Summary of the 1st Joint FAA – EASA Workshop on Q&C of AM Components

Federal Aviation Administration

Presented at:

2nd Joint EASA-FAA Workshop on AM

Nov. 5-7, 2019

Cologne, Germany

Prepared by:

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Chief Scientist for F&DT

Federal Aviation Administration

Acknowledgments

- **Dr. Rollie Dutton, UTC**
  - Workshop facilitator and author of the workshop's external report (to be published by the FAA)
- **Dr. Simon Waite and Dr. Matthew Mercy, EASA**
  - Co-organizers of the 2018 Workshop
- **NIAR staff and facilities, WSU**
  - Host of the 2018 AM Workshop

Workshop Evolution (*2015 → 2017*)

Joint FAA - USAF AM Workshops

2015 Workshop

- First in the series (*for FAA*)
- Focus on overview of AM technologies and identification of potential certification concerns and considerations
- First exposure to AM for many FAA attendees
- Main focus on getting perspective from the government agencies and major OEMs

2016 Workshop

- More in-depth discussions on specific qualification approaches reflect industry progress (some presentations are benchmarked by industry working groups)
- Expanded coverage to include supply chain perspective (Tier 1, raw materials, …)
- Continued education of FAA workforce
- Significant coverage of government AM activities

2017 Workshop

- First "global" workshop – open to foreign participants, including several NAAs
- Twice bigger than the prior workshops – significantly expanded industry "demographics"
- Focused Training & Education panel
- Continued Q&C topics coverage, including process monitoring, part family and feature-based qualification etc.
- Progress on AM standardization

2018 Workshop

- **First *joint* FAA – EASA workshop**
  - Responding to external /internal stakeholders
- **First workshop with parallel breakout sessions**
- **Continued focus on Q&C**
- **Tracking of the key industry trends (in the Q&C context) → *see next chart***

Workshop presentations can be downloaded here:

meeting website

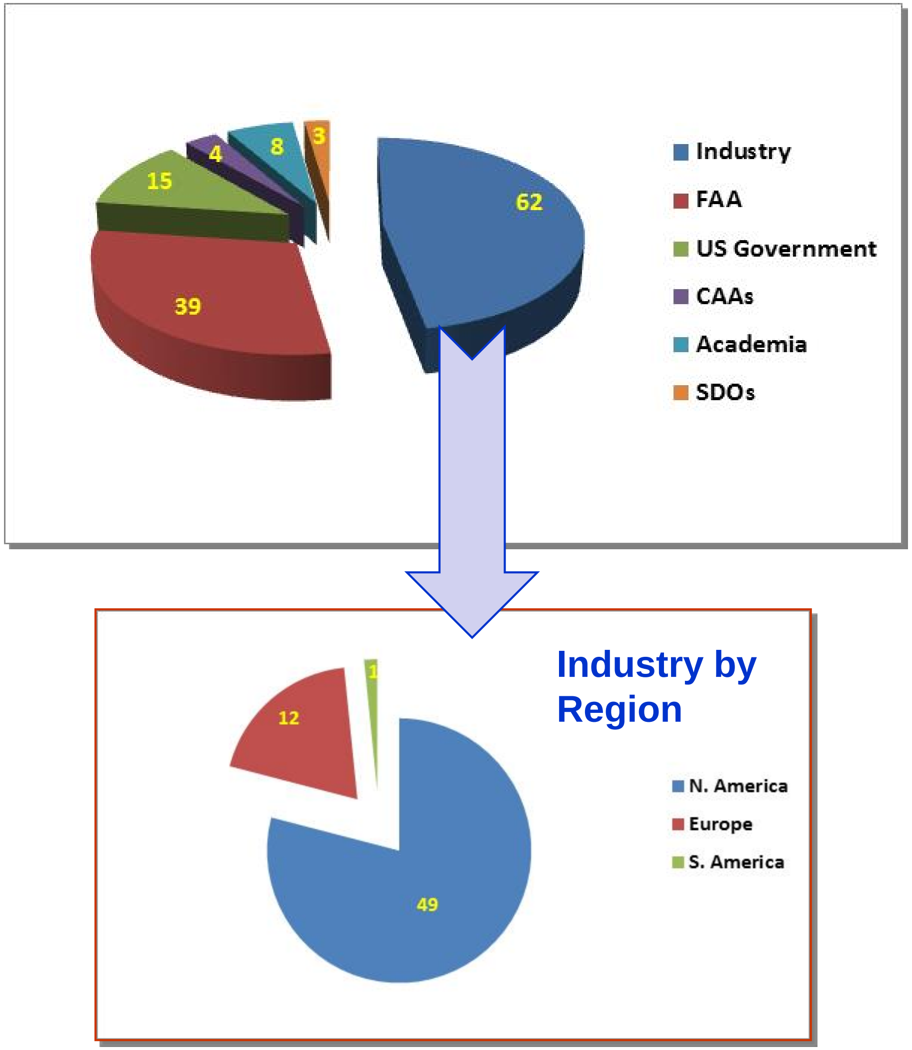
Key Trends *(a partial list)*

- **Rapid increase in parts criticality (both engines and airframes)**
- **Moving from *Point Design* to *Part Family* Q&C**
- **Rapid expansion of Supply Chain**
  - *New entrants; existing suppliers moving up the chain*
- **Evolution of AM machines (bigger, faster, …)**
  - Multi-laser systems, in-situ process monitoring, …
- **Evolution of Public Standards (SDOs) landscape**
  - ***AMSC AM Standards Roadmap Ver. 2.0***
- **Expanding applications domain**
  - *New Products, Repairs / MRO, Aftermarket*
- **More R&D programs with focus on Q&C**

