



EXPLORESpace TECH
TECHNOLOGY DRIVES EXPLORATION

Digital Twin Consortium 2023 Q2 Member Meeting

Digital Twin Evolution and Institutionalization

John Vickers | Principal Technologist, Space Technology Mission Directorate | June 13, 2023

How We Explore... NASA Manufacturing





Digital Twin Institutionalization



dig·i·tal

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

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

in·sti·tu·tion·al·i·za·tion

noun: the action of establishing something as a convention or norm in an organization or culture

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)

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

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 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



**Next-Generation Manufacturing
A Framework for Action
1997**

**Intelligent and Integrated Manufacturing Systems (IIMS)
National Science and Technology Council
Interagency Working Group on Manufacturing Research
and Development
2004**

**Manufacturing the Future
National..., Interagency Working Group on Manufacturing
R&D 2008**

**Radical Innovation in Design and Manufacturing
A workshop – Disneyland
2009**

**NASA Materials and Manufacturing Technology Roadmap
2010 **Digital Twin**

**SME Magazine (Kip Hanson) - Where the 'Digital Universe'
Is Going and Where Wild Savings Can Be Had Today
2021**

**"Conceptual Ideal for PLM"
Product Lifecycle Management (PLM) Center
University of Michigan
2002**

**Product Lifecycle Management: Driving the Next
Generation of Lean Thinking: 2006**

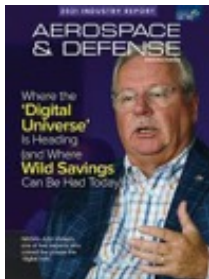
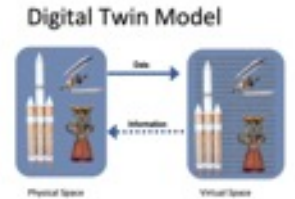
Vickers/Grieves introduction 2007

