National Aeronautics and
Space Administration

Space Technology Mission Directorate

ASEB Meeting

Presented by:
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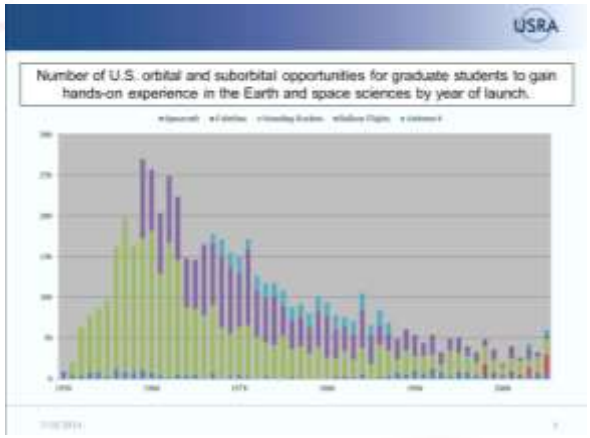
Associate Administrator, STMD

April 21,2015

Space Technology…
…. an Investment for the Future

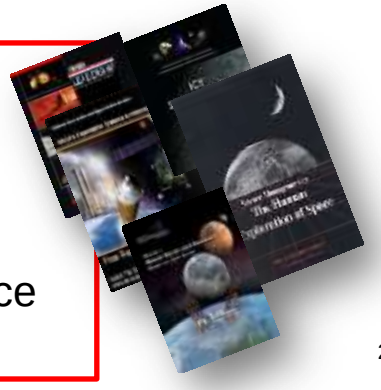
- Enables a **new class of NASA missions** beyond low Earth Orbit.
- **Delivers innovative solutions** that dramatically improve technological capabilities for NASA and the Nation.
- Develops technologies and capabilities that make NASA's missions **more affordable and more reliable.**
- Invests in the economy by **creating markets and spurring innovation** for traditional and emerging aerospace business.
- **Engages the brightest minds** from academia in solving NASA's tough technological challenges.

Addresses National Needs
A generation of studies and reports (40+ since 1980) document the need for regular investment in new, transformative space technologies.

