Space Technology Overview
STIGUR 2021 Summer Meeting

Mr. James Reuter | Associate Administrator, Space Technology Mission Directorate | 06.24.2021

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

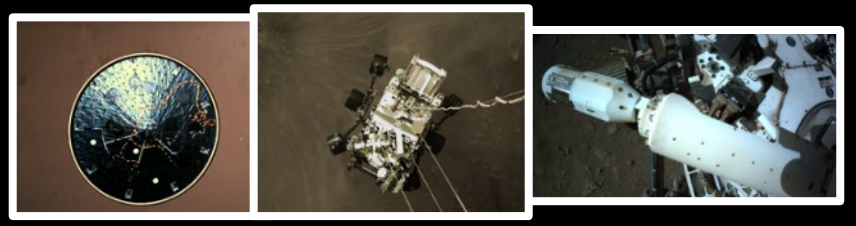
STMD FY 2021-2022 Highlights

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
Fall 2021
Launch

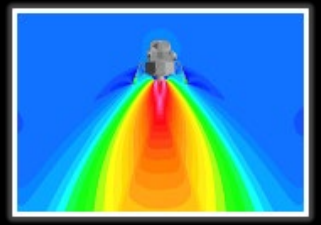
Flight Ops and Small Spacecrafts
40+ suborbital and small spacecraft flights planned 2021



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

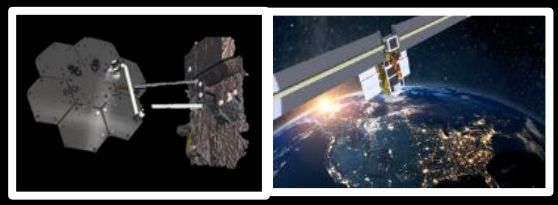
Cryo Fluid Management
April/May 2021
Initiate 4 Flight Demos

CAPSTONE/NRHO
Fall 2021
Launch

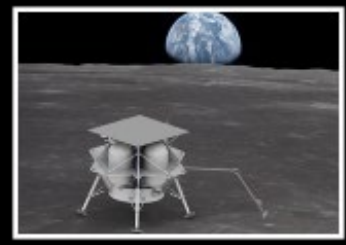


Plume Surface Interaction (PSI)
April 2021
Physics focused ground test

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**

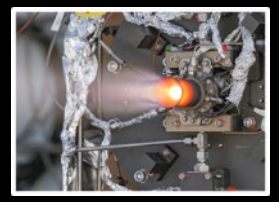


OSAM-1 and OSAM-2
Fall 2021
Critical Design Reviews



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

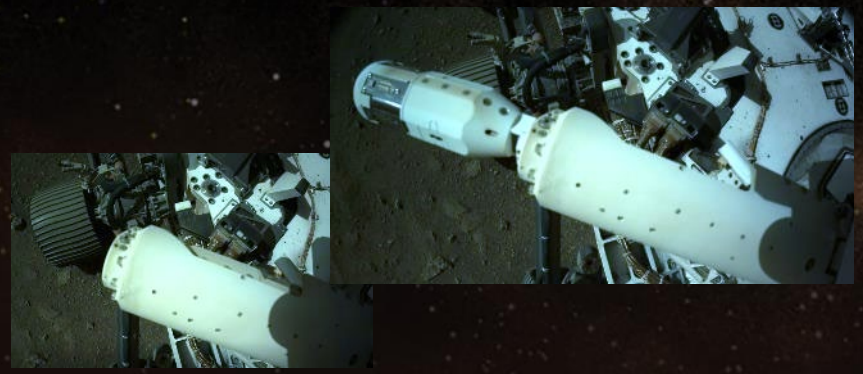
LOFTID
June 2022
Delivery to ULA

Deep Space Optical Comm
August 2022
Psyche Launch

Space Technology for Mars 2020 Perseverance

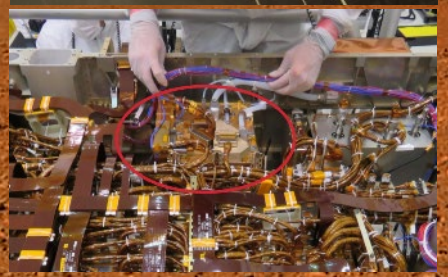
MEDA *(Mars Environmental Dynamics Analyzer)*

