



Computational Materials in AM: the Incremental Path to Certification

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Perspective on AM Qual & Cert

- Certification is a human endeavor: a value judgement
 - Typically, a rather conservative set of folks
- Psychology is important
- Technology acceptance is important
- Transparency of methodologies is important (no black boxes)
- Understanding throughout the certification chain is important
 - Those who describe and inform risk
 - Those who accept risk

Interesting parallel discussion:

- AI in health care
 - Implementation
 - Acceptance
 - Regulation



WBUR (Boston)
Public Radio





Aspects of AM 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 and certification

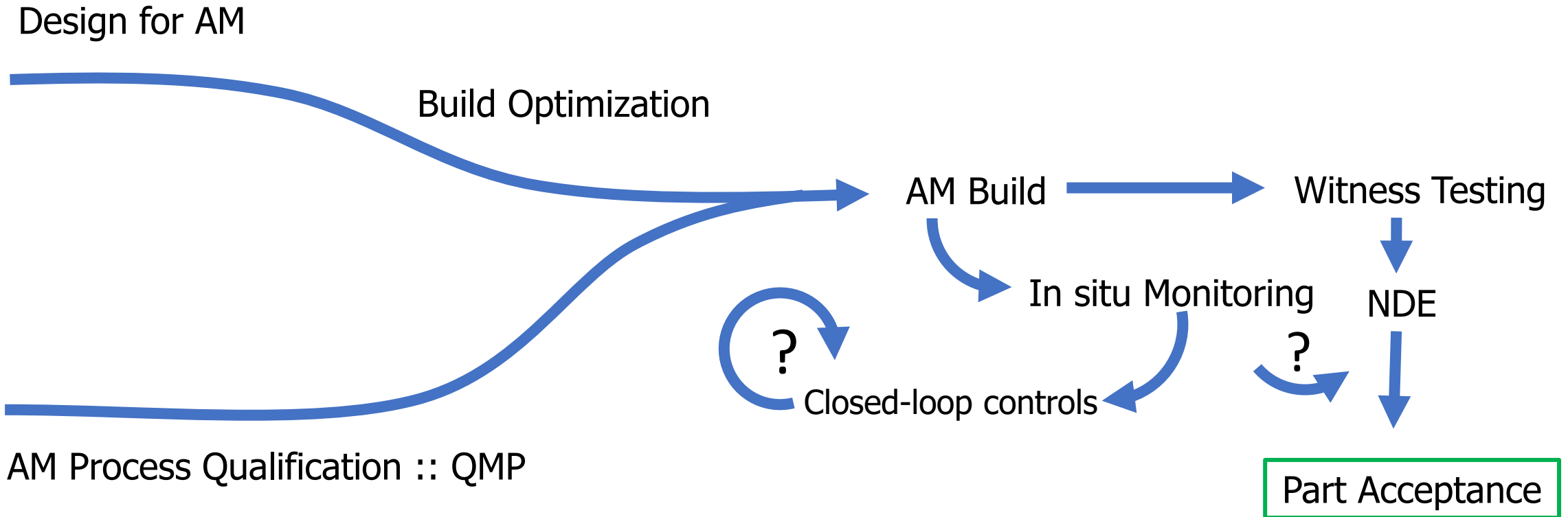
- ***Focus primarily on augmenting the existing Q&C processes, NOT replacing them***
- NASA AM Requirements neither endorse nor prohibit such methods
- Tools used in certification require verification and validation

