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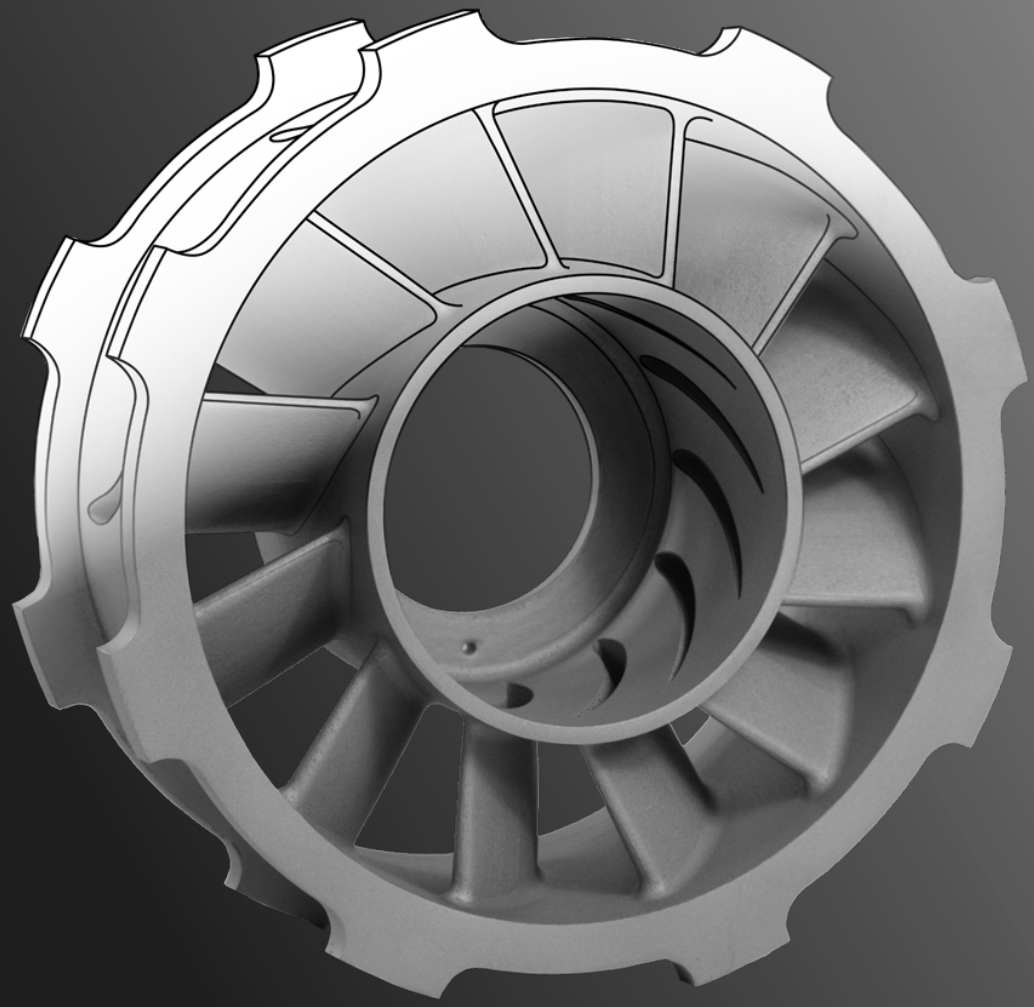
Elevating Commercial Aviation Manufacturing: Lessons from the Defense Industry



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September 18, 2024

COMMERCIAL & EXEC AEROSPACE
ADVANCED DESIGN BACKGROUND

- ✓ Bombardier Aerospace, Toronto, Ontario
- ✓ Advanced Design Department: Next Generation of Aircraft
  - Airbus A220 (C Series)
  - Lear 85
  - Global 7500
  - Clean sheet designs
- ✓ Aircraft designs have remained largely unchanged for the past half century
- ✓ Similar engineering challenges often lead to similar solutions
- ✓ Likewise, similar manufacturing methods frequently result in comparable solutions

