National Aeronautics and
Space Administration

Technology, Innovation & Engineering Committee Report
NASA Advisory Council

Presented by:
Dr. Bill Ballhaus, Chair

July 27, 2017

www.nasa.gov/spacetech

TI&E Committee Scope

"The scope of the Committee includes all NASA programs focused on technology research and innovation."

–NASA Advisory Council Technology & Innovation Committee Terms of Reference, signed 6/28/12

TI&E Committee Meeting Attendees
July 25, 2017

- Dr. William Ballhaus, Chair
- Dr. Kathleen Howell, Purdue University
- Mr. Michael Johns, Southern Research Institute
- Mr. David Neyland
- Mr. Jim Oschmann, Ball Aerospace & Technologies Corporation
- Dr. Mary Ellen Weber, Stellar Strategies, LLC

TI&E Committee Meeting Presentations July 25, 2017

- Welcome to LaRC remarks
  - Mr. David Dress, Associate Director, Space Technology and Exploration Directorate
- Space Technology Mission Directorate Update
  - Mr. Stephen Jurczyk, Associate Administrator, STMD
- Habitation Capability Development – HEO Tech Development Efforts
  - Mr. Jason Crusan, Director, Advanced Exploration Systems, HEO
- Centennial Challenges Program Review Findings and Response
  - Mr. Jim Reuter, Deputy AA, STMD
- Chief Engineer Update
  - Ms. Dawn Schaible, NASA Deputy Chief Engineer
- Advanced Materials and Structures Update
  - Dr. Keith Belvin, Principal Technologist, LaRC
- Future Technology Demonstration Missions and IRMA Update
  - Ms. Ginger Flores, TDM Program Manager, STMD
- STMD Strategy Framework Discussion
  - Mr. Patrick Murphy, Director, Strategic Planning & Integration, STMD

National Aeronautics and
Space Administration

Space Technology Mission Directorate

NAC TI&E Committee

Centennial Challenges Program Findings and Response

Jim Reuter
STMD Deputy Associate Administrator

July 25, 2017

Centennial Challenges Background

- **NASA's first prize program; established in 2005**
  - ~Million $+ prize; Multi-year
  - International participants not eligible for prize money
  - Partner: non-profit only
- **Objective (per NASA Prize Authority, 51 USC 20144):** "To stimulate innovation in basic and applied research, technology development, and prototype demonstration that have the potential for application to the performance of the space and aeronautical activities of the Administration."
- **Independent review of Centennial Challenges Program CCP) established in late 2016 with objective to review the CCP portfolio:**
  - Alignment of implemented CCP challenges with Agency Goals
  - Types and scope of CCP challenges in the context of other NASA Prizes and Challenges programs
  - Infusion of new technologies from completed CCP challenges into Agency programs and impact on Agency goals

Centennial Challenges Independent Review Team

Civil Servant Panelists	Affiliation
Michael Seablom, Panel Chair	NASA Headquarters
Danielle Wood	NASA Headquarters
Harry Partridge	NASA Ames Research Center
Nantel Suzuki	NASA Headquarters
Howard Ross	NASA Glenn Research Center
Heather Evans	National Institute of Standards and Technology
Jennifer Garson	Department of Energy
Sandeep Patel	Department of Health and Human Services
Denise Shaw	U.S. Environmental Protection Agency

Consultants	Affiliation
Robert Brammer	Brammer Technology, LLC
Jesse Goldhammer	University of California, Berkely
Dwayne Spradlin	Buzz Points, Inc.

