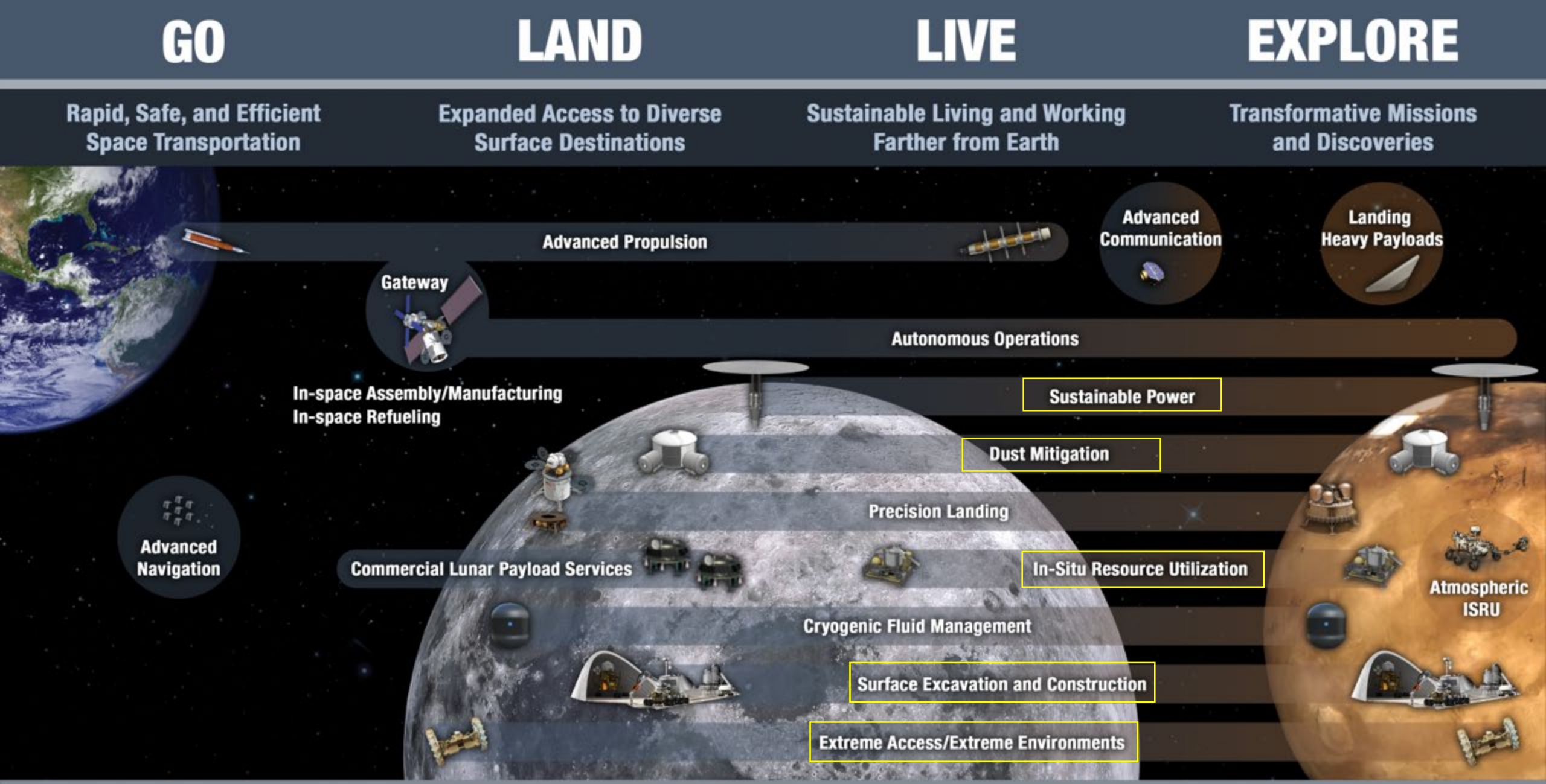
National Aeronautics and Space Administration

Lunar Surface Innovation Initiative (LSII) Status

NAC Technology, Innovation and Engineering Committee Meeting

Niki Werkheiser, NASA STMD, LSII Lead | March 2020



Lunar Surface Innovation Initiative (LSII)

Lunar Surface Innovation Initiative (LSII)

Aims to spur the creation of novel technologies needed for lunar surface exploration and accelerate the technology readiness of key systems and components. The LSII activities will be implemented through a combination of unique in-house activities, competitive programs, and public-private partnerships.

