

# Digital Twins- An Imitation of Life

John Vickers

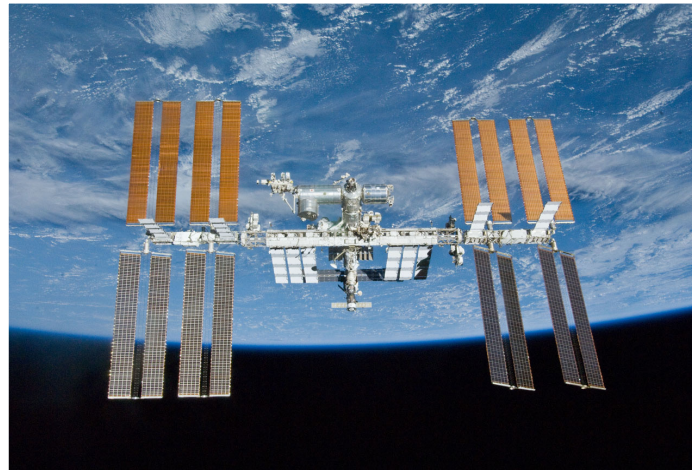
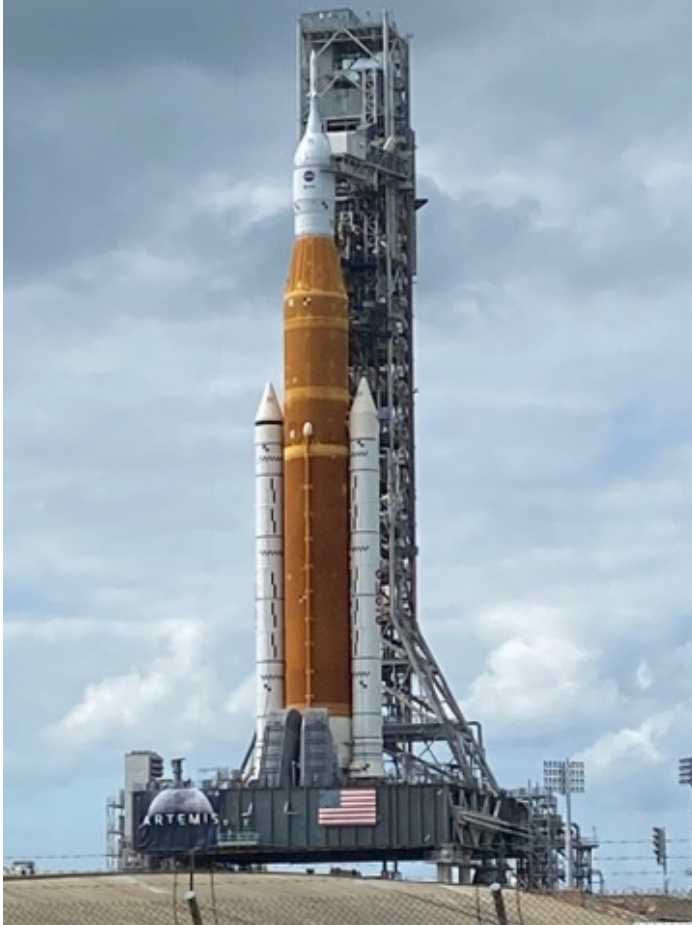
Principal Technologist, Advanced Manufacturing

NASA

“Somewhere, something incredible is waiting to be known.” Carl Sagan



# How We Explore... NASA Manufacturing



# Digital Twin



## Definition of *digital*

*adjective*: composed of data in the form of especially binary digits, of, relating to, or using calculation by numerical methods or by discrete units

*noun*: : media (such as a photograph) in a digital format

## Definition of *twin*

*adjective*: made up of two similar, related, or connected members or parts, paired in a close or necessary relationship, having or consisting of two identical units

*verb*: to bring together in close association

“Technology that will Revolutionize the World”





# What is a Digital Twin?

“Must a name mean something?” Alice asks Humpty Dumpty: “When I use a word... it means just what I choose it to mean, neither more nor less.” - Lewis Carroll.

