National Aeronautics and
Space Administration

Space Technology Mission Directorate Overview Briefing

Presented by:
Dr. James Reuther
Deputy Associate Administrator for Programs,
Space Technology Mission Directorate

July 17, 2013

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

Challenges for Deep Space Exploration

Communication

Environment Control & Life Supporting Systems

Power Generation & Storage

Logistics

Navigation

Manufacturing In Space & For Space

Entry, Descent & Landing

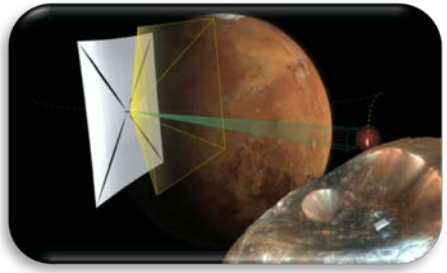
Radiation Mitigation

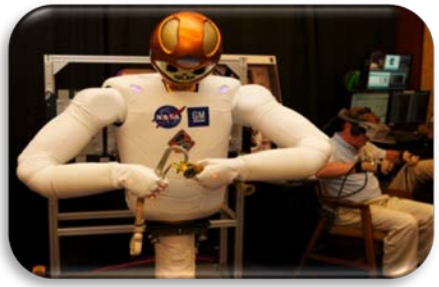
Propulsion

Guiding Principles of the Space Technology Programs

Space Technology Programs

- **Adheres to a Stakeholder Based Investment Strategy:** NASA Strategic Plan, NASA Space Technology Roadmaps / NRC Report and Strategic Space Technology Investment Plan
- **Invests in a Comprehensive Portfolio:** Covers low to high TRL, student fellowships, grants, prize competitions, prototype developments, and technology demonstrations
- **Advances Transformative and Crosscutting Technologies:** Enabling or broadly applicable technologies with direct infusion into future missions
- **Selects Using Merit Based Competition:** Research, innovation and technology maturation open to academia, industry, NASA centers and other government agencies
- **Executes with Structured Projects:** Clear start and end dates, defined budgets and schedules, established milestones, and project authority and accountability.
- **Infuses Rapidly or Fails Fast:** Rapid cadence of technology maturation and infusion, informed risk tolerance to infuse as quickly as possible
- **Positions NASA at the cutting edge of technology:** Results in new inventions, enables new capabilities and creates a pipeline of innovators for National needs

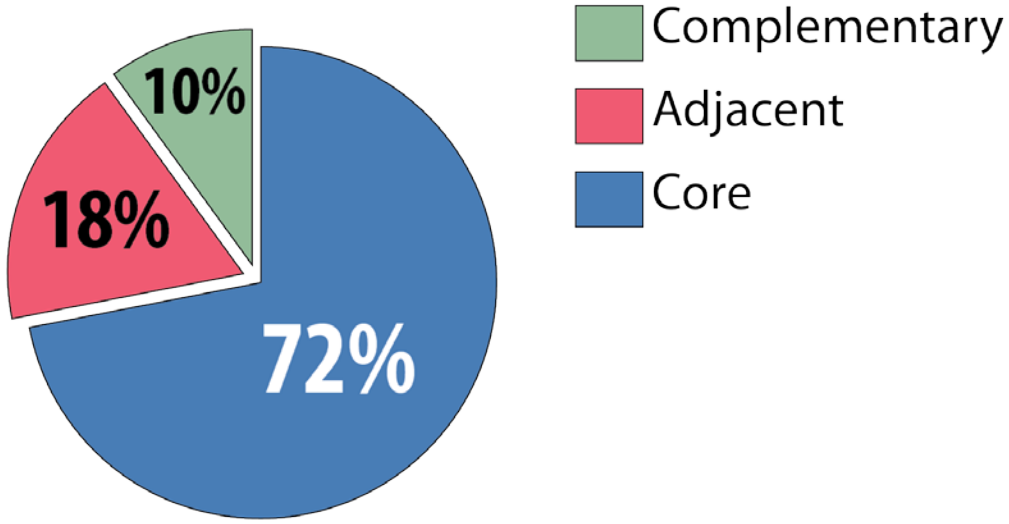




Strategic Investments in Technology

Evaluating current STMD investments as recommended by the Strategic Space Technology Investment Plan (SSTIP, NRC, other Stakeholders)

- Initial evaluation is consistent with the SSTIP Core, Adjacent, and Complementary recommendations
- Approximately 72% of investments are in Core areas
- STMD has investments in all 14 Technology Areas
- Approximately 10% of investments are low TRL (1-3) consistent with the recommendation by the National Research Council (NRC) Final Report on Space Technology Roadmaps and Priorities

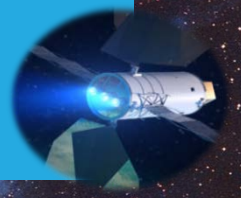


STMD investments are consistent with the Strategic Space Technology Investment Plan (SSTIP)

STMD Technology Investments within NRC's Top 16 Priorities

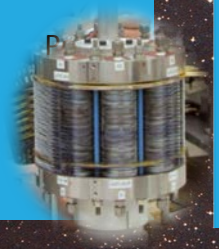
Electric Propulsion

Solar Electric Propulsion
- Solar Arrays
- Thruster & Power Processing Unit
- Propellant Feed System & Storage Tanks
- High Power Electric Propulsion Systems (SBIR)
- Hall Thruster & Erosion (Lifetime) Measurements (STRG)



Solar Power Generation

- Advanced Batteries
- Regenerative Fuel Cells
- Advance Photovoltaic Systems (SBIR)
- Nanostructured Photovoltaics for Space Power (STRG)
- "SPS-Alpha" Space Solar P architecture (NIAC)

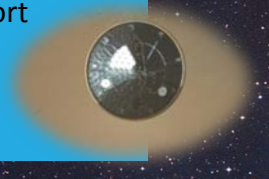


Environmental Control and Life Support System

- CO_2 to O_2 recovery
- Water Processing
- Air Regulators
- Biocomposites
- Crew Accommodations and Water Recovery for Long Duration Missions (SBIR)
- New Technology for Gas Absorption (STRG)
- Solid State Air Purification System (NIAC)

