National Aeronautics and
Space Administration

Space Technology Mission Directorate

Aeronautics and Space Engineering Board

Presented by:
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Associate Administrator, STMD

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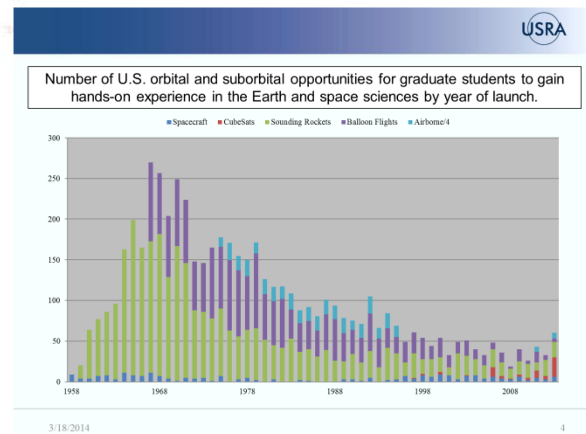
Space Technology…
…. an Investment for the Future

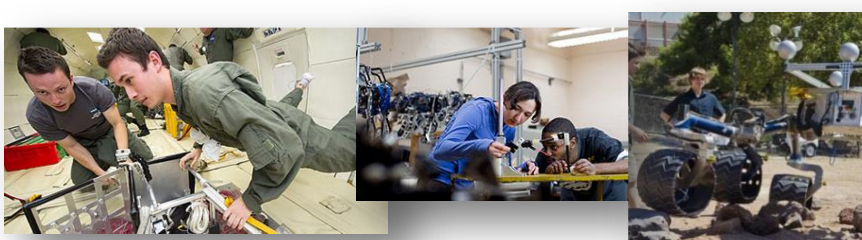
- Enables a **new class of NASA missions** beyond low Earth Orbit.
- **Delivers innovative solutions** that dramatically improve technological capabilities for NASA and the Nation.
- Develops technologies and capabilities that make NASA's missions **more affordable and more reliable.**
- Invests in the 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.



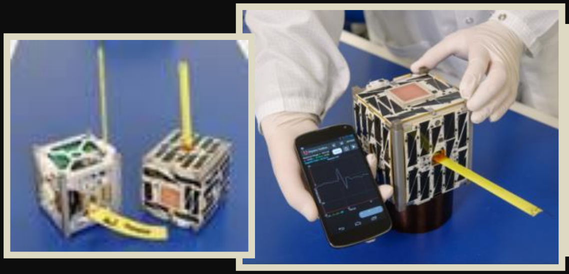
Value to NASA **Value to the Nation**



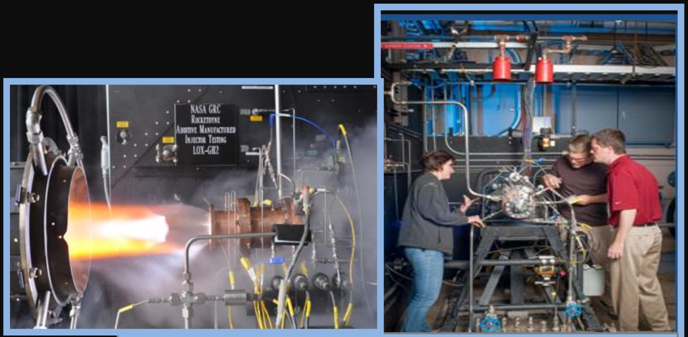
Who:

The NASA Workforce
Academia
Small Businesses
The Broader Aerospace Enterprise

Major Highlights

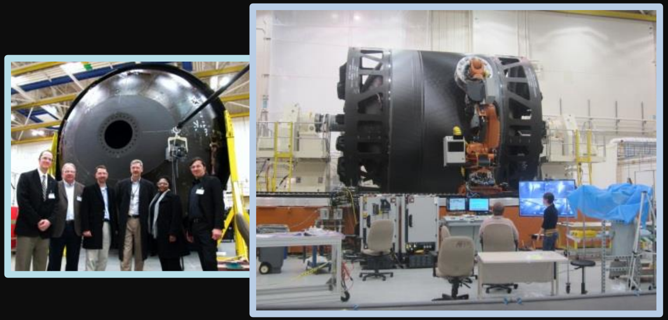


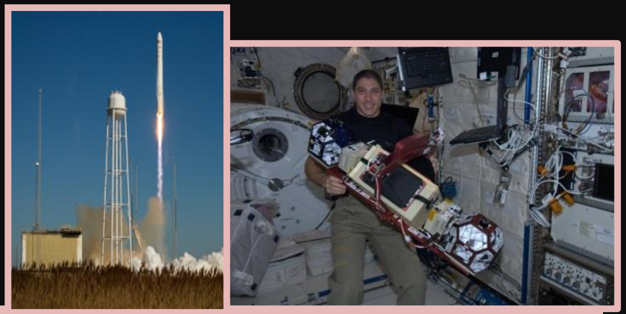
The PhoneSat 2.5 mission will be launched as a rideshare on SpaceX vehicle, to demonstrate command and control capability of operational satellites.



NASA engineers successfully hot-fire tested a 3-D printed rocket engine injector at NASA GRC, marking one of the first steps in using additive manufacturing for space travel.

Successfully fabricated a 5.5-meter composite cryogenic propellant tank and testing at Boeing's facility in Washington and will continue testing at NASA MSFC this year.



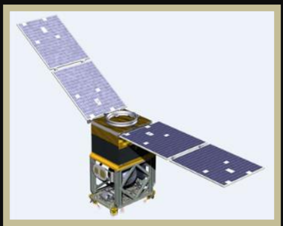


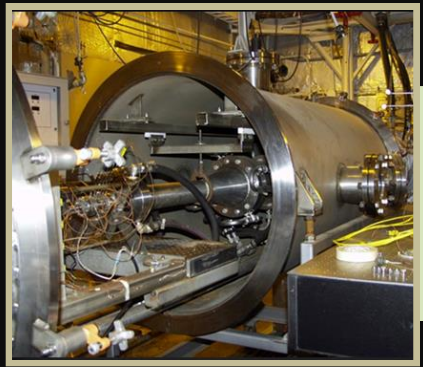
ISS Fluid SLOSH experiment launched on Antares /Orb-1 on Dec. 18, 2014 and now aboard ISS for testing that will be used to improve our understanding of how liquids behave in microgravity

The Flight Opportunities program enabled flight validation of 35 technologies that were tested in space-like environments on four different flight platforms .

At NASA MSFC, the largest 3-D printed rocket engine injector NASA has ever tested blazed to life at an engine firing that generated a record 20,000 pounds of thrust.

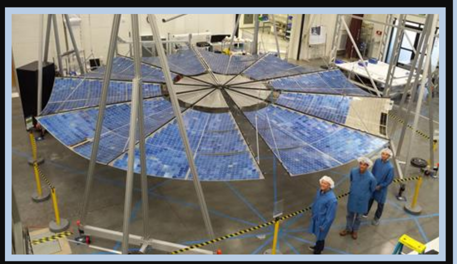
Major Highlights





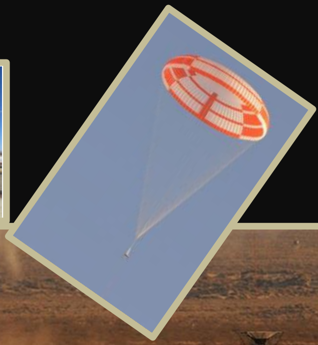
Green Propellant Infusion Mission took another step closer to infusion by proving capabilities for continuous thrust during testing and is preparing for flight test in 2015.

NASA's built and is sending a set of high-tech legs up to the ISS for Robonaut 2 (R2) that will provide R2 the mobility it needs to help with regular and repetitive tasks inside and outside the space station



ATK's “MegaFlex” (left) and DSS “ROSA” (right) solar array are two concepts NASA is maturing to support the development of next generation solar arrays in advancing Solar Electric Propulsion (SEP) technology

Low density supersonic decelerator parachute testing at China Lake, CA. Successfully demonstrated ability to deploy and pull a large parachute with 90,000 pounds of force taking the next steps to landing on Mars.



Surface Telerobotics-

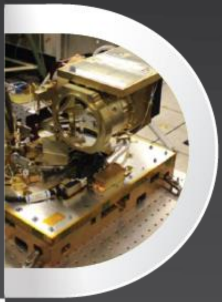
First real-time remote operations of a robotic rover from space and first simulation of human-robot waypoint mission

Space Technology Portfolio

Transformative & Crosscutting Technology Breakthroughs

Technology Demonstration Missions

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

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

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)

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

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

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

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.

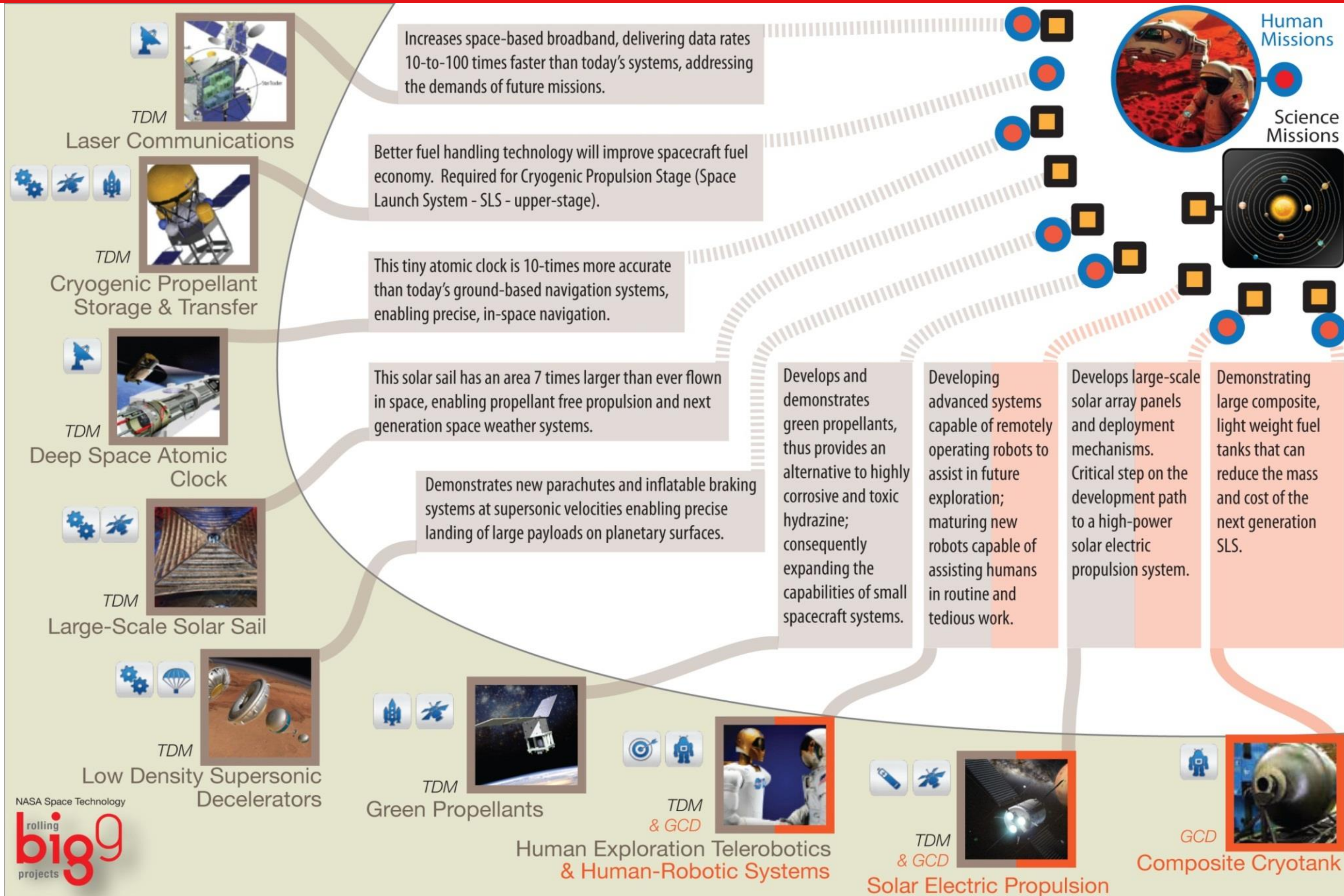
Flight Opportunities

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)

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.

FY2014 Big Nine

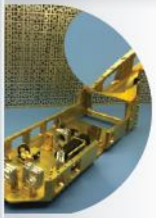


Deep Space Exploration is Near

Space Technology will focus investments in 8 key thrust areas that will enable or substantially enhance future NASA mission capabilities.

High Power Solar Electric Propulsion

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



Space Optical Comm.

Substantially increase the available bandwidth for near Earth space communications currently limited by power and frequency allocation restrictions, and increase the communications throughput for a deep space mission.

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.

Mars Entry Descent and Landing Systems

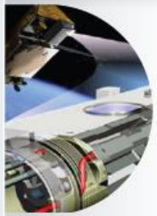
Permits more capable science missions, eventual human missions to mars including, hypersonic and supersonic aerodynamic decelerators, a new generation of compliant TPS materials, retro-propulsion technologies, instrumentation and modeling capabilities.

Space Robotic Systems

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

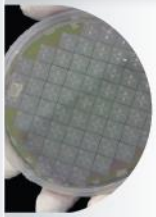
Lightweight Space Structures

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

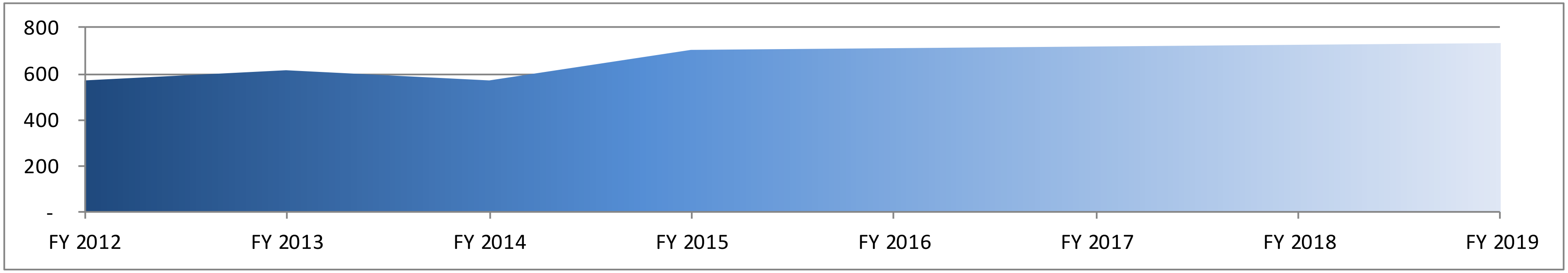


Space Observatory Systems

Allows for significant increases in future science capabilities including, AFTA/WFIRST coronagraph technology to characterize exo-planets by direct observation and advances in the surface materials as well as control systems for large space optics.

