National Aeronautics and Space Administration

Strategic Technology for NASA’s Science Mission Directorate (SMD)

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Presentation to NASA Advisory Council - 1 December 2014

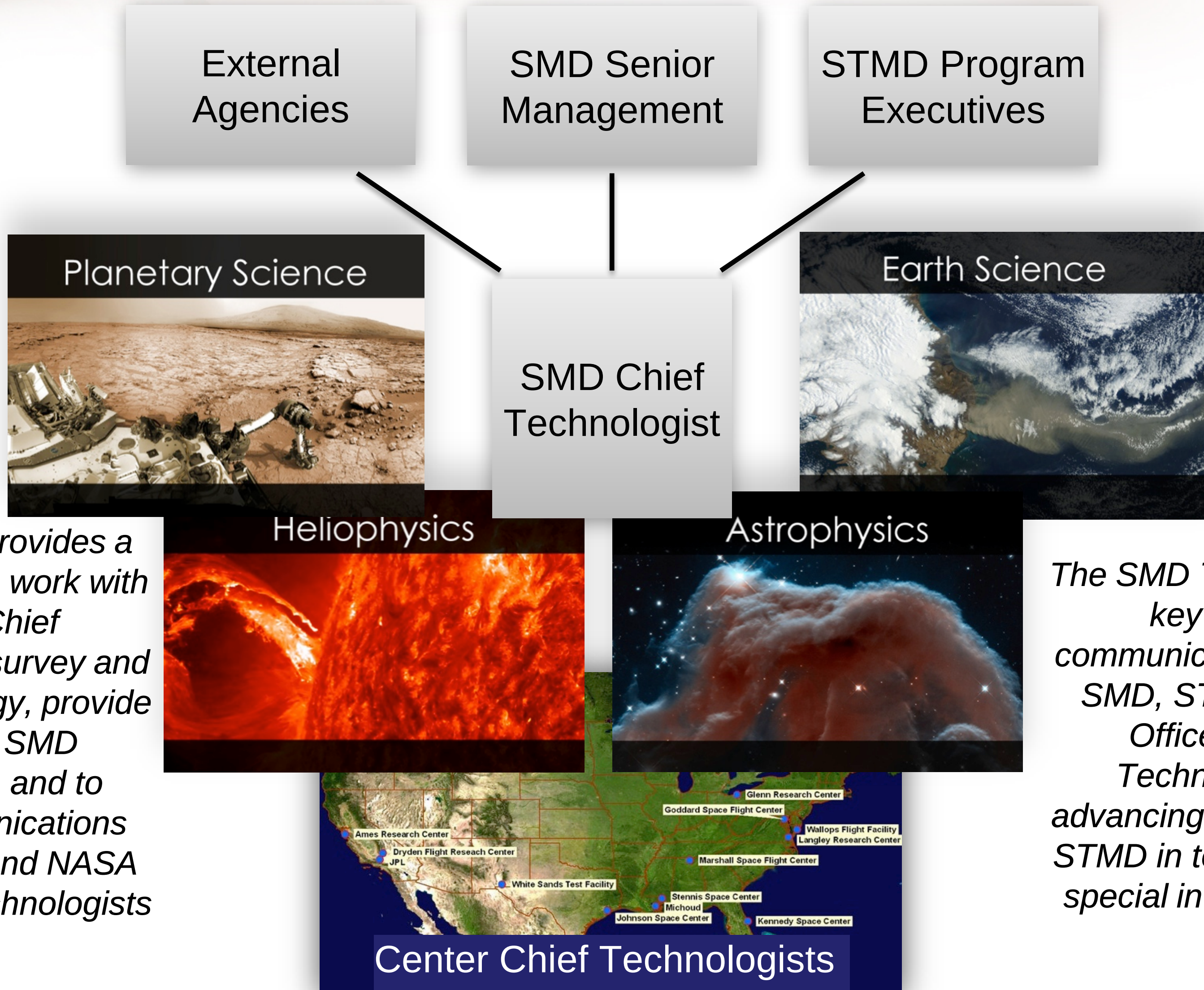
Background

Recommendation:
The Council recommends that the STMD AA & SMD AA engage with each other and their communities to determine how policies and procedures could be modified to allow the infusion of new mission-enabling and mission-enhancing technologies developed by Principal Investigators, STMD or others in small to medium class missions.

