems for Low-Altitude Aerial Surveys," *The Journal of Wildlife Management*. Sep. 2010. Vol. 74, Issue 7, pg(s) 1614-1619.

In-Development Standards: No standards in development have been identified specifically related to this issue.

No UAS standards gap has been identified. By way of further explanation, in considering the above environmental monitoring applications – and whether a specific standard is required to cover them – several important aspects need to be noted:

- UAS can be used effectively in support of environmental monitoring on both a small and large scale. Operations are usually conducted at low altitudes and over wide and unpopulated areas, where the general public is not exposed to the operation and its associated risks (i.e., no public safety and/or privacy issues).

- UAS operations in support of wide area environmental monitoring applications are primarily conducted BVLOS and are similar in operational context to UAS low-altitude aerial surveys/ inspections, for which standards either already exist or are in development.
- Each use case will have different requirements, including regulatory (such as 14 CFR part 137 or 14 CFR part 107 approvals) and company CONOPS, for which specialized standards could not be realistically developed.
- For use cases where the UAS is to be operated at higher altitudes and/or under ATC, standards for manned aviation conducting similar operations should apply.
- While no published or in-development standards have been identified related to the use of UAS for environmental monitoring applications, best practices are available through published articles and non-profit environmental organizations, including several specifically relating to the use of UAS.

A specific standard for UAS environmental monitoring operations is not required. Environmental monitoring should be covered by standards being developed for UAS BVLOS operations and UAS low-altitude aerial surveys/inspections. However, if it is determined that a more robust, focused standard or guideline is needed to improve the efficiency and safety of UAS operations for environmental monitoring applications, then environmental organizations, natural resource agencies, non-profits, and drone and sensor manufacturers should come together to develop such a document. Any standards, best practices, or guidelines need to comply with statutes such as the National Marine Sanctuaries Act (NMSA), the Marine Mammal Protection Act (MMPA), and the Endangered Species Act (ESA).

8.3.2. Pesticide Application

The application of pesticides (herein meant to include herbicides, insecticides, fungicides and other types of pesticides) is an important tool in food and fiber production but it is necessary to perform the application in a safe and sustainable way. Currently, in the U.S., it is legally required that pesticide label requirements are followed and these strongly influence application system design.

Aerial application is a statistically dangerous activity due to the inherent hazards of near-surface flight. Low altitude flights reduce decision/response time margins of error and potentially involve encounters with surface obstacles.

The practice of aerial spraying using UAS is operational in parts of the U.S. as well as internationally. Japan has been using remotely piloted aircraft in intensive agriculture for the past 25 years. The average farm size in Japan is 3.7 acres and UAVs generally have payload capacity of under 10 gallons. Given current UAS payload restrictions, manned aircraft have an approximate capacity of between 300 and 800 gallons, making them more suitable for the larger farms in the U.S., which average 441 acres. Waivers have been obtained from FAA increasing payload and UAS spraying is increasing in the US.

Pesticide application scenarios include broadcast application as well as spot spraying. All of the use cases imply the ability to identify, map, and return to a given location. In this sense, some level of remote sensing and identification is implied.

Published Standards and Other Documents: ISO/TC 23/SC 6, Equipment for Crop Protection, includes WG 20 on Aerial Sprayers and WG 25 on Unmanned Aerial Vehicle Spraying Systems. While international standards exist for many types of sprayers, standards specifically dealing with UAS do not yet exist but they are now being considered by WG 25. In addition, 14 CFR Part 137, agricultural aircraft operations, is applicable to enable pesticide application. Multiple research studies have been done on this topic including the following though this list is not exhaustive: *Qualitative Evaluation of Unmanned Aircraft Visibility during Agricultural Flight Operations*, conducted in 2015 by the Colorado Agricultural Aviation Association in conjunction with the Think Before You Launch (TBYL) safety coalition, and another study from the American Society of Agricultural and Biological Engineers (ASABE) that looks at pesticide drift when applied by a UAV: *Prediction of Aerial Spray Release from UAVs*.

In-Development Standards: There are two standards currently being developed under the Vienna Agreement between ISO/TC 23/SC 6 and CEN/TC 144, Tractors and machinery for agriculture and forestry (and in support of European legislation on safety of machinery and/or sustainable use of pesticides). They address operations with the pilot in-cockpit but they are potentially relevant for UAS operations:

- ISO/FDIS 16122-5, *Agricultural and forestry machines – Inspection of sprayers in use – Part 5: Aerial spray systems* is currently under CEN final vote/ISO FDIS until 4 February 2020.
- A prior work item, ISO/FDIS 16119-5, *Agricultural and forestry machinery – Environmental requirements for sprayers – Part 5: Aerial spray systems*, has been removed from both the ISO and CEN work programmes to be replace by new work item anticipated to be registered for parallel CEN enquiry/ISO DIS vote in January 2020.

In addition, the ISO member from Japan has submitted four Japanese standards as reference material for ISO/TC 23/SC6/WG 25's development of international standards for UAS spraying systems:

- ISO/TC 23/SC 6/WG 25 N 10 JAPAN 1, The inspection procedures for Multicopter and Spraying equipment for Multicopter
- ISO/TC 23/SC 6/WG 25 N 11 JAPAN 2, Guidelines for the usage of UAs for aerial spraying etc.
- ISO/TC 23/SC 6/WG 25 N 12 JAPAN 3, Performance validation standards for industrial multicopter and its spraying equipment
- ISO/TC 23/SC 6/WG 25 N 13, Japan's safety rules on Unmanned Aircraft Japan Civil Aviation Bureau April 2016

In terms of U.S. domestic activity, the American Society of Agricultural and Biological Engineers (ASABE) has three technical WGs that are discussing UAS and spraying. The first group was initiated in 2016 and is titled Unmanned Aerial Systems; the second is a long-standing committee on Precision Agriculture;

and the third is the Aerial Application Sub-committee of the Committee on Liquid Application Systems (23/06/02). Of these, the Precision Agriculture and Liquid Applications sub-committees have extensive experience with standards development. There is also an effort in the preliminary stages to develop a standard for UAS spraying initiated out of 23/06/02.

Gap I10: Pesticide Application Using UAS. Standards are needed to address pesticide application using UAS. Issues to be addressed include communication and automated ID, treatment efficacy (treatment effectiveness), operational safety, environmental protection, equipment reliability, and integration into the national air space, as further described below.

- **Communication.** As pesticide application occurs in near-ground air space, it is also the domain of manned aerial application aircraft. Automated ID and location communication is critical in this increasingly crowded, near surface airspace.
- **Treatment Efficacy.** Assumptions that spraying patterns and efficacy are similar to heavier, existing manned aircraft are incorrect for lighter, multi-rotor UAS. Equipment standards for differing size and rotor configurations may be needed.
- **Operational Safety and Environmental Protection.** Safety to operators, the general public, and the environment are critical. Transporting hazardous substances raises further safety and environmental concerns. As noted, UAS operate in low altitude air space with various surface hazards including humans and livestock. Standards for safety need to be developed based on the FAA's models of risk as a function of kinetic energy. See also section 9.2 on HAZMAT transport.
- **Equipment Reliability.** Aviation depends on reliability of the equipment involved. Failure at height often results in catastrophic damage and represents a serious safety hazard. Reliability of equipment and specific parts may also follow the FAA's risk curve, though catastrophic failure and damage of expensive equipment that is not high kinetic energy (precision sprayers, cameras, etc.) may require higher standards of reliability due to the potential for large economic loss due to failure.
- **Airspace Integration.** This is tied to automated ID and location communication so that other aircraft can sense the spraying UAS and avoid collisions. Detailed flight plans are probably not necessary and controlled airspace restrictions are already in place.

R&D Needed: Yes. Mostly engineering development and demonstration. There is some indication that treatment efficacy does not meet expectations in some scenarios.

Recommendation: Develop standards for pesticide application using UAS. Organizations such as NAAA, USDA Aerial Application Technology Research Unit (AATRU), ASABE, and ASSURE should be consulted in conjunction with such standards development activities.

Priority: High (Tier 3)

Organization(s): ISO/TC 23/SC 6, CEN/TC 144, ASABE, FAA

Status of Progress: Green

Update: As noted in the text, standards development is underway by ISO and CEN with respect to aerial application by manned aircraft that has potential relevance to UAS.

8.3.3. Livestock Monitoring and Pasture Management

One of the many applications of UAS in the agricultural sector is the growing use of UAS by farmers and ranchers to monitor livestock and manage pastures.

Traditionally, farmers and ranchers have used various means to monitor the location, number, and well-being of their herds. Until now, those means have required significant investment in labor and time, or, more recently, expensive infrastructure and/or equipment particularly where large-area operations (measured in square miles) are involved. The days where livestock monitoring on large land holdings was conducted by people on horseback over several days have almost disappeared. Horses have given way to off-road vehicles and helicopters, and experiments with installing wide-area remote sensor/observing networks have so far proven to be limited in application and problematic in operation.

The wide range of COTS UAS and accessories now available offers farmers and ranchers a relatively easier and cost-effective way to monitor livestock holdings and manage pastures, irrespective of the size of their operations. Farmers engaged in small-area livestock operations (typically measured in acres), such as an alpaca farm or a horse stud, might find it efficient/convenient to conduct routine UAS VLOS video operations to quickly check on the status of livestock, fences, gates, and water points. Ranchers, on the other hand, such as those operating cattle spreads, have similar requirements but on a much larger scale, and UAS BVLOS operations offers them a potentially viable alternative to their current means.

Published Standards and Related Materials: No published standards have been identified specifically related to the use of UAS for livestock monitoring and pasture management.

There are several published standards relating to the use of manned aircraft in support of agricultural operations (e.g., crop-spraying, livestock mustering), and these may also apply to UAS applications for precision agricultural operations, including livestock monitoring and pasture management. Some regulatory and best practice guidance on the use of UAS in agricultural aircraft operations also exist, for example:

- DOT, FAA Notice on National Policy N 8900.433 - Part 137 Guidance and Advisory Circular Update, Effective Date: August 21, 2017. Cancellation Date: August 21, 2018. This notice provides guidance to FAA aviation safety inspectors (ASI) concerning 14 CFR part 137 operators. The intent of the notice is to clarify former issues found in guidance and to include information on the use of UAS in agricultural aircraft operations. Background: In May 2015, a U.S. corporation was granted an exemption to operate a UAS in the NAS for agricultural aerial application operations. The same corporation later became the first part 137 UAS (55 pounds or more) certificated operator in the United States. In August 2016, a new rule, 14 CFR part 107, became effective allowing commercial operations of small UAS in the NAS. These significant events warranted the General Aviation and Commercial Division (AFS-800) to update all associated part 137 guidance in FAA Order 8900.1 and AC 137-1, Certification Process for Agricultural Aircraft Operators, for UAS inclusion.

- Barbedo, Jayme G.A., et al. "Perspectives on the use of unmanned aerial systems to monitor cattle," *Sage Journal Outlook on Agriculture*. First Published online: June 24, 2018.
- Hayhurst, Kelly J., et al. "Safety and Certification Considerations for Expanding the Use of UAS in Precision Agriculture," Proceedings of the 13th International Conference on Precision Agriculture, July 31 – August 3, 2016, St. Louis, Missouri, USA.
- Smith, Gayle "Drones, smart ear tags & cameras: The case for using technology in ranching," *Beef Magazine*, September 01, 2016.
- Sylvester, Gerard (ed). "E-Agriculture in Action: Drones for Agriculture," Food and Agriculture Organization of the United Nations and International Telecommunication Union. Bangkok, 2018.
- Watts, Adam C., et al. "Small Unmanned Aircraft Systems for Low-Altitude Aerial Surveys," *The Journal of Wildlife Management*. December 13, 2010. Volume 74, Issue 7: 1614-1619. 2010.

In-Development Standards: No standards in development have been identified specifically related to this issue.

No UAS standards gap has been identified. By way of further explanation, in considering the above scenarios – and whether a specific standard is required for them – several important aspects need to be noted:

- UAS agricultural operations in the United States are required by the FAA to be conducted by 14 CFR part 137 or 14 CFR part 107 operators.
- UAS agricultural operations are usually conducted within the boundaries of a private or commercial property where the general public is not exposed to the UAS operation and its associated risks (i.e., no public safety and/or privacy issues).
- Livestock monitoring and pasture management are examples of where UAS can be used effectively in support of precision agriculture, both on a small or large scale.
- UAS operations in support of precision agriculture are primarily conducted BVLOS and similar in operational context to UAS low-altitude aerial surveys/inspections, for which standards either already exist or are in development.
- Every type of aerial survey/inspection will have different requirements, both regulatory (such as 14 CFR part 137 or 14 CFR part 107 approvals) and company CONOPS for which specialized standards could not be realistically developed (e.g., for environmental surveys/inspections).

Therefore, a specific standard for UAS operations for livestock monitoring and pasture management is not required. These applications should be covered as examples in the standards being developed for UAS BVLOS operations and UAS low-altitude aerial surveys/inspections, or a standard that encompasses UAS uses in agriculture (which could be adopted from existing standards for manned agricultural aircraft operations).

There are many published best practices for precision agriculture available, including several specifically relating to the use of UAS to monitor livestock. However, if it is determined that a more robust, focused standard or guideline is needed to improve the efficiency and safety of operations for livestock monitoring and pasture management, then agricultural associations and drone and sensor manufacturers should come together to develop such a document.

8.4. Commercial Services

There is a growing desire to expand UAS operations in order to increase transport services of goods and enable transport of people for commercial purposes. Such services operate within a larger framework that is generically built upon the following pillars:

- Operational Vehicle Capabilities – to include such capabilities as BVLOS, automated take-off/landing, waypoint following, obstacle detection and avoidance, aircraft tracking, identification, detection and avoidance, as well as V2V and V2I communication;
- Infrastructure Capabilities – to include such capabilities as take-off/landing locations, emergency landing locations, fueling/recharge, inter-modal transfers;
- Management Services – to include such capabilities as security, fleet management, maintenance/repair, training, airspace management, reservation/manifest management; and
- Practices – to include such provisions as engineering and development, verification/validation, certification, licensing, insurance/liability, inspection, forensics.

Commercial services are expected to utilize UAS of varying size, weight, performance, propulsion type, payload capacity, etc. Such aircraft will operate and cooperate within the framework identified above and will coordinate with existing and future manned and unmanned vehicles, fleet and airspace management systems. Within this context, commercial services are subdivided into the movement of goods and people and the provision of airborne services as described in the following sections.

8.4.1. Commercial Package Delivery via UAS

A number of commercial, service-oriented companies are interested in using UAS to increase product distribution, reduce product delivery times and achieve corresponding potential cost savings. Commercial package delivery in this context means the delivery segment of a package to its final destination (i.e., the last mile). Delivery can be directly to a recipient’s desired/selected location from the point of origin or distribution centers (fixed or mobile). These delivery locations may be in urban, suburban, and rural areas. As further described below, the standards and regulatory framework supporting UAS capabilities need to evolve before such operations can become ubiquitous.

The following concepts are not standardized:

- How is the package carried in or on the aircraft? For example, an integrated cargo compartment, clamping arrangement, an underslung load, or some other configuration?

- Which types of materials (hazardous and non-hazardous) can be delivered and how?
- What are the mechanisms and procedures for releasing the package at the delivery point? Does it require human intervention?
- How do operators or highly and fully automated agents determine that the nominated delivery point is safe for both the drones to land and the package that is being delivered? Will the industry develop standards and standard practices for regulated delivery zones?
- How will safety features or algorithms be tested and evaluated? Will this be a continuous recertification and evaluation process? How will different operating conditions (like weather or congested environments) be certified?
- How dynamic will delivery zones be? Will no-fly zones be continuously updated based on surroundings (for example, via a GPS navigational app for routes if there is construction)? Or will platforms have some sort of onboard sensing and logic to update routes on the fly? If so, how will these algorithms be tested, standardized, and validated?

Published Standards and Regulations:

- 14 CFR Part 133, Rotorcraft External-Load Operations

In-Development Standards:

- ASTM WK62644, Revision of F3196 - 17 Standard Practice for Seeking Approval for Extended Visual Line of Sight (EVLOS) or Beyond Visual Line of Sight (BVLOS) Small Unmanned Aircraft System (sUAS) Operations
- SAE AIR7121, Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems
- SAE AS7209, Development Assurance Objectives for Aerospace Vehicles and Systems

Gap I11: Commercial Package Delivery via UAS. Standards are needed to enable UAS commercial package delivery operations.

R&D Needed: Yes

Recommendation:

1) Complete work on ASTM WK62344 and SAE AIR7121. Review small UAS oriented standards for scaling into larger UAVs (those that exceed Part 107 and have Part 135 applicability).
2) Write new standards to address commercial package delivery UAS and its operations.

Priority: High (Tier 3)

Organization(s): ASTM, SAE, RTCA, EUROCAE, SAE ARINC

Status of Progress: Green

Update: Relevant standards in development are noted above.

8.4.2. Commercial Cargo Transport via UAS

A number of companies including but not limited to air cargo operators, are interested in using UAS to increase product distribution, reduce product delivery times, optimize air cargo operations, and achieve corresponding potential cost savings while maintaining safety and security of air cargo operations. Industry consensus standards are needed to support this evolving use of UAS and related technologies. Commercial cargo transport by UAS is distinctly different to commercial package delivery (section 8.4.1), which is the delivery segment of a package to its final destination (i.e., the last mile). Commercial cargo transport in this context means the delivery segment of a consolidated amount of goods (i.e., many items, usually regarded as freight in sea, rail, and road transport) from one major distribution center to another, such as air cargo/freight terminals at airports. Commercial cargo transport operations by UAS would typically be conducted over large distances by large aircraft capable of carrying bulky and heavy consignments.

Published Standards and Regulations: Published standards and committees that have developed relevant standards include:

- FAA 14 CFR Sec. 27.865, External loads
- FAA 14 CFR Sec. 29.865, External loads
- FAA 14 CFR part 133
- FAA AC 133-1B, Rotorcraft External-Load Operations, 05/31/2017
- ASME B30.12 -2011 Handling Loads Suspended From Rotorcraft
- SAE AGE-2 Air Cargo Committee
- SAE AGE-4 Packaging, Handling and Transportability Committee
- S-18 Aircraft and Systems Development and Safety Assessment Committee
- RTCA Committees
    - RTCA SC-206, Aeronautical Information and Meteorological Data Link Services
    - RTCA SC-214, Standards for Air Traffic Data Communication Services
    - RTCA SC-216, Aeronautical Systems Security
    - RTCA SC-217, Aeronautical Databases
    - RTCA SC-222, AMS(R)S
    - RTCA SC-223, Internet Protocol Suite (IPS) and AeroMACS
    - RTCA SC-227, Standards of Navigation Performance
    - RTCA SC-228, Minimum Performance Standards for Unmanned Aircraft Systems
    - RTCA SC-229, 406 MHz Emergency Locator Transmitters (ELTs)
    - RTCA SC-230, Airborne Weather Detection Systems
    - RTCA SC-231, Terrain Awareness Warning System (TAWS)
    - RTCA SC-236, Standards for Wireless Avionics Intra-Communication System (WAIC) within 4200-4400 MHz
    - RTCA SC-237, Helicopter Terrain Awareness Warning System (HTAWS)

    - RTCA SC-239, Low Range Altimeter
- SAE ITC AEEC (ARINC) Standards
- EUROCAE Working Groups

In-Development Standards: In-development standards and committees that are developing relevant standards include:
- SAE AGE-2 Air Cargo Committee
- SAE AGE-4 Packaging, Handling and Transportability Committee
- SAE G-27 Lithium Battery Packaging Performance Committee
- SAE AS6342 Minimum Operation Performance Standard for Helicopter Hoist
- S-18UAS Autonomy Working Group
- SAE AIR7121, Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems
- SAE AS7209, Development Assurance Objectives for Aerospace Vehicles and Systems
- RTCA Committees
    - RTCA SC-206, Aeronautical Information and Meteorological Data Link Services
    - RTCA SC-214, Standards for Air Traffic Data Communication Services
    - RTCA SC-216, Aeronautical Systems Security
    - RTCA SC-217, Aeronautical Databases
    - RTCA SC-222, AMS(R)S
    - RTCA SC-223, Internet Protocol Suite (IPS) and AeroMACS
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    - RTCA SC-236, Standards for Wireless Avionics Intra-Communication System (WAIC) within 4200-4400 MHz
    - RTCA SC-237, Helicopter Terrain Awareness Warning System (HTAWS)
    - RTCA SC-239, Low Range Altimeter
- SAE ITC AEEC (ARINC) Standards
- EUROCAE Working Groups
- SAE CMH-17 Handbook

New Gap I16: Commercial Cargo Transport via UAS. Additional standards may be needed to enable UAS commercial cargo transport and operations.

