Technology Maturation: Building the mid-TRL Bridge

Biological and Physical Sciences (BPS) Research 2023-2032
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NASA Space Technology Mission Directorate (STMD)

SPACE TECHNOLOGY PORTFOLIO

EARLY STAGE INNOVATION AND PARTNERSHIPS

- Early Stage Innovation
  - Space Tech Research Grants
  - Center Innovation Fund
  - Early Career Initiative
  - Prizes, Challenges & Crowdsourcing
  - NASA Innovation Advanced Concepts
- Technology Transfer

SBIR/STTR PROGRAMS

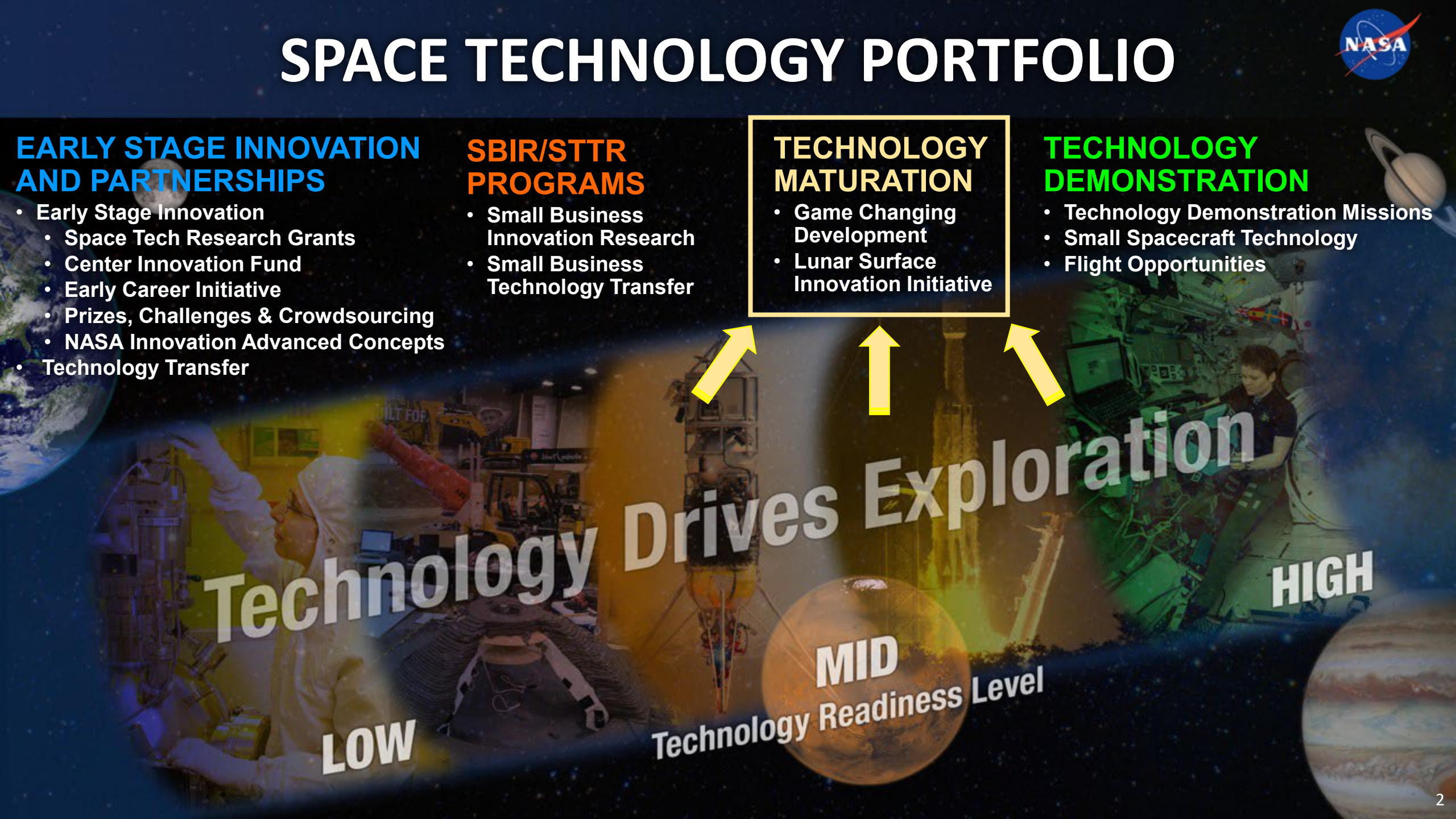
- Small Business Innovation Research
- Small Business Technology Transfer

TECHNOLOGY MATURATION

- Game Changing Development
- Lunar Surface Innovation Initiative

TECHNOLOGY DEMONSTRATION

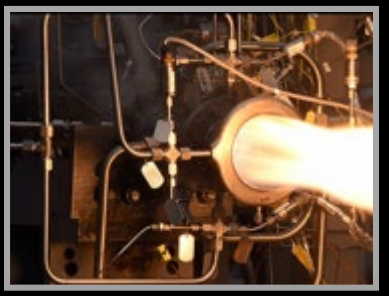
- Technology Demonstration Missions
- Small Spacecraft Technology
- Flight Opportunities