Entry, Descent and Landing

- Woven Thermal Protection
- Deployable Aeroshell Concepts
- Hypersonic Entry Systems
- Supersonic Descent Systems
- Ablative Thermal Protection Systems (SBIR)
- Quantitative Measurements of Ablation-Products Transport for Turbulence Model Validation (STRG)



Active Thermal Control of Cryogenic Systems

- Cryogenic Propellant Storage and Transfer
- Integrated Multilayer Insulation
- Cryogenic Systems for Sensors and Detectors (SBIR)
- Two-Stage, 20 K Pulse Tube Cryocooler for Space Studies (STRG)

Extreme Terrain Mobility

- Human Robotic Systems
- Robotic Satellite Servicing
- Autonomous Systems
- Robotic Mobility, Manipulation and Sampling (SBIR)
- Exploration of Under-Ice Regions with Ocean Profiling Agents (EUROPA) (NIAC)

STMD Technology Investments within NRC's Top 16 Priorities

Early Stage Innovation:
GCD, CIF, NIAC, STRG, SBIR/STTR

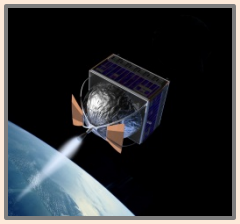
- (Nuclear) Thermal Propulsion
- Fission (Power)
- Long-Duration (Crew) Health
- Detectors & Focal Planes
- (Instrument and Sensor) Optical Systems
- High-Contrast Imaging and Spectroscopy Technologies
- In Situ (Instruments and Sensor)
- Radiation Mitigation for Human Spaceflight
- Lightweight and Multifunctional Materials and Structures
- Guidance, Navigation, and Control

Space Technology Portfolio

Transformative & Crosscutting Technology Breakthroughs

Game Changing Development (ETD/CSTD)

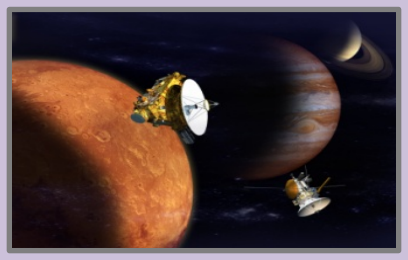
Technology Demonstration Missions (ETD/CSTD)



Small Spacecraft Technologies (CSTD)

Pioneering Concepts/ Developing Innovation Community

Space Technology Research Grant (CSTD)

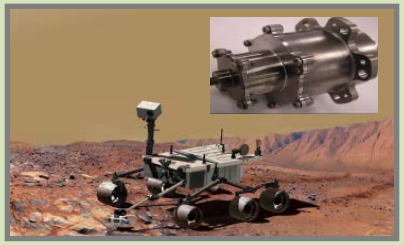


NASA Innovative Advanced Concepts (NIAC) (CSTD)

Center Innovation Fund (CSTD)

Creating Markets & Growing Innovation Economy

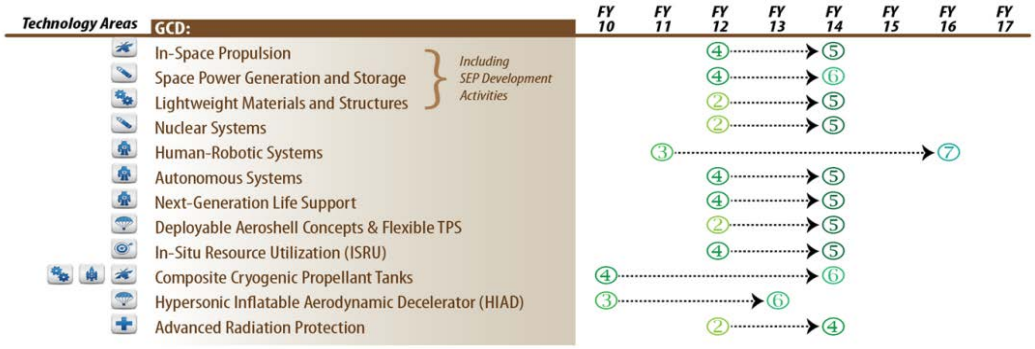
Centennial Challenges (CSTD)

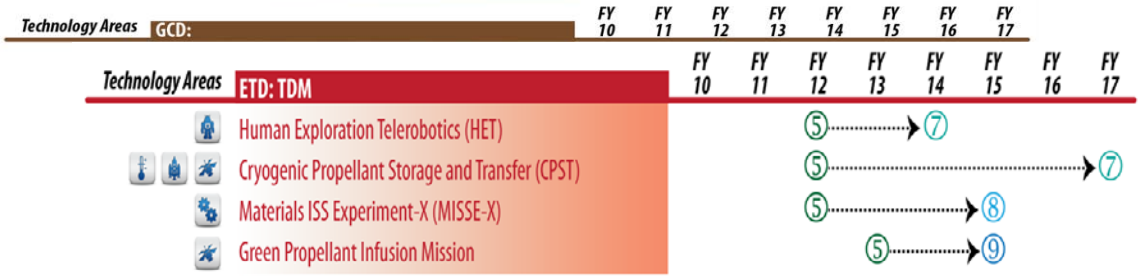


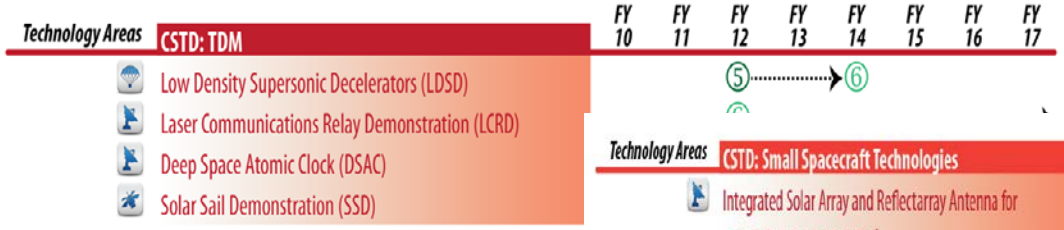
Small Business Innovation Research & Small Business Technology Transfer (SBIR/STTR)

