EXPLORESPACE TECH
TECHNOLOGY DRIVES EXPLORATION

# America Makes Fall TRX 2022
# NASA Advanced Manufacturing Perspective

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

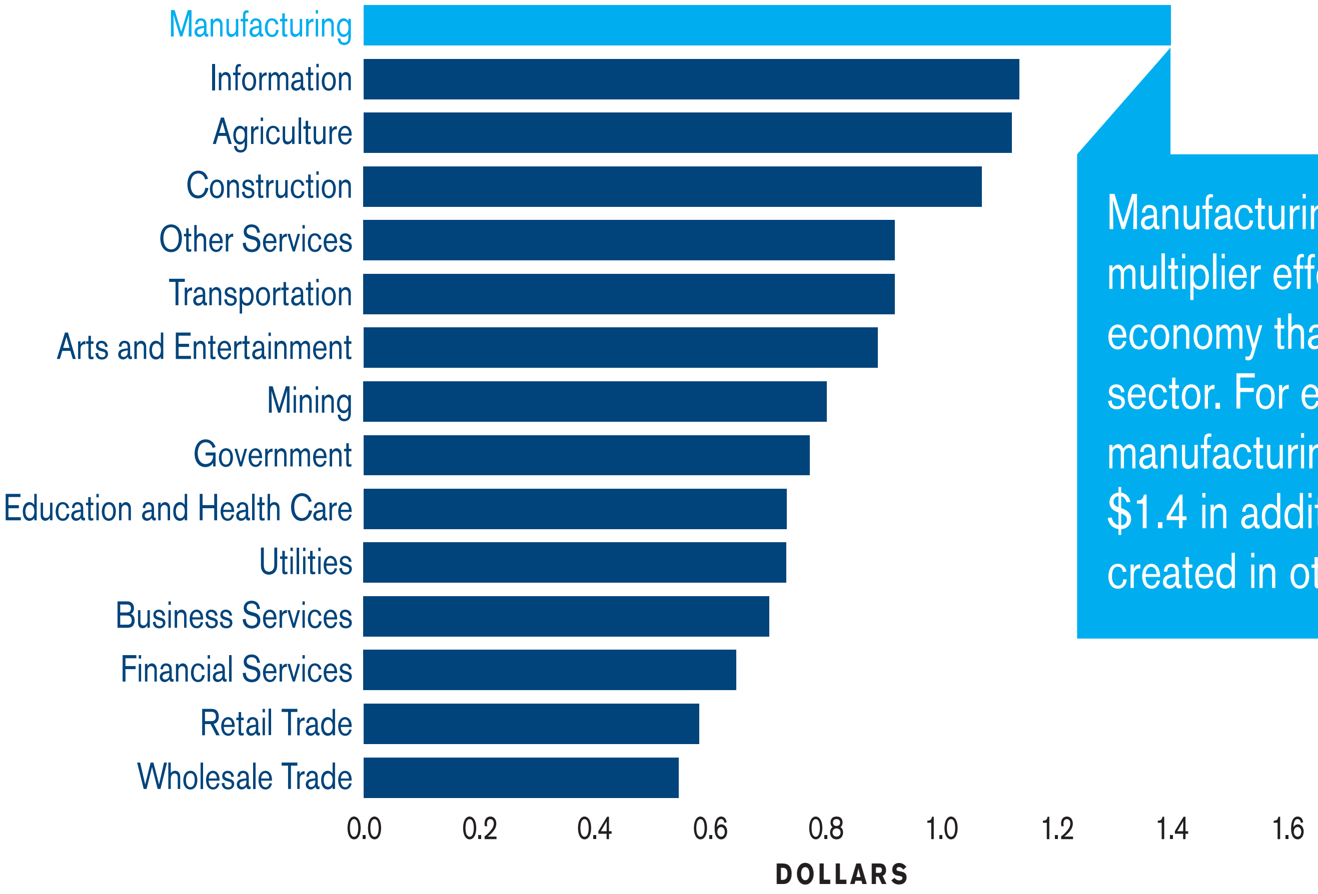
John Vickers I Principal Technologist I NASA Space Technology Mission Directorate
October 18, 2022

