National Aeronautics and
Space Administration

NASA Space Technology Mission Directorate Technology Needs

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Space Technology Mission Directorate

October 1, 2013

Why Invest in Space Technology?

...need for regular investment in new, transformative space technologies...

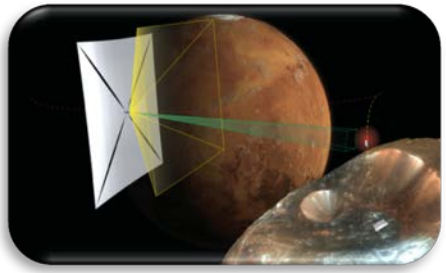
...from 40+ studies since 1980...

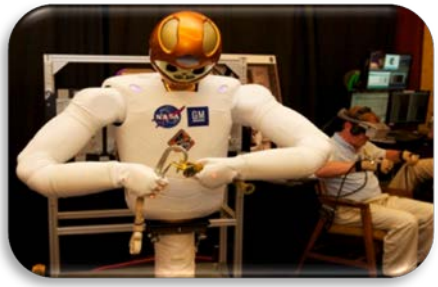
- Enable **new class of NASA missions** beyond LEO
- Provide **innovative solutions** to dramatically improve technological capabilities **for NASA and the Nation**.
- Develop **affordable & raliable** technologies & capabilities for future NASA missions
- Create **new markets**, spurring innovation for traditional and emerging aerospace business
- Engages the brightest minds from **academia** to solve NASA's tough technological challenges

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

Guiding Principles of the Space Technology Programs

- **Adheres to a Stakeholder Based Investment Strategy** (NRC/SSTIP/TAs)
- **Invests in a Comprehensive Portfolio:** (full TRL range)
- **Advances Transformative and Crosscutting Technologies**
- **Selects Using Merit Based Competition** (open to everybody)
- **Executes with Structured Projects** (cost/schedule/oversight/NPRs)
- **Infuses Rapidly or Fails Fast** (informed risk)
- **Positions NASA at the cutting edge of technology** (innovation pipeline)



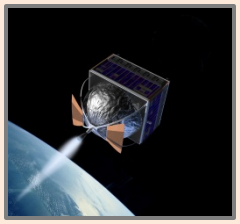


Space Technology Portfolio

Transformative & Crosscutting Technology Breakthroughs

Game Changing Development (ETD/CSTD)

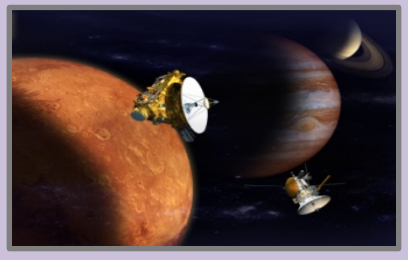
Technology Demonstration Missions (ETD/CSTD)



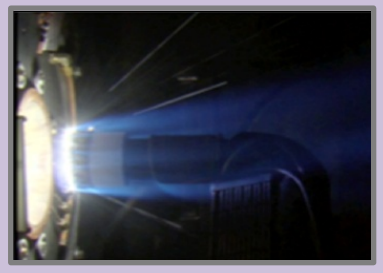
Small Spacecraft Technologies (CSTD)

Pioneering Concepts/ Developing Innovation Community

Space Technology Research Grant (CSTD)



NASA Innovative Advanced Concepts (NIAC) (CSTD)



Center Innovation Fund (CSTD)

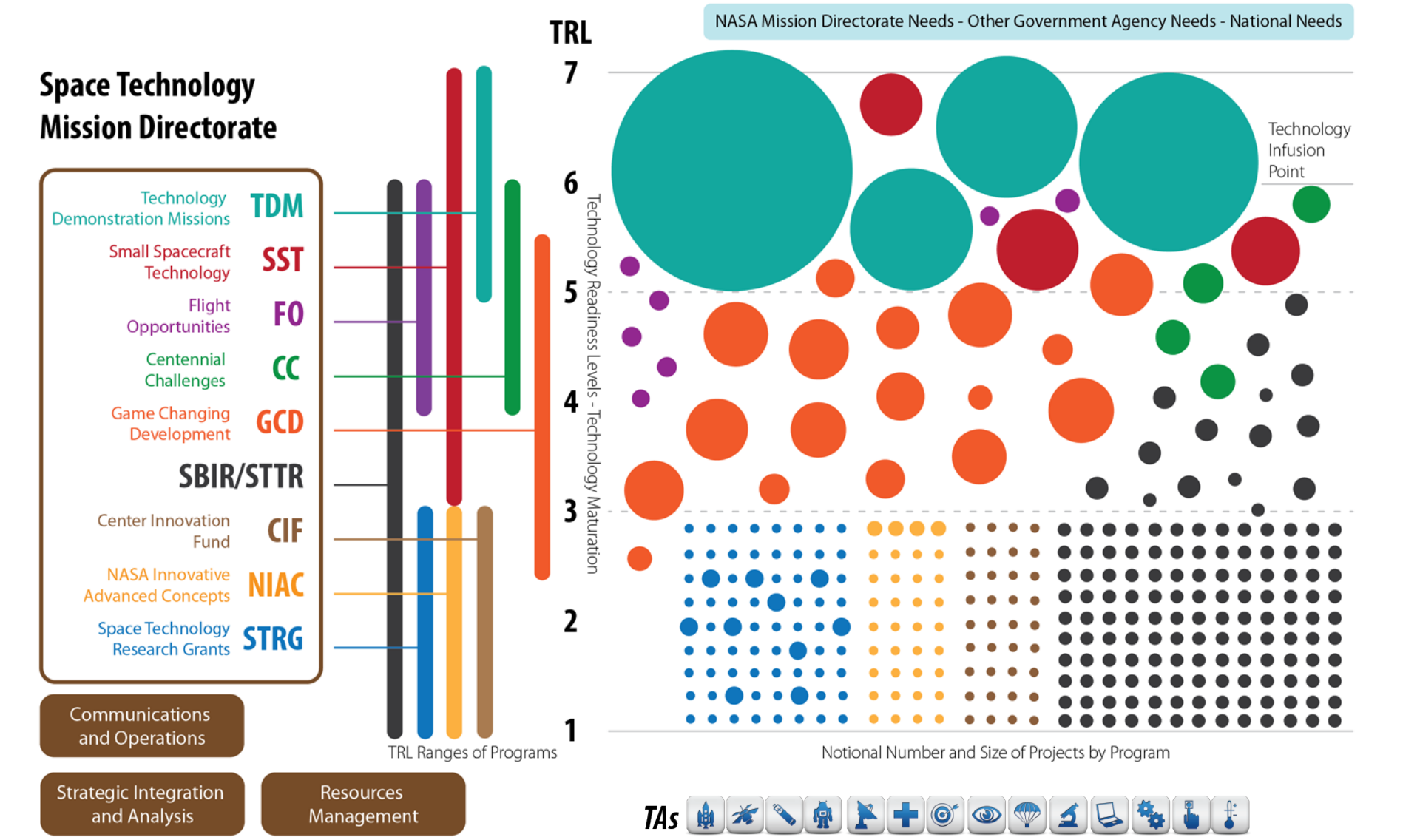
Creating Markets & Growing Innovation Economy

