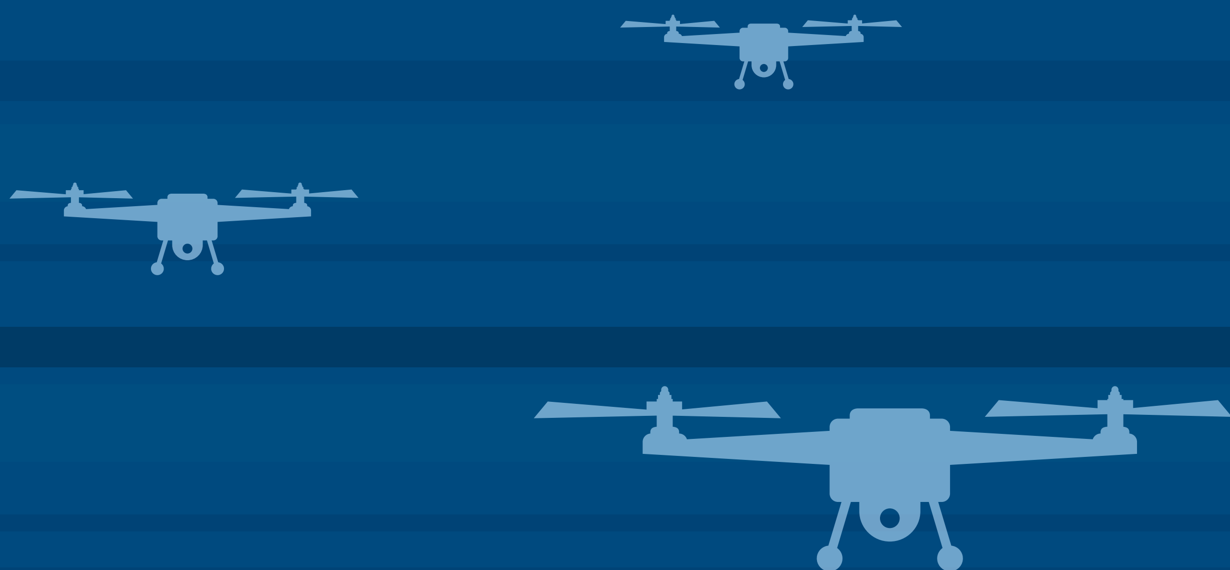
STANDARDIZATION ROADMAP

For Unmanned Aircraft Systems, Version 1.0



Prepared by the ANSI Unmanned Aircraft Systems Standardization Collaborative (UASSC)

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Table of Contents

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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 1.0* ("roadmap") represents the culmination of the UASSC's work to identify existing standards and standards in development, assess gaps, and make recommendations for priority areas where there is a perceived need for additional standardization and/or pre-standardization R&D.

The roadmap has examined 64 issue areas, identified a total of 60 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, 40 gaps/recommendations have been identified as high priority, 17 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 36 cases, additional R&D is needed.

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 be widely promoted and discussed over the course of the coming year, to assess progress on its implementation and to identify emerging issues that require further elaboration.

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Summary Table of Gaps and Recommendations

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
			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 that of primary UAS elements (i.e., UA, GCS). However, these standards fail to address the critical and novel aspects essential to the safety of unmanned operations (i.e., DAA, software, BVLOS, C3, 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 standards capable of establishing an acceptable baseline of D&C for these critical fight operation elements to support current regulatory flight operations and those authorized by waiver and or grants of exemption.	No	1) Complete work on in-development standards. 2) Develop D&C standards and consider operations beyond the scope of regular Part 107 operation such as flight altitude above 400 feet AGL, and any future technological needs.	High	ASTM, ISO, others?
2.	6.2	Safety	**Gap A2: UAS 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 customer or regulatory body 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, remotely controlled, optionally piloted, autonomous, and types of UAS to which they are most relevant. Such a report should address design, production and operational approval safety aspects. Recently SAE's two technical committees SAE S-18 and SAE AS-4 have initiated a liaison activity to draw from both technical committees' expertise in UAS, safety assessment and development assurance to assess this specifically and this may in-turn lead to a document to describe how to apply the strong guidance in ARP4754 and ARP4761 to UAS, perhaps an SAE AIR. This was initiated in the SAE Automated Flight 4 workshop on 4 Oct 2018 and confirmed from the S-18 technical committee perspective at the 15-19 Oct 2018 meeting.	No	Develop 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 to which they are most relevant.	Low	RTCA, SAE, IEEE, American Institute of Aeronautics and Astronautics (AIAA), ASTM, DOD, NASA, FAA
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 published QA/QC standard (ASTM F3003-14, *Standard Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS)*) that is specific to UAS and it covers sUAS. There is also only one QA/QC standard in development for manufacturers of aircraft systems (ASTM WK51467, *New Specification for Quality Assurance for Manufacturers of Aircraft Systems*) and 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.	Medium (Scoring: Criticality-2; Achievability-1; Scope-3; Effect-3)	ASTM, ISO, SAE, FAA, DOD
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:	Yes	1) One approach is to recommend that existing standards be revised to include provisions that address the points listed	High	**For Avionics Issues:** RTCA, SAE, IEEE, AIAA,

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
			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.		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.		ASTM, DOD, NASA, FAA, ICAO **For Spectrum Issues:** FAA, FCC, NTIA, International Telecommunica tion Union (ITU)
5.	6.4.1	Avionics and Subsystems: Command and Control (C2) Link	**Gap A5: Command and Control (C2)/Command, Control and Communications (C3) Link Performance Requirements.** Standards setting forth C2/C3 link performance requirements are needed by the telecommunications industry to understand how to modify or create networks to serve UAS. These performance requirements must define the virtual cockpit awareness that networks must provide to operators. Some definitions that have been adapted from current manned aviation communications standards include availability, continuity, latency, and security. In other words, what is the reliability that a message can be sent, how quickly is the message needed, and what security mitigations are necessary to avoid nefarious activity. The industry is ready and willing to support UAS, but the remote nature of UAS requires clarity on what is required to meet aviation safety standards.	Yes	Complete work on RTCA, *Command and Control Data Link Minimum Aviation Systems Performance Standard (MASPS)* (RTCA SC-228 WG2) and related standards and documents now in development.	High	RTCA, ASTM, JARUS
6.	6.4.1	Avionics and Subsystems: Command and Control (C2) Link	**Gap A6: Technical support for C2/C3 link performance requirements in telecommunications standards.** 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/C3 link will require further standardization activities.	Yes	Advance existing work in 3GPP and ensure C2/C3 requirements are communicated to that group.	High	3GPP, ATIS

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
			Collaboration between the UAS industry and communications industry is required to ensure feasibility of implementation.				
7.	6.4.2	Avionics and Subsystems: Navigational Systems	**Gap A7: UAS Navigational Systems.** There is a lack of standards specifically for UAS navigation. UAS navigation can leverage many of the same standards used for manned aircraft, but at a smaller scale and lower altitudes.	Yes. A specific R&D effort geared towards applying tracking innovations in satellite navigation for UAS is needed.	Depending on the operating environment, apply existing navigation standards for manned aviation to UAS navigation and/or develop UAS navigation standards for smaller scale operations and at lower altitudes. 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.	High	SAE, FAA, NASA, DOT
8.	6.4.2	Avionics and Subsystems: Navigational 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 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.	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.	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.	High	SAE, FAA, DOD, NASA, DOT
9.	6.4.3	Avionics and Subsystems: Detect and Avoid (DAA) Systems	**Gap A9: Detect and Avoid (DAA) Systems.** No published standards have been identified that address DAA systems for UAS that cannot meet the size, weight, and power (SWAP) requirements of 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 DAA systems impairs the FAA's ability to establish a TSO for those DAA systems.	Yes	1) Complete the above listed in-development standards. 2) Encourage the development of standards to address and accommodate DAA systems for UAS that cannot meet the current SWAP requirements. This is a necessary first step toward an eventual publication of a TSO for smaller or limited performance DAA systems and full and complete integration of UAS into the NAS.	High	RTCA, SAE, AIAA, ASTM, DOD, NASA, 3GPP
10.	6.4.4	Avionics and Subsystems: Software Dependability and Approval	**Gap A10: Software Dependability and Approval.** Standards are needed to address software dependability 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.	No	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.	High	ASTM, RTCA, SAE
11.	6.4.5	Avionics and Subsystems: Crash Protected Airborne	**Gap A11: Crash Protected Airborne Recorder Systems (CPARS) for UAS.** No published or in-development standards have been identified to fill the need of a CPARS or flight data recorder system for UAS. The traditional use of cockpit voice recorder (CVR) in manned aviation is meant to provide voice data occurred amongst	Yes. Research should be conducted to determine the proper: 1) Size requirements, based on the class of UAS, class of	Revise an existing standard, or draft a new standard, similar to ED-112A, for a CPARS for UAS.	Medium (Scoring: Criticality-2; Achievabilit	SAE, RTCA, ASTM, IEEE

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
		Recorder Systems (CPARS)	the pilots, other users of the NAS, and the air traffic controllers. The CVRs installed on UAs do not meet the intent of the CVR since the pilots are not stationed on the UAs, if the CVR is not installed on the ground control station (GCS). This necessitates the need for a CVR to be installed on the GCS, to fulfill the complete function of the CVR thereby requiring industry standards. By way of further analysis: 1) EUROCAE ED-112A, *Minimum Operational Performance Specification (MOPS) for Crash Protected Airborne Recorder Systems* 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. 2) ED-112A recommends redundancy (cockpit and aft) in CPARS that may not be necessary for many classes of UAS. 3) ED-112A requires certain testing for penetration, shock, shear force, tensile force, crush, and others that are unnecessary and inconsistent with the scenario 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 onboard a UAS (e.g., formaldehyde-based toilet fluids)). 4) 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 GCS. This suggests that a CPARS for UAS should reside on the aircraft, and a non-crash-protected data recorder system should reside in the GCS. An example of this is CVRs. 5) CPDLC may apply to some classes of UAS, particularly large UAS flying in oceanic airspace, but is unnecessary for many classes of UAS. 6) EUROCAE ED-155, *Minimum Operational Performance Specification (MOPS) for Lightweight Flight Recording Systems* may be more applicable for some classes of UAS, but still shares some deficiencies with ED-112A. 7) MOPS should explicitly state CAA equipage requirements for UAS based on size, weight, CONOPS, airspace access, and/or an ORA. 8) ASTM F3298-18, *Standard Specification for Design, Construction, and Verification of Fixed-Wing Unmanned Aircraft Systems (UAS)* (section 12.2) 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, F3298-18 does not include the recording of voice communication between a remote pilot and (a) additional crew members (e.g., a sensor operator), (b) ATC or other air navigation service provider (ANSP) personnel. 9) ASTM F3298-18 does not include rotorcraft UAS.	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 GCS.		y-2 (this would require a new standard that is not currently in development but there are existing methods for testing and evaluating such a standard, in most cases ED-112A can be used as a framework that can be tailored to the performance and operational characteristics of UAS); Scope-2; Effect-3 (increasing safety with the addition of critical avionics is of paramount importance to integrating 'commercial/industrial' UAS into non-segregated civil airspace))	
12.	6.4.6	Avionics and Subsystems: Cybersecurity	**Gap A12: UAS Cybersecurity**. Cybersecurity needs to be considered in all phases of UAS design, construction, and operation	Yes	Since there exists such a wide spectrum in UAS designs, CONOPS, and operator capabilities, a risk-based process during	High	JARUS, RTCA, SAE, IEEE, AIAA,

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
					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.		ASTM, DOD, NASA, UL
13.	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 ground control stations (GCS)s, 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, GCS, and auxiliary system(s).	High	ICAO, RTCA, SAE, AIAA, ASTM, DOD, NASA, UL, IEC, IEEE
14.	6.6	Power 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	High	ICAO, RTCA, SAE, AIAA, ASTM, DOD, NASA, UL, IEC, IEEE
15.	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	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.	High	ICAO, RTCA, SAE, AIAA, ASTM, DOD, NASA
16.	6.8	Mitigation Systems for Various Hazards	**Gap A16: Mitigation Systems for Various Hazards.** There are no UAS-specific standards in the areas of hazard mitigation systems for bird and/or UAS strikes on UAS, UAS strikes on manned aviation (including to persons, property and other users of the NAS), engine ingestion, hail damage, water ingestion, lightning, electrical wiring, support towers, etc.	Yes. There is some data from FAA Assure that is being used for standards development now.	1) Complete in-development standards. 2) Create new standards to include Hazard Mitigation Systems for Bird and/or UAS strikes on UAS, UAS strikes on manned aviation (including to persons, property, and other users of the NAS), engine ingestion, icing, and lightning.	High	SAE
17.	6.9	Parachutes for Small UAS	**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 WK52089, *New Specification for Operation over People* and ASTM WK56338, *New Test Methods for Safety of Unmanned Aircraft Systems for Flying over People*.	High	ASTM, AIAA, SAE, PIA, DOD, NASA
18.	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.	High (Scoring: Criticality-3; Achievability-1; Scope-3, Effect-3)	ASTM, ISO, SAE
19.	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	High	SAE, ARINC, RTCA, AIAA, ASTM, DOD, NASA, FCC

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
					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.		
			Chapter 7. Flight Operations Standards: General – WG2				
20.	7.1	Privacy	**Gap O1: Privacy**. UAS-specific privacy standards are needed. Privacy law and rulemaking related to UAS, including topics such as remote ID and tracking, are yet to be clearly defined.	No	Complete work on ISO/DIS 21384-3, *Unmanned Aircraft Systems – Part 3: Operational Procedures*. Monitor the ongoing policy discussion.	Low	Lawmakers, FAA, ISO/IEC JTC1/SC 27, ISO/TC 20/SC 16, APSAC, IACP
21.	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.	High (Scoring: Criticality-1 (published risk framework exists); Achievability-3 (risks being addressed in use cases. Public risks addressed through legislation - complex); Scope-3 (risks being addressed in use cases. Public risks addressed through legislation - complex); Effect- 3	Standards bodies publishing UAS standards and/or regulators

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
						(high return - reduce risks and managed public perception)	
22.	7.3	Beyond Visual Line of Sight	**Gap O3: Beyond Visual Line of Sight (BVLOS)**. Although there is an existing BVLOS standard with supplemental revisions in the works and a best practice document, robust BVLOS operations will require a comprehensive DAA solution, Remote ID and UTM infrastructure to be completely effective. 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 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.	High (Scoring: Criticality-3, Achievability-3, Scope-1, Effect-3)	ASTM
23.	7.4	Operations Over People	**Gap O4: UAS Operations Over People (OOP).** There are no published standards for UAS OOP.	No	Complete work on ASTM WK56338, *New Test Methods for Safety of Unmanned Aircraft Systems for Flying Over People* and ASTM WK52089, *New Specification for Operation over People*.	High (Scoring: Criticality-3; Achievability-2; Scope-2; Effect-3)	ASTM
24.	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: 1) Weather requirements for flight operations of UAS. For example, to operate in Class A 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 GCS).	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,	Encourage relevant research, amending of existing standards, and drafting of new standards (where applicable).	High	RTCA, SAE, NOAA, WMO, NASA, universities, National Science Foundation (NSF) National Center for Atmospheric Research (NCAR)

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
				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?			
25.	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 needed to identify standards-based "architectural guidance" for different UAS operations.	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.	Medium. A score of 9 was derived in part because of the criticality of best practices in assuring efficient and mission responsive UAS observation capability, and given the range of UAS platforms, variety of sensing platforms, and myriad of mission scenarios.	OGC, ISO TC/211, ASTM
26.	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	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	High	NASA, FAA, ASTM, ISO, et al.

