A Technology-Enabled Strategy for Exploration

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NASA Chief Technologist
June 14, 2010

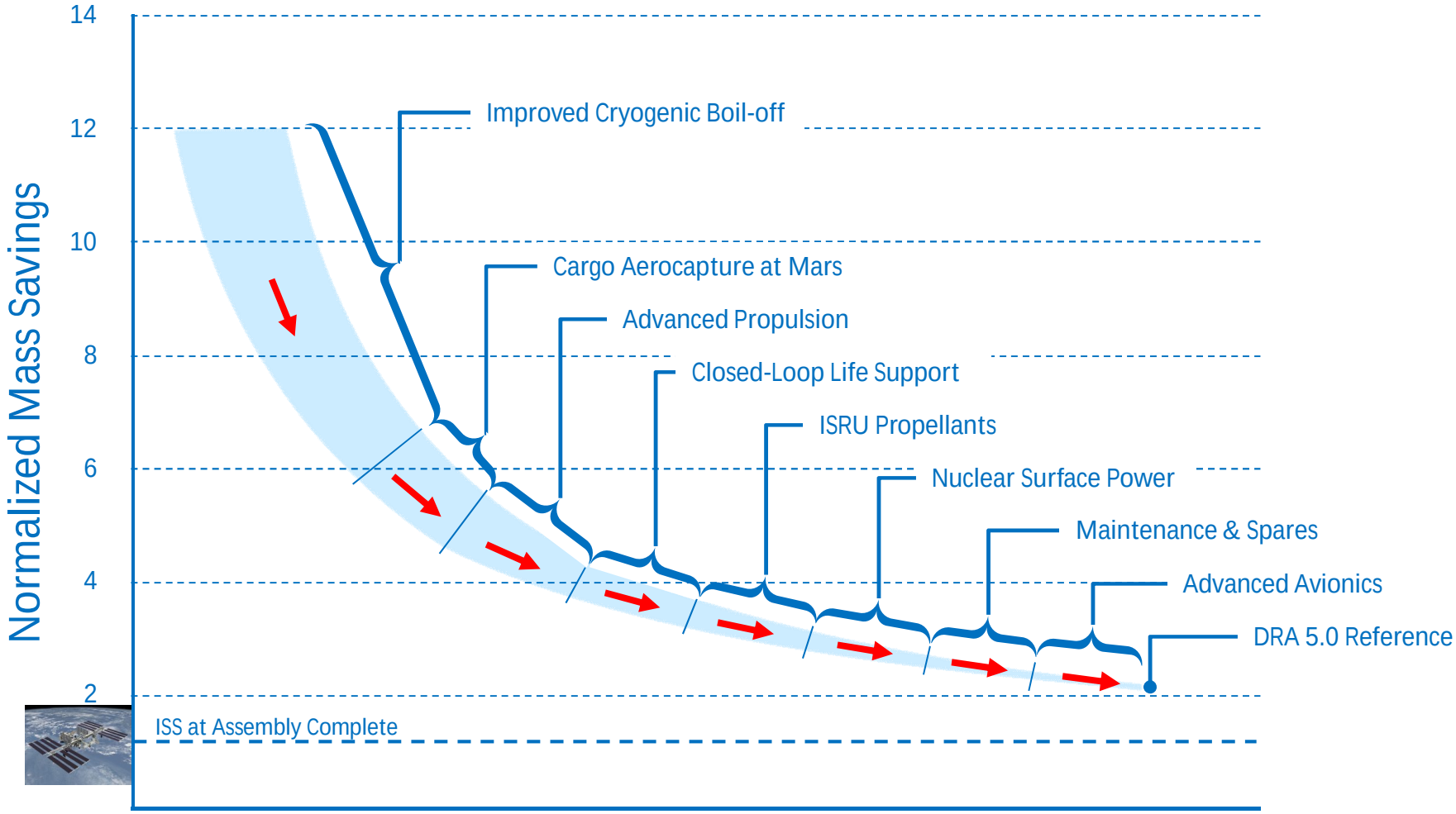
Themes of the President's FY11 NASA Budget Request

- **Top-line increase of $6B over 5 years** -- National investment in NASA is $100B over 5 yrs
- **Increase for Science ($2.5B over 5 years)** -- Largely focused in Earth science
- **Reverse past decline and provide modest increase for Aeronautics (~15% or $75M/yr)**
- **Shift in approach for Human Exploration program. The goal remains the same.**
  - Additional $600M to complete 5 remaining Shuttle flights (3 as of today)
  - Extension of International Space Station to at least 2020
  - Commercial approach to Low Earth Orbit access ($6B over 5 years)
  - Modernization of the Kennedy Space Center launch complex ($2B over 5 years)
  - Flexible Path strategy to extend human presence beyond Low Earth Orbit
  - Restructure of Constellation Program; Modified Orion development continues
- **Significant focus on Technology Development to reposition NASA on the cutting-edge**
  - Central principle of new Human Exploration strategy
  - New DARPA-like Space Technology Program ($5B over 5 years)
- **Increased emphasis on partnerships and STEM education**
  - Other government agencies, academia, industry and international

