National Aeronautics and Space Administration

Considerations for Qualification and Certification of Un-inspectable AM Hardware

Information for discussion with the
FAA / EASA Additive Manufacturing Workshop
Working Group 2, Fatigue and Damage Tolerance

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PRELIMINARY:
For Discussion Only

General Considerations

Problem: Fracture Critical (Safety Critical) AM components with limited or no post-build inspectability will be used for NASA programs.

Approach: Develop a governing philosophy for a systematic and consistent approach for fracture control for AM parts of this class.

- Assemble a framework for general certification of fracture critical AM components without full inspectability
- Develop a methodology that can be applied to various flight program needs.

Difficult and complicated problem – approach is to incrementally develop the philosophy, while acknowledging potential redirections and future adaptations. Expectation is a need for risk-based acceptance.

First steps, work the "inherent flaw" problem:

1. Define and catalog two AM flaw categories – "inherent" and "escape".
2. Understand the occurrence rates and flaw sizes associated with different "inherent" flaw types.
3. Develop methodologies for evaluating and characterizing "inherent" flaw populations.

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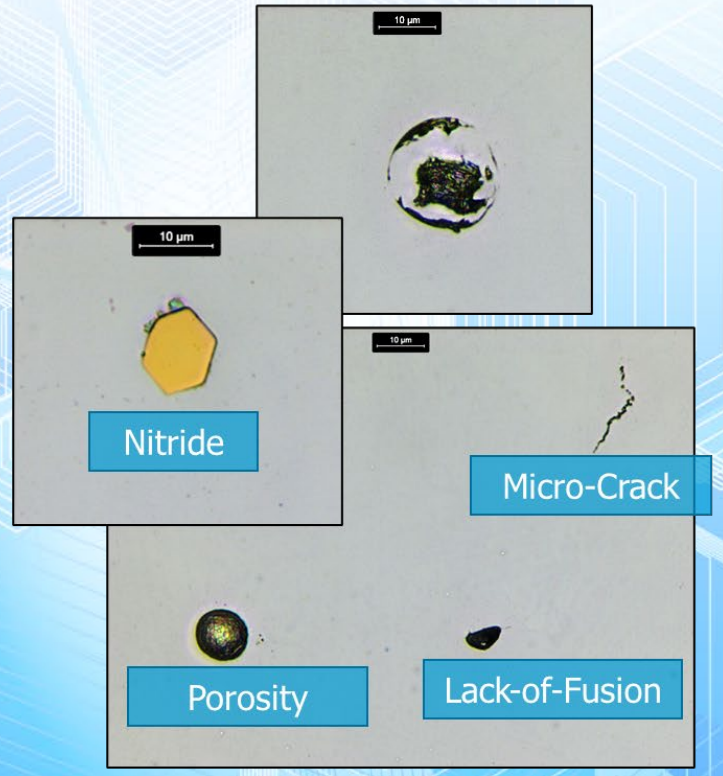
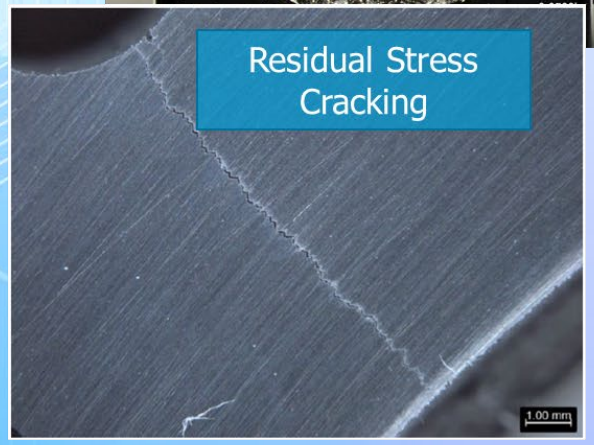
Definitions are a Challenge

- **Flaw** – an imperfection or discontinuity that may be detectable by nondestructive testing and is not necessarily rejectable.
- **Defects** – one or more flaws whose aggregate size, shape, orientation, location, or properties do not meet specified acceptance criteria and are rejectable.





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Definitions are a Challenge

- **Inherent flaws** – Flaws that are representative of the characterized nominal operation of a qualified AM process.
  - "Qualified" implies that the subject AM process is sufficiently developed, as demonstrated by compliance with an AM material standard such as NASA-STD-6030.
  - "Characterized" implies flaws that have been observed as part of AM process development and that are included in the metallurgical and mechanical qualification data set.
  - Each AM process is assumed to have a characteristic inherent flaw population.
  - Inherent flaws are expected to be common enough that direct characterization is feasible.
  - Established inherent flaw distributions cannot be assumed when process escapes are indicated.

- **Escape flaws** – Flaws that are not representative of the characterized nominal operation of a qualified AM process.
  - Escape flaws may or may not be indicated by process monitoring – "Detected" & "Non-detected".
  - Escape flaws may or may not be larger than inherent flaws, though generally expected/assumed larger.
  - Escape flaws are assumed to have lower occurrence rates than (most?) inherent flaws.
  - Escape flaws may be associated with specific escape events, but are not defined by those events (i.e., spatter, short-feed, ventilation flow, etc.)

