National Aeronautics and Space Administration

Technology & Innovation Committee

NAC Advisory Council

Dr. Bill Ballhaus, Chair
April 25, 2013

Technology & Innovation Committee

"The scope of the Committee includes all NASA programs that could benefit from technology, research and innovation."

T&I Committee Meeting Participants April 18, 2013

- Dr. William Ballhaus, Chair
- Dr. Erik Antonsson, Northrop Grumman
- Dr. Randall Correll, Consultant
- Dr. Dava Newman, MIT
- Mr. David Neyland, Office of Naval Research
- Dr. Mary Ellen Weber, Stellar Strategies, LLC

T&I Committee Meeting Presentations

- Space Technology Mission Directorate (STMD) Update
  - Dr. Michael Gazarik, Associate Administrator, NASA STMD
- Solar Sail Project Overview
  - Mr. Nathan Barnes, President, L'Garde Inc.
- Ethics Training
  - Mr. J.A. Reistrup, Staff Attorney, NASA OGC
- Chief Technologist Update and Basic Research in Engineering Science Discussion
  - Dr. Mason Peck, NASA Chief Technologist
- NASA Robotics Technologies and National Robotics Initiative Update
  - Dr. Rob Ambrose, Principal Investigator, NASA JSC

National Aeronautics and
Space Administration

FY 14 Space Technology Mission Directorate Briefing

NASA Advisory Council

Presented by:
Dr. Michael Gazarik,
NASA Associate Administrator for
Space Technology Mission Directorate

April 18, 2013

www.nasa.gov/spacetech

Summary: Space Technology Critical to our Future

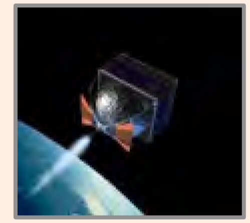
- NASA's investments in Space Technology provide the transformative capabilities to enable new missions, stimulate the economy, contribute to the nation's global competitiveness and inspire the nation's next generation of scientists, engineers and explorers.
- The next great leaps in space exploration require significant and sustained investments in Space Technology
- Space Technology is delivering what we promised: hundreds of new technologies and capabilities – on time and within budget. FY14 demos for Small Spacecraft, Green Propellant, Composite Cryotank and LDSD.
- Space Technology will continue to engage U.S. universities and academic institutions to develop and demonstrate technologies with approximately 350 activities in FY12 including: fellowships, direct competitive awards of grants and contracts, and partnerships with NASA centers and commercial contractors.
- This budget request supports an accelerated development of a Solar Electric Propulsion (SEP) demonstration effort within Technology Demonstration Missions. SEP is critical and enabling for NASA's robotic mission to an asteroid. SEP technologies are also needed for future commercial satellites and essential for deep space human exploration missions.

Space Technology Portfolio

Transformative & Crosscutting Technology Break throughs

Game Changing Development (ETD/CSTD)

Technology Demonstration Missions (ETD/CSTD)



Small Spacecraft Technologies (CSTD)

Pioneering Concepts/ Developing Innovation Community

Space Technology Research Grant (CSTD)

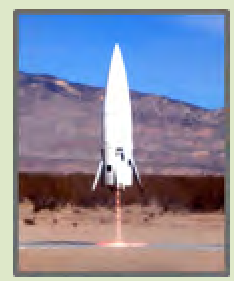
NASA Innovative Advanced Concepts (NIAC) (CSTD)

Center Innovation Fund (CSTD)

Creating Markets & Growing Innovation Economy

Centennial Challenges Prize (CSTD)

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



Flight Opportunities Program (CSTD)

Space Technology's FY 2014 Strategy

- **Align the Space Technology Program with the Administration's Research and Development Priorities**
  - Prioritize areas based on Strategic Space Technology Investment Plan (SSTIP) and the NRC report on the NASA Space Technology Roadmaps
- **Aligns and supports proposed asteroid retrieval and redirect mission**
  - Accelerate high-powered Solar Electric Propulsion Demonstration Mission
- **Ensure Progress on Transformative and Crosscutting Technology Projects**
  - Continue a steady cadence of new solicitations
  - Key Projects: CPST, LCRD, Green Propellant, Small Spacecraft Technologies
  - In FY 2014, will conduct 3 major CDRs, 6 Ground or Flight Demos, and 1 Small Spacecraft Demo
- **Maintain a Sustainable Pipeline of Revolutionary Concepts and Develop the Workforce for the Future US Aerospace Enterprise**
  - Fellowships, University Grants, Center Innovation and Concept Studies
  - Programs: STRG, CIF and NIAC with yearly solicitations (CSTD)
- **Create New Space Markets and Explore Alternate Technology Approaches**
  - Small businesses, prize authority, sub-orbital flights
  - Programs: SBIR/STTR, Centennial Challenges, Flight Opportunities (CSTD)
- **Enhance Tech Transfer and Commercial Partnerships Opportunities** (PD/SI)

Space Technology Mission Directorate

With successful formulation and implementation of Space Technology program, NASA officially separates Office of the Chief Technologist (OCT) into two organizations: OCT and Space Technology Mission Directorate (STMD).

Space Technology Mission Directorate

- Has direct management and budget authority of the Space Technology programs, which are performed by all 10 NASA Centers;
- Focuses on project execution and technology infusion into the Agency's exploration and science mission needs;
- Takes a customer driven approach, proving capabilities needed for future NASA missions and the national aerospace community; and
- Develops the Nation's innovation economy.