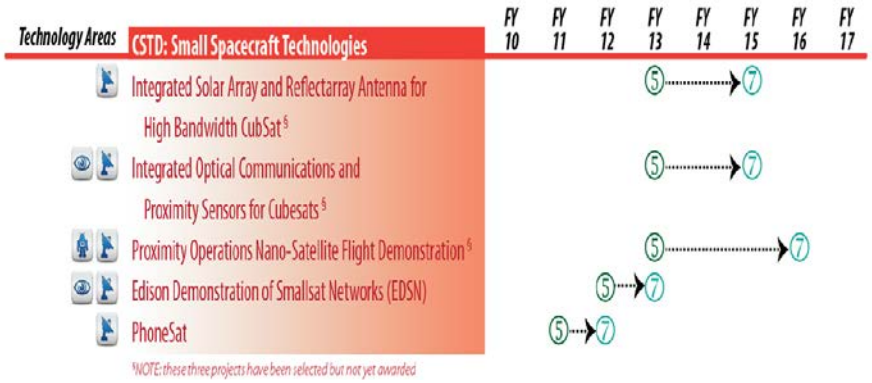
Flight Opportunities Program (CSTD)

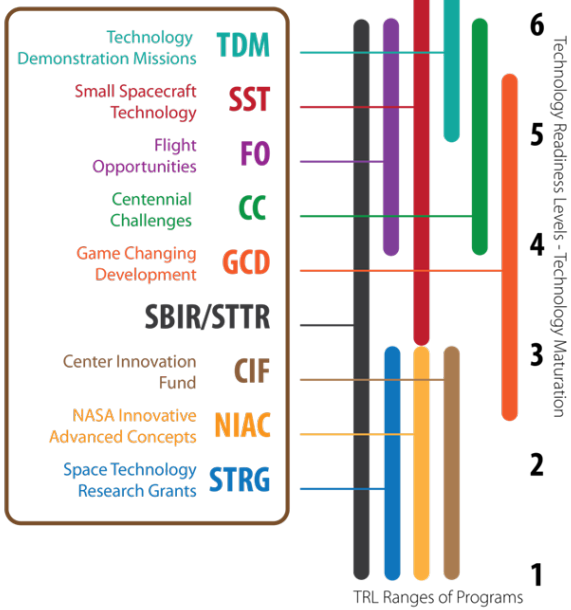
Portfolio Approach



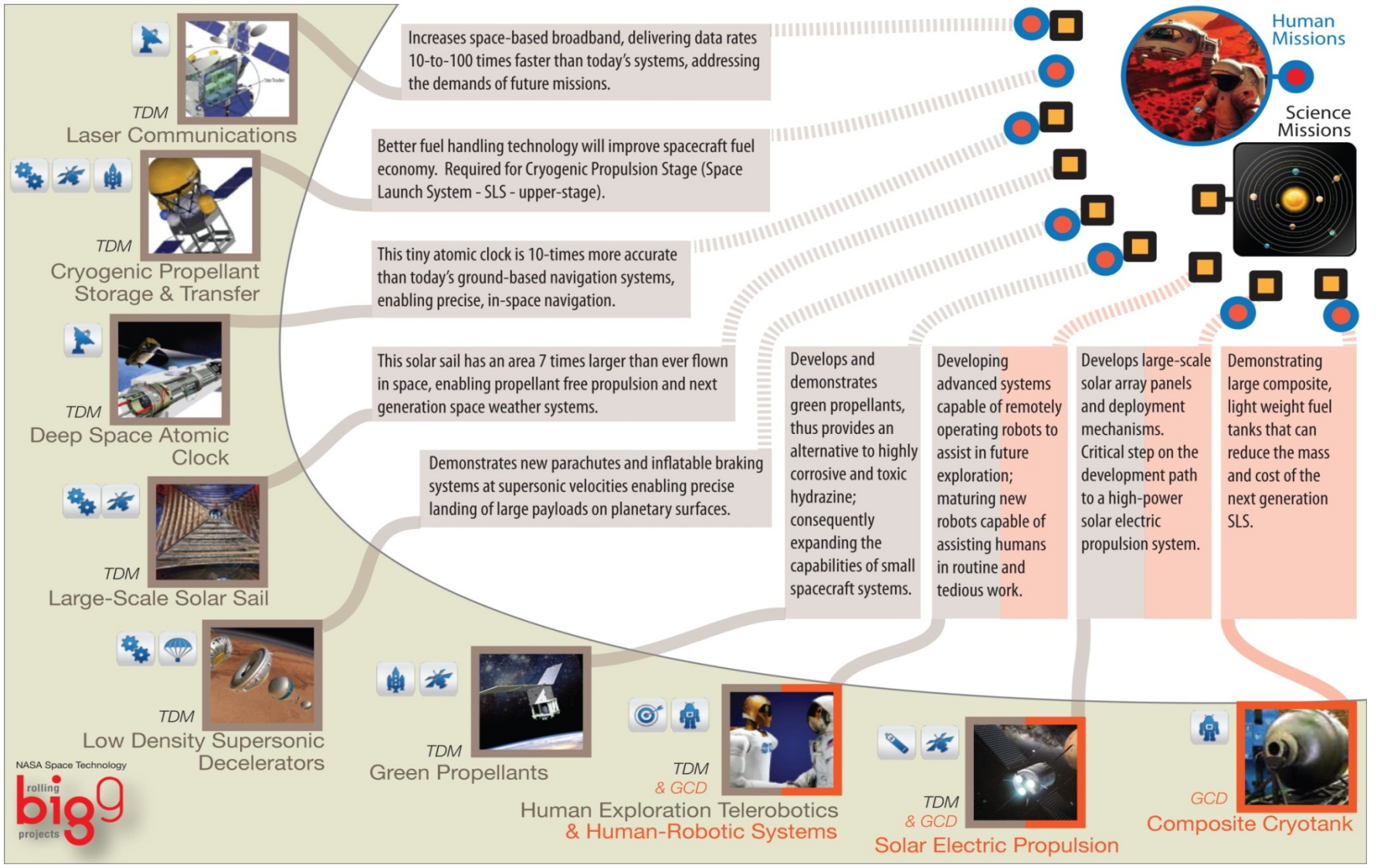






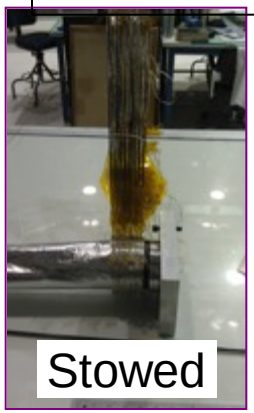


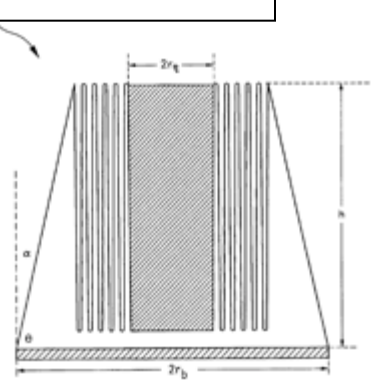
FY2014 Big Nine



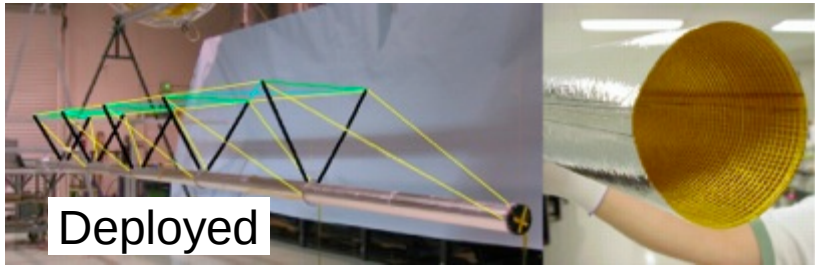
L'Garde Solar Sail 101

The L'Garde Sail Is a Unique Design Well Suited to Very Large (High Performance) Solar Sails





L'Garde Patented Sub-Tg Conical Deployable Booms



Vanes - Sail Control Surfaces

Sailcraft Bus

Striped-Net Sail Architecture
Unstressed Sail Material

1200 m^2 Sail Area
~40m on a Side
5um Kapton Film (8.5kg)

Sail Quadrant

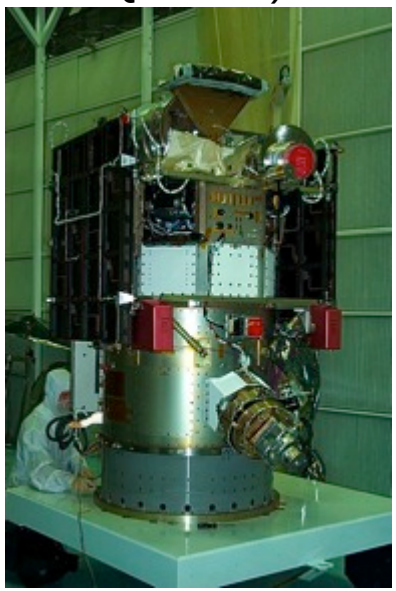
Total Cost of Project ~ $25M

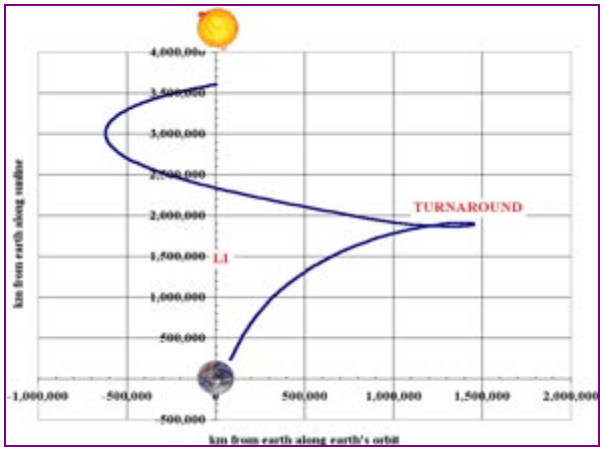
Solar Sail Mission Overview

Demonstration Objectives

1. **Demonstrate segmented deployment of a solar sail**
