National Aeronautics and Space Administration

Space Technology Program

NASA Advisory Council

Michael Gazarik
Office of the Chief Technologist
November 18, 2011

Space Technology: Investments in Our Future

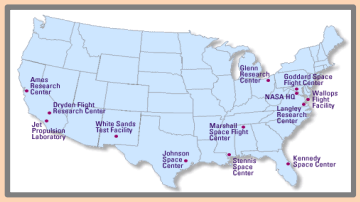
- **Enabling Our Future in Space:** By investing in high payoff, disruptive technology that industry cannot tackle today, *Space Technology* matures the technology required for NASA's future missions in science and exploration while proving the capabilities and lowering the cost of other government agencies and commercial space activities.
- **Building U.S. Economic Competitiveness:** With a portfolio of innovative, high-risk, high-return research, *Space Technology* will stimulate the economy and build our Nation's global economic competitiveness through the creation of new products and services, new business and industries, and high-quality, sustainable jobs.
- **Technological Leadership is Key to Winning the Future**: *Space Technology* is the central NASA contribution to a revitalized set of federal investments in research, technology and innovation across the Nation. Through these investments, NASA can be a significant part of the solution to our nation's economic, national security and geopolitical challenges.
- **NASA Makes a Difference in Our Lives Everyday:** Knowledge provided by weather and navigational spacecraft, efficiency improvements in both ground and air transportation, super computers, solar- and wind-generated energy, the cameras found in many of today's cell phones, improved biomedical applications including advanced medical imaging and even more nutritious infant formula, as well as the protective gear that keeps our military, firefighters and police safe, have all benefitted from our nation's investments in aerospace technology. By investing in *Space Technology*, NASA will continue to make a difference in the world around us.

The 10 Programs of Space Technology

Early Stage Innovation

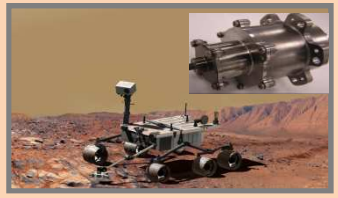
Space Technology Research Grant Program

NASA Innovative Advanced Concepts (NIAC) Program



Center Innovation Fund Program

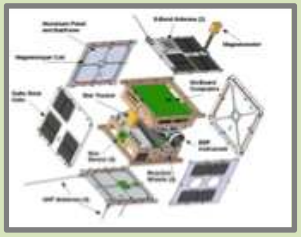
Centennial Challenges Prize Program



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

Game Changing Technology

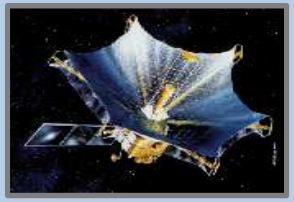
Game Changing Development



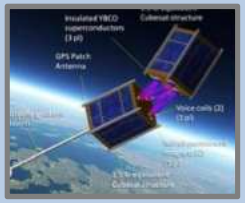
Franklin Small Satellite Subsystem Technology

Crosscutting Capability Demonstration

Flight Opportunities



Technology Demonstration Missions



Edison Small Satellite Demonstration Missions

FY 2011 Highlights

- Space Technology included in NASA Authorization Act of 2010
- NASA is implementing an Operating Plan for FY 2011 that funds Space Technology at approximately the authorization level at $350M. In addition, Exploration Technology is funded at $185M
- FY 2011 guided technology efforts, some of which were initiated in FY 2010, are proceeding across the NASA Centers
- FY 2011 Space Technology competitive awards announcements made for:
  - Space Technology Research Fellowships
  - Flight Opportunities
  - NASA Innovative Advance Concepts
  - Game Changing Development
  - Technology Demonstration Missions

- Development of FY 2012 solicitations is underway

FY 2011 Competitive Selections

- **NIAC** selected 30 advanced concept proposals from hundreds of submittals. Addresses early-stage concepts address challenging problems in space operations research and development.

- **STRF** selected inaugural class of 80, highly-qualified and talented graduate students from 37 universities and colleges.

- **Green Flight Challenge:** Fourteen teams registered for competition. Three teams met requirements and competed. First prize of $1.35M awarded to Pipistrel-USA.com. Second place prize of $120,000 awarded to team eGenius.

- **SBIR/STTR** awarded 450 SBIR Phase 1 awards across 37 states and 213 SBIR Phase 2 awards across 35 states. 45 STTR Phase I awards were made across 15 states as well as 27 Phase II awards across 18 states. Awarded 22 Phase 3 awards in FY 2011. FY 2011 is solicitation on track with crosswalk to Space Technology roadmaps and with greater Center involvement.

