
# Space Technology Overview

## Aeronautics and Space Engineering Board Spring 2021 Meeting

Mr. James Reuter | Associate Administrator, Space Technology Mission Directorate | 05.25.2021

# SPACE TECHNOLOGY PORTFOLIO

## EARLY STAGE INNOVATION
- NASA Innovative Advanced Concepts
- Space Tech Research Grants
- Center Innovation Fund/ Early Career Initiative

## PARTNERSHIPS AND TECHNOLOGY TRANSFER
- Technology Transfer
- Prizes and Challenges
- iTech

## SBIR/STTR PROGRAMS
- Small Business Innovation Research
- Small Business Technology Transfer

## TECHNOLOGY MATURATION
- Game Changing Development
- Lunar Surface Innovation Initiative

## TECHNOLOGY DEMONSTRATIONS
- Technology Demonstration Missions
- Small Spacecraft Technology
- Flight Opportunities

Technology Drives Exploration

LOW

MID

HIGH

Technology Readiness Level

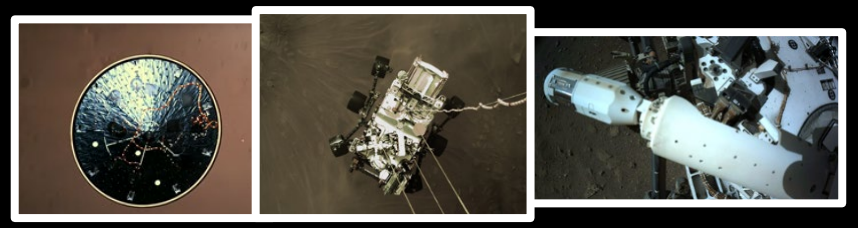
# STMD FY 2021-2022 Highlights

**Blue Origin Deorbit Descent & Landing (BODDL-TP)/SPLICE**
**October 2020**
Flight demo 1 aboard suborbital rocket

**Robotic Refueling Mission 3 On Orbit Robotics Ops**
**October 2020**
Operations Complete

**Laser Comm Relay Demo**
**June 2021**
Launch

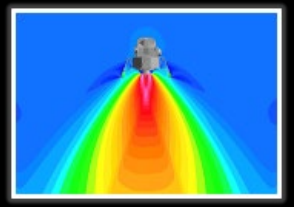
**Flight Ops and Small Spacecrafts**
40+ suborbital and small spacecraft flights planned 2021



**Mars 2020 Perseverance: MOXIE, MEDLI2, MEDA and TRN**
**February 2021 and beyond..**
Mars Landing & Surface Operations and Demo

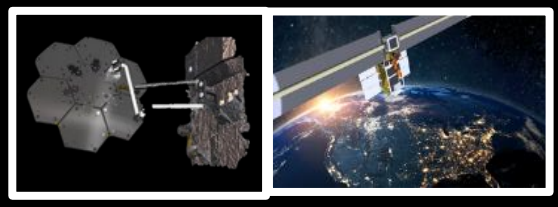
**Cryo Fluid Management**
**April/May 2021**
Initiate 4 Flight Demos

**CAPSTONE/NRHO**
**Fall 2021**
Launch

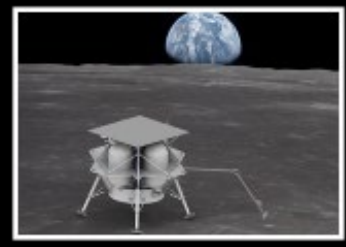


**Plume Surface Interaction (PSI)**
**April 2021**
Physics focused ground test

**Polar Resources Ice Mining Experiment 1 (PRIME-1)**
**April 2021**
MSolo and TRIDENT assembled for environmental testing w/ delivery to CLPS provider Intuitive Machine in **Spring 2022**