2. **Demonstrate attitude control plus passive stability and trim using beam-tip vanes.**
3. **Execute a navigation sequence with mission-capable accuracy.**
4. **Fly to and Possibly Maintain Position at sub-L1 and/or Pole Sitter Positions**

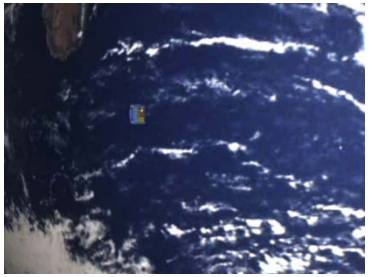
Access to Space:
Manifested as Secondary on DSCOVR Launch to L1
(F9 1.1 in Q4 2014)





Notional Trajectory After Earth Escape Burn

Sail Deployment Simulation



Space Technology
Major Events & Milestones

2012

HIAD
IRVE 3

Telerobotics

MEDLI

2013

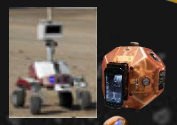
Telerobotics

PhoneSat

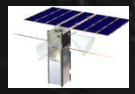
Edison Demo
SmallSat

2014

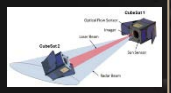
Solar
Sail



Telerobotics



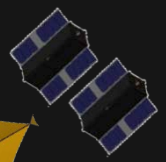
ISARA



OCSD

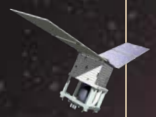
Supersonic
Inflatable
Aerodynamic
Decelerator