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

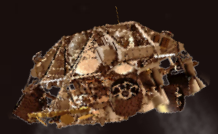


MOXIE *(Mars Oxygen In-Situ Resource Utilization Experiment)*

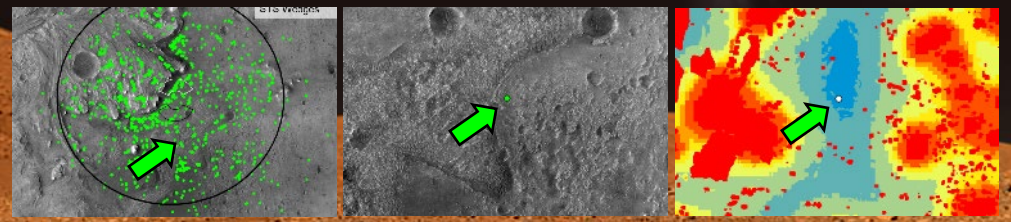
MOXIE will demonstrate a way that future explorers might produce oxygen from the Martian atmosphere for propellant and for breathing.

TRN *(Terrain Relative Navigation)*

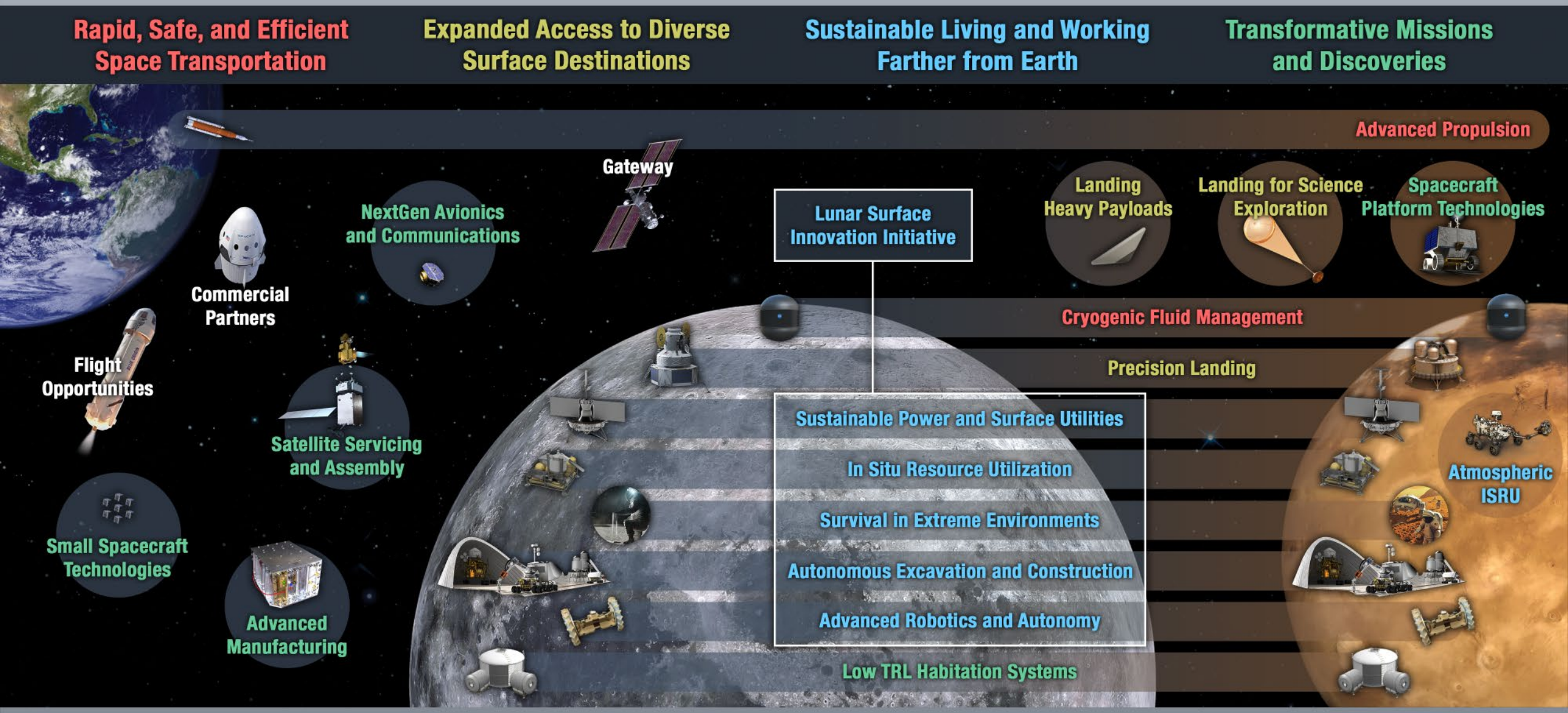
TRN gives a spacecraft the ability to autonomously avoid hazards we already know about and can land in more (and more interesting) landing sites with far less risk