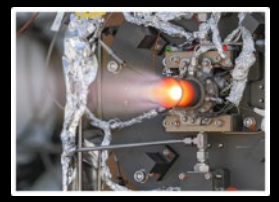


**OSAM-1 and OSAM-2**
**Fall 2021**
Critical Design Reviews



**Cold Operable Deployable Arm (COLDArm)**
**April 2021**
Mission Concept Review

**Blue Origin Deorbit Descent & Landing Sensor (BODDL-TP)/SPLICE**
**Summer 2021**
Flight demo 2 aboard suborbital rocket



**TALOS and A-TRN**
**December/TBD 2021**
TALOS and A-TRN flight on Astrobotic Peregrine 1 lander

**CLPS Mission**
**Spring 2022**
Intuitive Machine's "hopper" mission in partnership with Nokia to est. 4G/LTE tech for lunar exploration

**SEP**
**January 2022**
Critical Design Review

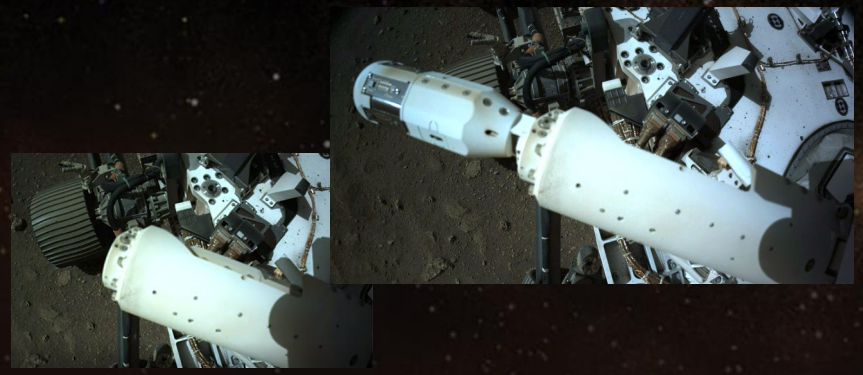
**LOFTID**
**June 2022**
Delivery to ULA

**Deep Space Optical Comm**
**August 2022**
Psyche Launch

# Space Technology for Mars 2020 Perseverance

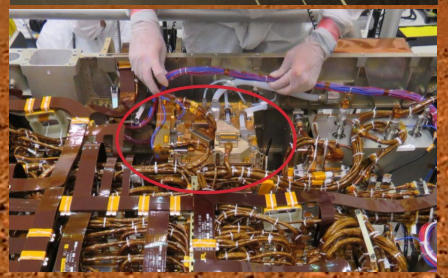
**MEDA** *(Mars Environmental Dynamics Analyzer)*

A set of sensors that will provide measurements of temperature, wind speed and direction, pressure, relative humidity and dust size and shape in the Martian atmosphere



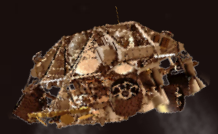
**MEDLI2** *(Mars Entry, Descent and Landing Instrumentation 2)*

MEDLI2 is a next-generation sensor suite for entry, descent and landing (EDL). It collects temperature and pressure measurements on the heat shield and afterbody during EDL

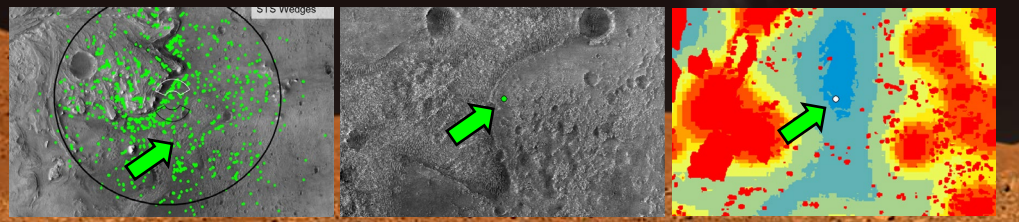


**TRN** *(Terrain Relative Navigation)*

TRN gives a spacecraft the ability to autonomously avoid hazards we already know about and can land in more (and more interesting) landing sites with far less risk