LSII Roles and Responsibilities Include:

- Ensuring that there is an ambitious, cohesive, executable Agency strategy for development and deployment of the technologies required for successful lunar surface exploration.
- Integrating a broad spectrum of stakeholders to develop an acquisition strategy which efficiently facilitates robust collaborations and partnerships with industry and academia.
- Addressing planning, implementation, and budget needs to enable lunar surface activities across the Space Technology Mission Directorate (STMD) Programs.
- Collaborating with Agency stakeholders (across Mission Directorates, NASA Centers, etc.), as well as Other Government Agencies (OGAs), universities, industry, and international partners in order to better align the Agency's investments relative to lunar surface demonstrations.

Lunar Surface Innovation Initiative (LSII)

STMD develops and performs demonstrations that allow the primary technology hurdles to be retired for a given capability at a relevant scale. While there may be additional engineering development required for scale-up, there should be none required for the foundational technologies.

In Situ Resource Utilization

Collection, processing, storing and use of material found or manufactured on other astronomical objects

Surface Power

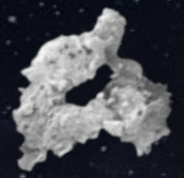
Enable continuous power throughout lunar day and night

Extreme Access

Access, navigate, and explore surface/subsurface areas

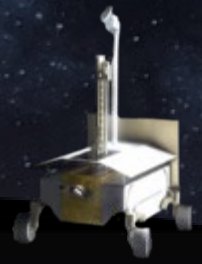
Surface Excavation & Construction

Enable affordable autonomous manufacturing or construction



Lunar Dust Mitigation

Mitigate lunar dust hazards

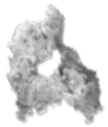


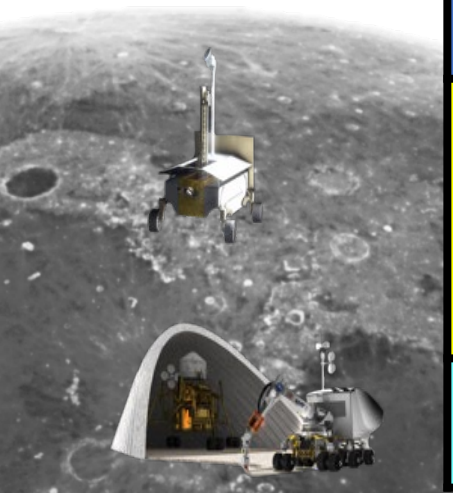
Extreme Environments

Enable systems to operate through out the full range of lunar surface conditions

- **Accelerate technology readiness for key lunar infrastructure capabilities enabling technology demonstrations for early un-crewed commercial missions, as well as informing development of crewed flight systems.**
- **Implement through a combination of in-house activities, competitive programs, and public-private partnerships.**
- **Coordinate with NASA's Science Mission Directorate and Human Exploration and Operations Mission Directorate to identify priorities.**