THRUST AREAS

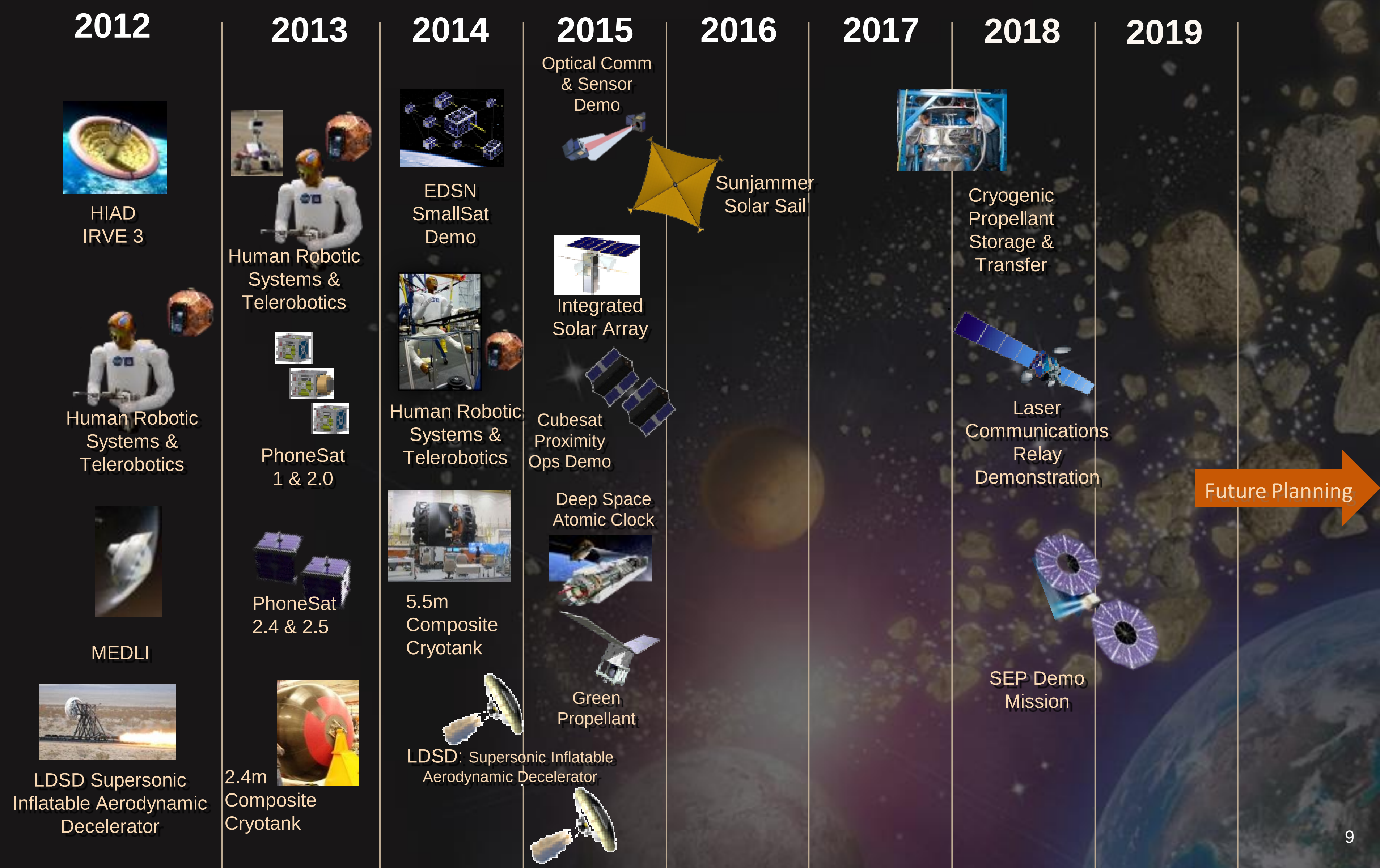
STMD FY2015 President's Budget



	Budget Authority ($M)	FY 2015	Notional FY 2016	FY 2017	FY 2018	FY 2019
	FY 2015 President's Budget Request	**706**	**713**	**720**	**727**	**734**
OCT	Partnership Developments and Strategic Integration	**34**	**34**	**34**	**34**	**34**
Space Tech Mission Directorate	SBIR and STTR	**191**	**201**	**212**	**212**	**212**
	Crosscutting Space Tech Development	**257**	**190**	**186**	**199**	**204**
	Early Stage Innovation	67	67	68	69	69
	Flight Opportunities	15	15	15	15	15
	Small Spacecraft	17	17	17	17	17
	Game Changing Development	50	45	49	36	39
	Technology Demonstration Missions	106	46	36	61	63
	Exploration Technology Development	**224**	**288**	**288**	**282**	**285**
	Game Changing Development	103	129	126	132	129
	Technology Demonstration Missions	121	159	162	150	156

*Numbers do not total due to rounding

CY Major Events & Milestones



Technology Demonstration Missions

Goal:

- Bridge the gap between early developments and mission infusion by maturing crosscutting, system-level, technologies through demonstration in a relevant operational environment.

Demos:

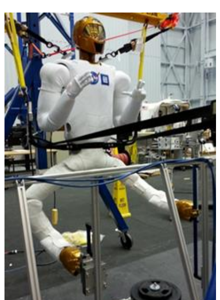
- **Ground-based and atmospheric demonstrations** of a supersonic parachute and inflatable decelerator
- **Spaceflight** of new technologies including: a space-borne atomic clock, laser communications relay, "green" propellant demonstrator, solar sail, cryogenic propellant storage and transfer, instrumentation on the MSL aeroshell, and telerobotics on the ISS.

Highlights:

- Selection of two deployable solar array designs to be developed for the Solar Electric Propulsion (SEP) project
- Successful development and testing of 22N thrusters under the Green Propellant Infusion Mission (GPIM)
- Completion of mission design, fabrication and testing of prototype boom, and sail quadrant under Solar Sail Demonstration
- Successful demonstration of a robotics-class Supersonic Inflatable Aerodynamic Decelerator (SIAD) on a rocket sled at China Lake Naval Air Weapons Station by Low Density Supersonic Decelerator Project
- Human Exploration Telerobotics conducted Robonaut 2 testing on ISS, Smart SPHERES testing on ISS, and surface telerobotics testing with astronauts on the ISS controlling the K10 rover on the ground.

Plans for FY 2015:

- Conduct two atmospheric supersonic flight demonstrations of an inflatable decelerator system under the Low Density Supersonic Decelerator project
- Down-select one deployable solar array and continue development under SEP project
- Complete integration, test, and launch the GPIM spacecraft

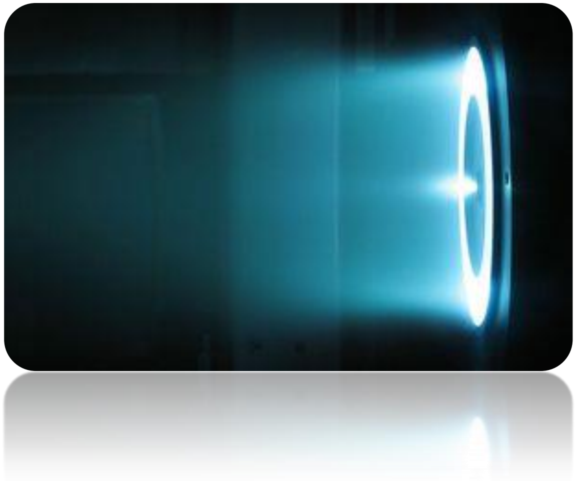


Game Changing Development (GCD)

Goals:

- To identify and rapidly mature innovative/high impact capabilities and technologies that may lead to entirely new approaches for the Agency's future space missions.

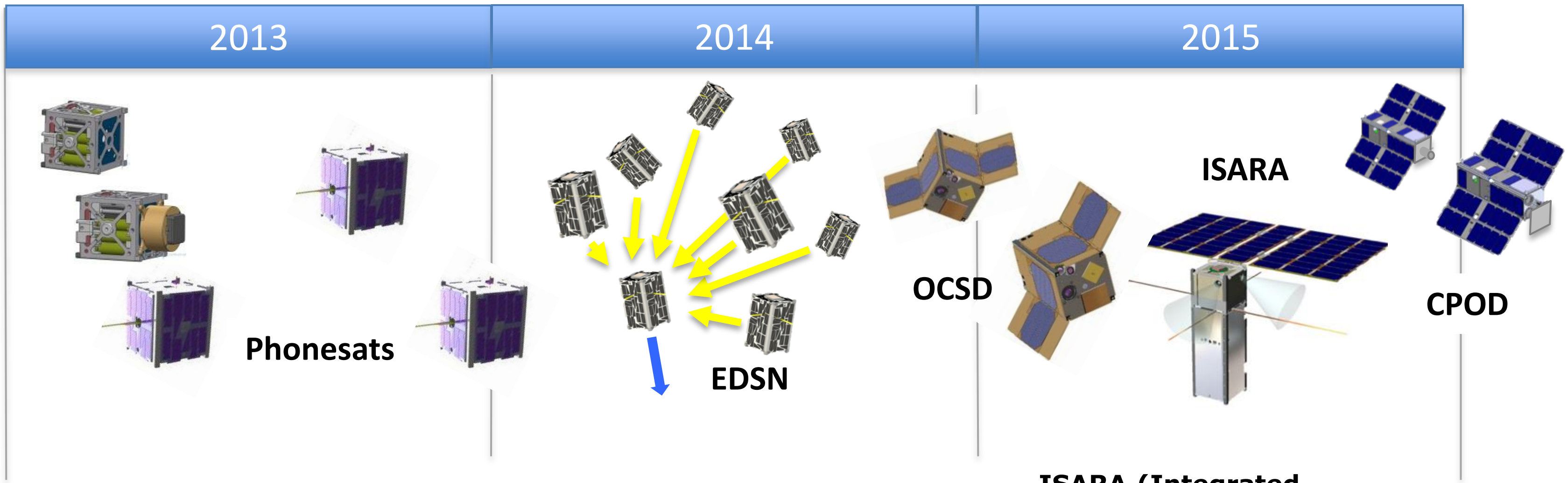
- The program will investigate novel ideas and approaches that have the potential to revolutionize future space missions.



MILESTONES/ACCOMPLISHMENTS FY2014-2015

- **Composite Cryotank Technologies and Demonstration (CCTD):**
  - *Design & fabricate 5.5 meter diameter composite cryotank.*
  - *The tank will undergo a rigorous test program at liquid hydrogen temperatures.*
- **EDL Technologies:**
  - *Complete the technology development of f 3D Woven TPS materials for infusion into Orion.*
  - *Complete fabrication of 4 meter Hypersonic Inflatable Aerodynamic Decelerator (HIAD).*
  - *Initiate the development of Mars EDL Instrument (MEDLI) for Mars 2020.*
- **Human Robotic Systems (HRS):**
  - *Deliver Robonaut 2 legs to ISS via SpaceX launch.*
- **Other Accomplishments:**
  - *Deliver advanced Portable Life Support System (PLSS) components to HEOMD for terrestrial demonstration.*
  - *Develop three competing Microfluidic Electrospray Propulsion (MEP) designs.*
  - *Perform first demonstration of a 3D printer on ISS.*
  - *Complete ISS operations of a SPHERES SLOSH experiment to provide critical data for understanding fluid movement in microgravity.*
  - *Complete performance test program for 3 kW fuel cell.*
  - *Perform hot fire test of an additively manufactured nozzle.*
  - *Complete terrestrial demonstration of a non-nuclear fission power system.*
  - *Initiate development of an ISRU payload for Mars 2020.*

Flight Demonstration Projects



Phonesat
Demonstrating use of a smartphone as the spacecraft control and data handling system - yielding extremely low cost satellites for many uses.

Led by NASA Ames Research Center

Launches: April 2013
Nov 2013
March 2014

EDSN (Edison Demonstration of Smallsat Networks
Demonstrating a small spacecraft swarm (8 cubesats) operating as a network for distributed sensors and communication

Led by NASA Ames Research Center

Launch: Fall 2014

OCSD (Optical Communication & Sensor Demonstration)
Demonstrating space-to-ground laser communications, low-cost navigation sensors, and proximity operations with two 1.5U cubesats

Led by Aerospace Corp.

Launch: 2015

ISARA (Integrated Solar Array and Reflectarray Antenna)
Demonstrating increased bandwidth for Ka-band radio communications by using the back of a deployed solar array as a radio antenna reflector

Led by JPL with Pumpkin, Inc.

Launch: 2015

CPOD (Cubesat Proximity Operations Demonstration)
Proximity operations and docking demonstration with two 3U cubesats

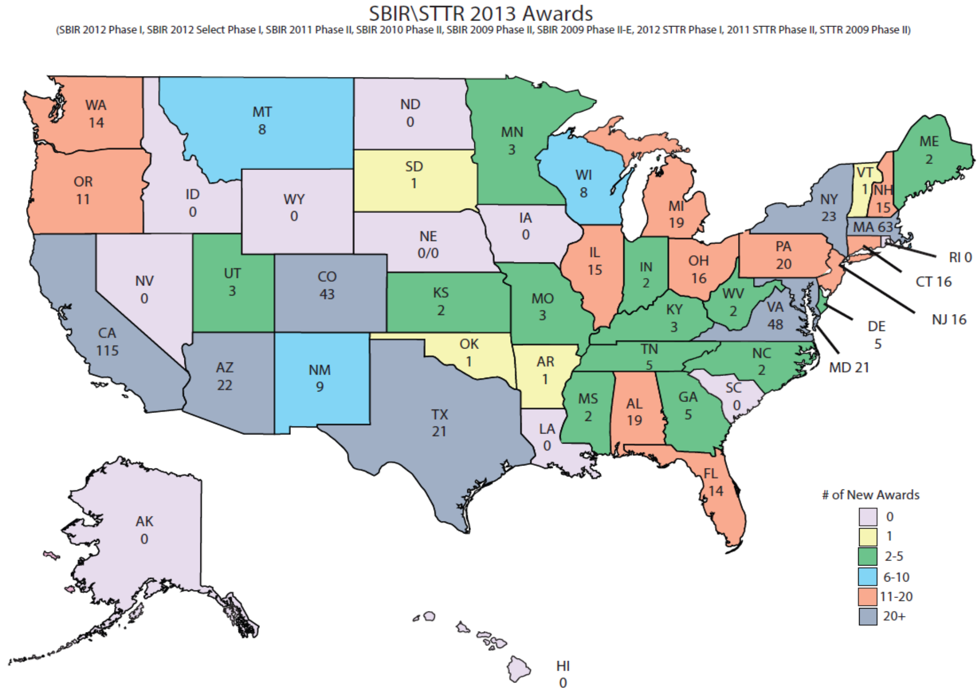
Led by Tyvak, LLC

Launch: 2015

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

Provides small business sector with opportunity to compete for funding to develop technology for NASA and commercialize that technology to spur economic growth.

- Annual Solicitations for Phase I awards
- Phase II proposed 6 months later
  - Phase II Enhancement (II-E): cost sharing opportunity to incentive extended research and development efforts of current Phase II contract.
- Phase III-commercialization of Phase II projects.
  - Contract funded from sources other than the SBIR/STTR programs and may be awarded without further competition.



FY 2013 Awards:

- **SBIR -** 233 SBIR 2012 Phase I were awarded from 192 US small businesses; 26 SBIR 2012 Select Phase I were awarded; 81 SBIR 2011 Phase II were awarded; 1 SBIR 2010 Phase II were awarded; 194 SBIR 2009 Phase II were awarded; and 25 SBIR 2009 Phase II-E were awarded
- **STTR -** 33 2012 STTR Phase I were awarded from 32 US small businesses; 14 2011 STTR Phase II were awarded; and 21 STTR 2009 Phase II were awarded

FY 2014 Awards: Phase II Selections announced on March 7, 2014 -108 selections $87 million. Phase I Sections scheduled for end of April 2014.

- 42 SBIR 2010 Phase II-E were selected; $2.97 M of NASA funds leveraging $3.97 M funds from non-SBIR sources

FY 2015 Plans: NASA increases the SBIR investment by 0.1 percent to 2.9 percent of Extramural R&D; STTR investment is 0.40 percent of Extramural R&D

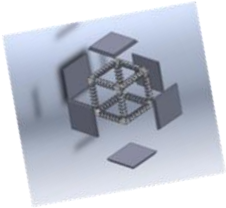
Multi-Agency Priorities

National Network for Manufacturing Innovation

Major Activities:

- Hosted National Advanced Manufacturing Institute workshop in Cleveland, OH and co-hosted workshops in Irvine, CA and Huntsville, AL
- Commissioned an NRC study to address Space Based Additive Manufacturing in collaboration with Air Force Space Command and AFRL. (Report due in Fall of 2014.)
- Committed to support prizes, challenges and university research grants to both the DOE Clean Energy Manufacturing Innovation Institute (supporting wide bandgap semiconductor for power electronic devices) and the DOD Digital Manufacturing and Design Innovation Institute. (Est. annual Cost: up to $2M each institute plus FTE FY14-FY16)
- Committed FTE support for *Lightweight and Modern Metals Manufacturing Institute* in the form of technical reviewers during the solicitation process
- Discussions with National Additive Manufacturing Innovation Institute on future prize competitions (FY14/FY15)

Other Manufacturing Achievements:



- FIRST PRINT IN SPACE. In a collaboration between STMD/ISS/ AES a demonstration printer (Made in Space) will be launched on a Space X-5 in October 2014 and Astronauts will print hardware on the ISS
- 2.4 meter Composite Cryotank, built using out of autoclave procedures, was successfully pressure tested. 5.5 meter development is underway and being tested.