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
				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.	address the subject. What is needed is direction to adopt the performance 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 then apply their expertise in defining testable and relevant performance-based requirements and thus quickly converge to published standards.		
27.	7.8	Remote ID & Tracking	**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.	Yes	1) Review existing standards relating to the broadcast of ID and tracking data for manned aviation outside ATC to address UAS operations in similar environments and scenarios. 2) Continue development of the Open Drone ID standard which is also addressing how multiple solutions interface with an FAA-approved internet-based database. 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.	High	Open Drone ID, ASTM, 3GPP, ATIS
28.	7.8	Remote ID & Tracking	**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 network and cloud-based services. Nor do they describe how that data is received by and/or accessed from an FAA-approved internet-based database. However, the ASTM F38 Remote ID Workgroup / Open Drone ID project includes a network access API within their scope of work.	Yes	1) Continue development and complete ASTM WK65041, *New Practice for UAS Remote ID and Tracking* and the Open Drone ID project's efforts to include standards for UAS ID and tracking over established communications networks (such as cellular and satellite), which should also address how multiple solutions (and service providers) interface with an FAA-approved internet-based database. 2) Continue development of 3GPP specs and ATIS standards related to remote ID of UAS and UTM support over cellular.	High	Open Drone ID, ASTM, 3GPP, ATIS
29.	7.9	Geo-fencing	**Gap O10: Geo-fence Exchange**. Standards 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,	High	OGC, ISO / TC 20 / SC 16, EUROCAE, UAST, ICANN

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
					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.		
30.	7.9	Geo-fencing	**Gap O11: Geo-fence Provisioning and Handling.** There is a need for a best practice document to inform manufacturers of the purpose and handling 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
			Chapter 8. Flight Operations Standards: Critical Infrastructure Inspections and Commercial Services – WG3				
31.	8.1.1	Vertical Infrastructure Inspections: Boilers and Pressure Vessels	**Gap I1: UAS Inspections of Boiler and Pressure Vessels (BPV).** No published or in-development UAS standards have been identified for BPV inspections.	Yes. Identify impact on the C2 link to operations in an enclosed space.	Develop standards for power plant inspections using UAS both internal and external to the BPV. Efforts by the ASME BPV Section V Committee on Nondestructive Examination will be considered in the recommendation.	Medium	ASME BPV Committee on Nondestructive Examination (V) and proposed Mobile Unmanned Systems (MUS) Standards Committee

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
32.	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 ASME B30.32-20XX, *Unmanned Aircraft Systems (UAS) used in Inspection, Testing, Maintenance, and Lifting Operations* to address crane inspections using UAS.	Medium	ASME
33.	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 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.	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.	Medium	ASTM
34.	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.	Medium	ASHI, ASTM
35.	8.1.5	Vertical Infrastructure Inspections: Communications Towers	No Gap	N/A	N/A	N/A	N/A
36.	8.2.1	Linear Infrastructure Inspections: Bridges	**Gap I5: Bridge Inspections**. There are no known published or in-development standards for conducting bridge inspections using a UAS. Standards are needed 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	Yes, for navigation systems to mitigate potential GPS reception loss while operating in close proximity to structures that might obstruct GPS transmission signals. Also, for evaluating and documenting UAS-mounted sensor capabilities to meet bridge inspection data needs in	Develop standards for bridge inspections using a UAS.	Medium	AASHTO, ASTM

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
			purposes. All bridge types should be considered, including rail, road, and pedestrian. 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.	light of state and federal reporting requirements.			
37.	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.	No. 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.	Low	FRA, FAA, SAE, OSHA
38.	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 on going 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.	No. Current Pathfinder program activities likely will address R&D considerations.	It is recommended that standards be developed that define a framework for operating UAS BVLOS for rail system infrastructure inspection.	Medium	FRA, FAA, SAE
39.	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.	Medium	FRA, FAA, SAE
40.	8.2.3	Linear Infrastructure Inspections: Power Transmission Lines	**Gap I9: Inspection of Power Transmission Lines 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 in telecommunication corridors that share poles with transmission and distribution equipment. This includes telephone, fiber, and cable assets. A standard is needed to address these issues as well as operational best practices in how to conduct a safe inspection of power transmission lines using drones.	Yes. There is a need to study acceptable methods of airspace confliction data in transmission corridors. Identifying acceptable data to collect and study airspace activity around transmission corridors 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	Develop standards related to inspections of power transmission lines using UAS. Review and consider relevant standards from other organizations to determine manufacturer requirements. As part of the standard, include guidelines on safe flight operations in proximity to energized equipment to avoid arcing damage to physical infrastructure.	High	SAE, IEEE, Department of Energy (DOE), North American Electric Reliability Corporation (NERC), FERC, ORNL

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
				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.			
41.	8.3.1	Wide Area Environment Infrastructure Inspections / Precision Agriculture: Environmental Monitoring	No Gap	N/A	N/A	N/A	N/A
42.	8.3.2	Wide Area Environment Infrastructure Inspections / Precision Agriculture: 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 might also be the domain of manned aerial application aircraft. Automated ID and location communication is critical in this dangerous, near surface airspace. • **Treatment Efficacy.** Assumptions that spraying patterns and efficacy are similar to heavier aircraft may be incorrect for small 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. • **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,	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/AATRU, and ASSURE should be consulted in conjunction with such standards development activities.	High	ISO/TC 23/SC 6, American Society of Agricultural and Biological Engineers (ASABE), AIAA, FAA

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
			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.				
43.	8.3.3	Wide Area Environment Infrastructure Inspections / Precision Agriculture: Livestock Monitoring and Pasture Management	No Gap	N/A	N/A	N/A	N/A
44.	8.4	Commercial Package Delivery	**Gap I11: Commercial Package Delivery.** Standards are needed to enable UAS commercial package delivery operations.	Yes	Complete work on ASTM WK62344, *Risk Mitigation Strategies for Package Delivery sUAS BVLOS Operations (Appendix to F3196)*; ASTM WK65041, *New Practice for UAS Remote ID and Tracking*; and ASTM WK63418, *New Specification for Service provided under UAS Traffic Management (UTM)*. Consider adapting SAE J2735_201603, *Dedicated Short Range Communications (DSRC) Message Set Dictionary* for UAS.	High	ASTM, SAE
45.	8.5	Occupational Safety Requirements for UAS Operated in the Workplace	**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), 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.	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.	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	High	SAE, ASTM, ASSP, OSHA, NIOSH, ISO/TC 20/SC 16, etc.

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
					involving UAS in workplace environments.		
			Chapter 9. Flight Operations Standards: Public Safety – WG4				
46.	9.1	sUAS for Public Safety Operations	**Gap S1: Use of sUAS for Public Safety Operations.** Standards are needed on the use of drones by the public safety community.	No	With the recent 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.	High (Scoring: Criticality-3; Achievability-3; Scope-3; Effect-3)	NFPA, ASTM
47.	9.2	Hazardous Materials Incident Response and Transport	**Gap S2: Hazardous Materials Response and Transport Using a UAS**. There are no known UAS standards addressing the transportation of known or suspected 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 IP ratings when dealing with HAZMAT • The method of decontamination of a UAS that has been exposed to HAZMAT	Medium	ASTM, NFPA, OSHA, U.S. Army, DOT
48.	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.	High	UN, PHMSA, FAA, WHO, ICAO, DOD, DHS, CDC, USDA, NIH, NFPA, SAE
49.	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.	Medium	APSAC, ASPRS, OGC, NFPA, NIST, ASTM
50.	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.	High	ASTM, DOJ, NFPA, DHS, NIST

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
51.	9.6.1	Search and Rescue: sUAS FLIR Camera Sensor Capabilities	**Gap S6: sUAS Forward-Looking Infrared (FLIR) Camera Sensor Capabilities.** No published or in-development UAS standards have been identified for FLIR camera sensor capabilities. A single standard could be developed to ensure FLIR 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 FLIR camera sensor sensitivity, radiometric capabilities, zoom, and clarity of imagery for identification of a person/object for use in public safety/SAR missions.	Develop a standard for FLIR camera sensor specifications for use in public safety and SAR missions.	Medium (Scoring: Criticality-2; Achievability-1; Scope-3; Effect-3)	NIST, NFPA, ASTM
52.	9.6.2	Search and Rescue: sUAS Automated Waypoint Missions	**Gap S7: Search and Rescue: Need for Command and Control Software Specifications for Automated Waypoint Missions.** No published or in-development UAS standards have been identified for waypoint mission programming parameters for SAR missions. SAR missions are essentially the only public safety missions which require fully automated waypoint programming. While this C2 technology may be used during other missions, such as damage assessment (tornados, hurricanes, etc.), the primary use case is for SAR.	No. Identification of C2 software specifications to complete automated waypoint missions can be used to write the standard.	Develop a standard for C2 software specifications to allow fully automated waypoint missions for SAR. See also the section of this document on the C2 link.	Medium (Scoring: Criticality-2; Achievability-1; Scope-3; Effect-3)	NIST, NFPA, ASTM
53.	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*.	Medium	NIST, ASTM, NFPA, DHS
54.	9.8	Law Enforcement Tactical Operations	No Gap	N/A	N/A	N/A	N/A
55.	9.9	Counter-UAS (C-UAS)	**Gap S9: Counter-UAS/Drone (C-UAS) Operations**. The following concerns exist: 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.	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 different standards protocol than a kinetic, acoustic, or RF-based solution.	High	DOD, DHS, DOJ, DOE, FCC, NTIA, FAA, SDOs, etc.
			Chapter 10. Personnel Training, Qualifications, and Certification Standards: General – WG2				
56.	10.1	Terminology	**Gap P1: Terminology.** 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	Complete work on terminology standards in development.	High	ASTM, IEEE, ISO, RTCA

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
57.	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.	High	ASTM, JARUS, NPTSC, NFPA
58.	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.	High	SAE, ASTM, AUVSI, PPA
59.	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.	Medium	SAE, ASTM, AUVSI, JARUS
60.	10.5	Maintenance Technicians	**Gap P5: UAS Maintenance Technicians.** No published UAS standards have been identified for UAS maintenance technicians. However, ASTM is developing one and it will satisfy the market need.	No	Complete work on UAS maintenance technician standards currently in development.	High	ASTM
61.	10.6	Compliance / Audit Programs	**Gap P6: Compliance and Audit Programs**. No published UAS standards have been identified for UAS-specific compliance/audit programs. However, several are in development and will satisfy the market need.	No	Complete work on compliance and audit program standards currently in development.	High	ASTM, AUVSI
62.	10.7	Human Factors in UAS Operations	**Gap P7: Displays and Controls.**[1] 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.	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:[2]	High	RTCA, NASA, others?

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

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
			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 GCS. 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.		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.		
63.	10.7	Human Factors in UAS Operations	**Gap P8: Flight Control Automation and System Failures.**[3] 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	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	High	RTCA, others?

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

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
			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 GCS. 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.		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:[4] 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		

[4] Ibid

Row	Section	Title	Gap	R&D Needed	Recommendation	Priority	Organization(s)
					which carries out a recommended course of action unless commanded otherwise by the operator).		
64.	10.7	Human Factors in UAS Operations	**Gap P9: Crew Composition, Selection, and Training.**[5] 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:[6] 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.	High	RTCA, NFPA, MITRE, NASA, ICAO others?

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

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 five 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.

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.[7] 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. MarketsandMarkets™ valued the global market at USD 18.14 billion in 2017 and projected it to reach USD 52.3 billion by 2025, at a compound annual growth rate (CAGR) of 14.15% from 2018 to 2025.[8] McKinsey predicts a U.S. market of $31-46 billion by 2026.[9]

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[7] Federal Aviation Administration. *Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap,* Second Edition, July 2018.

8 Unmanned Aerial Vehicle (UAV) Market by Application (ISR, Precision Agriculture, Product Delivery), Class (Tactical, MALE, HALE, UCAV), System (Avionics, Sensors, Payload), MTOW (<25Kg, 25-150Kg, >150kg), Range, Type, and Region - Global Forecast to 2025. Report Code AS 2802. February 2018. Marketsandmarkets.com, accessed 9/8/2018

[9] Cohn, Pamela et al., "Commercial Drones are here: The Future of unmanned aerial systems," December 2017.

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.

Following an initial attempt to organize around operational use cases, the UASSC settled on the following working group (WG) structure, with the four WGs holding virtual meetings twice a month to develop the roadmap:

- **WG1 – Airworthiness**
    - Covers aircraft systems and communications with the ground control station (GCS)
- **WG2 – Flight Operations and Personnel Qualifications**
    - Covers general flight planning and operational concerns, plus personnel training, qualifications, and certification standards
- **WG3 – Critical Infrastructure and Environment**
    - Covers specific operational concerns for vertical, linear, and wide area environment infrastructure inspections, precision agriculture, and commercial package delivery
- **WG4 – Emergency and Medical Response**
    - Covers 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.

Throughout this process, the project was guided by a steering committee which met virtually on a monthly basis.

This resulting document, the *Standardization Roadmap for Unmanned Aircraft Systems, Version 1.0*, represents the culmination of the UASSC's work. 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.

In terms of what can be deemed out of scope, the consumer, recreational market for model aircraft is generally not addressed in this report.

1.3. Roadmap Structure

Chapter 2 of this document provides introductory context from FAA's perspective as regulator.

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.

Each gap has been assessed and ranked using the criteria described in Figure 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).

Figure 1: UASSC Prioritization Matrix

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)	

A table summarizing the gaps, recommendations, and priorities by issue as described in the text appears after the Executive Summary of this document. The final chapter 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). On its website, the FAA states that: “an unmanned aircraft system (UAS), sometimes called a drone, is an aircraft without a human pilot on board – instead, the UAS is controlled from an operator on the ground.”[10]

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, unless otherwise specified, UA 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 and 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.

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[10] Accessed 9/8/2018 from the FAA’s Unmanned Aircraft Systems webpage.

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

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. These UAS standards ensure a level playing field to support global fair trade and provide consumers the quality they expect.

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 1 below represents the public, civil, and hobbyist options currently available for UAS 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 1: Options for Current UAS Operation

Section/Part	Aircraft Requirements	Pilot Requirements	Airspace Requirements	
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)
Section 333 (Part 91)	As specified in exemption	FAA airman certificate	Blanket COA or Standard COA for specific airspace	UAS > 55 lbs.
Experimental Aircraft (Part 91)	Experimental Special Airworthiness Certificate	FAA airman certificate	Standard COA for specific airspace	Research and development, crew training, and market survey, showing compliance with regulations, and exhibition
Type Certificated Aircraft (Part 91)	Restricted type or special class certification	FAA airman 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.	Community-based organization (CBO) standards	Notification requirement within 5 miles of an airport	Hobby or recreational, VLOS, Section 336 operating rules, CBO standards

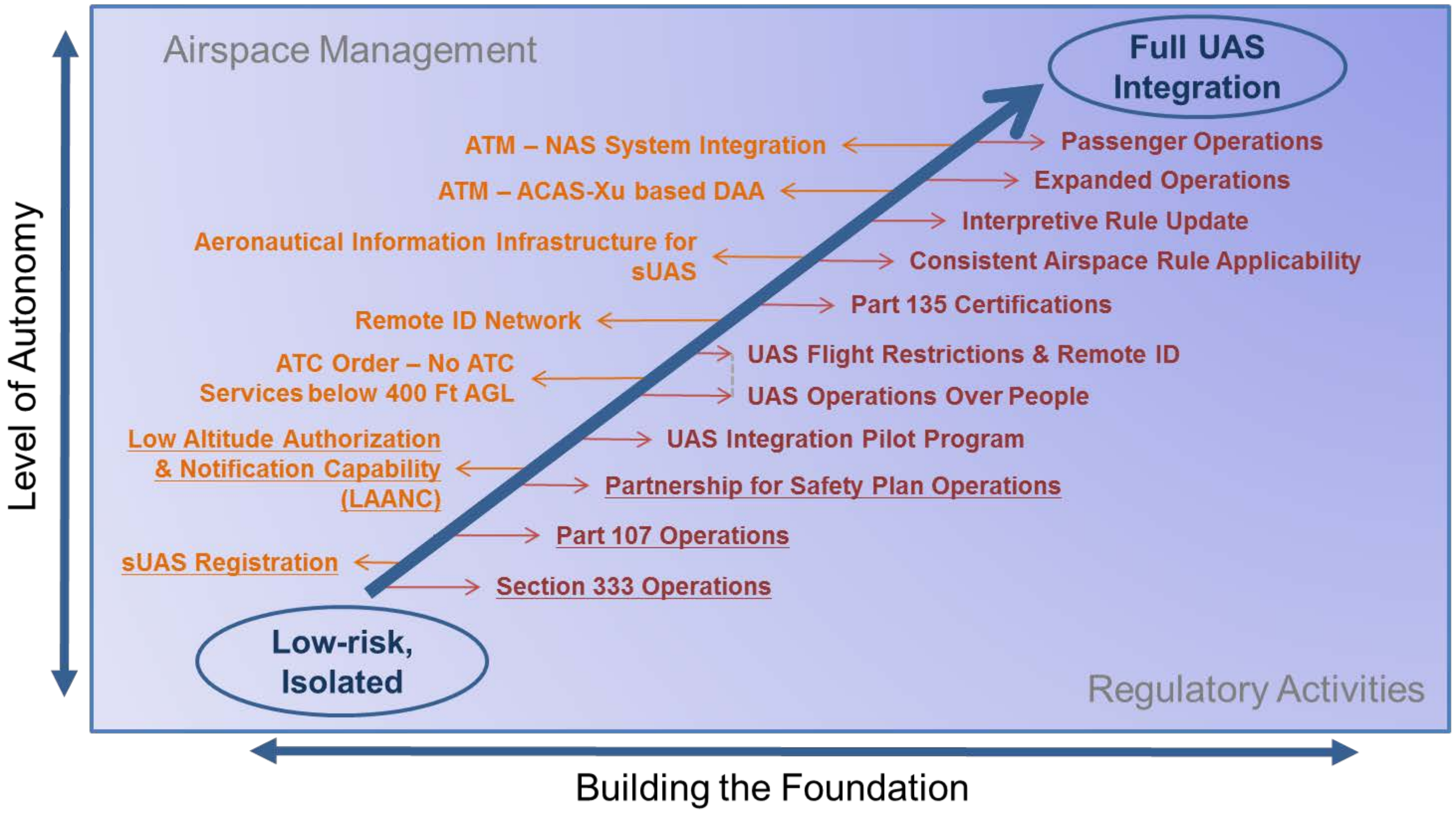
The Small UAS Rule includes the option to apply for a certificate of waiver, allowing a small UAS operation to deviate from specific operating rules if the FAA determines the proposed operation may be performed safely. During FY 2017 and FY 2018, thousands of requests for UAS waivers, airspace authorizations, and exemptions were received and processed.

[12] Part 336 will be affected as the FAA Reauthorization Act of 2018 is implemented.

2.3. The Movement Toward Full Operational Integration

The operational expansion of UAS envisioned by the FAA is illustrated in Figure 2, 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 2: The Path to Full UAS Integration



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, 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, it is important for the FAA to conduct global outreach in order 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 gathering to recommend requirements for use by civil aviation authorities around the world.

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

3.1. Department of Homeland Security (DHS)

The Department of Homeland Security (DHS) has a vital mission: to secure the nation from the many threats it faces. This requires the dedication of more than 240,000 employees in jobs that range from aviation and border security to emergency response, from cybersecurity analyst to chemical facility inspector.