Examples of LSII Demonstrations





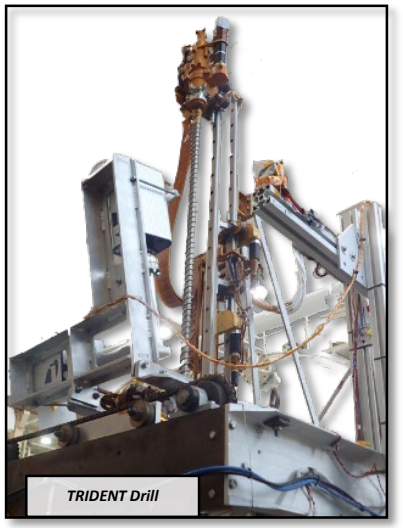
Capability Area	Activity	Flight Demo Timeline
ISRU	Polar Ice to Water Demonstration (includes Polar Resources Ice-mining Experiment -1)	CLPS FY22 (PRIME); FY24-26
	Regolith Extraction Processes & Technologies (O2 extraction, Ionic Liquids, Electrolyzer, Reactor)	FY20-23 Ground Dev; Flight FY24+
	Pilot ISRU Consumable Production Systems	FY28+
Surface Power		
	Regenerative Fuel Cell/PV Power	FY26+
	Chem Heat Int Power Source	FY24+
	Wireless Charging for Lunar Surface	FY26+
	Surface Power System Demonstrations	FY26+
Dust Mitigation	Lunar Dust Mitigation Demonstrations (Materials, Mitigation technologies, etc.)	FY22+
Extreme Environments	COLDArm	FY22/23
	Lunar Exposure Platform (Lunar MISSE)	FY22+
	Lunar Night and Material Survivability	FY22+
	Planetary & Lunar Environment Thermal Toolbox	FY23+
	Bulk Metallic Glass (BMG) for Rovers	FY23+
	Extreme Environments System Demonstration(s)	FY26+
Extreme Access	Surface Robotic Scouts Technology Demonstrations	FY24+
	Advanced Materials for Surface Suits	FY25+
	Technologies Enabling Exploration of Lunar Pits	FY24+
	Smart Video Guidance Center	FY22+
	Day/Night Lunar Rover Obstacle Avoidance	FY24+
	Lunar Surface Mobility Systems Demonstration(s)	FY26+
Excavation & Construction	Robotic Excavation on Lunar Surface (Centennial Challenge)	FY19-21
	Lunar Surface Excavation Development & Demo	FY22+
	Lunar Surface Construction Development & Demo	FY27+

In-Situ Resource Utilization

STMD is developing technologies for the collection, processing, storing and use of material found or manufactured on other astronomical objects

Technology Developments Underway:

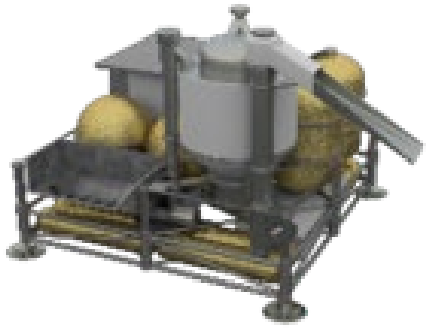
- Various TRL Maturation activities
- Polar Resources Ice Mining Experiment (PRIME-1) - CLPS
- Volatiles Investigating Polar Exploration Rover (VIPER) – SMD/CLPS
- Oxygen Extraction from Regolith technology development
- High fidelity simulant supply chain assessment - APL

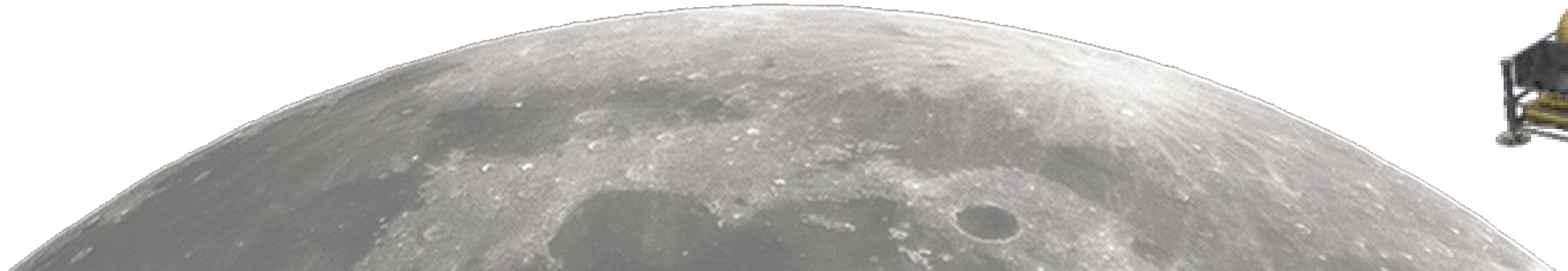


Two commercial versions of MSolo (Open Ion and Cross-Beam sensor configurations) in test configuration

Additional Investments:

- ISRU pilot plant demonstrations
- Demonstrate systems for collecting and purifying water on the lunar surface, capable of scaling to tens of metric tons per month, operating with little to no human involvement.
- Methods for size sorting granular lunar regolith.
- Methods for measuring mineral properties/oxygen content before and after processing



