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.

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

Value to NASA      Value to the Nation

**Who:**
The NASA Workforce
Academia
Industry & Small Businesses
Other Government Agencies
The Broader Aerospace Enterprise
Guiding Principles of the Space Technology Program

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
Space Technology Portfolio

Transformative & Crosscutting Technology Breakthroughs

Creating New Markets & Growing the Innovation Economy

Pioneering Concepts & Developing the Innovation Community

Technology Readiness Levels - Technology Maturity

1. STRG - Space Technology Research Grants
2. NIAC - NASA Innovative Advanced Concepts
3. CIF - Center Innovation Fund
4. CC - Centennial Challenges
5. FO - Flight Opportunities
6. GCD - Game Changing Development
7. SST - Small Spacecraft Technology
8. TDM - Technology Demonstration Missions
Evaluating current STMD investments as recommended by the Strategic Space Technology Investment Plan (SSTIP, NRC, other Stakeholders)

- Initial evaluation is consistent with the SSTIP Core, Adjacent, and Complementary recommendations
- Approximately 72% of investments are in Core areas
- STMD has investments in all 14 Technology Areas
- Approximately 10% of investments are low TRL (1-3) consistent with the recommendation by the National Research Council (NRC) Final Report on Space Technology Roadmaps and Priorities

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

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<td>TA03</td>
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<td>TA14</td>
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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

Technology Demonstration Missions will develop, test and demonstrate the SEP system as part of the retrieval mission:
- Advanced Solar Array Systems (SAS)
- Advanced magnetic shielded Hall thrusters
- Power processing units (PPUs)
- 30kW – 50 kW advanced solar arrays
- Magnetically shielded Hall thrusters & Power Processing
- Xenon propellant tanks

Additional Asteroid Retrieval funding in FY2014 will cover:
- Flight hardware solar array procurements
- Hall thruster engineering development units
- Design of Xenon propellant tanks
High-powered SEP Enables Multiple Applications

Deep Space Human Exploration

Commercial Space Applications

Satellite Servicing

Payload Delivery

Solar Electric Propulsion

ISS Utilization

Orbital Debris Removal

Space Science Missions

OGA Missions
• **Planetary Science (currently funded)**
  - **Woven TPS**: suitable for Venus, Giant Planets entries; Earth Sample Return capsules
  - **Conformal TPS**: suitable for MSL-2020 backshell
  - **ADEPT**: deployable aeroshell for Venus entry with lower g-loads
  - **LDSD**: suitable for high Mach number parachute for Mars entry
  - **Deep Space Optical Comm**: 1-2 orders of magnitude higher data rate; thus enabling full data return from planetary surface mapping missions
  - **Deep Space Atomic Clock**: low mass, low power, affordable solution for Discovery and New Frontiers class planetary missions
STMD Support for SMD – Planetary

- **Planetary Science** *(funded or under consideration)*
  - **Multi-core processor**: 100x increase for on-board data processing and autonomy (BAA)
  - **High performance battery**: for planetary surface operations

- **Kilowatt Power**: Small fission surface reactor for planetary missions
- **Amorphous Metals**: for lubrication free gears on MSL-2020
- **Variable Heat Rejection**: for interplanetary spacecraft and lander thermal management
• **Planetary Science (currently funded)**
  
  – *Spacecraft/Rover Hybrids for the Exploration of Small Solar System Bodies (NIAC):* develop a mission architecture that allows a systematic and affordable in situ exploration of small bodies, using hopping, rolling, and ballistic flight
  
  – *Robotic Asteroid Prospector (RAP) Staged from L-1: Start of the Deep Space Economy (NIAC):* to assess feasibility of asteroid mining in terms of means, methods, and systems
  
  – *Technologies Enabling Exploration of Skylights, Lava Tubes and Caves; Cavehopping Exploration of Planetary Skylights and Tunnels (NIAC)*
  
  – *Modern Estimation Techniques and Optimal Maneuver Targeting for Autonomous Optical Navigation around Small Bodies (STRG):* advance algorithms for estimation techniques, maneuver feedback control, and fast onboard processing
• Planetary Science (currently funded)
  – Rapid Design & Navigation Tools to Enable Small-Body Missions (STRG): broaden the number and scope of available missions by making the most of advances in astrodynamics and in computer software and hardware.

