National Aeronautics and Space Administration

NASA Technology Programs

- 2013 Update
- Basic Engineering Sciences

Dr. Mason A. Peck
NASA Chief Technologist

Overview

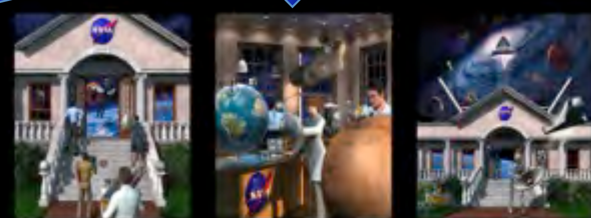
- Office of the Chief Technologist and the new Space Technology Mission Directorate
- Foundational engineering research
- The state of NASA technology programs in 2013
  - STMD, AES, SMD
  - Strategic Space-Technology Investment Plan (SSTIP)
  - Spinoffs and Tech Transfer
- Some new paradigms

Office of the Chief Technologist

Serves as Advisor to Administration

Integrates Technology Investment Across the Agency

New STMD: Direct Technology Management and Budget Authority for the Space Technology Program



Office of the Chief Technologist

Leads Tech Transfer, Partnerships and Commercialization Activities Across the Agency

Advocates Externally NASA's R&D Programs

Demonstrates and Communicates Societal Impacts of NASA Technology Investments

OCT and STMD

Following the successful formulation and implementation of the Space Technology program, NASA separated the Office of the Chief Technologist (OCT) into two organizations: OCT and the Space Technology Mission Directorate (STMD).

Space Technology Mission Directorate

- Has direct management and budget authority of the Space Technology programs, which are performed by all 10 NASA Centers;
- Focuses on project execution and technology infusion into the Agency's exploration and science mission needs;
- Takes a customer driven approach, proving capabilities needed for future NASA missions and the national aerospace community; and
- Develops the Nation's innovation economy.

Office of the Chief Technologist

- Serves as the Administrator's principal advisor and advocate on matters concerning Agency-wide technology policy and programs;
- Advocates for innovation through new economic models and partnerships
- Leads NASA's technology transfer and commercialization efforts; and
- Integrates, tracks, and coordinates all of NASA's technology investments and conducts strategic planning and policy development for technology activities, including the Technology Roadmaps and the Strategic Space Technology Investment Plan

This realignment does not affect the mission, content or budget authority of the Space Technology Programs.

Science and Technology?

Scientists discover the world that exists; engineers create the world that never was.

Theodore von Kármán

Science and Technology?

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

OMB Circular No. A-11 **Conduct of R&D****

6.1 Basic Research:	A study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products.
6.2 Applied Research:	Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.
6.3 Development:	Is directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

NASA's Basic Research in Engineering (in a Nutshell)

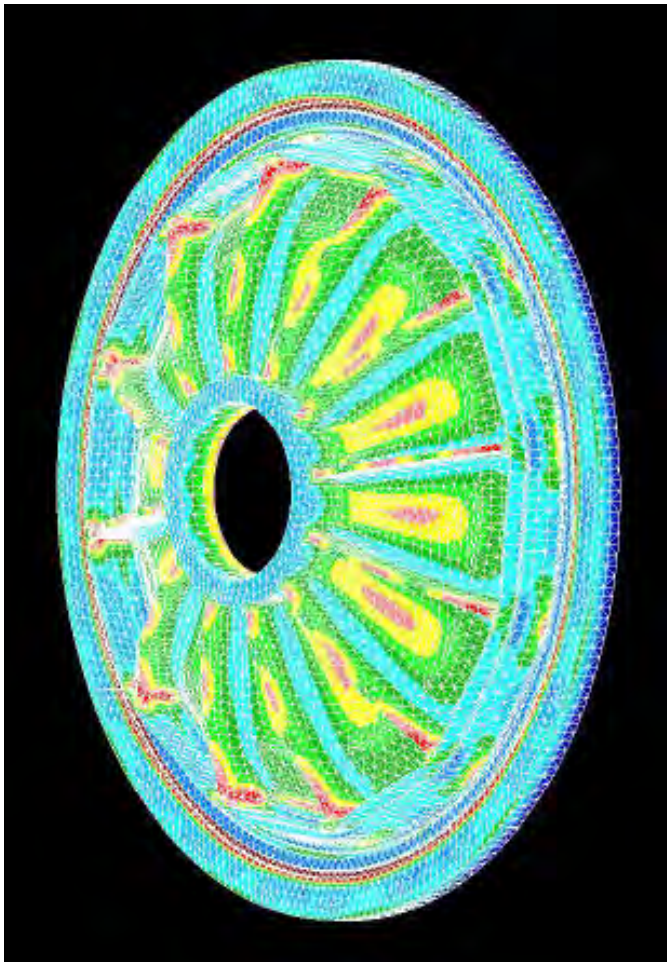
NASA performs and sponsors research in engineering science.

- Discoveries inform NASA's portfolio in space and aeronautics technology but are not technology development *per se*.
- This basic research is pre-TRL, not the applied technology development that is now part of the new Space Technology Mission Directorate.

NASA's investments in engineering research were once the basis of a successful national research enterprise in aerospace engineering sciences, both at NASA centers and in academia

- Near-term priorities in the past decade or more have resulted in a severely diminished investment.
- The NRC and others have flagged this as an area requiring more attention than has been given in recent years if the nation is to remain economically competitive in aerospace.

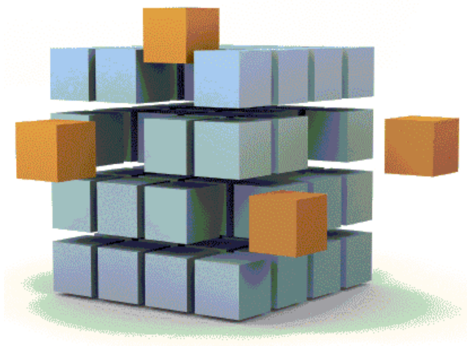
Now OCS, OCT, OCE working to bring together and prioritize engineering-science research, including internally directed and externally sponsored pre-TRL work.

