National Aeronautics and Space Administration

SMD Technology Development

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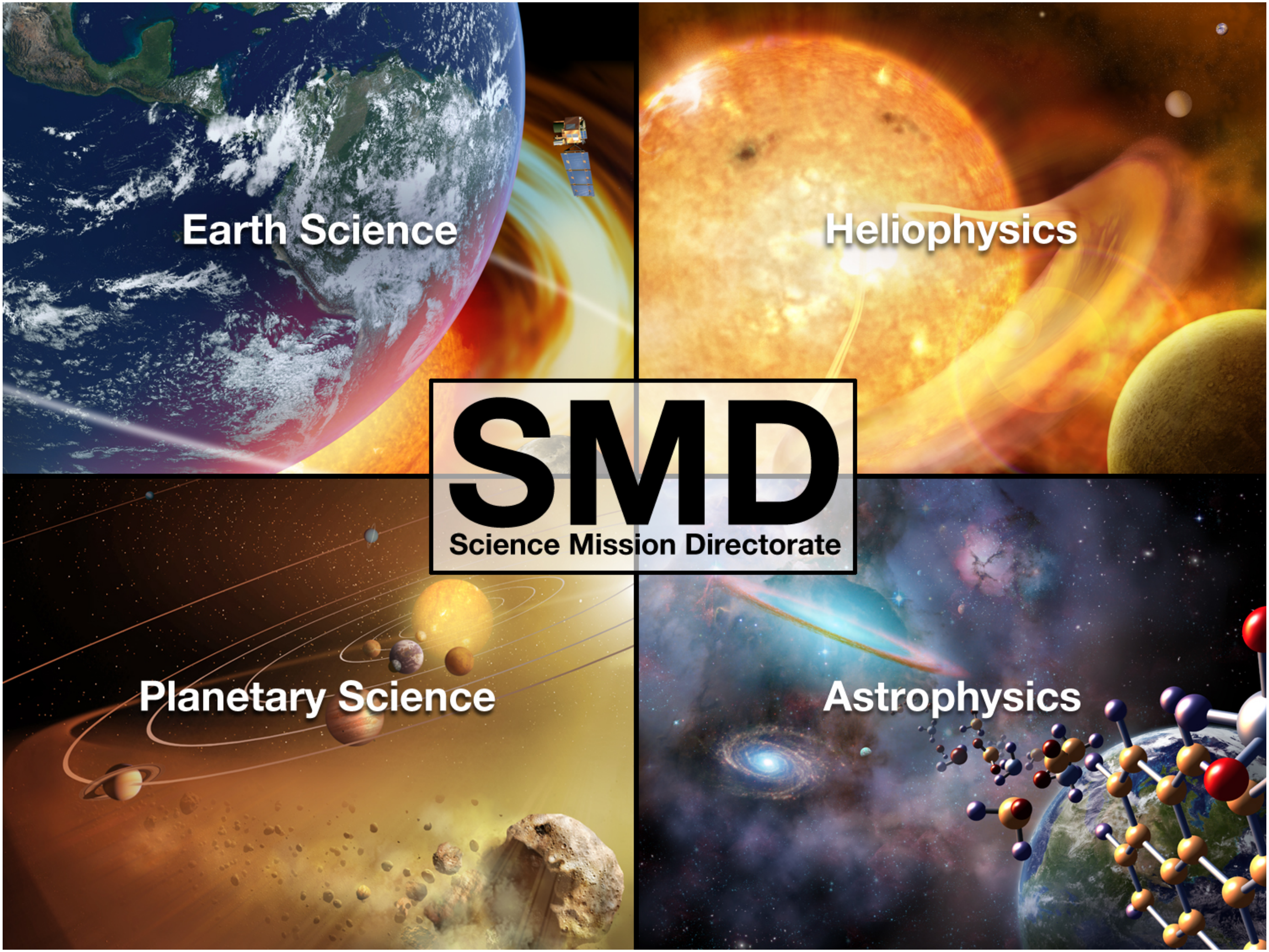
www.nasa.gov



Earth Science
Heliophysics
SMD
Science Mission Directorate
Planetary Science
Astrophysics

Overview

SMD Technology is managed at the Division level

It runs the gamut from TRL 1 to flight hardware

Our technology investments are science-driven and responsive to the recommendations outlined in each Division's respective Decadal report

Our technology processes emphasize competition and peer review, usually through the ROSES (Research Opportunities in Space and Earth Science) omnibus NRA

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Astrophysics

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

Technology Development Approach

Competed Technology Development (ROSES)

- Astrophysics Research & Analysis (APRA)
  - TRL 1-3
- Strategic Astrophysics Technology (SAT)
  - TRL 4-6

Directed Technology Development

- Strategic missions, typically TRL 6 and above

Suborbital Investigations

- Primary mission purpose is science, but typically results in technology maturation as well

3 SAT Technology Elements

Cosmic Origins SAT

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

Physics of the Cosmos SAT

- Microwave detectors
- X-ray detectors, mirrors, filters, gratings
- Laser metrology and microthrusters to support gravity wave missions

Exoplanet Exploration SAT (TDEM)

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

Astrophysics Division (ApD) Collaboration with STMD

ApD has written solicitation topics, chaired review panels, and provided reviews for:

- STRO-ESI Solicitations
- NASA Space Technology Research Fellowships (NSTRF)
- GCD's Flight Opportunities Payload Solicitation