Global Participation in 2018

- *Canada*
- *France*
- *Germany*
- *Italy*
- *Norway*
- *Singapore*
- *Spain*
- *UK*
- *US*

Demographics by Organization Type



Agenda at a Glance

- **Two Keynotes:**
  - **Director of Advance Repairs, *Delta TechOps***
  - **VP of Engineered Product and Process Technology, *Arconic***
- **15 presentations from industry and government**
- **3 Breakout Sessions**
- **Regulatory Panel**
- ***Professional Networking***

- ***Design Data for Q&C***
- ***F&DT Considerations***
- ***NDI and Process Monitoring***

EASA
European Aviation Safety Agency

Dress Code: ***Business Casual***

Joint FAA – EASA Workshop on Qualification / Certification of *Metal* Additively Manufactured Parts

August 21-23, 2018

Venue: National Center for Aviation Training (http://ncatkansas.org/)
Hosted by NIAR

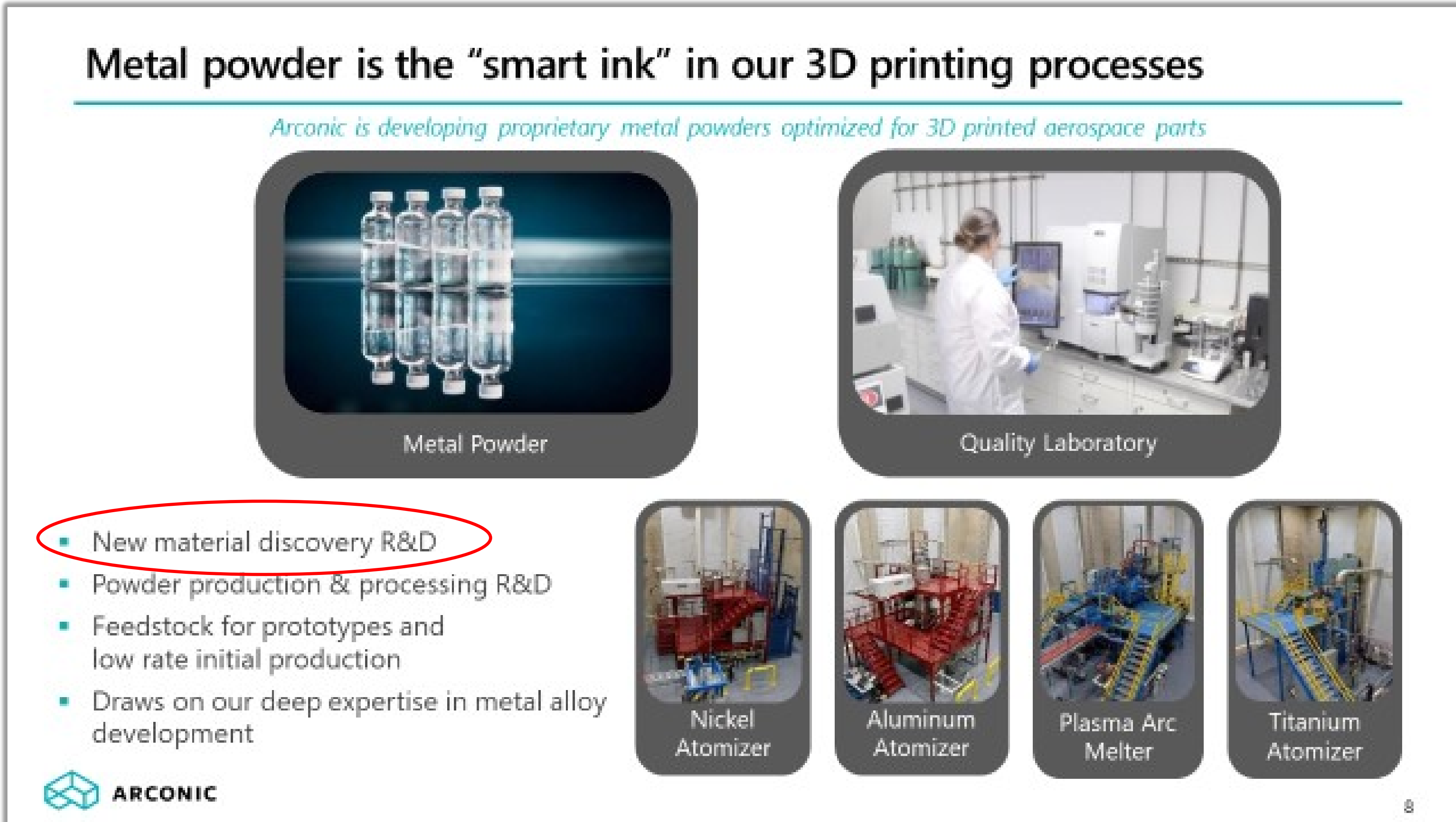
Wichita, KS

- **Workshop Co-organizers**: Dr. Michael Gorelik (*FAA*); Dr. Simon Waite and Dr. Matthew Mercy (*EASA*)
- **Workshop Facilitator**: Dr. Rollie Dutton (*Universal Technologies Corp.*)

Presentations Highlights

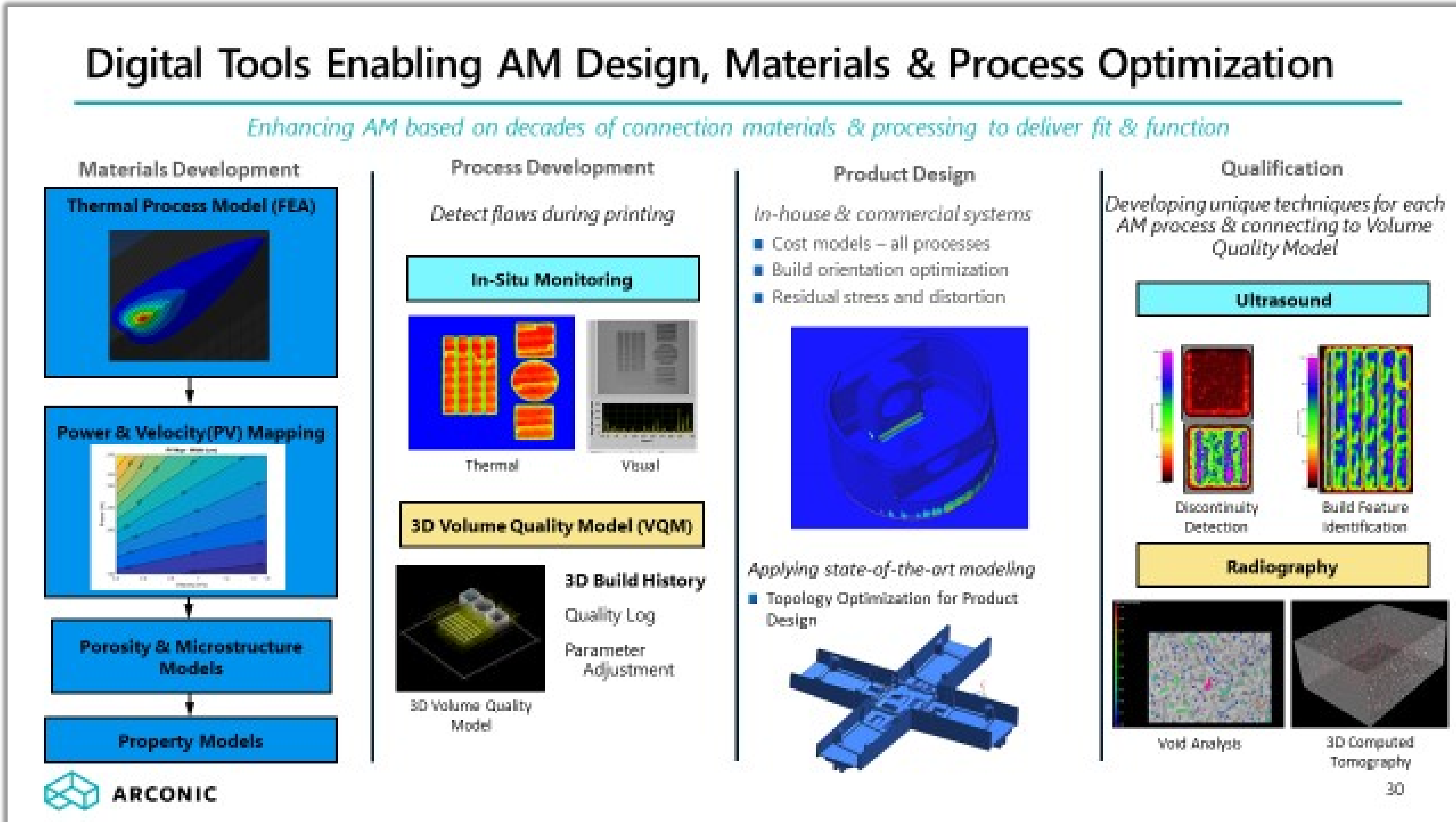
(a sample - limited due to the presentation's time constraints)