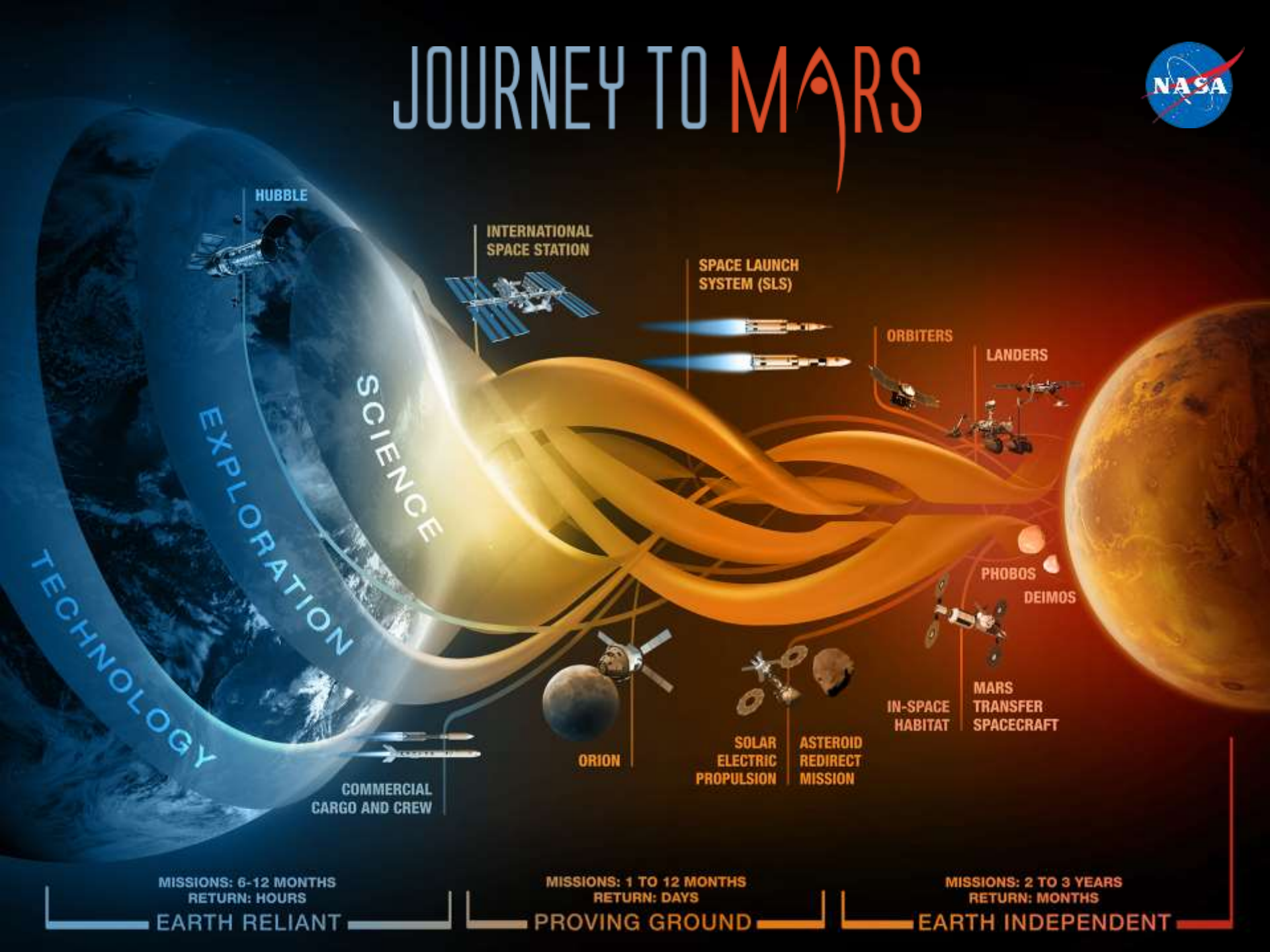


Value to NASA **Value to the Nation**

Who:
The NASA Workforce
Academia
Small Businesses
The Broader Aerospace Enterprise



JOURNEY TO MARS

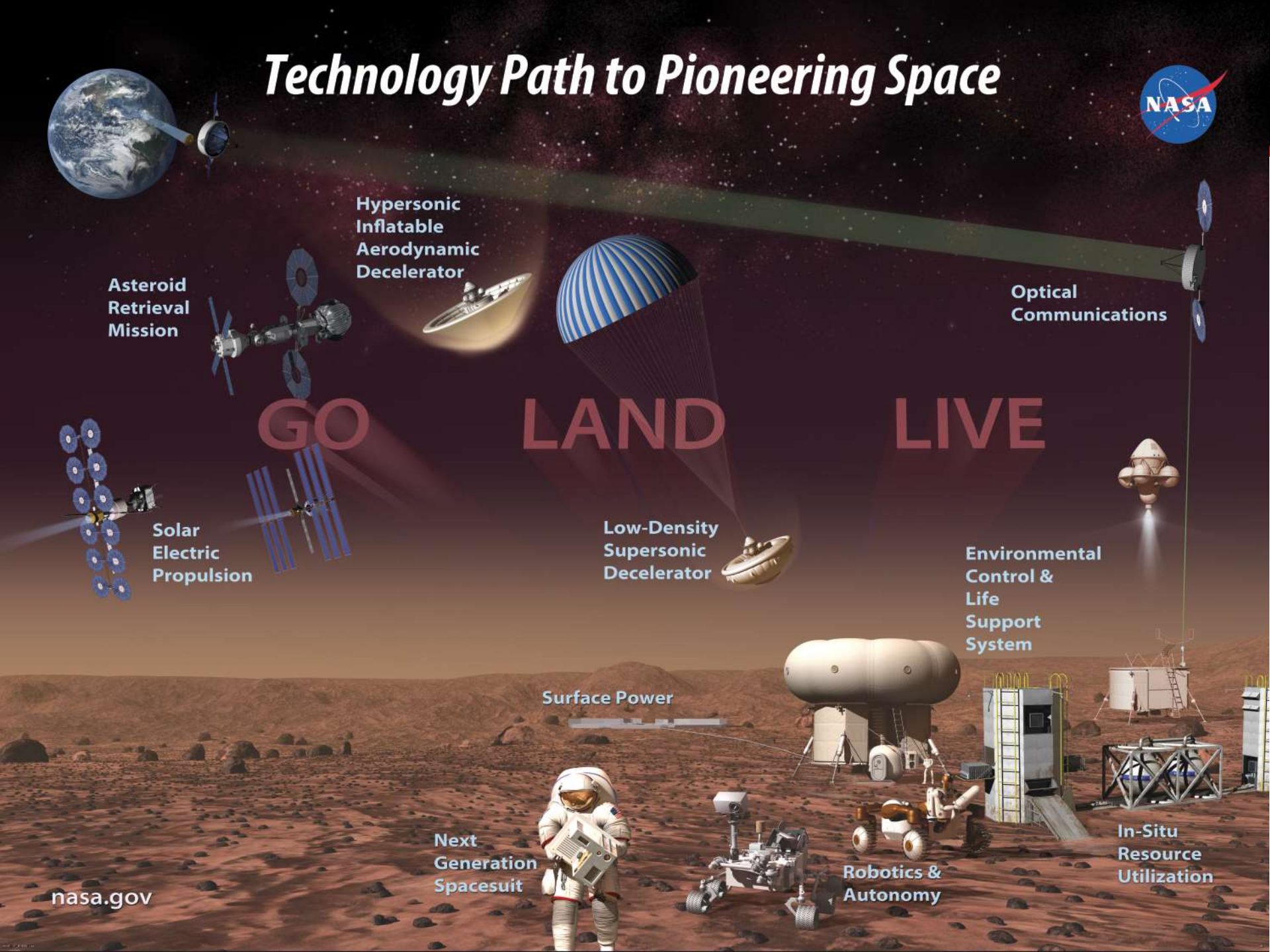


MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT

MISSIONS: 1 TO 12 MONTHS
RETURN: DAYS
PROVING GROUND

MISSIONS: 2 TO 3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

Technology Path to Pioneering Space



Technology Drives Exploration

Space Technology will focus investments in 8 thrust areas that are key to future NASA missions and enhance national space capabilities.