ApD and GCD Jointly funded two SAT proposals in 2012

ApD and STMD are planning joint development of AFTA-WFIRST Coronagraph

- Next ApD strategic mission

Examples of the Technology Efforts Underway

H4RG Near-IR Detector Array with 10 micron pixels for WFIRST and Space Astrophysics

PI: Bernard J. Rauscher/GSFC

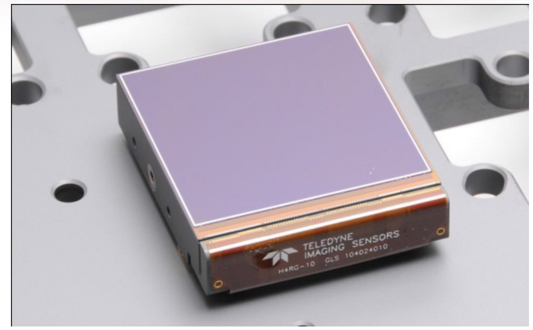
Co-PI: Selmer Anglin/Teledyne Imaging Sensors

Description and Objectives:

- Develop the 16 megapixel H4RG-10 near-IR detector array to TRL-6 for WFIRST in time for the Astrophysics Mid-Decadal Review
- WFIRST Science Definition Team identified the H4RG-10 as the critical enabling technology that is needed for achieving the aims of the Astrophysics Decadal Survey *New Worlds, New Horizons*
- Mature this technology to minimize risk, cost, and schedule
- Reduce the persistence and noise of large format high resolution infrared array detectors

Key Challenge/Innovation:

- Hybridization improvements to meet WFIRST pixel operability requirements in 4K x 4K, 10 um/pixel format
- Pixel design improvements to meet WFIRST read noise requirements and reduce persistence



This H4RG-10 is identical to one that was tested in the Goddard DCL in 2011. It consists of a 4K x 4K pixel array of HgCdTe pixels mated to a silicon readout. It met all WFIRST performance requirements except: (1) pixel operability and (2) read noise

Approach:

- Teledyne study to improve pixel interconnect yield
- Teledyne study to optimize process and improve read noise
- Fabricate lot splits of H4RG-10s at Teledyne
- Characterize H4RG-10s vs. WFIRST requirements in Goddard Detector Characterization Laboratory (DCL) and Teledyne
- Characterize H4RG-10s for WFIRST weak lensing and persistence at JPL/CalTech
- Environmental testing for TRL-6

Key Collaborators:

- Jason Rhodes (JPL: Institutional PI)
- Donald N. B. Hall (University of Hawaii)
- Bryan Dorland (U.S. Naval Observatory)
- Ed Cheng (WFIRST)
- Roger Smith (Caltech)

Development Period

- FY13 - FY15

Accomplishments and Next Milestones:

- Demonstrate pixel interconnect operability yield>98%: Sept 2013
- Demonstrate an H4RG-10 that meets WFIRST performance requirements: Dec 2013
- Demonstrate an H4RG-10 that meets WFIRST environmental requirements: Dec 2014
- Complete TRL-6 demonstration: End of performance period

Application:

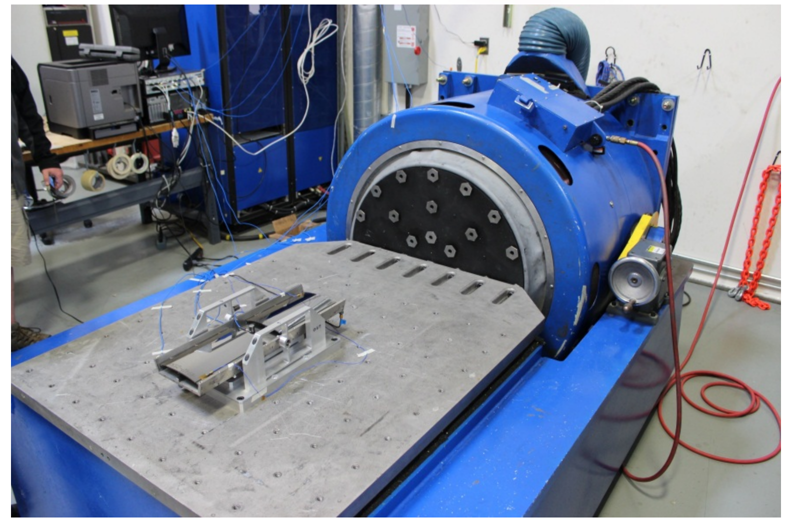
- WFIRST
- Explorer class near-IR missions
- Ground and space based astrophysics programs
- This is a broadly enabling technology for astrophysics

*TRLin = **4*** *TRLcurrent = **4*** *TRLtarget = **6***

PCOS Targeted Technology Significant Progress—X-ray

Mirror Technology – Will Zhang/GSFC

- Conducted another vibration test of TDM#5 at Washington Laboratory LLC in Frederick, MD
  - Used a fixture to damp very high frequencies, simulating a spacecraft environment
  - The mirror module survived vibrational level of 6.5 GRMS
  - Alignment and x-ray performance being verified after the test
- Conducted another Thermal Vacuum Test of TDM#5
  - 4 full cycles between 0 and 40C, to be compared with previous 10 to 30C
  - Mirror module survived the cycling
  - Module mechanical integrity and X-ray performance did not degrade



Technology Development Module (TDM) #5 fixtured on vibrations table at Washington Laboratory LLC

Mark Clampin (NASA GSFC)
Visible Nulling Coronagraph

Coronagraph Technology Milestone:
Demonstration of ≤ 10^{-8} monochromatic contrast through visible nulling.