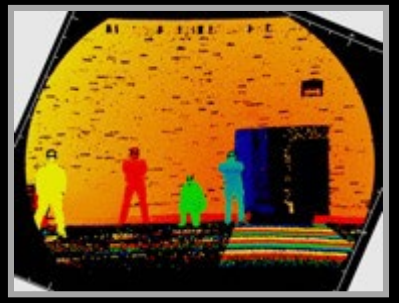
STMD Technology Maturation

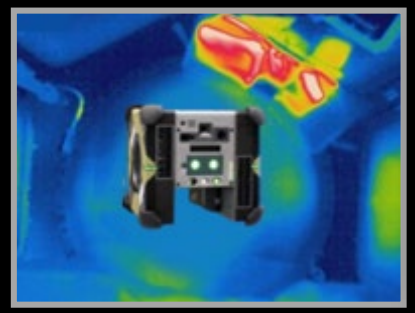
TechMat matures transformative and crosscutting technologies to enable NASA missions and sustain U.S. leadership in space technology. Activities are executed across multiple NASA centers and through robust partnerships and collaborations with industry, academia, and other government agencies.

- **The *Game Changing Development (GCD) Program*** advances exploratory concepts and delivers transition-ready solutions that enable new capabilities or radically alter current approaches



- **The *Lunar Surface Innovation Initiative (LSII)*** develops transformative capabilities for lunar surface exploration





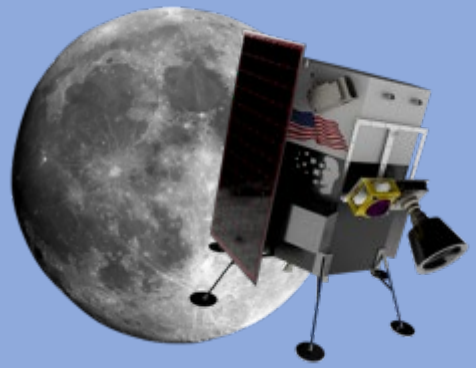
Industry Engagement: Collaboration spurs innovation

A key tenet of the GCD Program is active engagement with industry in order to spur innovation and entrepreneurship while meeting NASA mission needs.

Tipping Point Solicitations

Combines NASA Resources with Industry Contributions (10% small business, 25% others)

Deployable Hopper

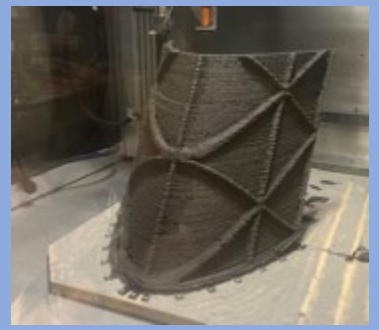


Intuitive Machines

Announcement of Collaborative Opportunities

NASA partners with selected companies to provide expertise, facilities, hardware and software.

Relevant Environment Additive Construction Technology



AI SpaceFactory Inc.

Commercial Partnerships

Novel commercial technology maturation through contracts

High Performance Spaceflight Computing

Microchip Technology Inc.

By sharing the technical and financial risks with the private sector, NASA stimulates emerging commercial markets in the process of developing new and needed capabilities.

GCD Capability Areas and Highlighted Projects

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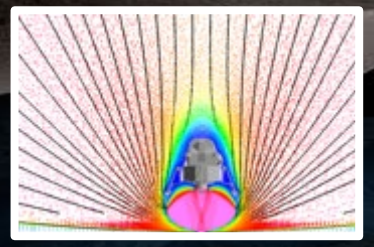
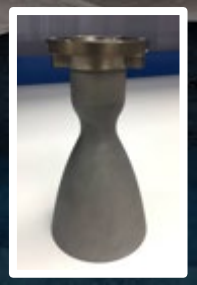
Game Changing Development (GCD) Capability Areas

- Entry, Descent, and Landing

- Propulsion Systems

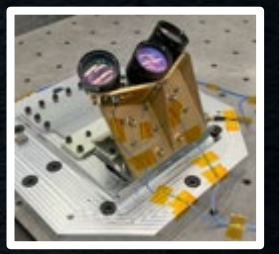



- Robotic Systems


- Surface Capabilities


- Autonomous Systems


- Sensors and Instruments



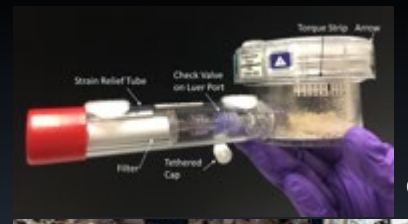

- Power and Energy Storage


- Materials, Structures, and Manufacturing

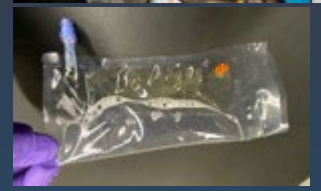

Synthetic Biology (SynBio) Overview

Technology Objectives: Develop and demonstrate an on-demand nutrient production system for long-duration missions to mitigate demonstrated nutrient degradation in stored foods.