Mars 2020 EDL Targeted Location



Ensuring American Global Leadership in Space Technology



Technology Drives the Space Economy

STMD FY 2022 Budget Summary

STMD FY 2022 Budget Summary ($M)	FY 2021 1,100.0	FY 2022 1,425.0	FY 2023 1,454.5	FY 2024 1,486.4	FY 2025 1,519.2	FY 2026 1,552.9
SBIR and STTR	**227.0**	**287.0**	**292.7**	**298.6**	**304.6**	**310.7**
Early Stage Innovation and Partnerships	**117.5**	**145.0**	**147.9**	**150.8**	**153.9**	**157.0**
Agency Technology and Innovation	**8.4**	**9.4**	**9.6**	**9.8**	**10.0**	**10.2**
Technology Transfer	**19.9**	**20.0**	**20.4**	**20.8**	**21.2**	**21.6**
Early Stage Innovation	**89.2**	**115.6**	**117.9**	**120.2**	**122.7**	**125.2**
Center Innovations Fund (CIF) / Early Career Initiative (ECI)	24.4	28.0	28.6	29.0	29.7	30.3
NASA Innovative Advanced Concepts (NIAC)	8.4	9.5	9.7	9.9	10.1	10.3
Space Technology Research Grants (STRG)	47.9	61.1	62.3	63.5	64.8	66.1
Prizes & Challenges (P&C)	8.6	17.0	17.3	17.7	18.0	18.4
Technology Maturation / Game Changing Development (GCD)	**227.1**	**491.2**	**501.0**	**511.1**	**521.3**	**531.7**
Rapid, Safe, & Efficient Space Transportation	11.0	44.0	33.8	26.6	12.0	12.0
Expanded Access to Diverse Surface Destinations	43.9	43.8	43.2	45.8	26.0	25.7
Sustainable Living and Working Farther from Earth	110.3	199.5	187.8	188.3	237.1	250.0
Transformative Missions and Discoveries	36.7	85.3	60.2	67.9	49.0	28.0
Industry & Commerce Innovation Opportunity	-	85.6	142.4	148.4	162.7	180.9
Tech Management & Integration	25.1	33.1	33.6	34.1	34.6	35.1
Technology Demonstration	**528.4**	**501.8**	**512.9**	**525.9**	**539.4**	**553.5**
Technology Demonstration Mission (TDM)	**461.2**	**430.6**	**440.3**	**451.9**	**463.9**	**476.5**
Cryogenic Fluid Management (CFM)	60.1	82.0	122.1	103.5	125.7	136.4
Space Nuclear Technologies (SNT)	57.9	34.0	34.1	87.2	186.7	258.3
OSAM-1 (Restore & SPIDER)	227.0	227.0	227.0	227.0	103.6	25.4
OSAM-2 (Archinaut)	17.7	16.1	16.5	-	-	-
Solar Electric Propulsion (SEP)	26.2	24.2	18.5	15.9	17.8	5.8
Low-Earth Orbit Flight Test of an Inflatable Dec (LOFTID)	20.4	13.0	2.4	-	-	-
Laser Comm Relay Demo (LCRD)	15.1	-	-	-	-	-
Deep Space Optical Comm (DSOC)	16.4	6.2	2.0	0.1	-	-
MOXIE, DSAC, TDM Management & Integration	20.5	28.1	17.8	18.2	30.1	50.6
Small Spacecraft Technology (SST)	**40.2**	**46.2**	**47.6**	**49.0**	**50.5**	**52.0**
Flight Opportunities (FO)	**27.0**	**25.0**	**25.0**	**25.0**	**25.0**	**25.0**

Lunar Surface Innovation Initiative

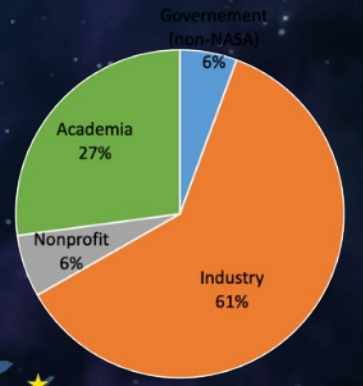
Since inception, LSII has engaged ~400 organizations across 48 states and Puerto Rico to advance the technologies needed to explore the lunar surface and stimulate economic development