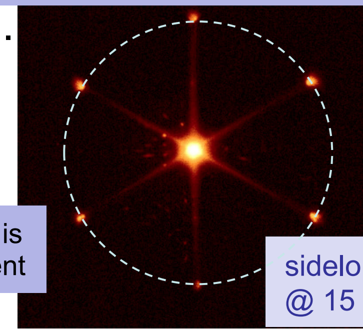
Facility: Visible Nulling Coronagraph Testbed, NASA GSFC.

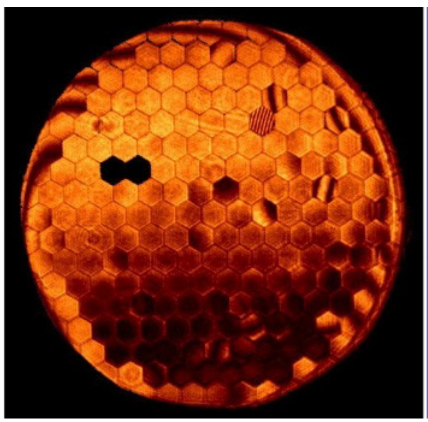
Current Status: 5.1 x 10^{-9} average @ 2λ/D contrast monochromatic.

Challenges: State of the art in segmented DMs.

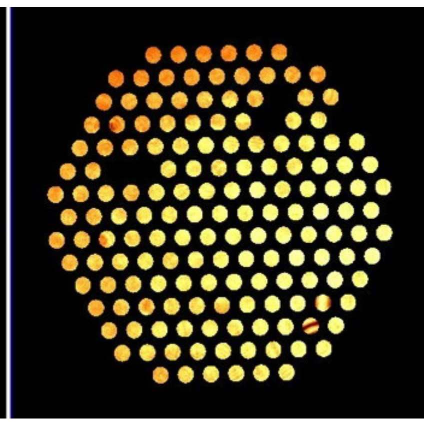
Future Work: Experiments completed, milestone under review.
Broadband demonstrations to be undertaken next.

Focal Plane Image thru Spatial Filter Array

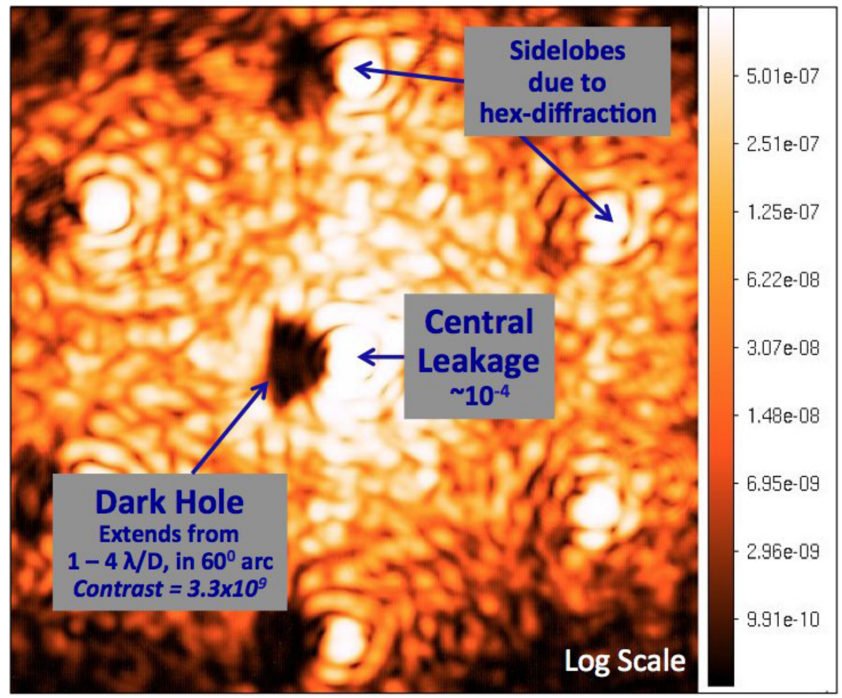




Interferometric Bright Image Without Lyot Stop



Interferometric Bright Image With Lyot Stop



TDEM work completed.
Milestone Report pending approval by TAC.