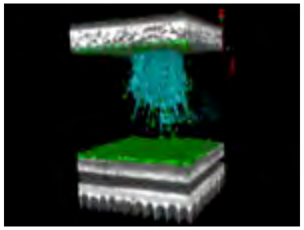


SpaceShipOne motor bulkhead analyzed in NEi NASTRAN

NASA's Engineering Science Investments

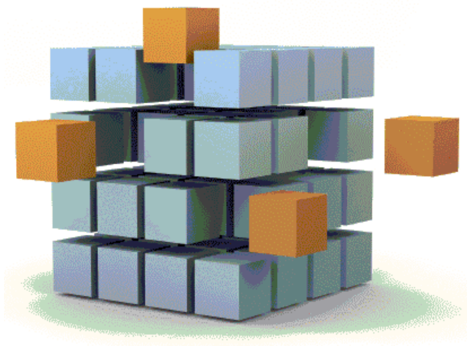
- **Foundational engineering science**
  - Provides the raw material for innovation, inventions, and discoveries; leads to new and unexpected solutions to major technical and cost barriers
  - Creates deeper expertise and knowledge
  - Improves the prediction, analysis, and design of engineered systems

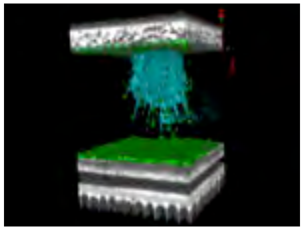




NASA's Engineering Science Investments

- **Foundational engineering science**
  - Combines basic engineering science with research in engineering methods
  - **BES**: Basic research in engineering science (BES) explores unknown or poorly understood scientific areas underlying engineering; provides the raw material for innovation, inventions, and discoveries, and leads to new and unexpected solutions to major technical barriers
  - **REM**: Research in engineering methods (REM) conceives the engineering tools, standards and techniques required for advances in engineering





NASA's Engineering Science Investments

- **Investments in engineering science have severely eroded over the last two decades and continue to diminish due to unrelenting budget pressures, resulting in**
  - Curtailment or elimination of funding for foundational engineering: eating our seed corn
  - Trying to solve new and more complex problems using our past engineering creativity
  - No organization being left with a critical mass of relevant activities and thus, the ability to adequately guide or coordinate Foundational Engineering Science investments across the Agency has been lost.
  - NASA's plans to go beyond LEO pose tremendous technical and cost challenges; revolutionary approaches are needed, which will come only thanks to basic research in these areas

NASA's Engineering Science Investments

- **The issue has also been highlighted by OSTP, OMB, and independent advisory groups:**
  - 2010 NRC Assessment Report:

    "the fundamental research community supported by NASA, both internally and externally, **has been severely impacted by these budget reductions and that the ability to achieve future NASA goals is in serious jeopardy**."

  - The NASA Advisory Council:

    "…that the Chief Technologist collaborate with the Chief Scientist and the Chief Engineer to establish formal guidance and to consolidate, and seek future funding for, space basic research in engineering science. The Council further suggests **that NASA begin by managing the Agency's space basic research portfolio as a pilot activity that is funded separately from the Space Technology Program**, similar to how the Office of Chief Technologist coordinates the Agency's technology portfolio."

NASA's Engineering Science Investments

- **A Foundational Engineering Sciences program or office would**
  - Develop the strategy for a program to provide foundational engineering knowledge and tools across the agency;
  - Coordinate the Agency's entire basic engineering science portfolio with strong linkages to NASA's science, technology, and engineering activities
  - Sponsor a cohesive portfolio of basic engineering science activities at NASA centers, academia, and other organizations as appropriate.
  - Seek to infuse the new engineering tools, techniques and standards into standard NASA practice.
  - Seek to identify 'on-ramps' into technology development for the knowledge gained in the basic engineering science studies
  - Seek to leverage and coordinate NASA basic engineering science activities with relevant activities in other agencies, as well as the industrial and academic sectors.
  - Seek to ensure that SME knowledge and capabilities remain at the cutting edge, which has repeatedly proven necessary to solve NASA's practical problems

NASA's Engineering Science Investments

- **Examples of potential investment areas**
  - Materials for NASA's Future (examples follow)
  - Engineering Biology in Exploration and Space Science
  - Advanced Communication Science
  - Underlying Physics of Advanced Energy in the Space Environment
  - Astrodynamics, Celestial Mechanics, and Navigation
  - Modeling and Simulation Methods unique to Exploration and Space Science
- **Focus on high priorities for NASA while leveraging OGA investments (e.g., materials science by DoE, DoD)**
- **Combination of external engagement (partnerships & sponsorship of academia, OGAs, industry) and internal engagement (directed work)**

EXAMPLE:
NASA's Unique Needs in Materials Science

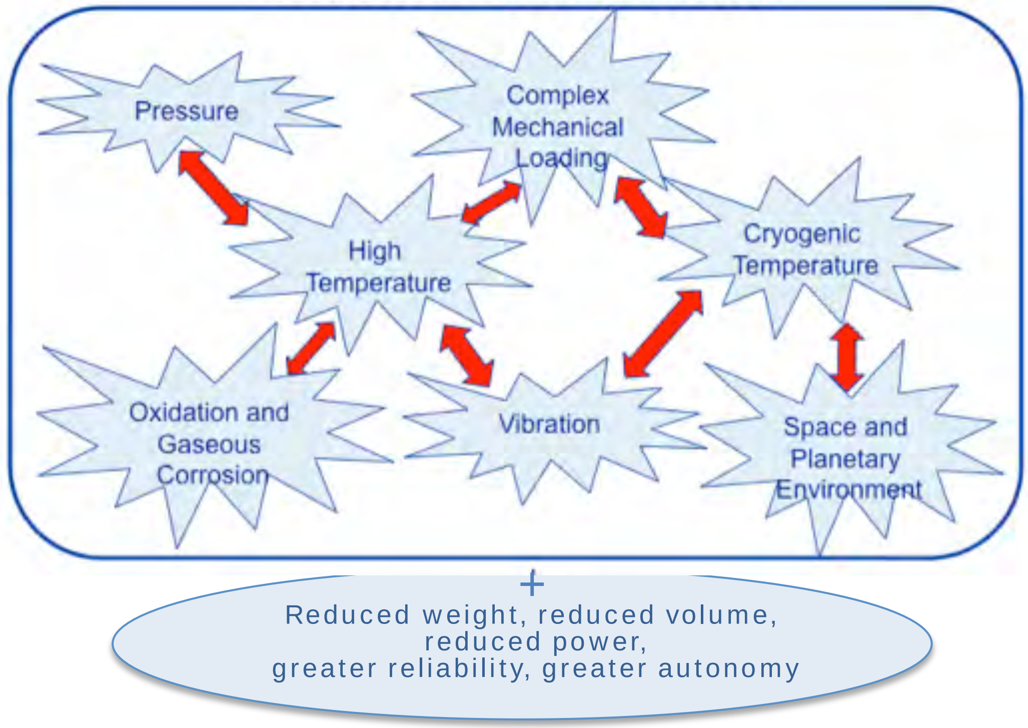
Focus on NASA-unique needs

- requirement for materials to perform well in harsh space environment (vacuum, radiation, microgravity beyond LEO), while simultaneously requiring less mass, volume, power, and achieving greater reliability and autonomy – these needs are different from needs of every other agency

Explore and Exploit Space

- use fundamental space experiments to gain new understanding with commercial benefit (e.g. through ISS utilization)

Extreme Environments



Dendrites grown in space in the Isothermal Dendritic Growth Experiment

Basic materials science space experiment in 1990's produced Internationally recognized benchmark property data – critical to metallurgists and the casting industry

Historical Impact of Materials Science at NASA

Material Design

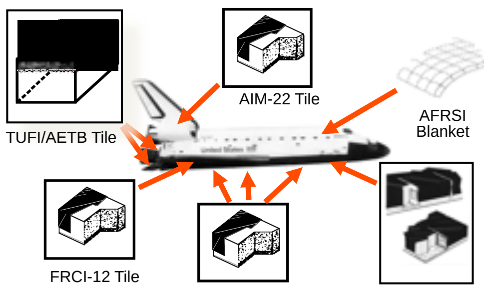
1970 – Fundamental physics of fatigue crack growth life prediction identified by NASA

1980's – NASGRO predictive modeling conceived and developed by NASA

1990's – Further developed by NASA / FAA / USAF

2000's – Widespread usage; industry standard

Material Synthesis



Orbiter TPS

Early 1980's – Basic research for Al-Li alloys with the aim of increasing specific strength & specific stiffness.

