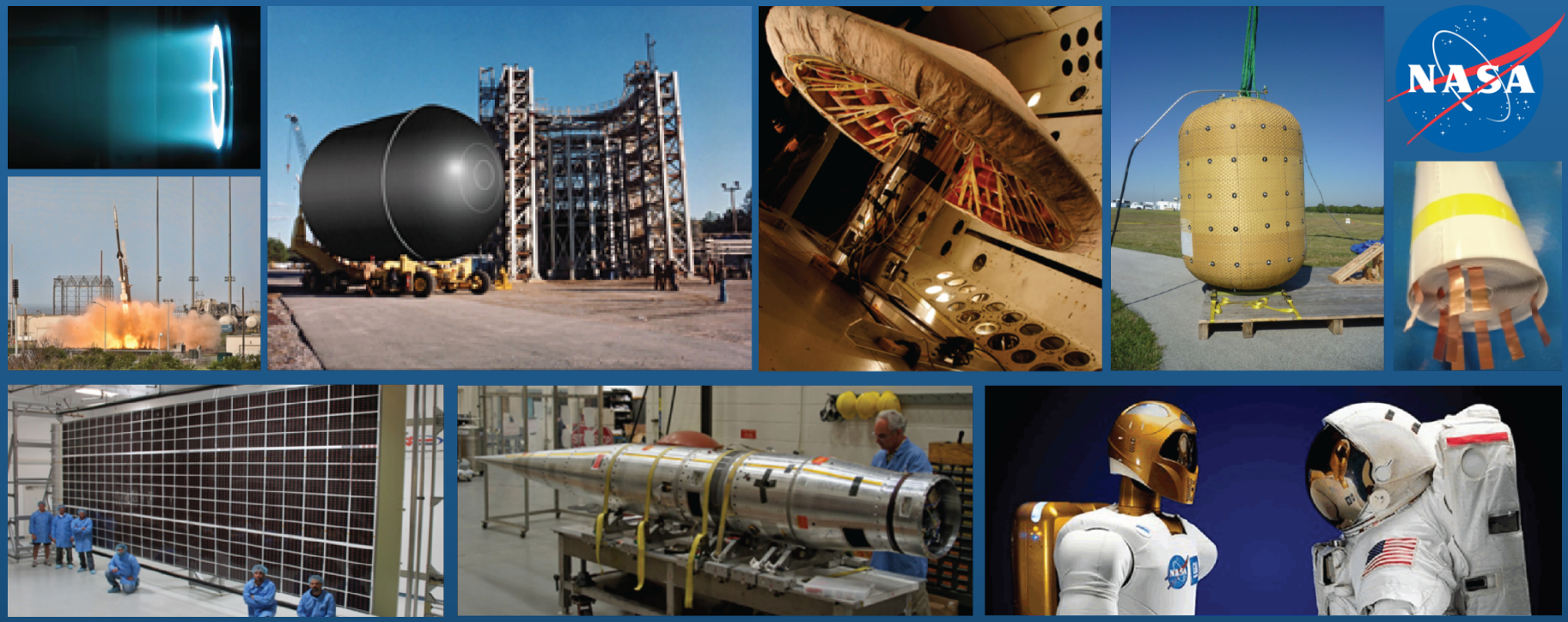


Innovation within NASA Space Technology and its Game Changing Development Program

Presented by
Stephen Gaddis

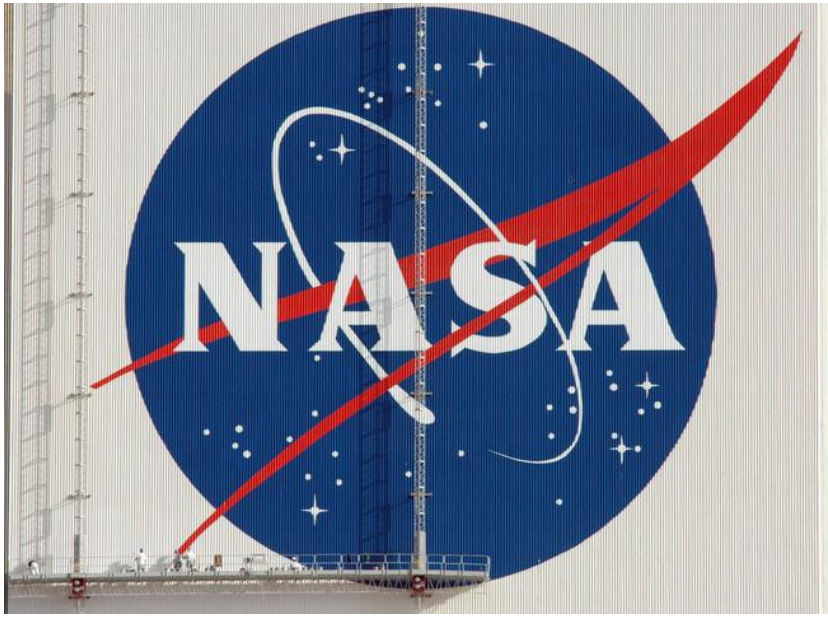
At the
OPAG Meeting
Atlanta, GA

01.10.2013

by
Tibor Balint, PhD - GCD Program Executive - HQ
Stephen Gaddis - GCD Program Manager - LaRC

Overview

- NASA Office of Chief Technologist / Space Technology Program
- Game Changing within Space Technology
  - Technology development pipelines, infusion paths, collaborations
- Game Changing Development Program
- Game Changing project examples
- Examples from different Space Technology Programs



NASA Logo on the Vehicle Assembly Building

Robonaut 2

OCT & STP Overview

- Office of the Chief Technologist (OCT)
  - Established two years ago
  - Agency-wide technology advocacy
  - Cross cutting technology development focus
  - Space Technology Program (STP) for portfolio management and implementation
  - Nine programs covering the full TRL range
  - STP executes more than 1,000 projects

30	NASA Innovative Advanced Concepts (NIAC)
80	Space Technology Research Grants (STRG) & Fellowships
~750	SBIR/STTR
~100	Center Innovation Fund (CIF)
2	Centennial Challenges
4	Small Spacecraft
23	Flight Opportunities (FO)
~53	Game Changing Development (GCD)
9	Technology Demonstration Missions (TDM)