Examples of Success from Prior Challenges

- **Astronaut Glove Challenge**
  - In 2016 winning team delivered a pair of functional Mechanical Counter Pressure gloves to Johnson Space Center, under contract with NASA’s Space Technology Mission Directorate, titled the “High Performance EVA Glove project”

- **Lunar Lander Challenge**
  - NASA uses Masten’s landers to test technologies for deep space exploration
    - Xombie lander to test the Landing Vision System (LVS), as part of the Autonomous Descent; Ascent Powered-flight Testbed (ADAPT) experimental technologies, for the Mars 2020 mission landing

- **3D Printed Habitat Challenge**
  - Winner of Challenge, Ice House design, was invited to join NASA/LaRC Center Innovation Fund (CIF) proposal; proposal funded in 2016

- **Sample Return Robot Challenge**
  - Winning team was awarded an EPSCoR proposal with JPL collaborators and also a USDA National Robotics Initiative proposal

Centennial Challenges Independent Review Summary

- **Independent Review Team offered 17 Findings addressing:**
  - Goals and objectives
  - Relevance of challenges to and use by Mission Directorates
  - Program management and organization
  - Cadence of awards
  - Registration fees
  - Optimization of challenge process time
  - Incorporation of external inputs
  - Communications and outreach
  - Analysis of long-term impact of challenges
- **STMD concurs with all findings and recommendations. Actions in work; overall plan being finalized.**

TI&E Observation

- TI&E observed that the independent review of the Centennial Challenges program appears to have been very effective and all the findings and recommendations are being accepted and implemented.

- TI&E endorses the review finding: “NASA’s Mission Directorates, in close coordination with the CCP, must significantly increase their roles into the crafting of future challenges. Past experience in government and industry indicates that the impact and usefulness of the challenges, even those deemed successful, is highly diminished without such buy-in.”

Office of the Chief Engineer Update

Dawn M. Schaible

NASA Deputy Chief Engineer

July 25, 2017

Capability Leadership Roles

- Advises Agency and ensures *proper alignment* across Missions and Centers
- Establishes *plans based on strategic needs* to provide technical guidance to the Agency
- Determines *gap areas* for advancement and strategic investment
- Advises on capability *sizing and strategic hiring*, including contracting, across all Centers
- Assesses opportunities for *investments and divestments* within capability scope, including advising Centers on assets
- Solicits *innovative ideas* from outside the capability area
- Establishes *standards and specifications* within capability scope

Technical Capability Areas

As of May 2017

Discipline Capabilities	Lead Org.	Over sight
Aerosciences	OCE	APMC
Avionics	OCE	APMC
Cryogenics	OCE	APMC
Electrical Power	OCE	APMC
Flight Mechanics	OCE	APMC
Guidance, Navigation & Control	OCE	APMC
Human Factors	OCE	APMC
Instruments and Sensors	OCE	APMC
Life Support/Active Thermal	OCE	APMC
Loads and Dynamics	OCE	APMC
Materials	OCE	APMC
Mechanical Systems	OCE	APMC
Non-Destructive Evaluation	OCE	APMC
Passive Thermal	OCE	APMC
Propulsion	OCE	APMC
Software	OCE	APMC
Space Environments	OCE	APMC
Structures	OCE	APMC
Systems Engineering	OCE	APMC

Service Capabilities	Lead Org.	Over sight
Aircraft Operations	MSD	APMC
Mission Operations	Centers	APMC

Red items are newly formed

System Capabilities	Lead Org.	Over sight
Entry, Descent and Landing	STMD	APMC
Autonomous Systems	STMD	APMC
In-Space Transportation	STMD	APMC
Rendezvous and Docking	STMD	APMC
ECLSS	HEOMD	APMC
ISRU	HEOMD	APMC
Communications & Navigation	HEOMD	APMC

Research Capabilities	Lead Org.	Over sight
Earth Science Research	SMD	APMC
Heliophysics Research	SMD	APMC
Astrophysics Research	SMD	APMC
Planetary Research	SMD	APMC
Life Sciences Research	HEOMD	APMC

Capability Portfolios	Lead Org.	Over sight
Aeronautics Evaluation & Test	ARMD	MSC
High End Computing	SMD	MSC
Rocket Propulsion Testing	HEOM D	MSC
Space Environments Testing	MSD	MSC