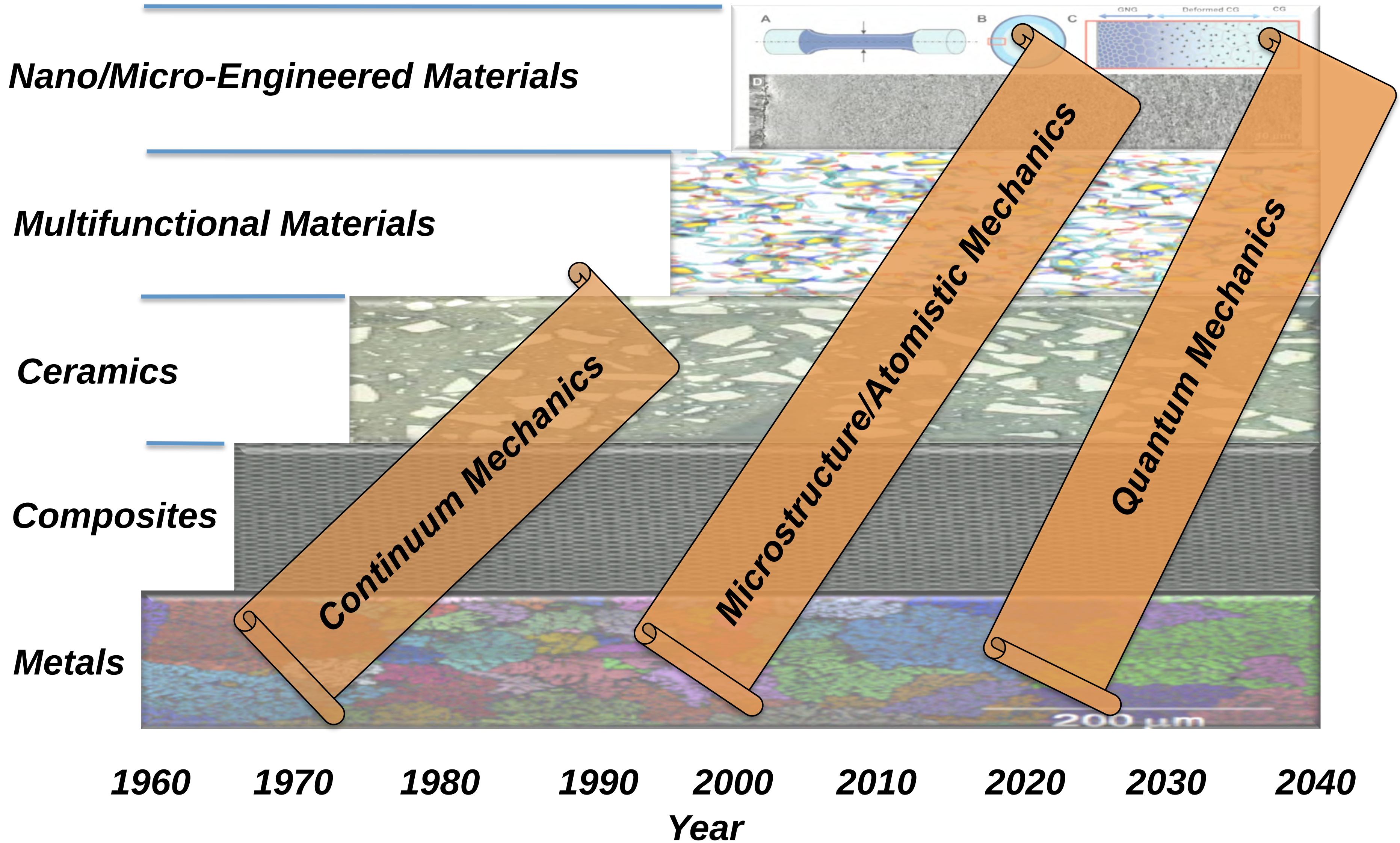
1998 - Al-Li 2195 for Shuttle super lightweight fuel tank enables ISS heavy module delivery to orbit

Spinoff: USAF F-16 redesigned bulkhead developed with Al-Li

NASA's resources toward basic research in aerospace materials has been declining for approx. 20 years