High Power Solar Electric Propulsion

Deep space human exploration, science missions with investments in advanced solar arrays and advanced electric propulsion systems, high-power Hall thrusters and power processing units.

Application: *Improved Affordability of commercial and OGA Satellites*

Space Optical Comm

Substantially increase available bandwidth for near Earth space communications currently limited by power and frequency allocation limits. Increase communications throughput for deep space missions.

Application: *More bandwidth for Commercial and OGA Satellites*

Advanced Life Support & Resource Utilization

Technologies for human exploration mission including Mars atmospheric In-situ resource utilization, near closed loop air revitalization and water recovery, EVA gloves and radiation protection.

Application: *Air Revitalization for Mining Industry & other closed environments*

Mars Entry Descent & Landing Systems

Permits more capable science and future human missions to Mars. Includes, hypersonic and supersonic aerodynamic decelerators, next-gen TPS materials, retro-propulsion technology, instrumentation and modeling.

Application: *Returning research from ISS and other assets from space*

Space Robotic Systems

Creates future humanoid robotics, autonomy and remote operations technologies to substantially augments the capability of future human space flight missions.

Application: *Human safe Robotics for industrial use, Disaster Response, and Autonomous Operations*

Lightweight Space Structures

Targets substantial increases in launch mass, and allow for large decreases in needed structural mass for spacecraft and in-space structures.

Application: *Industrial Materials and Composites for large transportation structures*

Deep Space Navigation

Allows for more capable science and human exploration missions using advanced atomic clocks, x-ray detectors and fast light optical gyroscopes.

Application: *Next Generation GPS & launch vehicles*

Space Observatory Systems

Allows for significant gains in science capabilities including: coronagraph technology to characterize exoplanets, advances in surface materials and better control systems for large space optics.

Application: *Industrial Materials, Earth Observation*

THRUST AREAS

Space Technology Portfolio

Transformative & Crosscutting Technology Breakthroughs

Technology Demonstration Missions bridges the gap between early proof-of-concept tests and the final infusion of cost-effective, revolutionary technologies into successful NASA, government and commercial space missions.

Small Spacecraft Technology Program develops and demonstrates new capabilities employing the unique features of small spacecraft for science, exploration and space operations.

Game Changing Development seeks to identify and rapidly mature innovative/high impact capabilities and technologies that may lead to entirely new approaches for the Agency's broad array of future space missions.

Pioneering Concepts/Developing Innovation Community

NASA Innovative Advanced Concepts (NIAC) nurtures visionary ideas that could transform future NASA missions with the creation of breakthroughs—radically better or entirely new aerospace concepts–while engaging America's innovators and entrepreneurs as partners in the journey.

Space Technology Research Grants seek to accelerate the development of "push" technologies to support future space science and exploration needs through innovative efforts with high risk/high payoff while developing the next generation of innovators through grants and fellowships.

Center Innovation Fund stimulates and encourages creativity and innovation within the NASA Centers by addressing the technology needs of the Agency and the Nation. Funds are invested to each NASA Center to support emerging technologies and creative initiatives that leverage Center talent and capabilities.

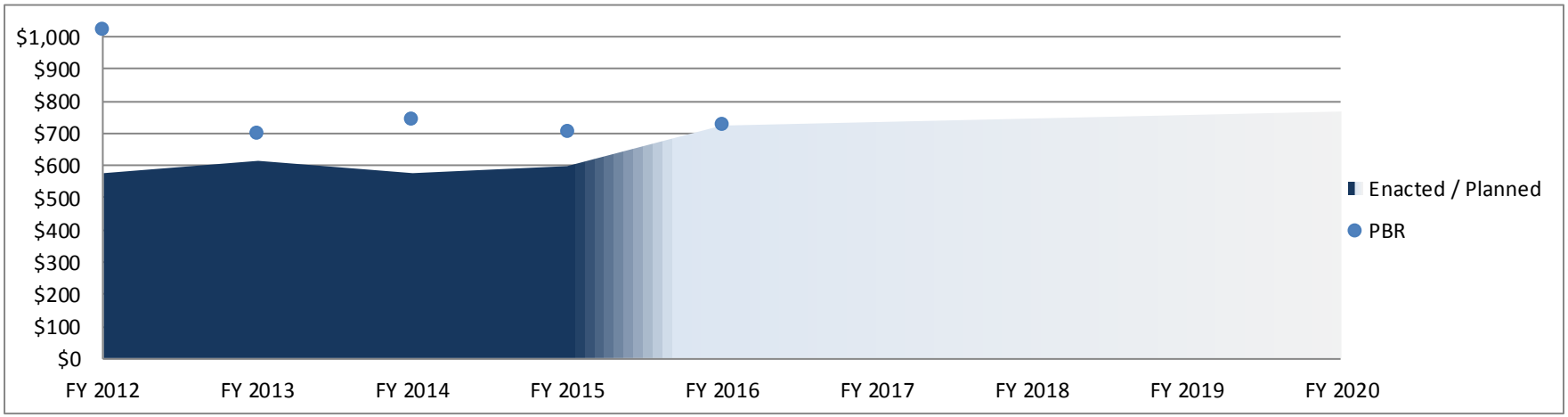
Creating Markets & Growing Innovation Economy