Centennial Challenges (CSTD)

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

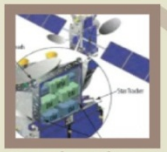
Flight Opportunities Program (CSTD)

Space Technology Portfolio



FY2014 Big Nine

TDM
Laser Communications



Increases space-based broadband, delivering data rates 10-to-100 times faster than today's systems, addressing the demands of future missions.

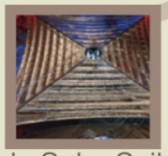
TDM
Cryogenic Propellant Storage & Transfer

Better fuel handling technology will improve spacecraft fuel economy. Required for Cryogenic Propulsion Stage (Space Launch System - SLS - upper-stage).

TDM
Deep Space Atomic Clock

This tiny atomic clock is 10-times more accurate than today's ground-based navigation systems, enabling precise, in-space navigation.

TDM
Large-Scale Solar Sail



This solar sail has an area 7 times larger than ever flown in space, enabling propellant free propulsion and next generation space weather systems.

TDM
Low Density Supersonic Decelerators

Demonstrates new parachutes and inflatable braking systems at supersonic velocities enabling precise landing of large payloads on planetary surfaces.

TDM
Green Propellants

Develops and demonstrates green propellants, thus provides an alternative to highly corrosive and toxic hydrazine; consequently expanding the capabilities of small spacecraft systems.

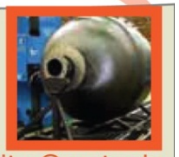
TDM & GCD
Human Exploration Telerobotics & Human-Robotic Systems

Developing advanced systems capable of remotely operating robots to assist in future exploration; maturing new robots capable of assisting humans in routine and tedious work.

TDM & GCD
Solar Electric Propulsion

Develops large-scale solar array panels and deployment mechanisms. Critical step on the development path to a high-power solar electric propulsion system.

GCD
Composite Cryotank



Demonstrating large composite, light weight fuel tanks that can reduce the mass and cost of the next generation SLS.

Human Missions

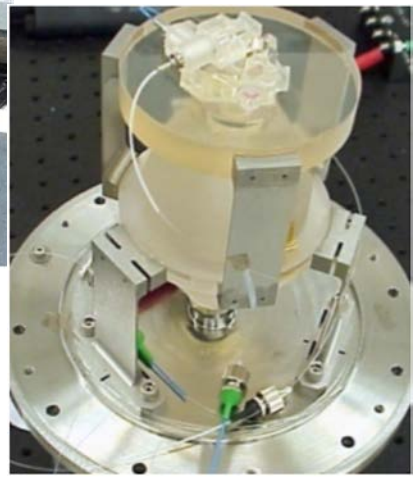
Science Missions

NASA Space Technology
rolling big9 projects

STMD support for SMD Astrophysics

- **NASA Innovative Advanced Concepts**
- **Space Technology Research Grants**
- **Game Changing Development**
  - NICER/SEXTANT
  - Adjustable Grazing Incidence X-ray Optics with 0.5 arc second resolution
  - Advanced laser frequency stabilization using molecular gases
- **Technology Demonstration Missions**
  - Solar Sail
- **Future Collaborations**
  - Exo-planet Spectroscopy
    - Internal coronagraphs and external occulters
  - Atomic Interferometer

NICER X-ray Mirror

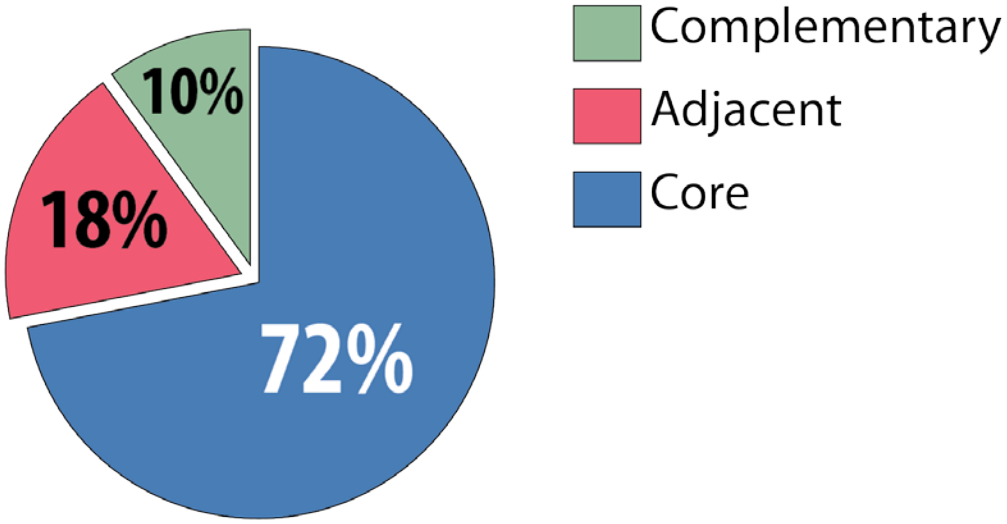


Optical cavity
by Ball Aerospace

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 TAs** (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