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)

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

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

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

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

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

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

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

APL LSII Integration and Lunar Surface Innovation Consortium

Note: FY20-21 Awards

Lunar Surface Technology Demonstration Planning

LSII leverages early lunar missions to accelerate development of core surface technologies

2020 → 2030

ISRU
- Polar Resources Ice Mining Experiment (PRIME)
- Volatiles Investigating Polar Exploration Rover (VIPER/SMD)
- ISRU Ice-Mining Demo
- ISRU Oxygen Extraction Demo
- ISRU Processing Demo
- ISRU Pilot Plant

Surface Power
- Regenerative Fuel Cell Power
- Wireless Charging for Lunar Surface Demo
- Vertical Solar Array Technology (VSAT)
- Chemical Heat Integrated Power Source (CHIPS)
- Fission Surface Power Demo

Dust Mitigation
- Electrodynamic Dust Shield
- Lunar Dust Level Sensor & Affects on Radiators
- Lunar Dust Smart Sensor for Crewed Environments
- Lunar Dust Removal Tool
- Lunar Dust Separation

Extreme Environments
- Lunar Arm w/ Bulk Metallic Glass Gears
- Lunar Materials Demo
- Lunar Camera
- Lunar Thermal Toolbox
- Lunar Night Material Survivability

Extreme Access
- Surface Robotic Scouts
- *Tipping Point Early Hopper CLPS Opportunity*
- Lunar Navigation Demo
- Video Guidance System
- Day/Night Lunar Rover Obstacle Avoidance
- Autonomous Robotics
- Deployable Hopper
- Autonomous Exploration of Lunar Pits

Excavation & Construction
- ISRU Pilot Excavator
- Lunar Surface Construction Demo 1
- Lunar Surface Construction Demo (Landing Pad)

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

OPPORTUNITIES TO ACCESS SUBORBITAL FLIGHT TESTS

➢ NASA TECHLEAP PRIZE

- Technology developers will compete for development funding and have access to a suborbital flight opportunity by addressing a current NASA technology need
- Competition launching June 2021, with applications due August 2021

➢ NASA TECH FLIGHTS

- Awardees receive a grant or cooperative agreement allowing them to purchase flights directly from any viable U.S. commercial flight vendor that best meets their needs
- Next solicitation release planned for early-summer 2021

➢ SBIR AND NASA INTERNAL R&D

- Rolling opportunities for small business with existing SBIR awards to receive additional funding to support suborbital flight testing with U.S. commercial providers
- Open call for NASA funded research to request support for suborbital flight testing with U.S. commercial providers

➢ NASA TECHRISE STUDENT CHALLENGE

- Students in grades 6-12 will propose technologies to be developed and flown on suborbital vehicles
- Teams from public or private schools in U.S. states/territories (including schools operated by the U.S. for American personnel overseas) are eligible
- Competition launching late-May 2021, with application period open August – November 2021
- Winning technologies will be flown in the first half of 2023

UPCOMING FLIGHT OPPORTUNITIES HIGHLIGHTS

➢ INVESTMENTS TO EXPAND COMMERCIAL SUBORBITAL TESTING CAPABILITIES

- **Partnership With Blue Origin To Enable Testing In Lunar Gravity Conditions**
  Blue Origin's New Shepard rocket system will use its reaction control system to rotate the capsule, resulting in two minutes of continuous lunar gravity, exposing the technologies to this challenging but difficult-to-test condition

  New capability is made possible with the help of development funding and early purchase of payload space by NASA as part of its strategic investment in the U.S. spaceflight industry

