



EXPLORESPACE TECH



Space Technology Mission Directorate Innovation and Opportunity Conference 2019

Mr. Walt Engelund Deputy Associate Administrator for Programs | November 2019

NASA IS...



The Artemis Program

Artemis is the twin sister of Apollo and goddess of the Moon in Greek mythology. Now, she personifies our path to the Moon as the name of NASA's program to return astronauts to the lunar surface by 2024.

When they land, Artemis astronauts will step foot where no human has ever been before: the Moon's South Pole.

With the horizon goal of sending humans to Mars, Artemis begins the next era of exploration.



Artemis Phase 1: Path to the Lunar Surface



2020

2024



Moon Before Mars

On the Moon, we can take reasonable risks while astronauts are just three days away from home.

There we will prove technologies and mature systems necessary to live and work on another world before embarking on what could be a 2-3 year mission to Mars.

Space Technology Mission Directorate (STMD) Strategic Investments

Exploration



Boots on the Moon by 2024
Lunar Sustainability by 2028
Mars Forward

Commerce



Investing in the
Growing Space Economy

STMD Mission and Guiding Principles



Space Technology develops critical technologies to enable:

- A sustainable Lunar surface presence,
- The future goal of sending humans to Mars, and
- Critical technologies to enable future science and commercial missions.

We accomplish this mission by:

- Funding critical technology gaps
- Keeping NASA's space technology pipeline growing with emerging, innovative technologies that promise to drive the future of exploration, science and commercialization.

- ✓ Spark Innovation
- ✓ Engage The Brightest Minds
- ✓ Enable Exploration and Discovery
- ✓ Embrace Competition and Public-Private Partnerships
- ✓ Invest in America



Key Technology Focus Areas

- ❖ Advanced environmental control and life support systems and In-Situ Resource Utilization
- ❖ Power and propulsion technologies
- ❖ Advanced communications, navigation and avionics
- ❖ In-space manufacturing and on-orbit assembly
- ❖ Advanced materials
- ❖ Entry, Descent and Landing
- ❖ Autonomous operations
- ❖ Enable humans to safely and effectively operate in various space environments



Early Stage Innovation

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

SBIR/STTR

Partnerships & Technology Transfer

- Technology Transfer
- Prizes and Challenges
- iTech

Technology Demonstrations

- Technology Demonstration Missions
- Small Spacecraft Technology
- Flight Opportunities



TECHNOLOGY PIPELINE

Technology Drives Exploration

GO

Rapid, Safe, and Efficient
Space Transportation

LAND

Expanded Access to Diverse
Surface Destinations

LIVE

Sustainable Living and Working
Farther from Earth

EXPLORE

Transformative Missions
and Discoveries



2020

203X

Go

Rapid, Safe, & Efficient Space Transportation



Solar Electric Propulsion



Nuclear Thermal Propulsion Technologies



Thruster Advancement for Low-temperature Operations in Space

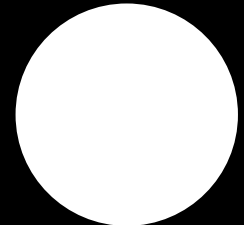
Cryogenic Fluid Management



Green Propellant Infusion Mission



Rapid Analysis and Manufacturing Propulsion Technology



- Reusable transportation between the Earth and Moon
- Reusable transportation between the Earth and Mars
- Rapid and efficient transportation through the solar system



Land

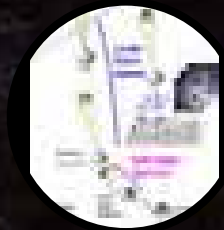
Expanded Access to Diverse Surface Destinations



Navigation
Doppler LIDAR



Mars EDL



Terrain Relative
Navigation



Low-Earth Orbit Flight
Test of an Inflatable
Decelerator



SPLICE

- Routinely landing crew and cargo on the Moon
- Safely and efficiently returning large payloads to Earth
- Delivering robotic payloads to challenging new destinations
- Routinely landing crew and cargo on Mars

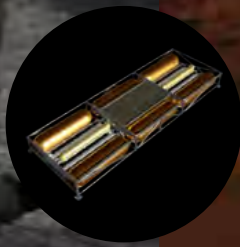
Live

Sustainable Living and Working Farther from Earth

In Space Manufacturing

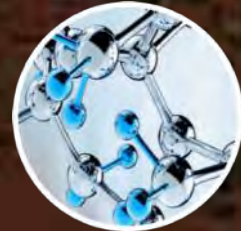


Regenerative Fuel Cells



Astrobee

Surface Power



Synthetic Biology

ISRU



Integrated Systems for Autonomous Adaptive Caretaking

- Routine crewed operations beyond low-Earth orbit
- Sustainable human presence on the Moon
- Producing propellant & consumables from local resources
- Sustainable human presence on Mars

Note: Mid TRL and High TRL Technology Development for Life Support and EVA suits are HEOMD Responsibility

Explore

Transformative Missions and Discoveries

- Reach challenging sites and resources on the Moon
- Survive and operate through the lunar night
- Reach challenging sites and resources on Mars and beyond