External Input Has Driven Development of NASA's Technology-Enabled Approach

- **NASA Authorization Act of 2008:** "*A robust program of long-term exploration-related research and development will be essential for the success and sustainability of any enduring initiative of human and robotic exploration of the solar system.*"
- **NRC report, A Constrained Space Exploration Technology Program: A Review of NASA's ETDP, 2008:** *"NASA has created a supporting technology program very closely coupled to the near-term needs of the Constellation Program. This program contains only incremental gains in capability and two programmatic gaps. NASA has effectively suspended research in a number of technology areas traditionally within the agency's scope. This could have important consequences for those portions of the VSE beyond the initial short-duration lunar missions, including extended human presence on the Moon, human exploration of Mars, and beyond."*
- **NRC report, America's Future in Space, 2009:** "*NASA should revitalize its advanced technology development program by establishing a DARPA-like organization within NASA as a priority mission area to support preeminent civil, national security (if dual-use), and commercial space programs."*
- **NRC report, Fostering Visions for the Future: A Review of the NASA Institute for Advanced Concepts, 2009:** "*To improve the manner in which advanced concepts are infused into its future systems, the committee recommends that NASA consider reestablishing an aeronautics and space systems technology development enterprise. Its purpose would be to provide maturation opportunities and agency expertise for visionary, far-reaching concepts and technologies."*
- **Augustine Committee, 2009:** "*The Committee strongly believes it is time for NASA to reassume its crucial role of developing new technologies for space. Today, the alternatives available for exploration systems are severely limited because of the lack of a strategic investment in technology development in past decades.*"
- **NRC report, Capabilities for the Future: An Assessment of NASA Laboratories for Basic Research, 2010:** "*To restore the health of the fundamental research laboratories, including their equipment, facilities, and support services, NASA should restore a better funding and leadership balance between long-term fundamental research/technology development and short- term mission-focused applications.*"

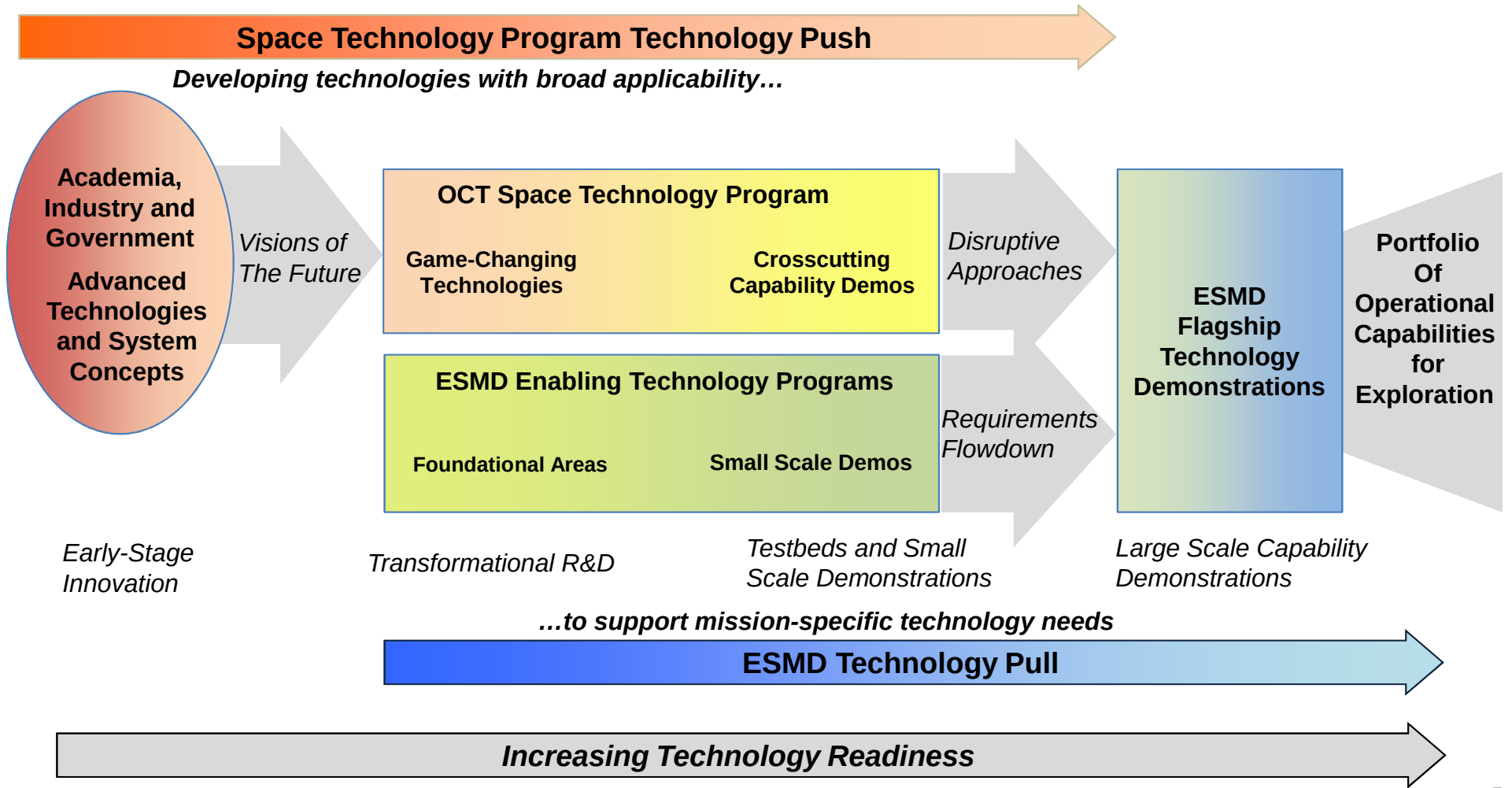
The Value of Technology Investments
Mars Mission Example