A digital twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person or other abstraction. - Gartner

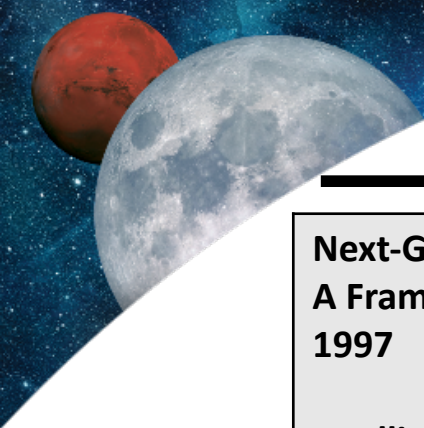
The ultimate vision for the digital twin is to create, test, build and operate our equipment in a virtual environment.  
– Economist: John Vickers (2015)

An integrated multiphysics, multiscale, probabilistic simulation of an as-built system, enabled by the Digital Thread, that uses the best available models, sensor information, and input data to mirror and predict activities and performance over the life of its corresponding physical twin. – Defense Acquisition University

A Digital Twin is a set of virtual information constructs that fully describes a potential or actual physical manufactured product from the micro atomic level to the macro geometrical level. At its optimum, any information that could be obtained from inspecting a physical manufactured product can be obtained from its Digital Twin. – Grieves, Vickers

A digital twin is a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity. – Digital Twin Consortium

A Digital Twin is a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning, and reasoning to help decision-making.  
– IBM



# Chronology and Origins

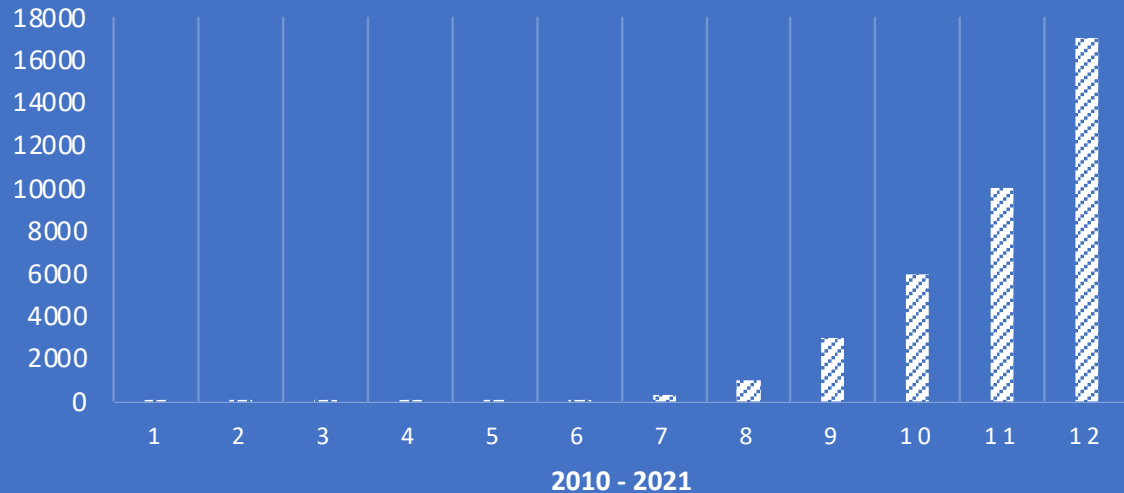
|   |   |
|---|---|
| <p>Next-Generation Manufacturing<br/>A Framework for Action<br/>1997</p>  | <p>“Conceptual Ideal for PLM”<br/>Product Lifecycle Management (PLM) Center<br/>University of Michigan<br/>2002</p>   |
| <p>Intelligent and Integrated Manufacturing Systems (IIMS)<br/>National Science and Technology Council<br/>Interagency Working Group on Manufacturing Research<br/>and Development<br/>2004</p> | <p>Product Lifecycle Management: Driving the Next<br/>Generation of Lean Thinking: 2006</p>   |
| <p>Manufacturing the Future<br/>National..., Interagency Working Group on Manufacturing<br/>R&amp;D<br/>2008</p>  | <p>Product Lifecycle Management and the<br/>Quest for Sustainable Space Exploration<br/>AIAA SPACE Conference &amp; Exposition<br/>2010</p>                               |
| <p>Radical Innovation in Design and Manufacturing<br/>A workshop – Disneyland<br/>2009</p>  | <p>Vickers/Grieves introduction 2007</p> <p>Virtually Perfect: Driving Innovative and Lean Products<br/>through Product Lifecycle Management<br/>2011 ** Digital Twin</p> |
| <p>NASA Materials and Manufacturing Technology Roadmap<br/>2010 ** Digital Twin</p>   | <p>Digital Twin: Mitigating Unpredictable,<br/>Undesirable Emergent Behavior in<br/>Complex Systems<br/>2017</p>  |
| <p>SME Magazine - Where the ‘Digital Universe’ Is Going<br/>2021</p>  |   |