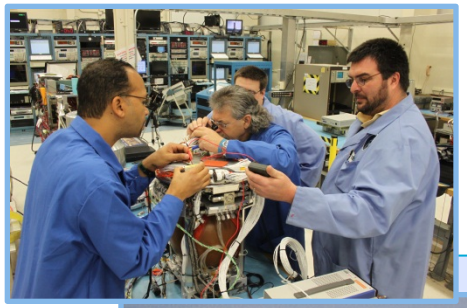
Space Technology Background

- February 2010 NASA Chief Technologist Appointed
- Space Technology included in NASA Authorization Act of 2010
- FY 2011 Operating Plan changed funded STP at approximately $350M
- February 2011 Exploration Technology Development budget and content (most) transferred to OCT
- FY 2012 Space Technology Program funded at $575M
- The Space Technology Program formulated a “Portfolio” with 9 programs:
  - Combination of new programs and existing programs
  - Combination of directed and competitively selected content
  - Approximately 400 NASA employees in FY 2011
  - Approximately 900 NASA employees in FY 2012
- Portfolio/Program Commitment Agreement signed August 2011
- FY2011 & FY2012 solicitations released and awarded

Space Technology: Investing in Our Future

- **Enabling Our Future in Space:** Space Technology matures the technology required for NASA's future missions in science and exploration while proving the capabilities and lowering the cost for other government agencies and commercial space activities.

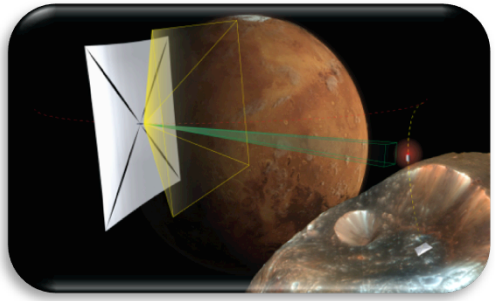
- **NASA at the Cutting Edge:** Pushing the boundaries of aerospace technology and seizing opportunities, Space Technology enables NASA and our nation to remain at the cutting edge.

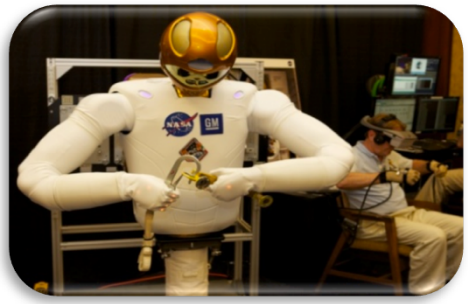


STP Strategic Investing Principles

Space Technology Program

- **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





9 Programs of Space Technology

Low TRL Technology Research & Development

Space Technology Research Grant Program

NASA Innovative Advanced Concepts (NIAC) Program

Center Innovation Fund Program

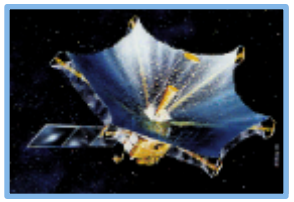
Mid TRL Technology Development

Game Changing Development Program

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

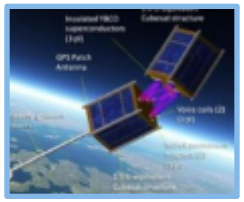
High TRL Technology Capability Demonstrations

Flight Opportunities



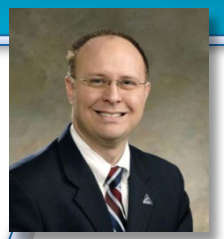
Technology Demonstration Missions

Centennial Challenges Prize Program



Small Spacecraft Technologies Program

GCD Mission











To be the **premier** organization within the Agency/Country to **rapidly** advance mid TRL disruptive space technologies from concept to demonstration

Premier means first in rank, first in importance, to be the leader

GCD Principal Investigators

Ryan Stephan
Thermal Control, EVA
Life Support

Chuck Taylor
In-Space Propulsion
Power Systems

Neil Cheatwood
Thermal Protection Systems
Entry, Descent, and Landing

Garry Qualls
Radiation Modeling
Radiation Protection
Avionics

Rob Ambrose
Robotics
Satellite Servicing

Keith Belvin
Structures and Materials
Manufacturing

What is Game Changing Development?

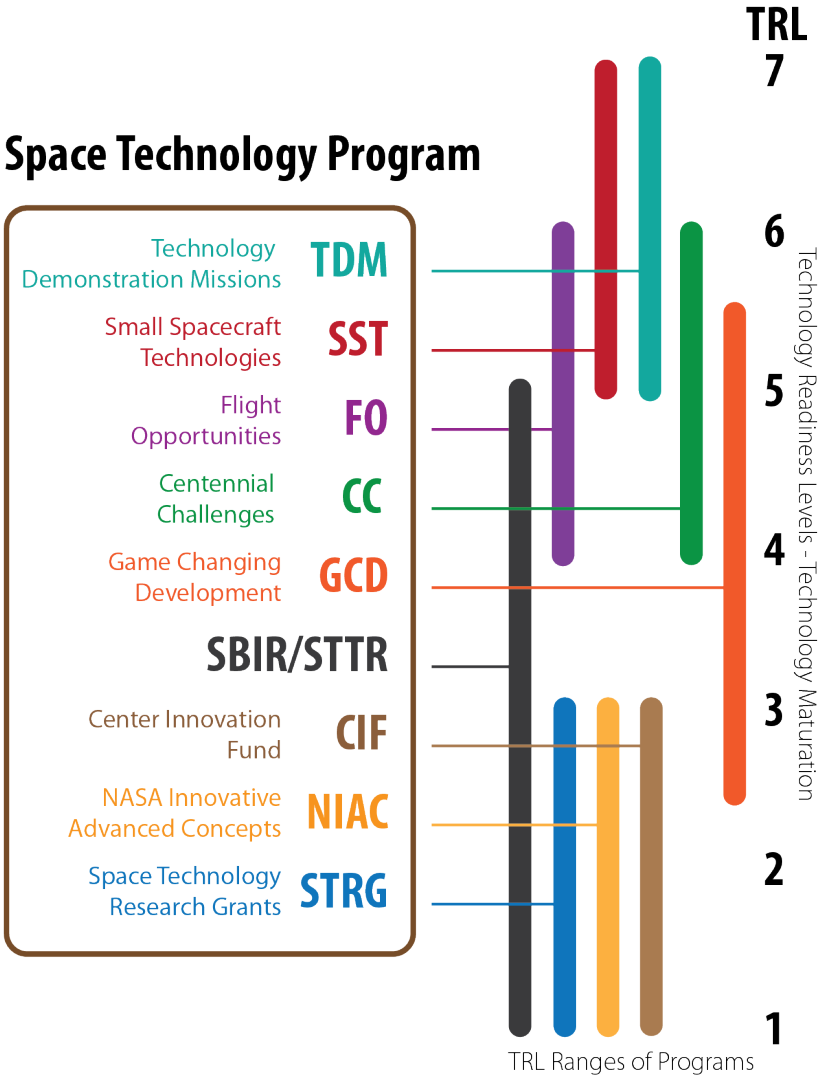
- **Disruptive** or **Transformative** Technologies
- **Orders of Magnitude** advancement enabling new missions and capabilities
- **Principal Investigator-led** investment strategy
- Planning for technology **infusion** to future NASA missions, other government agencies, the larger aerospace enterprise and national needs
- Investing in **High-Payoff** Technologies
- **Changing** the way a thing is done or made