UAS, commonly known as drones, are changing the homeland security landscape. DHS operational Components – the U.S. Coast Guard, the Federal Emergency Management Agency (FEMA), and others – employ UAS for a number of purposes. UAS allow operators to monitor remote locations and improve situational awareness. They are a critical tool in emergency response. However, UAS can also be used for illegal activities. Steps are being taken to address these challenges as more fully described below.

Science and Technology Directorate (S&T)

The DHS Science and Technology Directorate (S&T) is researching ways to protect against UAS-based threats and ways to make UAS more usable for the Homeland Security Enterprise. Through this multifaceted approach, S&T is helping to protect against nefarious UAS use while researching operational use for homeland security officials.

DHS S&T has established test sites to support 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, New York, conducts tests, evaluations, and operational assessments of homeland security technologies, including UAS, for the national first responder community.

This suite of test sites and capabilities allows DHS to evaluate current and emerging UAS technologies, evaluate the integration of sensors and other capabilities into the platforms, develop CONOPS, conduct training, and provide guidance on UAS capabilities and use to DHS Components and across the homeland security enterprise.

DHS S&T is also creating a suite of test methods 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 reliability measurements to ensure operator confidence in the capability of the drone, while building operator familiarity and skill. These test methods have been adopted by numerous organizations around the world and have informed more than $70 million in response robot procurements.

This is a very short summary of some of the main areas of continuing DHS S&T engagement in UAS-related activities. More information can be found on the DHS S&T UAS webpage and the DHS UAS Facts Sheets webpage. In addition, searching for "UAS" on the DHS Publications webpage provides access to other documents.

National Protection & Programs Directorate (NPPD)

To comprehensively inform critical infrastructure owners and operators of the evolving risks associated with UAS, the DHS National Protection & Programs Directorate (NPPD) develops resources on potential malicious use of UAS technology, implications to the operations of infrastructure, and a list of actions companies can take to mitigate risks. NPPD efforts include: maintaining UAS community of interest websites on security and response strategies and on the Homeland Security Information Network (HSIN-CI); managing a joint public-private sector working group under the Critical Infrastructure Partnership Advisory Council framework to serve as a coordinating mechanism to better address UAS risks and critical infrastructure; and creating policy, strategy, and analytical products on the voluntary application of UAS technology and risk mitigation considerations through NPPD's National Risk Management Center.

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) is the premier resource for American companies competing in the global marketplace. ITA has more than 2,200 employees assisting U.S. exporters in more than 100 U.S. cities and 75 markets worldwide. More information is available on ITA’s website.

Industry & Analysis (I&A) UAS-Related Equities

The Industry & Analysis (I&A) Aerospace Team has roles in both domestic and international development of the UAS market. To begin with, I&A serves as a gateway for industry to interact with relevant U.S. Government (USG) agencies, such as FAA, Transportation Security Administration (TSA), and National Aeronautics and Space Administration (NASA)) as well as the parts of the Department of Commerce (“Commerce”) directly involved in the development of UAS policies, procedures, operations, and standards (such as NIST and the National Telecommunications and Information Administration (NTIA).

Moreover, the Director of the I&A Office of Transportation and Machinery, Scott Kennedy, 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, Department of Justice (DOJ), DHS, DOI, and NASA. The EXCOM oversees rulemaking, addresses specific issues such as counter-UAS threats and solutions, and identifies research gaps. ITA is working towards introducing industry and/or market development topics into the EXCOM discussions.

To that end, Commerce hosted a UAS industry roundtable in November 2016. A wide cross-section of the UAS community was included in order to discuss ongoing activities in the sector and topics the participants wished to highlight that could be relevant to the UAS EXCOM and/or that should be briefed to the incoming administration.

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, while armed UAS will continue to be controlled under MTCR, commercial UAS have the possibility of being reclassified to allow for freer exports. BIS has indicated that the MTCR membership most likely will address lighter-than-air UAS in the near future and that BIS will seek industry input on further parameters for Category I such that more UAS could be exempted.

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 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). Continued movement of UAS-related products from International Traffic in Arms Regulations (ITAR) to the Commercial Control List (CCL)/Export Administration Regulations (EAR) will be dependent on changes to MTCR that raise the thresholds on distance and payload in order 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: 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: 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: In progress during spring 2018, this level focuses on creating and testing technologies that will help keep drones safely spaced apart and flying in their designated zones. The technology allows the UAS to detect and avoid (DAA) other drones over moderately populated areas.

TCL4: Scheduled to begin in spring 2019, the final level will build on the results and findings from TCL3, while also working to test how the UTM system can integrate drones into even more populated urban areas. Examples of this include testing package delivery, infrastructure inspection, aerial photography, news gathering, public safety, and first responder operations.

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 on the NASA's Ames Research Center website.

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 FY20. 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.

Resilient Autonomy (RA)

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.

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 the summer/fall of FY20 with an operational demonstration of a mission using high levels of autonomy conducted in 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. 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 15 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.

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, 10 of these test methods for Maneuvering and Payload Functionality have been included as measures of operator proficiency for Job Performance Requirements (JPRs) within NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations.*

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), Telecommunication Technology Committee (TTC) – known as "Organizational Partners" and 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).

The scope was subsequently amended 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 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 in WGs and at the Technical Specification Group (TSG) level.

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

The WGs, within the TSGs, meet regularly and come together for their quarterly TSG Plenary meeting, where their work is presented for information, discussion, and approval. 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.

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

Published Documents:

- 3GPP 22.825, *Study on Remote Identification of Unmanned Aerial Systems* (V16.0.0, Release 16)

In-Development Documents:

- SP-180771 Work Item "Remote Identification of Unmanned Aerial Systems" (ID-UAS)
- SP-180909 Work Item "Enhanced LTE Support for Aerial Vehicles" (ES-UAVs)

The estimated completion date for these items is in 2019/2020.

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 a special working group (SWG) under ASME Boiler and Pressure Vessel Code (BPVC) Section V Nondestructive Testing Committee tasked to develop guidelines for UAS for inspections. The SWG will develop a standard that will provide guidelines and requirements for safe and reliable use of UAS in the performance of examinations and inspections of fixed equipment including pressure vessels, tanks, piping systems, and other components considered part of the critical infrastructure.

The table of contents sections include: scope, general definitions, object of inspection, preparation for inspection and preliminary mission planning, equipment use for inspection, personnel qualification for operators, conduction of inspection, analysis of data, reporting data, and documentation. The SWG membership consists of 24 subject matter experts in nondestructive testing (NDT) and UAS/UAV, with more than 40 interested party individuals. The SWG meets four times per year in-person at the ASME Boiler and Pressure Vessel Code Week and holds 2-3 teleconferences in-between meetings.

The goal is to expand the scope to include inspections for renewable infrastructure, e.g., wind, solar, hydropower. The vision would be to either create a new committee for the use of UAS for renewables applications, or include the best practices for renewables applications as part of the standard.

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*

UAS Public Safety Joint Working Group

The ASTM International and NFPA UAS public safety joint working group (JWG) is a collection of experts from the UAS and public safety fields. This JWG was chartered to develop use case scenarios for various operations which are carried out by public safety personnel, including law enforcement, fire fighters, SAR teams, emergency medical services (EMS), and border patrol. Scenarios covering different environments, events, and operational needs are included.

The JWG will leverage the expertise and standards from committees such as NFPA® 2400, ASTM F38 Unmanned Aircraft Systems, ASTM E54 Homeland Security Applications, and F32 Search and Rescue.

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

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 WG23, UAS has a diverse membership including participants from drone manufacturers, service providers, chip makers, and others.

The UAS WG began with a standard addressing serial numbers for sUAS. ANSI/CTA-2063, *Small Unmanned Aerial Systems: Serial Numbers* (now freely available via CTA.tech) was published in April 2017. The standard provides manufacturers with the structure for the creation of both a physical serial number and an optional electronic serial number. Additionally, ANSI/CTA-2063 outlines the maintenance and management of the four-digit manufacturer code that is used to identify the manufacturer of the sUAS. The WG is working to facilitate international adoption of the standard.

4.7. 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.

4.8. 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 secretary is Chris Carnahan, Aerospace Industries Association (AIA). 21 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 currently has four 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 21384-4, *Terms and Definitions* (under development)
  - ISO/CD 21895, *Categorization and classification of civil unmanned aircraft systems* (under development)

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 is focusing 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. Future standards may include technical specifications for the design and manufacturing of UAS components, where creating a standard will enhance UAS safety or interoperability.
- Work item:
  - ISO/CD 21384-2, *Unmanned aircraft systems -- Part 2: Product systems* (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 (under development)
  - ISO 23665, *Unmanned Aircraft Systems -- Training of Operators* (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 item:

- ISO/AWI TR 23629-1, *UAS Traffic Management (UTM) -- Part 1: General requirements for UTM -- Survey results on UTM* (under development)

4.9. 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. 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. More information and free access to the document can be found on the NFPA® 2400 webpage.

4.10. 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.

4.11. 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.

4.12. SAE International (SAE)

In response to the market-driven proliferation of UAS of all sizes, SAE has responded to the needs of manufacturers and regulators for consensus standards by creating a number of new technical committees and augmenting the scope of a number of its 250+ aerospace technical committees. A selection of UAS related published standards are shown in the tables below along with a separate list of other publications.

SAE staff or committee representatives are working with a number of external agencies/programs including FAA, EASA, JARUS, Joint Architecture for Unmanned Systems (JAUS), the Unmanned Aircraft System Control Segment (UCS) of the US Army, Navy and Air Force, and the ANS UAS Standards Collaborative in order to provide a holistic approach to standardization.

UAS Committees

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 objective is to define and sustain a joint architecture for the domain of unmanned systems. Documents include the following:

- AS6009A, *JAUS Mobility Service Set*
- AS5684B, *JAUS Service Interface Definition Language*
- AS6062, *JAUS Mission Spooling Service Set*
- AS6060, *JAUS Environment Sensing Service Set*

- AS6040, *JAUS HMI Service Set*
- AS5710A, *JAUS Core Service Set*
- ARP6012A, *JAUS Compliance and Interoperability Policy*
- AS5669A, *JAUS/SDP Transport Specification*
- AS6091, *JAUS Unmanned Ground Vehicle Service Set*
- AS6057A, *JAUS Manipulator Service Set*
- ARP6128, *Unmanned Systems Terminology Based on the ALFUS Framework*
- ARP6227, *JAUS Messaging over the OMG Data Distribution Service (DDS)*

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. Peer interest in UCS includes the National Information Exchange Model (NIEM) MilOps Domain and the NATO Multi-Domain Vehicle Control architecture. Documents include the following:

- AS6969, *Data Dictionary for Quantities Used in Cyber Physical Systems*
- AS6522, *Unmanned Systems (UxS) Control Segment (UCS) Architecture: Architecture Technical Governance*
- AS6518, *Unmanned Systems (UxS) Control Segment (UCS) Architecture: UCS Architecture Model*
- AS6513, *Unmanned Systems (UxS) Control Segment (UCS) Architecture: Conformance Specification*
- AS6512, *Unmanned Systems (UxS) Control Segment (UCS) Architecture: Architecture Description*

E-39 Unmanned Aircraft Propulsion Committee: E-39 is a technical committee in SAE's Aerospace Propulsion Systems Group with the responsibility to develop and maintain standards for all facets of UA propulsion systems.

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 UAS types, sizes, operations, and missions. The Committee also will look to qualifications of the organizations that engage UAS. Documents include: ARP5707, *Pilot Training Recommendations for Unmanned Aircraft Systems (UAS) Civil Operations.*

Committees with Elements of UAS Activity

A-20 Aircraft Lighting Committee: A-20 addresses all facets of aircraft lighting equipment– design, manufacture, operation, maintenance, and in-service experience. Works in Progress include ARP6336, *Lighting Applications for Unmanned Aircraft Systems (UAS).*

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 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. Works in Progress include: AIR6962, *Ice Protection for Unmanned Aerial Vehicles.*

A-6 Aerospace Actuation, Control and Fluid Power Systems: A-6 addresses all aspects of aerospace flight and utility actuation and control systems as well as fluid power systems. Documents include:

- ARP94910, *Aerospace - Vehicle Management Systems - Flight Control Design, Installation and Test of, Military Unmanned Aircraft, Specification Guide For*
- ARP5724, *Aerospace - Testing of Electromechanical Actuators, General Guidelines For*

SMC-PNT Position, Navigation, and Timing: SAE – Positioning, Navigation, and Timing (PNT) Committee develops standards for technology that will ensure a robust and reliable backup to the Global Positioning System (GPS). Documents include:

- 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*

G-18 Radio Frequency Identification (RFID) Aerospace Applications: G-18 addresses RFID smart label standards and specification for the aerospace industry, with a primary focus on part-marking for airborne, flyaway applications. RFID standards may address RFID chip design, test, maintenance, and in-service experience. Documents include: AS6023, *Active and Battery Assisted Passive Tags Intended for Aircraft Use.*

AE-8A Elec Wiring and Fiber Optic Interconnect Sys Install: AE-8A 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. Documents include: AS50881F, *Wiring Aerospace Vehicle.*

Individual Technical Papers: SAE International has published 120+ technical papers on UAS. The collection of standards, books, and technical papers can be browsed on the SAE Mobilus website.

4.13. 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.

4.14. 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. UL 3030 covers the electrical system of UASs, as defined in the standard, used inflight for commercial applications or flight incidental to business applications.

5. Overviews of Selected UAS Industry Stakeholder Activities

5.1. 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.

5.2. Alliance for Telecommunications Industry Solutions (ATIS)

Background

As a leading technology and solutions development organization, the Alliance for Telecommunications Industry Solutions (ATIS) brings together the top global information and communications technology (ICT) companies to advance the industry's business priorities. ATIS' 150 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, QoS, 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.

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 understand the interaction of UAVs and communication technologies. The group's first publication, *Unmanned Aerial Vehicles: Cellular Service – A Key Technology for UAS Operation (ATIS-I-0000060)*, shows how mobile cellular networks can support the adoption of small, low-altitude UAVs, as well as provide additional services to help UAVs operate more safely and reliably. The report demonstrates how the technologies of UAVs and mobile cellular services have great synergy, and that their effective combined use will bring mutual benefits to both the communications industry and to the users applying UAV technology to a diverse range of uses.

The group's second publication "Support for UAV Communications in 3GPP Cellular Standards," released October 2018, helps a broad audience including UAV operators and regulatory bodies understand the features of the 3GPP standard that supports UAVs. The aim is to help bridge different silos of expertise by providing a common understanding of the capabilities of 3GPP standardized technology. The group will promote cooperation among ATIS members to ensure North American regional requirements for UAVs are reflected in 3GPP standards.

The group is currently working on a further report entitled "Use of UAVs for Restoring Communications in Emergency Situations" that will provide guidance on preparing for the deployment of UAVs following damage to communications infrastructure — an increasingly important application of UAV technology.

While much of the work to advance the 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 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 work best together.

5.3. 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.

5.4. 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. Its 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 Commercial Drone 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 NAS in a way that is safe and secure. The Alliance is 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, ARCs, 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.

5.5. 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 (FAA, Federal Communications Commission (FCC), DHS, NTIA), in Congress, and in the Administration to address how commercial wireless technology (sometimes referred to as "networked cellular") can support UAS communications functions. CTIA advocates for flexible policies and standards related to spectrum and wireless infrastructure that will enable the growing UAS industry to flourish. 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. CTIA provides a forum for UAS researchers from organizations, such as NASA and the MITRE Corporation, to explore concepts of UAS integration and communications needs. In November 2017, CTIA released a white paper focused on the role of networked cellular to advance safe and reliable drone operations, including BVLOS operations.

5.6. 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 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.

EUSCG Initiative

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 ***European UAS Standardisation Rolling Development Plan*** 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.

5.7. Global UTM Association (GUTMA)

The Global UTM Association (GUTMA) is a non-profit consortium of worldwide Unmanned Aircraft Systems Traffic Management 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. GUTMA members collaborate remotely.

GUTMA currently maintains three protocols aimed at facilitating data sharing among UTM stakeholders. All GUTMA protocols are open source, publicly available, and have a process of engagement, updates, reviews, and tests. Protocols include:

- 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 (under development). The Air Traffic Data protocol, currently under development, aims to standardize how sensor data are transmitted to the apps and services used during drone operations.

5.8. 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 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. At a recent meeting with the EPA, NAAA recommended the development of a committee to accurately study the drift characteristics of applications made by UAVs. This research could then be incorporated into the AgDRIFT model.

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.

5.9. 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.

5.10. 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.

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

5.11. 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.

5.12. 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 businesses to seize the benefits of UAS technology in the near term. Members include leading UAS manufacturers, software and hardware providers, end users, and service providers. The Coalition provides lawmakers and regulators with the technical expertise needed to develop a progressive, forward-leaning regulatory framework that will allow for full integration of UAS into the national airspace, including operations beyond the visual line of sight and over people, with varying degrees of autonomy, as well as implementation of an UTM.

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 the testing and operation of UAS in the United States and abroad by spurring and shaping UAS regulations and policies that will allow businesses to begin to fully realize the potential of UAS technology in order to maximize revenue.

Coalition members participate in FAA UAS initiatives, including the Aircraft Registration Task Force, the Drone Advisory Committee, the Micro Unmanned Aircraft Systems ARC, the UAS Identification and Tracking ARC, and the Unmanned Aircraft Safety Team. The Coalition also participates in the JARUS through its Stakeholder Consultation Body. Several members are part of the teams selected by the FAA for its UAS Integration Pilot Program.

The Coalition also works with Congress, the White House, DHS, the Department of Commerce, FCC, the Federal Trade Commission (FTC), and a host of other NGOs, including ANSI, to encourage coordination and to meet key goals. While focusing primarily on aviation safety and security issues, the Coalition also works on other policy issues including privacy, spectrum use, public interest concerns, international trade, and international collaboration on UAS regulations. This approach will ensure that the regulatory agencies that are critical to UAS success, beyond the FAA, are aligned with the FAA's timeline.

