National Aeronautics and
Space Administration

Certification: From the Outside Looking In

AIAA Transformational Flight Certification Symposium

4 August 2021

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NASA Langley Research Center

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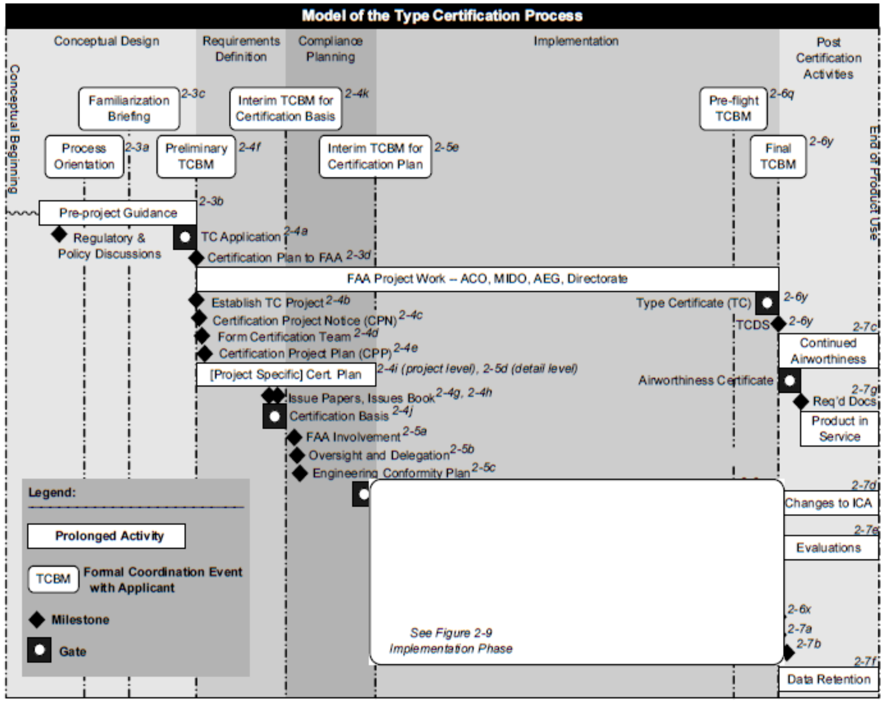
Introduction

- What do you think of when you hear "certification"?
  - Credentialing – people, things
  - Self-serving bureaucracy or something else to be endured
  - A service to applicants and the public
- How does it impact you?
  - As a regulator or applicant
  - As anything else



United States Department of Transportation, Federal Aviation Administration

United States Department of Transportation, Federal Aviation Administration

United States Army

A Random Walk Down Certification Street

- As an aerospace professional, certification and associated regulations impact you directly and indirectly
  - Direct impact can be straightforward – you are an applicant or a regulator
    - Can still have challenges, particularly if you are a new to the domain or returning after a long hiatus
  - Indirect impact is more challenging, but very important, to characterize
    - If you are developing a new technology, certification can impact implementation, access, safety, performance, integration, operation, cost, schedule, …
- I use my story to illustrate how my understanding of certification has evolved and impacted my work efforts and products