Summary

- OCE continues to support Agency-level actions and forward work items to address EMB integrated recommendations

- Discipline CLT cadence includes:
  - Review of newly formed discipline capabilities
  - Staggering of State of the Capability assessment on a 3-year cycle with a focus on a specific area of interest
  - Situational awareness review of all discipline capability areas

- Re-baselining only 6-7 Discipline CLTs each year allows the EMB to more actively engage in developing recommendations and to more fully address the specific focus area (e.g. Strategic Vectors for FY17)

- Working with Agency leadership to potentially expand cadence to all technical capability areas

STMD Technology Strategy
Structures, Materials & Nanotechnology

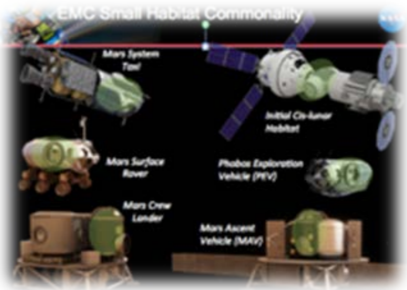
W. Keith Belvin
Principal Technologist, STMD
July 25, 2017

Briefing to NAC TI&E

Summary

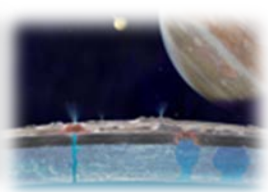
Structures/Materials/Nanotechnology

Human Composites



iSA & iSM

Advanced Structural Materials



Performance

- *30-50% lower mass*
- *Reduced packaging volume*

Resilience

- *Durability/Reparability*
- *Modular/Re-configurability*
- *Upgradable/Life Extension*

Affordability

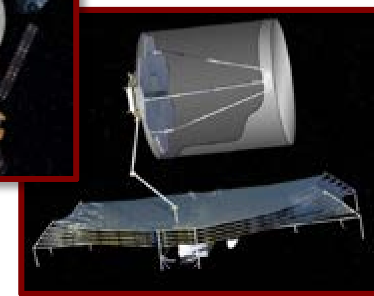
- *30-50% lower production cost*
- *Lower life-cycle cost*

Urgency

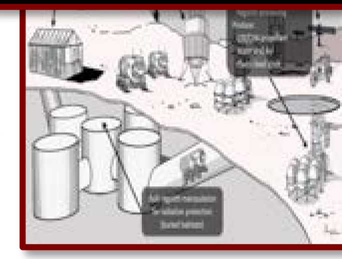
- *Mars Architecture & Habitats*
- *Planetary and Astrophysics*
- *iSA & iSM rev tech*

Human Cis-Lunar (EMC)

Planetary Science / Exoplanet Observatories



Human And Robotic Surface Systems



OGA and Commercial Space

National Aeronautics and
Space Administration

Space Technology Mission Directorate

Technology Demonstration Missions Program

NAC TI&E Committee Meeting Briefing

Ginger Flores
TDM Program Manager

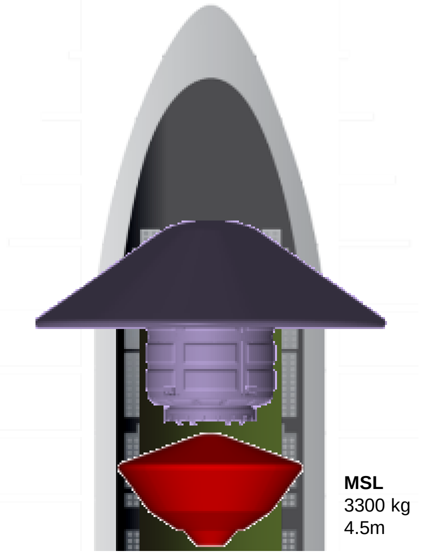
July 25, 2017

Executive Summary

A Hypersonic Inflatable Aerodynamic Decelerator (HIAD) is a deployable aeroshell consisting of an Inflatable Structure (IS) that maintains shape during atmospheric flight, and a Flexible Thermal Protection System (F-TPS) employed to protect the entry vehicle through hypersonic atmospheric entry.

