SAE AS6171:
Overview and Status Update
for ANSI Microelectronics Standards Briefings

Michael H. Azarian, Ph.D.
SAE G-19A Committee Chair
mazarian@umd.edu
Center for Advanced Life Cycle Engineering (CALCE)
University of Maryland
College Park, MD

Outline

- What is AS6171?
- What makes AS6171 unique among standards?
- What does the standard consist of?
- How does it work?
- What is the current status of AS6171?
- What should we expect in the future?
- Conclusions

AS6171: Test Methods Standard

- AS6171 was created to standardize practices for *testing* in order to mitigate the risks of receiving or using suspect/counterfeit Electrical, Electronic, or Electromechanical (EEE) parts.

AEROSPACE STANDARD	AS6171™	REV. A
	Issued 2016-10 Revised 2018-04 Superseding AS6171	
Test Methods Standard; General Requirements, Suspect/Counterfeit, Electrical, Electronic, and Electromechanical Parts		

RATIONALE

This standard provides uniform general requirements, practices, and methods for testing Electrical, Electronic, and Electromechanical (EEE) parts to mitigate the risks of receiving or using Suspect/Counterfeit (SC) EEE parts. It is intended to be used in conjunction with individual AS6171 slash sheets that provide detailed requirements for testing as well as methods for calculation of counterfeit defect and counterfeit type coverages by a sequence of tests.

This revision incorporates a limited number of changes intended to correct typographical errors in the original version, to clarify certain terms used in AS6171, to clarify accreditation requirements, and to clarify the methods that may be used to quantify counterfeit defect and counterfeit type coverages by a sequence of tests.

AS6171: Test Methods Standard

- The requirements apply to any laboratory performing testing to detect counterfeit parts, including independent as well as in-house testing facilities (e.g., distributors or OEMs)
- Flow down of AS6171 requirements by OEMs, Integrators, and End-Users ensures consistency of test techniques and requirements across the supply chain.

Uniqueness of AS6171

- AS6171 is unique among standards in these respects:
  - The **supply chain and the criticality of the application (risk)** determines the amount and type of testing that must be performed.
  - The **coverage of counterfeit defects** is quantified and used to identify a test set appropriate to the level of risk.
  - The suitability of a test laboratory for performing the tests is based on their **accreditation** by a third party accreditation body to ensure adequacy and consistency of *personnel training, methods, equipment, interpretation of results, and reporting.*
  - It contains requirements for **statistical sampling** of parts from a lot.
  - It contains a **wider array of test methods**, providing enhanced ability to detect well-made counterfeit parts and meet future challenges.