# Digital Twin Expansion

\*Google Scholar about 38,800 results vs Google about 9,240,000 results

## DIGITAL TWIN GOOGLE SCHOLAR SEARCH



## Expanding the Digital Twin Economy

Digital Twin Consortium

ASME Digital Twin Summit

MxD/DMDII, CESMII, IACMI, America Makes

Centre for Digital Built Britain, European Space Agency (ESA)

IBM, Siemens, Dassault, PTC, NVIDIA, Autodesk

The first direct consequence of the IoT is the generation of huge quantities of data, where every physical or virtual object may have a digital twin in the cloud... European Research Cluster, WP on the Internet of Things, December 2010

“Tomorrow’s winners will have very different characteristics than today’s winners.” Lester C. Thurow  
“The Future of Capitalism”

# You Can't Always Get What You Want



## What Digital Twins Are and Not about!

- ✓ **Interdisciplinary** - analyzes, synthesizes and harmonizes links between disciplines into a coordinated and coherent whole
- ✓ **Model Based** - Model of Models (MBx – model based everything)
- ✓ **Collaborative--Predictive--Descriptive--Investigative--Cognitive—Corrective**
- ✓ **As-Designed – As-Built – As-Operated**
- ⊘ **Digital Twin** requires a physical asset (apologies to my AIAA friends)
- ⊘ **Multidisciplinary** - draws on knowledge from different disciplines but stays within their boundaries
- ⊘ **Renaming other technology** - MBSE, Digital Thread
- ⊘ **Siloed environments** – “throwing it over the wall”

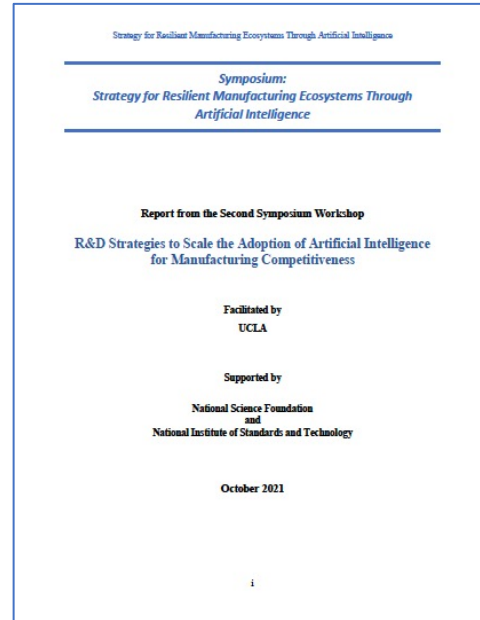
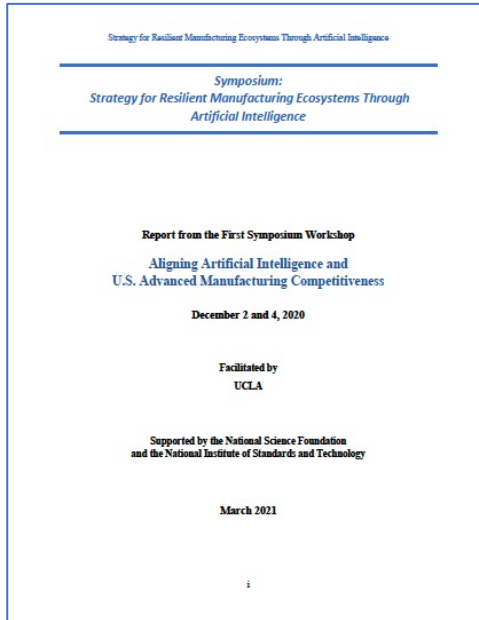
*DARPA - if the experts are laughing at you, then you're on the right track*