Office of the Chief Technologist

- Continues to serve as the Administrator's principal advisor and advocate on matters concerning Agency-wide technology policy and programs;
- Continues to lead NASA's technology transfer and commercialization efforts;
- Integrates, tracks, and coordinates all of NASA's technology investments; and
- Documents and communicates the societal impacts of the Agency's technology efforts.

Realignment will not affect the mission, content or budget authority of the Space Technology Programs.

NASA Technology Programs

- 2013 Update
- Basic Engineering Sciences

Dr. Mason A. Peck
NASA Chief Technologist

Science and Technology?

Technology *: A solution that arises from applying the disciplines of engineering science to synthesize a device, process, or subsystem to enable a specific capability.*

OMB Circular No. A-11 **Conduct of R&D**

6.1 Basic Research:	A study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products.
6.2 Applied Research:	Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.
6.3 Development:	Is directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

NASA's Basic Research in Engineering (in a Nutshell)

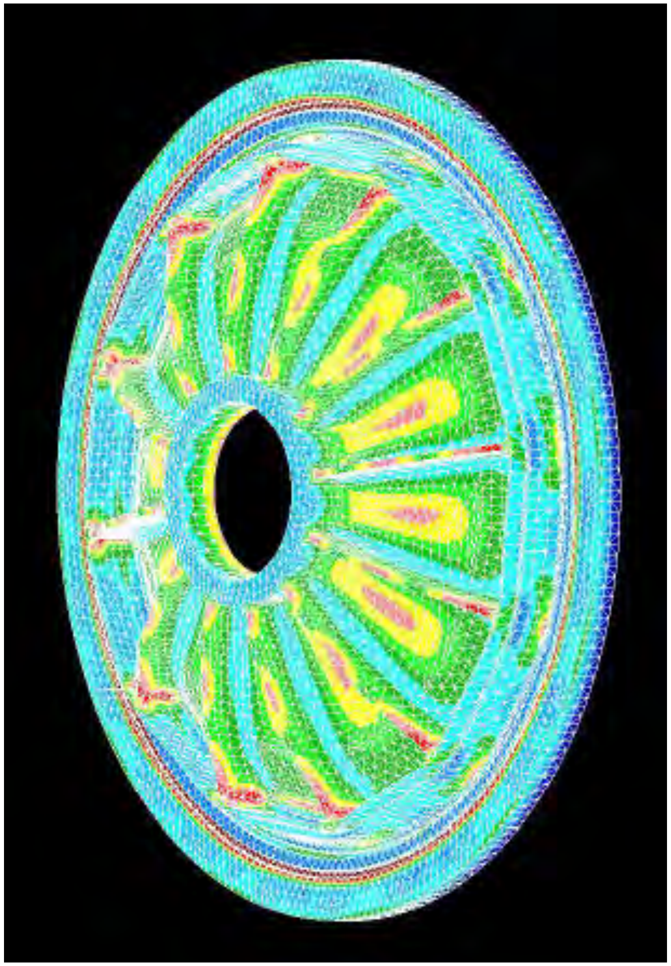
NASA performs and sponsors research in engineering science.

- Discoveries inform NASA's portfolio in space and aeronautics technology but are not technology development *per se*.
- This basic research is pre-TRL, not the applied technology development that is now part of the new Space Technology Mission Directorate.

NASA's investments in engineering research were once the basis of a successful national research enterprise in aerospace engineering sciences, both at NASA centers and in academia

- Near-term priorities in the past decade or more have resulted in a severely diminished investment.
- The NRC and others have flagged this as an area requiring more attention than has been given in recent years if the nation is to remain economically competitive in aerospace.

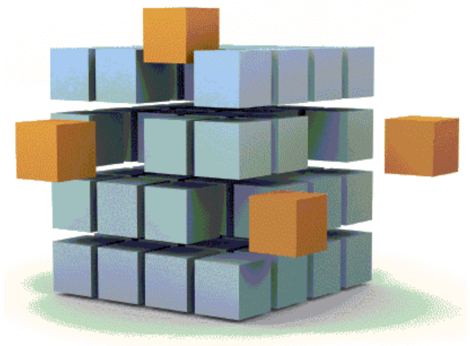
Now OCS, OCT, OCE working to bring together and prioritize engineering-science research, including internally directed and externally sponsored pre-TRL work.

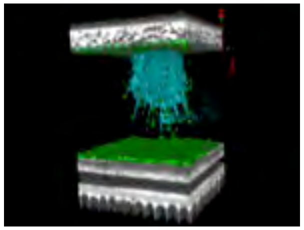


SpaceShipOne motor bulkhead analyzed in NEi NASTRAN

NASA's Engineering Science Investments

- **Foundational engineering science**
  - Combines basic engineering science with research in engineering methods
  - **BES**: Basic research in engineering science (BES) explores unknown or poorly understood scientific areas underlying engineering; provides the raw material for innovation, inventions, and discoveries, and leads to new and unexpected solutions to major technical barriers
  - **REM**: Research in engineering methods (REM) conceives the engineering tools, standards and techniques required for advances in engineering





