



Technology, Innovation & Engineering Committee Report NASA Advisory Council

Presented by:
Dr. Bill Ballhaus, Chair

April 1, 2016



TI&E Committee Meeting Attendees

March 29, 2016



- Dr. William Ballhaus, Chair
- Mr. Michael Johns, Southern Research Institute
- Mr. David Neyland, Consultant
- Mr. Jim Oschmann, Ball Aerospace & Technologies Corp.
- Dr. Mary Ellen Weber, Stellar Strategies, LLC



TI&E Committee Meeting Presentations

March 29, 2016



- Space Technology Mission Directorate Update
 - Mr. Stephen Jurczyk, Associate Administrator, STMD
- FY16-17 Technology Plans for HEO and SMD and Discussion
 - Mr. Chris Moore, Deputy Director, Advanced Exploration Systems, HEOMD
 - Mr. Michael Seablom, Chief Technologist, SMD
- Chief Technologist Update
 - Dr. David Miller, NASA Chief Technologist
- Annual Ethics Briefing
 - Rebecca Gilchrist, Ethics Attorney, OGC
- Technology Demonstration Missions (TDM) Update
 - Ms. Trudy Kortez, Program Executive, TDM, STMD
- Restore-L Mission Overview and Discussion
 - Mr. Ben Reed, Deputy Program Manager, Satellite Servicing Capabilities Office



Space Technology Mission Directorate

Update

NAC TI&E Committee

Presented by:
Stephen Jurczyk
Associate Administrator, STMD

March 29, 2016

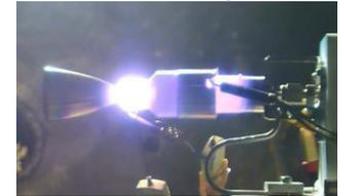
STMD Public-Private Partnerships



STMD continues to foster partnerships with the commercial space sector for expanding capabilities and opportunities in space.

Objective:

Deliver critical space technologies needed for future missions by leveraging previous investment by U.S. industry and providing new opportunities for collaboration that accelerate development and utilization.



Market Research Revealed Two Categories of Industry-led Space Technologies:

- Those at a “tipping point”, where a final demonstration or validation would result in rapid adoption and utilization - - “STMD Tipping Point Solicitation”
- Those that could directly benefit from NASA’s unique experience, expertise, facilities - - “STMD Announcement of Collaboration Opportunity (ACO)”

Results:

- Both Tipping Point and ACO were released **May 2015**
- Topics included: Robotic In-Space Manufacturing, Small S/C Systems, Remote Sensing Instrumentation, Advanced Thermal Protection, Launch Systems Development
- **Nine** Tipping Point and **Thirteen** ACO industry-led projects selected **November 2015**
- Issue new Tipping Point solicitation in **late FY16 and ACO in FY17**



Key Activities in FY 2016- 2017



New

Restore-L: Continue Formulation of technology demonstration for a low-Earth orbit satellite servicing mission, completing SRR/MDR in 2016 to support 2019 launch.



New

DSOC: Initiate technology demonstration mission for Deep Space Optical Communications for potential demonstration on the next Discovery mission.

Laser Communications Relay Demonstration (FY 2016 and FY 2017)

- Develops and assembles flight unit and conducts integrated testing to support late CY 2019 launch.



Solar Electric Propulsion: Develop electric propulsion subsystem hardware to support Asteroid Redirect Robotic Mission (KDP-B currently scheduled for Q4 FY 2016).

Green Propellant Infusion Mission: demonstrate propellant formula, thrusters, and integrated propulsion system, for higher performing, safe alternative to highly toxic hydrazine (1st Quarter-CY2017)



Deep Space Atomic Clock: New space clock improving navigational accuracy for deep space and improve gravity science measurements (1st Quarter-CY2017)

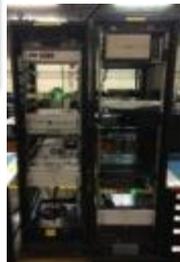
Deliver Small Spacecraft Technology: Conduct four demo missions in 2016

