National Aeronautics and Space Administration

Strategic Space Technology Investment Plan (SSTIP) Overview

NAC Technology and Innovation Committee Meeting
July 24, 2012
NASA Goddard Space Flight Center

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Agenda

- Office of the Chief Technologist and Space Technology Program
- NASA's Technology Portfolio
- National Science and Technology Priorities for FY 2014
- Space Technology
  - Investments in Our Future
  - Program Goals and Objectives
  - Portfolio
- Strategic Space Technology Investment Plan (SSTIP)
  - Overview and Development Process
  - Technology Investment Framework
  - Approach
  - Guiding Principles
  - Decision Making and Governance
  - Pillars and Goals
  - Technology Investments
  - Alignment with NRC Recommended Technologies

Technology definition: a solution that arises from applying the disciplines of engineering science to synthesize a device, process, or subsystem, to enable a specific capability

Request

- NASA has requested that the NASA Advisory Council (NAC) – Technology and Innovation (T&I) Committee review the Strategic Space Technology Investment Plan (SSTIP) and provide their recommendation to NASA Administrator Bolden that the Agency adopt or not adopt the SSTIP.

- Additionally, the NAC T&I has been asked to provide top-level general comments, as appropriate.

<u>Strategic Space Technology Investment Plan (SSTIP)</u>
(Includes by reference Space Technology Roadmaps and NRC recommendations)

Audience
- Internal Stakeholders (mission directorates and offices)
- External Stakeholders (other Govt. Agencies, international partners, academia and commercial space sector)

Purpose
- Document and communicate strategic framework, investment approach, and principles for NASA's Space Technology investments
- Strengthen internal Agency technology coordination through NTEC governance of strategic plan
- Maximizing the potential for collaboration on shared goals and objectives

<u>SSTIP Is Not:</u>

- An operational or execution plan.

Each Mission Directorate has program plans and/or project plans that document how they will execute technology development activities. These have schedules with milestones, reviews, and test dates, a appropriate. Similarly, these have budget and risk information.

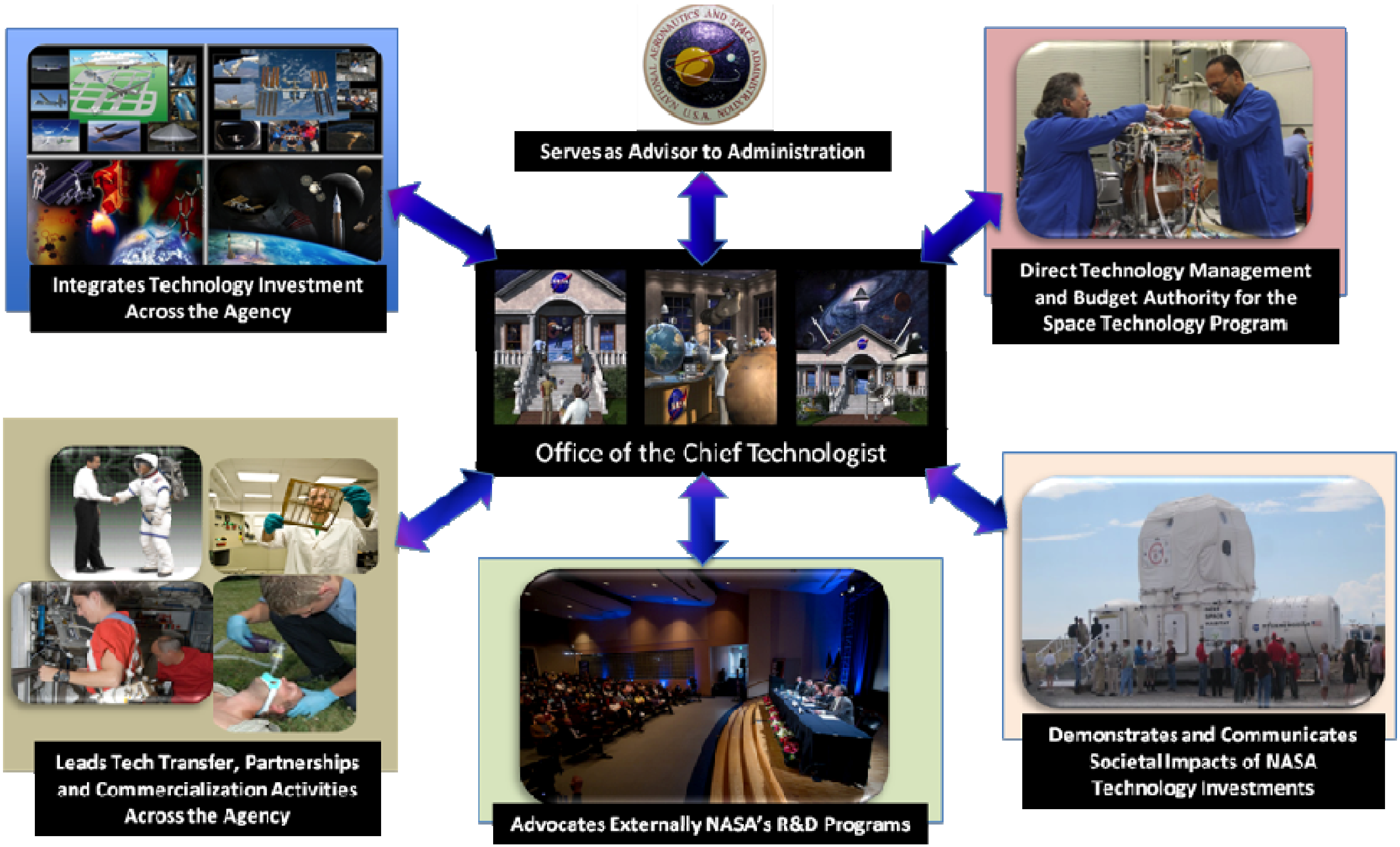
Space Technology: Stepping Stones to the Future

> *"Half or more of the growth in the nation's gross domestic product in recent decades has been attributable to progress in technological innovation"*
> *- NRC, Rising Above the Gathering Storm, Revisited*

- NASA must, through the development of technology
  - Provide capabilities fundamental to the Agency's direction and U.S. space enterprise
  - Transform the path for space science and exploration
  - Enhance national innovation and economic growth

- NASA technology development addresses National priorities
  - Recognizes NASA's role in advancing space science, exploration and discovery
  - Directs NASA to work with industry, academia and international partners to implement new space technology development
  - Encourages growth of U.S. commercial space sector
  - Maintain a space technology base that aligns mission directorate investments, increases capability, lowers mission cost and supports long term needs
  - Directs aggressive and prioritized technology investments to supports robotic and human exploration missions

Office of the Chief Technologist & Space Technology Program

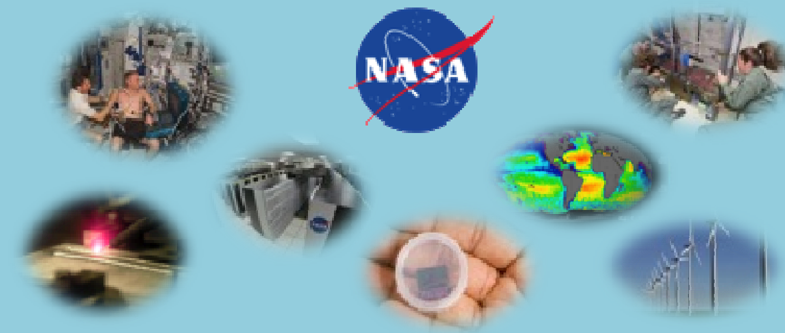


National Science and Technology Priorities for FY 2014

Scientific discovery, technological breakthroughs, and innovation are the primary engines for expanding the frontiers of human knowledge and are vital for responding to the challenges and opportunities of the 21st century.