Major Reasons for the Recommendation:
- In highly competitive program solicitations, such as Discovery and Explorer, there is a disincentive to propose new technology because of the perceived risk.
- As a result, NASA may be missing an opportunity to leverage scientifically beneficial technology through small and medium science missions. In the long-term, this could erode NASA's scientific and technical capabilities.
- If the Agency wants to encourage and infuse appropriate new technologies in its small and medium class missions, it must develop a policy that provides a pathway to the inclusion of these technologies in the solicitation release.

Consequences of No Action on the Recommendation:
Erosion of NASA's science and technical capabilities

SMD Technology Federation



Each Division provides a representative to work with the SMD Chief Technologist to survey and assess technology, provide guidance to SMD management, and to ensure communications between SMD and NASA Center Chief Technologists

The SMD TechFed is the key point of communication between SMD, STMD and the Office of Chief Technologist for advancing investment by STMD in technologies of special interest to SMD

Technology Investment Strategy

Continuous Improvement
Evolutionary changes throughout organizations, projects, missions

- Generally low cost
- Available to most organizations
- Low to medium payoff
- Necessary evolution of core technologies

Operational Transformation
Focused efforts that improve and leverage core processes

- Differentiating capabilities
- Substantial new products and/or new capabilities
- Step change in efficiency
- High value, moderately - widely available

Revolutionary Improvement
Complete reengineering and redefinition of the product

- Generally high cost and risk
- High value in rare cases for near- to mid-term investments
- Potentially high payoff in the far-term

“Core” (cost of doing business) ⟷ “Differentiating” (creating a competitive advantage)

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High Technology Readiness Level ←→ Low Technology Readiness Level

"Core" (cost of doing business) ←→ "Differentiating" (creating a competitive advantage)

COTS - Projects / Missions

SMD Tech Investments
(e.g., Instrument Incubator, Strategic Astrophysics Technology, Low-Cost Access to Space, PICASSO)

STMD Tech Investments
(e.g., Small Satellite, Game-Changing Technologies, Centennial Challenges, Flight Opportunities Programs)

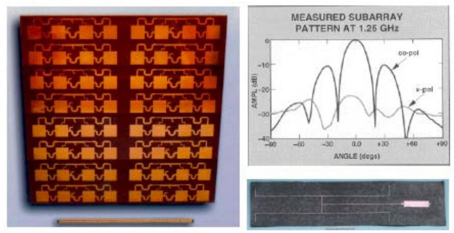
STMD Tech Investments
(e.g., NASA Innovative Advanced Concepts, Center Innovation Fund, Space Technology Research Grants)

Sustained Investments Yield Results

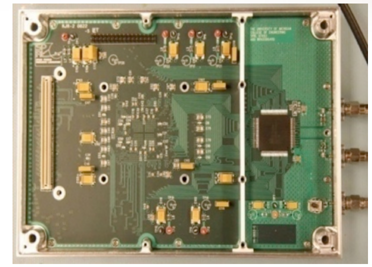
Study of a spaceborne microwave instrument for high resolution remote sensing of the Earth surface using a large-aperture mesh IIP-98: Eni Njoku