# US Manufacturing Economic Impact

## Manufacturing drives jobs throughout economy - including services

**10%** of Employment, average wages 20% higher

**12%** of gross domestic product

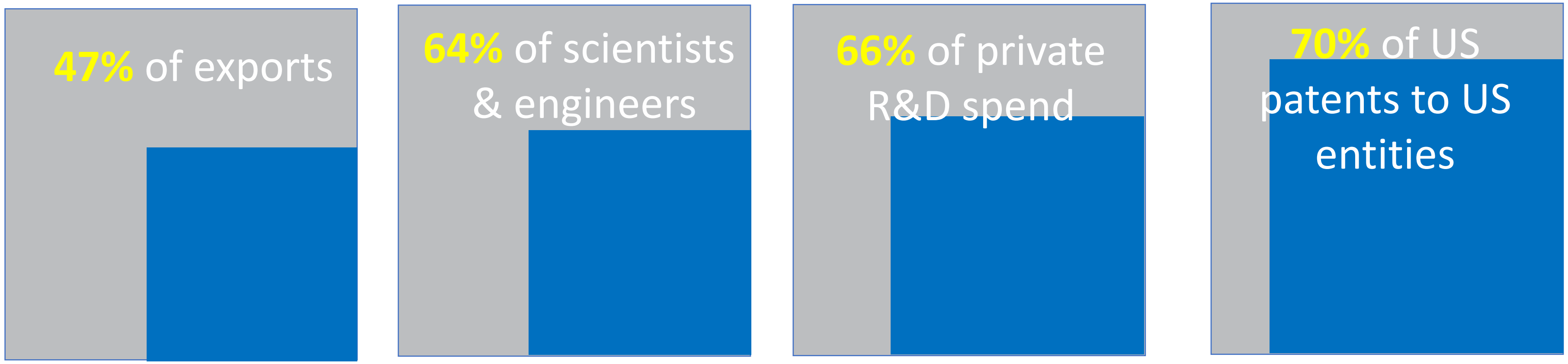



Manufacturing has a higher multiplier effect on the economy than any other sector. For every $1 in manufacturing value added, $1.4 in additional value is created in other sectors.

Source: U.S. Department of Commerce, Bureau of Economic Analysis

# US Manufacturing Innovation Impact

## U.S. manufacturers employ more than half of all R&D personnel in domestic industry




**50% of U.S Economic Growth is due to Innovation**

# Advanced Manufacturing Strategic Plan

**This strategic plan is designed to realize the following Vision and Goals for Advanced Manufacturing:**

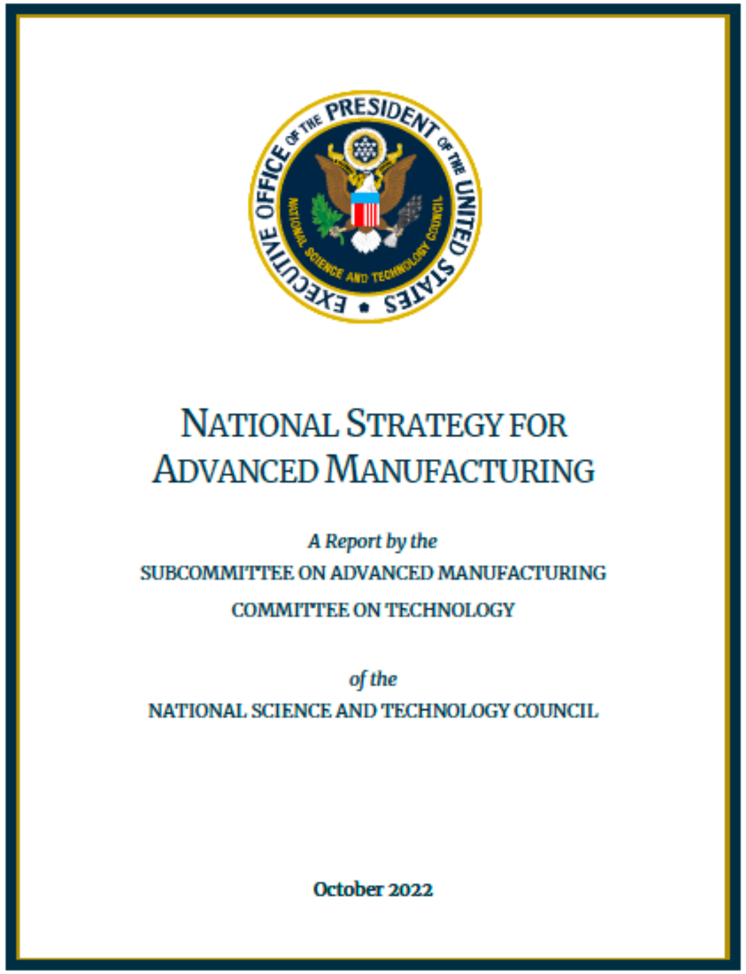
**American leadership in advanced manufacturing across industrial sectors to ensure national security and economic prosperity.**