- Develop an evolvable platform for future surface missions – capable of producing other compounds (e.g., Medicines) requiring minimal resources. Perform an ISS time-course hydration, incubation, freezing and return for analysis over 5-year period.
- Develop and demonstrate a prototype system that enables microbial manufacturing via abiotic CO_2 conversion to products that drive biomanufacturing for future long-duration missions.



BioNutrients -1 Flight Production Pack for on-orbit testing

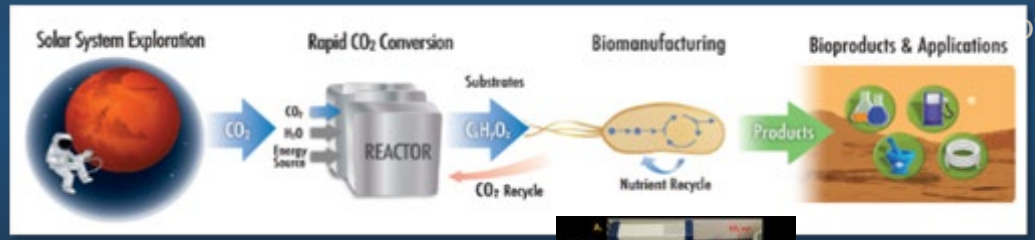


BioNutrients -2, Gen-1 Flight Production Pack

Technical Capabilities

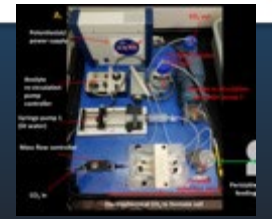
- Reduced gravity compatible bioreactor development
- Long-duration ambient storage of microorganisms
- Methods for ensuring quality and safety of biomanufactured products
- Development of ISRU based growth media
- Space-relevant biomanufacturing system development
- Space qualified organisms for biomanufacturing

Future Implementation Concept



Exploration & Science Applicability

- Cross-cutting: Supports crew health, enhanced logistics, mission sustainability and risk reduction for extended duration habitation missions on the moon (Artemis) and Mars and space-based outposts.



SynBio: Collaborations & Partnerships

STMD NSTRI

CUBES
- UC Berkeley
- UC Davis
- Stanford U
- Utah State U
- U of Florida

SBIR/STTR

Nature's Fynd
Mango
Materials

NASA

Exploration Capabilities
HRP
NASA Centennial CO_2 Conversion Challenge
ARCn Challenge

OGA

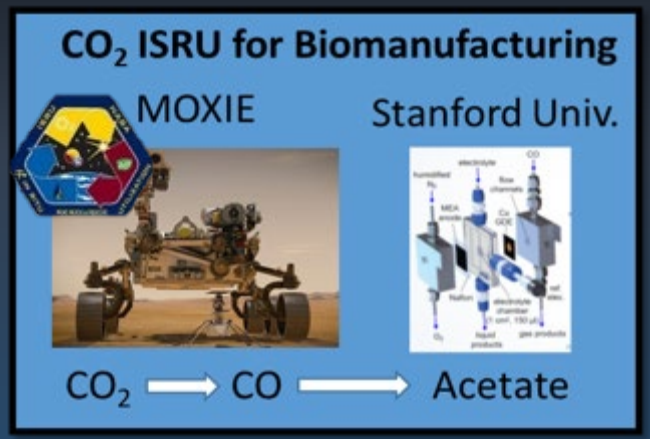
DARPA/DOD/Space Force
Biofoundries Program
BioMade

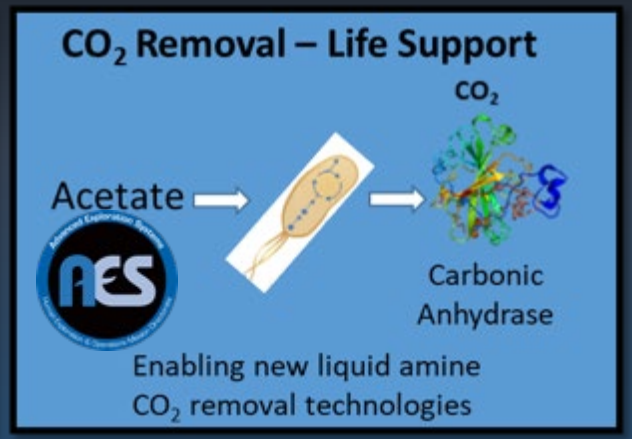
Academic

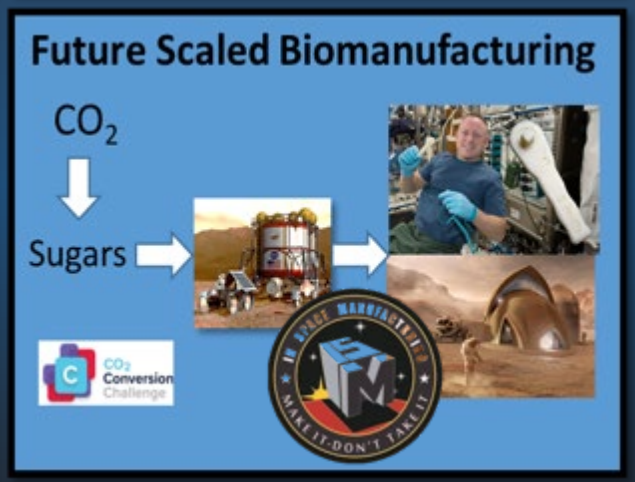
Stanford University
cooperative agreement
Kanan Lab

