



Space Technology Mission Directorate

Joint HEO/TI&E NAC
Committee Session

Mr. Stephen Jurczyk
Associate Administrator

July 2015

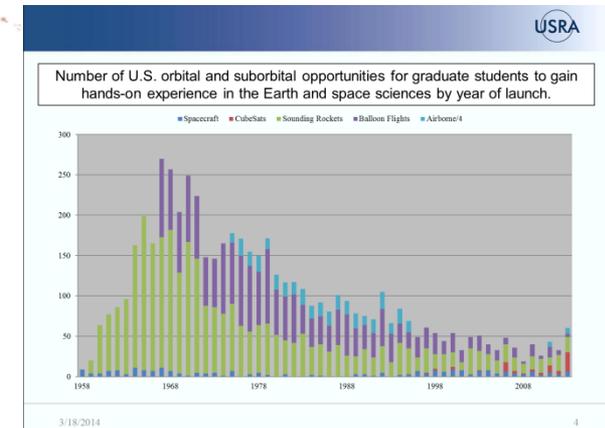
Space Technology... an Investment for the Future



- 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

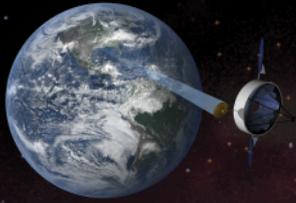


Guiding Principles of the Space Technology Programs

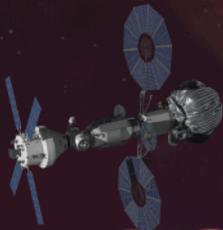


- **Adhere to a Stakeholder Based Investment Strategy:** NASA Strategic Plan; NASA Space Tech Roadmaps / NRC Report; NASA Mission Directorate / Commercial advocacy
- **Invest in a Comprehensive Portfolio:** Covers low to high TRL; Grants & Fellowships; SBIR & prize competitions; prototype developments & technology demonstrations
- **Advance Transformative and Crosscutting Technologies:** Enabling or broadly applicable technologies with direct infusion into future missions
- **Develop Partnerships to Leverage Resources:** Partnerships with Mission Directorates and OGAs to leverage limited funding and establish customer advocacy; Public – Private Partnerships to provide NASA resources and support to U.S. commercial aerospace interests
- **Select Using Merit Based Competition:** Research, innovation and technology maturation, open to academia, industry, NASA centers and OGAs
- **Execute with Lean Structured Projects:** Clear start and end dates, defined budgets and schedules, established milestones, lean development, and project level authority and accountability.
- **Infuse Rapidly or Terminate Promptly:** Operate with a sense of urgency; Rapid cadence of tech maturation; informed risk tolerance to implement / infuse quickly or terminate
- **Place NASA at technology's forefront – refreshes Agency's workforce:** Results in new inventions, enables new capabilities and creates a pipeline of NASA and national innovators, and refreshes the agencies technical capabilities / workforce

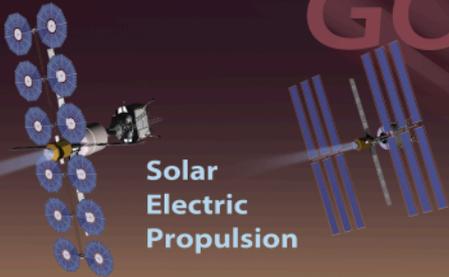
Technology Path to Pioneering Space



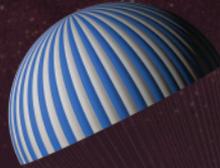
Asteroid Retrieval Mission



Solar Electric Propulsion



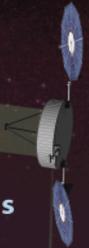
Hypersonic Inflatable Aerodynamic Decelerator