- Nodes – Deploy Nodes currently onboard ISS in 2016
- OCSD: Demonstrating in-space laser communications using 2 cubesats (Oct 2015 & June 2016)
- ISARA: Uses a deployed solar array as a Ka-band radio antenna reflector (June 2016)
- CPOD: Proximity operations and docking demo with 2 cubesats (NET Sep 2016)
- iSat: Complete Iodine Hall Thruster Critical Design Review in Spring 2016



GCD Delivers Coronagraph, ISRU, SEXTANT (FY 2016 and 2017)

- Game Changing Development delivers two coronagraph technologies for WFIRST/AFTA consideration (Occulting Mask Coronagraph and PIAACMC Coronagraph)
- Complete Critical Design Review in Sept. 2016 for Mars Oxygen In-Situ Resource Utilization Experiment payload on Mars 2020.
- SEXTANT delivery of ICER Unit launched to the ISS.
- Develop Nuclear Thermal Propulsion technologies in collaboration with Department of Energy and industry.



FY 2017 Budget Request



Budget Authority (\$M)		FY 2015	FY 2016	FY 2017 Total	Notional Plan			
			Enacted		FY 2018	FY 2019	FY 2020	FY 2021
Agency Technology & Innovation (AT&I)		\$31.3		\$34.3	\$35.0	\$35.7	\$36.4	\$37.1
SBIR & STTR		\$190.7		\$213.0	\$213.2	\$213.5	\$213.8	\$213.8
Space Technology Research & Development (STR&D)		\$378.3		\$579.4	\$456.2	\$469.3	\$482.7	\$496.6
S T T R & D	Early Stage	\$43.6		\$82.4	\$83.8	\$85.2	\$86.7	\$88.2
	Commerical Partnerships	\$14.2		\$22.9	\$23.3	\$23.8	\$24.3	\$24.8
	Game Changing Development (GCD)	\$129.3		\$158.4	\$111.1	\$117.6	\$124.3	\$131.2
	Technology Demonstration Missions (TDM)	\$172.0		\$288.9	\$210.5	\$214.8	\$219.0	\$223.4
	<i>In-Space Robotic Servicing (ISRS) / Restore-L</i>	<i>\$10.0</i>	<i>\$133.0</i>	<i>\$130.0</i>	<i>\$66.3</i>	<i>\$67.6</i>	<i>\$69.0</i>	<i>\$70.4</i>
	<i>All other TDM Projects</i>	<i>\$162.0</i>		<i>\$158.9</i>	<i>\$144.2</i>	<i>\$147.1</i>	<i>\$150.1</i>	<i>\$153.1</i>
Small Spacecraft Technologies (SST)		\$19.3		\$26.8	\$27.3	\$27.9	\$28.4	\$29.0
TOTAL SPACE TECHNOLOGY		\$600.3	\$686.5	\$826.7	\$704.4	\$718.5	\$732.9	\$747.5



Restore-L Overview



NASA's Restore-L is a groundbreaking mission that uses robotic technology to rendezvous with and refuel a government-owned satellite in low Earth orbit, autonomously and via remote control.

The primary mission objective is to advance technologies critical for human and commercial spaceflight infrastructure including advancing the following to operational status:

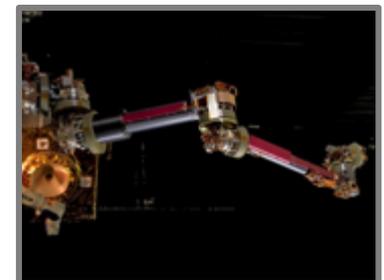
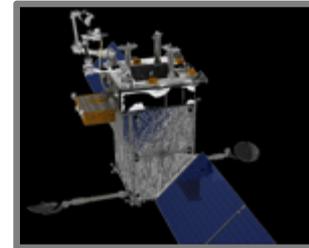
- non-cooperative autonomous rendezvous capability
- robotic capture and servicing
- non-cooperative refueling

Benefits of the project include:

- Establishing the U.S. as the leader in space robotic servicing
- Transfer robotic servicing technologies to U.S. industry
- Feed technology and lessons learned forward for ARM