R&D Needed: Yes. Review existing standards used for traditional commercial cargo transport and determine gaps that are unique to UAS.

Recommendation: Complete work on in-development standards. Engage with industry to determine intent for future services (e.g., replace short haul rail and road freight with small general aviation aircraft cargo operations).

Priority: High (Tier TBD)

Organization(s): SAE, RTCA, EUROCAE, SAE, ARINC, ASME

8.4.3. Urban Air Mobility (UAM, short-haul flights carrying few passengers)

Commercial passenger air taxi transport, a service that conceptually falls under intra-city urban air mobility (UAM), or on-demand mobility (ODM), is not a new capability. It is a subset of what is now being referred to more broadly as advanced air mobility (AAM) which encompasses urban, rural, and inter-city mobility. Helicopter passenger transport services are in common use to shuttle people through urban (i.e., intra-city) and other short-haul environments (e.g., from a city location to an airport terminal). UAS bring the potential for satisfying an increased demand with a reduced number of pilots by including automated capabilities on the aircraft and eventually removing an on-board pilot. In the shorter term, however, it will actually increase the pilot demand, as the first phase would include pilots on board these air taxis. At its broadest, the concept of intra-city UAM encompasses flight operations within city centers, between city centers and their suburbs, between edge/satellite cities and urban centers or other edge/satellite cities, and as transportation to large airports to connect to the airline system. These flights may be operated using a variety of different operational models, including (extremely) thin haul scheduled airline service, transit style or "air metro" operations that fly a set route with stops like a city bus, airport shuttle service, and the on-demand air taxi model that has received much popular attention in recent years. Figures 6 and 7 illustrate concepts of the UAM ecosystem.

Figure 6: UAM Concept. (Artist Rendition, Courtesy of Modern Technology Solutions Inc.)

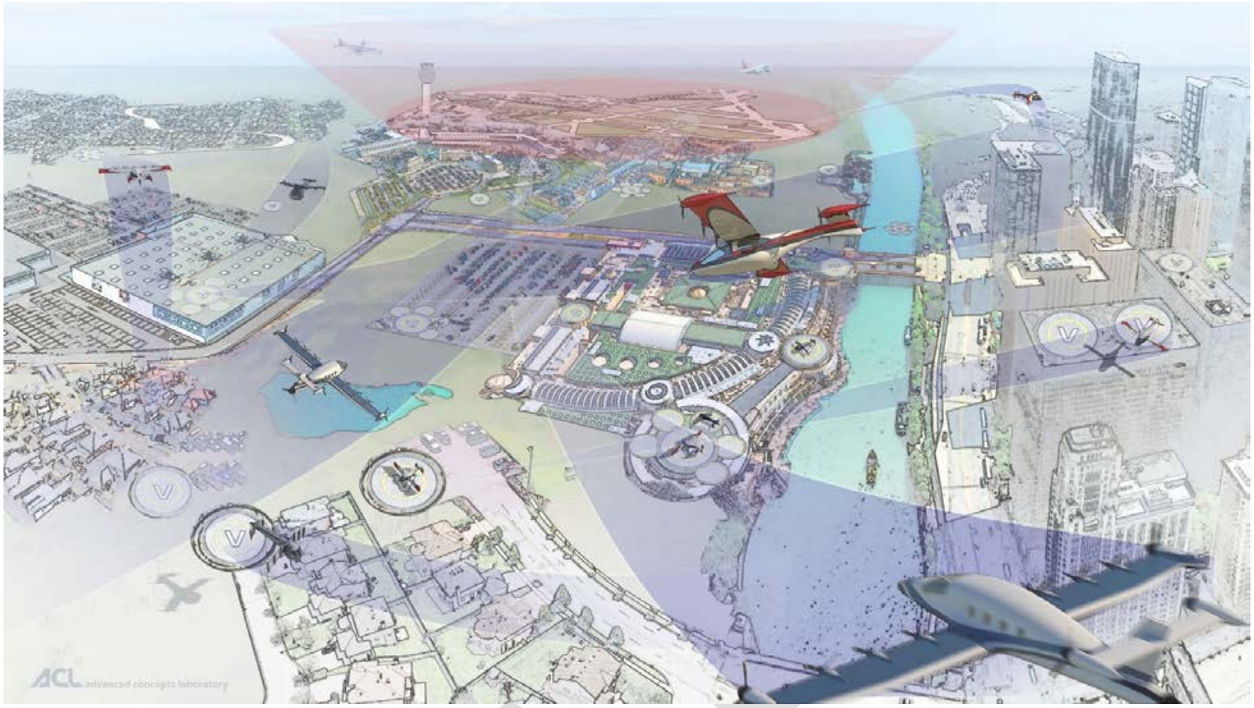

Figure 7: UAM Concept. (Image credit: NASA)

The standards associated with these services can reasonably be expected to parallel existing piloted aviation in urban environments with tailoring and modifications that use highly automated services instead of a full-time on-board or remote pilot. Over time, the expectation is that these autonomous aircraft will make increased use of artificial intelligence (AI) and machine learning techniques, not only in a flight support capacity but eventually in-flight control itself.

Infrastructure considerations (e.g., vertiports/skyports), environmental impacts (e.g., noise), and training for associated personnel are all active areas of development for both the UAM industry and its associated standards.

It is important to note that passengers engaged in these services are separate and distinct from the personnel identified in sections 10.3 (UAS Flight Crew) and 10.4 (Additional Crew Members). This section pertains to the commercial services rendered to the customers and passengers. As such, aircraft and operational standards related to this group represent a new area of focus for the industry.

A definition of UAM is being developed by aerospace stakeholders within the SAE International Shared and Digital Mobility Committee, which is drafting JA3163, Taxonomy of Shared Mobility. In a parallel effort, NASA is working with the FAA and the industry to develop a comprehensive concept of operations (ConOps) for UAM. The ConOps is the result of stakeholder engagement and is designed to provide a high-level, consensus-driven vision of the future. According to the NASA UAM ConOps initial draft, UAM is the concept of utilizing the airspace directly enveloping urban areas to build a transportation network that utilizes short flights to transport people and/or cargo within a metropolitan region. UAM represents a paradigm shift, taking aviation from predominately a long-distance public transportation mode to an integral component of regional and local transportation. This level of integration will require a phased approach, but today's technology demonstrates promise that it can be achieved.

One such training and personnel related component are the human-computer interaction (HCI) considerations associated with these systems. As autonomy and remote operation becomes available, most likely platforms will be integrated into existing processes alongside human operators. This introduces a whole host of HCI related issues. Highly automated or remote systems will need to be user friendly, communicate to humans in an understandable way, and communicate their uncertainty under certain conditions. User testing with highly automated systems before they are deployed will help ensure that any potential issues can be identified before platforms are released into safety critical situations. Also, thought should be given to how humans and these systems will communicate, especially, when they work in close proximity. In the foreseeable future it is unrealistic to assume a fully autonomous environment. There will be instances where humans and machines will need to co-operate. As a result, a way for machines and humans to communicate needs to be anticipated. Finally, due to algorithm limitations, highly automated systems will encounter situations where their models break down. A way for operators or monitors to handle this should be incorporated. If the system can determine when it is uncertain, it can then call upon other resources to help it execute its next actions safely.

To realize the vision of UAM, NASA published 5 main pillars of UAM, illustrated in Figure 8. For more information on NASA's involvement, visit https://www.nasa.gov/uam.

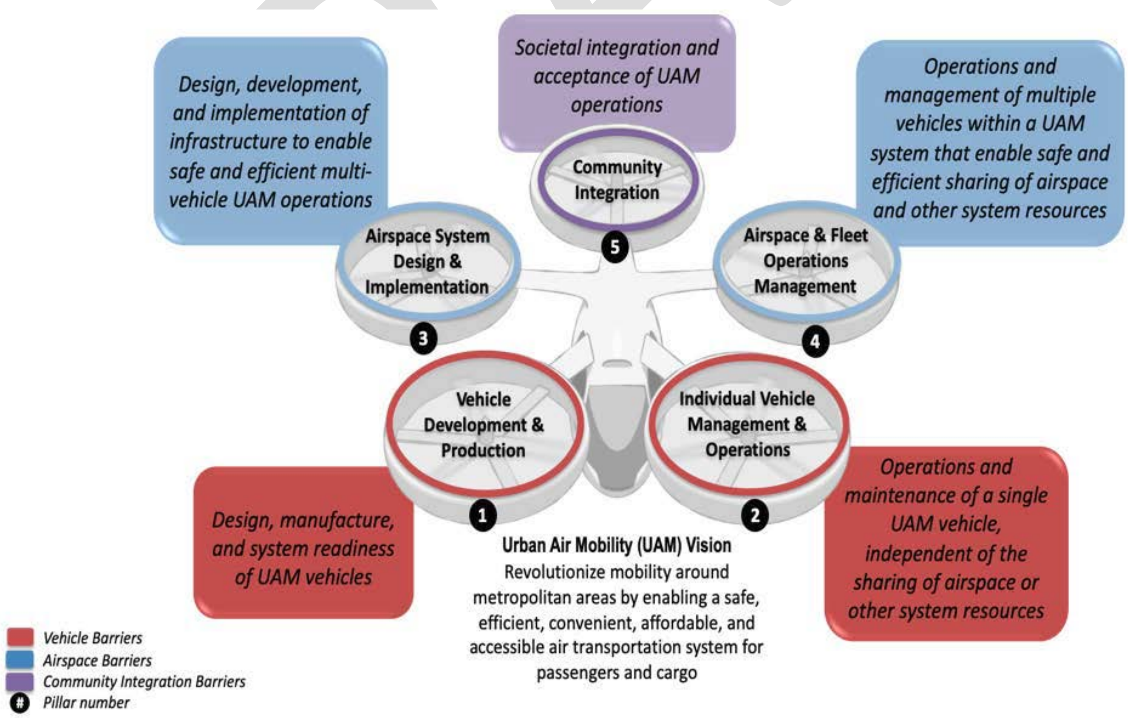

Figure 8: UAM Vision and Framework. (Image credit: NASA)

The NASA UAM ConOps explores the intermediate state of medium density and complexity operations with collaborative and responsible automated systems on the order of hundreds of operations over an urban area, i.e., UAM Maturity Level 4 (UML-4). The UAM Maturity Levels are illustrated in Figure 9.

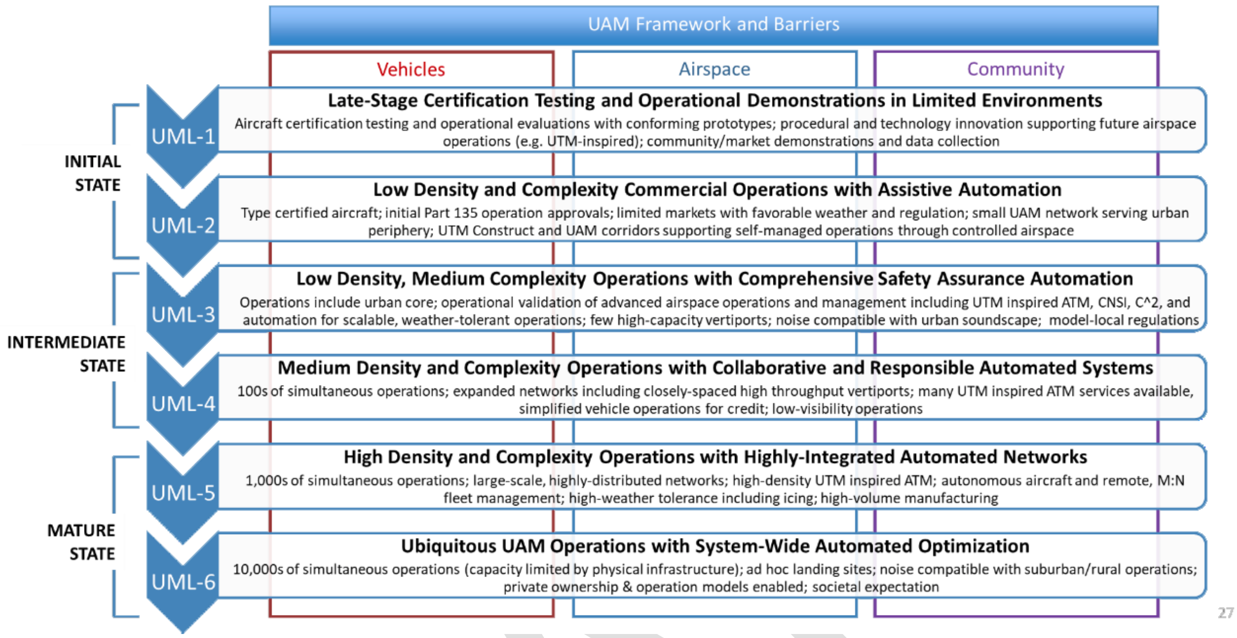

Figure 9: UAM Maturity Levels. (Image credit: NASA)

NASA is also sponsoring the UAM Grand Challenge. The Grand Challenge itself will be a full field demonstration in an urban environment that tests the readiness of companies' vehicles and airspace operators' systems to operate during a full range of passenger transport and cargo delivery scenarios under a variety of weather and traffic conditions. The goal of the Grand Challenge is to provide a proving ground where NASA, vehicle providers, airspace technology providers, and the public learn what it really requires to achieve urban air mobility. **Error! Reference source not found.**Figure 10 shows an abstract concept of the UAM proving ground, the objectives of which are to:

- Accelerate technology certification and approval
- Develop flight procedure guidelines
- Evaluate communication, navigation and surveillance options
- Demonstrate an airspace system architecture based on NASA's unmanned aircraft systems traffic management (UTM) construct
- Collect initial assessments of passenger and community perspectives on vehicle ground noise, cabin noise, and on-board ride quality

Figure 10: NASA UAM Grand Challenge serves as a proving ground for UAM demonstrations. (Image credit: NASA)

Current designs for electric and hybrid vertical takeoff and landing (eVTOL/hVTOL) aircraft already address barriers to urban air travel, using distributed electric power to lower lifecycle maintenance costs and emitted noise. Future advances in design and automation are expected to clear the remaining barriers to widespread urban air travel. The aircraft that are being tested and developed to serve these operations are equally varied with different passenger capacities, ranges, and combinations of propulsion systems (e.g., electric and hybrid electric) and sources of lift (e.g., wings and distributed rotors). The unifying technical characteristics of these aircraft are their reliance on electric motors for vertical takeoff and landing and their incorporation of autonomy, to at least some extent. Many of the technologies such as distributed electric propulsion and detect and avoid capabilities that enable UAS are also central to the next generation of passenger carrying aircraft (e.g., eVTOL aircraft) that are being developed for use in urban air mobility (UAM) and other emerging commercial passenger air transportation models. Many standards written for manned aircraft apply to UAS and some standards originally written for UAS may be appropriate (with modifications) for UAM applications.

Published Standards: Published standards and committees that have developed relevant standards include:

- ASTM Committees
  - F38 Unmanned Aircraft Systems
  - F39 Aircraft Systems
  - F44 General Aviation
  - D30 Composite Materials
- SAE Committees
  - SAE Aircraft SEAT Committee
  - SAE AGE-3 Aircraft Ground Support Equipment Committee
  - SAE A-10 Aircraft Oxygen Equipment Committee

- SAE AC-9 Aircraft Environmental Systems Committee
- SAE AC-9C Aircraft Icing Technology Committee
- SAE A-21 Aircraft Noise Measurement Aviation Emission Modeling
- SAE AE-7A Generators and Controls Motors and Magnetic Devices
- SAE AE-7C Systems
- SAE AE-7D Aircraft Energy Storage and Charging Committee
- SAE S-9A Safety Equipment and Survival Systems Committee
- SAE S-9B Cabin Interiors and Furnishings Committee
- SAE G-32 Cyber Physical Systems Security Committee
- SAE G-34 Artificial Intelligence in Aviation
- SAE HM-1 Integrated Vehicle Health Management Committee
- SAE S-18 Aircraft and Sys Dev and Safety Assessment Committee
- SAE AEEC (ARINC) Standards
- SAE S-18UAS Autonomy Working Group
- SAE A-4 Underwater Locator Device Working Group

- SAE ITC AEEC (ARINC) Standards
- SAE CMH-17 Handbook
- EUROCAE Working Groups

In-Development Standards: In-development standards and committees that are developing relevant standards include:

- SAE JA3163 Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies
- SAE AS6968 Connection Set of Conductive Charging for Electric Aircraft
- SAE ARP4721/1A Monitoring Aircraft Noise and Operations in the Vicinity of Airports: System Description, Acquisition, and Operation
- SAE ARP4721/2A Monitoring Aircraft Noise and Operations in the Vicinity of Airports: System Validation
- Revising SAE AIR1845A Procedure for the Calculation of Airplane Noise in the Vicinity of Airports
- ASTM Committees
  - F38 Unmanned Aircraft Systems
  - F39 Aircraft Systems
  - F44 General Aviation
- SAE AIR7121, Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems
- SAE AS7209, Development Assurance Objectives for Aerospace Vehicles and Systems
- SAE International Committees
  - SAE Aircraft SEAT Committee
  - SAE AGE-3 Aircraft Ground Support Equipment Committee
  - SAE A-10 Aircraft Oxygen Equipment Committee
  - SAE AC-9 Aircraft Environmental Systems Committee

  - SAE AC-9C Aircraft Icing Technology Committee
  - SAE A-21 Aircraft Noise Measurement Aviation Emission Modeling
  - SAE AE-7A Generators and Controls Motors and Magnetic Devices
  - SAE AE-7C Systems
  - SAE AE-7D Aircraft Energy Storage and Charging Committee
  - SAE S-9A Safety Equipment and Survival Systems Committee
  - SAE S-9B Cabin Interiors and Furnishings Committee
  - SAE G-32 Cyber Physical Systems Security Committee
  - SAE G-34 Artificial Intelligence in Aviation / EUROCAE WG-114
  - SAE HM-1 Integrated Vehicle Health Management Committee
  - SAE S-18 Aircraft and Sys Dev and Safety Assessment Committee
  - SAE S-18UAS Autonomy Working Group
- SAE ITC AEEC (ARINC) Standards
- EUROCAE Working Groups
- SAE CMH-17 Handbook

New Gap I17: Urban Air Mobility (UAM, short-haul flights carrying few passengers and/or cargo). Standards are needed to support UAM covering the areas such as vertiports, vertiport security, ground infrastructures, aircraft automation, charging stations, passenger cabin interiors and furnishings, safety equipment and survival, etc. Standards are needed for remotely piloted and eventually highly automated UAS (that may or may not be implemented with and using non-deterministic algorithms and techniques) flying in urban environments and also carrying passengers and/or cargo.