Administration's Multi-Agency Priorities (OSTP):

- **Resource sharing and cooperation** among multiple Federal Agencies for success
- Identify and pursue **"Grand Challenges"** that require advances in science, technology and innovation to achieve goals beyond single Agency scope
- **Support the research tools and infrastructure** needed to ensure the U.S. remains at the leading edge
- **Strategic prioritization of resources** to key science and technology activities
- **Promote Innovation and Commercialization** from Federal R&D investments
- **Promote Science, Technology, Engineering, and Mathematics (STEM) Education** where Federal government can have maximum impact
- **Key Focus Areas**
  - **Advanced Manufacturing**
  - **Clean Energy**
  - **Global Climate Change**
  - **Information Technology Research and Development**
  - **Nanotechnology**
  - **Biological Innovation**

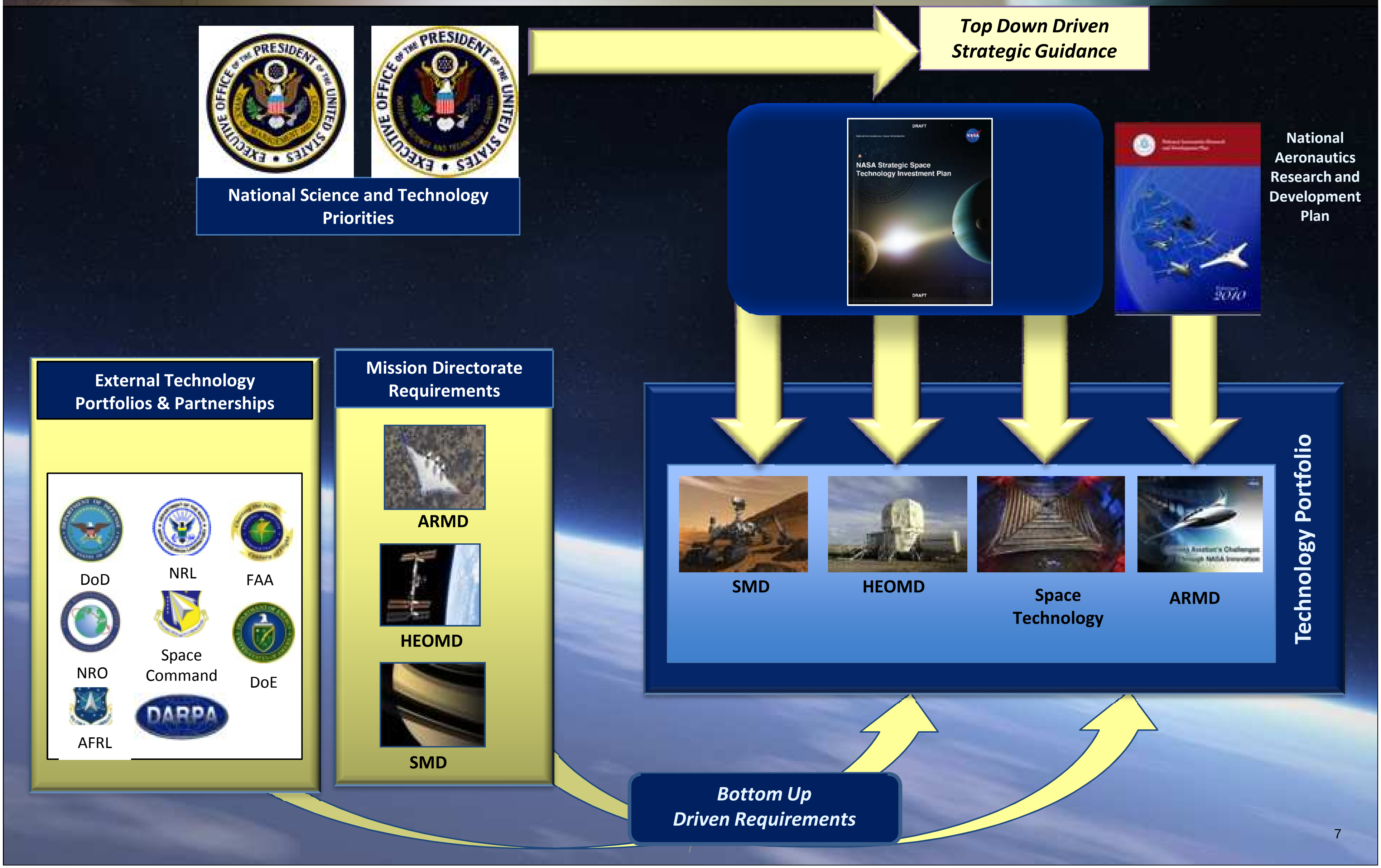


NASA's Office of the Chief Technologist (OCT) is responsible for direct management of NASA's Space Technology programs and for coordination and tracking of all technology investments across the Agency. The responsibility is shared across the Agency.

- **Across NASA's Space Technology Programs**
  - **Basic Research (Feeds Concept Development)**
  - **Pioneering and Crosscutting Technologies**
  - **Mission-Specific Technologies**
- **Across NASA's Mission Directorates and Offices**
  - **Aeronautics Research**
  - **Human Exploration and Operations**
  - **Science**
  - **Office of the Chief Scientist**
  - **Office of the Chief Engineer**
- **Partnerships with other government agencies, U.S. industry, and internationals**

NASA Technology is Aligned with the Nation's Priorities

NASA's Technology Portfolio



Office of the Chief Technologist and Space Technology Program Goals & Objectives

Strategic Goal 3	Create the innovative new space technologies for our exploration, science and economic future.

Strategic Outcomes	Strategic Objectives
3.1 Sponsor early-stage innovation in space technologies in order to improve the future capabilities of NASA, other Government agencies, and the aerospace industry.	3.1.1 Create a pipeline of new low Technology Readiness Levels (TRL) innovative concepts and technologies for future NASA missions and national needs.
3.2 Infuse game-changing and crosscutting technologies throughout the Nation's space enterprise to transform the Nation's space mission capabilities.	3.2.1 Prove the technical feasibility of potentially disruptive new space technologies for future missions.
	3.2.2 Spur the development of routine, low-cost access to space through small payloads and satellites.
	3.2.3 Demonstrate new space technologies and infuse them into future science and exploration small satellite missions and/or commercial use.
	3.2.4 Demonstrate new space technologies and infuse them into missions.
	3.2.5 Provide flight opportunities and relevant environments to demonstrate new space technologies.
3.3 Develop and demonstrate the critical technologies that will make NASA's exploration, science, and discovery missions more affordable and more capable.	3.3.1 Demonstrate in-space operations of robotic assistants working with crew.
	3.3.2 Develop and demonstrate critical technologies for safe and affordable cargo and human space exploration missions beyond low Earth orbit.
3.4 Facilitate the transfer of NASA technology and engage in partnerships with other Government agencies, industry, and international entities to generate U.S. commercial activity and other public benefits.	3.4.1 Promote and develop innovative technology partnerships among NASA, U.S. industry, and other sectors for the benefit of Agency programs and national interests.