Centennial Challenges directly engages nontraditional sources advancing technologies of value to NASA's missions and to the aerospace community. The program offers challenges set up as competitions that award prize money to the individuals or teams that achieve a specified technology challenge.

Flight Opportunities facilitates the progress of space technologies toward flight readiness status through testing in space-relevant environments. The program fosters development of the commercial reusable suborbital transportation industry.

Small Business Innovation Research (SBIR) and **Small Business Technology Transfer (STTR)** Programs provide an opportunity for small, high technology companies and research institutions to develop key technologies addressing the Agency's needs and developing the Nation's innovation economy.

STMD FY 2016 President's Budget

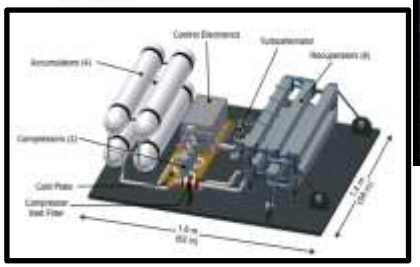


	Budget Authority ($M)	Actuals FY 2014	IOP FY 2015	PBR FY 2016	PPBE16 FY 2017	PPBE16 FY 2018	PPBE16 FY 2019	PPBE16 FY 2020
OCT	Agency Technology & Innovation	31	31	33	33	33	33	33
Space Tech Mission Directorate	SBIR and STTR	175	191	201	213	213	213	214
	Space Technology Research & Development	370	374	491	490	500	511	522
	Early Stage Innovation	45		73	75	75	75	75
	Centennial Challenges	1		5	5	5	5	5
	Flight Opportunities	10		15	15	15	15	15
	Small Spacecraft	17		19	17	17	17	17
	Game Changing Development	118		170	179	181	184	191
	Technology Demonstration Missions	180		210	198	208	216	219
	Space Technology Total	576	596	725	736	747	758	769

|----------NOTIONAL----------|

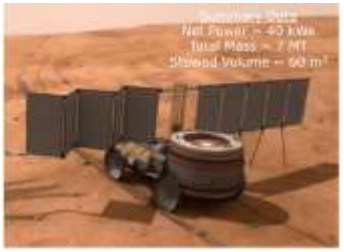
STMD Investments to Advance Future Capabilities of Space Launch System (SLS) & Orion

- Composite cryogenic propellant tanks (CCPT) and Composite Evolvable Upper Stage (CEUS), develops composite technologies for SLS upgrades
- Evolvable Cryogenics (eCryo) develops advanced cryogenic propellant management technologies, and high capacity cryocoolers for SLS future missions
- Additive manufacturing of upper stage injectors, combustion chambers and nozzles for potential SLS upgrades
- Phase change material heat exchangers for Orion in lunar orbit
- 3D Woven ablative TPS for Orion heat shield compression pads
- Advanced oxygen recovery for Orion upgrades



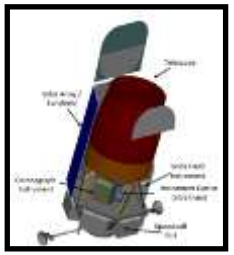
STMD Investments to Advance Human Exploration

- High Powered SEP – cargo & logistics transportation to Mars
- Small Fission Power / Stirling Cycle – Mars surface power
- HIAD / ADEPT – deployable entry systems for large downmass
- LDSD – supersonic aerodynamic decelerators & supersonic retro-propulsion for the descent of large landed mass at Mars
- Woven TPS – more efficient & flexible TPS materials for entry
- Closed loop air & water recovery – reduced consumables
- Mars atmospheric ISRU (oxygen) – life support and ascent vehicle oxidizer
- Humanoid robotics – enhanced exploration / reduced crew load
- Optical communications – high bandwidth communications