**This vision will be achieved by pursuing three goals:**

1. **Develop and Implement Advanced Manufacturing Technologies**
2. **Grow the Advanced Manufacturing Workforce**
3. **Build Resilience into Manufacturing Supply Chains**

**Five strategic objectives have been identified under Goal 1:**

**1.1. Enable Clean and Sustainable Manufacturing for Decarbonization**
**1.2. Accelerate Manufacturing Innovation for Semiconductors**
**1.3. Implement Advanced Manufacturing for the Bioeconomy**
**1.4. Develop Innovative Materials and Processing Technologies**
**1.5. Lead the Future of Smart Manufacturing**


NATIONAL STRATEGY FOR ADVANCED MANUFACTURING

*A Report by the*

SUBCOMMITTEE ON ADVANCED MANUFACTURING

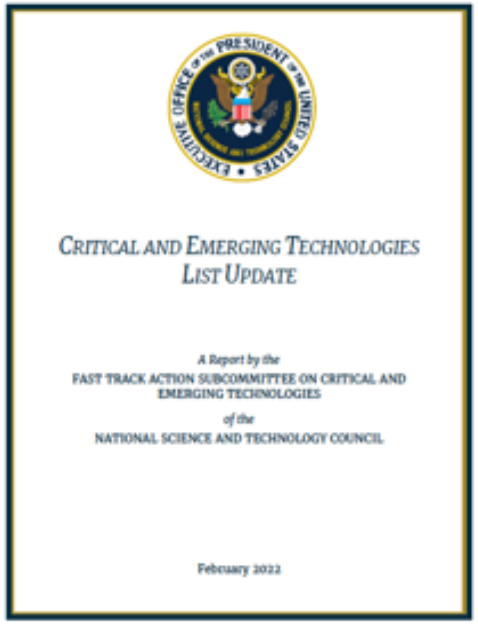
COMMITTEE ON TECHNOLOGY

*of the*

NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

October 2022

# Advanced Manufacturing National Strategy



CRITICAL AND EMERGING TECHNOLOGIES LIST UPDATE

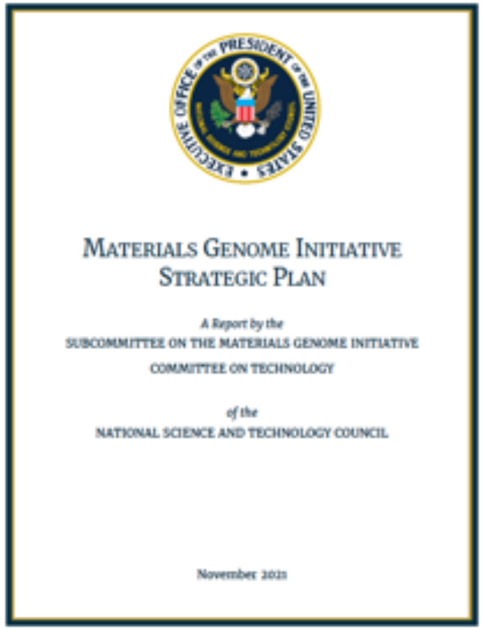
*A Report by the*
FAST TRACK ACTION SUBCOMMITTEE ON CRITICAL AND EMERGING TECHNOLOGIES
*of the*
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

