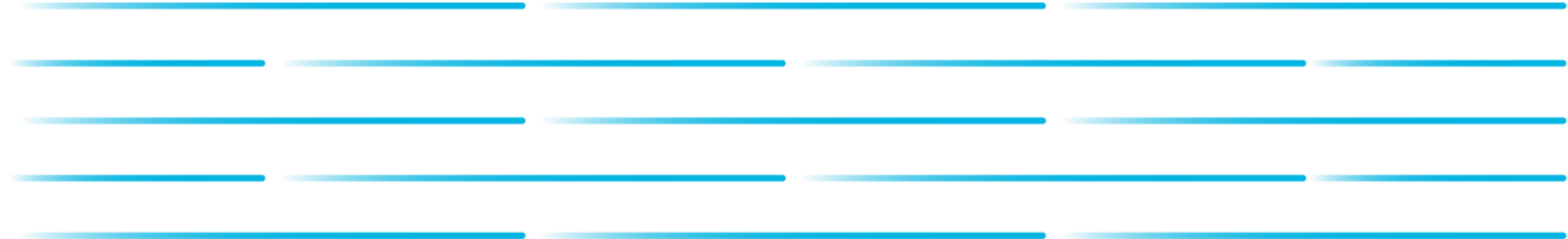




EASA - FAA AM Workshop

Nov 5, 2019



GE Follows Industry* Process



Process steps are often performed in parallel. Sequence may not be as shown., however the completion of each element is required

* Industry refers to the AIA Working Group for FAA qualification of AM components. Graphic taken from WG white paper

Development Process

- Material & parameter development
- Specification development
- Post-process development
- Part development
- Machine operational qualification