2015



CPOD

Atomic
Clock

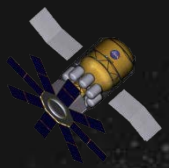


Green
Propellant

Supersonic
Inflatable
Aerodynamic
Decelerator

2016

2017



Cryogenic
Propellant

**SEP Demo
Mission**

2018

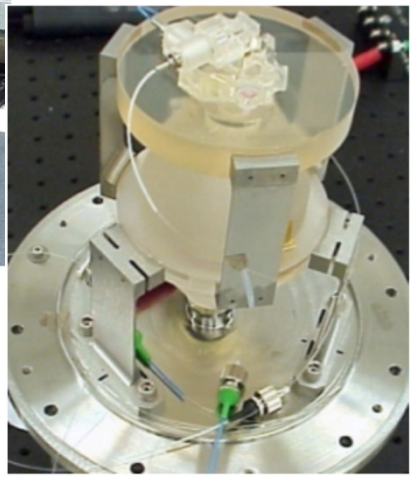
Laser
Communications

Future Planning

STMD support for SMD Astrophysics

- NIAC
- STRG
- Game Changing
  - NICER/SEXTANT
  - Adjustable Grazing Incidence X-ray Optics with 0.5 arc second resolution
  - Advanced laser frequency stabilization using molecular gases
- Future Collaborations
  - Exo-planet spectroscopy Internal coronagraphs and external occulters
  - Atomic Interferometer

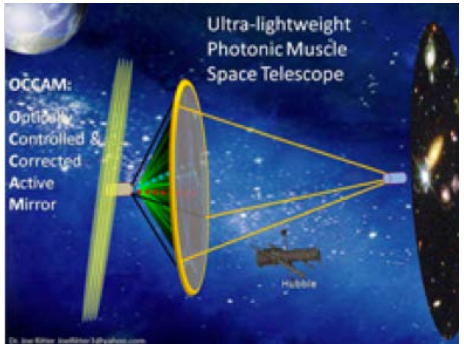
NICER X-ray Mirror



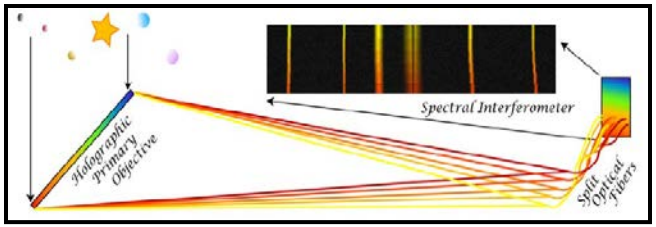
Optical cavity
by Ball Aerospace

NASA Innovative Advanced Concepts and Astrophysics – 2 Examples

- **OCCAMS Advanced Membrane Active Mirrors**
  Goal: Develop membrane mirrors able to deform at a molecular level, allowing huge, self-focusing mirrors
  - Low cost of manufacture, exceptionally light,
  - Active at the molecular level, back side of polymer chain expands when hit with a certain wavelength of LASER light, allowing on-orbit tuning of shape
  - 1 Lb. Mass for 2.4M (Hubble-sized) primary, could go much larger
  - $10k in materials cost for 2.4M primary



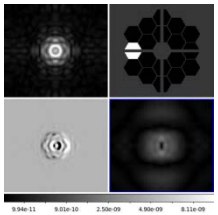
- **HOMES: Holographic Optical Method for Exoplanet Spectroscopy**
  Goal: Develop a preliminary architecture of a thin-film Holographic telescope able to analyze Exoplanet Spectroscopy
  - Replaces large heavy mirror optics with gossamer holograms
  - Holographic dispersion allows multiple spectrometer sensors, each tuned to a different wavelength, allowing faint signals to be readable
  - Potentially enables detection of habitable planets up to 30 light years away



Space Technology Research Grants Program

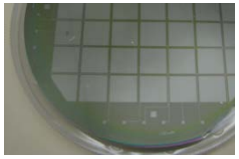
Astrophysics-Related Awards

- Recent (January 2013) *Early Stage Innovations* Awards:
  - *Wavefront Control for High Performance Coronagraphy on Segmented and Centrally Obscured Telescopes:* Olivier Guyon, University of Arizona



Goal: to develop and demonstrate an accurate and efficient approach to measure fine cophasing errors in support of future high contrast imaging missions.
This work is critical to understand how future large space telescopes can directly image and study habitable planets around nearby stars.

  - *Integrated Control Electronics for Adjustable X-Ray Optics:* Susan Trolier-McKinstry, Pennsylvania State University



Goal: to enable increased angular resolution and collection areas for future major X-ray observatories by incorporating improved figure control of the mirror surfaces.
This project will utilize thin film electro-mechanical actuators that allow the mirror surfaces to be adjusted after fabrication.

- NASA Space Technology Research Fellowship Awards

  - NSTRF11: 6
  - NSTRF12: 6
  - NSTRF13: 9

Significance of an NSTRF11 Award

The detector array will observe the Cosmic Microwave Background (CMB) polarization **with unprecedented sensitivity on arcminute angular scales.** This research **is pushing the state of the art** for far-infrared background limited detectors and will enable an improved understanding of how to use these devices in practical environments, which can potentially lower the risk of use in planned space- and balloon-borne scientific applications by NASA.