Current members include Amazon Prime Air, Google X Project Wing, Intel, Kespry, PrecisionHawk, Verizon, Aeronyde, AGI, AirMap, Dronecourse.com, Flirtey, Paladin Drones, Percepto, and T-Mobile.

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6. Airworthiness Standards – WG1

6.1. Design and Construction

Critical to full integration of UASs into the NAS beyond the limits of the current FAA Part 107 and applicable waivers, is the need for scalable, consensus-based, and acceptable design and construction (D&C) standards for UAS. Full integration of UASs 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), extended/beyond visual line of sight (E/BVLOS), and other operations can be issued and accepted. Such standards, developed to meet the Design and Production Approval requirements of the CAA (e.g., FAA), 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 needs of the system of the systems and the mission to support applications for waiver, exemptions, or airworthiness.

Published Standards:

- ASTM F2910-14, *Standard Specification for Design and Construction of a Small Unmanned Aircraft System (sUAS)*
- ASTM F3298-18, *Standard Specification for Design, Construction, and Verification of Fixed-Wing Unmanned Aircraft Systems (UAS)*
- ASTM F2911-14e1, *Standard Practice for Production Acceptance of Small Unmanned Aircraft System (sUAS)*
- JARUS CS-LUAS, *Recommendations for Certification Specification for Light Unmanned Aeroplane Systems*
- JARUS CS-LURS, *Certification Specification for Light Unmanned Rotorcraft Systems (CS-LURS)*
- JARUS AMC RPAS 1309, *Safety Assessment of Remotely Piloted Aircraft Systems (package)*
- EUROCAE ER-019, UAS System Safety Assessment Objectives and Criteria Inputs to “AMC 1309”
- ASTM F3003-14, *Standard Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS)*
- 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 WK59101, *New Specification for Structures, Design and Construction* (Light Sport Aircraft)
- ASTM WK61232, *New Practice for Low Stress Airframe Structure* (Light Sport Aircraft)
- ASTM WK53964, *Design, Construct, and Test of VTOL* (to be integrated in F3298 as a combined fixed wing and VTOL standard)
- ASTM WK62670, *New Specification for Large UAS Design and Construction* (for aircraft <19,000lbs)
- 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 Minimum Aviation Systems Performance Specification for Remote Pilot Stations supporting IFR operations into non-segregated airspace

Relevant Published General Industry Standards:

- 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* (General Aviation)
- ASTM F3180/F3180M-18, *Standard Specification for Low-Speed Flight Characteristics of Aircraft* (General Aviation)
- ASTM F3115/F3115M-15, *Standard Specification for Structural Durability for Small Airplanes* (General Aviation)
- ASTM F3116/F3116M-15, *Standard Specification for Design Loads and Conditions* (General Aviation)
- 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*

Relevant In-Development General Industry Standards:

- ASTM WK51467, *New Specification for Quality Assurance for Manufacturers of Aircraft Systems*

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 that of primary UAS elements (i.e., UA, GCS). However, these standards fail to address the critical and novel aspects essential to the safety of unmanned operations (i.e., DAA, software, BVLOS, C3, 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 standards capable of establishing an acceptable baseline of D&C for these critical fight operation elements to support current regulatory flight operations and those authorized by waiver and or grants of exemption.

R&D Needed: No

Recommendation:

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

Priority: High

Organization(s): ASTM, ISO, others?

6.2. Safety

Airworthiness safety and risk management are critical to integration of UAS into the U.S. airspace. The aviation safety process is well established. It includes the design and operation of UAS (discussed elsewhere in this roadmap) in accordance with FAA rules and regulations. Safety is based on appropriate mitigation and bounding of risks to people and property within the operating area. 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
- 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

ASTM:

- ASTM F2909-14, *Standard Practice for Maintenance and Continued Airworthiness of Small Unmanned Aircraft Systems (sUAS)*
- ASTM F3002-14a, *Standard Specification for Design of the Command and Control System for 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 F3178-16, *Standard Practice for Operational Risk Assessment of Small Unmanned Aircraft Systems (sUAS)*

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*

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 Documents*

- 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*

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

ASTM:

- ASTM WK52827, *New Practice for Safety Analysis of Systems & Equipment Retrofit in Small Aircraft*
- ASTM WK56374, *New Practice for Aircraft Systems Information Security Protection*

Gap A2: UAS 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 customer or regulatory body 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, remotely controlled, optionally piloted, autonomous, and types of UAS to which they are most relevant. Such a report should address design, production, and operational approval safety aspects.

Recently SAE's two technical committees SAE S-18 and SAE AS-4 have initiated a liaison activity to draw from both technical committees' expertise in UAS, safety assessment and development assurance to assess this specifically and this may in-turn lead to a document to describe how to apply the strong guidance in ARP4754 and ARP4761 to UAS, perhaps an SAE AIR. This was initiated in the SAE Automated Flight 4 workshop on 4 Oct 2018 and confirmed from the S-18 technical committee perspective at the 15-19 Oct 2018 meeting.

R&D Needed: No

Recommendation: Develop 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 to which they are most relevant.

Priority: Low

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

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. 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 June 2018, G-19 had published 23 documents and 23 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 June 2018, G-21 had published 3 documents and 1 is 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 June 2018, S-18 had published 8 documents and 6 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[13] 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)*

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

- 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*
- 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*
- AS6174/2, *Counterfeit Materiel; Assuring Acquisition of Authentic and Conforming Materiel – Fasteners Slash Sheet*
- 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[14]
- AC 145-5 Repair Station Internal Evaluation Programs
- AC 25.939-1 Evaluating Turbine Engine Operating Characteristics
- AC 20-156 Aviation Databus Assurance[15]
- 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[16]
- AC 91-36D Visual Flight Rules (VFR) Flight Near Noise-Sensitive Areas

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[14] AC 33.28-1 references the following SAE International documents: SAE ARP1834A; SAE ARP4754; SAE ARP4761; SAE ARP5107; SAE ARP926B.
[15] AC 20-156 references the following SAE International documents: SAE ARP4754; SAE ARINC429.
[16] AC 20-146 references the following SAE International documents: SAE AS8049A; SAE J211/1; SAE J211/2.

- 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[17]
- AC 150/5220-17A CHG 1 Change 1 to Design Standards for an Aircraft Rescue and Firefighting Training Facility[18]

Regulations:

- §13.401 - Flight Operational Quality Assurance (FOQA) program
- §21.137 - Quality System (Subpart G-PC)
- §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[19]:

- 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*

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[17] AC 150/5220-21B references the following SAE International documents: SAE ARP1247.
[18] AC 150/220-17A references the following SAE International document: SAE J551.
[19] 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.

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*
- 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: No in-development QA/QC standards for UAS have been identified. The only identified in-development QA/QC aviation/aerospace standard is:

- 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 published QA/QC standard (ASTM F3003-14, *Standard Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS)*) that is specific to UAS and it covers sUAS. There is also only one QA/QC standard in development for manufacturers of aircraft systems (ASTM WK51467, *New Specification for Quality Assurance for Manufacturers of Aircraft Systems*) and 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 (Scoring: Criticality-2; Achievability-1; Scope-3; Effect-3)

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

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 for manned aviation avionics and subsystems that may apply to UAS include those 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, Subchapter 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

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:

- F3269-17, *Standard Practice for Methods to Safely Bound Flight Behavior of Unmanned Aircraft Systems Containing Complex Functions*
- F3153-15, *Standard Specification for Verification of Avionics Systems*

FCC:

- Manual of Regulations and Procedures for Federal Radio Frequency Management

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, *Specification for Detect and Avoid Performance Requirements*
- WK62669, *Test Method for Detect and Avoid*
- WK65041, *New Practice for UAS Remote ID and Tracking*

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.

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

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

6.4.1. Command and Control (C2) Link

UASs involve either a remote pilot or no pilot, requiring a secure and reliable communications link to relay control and aircraft awareness to a monitoring or control station. This link is commonly known as Command and Control (C2), though some organizations have begun to call this link Command, Control, and Communications (C3). While potentially differing in architecture, the functionality remains similar if not the same. This link allows information exchanges such as monitoring the aircraft's flight path, systems, communications with ATC or other vehicles, and providing situational awareness information.

The industry is utilizing existing telecommunications technology to provide this link to the aircraft. The telecommunications industry is well regulated and has many existing industry standards. The issue is not how to communicate the data, rather what are the required metrics that communications systems need to meet to allow UAS to operate safely with manned aircraft and over people. While this is primarily a regulatory effort that must occur, standards groups can and have come together to inform what is possible and devise metrics that the regulators can adopt.

Published Standards and Related Documents:

Committee	Document	Date
ASTM F38.01, UAS – Airworthiness	ASTM F3002-14a, *Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)*	2014
JARUS WG5 – C3	JARUS, *Recommendations on the Use of Controller Pilot Data Link Communications (CPDLC) in the RPAS Communications Context.* The CPDLC document is meant to summarize the most relevant information about CPDLC and the supported ATS services, and to associate them with RPAS operations.	Jun 2016
JARUS WG5 – C3	JARUS, *RPAS "Required C2 Performance" (RLP) concept.* RCP acronym has been modified to RLP to avoid confusion between current RCP supporting ATM functions and the required C2 Link performance in support of the command and control functions.	May 2016
JARUS WG5 – C3	JARUS, *RPAS C2 Link, Required Communication Performance (C2 link RCP) concept.* Guidance material to explain the concept of C2 link RCP and identify the requirements applicable to the provision of C2 communications.(SEE UPGRADED C2 Link RLP document JAR-doc-13)	Oct 2014
RTCA SC-228, Minimal Operational Performance Standards for UAS	RTCA AWP-2, *Command and Control (C2) Data Link White Paper*	Mar 2014
RTCA SC-228, Minimal Operational Performance Standards for UAS	RTCA DO-362 with Errata, *Command and Control (C2) Data Link Minimum Operational Performance Standard (MOPS) (Terrestrial)*	Sep 2016
RTCA SC-228, Minimal Operational Performance Standards for UUAS	RTCA AWP-4, *Command and Control (C2) Data Link White Paper Phase 2*	Sep 2017

In-Development Standards and Related Documents:

Committee	Document
ASTM F38.01, UAS – Airworthiness	ASTM WK49440, *Revision of F3002 - 14a Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)*
JARUS WG5 – C3	JARUS, *RPAS C2 Link CONOPS*. This document is focusing on the C2 link. It includes a large section on the Aeronautical Information Service (AIS) and

	Meteorological Information (MET) that are needed from an aircraft (RPA) perspective when operating in airspace using the C2 link.
RTCA SC-228, Minimal Operational Performance Standards for UAS	RTCA, *Command and Control Data Link Minimum Aviation Systems Performance Standard (MASPS)*. This document defines functionality of a C2 link and performance requirements for each function to meet defined safety standards. The document, though, is limited in analyzed CONOPS, so while the method and requirements derived can be extrapolated to many scenarios, future work is required to understand additional network requirements created by individual use cases.
EUROCAE WG-105 SG-21, RPAS C2 Datalink	Minimum Operational Performance Specification for RPAS Command and Control Data Link (Terrestrial)
EUROCAE WG-105 SG-21, RPAS C2 Datalink	Minimum Operational Performance Specification for RPAS Command and Control Data Link (C-Band Satellite)
EUROCAE WG-105 SG-21, RPAS C2 Datalink	Minimum Aviation System Performance Specification for RPAS Command and Control Data Link
EUROCAE WG-105 SG-22, Spectrum	Minimum Aviation System Performance Specification 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	Minimum Aviation System Performance Specification on RPAS C3 Security
EUROCAE WG-105 SG-23, Security	Guidance on UAS C3 Security
3GPP	3GPP Study Item Enhancements for UAS (FS_EAV). The study item will study the Key Performance Indicators (KPIs) needed to support UAV operations, including the C2 interface, using mobile cellular networks. The study will consider what can be supported in LTE and 5G New Radio (NR). ATIS member companies will contribute any North American regional representatives to 3GPP. Status: Approved 3GPP study item in Release 17.

Gap A5: Command and Control (C2)/Command, Control and Communications (C3) Link Performance Requirements. Standards setting forth C2/C3 link performance requirements are needed by the telecommunications industry to understand how to modify or create networks to serve UAS. These performance requirements must define the virtual cockpit awareness that networks must provide to operators. Some definitions that have been adapted from current manned aviation communications standards include availability, continuity, latency, and security. In other words, what is the reliability that a message can be sent, how quickly is the message needed, and what security mitigations are necessary to avoid nefarious activity. The industry is ready and willing to support UAS, but the remote nature of UAS requires clarity on what is required to meet aviation safety standards.

R&D Needed: Yes

Recommendation: Complete work on [RTCA, *Command and Control Data Link Minimum Aviation Systems Performance Standard (MASPS)*] (RTCA SC-228 WG2) and related standards and documents now in development.

Priority: High

Organization(s): RTCA, ASTM, JARUS

Gap A6: Technical support for C2/C3 link performance requirements in telecommunications standards. 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/C3 link will require further standardization activities. Collaboration between the UAS industry and communications industry is required to ensure feasibility of implementation.

R&D Needed: Yes

Recommendation: Advance existing work in 3GPP and ensure C2/C3 requirements are communicated to that group.

Priority: High

Organization(s): 3GPP, ATIS

6.4.2. Navigational 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., dual band L1/L2, ionospheric correction, multipath mitigation, etc.) and integration with other sensors/components on the platform. For small UAS, the pilot typically operates the UAS remotely using visual contact with the assistance of a ground control station (small device, PC, or laptop) that receives GNSS signals and communicates with the UAS platform through a data link (transmitter-receiver configuration) to establish differential positions. For UAS > 55 pounds, satellite and ground-based RF navigation systems (i.e., VHF omni-directional range) may be more appropriate. Furthermore, a UAS platform equipped with a transponder allows its broadcasted position to be known/tracked by other UAS, ATC, etc. (See the section on remote ID and tracking.)

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). Likewise, operating a UAS in close proximity to transmission lines will impact the magnetometer/compass as well as the GNSS, as strong magnetic fields may result in GNSS signal interference/degradation.

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 navigational aids to precise tracking using satellite signals by requiring ADS technology starting in 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 aircraft 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 terrain, and give pilots important flight information, such as temporary flight restrictions, which would improve navigation for UAS operations BVLOS.

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
- RTCA DO-229, *Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment*
- RTCA DO-316, *Minimum Operational Performance Standards for Global Positioning System/Aircraft Base Augmentation System*

- SAE 6857, *Requirements for a Terrestrial Based Positioning, Navigation, and Timing (PNT) System to Improve Navigation Solutions and Ensure Critical Infrastructure Security*
- 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:

- SAE 6856, *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*

Gap A7: UAS Navigational Systems. There is a lack of standards specifically for UAS navigation. UAS navigation can leverage many of the same standards used for manned aircraft, but at a smaller scale and lower altitudes.

R&D Needed: Yes. A specific R&D effort geared towards applying tracking innovations in satellite navigation for UAS is needed.

Recommendation: Depending on the operating environment, apply existing navigation standards for manned aviation to UAS navigation and/or develop UAS navigation standards for smaller scale operations and at lower altitudes. 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

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

Protection from GNSS Signal Interference Including Spoofing and Jamming

Every GNSS satellite transmits an accurate position and time signal to a GNSS receiver such as those equipped on certain UAS platforms. The GNSS receiver measures the time delay for the signal to reach the receiver from the satellite. There continues to be significant concern that GNSS satellite signals, like any other navigational signals, are subject to interference, whether intentional or unintentional. Interference by spoofing (intentional or unintentional) degrades the integrity of the GNSS signals by falsifying positions or timing offsets. Interference by jamming the signals blocks the signal from the receiver; thus, losing the ability to navigate using GNSS. 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 FAA will need to incorporate a similar approach or fold in specific UAS-related considerations with current efforts to ensure standards are in place.

As described below, there are several actions that UAS manufacturers can take to protect against spoofing and jamming activities. Anti-spoofing measures include ensuring that GNSS receivers simultaneously track multiple constellations (e.g., GPS, GLONASS, Galileo, BeiDou, etc.) and incorporate an IMU. To spoof a GNSS receiver, an adversary would have to produce and transmit all possible GNSS signals simultaneously. 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.

Anti-jamming actions include:

- Filtering out-of-band radio frequencies. This is only effective with signals outside of GNSS frequency bands.
- Incorporating an IMU. IMUs are impervious to radio-frequency interference and can bridge GNSS positioning gaps quickly.
- 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.

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

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

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

6.4.3. Detect and Avoid (DAA) Systems

The lack of maturity in technology for the design, manufacture, installation, and operation of UAS DAA systems has created a gap in approvals of DAA systems within the civil regulatory framework. Small and medium UAS may have size, weight, and/or power (SWAP) limitations that prevent full implementation of DAA systems as defined by the FAA TSOs (TSO-211, TSO-212 and TSO-213). 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 required or typical on commercial aircraft in addition to DAA technology that meets current guidance. This challenge of installing a DAA system contributes to a lack of verification, validation, reliability, and confidence in the operations of an installed DAA system for UAS, as none of the UAS installed with a DAA system are type-certified.

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 system performance requirements, such as ADS-B, TCAS II, etc. These requirements are currently required for commercial aircraft and UAS operating in certain airspace. These TSOs and RTCA documents do not sufficiently address the DAA systems' requirements for UAS operating at low altitudes (below 500 feet AGL) or other segmented areas. 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 DAA system would require no further approval

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

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

Published Standards and Related Materials: Published UAS DAA system 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, *Minimum Operational Performance Standards 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, *Minimum Aviation System Performance Standards 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*
- 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.