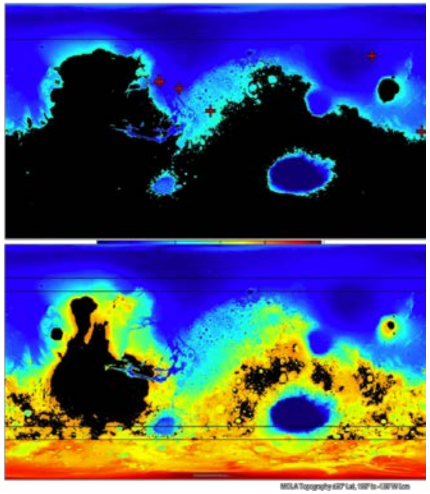
Executive Summary
Why HIAD?

- Entry mass at Mars (and other destinations with atmospheres) is limited by launch vehicle fairing size.
- Increased drag area is needed for higher mass and/or higher altitude landings.
- Inflatable heatshield technology
  - Allows payloads to use the full diameter of the launch fairing.
  - Can be stowed into available volume and somewhat irregular shapes.
  - Deploys a large aeroshell before atmospheric interface.
  - Enables landing more payload mass and/or at higher altitude.



MSL
3300 kg
4.5m

Mars Surface Access



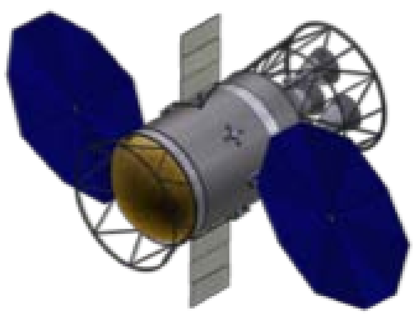
Rigid aeroshells limited to low altitude sites (blue)

Inflatables allow access to southern highlands

CFM Roadmapping Activity

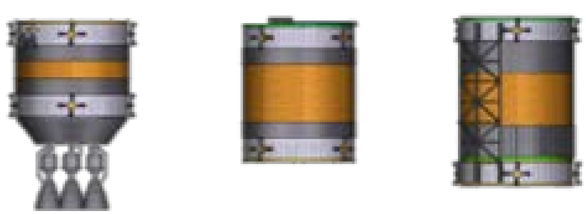
- **Cryogenic Fluid Management (CFM) Roadmap:**
  - Team performed a CFM Roadmap technology assessment for architectures identified by the Mars Study Capabilities Team.
  - Assessed 25 CFM technologies against potential Mars architectures for future CFM Demonstrations.
  - The CFM Roadmap identified technologies requiring flight demonstrations for infusion into future deep space missions.

Potential Mars Elements Requiring CFM



Methane Cryogenic Propulsion Stage (MCPS)

Mars Ascent Vehicle (MAV)



Nuclear Core Stage In Line Tank Drop Tank

Nuclear Thermal Propulsion (NTP)

Mars Lander

Future Potential Flight Demo CFM

- **Schedule:** FY18 (possible Broad Agency Announcement Studies) or FY19 (possible project start).
- **Technical: CFM RFI issued on July 12 with 30 day response period.**
  - The intent of the RFI is to establish a public-private partnership with industry for the further development of CFM technologies in the functional areas of: Storage, pressure control, transfer, and mass gauging. While NASA in primarily concerned with CFM applications in the below areas, the CFM does request input from industry on applications that NASA may not be currently pursuing.
    - Nuclear thermal propulsion and other chemical in-space propulsion systems.
    - Reaction Control Systems (RCS) and Main Propulsion Stage (MPS) operations during planetary ascent and descent flight phases.
    - In-Situ Resources Utilization (ISRU) based production systems.
    - Propellant depots for refueling in-space transportation systems.
    - Ground-based cryogenic propellant storage and transfer for autonomous fueling of launch vehicles.