R&D Needed: Yes

Recommendation:

1) Complete work on in-development standards. Complete work on use of AI and non-deterministic techniques on autonomous, non-piloted UAS. Develop safety and operations standards applicable to non-piloted UAS carrying passengers.
2) Consult the NASA UAM ConOps and write standards to address UAM

Priority: High (Tier TBD)

Organization(s): ASTM, RTCA, SAE, EUROCAE

8.4.4. Commercial Passenger Transport via UAS (long-haul flights carrying many passengers)

A number of companies are interested in using unmanned aircraft to provide commercial passenger services. Initially, operations would consist of small short haul flights, carrying a few passengers (e.g., intra-city services, such as from the airport to the city center or from one city location to another). Over time, these operations might evolve to larger, longer haul flights with more passengers, such as inter-city shuttle services. The standards and regulatory framework supporting commercial passenger transport operations that include but are not limited to 14 CFR Part 91, 119, 121, 125, 135, may have to be amended to include the development of performance requirements for communication, navigation and surveillance (CNS), and UAS traffic management (UTM). These performance requirements need to take into account future highly integrated systems (HIS). A HIS is a set of previously independent systems (e.g., communication-navigation, flight instruments) that are now inter-connected both functionally and architecturally.

Focus should be given on the scalability issues and technology opportunities to achieve more scalable operations.

- Advanced Interval Management
- CAT IIIC Operations
- Broadband IP
- 4D Conflict Resolution
- 4-D Flight Management System (4-D FMS)
- ADS-N with Interval Management Capability

Current aircraft to ground systems communications are limited to mechanisms such as voice, automated data surveillance transponders, controller-pilot data link communications, and data communication solutions. These systems limit the use of data exchange and trajectory sharing amongst systems and create a hurdle to evolution towards a full, trajectory-based operations (TBO) environment.

Commercial passenger transport UAS may use elements of existing instrument flight rules (IFR) and visual flight rules (VFR), and they will likely require new standards to seamlessly and efficiently conduct the flight. New standards are needed to achieve scalability for this type of operation and provide a link between the rules and technology, which will require further maturation, verification, and validation.

The standards needed to accomplish commercial passenger transport operations with UAS are those that support 14 CFR Part 91, 119, 121, 125, and 135. These rules apply to manned aviation. Updates are needed to enable UAS for commercial passenger transport operations. Commercial passenger transport UAS are at the top right of the FAA's UAS integration strategy depicted in Figure 11. Transport airplanes are currently certified to 14 CFR 25 and typically operate under 14 CFR 121 operating rules today. Developments are underway to initially use UAS to transport cargo with the expectation of transporting people in the long term.

UAS designers/manufacturers will need to consider the operational regulations in order to comply with the design of specific systems such as DAA, cybersecurity, AI, etc., based on the ConOps and operational risk assessment (ORA), and to follow the design processes set forth in published standards such as SAE ARP4754A, SAE ARP4761, and in-development standards such as SAE AIR7121, *Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems*.

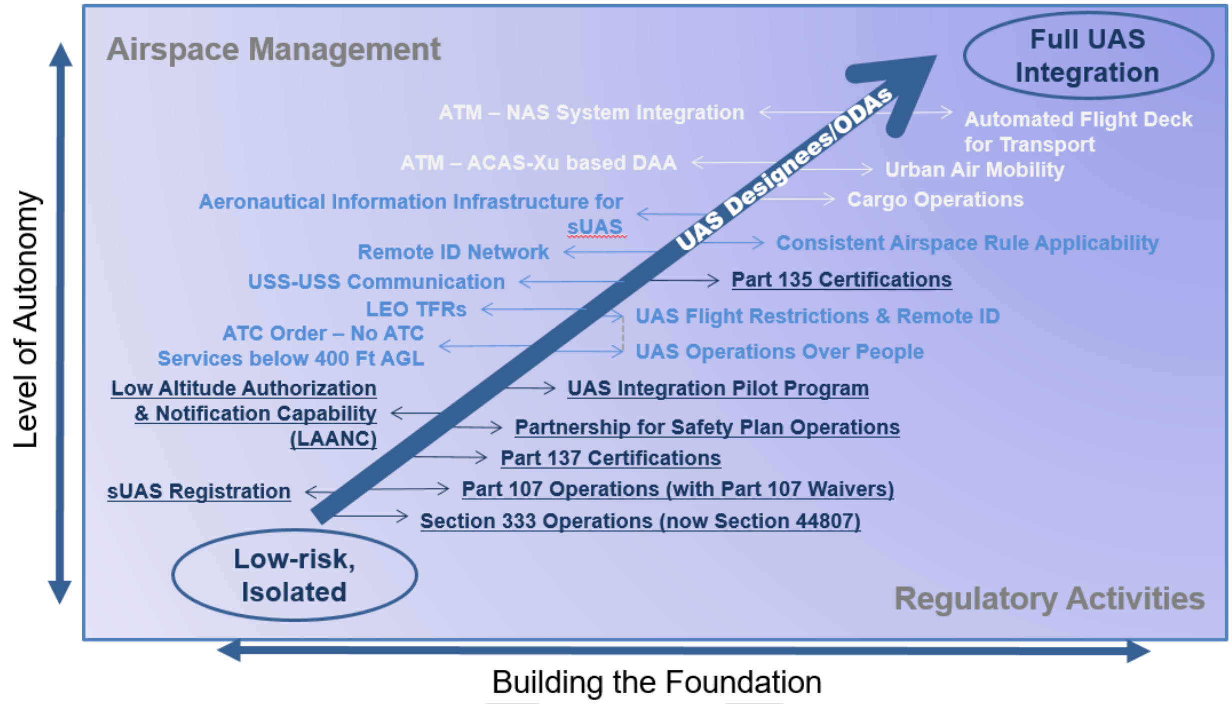

Figure 11: FAA's UAS Integration Strategy

Published Standards: Published standards and committees that have developed relevant standards include:

- RTCA DO-264, Guidelines for Approval of the Provision and Use of Air Traffic Services Supported by Data Communications
- SAE ARP4754A, Guidelines for Development of Civil Aircraft and Systems
- SAE ARP4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
- SAE AIR6219, Development of Atmospheric Neutron Single Event Effects Analysis for Use in Safety Assessments
- SAE ARP5150A, Safety Assessment of Transport Airplanes in Commercial Service
- SAE ARP5151A Safety Assessment of General Aviation Airplanes and Rotorcraft in Commercial Service
- RTCA Committees
    - RTCA SC-206, Aeronautical Information and Meteorological Data Link Services
    - RTCA SC-214, Standards for Air Traffic Data Communication Services
    - RTCA SC-216, Aeronautical Systems Security
    - RTCA SC-217, Aeronautical Databases
    - RTCA SC-222, AMS(R)S
    - RTCA SC-223, Internet Protocol Suite (IPS) and AeroMACS
    - RTCA SC-227, Standards of Navigation Performance
    - RTCA SC-228, Minimum Performance Standards for Unmanned Aircraft Systems

  - RTCA SC-229, 406 MHz Emergency Locator Transmitters (ELTs)
  - RTCA SC-230, Airborne Weather Detection Systems
  - RTCA SC-231, Terrain Awareness Warning System (TAWS)
  - RTCA SC-236, Standards for Wireless Avionics Intra-Communication System (WAIC) within 4200-4400 MHz
  - RTCA SC-237, Helicopter Terrain Awareness Warning System (HTAWS)
  - RTCA SC-239, Low Range Altimeter
- SAE International Committees
  - SAE Aircraft SEAT Committee
  - SAE AGE-3 Aircraft Ground Support Equipment Committee
  - SAE A-10 Aircraft Oxygen Equipment Committee
  - SAE AC-9 Aircraft Environmental Systems Committee
  - SAE AC-9C Aircraft Icing Technology Committee
  - SAE A-21 Aircraft Noise Measurement Aviation Emission Modeling
  - SAE S-9A Safety Equipment and Survival Systems Committee
  - SAE S-9B Cabin Interiors and Furnishings Committee
  - SAE G-32 Cyber Physical Systems Security Committee
  - SAE G-34 Artificial Intelligence in Aviation
  - SAE HM-1 Integrated Vehicle Health Management Committee
  - SAE S-18 Aircraft and Sys Dev and Safety Assessment Committee
  - SAE AEEC (ARINC) Standards
  - SAE S-18UAS Autonomy Working Group
  - SAE A-4 Underwater Locator Device Working Group
- SAE ITC AEEC (ARINC) Standards
- SAE CMH-17 Handbook
- EUROCAE Working Groups

In-Development Standards: In-development standards and committees that are developing relevant standards include:

- SAE AIR7121 Applicability of Existing Development Assurance and System Safety Practices to Unmanned Aircraft Systems
- SAE AS7209 Development Assurance Objectives for Aerospace Vehicles and Systems
- SAE ARP4754B Guidelines for Development of Civil Aircraft and Systems
- SAE ARP4761A Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
- SAE AIR6913 Using STPA During Development and Safety Assessment of Civil Aircraft
- SAE AS6968 Connection Set of Conductive Charging for Electric Aircraft
- RTCA Committees
  - RTCA SC-206, Aeronautical Information and Meteorological Data Link Services
  - RTCA SC-214, Standards for Air Traffic Data Communication Services
  - RTCA SC-216, Aeronautical Systems Security

  - RTCA SC-217, Aeronautical Databases
  - RTCA SC-222, AMS(R)S
  - RTCA SC-223, Internet Protocol Suite (IPS) and AeroMACS
  - RTCA SC-227, Standards of Navigation Performance
  - RTCA SC-228, Minimum Performance Standards for Unmanned Aircraft Systems
  - RTCA SC-229, 406 MHz Emergency Locator Transmitters (ELTs)
  - RTCA SC-230, Airborne Weather Detection Systems
  - RTCA SC-231, Terrain Awareness Warning System (TAWS)
  - RTCA SC-236, Standards for Wireless Avionics Intra-Communication System (WAIC) within 4200-4400 MHz
  - RTCA SC-237, Helicopter Terrain Awareness Warning System (HTAWS)
  - RTCA SC-239, Low Range Altimeter
- SAE International Committees
  - SAE Aircraft SEAT Committee
  - SAE AGE-3 Aircraft Ground Support Equipment Committee
  - SAE A-10 Aircraft Oxygen Equipment Committee
  - SAE AC-9 Aircraft Environmental Systems Committee
  - SAE AC-9C Aircraft Icing Technology Committee
  - SAE A-21 Aircraft Noise Measurement Aviation Emission Modeling
  - SAE S-9A Safety Equipment and Survival Systems Committee
  - SAE S-9B Cabin Interiors and Furnishings Committee
  - SAE G-32 Cyber Physical Systems Security Committee
  - SAE G-34 Artificial Intelligence in Aviation
  - SAE HM-1 Integrated Vehicle Health Management Committee
  - SAE S-18 Aircraft and Sys Dev and Safety Assessment Committee
  - SAE S-18UAS Autonomy Working Group
- SAE ITC AEEC (ARINC) Standards
- SAE CMH-17 Handbook
- EUROCAE Working Groups
- ASTM D30 Composite Materials
- ISO/NP 5015-1, Unmanned aircraft systems — Part 1: Operational procedures for passenger-carrying UAS (proposed)

New Gap I18: Commercial Passenger Transport via UAS (long-haul flights carrying many passengers). Standards are needed to support commercial passenger transport via UAS and its operations.

R&D Needed: Yes

Recommendation: Complete work on in-development standards to support commercial passenger transport via UAS and its operations. Industry and SDOs should work together to develop standards to enable this type of operation.

Priority: High (Tier TBD)

Organization(s): RTCA, SAE, EUROCAE, SAE ARINC

8.4.5. Commercial Sensing Services

Commercial sensing services potentially could be offered by commercial UAS operators across a wide range of applications. Commercial sensing services are specialized airborne remote sensing services (e.g., video, infrared, spectral imagery, etc.) provided by outsourced service providers under a fee-for-service (FFS) contract to corporations, companies, institutions, and/or government agencies. As FFS contracts typically require a service provider to take full responsibility for the safe conduct and statutory compliance of the UAS operation, it would reasonably be expected that a degree of rigor, inspection, licensing and certification would be applicable to these services. It is likely that standards for how to employ sensors for collecting, transmitting, and storing information would be developed by the industries that make use of such services. Such industries may include, for example, real estate, film production, farming, mining, utilities, civil infrastructure, disaster/emergency management, etc.

Published Standards, Codes, and Other Documents: No published standards have been identified for conducting commercial sensing services operations with a UAS. However, there are best practice guidelines published by various industry groups that have remote inspection components that potentially could apply including those listed below:

- ASME Boiler and Pressure Vessel Code, Section V – Nondestructive Examination
- API 510 - Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration
- API 570 - Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems
- API 572 - Inspection Practices for Pressure Vessels

See also the list of published standards in sections 8.1, 8.2, 8.3, 8.4.6, 8.5, 9.4, 9.6.1, 9.6.2, and 9.11 of this roadmap.

In-Development Standards and Committees: There are several standards in development for some of the potential applications for which commercial sensor services could be provided such as those listed below. See also roadmap sections 8.1, 8.2, 8.3, 8.4.6, 8.5, 9.4, 9.6.1, 9.6.2, and 9.11.

- ASME MUS-1, Use of UAS for visual Inspection (noted in section 8.1.1)
- NACE Task Group 587 *Large Standoff Magnetometry (LSM) Inspection of Pipelines* (noted in section 8.2.4).
- ASTM E54.09 work items include (noted in section 9.6.1):
  - WK58928 Evaluating Aerial Response Robot Sensing: Thermal Image Acuity
  - WK58929 Evaluating Aerial Response Robot Sensing: Thermal Dynamic Range
  - WK58930 Evaluating Aerial Response Robot Sensing: Latency of Video, Audio, and Control

New Gap I19: Commercial Sensing Services. Standards are needed to enable the provision of commercial sensing services by UAS operators. Such standards should address the integrity and security of the information collected, transmitted, and stored by the service provider on behalf of the client.

R&D Needed: Yes

Recommendation: Develop standards to enable commercial sensing services. Industry groups should be consulted to determine if additional and/or higher level standards are required for UAS sensor operations conducted by outsourced service providers.

Priority: High (Tier TBD)

Organization(s): ASME, NACE, ASTM

8.4.6. Use of sUAS for News Gathering

News organizations may use sUAS for assisting in the gathering of video and audio of public events, crime scenes, war zone coverage, and many other newsworthy events. Newsgathering involves both VLOS and BVLOS use cases. News coverage of local events in public squares, stadiums, or at a public roadway intersection may be able to be covered with VLOS operation. However, there are certainly BVLOS use cases for newsgathering such as coverage of rush hour traffic over a city or wide-scale interstate highway backups (both of which may be covered today by the use of helicopters but tomorrow could be covered with sUAS). Other BVLOS use cases for newsgathering include coverage of lengthy parades, marathons, bike races (e.g., the Tour de France), and ad hoc crime scenes which start in one place but may spread quickly to other areas (e.g., car-chase scenes). Some of the BVLOS use cases for long distance events may involve handover from one flight command/ground control station to another.

Coordination with local law enforcement is an important aspect of performing newsgathering with UAS, as law enforcement should be able to know who is flying in a given area. In many respects, the newsgathering use case looks very similar to many public safety use cases. Industry standards for safe operation for newsgathering can create a basis for promoting harmonization of sUAS-related rules/regs. across states/localities.

There are currently no known published standards specifically for sUAS newsgathering. Industry standards, including best practices, for safety management would be useful for this use case. Each news organization must currently work with the FAA to secure the proper authorization for flying over people and may identify themselves to local law enforcement to ease working with local authorities. The FAA UAS remote ID NPRM will assist all sUAS (including those used for newsgathering) to be able to identify themselves to local law enforcement and to others. The priority of standards in this area is high due to the public safety responsibility of news organizations to “get the message out” in coordination with law enforcement and first responders when important news events occur.

Published Standards: There are currently no known standards specific to sUAS newsgathering. ASTM F3411 (UAS Remote ID) will assist news organizations in providing an automated means to identify their respective sUAS to law enforcement.

In Development Standards: None known at this time.

New Gap I20: Use of sUAS for Newsgathering. Standards (including best practices) are needed on the use of drones by newsgathering organizations whether the drone controllers are stationary or mobile. sUAS use for newsgathering operations should also include safety and health considerations for participating crew and the public from the NIOSH and OSHA aspects.

R&D Needed: No

Recommendation: Develop operational best practices or standards on the use of UAS by newsgathering organizations

Priority: High (Tier 2)

Organization(s): companies, industry trade associations

8.5. Workplace Safety

UAS operated in the workplace environment have the potential to improve occupational safety. For example, UAS can be used to perform inspections and other dangerous tasks at elevation, thereby reducing fatalities among workers from falls, a leading cause of fatal injuries in the construction industry.[55] Drones can also be used to monitor the workplace practices identify hazards, for example, in connection with maintenance work by tower climbers.

At the same time, the use of UAS in areas such as agriculture, oil and gas, utilities, construction, etc. has created various safety issues and potential hazards to nearby workers. Such hazards include the UA causing worker distraction, variable worksite conditions, inadequate UAS operator training or competency leading to errors, and faulty equipment. The arrival of autonomous or semi-autonomous UAS[56] may also present new hazards to the health and safety of workers.

Published Standards and Documents

[55] In 2015, there were 985 construction fatalities and 35.8% of them were due to falls from elevation. Source: The Construction Chart Book, 6th edition, February 2018, p. 108, CPWR – The Center for Construction Research and Training, produced with support from the National Institute for Occupational safety and Health grant number OH009762, Silver Spring, MD.

[56] See section 6.11, Enterprise Operations: Level of Automation/Autonomy/Artificial Intelligence (AI).

While there are numerous regulations, standards, and guidelines to address occupational safety and health issues for general industry, there has been little published about the safety and health risks associated with the commercial use of UAS. Data supporting the potential hazards of UAS for workers is scarce. Safety professionals, non-participants, and construction workers need to be aware of these new hazards, assess the risks, and apply appropriate controls/mitigations to reduce those risks to an acceptable level.

Existing regulations and standards include:

- Various FAA regulations, guidance, policies from the perspectives of the safety of the National Airspace System (NAS) and aviation
- OSHA regulations, policies, guidance from the occupational safety and health perspective (does not include occupational safety implications due to UAS operations)
- The following references provide information on workplace related incidents involving UAS:
    - the FAA and National Transportation Safety Board (NTSB) databases
    - the Bureau of Labor Statistics (BLS) Survey of Occupational Injuries and Illnesses (SOII) and the Census of Fatal Occupational Injuries (CFOI), and
    - accident investigations by OSHA, and Fatality Assessment and Control Evaluation Program (FACE) investigations by NIOSH

In-Development Standards and Documents: As noted in section 4.4 of this roadmap, the American Society of Safety Professionals (ASSP) A10 Committee on Construction and Demolition is developing a technical report addressing the safe use of drones for construction and demolition operations.