N. Jeremy Kasdin (Princeton Univ.)
Advanced Starshade Technology

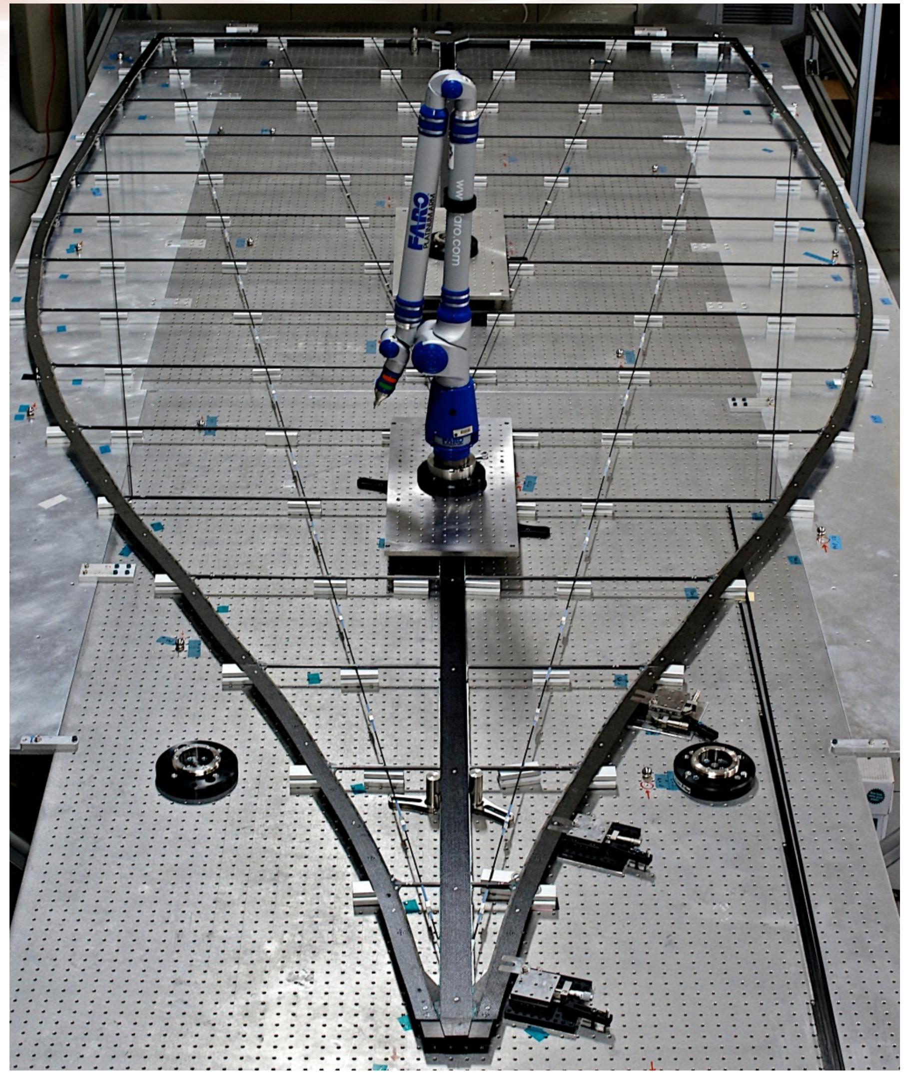
Starshade Technology Milestone: Demonstrate through mechanical measurements on a single petal made of flight-like materials using optical simulations based on those measurements that contrasts of $\leq 3 \times 10^{-10}$ at the inner working angle can be achieved.

Facility: Assembly Handling Facility (Bldg 299), JPL.

Current Status: Milestone completed.

Challenges: Mechanical measurements over a large structure.

Future Work: Demonstration of the accurate deployment of a three-petal prototype



TDEM work completed.
Milestone Report formally approved by TAC.

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Planetary Science

Planetary Science Technology Needs

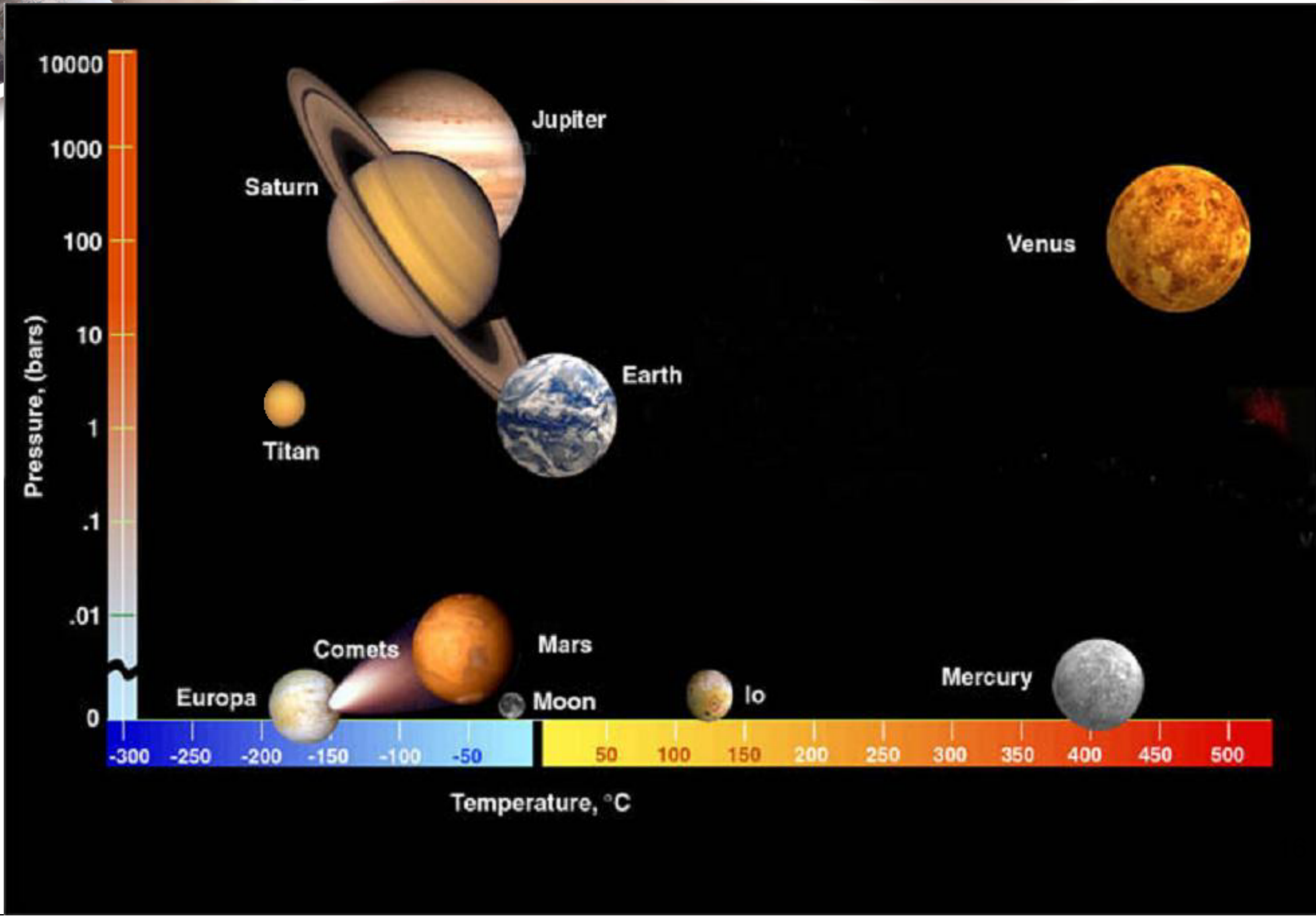
NRC Planetary Science Decadal Survey Technology Recommendations