CM Opportunities in AM Cert



Design Cert

Hardware Cert



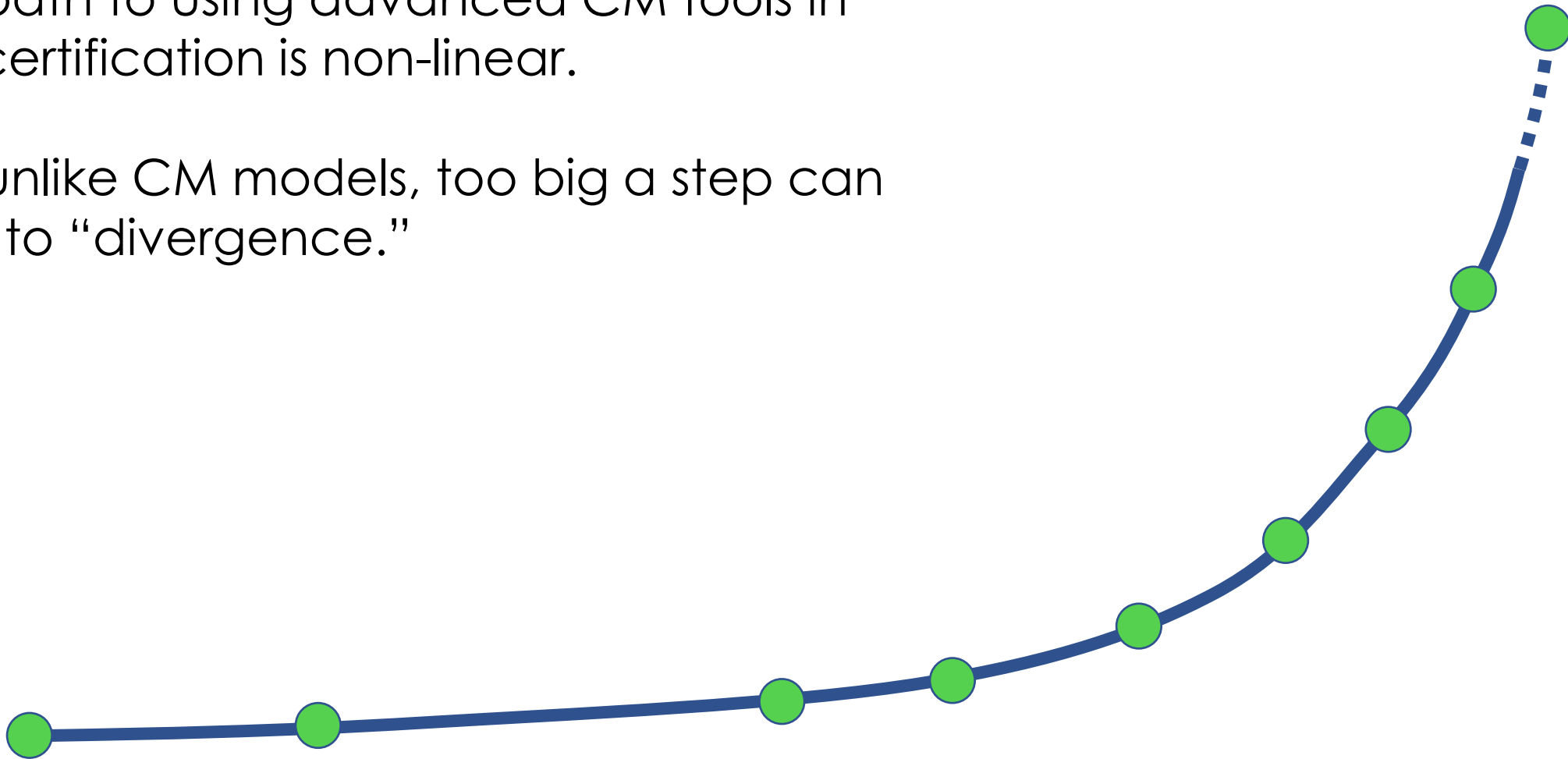
The Non-linear Path

The path to using advanced CM tools in AM certification is non-linear.

Not unlike CM models, too big a step can lead to “divergence.”