Technology Development as a Priority

- Government-wide emphasis on advancing technology to spur innovation in 2010
  - Agency-level Chief Technologist role established
  - Provide NASA a principle advisor on technology policy

- NASA focus on technology is evident through
  - Establishment of Space Technology Program (STP)
  - Establishment of NASA Technology Executive Council (NTEC)
  - Establishment of a database to consolidate NASA's technology investment data from across the Agency (TechPort)
  - Establishment of SSTIP process
  - Continued technology investment through Mission Directorates

NASA's Space Technology Portfolio

2010

Space Technology Roadmaps

- 140 challenges (10 per roadmap)
- 320 technologies
- 20-year horizon

- Revised every 4 years

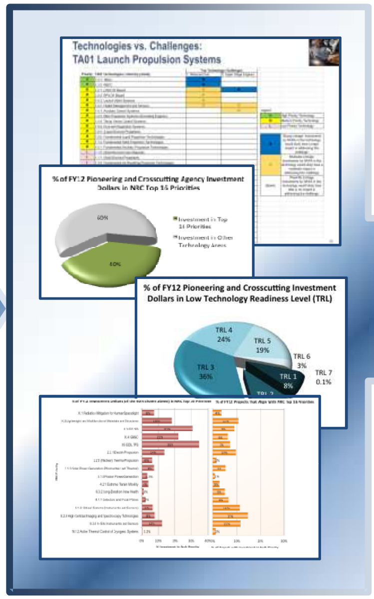
2011

National Research Council (NRC) Study

Prioritization:

- 100 top technical challenges
- 83 high-priority technologies (roadmap-specific)
- 16 highest of high technologies (looking across all roadmaps)

- Requested every 4 years



2012

SSTIP

Updated ST Roadmaps:

- Incorporate NRC Study Results

Developing a Strategic Space Technology Investment Plan:

- current investments
- current MD/Office priorities
- opportunities for partnership
- gaps vs. current budget and capabilities
- 20-Year horizon with 4-year implementation cadence

- Revised every 2 years

Execution

Investment Portfolio

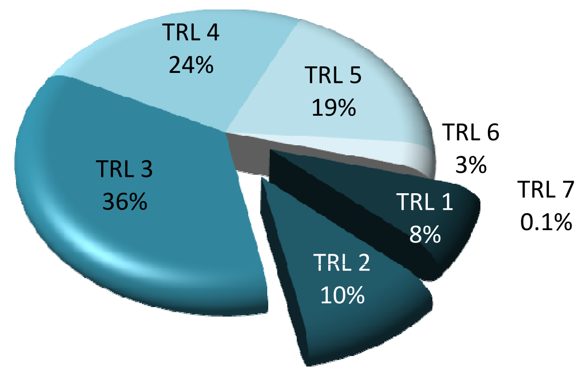
- Technology Developments (across full Technology Readiness Level (TRL) spectrum)
- Flight Demonstrations
- Must accommodate:
  - Mission Needs
  - Push Opportunities
  - Affordability
  - Technical Progress
  - Programmatic Performance
  - Commitments

- Budgeted annually

Types of Agency Technology Investments

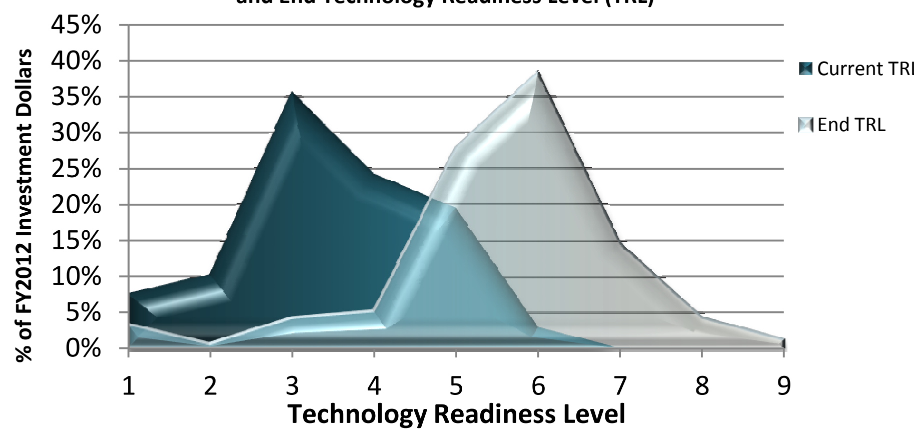
- Pioneering and crosscutting technology investments
  - Coordinated through Space Technology Program within OCT
  - Technologies that enable multiple missions
  - Span technology readiness levels from 1 to 7

% of FY2012 Pioneering and Crosscutting Investment Dollars in Low Technology Readiness Level (TRL)



- Mission-specific
  - Coordinated within mission directorates
  - Develop and mature technologies that provide capabilities for planned and future missions
  - Focus on higher technology readiness levels

% of FY2012 Pioneering and Crosscutting Investment Dollars by Current and End Technology Readiness Level (TRL)

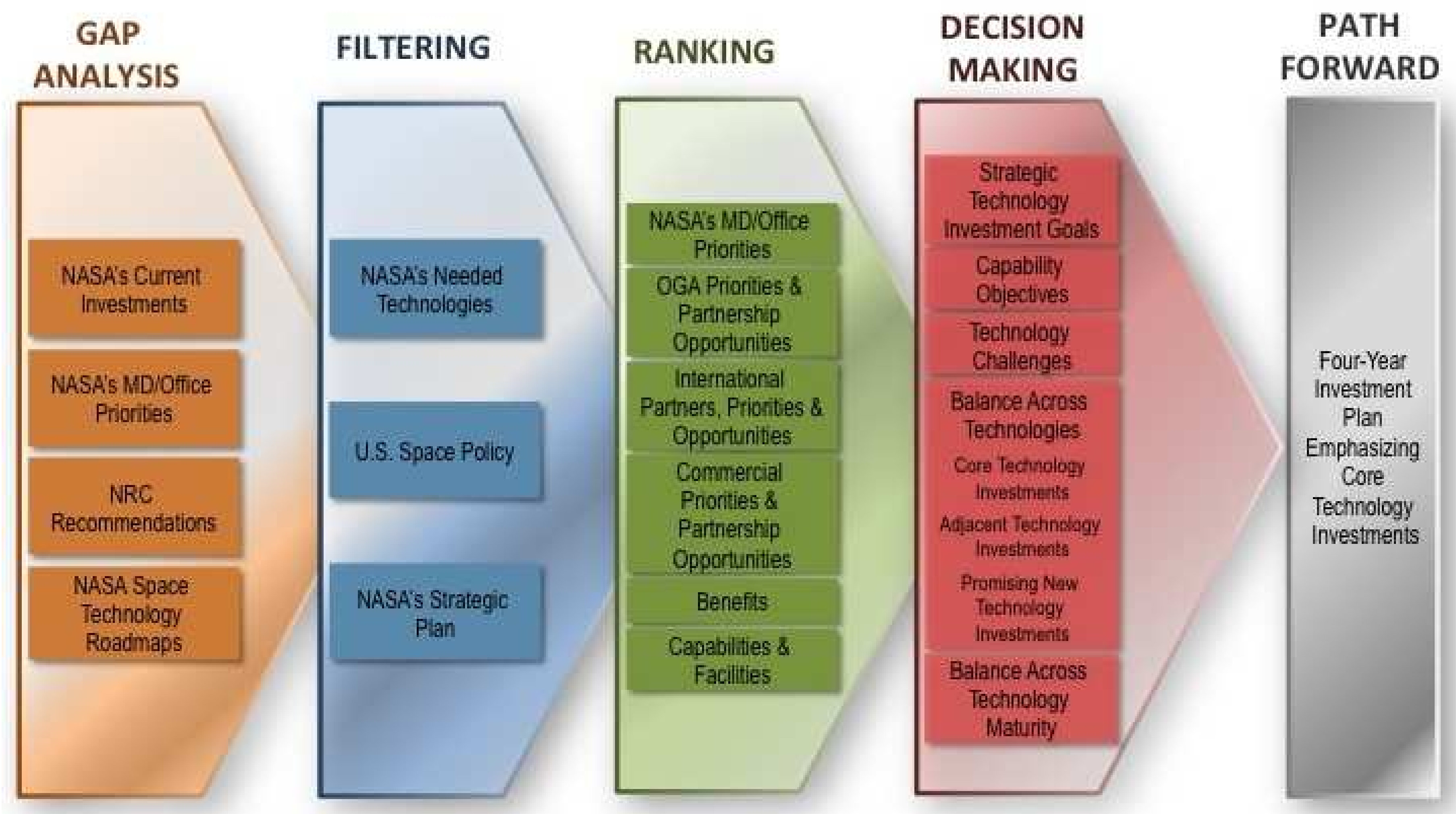


SSTIP Overview

The SSTIP is a comprehensive actionable plan that will produce technologies essential to the pursuit of NASA's mission and achievement of National goals