- Without technology investments, the mass required to initiate a human Mars mission in LEO is approximately twelve times the mass of the International Space Station
- Technology investments of the type proposed in the FY 2011 budget are required to put such a mission within reach

Integration of NASA's Technology Investments: ESMD Example

A portfolio of technology investments which will enable new approaches to NASA's current mission set and allow the Agency to pursue entirely new missions of exploration and discovery.



Human Exploration Phased Development Strategy

2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026

Phase I
Build the Foundation

Commercial Sector, Robotic Precursors, and Game-Changing Technology Development

Phase II
Systems Development

of Heavy-Lift and

Phase III
Sustainable Exploration of the Solar System

Human Exploration Missions to Solar System Destinations

The New Path for Human Space Exploration

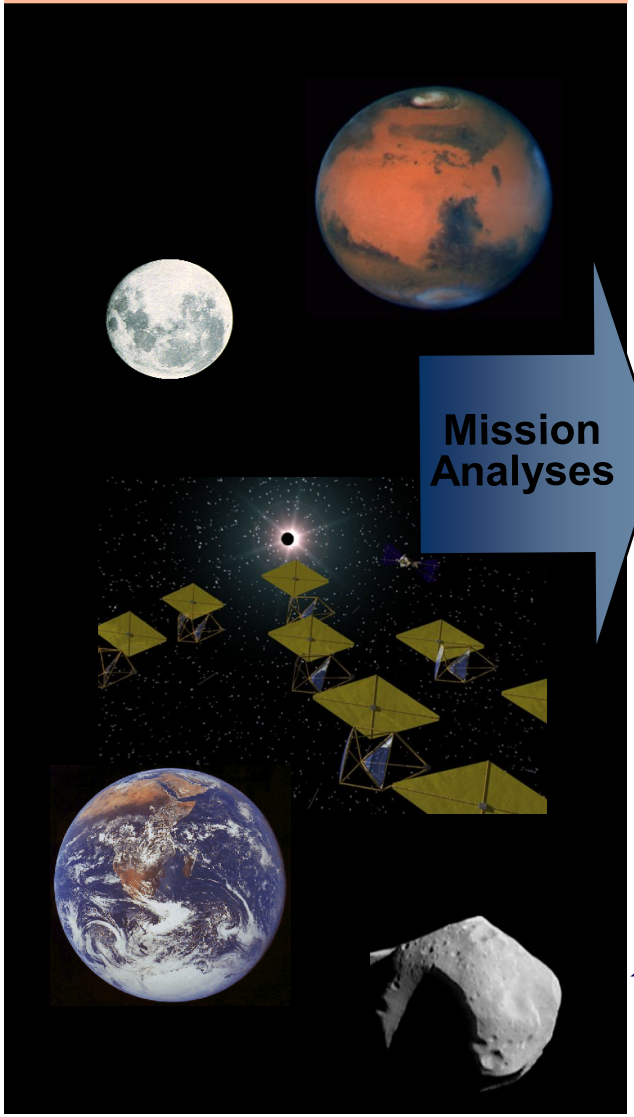
- **Funding is provided for critical enabling human exploration including:**
  - Technology development and demonstrations to reduce cost and prove required capabilities for future human exploration
  - Research & development of heavy-lift and propulsion engines and other key developments
  - Exploration precursor robotic missions to multiple destinations to cost-effectively scout human exploration targets and identify hazards and resources for future human exploration
  - Increased investment in Human Research utilizing ISS to prepare for long journeys beyond Earth
  - Expanded efforts to develop U.S. commercial human spaceflight capabilities, making space travel more accessible and affordable
- **Technology investment strategy: Needed capabilities are identified, multiple competing approaches to provide that capability are funded, and the most viable of these are demonstrated in flight so that our architectures can then reliably depend upon them.**
- **The FY2011 budget will continue the development of the an Orion-derived vehicle that will serve as an emergency return vehicle from ISS, and will be part of the technological foundation for advanced spacecraft to be used in future deep space missions.**