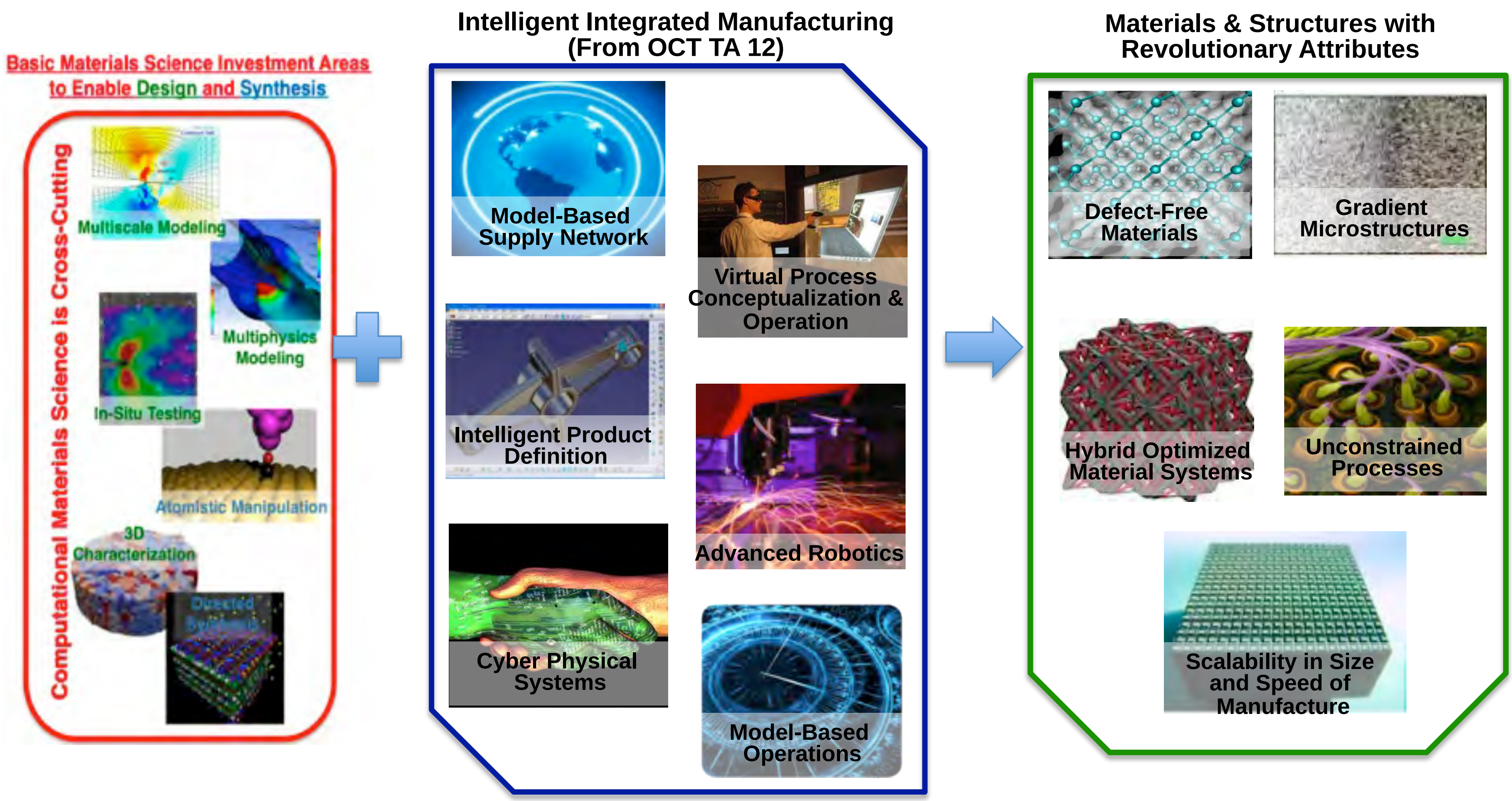
- Basic research is aimed not at specific applications; instead it is the foundation that leads to many applications.
- For nearly a generation, NASA has concentrated on short-term, applied research, though it is founded on the basic research done long ago by NASA's materials science workforce, only some of whom remain active today.

State-of-the Art in Modeling Approaches for Various Classes of Materials



Strategic View: Materials and Manufacturing

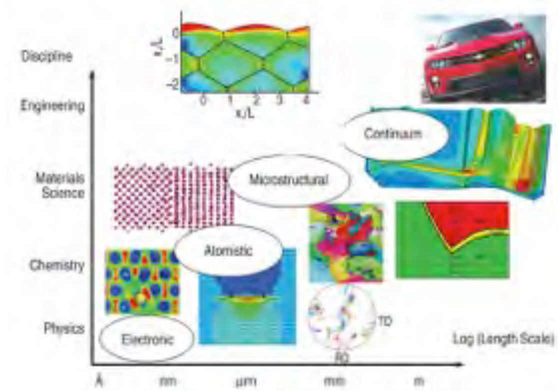
- Fully exploit the results of the basic materials science program by interfacing with elements of intelligent integrated manufacturing to enable development of revolutionary materials and structures



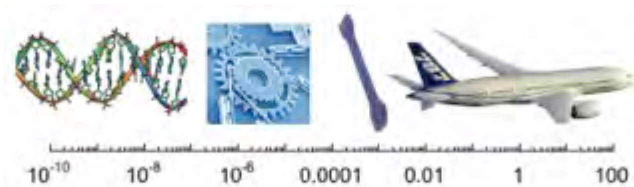
An Opportune Time for Materials Science at NASA: Leverage Current Investments by Others

- DoE, DoD, industry are making tremendous advances in basic materials modeling, characterization and synthesis
- Achieving NASA's mission places extreme, simultaneous demands on materials "ilities:" *durability, tailorability, multifunctionality, environmental & thermal stability, mass efficiency…*
- NASA can leverage what they are doing and focus on the specific scientific advances needed to meet NASA's challenging mission demands

DOD:AFRL/Materials & Manufacturing Directorate
AFRL/Structural Sciences Center
ONR/Materials in Extreme Environments
DARPA/Multifunctional Materials
etc…



Industry: Atoms to Autos



Industry: Atoms to Airplanes

OSTP: Materials Genome Initiative

DOE: Basic Energy Sciences research and user facilities—Spallation Neutron Source and Synchrotron Facilities

NASA's Engineering Science Investments: Summary

- **Investments in foundational engineering science (BES and REM) have severely eroded over the last two decades and continue to diminish due to unrelenting budget pressures**
- **A formal program or office to conduct basic research in engineering science at NASA, along with appropriate leadership, could remedy the situation by**
  - developing the strategy for foundational engineering knowledge and tools across the agency
  - creating and coordinating a cohesive foundational engineering science portfolio
  - infusing new engineering tools, techniques and standards into NASA practice
  - leveraging NASA foundational engineering science activities with relevant activities in other agencies, as well as the industrial and academic sectors

NASA's Basic Research - Summary

If you don't invest in basic research at some stage you start losing the basis of applied research.

Rolf-Dieter Heuer, Director General of CERN

NASA Technology Programs

Summary of Program Content and 2013 Budget Impacts

- Space Technology Mission Directorate
- Advanced Exploration Systems and the Human Research Program in HEOMD
- Technology programs in the Science Mission Directorate
- Aeronautics technology
- Information Technology

Space Technology Directorate projects impacted by CR & Sequestration

Funding reductions impact multiple STMD programs & projects

Reformulating –

- Materials International Space Station Experiment (MISSE-X)
- Advanced Radiation Protection (ARP)