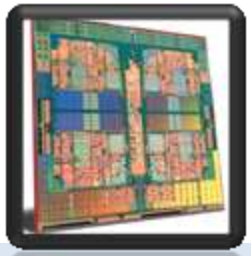
Advancing Science Mission Capabilities

- **Entry, Descent, & Landing**
  - MEDLI, MEDLI2 & Entry Systems Modeling – Mars EDL systems design
  - Woven TPS (HEEET) – Venus, Mars & Outer Planets
  - Low Density Supersonic Decelerator (LDSD) – Increased mass to Mars surface
  - Adaptable, Deployable Entry Placement Technology (ADEPT) – deployable heat shields for Venus and Mars provides much lower entry loads
- **Propulsion & Power**
  - Green Propellant Infusion Mission (GPIM)- alternative to hydrazine
  - Solar Electric Propulsion (SEP) – enabling new science missions
  - Small Fission – power for outer planet missions
- **Communication & Navigation**
  - Deep Space Optical Comm. (DSOC) & Laser Communication Relay Demo (LCRD) – up to 10x data return for planetary and near-Earth missions
  - NICER/SEXTANT & Deep Space Atomic Clock (DSAC) – Highly accurate deep space navigation, higher duty cycle for DSN data return
- **Instruments, Sensors, & Thermal**
  - High Performance Spaceflight Computing – broadly applicable to science missions
  - AFTA / WFIRST Coronagraph – to perform direct observations of exoplanets and determining their atmospheric content



STMD Investments to Advance Outer Planetary Exploration





STMD is developing TPS and deep space communication technologies for infusion in SMD's Discovery 2014 Announcement

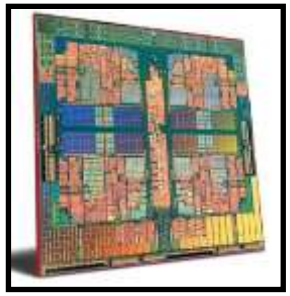
Technologies in FY 2015-2016

- Deep Space Optical Communications
- Deep Space Atomic Clock
- High Performance Space Computing
- Small Nuclear Fission / Sterling Power (kilo-power)
- Woven TPS for aerocapture and outer-planetary entry
- Europa Ice Penetration Challenge

Enabling Outer Planet Exploration

Technology investments in power (solar and nuclear), radiation protection, sensing, landing, navigation, and communications could enable a broad set of small missions to compelling planetary science targets

STMD- Aerospace Industry Alignment Examples



- **Structures and Materials**
  - Composite Exploration Upper Stage (CEUS) – Composite structures for improved launch vehicle performance
  - Manufacturing–Materials, Nanotechnology and Manf. Processes
- **Propulsion & Power**
  - Green Propellant Infusion Mission – improved spacecraft performance & reduced toxicity and ground processing costs
  - Solar Electric Propulsion (SEP) – enabling increased power, reduced mass and longer life for commercial communication satellites
- **Communication & Navigation**
  - LCRD – replacing RF based gateway links with optical links and reduce RF spectrum utilization on commercial satellites
  - Deep Space Atomic Clock – improved timing for next generation GPS satellites
- **Instruments, Sensors, & Robotics**
  - High Performance Spaceflight Computing – for more capable radiation hard avionics for commercial communication satellites
  - Human Robotic Systems (R5) – to perform environmentally hazardous tasks and operate within terrestrial settings

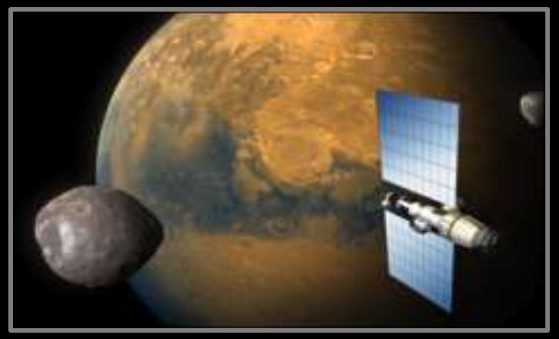
Technology Investment: High Power Solar Electric Propulsion

