Simplified MOC for AM Parts of Low or No Criticality

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Categories of Criticality

- **Generally based on risk to aircraft, passengers and crew and crew workload**
- **No standardized airplane-level definitions currently exist**
- **Challenge to create categories that can be directly correlated to different methods of compliance (MOC) for AM**
  - May have too few or too many categories
  - How to account for the criticality of the vehicle? (e.g., transport airplane versus small general aviation aircraft)

From AC 23.1309-1E

Classification of Failure Conditions	No Safety Effect	<----Minor----->	<----Major---->	<--Hazardous--->	< Catastrophic>
Allowable Qualitative Probability	**No Probability Requirement**	**Probable**	**Remote**	**Extremely Remote**	**Extremely Improbable**
Effect on Airplane	No effect on operational capabilities or safety	Slight reduction in functional capabilities or safety margins	Significant reduction in functional capabilities or safety margins	Large reduction in functional capabilities or safety margins	Normally with hull loss
Effect on Occupants	Inconvenience for passengers	Physical discomfort for passengers	Physical distress to passengers, possibly including injuries	Serious or fatal injury to an occupant	Multiple fatalities
Effect on Flight Crew	No effect on flight crew	Slight increase in workload or use of emergency procedures	Physical discomfort or a significant increase in workload	Physical distress or excessive workload impairs ability to perform tasks	Fatal Injury or incapacitation

Side Note on Major/Minor Classification

- **Major and minor change definition/evaluation is independent of the criticality of a part**
  - This means that changes to a non-critical part, such as to switch from traditional manufacturing to AM, are NOT automatically minor under § 21.93
  - Reminder of the US definition:
    - A “minor change” is one that has no appreciable effect on the weight, balance, structural strength, reliability, operational characteristics, or other characteristics affecting the airworthiness of the product.
    - All other changes are “major changes”

MOC for Different Criticality Levels

- **May help to think about reduced MOC by comparing to what it looks like for critical structure**
  - I find it useful to ask “what else would I be doing if the application were more critical?”
- **SAE has a work item to write a standard for composite modifications**
  - Covers structural and non-structural parts, but because it is composites, systems components are seldom (if ever) a consideration, the way they are for AM
  - Proposes 4 categories of criticality
  - Provides “reduced” MOC based on that criticality

SAE Draft Standard for Composite Modifications

Criticality	Material Control	Process Control	Design Values	Static Strength	F&DT	Flammability
1. High – parts whose failure directly affects continued safe flight and landing	X	X	X	X	X	As Required
2. Medium-High – parts whose failure indirectly affects continued safe flight and landing	X	X	X	S	S	As Required
3. Medium-Low – (1) structure whose failure does not affect continued safe flight and landing and (2) parts whose failure can affect passengers and crew	S	S	S	S	N	As Required
4. Low – all other parts	S	S	S, As Required	S, As Required	N	N

Notes:

- If used for AM, would need other columns/categories for engine regulations
- X = “full” compliance, S = simplified compliance, N = compliance not applicable
- Simplified methods of compliance are not the same between the levels

High Criticality Parts

Criticality	Material Control	Process Control	Design Values	Static Strength	F&DT	Flammability
1. High – parts whose failure directly affects continued safe flight and landing	X	X	X	X	X	As Required

- **Failure *directly* affects continued safe flight and landing**
  - Example composite parts: skins, spars and ribs in wing, fuselage and empennage
  - Example AM parts?: (need examples)
- **Methods of Compliance**
  - Follow AC 20-107B for critical composite structure
  - For example, may choose to apply AIA Recommended Guidance for Certification of AM Components

Medium-High Criticality Parts

Criticality	Material Control	Process Control	Design Values	Static Strength	F&DT	Flammability
2. Medium-High – parts whose failure indirectly affects continued safe flight and landing	X	X	X	S	S	As Required

- **Failure *indirectly* affects continued safe flight and landing**
  - Example composite parts: large antenna on top of a transport aircraft, shelf for critical avionics equipment
  - Example AM parts?: (need examples – would this be wire connectors?)
- **Methods of Compliance**
  - Follow AC 20-107B for critical composite structure
    - If F&DT is applicable, may be able to perform a combination of component, detail, and coupon tests to eliminate the need for full-scale cyclic loading of the structure
    - Static strength substantiation typically require coupon and point design testing, coupled with component or full-scale depending on complexity and geometry, but fewer tests than high criticality parts
  - Would we do anything differently for AM parts?

Medium-Low Criticality Parts

Criticality	Material Control	Process Control	Design Values	Static Strength	F&DT	Flammability
3. Medium-Low – (1) structure whose failure does not affect continued safe flight and landing and (2) parts whose failure can affect passengers and crew	S	S	S	S	N	As Required

- **Structure whose failure does not affect continued safe flight and landing (often called secondary or tertiary structure), or parts whose failure can affect passengers and crew**
  - Example composite parts: winglets, interior monuments, fairings
  - Example AM parts?: seat and interior trim pieces, ducting

Medium-Low Criticality Parts

- **Methods of Compliance**
  - F&DT not applicable
  - For composite:
    - Material qualification and design values may focus only on the material properties that are critical to the design. A moderate level of testing may be required in order to adequately control the material to ensure compliance with the other applicable regulations. For non-structural parts, the focus may be on properties such as flammability or conductivity.
    - The process specification must control the key process parameters that will govern final part performance but may incorporate less frequent receiving inspections, less receiving inspection parameters, and more MRB capability for deviations.
    - For design values, published data and equivalence testing may be used to meet many, if not all, requirements.
    - Structural substantiation may use a limited testing program if reliable analysis tools with conservative design values are utilized
  - What would we do for AM parts?

Low Criticality Parts

Criticality	Material Control	Process Control	Design Values	Static Strength	F&DT	Flammability
4. Low – all other parts	S	S	S, As Required	S, As Required	N	N

- **All other parts**
  - Example composite parts: access panels
  - Example AM parts?: (need examples)
- **Methods of Compliance**
  - For composites:
    - Limited material and process control, *but not zero*
    - Many of these applications use a systems-type approach, such as DO-160, which demonstrates strength (inertial loads) directly by test. However, when required, published industry or supplier data is acceptable for compliance to § 2x.613 and may be used for structural substantiation, if large margins of safety can be demonstrated.
  - What would we do for AM parts?

Another Category?

- **Are there truly parts with no criticality?**
  - Non-fly-away parts? (e.g., molds, shop aids, jigs)
    - *While they don't demonstrate compliance to airworthiness regulations in parts 23-35, they are defined and controlled under production approval requirements. Do we want to provide guidelines for those regulations?*
  - Are there any fly-away parts?
    - Small decal or component with a limit on size and number installed?
    - What would its reduced requirements look like? How could we further reduce M&P control and still meet §21.31 requirements to "define the configuration and the design features of the product"

Criticality	Material Control	Process Control	Design Values	Static Strength	F&DT	Flammability
5. No Criticality	?	?	N	N	N	N

Summary

- **Criticality is difficult to define, and also difficult to directly relate to methods of compliance**
- **Some methods of simplified compliance from the draft composite modification standard may be applicable to additive manufacturing**
- **Are there any on-aircraft parts with no criticality? Do we want to create a standard for non-fly-away parts?**