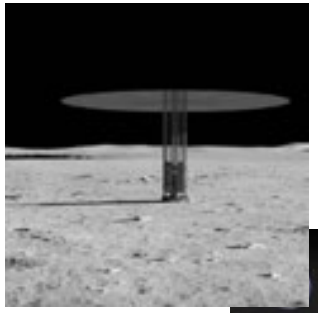


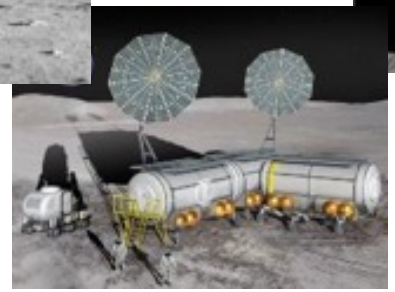
Surface Power

STMD is developing technologies which can provide the capability for continuous power throughout day and night for Lunar Surface missions

Technology Developments Underway:

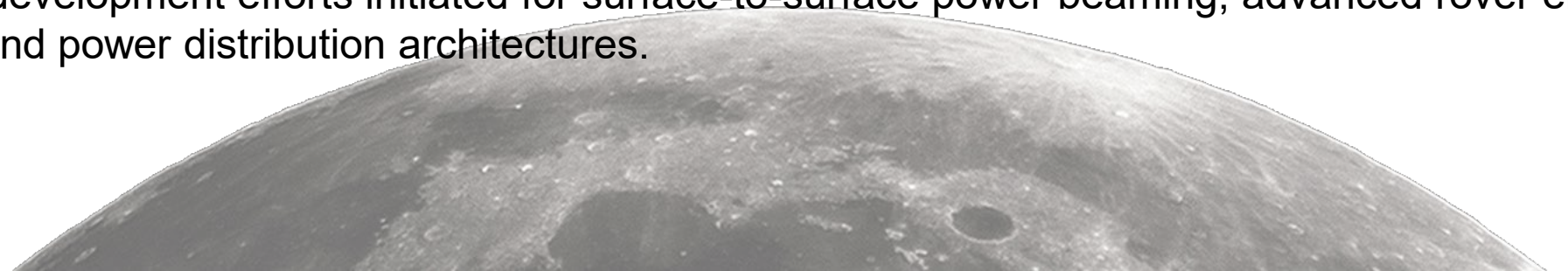
- Power Generation
  - Fission Surface Power
  - Adaptable Lunar Lander Solar Array Systems
  - Chemical Heat Integrated Power Source (CHIPS)
- Regenerative Fuel cell (RFC) for Energy Storage
- Surface Power Centennial Challenge – Coming Soon!





Additional Investments:

- Conducting a phased, system level assessment of power architecture for lunar surface missions
- Primary Fuel Cell Technology Tipping Point to demonstrate fuel cell element on early lander using propellant-grade hydrogen and oxygen reactants to extend the lander surface mission duration
- Technology development efforts initiated for surface-to-surface power beaming, advanced rover energy storage technology and power distribution architectures.



Dust Mitigation

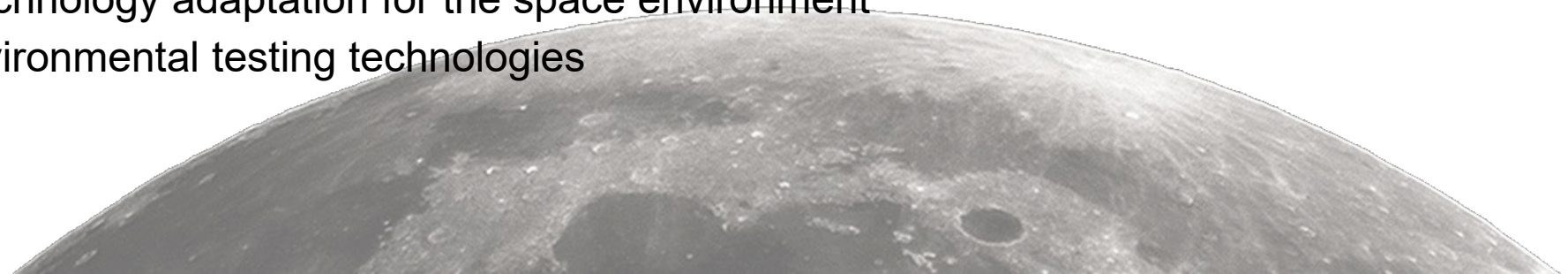
STMD is developing technologies to mitigate lunar dust hazards

Technology Developments Underway:

- Patch Plate Materials Compatibility
- Electrodynamic Dust Shield
- Dust Tolerant Mechanisms
- Nanomaterials and Coatings
- Lunar Dust Mitigation Best Practices
- yet2 Market Analysis
- 2020 SBIR Topic includes
    - Optical systems, thermal surfaces, fabrics, seals and soft goods, mechanisms

Additional Investments:

- High priority areas: surface stabilization, dust tolerant textiles, filtration, electromechanical and magnetics, and dust mitigation structures
- Terrestrial technology adaptation for the space environment
- Maturing environmental testing technologies

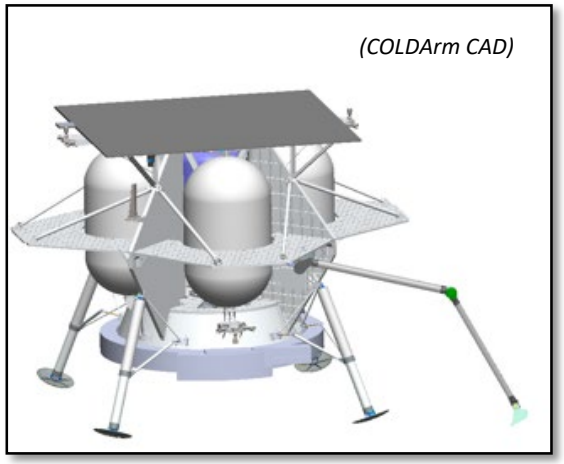


Extreme Environments

STMD is developing technologies that enable systems to operate through out the full range of lunar surface conditions

Technology Developments Underway:

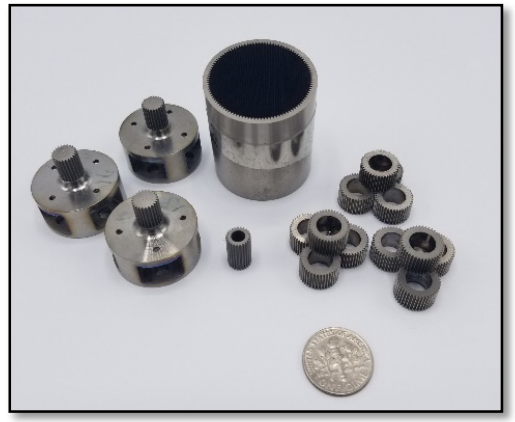
- Bulk Metallic Glass Gears
- Cold Operable Lunar Deployable Arm (COLD Arm) - CLPS
- Planet and Lunar Environment Thermal Toolbox Elements (PALETTE) which includes radiators, insulators, thermal isolators and switches, etc.
- Shape Memory Alloys for Regulating Thermal Control Systems
- yet2 Market Analysis - Materials



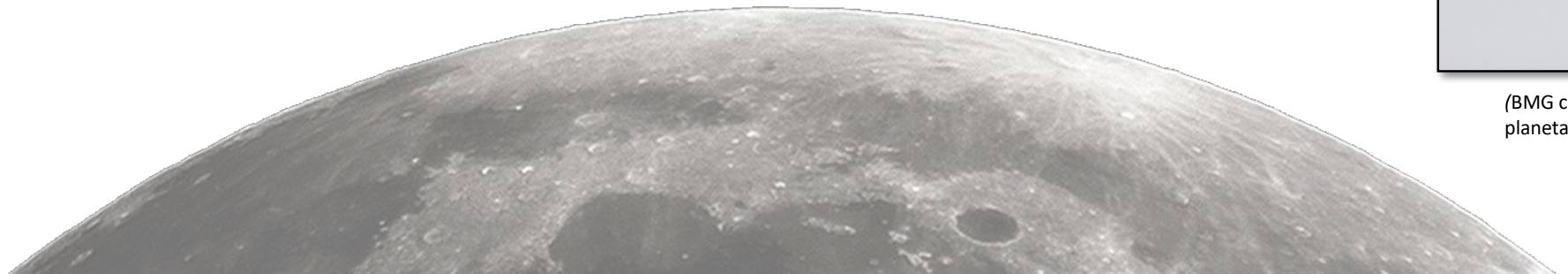
(COLDArm CAD)

Additional Investments

- Enable rovers, manipulators, and other systems to operate on the lunar surface with conditions including lunar noon (up to 150 ℃), night (down to - 180 ℃), multiple day/night cycles, and permanently shadowed regions (down to -240 ℃).
- Generate and publish an External Environment User's Guide.