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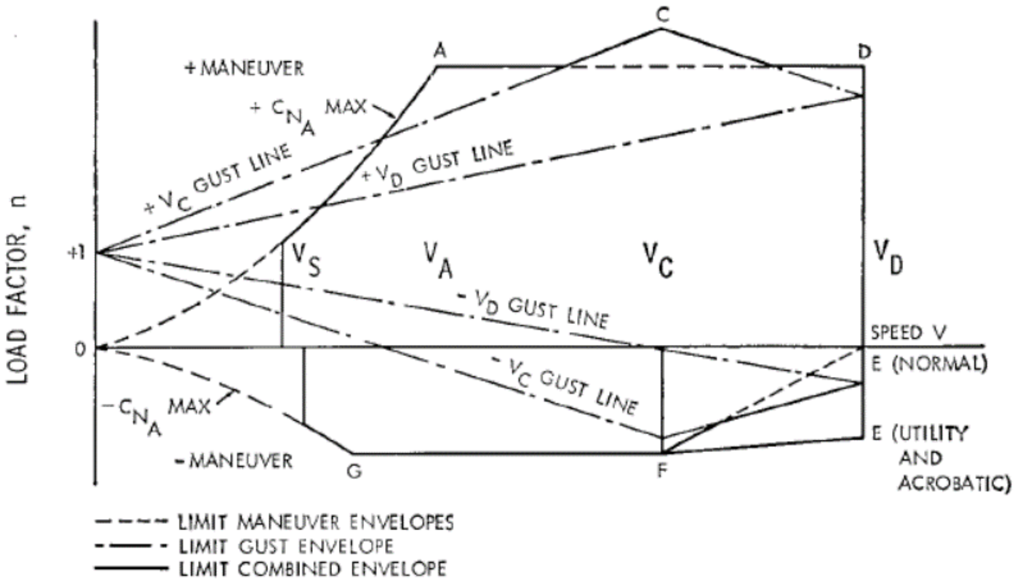
Certification as a Design Constraint

- Engineering classroom exercises largely considered regulations as a constraint to be satisfied
- Like other requirements, these were generally fixed – the goal was to create an optimum design that meets requirements
- Is capability a mission or an envelope?
- Consider focusing on impact of requirements to best designs, rather than solution in statically constrained space
  - Growth potential – what is next in the family of solutions?
  - Is the requirement articulated correctly? Does it make sense? Do you want to propose an alternative?



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United States Navy

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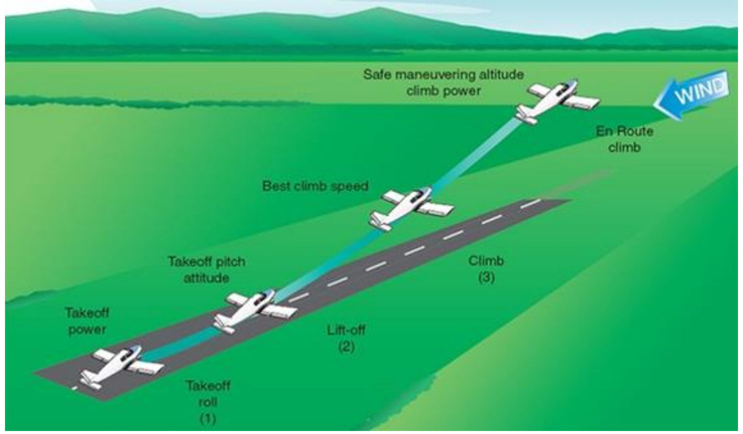
Operational Impacts on Design and Performance

- Pilot certification has been an eye-opening experience that has crossed over into aircraft design and performance disciplines
- Operating rules, control paradigms, and actual conditions have a huge impact on performance metrics
- Reserves and margin – not just what is required, but what is comfortable
- Think about what people may try to do, not just what you want it to do
- Fault detection, isolation, and recovery – can the flight crew do it? Can a machine?



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United States Department of Defense


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Reliability and Fault-Tolerance

- Work with high-reliability system architectures for space and air systems provided valuable lessons associated with reliability and operational responses to failure
- Reliability ≠ failure rate
- Integrated approach needed to capture cross-system interactions
- Better failure rates or better architectures?
  - Corollary: is it okay to operate with failed components?
- Design for margin and keep it