Gap I12: Occupational Safety Requirements for UAS Operated in Workplaces. There is a need for occupational safety standards for operating UAS in workplaces. In addition to collision avoidance and awareness systems that are required to be installed on critical infrastructure, at construction sites, and on buildings, such standards should address:

1) Hazard identification, risk characterization, and mitigation to ensure the safe operation of UAS in workplaces. This includes incorporating hazard prevention through safety design features/concepts such as frangible UAS, lightweight manipulators, passive compliant systems, safe actuators, passive robotic systems, operating warning devices (audio/visual), two-way communications between the operator and worker supervisor(s) or workers, etc. It also includes the deployment of Personal Protective Equipment (PPE) such as helmets and other equipment and gears.
2) Training, especially in relation to: a) the competency, experience and qualification of UAS operators; b) operator, bystander, and worker safety; c) identification of potential hazards to equipment such as cranes, elevators, fork lifts, etc.; and, d) corrective actions, procedures, and protocols that are needed to mitigate safety hazards. (See also section 10.3 on UAS Flight Crew.)

R&D needed: Yes. Collecting and analyzing objective data about negative safety outcomes is a key to identifying causes of injuries. This includes investigating:

1) navigation and collision avoidance systems in the design of commercial UAS so as to proactively address workplace safety.

2) the effects of stiffness and pliability in structural designs of UAS in relation to UAS collisions with critical infrastructure.
3) the severity of UAS collisions with workers wearing and not wearing helmets and other protective devices.
4) potential safety risks of drones in the workplace such as anti-collision lights distracting workers, increasing noise levels, psychological effects.
5) potential mitigation methods that follow the hierarchy of controls to reduce risks of drones to workers.

See also section 7.4 on Operations Over People and section 9.2 on HAZMAT (e.g operations at a chemical manufacturing plant).

Recommendation:

1) Develop proactive approach-based occupational safety standards/recommended best practices for UAS operations in workplace environments. Such work should be done in collaboration and consultation with diverse groups (governmental and non-governmental), to help integrate UAS operations in construction and other industries while ensuring the safety and health of workers and others in close proximity to the UAS.
2) Develop educational outreach materials for non-participating people in workplaces, including construction sites where UAS operations are taking place. Occupational safety and health professional organizations should invite speakers on UAS workplace applications to further increase awareness among their members.
3) Encourage the voluntary reporting of events, incidents, and accidents involving UAS in workplace environments.
4) Encourage BLS to modify the SOII and CFOI databases to facilitate search capability that would identify injuries caused by UAS.

Priority: High (Tier 2)

Organization(s): SAE, ASTM, ASSP, BLS, OSHA, NIOSH, CPWR, ISO/TC 20/SC 16, FAA, NTSB, etc.

Status of Progress: Yellow

Update: These recommendations require community efforts. It is believed that work is underway by NIOSH in regard to recommendations 1 and 2.

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9. Flight Operations Standards: Public Safety – WG4

9.1. sUAS for Public Safety Operations

Public safety officials (firefighters, police, EMS, et al.) are realizing the benefits of using drones in various operational scenarios including natural disaster response, SAR, structural fires, wildfires, HAZMAT release, and accident mapping/reconstruction.[57] A number of these use cases are explored in more detail later in this chapter.

During discussion of this topic, it was noted that standards have a role to play in helping first responders to take advantage of this emerging technology and to do it safely for sUAS pilots, public safety officials, and the public. It was also noted that the use of sUAS for public safety operations should include safety and health considerations for participating crew and public safety officials from the NIOSH and OSHA aspects.

In April 2017, ASTM and NFPA held a meeting on the opportunities to cooperate on the topic of UxS for first responders. A year later, the two organizations signed an MOU to support AC383 - UAS Public Safety Joint Working Group (ASTM/NFPA), comprising experts in public safety and drone technology.[58] The group undertook to develop use cases for using drones in various public safety operations, leveraging expertise from participants in ASTM F38 on UAS, ASTM F32 on SAR, ASTM E54.09 on response robots in homeland security applications, and NFPA® 2400 on public safety. The group is currently inactive.

Published Standards and Related Documents: There are many existing industry standards addressing the equipment used by public safety officials, as well as operational best practices, training, and professional qualifications. These include:

- NFPA 1500TM , Standard on Fire Department Occupational Safety, Health, and Wellness Program, specifies the minimum requirements for an occupational safety and health program for fire departments or organizations that provide rescue, fire suppression, emergency medical services, hazardous materials mitigation, special operations, and other emergency services.

Published standards and related documents specifically related to the use of UAS by the public safety community include:

[57] Werner, Charles. "Public Safety Professionals Need Drones," Aircraft Owners and Pilots Association. June 25, 2018.
[58] "New Joint Effort Boosts Drone Standards for Public Safety Officials," ASTM News Releases. April 16, 2018.

- *Standards for Public Safety Small Unmanned Aircraft Systems Programs*, published by APSAC in October 2017
- ASTM F3379, *Guide for Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement*, (previously WK61764)
- NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations.* This standard, begun in August 2016 and published in November 2018, covers organizational deployment, professional qualifications, and maintenance. It applies to all public safety departments with sUAS including fire service, law enforcement, and EMS. Risk assessment is mentioned in chapter 4; however, the standard does not address occupational safety. The public input period for the next iteration of the standard is open and it closes June 30, 2020. Additional information can be found in section 4.11 of this document.
- Public Safety UAS Flight Training and Operations, DRONERESPONDERS report dated 12/4/19

In-Development Standards: No in-development standards have been identified.

Gap S1: Use of sUAS for Public Safety Operations. The roadmap version 1 gap stated that "Standards are needed on the use of drones by the public safety community."

R&D Needed: No

Recommendation: The roadmap version 1 recommendation stated "With the publication of NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations,* complete work on the development of use cases by the ASTM/NFPA JWG." As noted above, the JWG is now inactive.

Priority: High (Tier 2)

Organization(s): NFPA, ASTM

Status of Progress: Closed

Update: Between the APSAC standards, ASTM F3379, and NFPA® 2400, the group is of the view that this gap is closed. The current edition of NFPA® 2400 will undergo a normal revision cycle. No further work is being done at this time by the ASTM/NFPA JWG. NFPA 1500™ and ASTM F3379 have been added to the list of published standards.

9.2. Hazardous Materials Incident Response and Transport

A dangerous good or hazardous material (HAZMAT) is any solid, liquid, or gas that can harm people, other living organisms, property, or the environment. A HAZMAT may be radioactive, flammable, explosive, toxic, corrosive, biohazardous, an oxidizer, an asphyxiant, a pathogen, an allergen, or may have other characteristics that render it hazardous in specific circumstances.

UAS are becoming a useful tool for responding to HAZMAT incidents. Pilots may be called to respond to a HAZMAT (e.g., chemical, biological, radiological, nuclear, or explosive) incident and not understand the risks associated with HAZMAT responses, including in both emergency and post-emergency operations.

Published Regulations and Guidance Material:

- FAA regulations on transport of HAZMAT are covered under part 107, 135
- OSHA has a set of standards and procedures for emergency first responders (Standards - 29 CFR Part 1910.120)
- DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) has published the *Emergency Response Guidebook* (2016) for first responders during the initial phase of a transportation incident involving dangerous goods/HAZMAT
- U.S. Army, Field Manual 3-11.5, *Multiservice Tactics, Techniques, and Procedures for Chemical, Biological, Radiological, and Nuclear Decontamination* (2006)
- ASTM F3379, *Guide for Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement*. The standard (previously WK61764) addresses hazardous materials but not transport, decontamination, or requirements for sensors in terms of sourcing and selecting them.
- NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations* – however this does not cover transportation or decontamination in any detail
- NFPA 470, *Hazardous Materials Standards for Responders*
- NFPA 471, *Recommended Practice for Responding to Hazardous Materials Incidents*
- NFPA 472, *Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents*
- NFPA 473, *Standard for Competencies for EMS Personnel Responding to Hazardous Materials/Weapons of Mass Destruction Incidents*
- NFPA 475, *Recommended Practice for Organizing, Managing, and Sustaining a Hazardous Materials/Weapons of Mass Destruction Response Program*
- NFPA 1072, *Standard for Hazardous Materials/Weapons of Mass Destruction Emergency Response Personnel Professional Qualifications*

In-Development Standards: None identified.

Gap S2: Hazardous Materials Response and Transport Using a UAS. Standards are needed to address the transportation of known or suspected HAZMAT by UAS and UAS being exposed to HAZMAT in a response environment.

R&D Needed: Yes. Research to assist policy makers and practitioners in determining the feasibility of using UAS in emergency response situations.

Recommendation: Create a standard(s) for UAS HAZMAT emergency response use, addressing the following issues:

- The transport of HAZMAT when using UAS for detection and sample analysis

- The design and manufacturing of ingress protection (IP) ratings when dealing with HAZMAT
- The method of decontamination of a UAS that has been exposed to HAZMAT

Priority: Medium

Organization(s): ASTM, NFPA, OSHA, U.S. Army, DOT, FAA

Status of Progress: Not Started

Update: The ASTM F38 Executive Committee gap analysis characterized this as a low priority for F38 that could potentially be addressed by a new standard but F38 has no plans to develop one at this time.

9.3. Transport and Post-Crash Procedures Involving Biohazards

A biological hazard, also known as a biohazard, is any infectious substance (Category A - 49 CFR 173.134/173.196) capable of causing permanent disability, life-threatening, or fatal disease in otherwise healthy humans or animals when exposure to them occurs. This can include samples of a microorganism, virus or toxin (from a biological source) that can affect human health. It can also include substances harmful to other animals. Biohazards are a subset of HAZMAT (see section 9.2) but the safety/threat impacts of biohazards are different from HAZMAT, and they are considered a national security issue.

The U.S. regulatory framework pertaining to biohazards transportation such as air transportation requires protection against the risks to life, property, and the environment that are inherent in the transportation of hazardous materials in intrastate, interstate, and foreign commerce.

Biohazards agents are classified for international transportation by UN number (a four digit number) by the United Nations. The U.S. government has adopted a similar nomenclature system, i.e., NA numbers (NA = North America). The U.S. Centers for Disease Control and Prevention (CDC) categorizes various diseases in levels of biohazards, Level 1 being minimum risk and Level 4 the extreme risk. CDC issues procedures, containments, and mitigations needed to handle biohazards. While the CDC is not an aviation entity, its procedures, regulations and mandates along with other government entities' requirements are still applicable to aviation, if the biohazards are transported through air transportation.

There is a lack of knowledge in compliance and enforcement relating to the transport of biohazards and applicable procedures and measures required to contain the biohazards during transport and after the crash of a UA. This has implications in terms of both safety and national security aspects. For example, the transportation of biohazards requires special considerations and approvals of an aircraft and UA at the design and construction phase and, during operations, in terms of communicating the presence of hazardous materials, handling, packaging, and storing the hazardous materials, maintenance of the UAS, etc.

When biohazards are transported using an aircraft, the operator of that aircraft is required to meet all the applicable transportation regulations, mandates, policies, guidance, standards, etc. of the United Nations World Health Organization, PHMSA which is part of DOT, FAA, DOD, CDC, USDA, DHS, U.S. Postal Service (USPS), ICAO and other agencies/entities.

Today, UAS are used to support emergency response and to transport medical supplies and biohazards such as blood, human organs, etc. While the rapidly growing deployment of UAS technology has tremendous benefits to society, the potential for negligence, non-compliance and misuse of this technology related to transportation of biohazards poses significant safety and national security challenges. Some of the challenges are biohazards identification and threat discrimination such as knowing who is flying a UAS, and what they are transporting. Information about onboard biohazards and the UAS flight path and destination will assist regulators and enforcement agencies (PHMSA, FAA, CDC, USDA, DHS, DOJ, DOD, ICAO, etc.) in understanding a UAS pilot's intent, and are critical to safety and threat assessment and appropriate mitigations/responses. See also section 9.9 on Counter-UAS.

Collaboration between regulators, enforcement agencies, and departments both domestic and international regarding transportation of biohazards and potential issues that may arise during flight and in post-crash events will lead to the safest and most efficient aviation system in the world.

State, city, local, and tribal governments may have additional requirements related to air transportation of biohazards using UAS, and the operators and pilots responsible to meet those requirements, in addition to the U.S. government regulations and mandates.

Published Standards and Related Materials: While not UAS-specific, a comprehensive list of published biohazards standards can be found in the *UASSC Reference Document*.

In-Development Standards: While not specific to UAS transport or post-crash events involving biohazards, the following general aviation standards may be relevant:

SAE International:

- AC-9M Cabin Air Measurement Committee
    - AS6923, Portable devices for measuring air contamination on aircraft
- AC-9 Aircraft Environmental Systems Committee
- AIR1266B, Fault Isolation in Environmental Controls Systems of Commercial Transports
- AIR1539C, Environmental Control System Contamination
- AIR1609B, Aircraft Humidification
- AIR1811B, Liquid Cooling Systems
- AIR4766/2A, Airborne Chemicals in Aircraft Cabins
- AIR5744, Aircraft Thermal Management System Engineering
- AIR64C, Electrical and Electronic Equipment Cooling in Commercial Transports
- ARP1270C, Aircraft Cabin Pressurization Criteria
- ARP292D, Environmental Control Systems for Helicopters

- ARP5743, Aircraft Galley Refrigeration Equipment Installation And Integration Recommendations
- ARP89E, Aircraft Compartment Automatic Temperature Control Systems

Gap S3: Transport and Post-Crash Procedures Involving Biohazards. No published or in-development standards have been identified that address UAS transport of biohazards and associated post-crash procedures and precautions.

R&D Needed: Yes

Recommendation:

1) Write standards to address UAS transportation of biohazards and post-crash procedures and containments
2) Encourage the development of standards to address and accommodate transport of biohazards and post-crash procedures and containments that cannot meet the current regulatory requirements and standards of manned aviation

Priority: High (Tier 3)

Organization(s): UN, PHMSA, FAA, WHO, ICAO, DOD, DHS, CDC, USDA, NIH, NFPA, SAE

Status of Progress: Unknown

Update: None provided at this time.

9.4. Forensic Investigations Photogrammetry

The use of sUAS by public safety agencies to photograph/document incident scenes has become one of the most popular uses for this technology. In some cases, such as natural disasters, the video/ photographs alone may provide sufficient documentation of the scene. In other cases, the imagery is used for “photogrammetry” which is defined as the "science of gathering dimensions from photographs.”[59] The input to photogrammetry is the aerial photographs, and the output is typically a map, a drawing, a measurement, or a 3D model of some real-world object or scene. To do this, multiple overlapping photos of the ground are taken as the aircraft flies along a flight path. These are then processed by a computer to map the scene, provide measurements, or generate the 3D model.

[59] Oklahoma v. Tyson Foods, Inc., 2009 U.S. Dist. LEXIS 112073 (N.D. Okla. Aug. 12, 2009)

Forensic investigations may include transportation accident reconstruction (motor vehicle/aircraft/rail) or crime scenes. In forensic investigations, the location of key pieces of evidence are located and measured as part of incident scene documentation. This is referred to as “mapping” the scene.

As an example, in traditional vehicular crash scene reconstruction, mapping involves using a surveyor’s instrument (total station) to physically measure key elements of the crash scene to determine the mechanics and, ultimately, the cause of the crash. This is a laborious, time consuming process. In most cases, for crashes involving death or serious injury, the roadway remains closed for hours while specially trained and equipped officers take the required measurements and photographs. Many studies have been conducted that show the economic costs of shutting down roadways, in particular interstate highways, not to mention the issue of inconveniencing the motorists. In this application, sUAS are used to photograph the crash scene. The photographs are then processed by a computer program that generates a geo-referenced 3D model and diagram that assures both relative and absolute positional accuracy.[60]

The accuracy of evidence produced through this method of investigation is critical because of the potential for criminal prosecution or other enforcement action against the at-fault driver, or for evidence in a civil action. In both cases, the measurements and photographs taken at the scene must be accurate to withstand the scrutiny of the court.

There are several tests for the admissibility of scientific evidence at trial, including the Frye Standard and the Daubert Standard. Factors that may be considered in determining the validity of the scientific evidence include the existence and maintenance of ***standards*** controlling the drone’s operation. The use of UAS are the “least mature and thus least established among the considered measurement techniques, regarding court acceptance.” (Johns Hopkins Applied Physics Lab, 2017)

Thus, the issue here is the lack of existing standards that outline the accuracy required of the payloads/sensors used to capture the data and the programs used for post-processing to assure admissibility in court.

Published Standards and Related Materials:

[60] The Geographic Information Technology Training Alliance defines these terms as follows: “Positional Relative Accuracy as the measure of how objects are positioned relative to each other. It is always illustrated as (+ or -) meter or feet or inch. … Positional Absolute Accuracy as the indicator or measure of how a spatial objects is accurately positioned on the map with respect to its true position on the ground, within an absolute reference frame such as UTM coordinate system.”

- *Standards for Public Safety Small Unmanned Aircraft Systems Programs*, published by APSAC in October 2017. These are operational standards for the use of sUAS, but they do not address technical standards for sensors or post-processing computer programs.
- Positional Accuracy Standards, published by the American Society for Photogrammetry and Remote Sensing (ASPRS) in November, 2014.
- Sensor Web Enablement (SWE) Standards (summary descriptions of the following SWE standards are found here):
  - OGC Sensor Model Language (SensorML)
  - OGC Sensor Observation Service (SOS)
  - OGC Sensor Planning Service (SPS)
  - OGC Observations & Measurements (O&M)
- OGC SensorThings API Part 1: Sensing (v1)
- OGC Web Processing Service – allows the insertion of processing algorithms on board the UAV or anywhere in a workflow to support the processing of sensor observations to support the end user, or the next application in a workflow
- OGC Wide Area Motion Imagery (WAMI) Best Practice – this OGC Best Practice recommends a set of Web service interfaces for the dissemination of Wide Area Motion Imagery (WAMI) products
- OGC Geography Markup Language (GML) — Extended schemas and encoding rules (v3.3)
- OGC KML 2.3 (v1)
- OGC OpenGIS Web Map Server Implementation Specification (v1.3)
- OGC OpenGIS Web Map Tile Service Implementation Standard (v1)
- OGC Web Coverage Service (WCS) 2.0 Interface Standard (v2)
- OGC LAS – is an OGC Community Standard representing a standardized file format for the interchange of 3D point cloud data between data users
- OGC GeoTIFF (v1.1). Geostationary Earth Orbit Tagged Image File Format (GeoTIFF) is used throughout the geospatial and earth science communities to share geographic image data. GeoTIFF was adopted as an OGC standard in 2019.
- US DOJ Community Policing & Unmanned Aircraft Systems (UAS) Guidelines to Enhance Community Trust
- National Institute of Justice (NIJ) Considerations and Recommendations for Implementing an Unmanned Aircraft Systems (UAS) Program, NCJ 250283
- ASTM Committee E30 on Forensic Sciences has a portfolio of some 62 published standards maintained by 3 technical subcommittees. These standards relate to all aspects of forensic sciences, including criminalistics, questioned documents, forensic engineering, fire debris analysis, drug testing analysis, and collection and preservation of physical evidence. The most relevant work related to this roadmap issue is within E30.12 Digital and Multimedia Evidence.
- NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*. The NFPA has developed operational standards similar to APSAC, but they are not designed to address the required technical standards.