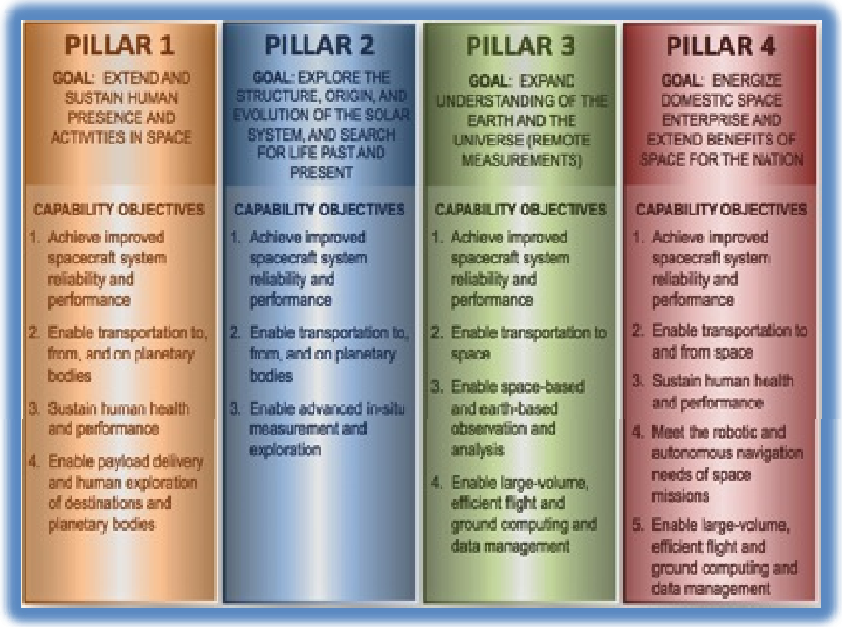
- Identifies:
  - Technology investment framework
  - Focused investment approach
  - Strategic decision making and governance
  - Six principles for execution of plan
- Guides investment over next 4 years, building to a 20-year horizon
  - Updated every two years, roadmap revisions every four years
- Optimizes benefits to stakeholders
  - NASA Mission Directorates, other U.S. Government agencies, the private sector, and the Nation
- Does not include aeronautics

SSTIP Development Process



Technology Investment Framework

- Four pillars of Agency Space Technology Investment
- Each pillar comprises:
  - Strategic investment goal
  - Capability objectives
  - Technical challenges
- Built upon:
  - NASA Space Technology Roadmaps
  - NRC recommendations
  - NASA technology portfolio assessments
  - Survey of stakeholder needs
  - U.S. National Space Policy
  - Office of Management and Budget (OMB) Science and Technology Priorities for the FY 2014 Budget



Investment Approach

- Three levels of investment
  1. Core
  2. Adjacent
  3. Complementary
- Together these investments:
  - Span the four pillars
  - Include pioneering, crosscutting and mission specific technology development
  - Guide future technology expenditures
  - Rapidly produce critical capabilities
  - Seed future innovation

Core:
- 70% investment
- Represent the majority of the NRC's top priority recommendations
- Focus on mission specific technologies and 8 critical pioneering and crosscutting areas
- Near-term investments necessary to accomplish demanding science and exploration missions

Adjacent:
- 20% investment
- Not part of the Core technologies, but part of NRC's 83 high priorities
- Development may take more time

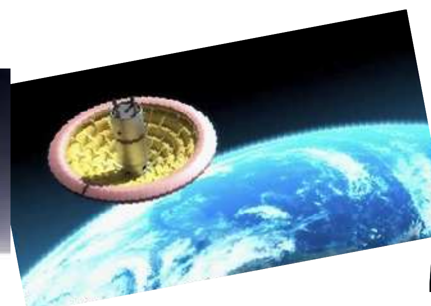
Complementary:
- 10% investment
- Does not include core or adjacent
- Does include the remaining technology capabilities in the pillars and corresponding Space Technology Roadmaps
- Seeds innovation providing some early development in technologies that are not needed immediately
- Provide technologies relevant within the 20-year horizon of this strategic plan

Strategic Decision Making and Governance

- NASA Technology Executive Council (NTEC) will be the governing body for the SSTIP

- NTEC will:
  - Evaluate the content and progress of the space technology program
  - Evaluate the Agency technology portfolio, balance the portfolio, or concur on a variation from the 70% - 20% - 10% approach
  - Make decisions on technology gaps, overlaps, and synergies

The Deep Space Atomic Clock
Source: NASA



Hypersonic Inflatable Aerodynamic Decelerator
Source: NASA

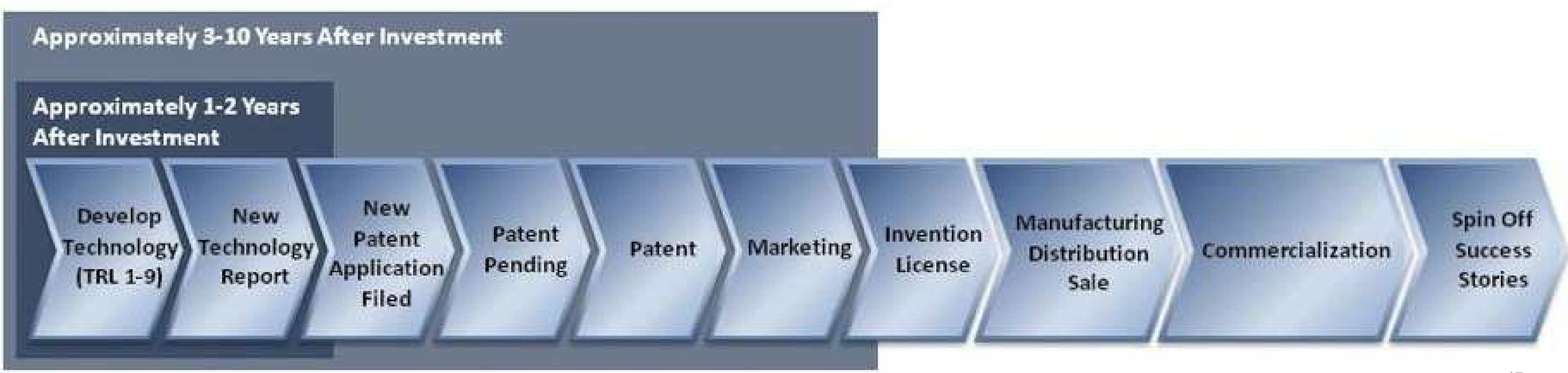
Computer simulations derived from data from years of Hubble observations indicate the Andromeda and Milky Way galaxies will collide in 4 billion years, depicted in this artist's rendering.