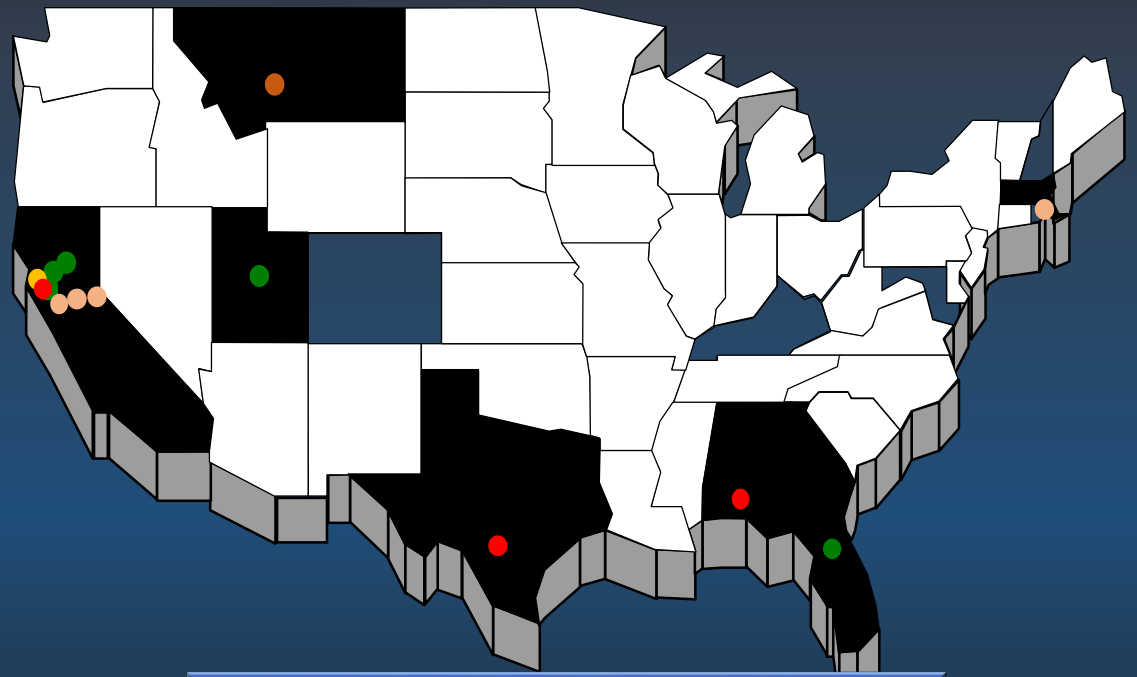
Commercial

ATUM
Claremont BioSolutions
ThermoFisher
Cytiva
Instant Systems









Leveraging technologies, data, and expertise developed for earth based biomanufacturing

SynBio: Infusion and Transition Plans

BioNutrients looks for transition into **Advanced Food Systems/HRP and Exploration Capabilities**

- Through discussion with HRP Advanced Food Systems, the BioNutrients mission and microbial, fungal, algal based food products are now represented part of the Food Roadmap/Integrated Research Plan. The goal is to be transitioned into their program.
- Continue to be engaged with STTR partner developing an alternate organism platform for support of nutrition via biomanufacturing.

CO_2-based Manufacturing: first product targets **Exploration Capabilities**, platform targets **ISRU**

- Demonstration product is carbonic anhydrase (CA), a catalytic enzyme that facilitates the liquid amine-based CO_2 air revitalization technology. AES acted as a partner and supported a directed evolution project to produce an optimized CA enzyme. AES will ultimately determine the air revitalization technology for exploration missions and the specific need for CA will be determined based on this decision.
- CO_2-based conversion technologies are still nascent. Plan to leverage CO_2 Conversion Centennial Challenge to investigate the product's ability to support a biomanufacturing system.
- Cooperative Agreement with academic partners to further develop CO_2 conversion capabilities.

Synthetic Biology plans to leverage advancements made by the external community: new products, new systems, to meet the evolving needs of sustainable exploration.

- The Center for the Utilization of Biological Engineering in Space (**CUBES**) and the external research community have demonstrated numerous new products and conversion systems that highlight the potential for synthetic biology and biomanufacturing to support exploration. Potential products include adhesives/additives for construction, materials, food products, fuel, media resupply components, recycling capabilities, medicines and nutrients.
- OGA/& GOV/Industry private partnerships: **BioMade** -Building a sustainable, domestic end-to-end bioindustrial manufacturing ecosystem- looks to solve issues of scalability. **DARPA/DOD/Space Force -**Biofoundries Program.