Low-Density Supersonic Decelerator



Optical Communications



Environmental Control & Life Support System



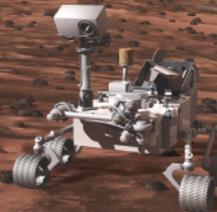
Surface Power



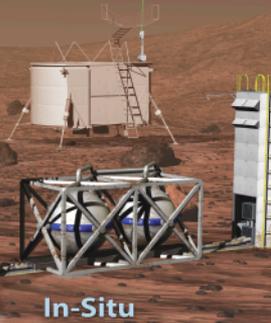
Next Generation Spacesuit



Robotics & Autonomy



In-Situ Resource Utilization





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 augment 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

Pioneering Concepts/Developing Innovation Community

Creating Markets & Growing Innovation Economy

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.



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.



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.



Small Spacecraft Technology Program

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



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.



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.

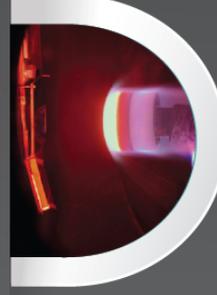
Game Changing Development

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.



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.

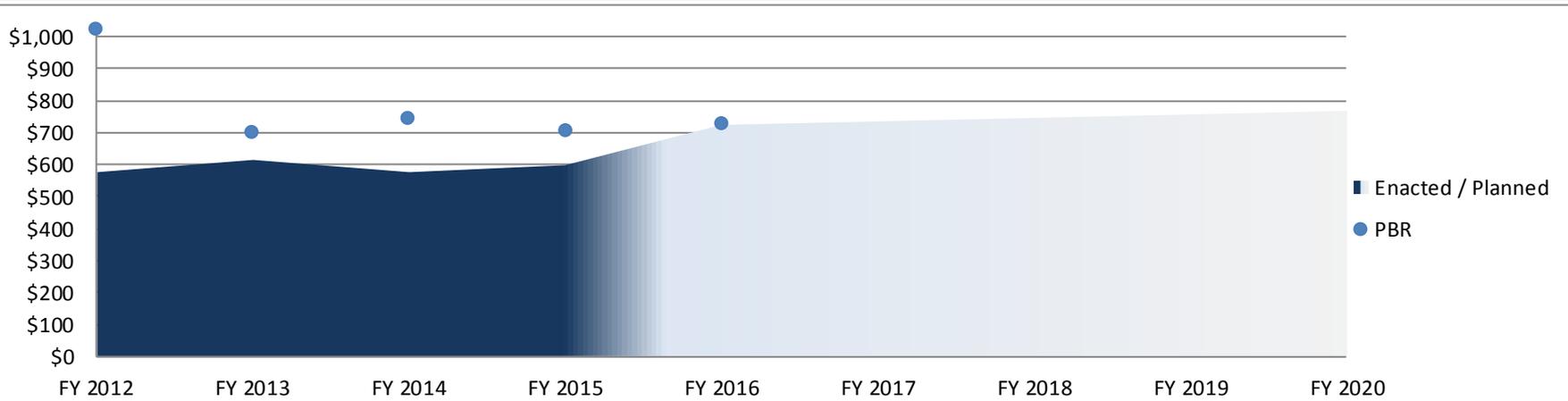


Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)

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	FY 2018	FY 2019	FY 2020
OCT	<u>Agency Technology & Innovation</u>	31	31	33	33	33	33	33
	<u>SBIR and STTR</u>	175	191	201	213	213	213	214
Space Tech Mission Directorate	<u>Space Technology Research & Development</u>	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
	<u>Space Technology Total</u>	576	596	725	736	747	758	769

-----NOTIONAL-----



STMD & AES Development Objectives



Exploration Technology Development element in STMD

- Develop long-range foundational and transformative technologies and components to support exploration needs (GCD program)
- Conduct flight demonstration missions of high-priority exploration capabilities such as solar electric propulsion (TDM program)
- Mature technologies for infusion into mission-level programs and agency initiatives such as ISS, Orion, SLS, and ARM
- Leverage synergies with game-changing and crosscutting technologies to support multiple customers and mission applications such as SMD, other government agencies, and the commercial sector