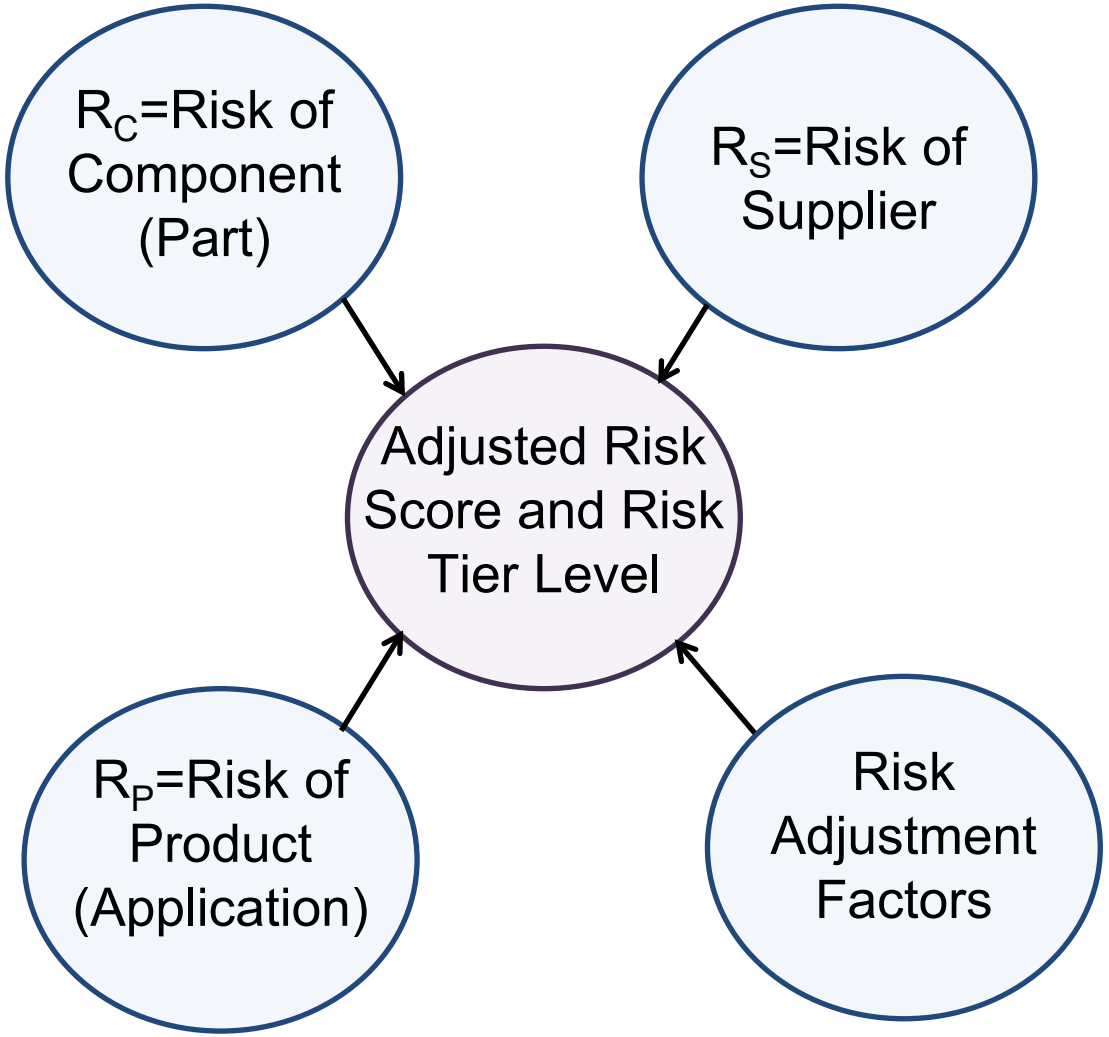
Risk-Based Testing

- The DFARS[1] requires "*Risk-based policies and procedures for counterfeit part detection and avoidance.*"
- DOD Instruction 4140.671[2] explains risk-based testing:
  - *anti-counterfeiting measures are required to balance the risk represented by counterfeit goods against the impact to readiness and cost of the measures.*
- AS6171 implements a risk-based approach to counterfeit part detection, and is unique among standards in doing this.

1 Defense Federal Acquisition Regulation Supplement, Clause 48 CFR 252.246-7007, Contractor Counterfeit Electronic Part Detection and Avoidance System, issued August 30, 2016.
2 DOD Instruction 4140.67, "Counterfeit Prevention," Enclosure 2, section 8d, Apr. 26, 2013.