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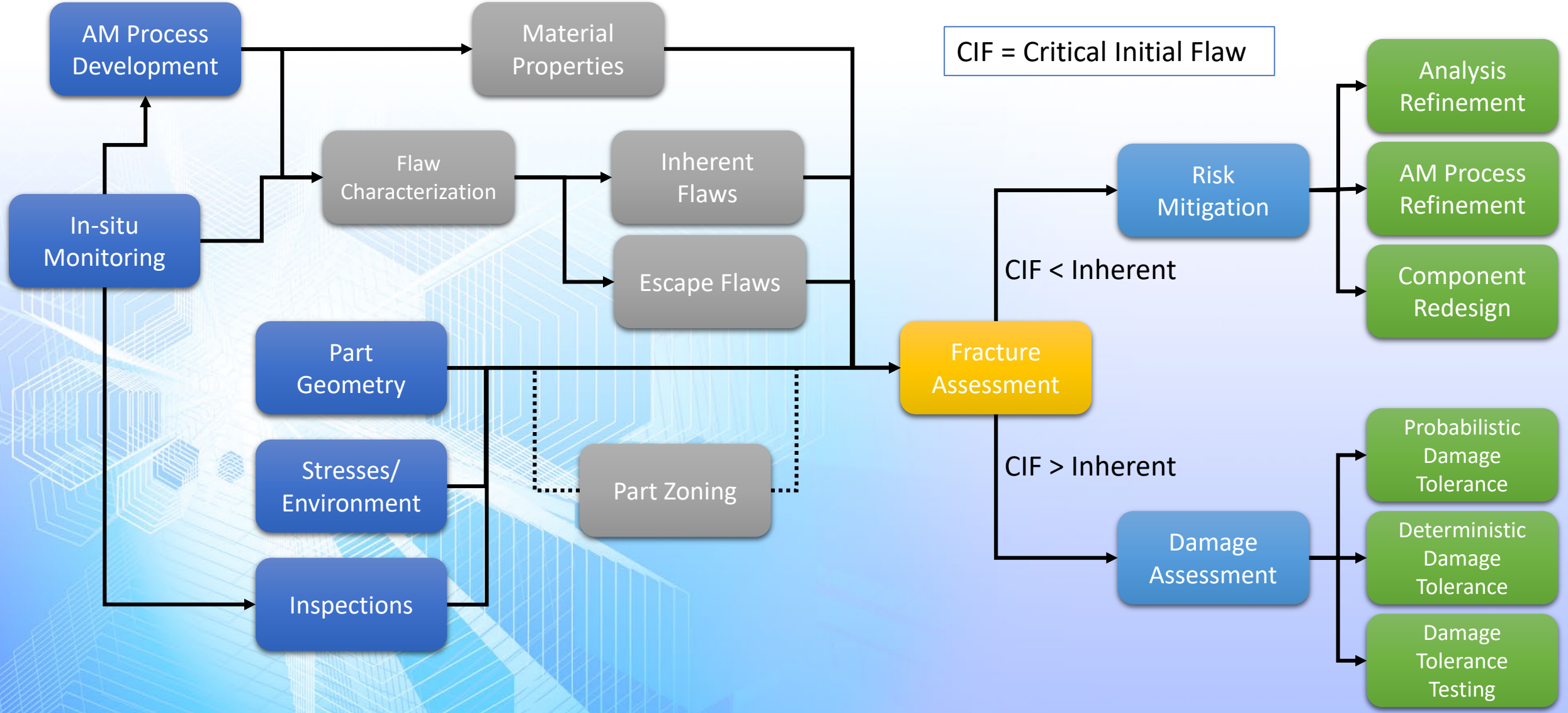