Advanced Exploration Systems program in HEOMD

- Development of exploration systems to reduce risk, lower lifecycle cost, and validate operational concepts for future human missions beyond Earth orbit
- Demonstrate prototype systems in ground test beds, field tests, underwater tests, and ISS flight experiments
- Use and pioneer innovative approaches for affordable rapid systems development and provide hands-on experience for the NASA workforce
- Maintain critical competencies at the NASA Centers and provide NASA personnel with opportunities to learn new and transform skills
- Infuse new STMD/ETD-developed technologies into exploration missions and AES test beds
- Support robotic missions of opportunity to characterize destinations for human exploration

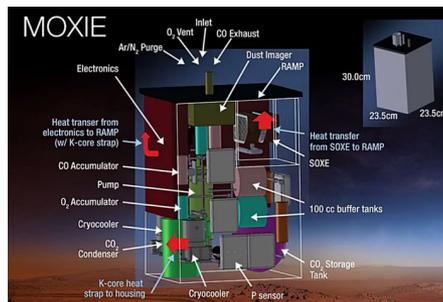


AES – STMD Cooperation Status



Three major categories of STMD and AES cooperation:

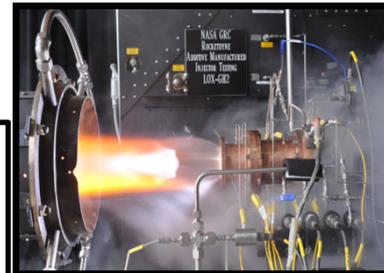
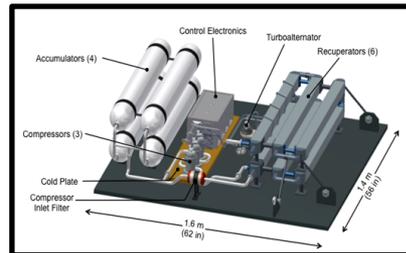
- **Deliveries:** STMD matures technology and delivers to AES for system-level evaluation
 - Examples include Rapid Cycle Amine, Variable Oxygen Regulator, EVA Gloves, and Resource Prospector Mission instruments
- **Partnerships:** STMD and AES co-fund the development of technologies that are of mutual interest
 - Examples include Mars Oxygen ISRU Experiment (MOXIE), Mars EDL Instrumentation 2 (MEDLI-2), and Spacecraft Oxygen Recovery
- **Coordinations:** STMD and AES define specific divisions of responsibility within a technical discipline area
 - Examples include nuclear systems and advanced manufacturing



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



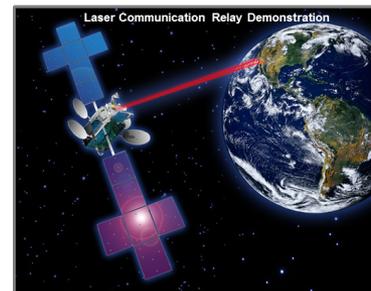
- Composite cryogenic propellant tanks (CCPT) and Composite Evolvable Upper Stage (CEUS), develops composite technologies for SLS upgrades
- Evolvable Cryogenics (eCryo) develops advanced cryogenic propellant management technologies, and high capacity cryocoolers for SLS future missions
- Additive manufacturing 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



STMD- Aerospace Industry Alignment Examples



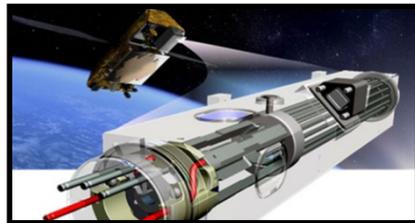
➤ Structures and Materials

- Composite Exploration Upper Stage (CEUS) – Composite structures for improved launch vehicle performance
- Manufacturing–Materials, Nanotechnology and Manf. Processes