Factors Used to Calculate Risk

Worst-case effect on product function if the component fails

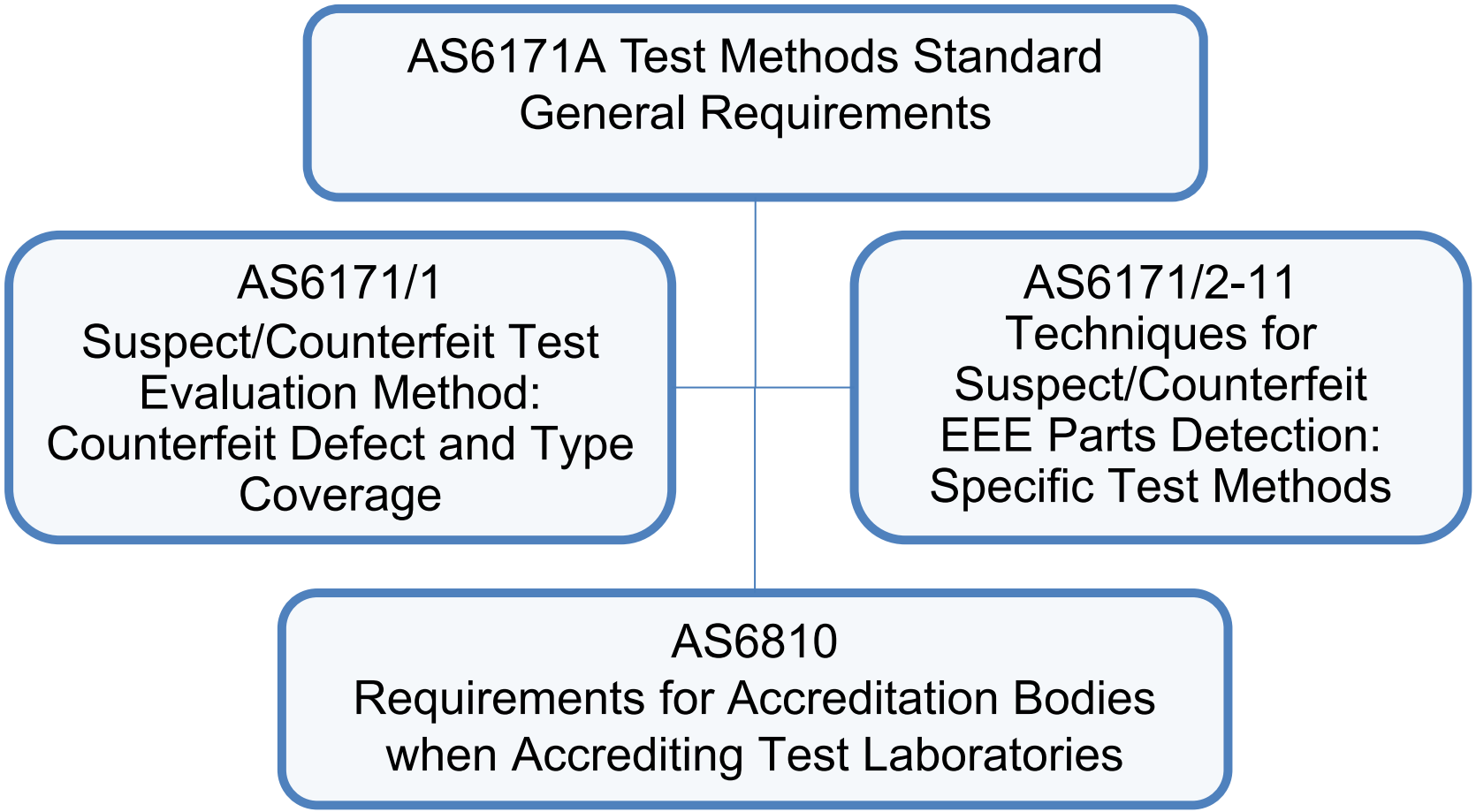


Risk that part is counterfeit

Worst-case effect of product failure

Part availability and prior problem reports

Organization of SAE AS6171



Counterfeit EEE Part Types Covered in AS6171

- Counterfeit Electrical, Electronic, or Electromechanical (EEE) parts may be reclaimed from e-waste, product overruns, modified authentic parts, or copies.
- Note: Tampered parts are not addressed in the current release of AS6171, but will be included in future releases

Recycled
Remarked
Overproduced
Out-of-spec/Defective
Forged Documentation
Cloned
Tampered