1998

Lightweight Feed For Future Salinity Missions
ACT-02: Simon Yueh



2002



Agile Digital Detector for RFI Detection & Mitigation
IIP-04: Christopher Ruf

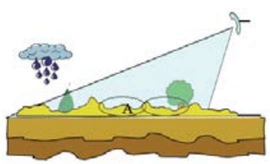
2004

Soil Moisture Active/Passive (SMAP) Mission

Tier I Mission

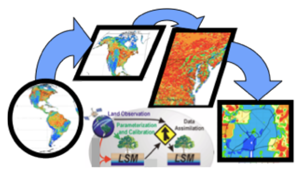
2015

2008



Dynamic near-real-time science validation
AIST-08: Mahta Moghaddam

2008

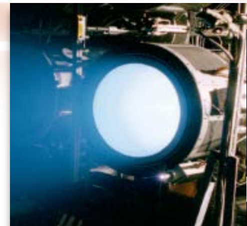


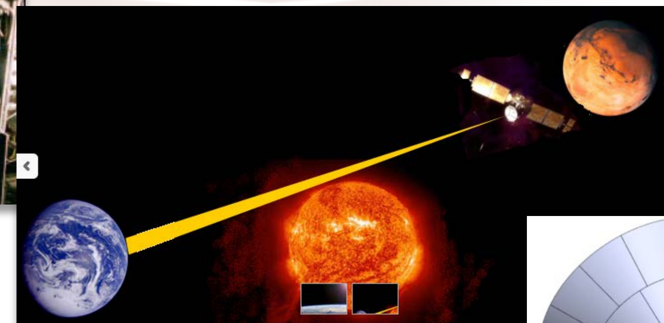
Integrate data, stochastic optimization, uncertainty modeling in LIS
AIST-08: Christa Peters-Lidard

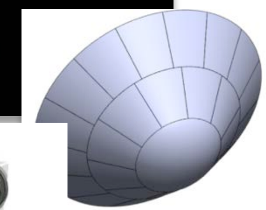
2008

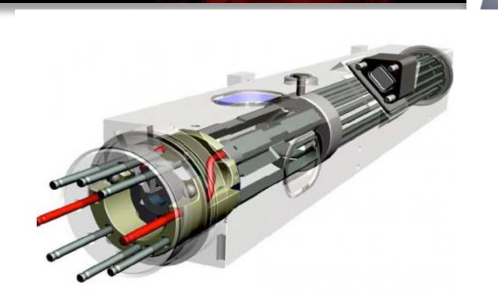
Automated anomaly detection, confirmation and on-demand data/model analysis AIST-08: Rama Nemani

Technology Infusion - Discovery ‘14









NASA Evolutionary Xenon Thruster (NEXT)

- 2 thrusters, 2 PPUs are GFE
- Risk of thruster, PPU readiness will not impact proposal evaluation

Deep Space Optical Communications (DSOC)

- DSOC Hardware is GFE
- Risk of DSOC readiness will not impact proposal evaluation
- $30M incentive for use

Heatshield for Extreme Entry Environment Technology (HEEET)

- HEEET team, consulting, tech transfer provided
- Cost of 3D Woven TPS material covered to $10M

Deep Space Atomic Clock (DSAC)

- Risk of DSAC readiness will not impact proposal evaluation
- $5M incentive for use

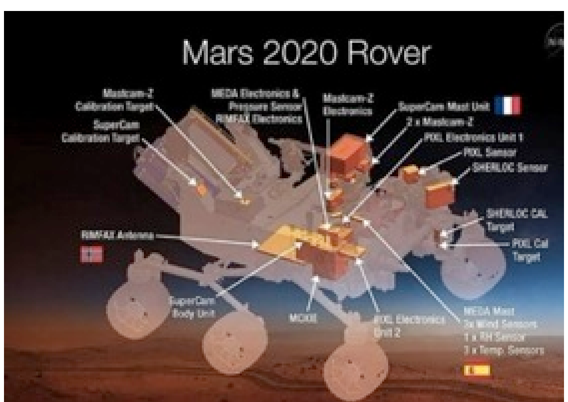
… and others!