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

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

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:

- ACAS Xu system (document number TBD) – designed specifically to support unmanned aircraft. It will be assigned a number once it is approved by the PMC, scheduled for September 2020.

SAE:

- AS6111, *JAUS Unmanned Maritime Vehicle Service Set*
- AS8024, *JAUS Autonomous Behaviors 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]

EUROCAE:

- Minimum Aviation System Performance Specification for Detect & Avoid [Traffic] in Class A-C airspaces under IFR;
- Minimum Operational Performance Specification for Detect & Avoid [Traffic] in Class A-C airspaces under IFR
- Operational Services and Environment Description for Detect & Avoid [Traffic] in Class D-G airspaces under VFR/IFR
- Minimum Aviation System Performance Specification for Detect & Avoid [Traffic] under VFR/IFR
- Minimum Operational Performance Specification for Detect & Avoid [Traffic] under VFR/IFR
- Operational Services and Environment Description for Detect & Avoid in Very Low Level Operations
- Minimum Operational Performance Specification for Detect & Avoid in Very Low Level Operations

3GPP:

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

Gap A9: Detect and Avoid (DAA) Systems. No published standards have been identified that address DAA systems for UAS that cannot meet the size, weight, and power (SWAP) requirements of 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 DAA systems impairs the FAA's ability to establish a TSO for those DAA systems.

R&D Needed: Yes

Recommendation:

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

Priority: High

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

6.4.4. Software Dependability and Approval[20]

While the FAA and the UAS community have robust structures (regulations, standards, orders, advisory circulars (ACs), etc.) related to software dependability and approval (in some cases referred to as certification) for manned aviation, the applicability and sufficiency of those structures are not fully in place for UAS operations outside of Part 107. In addition, current standards and regulations related to software dependability and approval do not address control stations and associated equipment. As an additional matter, the proliferation of small UAS operations in the NAS has given rise to the use of COTS software on UAS. However, 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. They may also not allow users to make necessary changes to software configurations.

Published Standards:

- 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*

Published software dependability standards and regulatory materials for software approval that are not specific to UAS include:

[20] 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 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.

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

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:

- ARINC 667-2, *Guidance for the Management of Field Loadable Software*, 7-1-17
- ARIR675, *Guidance for the Management of Aircraft Support Data*, 6-26-17
- ARP 4754A, *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
- AS-4UCS, *Unmanned Systems Control Segment Architecture Committee*

SAE 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*

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:

ASTM:

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

SAE:

SAE 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 Dependability and Approval. Standards are needed to address software dependability 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: No

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

Organization(s): ASTM, RTCA, SAE

6.4.5. Crash Protected Airborne Recorder Systems (CPARS)

Crash protected airborne recorder systems (CPARS), also known as flight data recorders 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. CPARS include recordings of voice, data link, and other aircraft data including but not limited to video. The use of CPARS have been an integral part of improving aviation safety since the 1960s.

Published Standards: No published standards for CPARS in UAS have been identified.

The primary international standard for CPARS is EUROCAE ED-112A, *Minimum Operational Performance Specification (MOPS) for Crash Protected Airborne Recorder Systems* (Sept 2013). This 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), and Advisory Circulars AC 20-186 (*Airworthiness and Operational Approval of Cockpit Voice Recorder Systems,* July 2016) and 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, *Minimum Operational Performance Specification (MOPS) for Lightweight Flight Recording Systems* (July 2009) are referenced in ED-112A.

ASTM F3298-18, *Standard Specification for Design, Construction, and Verification of Fixed-Wing Unmanned Aircraft Systems (UAS)*, includes a basic overview of a digital flight data recorder system for fixed-wing UAS; however, it lacks meaningful technical specifications against which an aircraft could be verified or certified.

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. Topics covered include:

- General Requirements
- Design Considerations
- Minimum Performance Standards in Ambient Environment
- Minimum Performance Standards in Severe Environments
- Crash Survivability

SAE AS8039 is due for review/revision, which offers an opportunity to make this standard applicable to UAS.

There are also SAE/ARINC standards:

- SAE ARIC767-1, *Enhanced Airborne Flight Recorder*, published 2017-05-29
- SAE ARIS647A-1ERR1, *Flight Recorder Electronic Documentation (FRED)*, published 2009-07-01
- SAE ARIC757-6, *Cockpit Voice Recorder (CVR)*, published 2015-08-05

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

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

In-Development Standards: No in-development standards for CPARS in UAS have been identified.

Gap A11: Crash Protected Airborne Recorder Systems (CPARS) for UAS. No published or in-development standards have been identified to fill the need of a CPARS or flight data recorder system for UAS. The traditional use of cockpit voice recorder (CVR) in manned aviation is meant to provide voice data occurred amongst the pilots, other users of the NAS, and the air traffic controllers. The CVRs installed on UAs do not meet the intent of the CVR since the pilots are not stationed on the UAs, if the CVR is not installed on the ground control station (GCS). This necessitates the need for a CVR to be installed on the GCS, to fulfill the complete function of the CVR thereby requiring industry standards. By way of further analysis:

1) EUROCAE ED-112A, *Minimum Operational Performance Specification (MOPS) for Crash Protected Airborne Recorder Systems* 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.
2) ED-112A recommends redundancy (cockpit and aft) in CPARS that may not be necessary for many classes of UAS.
3) 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)).
4) 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 GCS. This suggests that a CPARS for UAS should reside on the aircraft, and a non-crash-protected data recorder system should reside in the GCS. An example of this is CVRs.
5) CPDLC may apply to some classes of UAS, particularly large UAS flying in oceanic airspace, but is unnecessary for many classes of UAS.

6) EUROCAE ED-155, *Minimum Operational Performance Specification (MOPS) for Lightweight Flight Recording Systems* may be more applicable for some classes of UAS, but still shares some deficiencies with ED-112A.
7) MOPS should explicitly state CAA equipage requirements for UAS based on size, weight, CONOPS, airspace access, and/or an ORA.
8) ASTM F3298-18, *Standard Specification for Design, Construction, and Verification of Fixed-Wing Unmanned Aircraft Systems (UAS)* (section 12.2) 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, F3298-18 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.
9) ASTM F3298-18 does not include rotorcraft 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 GCS.

Recommendation: Revise an existing standard, or draft a new standard, similar to ED-112A, for a CPARS for UAS.

Priority: Medium (Scoring: Criticality-2; Achievability-2 (this would require a new standard that is not currently in development but there are existing methods for testing and evaluating such a standard, in most cases ED-112A can be used as a framework that can be tailored to the performance and operational characteristics of UAS); Scope-2; Effect-3 (increasing safety with the addition of critical avionics is of paramount importance to integrating 'commercial/industrial' UAS into non-segregated civil airspace))

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

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.

RTCA C216 is also addressing cybersecurity as well as air navigation systems as further described below.

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

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

ASTM:

- ASTM WK65041, *New Practice for UAS Remote ID and Tracking*
- ASTM WK56374, *New Practice for Aircraft Systems Information Security Protection*

Gap A12: UAS Cybersecurity. Cybersecurity needs to be considered in all phases of UAS design, construction, and operation.

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

Organization(s): JARUS, RTCA, SAE, IEEE, AIAA, ASTM, DOD, NASA, UL

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 petitions, Part 107 waivers, etc., due to a lack of UAS-specific industry standards. Currently, there are no aviation standards for ground 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-8A Elec Wiring and Fiber Optic Interconnect Sys Install:

- AIR4465, *Design and Handling Guide Radio Frequency Absorptive Type Wire and Cables (Filter Line, MIL-C-85485)*
- 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*
- ARP4404C, *Aircraft Electrical Installations*
- 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*
- AS24122, *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*
- AS50881F, *Wiring Aerospace Vehicle* [Note: It applies to UAS too.]
- AS5649, *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-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*
- AS20708B, *Synchros, General Specification For*
- AS8011B, *Minimum Performance Standards for A-C Generators and Associated Regulators*
- AS8020, *Minimum Performance Standards for Engine Driven D.C. Generators/Starter-Generators and Associated Voltage Regulators*

SAE EUROCAE Fuel Cell Task Group [Note: This is also listed in the "Power Sources and Propulsion Systems" section.]

- AIR6464, *EUROCAE/SAE WG80/AE-7AFC Hydrogen Fuel Cells Aircraft Fuel Cell Safety Guidelines*
- 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*
- AS4361A, *Minimum Performance Standards for Aerospace Electric Power Converters*
- 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*
- AS8023B, *Minimum Performance Standards for Static Electric Power Inverters*
- AS8033, *Nickel Cadmium Vented Rechargeable Aircraft Batteries (Non-Sealed, Maintainable Type)*

AE-7C Systems:

- 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-7M Aerospace Model Based Engineering:

- AIR6326, *Aircraft Electrical Power Systems, Modeling and Simulation, Definitions*
- ARP6538, *Dynamic Modeling of Aerospace Systems (DyMAS)*

AE-7EU Europe Subcommittee: The scope of the AE-7 Aerospace Electrical Power and Equipment Committee is dedicated to developing standards and specifications relative to the generation and control, storage, conversion, 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.

A-20B Exterior Lighting Committee:

- 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*
- ARP5029A, *Measurement Procedures for 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*
- ARP5414A, *Aircraft Lightning Zoning*
- ARP5577, *Aircraft Lightning Direct Effects Certification*
- ARP5415A, *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, *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:

- WK56160 *Revision of F3005 - 14a Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)* – specific to UAS
- WK60937, *New Specification for Design of Fuel Cells for Use in UASs*

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*
- WK52827, *Safety Analysis of Systems & Equipment Retrofit in Small 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-8A Elec Wiring and Fiber Optic Interconnect Sys Install:

- AIR6808, *Aerospace Vehicle Wiring, Lessons Learned*
- AIR6820, *Electrical Wiring Fuel Compatibility*
- ARP6881, *Guidelines for the Use and Installation of Bonded Cable Harness Supports*
- AS50881G, *Wiring Aerospace Vehicle*
- AS5649A, *Wire and Cable Marking Process, UV Laser*

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:

- AIR6343, *Design and Development of Rechargeable Aerospace Lithium Battery Systems*
- AIR6897, *Lithium Battery Systems – Prognostics and Health Management*
- ARP5584A, *Document for Electric Power Management*
- 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*
- AIR6540, *Fundamentals in selecting Wire Sizes in Aerospace Applications*
- AS5698A, *Space Power Standard*

AE-7M Aerospace Model Based Engineering:

- AIR6387, *Aircraft electrical power systems. Modeling and simulation. Validation and verification methods.*

AE-7EU Europe Subcommittee

A-20 Exterior Lighting:

- AS8037D, *Minimum Performance Standard for Aircraft Position Lights*
- ARP4087D, *Wing Inspection Lights - Design Criteria*
- ARP6336, *Lighting Applications for Unmanned Aircraft Systems (UAS) – specific to UAS*

AE-9 Electrical Materials:

- AIR7219, *Degradation in electrical materials*

AE-2 Lightning Committee:

- 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 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 ground control stations (GCSs), 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, GCS, and auxiliary system(s).

Priority: High

Organization(s): ICAO, RTCA, SAE, AIAA, ASTM, DOD, NASA, UL, IEC, IEEE

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:

The following FAA TSOs may contain companion industry standards.

- 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:

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

- AS21378A, Plugs And Cable Assemblies, External Power, Aircraft, 230/400 VOLT, 400 Hertz
- AS24122, 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

AE-7A Generators and Controls Motors and Magnetic Devices:

- AS8011B, Minimum Performance Standards for A-C Generators and Associated Regulators
- AS8020, Minimum Performance Standards for Engine Driven D.C. Generators/Starter-Generators and Associated Voltage Regulators

AE-7B Power Management, Distribution and Storage:

- AIR5561, Lithium Battery Powered Portable Electronic Devices
- ARP5584, Document for Electric Power Management
- AS4361A, Minimum Performance Standards for Aerospace Electric Power Converters
- 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
- AS8023B, Minimum Performance Standards for Static Electric Power Inverters
- AS8033, Nickel Cadmium Vented Rechargeable Aircraft Batteries (Non-Sealed, Maintainable Type)

AE-7C Systems:

- AIR6139, Ways of Dealing with Power Regeneration onto an Aircraft Electrical Power System Bus
- ARP4729A, Document for 270 Voltage Direct Current (270 V DC) System
- AS1212A, Electric Power, Aircraft, Characteristics and Utilization of

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 [Note: This is also listed/discussed in "Electrical Systems" section.]

- 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:

- WK56160, *Revision of F3005 - 14a Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)* – specific to UAS
- WK60937, *Design of Fuel Cells for Use in Unmanned Aircraft Systems (UAS)* – 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*

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:

- AS8441, *Minimum Performance Standard for Permanent-Magnet Propulsion Motors and Associated Variable-Speed Drives*

AE-7B Power Management, Distribution and Storage:

- AIR6343, *Design and Development of Rechargeable Aerospace Lithium Battery Systems*
- AIR6897, *Lithium Battery Systems – Prognostics and Health Management*
- ARP5584A, *Document for Electric Power Management*
- 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*

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.

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

Organization(s): ICAO, RTCA, SAE, AIAA, ASTM, DOD, NASA, UL, IEC, IEEE

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 GCS produce noise levels that are not totally addressed by aviation standards and/or regulations. While the operating situation and environment of a GCS 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 including but not limited to GCS, UA, etc.

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.

<u>FAA:</u>

- 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*
- Others documents

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

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

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

Organization(s): ICAO, RTCA, SAE, AIAA, ASTM, DOD, NASA

6.8. Mitigation Systems for Various Hazards

Potential hazards that drones may encounter during operations include: bird and/or UAS strikes on UAS, UAS strikes on manned aviation (including to persons, property, and other users of the NAS), engine ingestion, icing, hail damage, lightning, electric wiring, support towers, etc. Standards have a role to play in mitigating potential adverse outcomes associated with these hazards. Airborne and/or ground collision, and UAS strikes on UAS and manned aviation, are more fully covered in the DAA Systems section. Some of the hazards associated with sUAS will have to be mitigated through CONOPS.

Published Standards and Related Materials:

Hazard Mitigation Systems for Bird Strikes, Bird Ingestion, Rain, Hail, Foreign Object Ingestion

- 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.
- 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[21]
- UAS Ground Collision Severity Evaluation, NIAR, FAA Center of Excellence for UAS Research[22]

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

Policies: PS-ANM-25-10, PS-ACE-23-05, PS-ANE-2003-35-1-R0

SAE's 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.

Document	**Title**	**Date**
AIR1168/4B	*SAE Aerospace Applied Thermodynamics Manual, Ice, Rain, Fog, and Frost Protection*	Aug 29, 2016
AIR1667A	*Rotor Blade Electrothermal Ice Protection Design Considerations*	Apr 23, 2013
AIR4015D	*Icing Technology Bibliography*	Mar 15, 2013
AIR4367A	*Aircraft Inflight Ice Detectors and Icing Rate Measuring Instruments*	Oct 11, 2012
AIR4906	*Droplet Sizing Instrumentation Used in Icing Facilities*	Apr 23, 2013
AIR5320A	*Summary of Icing Simulation Test Facilities*	Sep 25, 2015
AIR5396A	*Characterizations of Aircraft Icing Conditions*	Aug 24, 2015
AIR5666	*Icing Wind Tunnel Interfacility Comparison Tests*	Oct 03, 2012
ARP5624	*Aircraft Inflight Icing Terminology*	Apr 23, 2013
ARP5903	*Droplet Impingement and Ice Accretion Computer Codes*	Jun 01, 2015
ARP5904	*Airborne Icing Tankers*	Oct 11, 2012
ARP5905	*Calibration and Acceptance of Icing Wind Tunnels*	Sep 26, 2015

[21] The reports embedded in this hyperlink discuss hazard mitigation systems for Bird and/or UAS Strikes on UAS, UAS Strike on manned aviation including but not limited to persons, property and other users of the National Airspace System (NAS), Engine Ingestion, etc.
[22] The reports embedded in this hyperlink are specific to UAS Ground Collision Severity.

AS5498A	*Minimum Operational Performance Specification for Inflight Icing Detection Systems*	Dec 05, 2017
AS5562	*Ice and Rain Minimum Qualification Standards for Pitot and Pitot-static Probes*	Aug 07, 2015

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 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:

Document	Title	Date
ARP5412B	*Aircraft Lightning Environment and Related Test Waveforms*	Jan 11, 2013
ARP5414A	*Aircraft Lightning Zoning*	Sep 28, 2012
ARP5415A	*User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning*	Feb 16, 2008
ARP5416A	*Aircraft Lightning Test Methods*	Jan 07, 2013
ARP5577	*Aircraft Lightning Direct Effects Certification*	Mar 26, 2008
ARP5672	*Aircraft Precipitation Static Certification*	Apr 13, 2016

In-Development Standards/Documents:

Hazard Mitigation Systems for Bird and UAS Strikes

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 foreign object debris (FOD) impact/ingestion are necessary, the committee is prepared to help develop artificial simulant standards.

Document	Title
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, there is SAE AIR6962, *Ice Protection for Unmanned Aerial Vehicles,* 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.

Document	Title
AIR4367B	*Aircraft Inflight Ice Detectors and Icing Rate Measuring Instruments*
AIR4906A	*Particle Sizing Instrumentation for Icing Cloud Characterization*
AIR5666A	*Icing Wind Tunnel Interfacility Comparison Tests*
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*
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.