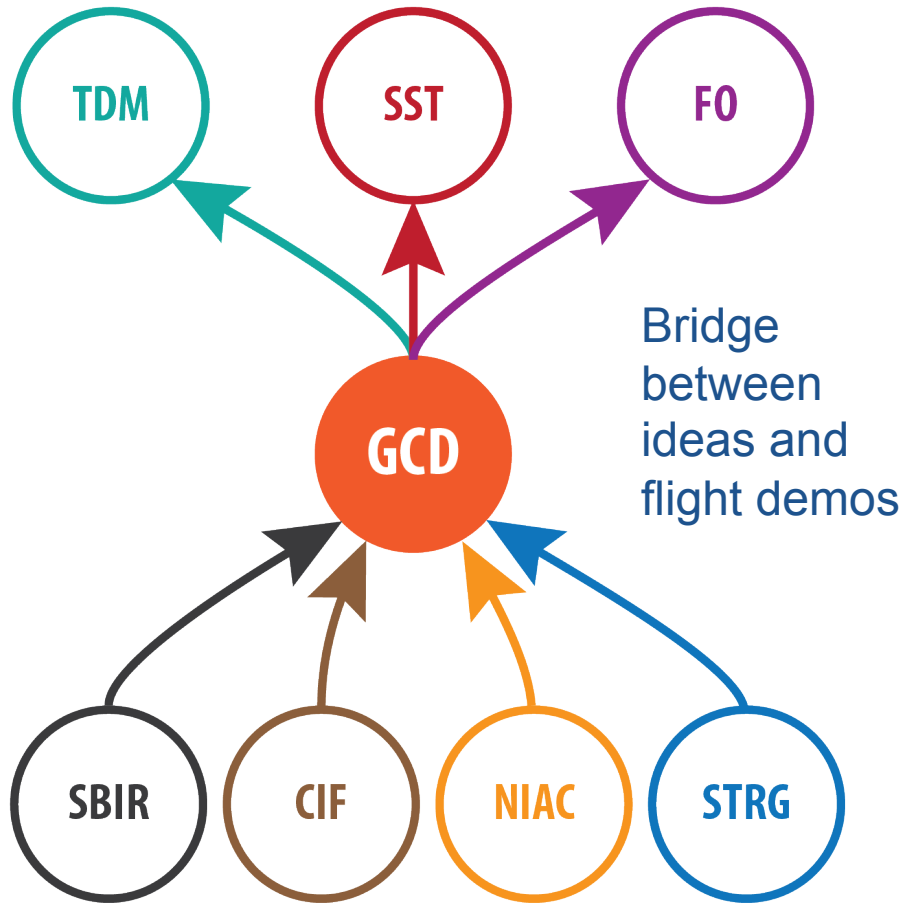
GameOn.nasa.gov

Program Goals

- Formulate and implement high payoff, high risk technology projects that capitalize on
  - Short development cycles (2-3 years)
  - Lean development strategies
  - Competitive acquisitions
  - Accountability through continuation reviews
- Deliver technological knowledge and develop technology infusion plans that are used for and support NASA missions, the aerospace community, and other government agencies
- Effectively engage and partner within STP, across the Agency, and with industry to enable technology maturation from concept to flight

GCD fits into the STP Pipeline



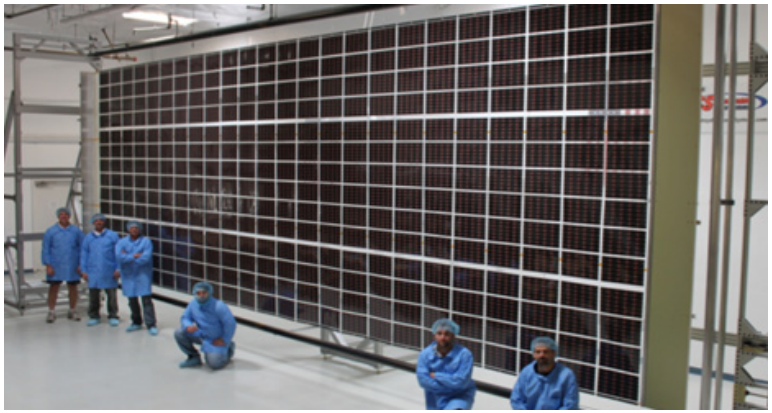


GCD FY12 Solicitations

Industry involvement through

4

Solicitations



DSS: Solar Array Systems

- BAA: U&I - Unique and Innovative Space Technologies
  - 5 awards in Q4; 2 awards in Q2
- NRA Appx. A: FOP - Tech Development for Suborbital Flight Opportunities
  - 14 awards in payload and vehicle capability enhancements
- NRA Appx. B: SAS - Tech Development for Solar Array Systems in Support of Electric Propulsion
  - 2 awards (DSS & ATK)
- NRA Appx. C: Tech Development for Variable Heat-Rejection
  - Closed; Reviews are ongoing