Green Propellant, Lightweight Radio-isotope Heater Units,

Tech Infusion for Discovery ’14 is a partnership between SMD and the Game-Changing and Technology Demonstration Programs of STMD

Proposers may also include their own demonstrations without additional penalties for inherent technical risks

STMD Game-Changing Program Supporting Mars 2020



<u>STMD & HEOMD Will Develop Instrument Payloads for Infusion into the Mars 2020 Mission</u>:

In Situ Resource Utilization (ISRU) Demonstration

- *Competitively selected technology to convert Mars' atmosphere into oxygen (propellant & life support)*
- *Benefits both robotic & human exploration:*
  - *Reduced Earth-launch mass & mission cryogenic storage burden*
  - *Reduced burden on EDL systems*

Mars Entry, Descent, and Landing Instrument (MEDLI-2)

- *Developing sophisticated instrumentation suite to acquire critical EDL data benefiting future exploration missions*
- *Instrument both heat shield AND backshell*
- *Benefits Include:*
  - *Valuable flight data to validate analytical models (Reduced TPS design margins)*
  - *Data necessary to reconstruct planetary entry*

Weather Instrument Suite

- *Instrument suite contributed by Spain to measure temperature, wind speed and direction, pressure, relative humidity, and dust size/shape*

Courtesy: R. Stephan

Astrophysics Technology Elements

Science Programs

Cosmic Origins (COR)
- UV, Optical, IR (UVOIR) detectors
- Large UVOIR Space Optics (mirrors, coatings)
- Far IR detectors

Physics of the Cosmos (PCOS)
- Microwave detectors
- X-ray detectors, mirrors, filters, gratings
- Laser metrology and microthursters to support gravity wave missions

Exoplanet Exploration
- Internal coronagraph technologies
- External coronagraph (starshade) technologies
- Photon counting detectors
- Active optics (deformable mirrors)

Astrophysics Research & Analysis (APRA)
- Low- to mid-TRL technologies
- Instrument feasibility studies / proofs of concepts
- Suborbital

Strategic Astrophysics Technology (SAT)
- Mid-TRL technologies
- Brings technology development to maturation for infusion into a mission

Technology Programs

Heliophysics Program Elements

Science Programs

Solar-Terrestrial Physics Program
Missions to examine unsolved questions regarding the mass, momentum, and energy flow within the Sun-Earth system

Living With a Star Program
Examines predictive capabilities for aspects of the space weather environment that impact society

Heliophysics Explorers Program
Mix of S/M/L competitively selected PI-led missions; maintain cadence of high science return MoOs

Heliophysics Research Program
Applies theory, numerical simulations, data analysis, modeling, and instrument development

Heliophysics Technology and Instrument Development for Science (H-TIDeS)
- Mid-TRL technologies
- Brings technology development to maturation for infusion into a mission

Low-Cost Access to Space (LCAS)
- Balloon, sounding rockets, ISS, commercial reusable suborbital launch vehicles for science investigations
- CubeSats and other small satellites

Technology Programs

Planetary Sciences Technology Overview

The **Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO)** Program invests in low-TRL technologies and funds instrument feasibility studies, concept formation, proof-of-concept instruments, and advanced component technology.

The **Maturation of Instruments for Solar System Exploration (MatISSE)** Program invests in mid-TRL technologies and enables timely and efficient infusion of technology into planetary science missions.

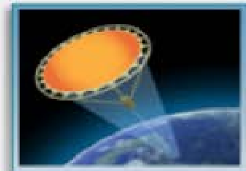
Earth Science Technology Office

NASA's Earth Science Technology Office (ESTO) is a ***targeted, science-driven, competed, actively managed, and dynamically communicated technology program*** and serves as a model for technology development.

Competitive, peer-reviewed proposals enable selection of best-of-class technology investments that ***retire risk*** before major dollars are invested: a cost-effective approach to technology development and validation.