In-Development Standards:

- OGC is advancing best practices through its UxS DWG and through a series of ongoing interoperability pilot activities.
- OGC is also developing standard quality measures to describe the accuracy of the location of images collected from overhead as well as a means to describe the color of the pixels in the images in a consistent way.

Gap S4: Forensic Investigations Photogrammetry. Standards are needed for UAS sensors used to collect digital media evidence. The equipment used to capture data needs to be able to survive legal scrutiny. Standards are also needed for computer programs performing post-processing of digital media evidence. Processing of the data is also crucial to introducing evidence into trial.

R&D Needed: Yes. R&D will be needed to develop the technical standards to meet legal requirements for the admissibility of digital media evidence into court proceedings.

Recommendation: Develop standards for UAS sensors used to collect digital media evidence and for computer programs performing post-processing of digital media evidence. These standards should take into account data, security and accountability.

Priority: Medium

Organization(s): OGC

Status of Progress: Green

Update: As noted in the text, the OGC GeoTIFF standard was adopted as an OGC standard in 2019, and best practices are in development in OGC UxS DWG.

9.5. Payload Interface and Control for Public Safety Operations

In an examination of UAS utilization among public safety / law enforcement users, a common concern that emerges is how to find appropriate aircraft and payloads for a particular mission. Currently, most public safety drone operators rely on consumer-grade equipment since the capability and price is more affordable. However, the market for these aircraft is very different than the public safety market, and performance/mission ops compromises are typical. Consumer-grade drones are sold with a limited selection of payload options – usually Electro-Optical/Infra-red (EO/IR) cameras – that typically cannot be interchanged or upgraded, meaning that the failure of a payload may take the drone system out of service. EO/IR payloads have obvious uses for government operators, but there are many more mission scenarios that cannot be fulfilled with only a camera. Audio systems, grappling payloads, CBRNE detection, and multispectral imaging are some examples of payloads that have utility within the public safety community. Additionally, data processing support for object detection and tracking as well as communications needs can be handled using interchangeable payloads.

The public safety community is in need of more rigid design requirements to foster cross-agency use and collaboration, as well as generating an interest among the UAS development community to provide mission-specific solutions for public safety. The specialized payloads needed by public safety UAS operators are unique to the community and do not appear in other operational sectors, and the utilization of the aircraft cross-agency with a selection of payloads is also unique. Additionally, communications requirements for fire, public safety, and law enforcement are specific to the users and mission, and are generally not available to the public.

Payloads that are dropped during flight also represent a design consideration for mounting that should be defined for interchangeability. With a strong interest in droppable payloads from the commercial sector, these standards may also apply to delivery drones. Public safety payloads would include items such as medical supplies, sustenance, and equipment. Operators that are not concerned about the aircraft, considering it only as a means of delivering a product may utilize user designed/installed payload drop mechanisms or third-party mechanisms designed for the purpose of dropping a payload.

Current public safety users may have operational needs for payload control, thereby using a UAS platform outside of the manufacturer’s design specifications in order to accomplish payload attachment with limited control of the payload. There are minimal third-party payload control options on the market designed for specific UAS platforms. These third-party options may not have been designed in partnership with the UAS platform manufacturer, thereby limiting full integration with the UAS and the absence of safety features. It is imperative that payload control mechanisms contain safety features that would prevent accidental payload release, etc. Additionally, payload control mechanisms designed without full integration with the UAS manufacturer may lead to aircraft weight and balance (W&B) and UAS performance issues, unknown to the end user.

To facilitate platform agnostic payloads, mechanical and electrical interface standards should be developed for all payloads, including those that are dropped. These standards will, for the first time, create a market for payloads without reference to a particular aircraft design. Operators will be able to use any aircraft available for any payload, provided both conform to the mechanical, electrical, and software standards for communications. As payloads evolve, aircraft usage will be extended because of the platform agnostic design of the system. Figure 12 shows a diagram of the proposed architecture.

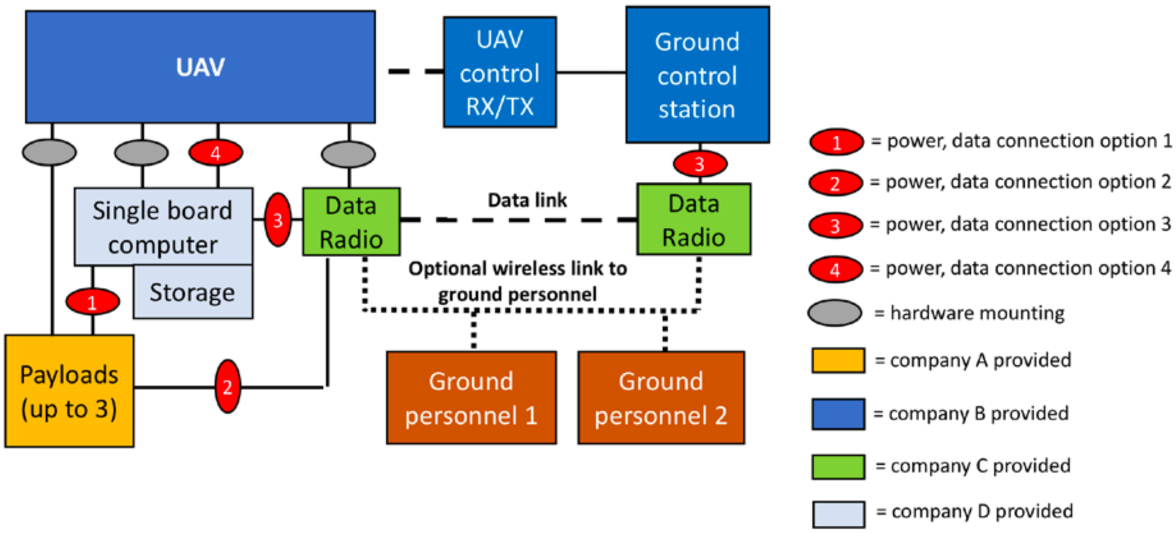

Figure 12: Public Safety UAS Architecture. Used with the permission of Kevin Kochersberger

Published Standards: There are currently no published standards for UAS payloads in public safety operations. The FAA has used various mechanisms to encourage standards development, such as the designation of test sites across the country, pathfinder projects, and integration pilot programs (IPP) that examine future use cases under controlled conditions. Many of these programs could benefit from the integration of public safety drone use cases into the studies. This work will provide guidance to the FAA to help with final rulemaking.

In-Development Standards: ASTM E54.09 has several proposed new standards pertaining to the system-level performance of drones in public safety applications. However, these standards will not address aircraft/payload compatibility or manufacturing standards that are needed to support the public safety drone community. A related work item concerning package delivery in development in ASTM F38.02 is ASTM WK62344, *Revision of F3196 - 17 Standard Practice for Seeking Approval for Extended Visual Line of Sight (EVLOS) or Beyond Visual Line of Sight (BVLOS) Small Unmanned Aircraft System (sUAS) Operations*. Also in development is IEEE P1937.1, *Standard Interface Requirements and Performance Characteristics for Payload Devices in Drones*.

Gap S5: Payload Interface and Control for Public Safety Operations. Standards are needed for public safety UAS payload interfaces including:

- Hardware
- Electrical connections (power and communications)
- Software communications protocols

Additional standards development may be required to define location, archiving, and broadcast of information which will grow in need as data analytics plays a larger role in public safety missions.

There currently are no published standards that define the expected capabilities, performance, or control of sUAS payload drop mechanisms.

R&D Needed: Yes. Need to examine available options in universal payload mounting as well as electrical connections and communications. Stakeholders including end users and manufacturers of drones should be engaged to contribute to the process of defining acceptable standards. Existing payload drop and control systems should be researched with attention to weight, degree of operator control, and interoperability considered in defining standards that are useful for both public safety and commercial operators.

Recommendation: Develop standards for the UAS-to-payload interface, which includes hardware mounting, electrical connections, and software message sets. Develop a standard for a UAS payload drop control mechanism that includes weight, control, safety and risk metrics, and remote status reporting.

Priority: High (Tier 3)

Organization(s): ASTM, DOJ, NFPA, DHS, NIST, IEEE

Status of Progress: Green

Update: As noted in the text.

9.6. Search and Rescue (SAR)

9.6.1. sUAS IR Camera Sensor Capabilities

sUAS are becoming a primary tool for Search And Rescue (SAR) missions. Specific sensor packages are required to ensure sUAS are properly equipped to fulfill the mission objectives. Although sUAS may be flown up to an altitude of 400' AGL without additional waivers, the camera sensors must be capable of providing needed imagery definition [imagery definition here means whether it is HD or Ultra HD (UHD) or Super Ultra HD (SUHD)] that would allow a person to accurately identify an individual in the frame.

There are several forward-looking infrared (IR) cameras that are being fitted to UAS platforms by third parties. These cameras may not have the ability to be fully controlled by the RPIC or sensor or payload operator. Additionally, these IR cameras may not have the necessary screen resolution and/or thermal resolution to accurately identify the intended subject(s). Public safety entities have purchased IR cameras only to determine that the IR capabilities will not allow them to fulfill the operational objectives due to camera's limited performance capabilities. Public safety IR cameras should include user controls for thermal resolution, radiometric measurement, temperature measurement, etc.

Infrared imagery requirements for the SAR missions differ from IR requirements for structural fires. Structural fires may simply require identification of thermal differences to identify lateral and/or vertical fire spread. Public safety organizations may or may not desire radiometric capabilities, etc. The screen and thermal resolution requirement to identify fire spread is lower than what would be needed to identify a person in a SAR mission.

Published Standards: No UAS standards in development specific to this topic have been identified. With respect to SAR standardization generally, ASTM F32 and its subcommittees cover equipment, testing, and maintenance (F32.01); management and operations (F32.02); and personnel, training, and education (F32.03).

In-Development Standards: ASTM E54.09 work items include:

- WK58928 Evaluating Aerial Response Robot Sensing: Thermal Image Acuity
- WK58929 Evaluating Aerial Response Robot Sensing: Thermal Dynamic Range
- WK58930 Evaluating Aerial Response Robot Sensing: Latency of Video, Audio, and Control

Gap S6: sUAS Forward-Looking Infrared (IR) Camera Sensor Capabilities. UAS standards are needed for IR camera sensor capabilities. A single standard could be developed to ensure IR technology meets the needs of public safety missions, which would be efficient and would ensure an organization purchases a single camera to meet operational objectives.

R&D Needed: Yes. R&D (validation/testing) is needed to identify IR camera sensor sensitivity, radiometric capabilities, zoom, and clarity of imagery for identification of a person/object for use in public safety/SAR missions.

Recommendation: Complete work on standards in development related to IR camera sensor specifications for use in public safety and SAR missions.

Priority: Medium

Organization(s): NIST, NFPA, ASTM

Status of Progress: Green

Update: As noted in the text.

9.6.2. sUAS Automated Missions during Emergency Response

UAS that allow the public safety RPIC and/or sensor operator to pre-program waypoints, sensor orientation, sensor trigger points, altitudes, etc., ensure that public safety/emergency response missions are completed in the most timely and efficient manner, directly improving outcomes.

For example, wide-area search and rescue (SAR) missions, in wilderness and urban environments, are normally conducted via a grid pattern by air or ground assets. Although a RPIC can manually control a UAS for wide-area SAR missions, there may well be a loss of efficiency and incident mitigation due to missed search areas or redundancy in areas covered. Small area searches may provide adequate landmarks which may be used as reference points for manually flown SAR missions. The presence and use of adequate landmarks throughout the operational area could mitigate redundancy of flight paths. Manually flown SAR missions would be most applicable when the victim's general location is known.

While professional- or survey-grade UAS exist that have these capabilities, many public safety agencies use consumer-grade UAS as a low-cost alternative to expensive systems. Many consumer-grade systems are manufactured to evade restrictions under the ITAR, EAR and the U.S. Import Munitions List while having maximum market coverage. The FAA reports that 93% of all sUAS are imported consumer-grade systems (see NPRM for RID).

Published Standards: With respect to SAR standardization generally, ASTM F32 and its subcommittees cover equipment, testing, and maintenance (F32.01); management and operations (F32.02); and personnel, training, and education (F32.03). ASTM E54.09 covers response robots, including UAS, and has several standards in development. NIST has published several standards for evaluating aerial response robots (aka UAS).

OGC has published a Wide Area Motion Imagery (WAMI) Best Practice that will likely mature into a full standard. It includes defined coverage area, automated optical inspection (AOI) selection, where each image in video is spatially / temporally related to the next -- for surveillance and wide area incident ops.

In-Development Standards: Standards in development include the aforementioned work by ASTM F32 and E54.09.

Gap S7: Need for Command and Control Software Specifications for Automated Missions during Emergency Response. While standards exist for software specifications to complete automated missions, there remains a need to encourage the user community to purchase professional grade equipment that is compliant with these standards, rather than using low-cost, consumer grade equipment.

R&D Needed: No.

Recommendation: Encourage UAS OEMs to adopt existing standards. Encourage public safety agencies to consider equipment that is compliant with industry standards, and NIST/FEMA guidelines, prior to acquiring UAS. See section 7.6 on data handling and processing.

Priority: Low

Organization(s): NIST, NFPA, ASTM, OGC, UAS OEMs, public safety agencies/organizations

Status of Progress: Green

Update: Standards exist for software specifications to complete automated missions. Other standards are under development.

9.7. Response Robots

In response to various presidential policy directives on national preparedness, NIST, with support from the DHS and others, has been working to develop a comprehensive suite of standard test methods and performance metrics to quantify key capabilities for robots used in emergency response operations. While the project applies to remotely operated ground, aquatic, and aerial systems, the most recent U.S. presidential directive in 2017 highlighted the urgency of standards development for sUAS. Accordingly, the NIST project addresses how to measure and compare sUAS capabilities and remote pilot proficiencies. The standardized test methods resulting from these efforts will enable users to generate performance data to evaluate airworthiness, maneuvering, sensing, payload functionality, etc. This data can be used to inform user community purchasing decisions, develop training programs, and set thresholds for pilot proficiency. NIST and its associates in the project are developing a usage guide.

Published Standards: The test methods resulting from the NIST R&D are being standardized through ASTM Committee E54 on Homeland Security Applications, Subcommittee E54.09 Response Robots. UAS-specific published standards include:

- ASTM E2521-16, *Standard Terminology for Evaluating Response Robot Capabilities*
- ASTM E2854 – 12, Standard Test Method for Evaluating Emergency Response Robot Capabilities: Radio Communication: Line-of-Sight Range
- ASTM E2855 – 12, Standard Test Method for Evaluating Emergency Response Robot Capabilities: Radio Communication: Non-Line-of-Sight Range

In addition, the following ASTM F38 standard references the E54.09 test methods:

- ASTM F3379, *Guide for Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement*

In-Development Standards: UAS-specific in-development standards in ASTM E54.09 include:

- ASTM WK58677, *Evaluating Aerial Response Robot Sensing: Visual Image Acuity*
- ASTM WK58925, *Evaluating Aerial Response Robot Sensing: Visual Color Acuity*
- ASTM WK58926, *Evaluating Aerial Response Robot Sensing: Visual Dynamic Range*
- ASTM WK58927, *Evaluating Aerial Response Robot Sensing: Audio Speech Acuity*
- ASTM WK58928, *Evaluating Aerial Response Robot Sensing: Thermal Image Acuity*
- ASTM WK58929, *Evaluating Aerial Response Robot Sensing: Thermal Dynamic Range*
- ASTM WK58930, *Evaluating Aerial Response Robot Sensing: Latency of Video, Audio, and Control*
- ASTM WK58931, *Evaluating Aerial Response Robot Maneuvering: Maintain Position and Orientation*
- ASTM WK58932, *Evaluating Aerial Response Robot Maneuvering: Orbit a Point*
- ASTM WK58933, *Evaluating Aerial Response Robot Maneuvering: Avoid Static Obstacles*
- ASTM WK58934, *Evaluating Aerial Response Robot Maneuvering: Pass Through Openings*
- ASTM WK58935, *Evaluating Aerial Response Robot Maneuvering: Land Accurately (Vertical)*

- ASTM WK58936, *Evaluating Aerial Response Robot Situational Awareness: Identify Objects (Point and Zoom Cameras)*
- ASTM WK58937, *Evaluating Aerial Response Robot Situational Awareness: Inspect Static Objects*
- ASTM WK58938, *Evaluating Aerial Response Robot Situational Awareness: Map Wide Areas (Stitched Images)*
- ASTM WK58939, *Evaluating Aerial Response Robot Energy/Power: Endurance Range and Duration*
- ASTM WK58940, *Evaluating Aerial Response Robot Energy/Power: Endurance Dwell Time*
- ASTM WK58941, *Evaluating Aerial Response Robot Radio Communications Range: Non Line of Sight*
- ASTM WK58942, *Evaluating Aerial Response Robot Radio Communication Range : Line of Sight*
- ASTM WK58943, *Evaluating Aerial Response Robot Safety: Lights and Sounds*

NFPA is adopting the NIST and ASTM E54.09 draft standard test methods as measures of operator proficiency for the JPRs spelled out in NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*.

In addition, ASTM F38 has an accelerated work item which will specify performance-based test methods for UAS: ASTM WK70877, *New Practice for Showing Durability and Reliability Means of Compliance for Unmanned Aircraft Systems*.

Gap S8: UAS Response Robots. There is a need for standardized test methods and performance metrics to quantify key capabilities of sUAS robots used in emergency response operations and remote pilot proficiencies.

R&D Needed: Yes

Recommendation: Complete work on UAS response robot standards in development in ASTM E54.09 and reference them in NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*

Priority: Medium

Organization(s): NIST, ASTM E54.09, NFPA, DHS

Status of Progress: Green

Update: Standards in development are noted in the text.

9.8. Public Safety Tactical Operations

Law Enforcement Tactical Operations

Like most law enforcement operations, tactical situations can involve an endless number of scenarios and variables. However, two of the most common, and similar in many respects, involve the service of high-risk arrest and search warrants and barricaded subjects. One key difference is that there usually is time to plan for warrant service, while barricaded subjects evolve from some type of event that leads to a subject(s) refusing to surrender and in some cases holding hostages. These types of events can result from such things as a domestic dispute, a mental health crisis, or the escape from a crime scene that is stopped by arriving officers. In some cases, an attempted warrant service may result in a barricaded suspect.

In both cases, warrant service and barricade, there are common factors. First, the location of the event is most likely fixed; it is not a mobile situation. Second, such incidents many occur during hours of darkness. Third, access to the location of the event is controlled by police with an inner perimeter where only police, usually tactical officers, are permitted and an outer perimeter within which non-involved people are evacuated, or told to shelter in place. No one, except authorized personnel, is allowed to enter the perimeter until the incident is resolved.

High-risk warrant service includes those incidents where there are multiple suspects, they are known to be armed, they have used or threatened violence in the past, and/or there is the possibility of the destruction of evidence. Absent exigent circumstances, these operations may be conducted in the early morning hours when people, including suspects, are asleep, giving officers the benefit of surprise. A sUAS can be used to obtain situational awareness of the location prior to entry, including access and escape points (doors and windows), animals that could alert the suspect of approaching officers, trip hazards, stairs, suspect(s)/others moving about inside the building, lighting (interior and exterior), etc. With this intelligence, officers can make an approach and entry in a much more efficient and safe manner. During the entry phase, the sUAS can be put into a position above the location to enable the incident commander (IC) to monitor the entire situation from an aerial vantage point. Should the suspect(s) escape, the sUAS can be used to track and apprehend them.