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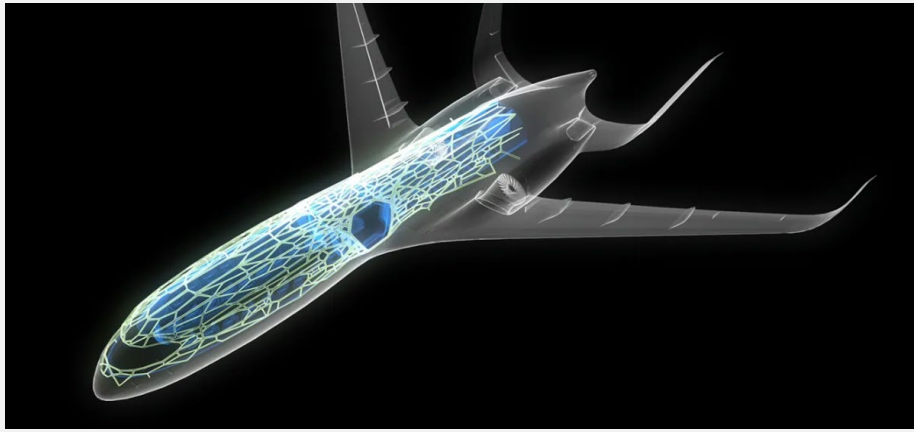
ADVANCED COMPONENT MANUFACTURING CRITICAL TO FUTURE GENERATION AIRCRAFT

- ✓ Unique aircraft designs continue to be limited
  - The Lear 85 never entered service, mainly due to challenges with its composite structure
  - Blended wing body design (Bombardier EcoJet, Airbus ZEROe) still remain ‘paper’ designs
- ✓ To meet future marketing objectives and requirements, including sustainability and competitive cost targets, the OEM industry must begin designing and manufacturing **flight components** with a focus on topology optimized, monolithic components
- ✓ Enabled by Advanced Manufacturing technologies such as LPBF (Laser Powder Bed Fusion)



SINTAVIA, LLC

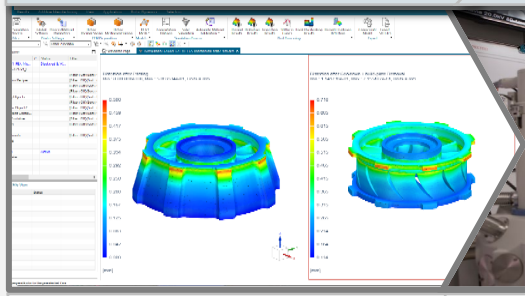
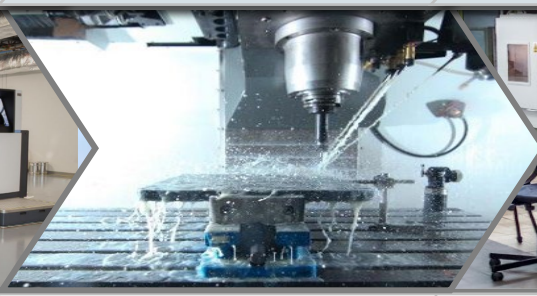
- ✓ World's first all-digital aerospace component manufacturer
- ✓ Leading additive technology supplier to Aerospace & Defense Lead Systems Integrators
- ✓ Founded in 2015; 106 employees (47 engineers)
- ✓ Owned 80/20 between Brian Neff and Lockheed Martin Corporation
- ✓ Three product demand drivers:
    1. Heat exchangers for military aircraft
    2. Pump/valve systems for Naval Nuclear Propulsion Program
    3. Propulsion components for next generation missile programs