# Aligning Artificial Intelligence and U.S. Advanced Manufacturing Competitiveness



## Strategy for Resilient Manufacturing Ecosystems through Artificial Intelligence



<https://oarc.ucla.edu/nsf-nist-symposium>

- **Goal 1: Support small and medium-sized manufactures (SMMs) to digitalize their operations**
  - **Layer 1: Factory floor machine/process asset management**
- **Goal 2: Incentivize large companies to work within their established supplier networks to implement AI methods**
  - **Layer 2: Entire factory and supply chain interoperability**
- **Goal 3: Enable new business models**
  - **Layer 3: Supply chain ecosystem resilience as a result of scaled access to US manufacturing capabilities**



# Materials Genome Initiative Strategic Plan



The Materials Genome Initiative was launched to accelerate the discovery, design, development, and deployment of new materials, at a fraction of the cost, by harnessing the power of data and computational tools in concert with experiment.

Significant advances have been made from academia, industry, and government in both expanding understanding and building the foundation of the required infrastructure of models, computational and experimental tools, and data.

Three primary goals for the next five years:

1. Unify the Materials Innovation Infrastructure
2. Harness the Power of Materials Data
3. Educate, Train, and Connect the Materials R&D Workforce



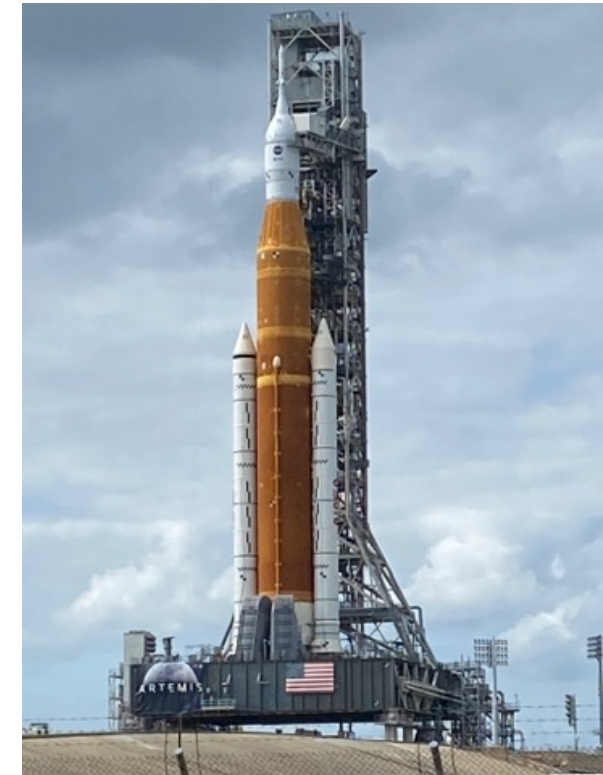
## MATERIALS GENOME INITIATIVE STRATEGIC PLAN