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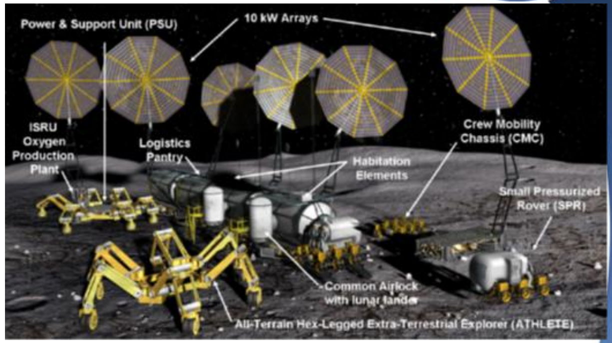

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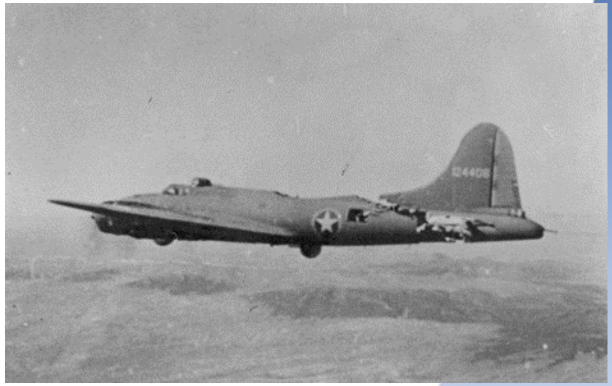

United States Air Force

AIRCRAFT: (Insert aircraft make and model)					TABLE KEY 1. REPAIR CATEGORY 2. NO. INSTALLED 3. NO. REQUIRED FOR DISPATCH 4. REMARKS OR EXCEPTIONS	
34. Navigation						
Sequence No.	**Item**	**1**	**2**	**3**	**4**	**Change Bar**
-43-1	Weather Radar System	C	2	0	(O) May be inoperative provided: a) Weather radar is not required by 14 CFR, and b) Reactive wind shear alert (GPWS Mode 7) operates normally.	

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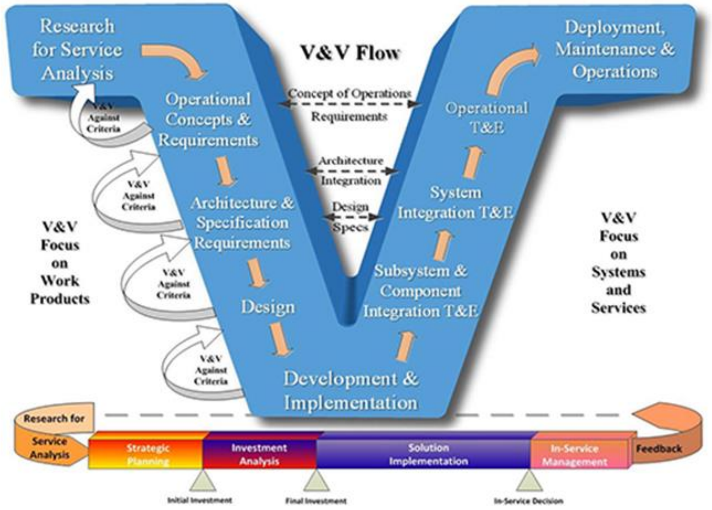
Data Drives Standards

- Consensus standards play an increasingly critical role in certification
- Balance of roles in consensus organization necessary for continuous improvement
  - Regulators clarify intent of rules
  - Producers look to increase throughput
  - Researchers, startups can push new ideas and provide data on new approaches
- Successful standards should be grounded in principles and data as necessary
  - Reports, databases from decades ago still useful
  - Publish!



