

Economic Security and the Future of Space

Anne Cheever, PhD
RAND Corporation



B-SURE

Biomanufacturing- Survival, Utility, and Reliability beyond Earth



Space Biomanufacturing is a Go: Survivability, Usability, and Reliability for Next Generation Life Support Systems

Hannah I. Roberts 1 , Anya Volter 2 , Jithran N. Ekanayake 3 , Joshua Hang Sai Ip 4 , Richa Guleria 5 , Adrien Kellens 6 , Onika J. F. Lyman 7 , Olivia Gamez Holzhaus 8 , Heath J. Mills 8 , Sean R. Neimi 9 , Andrew K. D. Younger 10 , Anne E. Cheever 11 , Yousong Ding 7 , Jamie S. Foster 6 , Mark A. Blenner 5 , Ali Mesbah 4 , and Amor A. Menezes 1,2,3,9,12

Nature, under review



nature communications



Article

<https://doi.org/10.1038/s41467-025-56088-2>

Developing an alternative medium for in-space biomanufacturing

Received: 26 June 2024

Accepted: 8 January 2025

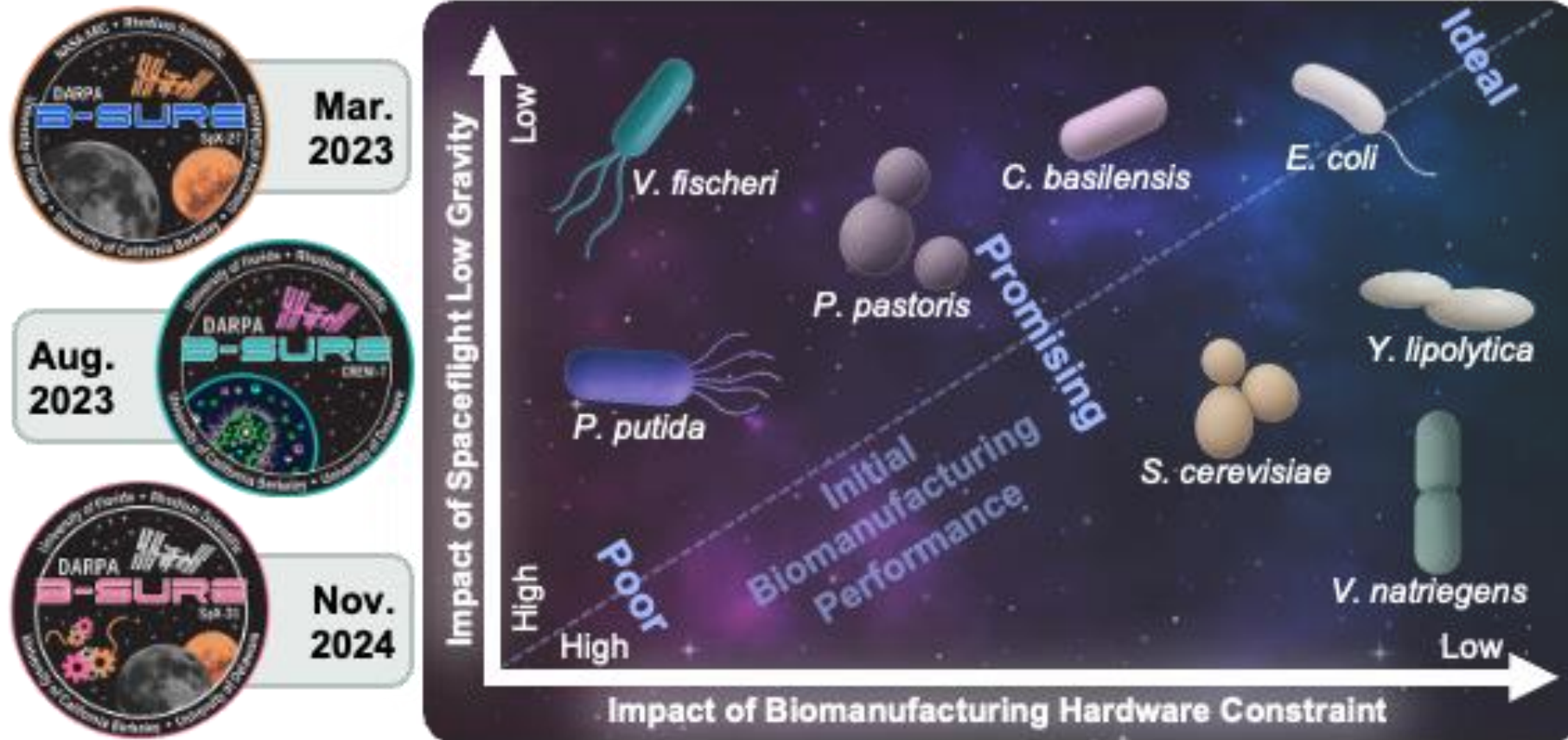
Hakyung Lee¹, Jinjin Diao¹, Yuxin Tian^{1,2}, Richa Guleria³, Eunseo Lee¹, Alexandra Smith⁴, Millie Savage⁵, Daniel Yeh⁴, Luke Roberson⁶, Mark Blenner³, Yinjie J. Tang¹ & Tae Seok Moon^{1,2}



