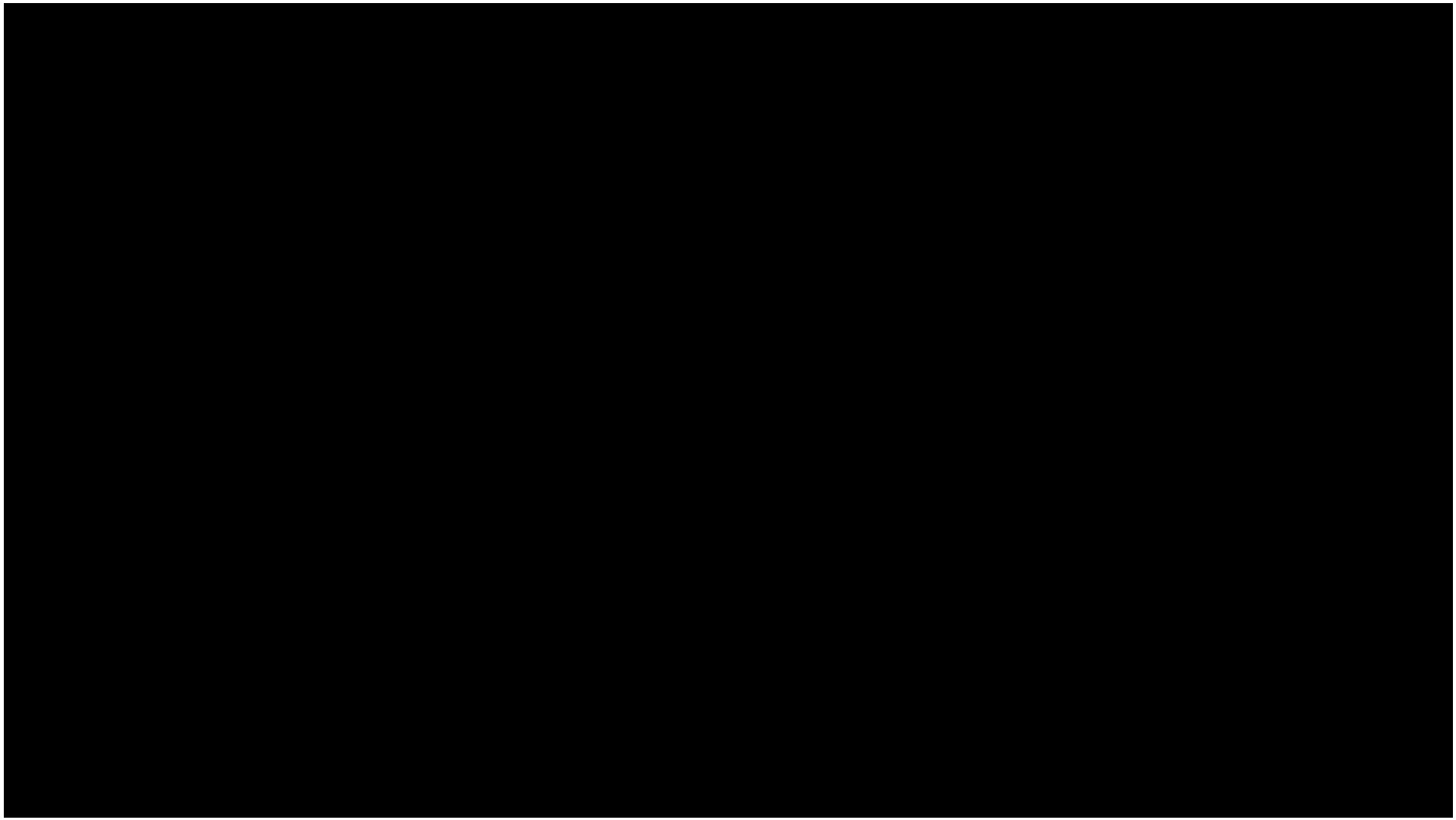
National Aeronautics and Space Administration