Document	Title
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. There are no UAS-specific standards in the areas of hazard mitigation systems for bird and/or UAS strikes on UAS, UAS strikes on manned aviation (including to persons, property, and other users of the NAS), engine ingestion, hail damage, water ingestion, lightning, electrical wiring, support towers, etc.

R&D Needed: Yes. There is some data from FAA Assure that is being used for standards development now.

Recommendation:

1) Complete in-development standards.
2) Create new standards to include hazard mitigation systems for bird and/or UAS strikes on UAS, UAS strikes on manned aviation (including to persons, property, and other users of the NAS), engine ingestion, icing, and lightning.

Priority: High

Organization(s): SAE

6.9. Parachutes for Small UAS

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 WK52089, *New Specification for Operation over People*
- ASTM WK56338, *New Test MGethods for Safety of Unmanned Aircraft Systems for Flying over People*

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 WK52089, *New Specification for Operation over People* and ASTM WK56338, *New Test Methods for Safety of Unmanned Aircraft Systems for Flying over People*.

Priority: High

Organization(s): ASTM, AIAA, SAE, PIA, DOD, NASA

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:

- F2909-14, *Standard Practice for Maintenance and Continued Airworthiness of Small Unmanned Aircraft Systems (sUAS)*, developed by ASTM F38.02
- 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*

In terms of general aviation standards, there are in ASTM F39.02:

- F2696-14, *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*

Other general aviation 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*

In-Development Standards: In terms of UAS-specific standards in development, there are:

- WK63991, *Revision of F2909-14, Standard Practice for Maintenance and Continued Airworthiness of Small Unmanned Aircraft Systems (sUAS)*, under ASTM F38.02. The standard is being revised to be applicable for UAS without reference to sUAS.
- WK60659, *UAS Maintenance Technician Qualification*, under ASTM F38.03
- WK62734, *New Specification for Specification for the Development of Maintenance Manual for Lightweight UAS*, under ASTM F38.03
- WK62743, *New Specification for Development of Maintenance Manual for Small UAS*, under ASTM F38.03
- ISO/DIS 21384-3, *Unmanned aircraft systems -- Part 3: Operational procedures*, which covers maintenance

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

Other general aviation 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 *a*nd 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 (Scoring: Criticality-3; Achievability-1; Scope-3, Effect-3)

Organization(s): ASTM, ISO, SAE

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 ARP 4761, SAE ARP 4754A, SAE ARP 5150, D0-178C, etc. are sufficient to address fully autonomous flights of an enterprise or fleet of UAS from airborne, land and sea launches. This has raised some questions 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[23] 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?

[23] 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.

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)
- §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

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

SAE International Documents:

S-18, Aircraft and Systems Development and Safety Assessment Committee

- ARP 4754A, Guidelines for Development of Civil Aircraft and Systems
- ARP 4761, Guidelines And Methods For Conducting The Safety Assessment Process On Civil Airborne Systems And Equipment
- ARP 5150, Safety Assessment of Transport Airplanes in Commercial Service

AS-4JAUS, Joint Architecture for Unmanned Systems Committee

- AIR5645A, AIR5664A, AIR5665B, ARP6012A, ARP6128, 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

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

Aeronautical Radio, Incorporated (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
- RTCA/DO-344 Volume 2-Appendices F & G - Operational and Functional Requirements and Safety Objectives for UAS Standards, 2013

In-Development Standards

SAE International Documents:

S-18, Aircraft and Systems Development and Safety Assessment Committee

AS-4JAUS Joint Architecture for Unmanned Systems Committee

- AS6111, JAUS Unmanned Maritime Vehicle Service Set
- AS8024, JAUS Autonomous Behaviors Service Set

AS-4UCS Unmanned Systems Control Segment Architecture

- AIR6514A, UxS Control Segment (UCS) Architecture: Interface Control Document (ICD)
- AS6512A, Unmanned Systems (UxS) Control Segment (UCS) Architecture: Architecture Description
- AS6518A, UxS Control Segment (UCS) Architecture: UCS Architecture Model
- AS6522A, UxS Control Segment (UCS) Architecture: Architecture Technical Governance
- AS6969A, Data Dictionary for Quantities Used in Cyber Physical Systems

ASTM International Documents:

- WK63418, New Specification for Service provided under UTM
- ASTM Administrative Collaborative AC377 on Autonomy Design and Operations in Aviation, to be published as a technical report, not a standard.

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

Organization(s): SAE, ARINC, RTCA, AIAA, ASTM, DOD, NASA, FCC

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7. Flight Operations Standards: General – 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[24] 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

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

[24] 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.[25] 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.[26] 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.[27]

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."

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 Recommended Guidelines for the Use of Unmanned Aircraft also touch on privacy. The FAA Reauthorization Act of 2018 also contains several privacy-related provisions.

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: ISO/DIS 21384-3, *Unmanned Aircraft Systems – Part 3: Operational Procedures*, is in development within ISO/TC 20/SC 16/WG 3. It includes brief discussions of data protection and privacy etiquette.

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[25] 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.
[26] "Commercial Drone Alliance Opposes Aircraft Privacy and Transparency Act of 2017," Commercialdronealliance.org. March 29, 2017.
[27] "DC Circuit Denies EPIC's Petition, Will Not Mandate Privacy Rules for Drones," *Epic.org*. June 19, 2018.

Gap O1: Privacy. UAS-specific privacy standards are needed. 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: Complete work on ISO/DIS 21384-3, *Unmanned Aircraft Systems – Part 3: Operational Procedures*. Monitor the ongoing policy discussion.

Priority: Low

Organization(s): Lawmakers, FAA, ISO/IEC JTC1/SC 27, ISO/TC 20/SC 16, APSAC, IACP

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[28] 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 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

- ASTM F3178-16, *Standard Practice for Operational Risk Assessment of Small Unmanned Aircraft Systems (sUAS)*
- JARUS *Guidelines on Specific Operations Risk Assessment* (SORA) JAR-DEL-WG6-D.04, 7/28/17

[28] Safety risks are addressed in documents such as JARUS WG-6 SORA, ASTM F3178-16, FAA – CFR Title 14 Part 107, Small UAS.

- FAA – CFR Title 14 Part 107, *Small Unmanned Aircraft Systems*

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
- DO-320 - *Operational Services and Environmental Definition (OSED) for Unmanned Aircraft Systems* - Assessing and establishing operational, safety, performance, and interoperability requirements for UAS operations in the US NAS
- SAE ARP 4754A, *Guidelines for Development of Civil Aircraft and Systems*

In-Development Regulations, Standards, and Guidance Material: External consultation on the JARUS SORA Version 2.0 took place in June-August 2018. Following comment adjudication, the document is targeted for completion in 2019. EUROCAE WG 105 is currently evaluating industry standards to support SORA objectives. NFPA® 2400 calls for risk assessment on an operational basis.

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 (Scoring: Criticality-1 (published risk framework exists); Achievability-3 (risks being addressed in use cases. Public risks addressed through legislation - complex); Scope-3 (risks being addressed in use cases. Public risks addressed through legislation - complex); Effect- 3 (high return - reduce risks and managed public perception)

Organization(s): Standards bodies publishing UAS standards and/or regulators

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:

- ASTM WK62344, *Risk Mitigation Strategies for Package Delivery sUAS BVLOS Operations (Appendix to F3196)*

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. 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 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 (Scoring: Criticality-3, Achievability-3, Scope-1, Effect-3)

Organization(s): ASTM

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.

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 Methods for Safety of Unmanned Aircraft Systems for Flying Over People*
    - Using Data from the ASSURE UAS Ground Collision Severity Evaluation Final Report
- ASTM WK52089, *New Specification for Operation over People*

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 Methods for Safety of Unmanned Aircraft Systems for Flying Over People* and ASTM WK52089, *New Specification for Operation over People*.

Priority: High (Scoring: Criticality-3; Achievability-2; Scope-2; Effect-3)

Organization(s): ASTM

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-358, *Minimum Operational Performance Standards (MOPS) for Flight Information Services Broadcast (FIS-B) with Universal Access Transceiver (UAT)*
- 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)

In-Development Standards:

- RTCA DO-358, *Minimum Operational Performance Standards (MOPS) for Flight Information Services Broadcast (FIS-B) with Universal Access Transceiver (UAT)*
    - Currently being updated to add new weather information to the broadcast.
    - Weather products being added include:
        - Lightning
        - Turbulence
        - Icing
        - Cloud Tops
        - Center Weather Advisory (CWA)
        - Graphical Airmen's Meteorological Advisory (G-AIRMET)

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:

1) Weather requirements for flight operations of UAS. For example, to operate in Class A 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 GCS).

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

Organization(s): RTCA, SAE, NOAA, WMO, NASA, universities, National Science Foundation (NSF) National Center for Atmospheric Research (NCAR)

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)*

In-Development Standards:

- OGC GeoTIFF – Currently an open but proprietary standard, GeoTIFF is presently being advanced in the OGC for adoption in mid-2019 as an OGC Standard.
- OGC is advancing best practices through its UxS DWG and through a series of ongoing interoperability pilot activities

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. A priority level of 9 was derived in part because of the criticality of best practices in assuring efficient and mission responsive UAS observation capability, and given the range of UAS platforms, variety of sensing platforms, and myriad of mission scenarios.

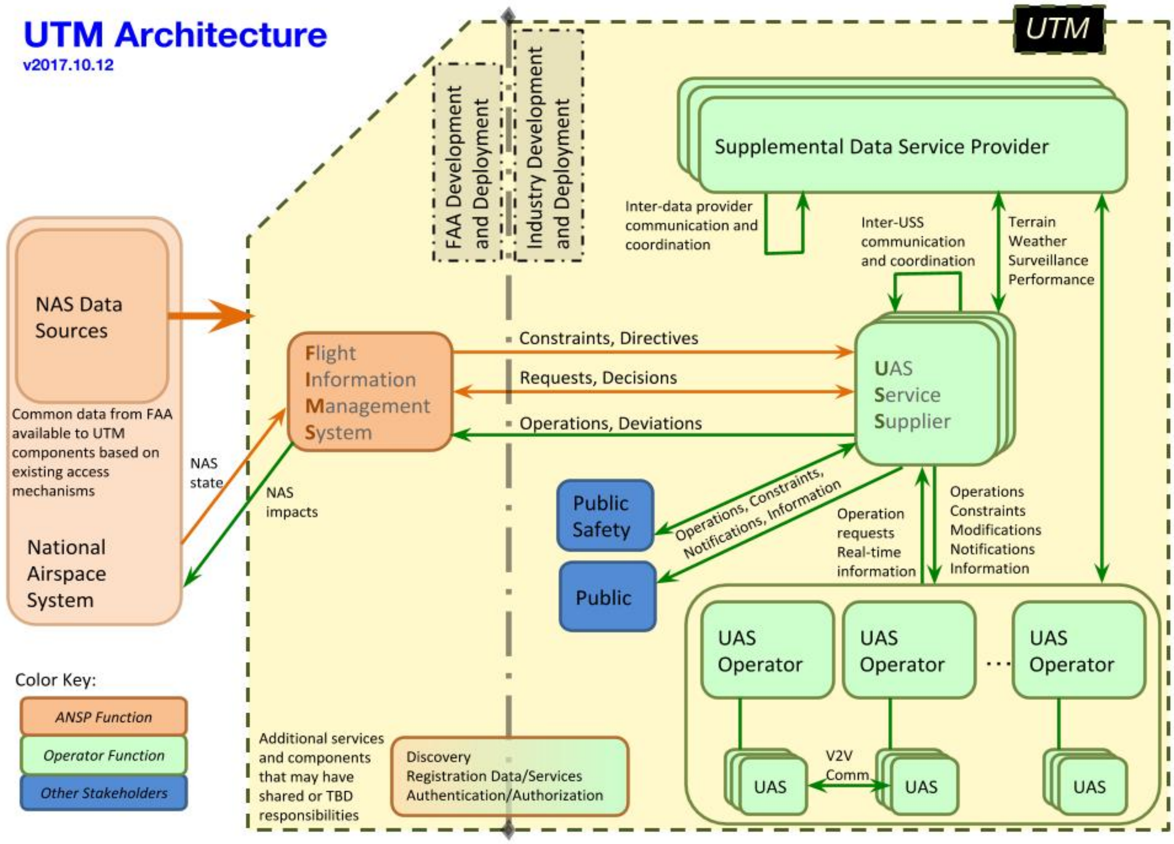
Organization(s): OGC, ISO TC/211, ASTM

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. Figure 3 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.

Figure 3: Notional UTM Architecture

Source: FAA's UTM CONOPS, Version 1.0, May 18, 2018 (p. 7)



A UAS Service Supplier (USS) is an entity that provides services to support the safe and efficient use of airspace by providing services to the operator in meeting UTM operational requirements. USS services proposed thus far are:

Messaging Service: provides on-demand, periodic, or event-driven information on UAS operations (e.g. position reports, intent information, and status information) occurring within the subscribed airspace volume and time. Additional filtering may be performed as part of the service.

Discovery Service: allows for service suppliers and UAS operators to be aware of other service suppliers providing specific services of varying levels of capability in a specific geographical region.

Registration Service: provides the ability for vehicle owners to register data related to their UAS and a query function to allow appropriate stakeholders to request registration data.

Airspace Authorization Service: provides airspace authorization from the Airspace Authority/ANSP to a UAS operator.

Restriction Management Service: manages and pushes operational restrictions from the Airspace Authority/ANSP to effected UAS operations.

Communication Services:

Command and Control Service - provides infrastructure and QoS assurance for RF C2 capabilities to UAS operators.

Separation Services:

Strategic De-Confliction Service - arranges, negotiates, and prioritizes intended operational volumes/ trajectories of UAS operations with the intention of minimizing the likelihood of planned airborne conflicts between operations.

Conformance Monitoring Service - provides real-time alerting of non-conformance to intended operational volume/trajectory to an operator or another airspace user.

Conflict Advisory and Alert Service - provides real-time monitoring and alerting through suggestive or directive information of UA proximity for other airspace users.

Dynamic Reroute Service - provides real-time modifications to intended operational volumes/ trajectories to minimize the likelihood of airborne conflicts and maximize the likelihood of conforming to airspace restrictions and maintaining mission objectives. This service arranges, negotiates, and prioritizes inflight operational volumes/trajectories of UAS operations while the UAS is aloft.

Weather Services: provide forecast and/or real-time weather information to support operational decisions of individual operators and/or services.

Flight Planning Service: prior to flight, arranges and optimizes intended operational volumes/ trajectories for safety, dynamic airspace flight rules, airspace restrictions, and mission needs.

Mapping Service: provides terrain and/or obstacle data appropriate and necessary to meet the safety and mission needs of an individual UAS operation, or support the needs of separation or flight planning service.

In addition to the USS services listed above, 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.

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 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 that have been successfully demonstrated in numerous flight tests events around the world. While a data interface control document (ICD) or application programming interface (API) can be interpreted as a "standard," what the industry really needs are performance standards.

In-Development Standards:

ASTM: Work includes:

- ASTM WK65041, *New Practice for UAS Remote ID and Tracking*
- ASTM WK63418, *New Specification for Service provided under UAS Traffic Management (UTM)*

ISO: ISO/TC 20/SC 16/WG 4 on UAS Traffic Management has been created. An approved work item under development is ISO/AWI TR 23629-1, *UAS Traffic Management (UTM) -- Part 1: General requirements for UTM -- Survey results on UTM.*

EUROCAE: A WG has been established to support UTM standards. However, this group has yet to produce anything of note. The Geofence group recently recommended to EUROCAE leadership that the Remote ID subgroup should begin work in earnest.

RTCA: There is no activity.

SAE: Activity is unknown.

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.

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 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 performance-based requirements and thus quickly converge to published standards.

Priority: High

Organization(s): NASA, FAA, ASTM, ISO, et al.

7.8. Remote ID & Tracking

Essential to the future of the UAS industry is implementation of a safe and secure airspace management system for civilian UAS operations – a system that enables new and innovative UAS applications while resolving the issues of policy makers, the needs of regulators and law enforcement agencies, and the concerns of the public. Critical to an effective airspace management system for low flying UAS is the ability to remotely identify in real-time an operating aircraft, its owner and pilot, and its precise location.

The FAA (and several other major national aviation authorities) has acknowledged it is not a question of *if*, but *when*, government must require that civilian UAS be able to be remotely identified and tracked. In 2017, the FAA instituted a UAS Identification and Tracking (UAS ID) ARC. The ARC's 74 members represented a diverse array of stakeholders that included the aviation community and industry member organizations, law enforcement agencies and public safety organizations, manufacturers, researchers, and standards entities involved with UAS.

In its final report, released by the FAA in December 2017, the ARC made detailed recommendations and suggestions, covering issues related to existing and emerging technologies, law enforcement and security, and implementation of remote ID and tracking.[29] Highlights of the recommendations include:

- The FAA should consider two methods for remote ID and tracking of drones: (1) direct broadcast (transmitting data in one direction only with no specific destination or recipient), and (2) network publishing (transmitting data to an internet service or group of services). Both methods would send the data to an FAA-approved internet-based database.
- The data collected must include a unique identifier for UA, tracking information, and drone owner and remote pilot identification.

[29] See this FAA news item announcing release of the UAS Remote Tracking & ID ARC Report, with a link to the actual report on the FAA website.

- The FAA should promote fast-tracked development of industry standards while a final remote ID and tracking rule is developed, potentially offering incentives for early adoption and relying on educational initiatives to pave the way to the implementation of the rule.
- The FAA should coordinate any ID and tracking system with the existing ATC system and ensure it does not substantially increase workloads.
- The FAA should exempt drones operating under ATC or those operating under the agency's discretion (public aircraft operations, security or defense operations, or with a waiver).
- The FAA must review privacy considerations, in consultation with privacy experts and other Federal agencies, including developing a secure system that allows for segmented access to the ID and tracking information. Within the system, only persons authorized by the FAA (e.g., law enforcement officials, airspace management officials, etc.) would be able to access personally identifiable information.