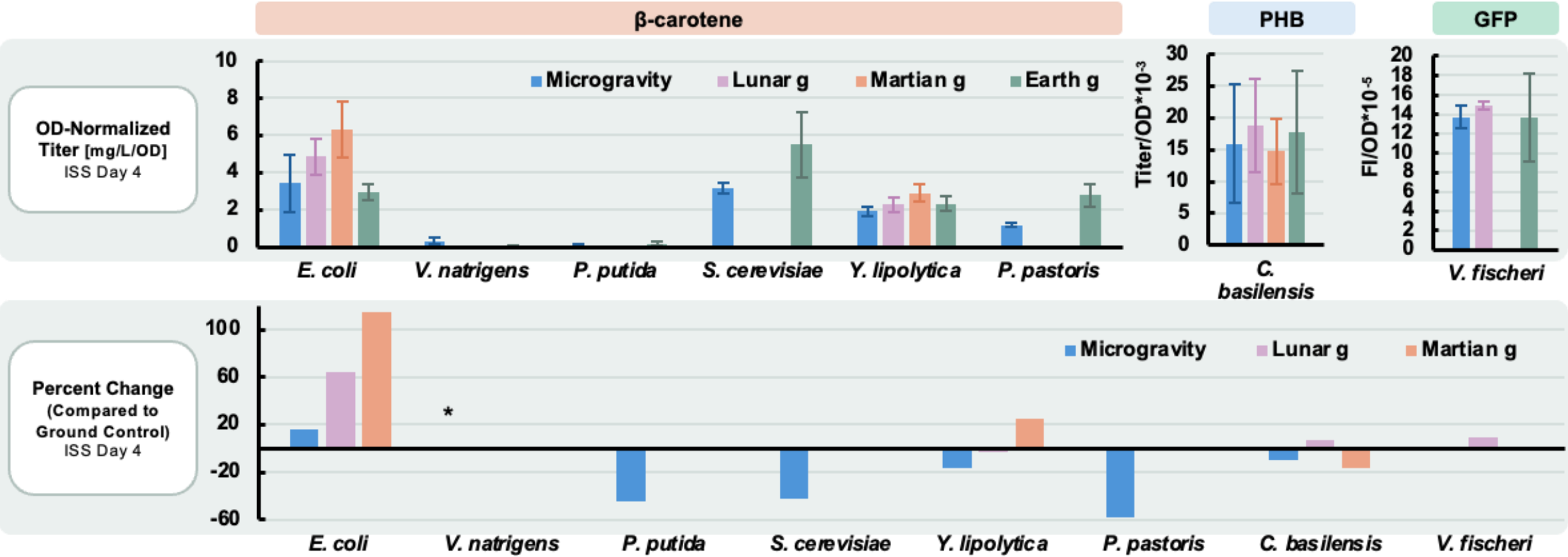
Testing “shelf stability” of biomanufacturing chassis organisms in the presence of radiation and space conditions