National Aeronautics and
Space Administration

STMD’s new Strategic Framework

Presented by:
Patrick Murphy, Director, STMD Strategic Planning and Integration

Kevin D. Earle, William M . Cirillo
Systems Analysis & Concepts Directorate
NASA Langley Research Center

July 25, 2017

www.nasa.gov/spacetech

Revising Space Technology's Strategic Framework

Approach modeled after Aeronautics Research Mission Directorate's (ARMD's) highly successful strategic framework, incorporating lessons learned and changes where appropriate.

Overall Goal

…is to reframe/repackage our strategy to focus our investment prioritization and communication on impacts, outcomes, and challenges first, and on technologies & systems second.

Customer derived framework.

Shift to customer-oriented, impact-centric focus, with the intent of more transparently communicating impacts to customers & stakeholders.

Increase use of quantifiable measures to increase traceability of decisions, provide clearer guidance, and empower management & technical workforce.

Planned Framework

Mega-Drivers
"Overarching Trend"

Strategic Thrusts
"Vision for Future"

Outcomes
"Overarching, Measurable Goals"

Technical Challenges
"STMD Technical Deliveries"

Revising STMD's Strategic Framework

Planned Framework	Definitions	Development Timeline
Mega-Drivers "Overarching Trend"	Overarching trends that have, are, and will largely shape civilian space research over many years. They are a product of analysis of space industry trends and conversations with STMD customers (e.g. NASA mission directorates, commercial space, U.S. industry, & other governmental agencies). **Today's Focus**	May-Aug 2017
Strategic Thrusts "Vision for Future"	Represent STMD's overarching view of the community's response to the Mega-Drivers as they affect the civilian space industry. Taken together, the Strategic Thrusts constitute a vision for the future of space.	Jun-Aug 2017
Outcomes "Overarching, Measurable Goals"	Overarching space goals that are more than NASA alone can do. They are measurable goals to be achieved through joint efforts across the space community.	Jun-Dec 2017
Technical Challenges "STMD Technical Deliveries"	Represents STMD's contributions to achieving the outcomes: the fundamental questions to be answered, and/or capability developed and delivered. Each STMD project will be responsible for answering one or more Technical Challenges.	2018

Mega-Drivers

Increasing Access

Major Trends:

- Decreasing cost & increasing availability of access to space (i.e. reusability).
- Lowering barriers of entry to space due to reduced operations costs and increasingly reliance on low-cost platforms (e.g. CubeSats).
- Increasing demand for new platforms to conduct new missions and provide access to new destinations, both in near-Earth space and beyond.
- Growing demand for efficient, scalable transportation solutions to enable human-class, long-duration missions to planetary surfaces.

Accelerating Pace of Discovery

Major Trends:

- Humanity has continually expanded into frontiers for many reasons throughout history, including: to satisfy our curiosity, to start a better life, and to pursue new opportunities.
- An increasing demand for new scientific discoveries, driven by the need to understand the world & universe we live in and to continue to fuel the accelerating advancement of technologies for use on Earth and in Space.

Democratization of Space

Major Trends:

- Broadening participation in space: US, other governments, traditional/emerging commercial companies, start-ups, citizens, academia, STEM education.
- Substantial growth in private investment to provide space services (e.g. GPS, remote sensing, manufacturing, tourism).
- Broadening international presence/collaboration in space, with more countries establishing national space programs and growing international private investment in space.

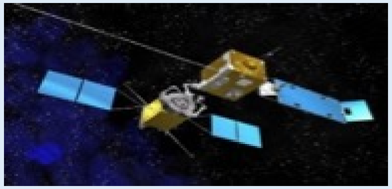
Growing Utilization of Space

Major Trends:

- Growing use of space, with global satellite industry revenues nearing $300B in 2016 and estimates in the $600B in 2024, well surpassing U.S. average GDP growth.
- Increasing reliance on space systems for a variety of applications (e.g. communication, navigation, weather forecasting, remote sensing) and to address global challenges (e.g. constraints on terrestrial resources).
- Growing private investment in new space markets (e.g. satellite servicing, assembly, manufacturing, resource utilization, and tourism).

