Effective and pragmatic introduction of simulation and CM into AM certification activities

Information for discussion with the
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Douglas N. Wells

NASA Marshall Space Flight Center
Huntsville AL, USA

Aspects of Qual & Cert

Two aspects of qualification & certification to consider:

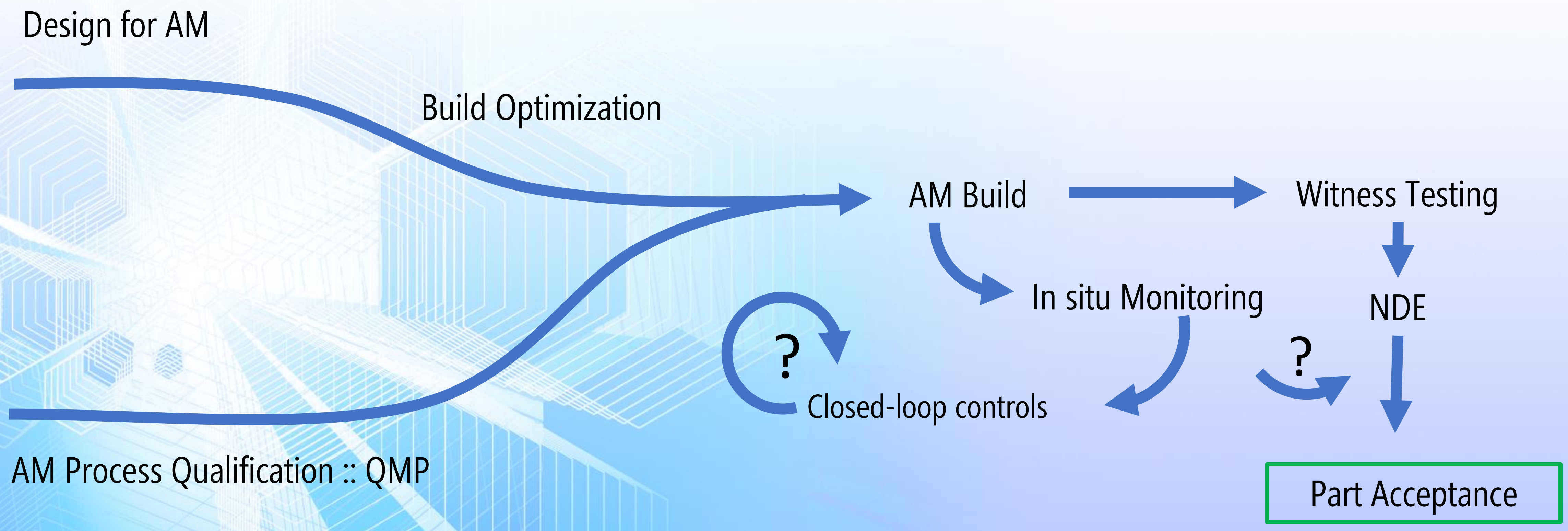
1. Design Certification
   - Demonstration that design meets all requirements of the defined mission
2. Hardware Certification
   - Demonstration that hardware meets all requirements of the certified design

Opportunities for computationally-assisted qualification & certification

- ***Focus primarily on augmenting the existing Q&C processes, NOT replacing them***
- NASA AM Requirements neither endorse nor prohibit such methods
- Tools used in certification require verification and validation
- Best approach to leverage opportunities:
  - Support incremental progress in addition to revolutionary tools
  - Focus on beneficial tools with tractable validation strategies
  - Identify areas of emphasis for industry tool development
  - Establish government-industry partnerships