National Robotics Initiative

Major Activities:

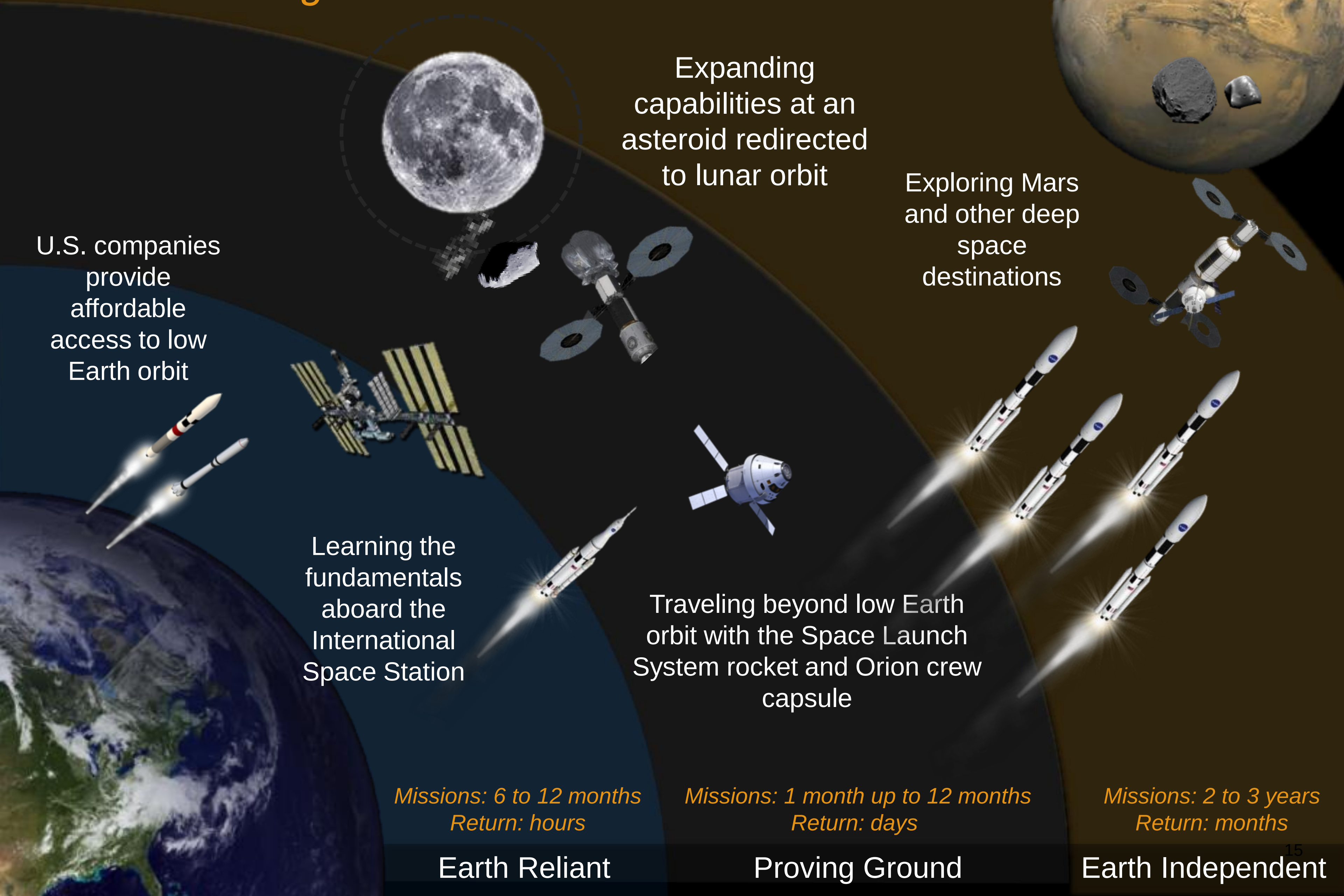
In first year, novel results seen from FY12 co-robotics grants to universities including:

- SUNY at Buffalo developed a new tactile sensor which uses gel, light and a camera to improve robot dexterity
- MIT developed a novel powered leg prosthesis by creating a new tendon that enables soft wearable robotics
- Carnegie-Mellon University uses laser and thermal imaging to improve surface hazard detection to prevent rovers from getting stuck in soft soil.

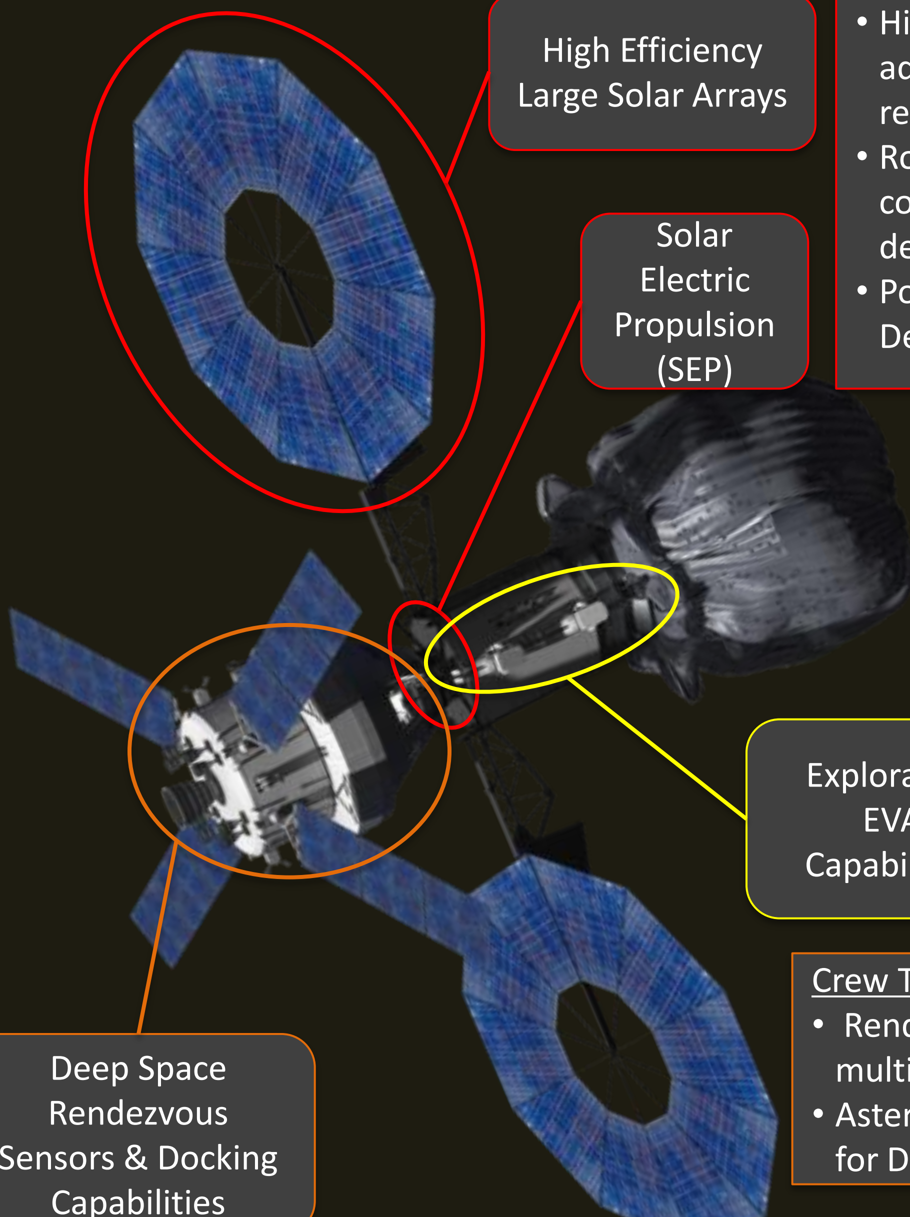
Each grantee is assigned a NASA center group or lab to work with for the remainder of their research

The Future of Human Space Exploration

NASA's Building Blocks to Mars



Asteroid Redirect Mission Provides Capabilities For Deep Space/Mars Missions



In-space Power and Propulsion :
- High Efficiency Solar Arrays and SEP advance state of art toward capability required for Mars
- Robotic ARM mission 50kW vehicle components prepare for Mars cargo delivery architectures
- Power enhancements feed forward to Deep Space Habitats and Transit Vehicles

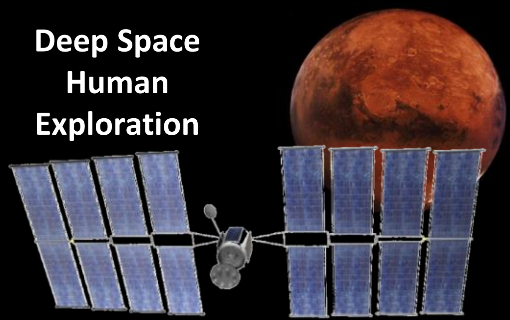
EVA:
- Build capability for future exploration through Primary Life Support System Design which accommodates Mars
- Test sample collection and containment techniques including planetary protection
- Follow-on missions in DRO can provide more capable exploration suit and tools

Crew Transportation and Operations:
- Rendezvous Sensors and Docking Systems provide a multi-mission capability needed for Deep Space and Mars
- Asteroid Initiative in cis-lunar space is a proving ground for Deep Space operations, trajectory, and navigation.

High-powered SEP Enables Multiple Applications

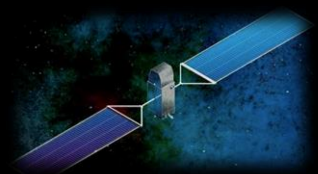
Satellite Servicing

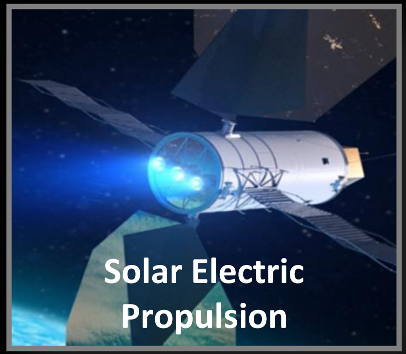
Deep Space Human Exploration



Payload Delivery

Commercial Space Applications

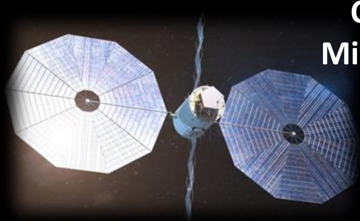




Solar Electric Propulsion

ISS Utilization

OGA Missions

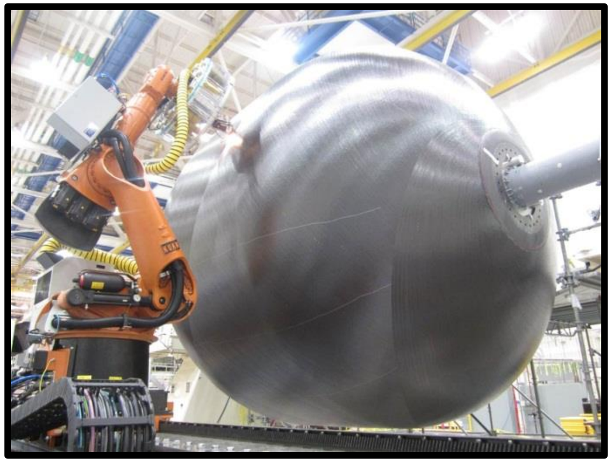


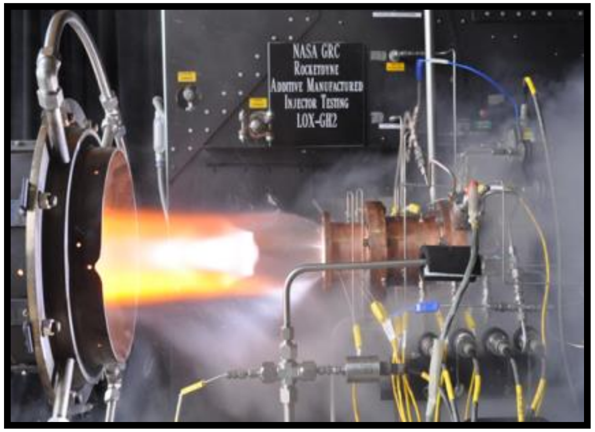
Orbital Debris Removal

Space Science Missions

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

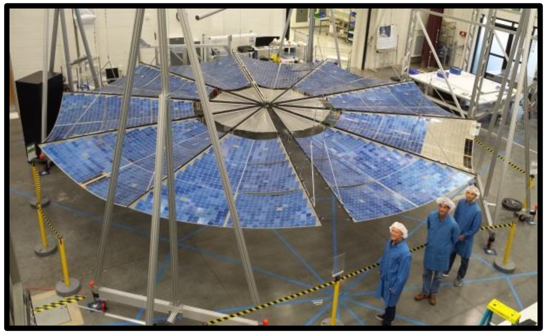
- Composite cryogenic propellant tanks and dry structures for SLS block upgrades
- Cryogenic propellant storage and transfer for upper stage block upgrades
- Additive manufacturing and testing of upper stage injectors, combustion chambers and nozzles
- Phase change material heat exchangers for Orion in lunar orbit
- Woven TPS for Orion heat shield compression pads
- Advanced air revitalization for Orion upgrades

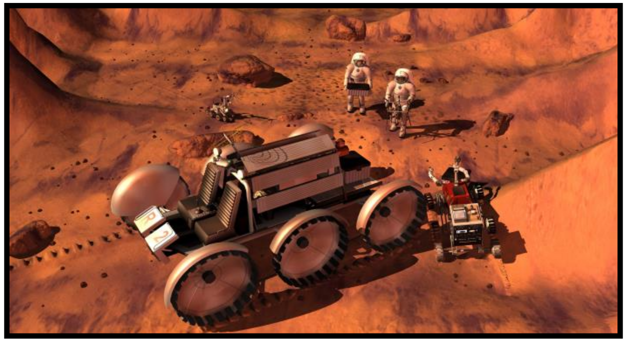




STMD Investments to Advance Human Exploration of Mars

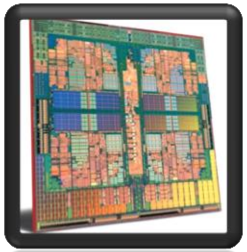
- High Powered SEP – cargo and logistics transportation to Mars
- CPST – either chemical or nuclear thermal in-space propulsion for crew transportation
- Composite cryogenic propellant tanks and dry structures – exploration upper stage
- Small Fission Power / Stirling Engine Power – Mars surface power
- HIAD / ADEPT – deployable entry systems for large mass landers
- LDSD – supersonic descent of large landed mass at Mars
- Woven TPS – more efficient and flexible TPS materials for entry
- Advanced close loop Air revitalization and water recovery – reduced consumables
- Mars atmospheric ISRU (oxygen) – life support and ascent vehicle oxidizer
- Humanoid robotics – enhanced exploration and crew workload relief
- Advanced mobility rover – remotely operated exploration
- Optical communications – high bandwidth communications at Mars

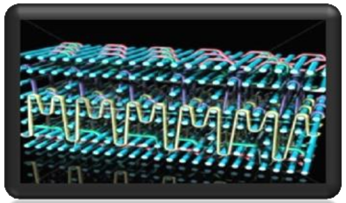




STMD Investments to Advance Outer Planetary Exploration





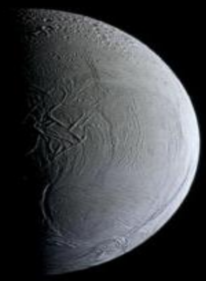
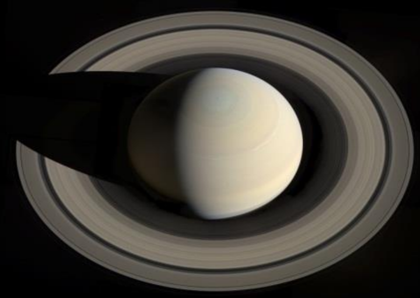


STMD is developing TPS and deep space communication technologies for infusion in SMD's Discovery 2014

Technologies in FY15

- 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



Snapshot of Space Technology Partners

The Aerospace Corporation
Pumpkin Incorporated
tyvak Nano-Satellite Systems LLC
MSNW
BRM Bally Ribbon Mills
Saft
Applied Defense Solutions
Busek
Airborne Systems
406 Aerospace
ILC Dover
Micro Aerospace Solutions
L3
Honeybee Robotics
Ball Aerospace & Technologies Corp.
Aerojet Rocketdyne
Honeywell
Aster Labs
Draper Laboratory
UP Aerospace
Princeton Lightwave
Cobham
Teledyne Brown Engineering, Inc
A Teledyne Technologies Company
L'Garde Est. 1971
nanocomp Technologies, Inc.
BAE Systems
United Technologies
DSS Deployable Space Systems
Quest Thermal Group
Surrey Satellite Technology Ltd
Quest Thermal Group
Symmetricom
Moog
Analex Corporation
Nammo
Oceaneering
Boeing
Planetary Systems Corporation
Sierra Lobo
ATK
SEAKR Engineering, Inc.
Frequency Electronics, Inc.
Stinger Ghaffarian Technologies
Lockheed Martin
Space Systems Loral
Virgin Galactic
Orbital
SNC Sierra Nevada Corporation Space Systems
PowerSafe Technology Corporation
MIT Lincoln Laboratory
Microcosm Inc
Adcole
Masten

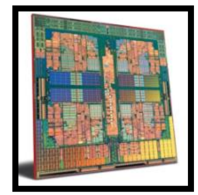
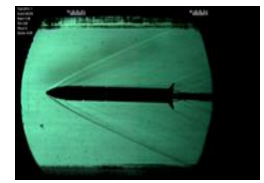
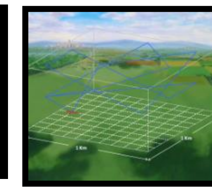
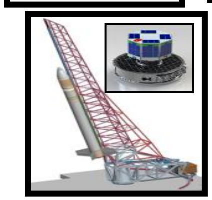
Collaborations with Other Government Agencies

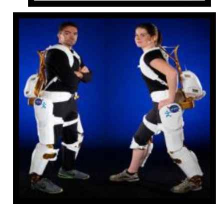
STMD has ***45 activities*** with ***43 other government agencies***, and ***10 activities*** with ***14 international organizations***. STMD is sharing rides for ***13 activities***.