Consistent Set of Exploration Capability Investments

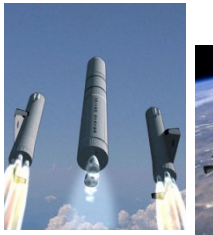
	1969	1986	1987	1988	1989	1990	1991	1997	2004	2009
	Post-Apollo Space Program (NASA STG)	Pioneering the Space Frontier (Paine)	America's Future in Space (Ride)	Beyond Earth's Boundaries (NASA)	90-Day Study (NASA)	Future of U.S Space Program (Augustine)	America at the Threshold, SEI (Stafford)	Human Exploration of Mars DRM (NASA)	President's Commission on U.S. Space Exploration Policy (Aldridge)	Report of U.S. Spaceflight Committee (Augustine)
Advanced/Closed Loop Life Support		X	X	X	X	X	X	X	X	X
Advanced Power Generation & Storage (in-space and surface, Solar and nuclear)	X	X	X	X	X	X	X	X	X	X
Advanced In-Space Propulsion (chemical, solar electric, nuclear thermal, nuclear electric)	X	X	X	X	X	X	X	X	X	X
In-Space Cryo/Propellant Transfer and Storage		X	X	X	X		X	X	X	X
Heavy Lift Launch Vehicle			X	X	X	X	X	X	X	
Autonomous/Expert Systems		X	X			X		X	X	X
Robotics (tele-robotic & autonomous operation)		X	X		X	X	X	X	X	X
EDL (includes aerocapture, aerobraking, aeroentry)		X	X	X	X	X	X	X	X	X
Human Health and Performance (Radiation, gravity, psychological effects and mitigation, medical technologies)	X	X	X		X	X	X	X	X	X
Autonomous Rendezvous and Docking				X	X		X		X	X
In-Situ Resource Utilization (Lunar, NEO, and Mars based)		X	X	X	X	X	X	X	X	X
Lightweight Structures and Materials		X					X	X	X	X
Advanced In-Space Engine					X	X	X		X	X
Advanced EVA Systems		X		X	X	X	X	X	X	
Communication Technology	X				X	X	X		X	
Reliable Efficient Low Cost Advanced Access to Space	X		X							X
Reusable In-Space Transfer	X	X	X		X	X				
Surface Rovers				X		8	X	X		

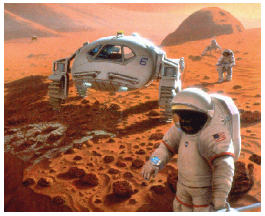
Requirements Flowdown Approach to Human Exploration Technology Development

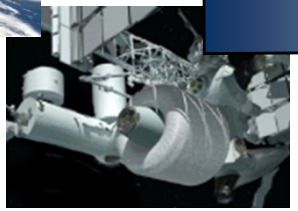
Potential Destinations	Common Capabilities	Technology Building Blocks