NASA's Engineering Science Investments

- **Investments in engineering science have severely eroded over the last two decades and continue to diminish due to unrelenting budget pressures, resulting in**
  - Curtailment or elimination of funding for foundational engineering: eating our seed corn
  - Trying to solve new and more complex problems using our past engineering creativity
  - No organization being left with a critical mass of relevant activities and thus, the ability to adequately guide or coordinate Foundational Engineering Science investments across the Agency has been lost.
  - NASA's plans to go beyond LEO pose tremendous technical and cost challenges; revolutionary approaches are needed, which will come only thanks to basic research in these areas

NASA's Engineering Science Investments

- **The issue has also been highlighted by OSTP, OMB, and independent advisory groups:**
  - 2010 NRC Assessment Report:

    "the fundamental research community supported by NASA, both internally and externally, **has been severely impacted by these budget reductions and that the ability to achieve future NASA goals is in serious jeopardy**."

  - The NASA Advisory Council:

    "…that the Chief Technologist collaborate with the Chief Scientist and the Chief Engineer to establish formal guidance and to consolidate, and seek future funding for, space basic research in engineering science. The Council further suggests **that NASA begin by managing the Agency's space basic research portfolio as a pilot activity that is funded separately from the Space Technology Program**, similar to how the Office of Chief Technologist coordinates the Agency's technology portfolio."

Recommendations for the NASA Advisory Council

Recommendation:

The Council recommends that NASA establish a basic research (engineering science) program relevant to its long-term needs and goals.

- The Council suggests that the Chief Technologist collaborate with the Chief Scientist and the Chief Engineer to establish formal guidance and seek funding for basic research in engineering science. The Council further suggests that NASA begin by managing the agency's basic research portfolio as a pilot activity that is funded separately from the Space Technology Program, similar to how OCT coordinates the agency's technology portfolio.

Major Reasons for the Recommendation:

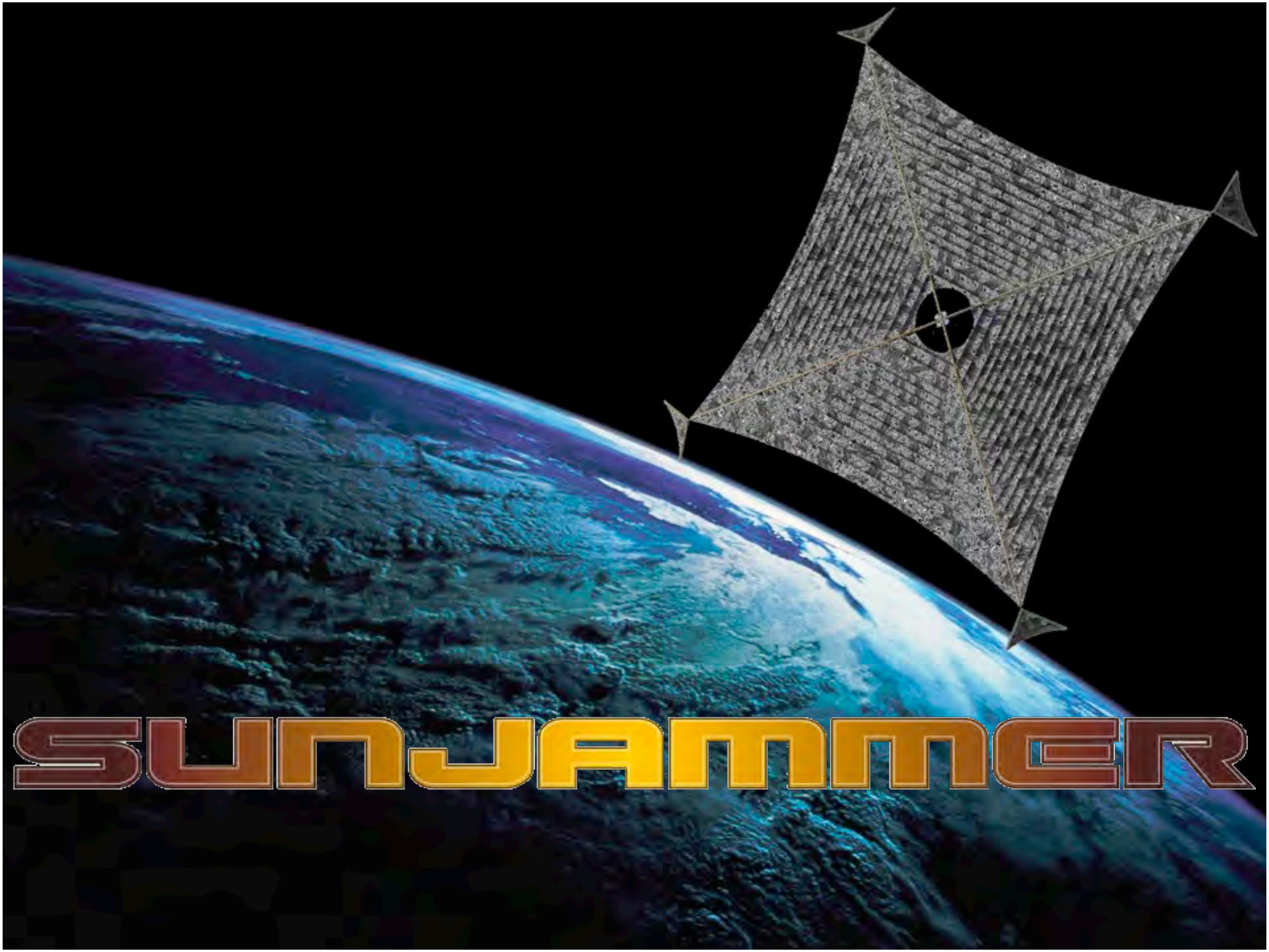
The Council recognizes that the distinction has been established between basic research and technology. NASA's technology programs now have advocacy and, in the form of the Strategic Space Technology Investment Plan (SSTIP), strategic guidance. However, basic research (or engineering science) that may lead to the development of technology and engineering tools are no longer explicitly part of NASA's technology enterprise.