February 2022

IN-SPACE SERVICING, ASSEMBLY, AND MANUFACTURING NATIONAL STRATEGY

*Product of the*
IN-SPACE SERVICING, ASSEMBLY, AND MANUFACTURING INTERAGENCY WORKING GROUP
*of the*
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

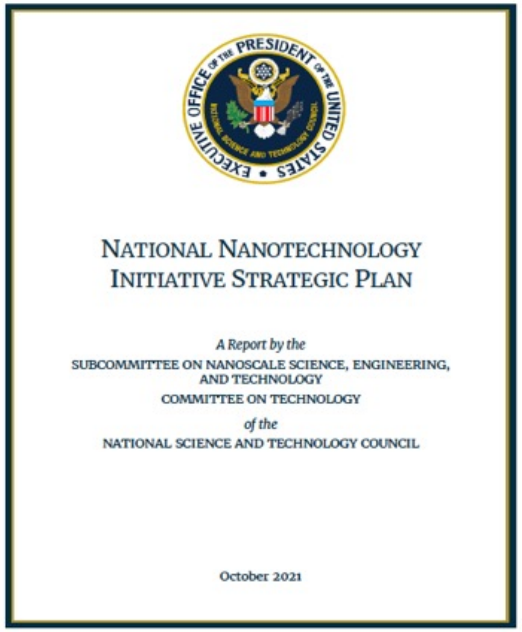
April 2022



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

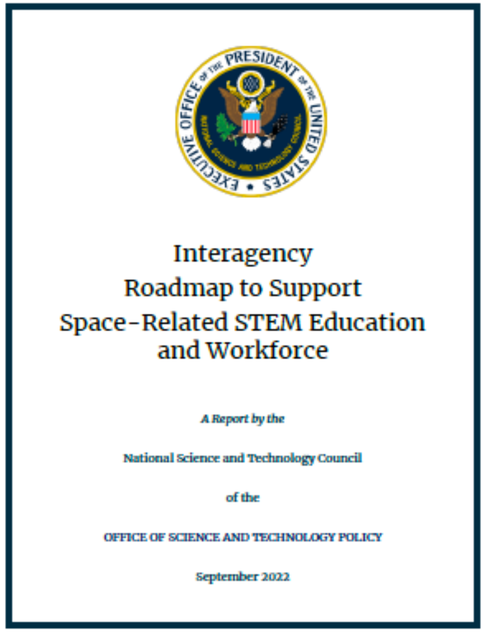
November 2021



NATIONAL NANOTECHNOLOGY INITIATIVE STRATEGIC PLAN

*A Report by the*
SUBCOMMITTEE ON NANOSCALE SCIENCE, ENGINEERING, AND TECHNOLOGY
COMMITTEE ON TECHNOLOGY
*of the*
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