A Report by the  
SUBCOMMITTEE ON THE MATERIALS GENOME INITIATIVE  
COMMITTEE ON TECHNOLOGY

of the  
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

November 2021

# Digital Twins Creating a Next Generation Capability for NASA's Michoud Assembly Facility





# Digital Transformation @ NASA



3 GOALS

4 TARGETS

5 LEVERS

6+ OUTCOMES

Transform the way we **Work**

Transform the experience of our **Workforce**

Transform the agility of our **Workplace**



Establish Enabling *Architectures*

Transform! Critical *Processes*

Maximize the Impact of our *Data*

Define Common *Tools*

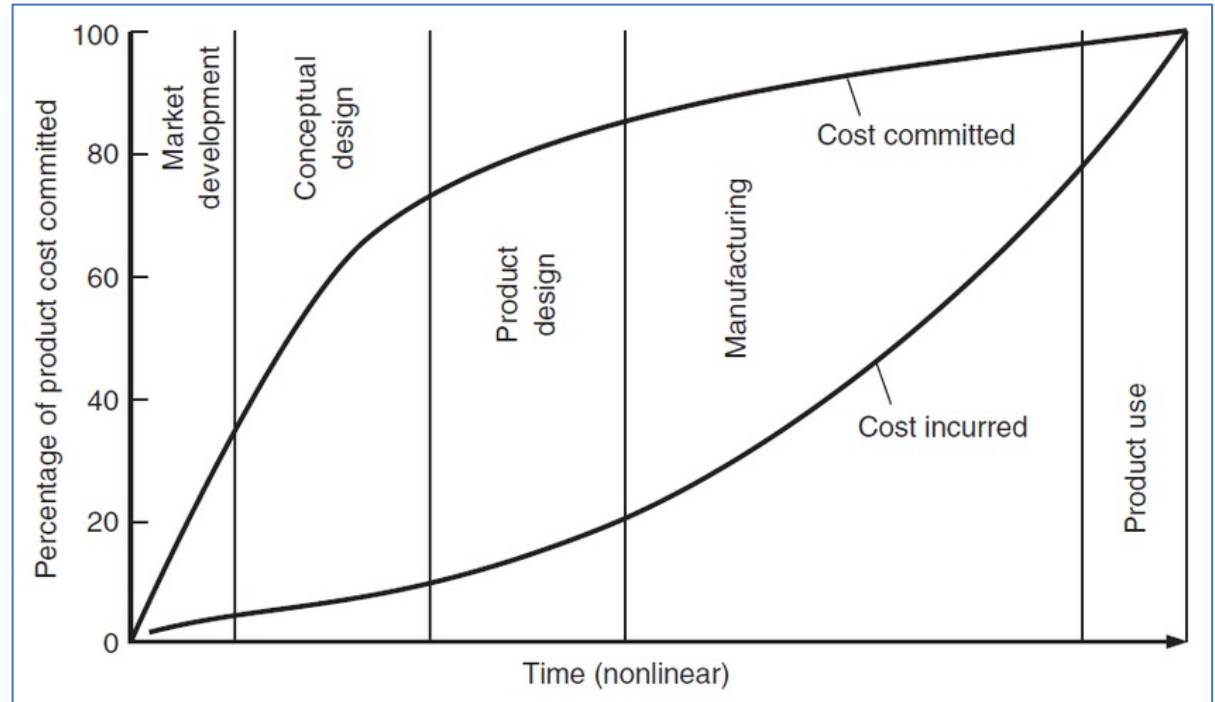
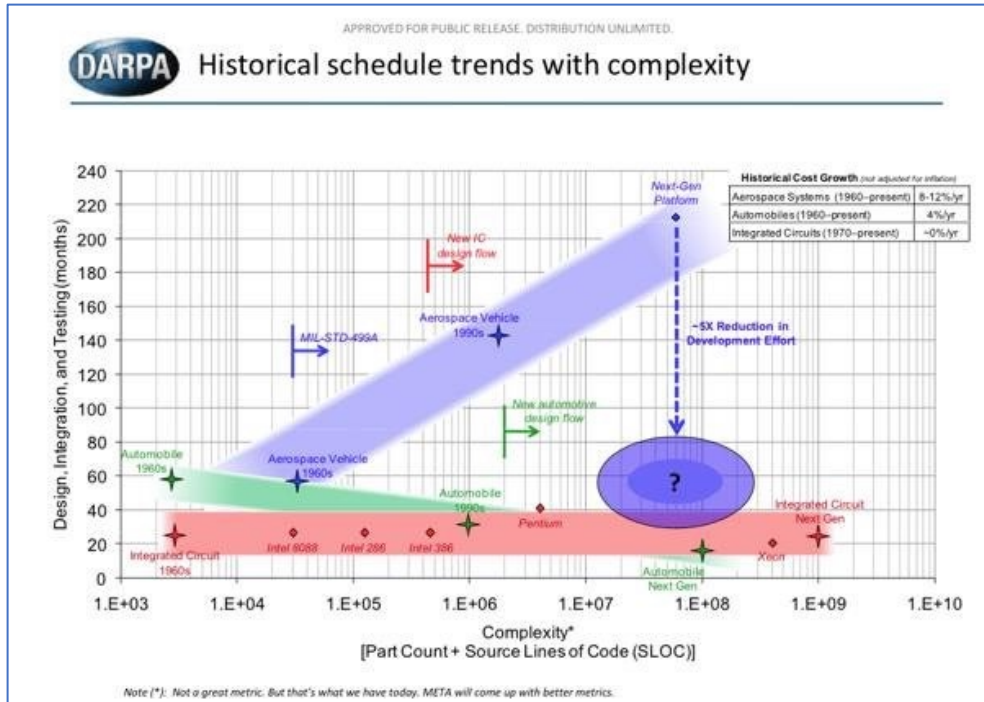
Strengthen Inclusive<sup>3</sup> *Teaming*



