Space Technology Mission Directorate Briefing

NAC T&I Committee

Presented by:
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Deputy Associate Administrator,
Space Technology Mission Directorate

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Why Invest in Space Technology?

- Enables a **new class of NASA missions** beyond low Earth Orbit.
- **Delivers innovative solutions** that dramatically improve technological capabilities for NASA and the Nation.
- Develops technologies and capabilities that make NASA’s missions **more affordable and more reliable**.
- Invests in the economy by **creating markets and spurring innovation** for traditional and emerging aerospace business.
- **Engages the brightest minds** from academia in solving NASA’s tough technological challenges.

**Value to NASA**

**Value to the Nation**

Addresses National Needs

A generation of studies and reports (40+ since 1980) document the need for regular investment in new, transformative space technologies.

**Who:**

- The NASA Workforce
- Academia
- Industry & Small Businesses
- Other Government Agencies
- The Broader Aerospace Enterprise
Challenges for Deep Space Exploration

- Communication
- Environment Control & Life Supporting Systems
- Navigation
- Power Generation & Storage
- Radiation Mitigation
- Manufacturing In Space & For Space
- Propulsion
- Logistics
- Entry, Descent & Landing
Guiding Principles of the Space Technology Programs

Space Technology Programs

- **Adheres to a Stakeholder Based Investment Strategy:** NASA Strategic Plan, NASA Space Technology Roadmaps / NRC Report and Strategic Space Technology Investment Plan

- **Invests in a Comprehensive Portfolio:** Covers low to high TRL, student fellowships, grants, prize competitions, prototype developments, and technology demonstrations

- **Advances Transformative and Crosscutting Technologies:** Enabling or broadly applicable technologies with direct infusion into future missions

- **Selects Using Merit Based Competition:** Research, innovation and technology maturation open to academia, industry, NASA centers and other government agencies

- **Executes with Structured Projects:** Clear start and end dates, defined budgets and schedules, established milestones, and project authority and accountability.

- **Infuses Rapidly or Fails Fast:** Rapid cadence of technology maturation and infusion, informed risk tolerance to infuse as quickly as possible

- **Positions NASA at the cutting edge of technology:** Results in new inventions, enables new capabilities and creates a pipeline of innovators for National needs
Space Technology Portfolio

- Game Changing Development (ETD/CSTD)
- Technology Demonstration Missions (ETD/CSTD)
- Small Spacecraft Technologies (CSTD)
- Space Technology Research Grant (CSTD)
- NASA Innovative Advanced Concepts (NIAC) (CSTD)
- Center Innovation Fund (CSTD)
- Centennial Challenges (CSTD)
- Small Business Innovation Research & Small Business Technology Transfer (SBIR/STTR)
- Flight Opportunities Program (CSTD)
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.

- **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.

- **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.

- **Composite Cryotank**
  - Demonstrating large composite, light weight fuel tanks that can reduce the mass and cost of the next generation SLS.
Space Technology
Major Events & Milestones

2012
- HIAD
- IRVE 3
- MEDLI
- Telerobotics

2013
- Telerobotics
- PhoneSat
- Edison Demo SmallSat

2014
- Solar Sail
- ISARA
- CPOD

2015
- Atomic Clock
- Green Propellant
- Supersonic Inflatable Aerodynamic Decelerator

2016
- SEP Demo Mission
- Supersonic Inflatable Aerodynamic Decelerator
- Laser Communications

2017
- Cryogenic Propellant

2018
- Future Planning

Future Planning
Asteroid Initiative: Asteroid Redirect Mission & Agency Grand Challenge

• NASA is planning a first-ever mission to capture and redirect an asteroid to earth-moon space. The effort aligns and leverages relevant portions of NASA’s Science, Space Technology, and Human Exploration capabilities.

• NASA will also lead a broad effort to find all asteroid threats to human populations and know what to about them: a “Grand Challenge”.