While the UAS ID ARC provided the FAA with a substantial amount of useful data, including very detailed technology evaluations, it purposely did not recommend specific technology solutions to the issues addressed.

Published Standards and Related Materials: There are no published standards specific to UAS ID and tracking that have been identified. There are many published standards relating to the ID and tracking of manned aircraft, and these may also apply to UAS operated under ATC. This was considered by the UAS ID ARC in recommending (pp. 31-32) that "UAS operated under ATC and containing the equipment associated with such operations (including ADS-B, transponder, radar and communication with ATC)" be exempt from the remote ID and tracking requirement.

- 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)*, and further standardizing of 3GPP R16 international specs to handle requirements unique to the United States or North America.
- ANSI/CTA-2063, *Small Unmanned Aerial Systems Serial Numbers* (published April 2017) (largely deals with registration requirement for UAS but not specific to remote ID and tracking)

In-Development Standards and Related Materials Include:

- ASTM WK65041, *New Practice for UAS Remote ID and Tracking*. The remote ID standard and tracking workgroup within ASTM F38 is developing an Open Standard for Secure Remote Drone Identification, called the Open Drone ID project.[30] The effort is developing a global standard, like Wi-Fi or Bluetooth, to provide broad scalability to many end users and use cases. As of this

[30] See this news item unveiling the new Open Standard for Secure Remote Drone Identification

writing, the current draft is Open Drone ID Specification 0.60.0. Additionally, this workgroup has created two sub-groups: (1) Broadcast, and (2) Common Data and Network API.

- 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 (including direct broadcast with or without the presence of a cellular network) and to provide UTM support over a cellular network. The ongoing 3GPP specification work is applicable to both 4G and 5G systems.
- EUROCAE - Minimum Aviation System Performance Specification for UAS e-identification
- EUROCAE - Minimum Operational Performance Specification for UAS e-identification

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: Yes

Recommendation:

1) Review existing standards relating to the broadcast of ID and tracking data for manned aviation outside ATC to address UAS operations in similar environments and scenarios.
2) Continue development of the Open Drone ID standard, which is also addressing how multiple solutions interface with an FAA-approved internet-based database.
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

Organization(s): Open Drone ID, ASTM, 3GPP, ATIS

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 network and cloud-based services. Nor do they describe how that data is received by and/or accessed from an FAA-approved internet-based database. However, the ASTM F38 Remote ID Workgroup / Open Drone ID project includes a network access API within their scope of work.

R&D Needed: Yes

Recommendation:

1) Continue development and complete ASTM WK65041, *New Practice for UAS Remote ID and Tracking* and the Open Drone ID project's efforts to include standards for UAS ID and tracking over established communications networks (such as cellular and satellite), which should also address how multiple solutions (and service providers) interface with an FAA-approved internet-based database.
2) Continue development of 3GPP specs and ATIS standards related to remote ID of UAS and UTM support over cellular.

Priority: High

Organization(s): Open Drone ID, ASTM, 3GPP, ATIS

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, geofence, 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. It is known that EUROCAE WG-105 (Unmanned Aircraft Systems) is also assessing standardization targets for geo-fencing.

Published Standards: The following geospatial standards are relevant for defining, disseminating, and interacting with geo-fences:

- OGC 06-103r4, *OpenGIS® Implementation Standard for Geographic* informatio*n - 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.

In-Development Standards:

- OGC WFS 3.0: OGC is undertaking a major revision to the WFS standard to be based on more modern web architectures, to better support linked data concepts, and to increase flexibility in data delivery.
- EUROCAE: Minimum Aviation System Performance Specification for UAS geo-fencing
- EUROCAE: Minimum Operational Performance Specification for UAS geo-fencing

Gap O10: Geo-fence Exchange. Standards 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.

Priority: High

Organization(s): OGC, ISO / TC 20 / SC 16, EUROCAE, UAST, ICANN

Gap O11: Geo-fence Provisioning and Handling. There is a need for a best practices document to inform manufacturers of the purpose and handling 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

8. Flight Operations Standards: Critical Infrastructure Inspections and Commercial Services – WG3[31]

8.1. Vertical Infrastructure Inspections

8.1.1. Boilers and Pressure Vessels

Companies are utilizing sUAS to perform boiler and pressure vessel (BPV) inspections inside the cavity, on external surfaces, and within systems. UAS are not included in the current guidelines by ASME for inspections of BPV.

Published Standards: No published UAS standards have been identified. Relevant published general industry standards include those from the ASME Boiler and Pressure Vessel (BPV) Code Committee.

In-Development Standards: UAS standards in development have not been identified. Relevant general industry standards in development include:

- The ASME BPV Section V Committee on Nondestructive Examination is in the process of developing a standard that would provide requirements for the safe and reliable use of UAS to perform inspections. Solar, wind, and hydropower inspection case studies are being considered.

Gap I1: UAS Inspections of Boiler and Pressure Vessels (BPV). No published or in-development UAS standards have been identified for BPV inspections.

R&D Needed: Yes. Identify impact on the C2 link to operations in an enclosed space.

Recommendation: Develop standards for power plant inspections using UAS both internal and external to the BPV. Efforts by the ASME BPV Section V Committee on Nondestructive Examination will be considered in the recommendation.

Priority: Medium

Organization(s): ASME BPV Committee on Nondestructive Examination (V) and proposed Mobile Unmanned Systems (MUS) Standards Committee

[31] In addition to the topics listed below, ASME is considering covering inspections of wind and solar farms (see 4.3 and 8.1.1), while ASSP is looking at the use of drones for construction and demolition operations (see 4.4).

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 ASME 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

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

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

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: The National Association of Tower Erectors (NATE) has published a best practices document entitled *Unmanned Aerial Systems Operations around Vertical Communications Infrastructure (2nd Edition, January 2017)* which is freely available to the public on their website.

The intended focus of the best practices document is on UAS operations around wireless infrastructure, cellular towers, broadcast towers, and utility structures. The document intends to improve UAS operations by suggesting additional items to consider above and beyond the established FAA, federal, state, and local requirements. The operational suggestions in this document are in support of all FAA regulations in this arena.

Other related standards 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

In-Development Standards: As of late August 2018, the NATE UAS Committee has created a new Standards and Resource Development group and plans to develop standards for inspecting and operating drones near communications towers.

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 UAE 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 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. UAS are proving to offer a safer, faster, more cost-effective alternative for performing bridge inspections.[32] 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 such as: 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)
- 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)

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.

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[32] Zink, Jennifer. "Will drones transform bridge inspection?" *Roads & Bridges*, September 6, 2016
LeBlanc, Steve. "Michigan testing drones for bridge inspections," *The Detroit News*, March 28, 2016
"35 State DOTs are Deploying Drones to Save Lives, Time and Money," AASHTO News Release. March 27, 2018

- 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.
- 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.

In-Development Standards and Related Activity: There are no known UAS bridge inspection standards in development. However, related in-development standards and 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 to help understand the benefits of UAS for highway, bridge, and construction inspection.

Gap I5: Bridge Inspections. There are no known published or in-development standards for conducting bridge inspections using a UAS. Standards are needed 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 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.

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. 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

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.

Maintenance inspections of railroad infrastructure focus on the prevention of incidents related to track, equipment (rolling stock, signals, etc.), and human factors. The Federal Railroad Administration (FRA) offers several techniques that may be employed for inspecting tracks and structures including rail defect detection, alternative techniques for the detection of broken rail or track hazards, longitudinal rail stress measurement, vertical track support measurement, automated inspection of roadbed, and non-destructive evaluation of bridges.[33] Most of these techniques have the potential of leveraging UAS technology through high-resolution imagery, lidar, radar, video, chemical detectors, or other remote sensing technology that is able to be mounted on a UAS platform.

Transporting hazardous materials (HAZMAT)[34] by rail is regulated by the DOT and codified in 49 U.S.C. Chapter 51 and 49 C.F.R. Parts 171–180. The main objective of the hazardous material regulations (HMR) is that the "*offering for transportation, acceptance for transportation, or transportation of a hazardous material is prohibited unless certain standards are met*." A HAZMAT shipment that is not prepared in accordance with the requirements of the HMR may not be transported.[35]

FRA Hazardous Material Inspectors monitor regulatory compliance of HAZMAT shipments by rail. Generally, there are seven reasons for conducting HAZMAT inspection activities: regular inspections, complaint investigations, accident/incident investigations, special inspections or investigations, waiver investigations, nuclear route inspections, and re-inspections. Specifically related to the use of UAS,

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[33] Federal Railroad Administration. Inspection Techniques. [Online] [Cited: June 11, 2018.].
[3434] See section 9.2 for a definition of HAZMAT.
[35] Federal Railroad Administration. *Harzardous Materials Compliance Manual.* Office of Railroad Safety. Washington D.C. : Federal Railroad Administration, 2017. p. 151.

inspections of rolling stock (i.e., containers) used for transporting HAZMAT are required to determine compliance with regulations for construction, testing, maintenance, and qualifications.[35]

The standards available from the Occupational Health and Safety Administration (OSHA) apply (29 C.F.R. 1910) comprehensively to cover employee safety. UAS operators within line of sight are likely required to equip themselves with the necessary PPE to ensure safety while in close proximity to HAZMAT.

The raw data collected from the UAS platform can be further processed to extract meaningful information (measurements, assessments, situational awareness, etc.) to support inspection requirements and enable data-driven decisions.

Published Standards: There are no known published standards concerning the specific application of UAS for railroad inspections, HAZMAT, or otherwise.

In-Development Standards: SAE is planning a future work item.

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: No. 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

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.

R&D Needed: No. Current Pathfinder program activities likely will address R&D considerations.

Recommendation: It is recommended that standards be developed that define a framework for operating UAS BVLOS for rail system infrastructure inspection.

Priority: Medium

Organizations: FRA, FAA, SAE

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: Medium

Organization(s): FRA, FAA, SAE

8.2.3. Power Transmission Lines

UAS performing power transmission line inspections 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.

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."

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.

Gap I9: Inspection of Power Transmission Lines 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 in telecommunication corridors that share poles with transmission and distribution equipment. This includes telephone, fiber, and cable assets. A standard is needed to address these issues as well as operational best practices in how to conduct a safe inspection of power transmission lines using drones.

R&D Needed: Yes. There is a need to study acceptable methods of airspace confliction data in transmission corridors. Identifying acceptable data to collect and study airspace activity around transmission corridors 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 using UAS. Review and consider relevant standards from other organizations to determine manufacturer requirements. As part of the standard, include guidelines on safe flight operations in proximity to energized equipment to avoid arcing damage to physical infrastructure.

Priority: High

Organization(s): SAE, IEEE, Department of Energy (DOE), North American Electric Reliability Corporation (NERC), FERC, ORNL

8.3. Wide Area Environment Infrastructure Inspections/Precision Agriculture

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[36] 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:

- **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

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[36] Source: [Wikipedia Environmental Monitoring page](https://en.wikipedia.org/wiki/Environmental_monitoring).

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[37]:

- 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, 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

[37] See https://en.wikipedia.org/wiki/Environmental_monitoring#Sampling_methods for a definition of each method.

- 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., pesticide label requirements 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. 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.

Eventually, all pesticide application scenarios will include wide area application as opposed to precision application or 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. Recently, ISO/FDIS 16119-5 was initiated and completed for "Aerial spraying: new equipment" and ISO/DIS 16122-5 has been initiated and is in development for "Aerial spraying: existing equipment." 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. A relevant study is "Qualitative Evaluation of Unmanned Aircraft Visibility during Agricultural Flight Operations."

In-Development Standards: The two standards below are currently moving through ISO and address operations with the pilot in-cockpit. They are potentially relevant for UAS operations.

- ISO/FDIS 16119-5, *Agricultural and forestry machinery – Environmental requirements for sprayers – Part 5: Aerial spray systems*

- [ISO/DIS 16122-5, *Agricultural and forestry machines – Inspection of sprayers in use – Part 5: Aerial spray systems – Environmental protection*]

In addition, the ISO member from Japan has submitted four documents for WG 25's consideration toward the 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 three, only the latter has experience with standards development (SD), though an effort is now underway to distribute the SD efforts involving UAS across the three groups. 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 might also be the domain of manned aerial application aircraft. Automated ID and location communication is critical in this dangerous, near surface airspace.
- **Treatment Efficacy.** Assumptions that spraying patterns and efficacy are similar to heavier aircraft may be incorrect for small 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.
- **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/AATRU, and ASSURE should be consulted in conjunction with such standards development activities.

Priority: High

Organization(s): ISO/TC 23/SC 6, American Society of Agricultural and Biological Engineers (ASABE), AIAA, FAA,

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 Package Delivery

A number of commercial, service-oriented companies are interested in using drones to reduce product delivery times and achieve potential cost savings. Operations include deliveries made directly to consumer homes in suburban and rural areas and to drop-off stations in more densely populated urban locales. As further described below, the standards and regulatory framework supporting BVLOS operations, remote ID & tracking, and UTM need to evolve before such operations can become ubiquitous.

Published Standards: Most of the standards needed to accomplish commercial package delivery operations are those that support BVLOS use cases. These include:

- ASTM F3196-18, *Standard Practice for Seeking Approval for Beyond Visual Line of Sight (BVLOS) Small Unmanned Aircraft System (sUAS) Operations*, developed by ASTM F38.02

In addition, SAE J2735_201603, *Dedicated Short Range Communications (DSRC) Message Set Dictionary* leverages IEEE 802.11P protocols to provide for vehicle anti-collision. This standard potentially could be adapted for UAS to enable vehicle to vehicle (V2V) communications and active separation assurance.

In-Development Standards: There is an appendix to ASTM F3196-18 in development in ASTM F38.02:

- ASTM WK62344, *Risk Mitigation Strategies for Package Delivery sUAS BVLOS Operations (Appendix to F3196)*, which will introduce operational standards specific to delivery operations.

Also in development in F38.02 are:

- ASTM WK65041, *New Practice for UAS Remote ID and Tracking*. Absent any means of creating electronic conspicuity and the means by which UAS can be identified remotely, rulemaking will be held up for expanded operations to include OOP and BVLOS operations. The first draft of the terms of reference (TOR) is in the works right now and this will be critical for package delivery especially in urban locales.
- ASTM WK63418, *New Specification for Service provided under UAS Traffic Management (UTM)*. In order to support more complex use cases, the FAA will require a networked solution. This standard will be supported by the aforementioned remote ID & tracking standard and it will be indexed to the UTM CONOPS 1.0 document that the FAA released in May 2018.

Gap I11: Commercial Package Delivery. Standards are needed to enable UAS commercial package delivery operations.

R&D Needed: Yes

Recommendation: Complete work on ASTM WK62344, *Risk Mitigation Strategies for Package Delivery sUAS BVLOS Operations (Appendix to F3196)*; ASTM WK65041, *New Practice for UAS Remote ID and Tracking*; and ASTM WK63418, *New Specification for Service provided under UAS Traffic Management (UTM)*. Consider adapting SAE J2735_201603, *Dedicated Short Range Communications (DSRC) Message Set Dictionary* for UAS.

Priority: High

Organization(s): ASTM, SAE

8.5. Occupational Safety Requirements for UAS Operated in Workplace

In addition to meeting regulatory requirements related to operation of UAS, the occupational safety requirements are also critical in achieving the overall safety goals in the workplace environment, such as construction sites and other work areas and conditions.

The widespread use of UAS in the areas of agriculture, oil and gas, public safety, public administration, utilities, warehouses and construction, etc. has also created various safety issues and potential hazards contributing to the occupational safety and health of the workers. Such scenarios include the use of UAS in the construction industry ranging from aerial mapping of construction sites, site inspections, assisting in extending the actual building of structures, etc. Unstable flying conditions, human factors issues (from both aviation and occupational safety perspectives), operator and flight crew errors, inadequate pilot training, competency of pilots and flight crews, and faulty equipment may pose potential safety hazards to nearby workers from the use of UAS. Adding to that the uncertainty about the hazards to workers from the use of UAS in construction and other industries, as well as the arrival of autonomous or semi-autonomous (autonomous is explained in detail in Enterprise Operations: Level of Automation/ Autonomy/Artificial Intelligence (AI) section in WG1) UAS, may introduce new hazards to workplace health and safety, for example, in other use cases described in this chapter.

Published Standards and Documents

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 hazards and risks associated with the commercial use of UAS associated in both indoor and outdoor workplace environments. The presence of a UAS flying near workers can create new hazards at construction sites, although 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 perspectives (does not include occupational safety implications due to UAS operations)
- The following references provide UAS related information on injuries to workers:
  - the FAA and NTSB databases of injuries caused by UAS
  - the BLS Survey of Occupational Injuries and Illnesses (SOII) and the Census of Fatal Occupational Injuries (CFOI) modified to facilitate identification of injuries caused by UAS, 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), 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.

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.

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.

Priority: High

Organization(s): SAE, ASTM, ASSP, OSHA, NIOSH, ISO/TC 20/SC 16, etc.

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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.[38] A number of these use cases are explored in more detail later in this chapter. Standards have a role to play in helping first responders to take advantage of this emerging technology.