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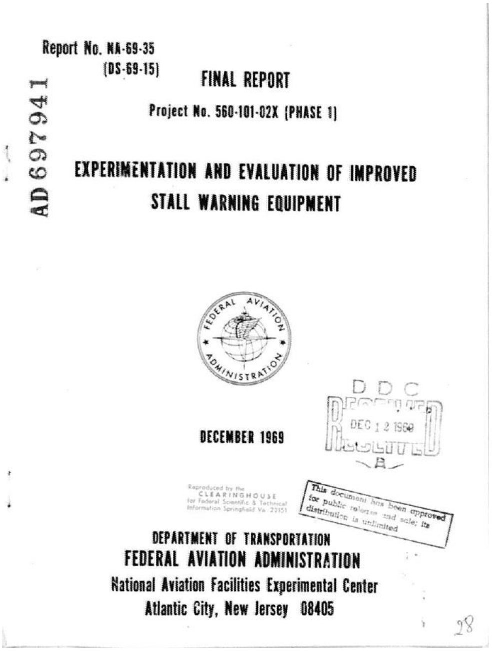

Report No. NA-69-35
(DS-69-15)

AD 697941

FINAL REPORT

Project No. 560-101-02X (PHASE 1)

EXPERIMENTATION AND EVALUATION OF IMPROVED STALL WARNING EQUIPMENT

DECEMBER 1969

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DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

United States Department of Transportation, Federal Aviation Administration

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Opportunity: Model-Based Certification Management

- The certification approach as it exists today is managed as a document-based process
- A shift to *model-based* processes can help retain the best features of performance-based rules, but eliminate the challenges associated with numbering changes, multiple cross-references, etc.
  - Initially seems like as a database exercise – document language is coded with metadata to enable linking, searching, sorting, etc.
  - Once implemented, opens numerous possibilities for certification plan management
- Standards developed as models instead of documents

history shows, may occur within the structural design envelope.

(c) Inertial properties including weight, center of gravity, and mass moments of inertia, accounting for—

(1) Each critical weight from the airplane empty weight to the maximum weight; and

(2) The weight and distribution of occupants, payload, and fuel.

(d) Characteristics of airplane control systems, including range of motion and tolerances for control surfaces, high lift devices, or other moveable surfaces.

(e) Each critical altitude up to the maximum altitude.

§ 23.2205 Interaction of systems and structures.

For airplanes equipped with systems that modify structural performance, alleviate the impact of this subpart's requirements, or provide a means of compliance with this subpart, the applicant must account for the influence and failure of these systems when showing compliance with the requirements of this subpart.

Structural Loads

§ 23.2210 Structural design loads.

(a) The applicant must:

(1) Determine the applicable structural design loads resulting from likely externally or internally applied pressures, forces, or moments that ma occur in flight, ground and water operations, ground and water handlin and while the airplane is parked or moored.

(2) Determine the loads required by paragraph (a)(1) of this section at all critical combinations of parameters, o and within the boundaries of the structural design envelope.

(b) The magnitude and distribution the applicable structural design loads required by this section must be base on physical principles.

§ 23.2215 Flight load conditions.

The applicant must determine the structural design loads resulting from the following flight conditions:

(a) Atmospheric gusts where the magnitude and gradient of these gusts are based on measured gust statistics.

(b) Symmetric and asymmetric maneuvers.

(c) Asymmetric thrust resulting fro the failure of a powerplant unit.

§ 23.2220 Ground and water load conditions.

The applicant must determine the structural design loads resulting from taxi, takeoff, landing, and handling conditions on the applicable surface i normal and adverse attitudes and configurations.

§ 23.2225 Component loading conditions.

The applicant must determine the structural design loads acting on:

(a) Each engine mount and its supporting structure such that both are designed to withstand loads resulting from—

(1) Powerplant operation combined with flight gust and maneuver loads; and

(2) For non-reciprocating powerplants, sudden powerplant stoppage.

(b) Each flight control and high-lift surface, their associated system and supporting structure resulting from—

(1) The inertia of each surface and mass balance attachment;

(2) Flight gusts and maneuvers;

(3) Pilot or automated system inputs;

(4) System induced conditions, including jamming and friction; and

(5) Taxi, takeoff, and landing operations on the applicable surface, including downwind taxi and gusts occurring on the applicable surface.

other procedures developed under this section must be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by § 23.1529.