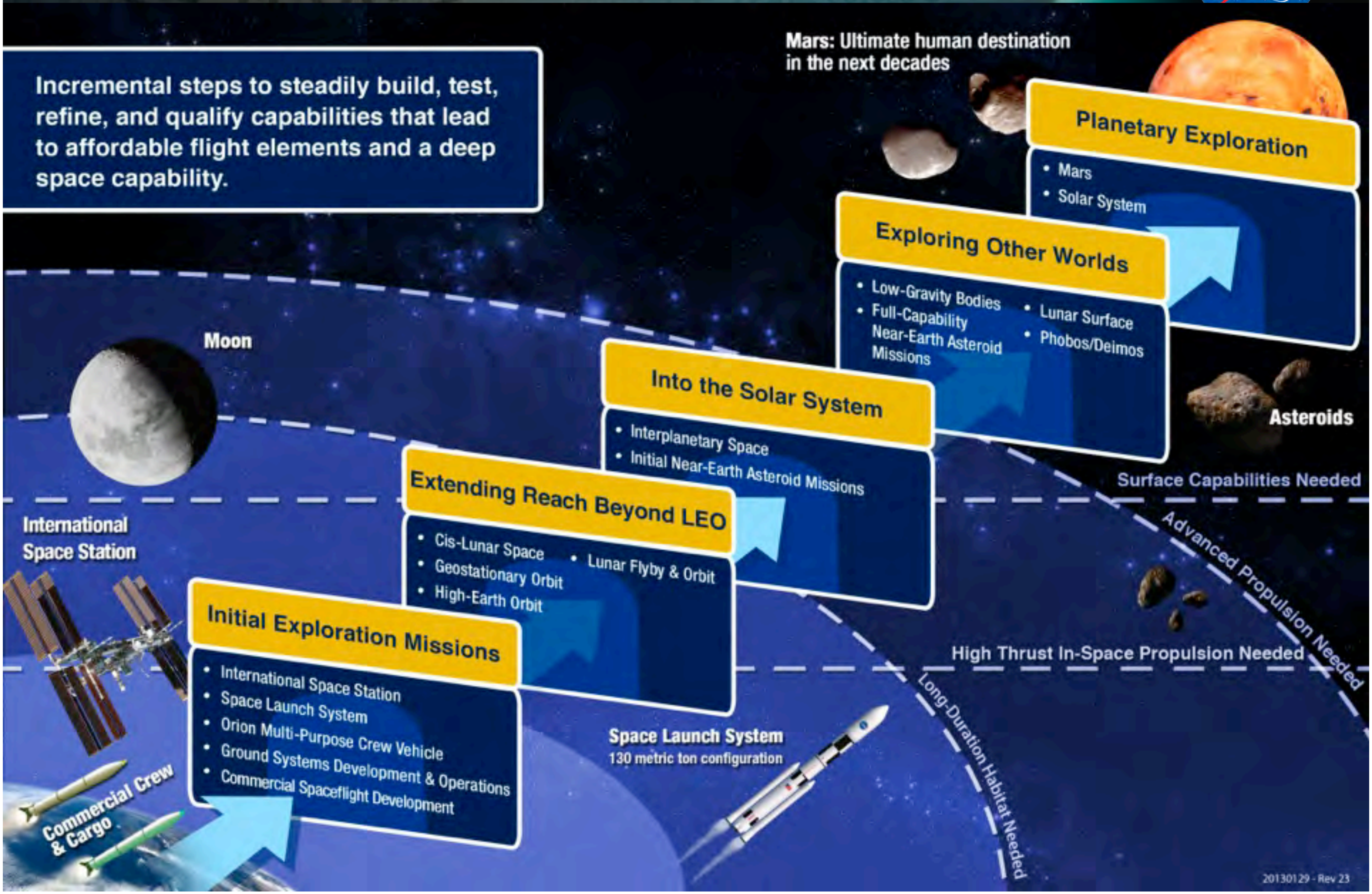
Descoping –

- Deep Space Optical Communication (DSOC)
- Autonomous Systems (AS)
- Hypersonic Inflatable Aerodynamic Decelerator (HIAD)
- Hypersonic Entry, Descent, and Landing
- Deployable Aeroshell Concepts

Delaying –

- Nuclear Systems (NS)
- HIAD Earth Atmospheric Re-entry Test (HEART)

Human Space: Capability-Driven Framework



AES Pioneers Innovative Approaches for Affordably Developing New Capabilities

AES uses a skunkworks-like model:

- Rapid development of prototype systems
- Project teams are multi-disciplinary, highly collaborative, and work across organizational lines.
- Teams consist primarily of NASA personnel, and most of the work is performed in house.

AES uses a range of development tactics:

- Maintains critical competencies at the NASA Centers and provides NASA personnel with opportunities to learn new skills and gain hands-on experience
- Leverages partnerships with external organizations to amplify investments. Partnerships include CSA for in-situ resource utilization, CERN for radiation sensors, and DOE for nuclear propulsion.
- Through NASA's Center of Excellence for Collaborative Innovation (COECI), explores new models for problem solving using open innovation and crowd sourcing:
  - The NASA Tournament Lab sponsors competitions to engage the public in developing software to solve NASA challenges.
  - The COECI is working with OSTP to implement collaborative innovation across the Government.

Advanced Exploration Systems (AES)

Rapid development and testing of prototype systems and validation of operational concepts to reduce risk and cost of future exploration missions:

Crew Mobility Systems

- Systems to enable the crew to conduct "hands-on" surface exploration and in-space operations, including crew excursion vehicles, advanced space suits, and crew egress

Deep Space Habitation Systems

- Systems to enable the crew to live and work safely in deep space, including deep space habitats, reliable life support, radiation protection, and fire safety

Vehicle Systems

- Systems for in-space propulsion stages and small robotic landers, including nuclear propulsion, modular power systems, lander technology test beds, and autonomous precision landing

Operations

- Systems to enable more efficient mission and ground operations, including integrated testing, autonomous mission ops, integrated ground ops, and logistics reduction

Robotic Precursor Activities

- Acquire strategic knowledge on potential destinations for human exploration to inform systems development, including prospecting for lunar ice, characterizing the Mars surface radiation environment, radar imaging of NEAs, instrument development, and research and analysis

Major FY13 AES Milestones

Established 63 project milestones for FY13. Goal is to achieve at least 80%.

Highlights include:

Nov 2012	**Spacecraft Fire Safety**: Complete Mission Concept Review and Systems Requirements Review
Jan 2013	**Radiation Protection**: Complete the Critical Design Review for the EFT-1 Radiation Environment Monitor
May 2013	**Bigelow Expandable Activity Module**: Complete Phase 1 Safety Review
May 2013	**Deep Space Habitat:** Complete Systems Definition Review for MPLM-based deep space habitat
Jul 2013	**Morpheus/ALHAT**: Complete KSC flight tests of ALHAT on Morpheus lander to demonstrate autonomous hazard detection and avoidance.
Jul 2013	**EVA**: Complete assembly and integrated testing of Portable Life Support System 2.0 to validate schematic and packaging concept.
Aug 2013	**Habitable Airlock**: Test mockup Habitable Airlock with crew in Neutral Buoyancy Facility
Sep 2013	**RESOLVE**: Complete Mission Concept Review.

HEOMD / STMD Programmatic Synergy

Exploration Technology Development (ETD) work resides in two Space Technology Programs:

- Game Changing Development (GCD)
- Technology Demonstration Missions (TDM)

Focus:

- cross-cutting, pioneering technology development
- not system integration
- TRL 7 or below
- Infusion into HEO or other MDs

AES Program within HEOMD manages system-level integration work and prototype / design development for future exploration architecture elements.