October 2021

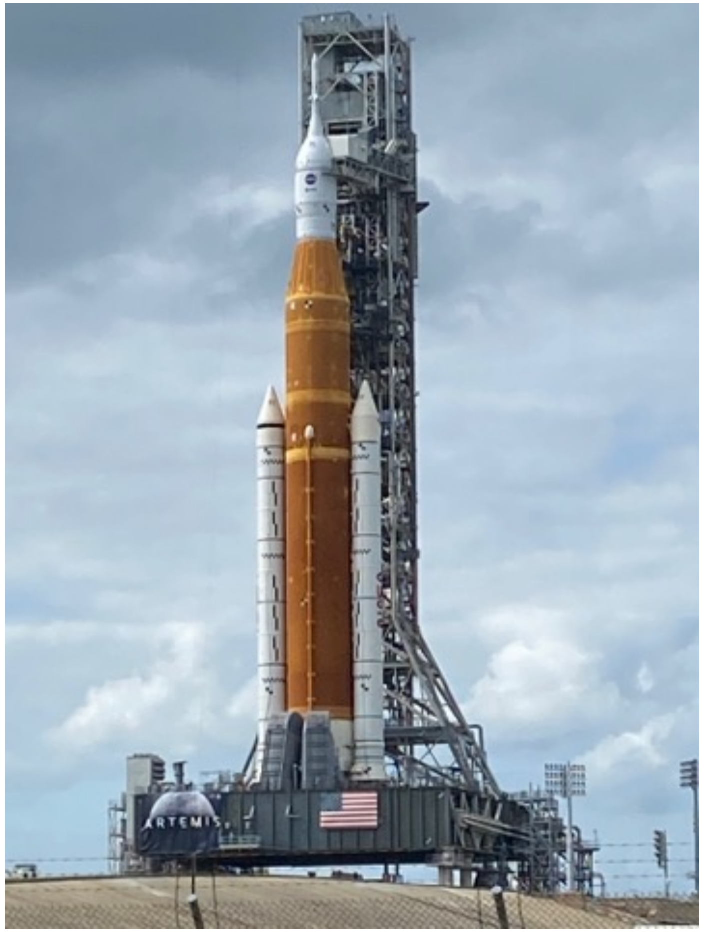


Interagency Roadmap to Support Space-Related STEM Education and Workforce

*A Report by the*
National Science and Technology Council
of the
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

