SPACE RUSH, SPACE 2.0
IN SPACE SECURITY, COMMERCE, AND EXPLORATION

in-space manufacturing for life on Earth and in-space

Ajay P. Malshe

Member, National Academy of Engineering (NAE)

R. Eugene and Susie E. Goodson Distinguished Professor of Mechanical Engineering; President's Fellow

Co-Director, XMO, eXcellence in Manufacturing and Operations (a Purdue Engineering Initiative)

Inaugural Director, Manufacturing and Materials Research Laboratories (MMRL)

Contact: amalshe@purdue.edu

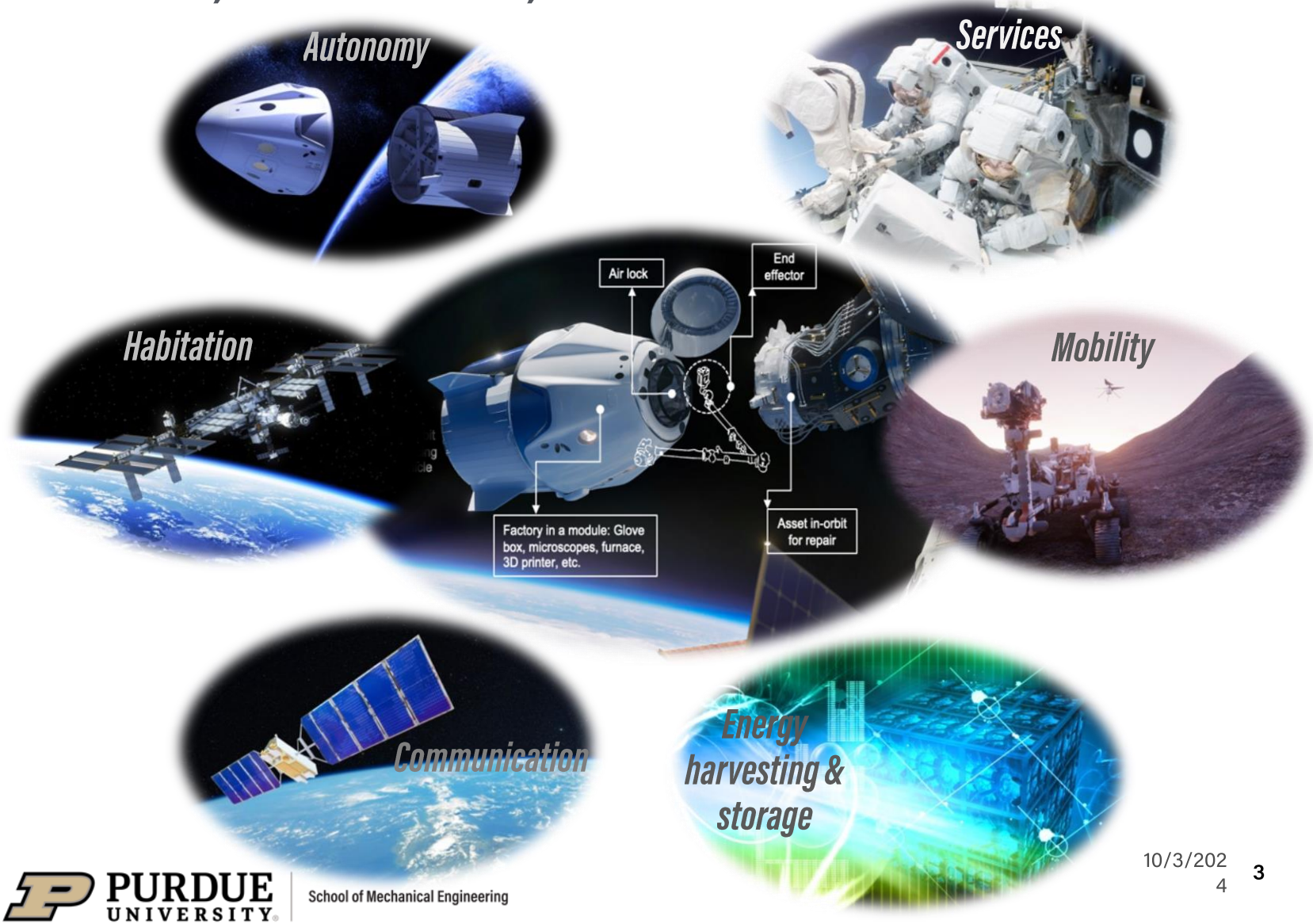
PURDUE UNIVERSITY

Space 1.0 (THEN)

Background: "exploration"