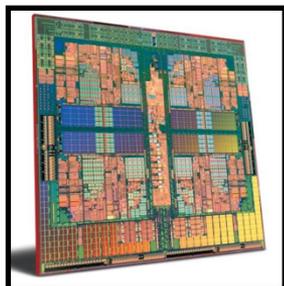
➤ Propulsion & Power

- 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

Advancing Mars Capabilities: Progress through Missions to GO and LAND



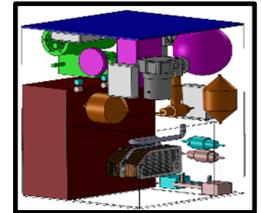
Mars Science Laboratory (MSL)

- First-ever comprehensive **entry, descent, and landing (EDL)** measurements on flight through Martian atmosphere in 2012 landing
- Understanding the Martian environment: measurements of water, atmosphere, and radiation



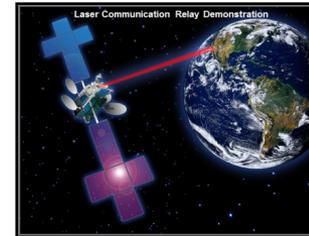
Mars 2020

- **In-situ resource utilization (ISRU):** Demonstrate oxygen conversion on Mars 2020
- Continue EDL measurements on landing and include first-ever measurements on backshell



Discovery 2014

- **Thermal protection system (TPS):** New class of materials (woven TPS) in development for Venus entry in Discovery 14 Opportunity
- **Deep-space optical communications:** First-ever demonstration of high-bandwidth communications from deep-space



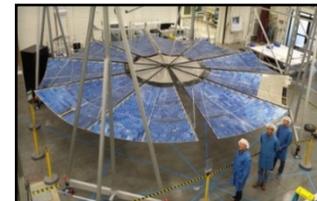
Orion EM-1

- **Thermal Protection System:** Variant of woven TPS will be flown on EM-1 mission as the compression pads.



Asteroid Redirect Mission

- **In-space propulsion and power:** high-power solar electric propulsion demonstration
- Possible demonstration of high-power solar arrays on ISS





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	<ul style="list-style-type: none"> • Early Career Faculty • Early Stage Innovations • NASA Space Technology Research Fellowships <i>Annually</i>
 NIAC	93	26	<ul style="list-style-type: none"> • NIAC Phase I • NIAC Phase II <i>Annually</i>
 Game Changing Technology Dev	37	14	Various topics released as Appendices to SpaceTech-REDDI <i>Annually</i>
 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. <i>Twice Annually</i>
 STTR	192	181 w/ univ partners	<i>Annual STTR solicitation</i>
 Centennial Challenges	4 Challenges (2 university-run)	40 teams (9 univ-led, 1 univ-led winner)	<ul style="list-style-type: none"> • One or more challenges annually • Challenge competitions with a procurement track to fund university teams via grants

Snapshot of Space Technology Partners





Key Milestones in 2015-16



Green Propellant: demonstrates propellant formula, thrusters, and integrated propulsion system, for higher performing, safe alternative to highly toxic hydrazine. (Launch STP-2 NET 9/2016)

Deep Space Atomic New space clock improving navigational accuracy for deep space (Launch STP-2 NET 9/2016)

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

Small Spacecraft Technology: Four small spacecraft demonstration missions:

EDSN: Small spacecraft swarm operating as a network for distributed science observations.

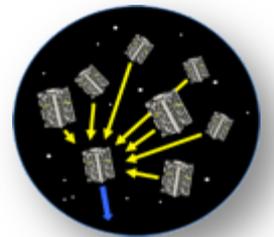
ISARA: Uses a deployed solar array as a Ka-band radio antenna reflector

OCSD: Demonstrating in-space laser communications using 2 cubesats.

CPOD: Proximity operations and docking demo with 2 cubesats

Delivers Low Density Supersonic Decelerators

Conducted second supersonic flight demonstrations of a ring-sail parachute and a supersonic inflatable aerodynamic decelerator.