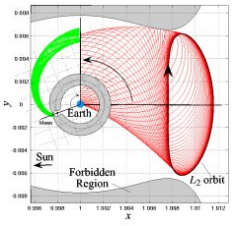


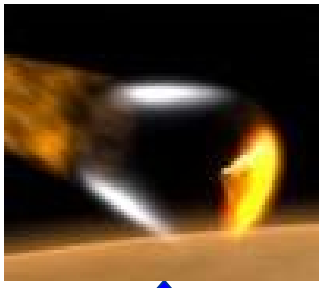
Mission Analyses











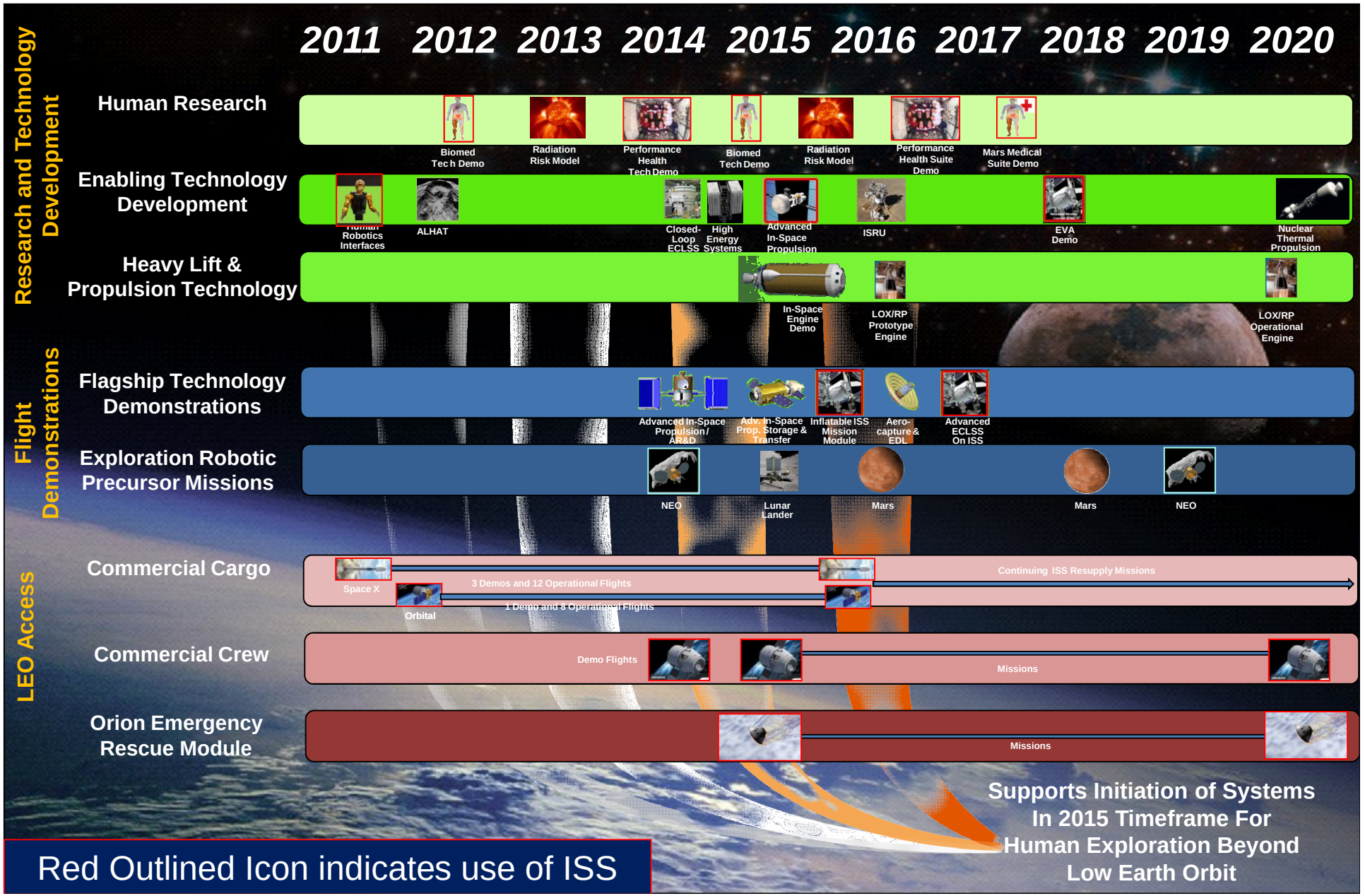
Systems Design

- Efficient In-Space
- Aerocapture
- Low-cost Engines
- Cryo Fluid
- Robust/Efficient
- Lightweight
- Radiation Research
- Zero/Low-g Research
- Regenerable Life
- Advanced Lightweight EVA

"Breakthrough" Technologies

- Hypersonic Inflatable
- Regenerative
- Revolutionary ETO
- Innovative Mission Concepts

ESMD Initial Point of Departure Program Plan



Red Outlined Icon indicates use of ISS

Space Technology Program Foundational Principles

The Space Technology Program shall:

- Advance non-mission-focused technology.
- Produce technology products for which there are multiple customers.
- Meet the Nation's needs for new technologies to support future NASA missions in science and exploration, as well as the needs of other government agencies and the Nation's space industry in a manner similar to the way NACA aided the early aeronautics industry.
- Employ a portfolio approach over the Technology Readiness Level spectrum.
- Competitively sponsor research in academia, industry, and the NASA Centers based on the quality of the research proposed.
- Leverage the technology investments of our international, other government agency, academic and industrial partners.
- Establish a deliberative panel of internal and external stakeholders, including industry and other government agencies, to review and advise OCT on technology development priorities through a transparent and balanced process.
- Result in new inventions, new capabilities and the creation of a pipeline of innovators trained to serve future National needs.