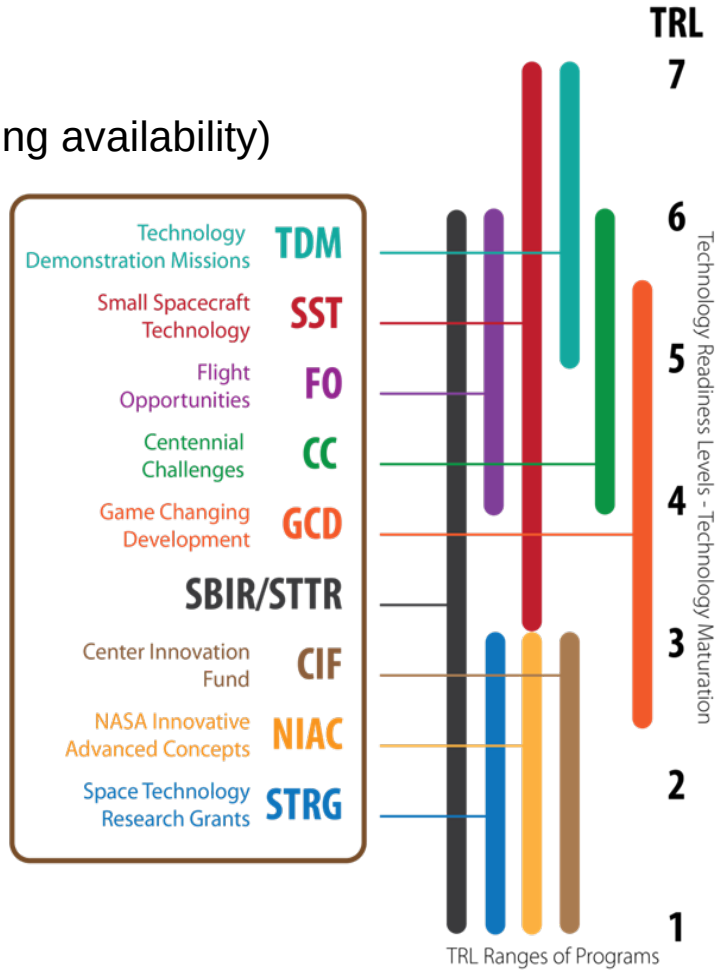
STMD investments are consistent with the Strategic Space Technology Investment Plan (SSTIP)

STMD Funding / Announcement Opportunities

- STMD Programs are periodically release solicitations
- These are open to all (NASA, OGAs, Academia, Industry)
- More information can be found at the STMD website or NSPIRES
  - http://www.nasa.gov/spacetech/

Typical cadence for relevant solicitations (function of funding availability)

- SBIR: FY Q1
- Space Technology Research Grants:
  - Space Technology Research Fellowships: FY Q1
  - Early Career Faculty: FY Q1
  - Early Stage Innovation: FY Q2
- NIAC:
  - Phase 1: FY Q1
  - Phase 2: FY Q2
- Center Innovation Funds: FY Q1
- Game Changing Development Program:
  FY Q1-FYQ3 in focused topics
  - Lightweight Materials and advanced Manufacturing
  - Future Propulsion and Energy Systems
  - Affordable Destination Systems and Instruments
  - Advanced Entry, Descent and Landing
  - Revolutionary Robotics and Autonomous Systems



Space Technology
Major Events & Milestones

2012

HIAD
IRVE 3

Telerobotics

MEDLI

2013

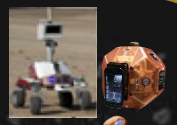
Telerobotics

PhoneSat

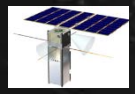
Edison Demo
SmallSat

2014

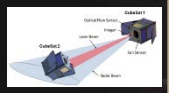
Solar
Sail



Telerobotics



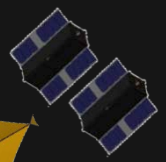
ISARA



OCSD

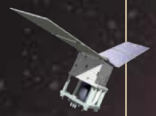
Supersonic
Inflatable
Aerodynamic
Decelerator

2015



CPOD

Atomic
Clock

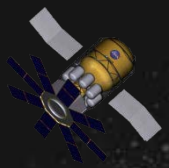


Green
Propellant

Supersonic
Inflatable
Aerodynamic
Decelerator

2016

2017



Cryogenic
Propellant

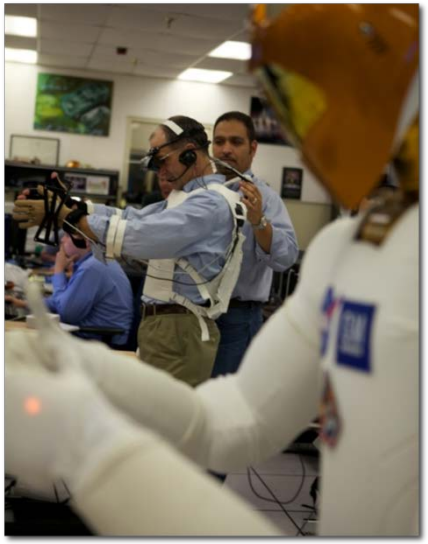
**SEP Demo
Mission**

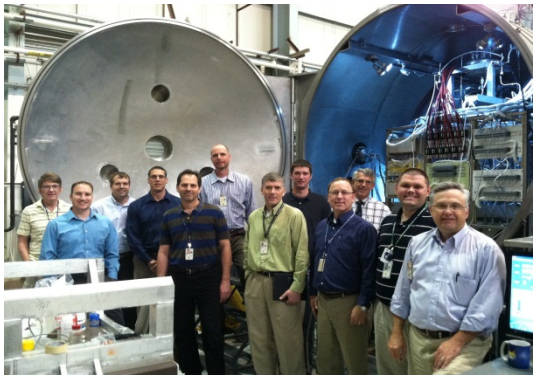
2018

Laser
Communications

Future Planning

Working Together to Innovate





http://www.youtube.com/watch?v=vsvisuLau5c

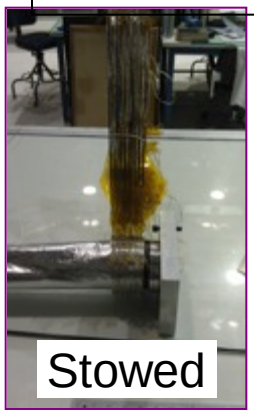
National Aeronautics and Space Administration