ESTO investment elements include:

Observation



Instrument Incubator Program
Provides robust new instruments and measurement techniques
TRL 3-6; 18 active projects

Advanced Component Technology Program
Provides critical components and subsystems for instruments and platforms
TRL 2-6; 15 active projects

Information

Advanced Information System Technology Program
Provides innovative on-orbit and ground capabilities for collecting, processing, and managing remotely-sensed data and generation of data products; TRL 2-6; 22 projects

Validation

In-Space Validation of Earth Science Technologies (InVEST)
Provides in-space, orbital technology validation and risk reduction for small instruments and components in lieu of ground/aircraft testing; TRL 5-7; 3 projects

Tech Advancement - SMD Suborbital Missions

Over the last 4 decades, over 50 precursor spacecraft instruments first flew on aircraft, sounding rockets and balloons.

MODIS, MOPPITT, and MISR instruments for **Terra** and **Aqua** were developed on Airborne Science aircraft.

CMB balloon flights in the late 80s and 90s laid the critical ground work for the design of Wilkinson Microwave Anisotropy Probe (**WMAP**)

The multi-Anode micro channel array developed on Sounding Rockets is basis for STIS, ACS, and COS on Hubble Space Telescope (**HST**)

The Sounding rocket EUV Spectroscopy flights served to develop instrument on Solar and Heliospheric Observatory (**SOHO)**, and **Hinode**.

Detectors on Reuven Ramaty High Energy Solar Spectroscope Imager (**RHESSI)** were first developed and demonstrated on balloon-borne instruments.

The scintillating fiber trajectory detector on the Advance Composition Explorer (**ACE**) Cosmic Ray Isotope Spectrometer was demonstrated first in a balloon flight.

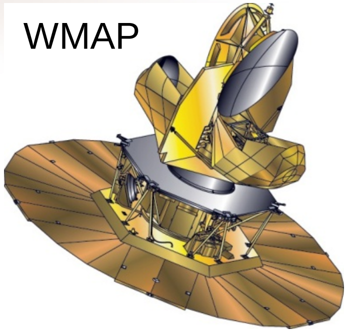
On the **Aura** satellite, the MLS, TES, and HIRDLS instruments all trace their heritage to instruments that first flew on balloons.

The Microwave Limb Sounder (MLS) on the Upper Atmosphere Research Satellite (**UARS**) and the **Aura** satellite were developed on balloon and aircraft science missions.

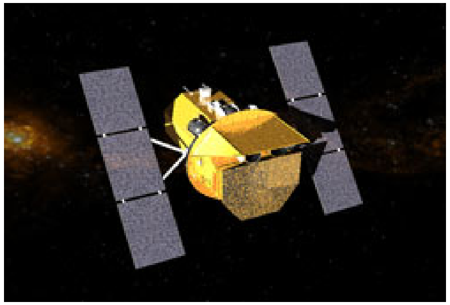
Balloon flights of the cadmium-zinc-telluride (CZT) array led to the design of the **Swift** Burst Alert Telescope (BAT) instrument.

Balloons supported full engineering prototype flights of the **Fermi**/Gamma-ray Large Area Space Telescope

WMAP



RHESSI



Swift

Reference: NRC Study: Revitalizing NASA's Suborbital Program: Advancing Science, Driving Innovation, and Developing a Workforce

Technology Infusion Examples

Astrophysics

- Partnership with STMD for AFTA coronagraph
- Thin-film physics/optical coatings
- Superconducting bolometer developed and deployed on BICEP2
- REXIS instrument is scheduled to fly on OSIRIS-Rex
- Slumped-glass mirror segments developed for NuSTAR (technology developed under Physics of the Cosmos program)

Heliophysics

- RHESSI and SDO-EVE developed and matured using suborbital assets
- Heliophysics Technology and Instrument Development for Science (H-TIDeS) released under LCAS; targeted suborbital & cubsat investigations

Hot Topic: New Role for Small Satellites

CubeSat-class missions (containerized spacecraft) were first launched in 2003 and have evolved rapidly in terms of instrument and platform technologies

By 2012 there were 112 such missions by 80 organizations from 24 countries on 24 rockets; 115 more launched since 2012

