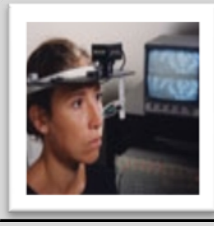
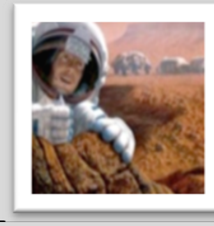
Space Technology Grand Challenges

The Space Technology Grand Challenges are an open call for cutting-edge technological solutions that solve important space-related problems, radically improve existing capabilities or deliver new space capabilities altogether. The challenges are centered on three key themes: (1) Expand human presence in space, (2) Manage in-space resources, and (3) Enable transformational space exploration and scientific discovery. These challenges are designed to initiate thought and discussion among our nation's innovators about future NASA missions and related national needs. The challenges will be updated to serve as a reflection and long-term measure of our nation's space technology needs.

Space Technology Grand Challenges			
Expand Human Presence in Space			
			
Economical Space Access Provide economical, reliable and safe access to space, opening the door for robust and frequent space research, exploration and commercialization.	**Space Health and Medicine** Eliminate or mitigate the negative effects of the space environments on human physical and behavioral health, optimize human performance in space and expand the scope of space based medical care to match terrestrial care.	**Telepresence in Space** Create seamless user-friendly virtual telepresence environments allowing people to have real-time, remote interactive participation in space research and exploration.	**Space Colonization** Create self-sustaining and reliable human environments and habitats that enable the permanent colonization of space and other planetary surfaces.
Problem: Today it costs about $10,000 to get a single pound of mass into low earth orbit. A significant part of this cost is related to the design and production of the launch system. Nearly 40% of the total mission cost is related to ground and launch processing. The full-lifecycle cost must be lowered by an order of magnitude to enable frequent human and robotic operations in space.	Problem: Space is an extreme environment that is not conducive to human life. Today's technology can only partially mitigate the effects on the physical and psychological well-being of people. In order to live and effectively work in space for an extended period of time, people require technologies that enable survival in extreme environments; countermeasures that mitigate the negative effects of space; accommodations that optimize human performance; comprehensive space-based physiological and physical health management and prompt and comprehensive medical care in a limited infrastructure.	Problem: Today, access to space is limited to robotic spacecraft and to select highly-trained individual participants who perform experiments on behalf of others. Scientists develop experiment plans, wait for an astronaut or a robot to conduct the experiment for them, and download the results for analysis. This approach decouples the experiment from the principal investigator, requires considerable pre-planning and coordination and does not allow for the flexible learning and experimentation that can take place in a lab. Moreover, this approach limits possible participants and the public from fully participating in the exploration of space.	Problem: Currently, the infrastructure and integrated technologies needed to enable permanent, self-sufficient human settlements away from Earth do not exist. Effective close-loop systems do not exist to replenish consumable resources. This makes long-term stays cost-prohibitive and poses significant risk to personnel if resupply missions do not arrive on time.

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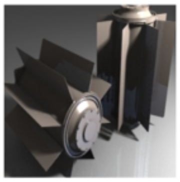
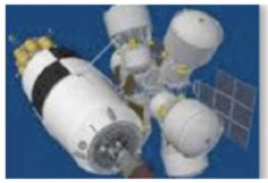
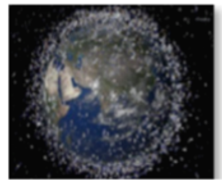
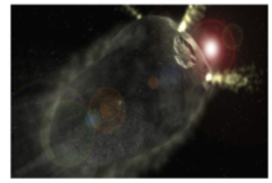
Manage In-Space Resources