The Human Research Program (HRP) undertakes technology development and basic research in related areas, e.g. radiation mitigation

HEOMD / STMD Synergistic Objectives

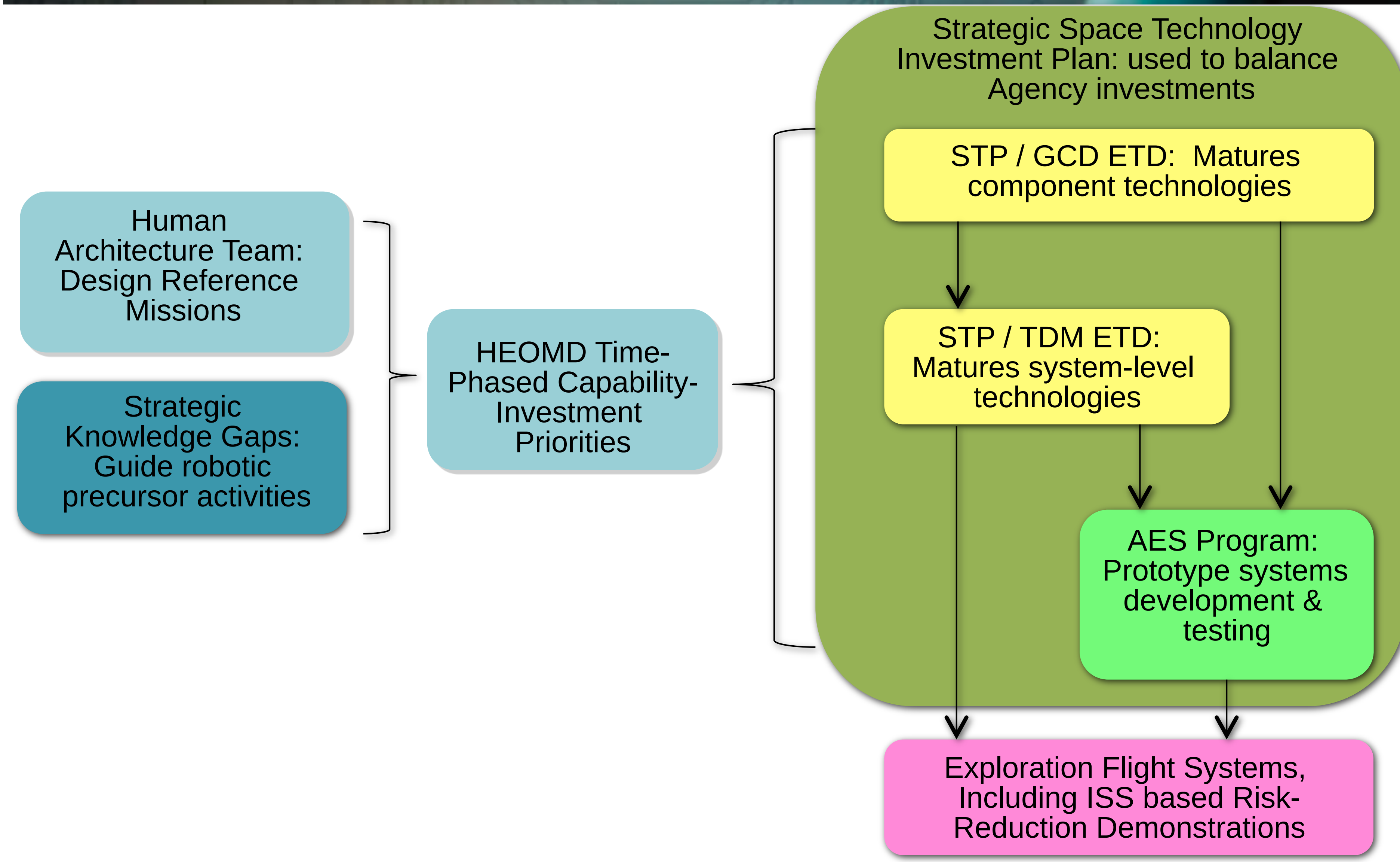
Exploration Technology Development (STMD)

- Develop long-range foundational technologies and components to support human exploration needs.
- Conduct flight demonstration missions of high-priority exploration capabilities such as cryogenic propellant storage and solar electric propulsion.
- Mature technologies for infusion into mission-level programs and agency initiatives.
- Leverage synergies with game-changing and crosscutting technologies to support multiple customers and mission applications.

Advanced Exploration Systems (HEOMD)

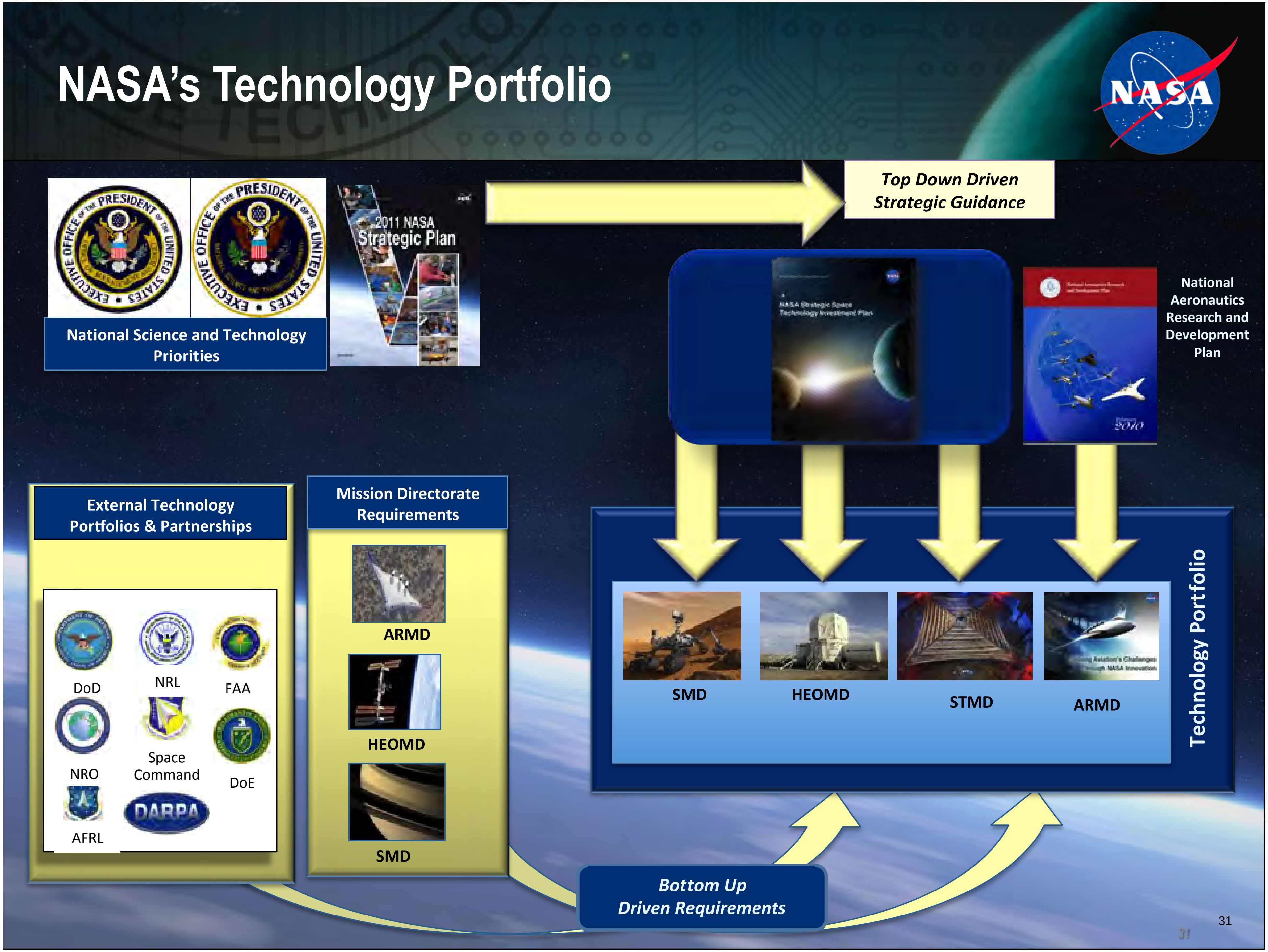
- Advanced development of exploration systems to reduce risk, lower lifecycle cost, and validate operational concepts for future human missions beyond Earth orbit.
- Demonstrate prototype systems in ground test beds, field tests, underwater tests, and ISS flight experiments.
- Use and pioneer innovative approaches for affordable rapid systems development and provide hands-on experience for the NASA workforce.
- Maintain critical competencies at the NASA Centers and provide NASA personnel with opportunities to learn new and transform skills.
- Infuse new technologies developed by STP / ETD into exploration missions.
- Support robotic missions of opportunity to characterize potential destinations for human exploration.