Space Technology Mission Directorate Overview

Mirror Technology Days SBIR/STTR Workshop

Presented by:
Joseph Grant

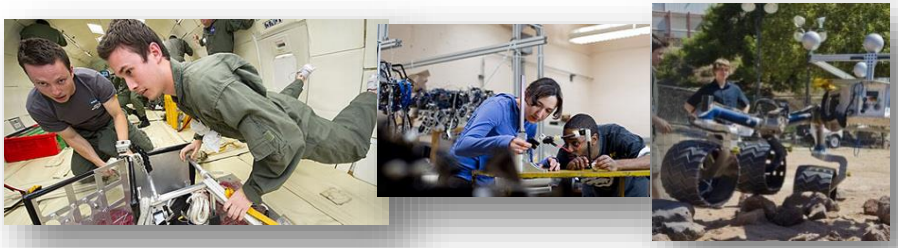
November 2017



Space Technology…
…. an Investment in Global Leadership

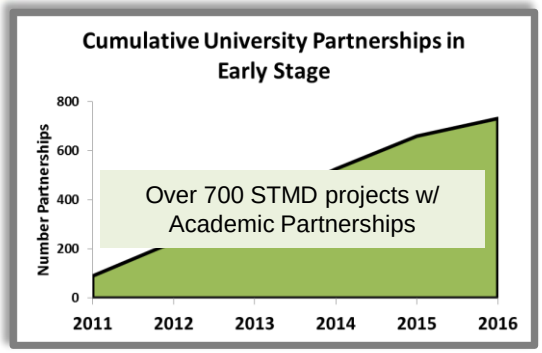
- Enables a **new class of NASA missions** beyond low Earth Orbit.
- **Delivers innovative solutions** that dramatically improve technological capabilities for NASA and the Nation.
- Develops technologies and capabilities that make NASA's missions **more affordable and more reliable.**
- Invests in the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



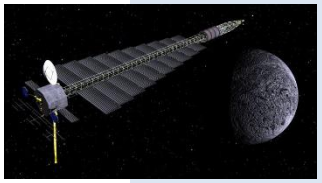
Benefits from STMD:

The NASA Workforce
Academia
Small Businesses
The Broader Aerospace Enterprise

STMD Strategic Thrusts

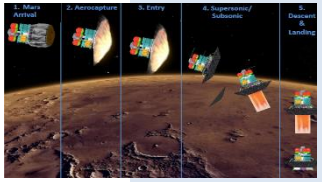
ST1: Expand Utilization of Near-Earth Space

- Provide safe and affordable routine **access to space**
- Enable **extension, reuse, and repair** of near-Earth assets
- Expand **near-Earth infrastructure** to support human and science exploration beyond LEO



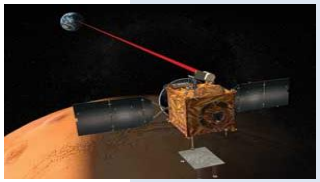
ST2: Develop Efficient & Safe Transportation Through Space

- Provide cost-efficient, reliable **propulsion for long duration missions**
- Enable **significantly faster**, more efficient deep space missions



ST3: Increase Access to Planetary Surfaces

- Safely and precisely **deliver humans & payloads to planetary surfaces**
- Increase **access to high-value science sites** across the solar system
- Provide efficient, highly-reliable **sample return** reentry capability



ST4: Enable the Next Generations of Science Discoveries

- Expand access to new environments and measurement **platforms** to enable high-value science
- Enable **substantial increases** in the quantity and quality of science data returned
- Enable **high-power measurements** for long duration science missions

ST5: Enable Humans to Live and Explore in Space and on Planetary Surfaces

- Enable humans to **survive** on other planets
- Provide efficient/scalable **infrastructure** to support exploration at scale
- Increase crew effectiveness and **access to diverse, high-value sites**
- Provide shielded **in-space habitation**