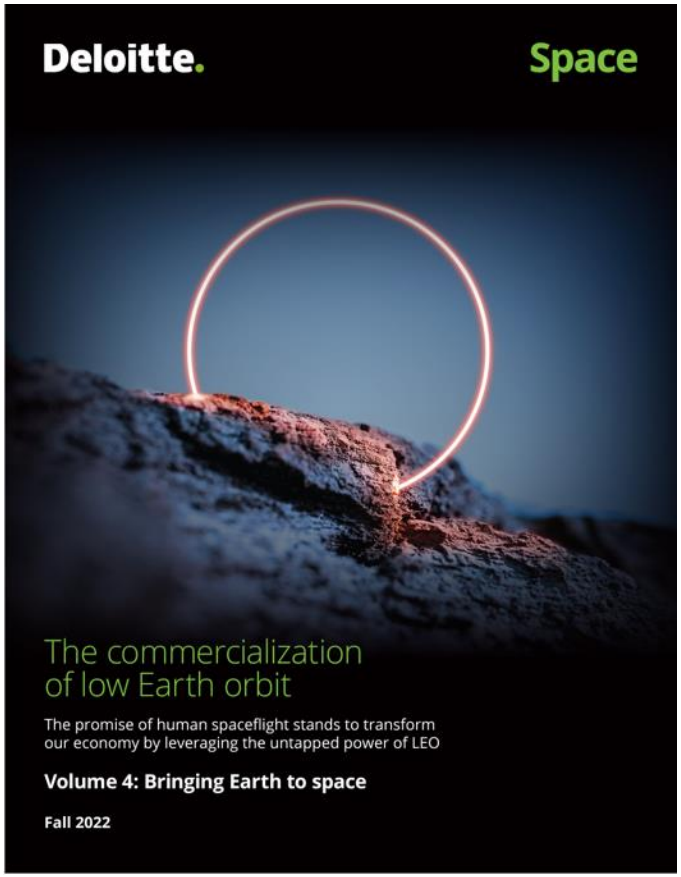
Space 2.0: Infrastructure for Earth-space supply chain for resilient operations

Secured, commercialized, harsh conditions and vast



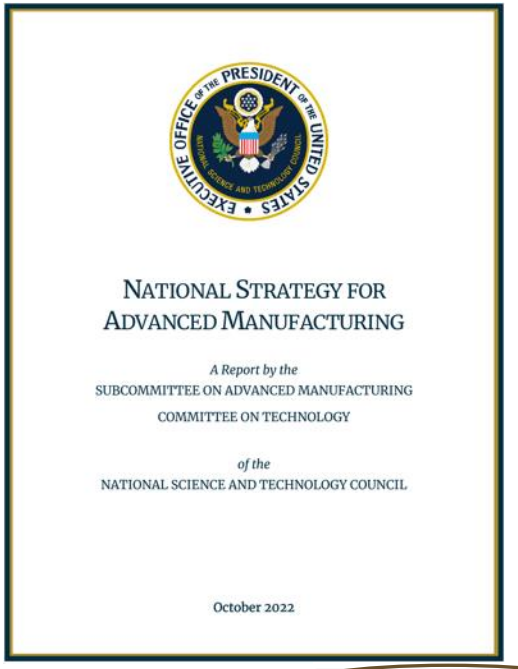
Physical, digital, and sustainable opportunities envelop

Foundations and this decade



Urgency: Space Infrastructure in the 3rd axis of earth

Physical and digital infrastructure across Kármán line

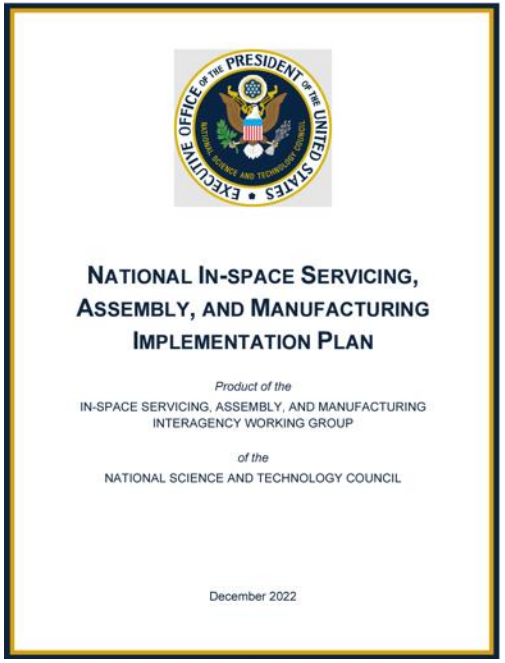


NATIONAL STRATEGY FOR ADVANCED MANUFACTURING

A Report by the
SUBCOMMITTEE ON ADVANCED MANUFACTURING
COMMITTEE ON TECHNOLOGY

of the
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

October 2022



NATIONAL IN-SPACE SERVICING, ASSEMBLY, AND MANUFACTURING IMPLEMENTATION PLAN

Product of the
IN-SPACE SERVICING, ASSEMBLY, AND MANUFACTURING INTERAGENCY WORKING GROUP

of the
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

December 2022

Congressional Research Service
Informing the legislative debate since 1914

The Office of Science and Technology Policy (OSTP): Overview and Issues for Congress