CM-Enabled AM Cert



The Non-linear Path

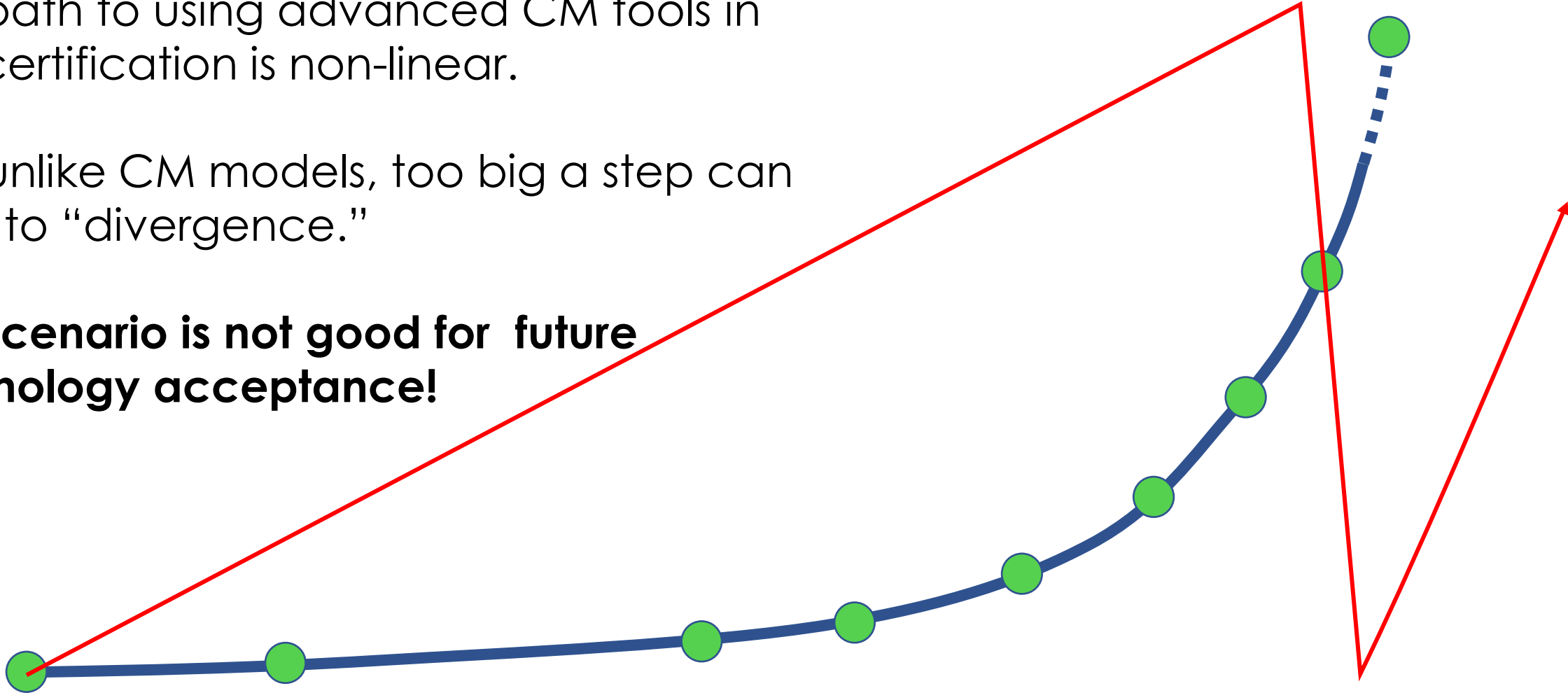


CM-Enabled AM Cert

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Not unlike CM models, too big a step can lead to “divergence.”

This scenario is not good for future technology acceptance!