Example – Customizing Materials for AM



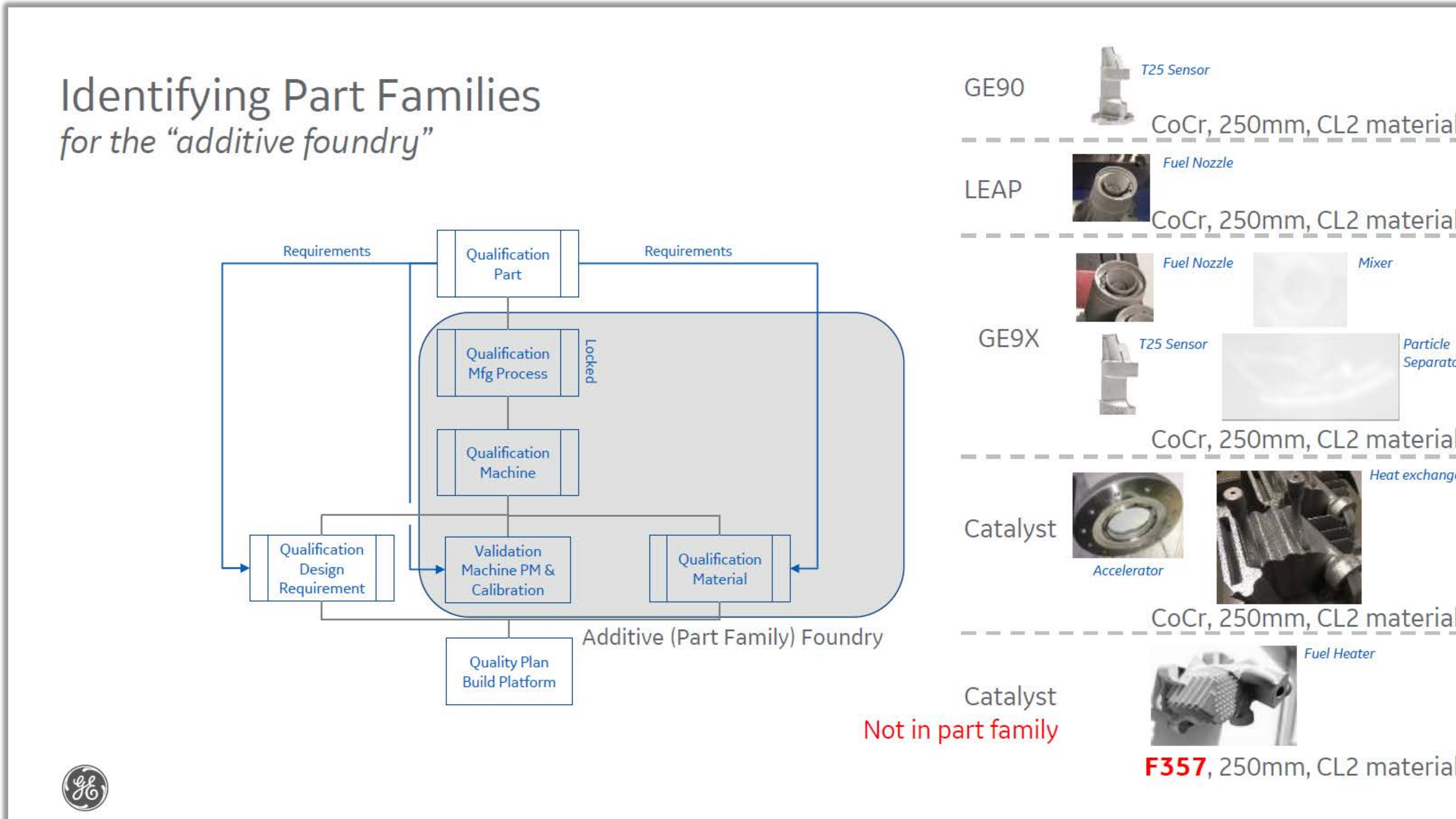
Credit: Dr. M. Heinimann, Arconic

Example - Developing AM Echo System

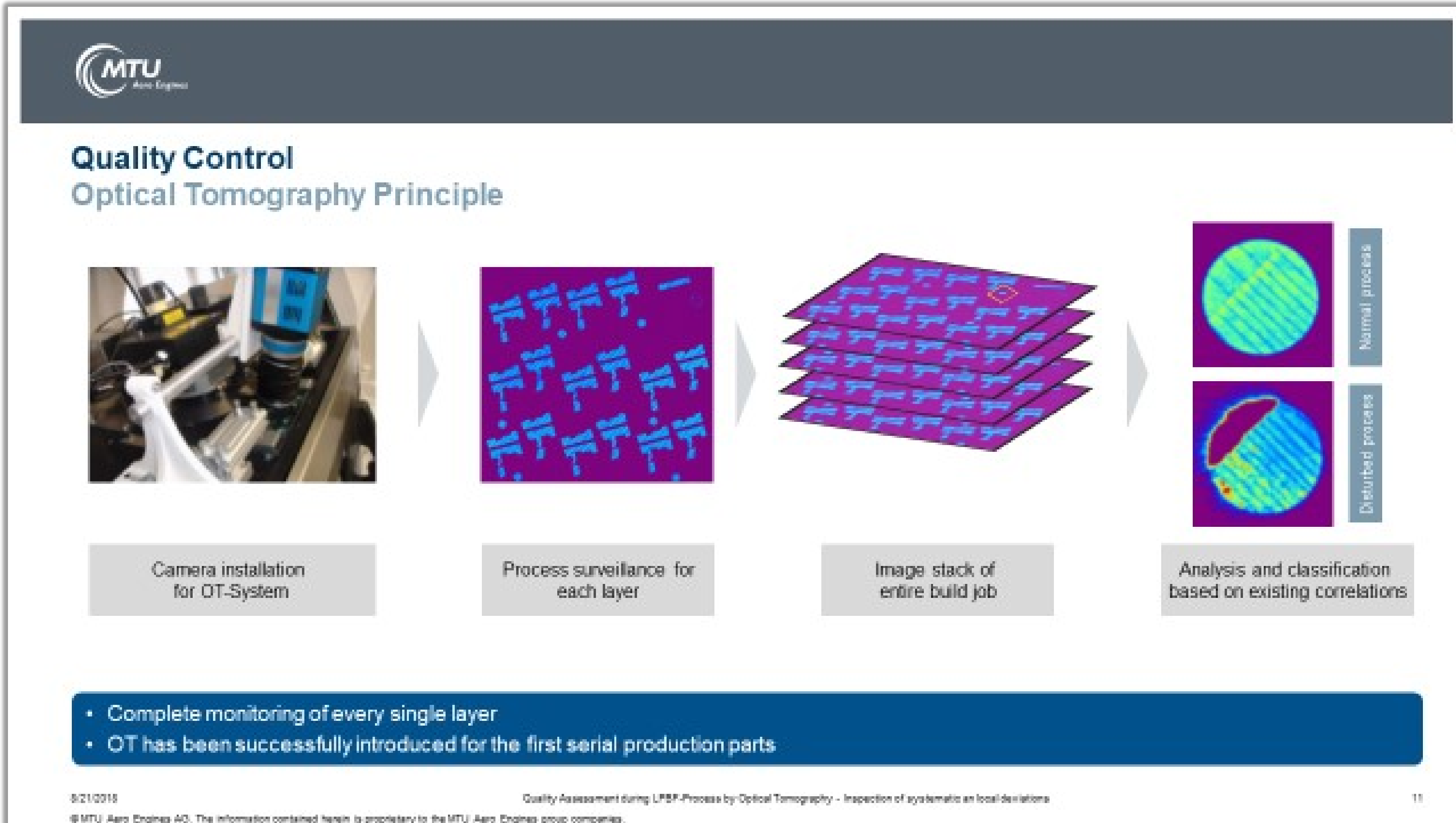


Credit: Dr. M. Heinimann, Arconic

Example – “Part Family” Considerations

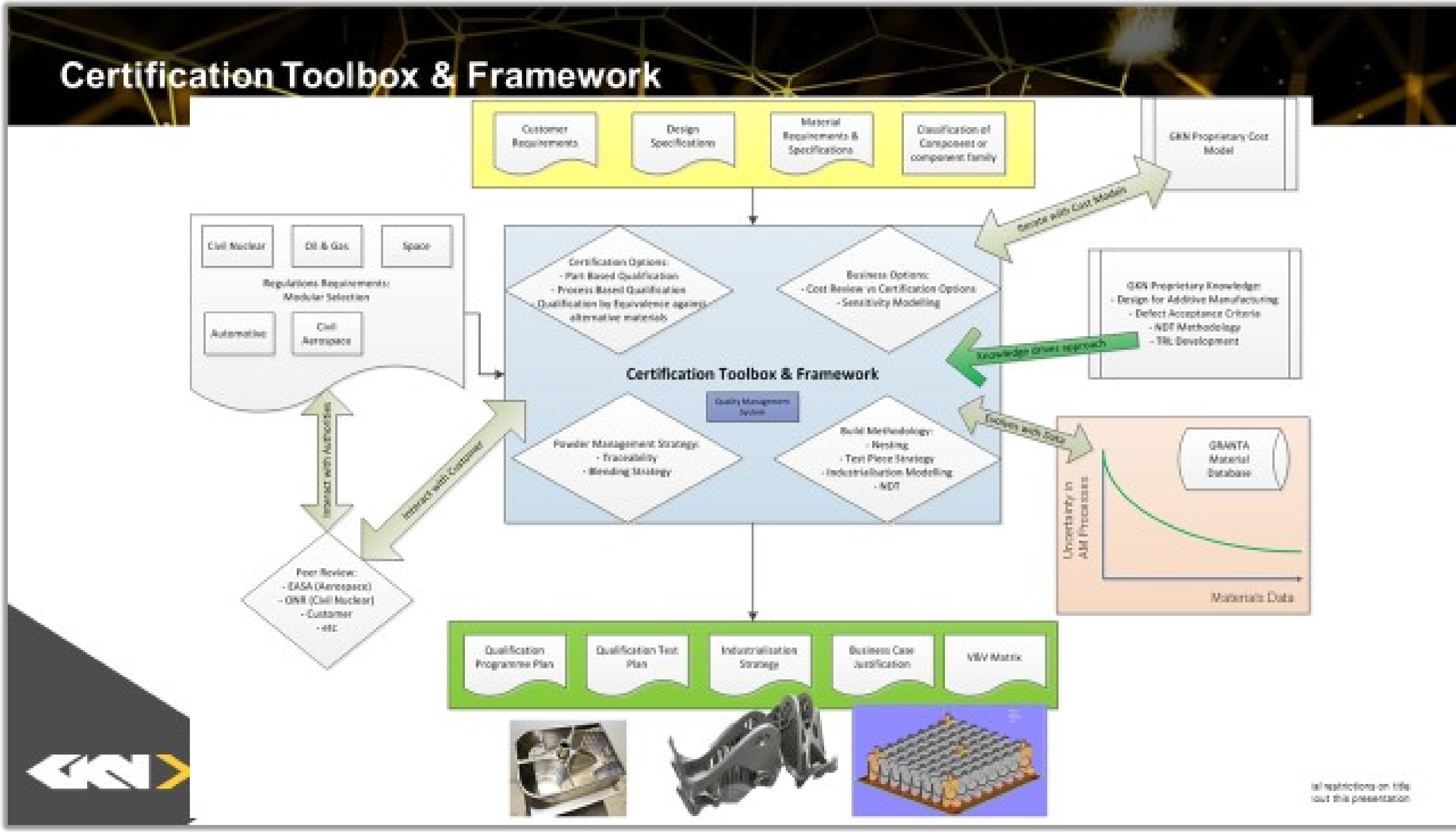


Example – Use of Advanced QC Methods
(optical tomography)



Credit: Mr. A. Ladewig, MTU Aero Engines