February 7, 2023

Congressional Research Service
https://crsreports.congress.gov
R47410

CRS REPORT
Prepared for Members and Committees of Congress

The National Security Team

Led by OSTP's Principal Assistant Director for National Security[a]

The National Security Team also includes the National Quantum Coordination Office (NQCO), which supports and coordinates activities related to the National Quantum Initiative.[b]

"The National Security Team advances the President's agenda by strengthening our long-term global competitiveness and reducing catastrophic risks through the assessment, development, deployment, and governance of current and emerging technologies. To strengthen global competitiveness, the team works to develop long-term science and technology (S&T) strategies, improve S&T intelligence, shape new investments in foundational technologies, modernize national security systems, ensure supply chain security, cultivate an agile innovation base, enhance export and investment controls, and build the world's best STEM workforce. They also work to reduce catastrophic risks at the intersection of technology and global security, spanning nuclear, biological, cyber, and autonomous technologies, associated risks of war, pandemics, and large-scale disasters, as well as emergent risks in space, ocean, and polar domains."

References: https://www.whitehouse.gov/wp-content/uploads/2022/12/NATIONAL-ISAM-IMPLEMENTATION-PLAN.pdf; https://www.whitehouse.gov/wp-content/uploads/2022/12/NATIONAL-ISAM-IMPLEMENTATION-PLAN.pdf; https://sgp.fas.org/crs/misc/R47410.pdf

EXTREME Initiative for a Center for Excellence
Extra-terrestrial Resilient Manufacturing Enterprise

Response to this national urgency

In-space Servicing, Assembly and Manufacturing

In-space Services, Assembly & Manufacturing Space Infrastructure

ISAM for managing resources and delivering services at the point-of-need

Ground-0

Harsha and Ajay Malshe

Depiction of a "Factory-in-Space", a centralized industrialization hub for extracting/processing materials, assembling products, and transporting finished goods to their final destination.

Mission and Goals

- Discovering equitable new value enterprise at the convergence of traditional and future innovations to realize Space 2.0 for *comm erce, habitation and exploration, and workforce creation*.

Academic and Business Executive Experience

- 27 years in academia; 17 years in industry as an entrepreneur and business executive

Reference: **2018 Bluesky Award, one of the top two spots** https://www.sme.org/globalassets/sme.org/about/awards/2018-dornfeld-abstracts/malshe-2018-abstract.pdf

Step-1:

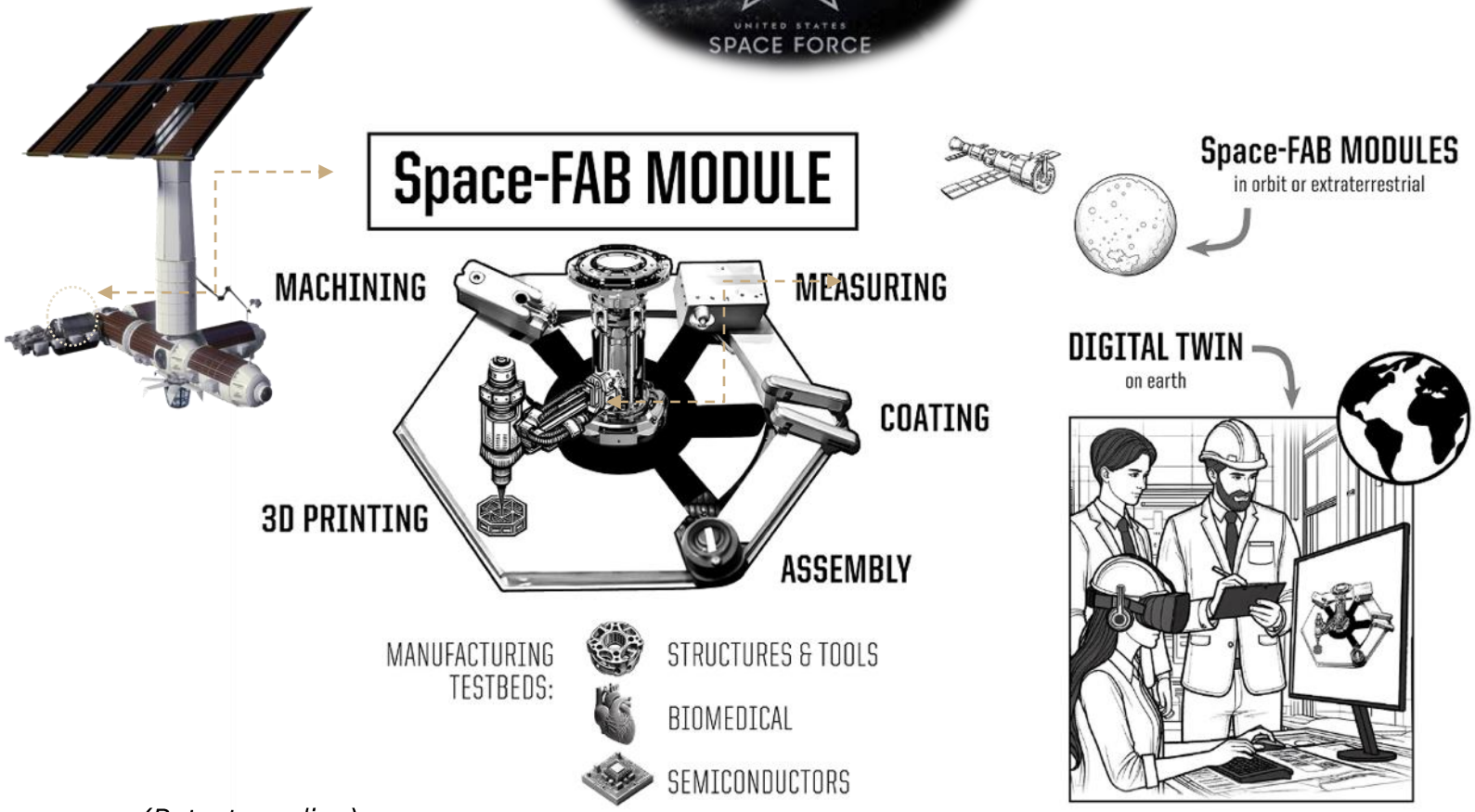
On October 7 (today), National Manufacturing Day, Purdue University (the Cradle of Astronauts) joins with leaders in industry and government to launch the world's first national and international webinar series for this new age of *equitable space*. The objective is to engage, interact and act to enable a national network.