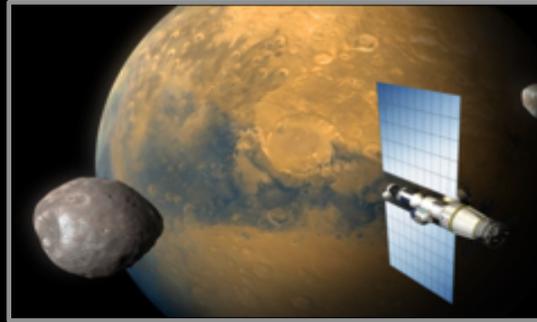
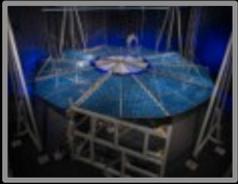
Technology Drives Exploration

www.nasa.gov/spacetech

Technology Investment: High Power Solar Electric Propulsion



Solar Arrays



SEP
"Space Tugboat"

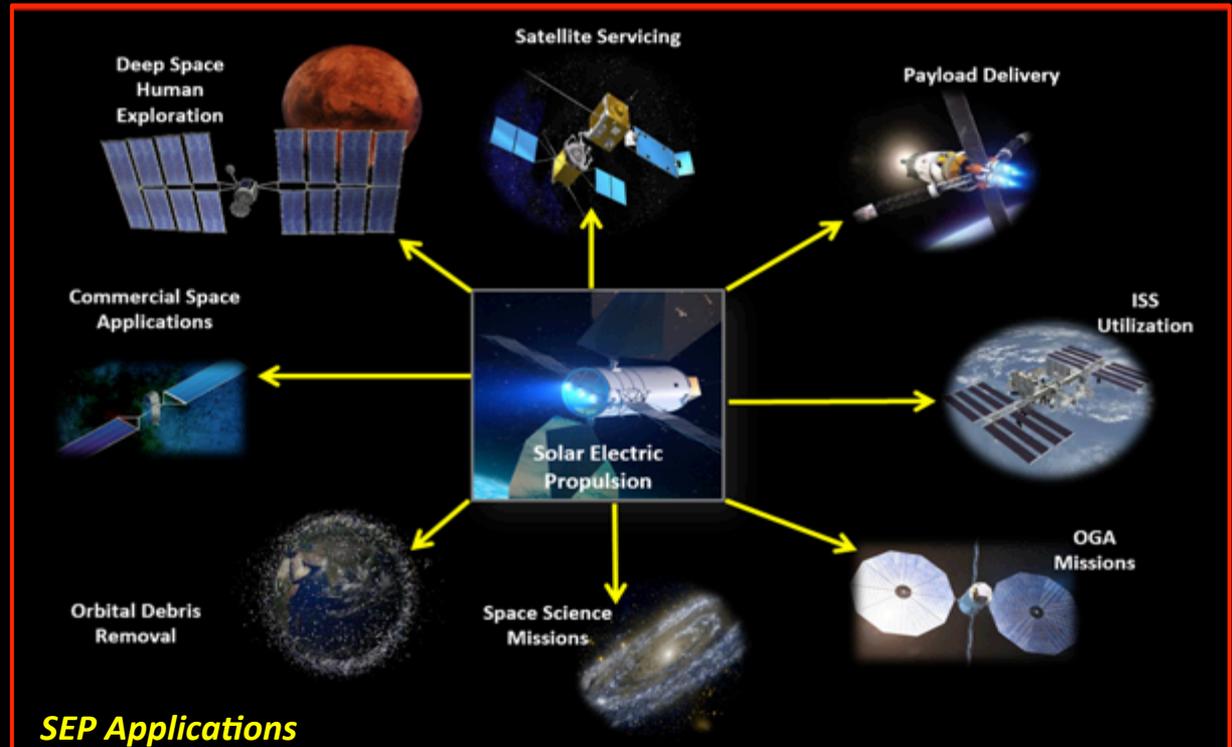
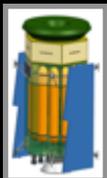
Power Processing Units (PPUs)