Example – Developing “Certification Toolbox”

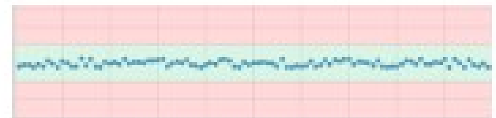


Credit: Dr. M. White, GKN Aerospace

Example – AFRL Perspective on D&DT

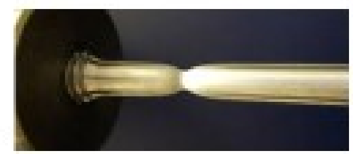
Durability & Damage Tolerance

1. **Stability** - consistent and repeatable quality and predictable costs can be achieved to meet system performance and production requirements.



2. **Producibility** - scale-up to production sizes and rates can be achieved without adversely affecting performance, costs, and quality.

3. **Characterization** – Well understood mechanical and physical properties for the appropriate environments in the as-fabricated condition using the manufacturing processes and joining methods.



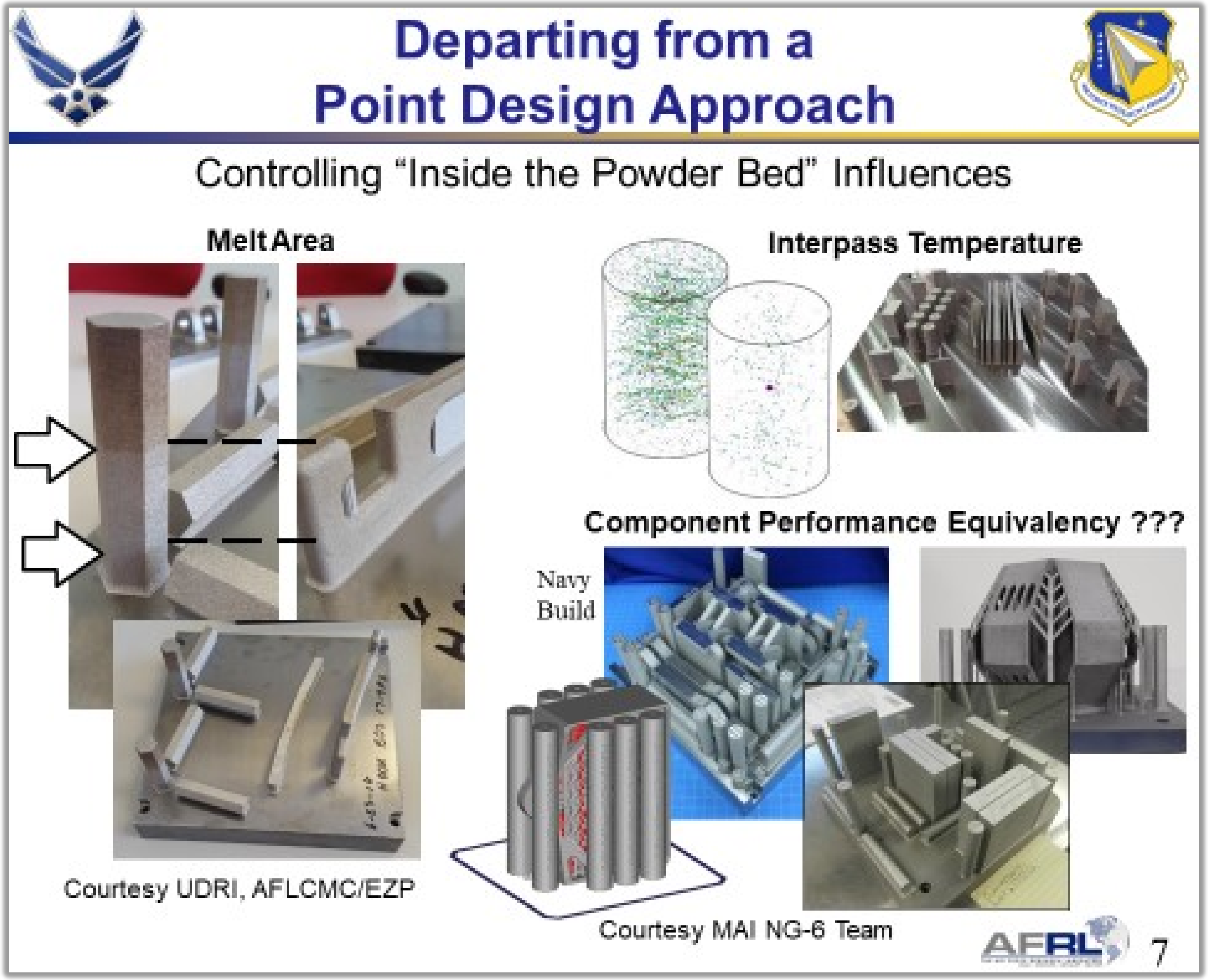
4. **Predictability** - validated analysis/empirical methods are established to enable <u>accurate prediction of structural performance</u>