GCD Collaborations within STP (pipeline)

- Collaboration with Flight Opportunities
  - FOP provided funding for NRA App. A
  - GCD develops / matures technologies
  - Makes them available to FOP after 1 year

- Collaboration with TDM
  - **In Phase 1: GCD** matures technology
  - **In Phase 2: TDM** develops it to a free flyer Demo mission

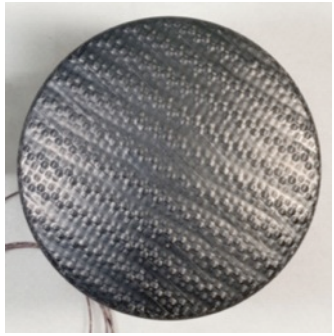
We are also working with SST on future collaborations

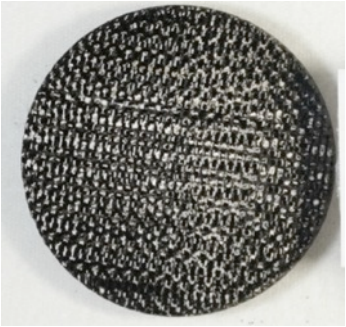
CIF / GCD Pipeline Example: 3D Woven TPS

Started under CIF (low-TRL), now it is further developed under GCD

Project Summary:

3-D Woven Thermal Protection System (WTPS) utilizes mature weaving technologies to manufacture preforms. Varying the material composition by controlling placement of fibers, and optionally infusing with resins, yields ablative TPS to meet a wide range of entry conditions.





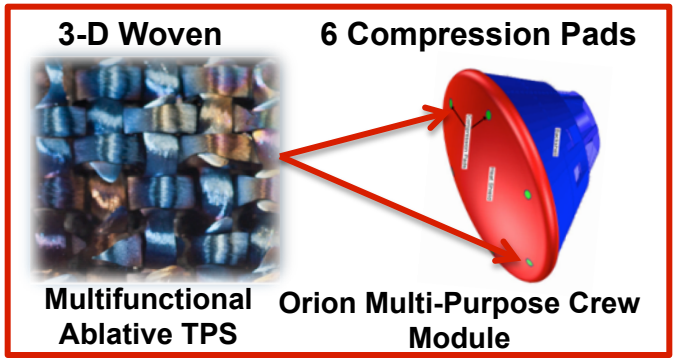
Resin infused, pre & post arc jet tested coupons, left and right, respectively. Condition: 0.625 atm & ~700 W/cm^2.

Innovation summary:

A game changing approach to manufacturing thermal protection systems that use precisely engineered 3-D weaving techniques

NASA/Government Application:

Woven TPS could enable robotic missions that encounter extreme entry environments (e.g., Venus, Saturn, high-speed sample return), and human missions from beyond the Moon



3-D Woven TPS is being evaluated for a possible Lunar Flight test in 2017.

See TPS talk later today

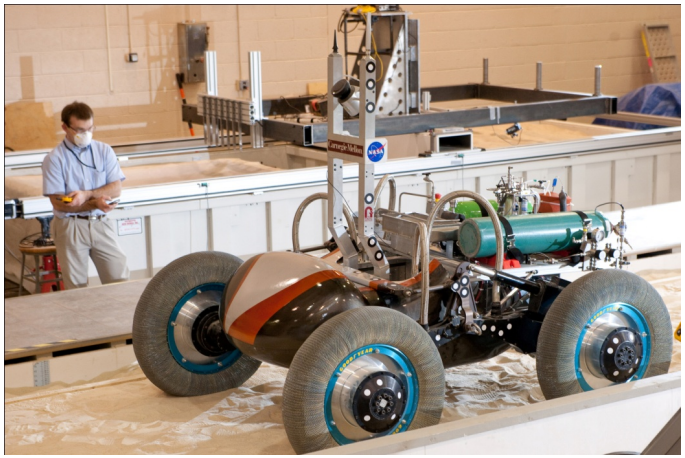
Could enable probe missions to the Giant Planets; missions to Titan

GCD Collaboration with MDs (& infusion)

- **Pioneering collaboration** between STP/GCD and the Science Mission Directorate (SMD) / Astrophysics Division
  - Co-funding of two tech development projects
  - Developments by universities & institutes
  - STP is planning to expand this pilot to other STP Programs & SMD Divisions

Variable Oxygen Regulator VOR 2.0 design (for AES)

- **Cross-MD collaboration** between STP/GCD/(TDM) and HEOMD/Advanced Exploration Systems (AES)
  - Making multiple hardware and software deliveries to AES for System level demo

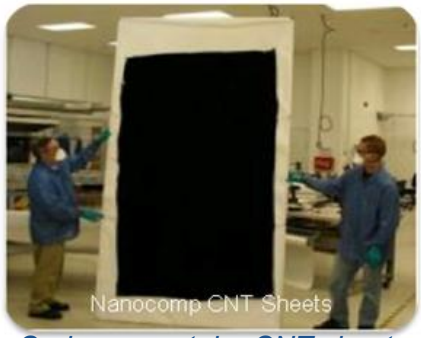


Fuel Cell Integrated to Scarab rover (for AES)

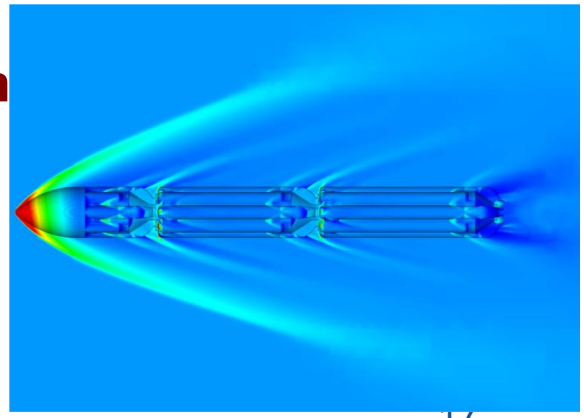
GCD Addressing National Needs

- **Partnering with US Industry, Academia and Other Government Agencies to develop technologies**
  - Partnering with Industry through **National Initiatives**:
    - National Robotic Initiative
    - Synthetic Biology
    - Advanced Manufacturing Initiative
    - Nanotechnology
    - Materials Genome Initiative (New for FY 2013)
  - **DARPA (Defense Advanced Research Projects Agency) collaboration on robotics**
    - "Next Generation Humanoid for Disaster Response"
  - **Army/Strategic Missile Defense collaboration on low cost access to space launchers**
    - SWORDS (Soldier-Warfighter Operationally
    - Responsive Deployer for Space)
    - Multi-agency effort to develop a low-cost access to space for small payloads