Consequences of No Action on the Recommendation:

Erosion of NASA's research and technology capabilities

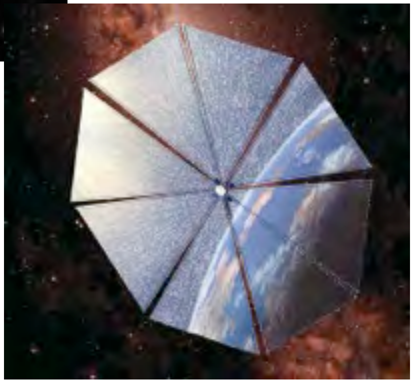
NASA's Engineering Science Investments

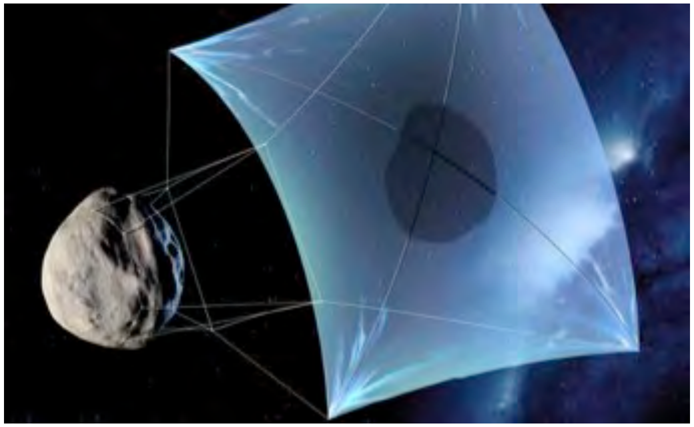
- **A Foundational Engineering Sciences program or office would**
  - Develop the strategy for a program to provide foundational engineering knowledge and tools across the agency;
  - Coordinate the Agency's entire basic engineering science portfolio with strong linkages to NASA's science, technology, and engineering activities
  - Sponsor a cohesive portfolio of basic engineering science activities at NASA centers, academia, and other organizations as appropriate.
  - Seek to infuse the new engineering tools, techniques and standards into standard NASA practice.
  - Seek to identify 'on-ramps' into technology development for the knowledge gained in the basic engineering science studies
  - Seek to leverage and coordinate NASA basic engineering science activities with relevant activities in other agencies, as well as the industrial and academic sectors.
  - Seek to ensure that SME knowledge and capabilities remain at the cutting edge, which has repeatedly proven necessary to solve NASA's practical problems


SUNJAMMER

What is a Solar Sail?

- Traveling through the heavens on starlight may sound like science fiction but that is what solar sailors aim to accomplish.
- Sunlight will create a pressure on a surface that is strikes.
- The solar pressure felt on earth is roughly 1,000,000 times weaker than the wind pressure from a gentle breeze (9mph).
- A solar sail is a spacecraft that harnesses the pressure provided by sunlight.
- In its simplest form, a solar sail spacecraft consists of a large area of reflective material, held in the “wind” of sunlight, joined to the spacecraft bus.