ST6: Grow & Utilize the U.S. Industrial and Academic Base

- **Transfer NASA technology** to grow the U.S. industrial & technology base
- Open and **foster new space markets** for U.S. commerce
- Expand **public-private partnerships** for mutually-beneficial technology developments
- **Drive U.S. innovation** & expand opportunities to achieve the NASA dream

Mega Drivers

Increasing Access

Major Trends:

- Lowering **costs**
- Increasing launch **availability**
- Decreasing **travel time**
- Diversifying **platforms** (e.g. CubeSats)
- Scalable **transportation** solutions
- New accessible **destinations**

Accelerating Pace of Discovery

Major Trends:

- **Major discoveries** of potentially life-harboring icy moons and exoplanets
- Growing urgency for **Earth-Moon-Sun science** discovery and understanding
- Humanity's desire for ambitious **exploration** of the solar system and ultimately interstellar travel

Democratization of Space

Major Trends:

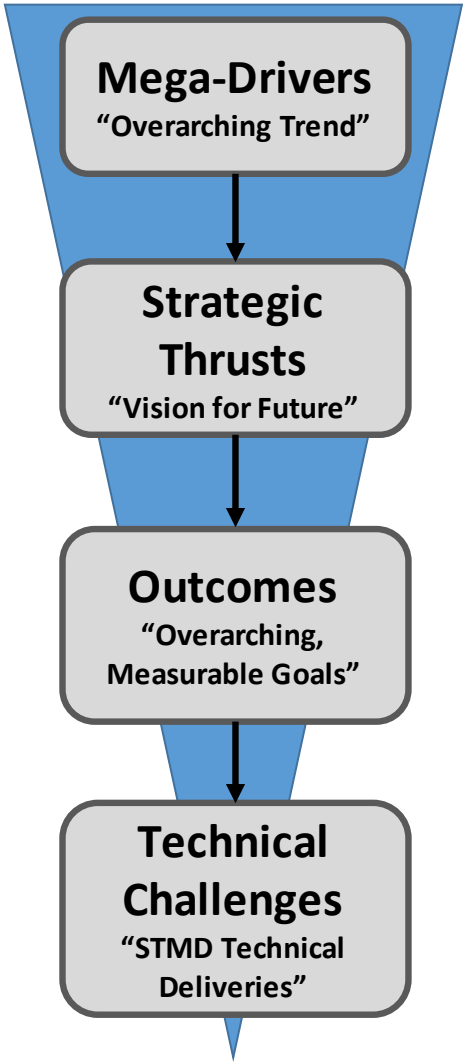
- Broadening **participation** spectrum, from governments to citizens
- Growth in **private investment** in space
- **Public-private partnerships**
- **International** collaborations

Growing Utilization of Space

Major Trends:

- Space market **diversification** (e.g. servicing, manufacturing, mining, debris removal, tourism)
- Space industry **growth** well surpassing U.S. average GDP growth
- Space-based solutions addressing growing **global challenges**

Strategic Framework



Overarching trends that have, are, and will largely shape the course of civilian space over many years

Strategic Thrusts constitute STMD's vision for the future of civilian space

Measurable goals within the Strategic Thrusts that STMD chooses to pursue through joint efforts across the space community

Represents the product and/or capability delivered by STMD to enable the community-level outcomes

Public-Private Partnerships: Tipping Point Technologies

Tipping Point Technologies

- Increased focus on **collaboration** with the commercial space sector
- Fixed price contracts with milestone payments
- Requires a minimum **25 percent minimum contribution from** corporation or customer
- Leverage emerging markets and capabilities to meet NASA's strategic goals AND focus on **industry needs**
- **Increase likelihood of infusion** into a commercial space application
- Substantial benefit to both **commercial and government sectors**

Tipping Point Technology Topics – 2016 (9 awards)

- Robotic in-space manufacturing and assembly of spacecraft/space structures (3 awards)
- Low size, weight and power instruments for remote sensing applications (2 awards)
- Small spacecraft attitude determination and control sensors and actuators (2 awards)
- Small spacecraft propulsion systems (2 awards)