Electron beam manufacturing



Carbon nanotube CNT sheet



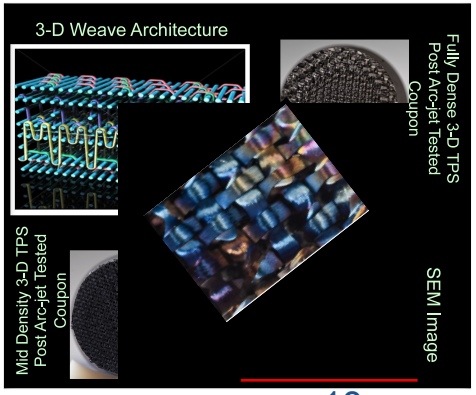
SWORDS

GCD Partnering with Industry

- **Partnering with U.S. industry to develop technologies**
  - With both small and large companies;
  - Through various funding channels, e.g.,
    - Competitive Awards
    - Grants
    - Guided projects

Boeing: 2.4m diameter cryotank

Ohio's first electrolysis-based hydrogen refueling station



BRM: Woven TPS

GCD Projects by Numbers

53

Activities

- 12 Projects in Formulation
- 31 Projects in Implementation,
- 10 Grants

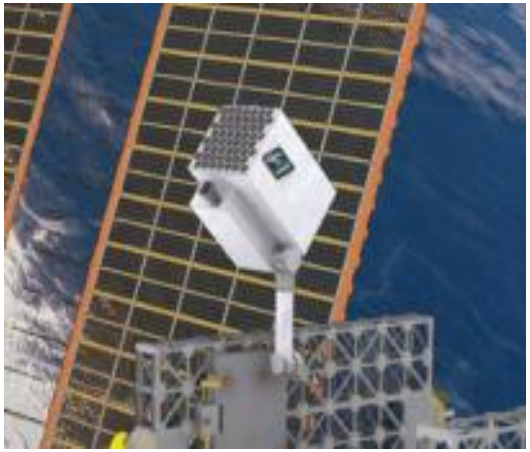
At the end of FY12

GCD Projects in Formulation (12)

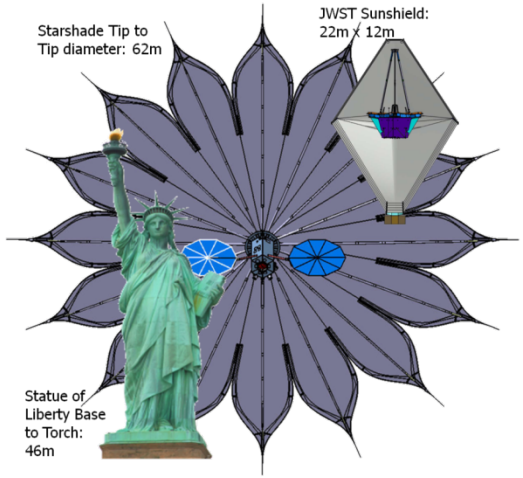
- **20 Kelvin, 20 Watt Cryocooler**
- 3-D MAT Compression Pad
- Advanced Space Propulsion Workshop*
- Exoplanet Light Imaging and Spectroscopy
- **Heat Shield for Extreme Entry Environment Testing Technology**
- **High Energy Density Battery (AMPRIUS)**

NOTE: Potential relevance to OPAG

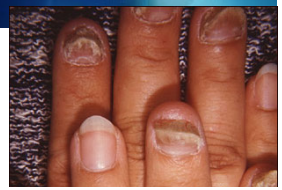
- High Performance EVA Gloves Technology Development*
- **High Performance Spaceflight Computing**
- **Solar Electric Propulsion**
- **Station Explorer for X-Ray Timing and Navigation Technology**
- **Variable Heat Rejection**
- **Woven Thermal Protection Systems**



SEXTANT



ELIAS – Exoplanet spectroscopy



EVA gloves

*Note: These formulations are considered seedlings which is dependent on the amount of funding requested for the activity.

GCD Projects in Implementation (31)

Technology Areas ETD: GCD	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17	FY 18	Infu-sion
In-Space Propulsion (ISP)			4		5					
Space Power Generation and Storage			4		6					
Lightweight Materials and Structures			2		5					
Solar Array System (SAS)				4		5				
Nuclear Systems			2		5					
Human-Robotic Systems (inc. National Robotic Initiative)		3					7			
Autonomous Systems (AS)			4		5					
Next-Generation Life Support (NGLS)			4		5					
Deployable Aeroshell Concepts & Conformal TPS			2		5					
In-Situ Resource Utilization (ISRU)			4		5					
Composite Cryogenic Propellant Tank (CCPT)	4				6					
Hypersonic Inflatable Aerodynamic Decelerator (HIAD)	3			6						
Advanced Radiation Protection (ARP)			2		4					

Including SEP Development Activities

Technology Areas CSTD: GCD	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17	FY 18	Infu-sion
Manufacturing Innovation			3		5					
Robotic Satellite Servicing	3				5					
Nanotechnology			3		5					
Space Synthetic Biology			2		3					

NOTE: Partial list with larger GCD projects

Technology Areas (TA)

- TA.1. Launch Propulsion
- TA.2. In-Space Propulsion
- TA.3. Space Power/Storage
- TA.4. Robotics
- TA.5. Comm./Navigation
- TA.6. Human Health
- TA.7. Human Expl. Dest.
- TA.8. Sci. Instr./Sensors
- TA.9. EDL
- TA.10. Nanotechology
- TA.11. Modeling/Simulation
- TA.12. Materials/Structures
- TA.13. Ground/Launch
- TA.14. Thermal