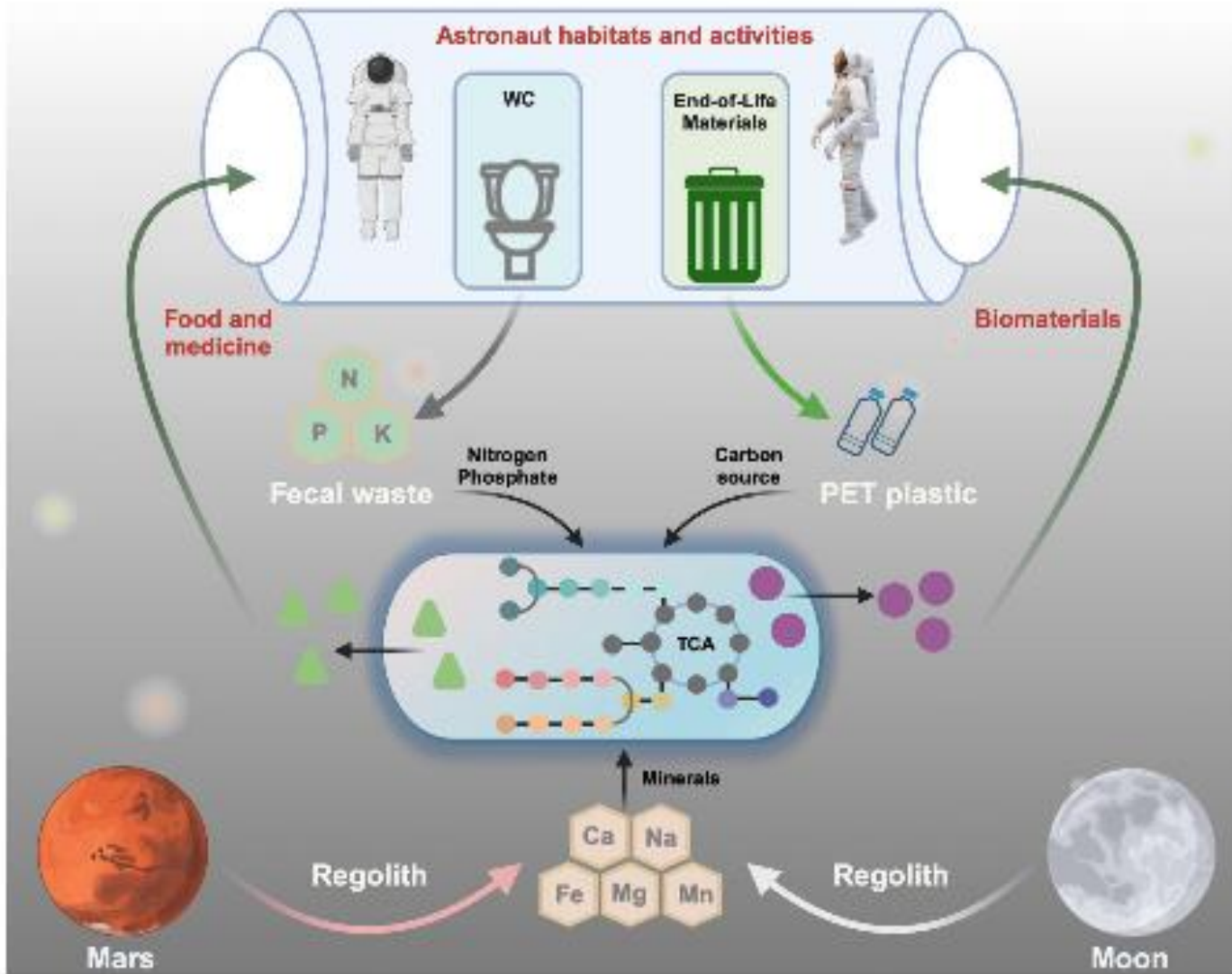
B-SURE Spaceflight experiments and organisms tested in partial gravity



B-SURE Chassis organisms: Usability in partial gravity and spaceflight conditions



Alternative Feedstock (AF) for in-space biomanufacturing



Bacterial Strain

- *Rhodococcus jostii* (RPET S6)

Testing 3 space sourced feedstocks

- Martian and Lunar regolith
- PET (plastic waste)
- Fecal waste

Combined growth medium

- Regolith simulant particles
- Fecal waste

Conclusion: *RPET* can directly utilize AF for cell growth and lycopene productions