Growth of investments within SMD (Headquarters & field centers) over the past 3 years

SMD has funded small satellite technology demonstrations and nascent science missions in Astrophysics, Earth Science, Heliophysics, and Planetary Science

Studies are now being drafted to determine the potential for small satellites to satisfy Decadal Survey measurement requirements

Earth Venture-Class

Venture-Class was a recommendation from the NRC Decadal Survey

- Science-driven, PI-led, competitively selected, cost- and schedule-constrained
- Provides more flexibility to accommodate scientific advances and new implementation approaches

Video: The Cyclone Global Navigation Satellite System (CYGNSS) will make measurements of ocean surface winds. The novel approach will make use of a constellation of eight small spacecraft.

BACKUPS

Astrophysics Technology Overview

Technology needs are driven by Decadal Survey Recommendations
- Additional input received from science community (PAGs)
- Technology plans assessed annually by program offices

Technology spending is about 15% of overall Astrophysics budget

APRA (ROSES) budget increased in FY12 in response to Decadal Survey

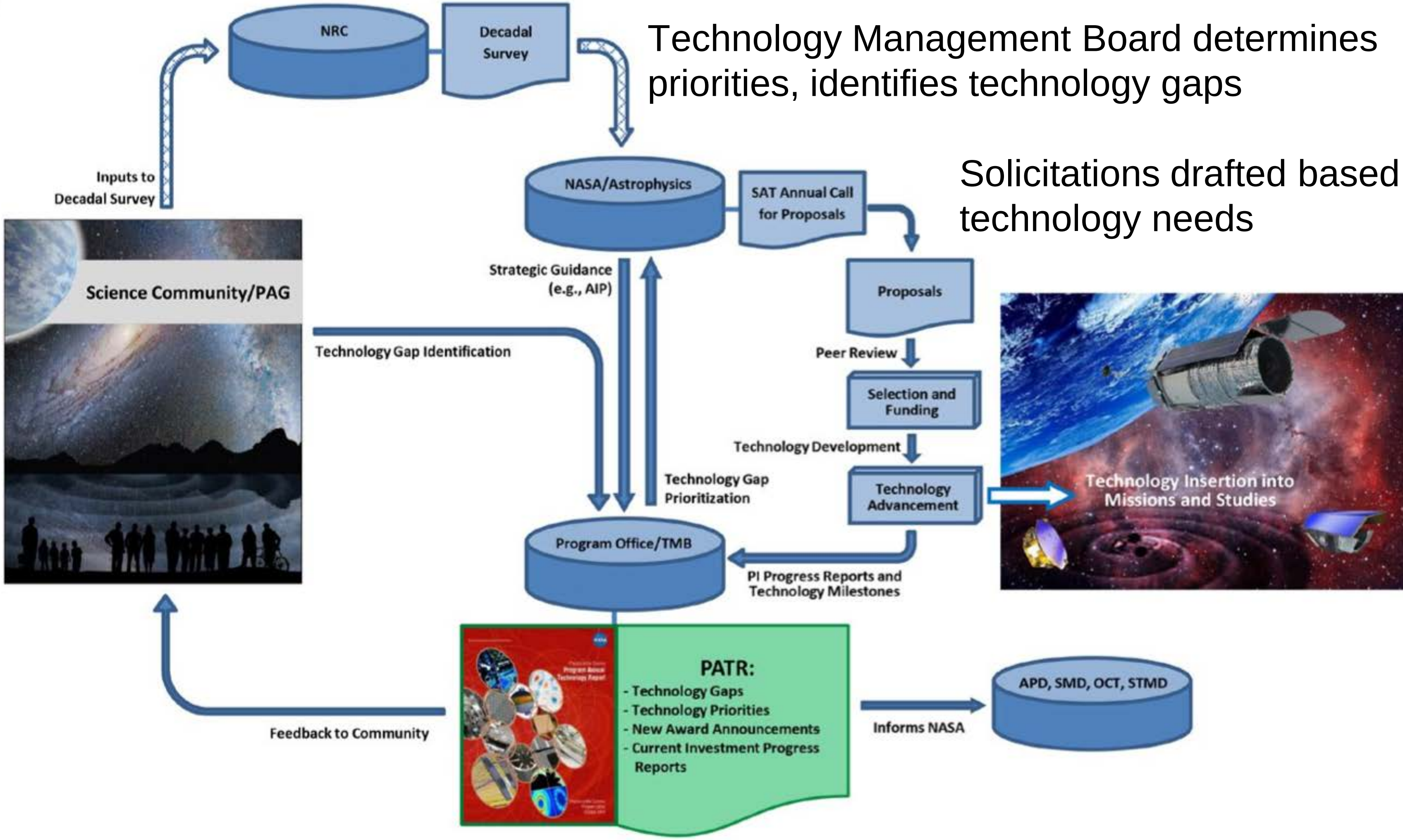
SAT (ROSES) established in response to Decadal Survey recommendation for mid-TRL element