Preliminary schedule

- FY 2016: Mission Concept Review (MCR) and Key Decision Point (KDP)-A
- FY 2017: System Requirements Review (SRR)/Mission Design Review (MDR), Key Decision Point (KDP-B)
- LRD notionally scheduled for late CY 2019, consistent with FY 2016 PL 114-113 direction, STMD will refine the project's plan and schedule at KDP-C as NASA establishes cost and schedule commitments for the Restore-L project



STMD Near-Term Accomplishments



- **Solar Electric Propulsion:**
 - Accomplishment: Successfully tested a new 12.5 kilowatt Hall thruster with magnetic shielding throughout the full performance range that will be required to efficiently move large cargos in Earth orbit and on to Mars. In addition, the roll out solar array technology developed under STMD is being incorporated into a commercial spacecraft product line for high power applications.
 - Importance: The Solar Electric Propulsion thruster and solar array technologies are the foundation for human exploration plans, including the Asteroid Redirect Mission and ultimately the transportation system for human exploration to Mars. These technologies also have direct applicability to enhancing the commercial spacecraft market. Compared to chemical propulsion systems, these Hall thruster electric propulsion systems have a 4 to 6 times higher specific impulse, requiring 5 to 10 times less propellant for the same mission. The thrusters will operate at ~2.5 times the power level of the highest powered electric thrusters now in use. The advanced solar arrays are 2 times lighter and use 4 times less stowed volume for the amount of electricity produced than commercially available arrays, with an ability to withstand 4 times more radiation exposure.
- **Low Density Supersonic Decelerator:**
 - Accomplishment: Completed a second high-altitude atmospheric flight test. The 6 m diameter supersonic inflatable aerodynamic decelerator (SIAD) and the 4.4 m inflatable trailing ballute performed exceptionally well and are ready for infusion by planetary missions. Although the 30 m diameter supersonic parachute failed after deployment, the data obtained will have a critical impact on better understanding supersonic parachute dynamics for future development efforts.
 - Importance: The SIAD & ballute technologies provide enhanced landing capabilities for future planetary missions. The knowledge gained by the supersonic parachute test anomaly provides an one-of-a-kind set of supersonic parachute data set that will have a critical impact on better understanding deployment dynamics, providing a basis for developing and demonstrating a 27 to 30 m diameter supersonic parachute for infusion on a Mars Sample Return mission.

STMD Near-Term Accomplishments



- **Green Propellant Infusion Mission:**
 - Accomplishment: The Green Propellant Infusion Mission (GPIM) spacecraft is ready to be integrated for flight in early CY 2017 after successfully completing integration with the advanced propulsion system and spacecraft-level environments testing.
 - Importance: The GPIM propulsion system utilizes AFM-315E, a non-toxic replacement for hydrazine that delivers a 40% improvement in volumetric impulse while reducing spacecraft propellant system processing and fueling costs by at least 50%. This results in a ~50% increase in spacecraft maneuvering capability for a given volume. The AFM-315E propellant also has a freezing point ~80 degrees Celsius lower than that of hydrazine, requiring less spacecraft power to maintain its temperature.
- **Deep Space Atomic Clock:**
 - Accomplishment: The DSAC flight hardware has been integrated and is in final environments testing in preparation for delivery to the host spacecraft and integration for flight in early CY 2017.
 - Importance: DSAC will provide unprecedented navigation accuracy in an on-board system for deep space navigation and timing, only drifting one second every 10,000,000 years. This will increase navigation and radio science data quantity by two to three times, improve data quality by up to 10 times and reduce mission costs by shifting toward a more flexible and extensible one-way radio navigation architecture.
- **Small Spacecraft Technologies:**
 - Accomplishment: Sixteen Cubesat spacecraft supporting six technology demonstration missions aimed at demonstrating a wide array of technologies have launched or are nearing readiness for flight. The missions include demonstrations of high-data-rate laser communication, autonomous rendezvous and docking, a reflect-array high gain radio antenna, and autonomous communications for satellite networks.
 - Importance: Collectively, the projects demonstrate technologies to enable NASA missions and commercial applications at much lower cost.