- **Game Changing Development** is soliciting proposals for research and technology development for revolutionary improvements in America's space capabilities. Initial selections:
  - Lightweight Composite Cryogenic Propellant Tank – Boeing
  - Ultra-high energy density Silicon Nanowire Lithium Ion Batteries – Amprius
  - Ride the Light (Formulation Phase) – 9 companies/universities

- **Flight Opportunities** selected seven companies to integrate and fly technology payloads on commercial suborbital reusable platforms. The seven companies receiving IDIQ contracts are:
  - Armadillo Aerospace; Near Space Corp; Masten Space Systems; Up Aerospace; Virgin Galactic; Whittinghill Aerospace; XCOR.
  - Flight Opportunities has also made 25 Suborbital/Parabolic Payload Selections in FY 2011.

- **Technology Demonstration Mission** proposals were sought in four areas:
  - High-bandwidth deep space communication, navigation and timing; orbital debris mitigation or removal systems; advanced in-space propulsion systems; autonomous rendezvous, docking, close proximity operations and formation flying
  - Selected three proposals for award: Solar Sail (L`Garde); Deep Space Atomic Clock (JPL); Laser Communications Relay Demo (GSFC)

FY 2011 Small Business Programs

The Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs are integral to the NASA Space Technology program

- Continues to foster the development of innovative ideas by small companies across the Nation
- Strategic at each stage, from solicitation to selection through technology maturation, to increase infusion of successful SBIR and STTR technologies into NASA missions.
  - Solicitation topic areas selected to increase synergy between the SBIR and STTR projects and overall Agency technology goals.
  - Technologies selected for Phase 2 and 2E have high potential to meet NASA need.
- NASA is working with House and Senate Small Business Committees as they reauthorize the program. May increase funding ratios for participating agencies.
- Next solicitation cycle will increase emphasis of Agency's Space Technology roadmaps

Awards	FY11
SBIR	**$179.3**
Phase 1 Awards	450
Phase 2 Awards	215
Phase 2E Awards	23
STTR	**$26.0**
Phase 1 Awards	45
Phase 2 Awards	27
Phase 2E Awards	n/a

FY 2011 Space Technology Projects by Technology Area

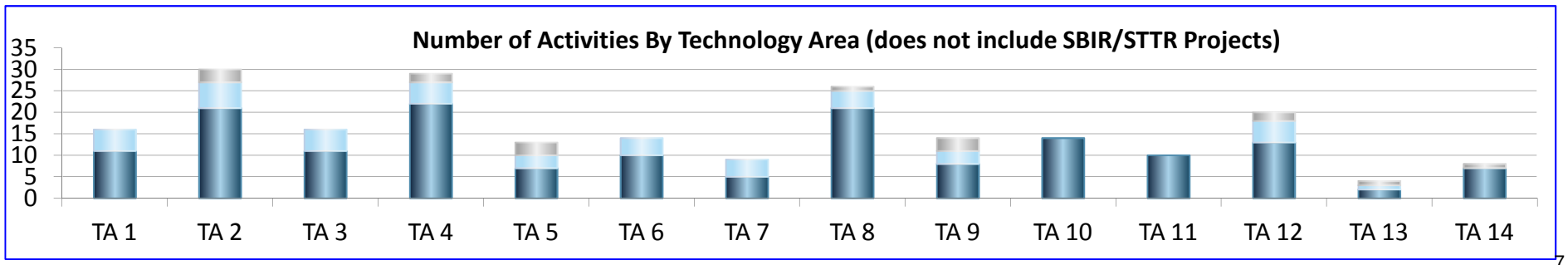
NASA SPACE TECHNOLOGY ROADMAP TECHNICAL AREA BREAKDOWN STRUCTURE

STR • TABS
TECHNOLOGY AREA BREAKDOWN STRUCTURE

- TA01 • LAUNCH PROPULSION SYSTEMS
- TA02 • IN-SPACE PROPULSION TECHNOLOGIES
- TA03 • SPACE POWER & ENERGY STORAGE
- TA04 • ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS
- TA05 • COMMUNICATION & NAVIGATION
- TA06 • HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS
- TA07 • HUMAN EXPLORATION DESTINATION SYSTEMS
- TA08 • SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS
- TA09 • ENTRY, DESCENT & LANDING SYSTEMS
- TA10 • NANOTECHNOLOGY
- TA11 • MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING
- TA12 • MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING
- TA13 • GROUND & LAUNCH SYSTEMS PROCESSING
- TA14 • THERMAL MANAGEMENT SYSTEMS