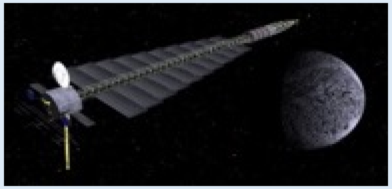
STMD Strategic Thrusts

1. Expand Utilization of Near-Earth Space



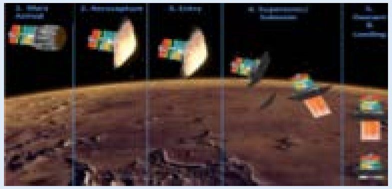
- Provide safe and affordable routine **access to space**
- Enable **extension, reuse, and repair** of near-Earth assets
- Expand **near-Earth infrastructure** to support human and science exploration beyond LEO

2. Develop Efficient & Safe Transportation Through Space



- Provide cost-efficient, reliable **propulsion for long duration missions**
- Enable **significantly faster**, more efficient deep space missions
- Enable **long-duration** crew transport

3. Increase Access to Planetary Surfaces

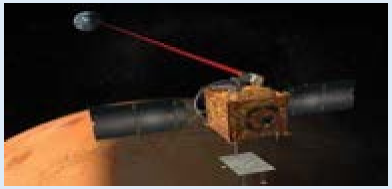


- Safely and precisely **deliver humans & payloads to planetary surfaces**
- Increase **access to high-value science sites** across the solar system
- Provide efficient, highly-reliable **Earth sample return** reentry capability

4. Enable Humans to Live and Explore on Planetary Surfaces

- Enable humans to **survive** on other planets
- Provide efficient/scalable **infrastructure** to support exploration at scale
- Increase crew effectiveness and **access to diverse, high-value sites**

5. Enable the Next Generation of Science Missions



- Expand access to new environments and measurement **platforms** to enable high-value science
- Enable **substantial increases** in the quantity and quality of science data returned
- Enable **high-power measurements** for long duration science missions

6. Grow & Utilize the U.S. Industrial and Academic Base

- **Transfer NASA technology** to grow the U.S. industrial & technology base
- Open and **foster new space markets** for U.S. commerce
- **Drive U.S. innovation** & expand opportunities to achieve the NASA dream

Path Forward

Planned Framework	Development Timeline	Current Status
Mega-Drivers "Overarching Trend"	May-Aug 2017	**Vetting** with external community.
Strategic Thrusts "Vision for Future"	Jun-Aug 2017	**Refining** in response to new Mega-Drivers and outcome development activities.
Outcomes "Overarching, Measurable Goals"	Jun-Dec 2017	Started **development** internally.
Technical Challenges "STMD Technical Deliveries"	2018	Establishing **development** approach.