Key Milestones in 2016-17



Green Propellant: demonstrates propellant formula, thrusters, and integrated propulsion system, for higher performing, safe alternative to highly toxic hydrazine. (1st Quarter – CY 2017)

Deep Space Atomic New space clock improving navigational accuracy for deep space (1st Quarter – CY 2017)

Purchasing major subsystems for **Solar Electric Propulsion and Laser Communications demonstrations**

Restore-L begins mission formulation to advance satellite servicing technologies.

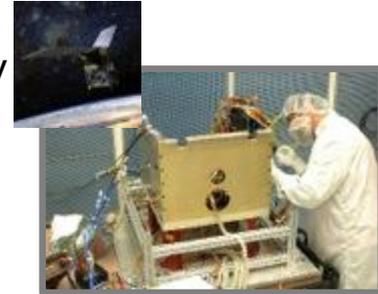
Initiate **Deep Space Optical Communication** demonstration to provide high bandwidth communications for future deep space exploration.

Small Spacecraft Technology: Three small spacecraft demonstration missions:

- ISARA: Uses a deployed solar array as a Ka-band radio antenna reflector
- OCSL: Demonstrating in-space laser communications using 2 cubesats.
- CPOD: Proximity operations and docking demo with 2 cubesats

Establishing Public-Private Partnerships: Tipping Point and Announcement of Collaborative Opportunity solicitations awards in FY16.

- Issue new Tipping Point solicitation in late FY 2016 and ACO in FY 17.





Advanced Exploration Systems: FY16 Activities

March 29, 2016

Chris Moore

Advanced Exploration Systems



Rapid development and testing of prototype systems and validation of operational concepts to reduce risk and cost of future exploration missions:

- **Crew Mobility Systems**
 - Systems to enable the crew to conduct “hands-on” surface exploration and in-space operations, including advanced space suits, portable life support systems, and EVA tools.
- **Habitation Systems**
 - Systems to enable the crew to live and work safely in deep space, including beyond earth orbit habitats, reliable life support systems, radiation protection, fire safety, and logistics reduction.
- **Vehicle Systems**
 - Systems to enable human and robotic exploration vehicles, including advanced in-space propulsion, extensible lander technology, modular power systems, and automated propellant loading on the ground and on planetary surfaces.
- **Foundational Systems**
 - Systems to enable more efficient mission and ground operations and those that allow for more Earth independence, including autonomous mission operations, avionics and software, in-situ resource utilization, in-space manufacturing, synthetic biology, and communication technologies.
- **Robotic Precursor Activities**
 - Robotic missions and payloads to acquire strategic knowledge on potential destinations for human exploration to inform systems development, including prospecting for lunar ice, characterizing the Mars surface radiation environment, radar imaging of NEAs, instrument development, and research and analysis.
- **Strategic Operations, Integration, and Studies**
 - Responsible for the management oversight of the HEO architecture and strategic planning, including mission and systems analysis and international coordination. Conduct studies and analyses to translate strategy into developmental (technology and capability) priorities and operational efficiencies.

FY16 Summary

- In FY16, AES has established 65 milestones and \$182 million budget.
- Goal is to achieve at least 80%. Completed 78% in FY15.
- AES includes 460 civil servants and 154 contractors in FY16

BEAM



- The Bigelow Expandable Activity Module (BEAM) is a public-private partnership to demonstrate a commercial inflatable module on ISS.
- BEAM is scheduled for launch on the SpaceX-8 mission on April 8.
- During its two-year mission, sensors inside BEAM will verify its structural integrity and characterize the radiation environment.