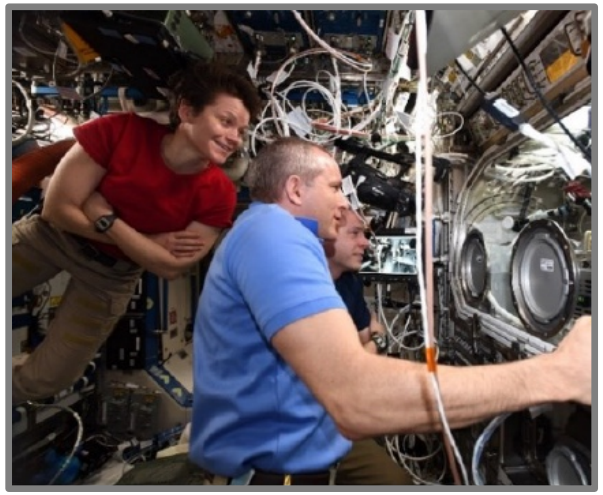
- **Public Private Partnership with Masten Space Systems for EDL Testbed**
  Tipping Point award for a vertical take-off, vertical landing vehicle that expands test capabilities for precision landing on the moon, Mars, and Earth

- **Collaboration with Rocket Lab USA for Reentry Testing**
  ACO award to explore first stage re-entry, which also has the potential to provide access to high-speed, high-temperature re-entry environments for technology testing

➢ SUPPORT FOR LEO COMMERCIALIZATION

Suborbital Testing of Advanced Space Manufacturing

- Two companies receiving NASA funding for ZBLAN technology development are leveraging suborbital flight tests for technology advancement prior to demonstrations on the International Space Station
- In-space manufacturing can reduce operational costs and improve on-site repair capabilities as well as offer production capabilities not achievable by ground-based systems



SMALL SPACECRAFT TECHNOLOGY

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.

20 Missions (27 Spacecraft Total) planned 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)

Key technologies in current demonstrations include:

- **10+** Propulsion Systems
  (HYDROS-C, TILE, ACS3, Lunar Flashlight, CAPSTONE, Lunar Photon, Courier SEP, DUPLEX, PACE 2, 3 & 4)
- **4** Orbital Cross Links
  (V-R3x, CLICK B/C, CAPSTONE, Starling)
- **3** Debris Mitigation Sys. (SSA / Deorbit / Avoidance)
  (Starling 1.5, PACE-2,3,4)
- **3** PN&T / GNC Systems
  (HyperXACT, X-NAV, CAPSTONE)
- **2** Optical Comm. Systems
  (CLICK A & B/C, TBIRD)
- **2** Distributed / Autonomous Systems
  (V-R3x & Starling / Starling1.5)
- **2** Advanced Structures
  (ACS3, LISA-T)
- **1** Advanced Power System
  (LISA-T)
- **1** RPOD
  (CPOD)