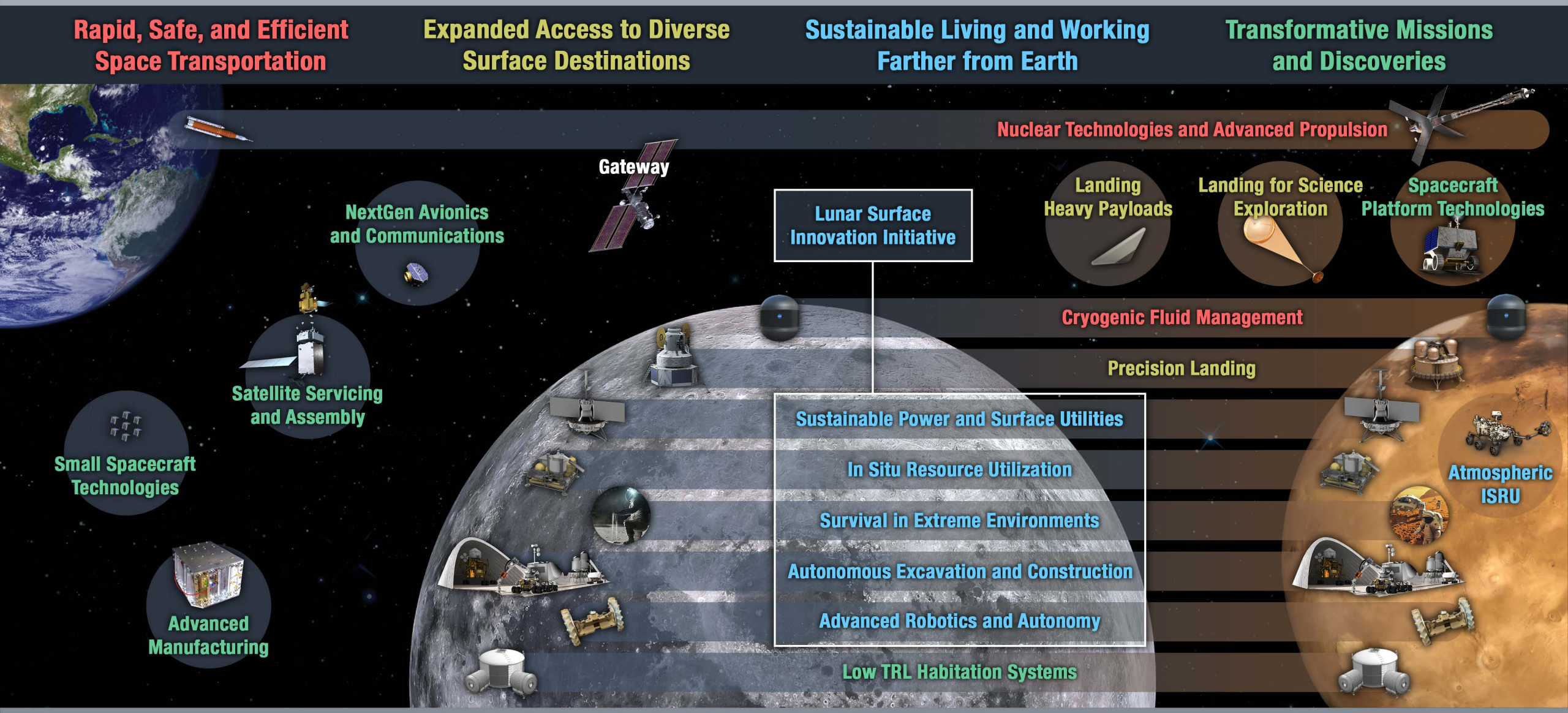
Mars 2020 EDL Targeted Location



**MOXIE** *(Mars Oxygen In-Situ Resource Utilization Experiment)*

MOXIE will demonstrate a way that future explorers might produce oxygen from the Martian atmosphere for propellant and for breathing.