- Core Multi-Mission Technologies
- Flagship Technologies
- Instrument Technologies

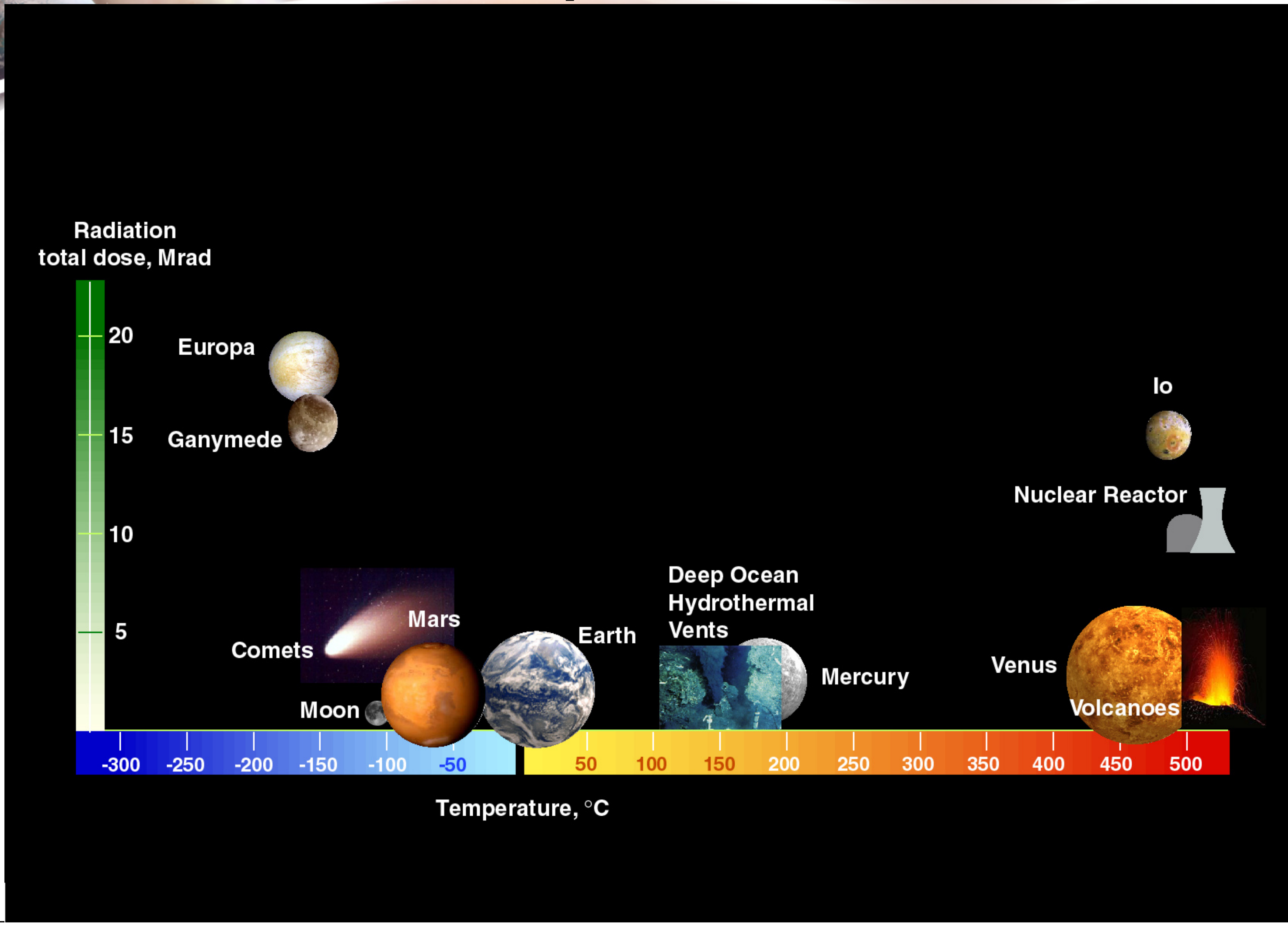
Further defined through

- Studies, e.g.,
  - Life Cycle Cost Growth Study for the Discovery and New Frontiers Program Office (February 2010)
- Workshops, e.g.,
  - Spacecraft Fault Management Workshop
  - Carbon Phenolic and Beyond Workshop
- Assessments
  - On-line at http://solarsystem.nasa.gov/scitech/reports.cfm
  - GN&C assessment reports to be added soon