	Early Stage Innovation	SBIR/STTR*	Game Changing Technology	Crosscutting Capability Demo
Projects	183	1088	23	10
FY11	$27M	$165M	$70M	$68M

Key
- Crosscutting Capability Demo
- Game Changing Technology
- Early Stage Innovation



FY 2011 Technical Topic Summary

NASA Innovative Advanced Concepts (NIAC)

- Orbital Debris & Near-Earth Object Mitigation
- Human Exploration
- Robotic Exploration
- Imaging, Sampling, & Communications
- Propulsion & Power

Game Changing Development (GCD)

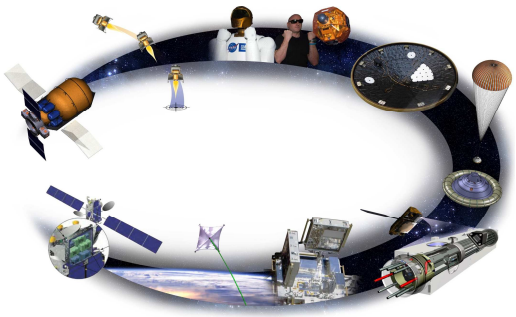
- Exploration
  - Space Power & Storage Systems
  - Next Generation Life Support
  - Autonomous Systems
  - Human Robotics Systems
  - In-situ Resource Utilization
  - Satellite Servicing
  - Composite Cyrotanks
- Cross-cutting
  - Low-cost access to space
  - Energy
  - Advanced Avionics
  - Space operations
  - Beamed Energy

Technology Development Mission (TDM)

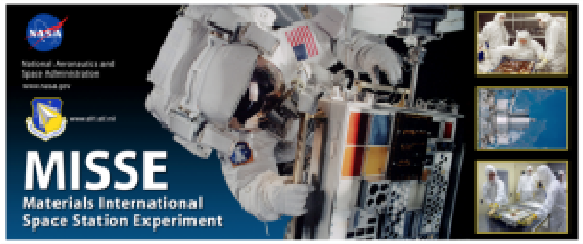
- High-bandwidth communications
- Deep-space navigation
- Inflatable decelerators
- Cryogenic fluid handling & storage
- Solar sails
- Precision landing and hazard avoidance
- EDL instrumentation
- Tele-robotics
- Materials

Centennial Challenges

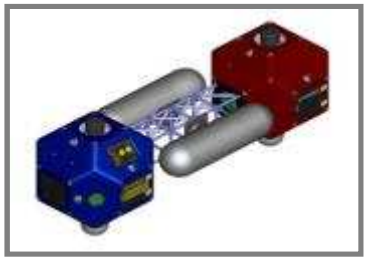
- Autonomous surface robots
- Low-cost access to space
- Energy storage



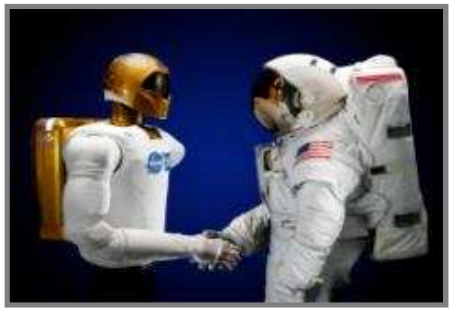
FY 2011 Space Technology Projects Engage All Centers



ISS MISSE-X Experiment (LaRC)



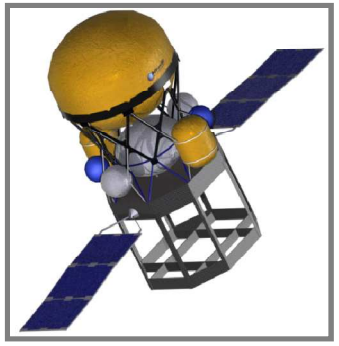
ISS SPHERES Fluid-Slosh Experiment (KSC)



Human-Robotic Systems (JSC)

Low Density Supersonic Decelerators (JPL)