# TECHNOLOGY DRIVES EXPLORATION




2020 **GO | LAND | LIVE | EXPLORE** 203X

# Lunar Surface Innovation Initiative

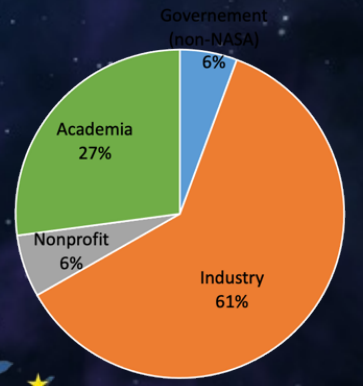
Since inception, LSII has engaged ~400 organizations across 48 states and Puerto Rico to advance the technologies needed to explore the lunar surface and stimulate economic development

## Focus Areas

- In-situ resource utilization
- Surface power
- Dust mitigation
- Extreme environment
- Extreme access
- Excavation and construction

***Johns Hopkins Applied Physics Lab is the lead for the LSIC and overall System Integrator for LSII***

**LSII Representation**



# Lunar Surface Innovation Initiative (LSII) Collaboration Highlights

LSII has awarded ~$200M over a broad range of STMD Programs to establish collaborations across industry and academia.

Collaborations & Partnerships

**Commercial Lunar Payload Services (CLPS) Technology Demonstrations** (i.e. PRIME-1 mass spectrometer and drill, Nokia 4G Wireless and Intuitive Machines Deployable Hopper)

**$127M – Tipping Points & Collaborative Opportunities (10 TPs & 5 ACOs selected in 2020)**

**$36M – SBIRs (Ph. I, II, III, CCRPP, Lunar Sequentials)**

STRG Program

**$14M – Space Technology Research Grants (6 LuSTR Opportunity, ECF, ESI)**

NextSTEP Next Space Technologies for Exploration Partnerships

**$9.9M – NextSTEP BAA (9 ISRU awardees with multiple ground demos)**

**$3.5M – Vertical Solar Array Technology (VSAT) Solicitation (5 Phase I Awards)**

NIAC NASA Innovative Advanced Concepts

**$3M – NIACs (including first Phase 3 award for Exploration of Lunar Pits)**

BIG IDEA CHALLENGE

**$2M – Breakthrough Innovative Game-changing (BIG) Challenge**
2020 Permanently Shadowed Region – 8 teams; 2021 Dust – 7 teams

NTL NASA Tournament Lab

**$1.4M – NASA Tournament Labs (GrabCAD, Yet2, HeroX) Open-source Challenges**

NASA CENTENNIAL CHALLENGES

**$1M – Centennial Challenges ('Watts on the Moon' & 'Break the Ice' Challenges)**

APL

**APL LSII Integration and Lunar Surface Innovation Consortium**

Note: FY20-21 Awards

# EXPLORE SPACE TECH

## THROUGH SUBORBITAL FLIGHT

The Flight Opportunities program rapidly demonstrates promising technologies for space exploration, discovery, and the expansion of space commerce through suborbital testing with industry flight providers

### SINCE 2011* FLIGHT OPPORTUNITIES HAS…

* As March 30, 2021

- Supported **212** successful fights
- Enabled **736** tests of payloads
- **307** technologies in the portfolio
- **12** active commercial providers
- In FY21 FO has had **22** suborbital flights and is projected to have a total of **31** flights

### COMMERCIAL FLIGHT PARTNERS:

Virgin Galactic
Blue Origin
Masten
UP Aerospace
exos Aerospace
zero G
World View
Raven
NSC
Ångstrom Designs
Stratodynamics
AMOCAL

# EXPLORE SPACE TECH

## WITH SMALL SPACECRAFT

The Small Spacecraft Technology program expands the ability to execute unique missions through rapid development and demonstration of capabilities for small spacecraft applicable to exploration, science and the commercial space sector.