Source: NASA

Guiding Principles

Six principles optimize investments, maintain a balanced portfolio, use developed technologies, and provide transparency to the American public

1. Balance investment across all 14 Space Technology Areas in the Roadmaps
2. Balance investment across all levels of technology readiness (TRL)
3. Ensure developed technologies are infused into Agency missions
4. Pursue partnerships to help achieve NASA's technology goals
5. Use a systems engineering approach when planning technology investments
6. Reach out to the public and share information about its technology investments



Pillars of Agency Space Technology Investment

PILLAR 1

GOAL: EXTEND AND SUSTAIN HUMAN PRESENCE AND ACTIVITIES IN SPACE

CAPABILITY OBJECTIVES

1. Achieve improved spacecraft system reliability and performance
2. Enable transportation to, from, and on planetary bodies
3. Sustain human health and performance
4. Enable payload delivery and human exploration of destinations and planetary bodies

PILLAR 2

GOAL: EXPLORE THE STRUCTURE, ORIGIN, AND EVOLUTION OF THE SOLAR SYSTEM, AND SEARCH FOR LIFE PAST AND PRESENT

CAPABILITY OBJECTIVES

1. Achieve improved spacecraft system reliability and performance
2. Enable transportation to, from, and on planetary bodies
3. Enable advanced in-situ measurement and exploration

PILLAR 3

GOAL: EXPAND UNDERSTANDING OF THE EARTH AND THE UNIVERSE (REMOTE MEASUREMENTS)

CAPABILITY OBJECTIVES

1. Achieve improved spacecraft system reliability and performance
2. Enable transportation to space
3. Enable space-based and earth-based observation and analysis
4. Enable large-volume, efficient flight and ground computing and data management

PILLAR 4

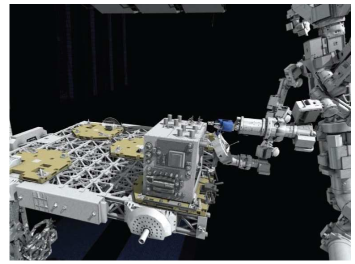
GOAL: ENERGIZE DOMESTIC SPACE ENTERPRISE AND EXTEND BENEFITS OF SPACE FOR THE NATION

CAPABILITY OBJECTIVES

1. Achieve improved spacecraft system reliability and performance
2. Enable transportation to and from space
3. Sustain human health and performance
4. Meet the robotic and autonomous navigation needs of space missions
5. Enable large-volume, efficient flight and ground computing and data management

Goal 1: Extend and Sustain Human Presence and Activities in Space

Autonomous systems such as satellite servicing will advance technologies to achieve improved spacecraft system reliability and performance.



Transportation to planetary bodies will be enabled through entry, descent, and landing (EDL) technologies, such as low density supersonic decelerators.

Surface systems, including lightweight reliable habitats, will enable human exploration of destinations.

PILLAR 1

GOAL: EXTEND AND SUSTAIN HUMAN PRESENCE AND ACTIVITIES IN SPACE

CAPABILITY OBJECTIVES

1. Achieve improved spacecraft system reliability and performance
2. Enable transportation to, from, and on planetary bodies
3. Sustain human health and performance
4. Enable payload delivery and human exploration of destinations and planetary bodies

Goal 2: Explore the Structure, Origin, and Evolution of the Solar System, and Search for Life Past and Present

Exploring the solar system will require high-bandwidth communications to improve spacecraft performance. The Mars Science Laboratory will use high-bandwidth communication technologies as it searches for life past and present.

Deep space atomic clock technologies are necessary for efficient and accurate navigation and enable transportation to and from planetary bodies.

Autonomous robotic technologies allow for maneuvering and manipulation of samples on planetary surfaces, enabling in-situ measurement and exploration.

PILLAR 2

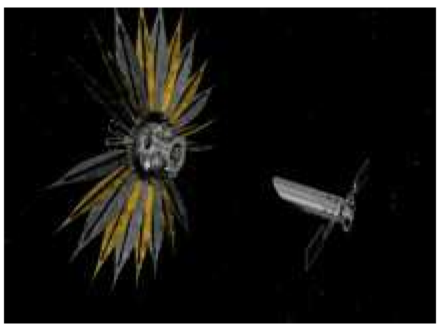
GOAL: EXPLORE THE STRUCTURE, ORIGIN, AND EVOLUTION OF THE SOLAR SYSTEM, AND SEARCH FOR LIFE PAST AND PRESENT

CAPABILITY OBJECTIVES

1. Achieve improved spacecraft system reliability and performance
2. Enable transportation to, from, and on planetary bodies
3. Enable advanced in-situ measurement and exploration

Goal 3: Expand Understanding of the Earth and the Universe (Remote Measurements)

Technologies such as those being advanced for solar electric in-space propulsion will help enable space transportation.



New techniques for using scientific instruments and sensors, like telescopes with a starshade, will enable future space-based observations.

Efficient computing and data management will be enabled by technologies for improving flight computers, such as low-power flight computers for cubesats.

PILLAR 3

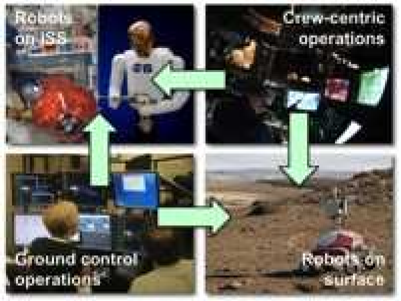
GOAL: EXPAND UNDERSTANDING OF THE EARTH AND THE UNIVERSE (REMOTE MEASUREMENTS)

CAPABILITY OBJECTIVES

1. Achieve improved spacecraft system reliability and performance
2. Enable transportation to space
3. Enable space-based and earth-based observation and analysis
4. Enable large-volume, efficient flight and ground computing and data management

Goal 4: Energize Domestic Space Enterprise and Extend Benefits of Space for the Nation

Technologies for hazard detection and avoidance enable descent and landing on Earth and other planetary bodies.



Advancements in robotic and autonomous technologies will support future on-orbit assembly activities

Autonomous mission operations require high data rates. Technologies to improve computing will extend benefits to domestic space enterprises.

PILLAR 4

GOAL: ENERGIZE DOMESTIC SPACE ENTERPRISE AND EXTEND BENEFITS OF SPACE FOR THE NATION

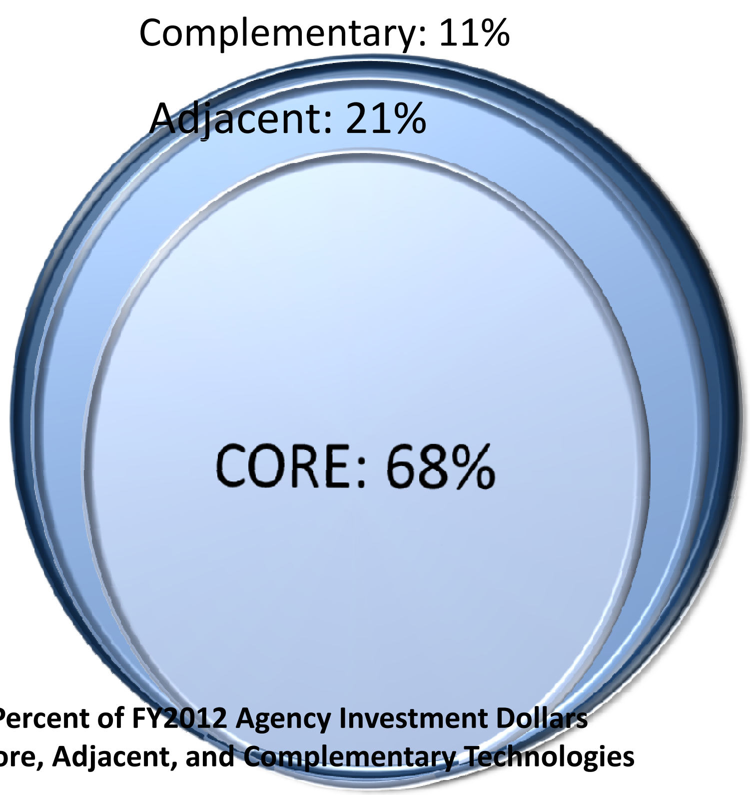
CAPABILITY OBJECTIVES

1. Achieve improved spacecraft system reliability and performance
2. Enable transportation to and from space
3. Sustain human health and performance
4. Meet the robotic and autonomous navigation needs of space missions
5. Enable large-volume, efficient flight and ground computing and data management