Technology Readiness Levels (TRL) 1 → 9

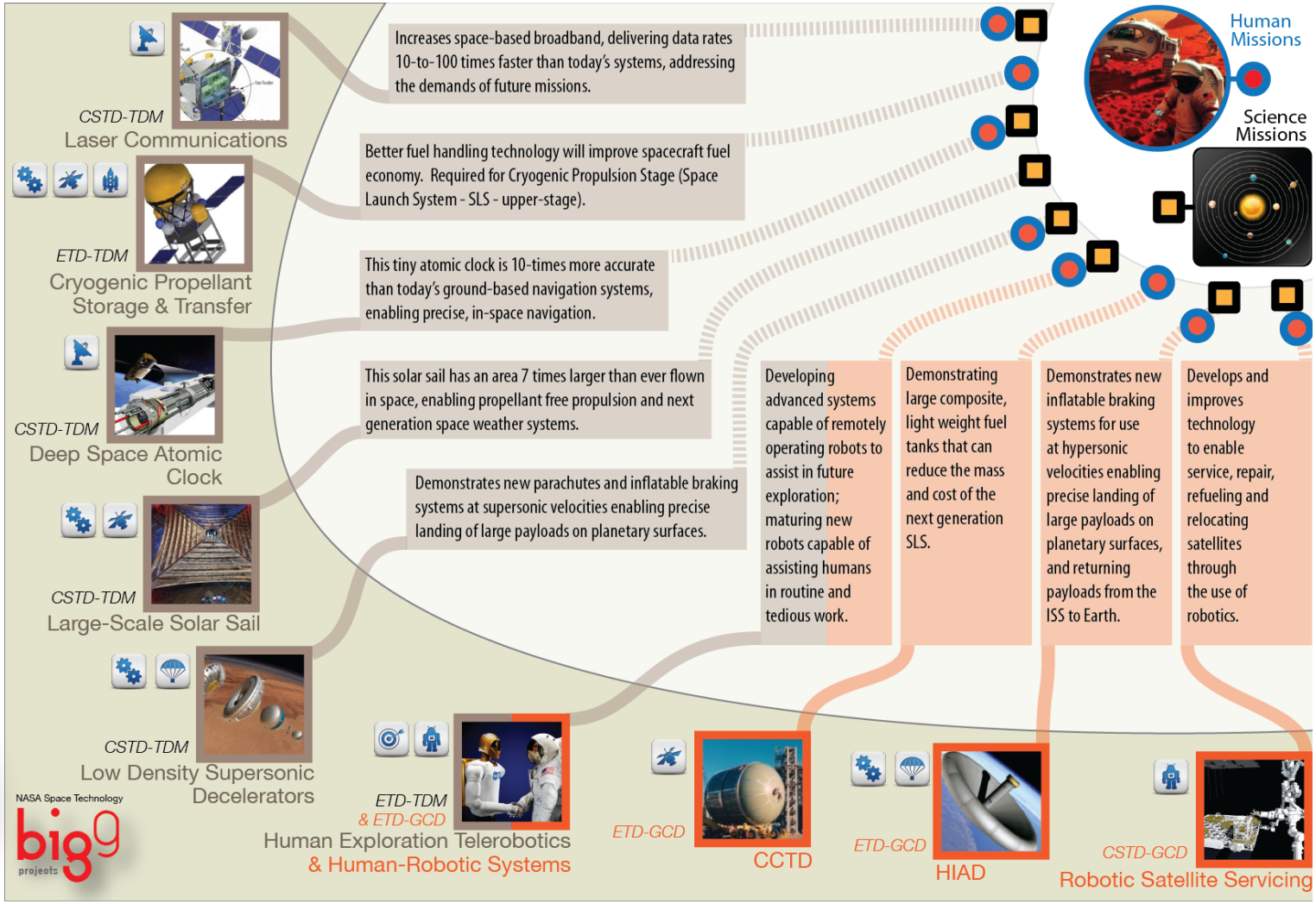
Infusion path to: Science, Exploration

GCD has 4 of STPs Big9 Projects

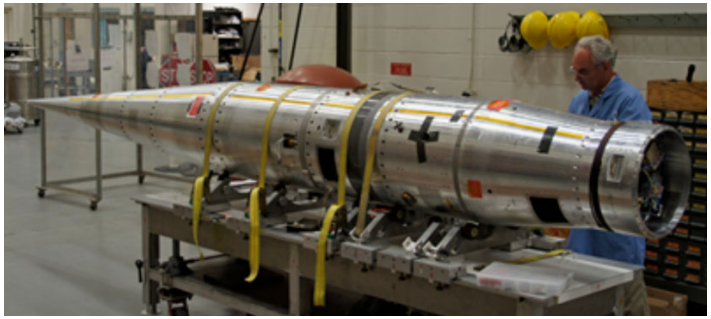
4

of the

NASA Space Technology rolling big9 projects



IRVE-3



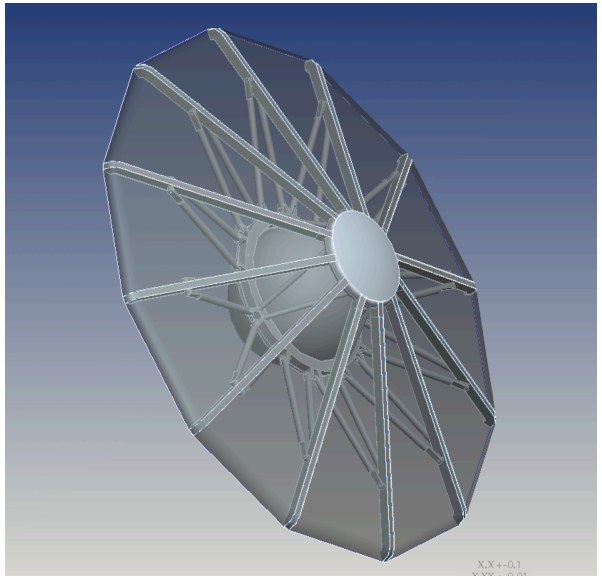
IRVE 3: First Successful Launch for STP Project