**Product Lifecycle Management and the
Quest for Sustainable Space Exploration
AIAA SPACE Conference & Exposition
2010**

**Virtually Perfect: Driving Innovative and Lean Products
through Product Lifecycle Management
2011 ** Digital Twin**

**Digital Twin: Mitigating Unpredictable,
Undesirable Emergent Behavior in Complex Systems
2017**

Holst Memorial Lecture and Award 2022

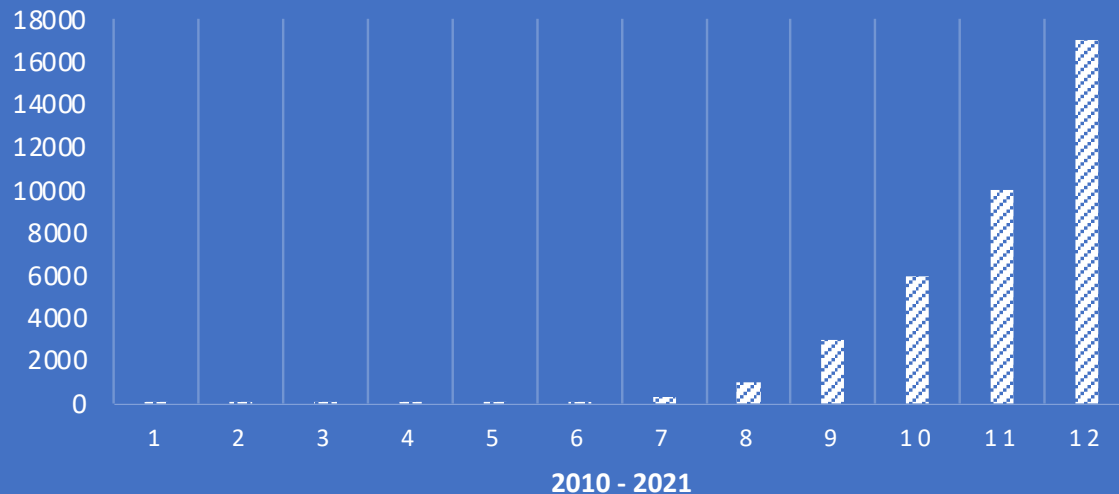




Digital Twin Expansion

*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

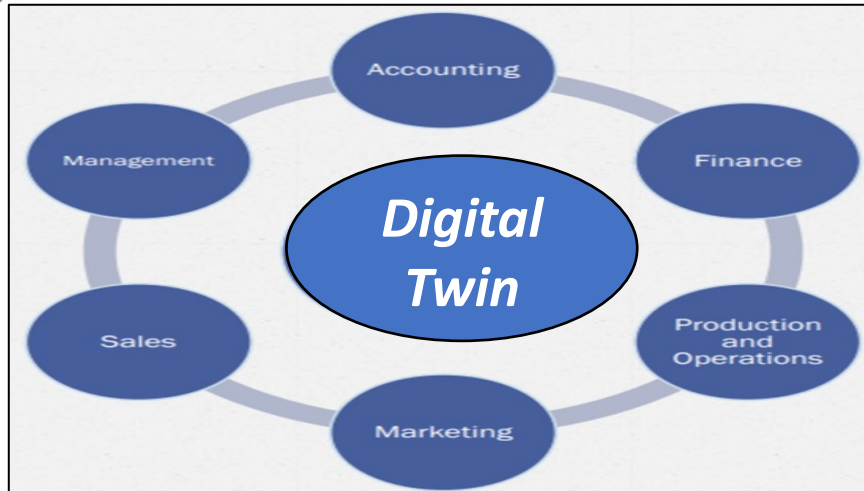
Centre for Digital Built Britain, European Space Agency (ESA)

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”

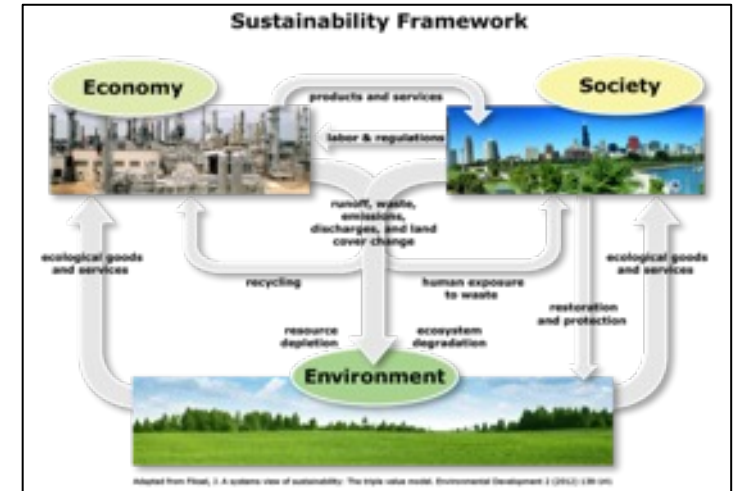
Digital Twin Broad Transformation



Business



Health



Environment



Digital Twin of Life

"Designed by pch.vector / Freepik"

You Can't Always Get What You Want



What Digital Twins Are and Not about!