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)**
- Solar Sail Demonstration partnership with **NOAA**
- **AFRL** collaboration Phase I of a High Performance Space Computing for a low power multi-core processor increasing performance a 100 fold.
- Soldier-Warfighter Operationally Responsive Deployer for Space (SWORDS) low-cost nano-launch system with **Army**
- UAS Airspace Operations Prize Challenge coordinated with **FAA**
- Working with the **USAF Operationally Responsive Space Office (ORS)** for launch accommodations for the Edison Demonstration of Smallsat Networks (EDSN) mission.
- Partnership for Ohio's first hydrogen generating fueling station with **Greater Cleveland Regional Transit Authority** to power city bus
- Partnership with **DARPA** on "Next Generation Humanoid for Disaster Response"
- In discussion with **Dept. of Veteran Affairs** for a collaborative project with (a) "Exoskeleton" and (b) finalizing agreement to have veterans test and evaluate NASA's RoboGlove in the Palo Alto and Cleveland clinics from our Human Robotics Systems Program
- Collaboration with **ARPA-e/Dept. of Energy** in new battery chemistries to aide in battery tech development



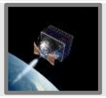








STMD Partners with Universities to Solve The Nation's Challenges

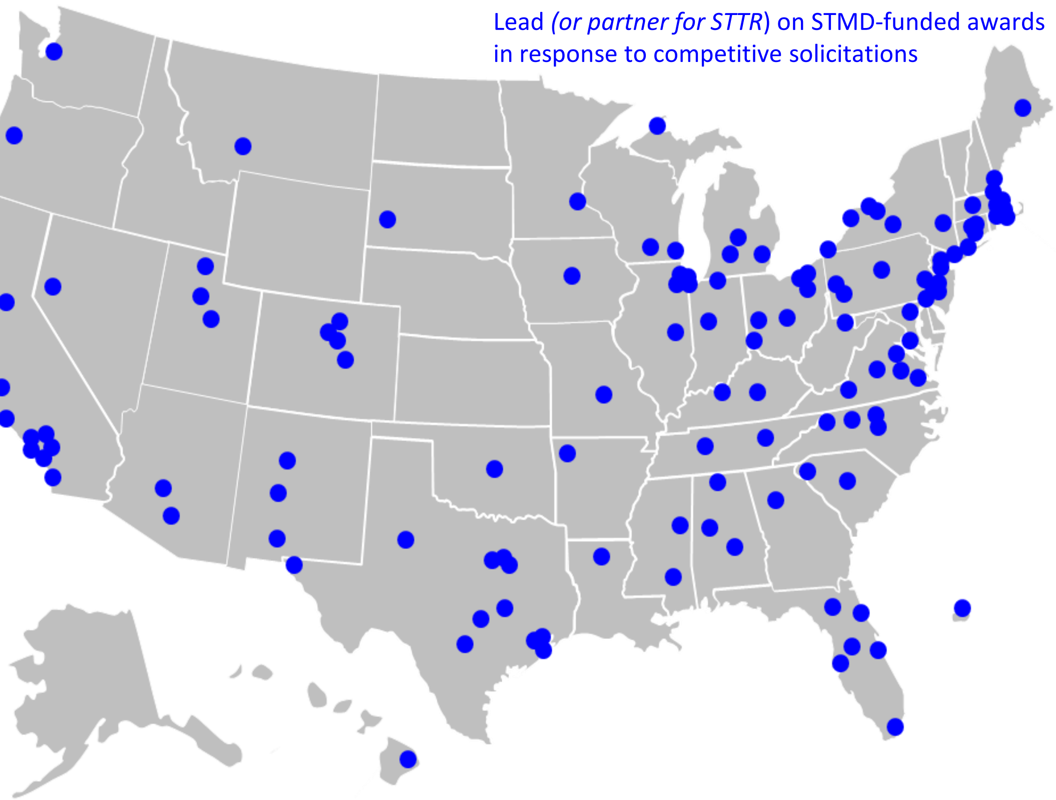
U.S. Universities have been *very* successful in responding to STMD's competitive solicitations

- STMD-funded university space technology research spans the entire roadmap space
- More than 120 U.S. universities have led (*or are STTR partners on*) more than 450 awards <u>since 2011</u>
- 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 	223	223	• Early Career Faculty • Early Stage Innovations • NASA Space Technology Research Fellowships ***Annually***
NIAC 	76	21	• NIAC Phase I • NIAC Phase II ***Annually***
Game Changing Technology Dev 	32	10	• Various topics released as Appendices to SpaceTech-REDDI ***Annually***
Small Spacecraft Technology 	22	13	• Smallsat Technology Partnerships Cooperative Agreement Notice every two years, with the next opportunity in 2015
Flight Opportunities 	114	46	• Announcement of Flight Opportunities - in the future, funded SAAs to U.S. universities, non-profits and industry to pay for flights on their own are planned. ***Twice Annually***
STTR 	*169*	*159 w/ univ partners*	• *Annual STTR solicitation*
Centennial Challenges 	*3 Challenges (1 Challenge university-run)*	*23 teams competed (4 univ-led)*	• *One or more challenges annually* • *Starting in FY14: challenge competitions with a **procurement track** to fund **university teams** via grants*

STMD Engages Over 120 Universities: *Rebuilding the Pipeline*

Lead *(or partner for STTR)* on STMD-funded awards in response to competitive solicitations



Appalachian State University
Arizona State University
Auburn University
Boston University
Brigham Young University
Brown University
California Institute of Technology
California Polytechnic State University
California State University - Northridge
Carnegie Mellon University
Carnegie Mellon University-Silicon Valley
Carthage College
Case Western Reserve University
Clemson University
College of William and Mary
Colorado School of Mines
Colorado State University
Cornell University
Drexel University
Duke University
Embry-Riddle Aeronautical University
Florida Institute of Technology
Gannon University
George Mason University
Georgia Institute of Technology
Harvard University
Illinois Institute of Technology
Iowa State University
John Carroll University
Johns Hopkins University
Kent State University
Louisiana Tech University
Massachusetts Institute of Technology
Michigan State University
Michigan Technological University
Mississippi State University
Missouri University of Science & Technology
Montana State University
New Jersey Institute of Technology
New Mexico Institute Of Mining And Technology
New Mexico State University
North Carolina State University
Northeastern University
Northwestern University
Ohio State University
Oregon State University

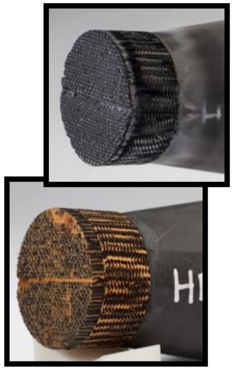
Pennsylvania State University
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Rochester Institute of Technology
Rutgers University
South Carolina Research Foundation
South Dakota School of Mines and Technology
Southern Methodist University
Stanford University
State University of New York at Buffalo
State University of New York at Stony Brook
Temple University
Texas A&M University
Texas Tech University
United States Air Force Academy
University of Alabama, Huntsville

University of Alabama, Tuscaloosa
University of Arizona
University of Arkansas
University of California, Davis
University of California, Irvine
University of California, Los Angeles
University of California, San Diego
University of California, Santa Barbara
University of California, Santa Cruz
University of Central Florida
University of Cincinnati
University of Colorado, Boulder
University of Connecticut
University of Delaware
University of Florida
University of Hartford
University of Hawaii

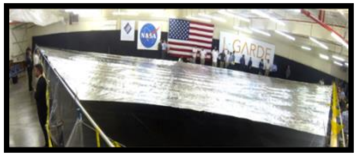
University of Houston
University of Houston Clear Lake
University of Illinois
University of Illinois at Urbana-Champaign
University of Kentucky
University of Louisville
University of Maine
University of Maryland
University of Massachusetts
University of Massachusetts, Amherst
University of Massachusetts, Lowell
University of Miami
University of Michigan
University of Minnesota
University of Nevada
University of New Hampshire
University of New Mexico
University of Notre Dame
University of Oklahoma
University of Pennsylvania
University of Pittsburgh
University of Puerto Rico, Rio Pedras
University of Rochester
University of South Florida
University of Southern California
University of Southern Mississippi
University of Tennessee
University of Texas at Austin
University of Texas at Dallas
University of Texas at El Paso
University of Texas, Arlington
University of Texas-San Antonio
University of Utah
University of Virginia
University of Washington
University of Wisconsin-Madison
Utah State University
Vanderbilt University
Villanova University
Virginia Commonwealth University
Virginia Tech
Wake Forest University
West Virginia University
Western Michigan University
William Marsh Rice University
Wright State University
Yale University

STMD-SMD Alignment Examples

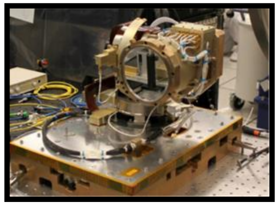
- **Entry, Descent, & Landing**
  - MEDLI, MEDLI+ & Entry Systems Modeling – Mars EDL systems design
  - Woven TPS (HEEET) – Venus, Mars & Outer Planets
  - Low Density Supersonic Decelerator – Increased mass to Mars surface
  - Hypersonic Inflatable Aerodynamic Decelerator (HIAD) & Adaptable, Deployable Entry Placement Technology (ADEPT) – deployable heat shields for Venus and Mars provides much lower entry loads



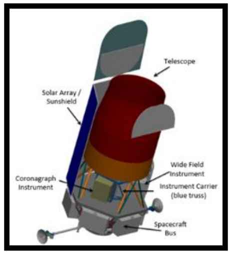
- **Propulsion & Power**
  - Green Propellant Infusion Mission (GPIM)- alternative to hydrazine
  - Solar Electric Propulsion (SEP) – enabling new science missions
  - Solar Sail – enables unique vantage points for heliophysics
  - Small Fission – power for outer planet missions



- **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

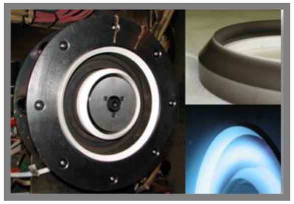


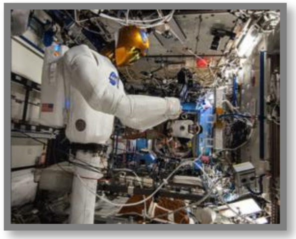
- **Instruments, Sensors, & Thermal**
  - High Performance Spaceflight Computing – broadly applicable to science missions
  - AFTA / WFIRST Coronagraph – to perform direct observations of exoplanets and determining their atmospheric content



STMD-HEOMD Alignment Examples

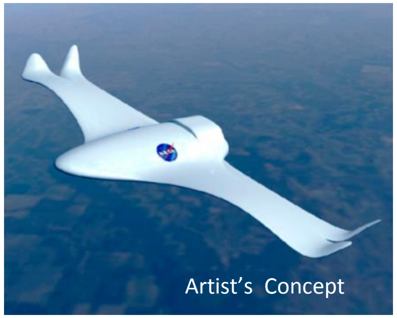
- **Solar Electric Propulsion (SEP)**
  - Enabling for ARM and humans to Mars
  - Technologies: Advanced Solar Arrays, High-Power Hall thrusters & PPUs
- **Life Support and Resource Utilization**
  - Mars Oxygen ISRU – testing on Mars 2020 and needed for humans to Mars
  - Next Gen. Life Support – Space suit components; Highly reliable closed loop air revitalization; Radiation dosimeter, modeling, forecasting and shielding
- **Mars Entry, Descent and Landing Technologies**
  - LDSD – allows up to 15 mt Mars landed mass
  - Woven TPS – potential use on Orion and later Mars entry system
  - HIAD & ADEPT – deployable entry systems for large heat shields
- **Space Launch System (SLS) Technologies**
  - CPST – long duration cryogenic storage for SLS upper-stage
  - Composite Tanks & Structures – upper-stage use to increase SLS payloads
- **Other Key Exploration Technologies**
  - Human Robotic Systems (R2, R3 & R5) – to reduce crew workload
  - Nuclear Fission systems for Mars surface power
  - Optical Communications (LCRD & DSOC) & Deep Space Navigation (DSAC)
  - Inflatable Air-Lock – to reduce structural mass



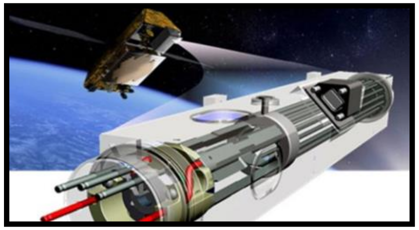


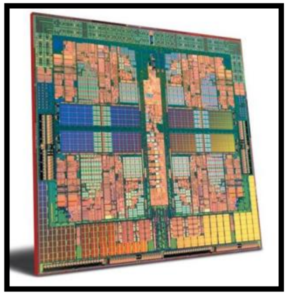
STMD-ARMD Synergies (FY14)

- **Aviation Safety**
  - External hazard sensors; pressure sensitive paint; wing tip vortex sensors
  - SBIR projects
- **Fundamental Aeronautics**
  - Advanced EDL - Computation (HEDL)
  - Parachutes under LDSD; Wings under Silent and Efficient Supersonic Bi-Directional Flying Wing
  - Advanced Manufacturing ; Nanotechnology ; Computational Materials ; Low mass cable harness structural health monitoring
  - Advanced composites/lightweight materials
  - SBIR projects
- **Airspace Systems:**
  - SBIR projects
- **Aeronautics Test Technologies:**
  - SBIR projects
- **Integrated System Research Project:**
  - UAS Challenge
  - SBIR projects



STMD- Aerospace Industry Alignment Examples



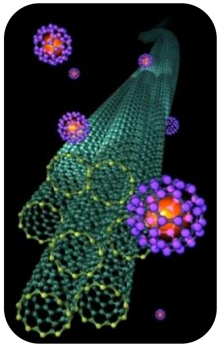


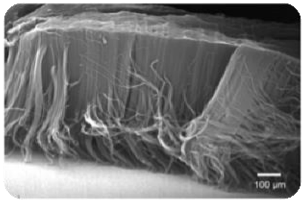
- **Structures and Materials**
  - Composite Tanks & Structures – for improved launch vehicle performance
  - HIAD – for orbital down mass capability
- **Propulsion & Power**
  - Green Propellant Infusion Mission – improved spacecraft performance & reduced toxicity and ground processing costs
  - Solar 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
  - DSAC – 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

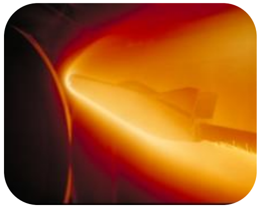
Space Technology Investments to Advance Future Capabilities