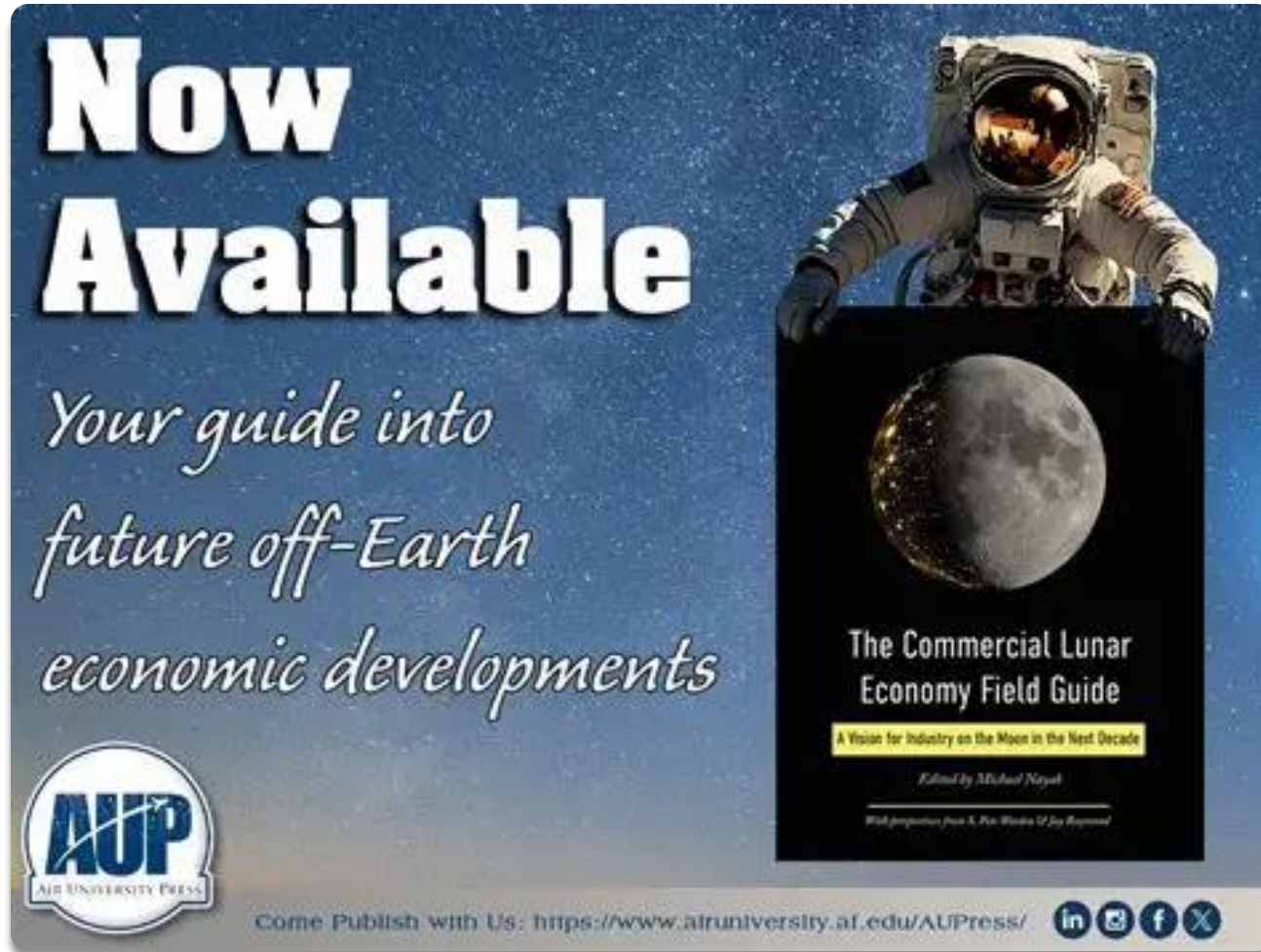
Broad Potential Applications

Leverage lessons from the terrestrial biomanufacturing market:

- Biologics, organoid, pharmaceuticals
- Agrotechnology
- Consumer products
- Fermentation applications and microbial growth

Adapt and apply in the unique environment of space

The Commercial Lunar Economy Field Guide



“This book serves as your guide to foundational technology concepts that will help move the nation into future off-Earth economic development.”

Chapter 20 : Biomanufacturing in Space and on the Lunar Surface
Anne E. Cheever, et al.