5. **Supportability** - cost-effective inspection and repair methods are available/ can be developed in a timely manner

AFRL 5

Credit: *Mr. A. Hicks, AFRL / USAF*

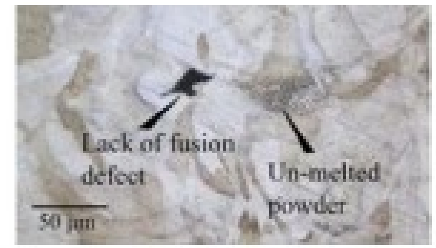
Example – AFRL Perspective (cont.)



Example – Perspective on NDI

Feedback from first serial manufacturing: Non destructive Inspection

Acceptable internal defect size set at a conservative level (challenge of detectability)



Detectability with high roughness

- ✓Surface defects: Penetrant testing need a proper **surface preparation** to be relevant
- ✓Internal and Surface defects: Need to position the NDI step at right place in the manufacturing flow

Airbus qualification approach by :
-> NDI inspections in qualification with Frozen process + regular NDI inspection in serial production
-> Extensive work performed on typical AM surface to insure external defect detection

10 August 2018 AIRBUS experience in Qualification of AM Products

AIRBUS

Credit: Mr. S. Bianco, Airbus

Federal Aviation Administration

Summary of Breakout Session #1

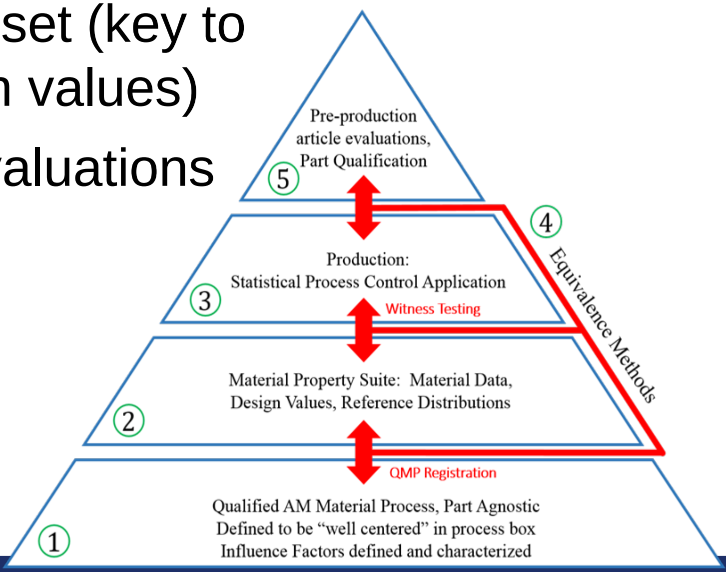
Design Data for Qualification and Certification

- **Opening presentations by GE Additive, Boeing and SAFRAN**
- **Starting point for group discussion - understanding of "Part Family" considerations**
  - Agreed that "point design approach" is not sustainable long-term
  - However, agreed that the term "Part Family" needs standardization before Q&C policy can be defined
  - Reached a strong consensus that better definition of the design data requirements for Q&C of individual parts is needed
- **A five-step system was proposed as a foundation for establishing design values suitable for Q&C of AM parts**
  - Based, in part, on the NASA MSFC standards *MSFC-STD-3716* and *MSFC-SPEC-3717*

Summary of Breakout Session #1 (cont.)