Physics of the Cosmos Technology Management

Integrates input from the science community via Decadal Survey

Technology Management Board determines priorities, identifies technology gaps

Solicitations drafted based on technology needs



PCOS Technology Gaps - 2014

- Improvements in X-ray detection and optics
- Millimeter-wave optics, detection, and polarization sensing
- Highly stable telescopes, optical benches, and lasers
- Phase measurement subsystems and gravitational reference sensors
- Gamma-ray telescopes
- Sub-Kelvin cooling

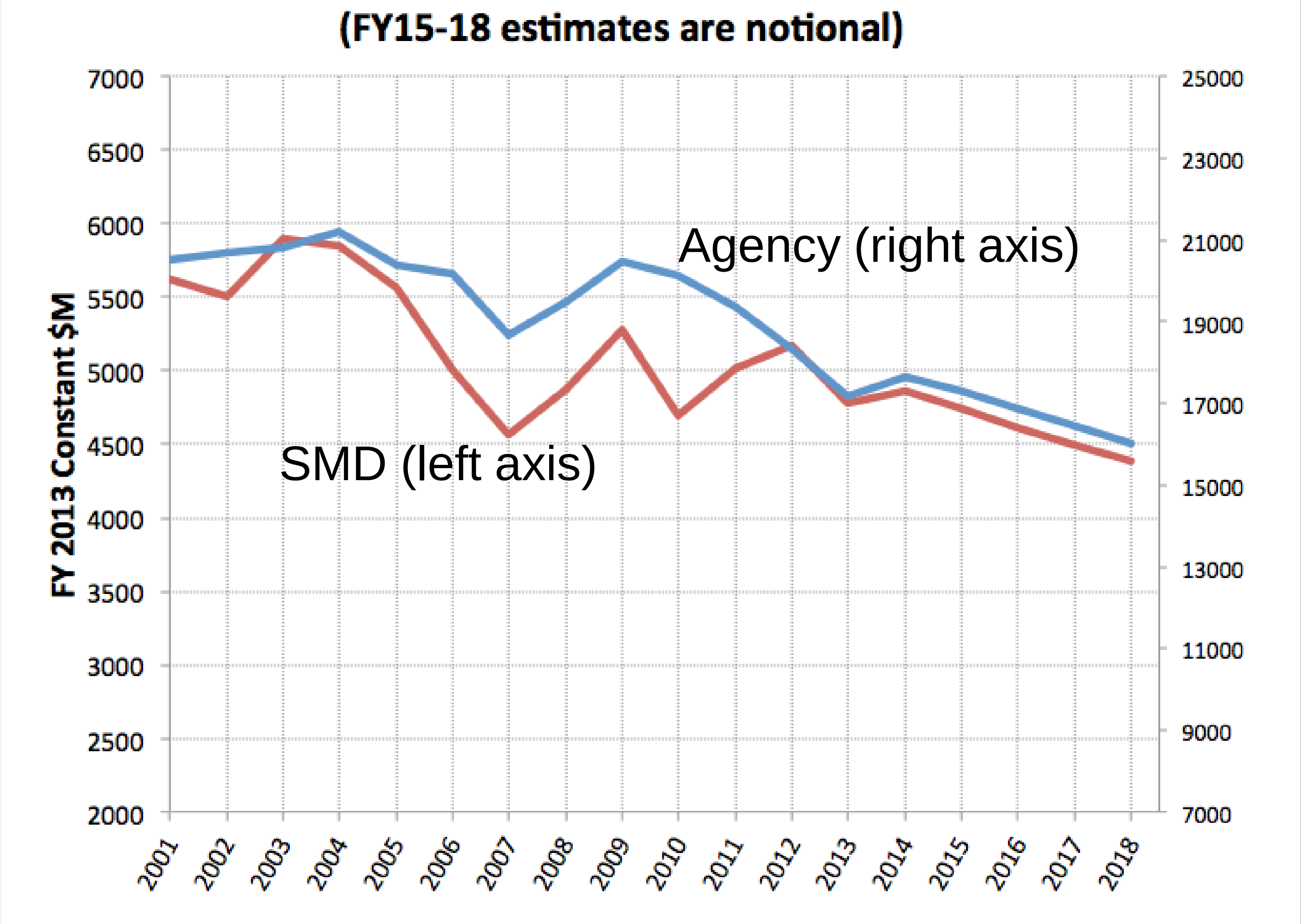
Technology Priorities for PICASSO

- Miniaturized, low-power, low-cost, instrument technologies for missions in the Discovery, New Frontiers, Mars Exploration, and other planetary programs.
- Instrument systems that are capable of measuring atmospheric, surface, and subsurface composition, particles and fields, and physical properties of bodies in the solar system.
- In situ instruments for sample selection and handling, age dating, organic detection and characterization and isotopic identification
- Instruments that function in extreme environments of temperature, pressure and high radiation

Heliophysics Technology Priorities

- Highest priority needs are identified and discussed in the 2012 *Solar and Space Physics* Decadal Survey
- Auroral and airglow imaging instruments with significant improvements in reflectance coatings, narrower-band filters, solar blind, and blazed gratings with high ruling densities
- Improved lidar instrumentation with higher power lasers and large array telescopes