In-Space Manufacturing: On-demand Manufacturing of Electronics (ODME) Overview

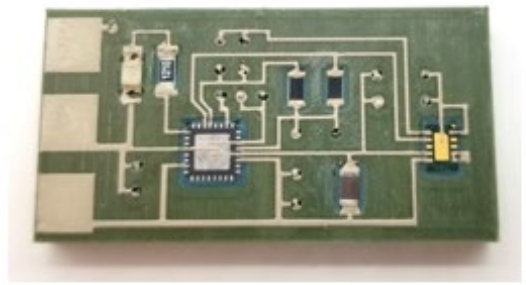
Thin-film deposition TRL/MRL development
- Multiple suborbital zero gravity parabolic flights (STMD/Flight Opportunities)

On-demand printed power generation and energy storage devices
- Printed RF power harvesting antennas (UAH)
- Printed thermoelectric devices (Boise State)
- Printed wearable bio-fuel cell generators (Cal Tech)
- Multiple supercapacitor technologies for energy storage (Georgia Tech, Auburn, NASA ARC)

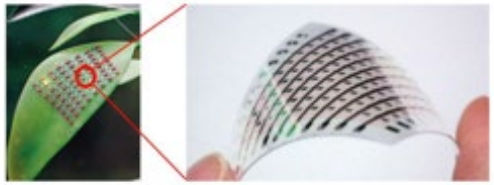
On-demand printed sensor technologies
- Radiation sensors (Georgia Tech)
- Strain sensors for structural health monitoring andPlant growth monitoring (Florida A&M University, West Virginia University, University of Illinois)
- Wireless sensors for crew health monitoring and printed cortisol sensors (Georgia Tech, Cal Tech, NASA ARC).

NextFlex flexible wireless crew health sensing device "AstroSense"
- The Potentiostat communications interface and the preliminary electrical and mechanical design is complete. https://www.nextflex.us/story/nasa-astrosense-in-space-manufacturing-multi-material-fabrication-with-printed-electronics/

Iowa State Parabolic Flight

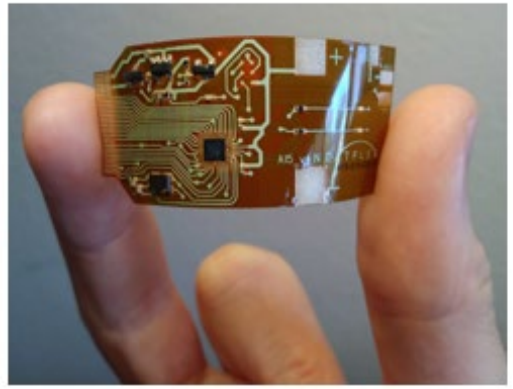


Printed CO2 Sensor (ODME ISS Demo)



University of Illinois Plant Growth Sensor

RF Power Harvesting Antennas- UAH



NextFlex Wireless Flexible Sensor Board

ODME: Collaborations & Partnerships

NASA Centers

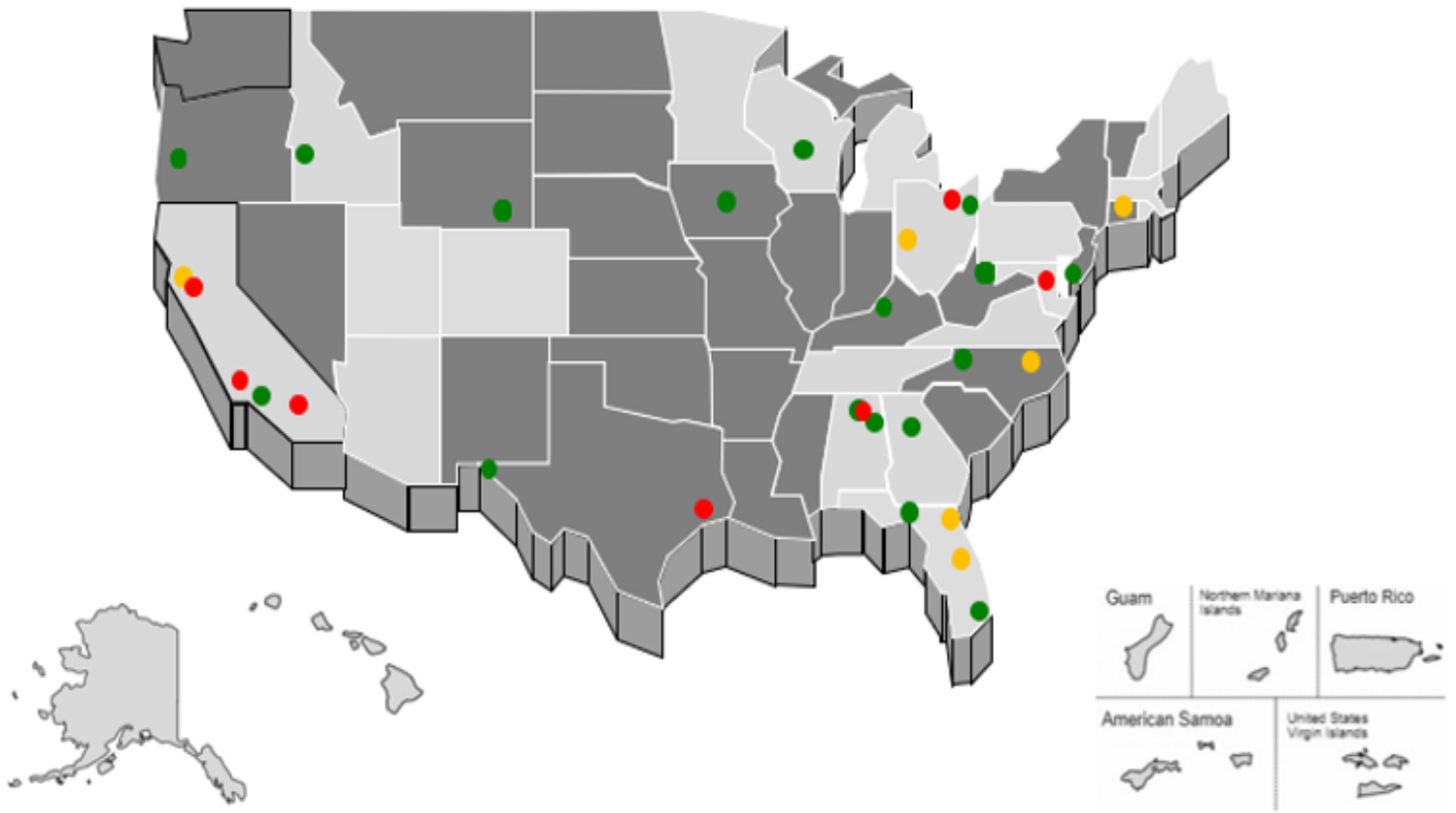
- MSFC
- GSFC
- ARC
- JSC
- JPL
- AFRC
- GRC