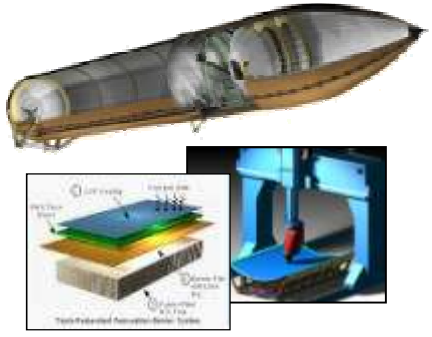
Robotic Satellite Servicing (GSFC)



Cryogenic Propellant Storage and Transfer (GRC)

PhoneSat (ARC)

Optical Communications (GSFC)



Composite Cryotanks (MSFC)

Exploration and Science Mission Directorate Technology Priorities

Technology Needs	Space Technology Response	Space Technology Program
Human Exploration Operations Mission Directorate (HEOMD)		
Deep space optical communications	➢ **Laser Communications Relay Demonstration Project** ➢ Deep Space Optical Communication ➢ Deep Space X-ray Navigation & Communication	**FY 2011 TDM Selection** GCD
Cryogenic propellant storage & transfer demo	➢ **Cryogenic Propellant Storage & Transfer Demonstration Mission**	**TDM**
In-Space Timing and Navigation	➢ **Deep Space Atomic Clock** ➢ Deep Space X-ray Navigation & Communication	**FY 2011 TDM Selection** GCD
Composite Cryotanks	➢ **Composite Cryotanks Project** ➢ Nanotechnology	**GCD**
Human Robotic Systems	➢ **Human-Robotic Systems Project**	**GCD**
Autonomous Systems & Avionics	➢ **Robotic Satellite Servicing Project** ➢ Autonomous Landing & Hazard Avoid Tech (ALHAT)	**GCD** TDM
Advanced In-Space Propulsion	➢ **Solar Sail Demonstration Project** ➢ In-Space Propulsion	**FY2011 TDM Selection** GCD
Mars entry, descent and landing systems	➢ **Low Density Supersonic Decelerators (LDSD)** ➢ Mars Science Laboratory Entry, Descent and Landing Instrumentation (MEDLI) ➢ **Hypersonic Inflatable Aerodynamic Decelerator (HIADS)** ➢ Deployable Aeroshell Concepts & Flexible Thermal Protection System ➢ Autonomous Landing & Hazard Avoid Tech (ALHAT)	**TDM** **GCD**
International Space Station (ISS) materials testbed	➢ Materials International Space Station Experiment (MISSE-X)	TDM
Advanced radiation protection	➢ Advanced Radiation Protection Project ➢ SBIR/STTR, CIF, NIAC Projects	GCD SBIR/STTR, CIF, NIAC
Solar electric propulsion demonstration	➢ Space Power Generation & Storage, Solar Electric Propulsion Demonstration	GCD

Big 9 projects are **Bold** & Underlined

Exploration and Science Mission Directorate Technology Priorities

Technology Needs	Space Technology Response	Space Technology Program
Human Exploration Operations Mission Directorate (HEOMD) – cont'd		
Next generation life support	➢ Next Generation Life Support Project	GCD
In-Situ Resource Utilization	➢ In-Situ Resource Utilization ➢ Space Synthetic Biology	GCD
High Efficiency Space Power Systems: High Specific Energy Battery, Advanced Batteries, Regenerative Fuel Cells, High Strength/Stiffness Deployable 10-100kW leading to 300kW Class Solar Arrays	➢ Space Power Systems ➢ Nuclear Systems ➢ Lightweight Materials & Structures	GCD
High Reliability Life Support Systems	➢ Next Generation Life Support	GCD
Key exploration technology projects	➢ Exploration priorities coordinated with HEOMD, complementary with Advanced Exploration Systems (AES) Program	GCD
Science Mission Directorate (SMD)		
Deep space optical communications	➢ **Laser Communications Relay Demonstration Project** ➢ Deep Space Optical Communication ➢ Deep Space X-ray Navigation & Communication	**FY 2011 TDM Selection** GCD
Mars entry, descent and landing systems	➢ **Low Density Supersonic Decelerators**, ➢ Mars Science Laboratory Entry, Descent and Landing Instrumentation (MEDLI) ➢ **Hypersonic Inflatable Aerodynamic Decelerator (HIADS)**, ➢ Deployable Aeroshell Concepts & Flexible Thermal Protection System ➢ Autonomous Landing & Hazard Avoid Tech (ALHAT)	**TDM** **GCD**
Advanced sensors	➢ Opportunities exist in multiple programs	GCD, NIAC, SBIR
Robust in-space tech demonstration program	➢ Currently 9 projects in TDM Program	TDM