BEAM being installed in Dragon trunk



BEAM attached to ISS



BEAM integrated with Dragon trunk

HEOMD/STMD Engagement on Technology Needs



- **Evolvable Mars Campaign (EMC) has a strategic set of needs for enabling long-range capabilities; Orion and SLS needs are primarily near-term and mission focused.**
- **Crosscutting needs identified by HEOMD:**
 - Radiation monitoring & protection (ISS, Orion, HRP, EMC)
 - EVA suit & PLSS (Orion, ISS, ARM, EMC)
 - Environmental monitoring (Orion, ISS, EMC)
 - Spacecraft fire safety (Orion, ISS, EMC)
 - Exercise equipment (Orion, HRP, EMC)
 - Advanced solar arrays (ARM, ISS, EMC)
 - Automated rendezvous & docking (Orion, ARM, EMC)
- **Areas with greatest number of gaps:**
 - Human Health, Life Support, & Habitation Systems (Orion, HRP)
 - Communications & Navigation (SCAN)
- **Categories of collaboration:**
 - **Deliveries:** STMD matures technology and delivers to AES for system-level evaluation (e.g advanced space suit components.)
 - **Partnerships:** STMD and HEOMD/AES co-fund the development of technologies that are of mutual interest (e.g. Mars 2020 payloads.)
 - **Coordination:** STMD and HEOMD/AES define specific divisions of responsibility within a technical discipline (e.g. synthetic biology, advanced manufacturing, etc.)



Space Technology Mission Directorate

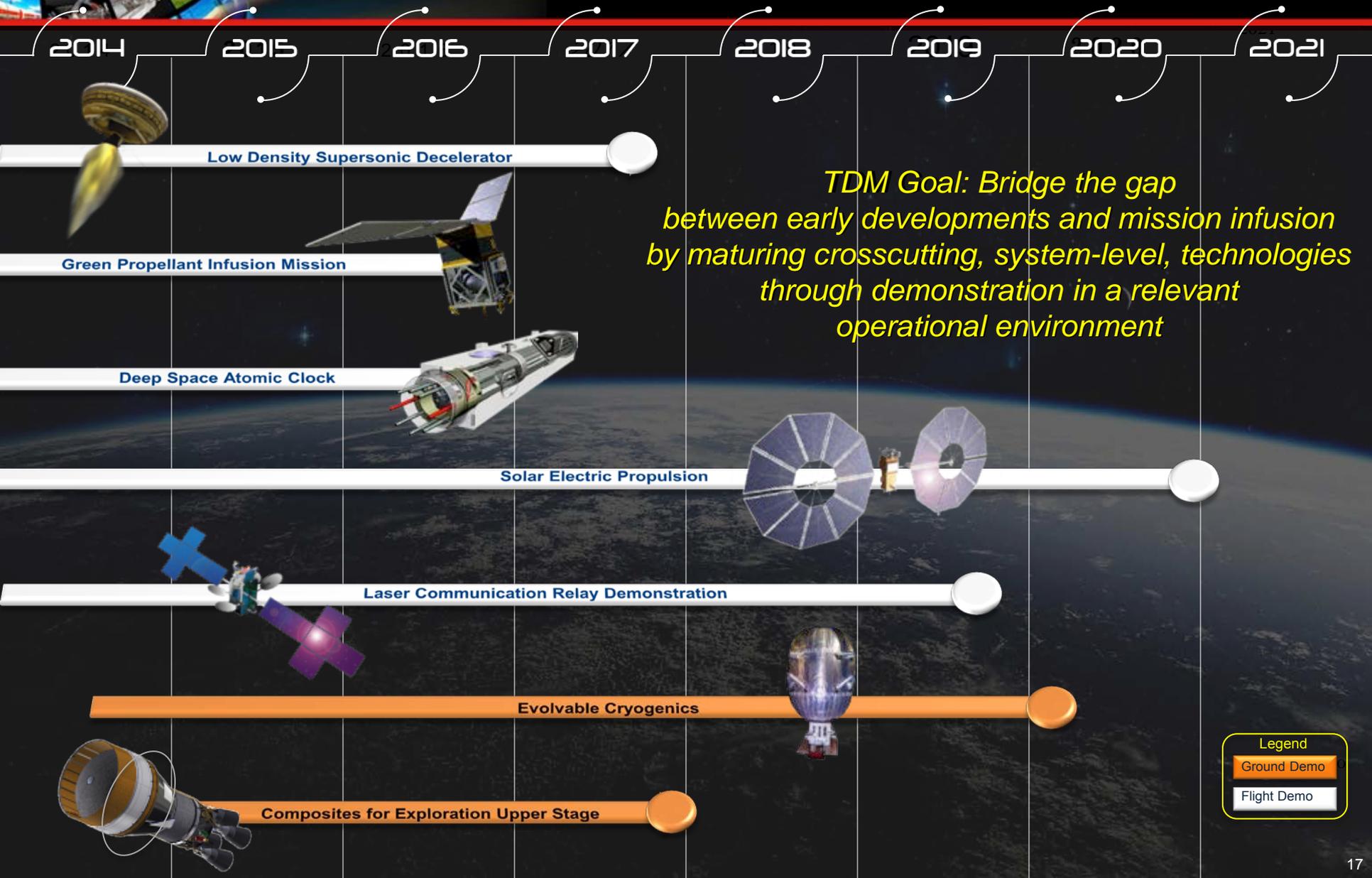
Technology Demonstration Missions
Program Update
for the NAC Technology, Innovation,
and Engineering Committee