Laser and Optical Communications



Small Spacecraft Demos

SPIDER



Atomic Clock

Archinaut



Bulk Metallic Glass Gears



Surface Robotic Scouts

Engaging Academia and Emerging Industries



SBIR/STTR engages small businesses



Centennial Challenges



Public Private Partnerships (Tipping Point and ACO solicitations)



Technology Transfer

Flight Opportunities

NASA iTech



Early Stage Innovation



Public-Private Partnerships: Tipping Point Technologies

- **Tipping Point:**
 - Increased focus on **collaboration** with the commercial space sector
 - Fixed price contracts with milestone payments
 - Requires a **minimum 25 percent contribution (10% for small businesses)** from corporation or customer
 - Leverage emerging marks and capabilities to meet NASA's strategic goals AND focus on **industry needs**
 - **Increase likelihood of infusion** into a commercial space application
 - Substantial benefit to both **commercial and government sectors**
- **Tipping Point Awards:**
 - **2016 – 9 Awards**
 - **2017 – 6 Awards**
 - **2018 – 6 Awards**
 - **2019 – 14 Awards**
- Next Opportunity – Utilizing Public-Private Partnerships to Advance Tipping Point Technologies released January 2020 (target)
- Space Tech Solicitations: <https://go.usa.gov/xQRwV>

NASA anticipates releasing Tipping Point with targeted topics every year

Public-Private Partnerships: Announcement of Collaborative Opportunity (ACO)

- **Announcement of Collaborative Opportunity (ACO):**
 - Focus on industry-developed space technologies that can advance the commercial space sector and benefit future NASA missions
 - NASA provides technical expertise and test facilities, as well as hardware and software to aid industry partners in maturing technologies
 - Non-Reimbursable Space Act Agreements (no funds exchanged)
- **ACO Awards:**
 - 2015- 13 awards
 - 2017- 10 awards
 - 2019- 19 awards
- **ACO2020:**
 - Release date: January 2020 (target)
 - 6-10 awards are anticipated
 - NASA expects to select projects worth a combined total of up to \$10 million to U.S. industry
- Space Tech Solicitations: <https://go.usa.gov/xQRwV>

NASA anticipates releasing ACO every year

Goal: Stimulate research and technology solutions to support NASA missions and inspire new national aerospace capabilities through public prize competitions.



Cube Quest
\$5,000,000

Flight-qualified CubeSats near and beyond the moon

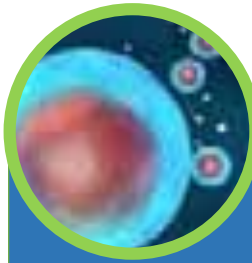
- \$460K awarded
- 15 US Teams
- Innovative propulsion and communication
- 3 payload slots on SLS EM-1
- NASA-led Challenge



3D-Printed Habitat
\$3,150,000

Additive construction technology for space

- \$2.060 M awarded
- 60 teams participated
- Collaboration with Bradley University, Caterpillar Inc., Bechtel Corp, Brick and Mortar Ventures



Vascular Tissue
\$500,000

Viable thick tissue for research

- 12 U.S. teams currently registered
- Innovation in engineered tissue that can stay viable for more than 30 days
- Collaboration with New Organ Alliance



Space Robotics
\$900,000

Advance robotics software for full autonomous operations

- \$570K awarded in Phase 1; 92 teams
- Phase 2 opened Aug 12, 2019
- Collaboration with Space Center Houston



CO₂ Conversion
\$1,000,000

Bio-manufacturing from in-situ resources

- Enable biomanufacturing of products in space
- Phase 1 awarded \$250K; Phase 2 opening this month
- NASA-led Challenge; HEOMD and STMD collaboration

Plans for FY20-21

- Prioritize challenge topics to align with NASA's Exploration Campaign objectives
- Contributing to LSII, NASA is in the process of formulating additional challenges, to include In Situ Resource Utilization production prize competition targeting a large scale, end-to-end, system; and a portable energy storage challenge to enable powering a rover through several cycles of lunar daylight and darkness.
- Cube Quest, Vascular Tissue, CO₂ Conversion, and Space Robotics will remain active in FY20.



3DPH P3 Level 1 Winner: Zopherus

FY 2019-2020 Plans

MOXIE

March 2019 delivery to Mars 2020 for
July 2020 Launch



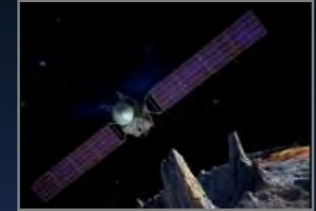
Terrain Relative Navigation

November 2018
Delivery for integration on Mars 2020



Laser Comm Relay Demo

October 2019
Payload delivery for bus integration



Deep Space Optical Comm

June 2019 KDP-C for the flight terminal



MEDLI2

November 2019
Hardware Delivery for integration on Mars 2020 entry system



Astrobee

August 2019
Three free-fliers onboard ISS for demonstration

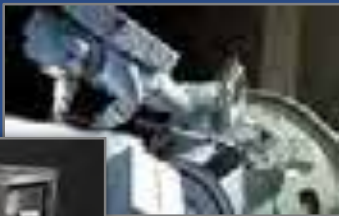


In Space Robotic Manufacturing and Assembly project

July 2019 Awarded Made in Space Archinaut mission to manufacture and assemble spacecraft components in LEO. Maxar award likely in Sept.