Big 9 projects are **Bold** & Underlined

Aeronautics and Chief Offices Technology Priorities

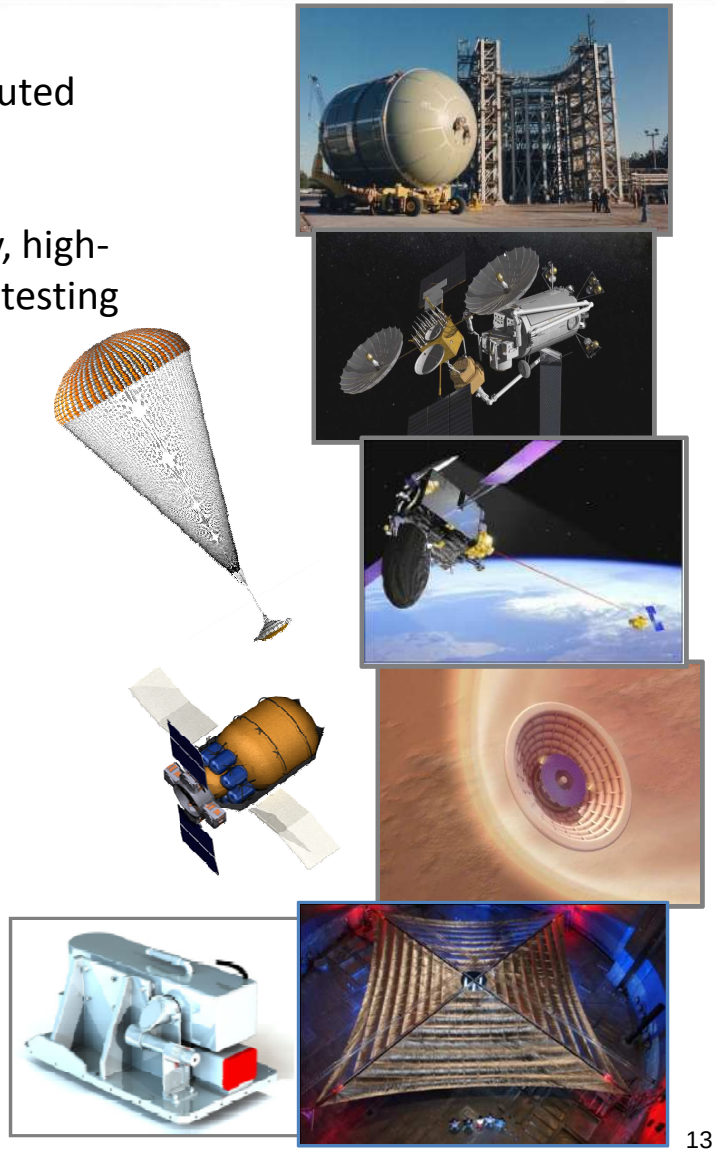
Technology Needs	Space Technology Response	Space Technology Program
Aeronautics Research Mission Directorate (ARMD)		
Entry, descent and landing hypersonics materials and systems	➢ **Low Density Supersonic Decelerators** ➢ Mars Science Laboratory Entry, Descent and Landing Instrumentation (MEDLI) ➢ **Hypersonic Inflatable Aerodynamic Decelerator (HIADS)** ➢ Deployable Aeroshell Concepts & Flexible Thermal Protection System ➢ Autonomous Landing & Hazard Avoid Tech (ALHAT)	**TDM** **GCD**
Aeronautics content in Center Innovation Fund (CIF), NIAC and Centennial Challenges (CC)	➢ Green Flight Aviation Challenge ➢ Program plans consistent with aeronautics content	CIF, NIAC, CC
Office of the Chief Engineer and Office of the Chief Health and Medical Officer		
Deep space optical communications	➢ **Laser Communications Relay Demonstration Project**	**FY 2011 TDM Selection**
Mars entry descent and landing systems that enable large payload landings	➢ **Low Density Supersonic Decelerators** ➢ Mars Science Laboratory Entry, Descent and Landing Instrumentation (MEDLI) ➢ **Hypersonic Inflatable Aerodynamic Decelerator (HIADS)** ➢ Deployable Aeroshell Concepts & Flexible Thermal Protection System	**TDM** **GCD**
Breakthrough low-cost space access	➢ Airborne Launch Assist Space Access (ALASA) ➢ Nanotechnology Propellants ➢ Beamed-power Project	GCD
In-space power	➢ Space Power Generation and Storage	GCD
Low gravity and confinement protection	➢ Lightweight Materials and Structures ➢ Advanced Radiation Protection	GCD
Radiation protection	➢ Advanced Radiation Protection Project ➢ SBIR/STTR, CIF, NIAC Projects	GCD SBIR/STTR, CIF, NIAC

