



Forward Considerations in Methodologies for Qualification and Certification of Additively Manufactured Parts

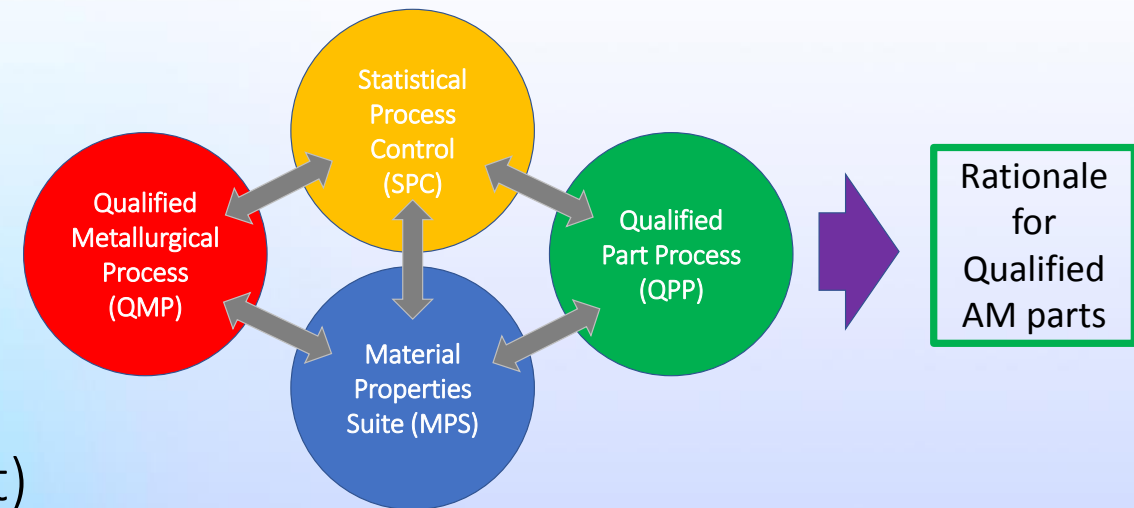
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Douglas N. Wells

NASA Marshall Space Flight Center
Huntsville AL, USA

There are two primary opportunities to ensure AM reliability for qualification and certification rationale:

1. In-Process Controls (Control what you do)
 - Qualify the AM Process and the AM Part Process
 - Understanding fundamentals
 - Recognizing the process failure modes (pFMEA)
 - Identifying observable metrics and witness capabilities
 - Meticulous process scrutiny through SPC
2. Post-Process Evaluation (Evaluate what you get)
 - Non-destructive Evaluation, Proof testing
 - Post-build process monitoring data evidence



Part reliability rationale comes from sum of both in-process and post-process controls, weakness in one must be compensated in the other

Coming Reliance on In-Situ Monitoring



How to approach in-situ monitoring of AM processes?

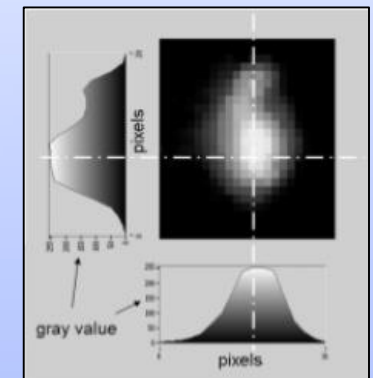
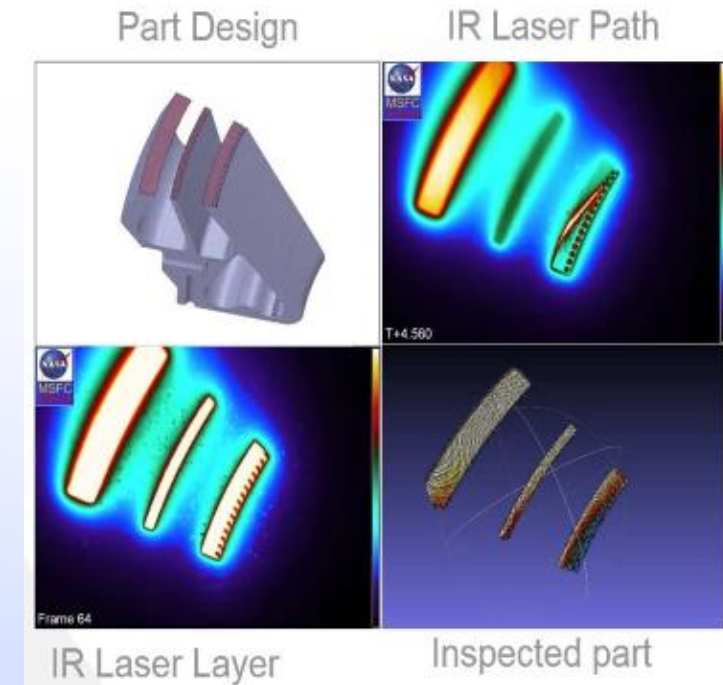
- Harnessing the technology is only half the battle
 - Detectors, data stream, data storage, computations
- Second half of the battle is quantifying in-situ process monitoring **reliability**

Community must realize that passive in-situ monitoring is an NDE technique

1. Understand physical basis for measured phenomena
2. Proven causal correlation from measured phenomena to a well-defined defect state
3. Proven level of reliability for detection of the defective process state
 - False negatives and false positives → understanding and balance is needed

Closed loop in-situ monitoring adds significantly to the reliability challenge

- No longer a NDE technique – may not be non-destructive
- Establishing the **reliability of the algorithm** used to interact and intervene in the AM process adds considerable complexity over passive systems

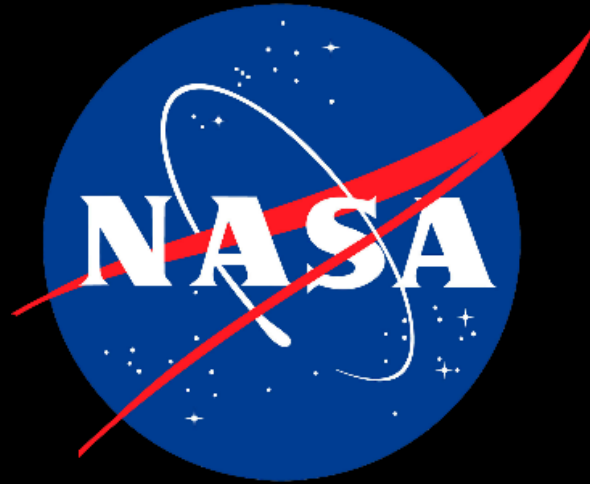


Concept Laser QM Meltpool

Enabling Technology Developments



- In situ process monitoring data stream management
 - How to manage and interpret the data stream reliably
 - In situ process monitoring certification methodologies, in situ data as an NDE process
- Computational NDE
 - Efficient simulations
 - Part-specific NDE simulation for process qualification/detection capability
 - Urgent need to make CT more practical on part by part basis with expected NDE reliability
 - Reduce dependence on physical Reference Quality Indicators (RQIs)
 - Improved inspection and defect scenarios over physical RQIs
- Part assessment framework for integrating “digital twin” information
 - Assimilation of the overall data stream to make part acceptance decisions
 - Probabilistic framework for managing part geometry, stress analysis, measured defect state, NDE reliability, etc.
 - ⁴ Build upon existing probabilistic engines, such as DARWIN



MSFC

Thank you!