# Faster, Better, Cheaper



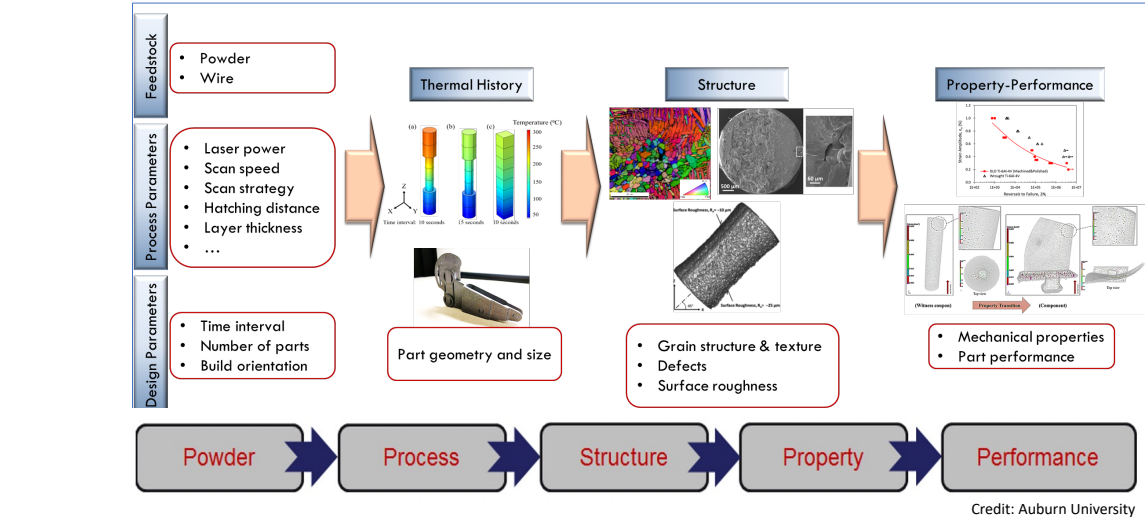
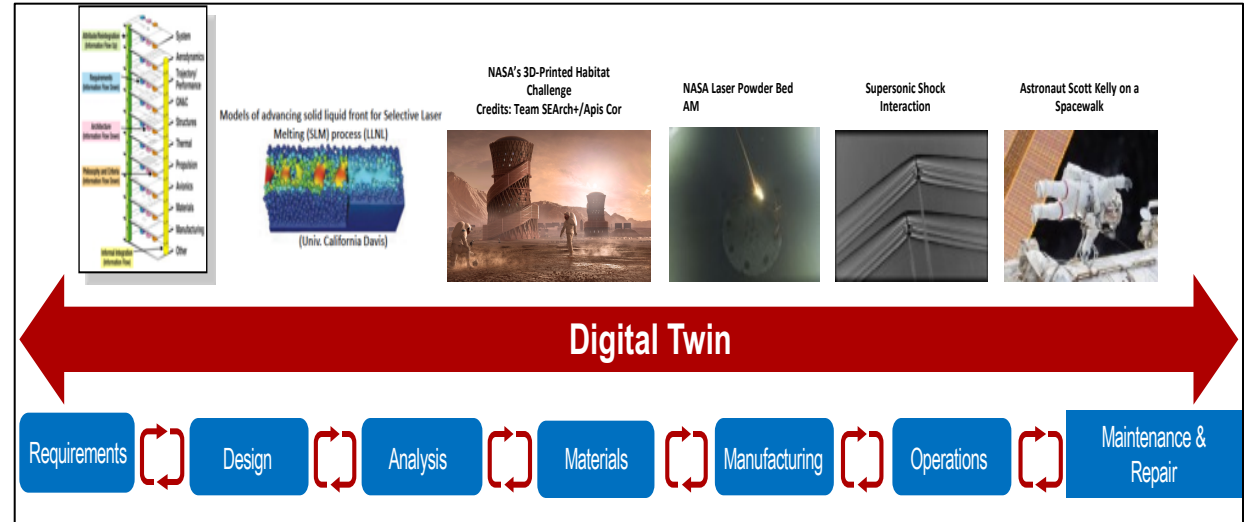