Test Methods Covered in the Slash Sheets

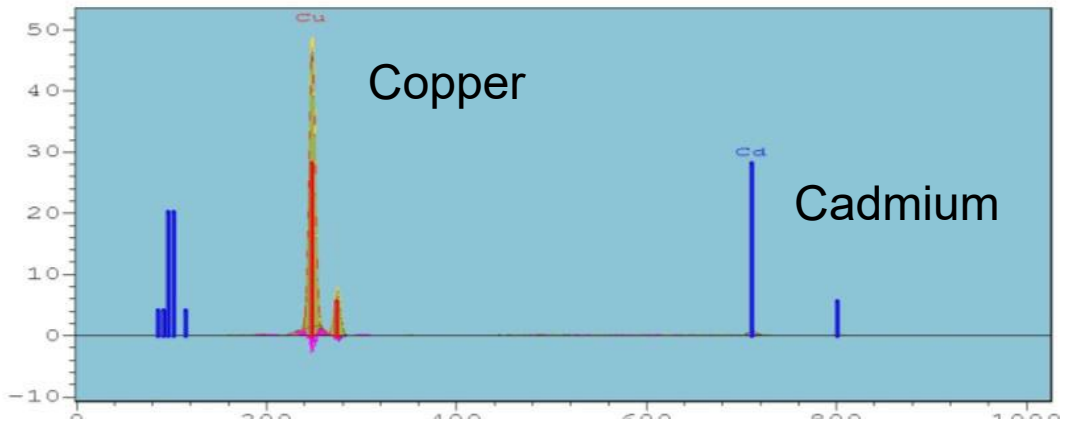
- **AS6171/2: External Visual Inspection** (EVI): incl. remarking, resurfacing, weight, dimensions, SEM
- **AS6171/3: X-Ray Fluorescence** (XRF): incl. lead finish, thickness
- **AS6171/4: Delid/Decapsulation Physical Analysis** (DDPA)
- **AS6171/5: Radiological Inspection** (RI): X-ray imaging
- **AS6171/6: Acoustic Microscopy** (AM): external and internal
- **AS6171/7: Electrical Test**: Curve Trace, Full DC, Key Electrical Parameters for AC, Switching, and Functional Tests; incl. environmental, burn-in, seal test
- **AS6171/8: Raman Spectroscopy**: materials identification
- **AS6171/9: Fourier Transform Infrared Spectroscopy** (FTIR): materials identification
- **AS6171/10: Thermogravimetric Analysis** (TGA): material analysis
- **AS6171/11: Design Recovery** (DR): device layout and function

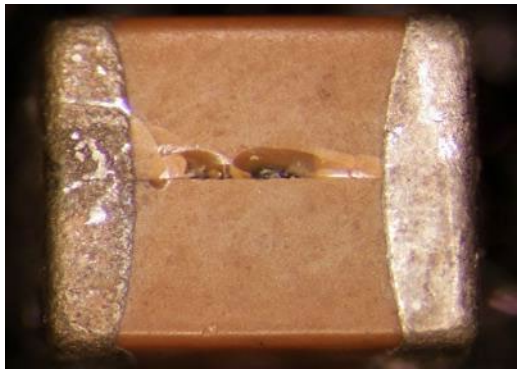
Each Test Method Slash Sheet Includes . . .

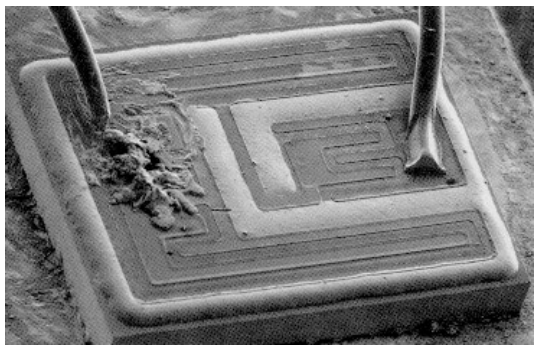
- Procedures associated with one or more test methods
- Apparatus and materials needed for the test method(s)
- Laboratory accreditation requirements
- Training requirements for laboratory personnel performing testing or analysis
- Requirements for reporting

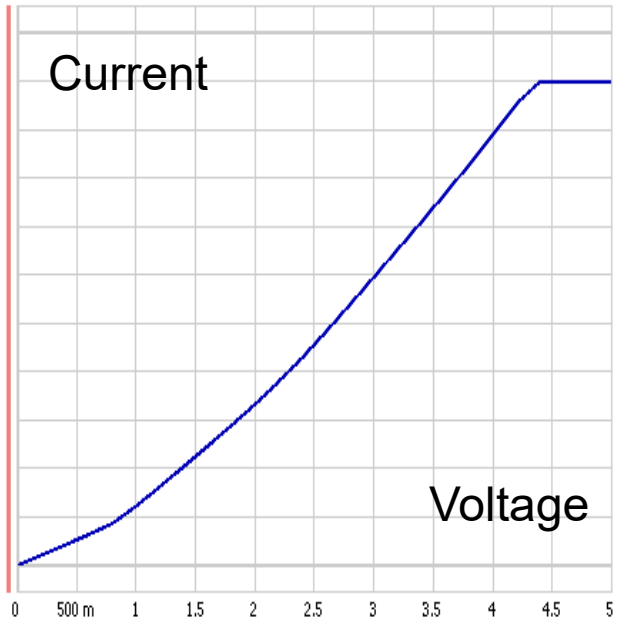
Counterfeit Defects

- AS6171/1 lists 69 different counterfeit defects, which are objective indicators of potential counterfeiting.
- They include such features as damaged terminations, ghost markings, missing or broken bond wires, incorrect materials, and out-of-specification electrical parameters.