Thrusters



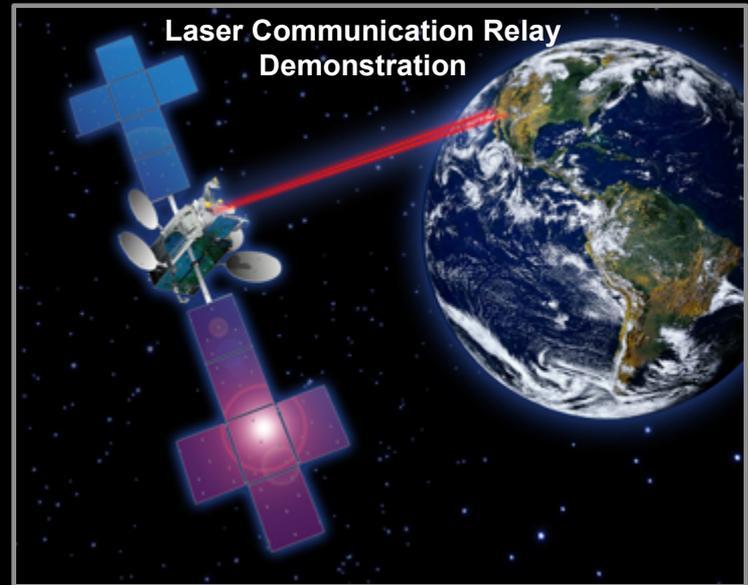
**Propellant Feed System &
Storage Tanks**



Technology Investment: Optical Space Communication

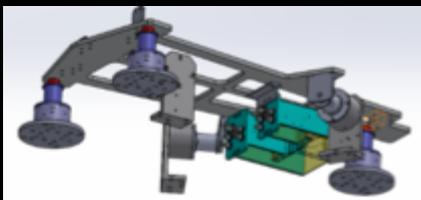


Spacecraft
Disturbance
Isolation

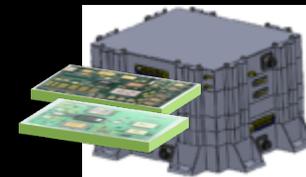
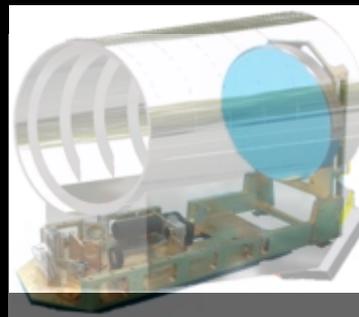


Flight Laser
Transceiver

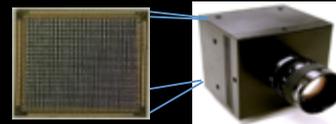
Electronics
& Control



Point-
Ahead
Mirror

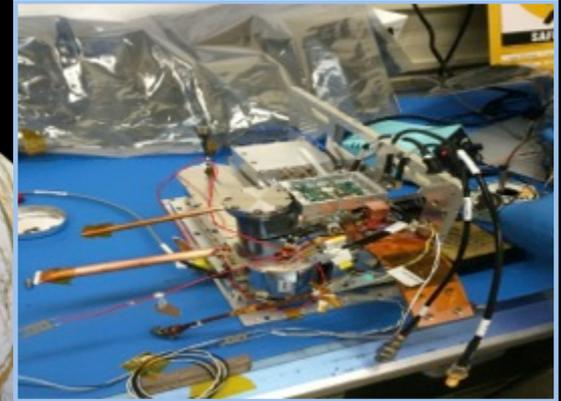
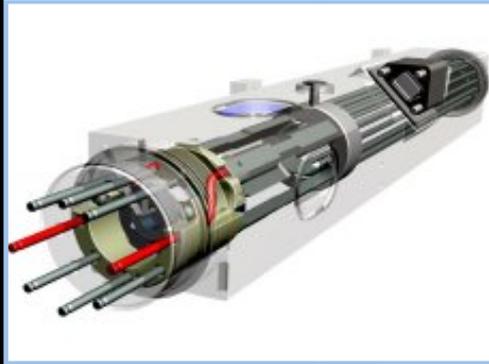