For a barricaded suspect, the intelligence gathering is the same, in particular the location of the suspect(s) inside the building, location of hostages, weapons, etc. These can be extended operations as negotiators attempt to resolve the situation by talking to the suspect. During negotiations, the sUAS can remain overhead giving the IC constant situational awareness.

Fire/Rescue Special Operations

Specialized rescue operations in the fire/rescue service are commonly referred to as very high risk - low frequency incidents. Such incidents include HAZMAT, bombs/suspicious packages, high angle rescue, structural collapse, etc. Technical rescue incidents can occur in any environment, any location, and during any time of day or night. These incidents typically involve lots of rescue personnel and many specialized apparatus and equipment. The use of UAS to gain a bird's eye view of an incident can provide responders with critical information for determining the strategies, tactics, and resources needed to mitigate an incident.

In most of these situations, the area surrounding the incident is secured by emergency responders (fire/rescue and/or law enforcement). Personnel entering or exiting the operational area are controlled and monitored. Areas surrounding an incident involving HAZMAT, bombs/suspicious packages, or other dangerous situations are usually evacuated and/or persons are protected in place. Only authorized persons involved in the incident are allowed in the operational area until the operation has concluded.

HAZMAT incidents are arguably one of the most challenging uses of UAS in the public safety arena. There is potential for unknowingly flying into a combustible, flammable, corrosive or other austere environment. There is also potential for aerosolizing or other spreading of a product with the UAS rotor wash. In many cases, however, the use of UAS during the early stages of a HAZMAT incident could provide valuable information to the IC and the HAZMAT team.

It is important that policies, standards, rules, etc. have provisions in place to allow emergency response personnel with the ability to transport HAZMAT during these incidents. At times there may be a need to package and transport a sample of the suspected HAZMAT to another controlled location within the operational area via UAS so it can be tested or further packaged for transportation to a lab, etc. This ability is currently not allowed by FAA regulations. See also section 9.2 on Hazardous Materials Incident Response and Transport.

Bomb/suspicious package incidents create their own issues regarding UAS use. However, they are similar in nature to a HAZMAT incident. The operational area is typically secured in the same manner and persons are either evacuated or protected in place, thus creating a safe area for UAS operations.

Both HAZMAT and bomb/suspicious package incidents require lengthy processes and preparations prior to sending personnel into the immediate area to begin reconnaissance or actual situation mitigation tasks. The use of UAS to provide critical information to the IC and special ops teams during this time is paramount.

HAZMAT, bomb/suspicious package incidents, certain law enforcement incidents (active shooter, barricaded subject, etc.), and various other emergency situations, create the need for flying the UAS in an area where it is dangerous to have the RPIC or visual observer (VO) within eyesight of the aircraft. The RPIC or VO cannot be placed into a position to see the UAS because of the potential to be in close proximity to the bomb/IED, HAZMAT, or nefarious actors, any of which could be a deadly location for these persons to be in. The ability of low altitude/close proximity BVLOS operations (i.e., operations at roof/tree top level, behind a building or wood line, etc.) would allow emergency services UAS to provide critical information to the IC or other critical decision makers in their efforts to mitigate a favorable of a given incident.

Published Standards and Other Documents:

- *Standards for Public Safety Small Unmanned Aircraft Systems Programs*, published by APSAC in October 2017. These are operational standards for the use of sUAS and provide adequate guidance for tactical operations.
- ASTM F3379, *Guide for Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement*
- NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*. The NFPA has developed operational standards similar to APSAC, that are designed to address tactical operations.
- *Standard Test Methods for Small Unmanned Aircraft Systems* and *Standard Test Methods for Small Unmanned Aircraft Systems, Public Safety Maneuvering with Payloads*, published by the National Institute of Standards and Technology (NIST), 2019. NIST developed these test methods standards to fill the gap left by Part 107, pilot certification, that has no practical skills assessment and to assist public safety agencies in evaluating UAS suitability to perform identified missions.

In-Development Standards: None identified

No general standards gap on tactical operations has been identified.

Actively Tethered UAS

To support public safety tactical operations Congress, in the FAA Reauthorization Act of 2018, established a separate class of small UAS and mandated specific operating rules for use by public (government) agencies. The newly defined systems are called "*Actively Tethered Unmanned Aircraft Systems.*" As defined in the Act, the term "actively tethered unmanned aircraft system" means an unmanned aircraft system in which the unmanned aircraft component weighs 4.4 pounds or less, including payload, but not the tether. The aircraft is physically attached to a ground station with a taut, appropriately load-rated tether that provides continuous power to the unmanned aircraft and is unlikely to be separated from the unmanned aircraft; and is controlled and retrieved by such ground station through physical manipulation of the tether.

Public actively tethered unmanned aircraft systems may be operated:

- Without any requirement to obtain a certificate of authorization, certificate of waiver, or other approval by the Federal Aviation Administration.
- Without requiring airman certification.
- Operated at an altitude of less than 150 feet above ground level.
- Within class G airspace; or at or below the ceiling depicted on the Federal Aviation Administration's published UAS facility maps for class B, C, D, or E surface area airspace.
- Not flown directly over non-participating persons.
- Operated within visual line of sight of the operator.
- Operated in a manner that does not interfere with and gives way to any other aircraft.

No published or in-development standards have been identified specifically related to tethered UAS operation in the public safety community.

New Gap S10: Use of Tethered UAS for Public Safety Operations. Training and operational standards are needed on the use of Actively Tethered sUAS by public safety agencies.

R&D Needed: Yes

Recommendation: Develop standards for Actively Tethered Public Safety sUAS operations

Priority: Medium

Organization(s): NFPA, APSAC, FAA, ASTM

9.9. Counter-UAS (C-UAS): Detection and Mitigation

9.9.1. C-UAS Detection

The most common drone detection tools are ground-based radio-frequency detection, acoustic detection, radar, electro-optical, and infra-red. In the absence of performance standards for UAS detection, agencies that need situational awareness of intruders in their airspace cannot judge which systems are effective. This risks not only wasting money, but providing an inaccurate picture of risk exposure.

C-UAS activities, as defined by the 2018 Preventing Emerging Threats Act established in Division H, § 1601 of the FAA Reauthorization Act of 2018, are currently possible only for few specific agencies under defined circumstances, as noted in section 9.10. However, many other entities are interested in being aware of drone operations within relevant airspace, even if mitigation is not possible. Examples include airports and other critical infrastructure, as well as public safety agencies involved in search, recovery, disaster response, or law enforcement missions.

It is recommended that, prior to the testing, acquisition, installation, or use of UAS detection and/or mitigation systems, entities seek the advice of counsel experienced with both federal and state criminal, surveillance, and communications laws.

Published Standards:

In-Development Standards: RTCA SC-238, Counter UAS special committee, is developing a consensus standard that details detection and mitigation standards. This committee will operate as a joint committee with EUROCAE Working Group (WG) 115. SC-238 and EUROCAE WG 115 are developing consensus documents that detail detection and mitigation performance standards for non-cooperative targets, their interoperability, and interfaces with stakeholders in the C-UAS domain such as airports, air navigation service providers, surveillance systems manufacturers, law enforcement, pilots, etc.

New Gap S11: Counter-UAS (C-UAS) Operations: Detection. No standards exist for the performance of UAS detection systems that might be used by operators of critical infrastructure or public safety agencies.

Given the importance of drone detection capabilities, standards must be developed for user identification, design, performance, safety, and operations. User identification insures accountability and provides a necessary tool to public safety officials and operators of critical infrastructure. Design, performance, and safety standards can ensure that risk management decisions are based on reliable and valid data.

A comprehensive evaluation template for testing UAS detection systems is needed to: (1) identify current capabilities and anticipated advancement for C-UAS technologies and (2) forecast trends in the C-UAS burgeoning market. The test and evaluation (T&E) community must have clear guidance and a framework to test and evaluate the needs of the end user.

R&D Needed: Yes

Recommendation: Encourage the development of detection standards addressing user identification, design, performance, safety, operational aspects, and various available technological methods for detecting UAS. For example, RF detection based systems will follow a different standards protocol than electro-optical or infra-red based systems.

Priority: High (Tier 1)

Organization(s): DOD, DHS, DOJ, DOE, FCC, NTIA, FAA, EUROCAE, RTCA

9.9.2. C-UAS Mitigation

Per the FAA Reauthorization Act of 2018, the term counter-UAS (C-UAS) system means a system or device capable of lawfully and safely disabling, disrupting, or seizing control of an unmanned aircraft or unmanned aircraft system. It is to be noted that the counter-UAS system is for use by the appropriate U.S. governmental agencies and departments only.

With the widespread use of UAS operations comes inappropriate and illegal use by those who either disregard applicable aviation regulations or remain unaware of them, potentially compromising national security, the national airspace system (NAS), critical infrastructure, and causing other security vulnerabilities.

C-UAS systems are new, complex, and continue to diversify. The most popular drone detection techniques are radar, RF detection, electro-optical (EO), and infra-red (IR). Standards gaps for detection of UAS are discussed in the prior section. Mitigation techniques include kinetic methods such as lasers, nets, projectiles, high power microwave, and trained animals, or non-kinetic, such as RF jamming, GNSS jamming, or signal substitution. A lack of common standards in the C-UAS industry establishes a wide variance in C-UAS systems design impacting the effectiveness and reliability of systems.

No published standards have been identified.

In-Development Standards: RTCA SC-238, Counter UAS special committee, is developing a consensus standard that details detection and mitigation standards. This committee will operate as a joint committee with EUROCAE Working Group (WG) 115. SC-238 and EUROCAE WG 115 are developing consensus documents that detail detection and mitigation performance standards for non-cooperative targets, their interoperability, and interfaces with stakeholders in the C-UAS domain such as airports, air navigation service providers, surveillance systems manufacturers, law enforcement, pilots, etc.

In-development standards and policy activities of U.S. government entities are not known to the public. This is due to the nature and mission of the military, national security, law enforcement, and for the security and protection of the NAS, as it relates to the implementation and use of the counter-UAS system by agencies and departments of the U.S. government in coordination with the FAA.

Currently, only the federal government has legislative authority to engage in C-UAS interdiction activities, specifically the following (4) agencies: Department of Defense (DOD), Department of Energy (DOE), Department of Justice (DOJ), and the Department of Homeland Security (DHS).

- In 2016, Congress authorized DOD and DOE to conduct C-UAS activities to protect covered facilities or assets.
- In the 2018, through the FAA Reauthorization Act, Congress granted both DOJ and DHS limited authority to operate C-UAS systems to protect covered facilities or assets.

State, local, and private entities currently do not have authority to operate C-UAS.

Gap S9: Counter-UAS (C-UAS) Operations: Mitigation. Given the imperative that C-UAS technologies be available for use by the proper authorities, user identification, design, performance, safety, and operational standards are needed. User identification insures accountability and provides a necessary tool to public safety officials. Design, performance, and safety standards can reduce the likelihood of harming or disrupting innocent or lawful communications and operations.

A comprehensive evaluation template for testing C-UAS systems is needed. Today's C-UAS technologies are often the result of an immediate need for a life-saving measure that was neither originally anticipated, nor given time to mature. The test and evaluation (T&E) community must have clear guidance on what to look for in order to test and evaluate to the needs of the end user. Put another way, clearly defined metrics and standards require foundational criteria upon which to build.

R&D Needed: Yes

Recommendation: Encourage the development of Counter-UAS standards addressing user identification, design, performance, safety, operational aspects, and various available technological methods for C-UAS. For example, laser-based systems will follow a different standards protocol than a kinetic, acoustic, or RF-based solution.

Priority: High (Tier 1)

Organization(s): DOD, DHS, DOJ, DOE, FCC, NTIA, FAA, EUROCAE, RTCA

Status of Progress: Green

Update: As noted in the text, standards development work is underway.

9.10. UAS for Emergency Management and Disasters

It is important to ensure the safe and effective utilization of UAS for rapidly expanding incidents, complex emergencies, and the management of significant disasters.

UAS technology assists first responders, emergency management professionals, and other key stakeholders in executing emergency and disaster management operations in accordance with FEMA's National Incident Management System (NIMS) and the Incident Command System (ICS). UAS can also be effectively deployed in support of FEMA's National Response Framework (NRF) core capabilities to include prevention, protection, mitigation, response, and recovery missions surrounding common threats and hazards.

The relatively compact and rugged nature of sUAS make for ideal deployable aviation assets in support of both planned incidents (sporting events, political rallies, music concerts) and unplanned incidents (tornados, earthquakes, major transportation accidents, wildfires).

During the 2017 hurricane season, UAS showed exceptional potential in helping a wide range of organizations respond and recover from major hurricane landfalls – a trend which continues through today. States and local jurisdictions are now integrating UAS into their emergency management operations to allow rapid deployment to a wide range of incident scenes including inaccessible areas suffering catastrophic damage.

<u>Examples of UAS Missions for Major Incidents, Complex Emergencies, and Disaster Management</u>

- **Prevention**
  - Security surveillance at a large protest or march
  - Crowd and traffic monitoring at a major sporting event
  - Fire break inspections in forests and parks during dry season

- **Protection**

- Nuclear power plant perimeter security
- Crowd overwatch at a large outdoor music festival
- Suspicious vehicle interdiction at a major political rally

- **Mitigation**
  - Aerial flood plain mapping for rural communities
  - Condition assessment and documentation of vital community assets
  - Assessing foliage overgrowth along power distribution circuits prior to hurricane season

- **Response**
  - Searching for, and marking the position of, survivors and victims of disasters
  - Conducting rapid aerial damage assessment of neighborhoods
  - Transporting urgent supplies to remote locations under austere conditions

- **Recovery**
  - Power and asset inspection and restoration
  - Debris management
  - Insurance inspections

Published Regulations, Standards, and Guidance Material:

- ASTM F3379, *Guide for Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement*
- ATIS-1-000071 Use of UAVs for Restoring Communications in Emergency Situations, December 2018
- Center for Disaster Risk Policy (CDRP), Florida State University (FSU), All Hazards UAS Team - Resource Definition, Draft October 4, 2019
- CDRP FSU, Small UAS Data Technician [SUASDT]- Resource Definition, Draft October 4, 2019
- CDRP FSU, Small UAS Pilot [SUASP]- Resource Definition, Draft October 4, 2019
- CDRP FSU, Small UAS Team Leader [SUASTL]- Resource Definition Draft October 4, 2019
- CDRP FSU, UAS Position Descriptions, Draft October 4, 2019
- CDRP FSU, UAS Position Task Book (PTB), Draft October 4, 2019
- Esri, Integrating UAS and GIS Improves Search-and-Rescue Effort, Spring 2016
- FEMA, Resource Typing Definition for Response, NIMS 509, Remote Pilot in Command, Technical Specialist – Unmanned Aircraft System, Unmanned Aircraft System Team
- FEMA, Unmanned Aircraft System Team Resource Typing Definition for Response Situational Assessment, September 2017
- Federal Highway Administration (FHWA), Tech Brief Use of Small Unmanned Aerial Systems for Emergency Management of Flooding, May 2019
- IBM Center for The Business of Government, Drones Shine in Emergency Management, February 11, 2019

- IssueLab by Candid, Drones for Disaster Response and Relief Operations, April 2015
- National Disaster Preparedness Training Center at the University of Hawai'I, Unmanned Aircraft Systems in Disaster Management (AWR-345)
- NFPA 2400 Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations, 2019
- National Wildfire Coordinating Group (NWCG), PMS 520: NWCG Standards for Airspace Coordination, May 2018
- NIST. *Standard Test Methods for Small Unmanned Aircraft Systems* and *Standard Test Methods for Small Unmanned Aircraft Systems, Public Safety Maneuvering with Payloads*, 2019. NIST developed these test methods standards to fill the gap left by Part 107, pilot certification, that has no practical skills assessment and to assist public safety agencies in evaluating UAS suitability to perform identified missions.
- NWCG, Standards for Fire Unmanned Aircraft Systems Operations, Feb 2019
- PSAAC, Public Safety Aviation Accreditation Commission Standards for Small Unmanned Aircraft System (sUAS) Programs, Drafted version June 5, 2017
- U.S. Department of Homeland Security (DHS), National Response Framework, Fourth Edition October 28, 2019
- U.S. Department of Justice (DOJ), 9-95.000 – Unmanned Aircraft Systems (UAS), November 2019
- U.S. Geological Survey (USGS), The National Map

In-Development Regulations, Standards, and Guidance Material: There is a FEMA "Imagery with Context" project underway.

New Gap S12: Integration of UAS into FEMA ICS Operations Section, Air Operations Branch. The FEMA NIMS does not fully address UAS operations. FEMA's ICS does not presently contain official guidance surrounding the use of UAS within the Operation Section, Air Operations Branch.

R&D Needed: Limited

Recommendation: The NIMS should be revised to integrate the use of UA of all types as part of the ICS. Specific recommendations include:

1) Air Operations Summary (ICS 220) should be updated to incorporate UAS as an aviation resource.
2) FEMA, Resource Typing Definition for Response, NIMS 509, should be expanded to include such positions as UAS Coordinator and UAS Base Manager, or similar positions necessary to manage UAS operations under the Air Operations Branch.
3) Update FEMA, National Training and Education Division, Course Number AWR-345, "Unmanned Aircraft Systems in Disaster Management."

Priority: Medium

Organization(s): FEMA

9.11. Standardization of Data Formatting for sUAS Public Safety Operations

Standards can enable inter-agency cooperation at the government (federal, state, local, and tribal) levels and between government agencies and public safety officials. Public safety agencies often need to exchange data having never worked together and this often needs to be done expediently in the field and sometimes with little or no connectivity and often to remote locations. Standards can also help to guide industry in the development of products specifically used by public safety.

Typical use cases:

a. Using a UAS to map a large crime scene or large damaged area for evidence, documentation or to coordinate the local response. This can be reviewed on location, but often needs to be processed and/or shared with multiple users off site. Many of the off site users will not have access to bespoke image review tools.
b. Live video dissemination is a powerful tool both on site and for off site review. The video needs to be distributed and format so that off site parties can see it live without the requirement for bespoke installed software packages.
c. UAS recorded GIS data and associated map marking is often recorded on scene where local referencing is available. Off site reviewing and sharing this data across multiple agencies is often hindered by differing recorded formats and mapping/display platforms.

Standardized formats for various types of data include:

a. Live Video
b. KLV Meta Data
c. Recorded Video
d. Still Imagery
e. Aerial Mapping
f. Digital Map Marking
g. GIS data

Published Standards and Related Documents: Existing formats for Live Video & KLV Meta Data that are applicable to UAS operations include those promulgated by the Motion Imagery Standards Board ([MISB]) and NATO (STANAG 4609) which refers to MISB.