Guidance for the Combined AES/STMD Portfolio



Technology in the Science Mission Directorate

- **General principle: SMD technology investments are guided by identified science objectives**
  - Instrumentation is a key area for SMD investment
  - Low TRL investments address long range mission recommendations provided by the National Research Council, and when they are narrowly focused on SMD priorities (vs. cross-cutting priorities taken on by STMD)
- **Programmatic technology funding:**
  - Strategic mission budget lines include support for focused technology maturation
  - Technology development is also supported via R&A grants programs, keyed once again to the science impact anticipated
  - SMD’s suborbital program (aircraft, sounding rockets, and balloons) is a major vehicle for technology demonstration, especially instrumentation; many space-mission instruments are derived from these programs
  - Earth science has a dedicated office, the Earth Science Technology Office, that identifies and supports high priority instrumentation development for flight on research satellites in that field
- **The cost-capped, PI-led mission lines tend to be technologically conservative, benefiting from advances in other program areas**


NASA's Technology Portfolio
NASA
National Science and Technology Priorities
2011 NASA Strategic Plan
Top Down Driven Strategic Guidance
NASA Strategic Space Technology Investment Plan
National Aeronautics Research and Development Plan
2010
External Technology Portfolios & Partnerships
DoD
NRL
FAA
NRO
Space Command
DoE
AFRL
DARPA
Mission Directorate Requirements
ARMD
HEOMD
SMD
SMD
HEOMD
STMD
ARMD
Technology Portfolio
Bottom Up Driven Requirements
31