  – Proximity Navigation Near & Mapping of Asteroids (STRG): using sensor algorithms for range sensors, with synchronized Inertial Momentum Unit (IMU) and HD video camera; provides insight into asteroid geometry

  – Stability Analysis of Spacecraft Motion in the Vicinity of Asteroids (STRG): modeling research, accounting for movement perturbations, gravity differences; solar pressure changes; s/c and asteroid rotations; stability and other factors
• Planetary Science (currently funded)
  – **Ghost Imaging of Space Objects (NIAC):** optical imaging using correlations between optical fields in two channels. One of the channels contains the object, however lacks any spatial resolution. In the other, empty channel, a space-resolving optical detection is allowed

  – **Deep Mapping of Small Solar System Bodies with Galactic Cosmic Ray Secondary Particle Showers (NIAC):** mapping interior structures using galactic cosmic ray (GCR) secondary particle shower products, such as pions and muons

  – **Vision Based Object Detection and Navigation for Spacecraft (STRG):** using small low cost IR and vision sensors, to operate over a wide distance range from a few meters to several km; COTS sensors combined with a robust algorithm
NICER/SEXTANT – explorer class ISS demo (2017)
Joint Science and Technology Demo Mission on ISS

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

- **SEXTANT**: X-ray navigation (XNAV) demonstration
  Station Experiment for X-ray Timing and Navigation Technology (SEXTANT) mission, would detect X-ray photons from known steady pulsars to demonstrate spacecraft navigation using these naturally-occurring cosmic beacons

**STMD-SMD collaboration**
- NICER by SMD / SEXTANT by STMD
- Shared hardware, ConOps, Data archive, Ops Center; ISS Platform, and target pulsars
Coronagraph for Direct Imaging of Exoplanets
Potential Joint SMD & STMD Initiative:
Develop a coronagraph for AFTA-WFIRST mission

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

- **Goal:** Develop an advanced high contrast coronagraph + occulter for AFTA-WFIRST
  - Observe fainter planets using advanced direct imaging (10x Earth mass or better)
  - High contrast, high sensitivity, & high optical throughput
  - Small inner working angle (close to star), large discovery space
  - AFTA-WFIRST concept: using a donated 2.4-m telescope;
    - First opportunity for an in-space high contrast coronagraph.
    - Pathfinder mission for future telescopes to characterize Earth-like planets.
• **Heliophysics**
  – *Space Weather prediction*
    • Ongoing GCD/AES collaboration for HEO infusion, but benefiting heliophysics as well
  – **Solar Sail**
    • To keep spacecraft at Sun / Earth Lagrangian (L1) point for space weather monitoring (ongoing)

• **Earth Sciences**
  – *Deployable space telescope on a 6U cube-sat* (TBC)
  – *Low cost propulsion technologies for small spacecraft*
    • ongoing GCD NRA Appendix under evaluation
How to get involved with STMD?

• STMD Programs are *periodically releasing solicitations*

• These are **open to all** (NASA, OGAs, Academia, Industry)

• Information on STMD’s future solicitations, in the form of Appendices added to the **umbrella solicitation REDDI-2014** can be found on NSPIRES:
  - Space Technology Research, Development, Demonstration, and Infusion 2014 (SpaceTech-REDDI-2014)
  - Solicitation: NNH14ZOA001N
  - [http://nspires.nasaprs.com/](http://nspires.nasaprs.com/)
STDM’s typical solicitation cadence

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Summary

- STMD’s technologies span across the **TRL spectrum**

- Our development **partners** include NASA, OGAs, academia, industry and the broad aerospace sector

- STMD developed technologies - both competed and directed - tend to be **crosscutting and overlap with other MD needs**

- We are looking for **feedback from you - the SBAG community** - to identify your future technology needs