Presented by:
Trudy Kortez
TDM Program Executive, STMD

March 29, 2016

TDM Portfolio

Was

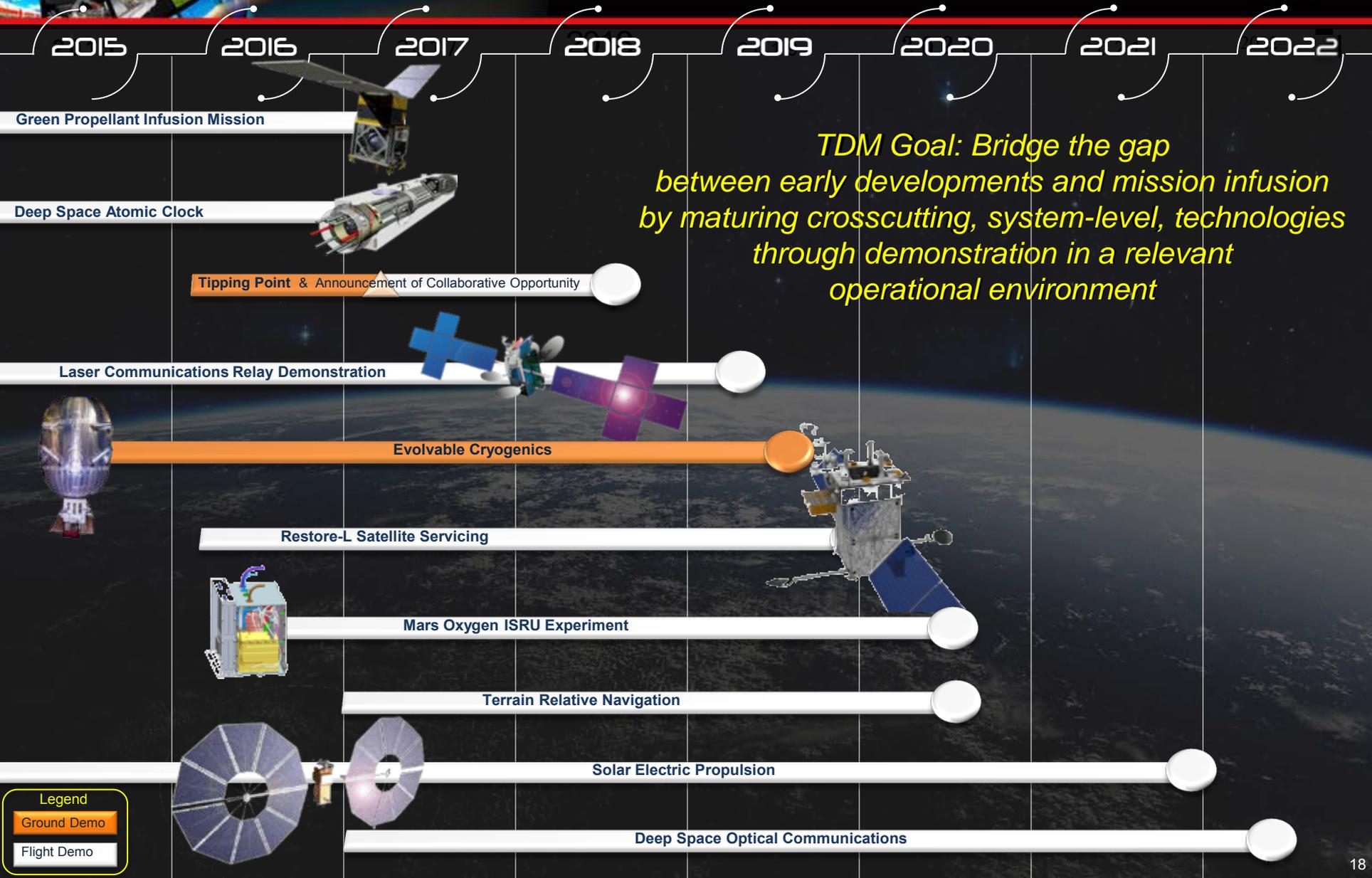


Legend

- Ground Demo
- Flight Demo

TDM Portfolio

Is



Legend
Ground Demo
Flight Demo

TDM Infusion Successes



1N AR Thrusters

TDM → **Industry**

- New class of green monopropellant thrusters have been developed and ground tested in preparation for pending spaceflight demonstration. Led by Ball Aerospace, the thrusters are already being marketed by Aerojet Rocketdyne.

GCD → **TDM** → **NASA Missions**

- A revolutionary deep space optical communication system has been developed under GCD and will be transitioned to TDM in FY17. DSOC technology has been offered for demonstration on **Discovery-class missions** and was included in four of the five proposals recently selected by SMD for further study.

Early Stage → **TDM** → **Industry**

- A University of Colorado student, under an NSTRF project, developed an approach to robotic assembly of large structures in space using intelligent precision robots. This has been transitioned to NASA and Orbital ATK as a new TDM project awarded under the FY15 Tipping Point solicitation.