### SMALL SPACECRAFT TECHNOLOGY BY THE NUMBERS:

- **20 Missions** (27 Spacecraft Total) project to launch between 2021 and 2023
  Missions include:
  - **17** LEO, **1** GTO, and **2** Cislunar
  - **11** Small Business Partners and **6** collaborating NASA Centers
- **11** Spacecraft slated for launch by the end of FY21 (4 launched already as of May 2021)

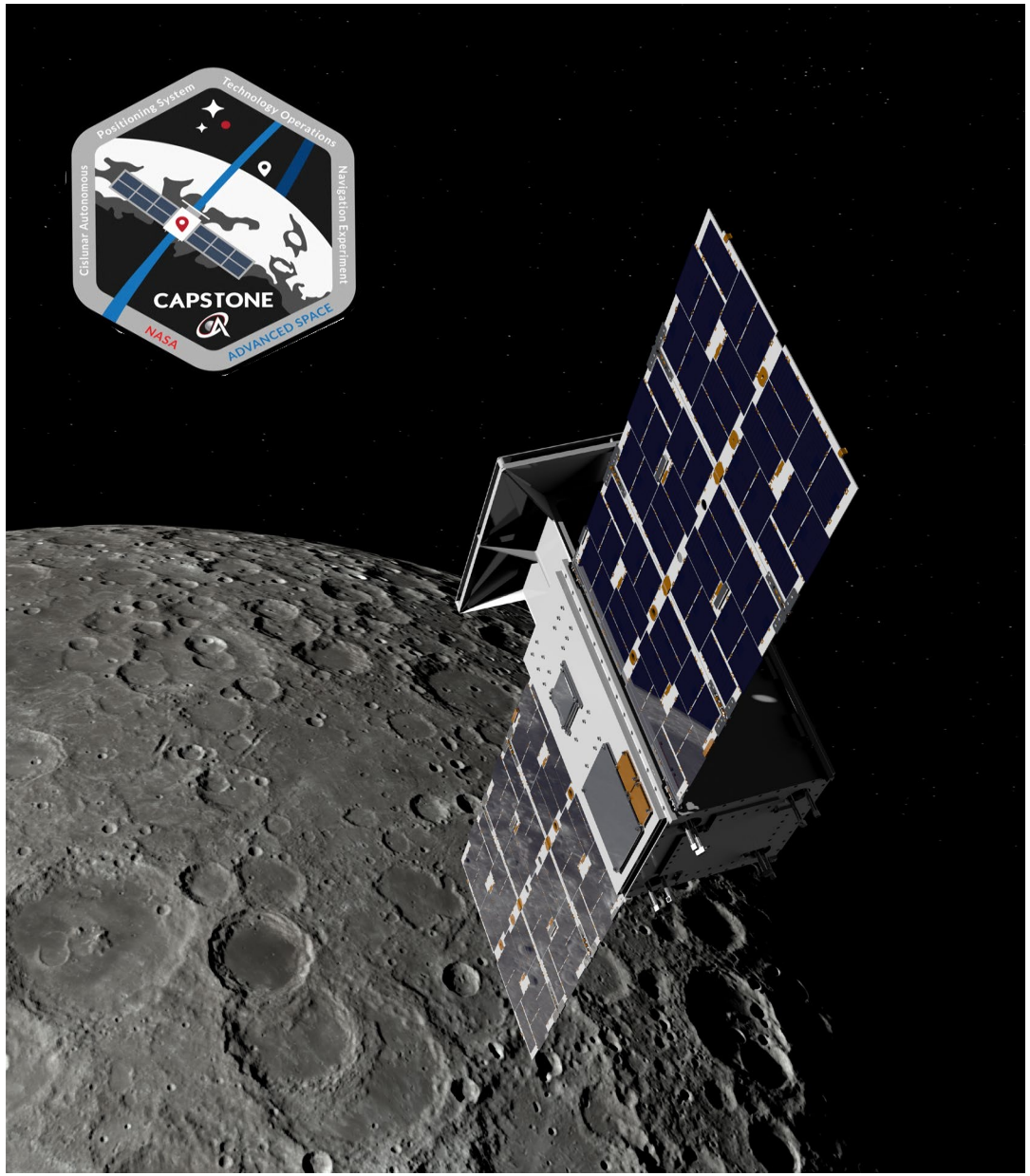
# CAPSTONE OVERVIEW & SCHEDULE

**12U CubeSat that is the first spacecraft to enter into a near rectilinear halo orbit (NRHO) designed for Gateway. First CubeSat to fly in cislunar space.**

**Launching on Rocket Lab Electron, with a 3rd stage developed for this commercial launch service.**

**MISSION HIGHLIGHTS:**

- Low Energy Lunar Transfer taking 90-120 days
- NRHO (Gateway orbit) pathfinder operations and flight dynamics assessment
- CAPSTONE to LRO cross-link experiment to establish absolute estimate of position and velocity
- Cislunar Autonomous Position System (CAPS) technology validation
- Baseline mission operations of 18 months
- CAPSTONE will lay a foundation for commercial support for future lunar operations




| Spacecraft Complete | Launch | Arrival NRHO | LRO-Crosslink | CAPS Demo | EOM |
|---|---|---|---|---|---|
| July 2021 | NET Oct 20, 2021 | Jan 2022 | Q1-Q2 2022 | Q3 2022-Q2 2023 | Mid 2023 |

# The Early Stage Innovation and Partnerships (ESIP) portfolio leads innovation by fostering diverse ideas and communities, while transferring space technology into the space economy and beyond

***The ESIP Portfolio advances 700+ ambitious projects annually across TRLs and communities to address NASA mission needs and seed future disruptive aerospace capabilities.***


| | |
|---|---|
| **NASA Innovative Advanced Concepts (NIAC)** | •Nurtures **visionary ideas** that could transform future NASA missions with the creation of breakthroughs while engaging America's innovators and entrepreneurs as partners in the journey. |
| **Space Tech Research Grants (STRG)** | •Challenges the spectrum of **academic researchers** to examine the theoretical feasibility of ideas and approaches that are critical to making science, space travel, and exploration more effective, affordable, and sustainable. |