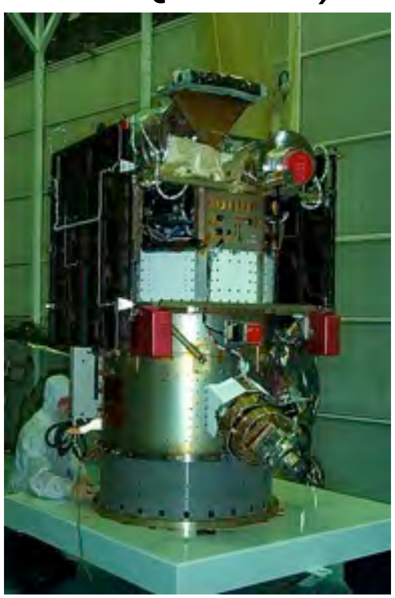


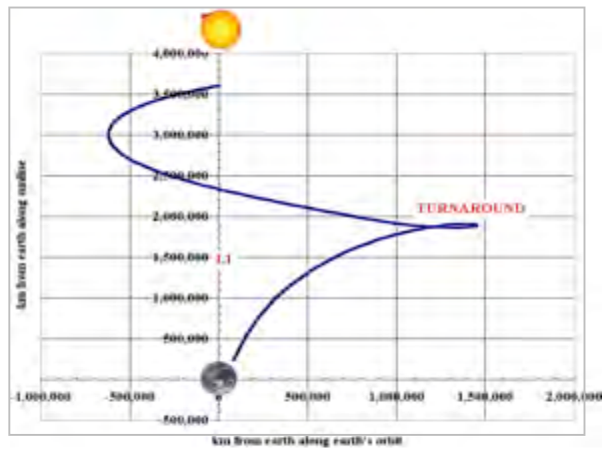
Mission Overview

Demonstration Objectives

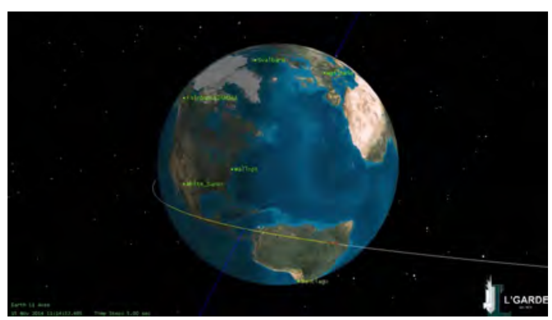
1. **Demonstrate segmented deployment of a solar sail**
2. **Demonstrate attitude control plus passive stability and trim using beam-tip vanes.**
3. **Execute a navigation sequence with mission-capable accuracy.**
4. **Fly to and Possibly Maintain Position at sub-L1 and/or Pole Sitter Positions**

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

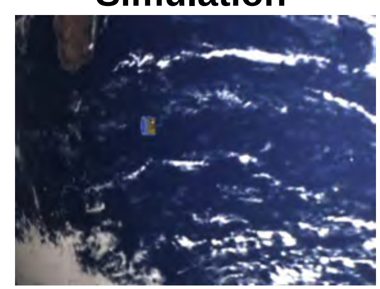




Notional Trajectory After Earth Escape Burn



Sail Deployment Simulation



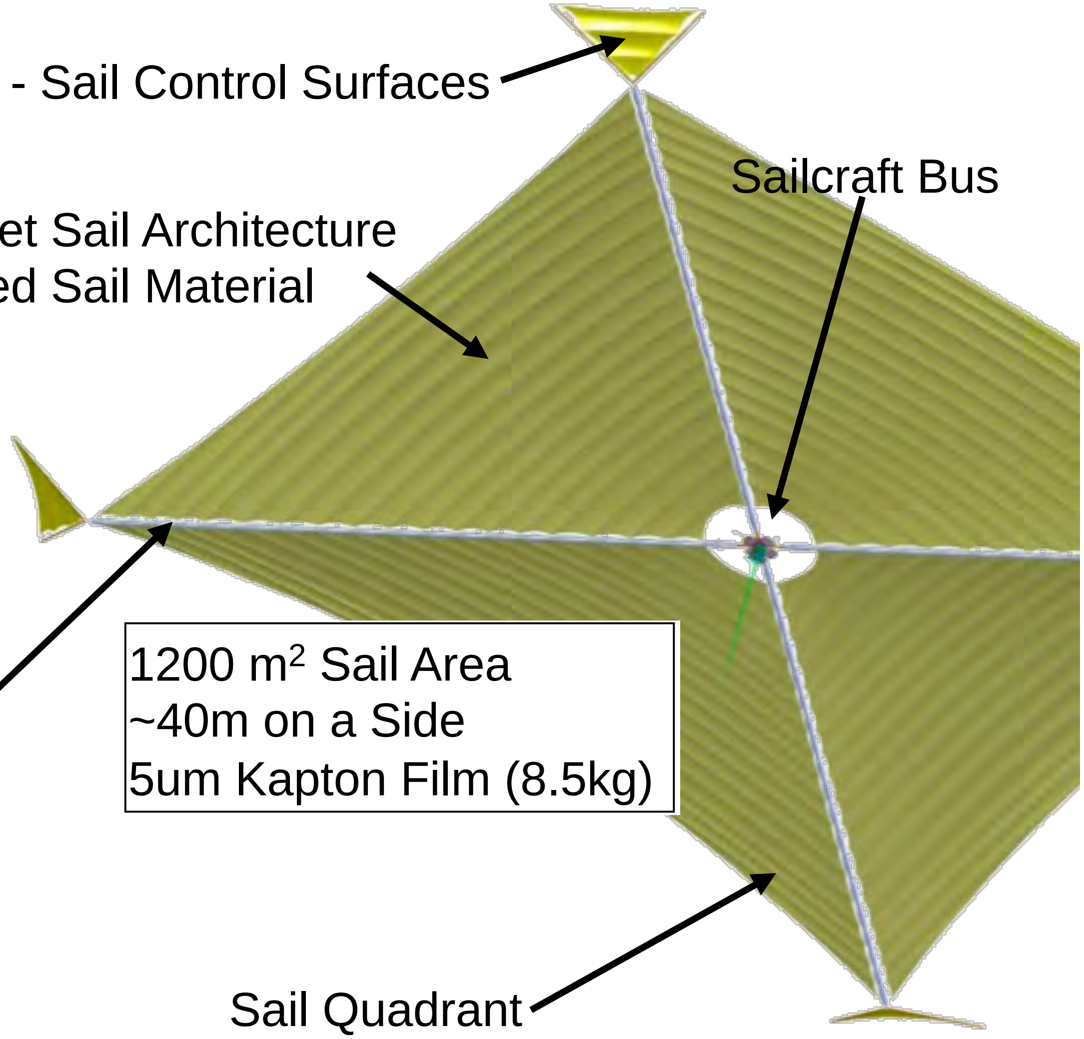
L' Garde Solar Sail 101

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

Vanes - Sail Control Surfaces

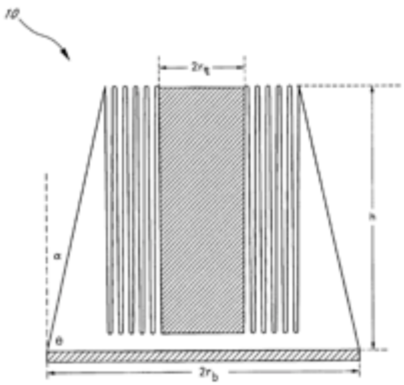
Striped-Net Sail Architecture
Unstressed Sail Material