MISB published UAS specific standard(s) include:

- ST 0601.8 through ST 0601.15, UAS Datalink Local Set
- ST 0601.2 through ST 0601.7, UAS Datalink Local Metadata Set
- EG 0601, EG 0601.1, UAS Datalink Local Metadata Set

Published general industry standard formats include:

- Recorded Video - Motion Picture Experts Board (MPEG)
- Still Imagery - Joint Photographic Experts Group (JPEG)
- Aerial Mapping - American Society for Photogrammetry and Remote Sensing (ASPRS)
- Digital Map Marking - GeoTiff, GeoJSON
- GIS data - KMZ, KML, Shape
- OGC Wide Area Motion Imagery (WAMI) Best Practice

No standards have been identified for UAS public safety applications associated with the following formats: Recorded Video; Still Imagery; Aerial Mapping.

In-Development Standards: No in-development standards have been identified

New Gap S13: Data Format for Public Safety sUAS Operations. Standards are needed for the formatting and storage of UAS data for the public safety community, especially to foster inter-agency cooperation and interoperability, and to help guide industry product development.

R&D Needed: No

Recommendation: Develop standards for accepted format of live video and still imagery and associated GIS data for use in sUAS public safety operations.

Priority: High (Tier 2)

Organization(s): NFPA, ASTM, Airborne Public Safety Association (APSA), DRONERESPONDERS, AIRT, OGC

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10. Personnel Training, Qualifications, and Certification Standards: General – WG2

10.1. Terminology

The UAS industry is formed from a community that includes both traditional manned aviators and new UAS aviators who are unfamiliar with aviation safety culture, practices, and regulations. This has led to some confusion within the stakeholder community as to the application or misuse of unfamiliar and highly technical jargon.

Published Standards: There are a number of standards that include terminology sections in them including, for example, standards DO-362 and DO-365 from RTCA SC-228. The list of standards below are those that are devoted specifically to terminology.

Committee	Document
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3341/F3341M-20, *Standard Terminology for Unmanned Aircraft Systems*
ASTM F44.91, General Aviation – Terminology	ASTM F3060-16a, *Standard Terminology for Aircraft*
ISO/TC 20/SC 16	ISO 21895:2020, *Categorization and classification of civil unmanned aircraft systems*
JARUS WG6	*JARUS guidelines on SORA, Annex I, Glossary of Terms*

In-Development Standards: It is the practice of ASTM F38.03 that whenever a new term is added to the terminology standard, it counts as a revision. At present, ASTM WK72025, (Revision of F3341/F3341M – 20), *Standard Terminology for Unmanned Aircraft Systems,* is underway to add the term "constrained space." IEEE P2025.1, *Standard for Consumer Drones: Taxonomy and Definitions,* is pending administrative withdrawal for lack of activity.

Gap P1: Terminology. The roadmap version 1 gap stated "There is an available aviation standard, but no UAS specific standard has been identified. Several are in development and will satisfy the market need for consumer and commercial UAS terminology"

R&D Needed: No

Recommendation: The roadmap version 1 recommendation was to "Complete work on terminology standards in development."

Priority: High (Tier 3)

Organization(s): ASTM, IEEE, ISO, RTCA

Status of Progress: Closed

Update: With the publication of ASTM F3341/F3341M-20, *Standard Terminology for Unmanned Aircraft Systems* (previously WK42416), and ISO 21895:2020, *Categorization and classification of civil unmanned aircraft systems,* this gap is deemed closed.

10.2. Manuals

A UAS operator should be able to demonstrate an adequate organization, method of control and supervision of flight operations, and training program as well as ground handling and maintenance arrangements consistent with the nature and extent of the specified operations. Currently, the methods for guiding such a demonstration are found in manual specifications.

The operator should be able to demonstrate arrangements for use of approved remote pilot station (RPS) and voice and data links that will meet the quality of service (QoS) appropriate for the airspace and the operation to be conducted.

Published Regulations, Standards and Other Guidance Documents Include:

Organization/Committee	Document	Date
FAA	*Order 8040.6, Unmanned Aircraft Systems Safety Risk Management Policy*	Oct 2019
ASTM F38.02, UAS – Operations	ASTM F2909-19, *Standard Specification for Continued Airworthiness of Lightweight Unmanned Aircraft Systems*	2019
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F2908-18, *Standard Specification for Unmanned Aircraft Flight Manual (UFM) for an Unmanned Aircraft System (UAS)*	2018
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3330-18, *Standard Specification for Training and the Development of Training Manuals for the UAS Operator*	2018
ASTM F38.03, UAS – Personnel Training, Qualification & Certification	ASTM F3366-19, *Standard Specification for General Maintenance Manual (GMM) for a small Unmanned Aircraft System (sUAS)*	2019
ASTM F37.20, LSA – Airplane	ASTM F2745-15, *Standard Specification for Required Product Information to be Provided with an Airplane*	2015

ASTM F37.70, LSA - Cross Cutting	ASTM F2483-18e1, *Standard Practice for Maintenance and the Development of Maintenance Manuals for Light Sport Aircraft*	2018
JARUS WG1 - Flight Crew Licensing	*JARUS FCL Recommendation*. The document aims at providing recommendations concerning uniform personnel licensing and competencies in the operation of RPAS	Sep 2015
JARUS WG1 - Flight Crew Licensing	*JARUS FCL GM, Guidance Material to JARUS-FCL Recommendation*	Apr 2017
JARUS WG 6	*JARUS Guidelines on SORA, ANNEX A – Guidelines on collecting and presenting system and operation information for a specific UAS operation*	Jun 2017
NFPA	NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*	Nov 2018
NPSTC	*Guidelines for Creating an Unmanned Aircraft System (UAS) Program (v2)*	2017

In-Development Standards:

Committee	Document
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK62734, *New Specification for Specification for the Development of Maintenance Manual for Lightweight UAS*
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK62744, *New Practice for General Operations Manual for Professional Operator of Light Unmanned Aircraft Systems (UAS)*
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK63407, *New Specification for Required Product Information to be Provided with a Small Unmanned Aircraft System*

Gap P2: Manuals. Several published UAS standards have been identified for various manuals. Several more are in development and will satisfy the market need for civil and public operators.

R&D Needed: No

Recommendation: Complete existing work on manual standards in development

Priority: High (Tier 2)

Organization(s): ASTM, JARUS, NPTSC, NFPA

Status of Progress: Green

Update: The ASTM F38 Executive Committee gap analysis characterized this as a high priority for F38. ASTM F2909-14 has been superseded by ASFM F2909-19 (previously WK63991). ASTM F3366-19 has been published (previously WK62743). ASTM WK29229 is no longer an active work item.

10.3. UAS Flight Crew

The regulatory focus for UAS flight crew has rightfully remained on the individuals necessary for entry and operations within the NAS (i.e., the remote pilots). While commercial aviation has evolved to rely on multiple pilots (i.e., a captain and a first officer who are either commercial or airline transportation pilots), the military and law enforcement have long used a structure of pilots and non-rated crewmembers (i.e., sensor operators/tactical flight officers) based on rank structure and the cost/length of training of new pilots. With the low barrier to entry of Part 107, anyone acting as UAS flight crew should be a certified remote pilot, with additional skills and training as applicable to the operation. See also section 7.5 of this roadmap on weather, and section 10.4 on additional crew members.

Published Standards and Other Guidance Documents Include: The AUVSI Trusted Operator Program™ (TOP) is a graduated series of protocols that leverage existing standards to meet the market need for flight crewmembers and functional area qualification.

Organization/Committee	Document/Program	Date
ACI	ACI UAS Pilots Code (Annotated Version 1.0)	27 Jan 18
ACI	ACI Flight Safety in the Drone Age (Version 1.0)	
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3266, *Standard Guide for Training for Remote Pilot in Command of Unmanned Aircraft Systems (UAS) Endorsement*	1-May-18
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3330-18, *Standard Specification for Training and the Development of Training Manuals for the UAS Operator*	2019
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3379, *Guide for Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement*	
AUVSI Remote Pilots Council	Trusted Operator Program™ (TOP) training protocols for remote pilots and training organizations	1-Nov-18

Professional Photographers of America (PPA)	PPA Certified Drone Photographer	2017
SAE G-30 UAS Operator Qualifications & G-10U Unmanned Aerospace Vehicle	SAE ARP5707, *Pilot Training Recommendations for Unmanned Aircraft Systems (UAS) Civil Operations*	3-Apr-16

In-Development Standards and Related Protocols:

Committee	Document
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK61763, *New Guide for Training for Remote Pilot Instructor (RPI) of Unmanned Aircraft Systems (UAS) Endorsement*
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK62741, *New Guide for Training UAS Visual Observers*
SAE G-30 UAS Operator Qualifications & G-10U Unmanned Aerospace Vehicle	Aerial photography

Gap P3: Instructors and Functional Area Qualification. Several published UAS standards have been identified for various crewmember roles. Several are in development and will satisfy the market need for remote pilot instructors and functional area qualification.

R&D Needed: No

Recommendation: Complete work on UAS standards currently in development

Priority: High (Tier 2)

Organization(s): SAE, ASTM, AUVSI, PPA

Status of Progress: Green

Update: ASTM F3330-18 and ASTM F3379 (previously WK61764) have been added to the list of published standards. The other ASTM work items listed (WK61763, and WK62741) are out for ballot. WK61763 may be published before the roadmap is finalized.

10.4. Additional Crew Members

As the size and complexity of commercial UAS technology expands, so too grows the number of UAS applications. These include surveying and mapping, surveillance, SAR, law enforcement, aerial photography and cinematography, aerial news reporting, disaster response, utility inspection, and traffic monitoring applications.

Some of these applications will often require an additional crew member other than the RPIC to safely and effectively operate the UA. The scope of these multi-crew UAS operations will likely increase with the advancement of commercial UAS greater than 55 pounds operating beyond the small UAS rule in 14 CFR Part 107. This exposes safety-of-flight risks and potential gaps in existing standards.[61]

Various names for these additional UAS crew members include: sensor operator, remote sensing specialist, aerial cinematographer/camera operator, payload operator, tactical flight officer, and navigator.

Depending on the aircraft and/or CONOPs, multi-crew operations will likely define a set of responsibilities for each crew member, but some responsibilities will also be shared. For example, the large military MQ-1/9 series RPA requires a crew of two: the pilot-in-command responsible for flying the UA (the final authority for the safe operation of the aircraft), and the sensor operator (SO) responsible for operating the sensor(s) to track points of interest. In the United States Air Force (USAF), the crew members have different titles and qualification criteria, but in the Army both are qualified as pilots. In each case, the crew member operating the sensor is considered a primary flight crew member who contributes to the safe operation of the UA in areas such as: checklist procedures, aircraft system monitoring, general airmanship and situational awareness, and participating during critical phases of flight including emergency procedures.

A primary concern is the introduction of undesired risks in civil, multi-crew UAS operations, resulting from untrained flight crew members participating in flight activities, particularly on large UAS. For example, in the case of sUAS, a flight crew member is not currently required to be trained or certified as a remote pilot to participate in commercial UAS operations as long as there is a certified RPIC. Should the Part 107 framework be expanded to other classes of UAS, then undesired risks – mainly around crew resource management concerns – are likely. These risks can be mitigated with proper training. If adequately trained, additional aircrew can increase the overall safety of the UA operation when compared to a single-crew operation. This training should *only* be necessary for flight crew members actively participating in flight duties that contribute to safety-of-flight.

Published Standards and Related Materials:

The USAF military training, evaluation, and operational duties of SOs are well understood and documented in *AFI 11-2MQ-1&9 Volume 1 – Aircrew Training, AFI 11-2MQ-1 Volume 2 – Evaluation Criteria, AFI 11-2MQ-9 Volume 2 – Evaluation Criteria,* and *AFI 11-2MQ-1&9 Volume 3 – Operations*

[61] It should be noted that FAA is looking at mission specific competency, not weight.

Procedures. The Army framework for the same aircraft (MQ-1) uses two similarly trained remote pilots, with one designated as a pilot-in-command equivalent.

An overarching standard is CJCSI 3255.01, *Joint Unmanned Aircraft Systems Minimum Training Standards*. CJCSI 3255 implements NATO STANAG 4670, *STANAG on Recommended Guidance for the Training of Designated Unmanned Aerial Vehicle Operator (DUO) Training*, and applies to all of the U.S. military. CJCSI 3255 establishes the minimum recommended training level for UAS crew who perform duties other than the pilot (e.g., aircraft operator/sensor operator). Such individuals must possess required aviation knowledge and UAS knowledge-based skills to fly under visual flight rules (VFR) in Class E, G, and restricted/combat airspace.

When CJCSI 3255 was published in 2009, 14 CFR Part 107 was not yet written. However, CJCSI 3255 clearly establishes a minimum level of training that meets or exceeds the contemporary Part 107 requirements for a remote pilot. A similar standard ensuring a minimum training for all flight crew members for the wide range of potential civil applications has yet to be developed, although ICAO Document 10019, *Manual on Remote Piloted Aircraft Systems (RPAS)*, addresses remote pilots, remote pilot instructors, and observers.

SAE ARP5707 covers pilot training recommendations across the UAS spectrum and mentions additional crew members (section 4) but does not detail any training standards for such crew members. ASTM F3266 mentions additional required crew members and acknowledges that flight operations outside the scope of "lightweight UAS" may require additional training.

Organization/Committee	**Document/Program**	**Date**
Airborne Sensor Operators (ASO) Group	ASO Guide, Professional Standards, 1st edition	2018
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3266, *Standard Guide for Training for Remote Pilot in Command of Unmanned Aircraft Systems (UAS) Endorsement*	1-May-18
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3330-18, *Standard Specification for Training and the Development of Training Manuals for the UAS Operator*	2018
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3379, *Guide for Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement*. The standard (previously WK61764) describes flight crew beyond the RPIC. This includes describing a Tactical Flight Officer as a trained remote pilot who assists the RPIC during public safety operations.	
AUVSI Remote Pilots Council	Trusted Operator Program™ (TOP) training protocols for remote pilots and training organizations	1-Nov-18

NFPA	NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*	25-Nov-18
Professional Photographers of America (PPA)	PPA Certified Drone Photographer	2017
SAE G-30 UAS Operator Qualifications & G-10U Unmanned Aerospace Vehicle	SAE ARP5707, *Pilot Training Recommendations for Unmanned Aircraft Systems (UAS) Civil Operations*	3-Apr-16

In-Development Standards and Training Protocols:

Organization/Committee	Document
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK61763, *New Guide for Training for Remote Pilot Instructor (RPI) of Unmanned Aircraft Systems (UAS) Endorsement*. The Remote Pilot Instructor is responsible for training flight crew.
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK62741, *New Guide for Training UAS Visual Observers*

Gap P4: Training and Certification of UAS Flight Crew Members Other Than the Remote Pilot. There is a standards gap with respect to the training and/or certification of aircrew other than the RPIC specifically around the following:

- Functional duties of the crew member
- Crew resource management principles
- Human factors
- General airmanship and situational awareness, and
- Emergency procedures

R&D Needed: No

Recommendation:

1) Develop a framework to classify additional UAS crew members around common flight activities identifying in particular those who directly or indirectly influence safety-of-flight.
2) Develop a standard(s) around training, evaluation, and best practices for the relevant UAS crew members other than the RPIC for UAS >55Lbs for activities affecting safety-of-flight.
3) Consider the possibility of recommending – through best practices or a standard – that *all* flight crew members actively participating in flight activities on UAS > 55Lbs meet the minimum training of a remote pilot for the applicable UA.

Priority: Medium

Organization(s): SAE, ASTM, AUVSI, JARUS

Status of Progress: Green

Update: ASTM F3330-18 and ASTM F3379 (previously WK61764) have been added to the list of published standards. The other ASTM work items listed (WK61763, and WK62741) are out for ballot and expected to be published before the roadmap is published.

10.5. Maintenance Technicians

The largest gap in the personnel, training, and certification block appears to be related to the lack of qualification for persons involved in UAS repair. While the current regulations for civil operation (14 CFR Part 107) do not mandate any specific qualification, *Flight Standards Information Management Systems (FSIMS) Volume 16 Unmanned Aircraft Systems, Chapter 5 Surveillance, Section 2, Site Visits of UAS Operations*, describes maintenance as an area of inspection. Recent Part 107 waivers approved by the FAA also place a growing emphasis on maintenance practices.

Published Standards and Other Documents:

- ASTM National Center for Aerospace & Transportation Technologies (NCATT), Unmanned Aircraft System (UAS) Maintenance Standard (2012)
- ASSURE, *A.5 UAS Maintenance, Modification, Repair, Inspection, Training, and Certification Considerations Task 4: Draft Technical Report of UAS Maintenance Technician Training Criteria and Draft Certification Requirements, 6 Nov 2017, Final Report*
- Aviators Code Initiative (ACI), Aviation Maintenance Technicians Model Code of Conduct (AMTMCC) (2009)

In Development Standards:

- ASTM WK60659, *New Guide for Lightweight UAS Maintenance Technician Qualification.*

Gap P5: UAS Maintenance Technicians. Standards are needed for UAS maintenance technicians. ASTM is developing one and it will satisfy the market need.

R&D Needed: No

Recommendation: Complete work on UAS maintenance technician standards currently in development

Priority: High (Tier 2)

Organization(s): ASTM

Status of Progress: Green

Update: As noted in the text, ASTM WK60659 is in development. It will be part of a standard in ASTM F46 and is likely to be published before the roadmap is finalized at which time the gap will be closed.

10.6. Compliance/Audit Programs

In the interests of aviation safety, minimum requirements for compliance/audit programs for UAS operators are desirable. This would cover initial assessments of operators bringing new aircraft to market and periodic review of existing operators. It would also include auditor qualifications.

Published Standards:

Organization/Committee	Document/Program	Date
ASTM F37.70, LSA - Cross Cutting	ASTM F2839-11(2016), *Standard Practice for Compliance Audits to ASTM Standards on Light Sport Aircraft*	2016
ASTM F37.70, LSA - Cross Cutting	ASTM F3205-17, *Standard Practice for Independent Audit Program for Light Aircraft Manufacturers*	2017
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3266, *Standard Guide for Training for Remote Pilot in Command of Unmanned Aircraft Systems (UAS) Endorsement*	1-May-18
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3364-19, *Standard Practice for Independent Audit Program for Unmanned Aircraft Operators* (previously WK62730)	2019
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F3365-19, *Standard Practice for Compliance Audits to ASTM Standards on Unmanned Aircraft Systems* (previously WK62731)	2019
AUVSI Remote Pilots Council	Trusted Operator ProgramTM (TOP) Protocol Certification Manual	1-Nov-18
NFPA	NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*	25-Nov-18

In-Development Standards: None.

Gap P6: Compliance and Audit Programs. The version 1.0 gap stated "No published UAS standards have been identified for UAS-specific compliance/audit programs. However, several are in development and will satisfy the market need."

R&D Needed: No

Recommendation: The version 1.0 recommendation stated "Complete work on compliance and audit program standards currently in development."

Priority: High (Tier 3)

Organization(s): ASTM, AUVSI

Status of Progress: Closed

Update: With the publication in 2019 of ASTM F3364-19, *Standard Practice for Independent Audit Program for Unmanned Aircraft Operators* and ASTM F3365-19, *Standard Practice for Compliance Audits to ASTM Standards on Unmanned Aircraft Systems*, this gap is now closed.

10.7. Human Factors in UAS Operations

Human factors is the study of human behavior and performance in relation to particular environments, products, or services. Human factors engineering is the application of human factors information to the design of tools, machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use.[62] Human Factors also includes non-technical skills, crew resource management, airmanship, and physiological factors including ergonomics.