| **Center Innovation Fund / Early Career Initiative (CIF/ECI)** | • Stimulate encourage creativity and innovation within the **NASA Centers** in and addressing the technology needs of NASA and the nation. |
| **Prizes, Challenges & Crowdsourcing* (PCC)** | • Makes opportunities available for **public participation** in NASA research and technology solutions to support NASA missions and inspire new national aerospace capabilities. |
| **Small Business Innovation Research (SBIR)/ Small Business Technology Transfer (STTR) Program*** | •Engages **small businesses, research institutions and entrepreneurs** in R&D of innovative technologies that meet NASA needs and have the potential for commercialization. |
| **Technology Transfer* (T2)** | •Ensures that innovations developed for exploration and discovery are broadly available to the public, maximizing the benefit to the Nation, and enabling **spinoffs**. |

***ESIP Portfolio-Level Objectives***

*Increase participation by underserved / underrepresented communities*

*Explore innovation pilots to enable breakthrough technology and R&D*

*Build evidence for what works to advance early -stage innovations and partnerships*

*Enable technology transition across NASA, OGAs, and Commercial Customers*

**Act as a steward for several agency-wide programs and innovation methods for NASA*

# Space Technology Research Grants (STRG)

***Engage Academia:*** *tap into* ***spectrum*** *of academic researchers, from graduate students to senior faculty members, to examine the theoretical feasibility of ideas and approaches that are critical to making science, space travel, and exploration more effective, affordable, and sustainable. Currently ~300 active awards which support ~850 student/faculty researchers.*

### NASA Space Technology Graduate Research Opportunities (NSTGRO)

- Graduate student research in space technology; research conducted on campuses and at NASA Centers and not-for-profit R&D labs