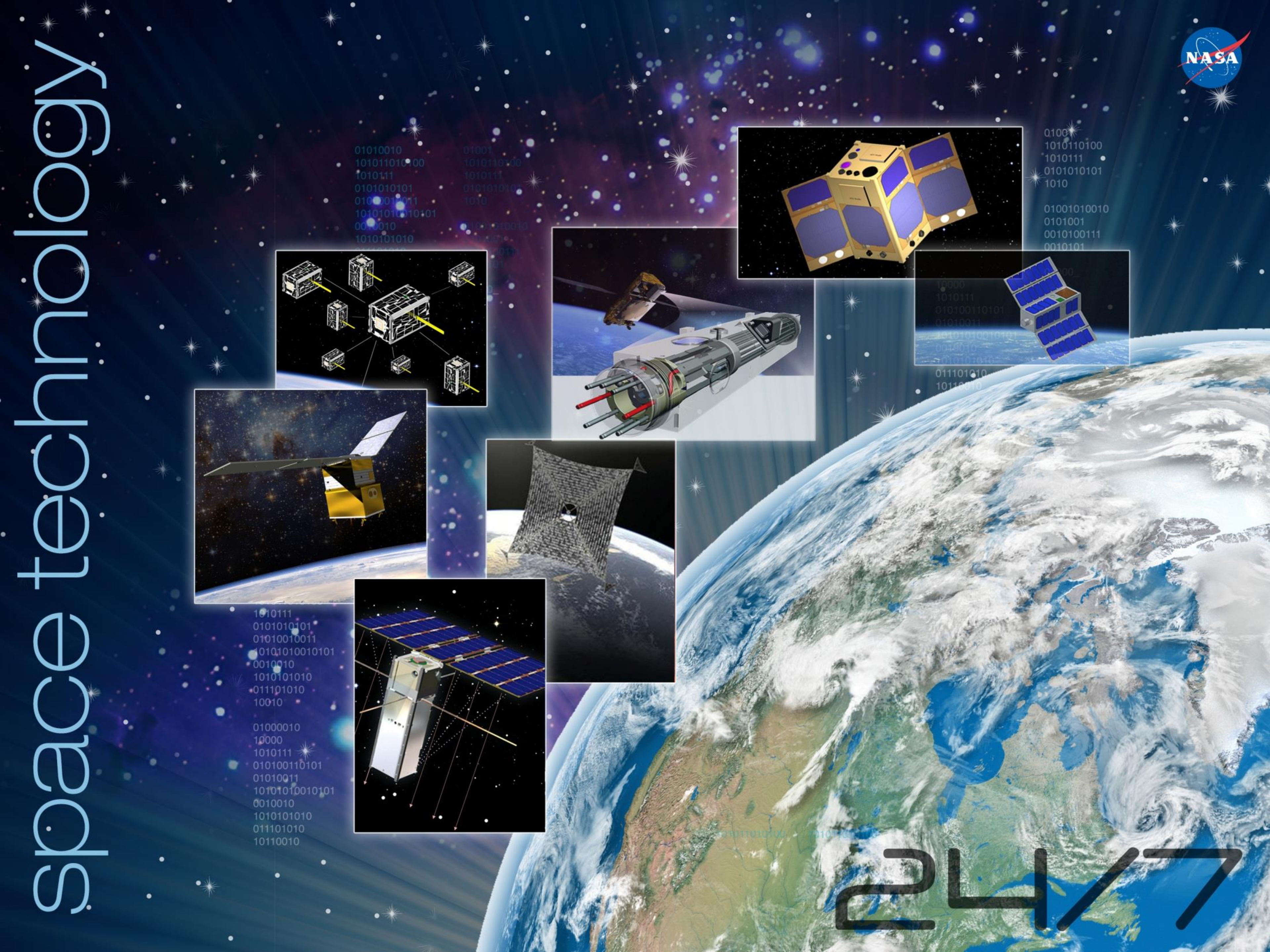
STMD continues to solicit the nation's best and brightest technologists across academia, industry, and government to drive innovative, enabling solutions in such areas as:

- **Solar Electric Propulsion** – Advanced high-power, low-volume solar arrays and high-power propulsion systems
- **Space Power-** Affordable, High Efficiency Power Generation and Energy Storage Systems
- **Life Support and Resource Utilization** - High Performance Resource Production and Recycling Systems
- **Entry, Descent, and Landing** - Advanced Computational Modeling and Analytical Simulation Tools
- **Space Robotic Systems** – High Reliability Sample Return Robots and low mass deep ice penetration systems
- **Space Optical Communications** – Enhanced Deep Space Optical Communication Capabilities for small space crafts and high efficiency laser systems
- **Lightweight Space Structures** – Ultralight, Ultrastrong Nanomaterials
- **Space Observatory Systems** – Advanced Optical Coating Materials for Space Environments








space technology
NASA
24/7

Summary: Space Technology Critical to our Future

- NASA's investments in Space Technology provide the transformative capabilities to enable new missions, stimulate the economy, contribute to the nation's global competitiveness and inspire the nation's next generation of scientists, engineers and explorers.

- Over the past three years, Space Technology has made significant progress on a wide array of new capabilities and technologies. We are delivering what we promised: new technologies and capabilities. FY15 demos or major tests for Small Spacecraft, Green Propellant, Deep Space Atomic Clock, and LDSD.

- Space Technology will continue to engage U.S. universities and academic institutions to develop and demonstrate technologies with more than 400 activities to date, including: fellowships, direct competitive awards of grants and contracts, and partnerships with NASA centers and commercial contractors.

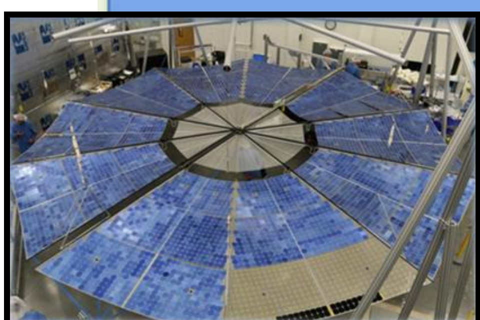
- This budget request supports an accelerated development of a Solar Electric Propulsion (SEP) demonstration effort within Technology Demonstration Missions. SEP is critical and enabling for NASA's robotic mission to an asteroid.
  - SEP technology advances are also essential for future commercial satellites and for deep space human exploration missions.

- With SLS and Orion coming online soon, the next great leaps in space exploration are within our grasp, but all of these leaps require significant and sustained investments in Space Technology beginning now.

BACKUPS

Technology Success: Solar Electric Propulsion Deployable Solar Array Systems

Image: Artist concept of a future SEP mission.



Images Above show the two types of deployable solar array systems under development.
(left) ATK fold-out "MegaFlex" EDU;
(right) DSS-developed roll-out "MegaROSA" EDU.

Project Summary: *High Power Solar Electric Propulsion (SEP) consisting of both power generation and propulsion, is extensible to human exploration missions at 300kW and is a required architecture element within the human exploration roadmap.*

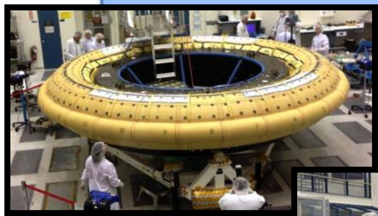
Accomplishments:

- Two industry-led teams, ATK and Deployable Space Systems (DSS), are currently developing deployable Solar Array Systems (SAS) through a two phase process.
  - Phase 1 the two teams have designed and fabricated Engineering Development Units (EDUs) and are analyzing and ground testing them, maturing the technology readiness level.
  - Phase 2, one team will further develop the down-selected SAS that concludes in a flight demonstration.

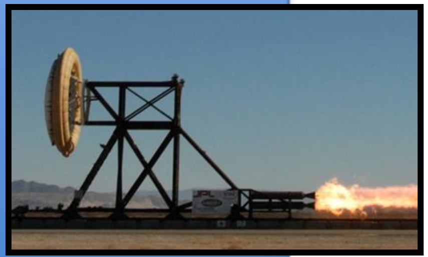
Plans:

- Complete 300V Power Processing Unit (PPU) development
- Complete thermal vacuum deployment testing of SAS systems
- Complete performance testing of 12.5 kW class Hall thruster
- Complete testing of the PPU with 12.5 kW Hall thruster

Technology Success: Low Density Supersonic Decelerator



Integration of Supersonic Inflatable Aerodynamic Decelerator (SIAD) onto first flight demonstration vehicle;
Top, inflated for dimensional verification;
Middle, deflated, being packaged;
Bottom, completed packaging



Rocket sled testing of robotics-class supersonic decelerator

Successful test firing of Ballute mortar (used to deploy supersonic parachute)

Project Summary: *Developing technologies to use atmospheric drag to dramatically slow a vehicle as it penetrates the skies over worlds beyond our own. Developing the largest ever supersonic parachute ever developed for Mars entry – potential infusion in the Mars 2020 mission.*

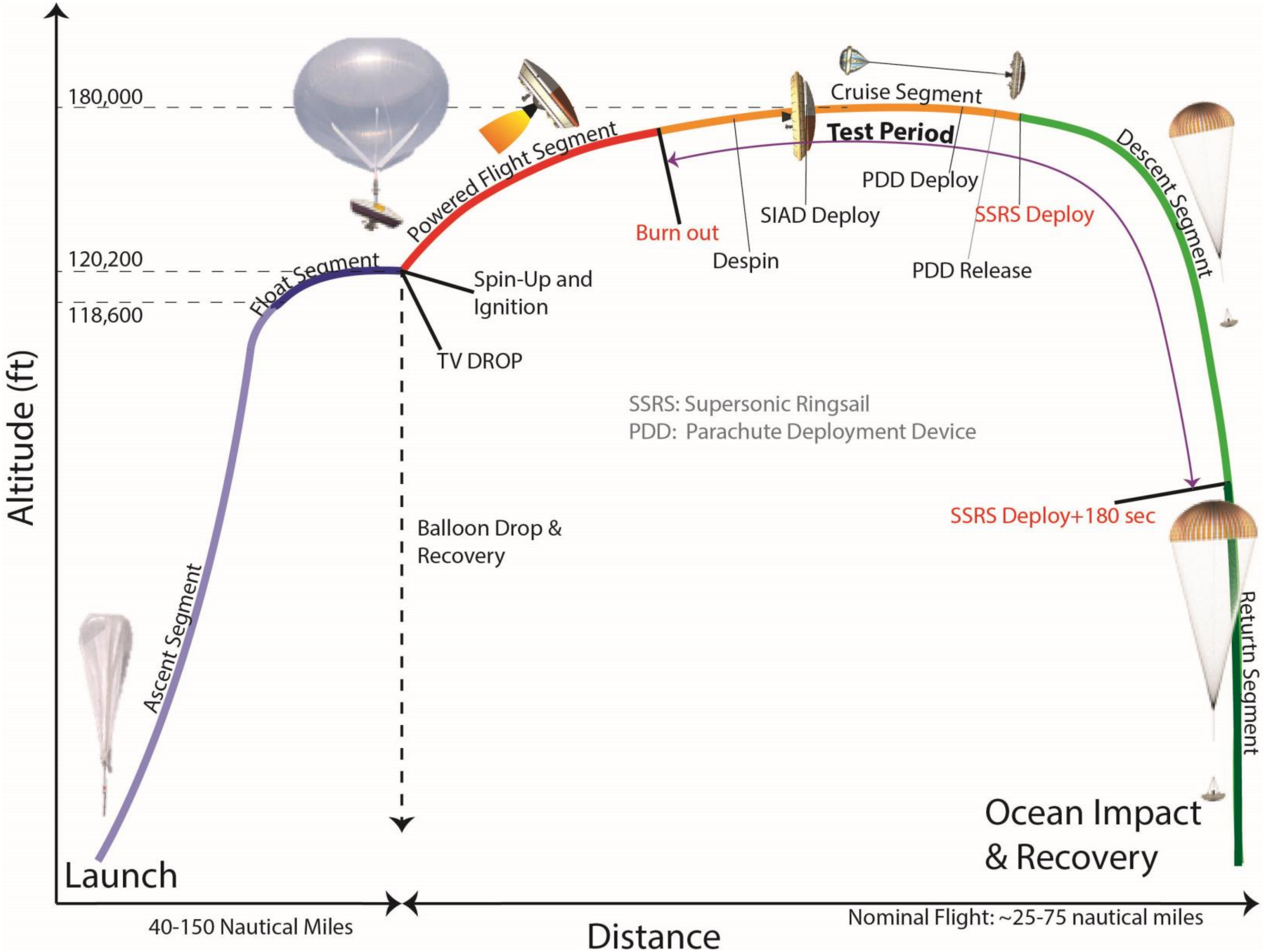
Accomplishments:

- Successfully performed two rocket sled tests on a robotics-class supersonic decelerator
- Wind tunnel tested 30 different parachute configurations
- Conducted two static balloon launch tests
- Successfully tested GLN-MAC navigation computer on two sounding rocket launches
- Thermal/Vacuum testing of ballute inflation aid and camera system

Plans:

- Assembly, Integration & Test of first supersonic flight demonstration vehicle
- Conduct first ever atmospheric supersonic flight test of an inflatable decelerator system

LDSD Supersonic Flight Plan
June 2014



Technology Success:
Human Robotic Systems and
Human Exploration Telerobotics Projects

Top Image: K10 Rover on Lunar roverscape being controlled by astronaut on the ISS
Left Image: Robonaut 2 (R2) is the first humanoid robot in space. The robot can work with the same hand tools and hardware (switches, connectors, etc.) as used by astronauts.

Smart SPHERES are free-flying robots that can perform mobile sensor tasks, such as environmental surveys and camera work inside the International Space Station.

The Exoskeleton can be used on Earth as an assistive walking device, as a resistance device for astronauts on the ISS, and as a robotic power boost to astronauts as they work on the surface of distant planetary bodies.

Project Summary: *Develops innovative new technologies in support of future human and robotic missions and demonstrates how advanced, remotely operated robots can improve human exploration missions.*

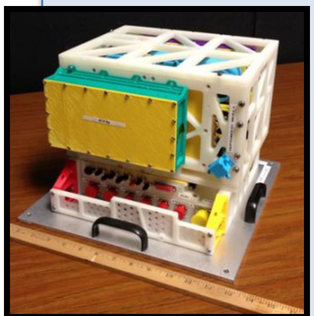
Accomplishments:

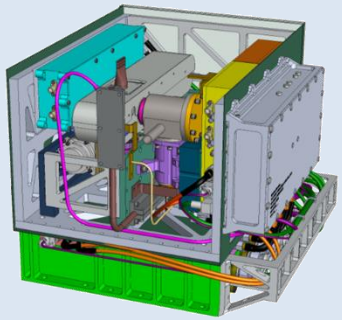
- The Telerobotics team demonstrates continued and progressively challenging operations for Robonaut 2 (R2) and Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) on the International Space Station. SPHERES has been on the ISS since 2006.
- Demonstrated first real-time remote robotic operations, where an astronaut on the ISS operated a rover on Earth on a simulated lunar landscape
- R2 testing continued with machine vision recognizing handrails, softgoods items, tool readouts, and valve positions
- R2 successfully manipulated softgoods: grasped wipes, transferred wipes from hand to hand, engaged/disengaged quarter turn fasteners, and removed/replaced a blanket
- The R2 climbing legs have been delivered and await launch to ISS
- First remote operation of a free-flyer on the ISS from the ground

Plans:

- Integration and testing of R2 climbing legs.
- Conduct first R2 mobility demonstration on the ISS

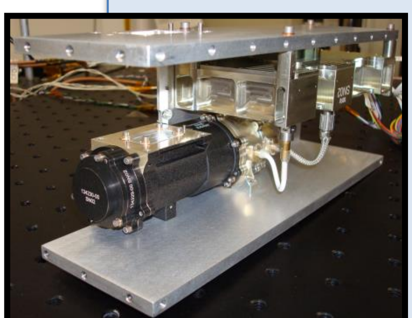
Technology Success: Deep Space Atomic Clock- Space-borne atomic clock





Top Left; Rapid-prototype Model of DSAC
Top Right: DSAC Demo Unit Configuration.

Clock Breadboard Testing



Detector Subassembly Flight Article

Project Summary: *Develop a small, low-mass atomic clock based on mercury-ion trap technology providing unprecedented stability needed for the next-generation of deep space navigation and radio science.*

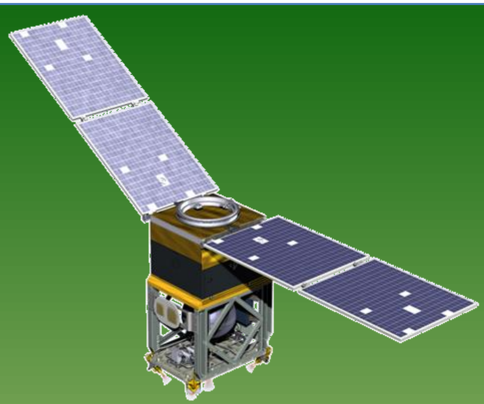
Accomplishments:

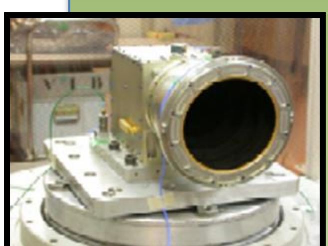
- The DSAC team have constructed two working breadboard (Payload Level and Clock Level)
- Low TRL issues (Lamp Bulb Manufacturing & Ion Tube Flight Design) have been resolved
- Secured a host mission for access to space
- Cultivated new infusion customers (NRO, Mil-Satcomm)

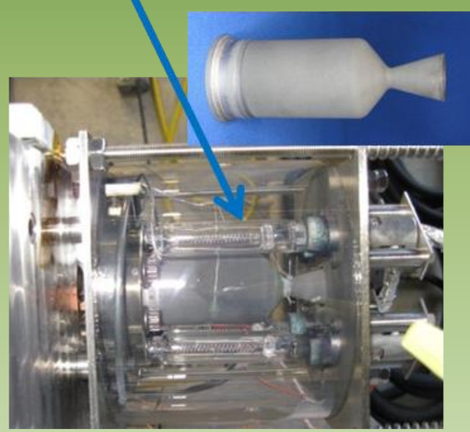
Plans:

- Conduct KDP-C
- Early I&T start with Ultra Stable Oscillator & GPS units

Technology Success:
Green Propellant Infusion Missions (GPIM)







Top image is an artist concept of the GPIM spacecraft.
Bottom left image is the flight start tracker undergoing vibration testing.
Bottom right image is engineering model for testing of the thrust chambers.