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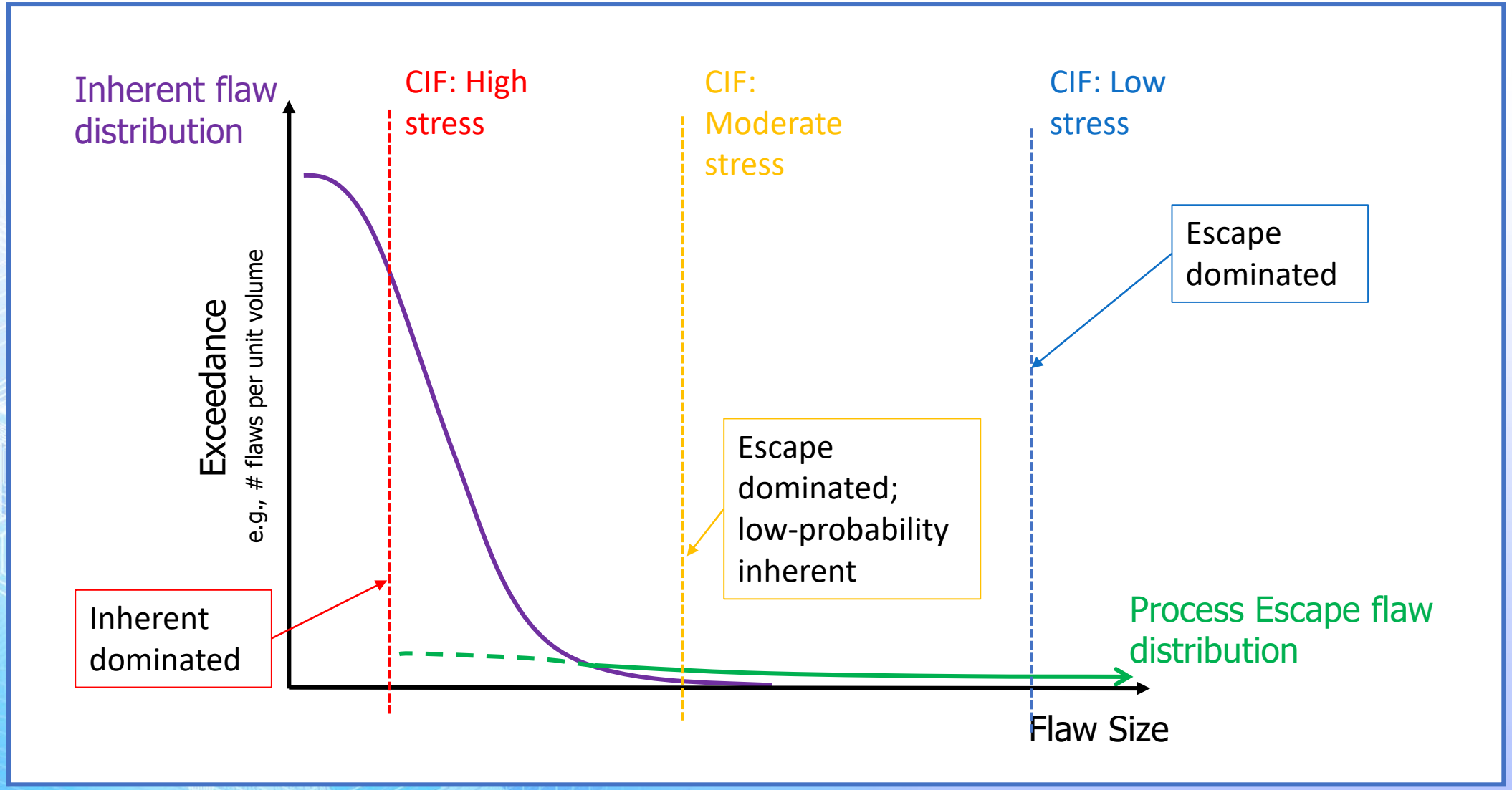

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Approach to Classes of Flaws

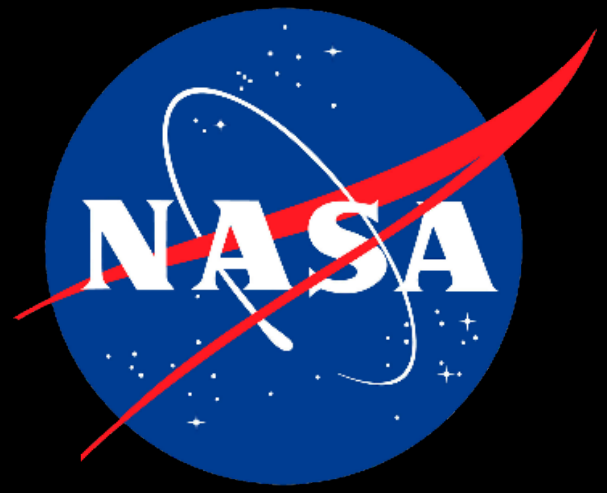
Inherent flaws

- Assumed always present
- Associated with a qualified process.
- Characterized as part of the "equivalency baseline" for defect state at time of process qualification
- Not all inherent defects states are the same
- Includes nominal, qualified extremes: Thermal history, geometric challenges, etc.
- Generally included in most material characterization that encompasses build and lot variability
- Low probability inherent flaws are a challenge – distinguishable from some escape flaws only by semantics?

Escape / Instability flaws, P-FEMA Systematic Limitation of Flaw Distributions

P-FEMA Escapes	Flaws	Controls					
		Witness	Video	Melt-pool	Profilometry	Thermography	●●●
Recoat quality							
Short feed	LoF, cracks, …	✓	✓	✓	✓	✓	
Streaking	LoF	?	✓	?	✓		
Super-elevation	LoF, cracks, …			?	✓		
Ventilation							
Plume interference	LoF, porosity, …	✓		✓			
Optical							
Power	LoF, porosity, …	✓		✓			
Chamber gas							
Oxygen level	LoF,	?					✓
●●●							

Conceptual - Example Only for Discussion



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Thank you!