• The overall mission is composed of three independently compelling elements:
  – Detection and characterization of candidate near earth asteroids
  – Robotic rendezvous, capture and redirection of an asteroid to earth-moon space
  – Crewed mission to explore and sample the captured asteroid using the Space Launch System (SLS) and the Orion crew capsule

• Space Technology will focus on high-powered Solar Electric Propulsion (SEP)
  – SEP is the primary propulsion for the robotic asteroid rendezvous and redirection
  – The retrieval mission is not possible without SEP
  – SEP is also enabling for deep space human exploration
  – SEP component technologies serve commercial needs
  – In FY14 STMD will accelerate SEP development
Both sets of activities leverage existing NASA work while amplifying participatory engagement to accomplish their individual objectives and synergize for a greater collective purpose.
Early Stage programs will foster innovation regarding:
- Asteroid detection, characterization and mitigation for planetary defense and asteroid retrieval mission target selection
- Asteroid proximity operations and resource utilization techniques

Game Changing will complete high power SEP tech development:
- Advanced solar array systems
- Advanced magnetic shielded Hall thrusters
- Power processing units (PPUs)

Technology Demonstration Missions will develop, test and demonstrate the SEP system as part of the redirect mission:
- 30kW – 50 kW advanced solar arrays
- EP thrusters & Power Processing
- Xenon propellant tanks

Additional Asteroid Redirect funding in FY2014 will cover:
- Flight hardware solar array procurements
- EP thruster engineering development units
- Design of Xenon propellant tanks
High-Powered Solar Electric Propulsion

Solar Arrays

Thruster and Power Processing Unit

Propellant Feed System and Storage Tanks
High-powered SEP Enables Multiple Applications

- Deep Space Human Exploration
- Satellite Servicing
- Payload Delivery
- Commercial Space Applications
- ISS Utilization
- Orbital Debris Removal
- Solar Electric Propulsion
- Space Science Missions
- OGA Missions
## Advancing Solar Electric Propulsion Technology

### Key Missions and Technologies

<table>
<thead>
<tr>
<th>Mission</th>
<th>Year</th>
<th>Technology Details</th>
<th>System Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep Space 1</td>
<td>1998</td>
<td>Technology Demonstrator</td>
<td>2.5 kW power system, 2kW EP system</td>
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<tr>
<td>Dawn</td>
<td>2007</td>
<td>Deep-Space Science Mission</td>
<td>10 kW power system, 2.5kW EP system</td>
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<tr>
<td>AEHF Recovery</td>
<td>2010</td>
<td>Satellite orbit established with Hall Thrusters</td>
<td>~16kW-class power, ~4.5kW-class EP</td>
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<tr>
<td>Asteroid Redirect Mission</td>
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<td>Robotic Mission to Redirect Asteroid to Trans-Lunar Orbit</td>
<td>50kW-class power system, 10 kW-class EP</td>
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<tr>
<td>Far-term Exploration Missions circa 2030’s</td>
<td></td>
<td>Crewed mission beyond Earth space</td>
<td>350kW-class power system, 300kW-class EP</td>
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</tbody>
</table>
Exploration Technology Development (ETD) work resides in two Space Technology Programs:

• Game Changing Development (GCD)
• Technology Demonstration Missions (TDM)

ETD Focus:

• Cross-cutting, pioneering technology development
• Not systems level development or integration
• TRL 7 or below
• Infusion into HEOMD; SMD, OGAs and the Aerospace Enterprise

AES Program within HEOMD manages system-level integration work and prototype / design development for future exploration architecture elements.

The Human Research Program (HRP) undertakes technology development and basic research in related areas, e.g. radiation mitigation
Guidance for the Combined AES/STMD Portfolio

Human Architecture Team: Design Reference Missions

Strategic Knowledge Gaps: Guide robotic precursor activities

HEOMD Time-Phased Capability-Investment Priorities

Strategic Space Technology Investment Plan: used to balance Agency investments

STP / GCD ETD: Matures component technologies

STP / TDM ETD: Matures system-level technologies

AES Program: Prototype systems development & testing

Exploration Flight Systems, Including ISS based Risk-Reduction Demonstrations
# First Steps Towards Mars

<table>
<thead>
<tr>
<th>Mission Sequence</th>
<th>Asteroid Redirect Mission</th>
<th>Long Stay In Deep Space</th>
<th>Humans to Mars Orbit</th>
<th>Humans to Mars Surface</th>
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<tbody>
<tr>
<td>ISRU &amp; Surface Power</td>
<td>X</td>
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<tr>
<td>Surface Habitat</td>
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<tr>
<td>EDL, Human Lander</td>
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<td>Aero-capture</td>
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<td>Adv. Upper Stage w Cryo-Prop storage &amp; Transfer</td>
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<td>X</td>
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<tr>
<td>Deep Space Habitat (DSH)</td>
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<td>High Reliability ECLSS</td>
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<td>Autonomous Assembly</td>
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<td>SEP for Cargo / Logistics</td>
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<td>Deep Space GNC</td>
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<td>Crew Operations beyond LEO (Orion)</td>
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<td>Crew Return from Beyond LEO – HS Entry (Orion)</td>
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<td>Heavy Lift to Beyond LEO (SLS)</td>
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STMD/ETD Investments