When applied to aviation operations, human factors knowledge is used to optimize the fit between people and the systems in which they work in order to improve safety and performance. Unmanned aviation presents many unique human factors considerations and challenges different from and beyond those of manned aviation, primarily because the aircraft and its operator are not co-located. In manned operations, the pilot is often relied on as the fail-safe, as the integrator of complex information and to make critical decisions in time sensitive, novel situations. However, in unmanned operations – particularly those involving UAS that are capable of operating BVLOS and at higher altitudes – the remote pilot's task is different and in some ways more difficult.

One of the biggest issues is 'See and Avoid' as described in FAR Sec. 91.113: "When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear." Remote pilots maintain the ability to see and avoid while the UAS is in VLOS. Once the UAS is no longer in VLOS, not assisted by a visual observer, the remote pilot's vision must be replaced with sensors and their judgment with algorithms. While sensors may provide superior ability for detect and avoidance of aircraft, the requirement for human training and recognition of the system remains.

[62] Chapanis, A. (1991). To communicate the human factors message, it is necessary to know what the message is and how to communicate it. *Human Factors Society Bulletin*, 34, 1-4.

Other human factors challenges that must be addressed for UAS to operate safely within civil airspace include:[63]

- **Reduced sensory cues.** The UAS pilot has no out-the-window view to assist with navigation, collision avoidance, or weather awareness. The absence of auditory, proprioceptive, and olfactory sensations may also make it more difficult to monitor the state of the aircraft. Onboard cameras, where available, typically present the pilot with a monocular image covering a restricted field of view. Appropriate task training to compensate for this is required.
- **Control and communication via radio link.** The UAS pilot must monitor and anticipate the quality of the control link and be prepared for link interruptions. Link latencies may make direct manual control difficult and may disrupt voice communications when these are relayed via the radio link.
- **Physical characteristics of the control station (CS).** CSs increasingly resemble control rooms or office workstations more than a traditional cockpit. The relative spaciousness of many CSs enables additional information displays to be added easily and without the forethought that would be needed to add them to a cockpit. It may be difficult to enforce 'sterile cockpit' procedures if the CS is housed in an office environment. Sterile cockpit is a time when operational discussions only are permitted, no general chatter, and any observers in the cockpit must be silent.
- **Transfer of control during ongoing operations.** Control of a UAS may be transferred during ongoing operations between adjacent control consoles within a CS or between geographically separated CSs. Each transfer may involve a risk of mode errors, inconsistencies between control settings, or miscommunication. Human factors training is needed for safe and complete 'handovers,' and transfer of control.
- **Flight termination (assuming the UAS is not being used to carry passengers).** In an emergency, the UAS pilot may choose to destroy the aircraft by ditching or other means rather than attempt a landing that could present a risk to people or property on the ground. Human factors training to integrate ground crews and other stakeholders should be considered.
- **Reliance on automation.** The pilot of a conventional aircraft will generally have the ability to turn off or minimize the use of automated systems and transition to manual control of the aircraft, even if this is accomplished via fly-by-wire systems. However, the nature of UAS design with the pilot located remotely from the UA requires reliance on automated systems for basic flight control and cannot provide options for complete pilot manual control.
- **Widespread use of interfaces based on consumer products.** Current CSs increasingly resemble office workstations, with keyboard, mouse, or trackball device, and interfaces operating on consumer computer software. Some CSs are housed entirely on a laptop computer. A CS that

[63] Adapted from Hobbs, A., & Lyall, B. (2016)

contains controls and displays sourced from diverse commercial off-the-shelf providers is likely to suffer from a lack of consistency and other integration issues.

- **Human factors training for accident investigations.** This will be an increasing need as the levels of automation increase at different rates of human integration, and training.

Human factors play a major role in almost every accident. Standards and regulations for unmanned flight in the national airspace must, therefore, pay particular attention to human factors training and procedures to support human factors considerations in UAS operations.

Published Standards and Related Materials: There are no published comprehensive standards specific to human factors for civilian UAS operations. However, there are several related standards and a wealth of published material on the subject (with many references therein). These include, for example:

- ICAO Human Performance (HP) Training Manual (Doc 9863-AN/950). A revised document is due to be released in 2020 with UAS HP standards.
- ICAO RPAS Manual Doc 10019. HP Chapter is due for release in 2020.

RTCA Special Committee (SC) 228, with substantial validation and testing support from NASA, developed DO-365, *Minimum Operational Performance Standards (MOPS) for Detect and Avoid Systems*, and DO-366, *MOPS for Air-to-Air Radar for Traffic Surveillance*. These RTCA standards were the basis for the Detect and Avoid system onboard the first NASA unmanned aircraft flight in public airspace without a chase plane. This flight was the first remotely-piloted aircraft to use airborne DAA technology to meet the intent of the FAA's "see and avoid" rules, with all test objectives successfully accomplished. MOPS for UAS, DO-365 and 366, were taken by the FAA to develop TSOs C211 on DAA and C212 on Airborne Radar for traffic surveillance.

EUROCAE:

- ED-251 Operational Services and Environment Definition for RPAS Automatic Taxiing
- ED-252 Operational Services and Environment Definition for RPAS Automatic Take-off and Landing

Others:

- Hobbs, A., & Lyall, B. (2016). Human Factors Guidelines for Unmanned Aircraft Systems. In Sage Journal *Ergonomics in Design* (Volume: 24 issue: 3, pp: 23-28)
- Hobbs, A. & Lyall, B. (2016). Human Factors Guidelines for Remotely Piloted Aircraft System (RPAS) Remote Pilot Stations (RPS). Guidelines version 1.1. Contractor Report prepared for NASA UAS in the NAS Project.
- Hobbs, A. (2017). Remotely Piloted Aircraft. In S.J. Landry (Ed.) *Handbook of Human Factors in Air Transportation Systems* (1st ed., Ch17, pp379-395). CRC Press.
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In-Development Standards and Related Materials: ICAO is currently modifying the Standards and Recommended Practices contained in Annexes to the Chicago Convention to enable remotely piloted aircraft systems (RPAS) to conduct international operations under instrument flight rules. ICAO is also adding RPAS human factors guidance to a new ICAO Human Performance Manual and to the next edition of the ICAO RPAS Manual.

The new Human Performance Manual will replace the existing ICAO Human Factors Training Manual, and will include human factors guidance material for all sectors of civil aviation, including (for the first time) remotely piloted operations. The current ICAO RPAS Manual contains limited information on human factors. The new edition will contain a chapter dedicated to RPAS human factors.

EUROCAE:

- Minimum Aviation Systems Performance Specification for RPAS Automatic Take-off and Landing
- Minimum Aviation Systems Performance Specification for RPAS Automatic Taxiing
- Operational Services and Environment Definition for RPAS Automation & Emergency Recovery functions
- Minimum Aviation Systems Performance Specification for RPAS Automation & Emergency Recovery functions

Gap P7: Displays and Controls.[64] Standards are needed for the suite of displays, controls, and onboard sensors that provide the UAS operator with the range of sensory cues considered necessary for safe unmanned flight in the national airspace.

The UAS operator is deprived of a range of sensory cues that are available to the pilot of a manned aircraft. Rather than receiving direct sensory input from the environment in which his/her vehicle is operating, a UAS operator receives only that sensory information provided by onboard sensors via datalink. Hence, compared to the pilot of a manned aircraft, a UAS operator must perform in relative "sensory isolation" from the vehicle under his/her control.

[64] Adapted from McCarley, J. & Wickens, C. (2005): pp1-3

Of particular interest are recent developments in the use of augmented reality and/or synthetic vision systems (SVS) to supplement sensor input. Such augmented reality displays can improve UAS flight control by reducing the cognitive demands on the UAS operator.

The quality of visual sensor information presented to the UAS operator will also be constrained by the bandwidth of the communications link between the aircraft and its CS. Data link bandwidth limits, for example, will limit the temporal resolution, spatial resolution, color capabilities and field of view of visual displays, and data transmission delays will delay feedback in response to operator control inputs.

R&D Needed: Yes

Recommendation:

1) Develop, with substantial validation and testing support, Minimum Operational Performance Standards for the suite of displays, controls, and onboard sensors that provide the UAS operator with the range of sensory cues considered necessary for safe unmanned flight in the national airspace.
2) Conduct further research and development in several areas, specifically, to:[65]

a. Identify specific ways in which this sensory isolation affects UAS operator performance in various tasks and stages of flight.
b. Explore advanced display designs which might compensate for the lack of direct sensory input from the environment.
c. Examine the costs and benefits of multimodal displays in countering UAV operators' sensory isolation, and to determine the optimal design of such displays.
d. Address the value of multimodal displays for offloading visual information processing demands. A related point is that multimodal operator controls (e.g., speech commands) may also help to distribute workload across sensory and response channels, and should be explored.
e. Determine the effects of lowered spatial and/or temporal resolution and of restricted field of view on other aspects of UAS and payload sensor control (e.g., flight control during takeoff and landing, traffic detection).

3) Examine the design of displays to circumvent such difficulties, and the circumstances that may dictate levels of tradeoffs between the different display aspects (e.g., when can a longer time delay be accepted if it provides higher image resolution). Research has found, not surprisingly, that a UAV operators' ability to track a target with a payload camera is impaired by low temporal update rates and long transmission delays.

Priority: High (Tier 3)

Organization(s): RTCA, NASA, others?

[65] Ibid

Status of Progress: Unknown

Update: The ASTM F38 Executive Committee gap analysis characterized this as a low priority for F38. ASTM F3002-14a notionally addresses this gap. Some aspects will be covered in design and construction standards for large UAS (e.g., WK62670). No further action is anticipated by F38 at this time.

Gap P8: Flight Control Automation and System Failures.[66] Standards are needed for the various forms of flight control automation, the conditions for which they are optimized, and the appropriate aircraft and operator response in the event of system failures.

UAS operations differ dramatically in the degree to which flight control is automated. In some cases, the aircraft is guided manually using stick and rudder controls, with the operator receiving visual imagery from a forward looking camera mounted on the vehicle. In other cases, control is partially automated, such that the operator selects the desired parameters through an interface in the CS. In still other cases, control is fully automated, such that an autopilot maintains flight control using preprogrammed fly-to coordinates.

Furthermore, the form of flight control used during takeoff and landing may differ from that used en route. The relative merits of each form of flight control may differ as a function of the time delays in communication between the operator and the UAS, as well as the quality of visual imagery and other sensory information provided to the operator from the UAS.

R&D Needed: Yes

Recommendation:

1) Develop standards and guidelines for the various forms of flight control automation, the conditions for which they are optimized, and the appropriate aircraft and operator response in the event of system failures.
2) Conduct further research and development to establish and optimize procedures for responding to automation or other system failures. For example, it is important for the UAS operator and air traffic controllers to have clear expectations as to how the UAS will behave in the event that communication with the vehicle is lost. Specific areas of R&D should include but not be limited to the following:[67]

[66] Adapted from McCarley, J. & Wickens, C. (2005): p3
[67] Ibid

a. Determine the circumstances (e.g., low time delay vs. high time delay, normal operations vs. conflict avoidance and/or system failure modes) under which each form of UAS control is optimal. Of particular importance will be research to determine the optimal method of UAS control during takeoff and landing, as military data indicate that a disproportionate number of the accidents for which human error is a contributing factor occur during these phases of flight.
b. Examine the interaction of human operators and automated systems in UAS flight. For example, allocation of flight control to an autopilot may improve the UAS operator's performance on concurrent visual mission and system fault detection tasks.
c. Determine which of the UAS operator's tasks (e.g., flight control, traffic detection, system failure detection, etc.) should be automated and what levels of automation are optimal. The benefits of automation will depend on the level at which automation operates. For example, in a simulated UAS supervisory monitoring task, it can be reasonably expected that there will be different benefits for automation managed by consent (i.e., automation which recommends a course of action but does not carry it out until the operator gives approval) compared to automation managed by exception (i.e., automation which carries out a recommended course of action unless commanded otherwise by the operator).

Priority: High (Tier 1)

Organization(s): SAE A-6, S-18, ASTM, RTCA, others?

Status of Progress: Unknown

Update: ASTM F3002-14a notionally addresses this gap. Some aspects will be covered in design and construction standards for large UAS (e.g., WK62670). No further action is anticipated by ASTM F38 on human factors at this time. No other updates provided at this time.

Gap P9: Crew Composition, Selection, and Training.[68] Standards are needed for human factors-related issues in the composition, selection, and training of UAS flight crews. UAS flight crews for BVLOS operations (whether short or long endurance, and/or low or high altitude) will typically comprise a minimum of two operators: one responsible for airframe control, and the other for payload sensor control. This and other multi-crew structures are based on research findings that the assignment of airframe and payload control to a single operator with conventional UAS displays can substantially degrade performance. Data also suggest, however, that appropriately designed displays and automation may help to mitigate the costs of assigning UAV and payload control to a single operator. It may even be

[68] Adapted from McCarley, J. & Wickens, C. (2005): pp3-4

possible for a single UAS operator to monitor and supervise multiple semi-autonomous vehicles simultaneously.

R&D Needed: Yes

Recommendation:

1) Develop standards and guidelines for human factors-related issues in the composition, selection, and training of UAS flight crews.
2) Conduct further research to:[69]

a. Determine the crew size and structure necessary for various categories of UAS missions in the NAS, and to explore display designs and automated aids that might reduce crew demands and potentially allow a single pilot to operate multiple UASs simultaneously.
b. Develop techniques to better understand and facilitate crew communications, with particular focus on inter-crew coordination during the hand off of UAS control from one team of operators to another.
c. Examine standards for selecting and training UAS operators. There are currently no uniform standards for UAS pilot selection and training. While data indicate significant positive skills transfer from manned flight experience to UAS control, research is needed to determine whether such experience should be required of UAS operators, especially those engaged in conducting BVLOS operations. Research is also necessary to determine the core content of ground school training for UAS operators, and to explore flight simulation techniques for training UAS pilots to safely conduct BVLOS operations in the NAS.

Priority: High (Tier 2)

Organization(s): RTCA, NFPA, MITRE, NASA, ICAO others?

Status of Progress: Unknown

Update: None provided at this time.

[69] Ibid

11. Next Steps

It is essential that this roadmap continue to be widely promoted among interested stakeholders so that its recommendations see broad adoption.

To the extent R&D needs have been identified, the roadmap can be used as a tool to help direct funding to the areas of research needed for UAS.

In terms of standards activities, an ongoing dialogue between industry, FAA, and the SDOs would be beneficial to continue discussions around coordination, forward planning, and implementation of the roadmap's recommendations. Such a dialogue can also identify emerging issues that require further elaboration.

It is recognized that standardization activity will need to adapt as the ecosystem for UAS evolves due to technological innovations and regulatory developments, and as additional industry sectors enter the UAS market.

Depending upon the realities of the standards environment, the needs of stakeholders, and available resources, it is envisioned that a mechanism may be established to monitor progress to implement the roadmap's recommendations.

Ultimately, the aim of such an effort would be to continue to guide, coordinate, and enhance standardization activity for UAS and to enable the market for UAS to thrive.

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Appendix A. Glossary of Acronyms and Abbreviations

AASHTO – American Association of State Highway and Transportation Officials
AC – advisory circular
ACAS – Airborne Collision Avoidance System
ADI – Alliance for Drone Innovation
ADS-B – automatic dependent surveillance-broadcast
AGL – above ground level
AIAA – American Institute of Aeronautics and Astronautics
ANSI – American National Standards Institute
APSA – Airborne Public Safety Association
APSAC – Airborne Public Safety Accreditation Commission
ARC – Aviation Rulemaking Committee
ASME – American Society of Mechanical Engineers
ASSP – American Society of Safety Professionals
ASSURE - FAA UAS Center of Excellence – the Alliance for System Safety of UAS through Research Excellence (ASSURE)
ASTM – ASTM International
ATC – air traffic control
ATIS – Alliance for Telecommunications Industry Solutions
ATM – air traffic management
AUVSI – Association for Unmanned Vehicle Systems International
BPV – boiler and pressure vessel
BVLOS – beyond visual line of sight
C2 – command and control
C3 – command, control, and communications
CAA – civil aviation authority
CFR – Code of Federal Regulations
COA – certificate of authorization
CONOPS – concept of operations
COTS – commercial off-the-shelf
CPDLC – Controller Pilot Data Link Communications
CS – control station
CTA – Consumer Technology Association
C-UAS – counter-UAS
DAA – detect and avoid
DHS – U.S. Department of Homeland Security
DOD – U.S. Department of Defense
DOE – U.S. Department of Energy
DOI – U.S. Department of the Interior
DOJ – U.S. Department of Justice
DOT – U.S. Department of Transportation
DWG – Domain Working Group
EASA – European Aviation Safety Agency
EMS – emergency medical services
EUROCAE – European Organisation for Civil Aviation Equipment
EUSCG – European UAS Standards Coordination Group
EWIS – electrical wiring interconnect system
FAA – Federal Aviation Administration
FCC – Federal Communications Commission
FEMA - Federal Emergency Management Agency
FERC – Federal Energy Regulatory Commission
GML – Geography Markup Language
GNSS – Global Navigation Satellite System
GUTMA – Global UTM Association
HAZMAT – hazardous materials
ICAO – International Civil Aviation Organization
IEC – International Electrotechnical Commission
IEEE – Institute for Electrical and Electronics Engineers
IFR – instrument flight rules
IoT – internet of things
ISO – International Organization for Standardization
ITA – International Trade Administration
JARUS – Joint Authorities for Rulemaking on Unmanned Systems
JPR – Job Performance Requirement
JWG – joint working group
LSA – light sport aircraft

MASPS – Minimum Aviation System Performance Standards
MOPS – Minimum Operational Performance Standards
NAS – national airspace system
NASA – National Aeronautics and Space Administration
NCPSU – National Council on Public Safety UAS
NERC – North American Electric Reliability Corporation
NFPA – National Fire Protection Association
NIOSH National Institute for Occupational Safety and Health
NIST – National Institute of Standards and Technology
NPSTC – National Public Safety Telecommunications Council
NTIA – National Telecommunications and Information Administration
OGC – Open Geospatial Consortium
OMB – White House Office of Management and Budget
OOP – operations over people
ORA – operational risk assessment
OSHA – Occupational Health and Safety Administration
PIA – Parachute Industry Association
PII – personally identifiable information
PPE – personal protective equipment
QA – quality assurance
QC – quality control
QoS – quality of service
R&D – research and development
RF – radio frequency
RPAS – remotely piloted aircraft systems
RPIC – remote pilot in command
RPS – remote pilot station
RTCA – RTCA, Inc.
SAE – SAE International
SAR – search and rescue
SC – subcommittee
SDO – standards developing organization
SIA – Security Industry Association
SORA – Specific Operations Risk Assessment
sUAS – small unmanned aircraft system
SWG – special working group
TC – technical committee
TCAS – Traffic Alert & Collision Avoidance System
TF – Task Force
TIA – Telecommunications Industry Association
TSO – Technical Standard Order
UA – unmanned aircraft
UAS – unmanned aircraft system
UAV – unmanned aerial vehicle
UCS – UxS control segment
UL – Underwriters Laboratories, Inc.
USDA – U.S. Department of Agriculture
USS – UAS service supplier
UTM – UAS traffic management
UxS – unmanned systems
VFR – visual flight rules
VLL – very low-level
VLOS – visual line of sight
VO – visual observer
VTOL – vertical take-off and landing
WG – working group