Challenge of Planetary Extremes
Pressure-Temperature Environments



Challenge of Planetary Extremes
Radiation-Temperature Environments



Planetary Science Technology Investments Distributed across Multiple Programs/Projects

Part of the PSD Technology Program (051A)

- In-Space Propulsion (346620) Project* –working with the ISPT, STMD and other stakeholders to define program to sustain capabilities and complete investments past FY14
- Part of the Nuclear Power Radioisotope System Development (138494) Project*
- Part of the Advanced Multimission Operations Systems Tech (AMMOS) (823153) Project*

Part of the Planetary Science Research Program (515A) - Planetary Research Program (811073) Project

- Maturation of Instruments for Solar System Exploration (MatISSE)*
- Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO)*

(The MatISSE and PICASSO Programs replace Planetary Instrument Definition (PIDDP)*, Astrobiology Science & Technology for Instrument Development (ASTID)*, and Mars Instrument Development Program (MIDP)*

- Astrobiology Science and Technology for Exploring Planets (ASTEP)*
- Moon and Mars Analog Mission Activities (MMAMA)*
- Some awards under Planetary Protection Research (PPR)*

* competitively selected through ROSES solicitation, AMMOS solicitation, or AO

Planetary Science Technology Investments are Distributed across Multiple Programs/Projects

Part of Mission Programs:

- New Frontiers (401A) Program
  - OSIRIS-REx (828928) KDP-C Kickoff (with HQ, Program, and Project), HQ, Aug 27
    - Bringing GN&C Lidar and TAGSAM to TRL 6 before PDR (March 2013)
- Discovery (502A) Program
  - Three Discovery AO Proposals competitively selected for Technology Development
    - Selection on 5/5/2011 of Primitive Material Explorer (PriME),* Whipple,* and NEOCam*
  - Part of ILN/Other Decadal Priorities (915563) Project [was under Lunar Quest (881D) Program]
    - ILN/Surface Science Lander Technology – phasing out, ends after FY13
  - Part of Discovery Research Project (231402)
    - Some awards under Laboratory Analysis of Returned Samples (LARS)*
- Mars Exploration (269B) Program
  - Mars Technology (627795) Project
    - Rover technologies
    - Mars Instrument Development Program (MIDP)* rolled into PICASSO and MatISSE
- Outer Planets (567W) Outer Planets Flagship Mission (809676)
  - FY12 only funding for Arc Jet tests/TPS development
  - FY13: Instrument Concepts for Europa Exploration (ICEE)

* competitively selected through ROSES solicitation, AMMOS solicitation, or AO

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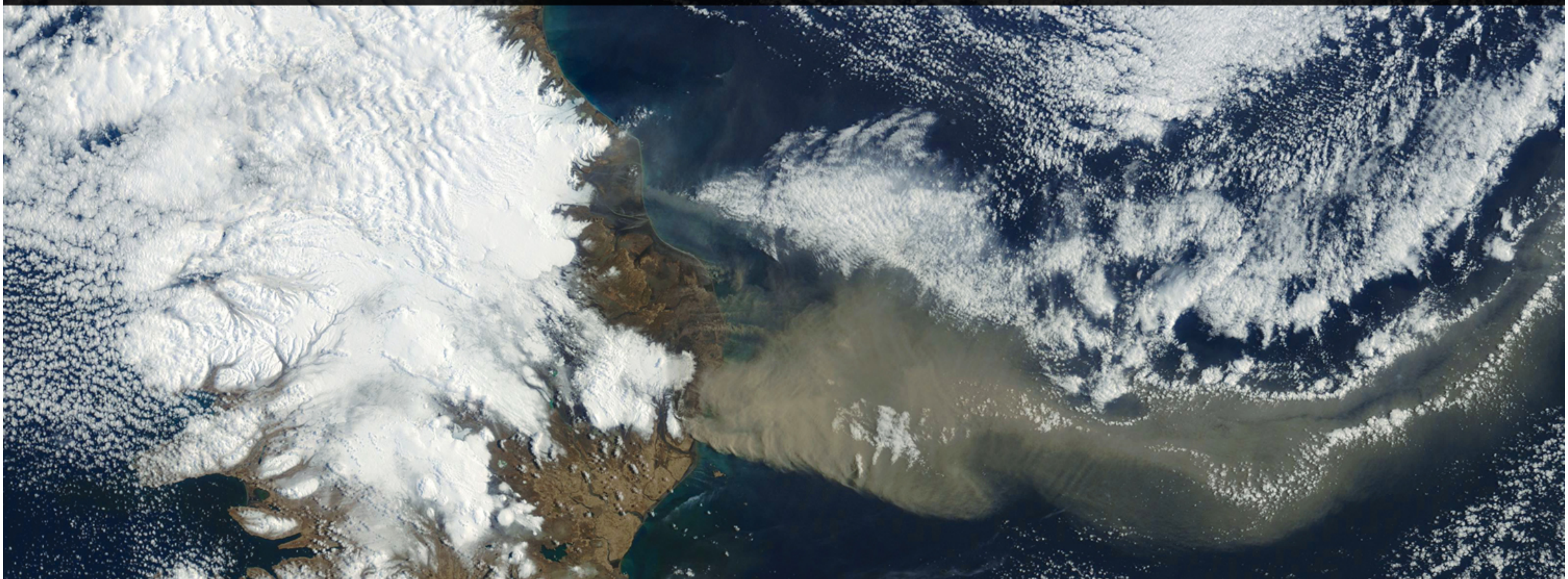