Photo: PACE-1 Spacecraft

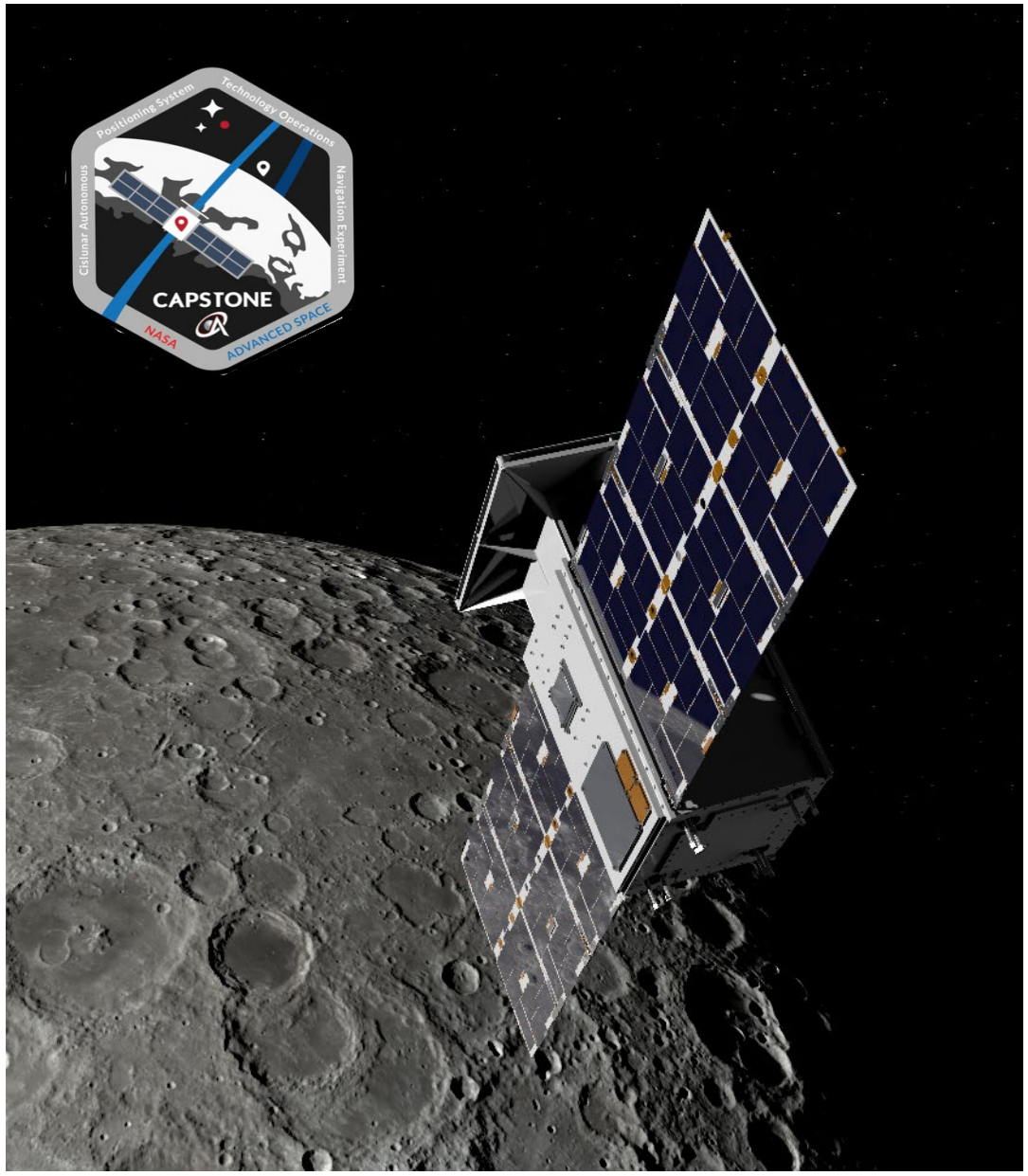
CAPSTONE OVERVIEW & SCHEDULE

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*

PRIZES, CHALLENGES AND CROWDSOURCING

Our prizes, challenges, and crowdsourcing program advances NASA's mission and enhances connections with the public through open innovation tools and approaches.

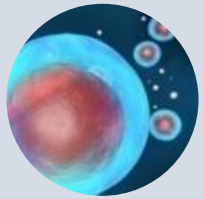
The FY 2022 budget request proposes approximately $8 million in new prize authority and additional awards to support multi-year challenges. This will continue the phase II prizes for *Break the Ice Lunar Challenge* and *the Deep Space Food Challenge* in addition to new activities related to climate and clean energy economy.

Public Competitions in FY21 and FY22 – some highlights:

Watts on the Moon
Phase 1 Awarded: May 20, 2021
Phase 1 Prize: $500K
Phase 2 Opens: NET Q1 FY22

Break the Ice Lunar
Phase 1 Closes: June 18, 2021
Phase 1 Prize: $500K
Phase 2 Opens: NET Q1 FY22

CO_2 Conversion
Phase 2 Target Award: June 29, 2021
Phase 2 Prize: $750,000



Vascular Tissue
Target Award: June 2021
Prize: $500,000

Deep Space Food
Phase 1 Closes: July 30, 2021
Phase 1 Prize: $500K
Phase 2 Opens: NET Q2 FY22

Space Robotics
Phase 2 Closes: July 23, 2021
Phase 2 Prize: $1M

CubeQuest
Closes: 1 year after 1st SLS launch
Prize: $4.5M

NASA TechLeap Prize and TechRise Student Challenge
Open: June 2021
TechRise Prize: $85k and Flight Opportunities
TechLeap Prize: $2M

Crowdsourcing Contenders
Award Date: June 2021
Prize: $600,000 to support ~12 NASA crowdsourcing projects
Challenges open: NET Q4 FY21