Key areas of strong interest from multiple organizations

- Continue SBIR as a effective low technology readiness level (TRL) program with a focus on mission directorate needs
- A robust in-space technology demonstration program to bridge the "TRL Valley of Death" → Addressed by Space Technology TDM program
- Deep space optical communications and in-space propulsion → Laser Communications Relay and Large Solar Sail Demonstration projects
- Entry, descent & landing → Low Density Supersonic Decelerators, Hypersonic Inflatable Aerodynamic Decelerator (HIADS)

“The Big Nine”

- Space Technology consists of hundreds of small projects distributed across the country.
- These projects include the following nine ongoing, high-priority, high-visibility, broadly-applicable activities, each of which has major testing milestones in FY 2012 and FY 2013
- The Big Nine:
  - Laser Communications Relay Demonstration (GSFC)
  - Low Density Supersonic Decelerators (JPL)
  - Cryogenic Propellant Storage and Transfer (GRC)
  - Deep Space Atomic Clock (JPL)
  - Hypersonic Inflatable Aerodynamic Decelerator (LaRC)
  - Composite Cryotanks (MSFC)
  - Robotic Satellite Servicing (GSFC)
  - Solar Sail (L’Garde Inc.)
  - Human-Robotic Systems (JSC)



"The Big Nine" Highlights

- **Laser Communications Relay Demonstration:** High-bandwidth communications for near-Earth and deep-space applications. Other government agency interest. HEOMD infusion partner. Project start in FY 2011; SRR in FY 2012.
- **Low Density Supersonic Decelerators:** New supersonic decelerator capabilities for high-mass Mars missions and other planetary destinations, enabling pinpoint landing and high-elevation landing sites. FY 2012 milestones: Rocket-sled testing and first high-altitude balloon drop test.
- **Cryogenic Propellant Storage and Transfer:** Long-term storage of cryogenic propellant in space. Highest priority flight demonstration of NASA's Human Architecture Team. Formulation complete. SRR in FY 2012.
- **Composite Cryotanks:** Large-scale test articles that prove the viability and performance advantages of composite tanks for future SLS, planetary landers, propellant depots and in-space propulsion systems. FY 2012: 5-meter diameter autoclave and out-of-autoclave test articles.
- **Robotic Satellite Servicing:** In FY 2012, complete RRM International Space Station (ISS) demonstration mission, share data with industry, focus future technology investments on those needed to facilitate commercial enterprise.
- **Deep Space Atomic Clock:** Order of magnitude increase in deep space navigation performance. HEOMD infusion partner. Project start in FY 2011; SRR in FY 2012.
- **Hypersonic Inflatable Aerodynamic Decelerator:** New entry system capabilities to enable ISS downmass and high-mass landings on Mars. HEOMD and OSC Cygnus interest. FY 2012 sounding rocket flight.
- **Solar Sail:** Development of solar sail flight demonstration mission. Sail area 7 times larger than previous flight articles; 4 times larger than what can be tested in ground-based facilities. NOAA, SMD and human exploration cargo mission interest. Project start in FY 2011; SRR in FY 2012.
- **Human-Robotic Systems:** In FY 2012, complete Robonaut2 demonstration mission on the ISS, share data with academia and industry, foster U.S. competitiveness in next-generation robotics.