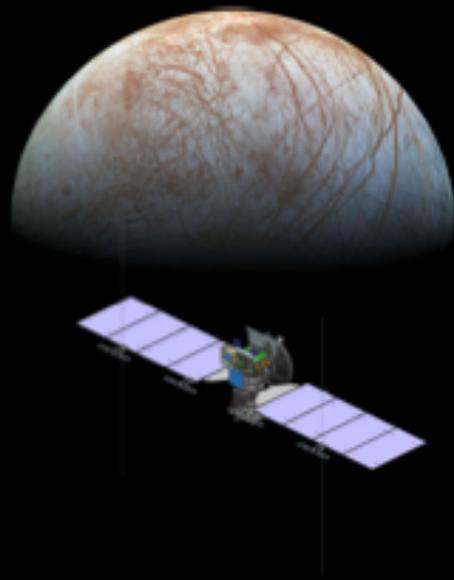


Science Mission Directorate Strategic Technology

Michael Seablom
SMD Senior Executive for Technology
March 29, 2016

Planetary Science - Technology Trends

Immediate need - augmentation of Europa mission(s)



Early Mission Technologies

- Entry, Descent, Landing
- Landers - Short Duration
- Battery Storage
- Passive Thermal Control
- Radiation Hardened Electronics
- Cold Temperature Mechanisms
- Autonomy
- Guidance, Navigation, and Control
- In Situ Instruments
- Planetary Protection

Advanced Mission Technologies

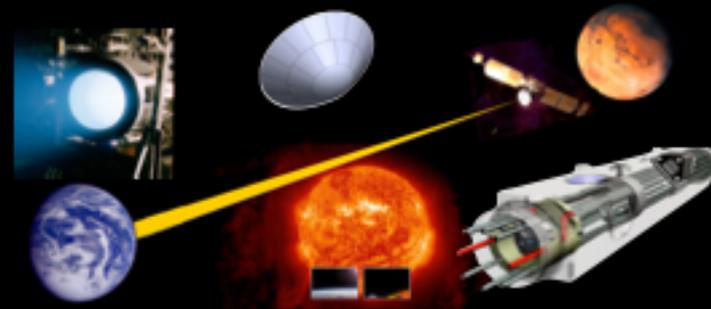
- Entry, Descent, Landing
- Landers - Long Duration
- Battery Storage
- Passive Thermal Control
- Radiation Hardened Electronics
- Cold Temperature Mechanisms
- Autonomy
- Guidance, Navigation, and Control
- In Situ Instruments
- Planetary Protection
- Mobile Surface Platforms
- Radioisotope Power
- Cold Temperature Electronics
- Communications
- In Situ Surface - Suborbital Platforms