Project Summary: *Led by a cross-cutting NASA, DoD and Industry team, the project will demonstrate the practical capabilities of a high-performance green alternative to hydrazine. This innovative, low-toxicity propellant will improve overall vehicle performance.*

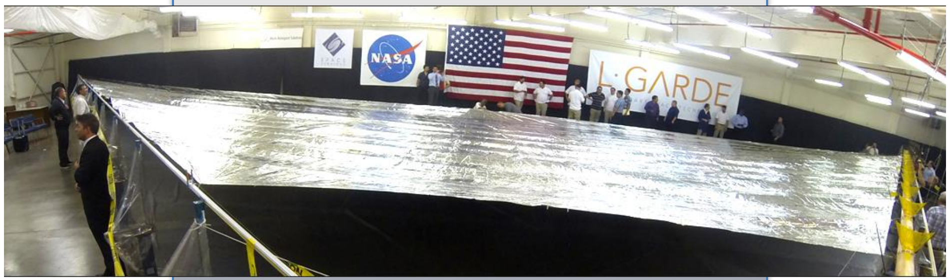
Accomplishments:

- GPIM is currently performing testing on 1N and 22N engineering model thrusters with the AFRL-developed green propellant.
- GPIM has completed SRR, KDP-B, PDR, IBR, and KDP-C.
- All spacecraft bus procurements
- Engaged KSC as a Co-I supporting IMLI, on-site fuel handling procedures, and fracture mechanics testing

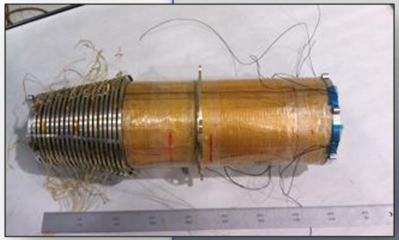
Plans:

- Conduct Payload/System CDR
- Begin 1N and 22N flight thruster testing
- Receive completed propulsion subsystem from Aerojet
- Complete spacecraft bus AI&T

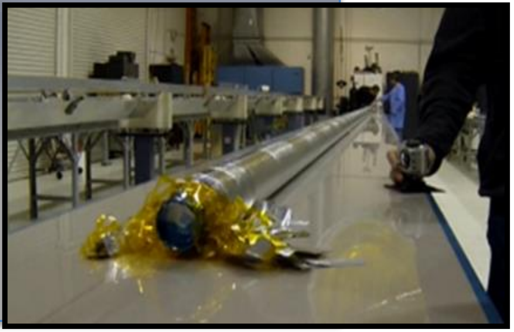
Technology Success: Sunjammer Solar Sail



Engineering Development Unit Solar Sail quadrant deployed during ground demonstration



Top image is boom stowed in configuration. **Right Top** shows boom as start of deployment/inflation sequence. **Right** Boom at full deployment state (~89 feet).



Project Summary: *In partnership with NOAA and L'Garde, the new Solar Sail demonstration mission, "Sunjammer", will deploy and operate a solar sail approximately 124 feet long and will test attitude control, and assess sail performance and stability*

Accomplishment:

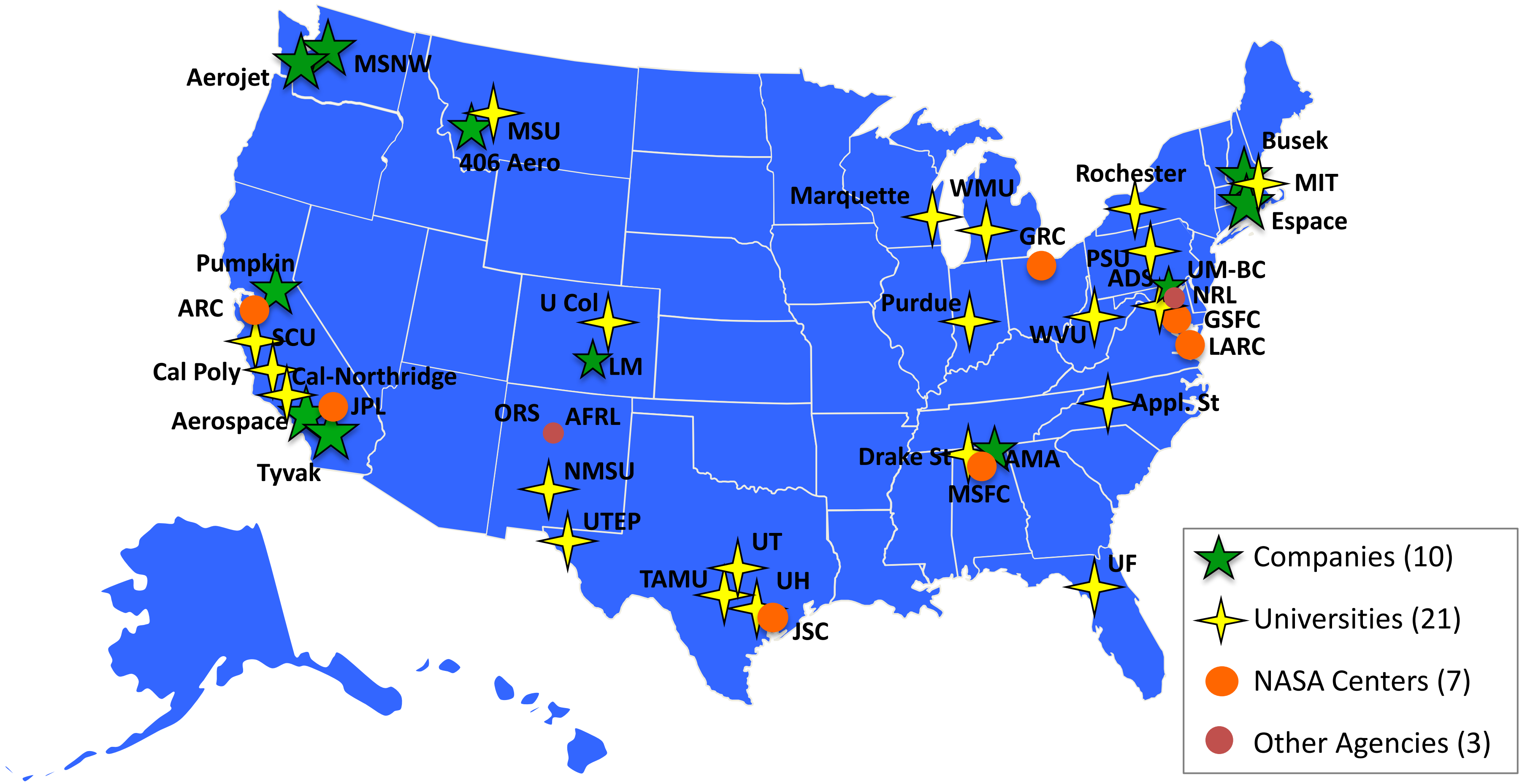
- Successfully passed KDP-C
- Team performed a series of deployment tests of the 89 foot prototype boom, and one deployment of an engineering development unit full-size sail quadrant
- Conducted seven subsystem peer reviews and several Technical Interchange meetings

Plans:

- Conduct Critical Design Review
- Conduct KDP-D
- Conduct ambient deployment testing of the flight sail
- Condcut System Integration Review

Small Spacecraft Technology

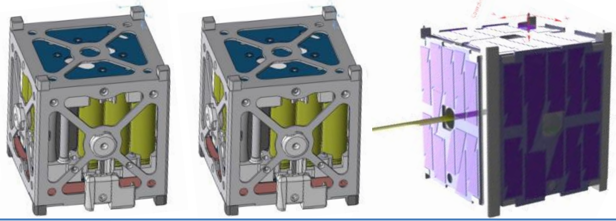
Nationwide Partners and Contractors

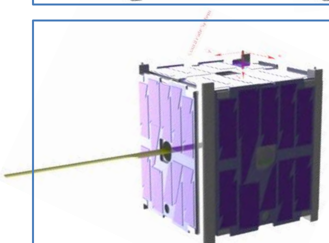


www.nasa.gov/smallsats

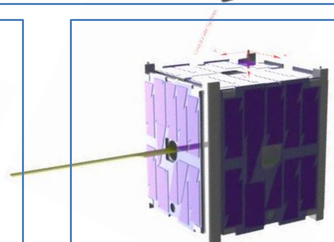
Technology Success:
Small Spacecraft Technology - Phonesat

Phonesat 1.0 and 2.0 – April 2013

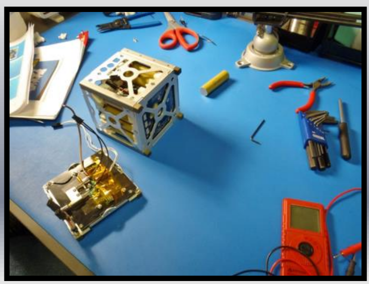




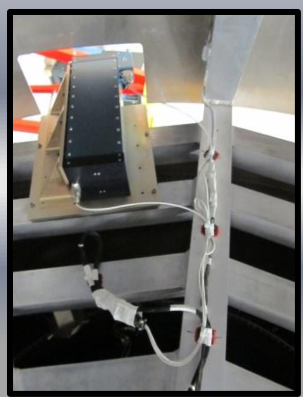
Phonesat 2.4 – November 2013



Phonesat 2.5 – March 2014



Phonesat 1.0 during assembly



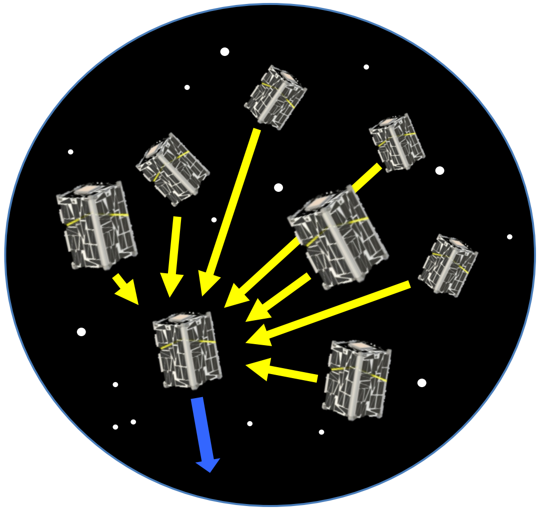
Phonesats within their deployer canister integrated on their launch vehicle

Project Summary: *Demonstrate the lowest-cost and easiest to build satellites ever flown in space – features enabled by using off-the-shelf consumer smartphones as the on-board computer and control system for the satellite.*
Led by: Ames Research Center

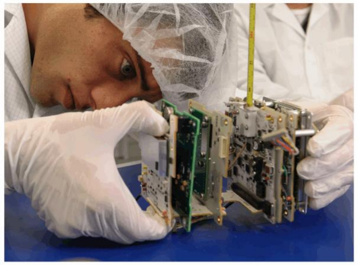
Accomplishments:

- NASA has built several prototype smartphone satellite versions and successfully tested them in extreme environments on sounding rocket and high-altitude balloon flights.
- Three NASA Phonesat satellites (two Phonesat 1.0's and one more advanced Phonesat 2.0) were launched aboard an Antares rocket from NASA's Wallops Flight Facility in April 2013. They operated for the full duration of their orbital lifetime.
- Phonesat 2.4 was launched in November 2013 on a Minotaur vehicle from the Wallops Flight Facility. It completed most of its mission and will remain in orbit for several years.
- Phonesat 2.5 is scheduled for launch in March 2014 on a Falcon 9 vehicle from Cape Canaveral.
- The Phonesat bus architecture is the basis for the upcoming EDSN mission.

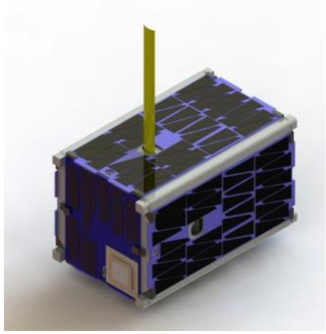
Technology Success: Small Spacecraft Technology - EDSN



Montana State University EPISEM Payload



Spacecraft Assembly



Individual EDSN satellite

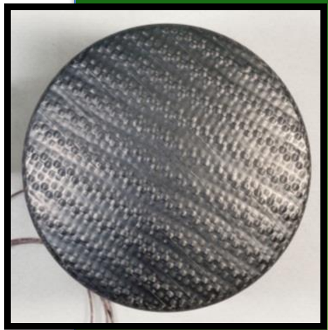
Project Summary: *Demonstration of multi-point space weather observations with a swarm of eight identical satellites*

Led by: NASA Ames Research Center
Partners: Montana State University (science instrument)
Santa Clara University (ground control)
NASA Marshall Space Flight Center

Accomplishments:

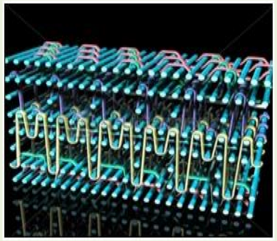
- Each 1.5U cubesat can collect and relay data from the others in the swarm to a single ground station
- Low-cost satellite bus based on Phonesat technology
- Launch scheduled for September 2014 on Super Strypi vehicle from Kauai, Hawaii

Technology Success:
3-D Woven Thermal Protection System



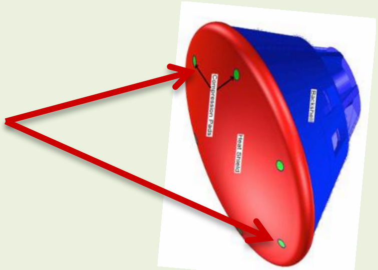
Above images: Resin infused, pre & post arc jet tested coupons, left and right, respectively at test conditions similar to those experienced during atmospheric entries.

3-D Woven



Multifunctional Ablative TPS

6 Compression Pads



Orion Multi-Purpose Crew Module

Woven Preform architecture shows the precise placement of different yarns and the inter-weave architecture that allows Woven ablative TPS to be tailorable. 3-D Woven TPS has superior performance to meet the challenges of Orion compression pad design and is currently being evaluated for flight test in 2017.

Project Summary: *Due to extreme heating as a spacecraft enters the atmosphere the Woven Thermal Protection System (TPS) uses carbon fiber, woven in three dimensional layers creating lightweight materials that are readily available and infused with resin. This cost effective system is fully customizable, providing TPS for a wide variety of atmospheric conditions.*

Accomplishments:

- Selected from the Center Innovation Fund in 2012 for continuation within Game Changing Development.
- Game Changing is in the process of validating this technology, subjecting the material to above 2,500 degrees Fahrenheit—which would melt steel.
- Game Changing will advance the TRL of this promising technology for infusion into an Orion flight test in 2017. The technology is also applicable to future planetary science missions.

Technology Success: Composite Cryogenic Propellant Tank

Top Image shows STMD management with the 5.5 meter diameter composite tank test article. **Bottom images** side view of tank and (right) shows the placement of fibers onto the 5.5 meter diameter tank.

Project Summary: *Developing composite cryogenic propellant tanks using composite materials and advanced manufacturing techniques potentially reducing the cost and fuel tank mass for heavy-lift launch vehicles*

Accomplishments:

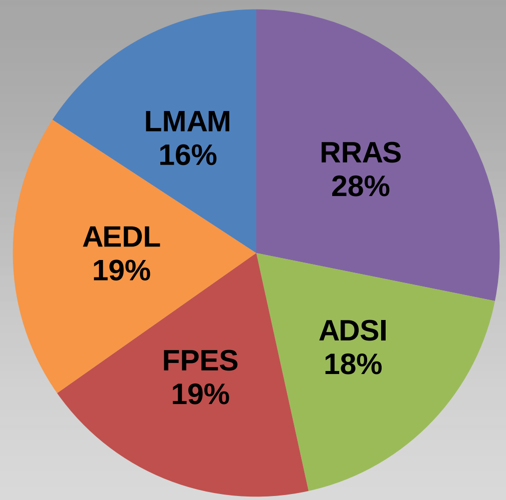
- The Boeing-led team developed the largest composite tank ever produced with new materials that do not require autoclave processing.
- The 5.5 meter diameter composite tank is scheduled to be delivered from Boeing to MSFC in early April 2014.
- Once arriving at MSFC, the tank will be subjected to a rigorous test program to verify the performance.