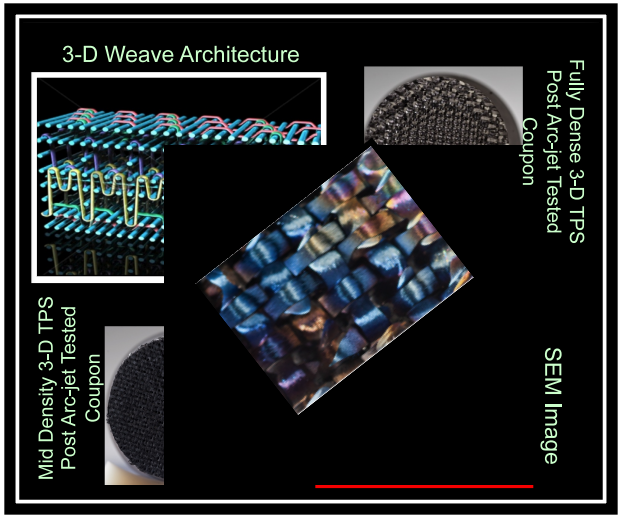
Potential application for Titan entry

IRVE-3 – Enabling Planetary Entries

EDL Technologies

- HIAD – Hypersonic Inflatable Aerodynamic Decelerators
- DACC – Deployable Aeroshell Concepts – Conformal TPS
- Woven TPS
- Hypersonics





See TPS talk today

Could enable probe missions to the Giant Planets; missions to Titan

Composite Cryogenic Propellant Tank

Project Summary: The primary objective of the Composite Cryotank Technologies and Demonstration (CCTD) project is to mature the technology readiness of composite cryogenic propellant tanks at diameters that are suitable for future heavy lift vehicles and other in-space applications. The concept being developed and demonstrated by this project involves advanced materials (composites), structural concepts (joints, splices, fasteners, etc), and manufacturing techniques.

Benefits: Project will produce a major advancement in technology readiness; successfully test a 5.5-meter diameter composite hydrogen fuel tank, achieve 30% weight savings and 25% cost savings compared to SoA metallic tanks (Al-Li). Develops and demonstrates composite tank critical technologies: Materials, Structures, and Manufacturing. Focuses on achieving affordability and technical performance that is verified through agreement between experimental results and analysis predictions.

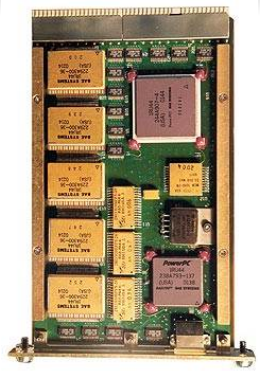
Could double payload to orbit, thus benefit Outer Planets missions

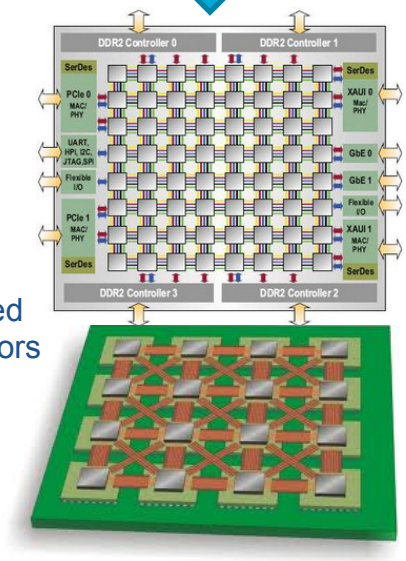
High Performance Spaceflight Computing

Formulation Activity designed to answer these important questions:

- Promises a 100-1000 fold performance increase in processing power
- What are the paradigm-shifting NASA space-based applications that will drive next generation flight computing?
- What are the future onboard computing requirements?
- Which computing architecture(s) will make the most impact?
- Given investment in computing technologies by commercial and military industry, how can NASA invest its limited resources to advance this technology into the Agency's space systems?

RAD750 Processor



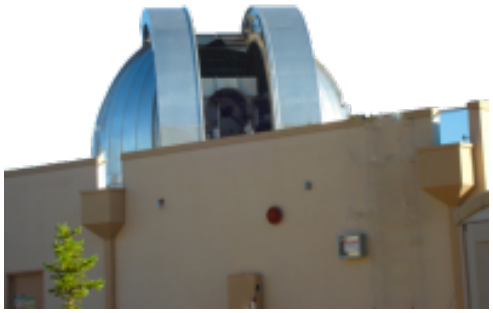


Advanced Processors

Benefits missions to Giant Planets, Europa, Titan and others

Laser Comm Relay Demo (TDM)

Project Summary: The **Laser Communications Relay Demonstration** mission is NASA's **first, long-duration optical communications mission**. The project will help mature concepts and deliver technologies applicable to both near-Earth and deep-space communication network missions.



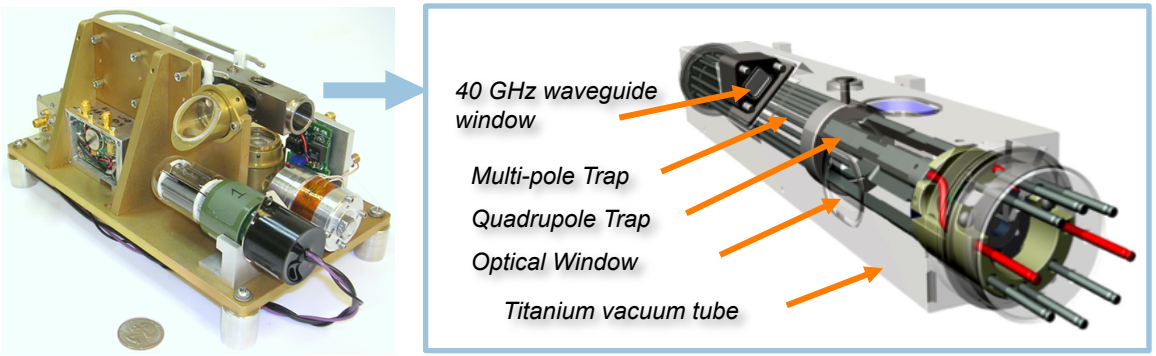
Benefits: The demonstration will use lasers to encode and transmit **data at rates 10-to-100-times faster than radio** -- or at the same data rate as today's fastest RF radios, but using significantly less mass and power.
The investigation will enable a variety of robust future science and exploration missions -- providing a higher data rate, and delivering more accurate navigation capabilities with reduced size, weight and power requirements.