Sailcraft Bus

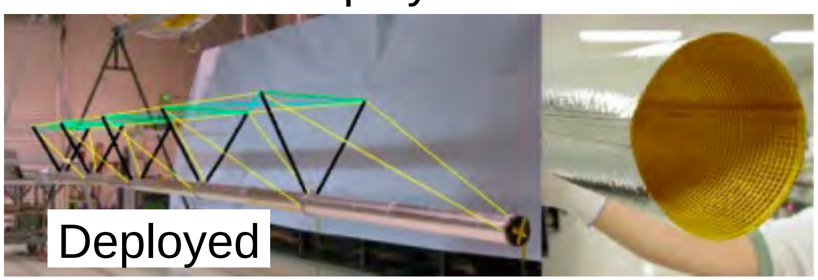


1200 m² Sail Area
~40m on a Side
5um Kapton Film (8.5kg)

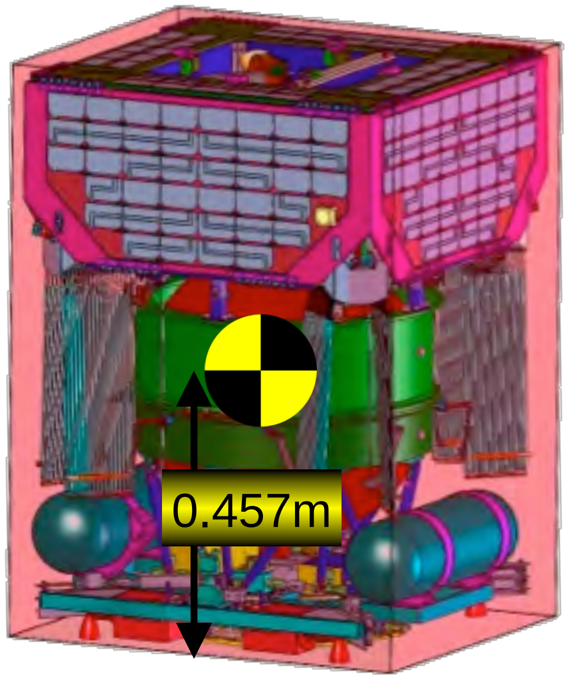
Sail Quadrant



L' Garde Patented Sub-Tg
Conical Deployable Booms



Secondary Payload Resume



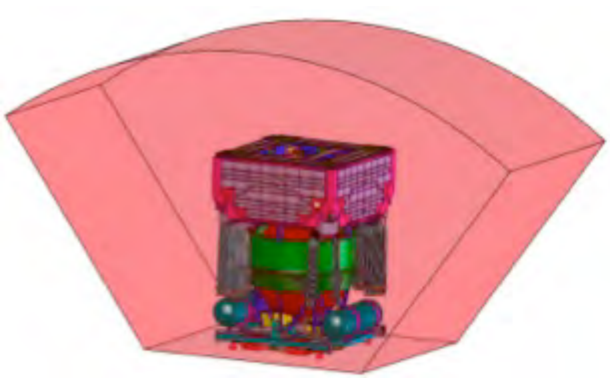
Dim.: 28in x 28in x 38in
Mass: 153kg (wet)
CG: 0.457m (18.7in)

Primary Spacecraft Safeguards:

- **Fully Welded Hydrazine System**
  (Tank to Pyro Iso Valve)
- **Full Bus Power Disconnect**
  (Two Switches on Lightband)
- **AFSPCMAN 91-710 Compliance**
- **0.3 m/s Separation Velocity**
  (Timer Delayed Power-Up)

Hazards:

- **Hydrazine System (57kg Fuel)**
  (May be Redundant with DSCOVR)
- **Pressurized Gas (31MPa (4500psi))**
  (2.7kg of Pressurant)
- **~15 Energetic (Pyro) Actuators**
  (Cable Cutters, Pin Pullers, Iso Valves)
- **Lithium Ion Secondary Batteries**
  (COTS Battery System 30Wh)
- **Lithium FeS2 Primary Batteries**
  (250Wh Energizer COTS)