Future-Scaping Our Skies
Award Date: July 28, 2021
Award: $21,000

Honey, I Shrunk the Payload
Closes: January 28, 2022
Award: $800K

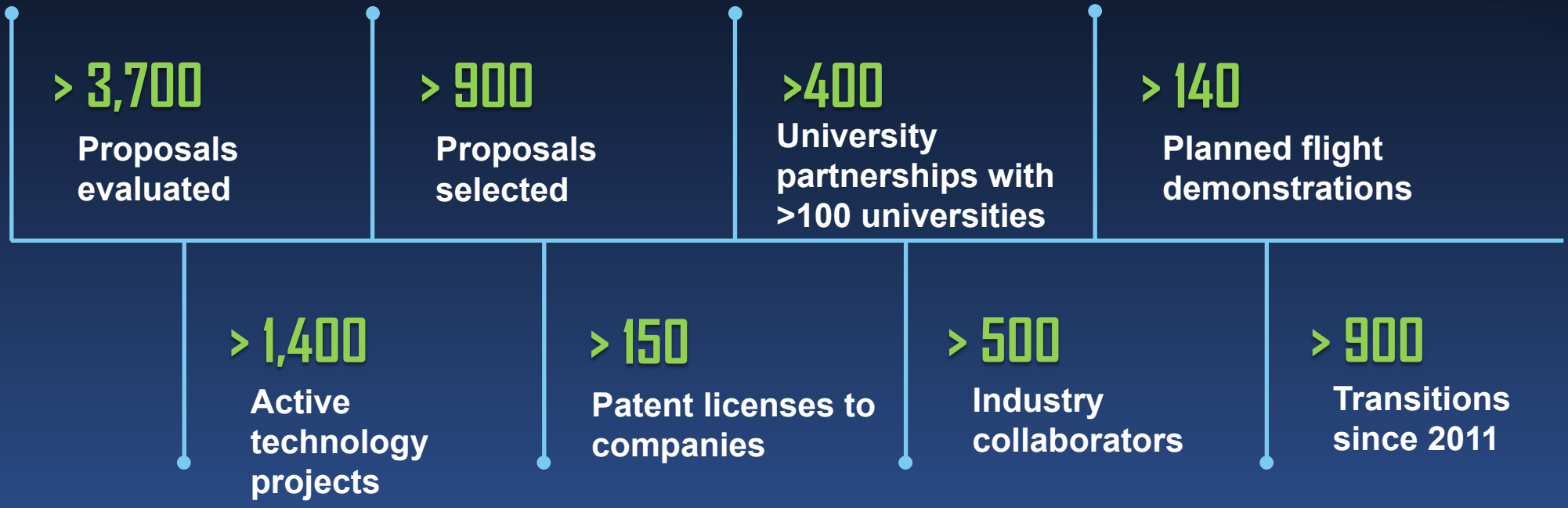
Centennial Challenges

NASA Tournament Lab

Diversity, Equity, and Inclusion through Space Technology

- **Partner with STEM Engagement's Minority University Research and Education Project (MUREP)** to engage and support Minority Serving Institutions (MSIs), including Historically Black Colleges & Universities (HBCUs), and to reach students from underserved and underrepresented communities.
  - **MUREP Space Technology Artemis Research (M-STAR)** aims to strengthen and develop the research capacity and infrastructure at MSIs in alignment with STMD's priorities and to promote MSI participation in STMD opportunities and programs. The 2021 M-STAR grants offer up to $250,000 per year for a two-year performance period to MSIs.
  - **MUREP Small Business Technology Transfer (M-STTR)** utilizes planning grants to incentivize partnerships between MSIs and Small Businesses, enhancing the potential and preparing teams to participate in the annual SBIR/STTR solicitation.
  - For the **2022 BIG Idea Challenge**, STMD is working with MUREP as well as Space Grant to increase access and representation through targeted outreach to MSIs, including HBCUs, and pre-proposal resources. With nearly $1M in available funding annually, BIG Idea Challenge offers the most money to student teams of any Artemis Student Challenge.
  - **MUREP Innovation & Tech Transfer Idea Competition (MITTIC)** is a higher education spinoff challenge established to develop new ideas for commercialization by seeking concept papers from multi-disciplinary student teams enrolled at MSIs. MITTIC is currently midway through it's second cycle.
- The SBIR/STTR program increased participation of HBCUs and MSIs by launching two pilot initiatives that work directly with HBCU and the MSI STEM Research and Development Consortium to increase involvement of HBCUs and MSIs in federal research.
- Collaborated with OSBP, OSTEM, and Science Mission Directorate (SMD) in an annual "Technology Infusion Road Tour" to reach HBCUs and MSIs and share information about how to participate in NASA research opportunities.
- Early Stage Innovation and Partnerships will also place additional emphasis on increasing participation by underserved communities, as well as individuals from those communities.

STMD BY THE NUMBERS (FY 2020)




NASA
EXPLORESPACE TECH
TECHNOLOGY DRIVES EXPLORATION