Tipping Point Technology Topics – 2017 (8 awards)

- Small Launch Vehicle Technology Development (6 awards)
- Small Spacecraft Capability Demonstration Missions (2 awards)

Planning to release solicitation with targeted topics ~annually

Laser Communications Relay Demonstration (LCRD)

Objectives:

•Demonstrate bidirectional optical communications between geosynchronous Earth orbit (GEO) and Earth

•Measure and characterize system performance over a variety of conditions

•Transfer laser communication technology to industry for future missions

•Provide an on orbit capability for test and demonstration of standards for optical relay communications

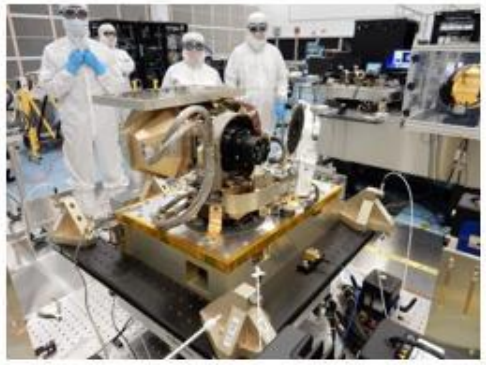
Current Status / Accomplishments:

•LCRD Payload is manifested to fly on STP-Sat6 Space Vehicle with Air Force Space Test Program which is the STP-3 Mission

•The LCRD project continues to complete component level hardware testing, readying for payload integration and test this fiscal year.

•LCRD payload delivery to Orbital ATK will occur late in FY18.

Flight Modem #1



Optical Module #2

Solar Electric Propulsion (SEP)

Objectives:

•Demonstrate high-power (HP) Solar Arrayand Solar Electric Propulsion (SEP) technology in relevant space environments

•Demonstrate sufficient ΔV to confirm throughput EP capability and lifetime of overall flight system

•Demonstration of operations in deep space or “proving ground”

•Observe and characterize performance of integral HP-SEP system including thrusters, arrays, bus, and payloads as they operate as an integrated system and as they respond to the in-space environment.

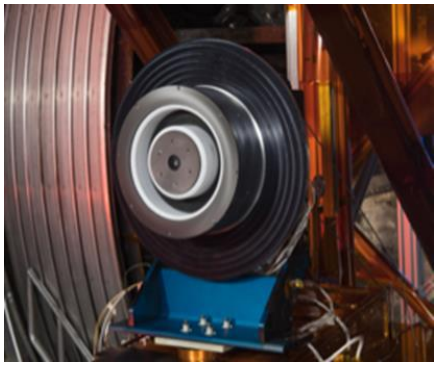
•Demonstrate HP SEP servicing and/or transport bus

•**Qualify next generation SEP bus**

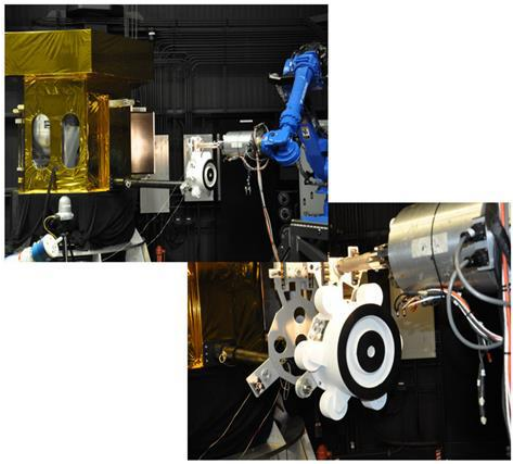
Current Status/Accomplishments:

•Advanced Electric Propulsion System (AEPS), awarded to AerojetRocketdyne, has completed through Preliminary Design Review in late FY17.

•Project is expected to complete EP thrusters, through qualification, in 2019.