September 2022

# How We Explore… NASA Manufacturing

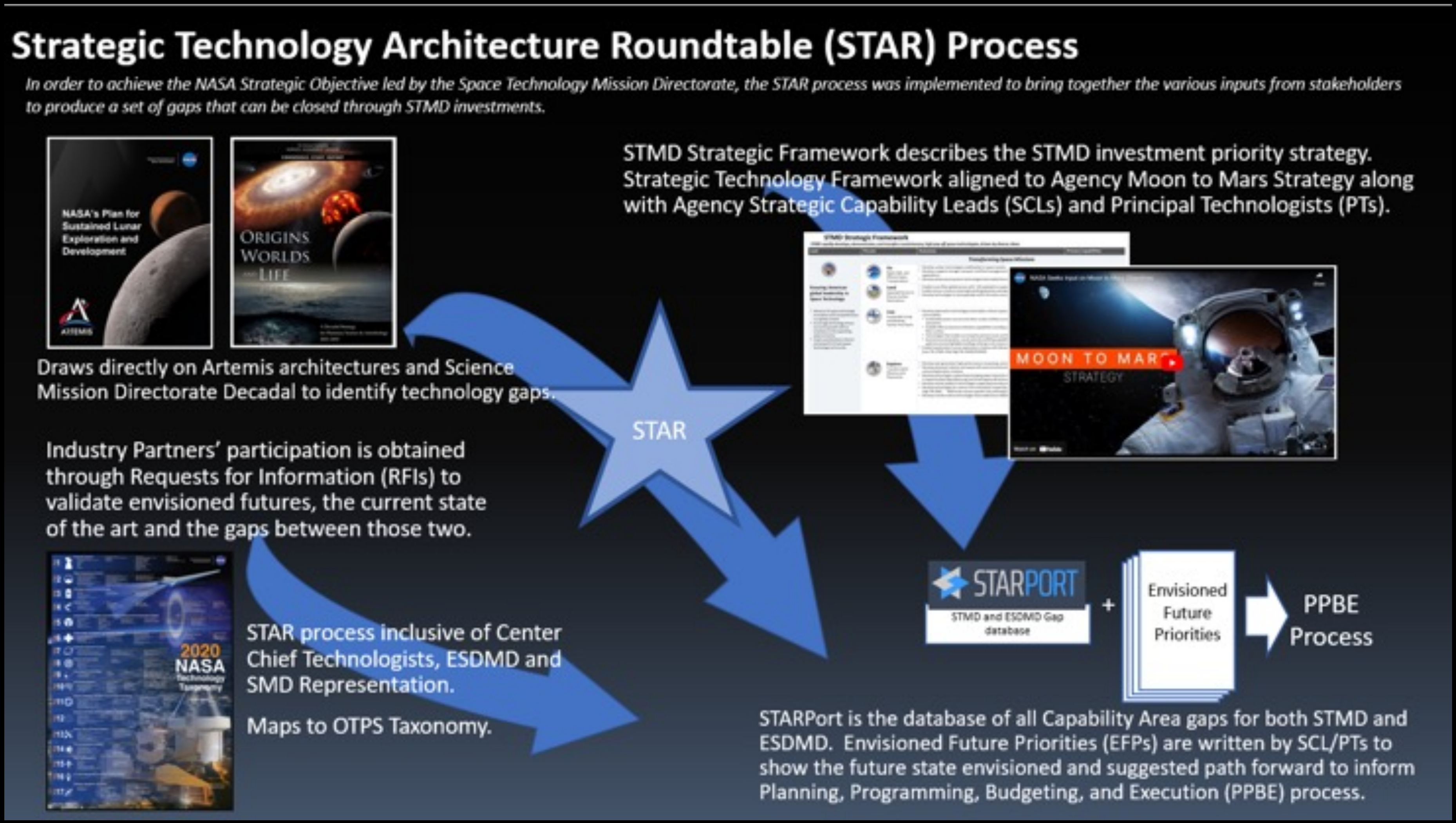



# Inclusive Strategic Technology Planning

**STMD utilizes STAR, the Strategic Technology Architecture Roundtable, to collect a diverse set of inputs into the strategic technology planning process.**

- Draws directly on Artemis/ISS needs and SMD Science Decadal Studies: all NASA Center Chief Technologists and Mission Directorates included.
- Regular inputs directly from industry-on-industry plans and needs.
- Secure coordination and collaboration with US Space Force and DoD entities.

https://techport.nasa.gov/framework



## EXPLORE: Develop technologies supporting emerging space industries

***Advanced Manufacturing technologies make NASA's missions more capable and affordable by bringing together industry, academia, and government***

## Plan to close gaps and achieve outcomes

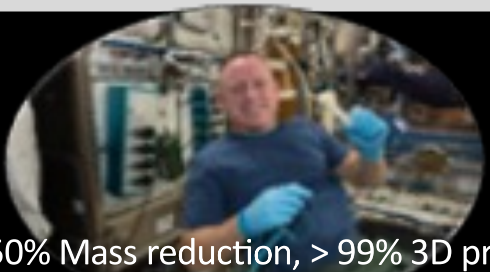
- Integrated plan across Mission Directorates and Centers; Across TRLs (e.g., leverage STRG), programs and projects pipeline; Industry/Academia alignment, Workshops/TIMs
- Increase collaboration and public private partnerships. Leverage National Strategic Plans: Office of Science and Technology Policy Subcommittee on Advanced Manufacturing; In-Space Servicing, Assembly, and Manufacturing; Materials Genome Initiative; National Nanotechnology Initiative; others
- Outcome based - Innovative advanced manufacturing technologies targeted at commercial drivers for performance, affordability, and sustainability. "Bridge the Valley of Death"



# EXPLORE: Develop technologies supporting emerging space industries

## *Priorities - Targeted advanced manufacturing outcomes aligned with space industry trends that will shape the course of research and development over many years*

### In-Space Manufacturing and Space Infrastructure



> 50% Mass reduction, > 99% 3D printer readiness. A catalyst for space infrastructure and economic opportunities

### 3D Printing/Additive Manufacturing

> 50% Cost reduction, 12 months instead of five years, Parts reduction >100 to 1

### Digital Transformation - Digital Twins and Artificial Intelligence

More intelligent and more accurate predictions and capabilities, > 50% of physical resources replaced with virtual

### Lightweight Composites Spacecraft

30% - 50% More payload, equipment, and experiments

# Additive Manufacturing at NASA

- Fully embraces advantages of AM
  - Cost/lead time/part count reduction, new design and performance opportunities, rapi design-fail-fix cycles
- While fully understanding the challenges
  - Especially in delivering high value, high performance AM hardware
- NASA has dual roles
  - Drive and foster AM technology research an development in support of broad industry adoption and industrialization
  - Develop protocols for spaceflight hardware certification for access to space that can safely meet mission objectives


Centers involved in AM

# Additive Manufacturing at NASA

## AM Technology Maturation

- AM Processes, Alloy, Part Development
- AM Process Selection – criteria, comparison, integrated evaluation
- New AM-able alloy development
- AIAA Book
- Material database metal AM properties to aid conceptual designs
- STRI Proposal call
- Tipping Point/ACOs/Commercial Partnerships
- Out of the world AM

## Spaceflight AM Hardware Certification and Qualification

- NASA-STD-6030 and 6033
- Agency-wide AACT Team– AM Cert competency development + associated projects
- Active flight program insight activities
- Role of NDE and In Situ Process Monitoring
- Computational models for AM process validation
- Fracture control of un-inspectable AM parts