(b) For Level 4 airplanes, the procedures developed for compliance with paragraph (a) of this section must be capable of detecting structural damage before the damage could result in structural failure.

(c) For pressurized airplanes:

(1) The airplane must be capable of continued safe flight and landing following a sudden release of cabin pressure, including sudden releases caused by door and window failures.

(2) For airplanes with maximum operating altitude greater than 41,000 feet, the procedures developed for compliance with paragraph (a) of this section must be capable of detecting damage to the pressurized cabin structure before the damage could result in rapid decompression that would result in serious or fatal injuries.

(d) The airplane must be designed to

United States Government Printing Office

Part 23 Rule		Accepted MOC[1]		Potential Supplemental MOC[2]
Section	Title	ASTM Standard	FAA Changes	and additional notes
23.2205	Interaction of systems and structures	*None*	*N/A*	ASTM standards do not contain means for showing compliance to §23.2205. If applying for certification of an airplane that requires compliance with §23.2205, applicants must use an MOC accepted by the Administrator in accordance with 14 CFR 23.2010. ASTM Committee F44 is developing standards for showing compliance to §23.2205.
23.2210	Structural design loads	F3264-17, Section 6.3	None	
23.2215	Flight load conditions	F3264-17, Section 6.4	Replace: ASTM F3116/F3116M-15, Section 4.1.4 With: FAA 4.1.4 "Appendix X1 through appendix X4 provide, within the limitations specified within the appendix, a simplified means of compliance with several of the requirements set forth in 4.2 to 4.26 and 7.1 to 7.9 that can be applied as one (but not the only) means to comply. If the simplified methods in appendix X1 through appendix X3 are used, they must be used together in their entirety." Replace: ASTM F3116/F3116M-15, Section 4.10.1.1 With: FAA 4.10.1.1 "In condition A, assume 100% of the semispan wing airload acts on one side of the airplane and 75% of this load acts on the other side. For airplanes with maximum weight of	ASTM F3264-17 does not include means for showing that mass balance weights are designed for appropriate loads. If applying for certification of an airplane with flight control surfaces incorporating mass balance weights, applicants may use the provisions of §23.659 at amendment 23-63 as a means of complying with this aspect of §23.2215, or may obtain FAA acceptance of a different means of compliance in accordance with §23.2010.