The Non-linear Path

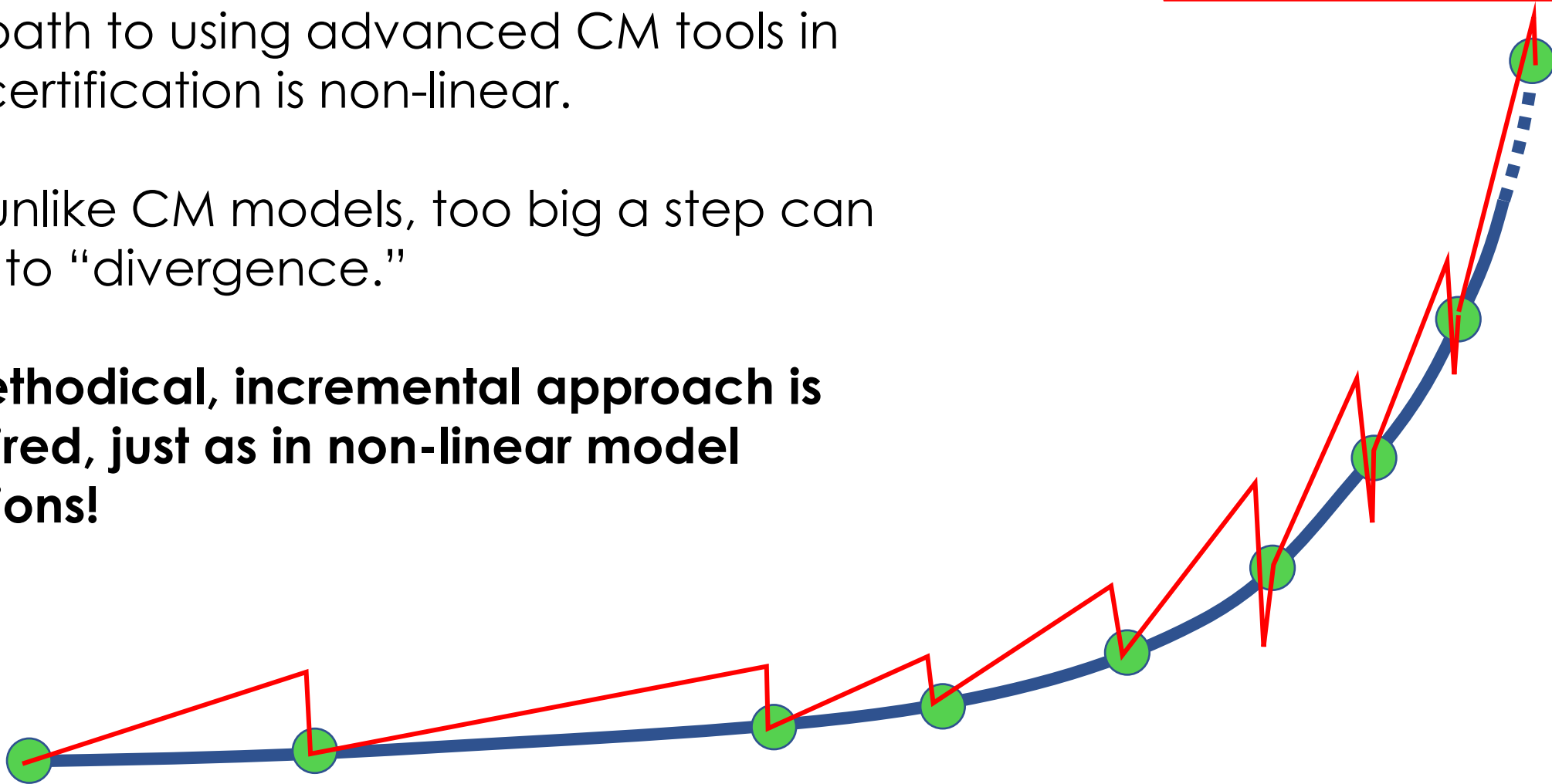
The path to using advanced CM tools in AM certification is non-linear.

Not unlike CM models, too big a step can lead to “divergence.”

A methodical, incremental approach is required, just as in non-linear model solutions!



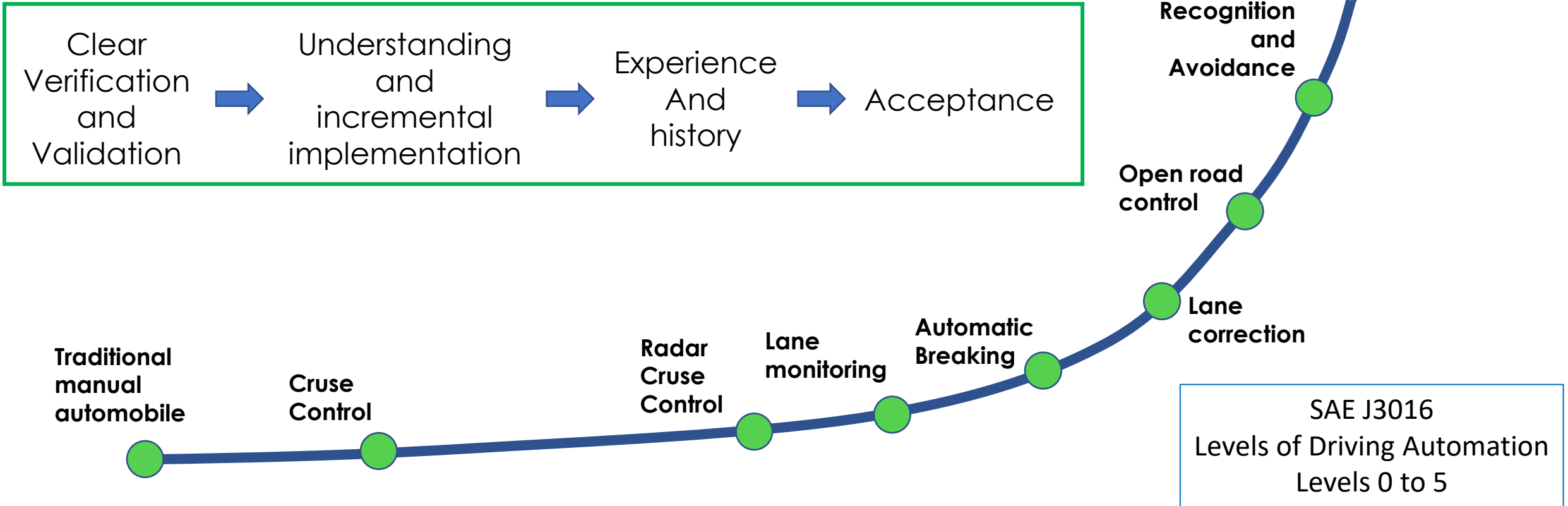
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The Non-linear Path