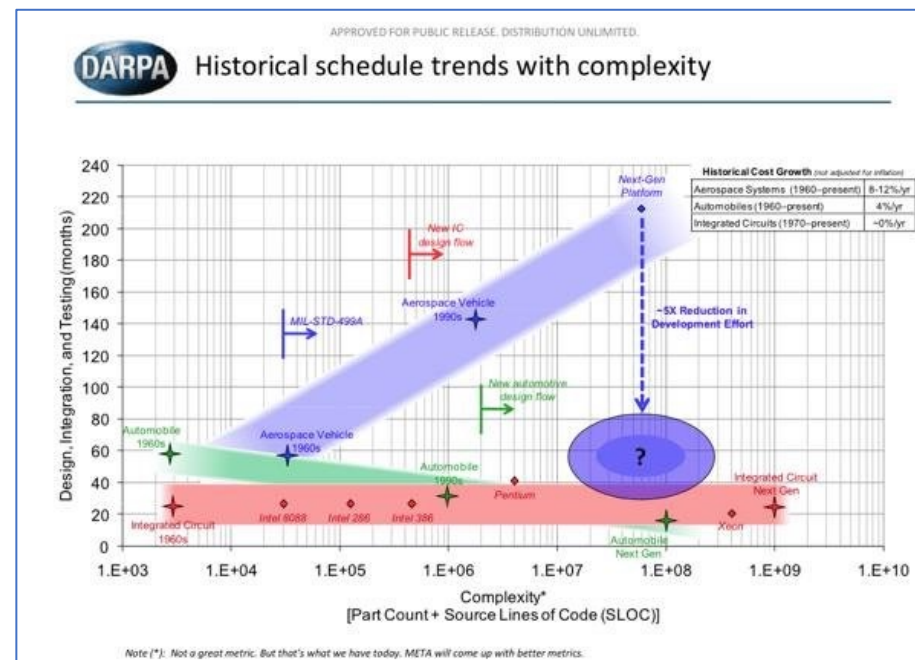
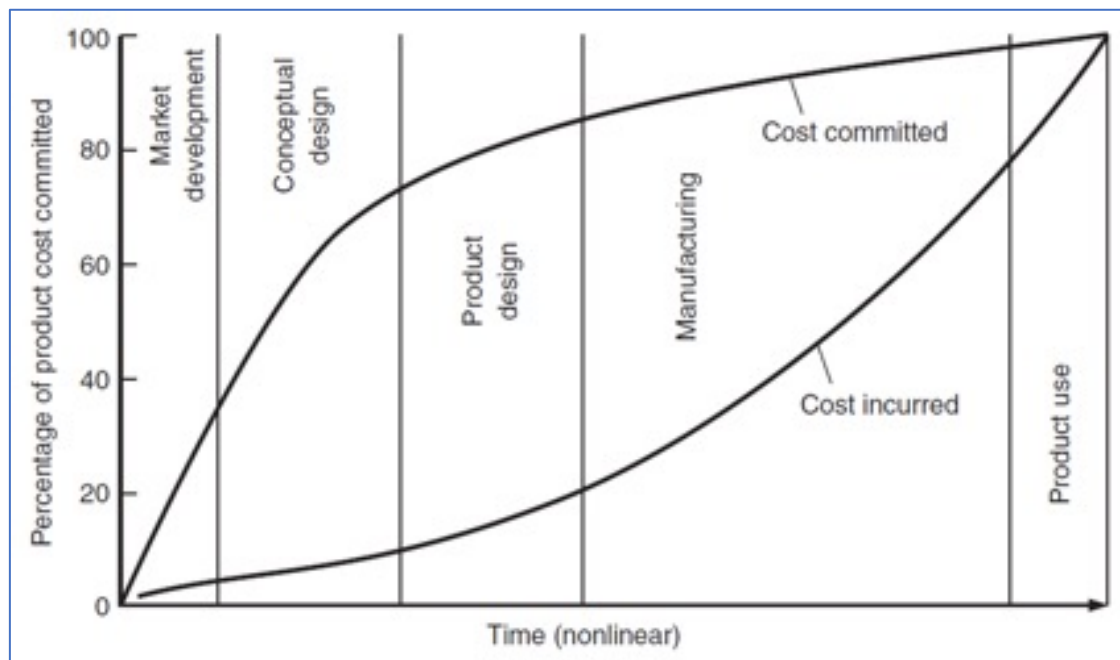
- ✓ Interdisciplinary - analyzes, synthesizes and harmonizes links between disciplines into a coordinated and coherent whole
- ✓ Model Based - Model of Models (MBx – model based everything)
- ✓ Collaborative--Predictive--Descriptive--Investigative--Cognitive—Corrective
- ✓ As-Designed – As-Built – As-Operated
- ⊘ 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



Faster, Better, Cheaper

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



Culture eats strategy for breakfast... Peter Drucker

“Incremental progress through existing regulations that provide a framework of the gradual requirements scale as a function of the application’s criticality”