Supply chain qualification

- Process control documents
- Process performance qualification

Material property development

- Material allowables
- Design values

Part design qualification

- Building block approach

Quality Controls

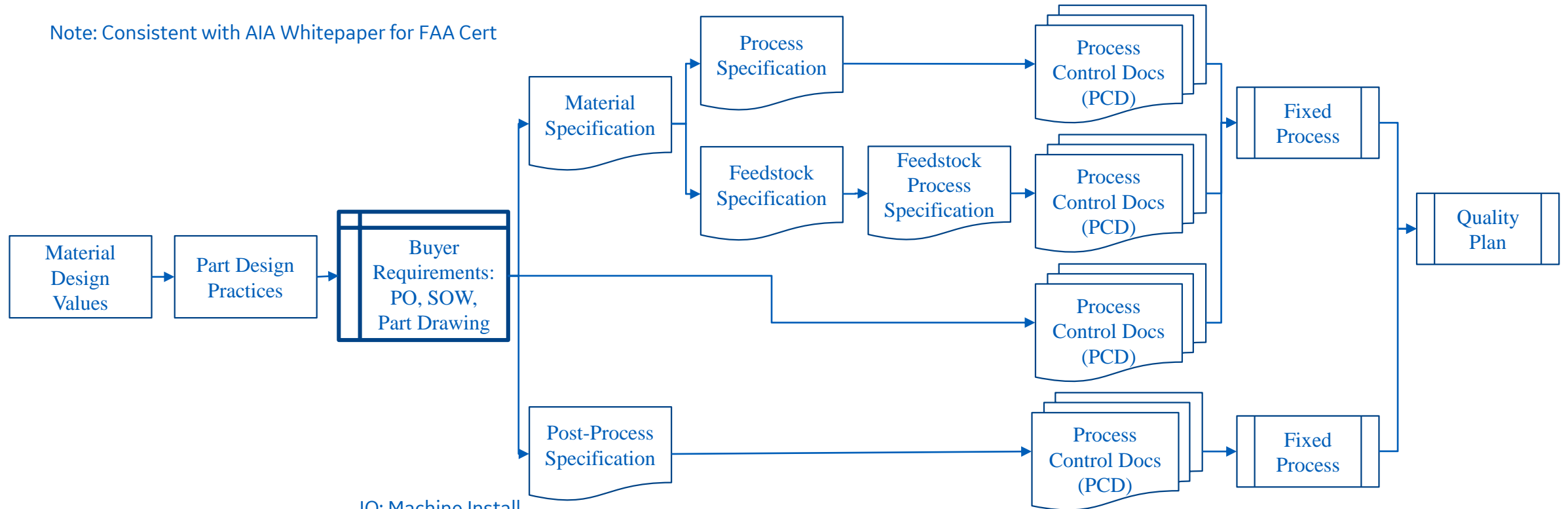
- Quality plan
- Inspection methods



GE Additive Part Qualification



Note: Consistent with AIA Whitepaper for FAA Cert




IQ: Machine Install



Note: IQ/OQ/PQ next page



IQ/OQ/PQ: Leveraging Qualification Language from the FDA



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Installation Qualification (IQ)


Simply put in guidance, is everything installed correctly. Things to consider...

- Equipment design features
- Installation and Environmental Conditions
- Safety features
- Supplier documents, Calibration, preventative maintenance and spare parts.

<http://www.imdrf.org/docs/ghf/final/sq3/technical-docs/ghf-sq3-n99-10-2004-qms-process-guidance-04010.pdf> (Guidance - Definitions Pg. 5 & Section 5.3)

15

Machine OEM Qual to Customer Req't



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Operational Qualification (OQ)


Challenge process parameters to assure the process will result in product that meets requirements. Things to consider...

- Determine process control limits
- Material specifications and handling
- Process change control and training
- Determine potential failure modes, action levels and worst case scenario
- Perform software V&V for intended use

<http://www.imdrf.org/docs/ghf/final/sq3/technical-docs/ghf-sq3-n99-10-2004-qms-process-guidance-04010.pdf> (Guidance - Definitions Pg. 5 & Section 5.4)

16

Machine Qual to Material Spec



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Performance Qualification (PQ)

Demonstrate the process will consistently produce acceptable product under normal operating conditions. Things to consider...

- Approved procedures and limits from OQ
- Acceptable product
- Simulate actual manufacturing conditions
- Is the process repeatable and stable long term

<http://www.imdrf.org/docs/ghf/final/sq3/technical-docs/ghf-sq3-n99-10-2004-qms-process-guidance-04010.pdf> (Guidance - Definitions Pg. 5 & Section 5.5)