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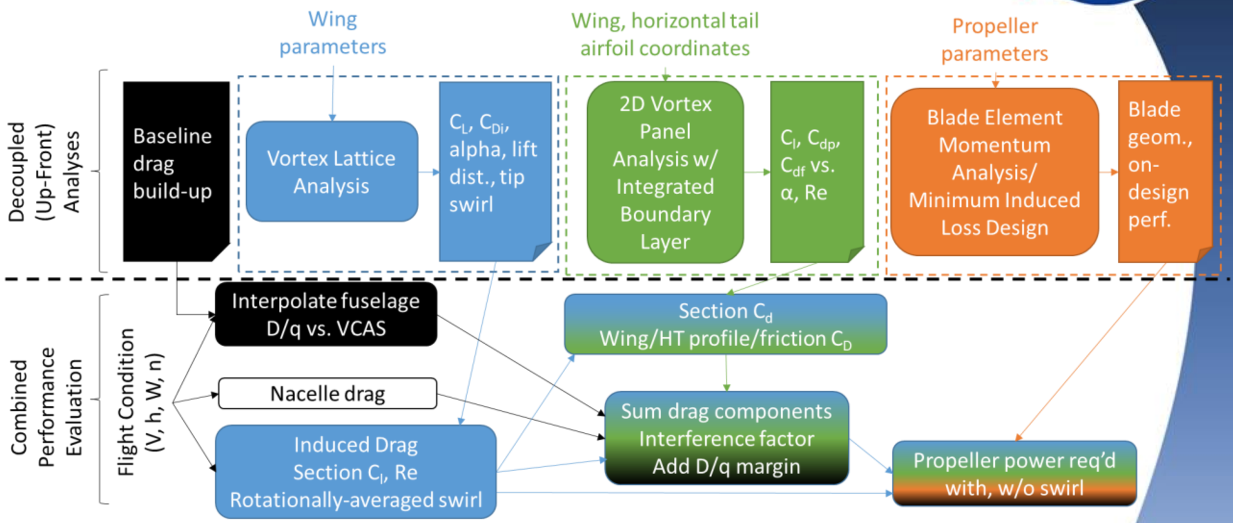
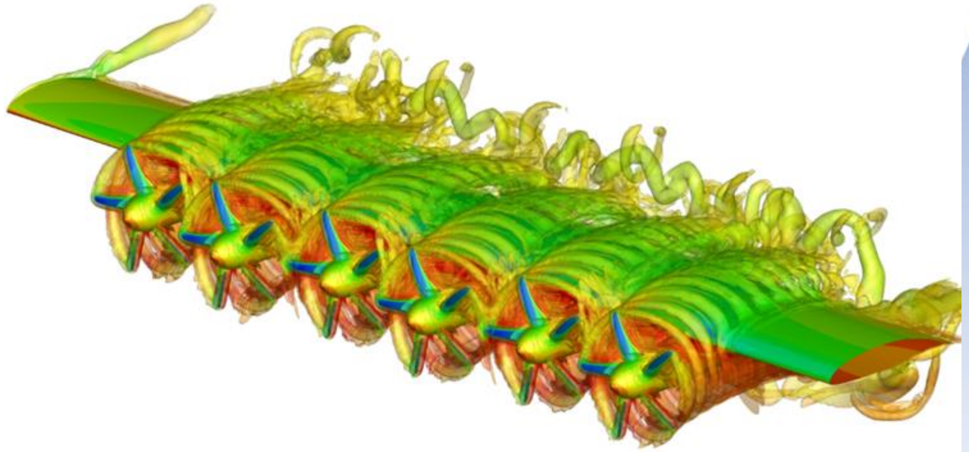
Opportunity: Model-Based Compliance

- Proliferation of increasingly sophisticated computational models used to develop systems
- Integrated models and data systems, properly maintained and updated, provide a "digital thread" that can be used for compliance
  - The model manages architecture, performance information, test data, safety analyses, etc.
  - Compliance artifacts can be exported as documents from the model, or eventually could be the model itself
  - Applications for continued airworthiness, retrofit, data retention during sales & mergers…





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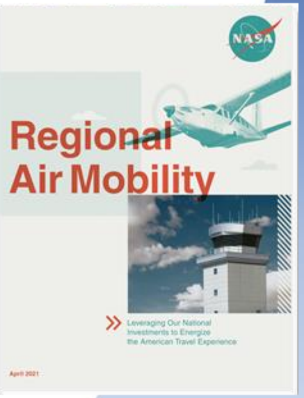
Opportunity: Advanced Air Mobility

- Advances in electrified propulsion, communications, automation, and autonomy, along with changes in regulations, have catalyzed development of advanced aircraft at smaller scales
  - Electric vertical takeoff and landing for dense urban operations
  - Electrified aircraft for more affordable regional operations, access to network of regional airports
- Recent pandemic has also seen a dramatic change in air cargo market
  - Logical adoption pathway for uninhabited aircraft operations



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Opportunity: Safety-Enhancing Features

- Regulators have provided updated pathways to bring safety-enhancing features onboard aircraft
  - Non-required safety enhancing equipment (NORSEE) policy allows for streamlined process to retrofit aircraft with such equipment
  - Use of safety-enhancing equipment encouraged by recent FAA airworthiness rulemaking and ASTM standards for low-speed flight characteristics
  - Automatic contingency systems approved by regulators
- Changes to system-level verification of avionics hardware and software to include more flexible approach

U.S. Department of Transportation
Federal Aviation Administration

Policy Statement

Subject: Approval of Non-Required Safety Enhancing Equipment (NORSEE)