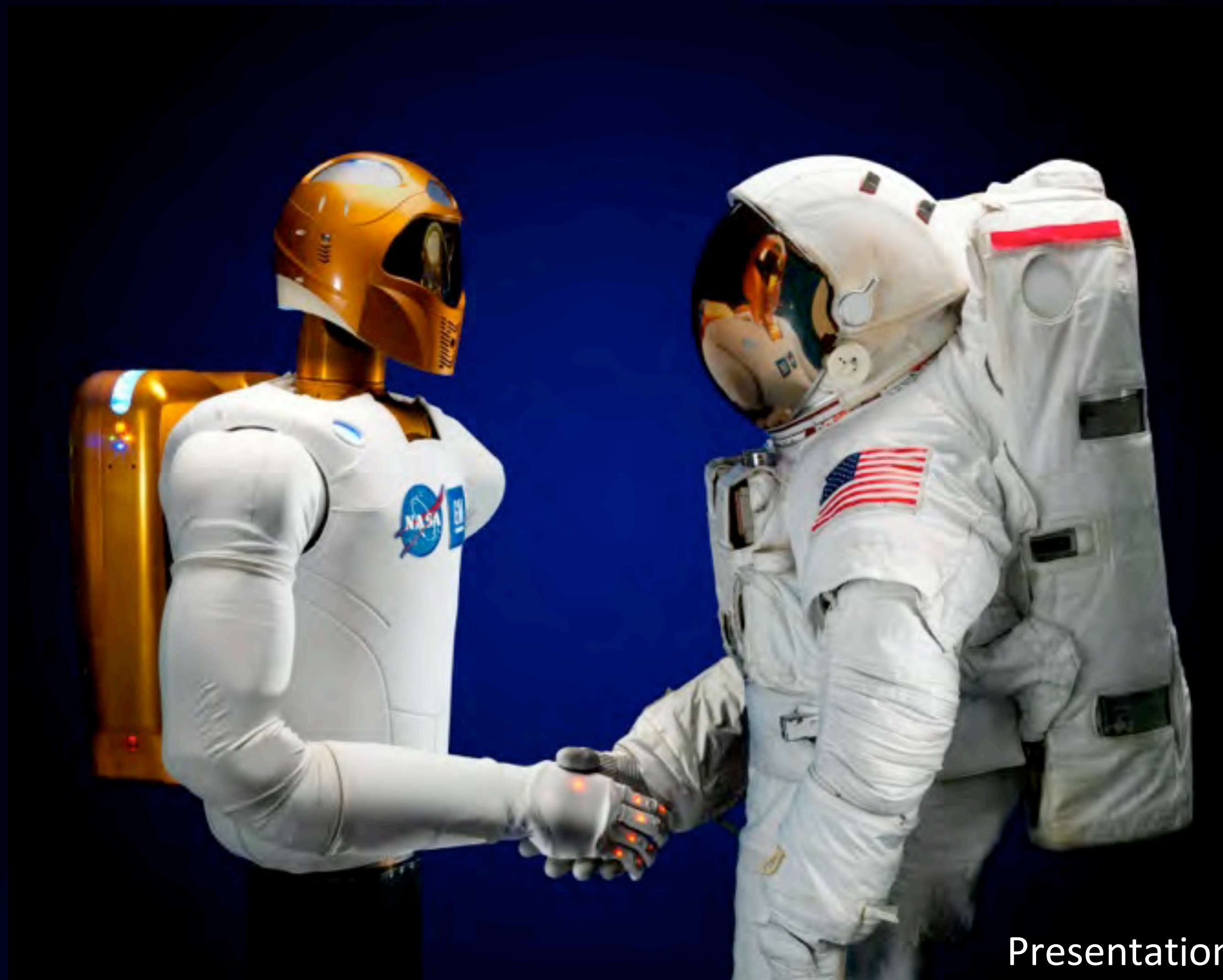


ESPA Grande on F9H

Interface:

- **15in Lightband**
  (Separation Signal)
- **Unconditioned Power**
  (For Trickle Charger)
- **No Command**
- **No Telemetry**

Robotics and Autonomous Systems



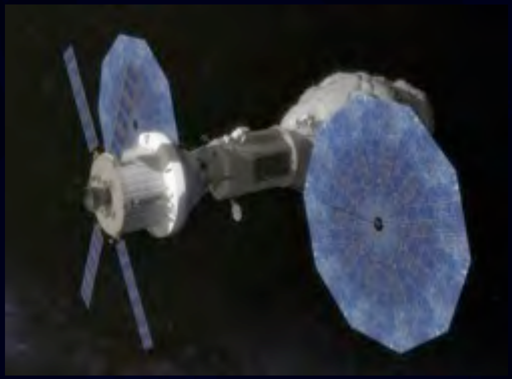
Presentation to the NAC

Dr. Rob Ambrose

April 2013

How Will NASA Use Robots?

<u>Capabilities like:</u>
Asteroid Capture
Access Extreme Terrain
Autonomous Control
Sample Processing



Precursors

Asteroid Sampling
Skylight Exploration
Search for Life on Mars

<u>Capabilities like:</u>
Spacecraft Grappling
Crew Mobility/Stabilization
Logistics / House Chores
Repair and Inspection

Assistants

Space Station
Asteroid Missions
Deep Space

<u>Capabilities like:</u>
Caretaker for Facility
Repair and Servicing
Contingency Ops
Long Term Science

Caretakers

Mars Missions
Asteroid Missions
Deep Space

Other Challenge: Extreme Terrain*

Lunar Precursor Missions

Non Geometric Hazards
Active Suspension
Novel Mechanisms

Asteroid Missions

Robotic Anchoring
Robot Grappling and Sampling
Astronaut Jet Packs

Mars Missions

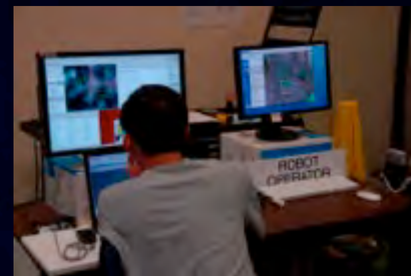
Visual Odometry
Rover Self Extraction

* Listed by NRC OCT Roadmap Review as one of the agency's Top 16 Challenges overall.