TDU-3 installed for testing at GRC



Thruster RDU Simulator Testing at GSFC

Deep Space Optical Communications (DSOC)

Objectives:

•Achieve 10 to 100 times greater data-rate performance from deep space with comparable mass and power to state-of-art radio frequency telecommunications systems

•Retire the implementation risks of utilizing optical communications technology on deep space missions

Current Status / Accomplishments:

•DSOC was matured to TRL 5 as an STMD Game Changing Development Program project and transferred in to TDM in FY17.

•DSOC will fly on the Psyche Mission, selected as part of the Science Mission Directorate Discovery 14 Program.

•Kickoff meeting has been held between DSOC, the Psyche Mission and the SSL spacecraft team to discuss accommodations.

•Project is readying for System Requirements Review and Mission Design Review.

Artwork depicting the Psyche spacecraftorbiting 16 Psyche

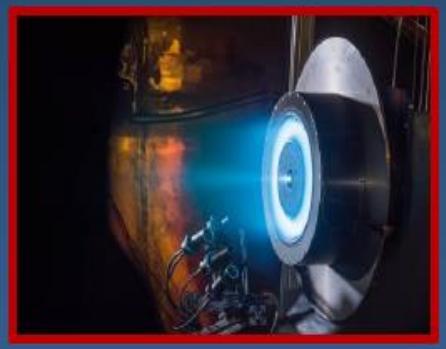
Develop Efficient & Safe Transportation Through Space

Spaceflight demo of ROSA on ISS

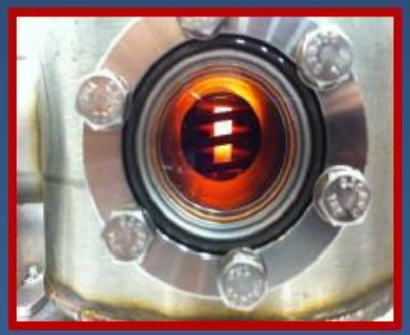
Green Propellant Infusion Mission ready for launch

Robotic Refueling Mission 3: eCryo Radio Frequency Mass Gauge flight demo

Solar Electric Propulsion cont. development and qualification



NASA 12.5 kW Hall thruster technology development unit



Nuclear Thermal Propulsion: Alternate fuel reactor conceptual design/analysis

eCryo: Cryocooler completes environmental tests

Expand Utilization of Near-Earth Space

Laser Communication Relay Demonstration

Nanotechnology launch: Composite Overwrapped Pressure Vessel

Low Cost Upper Stage

Affordable Vehicle Avionics Launch

Satellite Servicing

Integrated Solar Array and Reflectarray Antenna (ISARA)

CubeSat Proximity Operations Demonstration (CPOD)

In-Space Robotic Manufacturing and Assembly Nodes

Flight Opportunities Program providing sub-orbital capabilities

Public-Private Partnerships: Announcement of Collaborative Opportunity (AOC)

Advance Emerging Space Technology System Capabilities

- Focus on industry-developed space technologies that can advance the commercial space sector and benefit future NASA missions
- NASA provides technical expertise and test facilities, as well as hardware and software to aid industry partners in maturing technologies
- Non-Reimbursable Space Act Agreements (no funds exchanged)

2016 Technology Topics (13 awards)

- Suborbital reusable and small satellite launch systems development (4 awards)
- Wireless power transfer development (0 awards)
- Thermal protection system materials and systems development (3 awards)
- Green propellant thruster technology qualification (3 awards)
- Small, affordable, high performance liquid rocket engine development (3 awards)

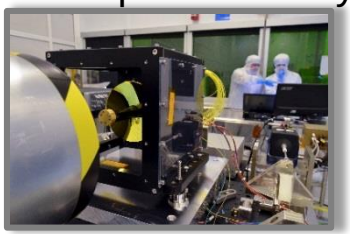
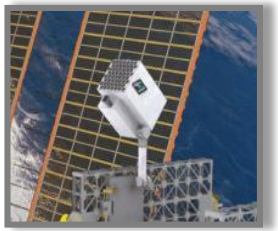
2017/2018 Topics (Final proposals received on May 31)