Photon-
Counting
Camera

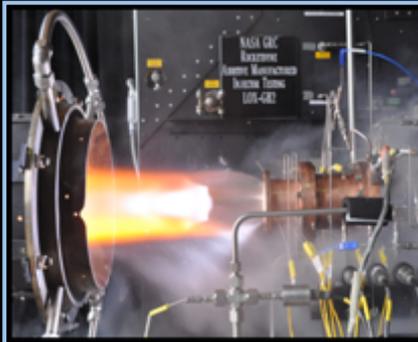


Laser
Transmitter

Technology Investment: Deep Space Atomic Clock



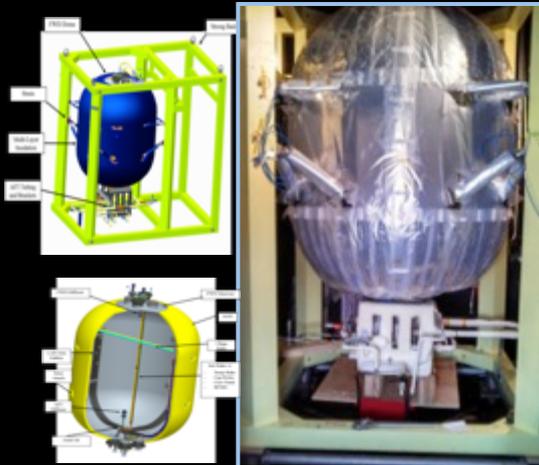
Technology Investment: Advanced Launch Systems



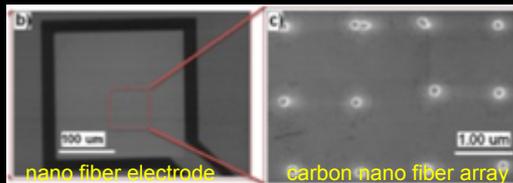
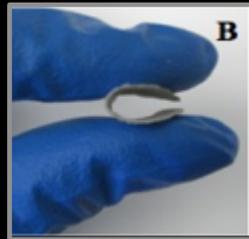
Additive Manufacturing for
combustion chambers and nozzles



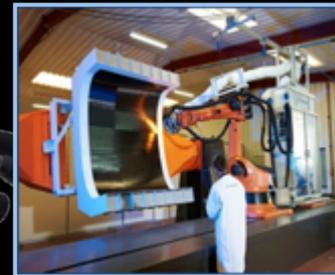
Composite Cryotank and dry
structures



eCryo for upper stage



Nanotechnology

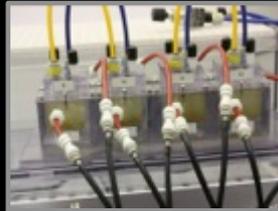
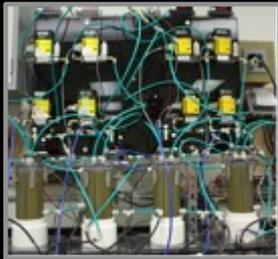