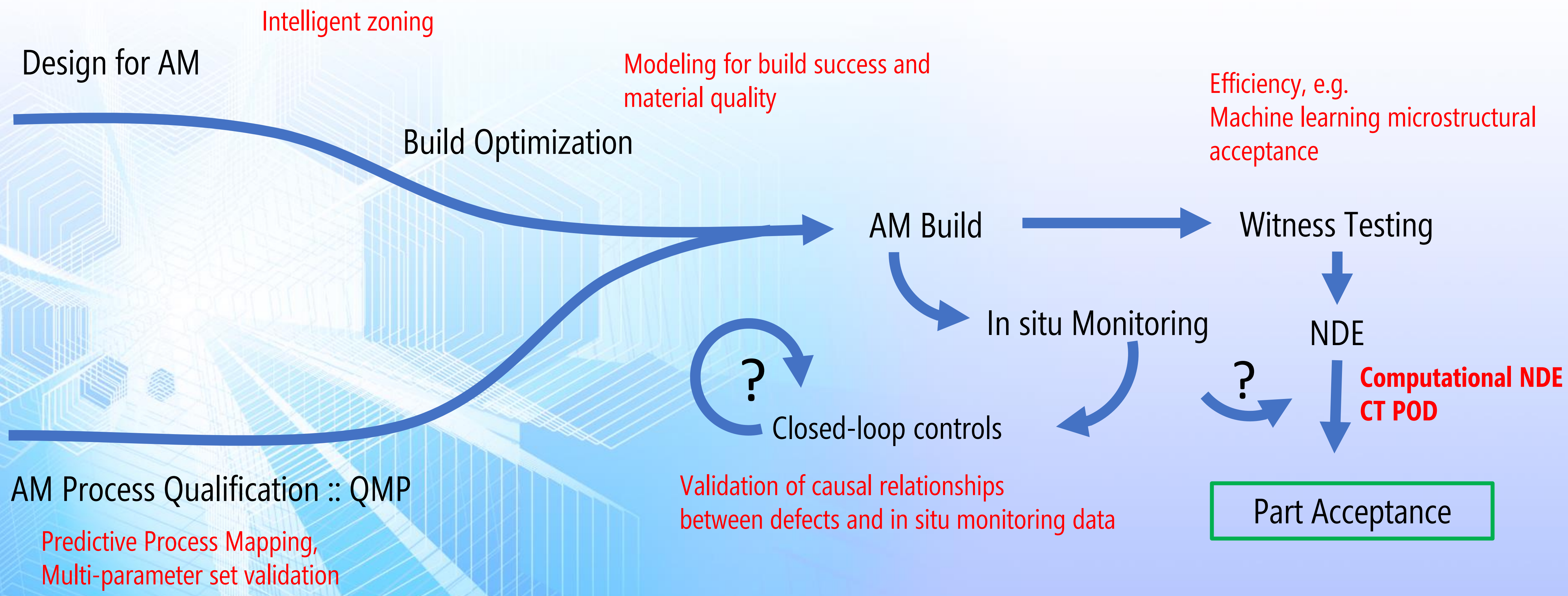
Opportunities

Design Cert | Hardware Cert



Opportunities

Design Cert | Hardware Cert



Opportunities: Design Qual & Cert

Design Cert — Hardware Cert

Intelligent risk-based part zoning through integrated assessment tools

- Prediction of process quality: flaw populations / microstructure
- Prediction of inspection capability
- Prediction of structural demand -- time history of stress

Modeling for build success and build material quality

- Optimal orientation, thermal control, support strategies
- Coupon to part geometry correlations based on flaw population and microstructure
- ***Prediction-based planning for pre-production article assessment***

Opportunities: Design Qual & Cert

Design Cert | Hardware Cert

Efficiencies in "Point Design" methodologies

- Predictive capabilities in process, build quality, material quality, inspection capability
  - Enables efficient point design evaluations
- Reduced physical evaluations: mechanical properties and pre-production articles

Rapid evaluation of changes to qualified and locked designs

- Prediction of process influence on changes
- Reduce pre-production article repetition

Assistance in definition of AM Process Box for process qualification

- Computational validation of parameters
- Prediction of process box boundaries
  - ***"Challenge Part" design – prove process box reliability through geometry and thermal history***

Opportunities: Hardware Cert

Design Cert — Hardware Cert

Efficiencies in routine part acceptance

- Machine learning tools
  - Microstructural evaluation
  - In situ process data evaluation

Validation of in situ monitoring techniques and data

- Causal relationship must be established between defects and monitored response
- Modeling of process and monitoring methods may reduce empirical burden
  - ***Enable in situ monitoring to serve a quantitative NDE role***

Integrated design analysis and MRB acceptance tools – assimilation of AM data streams

- Risk-based assessment for design and acceptance of defects (See DARWIN discussion)

Opportunities: Hardware Cert

Design Cert — Hardware Cert

Computational NDE

- Efficient simulations needed for RT and x-ray CT
- Part-specific NDE simulation for process qualification/detection capability
- Urgent need to make CT more practical on part-by-part basis with known NDE reliability
- Reduce dependence on physical Reference Quality Indicators (RQIs)
  - Concept of virtual RQIs
  - More complete inspection and defect scenario evaluations over physical RQIs
- Computationally derived spatial POD for RT and CT

Example: DARWIN development

To be productive in the regime of qualification and certification, computational tools must:

- Obtain high TRL
- Establish acceptable V&V state

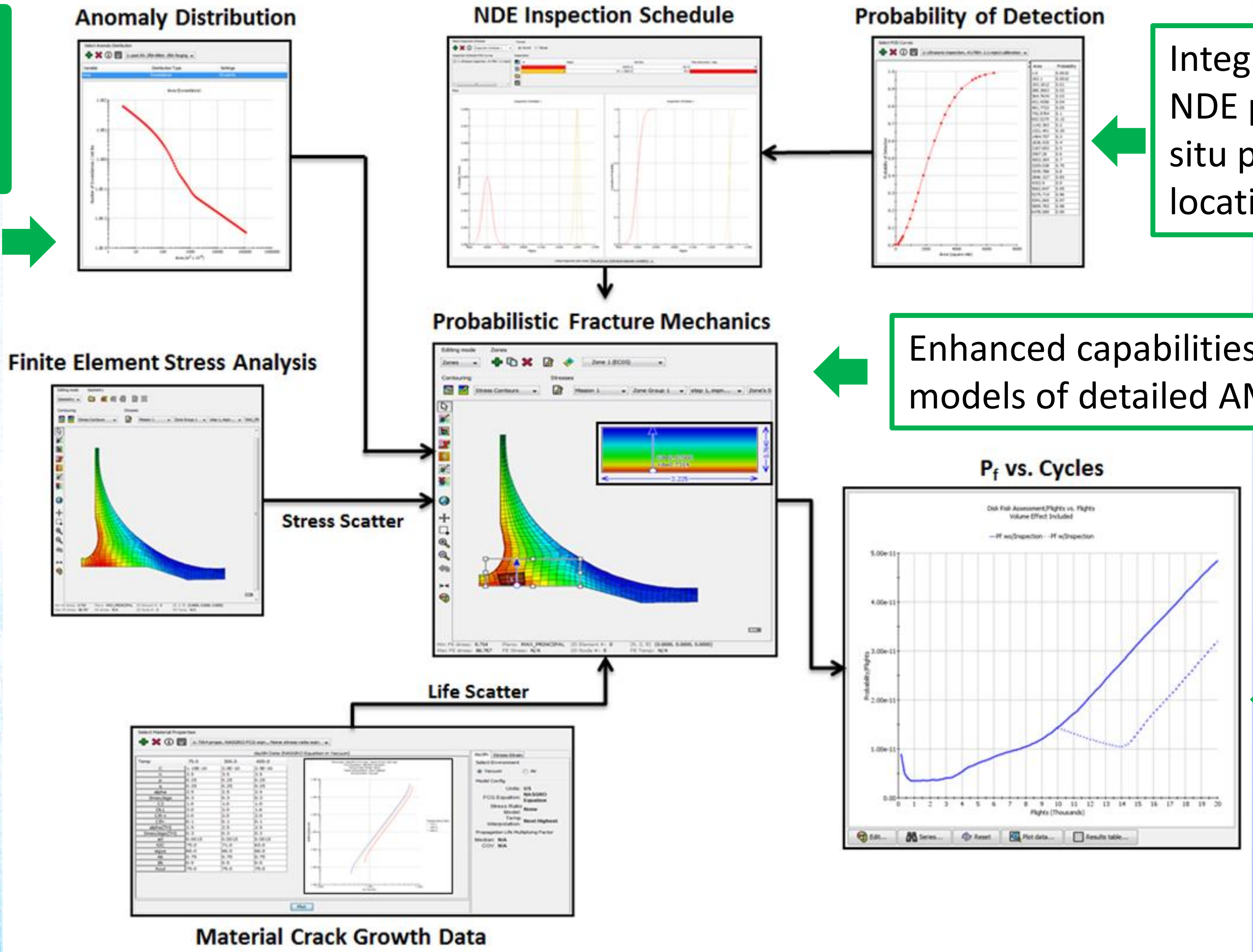
- Getting research codes past the mid-TRL doldrums is critical to establishing Q&C tools
- One methodology is government-industry partnerships in tool development
- Example: DARWIN code developed through FAA/SwRI/Industry collaborations

DARWIN

Example: DARWIN development

NASA/SwRI efforts, AM developments in DARWIN

Methods of anomaly distribution development for AM materials, including incorporation of potential for process escape flaws



Integration of computational NDE predictions of POD or in situ process data by spatial location

Enhanced capabilities for complex 3D models of detailed AM geometry

Efficient mapping of critical initial flaw size for zoning and risk assessment

Summary

- Important to think in terms of “computationally-assisted” qualification and certification to manage scope, near-term benefit, and expectations
- ***Focus primarily on augmenting the existing Q&C processes, NOT replacing them***
- NASA standards in AM are open to computationally-assisted qualification and certification strategies if they are appropriately developed and fully verified and validated
- There exist numerous opportunities in the relatively near-term for tools related to computationally-assisted Q&C to bring significant benefits
- Tools for computationally-assisted Q&C do not have to be grand to have high value
    - Machine learning microstructural acceptance
    - First-order AM build simulations for thermal history predicting flaw populations and microstucture
    - Integration and risk assessment tools, such as adapting DARWIN to AM scenarios
- *Computational tools with highest Q&C impact are likely related to part acceptance*
    - *Simulations to substantiate post-build NDE and tools to elevate in situ systems to quantitative NDE status*

MSFC

Thank you!