“The Big Nine” FY 2012 Milestones

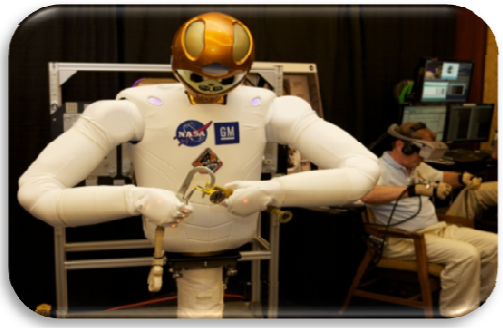
FY 2012

Projects	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sept-12
Composite Cryotank Tech and Demo									Develop 2m-Tank Fab. and Deliver to MSFC		2m Pressure Test	Develop 5m Demo. Unit
Hypersonic Inflatable Aerodynamic Decelerators			IRVE-3 Delta CDR	System Tests		NFAC Tests	MRR KDP-E Launch		Build-to-Print Fab. Complete	Wind Tunnel Test	LCAT Test	
Human Robotic Systems					Integrate Software on Rover			Complete Design Drawings	Complete Rover Cannon Assembly			
Low Density Supersonic Decelerators		PDR		SDV 1 Test		SDV 2 Test			SDV 3 Test	CDR		
Deep Space Atomic Clock				SRR KDP-B								
Mission Capable Solar Sail			SRR	Tubes Test Sail Test			Mechanism Test				PDR	
Cryogenic Propellant Storage and Transfer						MCR						SRR
Laser Comm. Relay Demo.									MCR			
Robotic Satellite Servicing	TBD											

Key
- KDP
- Launch
- Testing
- Development
- Review

Space Technology in FY 2012

- In FY 2012, Space Technology includes:
  - Movement of a majority of the Exploration Technology Development and Demonstration activities from the former Exploration Systems Mission Directorate.
  - The Crosscutting technology development activities that were part of the President's FY 2011 request.
  - FY 2011 same-content funding level inclusive of ETD totals $478M
- NASA has prioritized ongoing activities and engagement of existing workforce in planning FY12 Space Technology activities.
  - As part of FY 2012 human spaceflight workforce transition strategy, engage an additional 276 FTE from human spaceflight within Space Technology.
  - Space Technology would be able to move forward with most or all of its "big 9" high-priority investments. ETD projects that transferred into Space Technology in FY 2012 could proceed on a pace required to achieve progress commensurate with HEO needs for future space exploration missions.
- There are no new Space Technology programs in FY 2012.



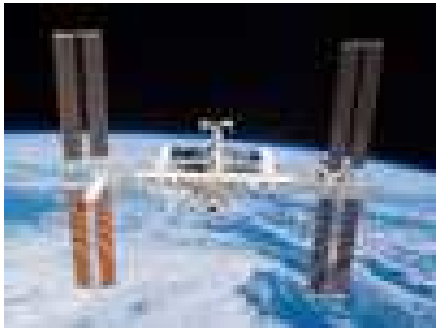
Exploration Technology Development (ETD)

- **Objective:** Develops and demonstrates critical technologies that provide the basis for a broad set of human exploration capabilities to enable future human missions beyond low Earth orbit based on the prioritized needs of NASA's human spaceflight enterprise.

- **FY 2012 Status**:
  - Five of the "Big 9" projects funded in FY 2011 with significant, high-visibility milestones in FY 2012
  - Satellite Servicing, Human-Robotic Systems (includes R2 and President's Robotics Initiative), Composite Cryotank, Hypersonic Inflatable Aerodynamic Decelerator (HIAD) and Cryogenic Propellant Storage and Transfer (CPST)
  - Transition and implementation plans complete for activities to transfer from ESMD to Space Technology on October 1, 2011

Space Technology ETD Projects in FY 2012

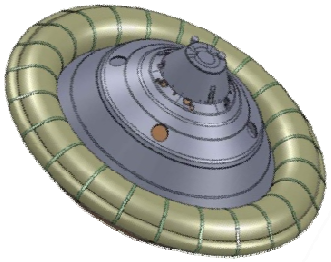
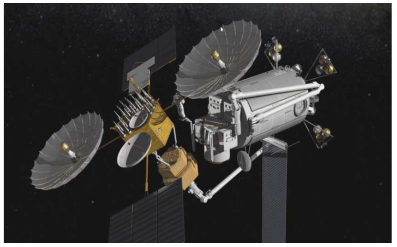
- **In-space Propulsion (GRC)**
- **Space Power Generation & Storage(GRC)**
- **Nuclear Systems(GRC)**
- **Lightweight Materials & Structures (LaRC)**
- **Human-Robotic Systems (JSC)**
- **Autonomous systems (ARC)**
- **Next Generation Life Support (JSC)**
- **Deployable Aeroshell Concepts & Flexible TPS (ARC)**
- **In-Situ Resource Utilization (ISRU) (KSC)**
- **Composite Cryogenic Propellant Tank (MSFC)**
- **Advanced Radiation Protection (LaRC)**
- **Hypersonic Inflatable Aerodynamic Decelerator (LaRC)**
- **Human Exploration Telerobotics (ARC)**
- **MSL Entry Descent and Landing Instrumentation (MEDLI) (LaRC)**
- **Autonomous Landing and Hazard Avoidance Technology (ALHAT) (JSC)**
- **Cryogenic Propellant Transfer and Storage (GRC)**
- **Solar Electric Propulsion (GRC)**
- **Satellite Servicing (GSFC)**



*Note that the funding level for these activities is dependent on the final appropriations level for Space Technology. As examples, the SEP TDM, and HIAD ISS Downmass TDM projects that had been proposed for an FY12 start will not be initiated until at least 2013.