TI&E Finding for STMD AA

Support for STMD Revised Strategic Framework

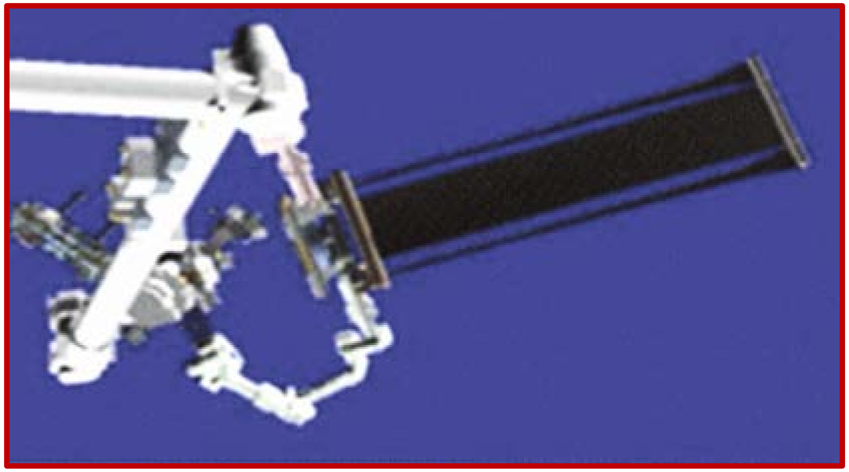
- TI&E agrees with the revised strategic framework presented
  - Suggest two additional considerations within the Mega-Drivers:
    - Consideration of safety/risk (Increasing Access)
    - Responsible stewardship/debris mitigation (Growing Utilization of Space)
- Outcomes are currently being defined
- The implementation plan and ownership of outcomes remain to be defined
- TI&E will reengage with STMD at the November 2017 meeting

Space Technology Highlights

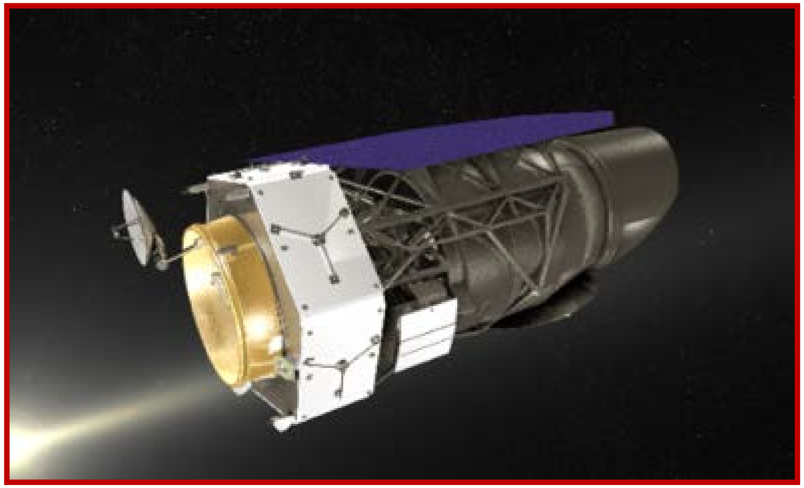
Important STMD Milestones in FY 2017:

- CoBALT flights with Masten to advance autonomous landing and hazard avoidance technology
- SEXTANT/NICER launched in May and completed check-out/began reporting science data
- Solar Electric Propulsion PDR in August 2017
- Restore-L (Satellite Servicing demo) PDR in September 2017
  - FY18 President's budget proposal restructures Restore-L into a satellite servicing technology development activity
- Small Spacecraft demos ready for launch in October 2017 (OCSD/ISARA/CPOD)
- DSAC/GPIM flight demonstrations awaiting launch on STP-2 (NET December 2017)
- Kilopower 1kW demo in January 2018

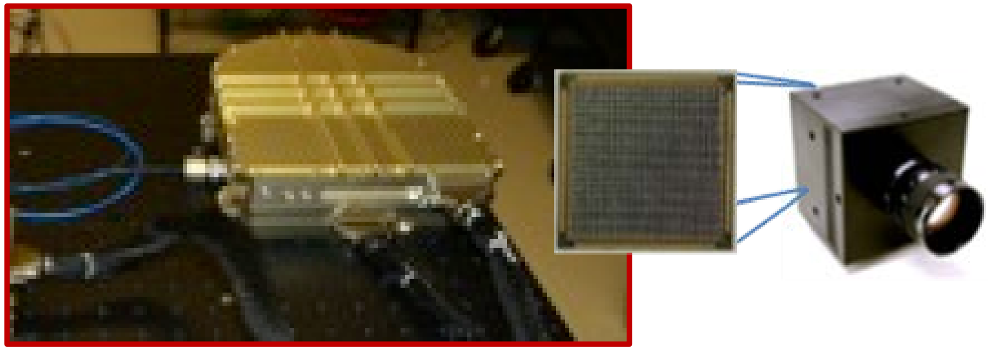
STMD Infusion Successes in FY17



Spaceflight demo of ROSA on ISS



Coronagraph achieves TRL5, resulting in measurements 100x better than existing tech