Public/Private Partnerships

- NextFlex
- nScrypt
- Multi3D
- LambdaVision
- Redwire/Made in Space
- Faraday Incorporated

Industry/Academia

- University of Alabama Huntsville
- Appalachian State
- Auburn University
- Boise State
- Georgia Tech
- Cal Tech
- Iowa State University
- University of Miami
- Florida A&M University
- Oregon State
- West Virginia University
- Youngstown University
- University of Texas El Paso (UTEP)
- University of Louisville
- University of Wisconsin
- University of Wyoming
- University of Delaware



Infusion/ Transition Plan: On-demand Manufacturing of Electronics is a critical need for future habitats and missions. The technology infusion plan involves flight tests (MISEE, Sounding Rocket, Parabolic Flights) and a FY24 planned ISS demonstration of the flight system. Elements of the technology are being developed in FY21-23.

ODME: Infusion and Transition Plans

Microgravity Testing Advances Space-Based Printing of Electronics Article

Redwire Sputtering Printer

inSPA Retinal Implant

- ODME-developed technologies can support
  - ISS and Commercial LEO platforms
  - Artemis, including potential for printing solar cells on the lunar surface
  - Science missions
- **Flight testing of thin film deposition systems-** ODME had extensive collaboration and support from STMD Flight Opportunities in FY22 for the evaluation of Thin Film Deposition systems and testing in zero gravity through four suborbital parabolic flights. This was a large contributor in advancing the TRL/MRL of this ODME technology.
- **InSPA In-Space Applications-** ODME involvement in InSPA projects is leading to the commercialization of manufacturing in low earth orbit. For example,
  - The thin layer by layer manufacturing of retinal implants by LambdaVision is leading to lower cost, higher volume manufacturing of retinal implants to cure macular degeneration.
  - Redwire is developing fabrication capabilities for printed semiconductors through and InSPA project.

On-Demand Manufacturing of Electronics is a key need for future habitats and science missions. The technology infusion plan involves flight tests (ISS MISEE, Sounding Rocket, Parabolic Flights) and a FY24 planned ISS demonstration of the flight system.

The Lunar Surface Innovation Initiative & Consortium (LSII/C)

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Lunar Surface Innovation Initiative (LSII)

LSII works across industry, academia, and government through in-house efforts and partnerships to develop transformative capabilities for lunar surface exploration.

- Formulate and integrate technology maturation activities across the TRL pipeline and space technology programs
- Utilize early robotic lunar surface flight opportunities to inform key technology development
- Establish the Lunar Surface Innovation Consortium (LSIC)
- Leverage innovative partnering and procurement approaches to expedite technology development

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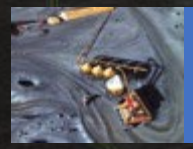
LSII Capability Areas

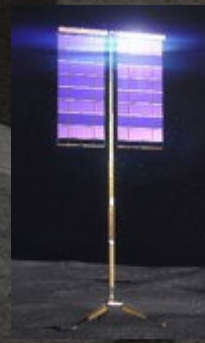


In-Situ Resource Utilization (ISRU)

The collection, processing & use of in-situ materials for production of consumables such as oxygen or propellant.

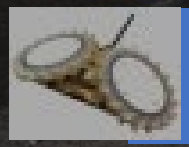
Excavation and Construction

Enables autonomous excavation of in-situ materials for construction of structures such as landing pads, habitats, etc.



Surface Power

Technologies that can provide continuous power throughout the lunar day and night.