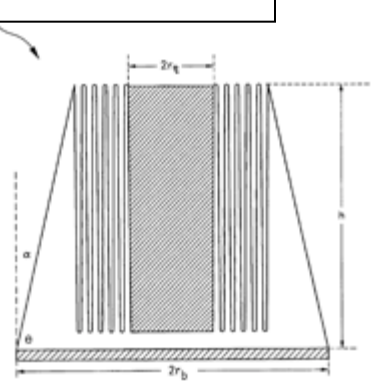
NASA

www.nasa.gov/spacetech

L'Garde Solar Sail 101

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





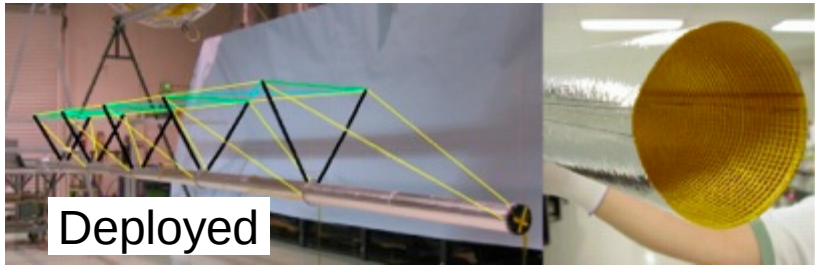
Vanes - Sail Control Surfaces

Sailcraft Bus

Striped-Net Sail Architecture
Unstressed Sail Material

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

L'Garde Patented Sub-Tg
Conical Deployable Booms



Sail Quadrant

Total Cost of Project ~ $25M

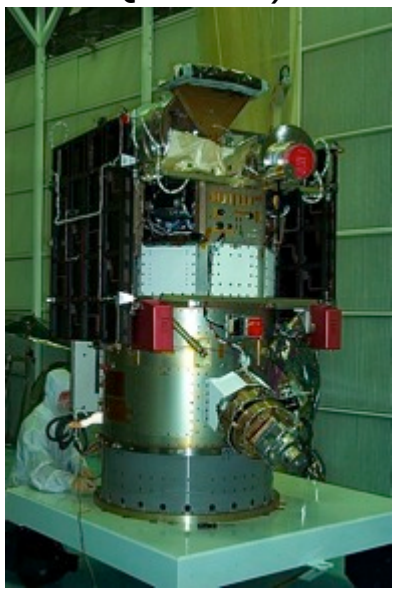
Return to STMD Support for SMD Missions

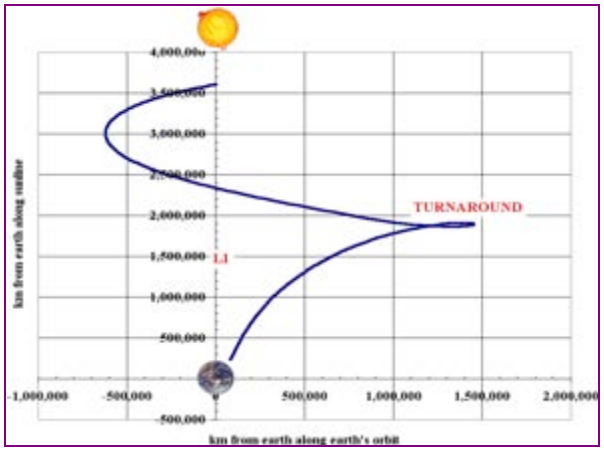
Solar Sail Mission Overview

Demonstration Objectives

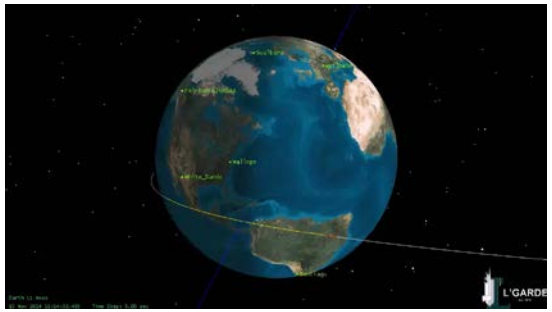
1. **Demonstrate segmented deployment of a solar sail**
2. **Demonstrate attitude control plus passive stability and trim using beam-tip vanes.**
3. **Execute a navigation sequence with mission-capable accuracy.**
4. **Fly to and Possibly Maintain Position at sub-L1 and/or Pole Sitter Positions**