Thematic Challenges

DRAFT

Make space part of our routine environment…

Achieve fast and economical space transportation

Enable in-space commercial/ marketable services

Improve spacecraft safety and protect astronaut health

Communications that enable virtual presence

Manage space as a natural resource…

Gain knowledge 0f climate change and natural disasters

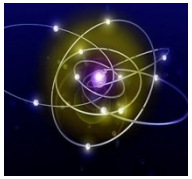
Provide economical energy on demand

Improve Knowledge of the near-earth environment

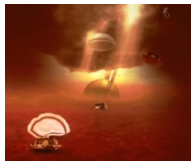
Invent the materials of exploration using in-situ manufacturing

Quests of the Future…

Exploit machine intelligence / robotic autonomy



Understand laws of the universe



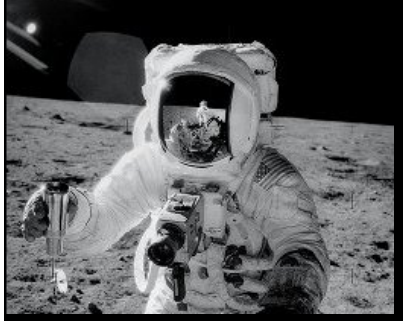
Discover life and earth–like worlds

Building Disruptive and Game Changing Technology

Strategic Opportunities	Enabling Capabilities	Transformational Technology Demonstration

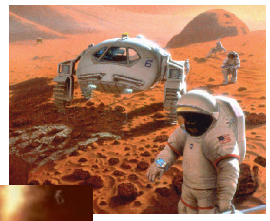
Scientific Discovery

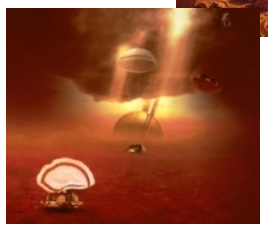
Human and Robotic Exploration



New and Innovative Space Technologies and Mission Capabilities

Challenge Goals



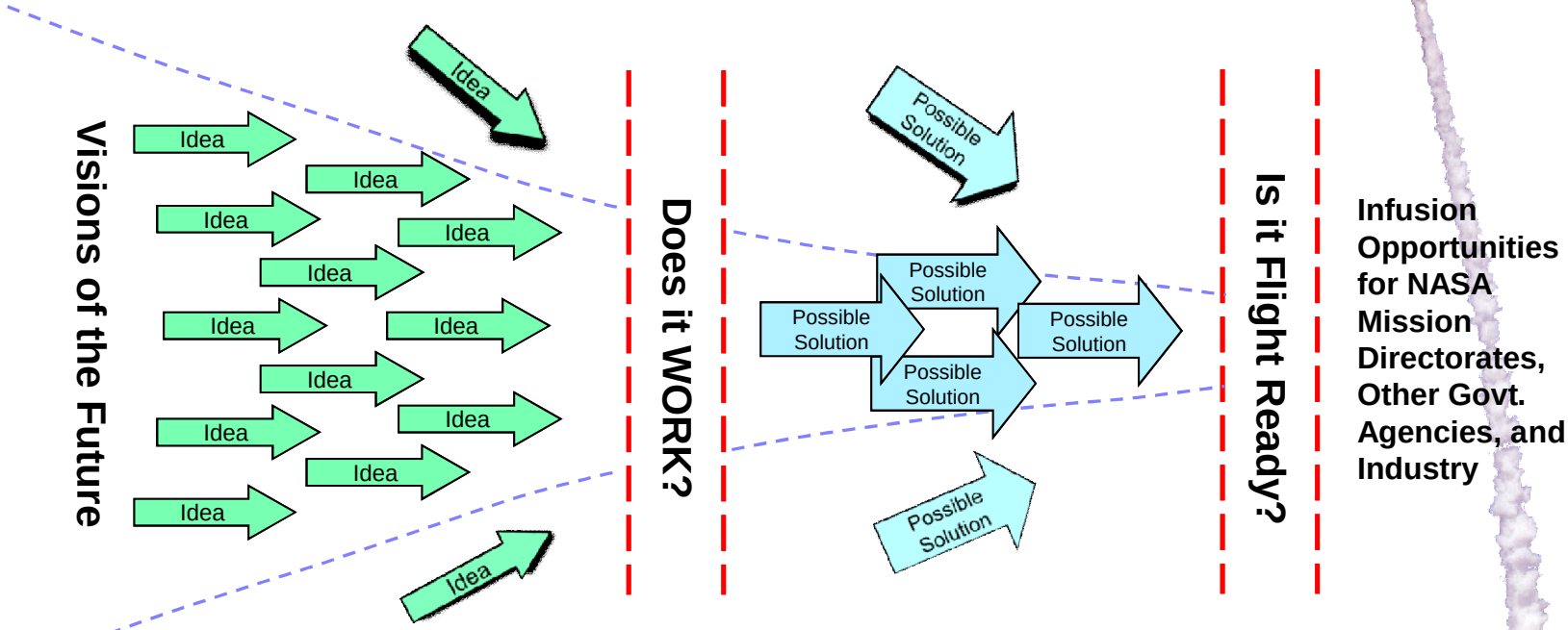


Systems Capabilities

- Energetic Materials
- Inflatable Aerocapture
- Optical Communication
- Nano electronics
- Radiation Shielding
- Expandable Structures
- Robotic Repair
- Engineered Materials