NASA Space Technology Roadmaps

TA01


- LAUNCH PROPULSION SYSTEMS

TA02


- IN-SPACE PROPULSION TECHNOLOGIES

TA03


- SPACE POWER & ENERGY STORAGE

TA04


- ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS

TA05


- COMMUNICATION & NAVIGATION

TA06


- HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

TA07

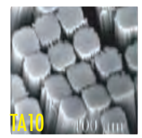

- HUMAN EXPLORATION DESTINATION SYSTEMS

TA08


- SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS

TA09


- ENTRY, DESCENT & LANDING SYSTEMS

TA10


- NANOTECHNOLOGY

TA11


- MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

TA12


- MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

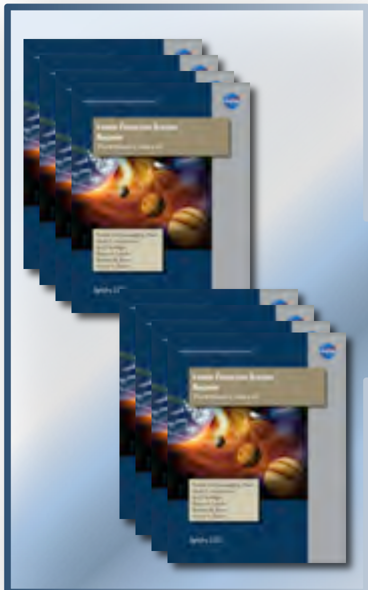
TA13

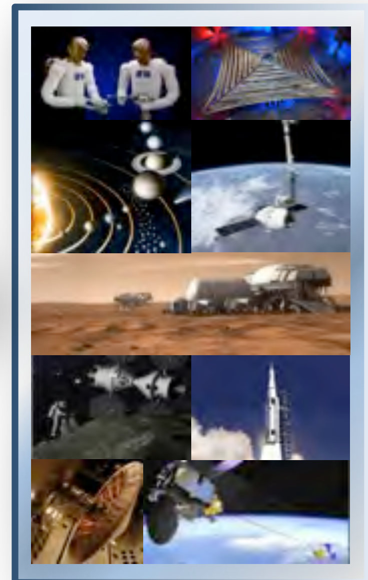

- GROUND & LAUNCH SYSTEMS PROCESSING

TA14


- THERMAL MANAGEMENT SYSTEMS

SSTIP Development





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 Development

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

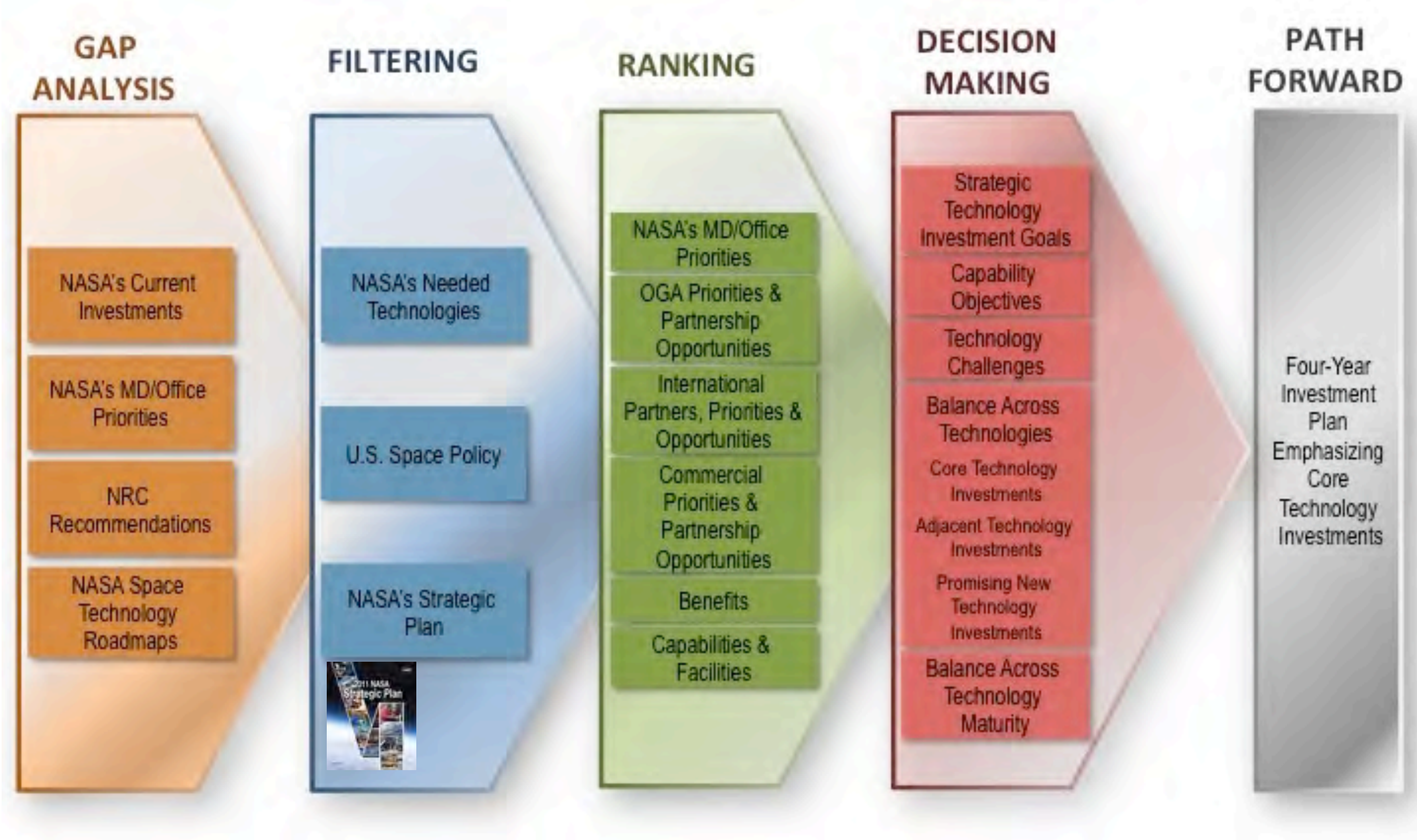
2013

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

SSTIP Development Process



SSTIP Content Overview

Framework

- Goals with capability objectives and technical challenges

4-year Investment Approach

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

Governance – NASA Technology Executive Council (NTEC)

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*

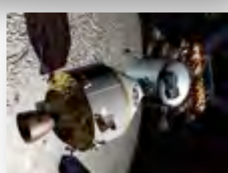
Complementary:
- *10% investment*
- *Does not include core or adjacent*
- *Does include the remaining technology capabilities in the goals and corresponding Space Technology Roadmaps*
- *Seeds innovation providing some early development in technologies that are not needed immediately*
- *Provide technologies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

Download the SSTIP: http://www.nasa.gov/pdf/726166main_SSTIP_02_06_13_FINAL_hires=TAGGED.pdf

SSTIP Overview
Core Technology Investments

- 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 (= highest investments now)

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 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 of high priority and integral to supporting the 4 goals of investment

Example Adjacent technologies:

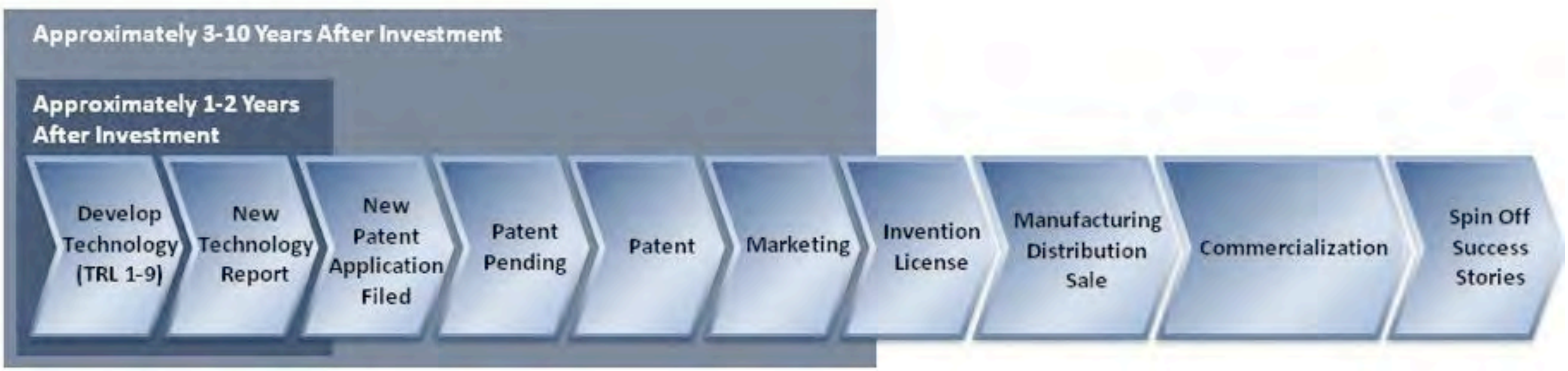
Technology Investment Classification	Associated SSTIP Technical Challenge Area	TABS	Associated NRC High Priorities
Adjacent	Advanced Power Generation, Storage and Transmission; Increased Available Power	3.2	Batteries
Adjacent	Efficient Accurate Navigation, Positioning and Timing	5.4	Timekeeping and Time 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

SSTIP Overview
Principles of Investment and Execution

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

<u>Principles Guide Future Portfolio Investment and Execution</u>

- Achieve the agreed upon balance among investments:
  - Across all 14 Space Technology Areas in the Roadmaps
  - Across all levels of technology readiness
- Ensure developed technologies are infused into Agency missions
- Develop technologies through partnerships and ensure developed technologies are infused throughout the domestic enterprise
- Use a systems engineering approach when planning technology investments
- Reach out to the public and share information about its technology investments



NASA Technology Transfer Goals

Raise the economic impact and public benefit of NASA's technologies by increasing the rate, volume, and quality of the technologies it transfers to industry, academia, and other Government agencies.

NASA Technology Transfer Benefits Life on Earth

- Each year since 1976, Spinoff magazine highlights 40-50 NASA technology transfer successes from the prior year.

- Nearly 1,700 Spinoff stories are available online in a searchable format at: http://www.sti.nasa.gov/spinoff/database

- National media continues to focus on commercialization benefits of NASA technologies. OCT has initiated a new weekly web series entity entitled "Space Tech Improving our Lives" at: http://www.nasa.gov/oct

- We can, and will, do more.

Some New Paradigms

- The 2014 STIP will incorporate information technologies and aeronautics. 2014 will kickoff the first Space Technology Roadmaps revision.

- Supporting emerging, entrepreneurial space enterprises

- Broadening of NASA's portfolio of space-systems paradigms for innovative science
  - including citizen science, hosted payloads, small sats
  - put potential science P.I. s in the same room with technologists to exploit the opportunities of ‘technology push’

- Multi-industry, multi-agency innovative partnerships that consist of collaborations on hard problems--grand challenges where no-one, not even NASA, can go it alone.