High Performance Spaceflight Computing (HPSC)

FY 2020
Completion of critical design



Refabricator Delivery and Installation aboard ISS February 2019

The first integrated recycler and 3D printer was successfully installed



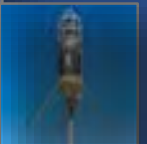
Restore-L

April 2019
Spacecraft critical design review
February 2020
Mission CDR



SPLICE

October 2019
Complete NDLE environmental testing; 2020 flight test



Flight Opportunities Campaigns

FY 2019-2020 Plans



eCryo
April 2020
 SHIVER Testing Complete



Deployable Composite Boom
November 2019
 Manufactured boom and deployment system will be demonstrated early 2020



DSAC & GPIM
June 2019
 Launched Aboard STP-2



LOFTID
June 2019
 KDP-C
April 2020
 CDR



Extreme Environment Solar Power
July 2019

Developing solar cell concentrator technology for low-intensity, low-temperature space power applications. Hardware will be demonstrated for subsequent technology demonstration on SMD's future mission DART



New Space Technology Research Institutes

To advance space habitat designs using resilient and autonomous systems, NASA selected Habitats Optimized for Missions of Exploration (HOME)-Univ of Calif; and Resilient ExtraTerrestrial Habitats institute (RETHi)-Purdue Univ



Nuclear Thermal Propulsion
October 2019
 Feasibility and risk assessment study of nuclear thermal propulsion



SpaceCraft Oxygen Recovery (SCOR)
June 2020
 Performance test results of two advanced oxygen recovery systems will be available in June 2020 for baseline comparison of capability

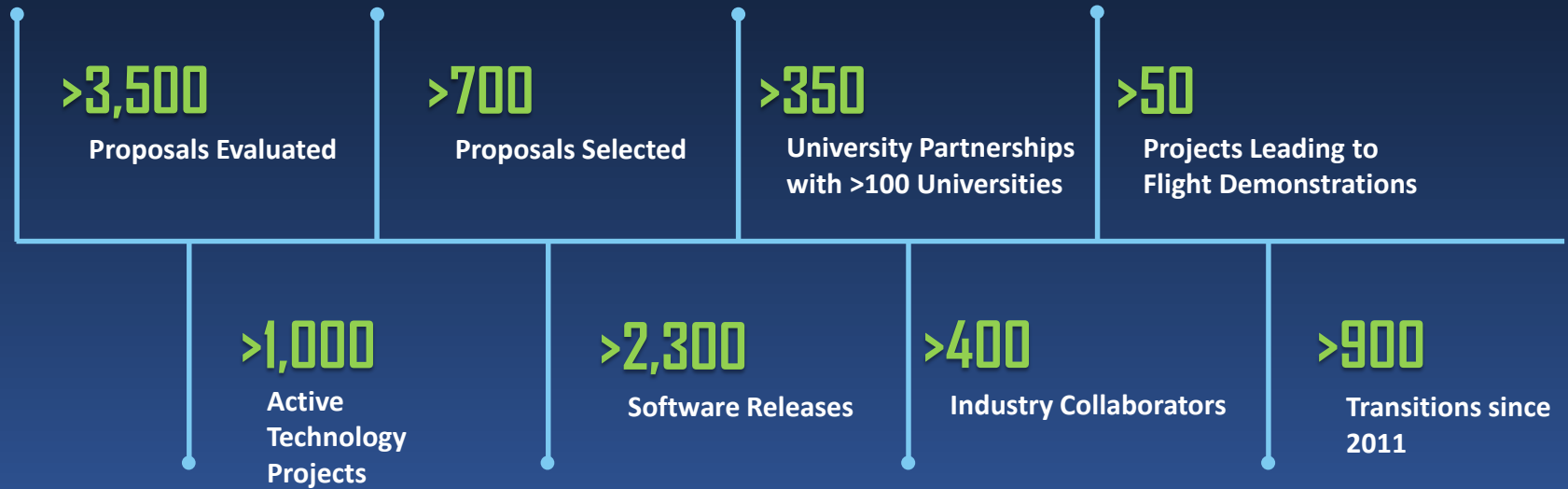


Solar Electric Propulsion
June 2019 KDP-C
FY19: Develop and test EDU/ETU/qualification hardware
FY20: Complete Critical Design Review, build qualification units and begin testing

Composite Technology for Exploration
September 2019
 Complete testing of composite joint technology that will reduce launch dry mass



STMD by the Numbers (FY 2019)



Sampling of Industry and OGA Participants in Exploration Technology





EXPLORESPACE TECH

TECHNOLOGY DRIVES EXPLORATION