Published Standards: While there are many existing industry standards addressing the equipment used by public safety officials, as well as operational best practices, training, and professional qualifications, standardization specifically related to the use of drones by the public safety community is a fairly recent phenomenon. Published standards include:

- *Standards for Public Safety Small Unmanned Aircraft Systems Programs*, published by APSAC in October 2017
- NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations.* NFPA recently completed the development of this standard. The standard, begun in August 2016, covers organizational deployment, professional qualifications, and maintenance. It applies to all public safety departments with sUAS including fire service, law enforcement, and EMS. Additional information can be found in section 4.9 of this document.

In-Development Standards: 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 a JWG comprising experts in public safety and drone technology.[39] The group has been working to develop use cases for using drones in various public safety operations. It leverages 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. One work item in development that has gone to ballot is ASTM WK61764, *Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement*. See also roadmap section 10.3 on UAS Flight Crew.

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[38] Werner, Charles. "Public Safety Professionals Need Drones," Aircraft Owners and Pilots Association. June 25, 2018.
[39] "New Joint Effort Boosts Drone Standards for Public Safety Officials," ASTM News Releases. April 16, 2018.

Gap S1: Use of sUAS for Public Safety Operations. Standards are needed on the use of drones by the public safety community.

R&D Needed: No

Recommendation: With the recent 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.

Priority: High (Scoring: Criticality-3; Achievability-3; Scope-3; Effect-3)

Organization(s): NFPA, ASTM

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:

- 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)
- 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

In-Development Standards:

- ASTM WK61764, *New Guide for Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement*

Gap S2: Hazardous Materials Response and Transport Using a UAS. There are no known UAS standards addressing the transportation of known or suspected 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 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

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 an unmanned aircraft (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.

While 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.

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 Documents:

- AC-9M Cabin Air Measurement Committee
  - AS6923, Portable devices for measuring air contamination on aircraft
- AC-9 Aircraft Environmental Systems Committee
- AIR1168/1A, Thermodynamics of Incompressible and Compressible Fluid Flow
- AIR1168/3A, Aerothermodynamic Systems Engineering and Design
- 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
- ARP85G, Air Conditioning Systems for Subsonic Airplanes
- ARP89E, Aircraft Compartment Automatic Temperature Control Systems
- AS4073B, Air Cycle Air Conditioning Systems for Military Air Vehicles
- AS8040C, Heater, Aircraft Internal Combustion Heat Exchanger Type

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

Organization(s): UN, PHMSA, FAA, WHO, ICAO, DOD, DHS, CDC, USDA, NIH, NFPA, SAE

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."[40] 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.

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.[41]

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)

[40] Oklahoma v. Tyson Foods, Inc., 2009 U.S. Dist. LEXIS 112073 (N.D. Okla. Aug. 12, 2009)

[41] 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."

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:

- *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
- 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 GeoTIFF – currently an open but proprietary standard, GeoTIFF is presently being advanced in the OGC for adoption in mid-2019 as an OGC Standard.
- OGC is advancing best practices through its UxS DWG and through a series of ongoing interoperability pilot activities.

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): APSAC, ASPRS, OGC, NFPA, NIST, ASTM

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 appealing. 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 4 shows a diagram of the proposed architecture.

Figure 4: Public Safety UAS Architecture

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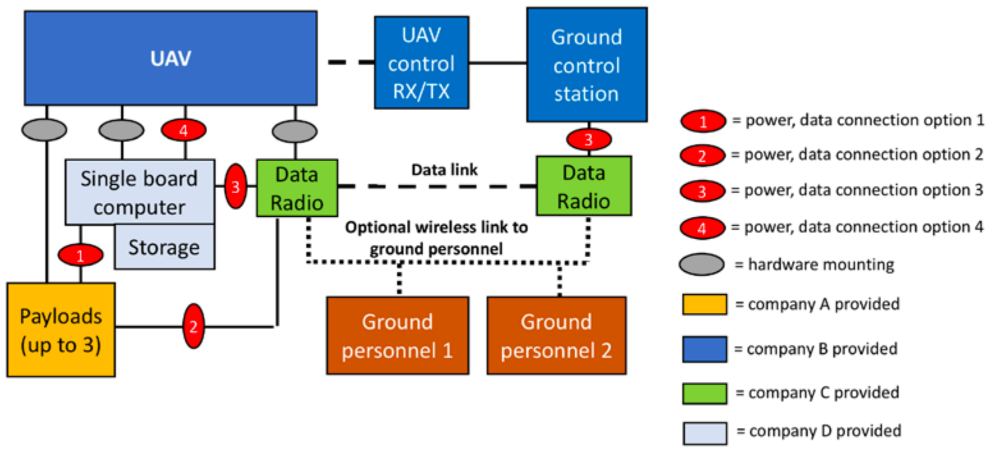

Published Standards: There are currently no published standards for UAS payloads in public safety operations. The FAA has used various mechanisms to encourage standards development, such as the designation of test sites across the country, pathfinder projects, and integration pilot programs (IPP) that 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, *Risk Mitigation Strategies for Package Delivery sUAS BVLOS Operations (Appendix to F3196)*.

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

Organization(s): ASTM, DOJ, NFPA, DHS, NIST

9.6. Search and Rescue (SAR)

9.6.1. sUAS FLIR Camera Sensor Capabilities

sUAS are becoming a primary tool for 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 imagery that would allow a person to accurately identify an individual in the frame.

There are several forward-looking infrared (FLIR) 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 operator. Additionally, these FLIR cameras may not have the necessary screen resolution and/or thermal resolution to accurately identify the intended subject. Public safety entities have purchased FLIR cameras only to determine that the FLIR capabilities will not allow them to fulfill the operational objective due to camera performance. Public safety FLIR cameras should include user controls for thermal resolution, radiometric measurement, temperature measurement, etc.

FLIR requirements for SAR missions differ from FLIR 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 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: No UAS standards in development have been identified.

Gap S6: sUAS Forward-Looking Infrared (FLIR) Camera Sensor Capabilities. No published or in-development UAS standards have been identified for FLIR camera sensor capabilities. A single standard could be developed to ensure FLIR 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 FLIR camera sensor sensitivity, radiometric capabilities, zoom, and clarity of imagery for identification of a person/object for use in public safety/SAR missions.

Recommendation: Develop a standard for FLIR camera sensor specifications for use in public safety and SAR missions.

Priority: Medium (Scoring: Criticality-2; Achievability-1; Scope-3; Effect-3)

Organization(s): NIST, NFPA, ASTM

9.6.2. sUAS Automated Waypoint Missions

UAS should provide automated flight modes, more specifically, waypoint missions. UAS C2 software should provide user level programming to select flight altitude, aircraft orientation, camera sensor orientation, sensor triggers, etc., and changes in all of the aforementioned attributes at any point during the mission. Each of these attributes should be pre-programmable by the user.

Wide-area SAR missions, whether air or ground, are normally conducted via a grid pattern. 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.

SAR missions over large bodies of water provide no geographical landmarks to ensure that search areas are not missed and/or repeated.

C2 software and UAS platforms that allow the RPIC and/or sensor operator to pre-program waypoints, sensor orientation, sensor trigger points, altitudes, etc., ensure that SAR missions are completed in the most timely and efficient manner, directly improving victim outcomes.

No published or in-development UAS standards 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).

Gap S7: Search and Rescue: Need for Command and Control Software Specifications for Automated Waypoint Missions. No published or in-development UAS standards have been identified for waypoint mission programming parameters for SAR missions. SAR missions are essentially the only public safety missions which require fully automated waypoint programming. While this C2 technology may be used during other missions, such as damage assessment (tornados, hurricanes, etc.), the primary use case is for SAR.

R&D Needed: No. Identification of C2 software specifications to complete automated waypoint missions can be used to write the standard.

Recommendation: Develop a standard for C2 software specifications to allow fully automated waypoint missions for SAR. See also the section of this document on the C2 link.

Priority: Medium (Scoring: Criticality-2; Achievability-1; Scope-3; Effect-3)

Organization(s): NIST, NFPA, ASTM

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 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*

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*

In addition, the NFPA is adopting the E54 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*.

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, NFPA, DHS

9.8. 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, 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 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 incident commander constant situational awareness.

Published Standards:

- *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.

- 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.

In-Development Standards: None identified

In the scenarios outlined above, APSAC and NFPA standards provide sufficient operational guidance for the use of sUAS, with no gaps identified. As for the regulatory environment, night operations and flights over people require waivers as do operations in certain classes of airspace. The law enforcement agency utilizing sUAS should seek those waivers as part of the sUAS program planning. However, there is one key operational requirement necessary for tactical operations that is not subject to waiver (as listed in Part 107.205), which is the requirement for anti-collision lights for civil twilight operations (and night operations if a waiver is granted). Given the need to operate in a covert fashion so the suspect(s) are not made aware that their actions are being monitored by sUAS, operating without anti-collision lights may be necessary. This may require a revision to Part 107.205 to include a waiver for anti-collision lights if and when a safety case can be made to support the waiver request. For agencies that have obtained a public aircraft certificate of authorization (COA), night operations and flights over people are authorized once the agency has obtained a jurisdictional COA. It is believed that covert operations are also authorized.

9.9. Counter-UAS (C-UAS)

Per the FAA Reauthorization Act of 2018, the term counter-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). The most popular interdiction technique is jamming. A lack of common standards in the C-UAS industry means that there is a wide variance in the effectiveness and reliability of systems.

No published standards have been identified. 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 such as DOD, DOE, DOJ, DOT FAA and DHS.

Gap S9: Counter-UAS/Drone (C-UAS) Operations. The following concerns exist:

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

Organization(s): DOD, DHS, DOJ, DOE, FCC, NTIA, FAA, SDOs, etc.

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 F44.91, General Aviation - Terminology	ASTM F3060-16a, *Standard Terminology for Aircraft*
JARUS WG6	*JARUS guidelines on SORA, Annex I, Glossary of Terms*

In-Development Standards:

Committee	Document
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK62416, *New Terminology for Unmanned Aircraft Systems*
IEEE CES/SC/DWG	IEEE P2025.1 *Standard for Consumer Drones: Taxonomy and Definitions*
ISO/TC 20/SC 16	ISO/CD 21895, *Categorization and classification of civil unmanned aircraft systems*

Gap P1: Terminology. 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: Complete work on terminology standards in development.

Priority: High

Organization(s): ASTM, IEEE, ISO, RTCA

10.2. Manuals

While ICAO has published recommendations, the FAA does not currently certify UAS operators, only remote pilots. 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 RPS and voice and data links that will meet the QoS appropriate for the airspace and the operation to be conducted.

Published Standards and Other Guidance Documents Include:

Organization/Committee	Document	Date
NPSTC	*Guidelines for Creating an Unmanned Aircraft System (UAS) Program (v2)*	2017
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM F2908-16, *Standard Specification for Aircraft Flight Manual (AFM) for a Small Unmanned Aircraft System (sUAS)*	2016
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 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*	

In-Development Standards:

Committee	Document
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK62743, *New Specification for Development of Maintenance Manual for Small UAS*
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 WK29229, *New Practice for Certification of Pilots, Visual Observers, and Instructor Pilots and Training courses for Small Unmanned Aircraft Systems (sUAS)*

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

Organization(s): ASTM, JARUS, NPTSC, NFPA

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., 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 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.

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
AUVSI Remote Pilots Council	Trusted Operator Program™ (TOP) training protocols for remote pilots and training organizations	
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
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

Professional Photographers of America (PPA)	PPA Certified Drone Photographer	2017

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 WK61764, *New Guide for Training for Public Safety Remote Pilot 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

Organization(s): SAE, ASTM, AUVSI, PPA

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.[42]

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 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*

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[42] It should be noted that FAA is looking at mission specific competency, not weight.

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**
AUVSI Remote Pilots Council	Trusted Operator Program™ (TOP) training protocols for remote pilots and training organizations	
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
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
Airborne Sensor Operators (ASO) Group	ASO Guide, Professional Standards	2018
Professional Photographers of America (PPA)	PPA Certified Drone Photographer	2017

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 WK61764, *New Guide for Training for Public Safety Remote Pilot of Unmanned Aircraft Systems (UAS) Endorsement*. The standard 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.
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK62741, *New Guide for Training UAS Visual Observers*
NFPA	NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*

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

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.

No published UAS standards have been identified. ASTM F38.03, UAS-Personnel Training, Qualification & Certification, has a standard in development: ASTM WK60659, *New Guide for UAS Maintenance Technician Qualification.*

Gap P5: UAS Maintenance Technicians. No published UAS standards have been identified for UAS maintenance technicians. However, 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

Organization(s): ASTM

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
AUVSI Remote Pilots Council	Trusted Operator ProgramTM (TOP) Protocol Certification Manual	
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
NFPA	NFPA® 2400, *Standard for Small Unmanned Aircraft Systems (sUAS) Used for Public Safety Operations*	2018

In-Development Standards:

Organization/Committee	Document
ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK62730, *New Practice for UAS Operator Audit Programs*

ASTM F38.03, UAS - Personnel Training, Qualification & Certification	ASTM WK62731, *New Practice for UAS Operator Compliance Audits*

Gap P6: Compliance and Audit Programs. 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: Complete work on compliance and audit program standards currently in development.

Priority: High

Organization(s): ASTM, AUVSI

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.[43] 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

[43] 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.

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.

Other human factors challenges that must be addressed for UAS to operate safely within civil airspace include:[44]

- **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

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[44] Adapted from Hobbs, A., & Lyall, B. (2016)

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 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.
- Hobbs, A. (2010). Unmanned aircraft systems. In E. Salas & D. Maurino (Eds.), *Human factors in aviation* (2nd ed., pp. 505–531). San Diego, CA: Elsevier.
- Kaliardos, B., & Lyall, B. (2014). Human factors of unmanned aircraft system integration in the national airspace system. In K. P. Valavanis & G. J. Vachtsevanos (Eds.), *Handbook of unmanned aerial vehicles* (pp. 2135–2158). Dordrecht, Netherlands: Springer.
- McCarley, J. & Wickens, C. (2005). Human factors concerns in UAV flight. Institute of Aviation, Aviation Human Factors Division, University of Illinois at Urbana-Champaign. Also available on the FAA website.

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.[45] 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.

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

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 GCS. 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:[46]
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

[46] Ibid

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

Organization(s): RTCA, NASA, others?

Gap P8: Flight Control Automation and System Failures.[47] 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 GCS. 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:[48]

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[47] Adapted from McCarley, J. & Wickens, C. (2005): p3
[48] 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

Organization(s): RTCA, others?

Gap P9: Crew Composition, Selection, and Training.[49] 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.

R&D Needed: Yes

Recommendation:

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

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:[50]

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

Organization(s): RTCA, NFPA, MITRE, NASA, ICAO others?

[50] Ibid

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11. Next Steps

It is essential that this roadmap be widely promoted 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.

Depending upon the realities of the standards environment, the needs of stakeholders, and available resources, it is envisioned that this roadmap may be updated in the future. Ultimately, the aim of such an effort would be to provide a means to continue to guide, coordinate, and enhance standardization activity and 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
APSAC – Airborne Public Safety Accreditation Commission
ARC – Aviation Rulemaking Committee
ASME – American Society of Mechanical Engineers
ASSP – American Society of Safety Professionals
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
FERC – Federal Energy Regulatory Commission
FLIR – forward-looking infrared
GCS – ground control station
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
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
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.
USS – UAS service provider
UTM – UAS traffic management
UxS – unmanned systems
VLL – very low-level
VLOS – visual line of sight
VTOL – vertical take-off and landing
WG – working group

PROJECT LEADERSHIP

The **American National Standards Institute** (ANSI) is a private non-profit organization whose mission is to enhance U.S. global competitiveness and the American quality of life by promoting, facilitating, and safeguarding the integrity of the voluntary standardization and conformity assessment system. Its membership is comprised of businesses, professional societies and trade associations, standards developers, government agencies, and consumer and labor organizations. The Institute represents and serves the diverse interests of more than 270,000 companies and organizations and 30 million professionals worldwide. ANSI is the official U.S. representative to the International Organization for Standardization (ISO) and, via the U.S. National Committee, the International Electrotechnical Commission (IEC).

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The **National Fire Protection Association** (NFPA) is a global nonprofit organization, established in 1896, devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. Part of working towards this goal includes supportive efforts in emerging technologies for first responders. The use of UAS in the responder industry is a new and growing technology that will greatly benefit many operations and contribute to a safer response.

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"The importance of establishing a framework for the development of Unmanned Aircraft System standards cannot be overstated. The need for a coordinated approach addressing performance, safety, testing and training for UAS systems and operators is critical to the Department of Homeland Security and Homeland Security Enterprise operations, and for numerous other use cases. Standards and the related policy and guidance will enhance the safe and effective integration of this rapidly evolving capability into operations. We look forward to continue working with ANSI and other standards organizations supporting the coordinated development and use of UAS standards in support of the homeland security mission."

Philip Mattson, Standards Executive, Department of Homeland Security

"Voluntary consensus standards created by the world's top UAS experts and leaders are laying the groundwork for smooth and safe integration of drones into our airspace. Standardizing the array of technical and operational considerations – design, performance, safety, operator training, and much more – is crucial to this industry's future. We must get it right, and organizations like ASTM International are leading the way by bringing hundreds of stakeholders together on a regular basis."

Philip Kenul, Chairman, Unmanned Aircraft Systems Committee (F38), ASTM International

"The first responder aspect of the UAS industry is a small portion yet its impact on safety is an important one. Clear, concise standards help set the operational tone for responder agencies. That tone must include safety. Having a team of subject matter experts with diverse backgrounds working together on a consensus driven process makes for quality standards. As we look to integrate UAS into the national airspace, we must have strong guidelines from which to develop our operational plans. The UASSC Roadmap process has risen to that challenge and will become the guiding light for safe aviation protocols."

Jim Pauley, President and CEO, National Fire Protection Association

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