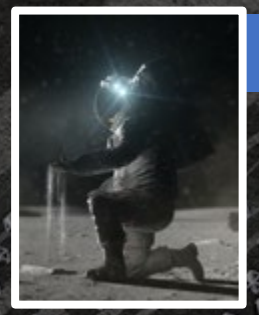
Extreme Environments

Enables operations across the full range of lunar surface conditions.

Lunar Surface Infrastructure

Extreme Access

Enables humans/robotic systems to access, navigate, assess, and explore previously inaccessible locations on the lunar surface.



Dust Mitigation

Active, passive & operational technologies to remediate lunar dust hazards.

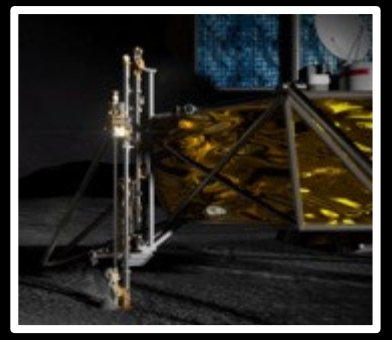
Near-term Lunar Surface Technology Demonstrations

Commercial Lunar Payload Services (CLPS) provides opportunities to mature key capabilities required for NASA and industry.

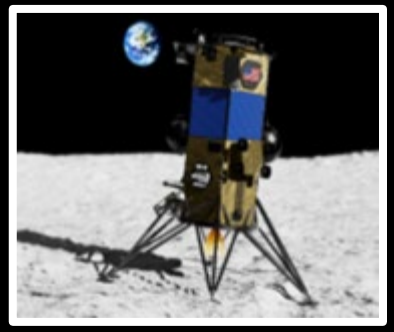
Astrobotic Peregine-1

Astrobotic Terrain Relative Navigation – Tipping Point

Intuitive Machines-2



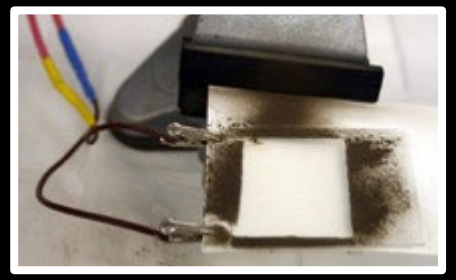
Deployable Lunar Hopper – Tipping Point



Polar Resources Ice-Mining Experiment (PRIME-1) – NASA project

Nokia 4G/LTE Proximity Comms – Tipping Point

Firefly Aerospace (CLPS 19D)



Electrodynamic Dust Shield – NASA project

Stereo CAmera for Lunar Plume Surface Studies (SCALPSS 1.1) – NASA project

Intuitive Machines-3 (CLPS CP-11)

Cooperative Autonomous Distributed Robotic Explorers (CADRE) – NASA project

Lunar Surface Innovation Consortium (LSIC)

Facilitated by Johns Hopkins APL, LSIC is a nationwide alliance of universities, industry, non-profits, NASA, and other government agencies with a vested interest in establishing a sustained presence on the Moon. LSIC engages the community through bi-annual meetings, monthly capability focus groups, and themed technical workshops.

5 **Bi-annual meetings**

- Attended by over 2,000 people
- 54% at kickoff had not previously worked with NASA Space Tech

1500 **People attended 6 thematic workshops**

- Topics driven by member interest
- Key takeaways and recommendations provided in outcome reports

6 **Focus groups**

- Virtual monthly meetings
- Average 100 people per meeting
- 35 subgroups defined and led by members
- Collaboration space
- Provides feedback and recommendations to NASA

678 **Organizations working toward one goal**

- Monthly newsletter
- Technology assessment reports
- Lunar simulants portal
- LSIC website

The LSIC Fall meeting will be held at the University of Texas El Paso Nov. 2-3, 2022
More information: www.lsic.jhuapl.edu

Developing Capabilities via LSII Collaborations

LSII has awarded ~$300M to industry and academia through various programs since 2020.