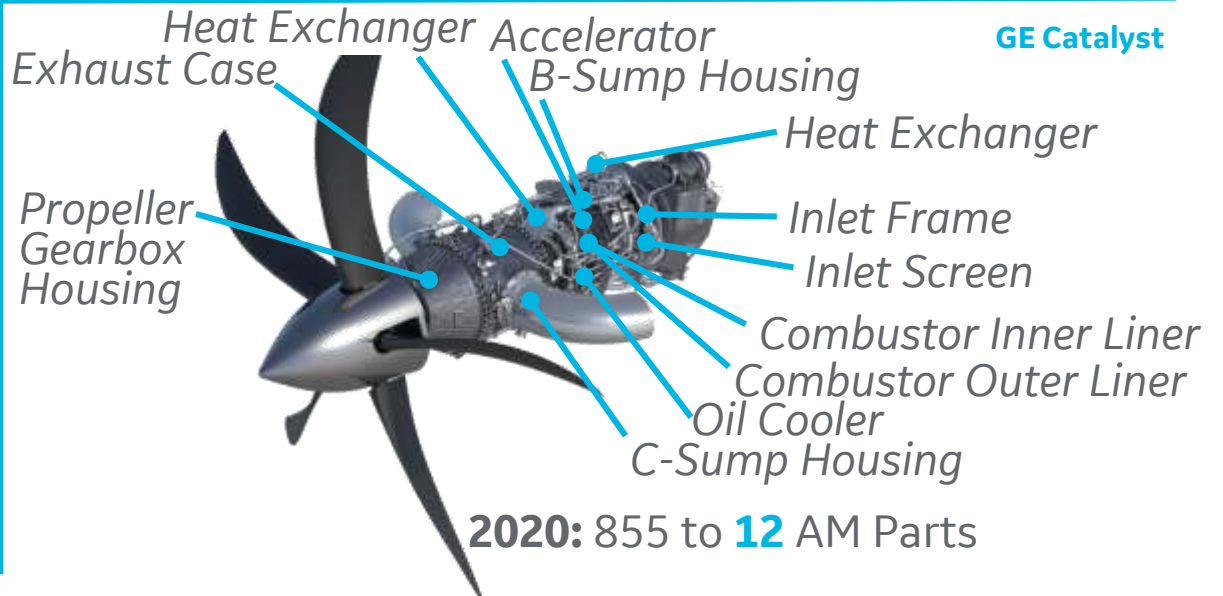
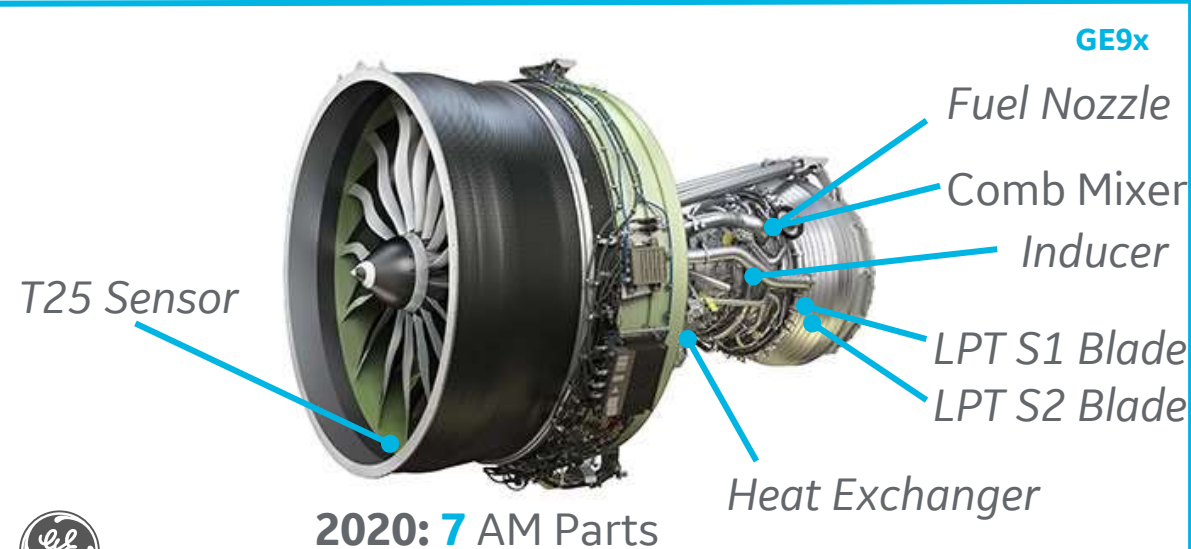
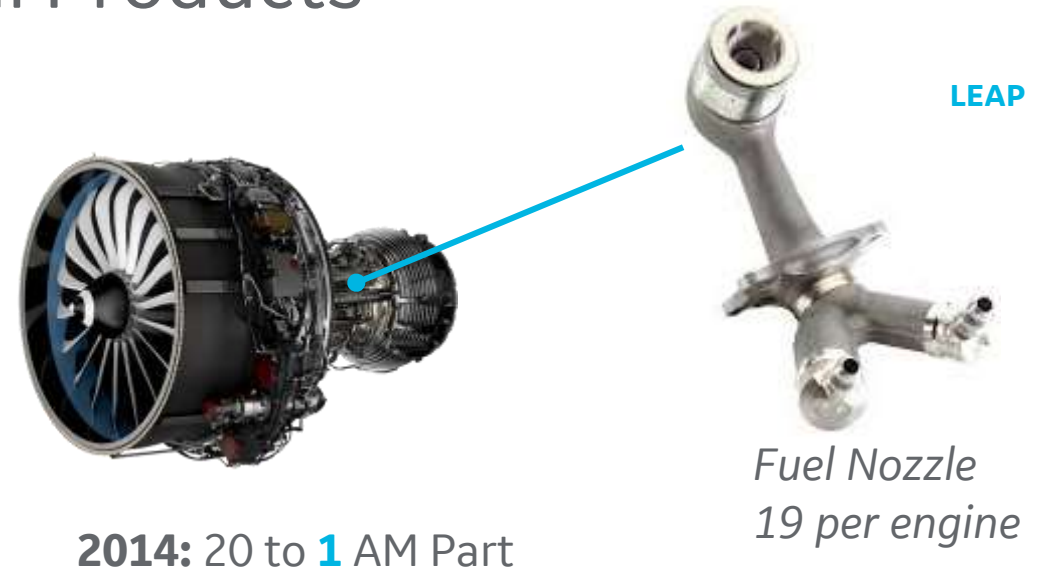
18