# NASA Space Technology Research Institute

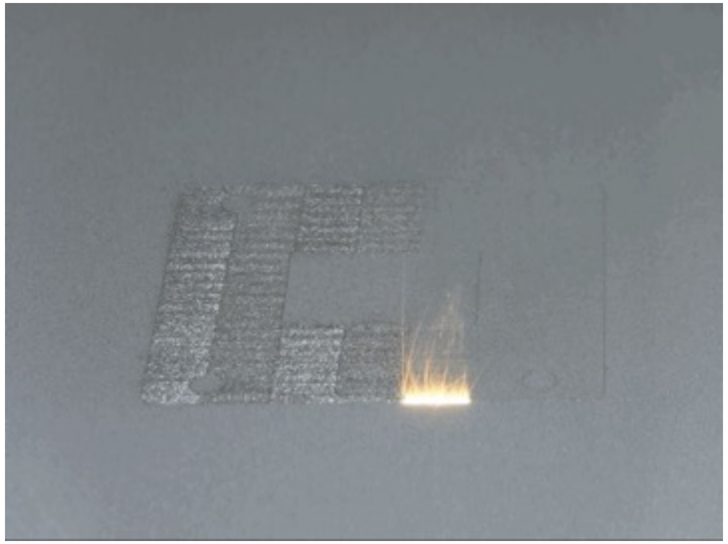
*Accelerating Additive Manufacturing Certification with Model-Based Tools*

**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**

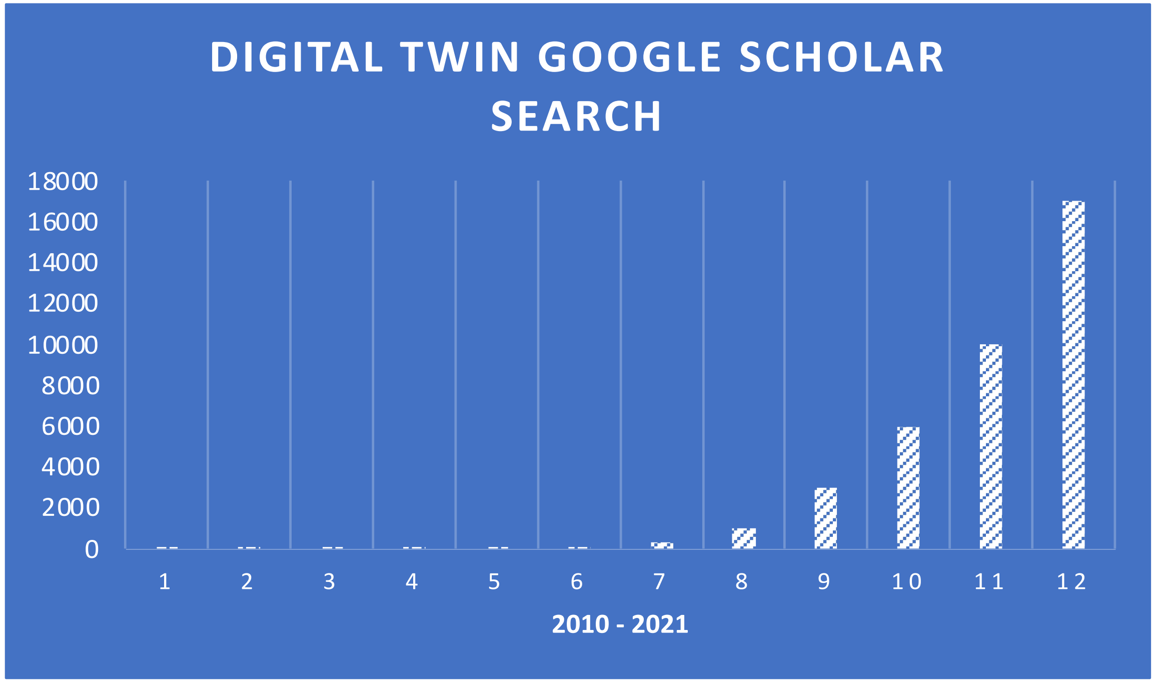
- **Expected duration: 5 years**
- **Award amount up to $3M per year over 5 years**
- **Award instrument: grants to U.S. universities**
- **Low to mid TRL**
- **Preliminary Proposals Due August 3**
- **https://www.nasa.gov/directorates/spacetech/solicitations**