OUTLINE

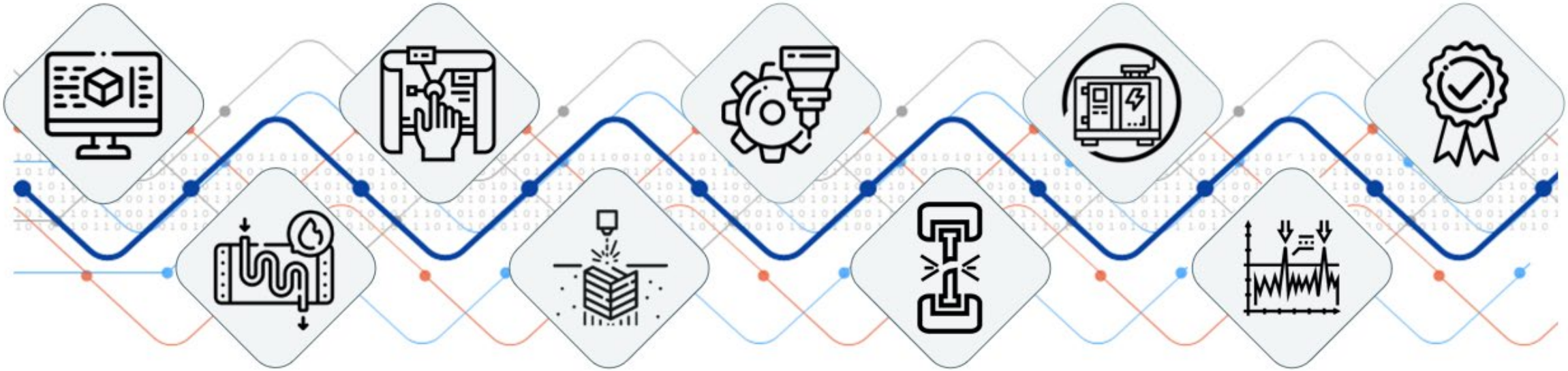
1. Vertical Integration of AM Production Capabilities
2. Vertical integration of AM Software Processes
3. Key Customer Verticals
4. Production Programs Supported
5. Commercial Aviation OEM History
6. Commercial Aviation Production Case Studies
7. Lessons Learned
8. Lessons Learned Compared to Successful Defense Counterparts
9. Industry Standards Benchmarks and Needs
10. Leverage Expertise
11. There is a Path Forward!

1. VERTICAL INTEGRATION OF AM PRODUCTION CAPABILITIES…

- ✓ We are differentiated by the vertical integration of the design, manufacturing, testing, and certification of our components
- ✓ By performing most processes in-house, we are able to rapidly iterate designs and

Design	Pre-Processing	Printing	Post-Processing	Testing & Inspection
				
▪ Topology Optimization ▪ Modeling and Simulation ▪ Part Consolidation ▪ Design Optimization	▪ Powder Characterization ▪ Design for Additive Manufacturing ▪ Manufacturing Plan	▪ Lean AM Production ▪ Powder Removal ▪ Support Removal	▪ Furnacing and Thermal Treatment ▪ Machining ▪ Surface Finishing	▪ Blue Light ▪ FPI and Radiography ▪ CT Scanning ▪ Operational Testing

2. VERTICAL INTEGRATION OF AM SOFTWARE PROCESSES



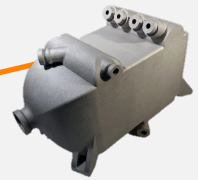
Digital Design	FEA/CFD Simulation	Digital Manufacturing Plan	Additive Manufacturing	Post-Processing	Metallurgical & Mechanical Testing	NDT Inspection	Performance Testing	Certification & Release
SIEMENS			EOS PRINT	SIEMENS				
SIEMENS NX	SIEMENS STAR-CCM+	TEAMCENTER	Materialise Magics	SIEMENS OPCENTER	SIEMENS OPCENTER	TEAMCENTER QUALITY	SIEMENS OPCENTER	TEAMCENTER QUALITY