Percent of FY 2012 Investment Dollars in Core, Adjacent, and Complementary Technologies

- Over the next 4 years, NASA will invest:
  - 70% in mission-specific and Core technologies
  - 20% in Adjacent technologies
  - 10% in Complementary technologies

- FY 2012 dollars align with these targeted investment percentages
  - 68% in Core technologies
  - 21% in Adjacent technologies
  - 11% in Complementary technologies



Percent of FY2012 Agency Investment Dollars in Core, Adjacent, and Complementary Technologies

Core Technology Investments

- The Core technologies represent 8 focus areas of technology investment that are indispensable for NASA's present and planned future missions
- Core technologies are the central focus of technology investment and will comprise approximately 70% of the Agency's technology investment of the next 4 years

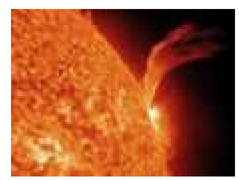
Launch and
In-space Propulsion

High Data-Rate
Communications

Lightweight Space
Structures and
Materials

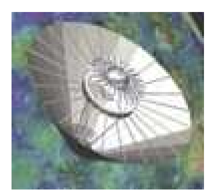
Robotics and
Autonomous Systems

Environmental Control and
Life Support Systems



Space Radiation

Scientific Instruments
and Sensors



Entry, Descent, and
Landing

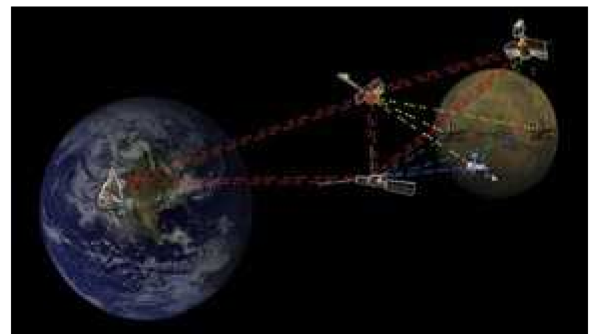
Adjacent Technology Investments

- Adjacent technologies are a significant focus of technology investment and will comprise 20% of the Agency's technology investment over the next 4 years
- Though not part of the Core, these technologies are still high-priority and integral to supporting the 4 pillars of investment
- The following is a sample of the Adjacent technologies:

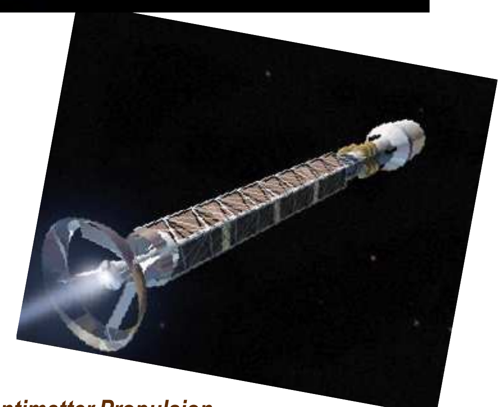
Technology Investment Classification	Associated SSTIP Technical Challenge Area	TABS	Associated NRC High Priorities
Adjacent	Advanced Power Generation, Storage and Transmission; Increased Available Power	3.2	Batteries
Adjacent	Efficient Accurate Navigation, Positioning and Timing	5.4	Timekeeping and Time Distribution
Adjacent	Long Duration Health Effects	6.3	Long Duration Crew Health
Adjacent	Surface Systems	7.4	Smart Habitats; Habitation Evolution
Adjacent	Improved Flight Computers	11.1	Flight Computing; Ground Computing

Complementary Technology Investments

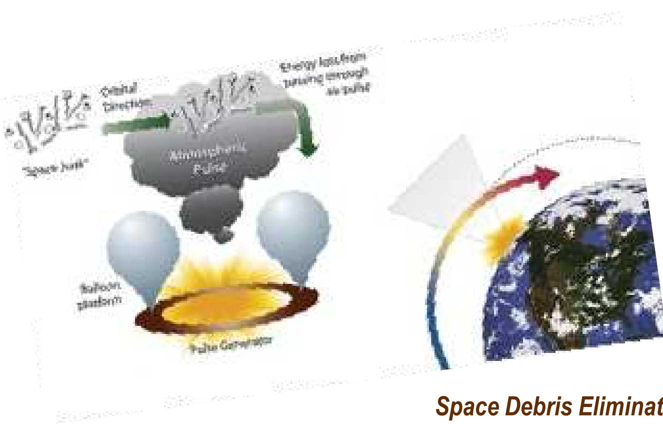
- Opportunities to invest in future technologies beyond nearer term needs
- Will comprise 10% of the Agency's technology investment over the next 4 years
- Investments might include:
  - Concepts for mitigating orbital debris
  - Innovative propulsion concepts
  - Ground processing technologies
  - New information technologies



Information Technologies support space exploration
Source: NASA



Antimatter Propulsion
Source: NASA



Space Debris Elimination (SpaDE)
Source: NASA

NASA Technology Transforms Exploration

- NASA can transform the path for space science and exploration:
  - Providing capabilities fundamental to the Agency's direction and the U.S. space enterprise
  - Supporting scientific, robotic, and human exploration missions through aggressive and prioritized technology investments
  - Seeking transformative opportunities through technology innovations from other parts of the economy
  - Maintaining an Agency space technology base to enable future missions

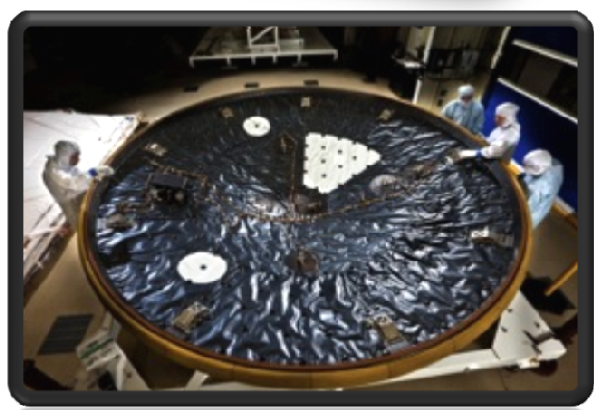
Strategic Space Technology Investment Plan (SSTIP) Summary

- 20-year horizon, investment guidance for next 4 years
- 4 pillars of Agency technology investment, each pillar has:
  - A Goal
  - Capability Objectives
  - Technical Challenges
- 4-year investment approach (focus on subset of pillar content)
  - 70% - 8 Core technologies - Represent 12 of 16 NRC top priority recommendations across 4 pillars
  - 20% - Adjacent Technologies - Not part of the Core but are part of the NRC's 83 high priorities
  - 10% - Seeding Innovation - Smaller Investments in remaining technologies described in the pillars that were not part of the NRC's 83 high priorities.
- Governance – NTEC
- 6 Principles of Investment