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

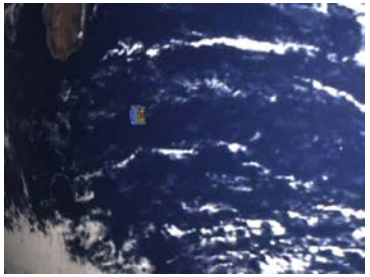




Notional Trajectory After Earth Escape Burn



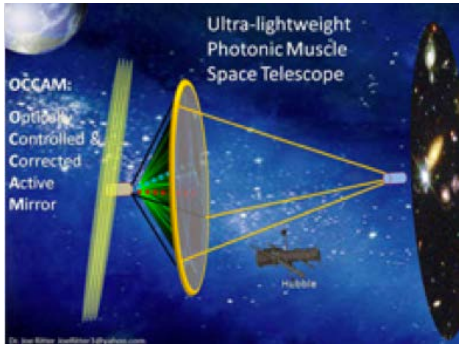
Sail Deployment Simulation



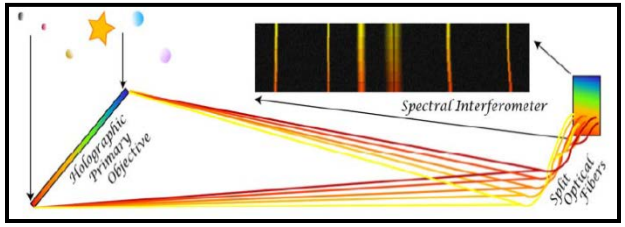
Return to STMD Support for SMD Missions

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

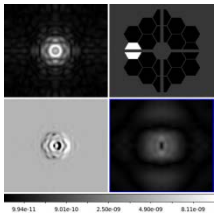


Return to STMD Support for SMD Missions

Space Technology Research Grants Program

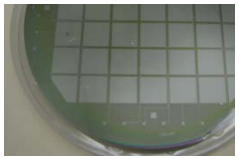
Astrophysics-Related Awards

- 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)

Return to STMD Support for SMD Missions

NICER / SEXTANT

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

  Joint Science and Technology Demo Mission on ISS

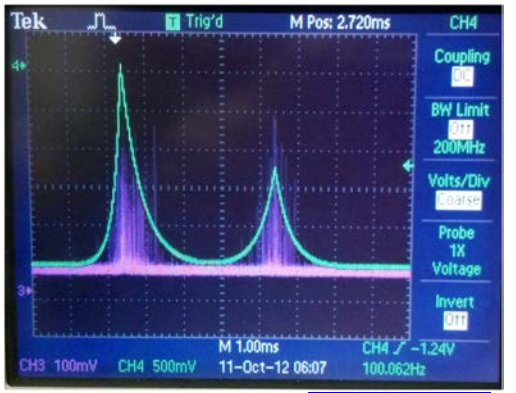
  - **NICER: X-ray optical telescope demonstration**

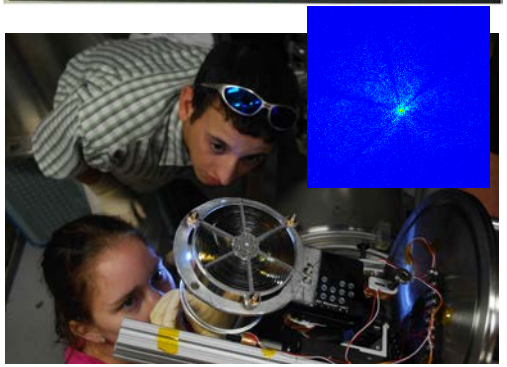
    Neutron star Interior Composition ExploreR (NICER), would observe (in the X-ray band) the thermal, magnetic, and rotational traits of neutron stars

  - **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

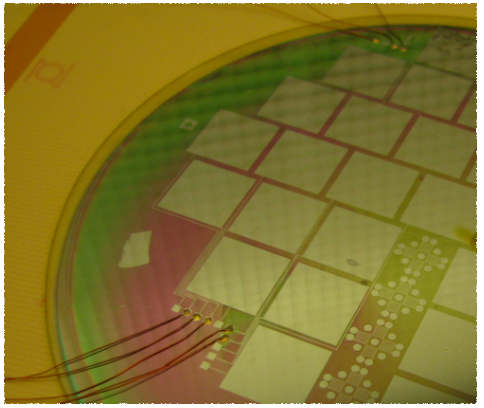




Return to STMD Support for SMD Missions

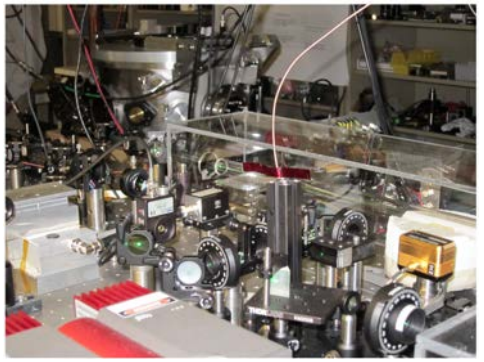
STMD/GCD - SMD/Astrophysics Collaborations

- **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

Return to STMD Support for SMD Missions

Coronagraph for Direct Imaging of Exoplanets

Potential Joint SMD & STMD Initiative:
Develop a coronagraph for AFTA-WFIRST mission

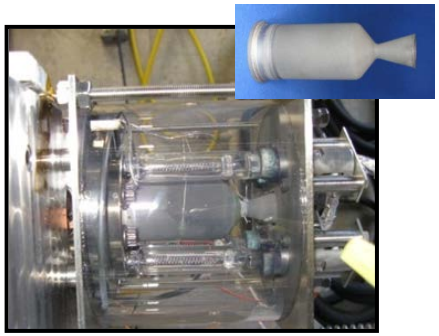
- **SoA Space based observatories:**
  - NASA's Kepler (2009) (Photometry);
  - NASA Hubble & Spitzer (Transit technique);
  - TESS (2017 launch planned)(transit spectroscopy)

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.