(BMG components in BMG 3-stage planetary gearbox assembly)



Extreme Access

STMD is developing technologies enabling humans or robotic systems to efficiently access, navigate, and explore previously inaccessible lunar or planetary surface or subsurface areas.

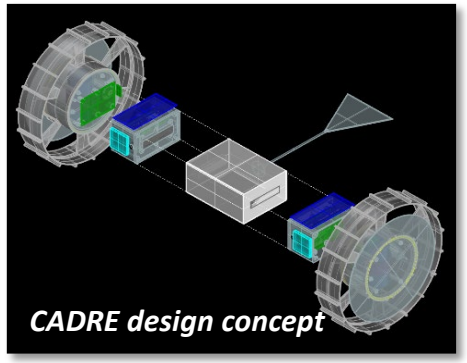
Technology Developments Underway:

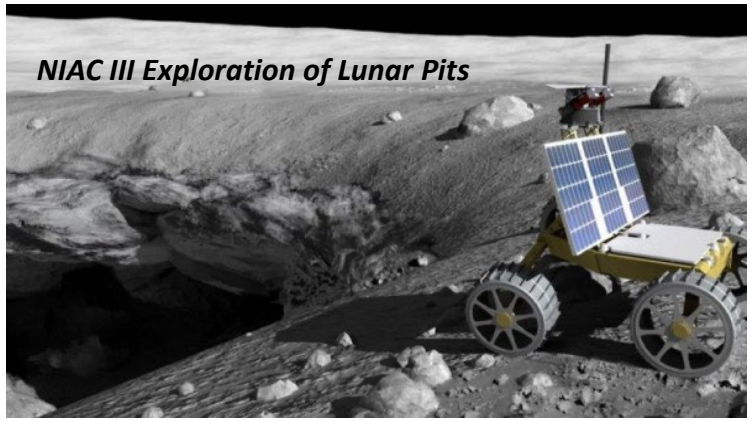
- Autonomous Pop Up Flat Folding Explorer Rover (A-PUFFER)
- Cooperative Autonomous Distributed Robotic Explorers (CADRE)
- CubeRover - Tipping Point
- Day/night lunar rover obstacle avoidance and localization
- Smart Video Guidance Sensor
- Exploration of Lunar Pits - Phase III NIAC
- Miniaturized Payloads for Small Rovers Ideation Challenge – Coming Soon!

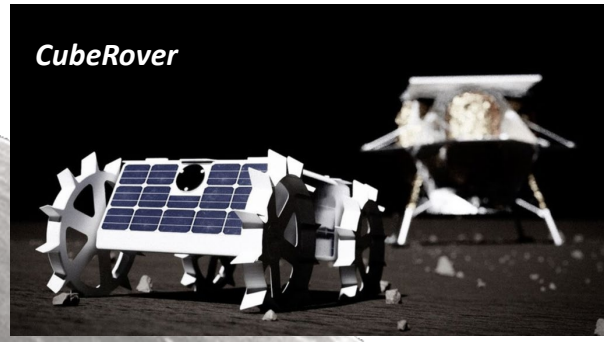
Additional Investments:

- Robust, sustained surface activities (bulk transport of regolith, etc.)
- Extended operations in permanently shadowed regions
- Ingress, exploration, and egress of subsurface voids
- Hazard detection in all lunar environments and conditions
- Navigation with minimal infrastructure
- Autonomous operations


A-PUFFER


CADRE design concept


NIAC III Exploration of Lunar Pits

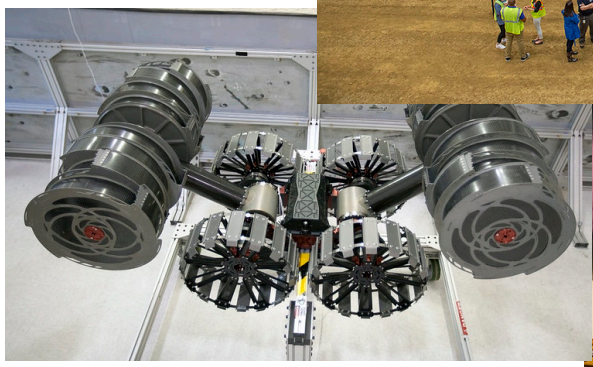

CubeRover

Excavation and Construction

STMD is developing technologies that enable affordable, autonomous manufacturing or construction