- Astrophysics subtopic included in 2013 *Early Stage Innovations* solicitation
  - Optical Coatings and Thin-film Physics (http://tinyurl.com/NASA-13ESI)

NICER / SEXTANT

- **NICER/SEXTANT – explorer class ISS demo (2017)**

  Joint Science and Technology Demo Mission on ISS

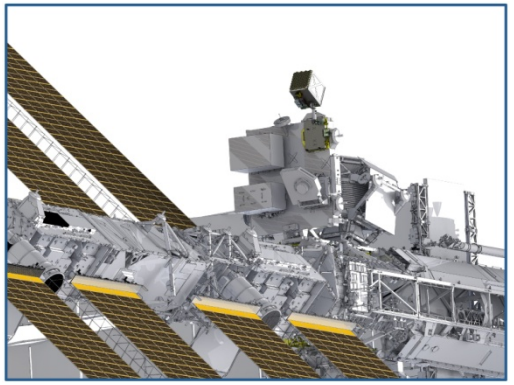
  - **NICER: X-ray optical telescope demonstration**

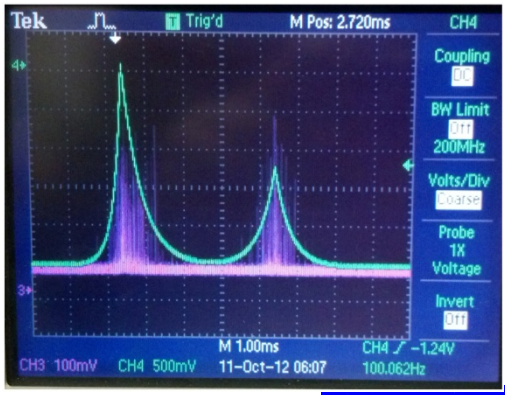
    Neutron star Interior Composition ExploreR (NICER), would observe (in the X-ray band) the thermal, magnetic, and rotational traits of neutron stars

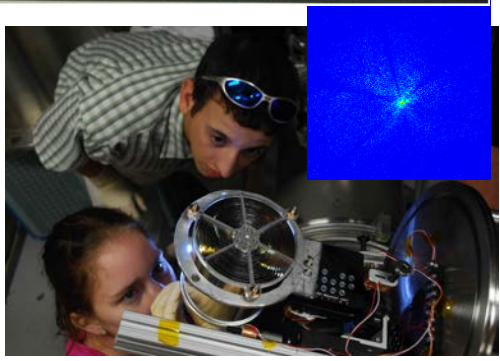
  - **SEXTANT: X-ray navigation (XNAV) demonstration**

    Station Experiment for X-ray Timing and Navigation Technology (SEXTANT) mission, would detect X-ray photons from known steady pulsars to demonstrate spacecraft navigation using these naturally-occurring cosmic beacons

- **STMD-SMD collaboration**
  - NICER by SMD / SEXTANT by STMD
  - Shared hardware, ConOps, Data archive, Ops Center; ISS Platform, and target pulsars

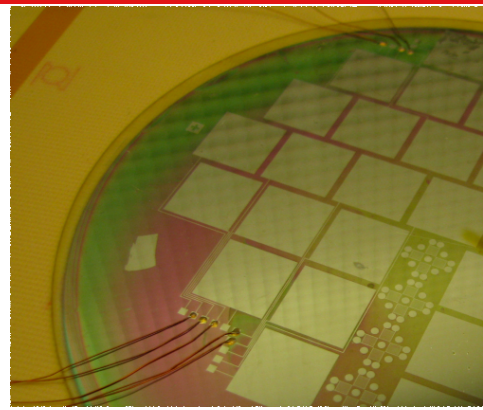






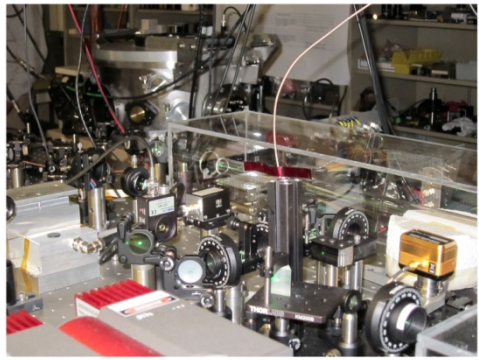
STMD/GCD - SMD/Astrophysics Collaborations

- **Adjustable Grazing Incidence X-ray Optics**
  Goal: Develop thin, lightweight mirrors with angular resolution of 0.5 arc sec, comparable to the Chandra X-ray Observatory
  - Low cost; and 30x more densely nested than Chandra
  - New design with thin segments of a Wolter-I grazing incidence mirror
  - Piezo-electric material deposited directly on the back surface
  - Localized mirror deformation by energized PZT cells; no need for reaction structure
  - Co-funded 3-years development between GCD & Astrophysics/PCOS



100 mm diameter flat Eagle test mirror (PZT electrode cells, printed electrode contacts, and strain gauge patterns, used for diagnostics).

- **Advanced laser frequency stabilization using molecular gases**
  Goal: Develop a laser stabilization scheme approaching the performance of ultra-cold neutral atom clocks
  - Simpler, lighter, and cheaper packaging, and operates at lower power levels
  - Operates near 1568 nm using low pressure CO gas as a molecular reference, with the possibility of migrating to near 1064 nm at a later date
  - Ultra-stable lasers are a corner stone of a future gravitational wave mission
  - Co-funded 3-years development between GCD & Astrophysics/PCOS



Iodine laser stabilization setup and cavity

Coronagraph for Direct Imaging of Exoplanets

Potential Joint SMD & STMD Initiative:

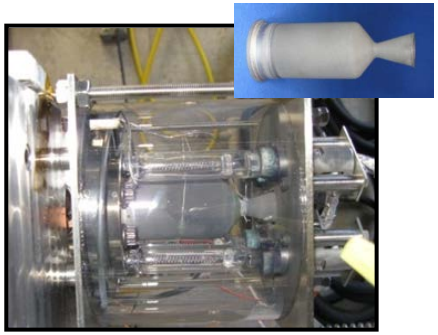
Develop a coronagraph for AFTA-WFIRST mission

- **SoA Space based observatories:**
  - NASA's Kepler (2009) (Photometry);
  - NASA Hubble & Spitzer (Transit technique);
  - TESS (2017 launch planned) (transit spectroscopy)

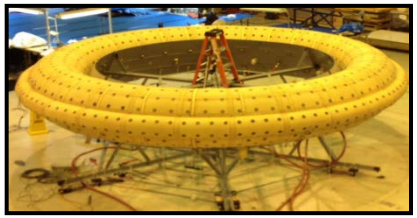
1000+ exoplanets discovered to date; Milky Way has 50B+ potentially habitable rocky-planets.