Five-step system description:

1. Process qualification (each S/N AM machine is treated as a mini-foundry)
2. Development of Material Property Suite (MPS)
3. Statistical process control (objective: to maintain the validity of design values over time and across a variety of AM machines)
4. Equivalence methodologies - need to define methods to show that one data set is equivalent to a master data set (key to implementation of this framework for design values)
5. Part qualification—pre-production article evaluations



Summary of Breakout Session #2

Fatigue and Fracture Considerations

- **Opening presentations by Arconic, Lockheed-Martin, SwRI, and P&W**
- **Discussed types of defects for Laser and eBeam PBF, and wire DED processes**
  - Reference: ASTM WK47031draft document – “catalogue of defects”
- **Surface / Sub-surface defects:**
  - Need to consider scan strategy (PBF) for exposed surfaces - may influence level of defects
  - Defects very close to the surface may need a special considerations
  - Conventional measures of surface roughness in AM may not be adequate for correlating to fatigue debits
- **Fatigue properties are typically more sensitive to process variation than static properties, and could be used as a more sensitive indicator of process stability**

Summary of Breakout Session #2 (cont.)

Fatigue and Fracture Considerations

- **Considerations for generating detailed defect data:**
  - Need mature and stable process (material and process specs)
  - Sharing of detailed defects data may be challenging due to proprietary concerns
  - One potential mechanism – similar to AIA RISC / RoMan groups
- **Could use S-N curves to account for *inherent anomalies* if the coupon's gage section contains representative set of anomalies (based on defects frequency)**
- **May need to revisit initial flaw size assumptions for some AM materials / applications**
  - Combination of defect size distributions and NDI capabilities
- **Characterization of inherent defects / anomalies**
  - Need to understand the range of *practical interest* (min size) – can be informed by FM sensitivity studies

Summary of Breakout Session #2 (cont.)

Fatigue and Fracture Considerations

- **Suggested R&D topics:**
  - **Defect populations and sizes for various AM process types – needs to be developed as a structured study**
  - **Seeded defects study (leveraging process maps, e.g. P-V maps) – to understand process boundaries and fatigue behavior of defects**
  - **Understanding of the fatigue behavior of defects below the NDI detectability threshold (interaction with NDE community)**
  - **Understanding of crack nucleation mechanisms for key types of AM anomalies (DT-based assessment may be too conservative)**
  - **Correlating in-situ process monitoring with actual defects formation**

Summary of Breakout Session #3

NDI Inspections and In-situ Process Monitoring

- **Opening presentations by AFRL and Universal Technology Corp.**
- **Considerations for in-process monitoring**
  - thermal imaging of melt pools
  - optical methods to address powder placement and sample consolidation
  - emphasis on using parameters that can be extracted from AM machines and how they could be used to ensure part quality
- **CT is held as gold standard for NDE, yet there are challenges in the types of defects it will detect and size ranges as a function of material, geometry, size, and defect geometry, plus it is slow and expensive**
- **Generic studies on the effect of defects have not been completed (at least in public domain), so it is not clear how to establish NDI requirements for AM parts**

Summary of Breakout Session #3 (cont.)

NDI Inspections and In-situ Process Monitoring

- **Discussed feasibility of using in-process measurements to capture defects during the build, and to allow for either corrective action, or a process halt before additional investments in a defective part**
  - Gaps exist in how to convert in-process data to effective machine diagnostics and/or decisional information during the build
- **Need to consider developing a “library” of defects, at least for an initial sensitivity evaluation of new NDE methods to determine their capability / maturity**
- **Identification of NDE limitations needs to be considered *during the part design phase***
- **Need to consider part criticality considerations (e.g., primary load carrying, or just a support structure) when defining NDE objectives**

Summary

- **Series of public AM workshops sponsored by the FAA (and co-sponsored by USAF and EASA) proved to be an effective mechanism for sharing on-going development and maturation of Q&C framework for AM**
- **These events were used for training of about 100 FAA employees (over the past 4 years)**
- **Proceedings are publically available and have been referenced by a number of working groups and organizations**
- **2018 marked the beginning of FAA – EASA collaboration in producing joint annual AM Q&C workshops**
  - ***Next joint event is planned for August 2020 at NIAR (Wichita, KS)***

APPENDIX

“Legacy” Proceedings of FAA AM Workshops (2015 - 2017)

DOT/FAA/TC-18/3

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Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Joint FAA – Air Force Workshop (FAA CSTA Workshop) Qualification/Certification of Metal Additively Manufactured Parts

- **2017 AM Workshop**
  - **External report:** http://www.tc.faa.gov/its/worldpac/techrpt/tc18-3.pdf
- **2016 AM Workshop**
  - **External report:** http://www.tc.faa.gov/its/worldpac/techrpt/tc17-35.pdf
- **2015 AM Workshop**
  - **External report:** http://www.tc.faa.gov/its/worldpac/techrpt/tc16-15.pdf