Solar Arrays

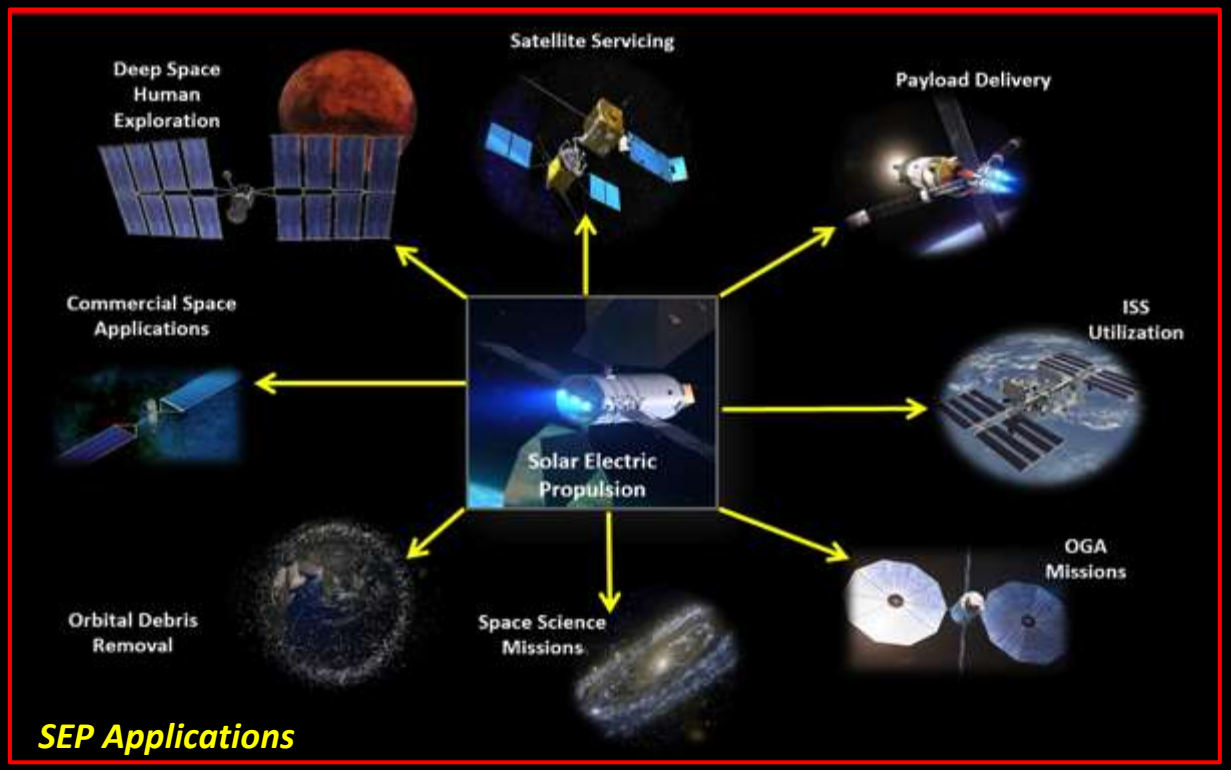
Power Processing Units (PPUs)

Thrusters

Propellant Feed System & Storage Tanks

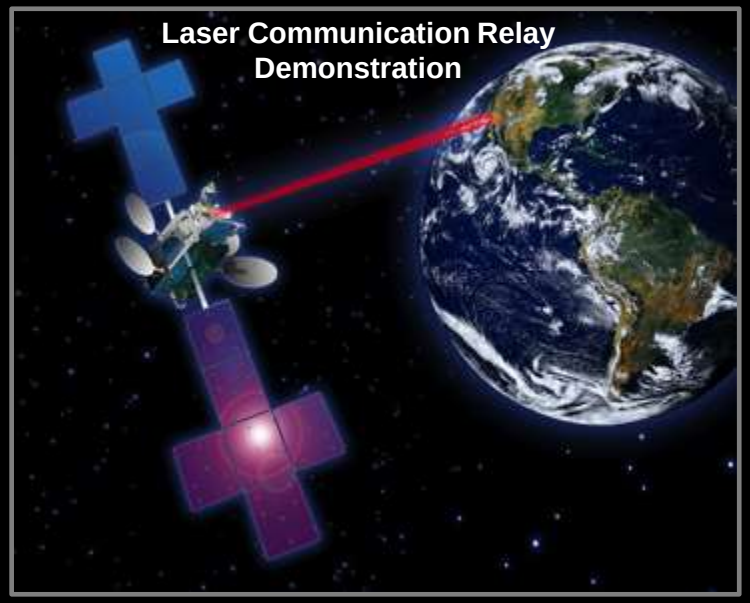


SEP "Space Tugboat"