Return to STMD Support for SMD Missions

New Hardware in Advancing Space Technology



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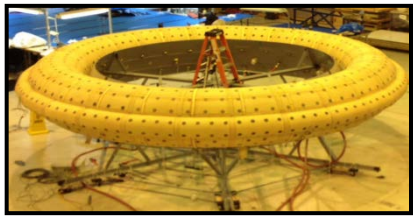

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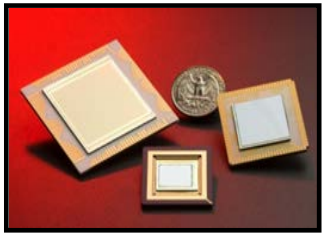

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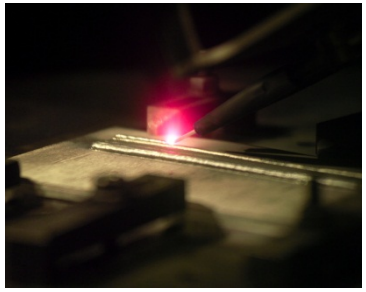

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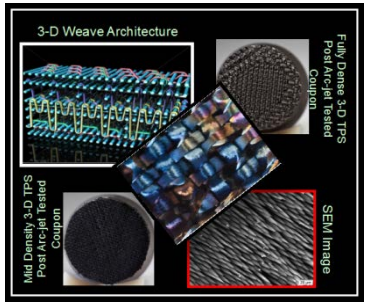

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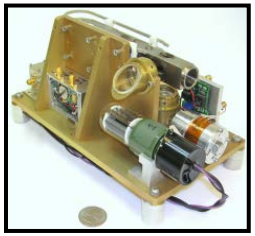

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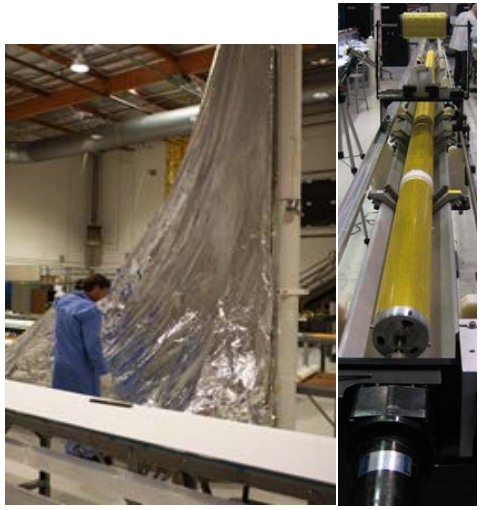

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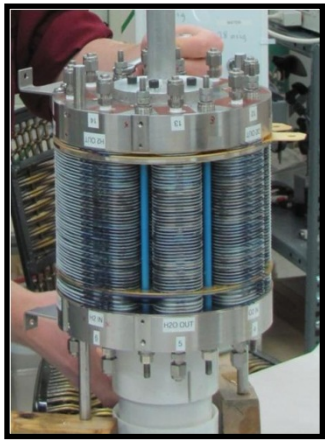

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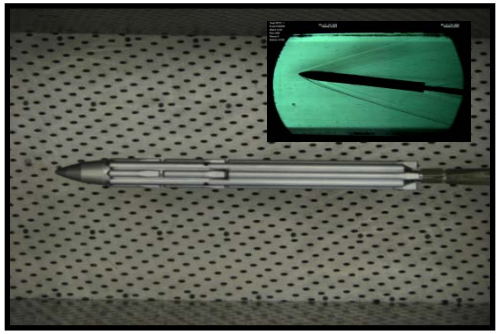

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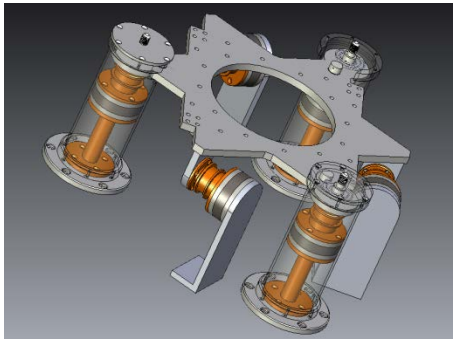

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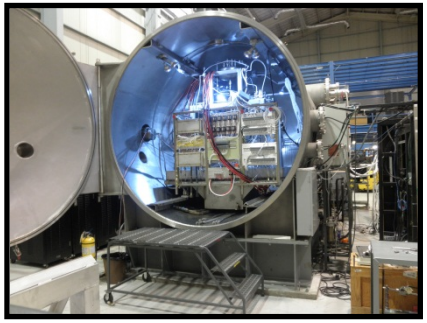

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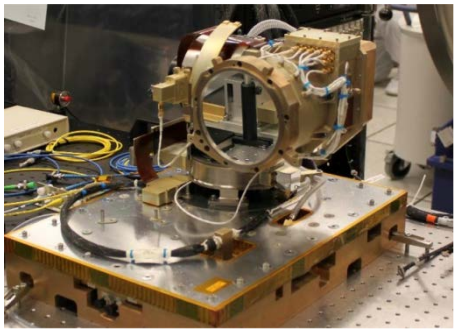

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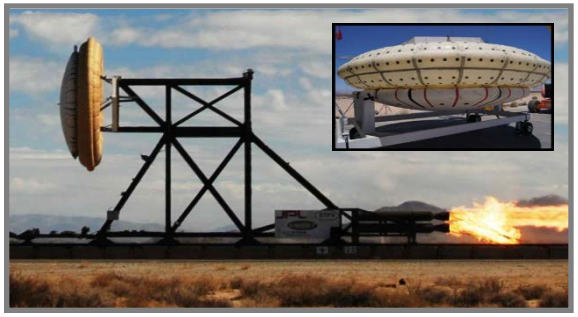

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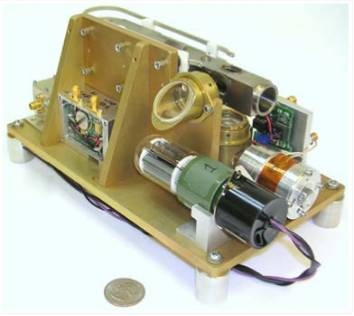

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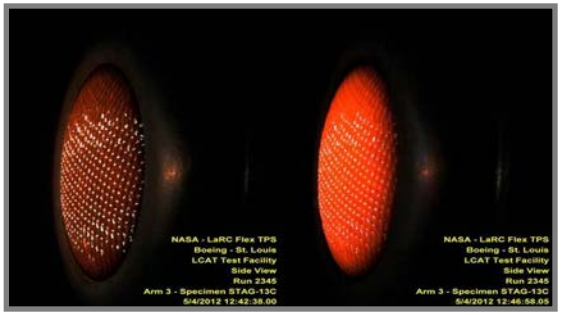