Date: 03/31/16

Initiated By: A.V AIR-100

Policy No: PS-AIR-21.8-1602

Summary

This policy statement addresses equipment that is not required by any Federal regulation with the intent to measurably increase aircraft safety. Section 1 provides guidance and procedures for issuing a design, and production approval to a U.S. manufacturer pursuant to Title 14 of the Code of Federal Regulations (14 CFR) 21.8(d), "Approval of articles", for equipment designated as "Non-Required Safety Enchancing Equipment" (NORSEE) that is determined to be a minor change to type design and whose failure condition is minor. Section 2 of this policy addresses NORSEE with failure condition above minor.

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Policy Statement

Subject: System Level Verification of Electronic Equipment (Software and Airborne Electronic Hardware) for 14 CFR Part 23 Airplanes

Date: 10/11/18

Initiated By: AIR-600

Policy No: PS-AIR-23-09

Summary

This policy statement provides guidance for using system level verification in lieu of design development for software and Airborne Electronic Hardware (AEH) for part 23 design and installation approval of equipment in showing compliance to the function/perform as intended aspects of 14 CFR 23.1301 and 23.1309[1] (§§ 23.2500, 23.2505, and 23.2510)[2]. This policy provides a process by which the intended function and compliance with safety objectives of systems containing software and AEH may be verified by a combination of system-level reviews, analysis, and testing. System, software, and AEH development assurance are not in the scope of this policy; therefore, this policy is only applicable when system level verification can detect development/design errors that contribute to or result in failure conditions at the airplane or system level. This guidance is applicable to approval of equipment intended for part 23 class I and II as defined in AC 23.1309-1 (certification levels 1 and 2)[3] airplanes to include type certificates (TC), supplemental type certificates (STC), amended type certificates (ATC), and amended supplemental type certificates (ASTC). This policy does not apply to equipment when specific design assurance levels are specified as part of the requirements.

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Moving Forward

- Certification is a critical element for the aerospace practice, and its impacts extend far beyond the direct role of regulator or applicant
- Changes to airworthiness regulations favoring performance-based rules enables new opportunities for technologies to be adopted in the mainstream
- How does this impact your domain?
  - Data, new approaches that can be shared?
  - Changes in processes, workflows, education?
  - Contributions to standards?

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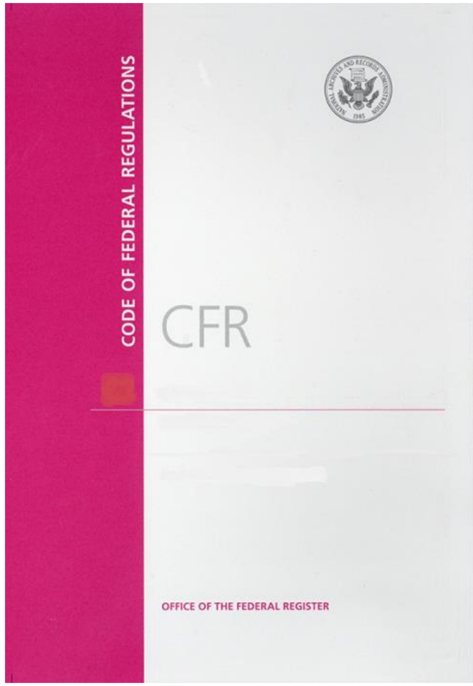
Thanks For Your Attention!