*Step-2: Roadmapping Workshop attendees and organizations represented (*Over 1,000+ years of experience in Space STEM for ISAM

Arizona State University · Auburn University · Axiom Space · Baylor University · Carnegie Mellon University The Robotics Institute · Cislunar Industries · G-SPACE · KPMG · Kratos Defense & Security Solutions · Lockheed Martin · The Pentagon · NASA · NSF · NIST National Institute of Standards and Technology U.S. Department of Commerce · Navajo Technical University · Northrop Grumman · Physical Sciences Inc. · United States Space Force · Purdue University · SNC Sierra Nevada Corporation · SwRI Southwest Research Institute · The University of Alabama · University of New Hampshire · UTEP · Varda Space Industries

Step-3: CHIPS in Space for Space and Earth

Think Big!



(Patent pending)

Step 4: National Network and Center of Excellence for Research Coalition

EXTREME: Extra-terrestrial Resource and Manufacturing Enterprise

(Sponsor/Collaborators; academic collaborators not listed due to limited space)

Step 5: "Study Above"

(Sponsor/Collaborators; academic collaborators not listed due to limited space)

Thank you and questions

ISAM, a Giant Leap

Backup slides

Creative Disruption: America and rushes…

Gold Rush

Dotcom Rush

Gold Rush

Gold mine, Jeans, Shelves, and Community

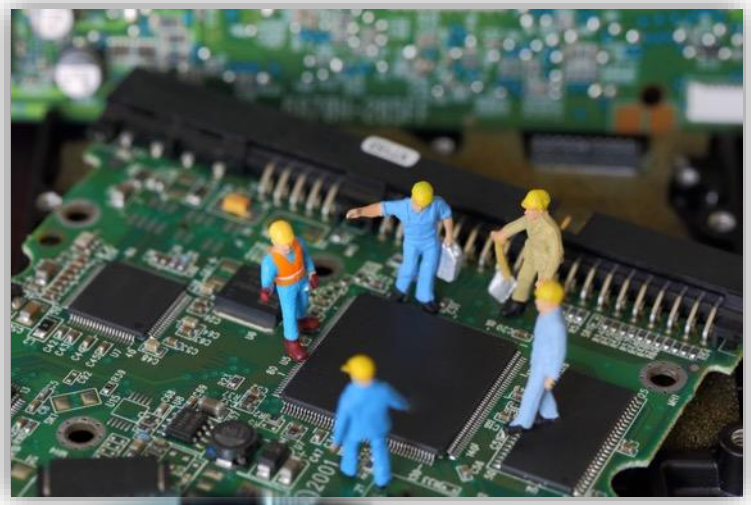
- a supply chain for the operation

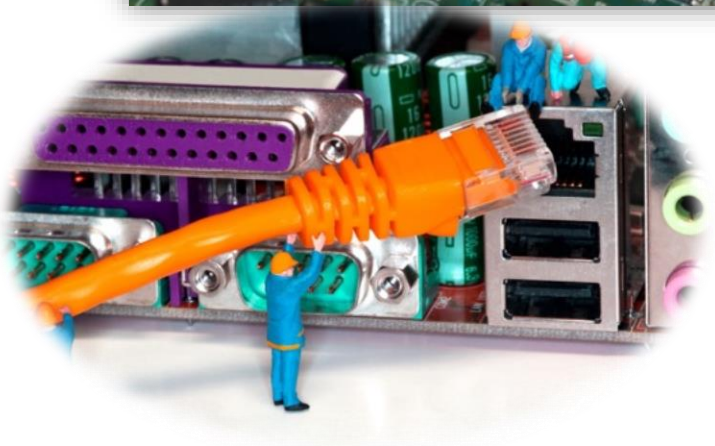
- Ambition for newness and new wealth
- Operational work field
- New science and engineering
- Designs and materials
- Manufacturing processes and products
- Infrastructure for executing ambition
- New jobs and inequity