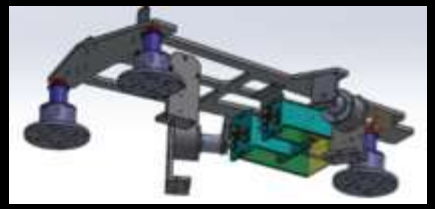


SEP Applications

Technology Investment: Optical Space Communication

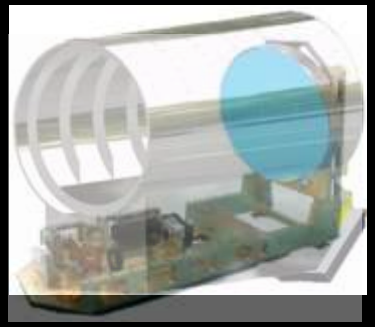


Spacecraft Disturbance Isolation

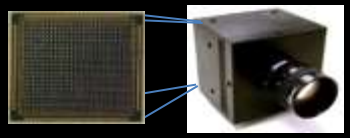


Point-Ahead Mirror

Flight Laser Transceiver



Photon-Counting Camera



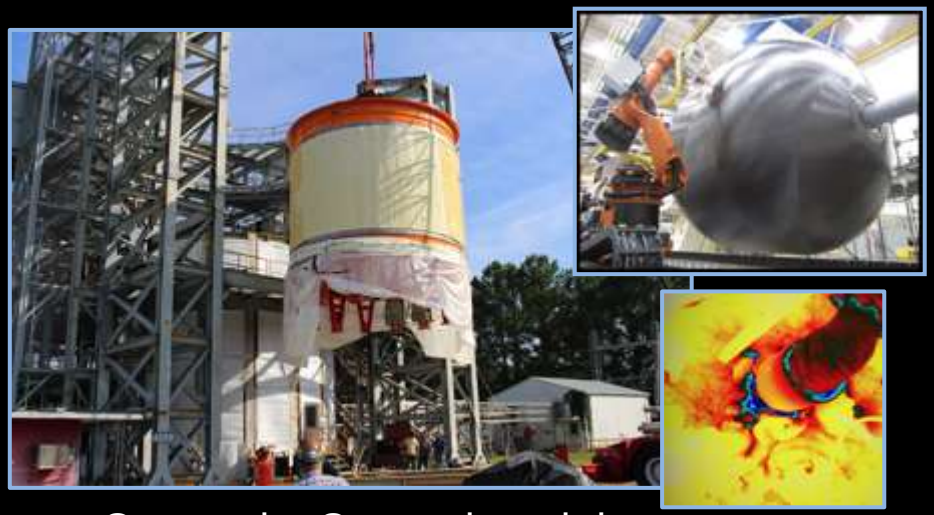
Electronics & Control

Laser Transmitter

Technology Investment: Deep Space Atomic Clock

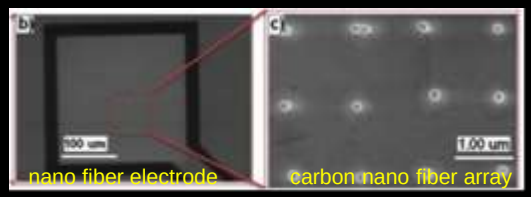
Technology Investment:
Advanced Launch Systems

Additive Manufacturing for combustion chambers and nozzles

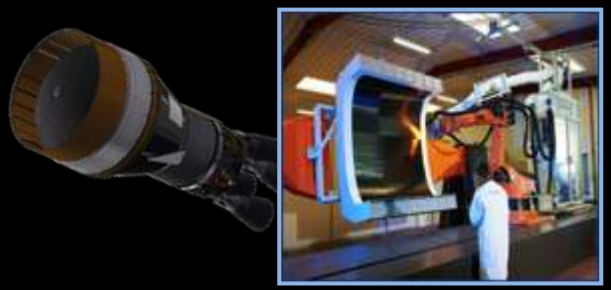


Composite Cryotank and dry structures

eCryo for upper stage



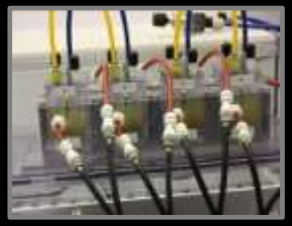
Nanotechnology



Composites for upper stage

Technology Investment: Advanced Life Support and In-Situ Resource Utilization

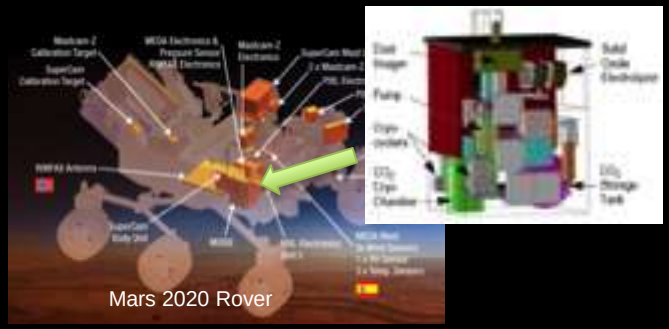
Life Support aboard ISS



Alternate Water Processor

Advanced Oxygen Recovery

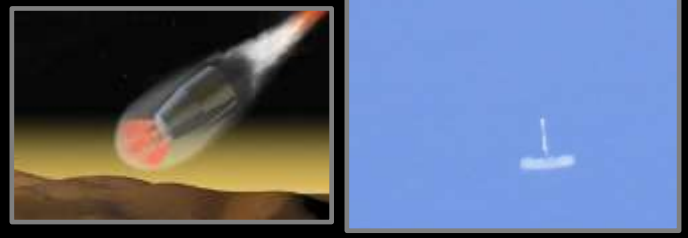
Variable Oxygen Regulator 3.0



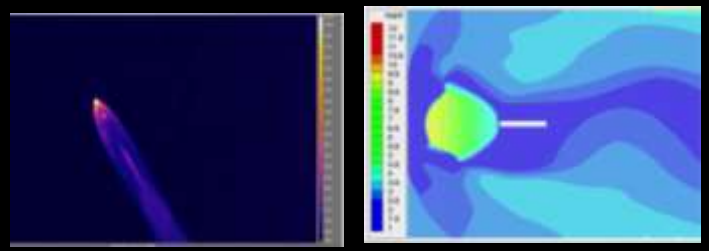
Mars Oxygen ISRU Experiment (MOXIE)