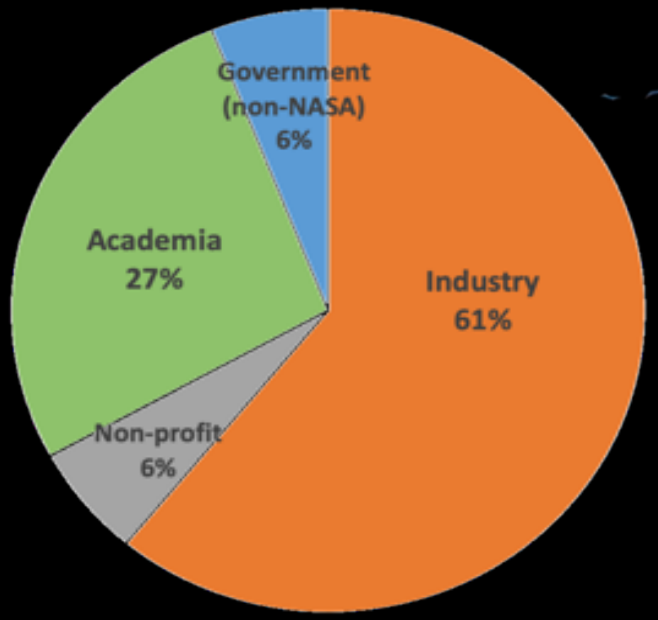
Collaborations & Partnerships

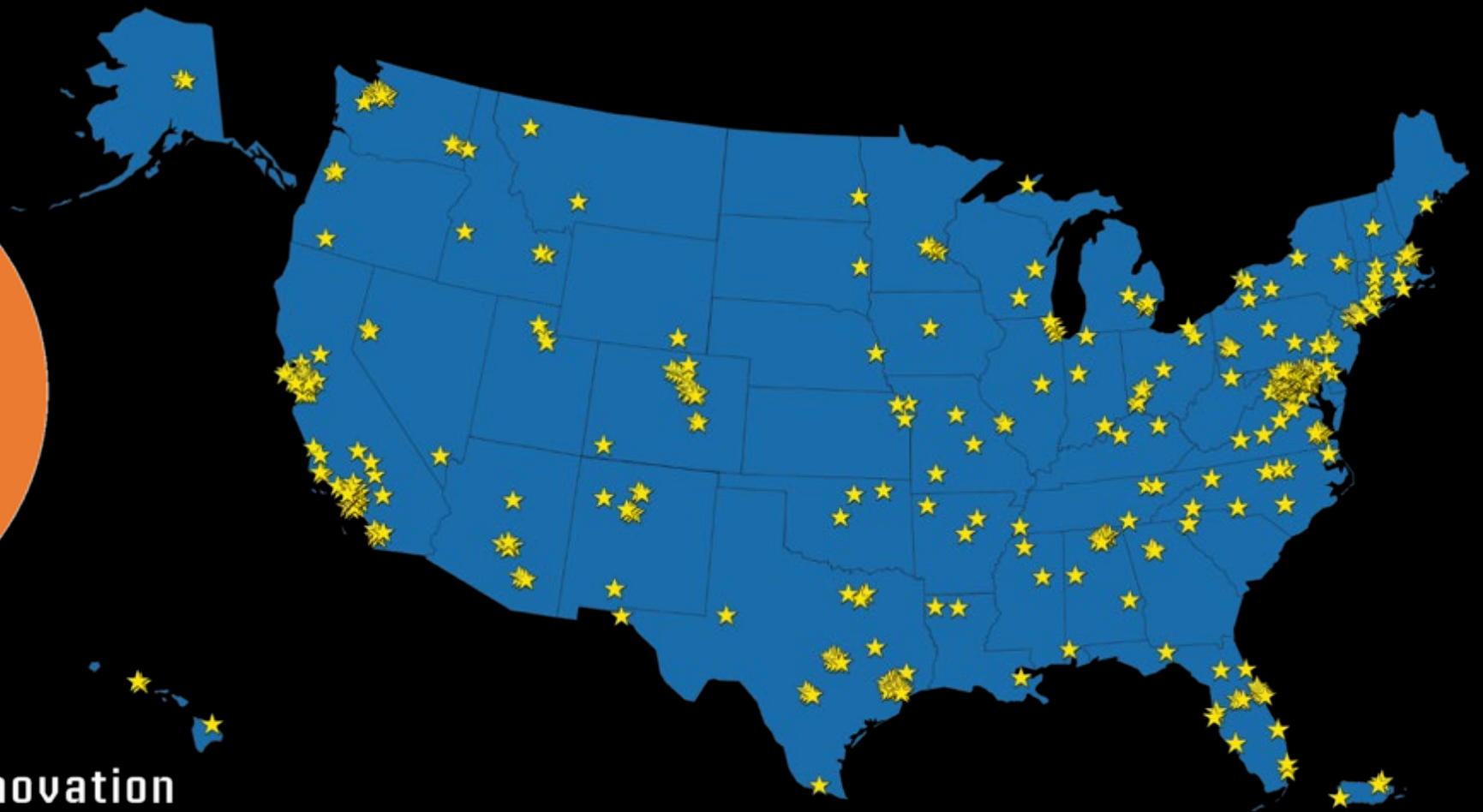
- Commercial Lunar Payload Services (CLPS) Flight Demonstrations
- Tipping Point Partnerships & Collaborative Opportunities
- APL LSII Integration and Lunar Surface Innovation Consortium (LSII)
- Vertical Solar Array Technology (VSAT) Prototype
- SBIRs (Ph. I, II, III, CCRPP, Lunar Sequentials)
- Breakthrough Innovative Game-changing (BIG) University Challenge
- Space Technology Research Grants (New LuSTR, ECF, ESI Grant Opportunities)
- NASA Tournament Lab Crowdsourcing (GrabCAD, Yet2, HeroX)
- NASA Innovative Advanced Concepts (NIAC)
- Centennial Challenges ('Watts on the Moon' & 'Break the Ice' Challenges)

LSII Continues to Grow

Since 2020, LSII has engaged over 700 organizations across industry, academia, non-profits, and other government agencies from 50 states, D.C., Guam, Puerto Rico and 46 countries through novel NASA collaborations and LSIC.

LSII Representation





Lunar Surface Innovation CONSORTIUM


NASA
EXPLORESPACE TECH
TECHNOLOGY DRIVES EXPLORATION