Regulations and Certification

- U.S. Code of Federal Regulations, Title 14 (Aeronautics and Space) Chapter I (Federal Aviation Administration, Department of Transportation)
  - Subchapter C – Aircraft
  - Subchapter D – Airmen
  - Subchapter E – Airspace
  - Subchapter F – Air Traffic and General Operating Rules
  - Subchapter G – Air Carriers and Operators for Compensation or Hire: Certification and Operations
  - Subchapter H – Schools and other Certificated Agencies
  - Subchapter I – Airports
  - Subchapter J – Navigational Facilities
- Regulations are developed and maintained according to a rulemaking process
- Certification indicates you have provided <u>acceptable evidence</u> that you meet the regulations from the issuing authority



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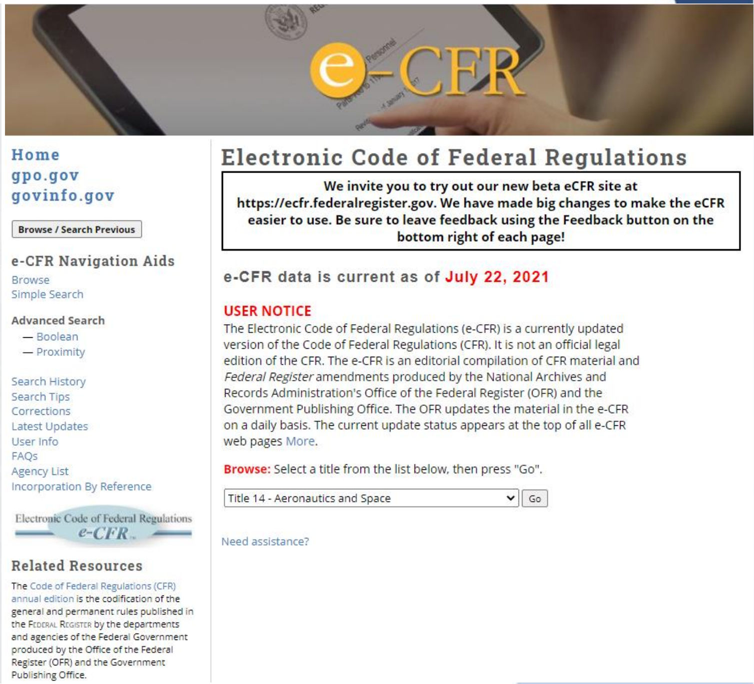

www.ecfr.gov

Performance-Based Airworthiness Approach

"What"
What proves the vehicle is airworthy?

"How"
How to apply specific technologies?
(Refinement of "what")

"How"
How to verify particular technology?

14 CFR §21 Certification Procedures for Products and Articles

14 CFR ("Legacy") Airworthiness Rules
- §23 Normal Category Airplanes (through Amdt. 63)
- §25 Transport Category Airplanes
- §27 Normal Category Rotorcraft
- §29 Transport Category Rotorcraft
- §31 Manned Free Balloons
- §33 Engines
- §35 Propellers

Advisory Circulars

Traditional Consensus Standards
(SAE, RTCA, ASTM F39)

Issue Paper Process (Proprietary)

14 CFR §23 Normal Category Airplanes (Amdt. 64+)

ASTM F44 Standard <u>Specifications</u>

ASTM F44 Standard <u>Practices</u>

Notice of Applicability

ASTM F3264
Top-Level Standard

Legend: FAA | Industry / Consensus

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Impact of Performance-Based Rules

- Performance-based rules are here!
- The Good: Increased flexibility
  - Prescriptive airworthiness requirements removed from rule language – rules now state acceptable level of performance rather than acceptable designs
  - Use of consensus standards can enable faster adoption of new concepts and technologies
- The Bad: Dude, where's my rule?
  - 14 CFR Part 23 Amendment 63 → Amendment 64: 377 → 71 rules
  - Almost all rules renumbered
  - Prescriptive requirements now encapsulated in dozens of consensus standards – behind a paywall
  - Legacy verification approaches (e.g. Advisory Circulars) not indexed to current rules, nor fully incorporated into standards
- The Ugly: Cross-cross-cross referencing
  - Rule → Notice of Applicability → Top-Level Standard → Standard Specification → Standard Practice, Standard Guide, Advisory Circular, other standards, …
  - Impact of changes to upstream/downstream references