Earth Science

Earth Science at NASA

- **Overarching goal**: to advance Earth System science, including climate studies, through spaceborne data acquisition, research and analysis, and predictive modeling
- Six major activities:
  - Building and operating Earth observing satellite missions, many with international and interagency partners
  - Making high-quality data products available to the broad science community
  - Conducting and sponsoring cutting-edge research
    - Field campaigns to complement satellite measurements
    - Analyses of non-NASA mission data
    - Modeling
  - Applied Science
  - **Developing technologies to improve Earth observation capabilities**
  - Education and Public Outreach

Earth Science
Technology Program Overview

National Aeronautics and Space Administration

The 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 (IIP)
provides robust new instruments and measurement techniques
16 new projects added in FY11 (total funding approximately $67M over 3 years)

Advanced Component Technologies (ACT)
provides development of critical components and subsystems for instruments and platforms
15 new projects added in FY11 (total funding approximately $16M over 3 years)

Information

Advanced Information Systems Technology (AIST)
provides innovative on-orbit and ground capabilities for communication, processing, and management of remotely sensed data and the efficient generation of data products
18 new projects added in FY12 (total funding approximately $23M over 3-4 years)

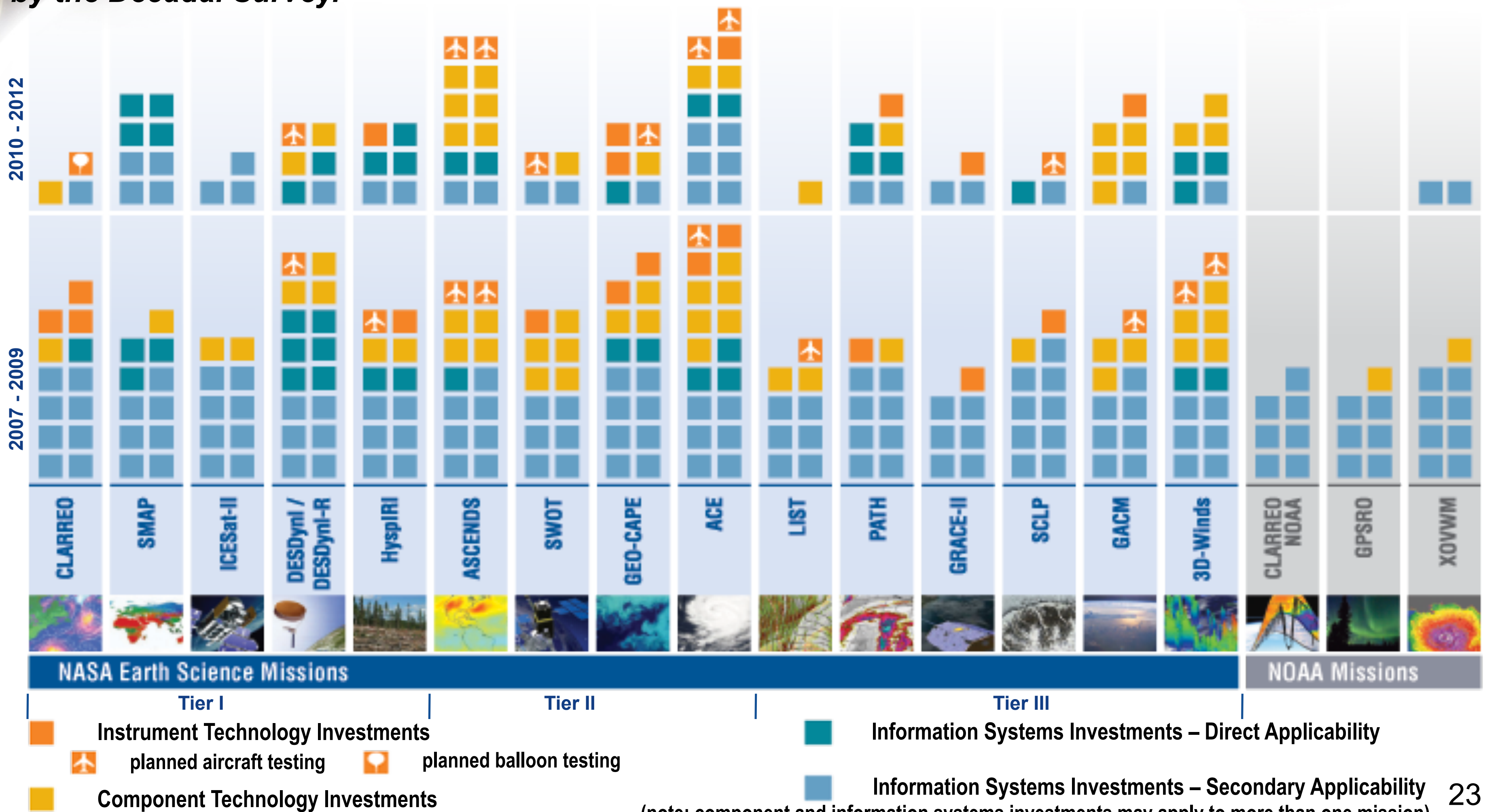
Validation

In-Space Validation of Earth Science Technologies (InVEST)
provides in-space, orbital technology validation and risk reduction for small instruments and instrument systems that could not otherwise be fully tested on the ground or in airborne systems *First Solicitation released 9/13/12*

Earth Science Technology:

Enabling the Earth Science Decadal Survey

Upon publication of the Earth Science Decadal Survey in 2007, ESTO investments **already supported all 18 of the recommended mission concepts**. Since then, ESTO has awarded **107 additional technology projects** representing an investment of ***over $211M directly related to the Earth Science priorities outlined by the Decadal Survey.***