Four Non-Traditional Space Segments and Addressable Markets

CAPABILITIES \$850B			
	Markets	Applications	
R&D	• Biotech/ Pharmaceutical • Agritech • Medical Devices • Semiconductor • Materials (Metals, Mining, Packaging) • Communications • Food & Beverage • Consumer Goods • Household & Personal Products	• Macromolecular Crystallization • Cellular Biology • Microorganisms • Accelerated Disease Modeling • Regenerative Medicine • Thermal Transport	• Agriculture and Crop Science • Product Stability • Fluid Dynamics • Material Science • Biofilms • Interfacial Studies
MFG	• Automotive • Energy • Textiles, Apparel, Luxury Goods	• Seed material for Proteins • Pharmaceutical Formulation • Organic and Inorganic Deposition • 3D Bioprinting	• Semiconductor deposition • Semiconductor furnace crystallization • 3D Printing • Seed Variants

Market Experts Predict more than \$1 Trillion by 2040 (\$500B today)

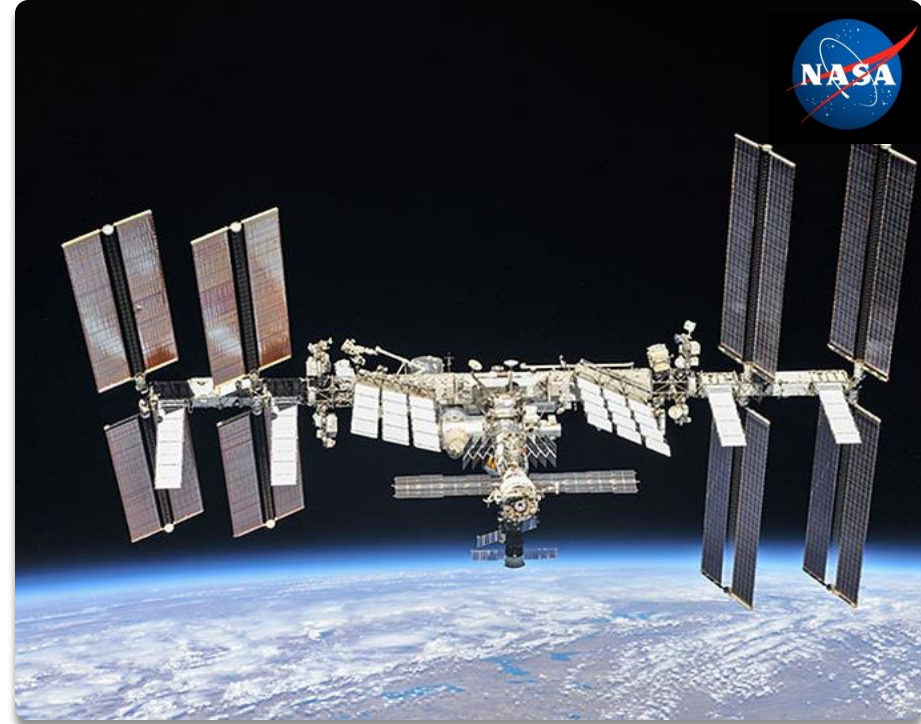
IN SPACE MARKETS \$400M +
• Tourism • Advertising & Marketing • Real-Estate Development • Construction Firms • Architects

DATA \$1.8T		
GPS	• Agriculture • Transportation • Energy	• Consumer Goods • Navigation • Rideshare
Remote Sensing – Earth and Space Observation	• Climate • Weather • Disaster Management • Mobility • Parking	• Environmental • Crop Yields • Soil Health • Insurance • Planets
Data Transmission	• Internet • Satellite-based broadband services	

RESOURCES \$2 – 30B	
Moon	• Water to support in-space propellants • Rare Elements and Minerals (iron, titanium) • Precious Metals (gold, platinum)
Mars	• Industrial base
Asteroids	• Metals and Minerals • Water
Polluting and Energy Inefficient Industries	• Semiconductors • Data Centers



Tiangong Space Station



ISS National Lab

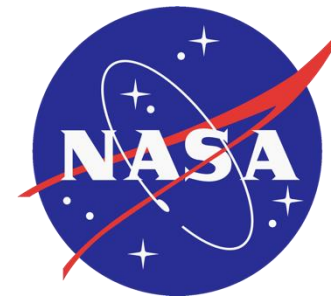
Economic Security and the Future of Space

Technological Innovation

- ▶ Lead world class space research
- ▶ Allied and partner nation joint projects
- ▶ Apply technologies
- ▶ Inspire the next generation

Economic Security and the Future of Space

Leveraging the Whole Ecosystem





Questions