Examples of New Technologies

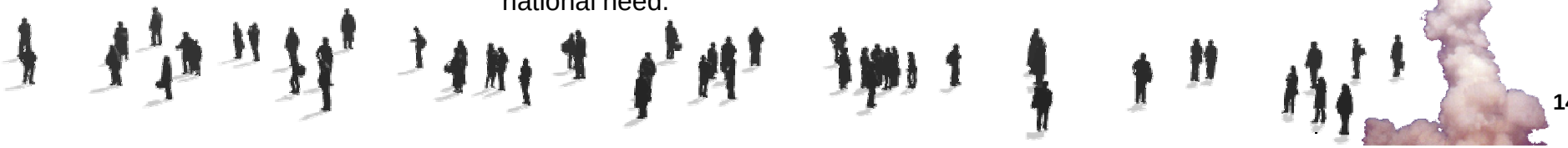
NASA Space Technology Program



Creative ideas regarding future NASA systems or solutions to national needs.

Prove feasibility of novel, early-stage ideas with potential to revolutionize a future NASA mission and/or fulfill national need.

Mature crosscutting capabilities that advance multiple future space missions to flight readiness status



Early Stage Innovation

The Early-Stage Innovation Division sponsors a wide range of low TRL efforts for advanced space system concept and initial technology development across academia, industry and at the NASA field Centers.

Early-Stage Innovation includes:

- **Space Technology Research Grants Program** that focuses on innovative research in advanced space technology & graduate fellowships for student research in space technology
- **NIAC Program** that focuses on innovative aeronautics and space system concepts for future NASA missions.
- **Center Innovation Fund Program** to stimulate aerospace creativity and innovation at the NASA field Centers
- **SBIR/STTR Program** to engage small businesses in our Nation's space enterprise and infuse these products across NASA missions
- **Centennial Challenges Prize Program** to address key technology needs with new sources of innovation outside the traditional aerospace community.

All Early Stage Innovation selections will be made competitively.

Game Changing Technology Division

- ***The Game Changing Technology Division focuses on maturing advanced space technologies that may lead to entirely new approaches for the Agency's future space missions and solutions to significant national needs.***
- ***Through significant ground-based testing and/or laboratory experimentation, the Game Changing Technology Division matures technologies in preparation for potential system level flight demonstration. Success is not assured with each investment; however, on the whole and over time, dramatic advances in technology, enabling entirely new NASA missions and potential solutions for a variety of society's technological challenges are expected.***
- ***A broad spectrum of space system technologies will be developed ranging from launch vehicle subsystems, spacecraft technologies, in-space capabilities, and surface systems that support robotic and human exploration.***

Game Changing Technology Division includes:

- **Game Changing Development Program** which focuses on innovative ideas enabling new capabilities or radically altering our current approaches to space systems
- **Small Satellite Subsystem Technology Program** which enables small satellites to provide game changing capabilities for the government and commercial sectors

Greater than 70% of GCT selections will be made competitively

Crosscutting Capability Demonstrations Division

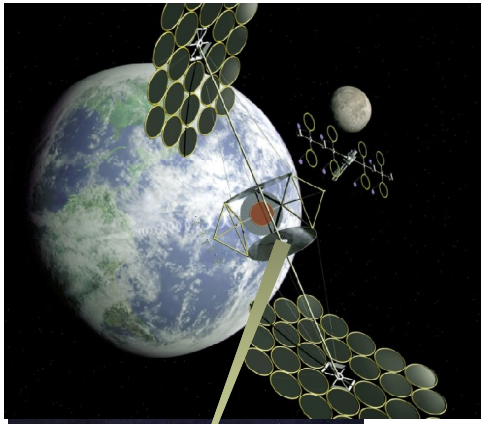
- ***The Cross-Cutting Capability Demonstrations Division focuses on maturation to flight readiness of cross-cutting capabilities that advance multiple future space missions, including flight test projects where in-space demonstration is needed before the capability can transition to direct mission application.***
- ***Matures a small number of technologies that benefit multiple customers to flight readiness status (TRL 6) through Projects that perform relevant environment testing***