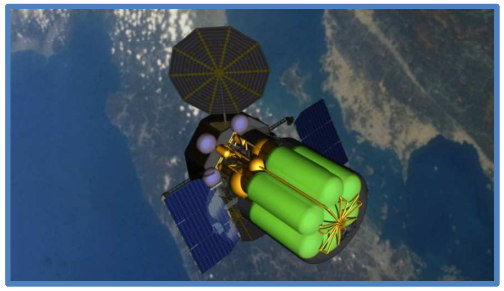
Crosscutting Space Technology Development (CSTD)

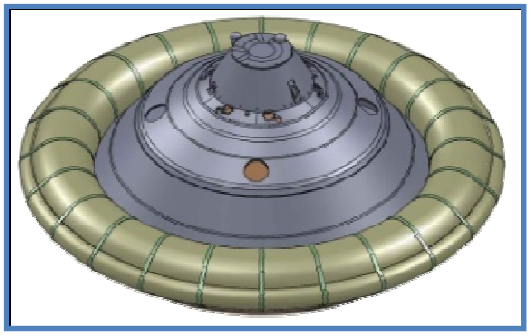
- **Objective:** Spans early-stage conceptual studies to flight demonstration, creating a steady pipeline of broadly-applicable technologies enabling NASA's future Science, Space Operations and Exploration missions. Open solicitation, competitive acquisition approach.
- **FY 2012 Status:**
  - Four of the “Big Nine” projects funded in FY 2011 with significant, high-visibility milestones in FY 2012
  - Low Density Supersonic Decelerator (LDSD), Laser Communications Relay Demonstration (LCRD), Deep Space Atomic Clock (DSAC) and Solar Sail Demonstration
  - Initial FY 2011 competitive awards made for Space Technology Graduate Fellowships (80), NIAC (30), Game Changing Development (2 and 5 new starts planning), Flight Opportunities (25 payloads and 7 platform providers), and Technology Demonstration Missions (3)

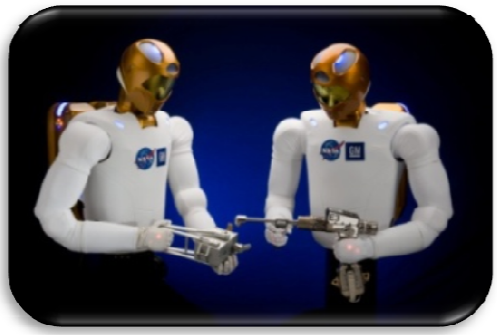
Space Technology CSTD Projects in FY 2012

- **Nanotechnology (GRC)**
- **Space Synthetic Biology (ARC)**
- **Low Density Supersonic Decelerators (JPL)**
- **ISS Demonstrations - MISSE-X (LaRC)**
- **Laser Communications Relay Demonstration (GSFC)**
- **Atomic Clock (JPL)**
- **Solar Sails (L'Garde Inc.)**





Space Technology: An Investment in our Future



NASA is encouraged by Congress' recognition that investing in NASA's Space Technology Program during tough economic times is in important investment in America's future.

The FY12 Appropriations level of $575M for NASA's Space Technology Program will allow the agency to continue developing made in America technologies and innovations that will enable NASA's future missions.

NASA's Space Technology Program acts as a catalyst for innovation throughout America's aerospace industries and will create new, high technology jobs and innovations in manufacturing that will guarantee American leadership in the new technology economy.

Backup Slides

Acronym List

- CDR – Critical Design Review
- Comm. – Communications
- Demo. – Demonstration
- DVT – Design Verification Test
- Fab. – Fabrication
- KDP – Key Decision Point
- LCAT – Large Core Arc Tunnel
- M – Meter
- MCR – Mission Control Review
- MRR – Mission Readiness Review
- MSFC – Marshall Space Flight Center
- NFAC – National Full-Scale Aerodynamics Complex
- PDR – Preliminary Design Review
- SRR – Systems Requirements Review
- TBD – To Be Determined
- Tech. – Technologies