FY13/FY14 GCD: Firsts!

Lightweight Materials and Advance Manufacturing

- **CCTD:** First and largest composite cryotank in the world to be fabricated out-of-autoclave
- **Adv. Man.** processes to create on-demand spacecraft parts, reducing waste by 80% and manufacturing time from months to weeks; 3D Printer to ISS for first on orbit demonstration
- Delivering a 3D Printer to ISS to demonstrate the feasibility of on demand manufacturing in the space environment

Distribution for FY13/FY14



Future Propulsion and Energy Systems

- Advanced **batteries** with double the life expectancy, and more than double the energy capacity of state of the art.
- A **fuel cell** that will operate up to 10,000 hours maintenance free.
- Inductive pulsed plasma **thruster** operated at a repetition rate at an input power above 1kW
- Developed 10kWe non-nuclear tech demo unit for fission power reactor to test heat-to-power conversion.

Affordable Destination Systems and Instruments

- **Water Processor** that recovers and reuses 85% more wastewater, and reduces water processor resupply requirements by 20%; needed to maintain the life support for astronauts.
- **Deep Space Optical Comm:** Developed new photon counting detector technology with highest efficiency and potential for >7 year lifetime in space.

Advanced Entry, Descent and Landing

- Novel materials for thermal protection of spacecraft that dramatically simplify manufacturing process; adaptable to variety of spacecraft demands.
- Demonstrated variability of woven TPS, provides new options to enhance performance and reduce mass of TPS.
- Developed first 4” thick conformal rayon felt for use on deployable aeroshell concepts.

Revolutionary Robotics and Autonomous Systems

- First successful test of a **hands free jet pack**
- Fully **automated loading** of cryogenic propellant; developed algorithms for simulating chill down and two phase flow loading.
- Developed a valve health monitoring system with embedded algorithms in the solenoid valves to monitor status, degradation and failures.

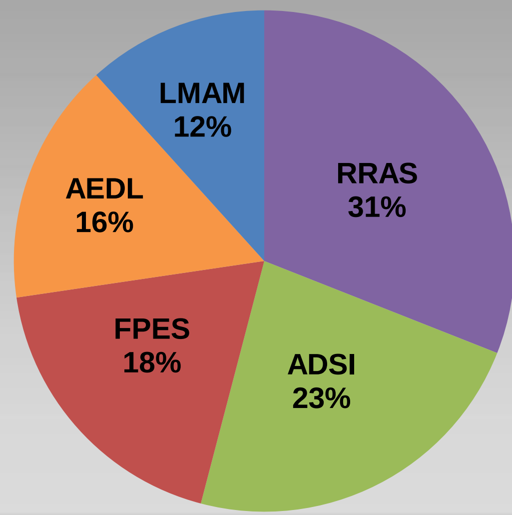
FY 2015 GCD Investment Priorities

Lightweight Materials and Advance Manufacturing

Advanced materials research and applications within Advanced Manufacturing Technology including:

- Materials Genome Initiative, Advanced Near Net Shape, Bulk Metallic Glass (amorphous metal)
- **Nanotechnology:** 20% weight reduction in payload faring beyond advanced composite materials used today

Budget Distribution for FY15



Future Propulsion and Energy Systems

- High Temperature power processing units.
- AMP-Solar cell fabrication techniques including micro-lens concentrators, mechanical cell stacking and bonding
- SWORDS testing support (collaboration with DoD/Army)
- Continue selected microfluidic electrospray thruster for crosscutting space applications

Affordable Destination Systems and Instruments

- In Situ Resource Utilization: breadboards and prototype hardware to demo Mars ISRU tech for Mars 2020 mission.
- High Performance Spaceflight Computing (Radiation hardened/tolerant advanced multicore flight processor).
- High Performance EVA Gloves
- SEXTANT: Instrument on SMD/NICER experiment to ISS for demo of real time X-Ray Navigation
- Compact and more precise fast light optical gyroscopes

Advanced Entry, Descent and Landing

- Hypersonic EDL-developing and advancing computational tools to evaluate EDL systems to improve mass, heat flux and structural load margins.
- Heat Shield for Extreme Entry Environment Technology (HEEET): uses woven TPS to develop high temp heat shields for planetary probes
- The MEDLI+ (follow on the MEDLI entry system instrumentation flown on Mars Curiosity) initiates design phase for Mars 2020 heatshield.

Revolutionary Robotics and Autonomous Systems

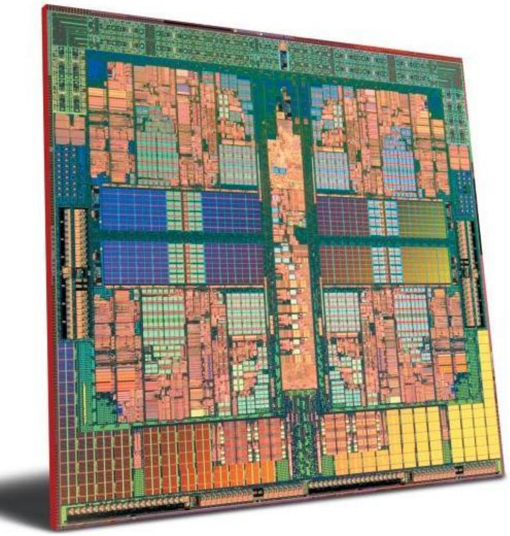
Competed work under the National Robotic Initiative and Human Robotic Systems to support the following areas:

- Habitat Automation
- Continued enhancements for Robonaut
- Supporting technologies for Asteroid Redirect Mission

Partner with DARPA on disaster relief robotics challenge

Continue Satellite Servicing (with HEOMD)

Multi-Agency Priority: High Performance Spaceflight Computing



Developing the next generation **high performance space processor**, for the 2020-30 time frame; Notional targets:

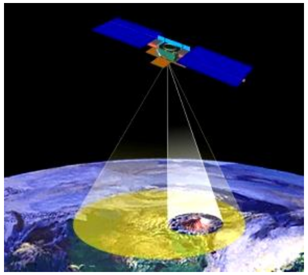
- 100x performance increase; low power (7W)
- Radiation hard; fault tolerant multi-core processor

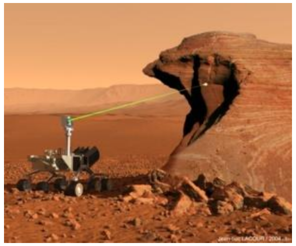
NASA & AFRL released a joint BAA in FY13

- Phase I: 1 year / $2M / multiple teams
  Develop spaceflight processing architecture solutions to a set of NASA & Air Force requirements
- Phase II: 4 years / $20M / one team to develop a high performance spaceflight microprocessor

Multiple Customers

- NASA's exploration & robotic missions: OGAs, for autonomous pinpoint landing with hazard detection and avoidance during EDL
- Real-time segmented mirror control for large space-based telescopes
- Onboard real-time analysis of multi-megapixel-level hyper-spectral image data
- Autonomous onboard situational analysis and real-time mission planning
- Real-time mode-based spacecraft-level fault protection





NASA Innovative Advanced Concepts (NIAC)

Goal:
NIAC funds early studies of visionary, long term concepts - aerospace architectures, systems, or missions and inspires new technology development across many scientific disciplines.

Scope:
Very early concepts:
Technology Readiness Level 1-2 or early 3;
10+ years focus.

Supports 2 Phases of Study:

Phase I: up to $100K, ~9 months, for concept definition and initial analysis in a mission context.

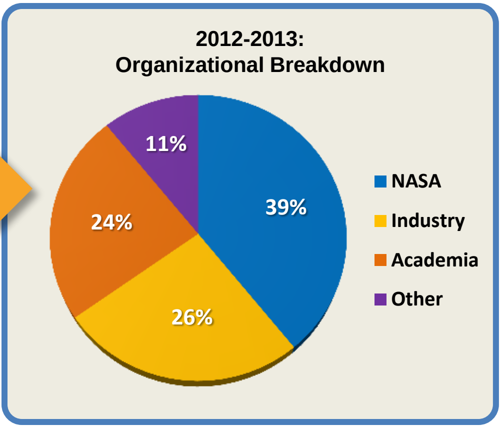
Phase II: up to $500K, 2 years, for further development of the most promising Phase I concepts, comparative mission analysis, pathways forward.

20112– 2013 NIAC FELLOWS

46 Proposals Selected
& Funded (2012-2013 Ph I & Ph II)
18 = NASA Funded Studies
28 = NON-NASA Funded Studies

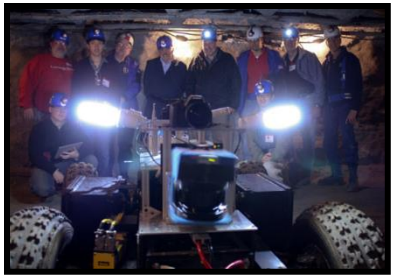
18 = GOV'T Funded Studies
28 = NON- GOV'T Funded Studies

2012 Ph I = 18
2012 Ph II = 10
2013 Ph I = 12
2013 Ph II = 6

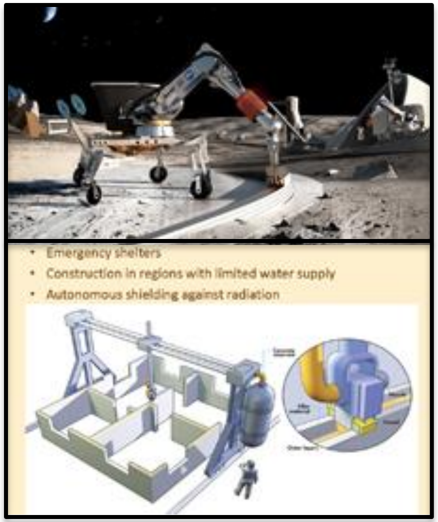


Upcoming FY 2014:
- Will award limited Phase I NIAC awards,
- Select promising Phase I concepts for Phase II NIAC studies

FY 2015:
- NASA will initiate new Phase I NIAC awards
- Further develop the most promising concepts for Phase II NIAC studies



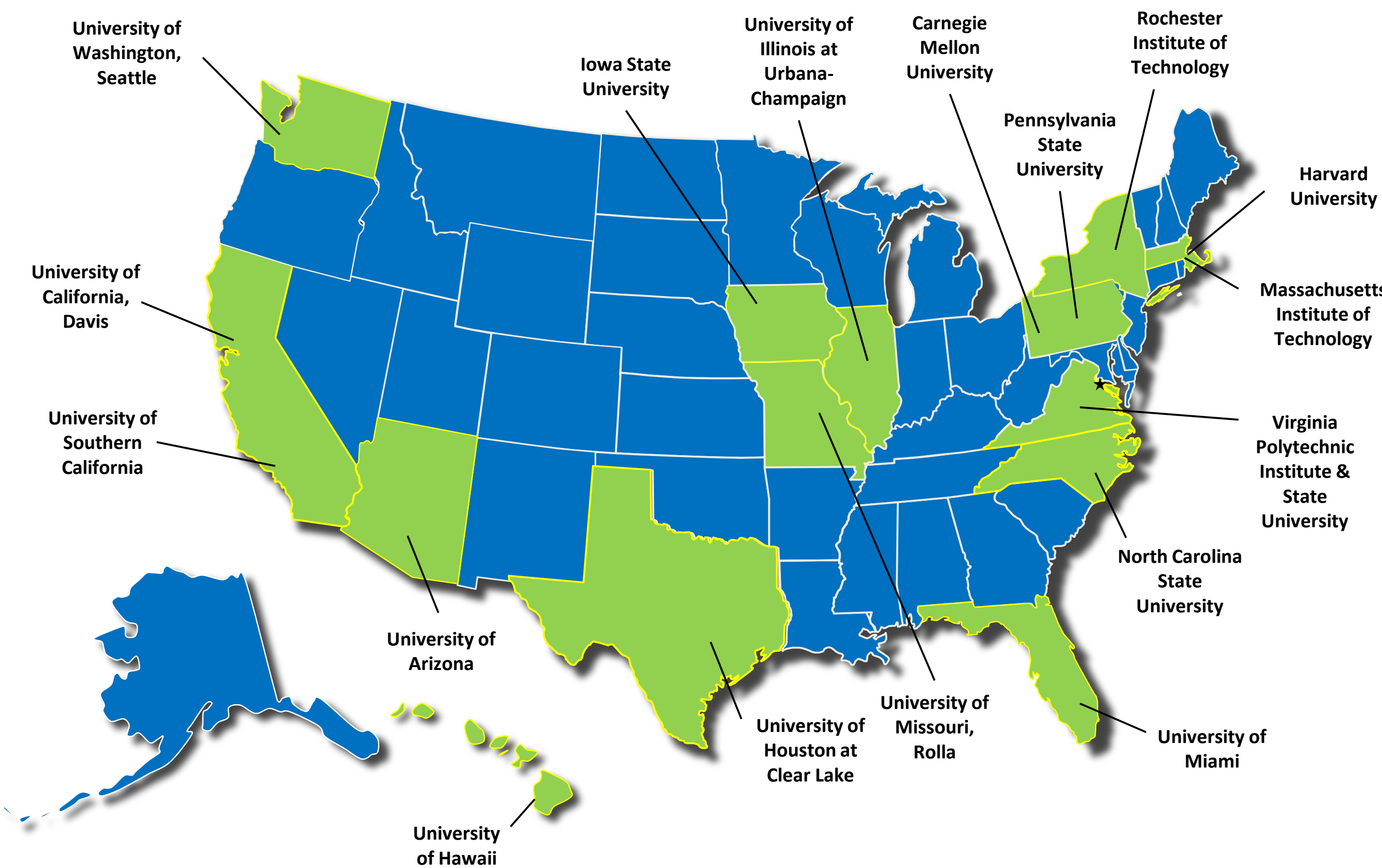
NIAC Fellow William Whittaker, Astrobotic Technology, Inc. (Carnegie Mellon Univ.): Cavehopping Exploration of Planetary Skylights and Tunnels **with terrestrial applications to the mining industry.**



NIAC Fellow Berok Khoshnevis:, University of Southern California: SRU-Based Robotic Construction Technologies for Lunar and Martian Infrastructures **with terrestrial applications to provide safe housing inexpensively, raising the living standards for billions of people around the world.**