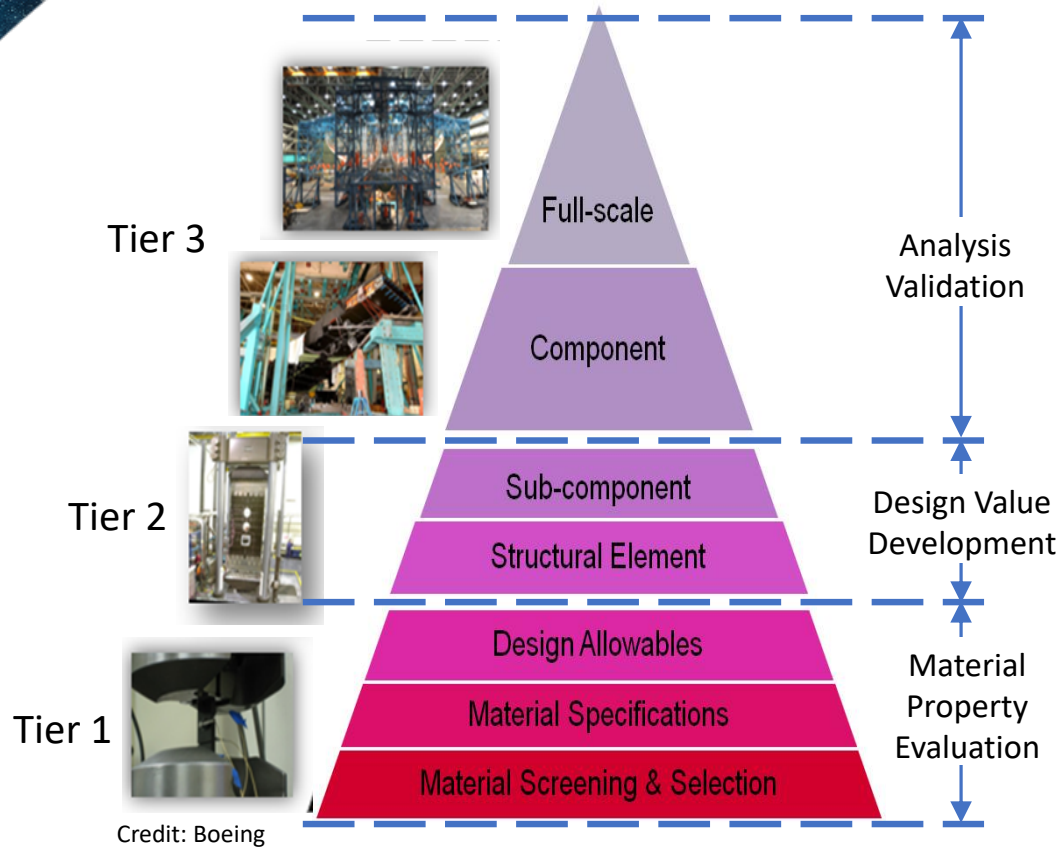
**Faster, Better, Cheaper: A maligned era of NASA's history... Elizabeth Frank**