CORE TECHNOLOGIES

1. Launch and In-Space Propulsion
2. High Data Rate Communications
3. Lightweight Space Structures
4. Robotics and Autonomous Systems
5. Environmental Control and Life Support Systems (ECLSS)
6. Space Radiation
7. Science Instruments and Sensors
8. Entry, Descent, and Landing

Flying, Building, Testing Technologies For Tomorrow



BACK UP

Alignment of SSTIP Technology Investments with NRC Recommended Technologies

The NRC Top 16 includes a total of 31 technologies derived from the TA Roadmaps

- Relative Guidance Algorithms, 4.6.2
- Onboard Autonomous Navigation and Maneuvering, 5.4.2
- GN&C Sensors and Systems (EDL), 9.4.6

- Rigid Thermal Protection Systems, 9.1.1
- Flexible Thermal Protection Systems, 9.1.2
- Ascent/Entry Thermal Protection Systems, 14.3.1

- ECLSS Water Recovery and Management, 6.1.2
- Air Revitalization, 6.1.1
- ECLSS Waste Management, 6.1.3
- Habitation, 6.1.4

- Radiation Monitoring Technology, 6.5.5
- Radiation Prediction, 6.5.4
- Radiation Risk Assessment Modeling, 6.5.1
- Radiation Mitigation, 6.5.2
- Radiation Protection Systems, 6.5.3

- (Nano) Lightweight Materials and Structures, 10.1.1
- Structures: Innovative, Multifunctional Concepts, 12.2.5
- Structures: Lightweight Concepts, 12.2.1
- Materials: Lightweight Structures, 12.1.1
- Structures: Design and Certification Methods, 12.2.2

NRC Top 16

- Electric Propulsion, 2.2.1
- (Nuclear) Thermal Propulsion, 2.2.3
- Extreme Terrain Mobility, 4.2.1
- GN&C, 4.6, 5.4, 9.4
- EDL TPS, 9.1, 14.3
- ECLSS, 6.1
- Radiation Mitigation for Human Spaceflight, 6.5
- Focal Planes, 8.1.1
- Optical Systems (Instruments and Sensors), 8.1.3
- High Contrast Imaging and Spectroscopy Technologies, 8.2
- In-Situ Instruments and Sensors, 8.3.3
- Lightweight and Multifunctional Materials and Structures, 10.1, 12.1, 12.2
- Active Thermal Control of Cryogenic Systems, 14.1.2
- Solar Power Generation (Photovoltaic and Thermal), 3.1.3
- Fission Power Generation, 3.1.5
- Long-Duration Crew Health, 6.3.2

SSTIP Core Investments

- Launch and In-Space Propulsion, 1.1-1.4, 2.1, 2.2, 2.4
- Robotics and Autonomous Systems, 4.1-4.6, 5.4
- Entry, Descent, and Landing, 9.1-9.4, 14.3
- Environmental Control and Life Support Systems, 6.1
- Space Radiation, 6.5
- Scientific Instruments and Sensors, 8.1-8.3
- Lightweight Space Structures and Materials, 12.1-12.3
- High Data Rate Communications, 5.1, 5.2, 5.5

SSTIP Adjacent Investments

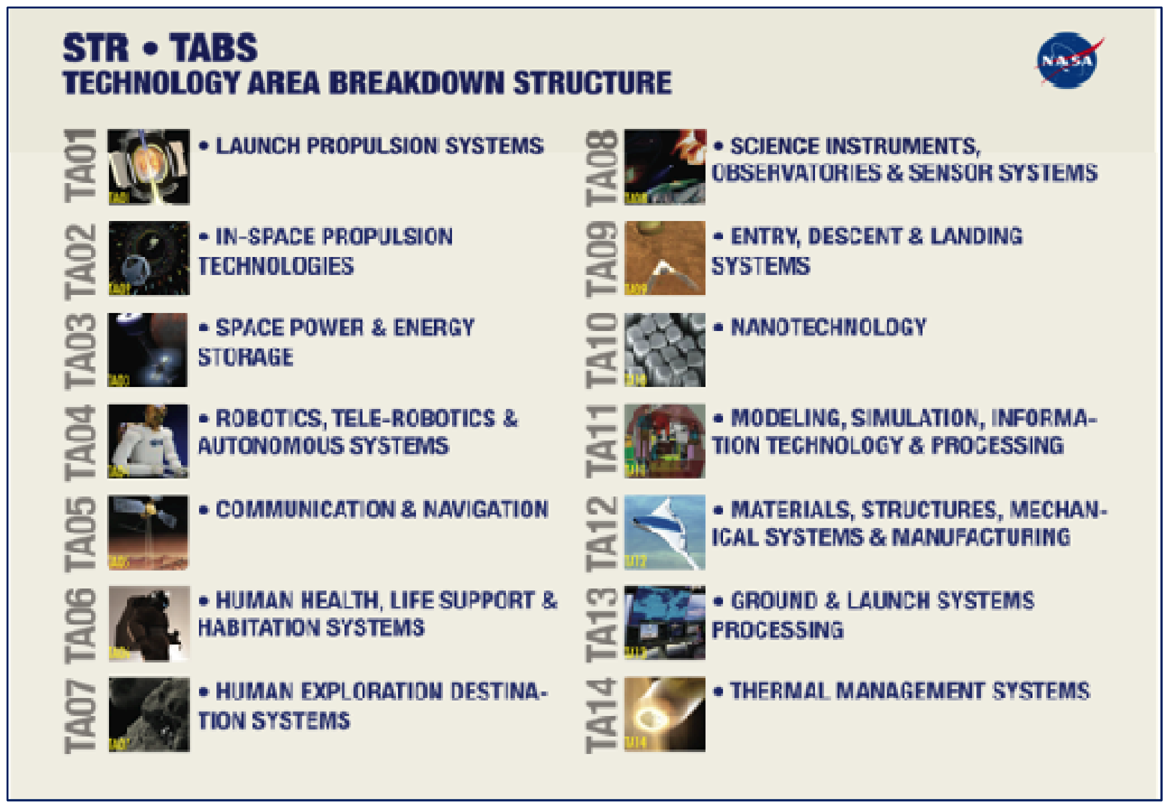
(Adjacent Investments incorporate all 83 NRC high priority technologies not included in Core Investments)

SSTIP Appendices

- Detailed mapping of investment categories to the space technology area breakdown structure and NRC 83 high priorities
- Summary of Agency FY 2012 pioneering and crosscutting investments
- Detailed SSTIP development process and overview of data collected for development
- Updated space technology roadmap technology area breakdown structure
- List of SSTIP contributors

NRC Report on NASA's Space Technology Roadmaps

- At the end of 2010, NASA drafted roadmaps to guide Agency-wide technology investment. The National Research Council (NRC) led a yearlong study to assess these roadmaps, prioritizing prospective technology-investment opportunities in terms of their value to NASA's future and the Nation as a whole.