Dotcom Rush

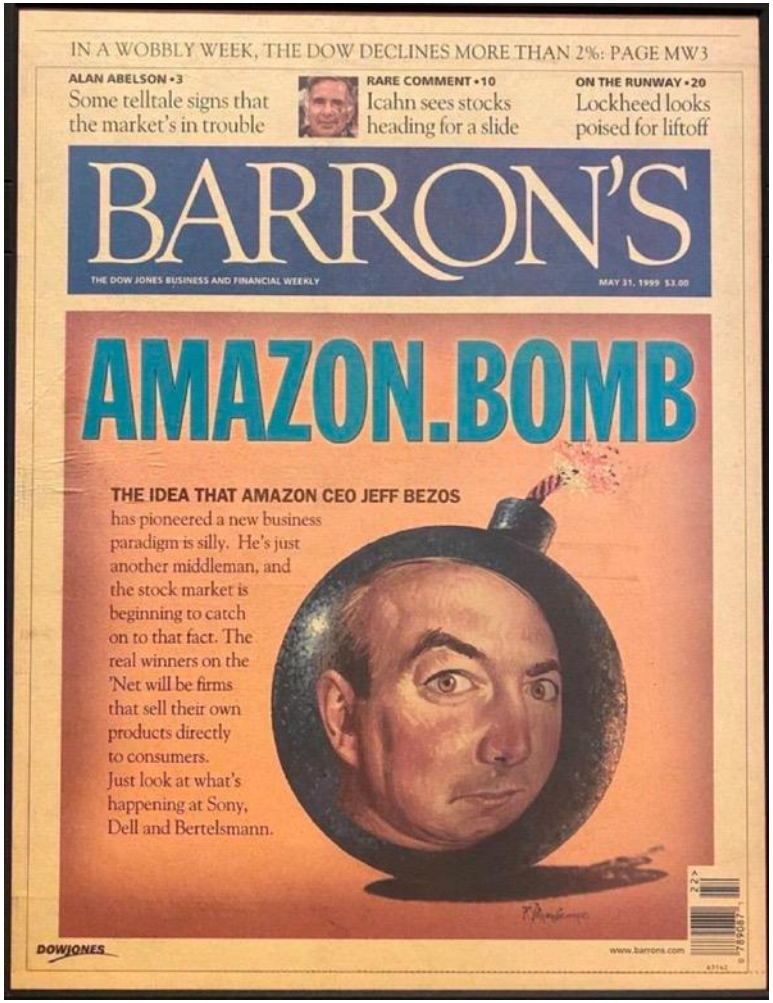
Multifunctional and connectivity, Chips, Processes, and Community - *a supply chain for the operation*

- Ambition for newness and new wealth
- Operational work field
- New science and engineering
- Designs and materials
- Manufacturing processes and products
- Infrastructure for executing ambition
- New jobs, education, and work toward equity





Nayers for every "tech rush"