Crosscutting Capability Demonstrations Division includes:

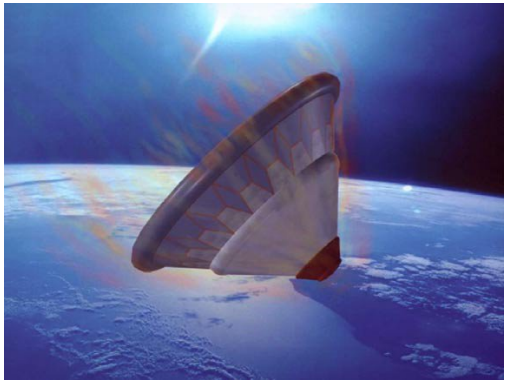
- **Technology Demonstration Missions Program** which matures, through flight demonstrations, a small number of Agency crosscutting technologies in partnerships with the Mission Directorates
- **Edison Small Satellite Missions Program** which develops and operates a series of NASA-focused small satellite demonstration missions in collaboration with academia and small business
- **Flight Opportunities Program** which provides flight opportunities of reduced-gravity environments, brief periods of weightlessness, and high-altitude atmospheric research

Greater than 70% of CCD selections will be made competitively

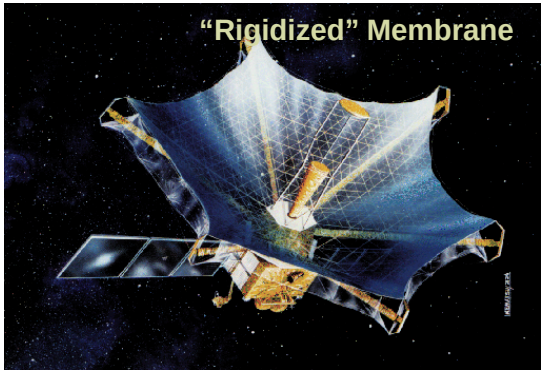
Potential Space Technology Demonstrations



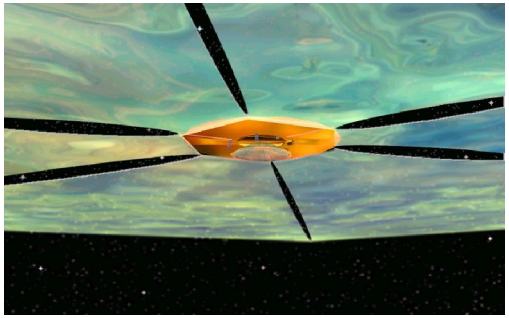
Space Solar Power: In-Space Power Transmission



Inflatable Decelerators

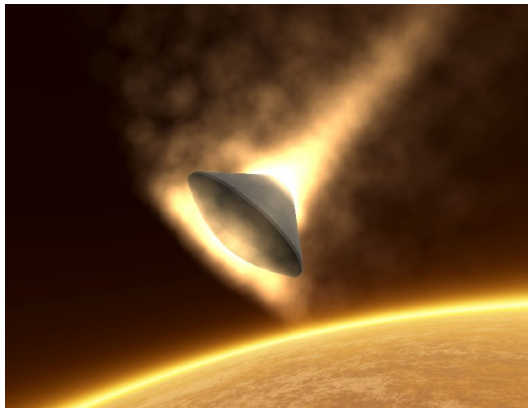


25-40 m Class Telescopes



Solar Sail Propulsion

Electrodynamic Tether Propulsion
Artist Concept of ISS Reboost



Aerocapture

Optical Communications

NASA: Part of a Broader National Strategy

- Through its FY11 budget request, the Obama administration is committed to a research, technology and innovation agenda for the Nation as a means of stimulating the economy and building our Nation's global economic competitiveness through the creation of new products and services, new business and industries, and high-quality, sustainable jobs
- The NASA budget request is aligned with this National strategy.
  - The renewed emphasis on technology in the President's FY11 budget request balances the long-standing NASA core competencies of R&T, spaceflight hardware development, and mission operations.
- In addition to providing a more more vital and productive aerospace future than our country has today, a NASA focused on technology and innovation,
  - Drives our Nation's economic competitiveness.
  - Serves as a strong inspiration for young people to pursue STEM education and career paths.
  - Allows NASA to apply its intellectual capital to the develop technological solutions addressing broader National needs in energy, weather & climate, Earth science, health & wellness, and National security.

I am 100 percent committed to the mission of NASA and its future. Because broadening our capabilities in space will continue to serve our society in ways we can scarcely imagine. Because exploration will once more inspire wonder in a new generation: sparking passions, launching careers. And because, ultimately, if we fail to press forward in the pursuit of discovery, we are ceding our future. President Obama, April 15, 2010.