HEOMD/ESD/AES Investments

HEOMD/ESD/AES + STMD/ETD Investments
Exploration Technology Development

Infusion

<table>
<thead>
<tr>
<th>ETD: GCD</th>
<th>SLS/MPCV</th>
<th>SEV</th>
<th>EVA</th>
<th>DSH</th>
<th>Mission Operations</th>
<th>Robotic Precursors</th>
<th>In-Space Propulsion</th>
<th>Asteroid Return</th>
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<tr>
<td>Electric Propulsion Thrusters</td>
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<td>Solar Array Systems (SAS)</td>
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<td>Advanced In-Space Power</td>
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<td>Human-Robotic Systems (HRS)</td>
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<td>Next-Generation Life Support (NGLS)</td>
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<td>In-Situ Resource Utilization (ISRU)</td>
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<td>Composite Cryogenic Propellant Tank (CCPT)</td>
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<td>Advanced Radiation Protection (ARP)</td>
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<td>Woven TPS (W-TPS)</td>
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<td>EVA Glove</td>
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| ETD: TDM | | | | | | | | |
| Cryogenic Propellant Storage and Transfer (CPST) | | | | | | | | |
| Solar Electric Propulsion (SEP) | | | | | | | | |
MARS CHALLENGES

Surface Power

Life Support

Human Ops Support and Robotics

Mars Resource Utilization and Ascent from Surface

Space Radiation

Entry, Descent, and Landing (EDL)

Communications and Navigation

Transit (Cargo and Humans)
MARS CHALLENGES

TECHNOLOGY SOLUTIONS

- **Surface Power**
  - Fission/solar power
  - Fuel cells/batteries

- **Life Support**
  - Next-Gen highly reliable and closed-loop life support.
  - Advanced EVA suits

- **Human Ops Support and Robotics**
  - Telerobotics
  - Robotics—task removal from astronauts
  - Autonomous systems

- **Mars Resource Utilization and Ascent from Surface**
  - Utilization of in-situ resources
  - Generation of human consumables
  - Creation of propellant

- **Space Radiation**
  - Radiation protection
  - Radiation modeling, characterization, and measurement

- **Entry, Descent, and Landing**
  - ECL Systems for Human Class Missions
  - Hypersonic entry systems
  - Supersonic descent systems

- **Communications and Navigation**
  - Optical communication
  - Advanced guidance systems

- **Transit (Cargo and Humans)**
  - Solar electric propulsion
  - Lightweight structures and materials
  - Cryogenic propellant storage and transfer
MARS CHALLENGES

STMD INVESTMENTS

**Surface Power**
- Advanced batteries
- Regenerative fuel cells
- Fission nuclear systems
- Solar arrays

**Life Support**
- CO₂ to O₂ recovery
- Water processing
- Air regulators

**Space Radiation**
- Advanced radiation protection
- Radiation modeling and forecasting
- Dosimeters

**Entry, Descent, and Landing**
- Hypersonic Inflatable Aerodynamic Decelerator/High-Energy Atmospheric Reentry Test
- Adaptive Deployable Entry Systems Project
- Low-Density Supersonic Decelerator
- MSL Entry, Descent, and Landing Instrument
- Heat Shield for Extreme Entry Environment Technology
- Supersonic Retro Propulsion
- Hypersonic Entry, Descent, and Landing
MARS CHALLENGES

STMD INVESTMENTS

Transit (Cargo and Humans)
- Composite Cryotank
- Cryogenic Propellant Storage and Transfer
- Lightweight Materials and Structures
- Solar Electric Propulsion

Mars Resource Utilization and Ascent from Surface
- $O_2$ from Mars atmosphere
- RESOLVE instruments
- Propellant production

Communications and Navigation
- Deep Space Atomic Clock
- Laser Communication Relay Demonstration
- Deep Space Optical Communications

Human Ops Support and Robotics
- Automated system ops
- Robotic, human safe, maintenance and ops
- Avionics/multicore processor