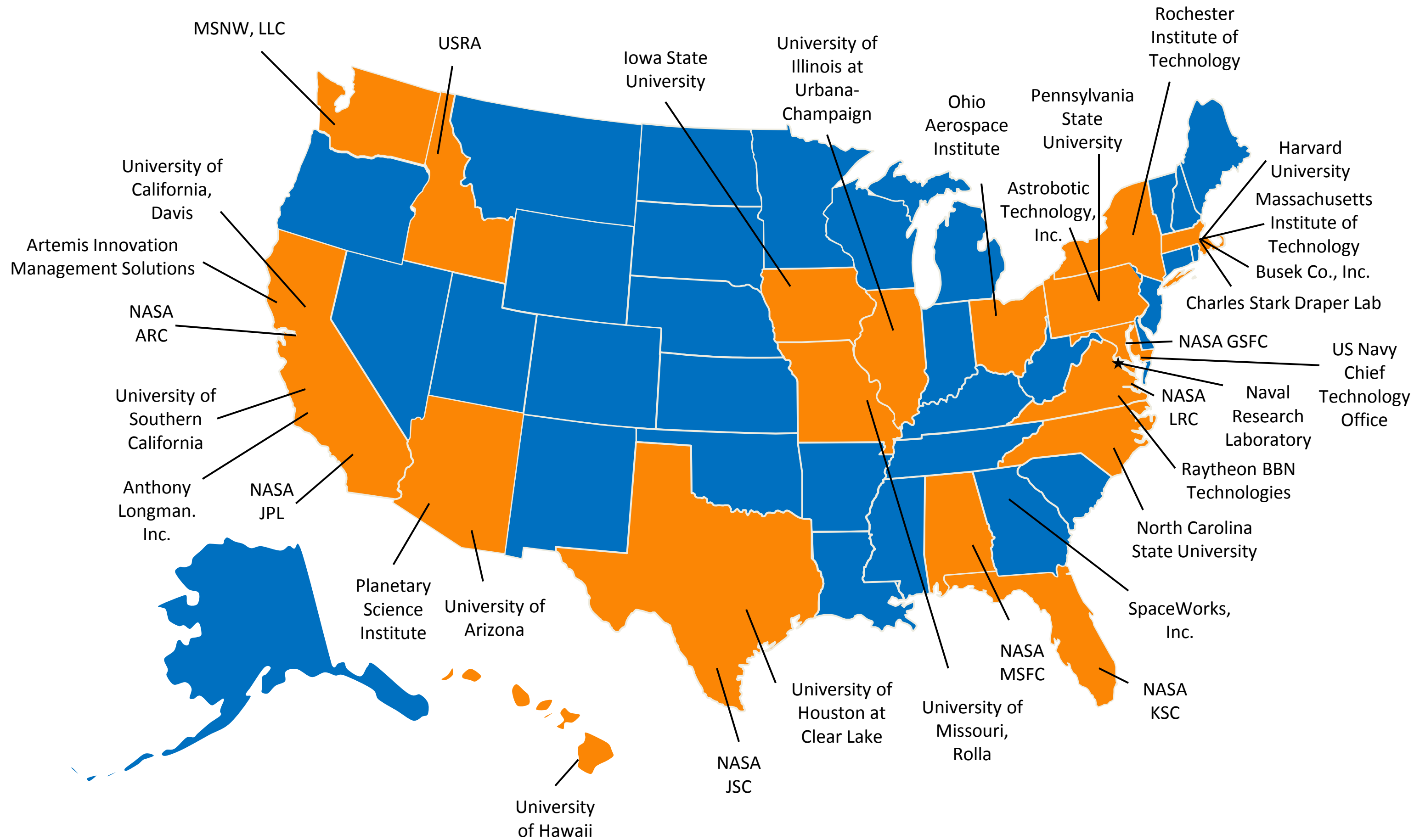
NIAC Educational Institutions: U.S. Map

UNIVERSITY PARTNERS: Inspiring Our Nation's Innovators



J.Falker / NASA

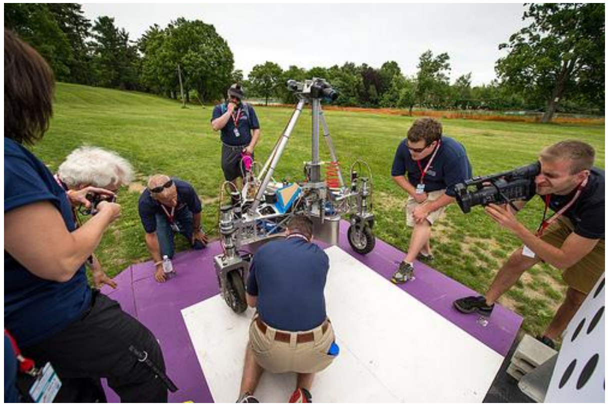
Benefits to the Nation: NIAC Partners



Centennial Challenges

Goal: Engage non-traditional participants such as independent inventors, non-government funded entities, and educational institutions to achieve the Nation's challenging technology goals.

How: Offers competitive challenges that award prize money to the individuals or teams that achieve the specified technology requirements.

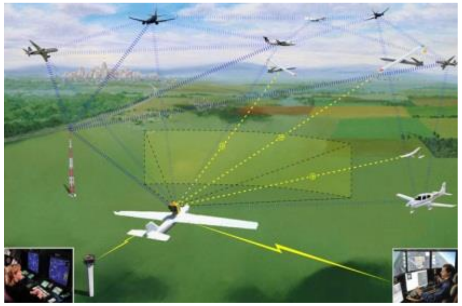


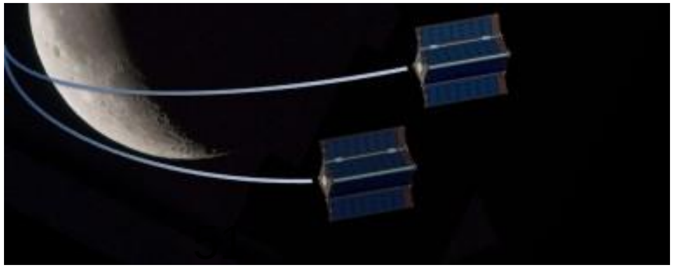
ACCOMPLISHMENTS:

- 2nd Sample Return Robot Challenge competition was held in June 2013 to demonstrate that a robot that can locate and retrieve geologic samples from a wide and varied terrain without human control or terrestrial navigation aids. Ten teams qualified. One Level I winner. Twenty teams registered for 3rd competition will be June 2014 for Level II prize.
- 7 teams registered for the 1st phase of the Unmanned Autonomous System (UAS) Airspace Operations Challenge. Competitors will demonstrate technologies critical to integration of UAS into the NextGen air transportation system.
- RFI released for Deep Space Spacecraft Challenge to demonstrate communication and propulsion technologies relevant to near Earth asteroid detection, characterization and mitigation efforts.

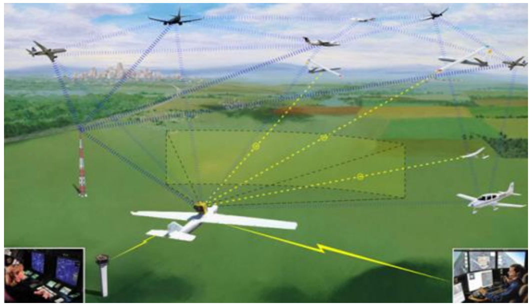
Plans for FY 2015

- Announce new challenges, including one relevant to planetary exploration.





Upcoming Challenges



UAS AOC Challenge

Goal: Demonstrate avionic capabilities for operation in the Next Generation (NextGen) Airspace concept.

- Phase 1 Competition ($500K) - robotic aircraft that can:
  - Fly 4-Dimensional Trajectories (4DT)
  - Employ ADS-B IN
  - Maintain safe separation from cooperative air traffic
  - Operate safely in a number of contingency situations.
- Phase 2 Competition ($1M)
  - Maintain safe separation from uncooperative air traffic
  - Employ ADS-B IN and OUT
  - Have onboard systems capable of communicating verbally with the Air Traffic Control (ATC) system.

- Expect Registration to open in Summer 2013
- Phase 1 Competition Spring 2014. Phase 2 will be one year after Phase 1 success.

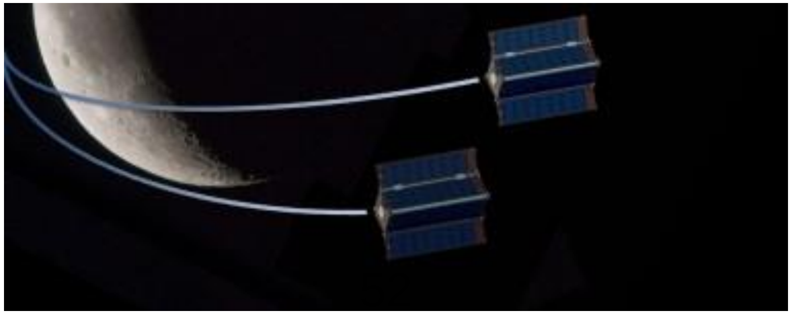
http://uasaoc.org

Deep Space Spacecraft Challenge

Goal: Stimulate innovations in deep space communications and primary propulsion for small spacecraft.

Demonstrate ability of CubeSats to communicate beyond lunar distances without use of DSN and to achieve and sustain lunar orbit.

- Challenge RFI announced February 2, 2014
- Phase A ground competition 2016-2017.
- Phase B space competition 2017-2018.



Flight Opportunities

Goals:

- Matures technologies by providing affordable access to space environments
- Facilitates the development of the commercial reusable suborbital transportation industry.

Flights:

- **Four companies** on contract to provide integration and flight services aboard commercial reusable sub-orbital vehicles.
- Uses Zero G Corporation for **parabolic flights** to carry payloads in reduced gravity and near the boundary of space.

Payloads:

- Unfunded payloads selected though Announcements of Flight Opportunities (AFO)
- Funded payloads selected through FY 2012 and FY 2013 NASA Research Announcements.
- Collaborating with Science Mission Directorate (e.g., USIP) and other NASA programs to make space available for technologies appropriate for the available platforms within the Flight Opportunities program.

Highlights:

- Conducted 5 parabolic flight campaigns and 7 reusable suborbital flight campaigns flying 35 technology payloads in relevant flight environments.
- UP Aerospace Corporation successfully launched SpaceLoft-7 (SL-7) with seven program sponsored technology payloads in June 2013 from the New Mexico Spaceport America
- Masten Space Systems flew in September 2013 the second flight of the Jet Propulsion Laboratory Fuel Optimal Large Divert Guidance (G-FOLD) for planetary pinpoint landing payload on their Xombie vertical takeoff vertical landing suborbital vehicle in Mojave, CA http://www.jpl.nasa.gov/video/?id=1270
- Near Space Corporation successfully completed first balloon flight of satellite-based Automated Dependent Surveillance-Broadcast (ADS-B) operations test in December 2013. Balloon achieved 97,000 feet test altitude for 105 minutes demonstrating balloon position tracking with National Airspace System Air Traffic Control (NAS ATC).
- Program plans to select next round of commercial suborbital flight vendors in FY2014
- Program plans to fly in FY2014 several of 24 technology payloads seeking parabolic flights and 41 payloads seeking suborbital flights

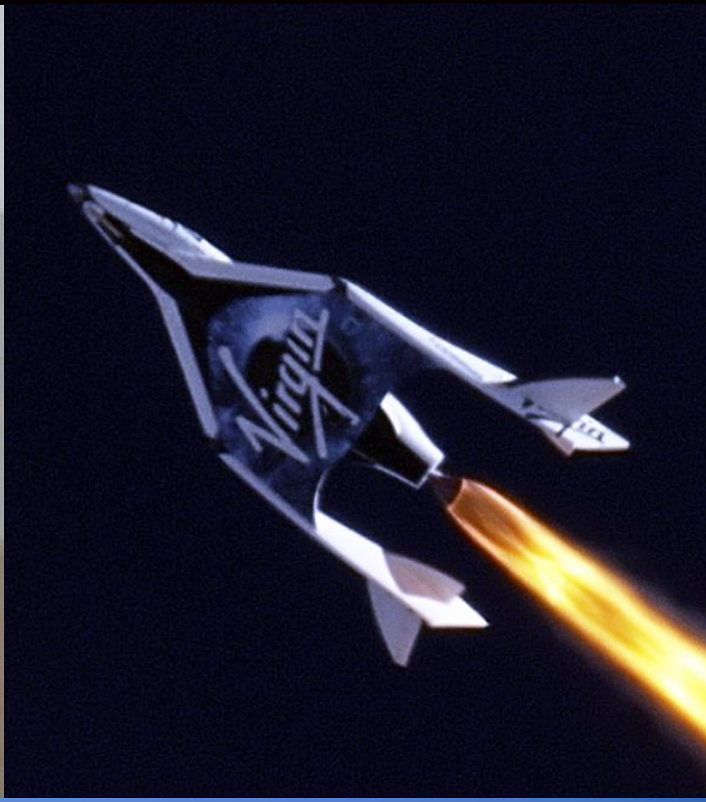
Plans for FY 2015

- Additional providers to be utilized for the first time in FY 2015
- Will schedule multiple flight campaigns based on payload demand using all eligible flight providers.
- With increasing demand for flights, the program will support additional flights on suborbital reusable platforms, conducting one or more flights every month



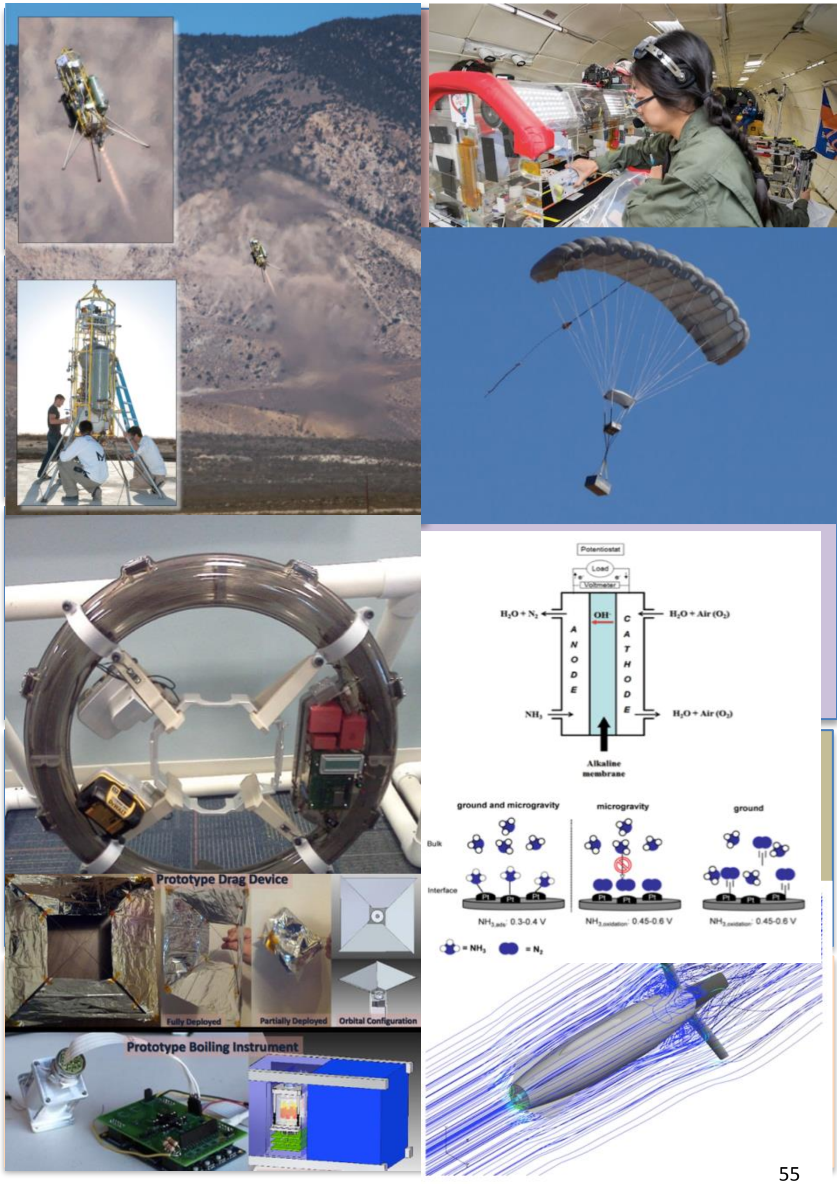



Program Flight Providers in Early FY2014



Announcement of Flight Opportunities(AFO) & NRA Selections To Date

AFO #	# Proposals selected
AFO 1	**16 (**12 parabolic; 2 sRLV; 2 parabolic/sRLV)
AFO 2	**9 (**4 p; 4 sRLV; 1 p/sRLV)
AFO 3	**24 (**16p; 5 sRLV; 2 balloon; 1 balloon + sRLV)
AFO 4	**2 (**1 sRLV; 1 balloon)
GCD-NRA 1	**14** sRLV
AFO 5	**13** (9 p; 2 b; 1 sRLV;1 b/ sRLV)
AFO 6	**21** (14 p; 3b; 2 sRLV; 1 p/sRLV; 1 b/sRLV
GCD-NRA2	**10** sRLV
TDM-AFO 7	-0- Orbital
SMD-USIP	**4** (2p; 1b; 1 sRLV)
AFO 8	TBD
Selections to-date	**113**



ARM Provides First Steps to Mars

Sequence	Mission	Current ISS Mission	Asteroid Redirect Mission	Long Stay In Deep Space	Mars Orbit	Mars Surface, Short Stay	Mars Surface, Long Stay
Mars Destination Capabilities	In Situ Resource Utilization & Surface Power						X
	Surface Habitat						X
	Entry Descent Landing, Human Lander					X	X
	Advanced Cryogenic Upper Stage				X	X	X
Initial Exploration Capabilities	Solar Electric Propulsion for Cargo		X	X	X	X	X
	Exploration EVA		X	X	X	X	X
	Crew Operations beyond LEO (Orion)		X	X	X	X	X
	Deep Space Guidance Navigation and Control/Automated Rendezvous		X	X	X	X	X
	Crew Return from Beyond LEO – High Speed Entry (Orion)		X	X	X	X	X
	Heavy Lift Beyond LEO (SLS)		X	X	X	X	X
ISS Derived Capabilities	Deep Space Habitat	*		X	X	X	X
	High Reliability Life Support	*		X	X	X	X
	Autonomous Assembly	*		X	X	X	X