- **Goal:** Develop an advanced high contrast coronagraph + occulter for AFTA-WFIRST
  - Observe fainter planets using advanced direct imaging (10x Earth mass or better)
  - High contrast, high sensitivity, & high optical throughput
  - Small inner working angle (close to star), large discovery space
  - AFTA-WFIRST concept: using a donated 2.4-m telescope;
    - First opportunity for an in-space high contrast coronagraph.
    - Pathfinder mission for future telescopes to characterize Earth-like planets.

New Hardware in Advancing Space Technology

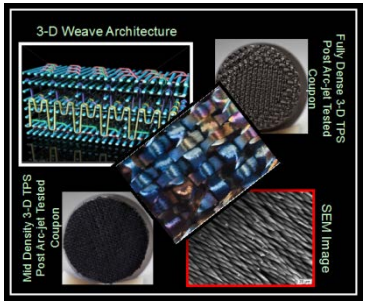


Green Propellant 22N Thruster

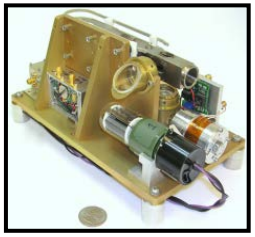


Low Density Supersonic Decelerator Proof Test

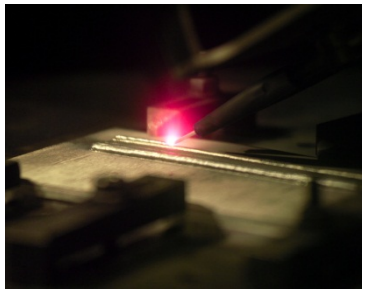
MSL Heat Shield with Instrumentation



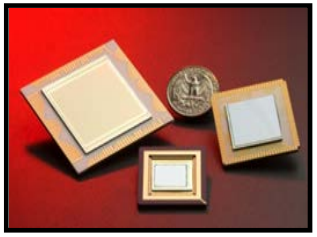
Woven TPS



Deep Space Atomic Clock

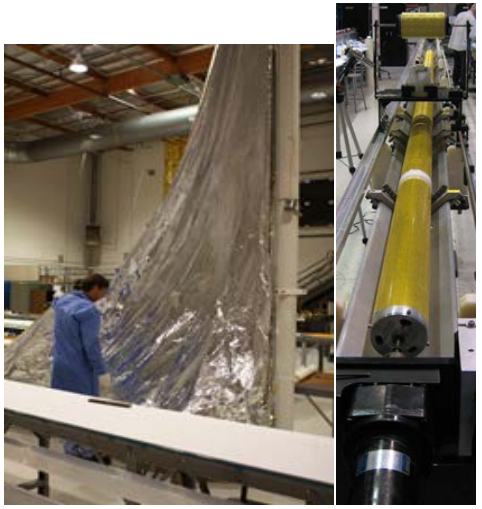


Additive Manufacturing



BIRD Focal Plane Arrays

NICER/SEXTANT

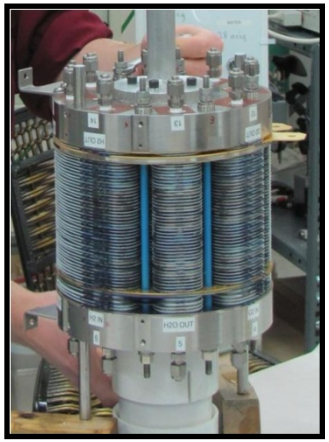


Solar Sail and Boom Fab

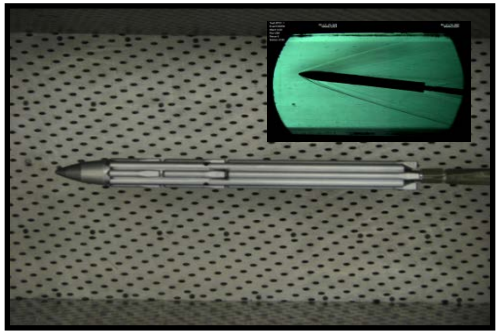
Inflatable Re-entry Vehicle Experiment

Game Changing Technology

Arrival and testing of 2.4m precursor tank, the largest out-of-autoclave tank fabricated in the world

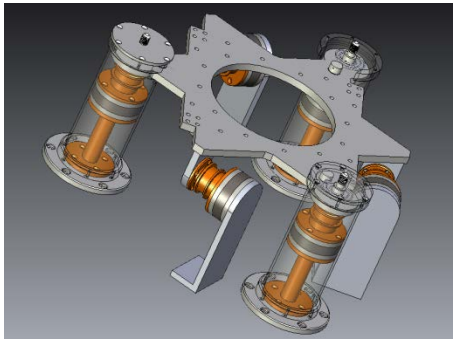


Space Power Systems
First build of flight-like fuel cells

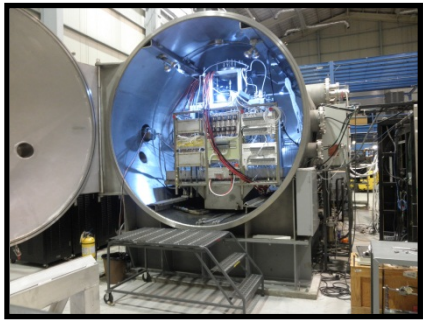


SWORDS model for wind tunnel testing at NASA MSFC

Launch of IRVE-3 – successful suborbital test of 3m HIAD



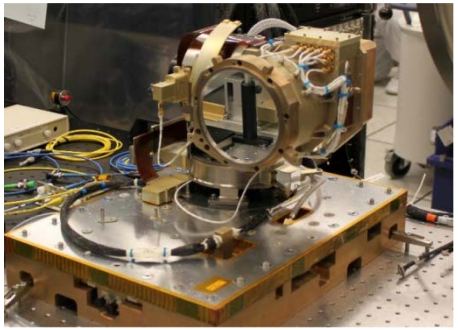
DSOC: Vibration Isolation Platform



Nuclear Systems delivered the Fission Power System Technology Demonstration Unit (TDU) Reactor Simulator