**“The largest obstacle to low-cost innovation is the belief that it cannot be done” ... Howard McCurdy**



# Digital Twin! "A Little Less Conversation A Little More Action Please"

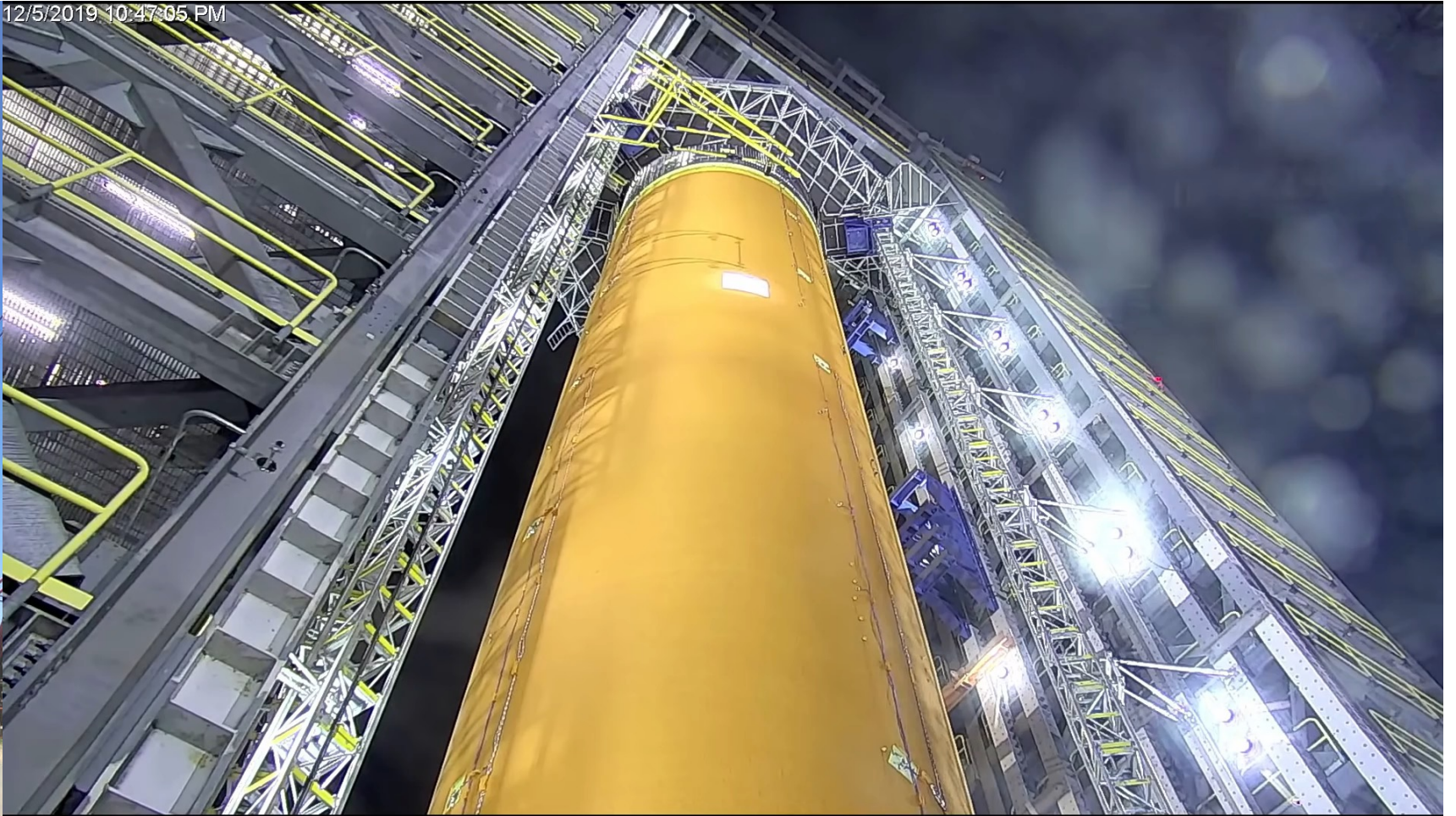


## Product Development, Testing and Certification Today

Exhaustive testing done to support analysis - "takes too long and costs too much to certify aerospace structures"



# Testing and Certification, Today







# Past is Prologue

## Linkages between Science, Technology, and Commerce



A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill. *Vannevar Bush, head of the U.S. Office of Scientific Research and Development during World War II*







Technology Drives Exploration

*Thank You!*

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