4. PRODUCTION PROGRAMS SUPPORTED[1]

HACM

Inlet/Isolator

F-35



Fuel Heat Exchanger

F-22

Chassis Housing

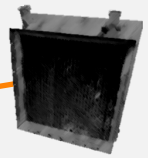
PrSM

Payload Structure

AARGM-ER

Thermal Protection Housing

UH-60



Air Oil Heat Exchanger

Virginia Class

Impeller

SiAW

Guide Housing

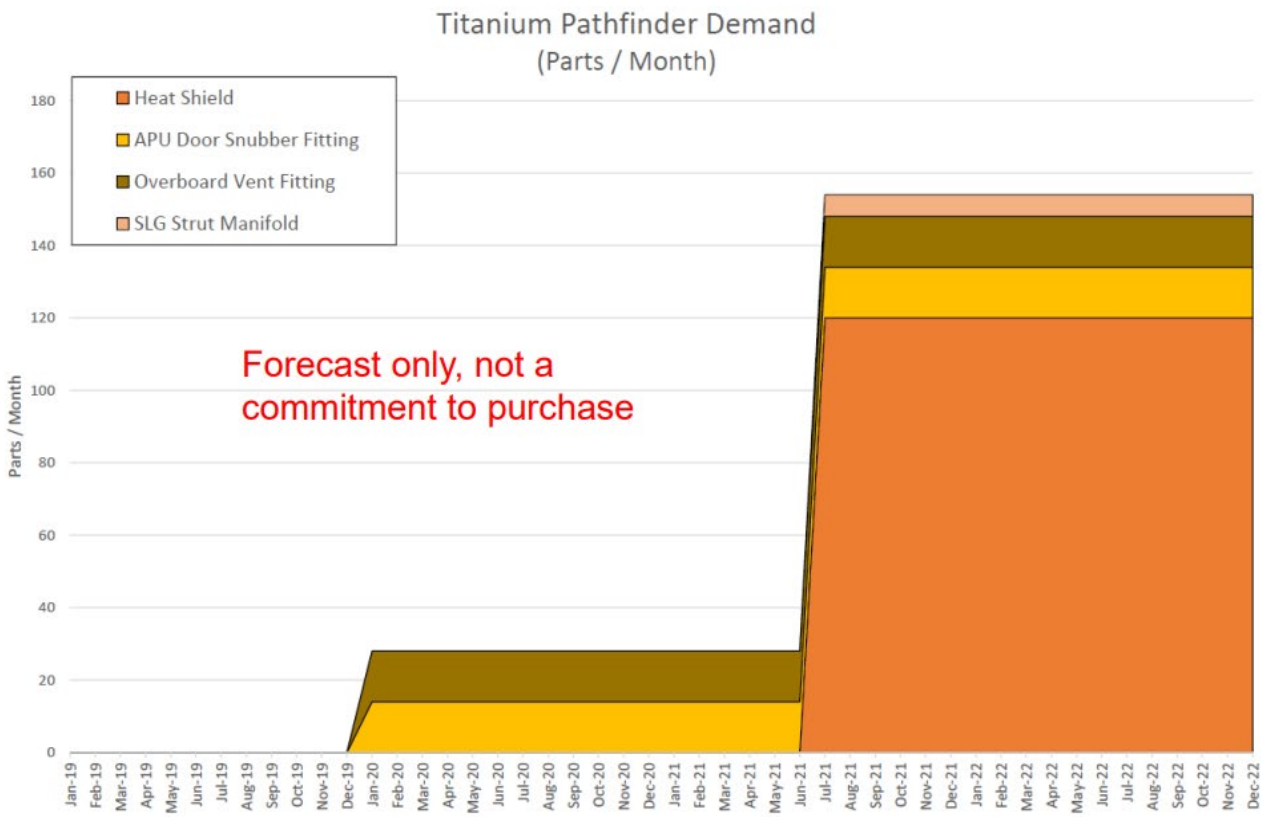
[1]Orange box denotes engineered products. Representative parts shown.

The demand is strong, and both designers and production suppliers are ready and capable - so why is commercial aviation lagging so far behind its defense counterparts?

5. COMMERCIAL AVIATION OEM HISTORY

- ✓ Airbus Group
  - First and last PO received in 2019
- ✓ Honeywell
  - First PO pre-2018
  - Top-ten customer in 2019-2021
  - Top customer in 2020
  - Last PO received in 2020
- ✓ The Boeing Company
  - First PO in 2018
  - Top-ten customer in 2019-2020
  - Last PO received in 2021