Technology Developments Underway:

- Regolith Advanced Surface Systems Operations Robot (RASSOR) Bucket GrabCAD Challenge – Kicked off March 16
- 3D Printed Habitat Centennial Challenge (2015-19)
- Excavation and Construction Centennial Challenge – Coming Soon!
- yet2 Market Analysis – Excavation and Construction

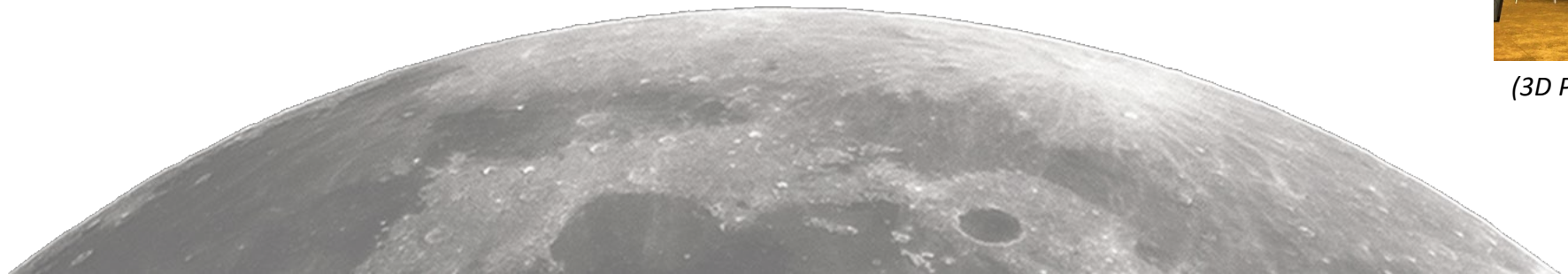


(RASSOR)

(3D Printed Habitat Challenge)

Additional Investments:

- Excavation of hard regolith/ice material
- Long duration operation of mechanisms
- Increased autonomy of operations
- Long distance travel and traverse ability to mining location
- Material and construction requirements and standards
- Hardware operation and product quality under lunar environment conditions



LSII – Built on Collaboration

LSII leverages the broad range of STMD Programs in order to identify and establish meaningful collaborations. Some examples currently underway include:

- Tipping Point and Announcement of Collaborative Opportunity (ACO) solicitations – Open through mid-March
- Small Business Innovative Research (SBIR) Surface Power Sequentials process underway ($5M)
- Selected 8 universities for the Breakthrough, Innovative and Game-changing (BIG) Idea Challenge for ideas on systems and technologies to explore and operate in Permanently Shadowed Regions in and near the Moon's polar regions (announced February 14, 2020)
- NextSTEP ISRU Broad Agency Announcements (BAA), including component and subsystem testing in simulated space environments
- Multiple NASA LSII focused Early Career Initiatives (ECI) selected in FY20
- NASA Innovative Advanced Concepts (NIAC) awarded for lunar technology enabling exploration of lunar pits
- Centennial Challenges Program is formulating LSII-related challenges, including Surface Power and Excavation.
- RASSOR Bucket GrabCAD Challenge – Kicked off March 16
- Miniaturized Payloads for Small Rovers Ideation Challenge – Coming Soon

Lunar Surface Technology Research (LuSTR) Opportunities

University-led efforts to improve critical systems and components or to catalyze development of new technologies that address high priority lunar surface challenges

Technical Characteristics:

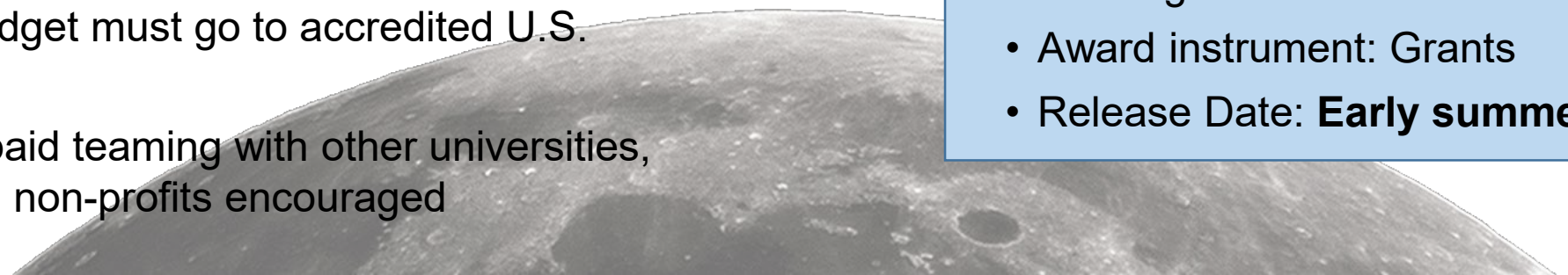
- Unique, disruptive or transformational lunar surface technologies: autonomous excavation and construction, mitigation of lunar dust hazards, in-situ resource utilization, surface power, and accessing and surviving the extreme lunar environment.
- Low to mid Technology Readiness Level (TRL): TRL 2-5
- Post-award infusion opportunities

Eligibility

- Organization submitting proposal must be an accredited U.S. university
- PI must be a professor at the submitting university; co-Is are permitted
- ≥ 70% of budget must go to accredited U.S. universities
- Up to 30% paid teaming with other universities, industry and non-profits encouraged

Award Information

- Expected duration: **2 years**
- Anticipated awards: **10-15 awards** valued at up to **$1-2M** each
- Oversight: Annual reviews by NASA/APL team and semi-annual briefings at LSIC meetings
- Award instrument: Grants
- Release Date: **Early summer 2020**



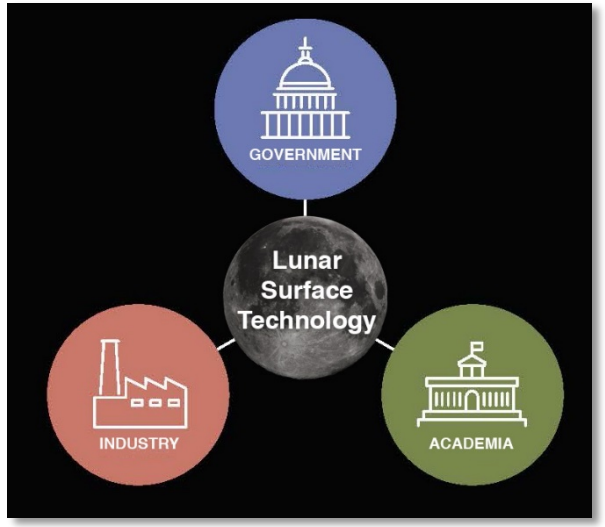
LSII System Integrator - APL

A key tenet of LSII is to implement a multitude of novel collaborations across industry, academia, and government in order to successfully develop the transformative capabilities for lunar surface exploration.

- LSII initiated a task through a University Affiliated Research Center (UARC), Johns Hopkins University Applied Physics Lab (APL), to assess system integration role for the Lunar Surface Innovation Initiative
- APL system integrator provided Lunar Regolith Simulant Supply Chain and Surface Power Assessments
- APL established a Lunar Surface Consortium with academia and industry representatives, as well as NASA experts, that span a broad range of capabilities to execute timely studies, tasks, and/or acquisitions

The Consortium will assist NASA in

- Identifying lunar surface technology needs and assessing the readiness of relative systems and components
- Making recommendations for a cohesive, executable strategy for development and deployment of the technologies required for successful lunar surface exploration
- Providing a central resource for gathering information, analytical integration of lunar surface technology demonstration interfaces, and sharing of results



Lunar Surface Innovation Consortium (LSIC) Kick-off February 28

- Over 250 attendees
- 52% of attendees had not worked with STMD before
  - 50 Companies
  - 25 Universities
  - 6 Nonprofit organizations
  - 6 Government entities
- Online views – 6,191
  - YouTube – 4,321
  - Facebook – 1,870

Sampling of Survey Responses

- 100% responded that they would like to join LSIC
- 70% are interested in presenting their institution's work at a focus group telecon
- 75% would like to have site visits
- 76% are interested in the LuSTR opportunity

Next Steps

- Form Executive Committee and determine focus area leads (internal and external to NASA)
- Quarterly meetings for each LSII focus area
- Fall meeting at Arizona State University

Technology Drives Exploration