NOTE: the GCD Deep Space Optical Comm Project advances this technology

Could be beneficial to any Outer Planets mission generating large data sets

Deep Space Atomic Clock (TDM)

Project Summary: Develop an **advanced prototype mercury-ion atomic clock** and demonstrate for a year in space, providing the unprecedented accuracy (Allan Deviation < 2.0E-14 at one day) needed for the next generation of deep space navigation and radio science**.** **Identify steps** needed **to build 5 kg/20 W** infusible **flight version**.

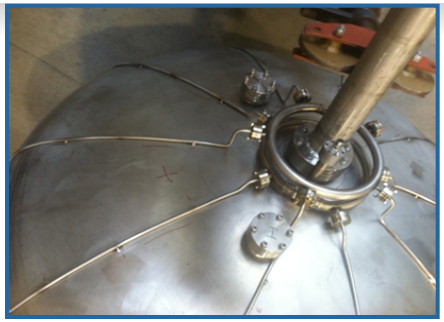


Benefits: **The Deep Space Atomic Clock will be orders of magnitude smaller, lighter and more stable than any other atomic clock flown in space**.

- Improve clock accuracy of the next GPS system by 100×
- Increase navigation & radio science tracking data quantity by 2×, Improve tracking data accuracy up to 10×
- Enable a shift to a more flexible/extensible 1-Way radio navigation architecture
- Enable multiple spacecraft per aperture tracking
- Designed for reliable in-space use: no lasers, cryogenics or consumables, utilizes existing vacuum technology and is radiation tolerant at levels similar to GPS Rb Clocks

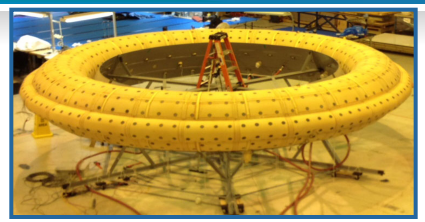
NOTE: **Could be beneficial to any Outer Planets mission requiring an inexpensive atomic clock**

Advancing Space Technology With New Hardware

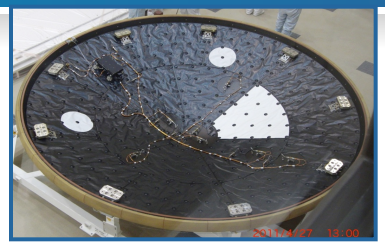


Cryogenic tank

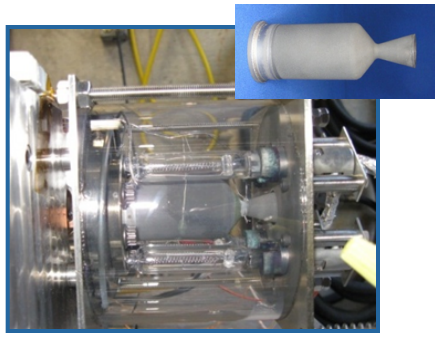
Composite Strut Structural Testing



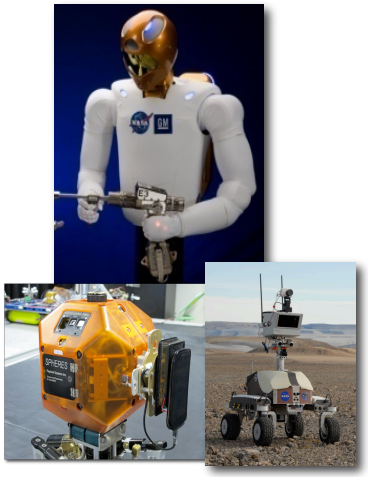
Low Density Supersonic Decelerator Proof Test



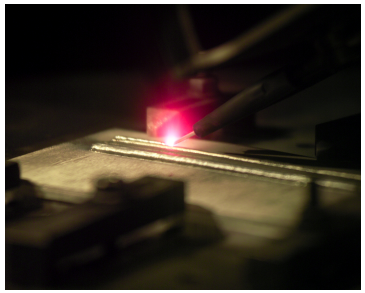
MSL heatshield with instrumentation



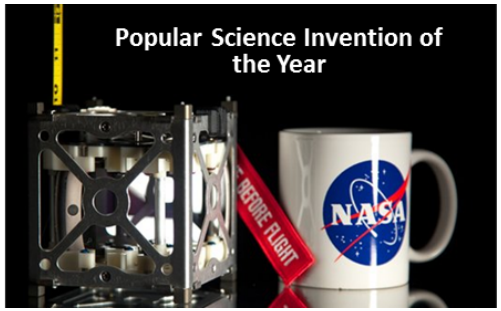
Green Propellant 22N thruster

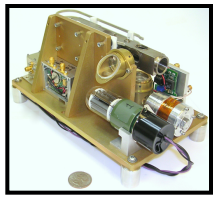


Telerobotic Systems



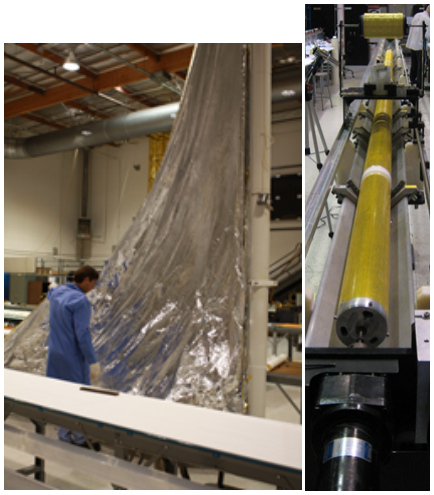
Additive Manufacturing





Deep Space Atomic Clock

System Test of Inflatable Re-entry Vehicle Experiment



Solar Sail and Boom Fab

Exoskeleton

Could potentially support OP missions

Conclusion

- What technologies can we develop for you?
  - Need to understand your top priority technical challenges
  - What demonstrations will be required for our technologies to find an entry point into your mission architectures
  - Request follow on discussion for a partnership

GAME ON