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

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

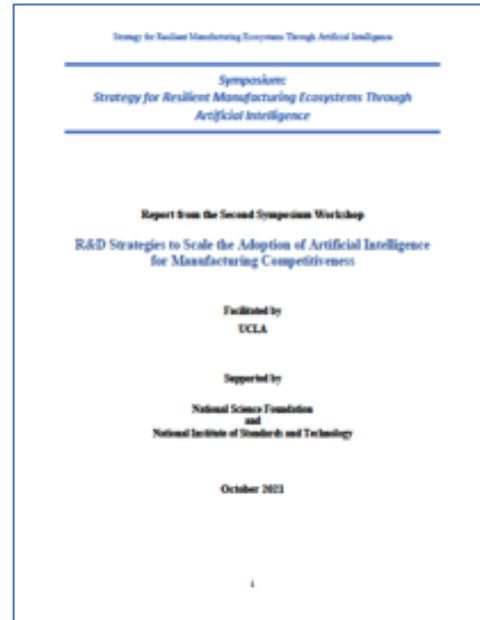
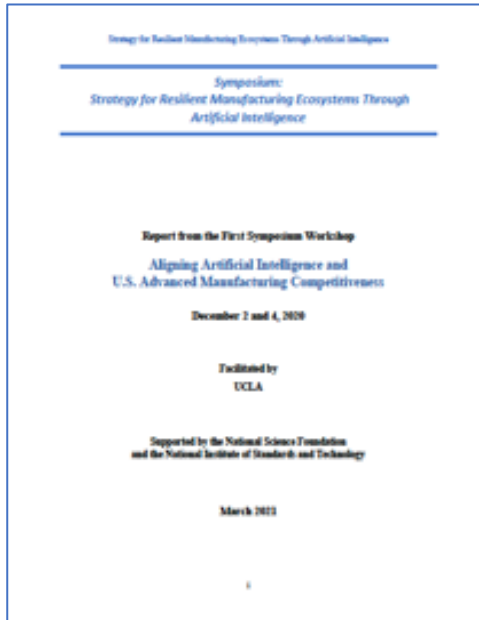
of the
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

November 2021

“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**

Digital Transformation @ NASA



3 GOALS

4 TARGETS

5 LEVERS

6⁺ OUTCOMES



NASA Space Technology Research Institute



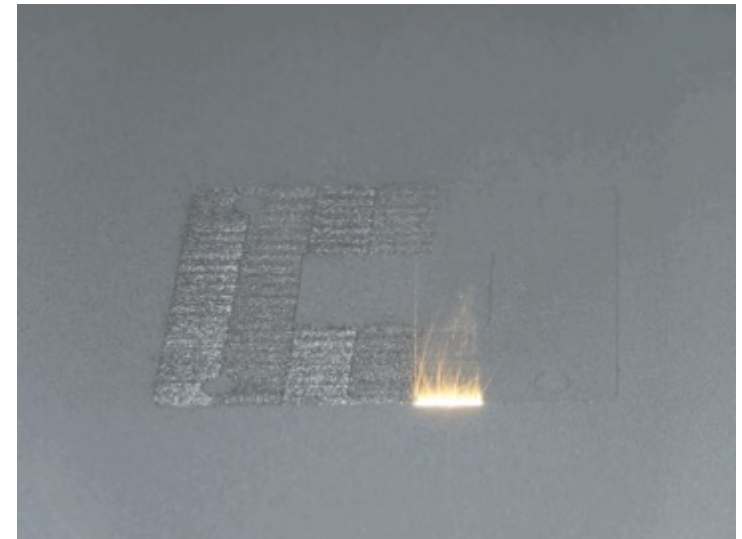
Accelerating Additive Manufacturing Certification with Model-Based Tools

The goal of the institute is to conduct ground-breaking interdisciplinary research to exploit new advancements in computational tools in concert with experimentation to advance the use of model-based tools for accelerated certification of critical additively manufactured aerospace products.

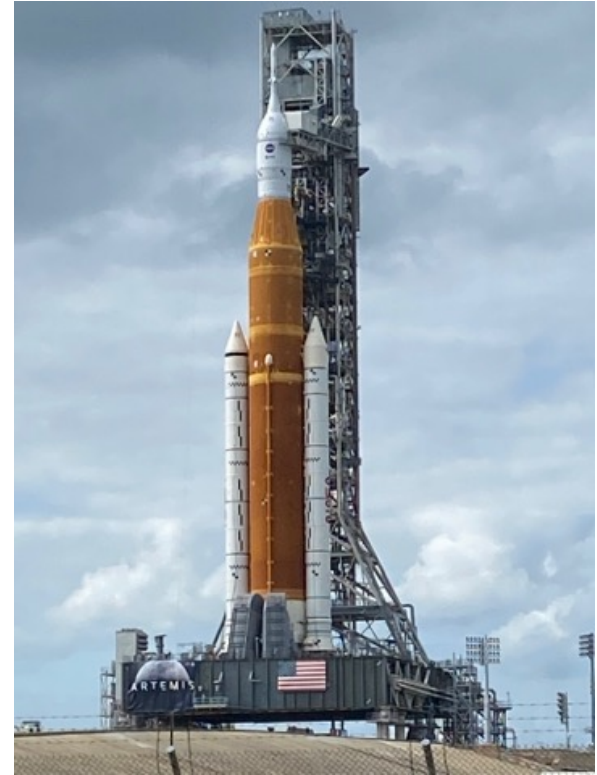
- The overall approach focuses on utilizing computational methods for AM through integrated computational materials engineering (ICME), materials genome initiative (MGI), and other model-based tools.
- This approach is desired instead of the traditional building block approach of trial-and-error experimental methods that progress step-by-step from the coupon level up to the final full-scale products, which “takes too long and costs too much”.