Composites for upper
stage

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



Life Support aboard ISS

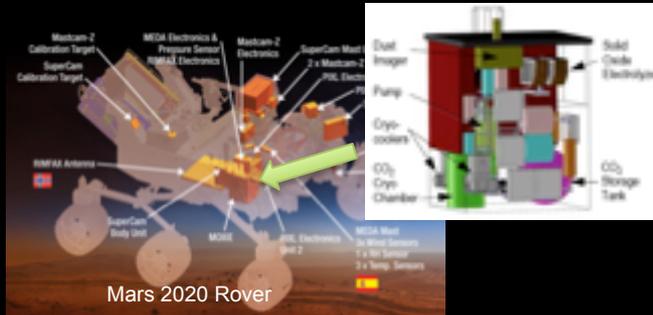


Alternate Water Processor

Advanced Oxygen Recovery



Variable Oxygen
Regulator 3.0



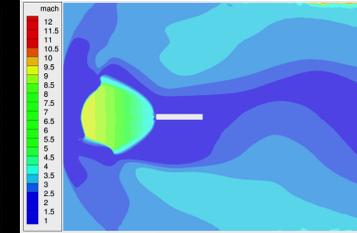
Mars Oxygen ISRU
Experiment (MOXIE)



Portable Life
Support
System
Integrated
Test

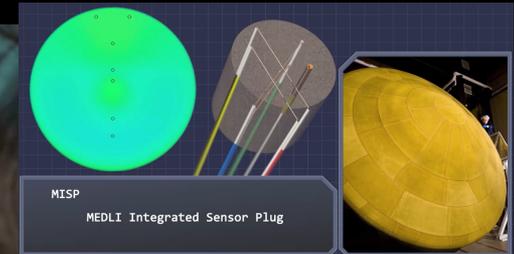
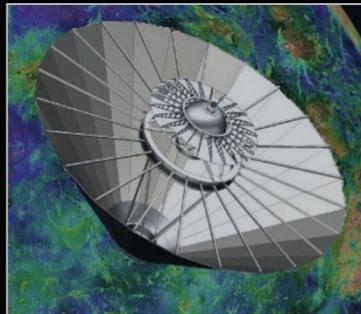


Technology Investment: Entry, Descent, and Landing



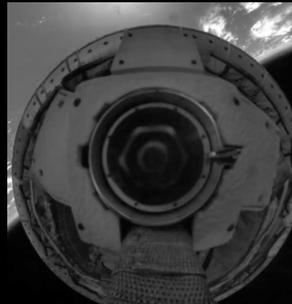
Supersonic Retro Propulsion

Computer Modeling and Data



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

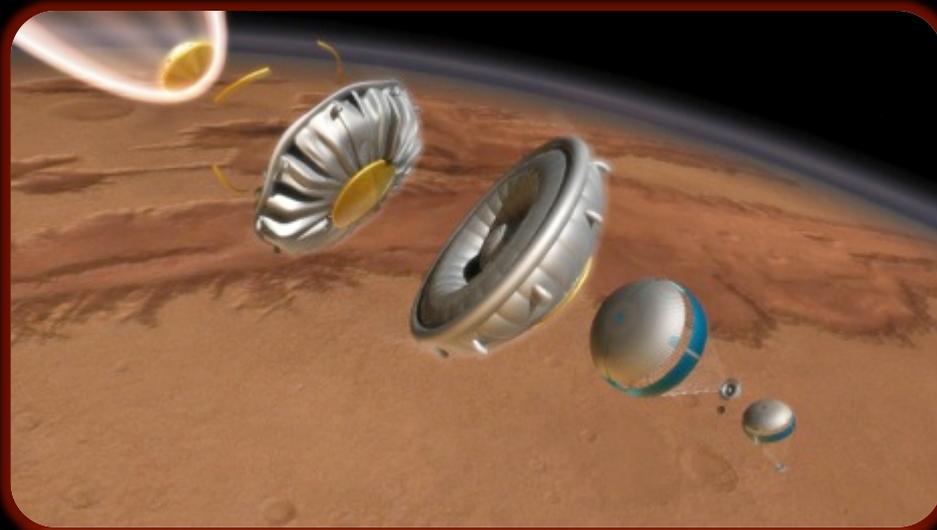
Instrumentation



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**

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**.