Portable Life Support System Integrated Test

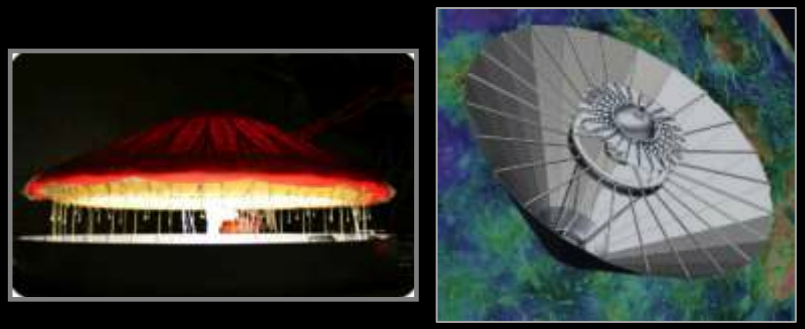
Technology Investment: Entry, Descent, and Landing



Supersonic Retro Propulsion



Computer Modeling and Data



Inflatable (HIAD) or Mechanically Deployable (ADEPT) Entry Systems

Instrumentation

Low Density Supersonic Decelerator

3-D, multi-layer preform weaving technology for thermal protection

Test Success:
Low Density Supersonic Decelerator

Successful LDSD flight test - Creating new knowledge and developing new capability

Partnering with Universities to Solve the Nation's Challenges

U.S. Universities have been *very* successful in responding to STMD's competitive solicitations

- STMD-funded university space technology research spans the entire roadmap space
- More than **130** U.S. universities have led (*or are STTR partners on*) more than **550** awards since 2011
- In addition, there are many other partnerships with other universities, NASA Centers and commercial contractors

Program	# awards	# University-led awards	Upcoming Opportunities
Space Technology Research Grants 	295	295	• Early Career Faculty • Early Stage Innovations • NASA Space Technology Research Fellowships — ***Annually***
NIAC 	93	26	• NIAC Phase I • NIAC Phase II — ***Annually***
Game Changing Technology Dev 	37	14	Various topics released as Appendices to SpaceTech-REDDI — ***Annually***
Small Spacecraft Technology 	22	13	Smallsat Technology Partnerships – new in 2013 – annual opportunities beginning in 2015
Flight Opportunities 	117	50	Tech advancement utilizing suborbital flight opportunities – NRA to U.S. Universities, non-profits and industry are planned. — ***Twice Annually***
STTR 	*192*	*181 w/ univ partners*	*Annual STTR solicitation*
Centennial Challenges 	*4 Challenges (2 university-run)*	*40 teams (9 univ-led, 1 univ-led winner)*	• *One or more challenges annually* • ***Challenge competitions*** *with a* ***procurement track*** *to fund* ***university teams*** *via grants*

Snapshot of Space Technology Partners

Working with Other Government Agencies

Currently, significant engagements include:

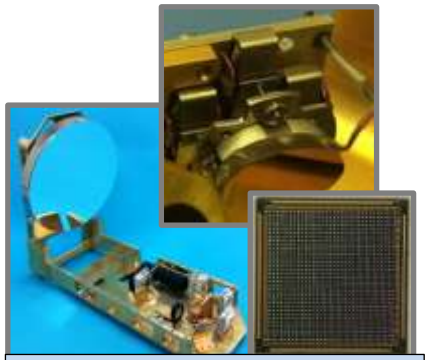
- Green Propellant Infusion Mission partnership with **Air Force Research Laboratory (AFRL)** propellant and rideshare with **DoD's Space Test Program (STP)**
- **AFRL** collaboration Phase I of a High Performance Space Computing for a low power multi-core processor increasing performance by 100 fold.
- Working with the **USAF Operationally Responsive Space Office (ORS)** for launch accommodations for the Edison Demonstration of Smallsat Networks (EDSN) mission
- Partnership with **DARPA** on "Next Generation Humanoid for Disaster Response"
- Collaboration with **ARPA-e/Dept. of Energy** in new battery chemistries to aide in battery tech development
- Collaboration with **Space Missile Command** developed a Hosted Payload IDIQ contract mechanism for low cost access to space

STMD has ***45 activities*** with ***43 other government agencies***, and ***10 activities*** with ***14 international organizations***. STMD is sharing rides for ***13 activities***.

STMD Successes Video

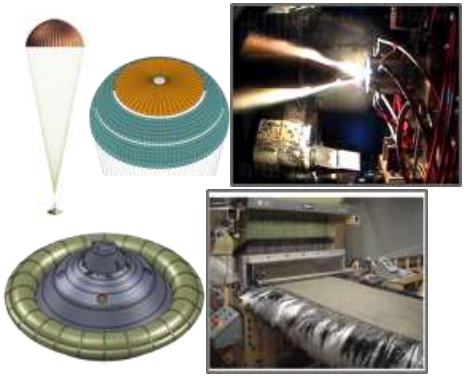
Looking Forward to Future Technology Successes

Flight Demo for Green Propellant Infusion Mission



Technology Development for Deep Space Optical Communication

Solar Electric Propulsion Testing



Completion of Entry, Descent and Landing Technology

Creating New Markets and Spurring Innovation while Engaging the Brightest Minds

Flight Demo for Deep Space Atomic Clock

Future Demos on ISS

National Aeronautics and
Space Administration

Technology Drives Exploration

www.nasa.gov/spacetech