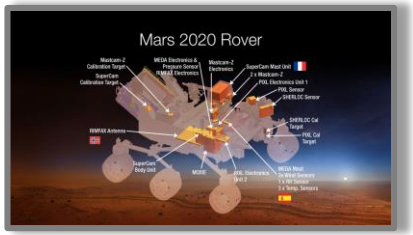
- Small Launch Vehicle Technology Development
- Reliable Electronics Technology Development
- Advanced Communications Technology Development
- In-space Propulsion Technology Development

Planning to release solicitation with targeted topics ~every other year

FY 2018: Key Activities

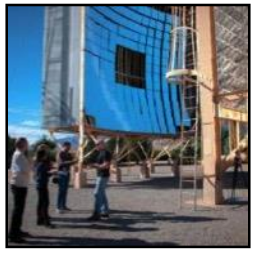
- Complete Laser Communication Relay Demonstration flight hardware and begin system integration and testing to support a 2019 launch readiness date
- Transform satellite servicing investment to support a nascent commercial satellite servicing industry as well as application by NASA and other government agencies
- Continue development of high-powered solar electric propulsion to meet demands by U.S. aerospace industry and for NASA exploration missions
- Enlist public-private partnerships to explore solutions to common challenges in areas such as robotics, manufacturing, and materials, accelerating technologies at the “tipping point” for use by industry, NASA and other government agencies
- Design, manufacture and test of fuel element segment for Nuclear Thermal Propulsion project and perform assembly and checkout of sub-scale exhaust capture system
- Finalize hardware development for MOXIE and Terrain Relative Navigation projects and begin integration and test to support the Mars 2020 schedule
- Grow and utilize the U.S. industrial and academic base with a steady cadence of early stage technology activities conducted by the NASA workforce, academia and businesses within the aerospace industry



Early Stage Portfolio (ESP) Overview

"Beyond the Next…" STMD's ESP pursues leaps in future capabilities by emphasizing creativity and innovation, exploring new approaches, and challenging limits



NASA Innovative Advanced Concepts (NIAC)
Push the boundaries of what is currently possible, engaging visionary innovators to explore radical concepts and redefine the future of aerospace

Space Technology Research Grants (STRG)
Examine the feasibility of critical ideas while inspiring, training, and leveraging the academic community, from graduate students to senior faculty

- Now includes **Space Technology Research Institutes (STRI) -** Advance scientific and technological areas key to NASA's future through sustained, coordinated investment in multi-disciplinary, university-led research

Center Innovation Fund (CIF)
Seed technology to transform future missions by stimulating innovation at all NASA Centers and partnering with researchers across the Nation

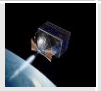
Early Career Initiative (ECI)
Invigorate NASA's technological base and management practices by partnering early career NASA leaders with world-class external innovators

ESP represents roughly 9% of the STMD budget and 30% of the projects – about 400 ongoing on average, with roughly 200 new starts and 200 completions each year.

Partnering with Universities to Meet National Technology Needs

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
- In addition, there are many other partnerships between academia and NASA Centers and/or commercial entities through the below Programs and other STMD Programs such as Center Innovation Fund and SBIR.
- **Hundreds** of universities have participated!

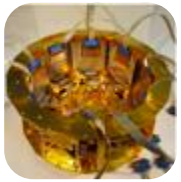
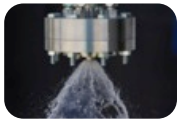
Program	# awards*	# University-led awards	Opportunities to Propose
Space Technology Research Grants 	517	517	• Early Career Faculty • Early Stage Innovations • NASA Space Technology Research Fellowships • Space Technology Research Institutes **new!**
NIAC 	158	45	• NIAC Phase I • NIAC Phase II
Game Changing Technology Dev 	66	19	Various topics released as Appendices to SpaceTech-REDDI
Small Spacecraft Technology 	41	29	Smallsat Technology Partnerships Cooperative Agreement Notice every two years.
Flight Opportunities 	149	75	Tech advancement utilizing suborbital flight opportunities – NRAs to U.S. Universities, non-profits and industry are planned.
STTR/SBIR 	434	*> 95% university partners*	*Annual STTR solicitation*
Centennial Challenges 	*7 Challenges (2 university-run)*	*52 university teams out of 104 registered*	• *One or more challenges annually* • *Open to university faculty and students*