Other Challenges

Time Delayed Teleoperation

Task Level Commands
Monitor Progress
Predictive Displays




Robot Dexterity

Robot Mobile Navigation
Robot Dexterous Manipulation
Safety (Alone and Near People)


System Automation

Vehicle System Automation (FDIR)
Reduced Crew Time
Reduced Ground Time

Other Challenges

Performance

- *Reduced Mass & Volume*
  - *Advanced Batteries*
  - *New Materials*
- *Radiation Tolerance*
  - *FPGA Developments*
  - *Beam Testing*

Rapid Software Adaptation

- *System Modeling*
  - *End-to-End System Models*
  - *Vehicle has Onboard Sim*
  - *Model Validation*
- *Software Tools*
  - *Code Generation*
  - *Verification and Validation*
  - *Electronic Procedures*

National Robotics Initiative (NRI)

Pipeline Approach

For decades NASA has been a strong supporter of educational robotics outreach, and is backing robotics competitions that engage tens of thousands of children each year. We believe that one of these young people will invent and build the next big thing for the US.
http://robotics.nasa.gov/

NSF, NASA and other agencies are partnering on a joint solicitation to provide grants for research in new aspects of robotics technology. Each agency has specific interests in research topics within the NRI's co-robotics theme.
http://www/nsf.gov/pubs/2011/nsf11553/nsf11553.html

NASA is looking for partnerships with companies that have independent research programs and share an aligned vision for products and capabilities sought by NASA. One example is the Robonaut partnership with General Motors.
http://robonaut.jsc.nasa.gov/default.asp

Upcoming Robotics Activities

Robonaut Legs

Zero Gravity Climbing

Launches to ISS on Space X-3 Sept 2013

Smart Spheres

Integrates Samsung Nexus

Conduct ISS Interior Survey

X1 Exoskeleton

Wearable Robotics

Exercise and Dynamometer Tests on ISS

DARPA Robotics Challenge

Build a Hero

Mobile Manipulation for Space

T&I Committee Findings for the NASA Advisory Council

- **There is a significant lag time, between deciding to support a technology and flying it in a mission.**
- **Hence, the missions we're flying today have been enabled by technology investments made years ago.**
- **The NASA technology shelf has been depleted over the last decade due to a lack of investment.**
- **NASA has begun to correct this over the last three years with the formation of OCT and the STMD. This has been supported by senior government decision-makers in the Agency and within the Administration.**

T&I Committee Findings for the NASA Advisory Council

- **The Committee commends Dr. Gazarik, Dr. Peck and their teams for rebuilding a program that effectively fosters technology development and innovation, especially in a challenging budget environment.**
- **We need to sustain and grow STMD’s technology program [in accordance with the SSTIP] to continue to enable future NASA missions.**

BACK-UP CHARTS

NASA's Engineering Science Investments

- **Examples of potential investment areas**
  - Materials for NASA's Future (examples follow)
  - Engineering Biology in Exploration and Space Science
  - Advanced Communication Science
  - Underlying Physics of Advanced Energy in the Space Environment
  - Astrodynamics, Celestial Mechanics, and Navigation
  - Modeling and Simulation Methods unique to Exploration and Space Science
- **Focus on high priorities for NASA while leveraging OGA investments (e.g., materials science by DoE, DoD)**
- **Combination of external engagement (partnerships & sponsorship of academia, OGAs, industry) and internal engagement (directed work)**

Infusion Partners

L'GARDE Est. 1971

Demonstration is Not Enough – TDM Programs Need Infusion

Sunjammer is Being Planned, Designed, and Executed with an Eye Always on Infusion

Partner	Contribution	Stakeholder Expectations
NOAA	• Ground Stations Website EPO • Mag. Analysis	• NOAA expects to receive magnetometer data from the sensor suite. • NOAA has interest in continuing work after demo is complete.
Celestis	$1M (Project Reserve Funds)	• L'Garde will accommodate a total of 4kg Celestis memorial payload on board the carrier and sailcraft portions of the spacecraft. MOA is in place.
SSHI	20% of Sponsorship Revenues	• L'Garde will grant certain commercial rights to SSHI who will sell sponsorship of the mission to commercial entities. A portion of L'Garde revenues will be directed to risk reduction cost offsetting efforts.
Imperial College London	$500 k Magnetometer	• Imperial College London will develop and provide flight/science quality magnetometers for Sunjammer. This work is funded by UK Space Agency. Data will shared with Imperial College. Flight qualification will be provided as well.
University College London	$500 k Plasma Sensor	• University College London will develop and provide a flight/science quality plasma detector for Sunjammer. This work is funded by UK Space Agency. Data will shared with University College. Flight qualification will be provided.
NASA SMD	Ride Share!! & Interest	• Committee on a Decadal Strategy for Solar and Space Physics (Heliophysics) urged development of a program **very** similar to Sunjammer