- Large format, high speed, high efficiency, CCD and CMOS detectors
- Energetic Neutral Atom detectors with 1° or better angular resolution
- Ultra-thin foils for improved sensitivity and lower energies in composition analyzers
- CubeSat subsystems (RF, power, thermal)

Agency and SMD Budget Trends



Flight Opportunity Programs - Examples

Astrophysics & Heliophysics Explorers: Provides frequent flight opportunities for science investigations from space, using innovative, streamlined and efficient management approaches.

Discovery Program: Complements Planetary Science flagship missions by launching many smaller missions using fewer resources and shorter development times. Focus is on new technology to explore the solar system.

Earth Venture Missions: A series of science-driven missions that are low- to moderate cost, small to medium-sized, competitively selected, full orbital missions (EVM), instruments (EVI), and sub-orbital projects (EVS).

SMD – Game Changing Development Collaborations

Station Explorer for X-Ray Timing and Navigation (SEXTANT)	High Performance Spaceflight Computing (HPSC)
In-Situ Resource Utilization (ISRU)	Nuclear Systems Thematic
Woven Thermal Protection System (Woven TPS)	Solar Electric Propulsion
Adjustable Grazing X-ray Optics	Advanced In-Space Propulsion (AISP)
Advanced laser frequence stabilization using molecular gases	Adaptable Deployable Entry and Placement Technology (ADEPT)
Coronagraph for WFIRST/AFTA	Advanced Space Power Systems
Deep Space Optical Communication (DSOC)	Hypersonic Inflatable Aerodynamic Decelerator

Planetary
Astrophysics
Earth Science
Heliophysics
Multiple