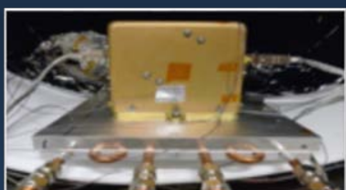


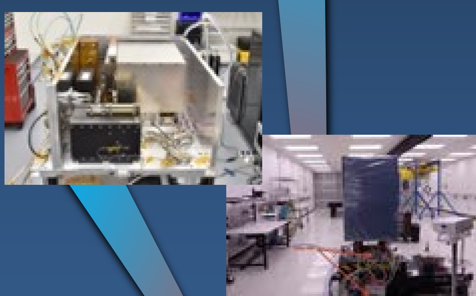
Hardware integration for testing of Deep Space Optical Communications

Boeing XS-1 project will use STMD composite cryogenic tanks

FY 2018-19 Program Highlights

RRM3
January 2018
RRM3 Launch, carrying the eCryo Radio Frequency Mass Gauge for demo

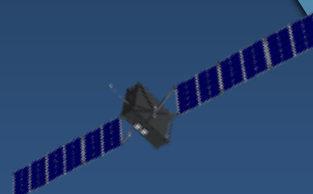




SEP
May 2019
Propulsion Subsystem Completion

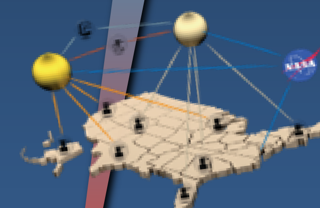
LCRD
June 2019 Launch

DSOC
June 2019
Critical Design Review



eCryo
May 2019
SHIVER testing

Pathfinder Demonstrators
2018 and 2019



Space Technology Research Institutes
Additional Institutes will be awarded

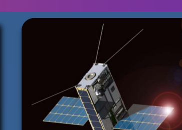
DSAC & GPIM
December 2017
Initial Launch Capability aboard STP-2

2017	2018	2019

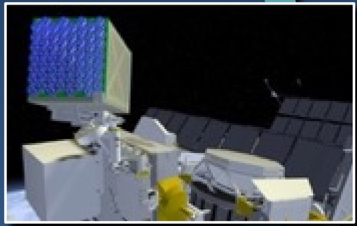
Ongoing

Flight Opportunities
provides access to suborbital test environment

Centennial Challenges
New challenges initiated; Cube Quest Cubesats ready for flight on EM-1



FY 2018-19 Highlights

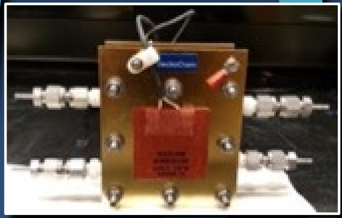


SEXTANT
November 2017
Experiment complete

Kilopower
January 2018
KRUSTY test

Astrobee
September 2018
Operations demo

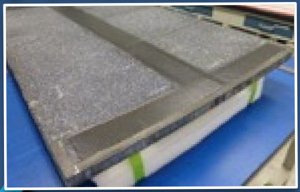
Nuclear Thermal Propulsion
September 2018
Depleted Uranium Fuel Element Test and NTP System Concept Review



Next Generation Life Support: Spacecraft Oxygen Recovery
September 2018
Deliver Phase II prototype

Mars Entry, Descent and Landing Instrumentation 2 (MEDLI2)
March 2019
Hardware delivery

High Performance Spaceflight Computing
April 2019
Critical design (middleware) complete



Composite Technology for Exploration
July 2019
Complete combined longitudinal & circumferential joint manufacturing & testing

2017	2018	2019

BACK-UP