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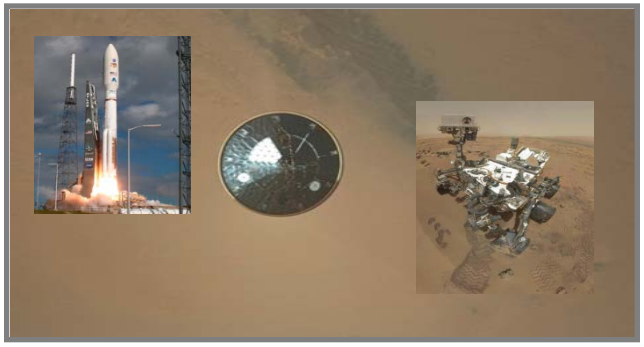
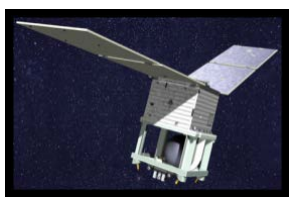


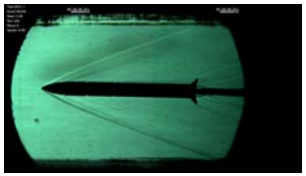
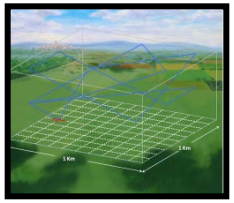
MSL Launch and MEDLI measurements successfully completed

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





Challenges for Deep Space Exploration

Communication

Environment Control & Life Supporting Systems

Logistics

Power Generation & Storage

Navigation

Entry, Descent & Landing

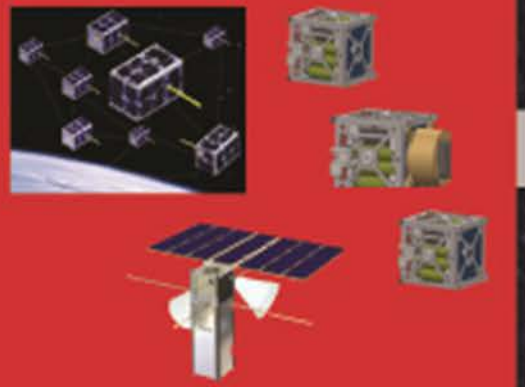
Manufacturing In Space & For Space

Radiation Mitigation

Propulsion

Trends in Space Technology

Small Spacecraft



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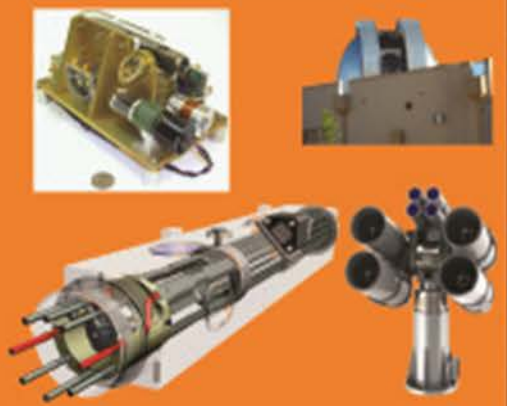

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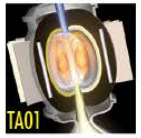
TA01 

• LAUNCH PROPULSION SYSTEMS

TA02 

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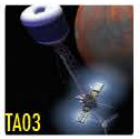
TA03 

• SPACE POWER & ENERGY STORAGE

TA04 

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TA05 

• COMMUNICATION & NAVIGATION

TA06 

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TA07 

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TA08 

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TA09 

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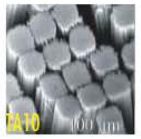
TA10 

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TA11 

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TA12 

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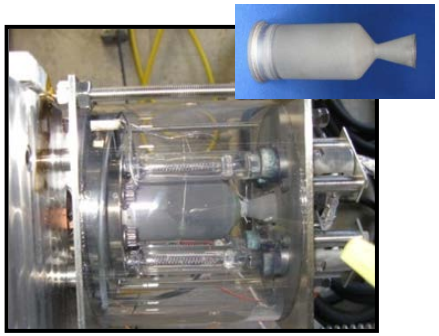

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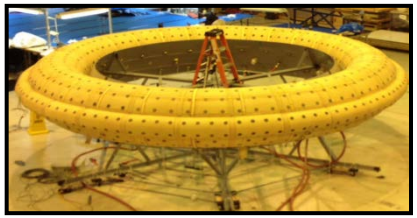

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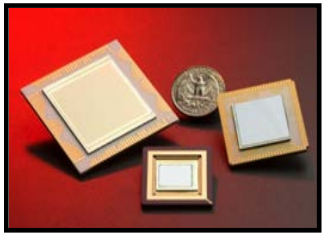

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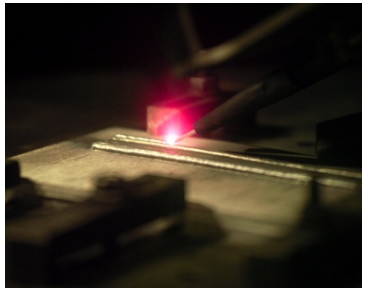

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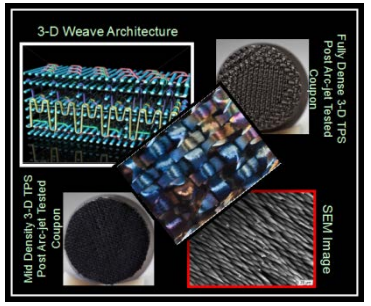

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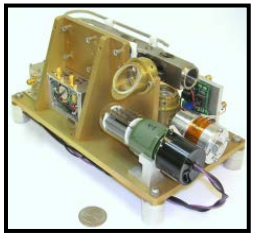