Process Qual to Product Req'ts

Commercial aviation qualification categories are consistent with FDA definitions. Qualification elements and requirements within each category are very different for FAA/EASA vs. FDA

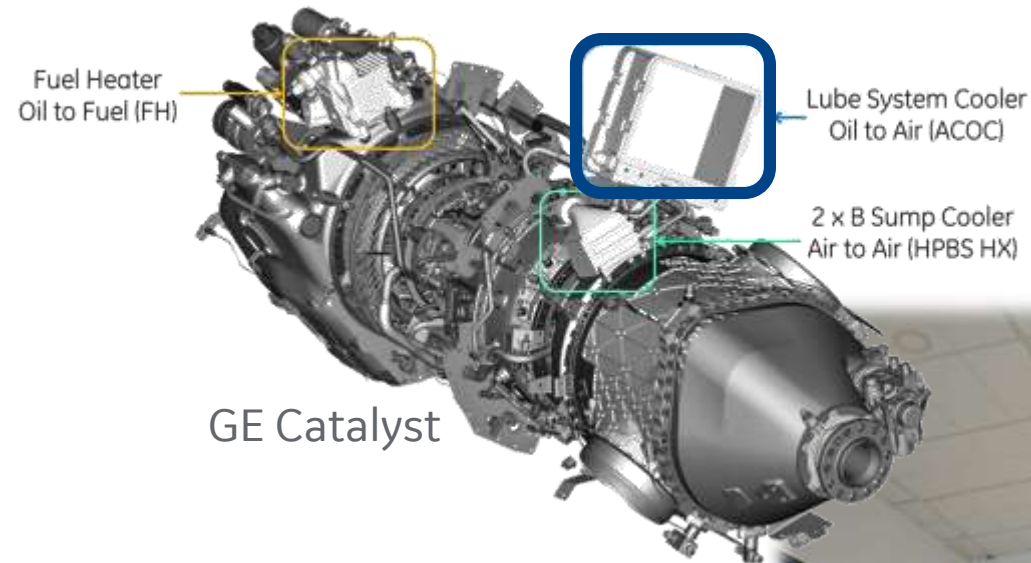


GE Aviation Use of AM in Commercial Products



Additive Heat Exchanger Design Example

*Additively designed ACOC (Air Cooled Oil Cooler).
The ~25 inch component can be produced in a single machine.*



Part Application and Criticality vs. Manufacturing Method

Regulations (*independent of method*)

Manufacturing Process	14 CFR 21	14 CFR 23	14 CFR 25	14 CFR 33	14 CFR 35
Fabrication	<div><p>GE Genx The GE Genx is the fastest-selling engine in US aviation history. The engine is a giant leap forward in propulsion technology, using the latest generation materials and design to reduce weight, improve performance and lower maintenance.</p><p>Powers the Boeing 737 Dreamliner and the Airbus A320neo</p><p>More than 1,300+ engines in service today</p><p>More than 1,900 engines ordered</p><p>15% lower fuel burn than the CF6 engine</p><p>More than 2 million flight hours in service</p><p>15% lower CO2 emissions than the CF6 engine</p><p>More than 12 million flight hours accumulated</p></div> <div><p><u>Qual & Cert Considerations</u></p><ul style="list-style-type: none">Material durabilityVibration & fatigue effectsOperating & max loadsEffects on systemWeight & CG<p>PDOS Bracket</p><p>example</p></div>				
Forging					
Casting					
Additive					