CDC: Metrics for Risk-Based Testing

- Counterfeit Defect Coverage (CDC): average confidence of detection across all defects relevant to a particular type of EEE part.
- Not-Covered Defects (NCD): defects that are not detected by the test plan.
- Under-Covered Defects (UCD): defects whose confidence of detection is below the target.

Risk Tier Level
Critical
High
Moderate
Low
Very Low

AS6171 matches the test plan to the level of risk associated with the part.
The plan's effectiveness is quantified by CDC metrics.

Sample Test Set for Moderate Risk

Applies to Complex Active Parts (Model 2)

Serves as the *default test set* when information concerning risk is not available

Test #	Test Method
1	EVI, General (Full Lot)
2	EVI, Detailed (Sample)
3	EVI, Remarking
4	EVI, Resurfacing
5	EVI, Part Dimensions
7	XRF, Lead Finish Analysis
9	XRF, Material Composition
10	DDPA, Internal Inspection
13	Radiological, 2D
19	Electrical, DC Test at ambient temp.

Moderate Risk Target Confidence: 65%

General Procedure for Implementation

- Parts are supplied by Requester to **Responsible Test Laboratory (RTL)**
- RTL verifies Test Requirements with Requester based on **Risk Level**, and reviews available documentation (incl. problem reports)
- RTL performs EVI testing, and extracts **samples** for remaining tests
- RTL, or a lab that they sub-contract, performs **remaining tests** according to the Test Requirements
- RTL compiles all results and conclusions into a single consolidated **Test Report** and provides this to the Requester
- RTL issues a **Certificate of Quality Conformance (CoQC)**
- RTL follows **Data Management and Material Control** requirements

Responsible Test Laboratory (RTL)

- Laboratories must be accredited per ISO/IEC17025 and AS6171
  - The accreditation requirement may reduce the need for vendor audits.
- Can be an in-house or an outside test facility
- May subcontract for further required testing, with the exception of External Visual Inspection (EVI)
  - But each test shall be performed by ISO17025 and AS6171 accredited laboratories
- Compiles and consolidates all data and reports
- Provides final conclusion and CoQC based on all the results

AS6171 Standards Undergoing Revision

- **AS6171A: General Requirements**

  changing accreditation requirements for subcontracted labs, modifying sampling plan, adding assemblies and tampered parts plus new test methods
- **AS6171/1: Suspect/Counterfeit Test Evaluation Method**

  removing counterfeit type coverage metric
- **AS6171/2A: External Visual Inspection (EVI)**

  removing SEM; adding more images
- **AS6171/4: Delid/Decapsulation Physical Analysis (DDPA)**

  adding cross-sectional analysis
- **AS6171/6: Acoustic Microscopy (AM)**

  including more part types
- **AS6171/11: Design Recovery (DR)**

  expanding to include electronic design recovery as input for Netlist Assurance

AS6171 Standards Recently Reaffirmed

- AS6171/3 (X-ray Fluorescence (XRF) Test Methods)
- AS6171/5 (Radiological Test Methods)
- AS6171/7 (Electrical Test Methods)
- AS6171/8 (Raman Spectroscopy Test Methods)
- AS6171/9 (Fourier Transform Infrared Spectroscopy (FTIR) Test Methods)
- AS6171/10 (Thermogravimetric Analysis (TGA) Test Methods)

New Test Methods Under Development

AS6171/13	Secondary Ion Mass Spectroscopy (**SIMS**) Test Method
AS6171/15	**Packaging** Test Methods
AS6171/16	**Netlist Assurance** Test Methods
AS6171/17	Laser Scanning Microscopy (**LSM**) Test Methods
AS6171/20	X-Ray Photoelectron Spectroscopy (**XPS**) Test Method

