

## NASA Space Technology Roadmaps and Priorities Revisited

Historically, the United States has been a world leader in aerospace endeavors in both the government and commercial sectors. The continuous development of advanced technologies is a key factor in maintaining aerospace leadership. NASA uses a roadmapping process to identify technology needs and improve the management of its technology development portfolio. In 2010 NASA created a set of 14 draft technology roadmaps to guide the development of space technologies. These roadmaps were the subject of a comprehensive external review by the National Academies of Sciences, Engineering, and Medicine, documented in the 2012 report *NASA Space Technology Roadmaps and Priorities—Restoring NASA’s Technological Edge and Paving the Way for a New Era in Space*. In 2015 NASA issued a revised set of roadmaps that were updated to assess the relevance of the technologies by showing their linkage to a set of mission classes and design reference missions from the Human Exploration and Operations Mission Directorate and Science Mission Directorate. In this report, the Academies assess the priority of space technologies in the 2015 roadmaps that were not included in the 2012 roadmaps report and recommends a methodology for conducting independent reviews of future NASA technology roadmaps, which are expected to occur every four years.

### NEW IMPORTANT TECHNOLOGIES

This report ranks five technologies not evaluated in the 2012 roadmaps report as high priority.

- **Grappling:** Enables the physical capture of small asteroids and asteroid-sourced boulders, the attachment of said objects to robotic spacecraft, and the capture of free-flying spacecraft. Grappling technology would have many valuable commercial applications.
- **Remote Interaction:** Provides control and communication methods that enable humans to remotely operate otherwise autonomous systems and robots and supports the design of game-changing science and exploration missions, such as new robotic missions at remote locations, and simultaneous robotic missions with reduced human oversight.
- **Terrain-Relative Sensing and Characterization:** Produces high-rate, high-accuracy measurements for algorithms that enable safe precision landing near areas of high scientific interest or predeployed assets.

### NASA'S TECHNOLOGY ROADMAPS

- TA 1. Launch Propulsion Systems
- TA 2. In-Space Propulsion Technologies
- TA 3. Space Power and Energy Storage
- TA 4. Robotics and Autonomous Systems
- TA 5. Communication, Navigation and Orbital Debris Tracking and Characterization Systems
- TA 6. Human Health, Life Support, and Habitation Systems
- TA 7. Human Exploration Destination Systems
- TA 8. Science Instruments, Observatories, and Sensor Systems
- TA 9. Entry, Descent, and Landing Systems
- TA 10. Nanotechnology
- TA 11. Modeling, Simulation, and Information Technology and Processing
- TA 12. Materials, Structures, Mechanical Systems, and Manufacturing
- TA 13. Ground and Launch Systems
- TA 14. Thermal Management Systems
- TA 15. Aeronautics

- Contain new technologies reviewed in this report
- Contain no new technologies
- New to 2015 roadmaps, not reviewed in this report

- **Autonomous Targeting:** Improves the ability of vehicles to assess and characterize the terrain they are facing for landing and exploration, thereby enabling the next step of autonomous targeting, which could be critical when interplanetary distances make remote guidance difficult or impossible.
- **Thermal Protection System Modeling and Simulation:** Reduces uncertainties in the modeling of strong radiative shocks, which are a major limitation in the design of effective heat shields for high-speed entry into the atmospheres of Earth, Mars, and other bodies. Reducing these uncertainties would enable the use of heat shields with lower weight, thereby reducing spacecraft weight and/or increasing allowable payload weight.

## HIGHEST PRIORITY TECHNOLOGIES

The 2012 report identifies 31 individual highest-priority technologies; the new report includes three of the five new technologies in this group: Grappling, Terrain-Relative Sensing and Characterization, and Autonomous Targeting. The report defines the highest-priority technologies in terms of their ability to support three technology objectives:

- **Human Space Exploration:** Extending and sustaining human activities beyond low Earth orbit.
- **In-Situ Planetary Science:** Exploring the evolution of

the solar system and the potential for life elsewhere through both robotic and human missions.

- **Remote Measurements:** Expanding our understanding of Earth and the universe in which we live via robotic missions.

## FUTURE INDEPENDENT REVIEWS

This report additionally recommends a methodology for conducting independent reviews of future updates to NASA's space technology roadmaps.

**RECOMMENDATION:** Independent reviews of the roadmaps should be conducted whenever there is a significant change to the roadmaps. NASA's technology roadmap revision cycle is expected to be performed every four years, but significant changes in NASA direction may necessitate a review more often. The reviews should be one of two forms, either a comprehensive review of the complete set of roadmaps, such as the one performed in 2012, or a focused review, such as the one in this 2016 report. Focused reviews can be conducted using more limited resources, as they only address a subset of the total technology portfolio. In making recommendations regarding the review methodology, each future independent review should focus on the methodology that should be used for the subsequent review, rather than a long-range plan covering multiple reviews.

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