Space 2.0 (NOW): Trends & Drivers

Space colonization

Colonization and conflicts

Cybersecurity across space

International co-shared assets

Government and monopolies

Shared Space

Debris & ISRU

Equity

Space governance

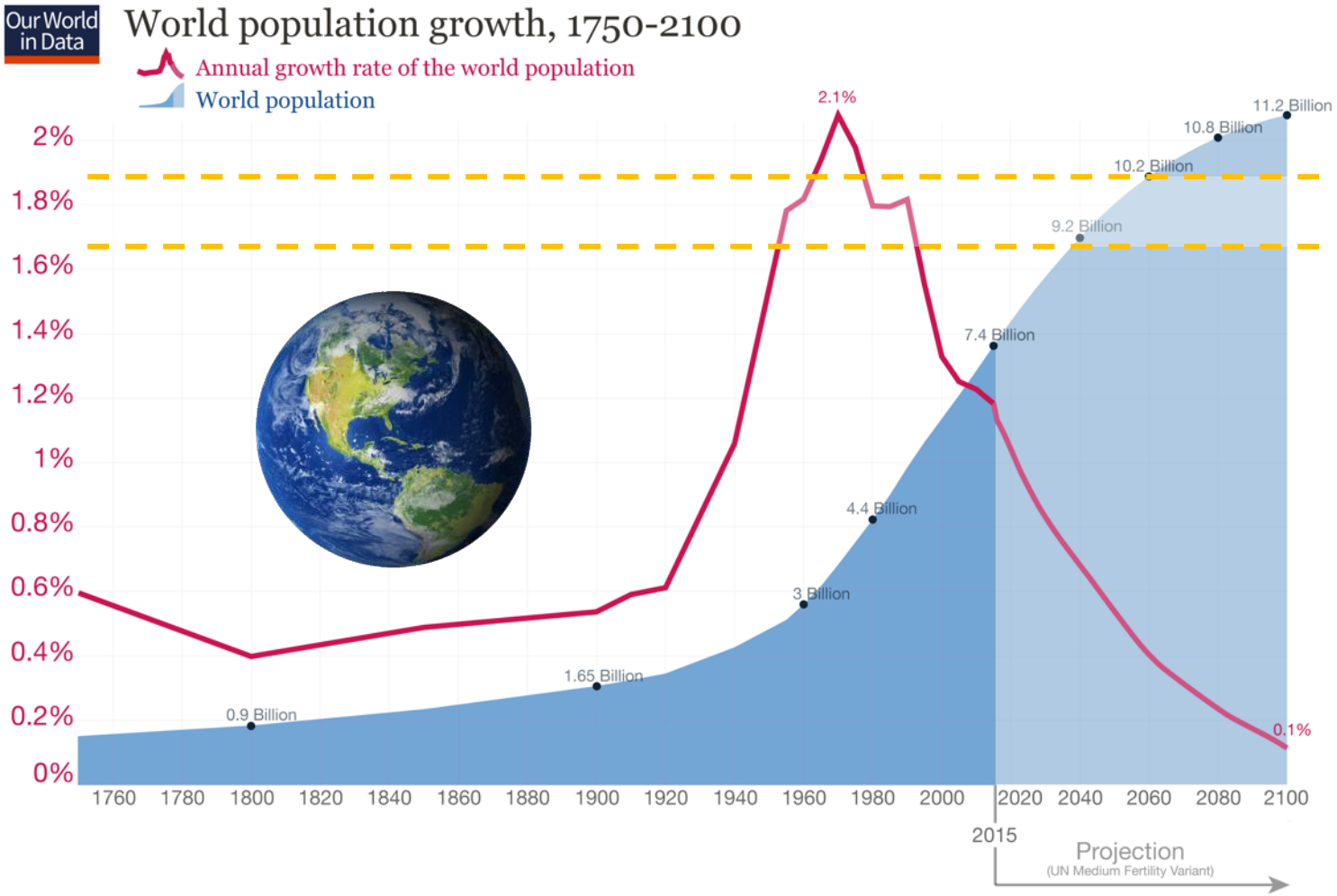
Driver-1: Survival

The world is expected to add another billion people within the next 15 years, bringing the total global population from 7.3 billion in mid-2015 to 8.5 billion in 2030, 9.7 billion in 2050, and 11.2 billion by 2100

(Ref: https://esa.un.org/unpd/wpp/Publications/Files/Key_Findings_WPP_2015.pdf)

"There is enough on Earth for everybody's need, but not enough for everybody's greed" – Gandhi

"Mankind must colonize space or die out" – Stephen Hawking


Our World in Data
World population growth, 1750-2100
Annual growth rate of the world population
World population
2%
1.8%
1.6%
1.4%
1.2%
1%
0.8%
0.6%
0.4%
0.2%
0%
2.1%
0.1%
0.9 Billion
1.65 Billion
3 Billion
4.4 Billion
7.4 Billion
9.2 Billion
10.2 Billion
10.8 Billion
11.2 Billion
1760 1780 1800 1820 1840 1860 1880 1900 1920 1940 1960 1980 2000 2020 2040 2060 2080 2100
2015
Projection
(UN Medium Fertility Variant)
Data sources: Up to 2015 OurWorldInData series based on UN and HYDE. Projections for 2015 to 2100: UN Population Division (2015) – Medium Variant.
The data visualization is taken from OurWorldinData.org. There you find the raw data and more visualizations on this topic.
Licensed under CC-BY-SA by the author Max Roser.

Driver-2: Exploration

- The transition from a consumer to an exploration-driven economy for continued human progress
- Transition from risk-averse to risk-seeking society
- Making space habitable through exploration driven by curiosity and discovery

Calling back to the **great explorers**

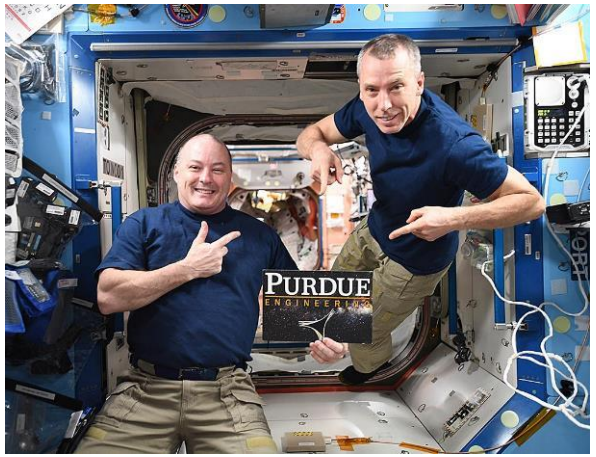
Driver-3: Democratization

- Space exploration is funded by sovereign nations (powerful countries)
- Space is commercialized by independent actors (ultra-wealthy)
- In the future, Space must be accessible to large democracies and not in the hands of a few