### Early Career Faculty (ECF)

- Focused on supporting outstanding faculty researches early in their careers as they conduct space technology research of high priority to NASA's Mission Directorates

### Early Stage Innovations (ESI)

- University-led, possibly multiple investigator, efforts on early-stage space technology research of high priority to NASA's Mission Directorates
- Paid teaming with other universities, industry, and non-profits permitted

### Lunar Surface Technology Research (LuSTR) Opportunities

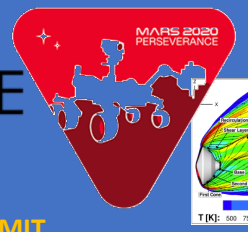
- University-led efforts addressing high priority lunar surface challenges
- Short duration, high value grants with emphasis on potential infusion
- Paid teaming with other universities, industry, and non-profits encouraged

### Space Technology Research Institutes (STRI)

- University-led, integrated, multidisciplinary teams focused on high-priority early-stage space technology research for several years

| | NSTGRO | ECF | ESI | LuSTR | STRI |
|---|---|---|---|---|---|
| Anticipated new awards in FY21 | 58 | 6 | 10 | 6 | 2 |
| Anticipated new awards in FY22 | 50 | 6 | 10 | 4 | 0 |

MOXIE




## Mars 2020 Mission

**NSTRF17 – Eric Hinterman / MIT**

Created a high-fidelity model of the oxygen producing MOxiE experiment onboard Perseverance which is used extensively by the MOxiE team. Eric now serves as the MOxiE payload uplink lead during Mars surface operations.

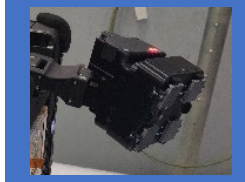
**ECF15 – Marco Panesi / University of Illinois:**

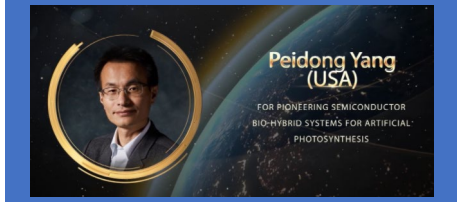
Developed new high-fidelity models of radiation on a planetary entry vehicles backshell. His model was used during aerothermal entry simulations of the Mars 2020 mission.

## Astrobee Gecko Gripper

**ESI15 – Mark Cutkosky / Stanford University:**

The Gecko Gripper built, installed, and successfully tested onboard ISS in April through an extension to Prof. Cutkosky's ESI15 project which developed the underlying adhesive technology. The gripper allows the Astrobee robots to grasp or perch onto nearly any flat surface. Several other STRG projects contributed to the effort: **Andrew Bylard (NSTRF15), Arul Suresh (NSTRF16), Abhishek Cauligi (NSTRF16)**






**STRI16 (CUBES) – Peidong Yang / University of California, Berkeley:**

Dr. Yang developed a biohybrid artificial photosynthesis process which can be used to produce various carbon-based resources like methane fuel, polymers, and pharmaceutical precursors on Mars. The process doubles the previously reported photon efficiency for plants and has potential terrestrial applications. Dr. Yang won the **2020 Global Energy Prize** for his work.

# Space Technology Research Grants (STRG)

## Selected six inaugural LuSTR awards

### In Situ Resource Utilization

**Ahsan Choudhuri**
**University of Texas in El Paso**
*Advanced Thermal Mining Approach for Extraction, Transportation, and Condensation of Lunar Ice*

**Alian Wang**
**Washington University in Saint Louis**
*WRANGL3R - Water Regolith ANalysis for Grounded Lunar 3d Reconnaissance*

**Paul Van Susante**
**Michigan Technological University**
*Percussive Hot Cone Penetrometer (PHCP) and Ground Penetrating Radar (GPR) for Geotechnical and Volatiles Mapping*