Planetary Science Technology Working Group assessing currently-identified technology gaps and will make recommendations for near-term investments

Infusion of New Technologies into Science Missions

Planetary Science Division Assessing Lessons Learned from Discovery '14 Tech Infusion

- Technology infusions promoted via GFEs, evaluation incentives, and commercialization options
- GFEs: NEXT-C ion propulsion system, Deep Space Optical Comm, Lightweight Radioisotope Heater Units (\$5M)
- Incentives: Deep Space Atomic Clock, 3D-woven thermal protection system (\$10M)
- Good response: 18 of 27 proposals included some technology demonstration or infusion option
- Tech Demo requirements need to be more detailed in future AOs
- Interfaces need to be better defined



Tech Infusion for Discovery '14 was a partnership between SMD and the Game-Changing and Technology Demonstration Programs of STMD

Proposers were also allowed to include their own demonstrations without additional penalties for inherent technical risks

Goal: Determine if this technology infusion model can be expanded to other Divisions



TI&E Committee Finding #1



In July 2014, the NAC recommended that the SMD and STMD Associate Administrators review the policy that disincentivizes infusion of new technology into small and medium class science missions. The flagship missions utilize new technologies, but smaller missions have not.

TI&E is pleased to see incentives were added to the last Discovery round for inclusion of new technologies that could benefit future science missions. For example, 4 out of 5 selected Phase A Discovery study teams took advantage of these incentives to include new technologies (i.e. Deep Space Optical Communications).

It would be useful to explore similar technology demonstration incentives for other science program mission areas

TI&E Committee Finding #2



Restore-L mission transferred from HEO to STMD

- STMD should be applauded for embracing Restore-L as a nationally important capability demonstration mission.
- However, there was a price, with a net reduction of \$37 million in budget to STMD portfolio. Majority of the reductions from TDM, eliminates:
 - Low Density Supersonic Decelerator (LDSD)
 - Inability to accomplish EDL for Mars Sample Return mission with supersonic parachutes
 - Composite Exploration Upper Stage (CEUS)
 - Indefinitely delays the tools and certification methods to enable large, heavily loaded primary composite structures on launch vehicles
 - Lose the early opportunity to improve SLS performance by reducing dry mass?
- It appears that Restore-L has much in common with the DARPA Phoenix program, with the differentiator being LEO vs GEO demonstration
 - Has NASA collaborated with DARPA to the maximum extent possible?
 - Cumulative government investment ~\$800 million using a common set of contractors and hardware

TI&E Committee Finding #3



A set of exploration proving ground missions is currently being defined.

- TI&E looks forward to reviewing the risk reduction matrices and technology investment plans associated with the proving ground missions.
- What portion of these risk reduction technology matrices require use of ISS?
- What is the plan to retire these technology risks by the time the ISS retires in 2024?

TI&E Committee Finding #4



The mission utility of small satellites is increasing rapidly and promulgated across industry, academia and government.

The end-of-life issue associated with the operational deployment of thousands of small satellites creates a continually increasing architectural debris problem. There is a need for mitigating this potential debris problem.

Should NASA play a role in helping the government deal with this problem?

TI&E Committee

Recommendation to STMD AA



Recommendation: STMD conduct an independent study of current small satellite technology developments to determine the appropriate focus for NASA's small spacecraft technology investments.

Reasons:

- NASA is at risk for having STMD's small satellite technology investments duplicated in commoditized capabilities.
(consequence of no action)
- Given this, what is the appropriate, discriminating role for STMD vis-à-vis all the other organizations that are developing small satellite technology?