"Competition is not only the basis of protection to the consumer but is the incentive to progress." Herbert Hoover

Purdue University: Cradle of Astronauts

https://www.purdue.edu/space/astronauts.php



Drivers for Urgency

Survival

Exploration

Democratization

Creative Disruption: America and rushes…

Gold Rush

Dotcom Rush

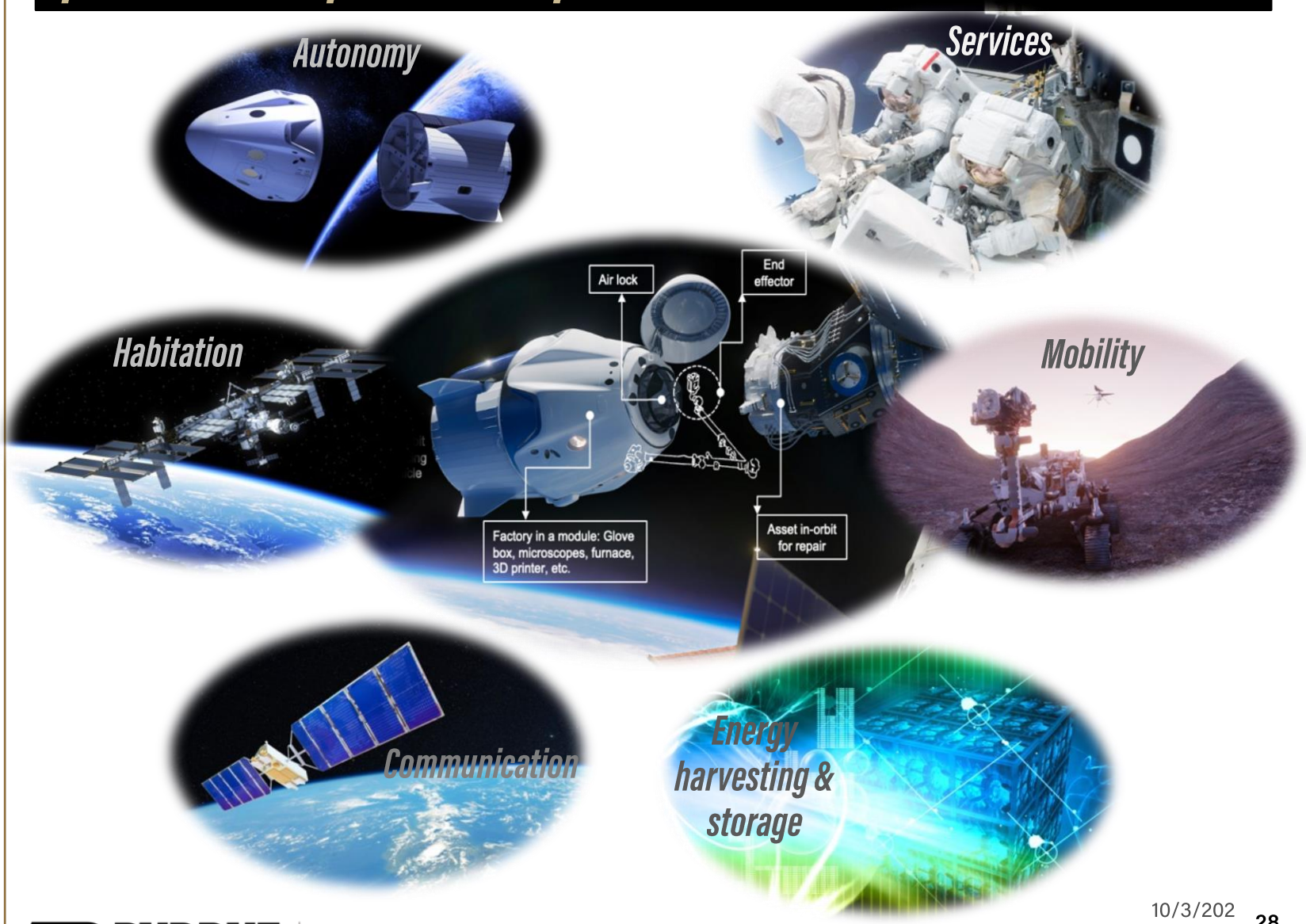
& now…

Space Rush

Response to this national urgency-

Introduction to Purdue University and collaborators' National In-space Manufacturing Network

Orbital and surface touchpoints for defense and commerce operations in space (examples)



ISM application drivers for earth

Molecules, heterogeneous devices, multifunctional processes, and community

- Hierarchical manipulation of materials, “new materials”
- Multifunctional physical, digital, and sustainable processing, “new processes.”
- Multi-signal integration: Connectivity and advanced responsivity, "new devices"
- Advanced products for the earth in semiconductors, biotech, energy, digital tech, and more
- Workforce and equity – one of the most considerable impacts immediately
- Brand new products, including services