Award Information

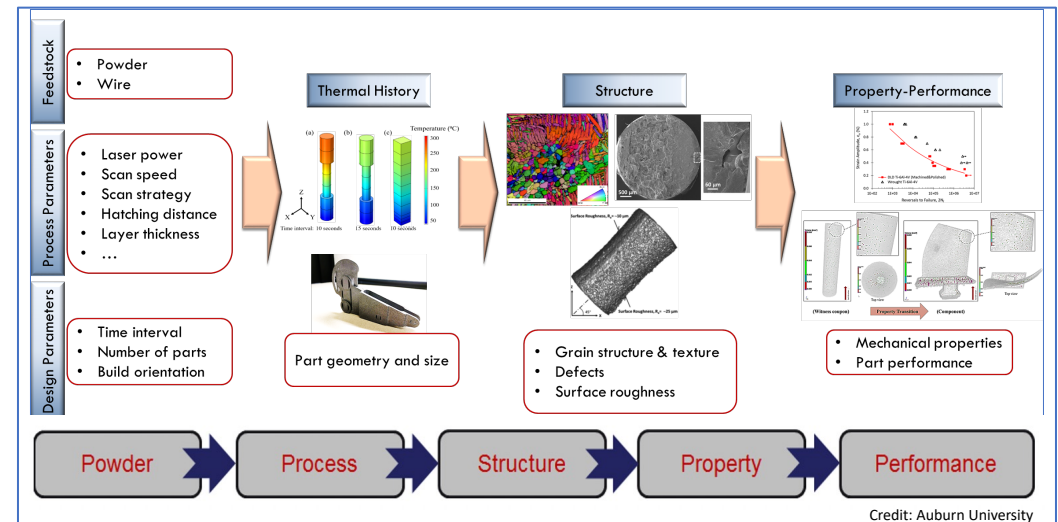
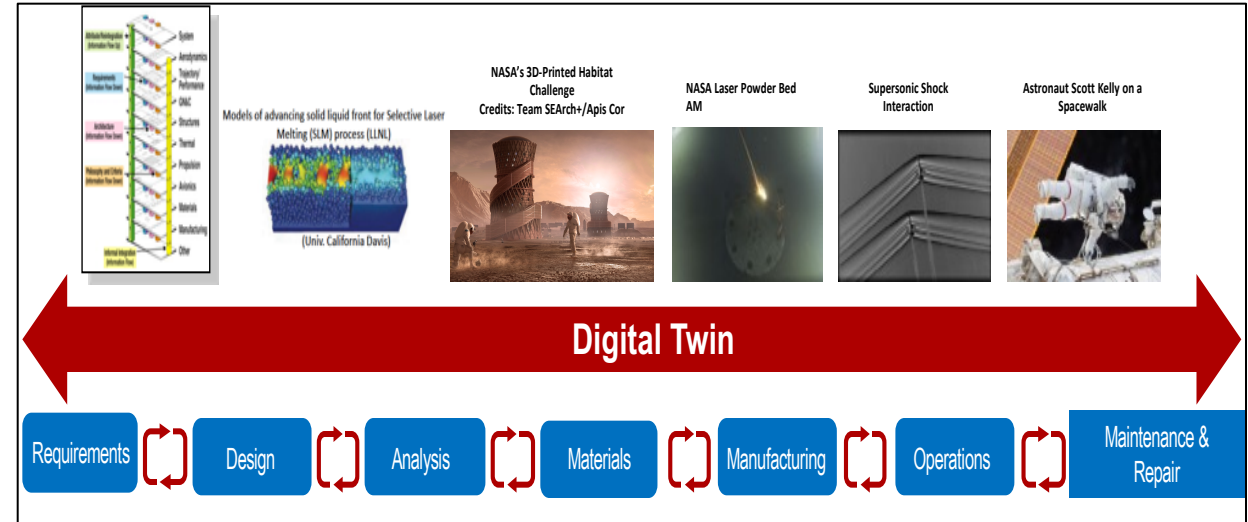
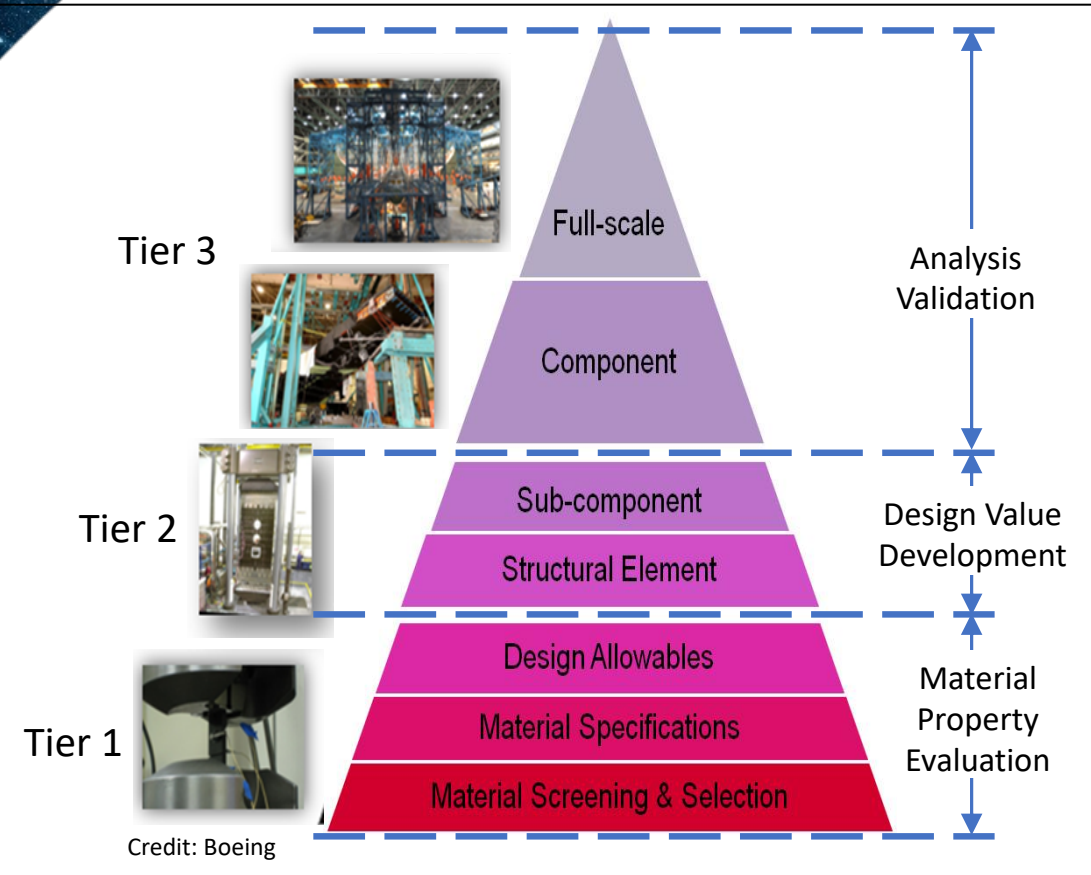
- Expected duration: 5 years
- Award amount up to \$3M per year over 5 years
- Award instrument: grants to U.S. universities
- Low to mid TRL
- <https://www.nasa.gov/directorates/spacotech/solicitations>



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

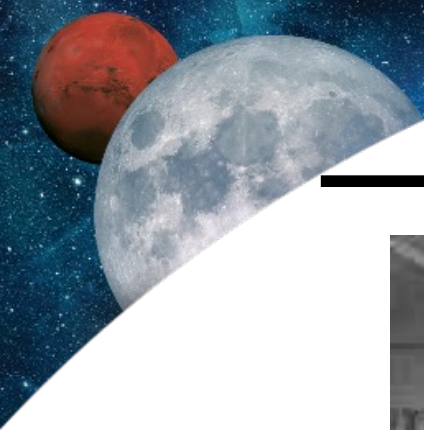


Digital Twin! “A Little Less Conversation A Little More Action Please”



Product Development, Testing and Certification Today

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



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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