[redacted] Additive Manufacturing



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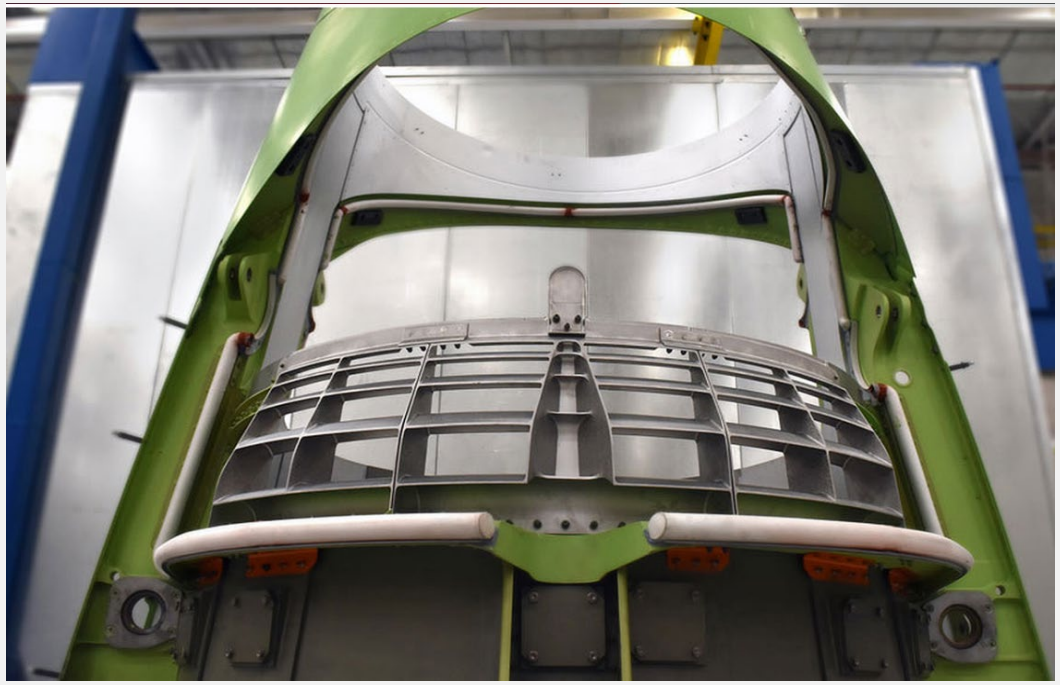
6. COMMERCIAL AVIATION PRODUCTION CASE STUDIES

- ✓ Raytheon (Collins – Rohr Aerostructures)
  - EBM Ti64
  - Pre-production
  - Production PO in 2021
  - Total 120 jet cascades delivered
  - QTY 10 Dassault 6X in flight with Sintavia components
- ✓ Honeywell
  - LPBF IN 718
  - Pre-production
  - QTY 3 limited production components
  - Buffer, tube, surge duct and three-way duct
  - Two of these parts LTC on 2022



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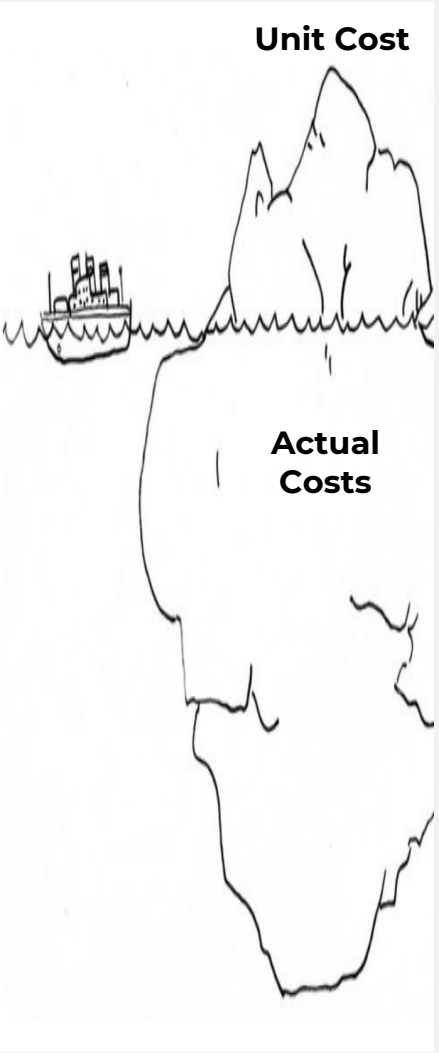
7. LESSONS LEARNED



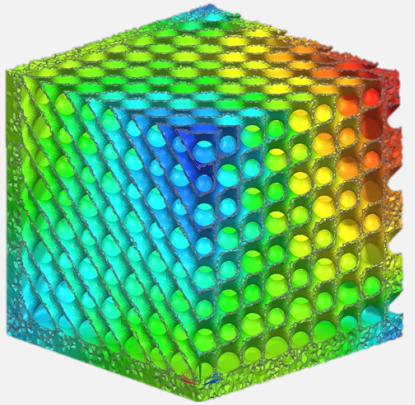
✓ Commercial Production Case Studies Commonalities