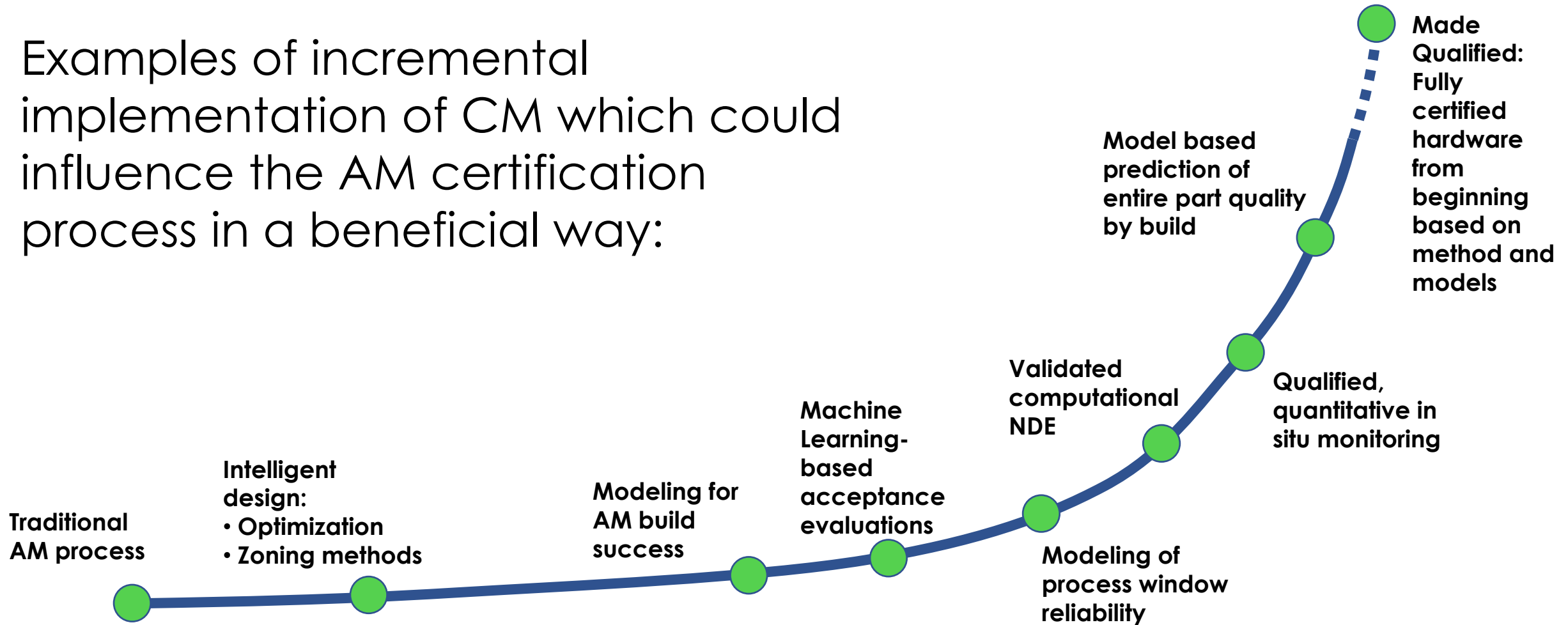
Analogy of incremental technology implementation:
Automobile controls, DOT certification, autonomous vehicles



