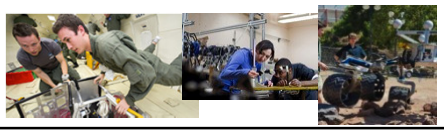
Why Invest in Space Technology?

- 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.

Value to NASA **Value to the Nation**



Addresses National Needs

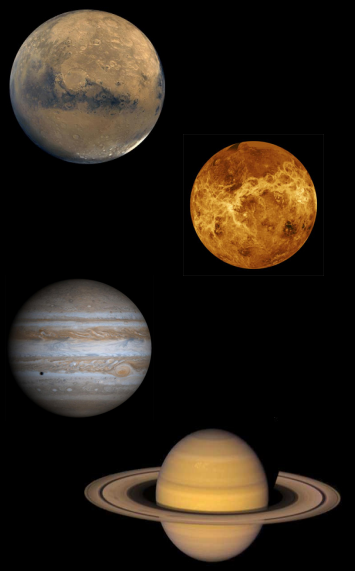
A generation of studies and reports (40+ since 1980) document the need for regular investment in new, transformative space technologies.

Who:
The NASA Workforce
Academia
Industry & Small Businesses
Other Government Agencies
The Broader Aerospace Enterprise

2

Space Technology Strategic Themes

- ***Getting There***: Improve the Nation's capabilities for access and travel through space.
- ***Land There***: Develop and demonstrate technologies that enable landing more mass, more accurately, in more locations throughout the solar system
- ***Live There***: Develop and demonstrate technologies to live and work in deep space and on planetary bodies
- ***Observe There***: Develop and demonstrate technologies that transform the ability to observe the universe and answer the profound questions in earth and space sciences



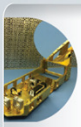
Deep Space Exploration is Near

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.

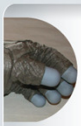
Application: Improved Affordability for Commercial and OGA Satellites



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 and other closed environments

Mars Entry Descent and Landing Systems

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

Application: Returning research from ISS and other assets from space

Space Robotic Systems

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

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

Lightweight Space Structures

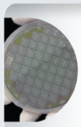
Targets substantial increases in launch mass, and allow for large decreases in needed structural mass for spacecraft and in-space structures.

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 and launch vehicles



Space Observatory Systems

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

Application: Industrial Materials, Earth Observation

THRUST AREAS

4

Snapshot of Space Technology Partners

STMD invests in more than 50 companies totaling over $300M

5

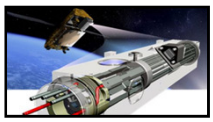
STMD Partners with Universities to Solve The Nation's Challenges

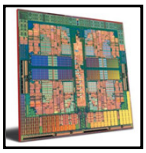
U.S. Universities have been *very* successful in responding to STMD's competitive solicitations

- STMD-funded university space technology research spans the entire roadmap space
- More than **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 	284	284	• Early Career Faculty • Early Stage Innovations • NASA Space Technology Research Fellowships — ***Annually***
NIAC 	93	26	• NIAC Phase I • NIAC Phase II — ***Annually***
Game Changing Technology Dev 	37	14	Various topics released as Appendices to SpaceTech-REDDI — ***Annually***
Small Spacecraft Technology 	22	13	Smallsat Technology Partnerships Cooperative Agreement Notice every two years, with the next opportunity in 2015
Flight Opportunities 	117	50	Tech advancement utilizing suborbital flight opportunities – NRA to U.S. Universities, non-profits and industry are planned. — ***Twice Annually***
STTR 	*192*	*181 w/ univ partners*	*Annual STTR solicitation*
Centennial Challenges 	*4 Challenges (2 university-run)*	*40 teams (9 univ-led, 1 univ-led winner)*	• *One or more challenges annually* • ***Challenge competitions*** *with a* ***procurement track*** *to fund* ***university teams*** *via grants*

STMD - Aerospace Industry Alignment Examples





- **Structures and Materials**
  - Composite Tanks & Structures – for improved launch vehicle performance
  - Hypersonic Entry Technology – for orbital down mass capability
- **Propulsion & Power**
  - Green Propellant Infusion Mission – improved spacecraft performance & reduced toxicity and ground processing costs
  - Solar Electric Propulsion – enabling increased power, reduced mass and longer life for commercial communication satellites
- **Communication & Navigation**
  - Laser Communications – replacing radio frequency based gateway links with optical links and reduces 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 – to perform environmentally hazardous tasks and operate within terrestrial settings

7

FY 2015: Game Changing's Path to the Future

Majority of Game Changing's inherited content is completing in FY 2014. FY 2015 provides the first opportunity to strategically select content focused on the following:

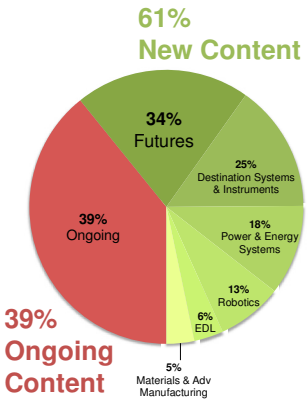
- Balancing between push/pull technologies and guided/competed projects
  (Competed: Advanced Energy Storage, Spacecraft Oxygen Recovery, Spaceflight Computing)
- Utilizing internal and external partnerships
- Leveraging on demonstration opportunities

GCD features new technology investments in:

- Deep Space Optical Comm - Acceleration for Discovery 2014
- In-Situ Resource Utilization - For Mars 2020 Demonstration
- Coronagraph Tech Dev - For WFIRST/AFTA Mission
- Advanced High-Performance In-Space Propulsion
- Rover Tech Dev - For Resource Prospector Mission