New cures

New devices

New education

New Science, Engineering, Translation, and Workforce

Materials, manufacturing processes, and services

- a supply chain for the operation across the Kármán line

- Ambition for newness and new wealth
- For Earth: New science and engineering
- ISS: Operational work field
- Designs and materials
- For Earth: Manufacturing processes and products
- ISS: Infrastructure for executing ambition
- New jobs, education, and work toward equity

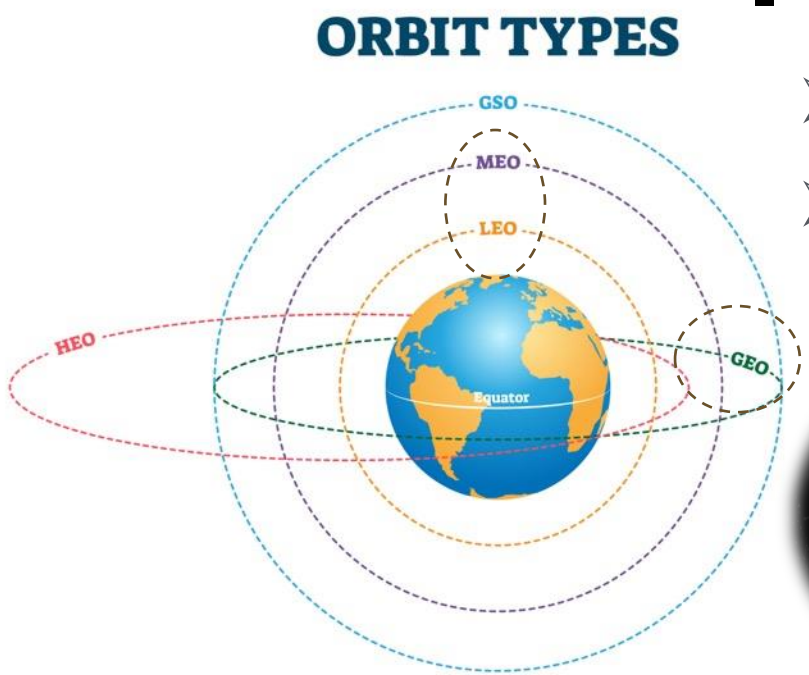
Pointers for drivers for a new science:

Microgravity, vacuum, cryogenic and high temps, access to solar energy, regolith, and more

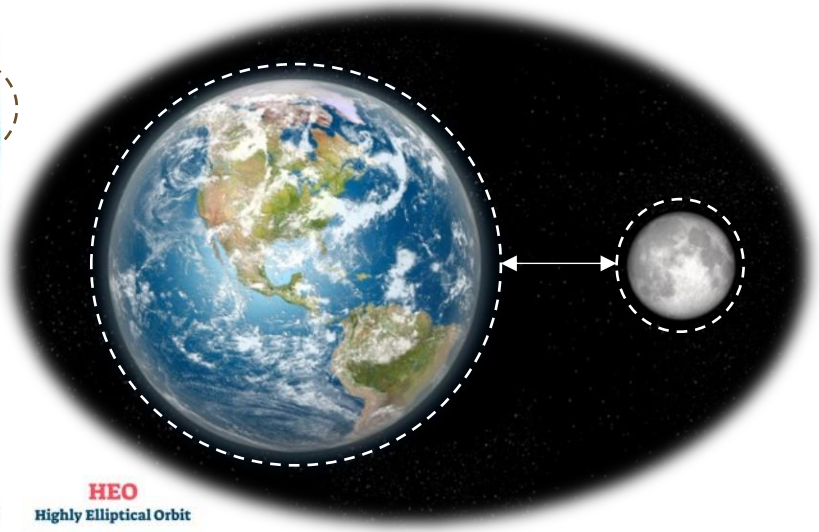
CHIPS in Space for Space and Earth

Edge Distribution Network for ISAM

Two parts: ISAM to serve Earth and off Earth



- ISAM
  - ➢in-orbit
  - ➢on extra-terrestrial surface



Step-2:
Road mapping In-Space Manufacturing

Sponsored by- Manufacturing USA Technology Roadmap (MfgTech) Grant Program, NIST, Department of Commerce

Objectives

- Identify the technical barriers and knowledge gaps towards the realization and deployment of ISM
- Identify the fundamental (TRL 1-3) and applied (TRL 4-7) research and commercialization opportunities for industries, academics, national labs, and government agencies
- Prioritize the development and deployment opportunities for ISM technologies over a 10-year time horizon

Image courtesy of NASA from BIG Idea Challenge

Scope

- Design, Materials, and Processes
- Products, Services
- Security
- Sustainability
- Workforce development and knowledge-skills-abilities
- Supply chains to facilitate, establish, and operate ISM
- Earth to low-earth orbit (LEO), LEO to moon (cislunar), and lunar surface
- Manufacturing in space for space and for earth