Technology Demonstration and Testing

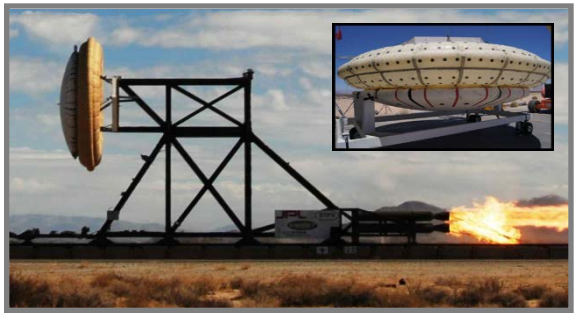
Mike Fossum with Smart SPHERES checkout



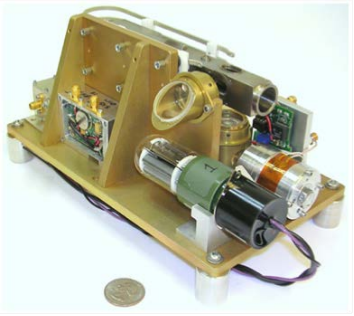
Laser Communication Relay Demonstration

Reduced Liquid Hydrogen boil off test

ARC Jet Testing

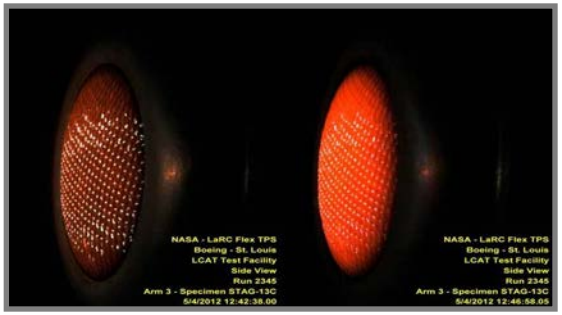


Low Density Supersonic Decelerator Sled Test

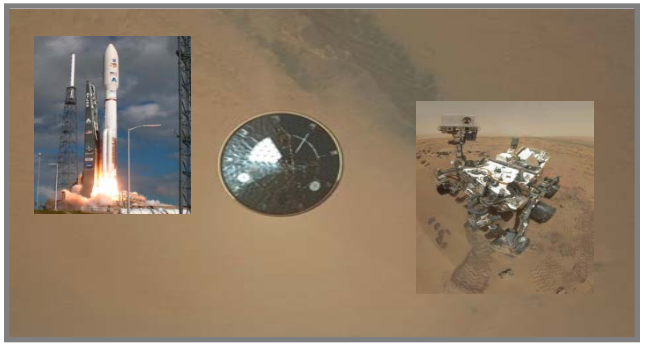


Deep Space Atomic Clock

K10 rover deploying polyimide film



LCAT Stagnation Test (50 W/cm2)

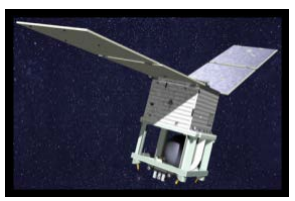


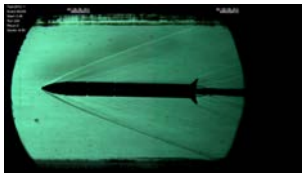
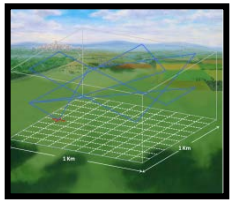
MSL Launch and MEDLI measurements successfully completed

Collaborations with Other Government Agencies

Currently, significant engagements include:

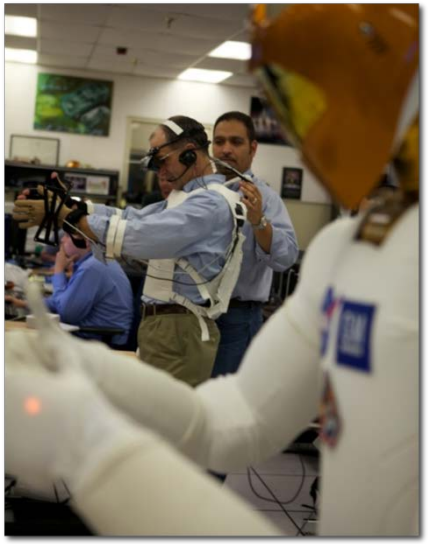
- Green Propellant Infusion Mission partnership with **Air Force Research Laboratory,** propellant and rideshare with **DoD's Space Test Program (STP)**
- Solar Sail Demonstration partnership with **NOAA,** and rideshare with **Air Force**
- Soldier-Warfighter Operationally Responsive Deployer for Space (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 **Department of Veteran Affairs** for a collaborative project with "Exoskeleton" from our Human Robotics Systems Program

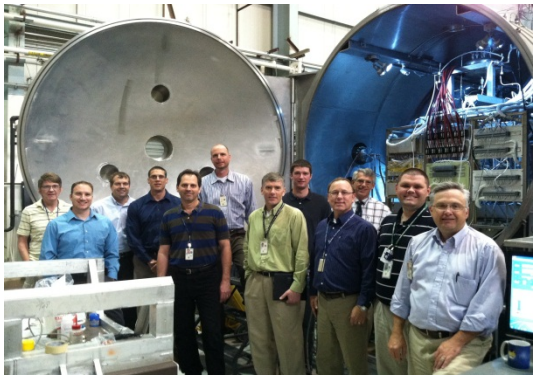




Working Together to Innovate






National Aeronautics and
Space Administration
NASA
www.nasa.gov/spacetech