AS6171/22	Technique for Suspect/Counterfeit EEE Parts Detection by Scanning Electron Microscopy (**SEM**) including Energy Dispersive X-Ray Spectroscopy Test Methods
AS6171/23	Techniques for Suspect/Counterfeit EEE **Assembly** Detection by Various Test Methods

Tampered Parts

- Tampered parts are a category of counterfeit part, in which the part has been deliberately altered to perform a surreptitious function or to deviate from its expected performance.
- The deviation of the part from its expected behavior may be programmed to occur upon some trigger condition, potentially allowing targeted sabotage or unauthorized signal transmission.
- Possible effects:
  - Change of functionality, potentially allowing targeted sabotage or defeat of security measures
  - Accelerated aging or failure, or
  - Unauthorized signal transmission.
- The G-19A committee has a sub-group dedicated to development of test methods for tampered parts.
- A method specifically addressing tampered parts that is currently under development is Netlist Assurance.

Hardware Trojans: Challenges and Threats

- Vulnerabilities can be introduced at various stages of development (e.g., register-transfer level (RTL), netlist, layout);
  - can be as subtle as modified dopant levels or thinned interconnects
- Can be introduced anywhere within supply chain:
  - 3rd party IP provider, system-on-chip integrator, foundry, distribution
- Must be able to pass all the usual manufacturing tests
  - Typical functional testing, fault testing, and superficial structural analysis not useful
- Tampered parts could be otherwise authentic, or they could be clones
  - Cloned devices require substantial resources to be effective (e.g., Nation-state engaged in cyber-warfare)

Defects Taxonomy for Tampered Parts: Proposed in SAE G19A Committee

T1	Unintended Communication
T2	Unexpected or Altered Netlist
T3	Exploitable Test Feature
T4	Unexpected Test Sequence Outcome
T5	Die Level Hardware Modification
T6	Unexpected Software Function and/or Performance
T7	Unexpected Software Code
T8	Unexpected Firmware Operation
T9	Unexpected Security Vulnerability
T10	Unexpected Emission or Signature

Unexpected Emissions (T10)

Examples of emissions or signatures include but are not limited to:

1. Electromagnetic Radiation
2. Conducted Radio Waves Frequency
3. Magnetic Characteristics
4. Power Behavior
5. Thermal Profile

- These are the basis for side channel attacks, and for detection methods using side channels (“second order effects”)

Test Methods for Tampered Parts in G-19A

- The G-19A's tampered sub-group is working on:
  - Netlist Assurance
  - Digital Content Assurance (proposed)
- Design Recovery (AS6171/11) is undergoing revision for improved applicability to this part type and for use in conjunction with Netlist Assurance
- Existing and in-development AS6171 test methods (e.g., DDPA, Electrical Testing (incl. burn-in), SIMS)
- Other methods for detection include those based on second order effects; e.g., involving emissions or power consumption

Netlist Assurance (AS6171/16)

- Examines hardware netlists recovered from physical components
- Assesses an implemented digital design netlist in a microcircuit for undesired device behavior
- Includes four approaches based on analysis of information flow and functional behavior to detect stealthy circuits and deviations from expected design

Possible Future Test Methods

- Checksum Assurance (may be integrated into Electrical Test Method)
- Auger Electron Spectroscopy (AES) Test Method
- Gas Chromatography/Mass Spectrometry (GC/MS) Test Methods
- Thermomechanical Analysis (TMA) Test Methods
- Side Channel Methods?

Future Directions and Needs for Risk-Based Counterfeit Detection

- Increased adoption and use of AS6171 by government and industry
- Accreditation of more test laboratories, especially RTLs
- Improved methods for quantifying risk
- Unbiased data on effectiveness of tests for counterfeit parts of varying types and levels of workmanship
- Greater involvement by government and industry in standards development

Conclusions

- AS6171 provides a method for a **risk-based selection** of a sequence of counterfeit detection tests.
  - It also provides **metrics** that quantify the effectiveness of a test set in detecting counterfeit EEE parts.
- The flexibility in selecting various combinations of tests to achieve a target CDC allows for **optimization** based on equipment availability, part construction, expected use, and likely failure modes and mechanisms.

➢ **Standardization of testing will increase the confidence of counterfeit detection.**

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