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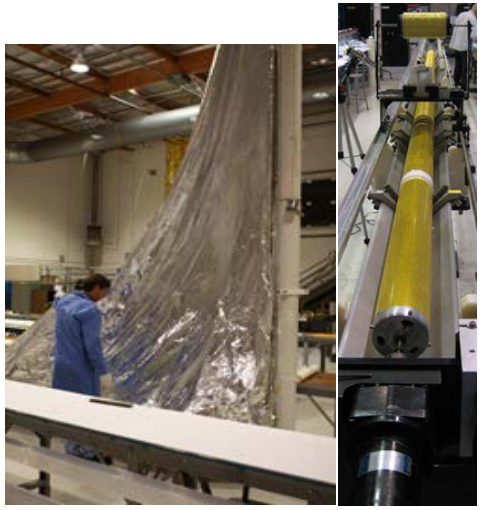

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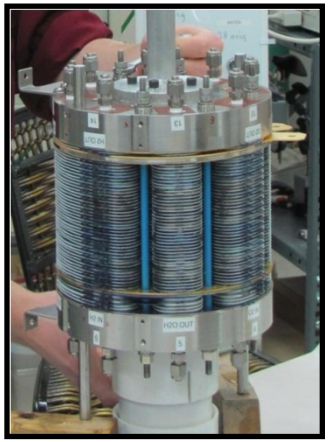

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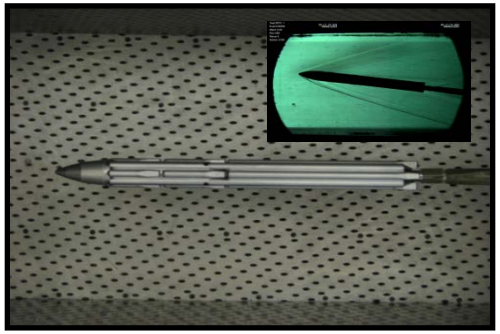

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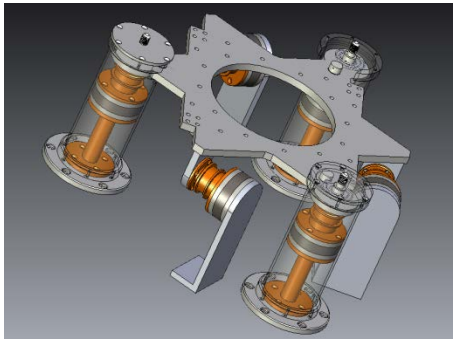

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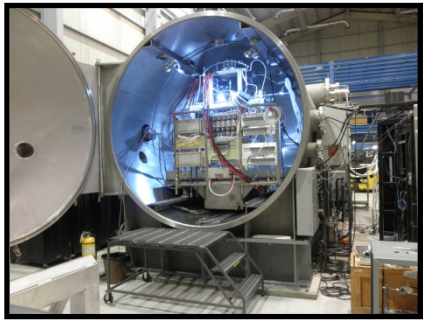

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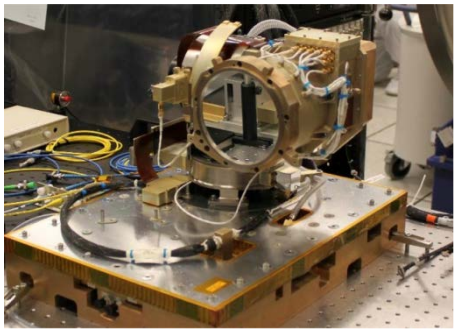

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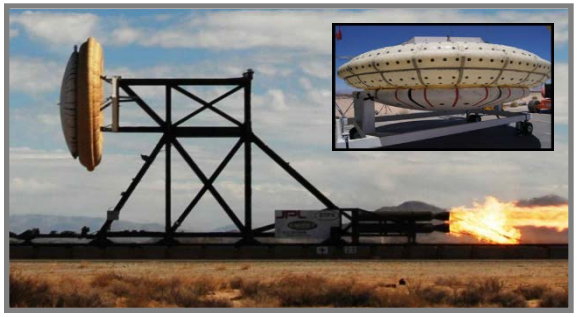

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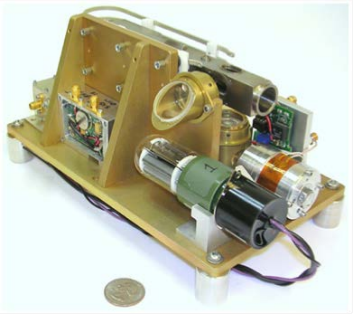

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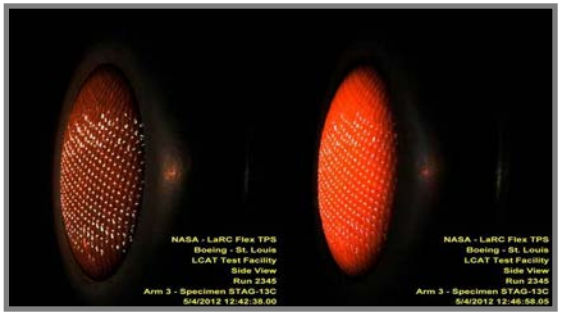

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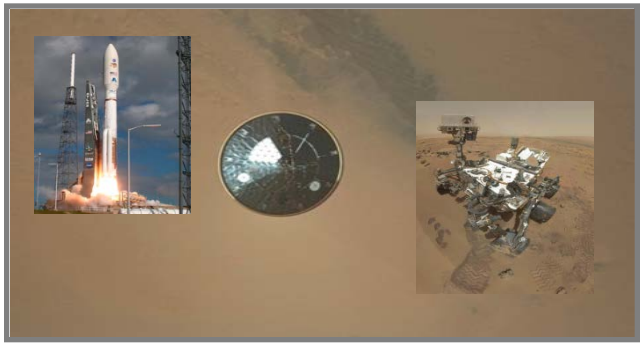

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