### Sustainable Power

**Philip Lubin**
**University of California, Santa Barbara**
*Moonbeam-Beamed Lunar Power*

**Arthur Witulski**
**Vanderbilt University**
*Silicon Carbide Power Components for NASA Lunar Surface Applications*

**Jin Wang**
**Ohio State University**
*Flexible DC Energy Router Based on Energy Storage Integrated Circuit Breaker*

## Two New Space Technology Research Institutes:

### Joint Advanced Propulsion Institute (JANUS)

**Mitchell Walker, Georgia Institute of Technology**

The JANUS institute will develop strategies and specific methodologies to overcome limitations in ground testing of high-power EP systems and to improve characterization of the wear and performance of these devices representative of in-space operation.

Partnering universities: University of Michigan; University of California, Los Angeles; University of Illinois at Urbana-Champaign; Colorado State University; Pennsylvania State University; Stanford University; University of Colorado Boulder; Western Michigan University; Clark Atlanta University; Chicago State University; and City Colleges of Chicago. Other partners: The Aerospace Corporation, Aerojet Rocketdyne, and Busek.

### Advanced Computational Center for Entry System Simulation (ACCESS)

**Iain Boyd, University of Colorado Boulder**

The ACCESS institute will advance the analysis and design of NASA entry systems by developing a fully integrated, interdisciplinary simulation capability. ACCESS will focus on thermal protection systems as well as prediction of the extreme environments experienced during entry. It will develop game-changing capabilities using high-fidelity, validated physics models. This advancement will be enabled by innovative numerical algorithms, high-performance computing, and uncertainty quantification methods, with the goal of enabling computational entry system reliability assessments.

Partnering universities: University of Illinois at Urbana-Champaign; University of Minnesota; University of Kentucky, and University of New Mexico.

# STEM and Challenge Opportunities

PRIZES, CHALLENGES AND CROWDSOURCING

https://www.nasa.gov/solve/index.html

## NASA Tournament Labs

Lunar Delivery Challenge

Honey, I Shrunk the NASA Payload, The Sequel

Unmanned Aircraft Systems Ground Control Station Software Challenge Series

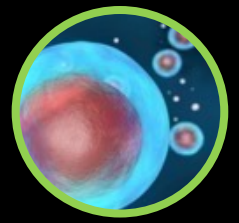
Water America's Crops Challenge

Future Competition: Flight Opportunities Flight Tests

## Current Centennial Challenges

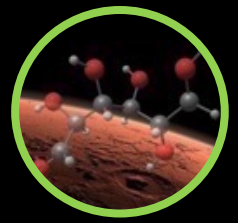
Cube Quest

$5,000,000



Vascular Tissue

$500,000



$CO_2$ Conversion

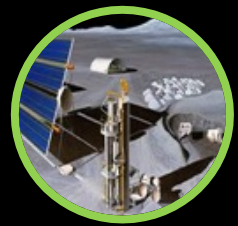
$1,000,000

Space Robotics

$1,900,000

Watts on the Moon

(Up to $5 M)



Break the Ice Lunar

(Up to $5 M)

Deep Space Food

(Up to $3 M)

ACTIVE

## Technology Maturation

BIG IDEA CHALLENGE

**Dust Mitigation Technologies for Lunar Applications**

http://bigidea.nianet.org/2021-challenge/

# NASA’s Watts on the Moon Challenge

- **NASA awarded $500,000 to seven winning teams in Phase 1 of the agency’s Watts on the Moon Challenge. The design competition, which opened in September 2020, invited American inventors to envision a next-generation lunar energy infrastructure. A flexible and robust system for surface power is key to safe and robust lunar exploration. Sixty teams submitted original concepts.**
- **Phase 2 of the challenge is planned to open in Fall 2021 with a $4.5 million demonstration competition, where participants must build working prototypes of their designs.**

# Tune In June 23rd….


NASA
EXPLORESPACE TECH
TECHNOLOGY DRIVES EXPLORATION