The Non-linear Path



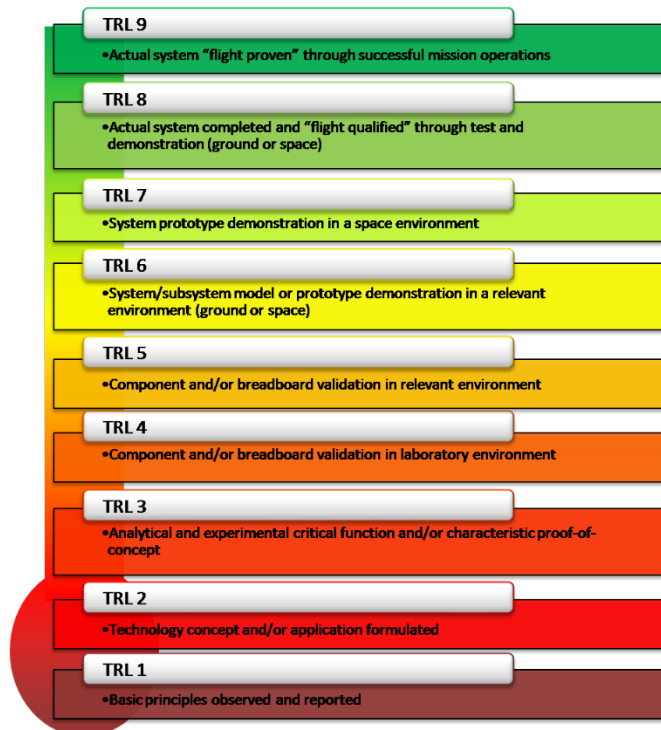
Examples of incremental implementation of CM which could influence the AM certification process in a beneficial way:





The Non-linear Path

TRL / MRL Scale



Reach down?

Barrier TRLs

or

Push up?

Easier with processes and hardware than CM models?

Traditional AM process

Intelligent design:
• Optimization
• Zoning methods

Modeling for AM build success

Machine Learning-based acceptance evaluations

Validated computational NDE

Modeling of process window reliability

Qualified, quantitative in situ monitoring

Model based prediction of entire part quality by build

Made Qualified: Fully certified hardware from beginning based on method and models

Opportunities: CM in AM Design Qual & Cert



- 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
 - Get busy!

Opportunities: CM in AM Design Qual & Cert



Design Cert

Intelligent risk-based part zoning through integrated assessment tools

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

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

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

Opportunities: CM in AM Design Qual & Cert



Design Cert

Rapid evaluation of changes to qualified and locked designs

- Prediction of process influence on changes (evaluation of deltas)
- 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: CM in AM Hardware Qual & 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



Opportunities: CM in AM Hardware Qual & Cert



Hardware Cert

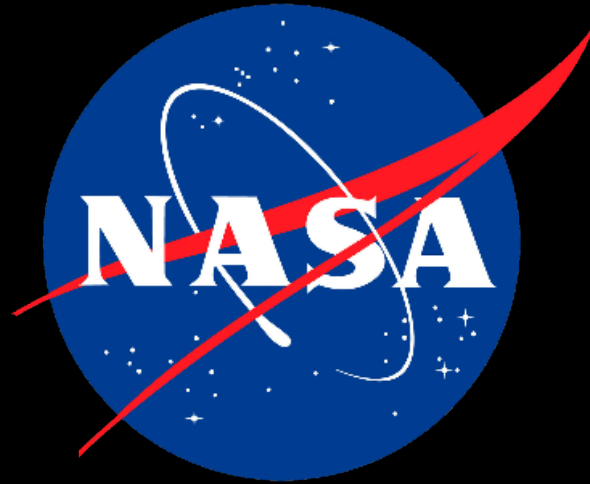
Computational NDE

- 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

Summary and Closing



- 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 microstructure
- ***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!