By securing a "futures wedge" for new investments, STMD can address future stakeholder priorities and needs

- Actively engaging and studying industry needs with an increased emphasis on public-private partnerships



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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.
- **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 38 technology payloads in relevant flight environments.
- UP Aerospace Corporation successfully launched SpaceLoft-7 (SL-8) with six program sponsored technology payloads in Nov 2013 from the New Mexico Spaceport America
- Masten Space Systems flew in Feb & Jun 2014 open-loop and closed-loop flights, respectively, of Astrobotic Technology's newly developed autonomous landing system (http://tinyurl.com/orwztfp). These tests validated Astrobotic's optical and Light Detection and Ranging (LIDAR) based system that will be used to perform a lunar soft landing in 2015 for the Google X-Prize.
- Near Space Corporation (NSC) successfully flew a small balloon from Madras, Oregon for University of Central Florida's Planetary Atmosphere Minor Species Sensor (PAMSS) payload in July 2014.
- Program plans to select next round of commercial suborbital flight vendors in FY2014
- Program has selected 12 technology experiments to fly on the first commercial research flight on Virgin Galactic's SpaceShipTwo. This flight is planned for early 2015.






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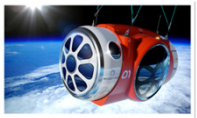
STMD/Flight Opportunities Program New Flight Providers

IDIQ 2 Providers



Company	Payload Capacity	Flight Profile
Masten	40kg	Up to 0.8km alt. 1.0km down-range vertical takeoff/landing
Paragon	20-285kg	Up to 43km alt.; minimum 1hr flight time
UP	37kg	115km alt. 3-4 minute micro-g
Virgin	453kg	80-100km alt. 3-4 minute micro-g

IDIQ 2 Selected September 2014

➢Firm-Fixed Price, Multiple Awards (IDIQ2)

➢Five Year Performance Period

➢New Flight Vendor Solicitation limited to **Vendors with Operational Capability**

➢Must Provide Commercial Operations

➢Purchase can be a **payload slot** or full manifest

➢Provision to **On-Ramp** New Vendors with Qualified Vehicles annually or when Government has a requirement

➢Provision to Solicit **Technology Expansion** in future

➢**SMD and HEOMD** able to procure flights through the contract

Opportunities for Vendors with Emerging Capabilities

Public Private Partnership for Development of Reusable Suborbital and Orbital Launch Systems

Transfers and capitalizes on NASA's long history in investments, knowledge, and expertise in launch systems

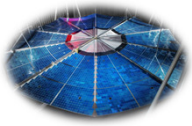
NASA contribution could include technical expertise, test facilities, hardware, and software

Partnership arrangements could include non-reimbursable Space Act Agreements, Cooperative Agreements, etc.

Successful partnership could enable vendors to compete for IDIQ2 on-ramp opportunities

Seeking input from partners: http://go.usa.gov/VRJW

A Look Ahead



- Technology Demonstration Mission Program
  - BAA (topic areas under consideration)
- Solar Electric Propulsion
  - SEP tug
  - High powered solar arrays
  - Electric propulsion system
  - Low-cost solar arrays
- Advanced In-Space Propulsion
- Ultra Lightweight Composite Core Materials
- Outer Planet Exploration Technologies
  - Icy surface landings
  - Radiation protection
  - Robotics
  - Navigation
  - Communication
- Advanced Manufacturing

12


National Aeronautics and Space Administration
NASA
Technology Drives Exploration
#321Techoff


CY Major Events & Milestones
NASA
2014
2015
2016
2017
2018
2019
2020
2021
Human Robotic Systems & Telerobotics
EDSN SmallSat Demo
Integrated Solar Array
Evolvable Cryogenics (eCryo)
SEP Demo Mission
Cubesat Proximity Ops Demo
Sunjammer Solar Sail Ground Demo
Laser Communications Relay Demonstration
Maraia (Suborbital)
5.5m Composite Cryotank
Green Propellant
Terrestrial HIAD with Orbital (THOR)
Optical Comm & Sensor Demo
LDSD: Supersonic Inflatable Aerodynamic Decelerator
Deep Space Atomic Clock
Composite Upper Stage
LDSD: Supersonic Inflatable Aerodynamic Decelerator
Future Planning
14


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.
Small Spacecraft Technology Program develops and demonstrates new capabilities employing the unique features of small spacecraft for science, exploration and space operations.
Game Changing Development seeks to identify and rapidly mature innovative/high impact capabilities and technologies that may lead to entirely new approaches for the Agency's broad array of future space missions.
NASA Innovative Advanced Concepts (NIAC) nurtures visionary ideas that could transform future NASA missions with the creation of breakthroughs—radically better or entirely new aerospace concepts–while engaging America's innovators and entrepreneurs as partners in the journey.
Space Technology Research Grants seek to accelerate the development of "push" technologies to support future space science and exploration needs through innovative efforts with high risk/high payoff while developing the next generation of innovators through grants and fellowships.
Center Innovation Fund stimulates and encourages creativity and innovation within the NASA Centers by addressing the technology needs of the Agency and the Nation. Funds are invested to each NASA Center to support emerging technologies and creative initiatives that leverage Center talent and capabilities.
Centennial Challenges directly engages nontraditional sources advancing technologies of value to NASA's missions and to the aerospace community. The program offers challenges set up as competitions that award prize money to the individuals or teams that achieve a specified technology challenge.
Flight Opportunities facilitates the progress of space technologies toward flight readiness status through testing in space-relevant environments. The program fosters development of the commercial reusable suborbital transportation industry.
Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs provide an opportunity for small, high technology companies and research institutions to develop key technologies addressing the Agency's needs and developing the Nation's innovation economy.
15