# Digital Twin Origin and Expansion

*Google Scholar about 38,800 results and Google about 9,240,000 results

| | |
|---|---|
| Next-Generation Manufacturing<br>A Framework for Action<br>1997 | "Conceptual Ideal for PLM"<br>Product Lifecycle Management (PLM) Center<br>University of Michigan<br>2002 **Digital Twin |
| Intelligent and Integrated Manufacturing Systems (IIMS)<br>National Science and Technology Council<br>Interagency Working Group on Manufacturing Research and Development<br>2004 | Product Lifecycle Management: Driving the Next Generation of Lean Thinking: 2006 |
| Vickers/Grieves introduction 2007 | |
| Manufacturing the Future<br>National..., Interagency Working Group on Manufacturing R&D 2008 | Product Lifecycle Management and the Quest for Sustainable Space Exploration<br>AIAA SPACE Conference & Exposition<br>2010 |
| Radical Innovation in Design and Manufacturing<br>Workshop – Disneyland<br>2009 | Virtually Perfect: Driving Innovative and Lean Products through Product Lifecycle Management<br>2011 ** Digital Twin |
| NASA Materials and Manufacturing Technology Roadmap<br>2010 **Digital Twin | Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems (Grieves, Vickers) 2017 |
| SME Magazine (Kip Hanson) - Where the 'Digital Universe' Is Going and Where Wild Savings Can Be Had Today<br>2021 | Holst Memorial Lecture and Award 2022 |




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 Transformation Expansion


Credit: Jeff Winter

**Where does the industrial base stand on adopting digital manufacturing?**

**Dassault… 38% of traditional businesses have adopted a digital strategy**

1) 292,825 factories in the United States. The vast majority (268,000) have less than 99 employees. There are 846 factories that employee 1,000 or more employees (Source: [https://lnkd.in/enEQzYxM](https://lnkd.in/enEQzYxM))

2) Roughly 12.8 million people are employed in manufacturing, making it the 5th largest employer (Source: [https://lnkd.in/eNSDg2T2](https://lnkd.in/eNSDg2T2))

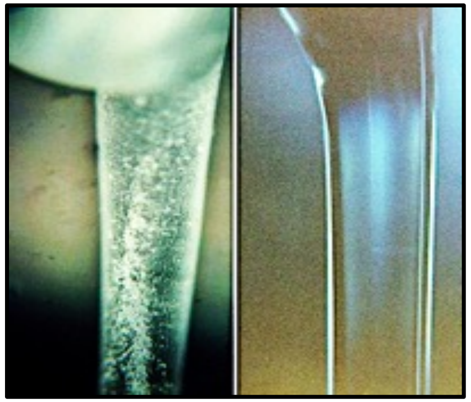
# In-Space Manufacturing

## What is In-Space Manufacturing

- In-space manufacturing (ISM) of materials and products for use on Earth and in space
- Manufacturing and assembly of large infrastructure in space
- Surface manufacturing and construction on planetary bodies beyond Earth

# In-Space Manufacturing

- **Build better or impossible products**
  - **For specific materials microgravity enables increased value**
  - **Some manufacturing process may not be possible in Earth's gravity**
  - **Improved mixing for super alloys, precision control of thin films, and increased consistency or larger crystals**
- **Manufacture on-demand with flexibility and speed**
  - **Quickly produce a replacement component when needed**
  - **Separates demand from the logistics of launch**
- **Building things too big or fragile to launch**
  - **"Tyranny of Launch" limits capability - Structures not bound by the constraints of rocket launch fairing volumes**
  - **Gossamer structures or ultra-thin mirrors too fragile to survive in Earth's gravity**
- **Using in-situ resources to reduce launch mass**



***Fiber Optic Glass Manufacturing in Space***

***Manufactured/Assembled Space Telescopes in Space rather than on the Earth***

# 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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