* Some recent selections are still in negotiation

Space Technology Research Grants
Opportunities to Propose

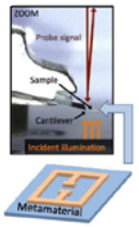
Engage Academia: *tap into **spectrum** of academic researchers, from graduate students to senior faculty members, to examine the theoretical feasibility of ideas and approaches that are critical to making science, space travel, and exploration more effective, affordable, and sustainable.*



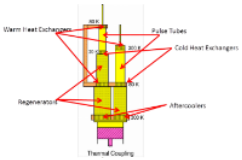
NASA Space Technology Research Fellowships

- Graduate student research in space technology; research conducted on campuses and at NASA Centers and not-for-profit R&D labs



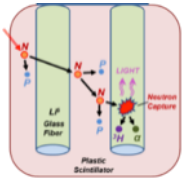
Early Career Faculty

- Focused on supporting outstanding faculty researchers early in their careers as they conduct space technology research of high priority to NASA's Mission Directorates

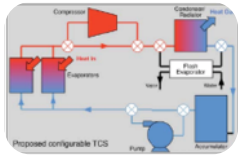


Early Stage Innovations

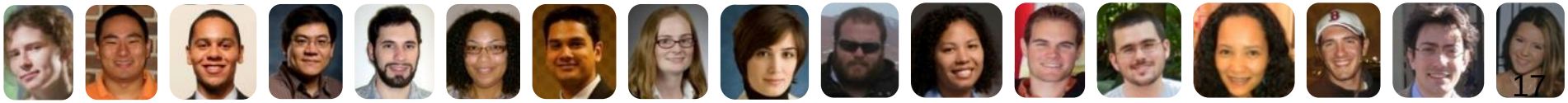
- University-led, possibly multiple investigator, efforts on early-stage space technology research of high priority to NASA's Mission Directorates
- Paid teaming with other universities, industry and non-profits permitted



Space Technology Research Institutes



Accelerate development of groundbreaking high-risk/high-payoff low-TRL space technologies



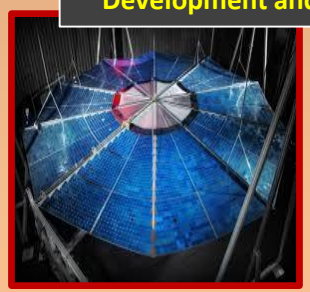
FY 2018: An Exciting Year in Space Technology

Deep Space Atomic Clock and Green Propellant Infusion Mission ready for launch

Astrobee will fly on ISS and perform on orbit operations

Solar Electric Propulsion cont. Development and Qualification

KiloPower- KRUSTY Testing



Small Spacecraft launches demonstrate technologies, enabling future missions

Complete testing of Laser Communication Relay Demonstration for flight test in 2019

Space Technology Drives Exploration

- Space Technology is delivering new technologies and capabilities to Agency and Commercial Partners
- Expanding Public-Private Partnerships with growth in Tipping Point and ACO; Increasing Early Stage investments with universities, including increase in number of Space Technology Research Institutes
    - ACO Announcement of Collaborative opportunity
- Continue advancements in high risk, high payoff research and technology development in Early Stage Portfolio engaging the Centers, industry and academia
- Resources to maintain a robust set of technology demonstrations and maturation projects over a period of a decade or longer – required for deep space human exploration

National Aeronautics and
Space Administration

Technology Drives Innovation

www.nasa.gov/spacetech