1. **Design** - Traditional components replaced like-for-like by additive manufacturing
2. **Business Case** - Competing against traditional unit prices, while designs not were bringing any added value or benefits
3. **Business Case** - Not quantifying the larger picture of weight optimized designs
   - Long-term weight savings
   - Sustainability metrics
4. **Business Case** – Not quantifying the cost of poor quality for supply 'problem parts'
5. **Specifications** - OEM or Tier One self-governed specifications
6. **Specifications** - Inspections and qualifications based on methods for traditional and current processes
   - CT, In-Situ Monitoring, etc.

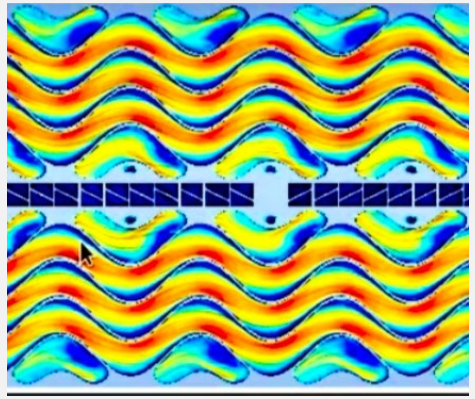
8. LESSONS LEARNED COMPARED TO SUCCESSFUL DEFENSE APPLICATIONS

	Commercial Aviation Business Cases	Successful Defense Programs
Design	○ Traditional components replaced directly by and AM version	○ Integrate value-added inner channels & larger monolithic designs ○ **Sintavia designing from the ground up to meet PBS, Manufacturing and Testing**
Business Case	○ Competing against traditional unit prices ○ Not quantifying weight & sustainability metrics ○ Not quantifying CoPQ	○ Unit Price & NRE are rationalized against improved performance and shorter lead times ○ CoPQ evaluated in price comparisons
Specifications	○ OEM or Tier-One self-governed specifications ○ Inspections and Qualifications adding more criteria	○ Some programs are still self-governed ○ Many (including flight components) are using **industry standards such as AWS D20.1 and NAVSEA S9074-AR-GIB-010-278**

9. LEVERAGE EXISTING EXPERTISE



- ✓ Designing from the ground up to meet PBS (Performance Based Specs), Manufacturing and Testing has been successful
- ✓ Example: Heat Exchangers
- ✓ Sintavia has designed and developed air to fluid heat exchangers that exceed incumbent designs in weight reduction and heat transfer



1. Design - Sophisticated modeling techniques and simulation allow for optimized features

2. Manufacturing - Sintavia operates some of the largest metal 3D printers in North America, with boundary conditions increasing

3. Test - operational thermodynamic testing capabilities to ensure that its components meet customer requirements

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10. INDUSTRY STANDARDS BENCHMARKS AND NEEDS

Machine Qualification

Procedure Qualification

Delta Qualification

- ✓ Industry standards such as AWS D20.1 and NAVSEA S9074-AR-GIB-010-278 have been successful
- ✓ Machine and Procedure (Part) Qualifications fairly well understood
- ✓ Customers typically call out the key specification
  - AWS D20.1
  - NAVSEA SPEC S9074-AR-GIB-010-278
  - WSU Common Qualification Plan Metal AM OQ Acceptance Test (Draft)
- ✓ Customers then typically have part-specific requirements (based on part criticality, etc) in AOR (Additional Order Requirements) document
- ✓ **Needs: Delta Qualifications, Communications Channels, New Aircraft Designs conducive for Advanced Manufacturing**

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11. THERE IS A PATH FORWARD!

- ✓ It's not too late for future Aircraft such as the X-66 and ZeroE
- ✓ What will this take?
  - OEMs and Tier-One suppliers need to be increasingly open to collaborating with experts, such as Sintavia, to offer input or even design solutions from the ground up
  - Continued education for designers, supply chain and Quality Engineers
  - Communication
  - Share success stories
- ✓ **By applying lessons learned from the defense sector, we can ensure the future of commercial aviation is not only safe and successful but also a source of pride**

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