Space Technology Roadmap Development Process

NASA Process

8: DRAFT NASA STRs
OCT released draft Space Technology Roadmaps to the NRC & to the Public

7: Internal Reviews
Each TA Roadmap reviewed by OCT & extended teams of subject experts

6: Roadmapping Process
Preliminary roadmaps for TA areas

5: Form Starting Point for TA Roadmaps
Assessed past roadmaps; MD & Center inputs

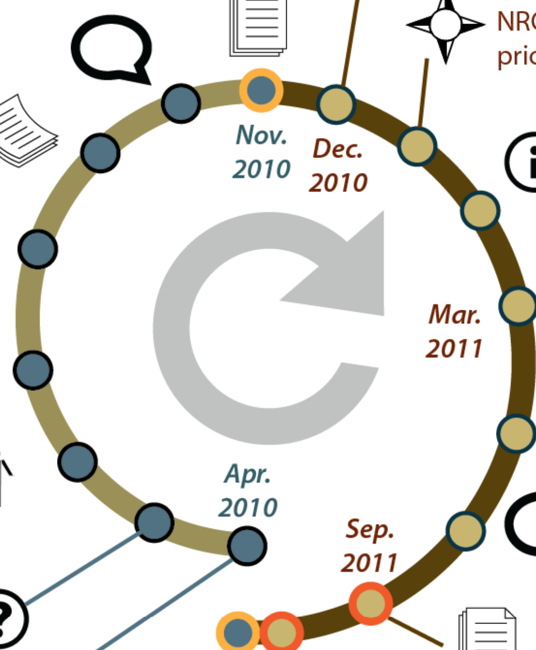
4: Common Approach for TA Teams
Guidelines, assumptions, deliverables

3: Establish TA Teams
OCT established NASA internal 6-member subject expert teams for each TA, with one or two chairs

2: Identify Technology Areas
Identified Technology Areas (TAs)

1: START & Input from MDs & Center
Identified MD Goals, Missions, Architectures & Timelines; MD Technology Roadmaps & Prioritizations; Center Technology Focus Areas

9: FINAL NASA STR REPORTS
NASA released Roadmap Reports



NRC Process

A: Establish NRC Teams
NRC appointed steering committee and 6 panels

B: Identify Common Assessment Approach
NRC established a set of criteria to enable prioritization within and among all TAs

C: Initial Community Feedback
NRC solicited external input from industry & academia

D: Additional Community Feedback
NRC conducted public workshops

E: Deliberations by NRC Panels
NRC panels met individually to prioritize technologies and suggested improvements to roadmaps

F: Documentation by NRC Panels
NRC Panels provided written summary to Steering Committee

G: NRC Interim Findings
NRC released a brief interim report that addressed high-level issues associated with the roadmaps, such as the advisability of modifying the number or technical focus of the draft NASA roadmaps

H: FINAL NRC REPORT
With decisional information, including: summary of findings and recommendations for each of the roadmaps; integrated outputs from the workshops and panels; identified key common threads and issues; priorities, by group (e.g., high, medium, low), of the highest priority technologies from the TAs

NASA Space Technology Roadmaps Process

NRC Recommendations – 3 Technology Objectives and 10 Associated Technical Challenges

Technology Objective A Extend and sustain human activities beyond LEO	Technology Objective B Explore the evolution of the solar system and the potential for life elsewhere (in-situ measurements)	Technology Objective C Expand understanding of the Earth and the universe (remote measurements)
A1. Improved Access to Space	B1. Improved Access to Space	C1. Improved Access to Space
A2. Space Radiation Health Effects	B2. Precision Landing	C2. New Astronomical Telescopes
A3. Long Duration Health Effects	B3. Robotic Maneuvering	C3. Lightweight Space Structures
A4. Long Duration ECLSS	B4. Life Detection	C4. Increase Available Power
A5. Rapid Crew Transit	B5. High Power Electric Propulsion	C5. Higher Data Rates
A6. Lightweight Space Structures	B6. Autonomous Rendezvous and Dock	C6. High Power Electric Propulsion
A7. Increase Available Power	B7. Increase Available Power	C7. Design Software
A8. Mass to Surface	B8. Mass to Surface	C8. Structural Monitoring
A9. Precision Landing	B9. Lightweight Space Structures	C9. Improved Flight Computers
A10. Autonomous Rendezvous and Dock	B10. Higher Data Rates	C10. Cryogenic Storage and Transfer

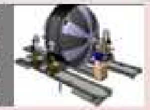
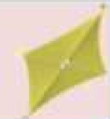
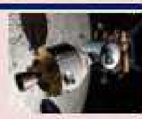
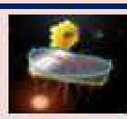
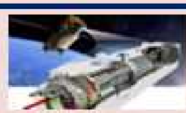
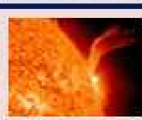
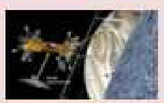
NRC Recommendations – Technology Objectives and Associated Top 16 Technology Priorities

Three technology objectives were defined by the NRC study steering committee

- Technology Objective A: Extend and sustain **human activities beyond low Earth orbit**. Technologies to enable humans to survive long voyages throughout the solar system, get to their chosen destination, work effectively, and return safely.
- Technology Objective B: Explore the evolution of the solar system and the potential for life elsewhere. Technologies that enable **humans and robots to perform in-situ measurements** on Earth (astrobiology) and on other planetary bodies.
- Technology Objective C: Expand our understanding of Earth and the universe in which we live. Technologies for **remote measurements** from platforms that orbit or fly by Earth and other planetary bodies, and from other in-space and ground-based observatories.

Top 16 Technology Priorities and Relative Rankings by Objective		Tech Objective A	Tech Objective B	Tech Objective C
2.2.1	Electric Propulsion		#3	#6
2.2.3	(Nuclear) Thermal Propulsion	#5		
3.1.3	Solar Power Generation (Photovoltaic and Thermal)	#7	#2	#7
3.1.5	Fission (Power)		#4	
4.2.1	Extreme Terrain Mobility		#8	
6.3.2	Long-Duration (Crew) Health	#2		
8.1.1	Detectors & Focal Planes			#3
8.1.3	(Instrument and Sensor) Optical Systems			#1
8.2.4	High-Contrast Imaging and Spectroscopy Technologies			#2
8.3.3	In Situ (Instruments and Sensor)		#6	
14.1.2	Active Thermal Control of Cryogenic Systems			#5
X.1	Radiation Mitigation for Human Spaceflight	#1		
X.2	Lightweight and Multifunctional Materials and Structures	#6	#7	#4
X.3	Environmental Control and Life Support System	#3		
X.4	Guidance, Navigation, and Control	#4	#1	
X.5	Entry, Descent, and Landing Thermal Protection Systems	#8	#5	

How the "Big 9" Map to Technology Investments

Technology Investments			"Big 9"
Core		Launch and In-space Propulsion	Composite Cryotank Tech and Demo  Cryogenic Propellant Storage and Transfer  Mission Capable Solar Sail 
Core		High Data-Rate Communications	Laser Comm. Relay Demo. 
Core		Lightweight Space Structures and Materials	
Core		Robotics and Autonomous Systems	Human Robotic Systems  Robotic Satellite Servicing 
Core		Environmental Control and Life Support Systems	
Core		Space Radiation	
Core		Scientific Instruments and Sensors	
Core		Entry, Descent, and Landing	Hypersonic Inflatable Aerodynamic Decelerators  Low Density Supersonic Decelerators 
Adjacent			Deep Space Atomic Clock 

Acronyms

ECLSS	Environmental Control and Life Support Systems
EDL	Entry, Descent, and Landing
NAC	NASA Advisory Council
NRC	National Research Council
NTEC	NASA Technology Executive Council
OCT	Office of the Chief Technologist
OMB	Office of Management and Budget
SSTIP	Strategic Space Technology and Investment Plan
STEM	Science, Technology, Engineering, and Mathematics
STP	Space Technology Program
T&I	Technology and Innovation
TRL	Technology Readiness Level