			
<u>Affordable Abundant Power</u> Provide abundant, reliable and affordable energy generation, storage and distribution for space exploration and scientific discovery.	**<u>Space Way Station</u>** Develop pre-stationed and in-situ resource capabilities, along with in-space manufacturing, storage and repair to replenish the resources for sustaining life and mobility in space.	**<u>Space Debris Hazard Mitigation</u>** Significantly reduce the threat to spacecraft from natural and human-made space debris.	**<u>Near-Earth Object Detection and Mitigation</u>** Develop capabilities to detect and mitigate the risk of space objects that pose a catastrophic threat to Earth.
<u>Problem</u>: Mass and lifetime considerations of today's space power systems limit our missions. Current spacecraft power systems degrade over time, thereby reducing the amount of power available for use as the mission progresses. Efficient use of space-based resources is critical for NASA's future missions of science and exploration.	<u>Problem</u>: Frequent and long-duration space travel requires substantial amounts of consumables, which can be costly to launch. Current capabilities are insufficient to extract, refine, form stock, and transport in-situ materials for in-space manufacturing, servicing, fueling and repair. In-space system repair and maintenance is cost-prohibitive and difficult, consequently, many spacecraft are de-orbited at end-of life.	<u>Problem</u>: Given the prevalence of Micrometeoroid and Orbital Debris (MMOD) in low earth orbit, there is a possibility of MMOD collision or interference with a range of national and international operating assets as well as a serious threat to in-space personnel. Mitigation is difficult and requires solutions that are practical, yet technically and economically feasible.	<u>Problem</u>: Near earth objects are comets or asteroids that pass within 45 million kilometers of the Earth's orbit. Some near earth objects are potentially large enough to be hazardous to the Earth in the event of a direct collision. Although impact with large objects is rare, the history of Earth indicates that such events do occur. A better understanding of the likelihood and consequence of these remote events are needed as are preparations for the possibility of having to divert a comet or asteroid on an impact trajectory with Earth.

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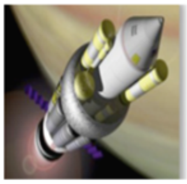
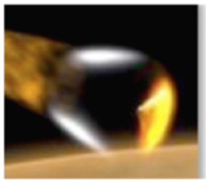
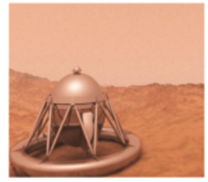
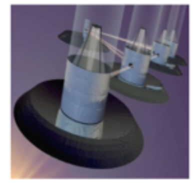
Enable Transformational Space Exploration and Scientific Discovery

				
Efficient In-Space Transportation Develop systems that provide rapid, efficient and affordable transportation to, from and around space destinations.	**High-Mass Planetary Surface Access** Develop entry, descent and landing systems with the ability to deliver large-mass, human and robotic systems, to planetary surfaces.	**All Access Mobility** Create mobility systems that allow humans and robots to travel and explore on, over or under any destination surface.	**Surviving Extreme Space Environments** Enable robotic operations and survival, to conduct science research and exploration in the most extreme environments of our solar system.	**New Tools of Discovery** Develop novel technologies to investigate the origin, phenomena, structures and processes of all elements of the solar system and of the universe.
Problem: Once in space, the ability to travel to a particular destination is a function of the laws of orbital mechanics, vehicle mass, and propulsion system efficiency. Human and robotic exploration requires transportation throughout the solar system and is limited by the performance of today's propulsion systems.	Problem: Entry, descent and landing is a challenging operation. A space system must be robust enough to accommodate a wide range of hazards associated with uncertain position and velocity knowledge, aerodynamic loading, atmospheric conditions, heating, particulates, and terrain characteristics to safely arrive at a desired surface location.	Problem: Exploration of comets, asteroids, moons and planetary bodies is limited by mobility on those bodies. Current robotic and human systems cannot safely traverse a number of prevalent surface terrains. Current systems travel slowly, requiring detailed oversight and planning activities. Consequently, these systems are often limited to exploring areas close to their original landing site.	Problem: Space travel can present extreme environments that affect machine operations and survival. Like humans, machines are impacted by gravity, propulsive forces, radiation, gases, toxins, chemically caustic environments, static discharge, dust, extreme temperatures, frequent temperature variations and more. To accomplish the goal of exploring a wide range of targets across our solar system requires the ability to survive extreme environments.	Problem Even with insatiable curiosity and strong motivation, we require specialized tools to learn about the Earth, solar system or universe. In part, our learning has been limited by the lack of sophistication of our technology to observe, probe, collect, distribute and analyze information about the geology, weather, climate, environment, and natural and man-made phenomena affecting the Earth and other elements in the universe.

The Broad Challenge of Space

The challenges of flying in space are such that a truly radical improvement in nearly any system used to design, build, launch, or operate a spacecraft has the potential to be transformative. In our search for technologies that will radically improve our existing capabilities or deliver altogether new space capabilities, it is likely that any great leap in capability will be the result of several, integrated advances. The Space Technology development portfolio extends across all systems critical to space missions and is not limited to the specific Space Technology Grand Challenges listed above. To meet the broad challenge of maintaining a robust and vibrant space program, investments will be considered in any space technology that has the potential to be transformative.

The future demands active curiosity, open minds, and a determination to resolve challenges as they present themselves.