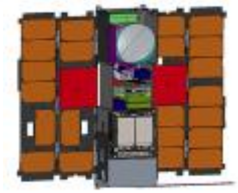


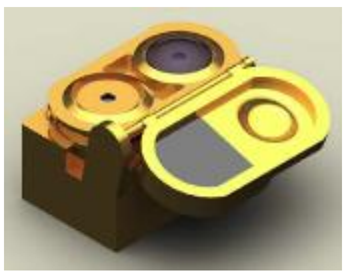
(note: component and information systems investments may apply to more than one mission)

In-Space Validation of Earth Science Technology (InVEST)

- ***The need to space-validate new technologies is critical to reduce risk for future Earth science measurements***
- ***The In-Space Validation of Earth Science Technologies (InVEST) program is intended to fill the gap***
- ***The first InVEST solicitation sought small instruments and subsystems that advance technology to enable relevant measurements and targeted the CubeSat platform***
- ***Four awards (out of 23 proposals) were selected in April 2013: $13M total over three years, launch in 2015/16***

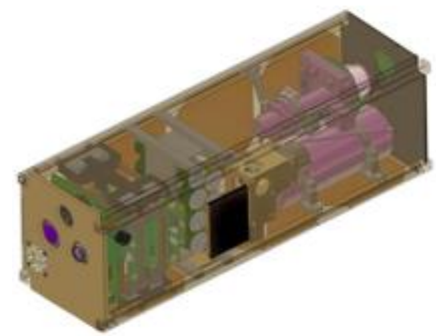
The ***Microwave Radiometer Technology Acceleration (MiRaTA) Cubesat*** will validate multiple subsystem technologies and demonstrate *new microwave radiometers* operating near 52-58, 175-191, and 206-208 GHz that could dramatically enhance the capabilities of future temperature and humidity measurements. - W. Blackwell, MIT Lincoln Laboratory

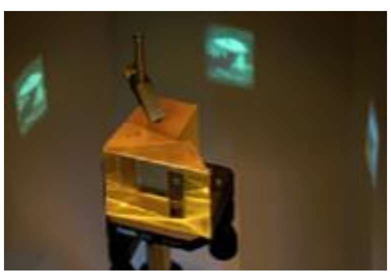




The ***Radiometer Assessment Using Vertically Aligned Nanotubes (RAVAN)*** project will demonstrate a *bolometer radiometer* that is compact, low cost, and absolutely accurate to NIST traceable standards. RAVAN could lead to affordable CubeSat constellations that, in sufficient numbers, might measure Earth's radiative diurnal cycle and absolute energy imbalance to climate accuracies (globally at 0.3 W/m2) for the first time.
- L. Dyrud, Johns Hopkins Applied Physics Laboratory

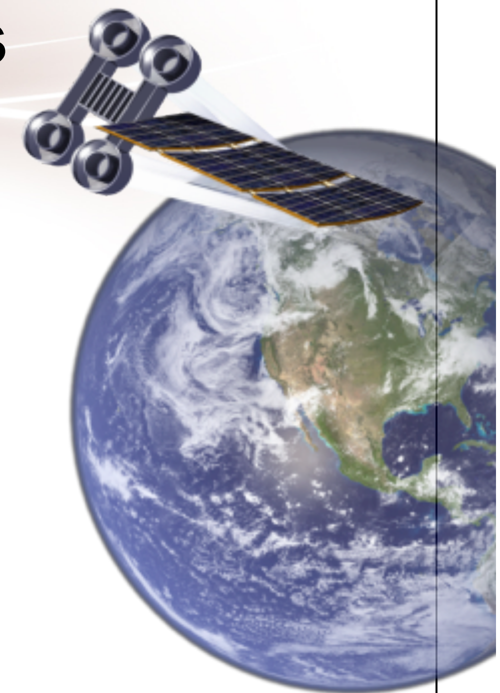
The objective of the ***Cubesat Flight Demonstration of a Photon Counting Infrared Detector (LMPC CubeSat)*** is to demonstrate in space, a *new detector with high quantum efficiency* and single photon level response at several important remote sensing wavelength detection bands from 1 to 2 microns.
- R. Fields, The Aerospace Corporation



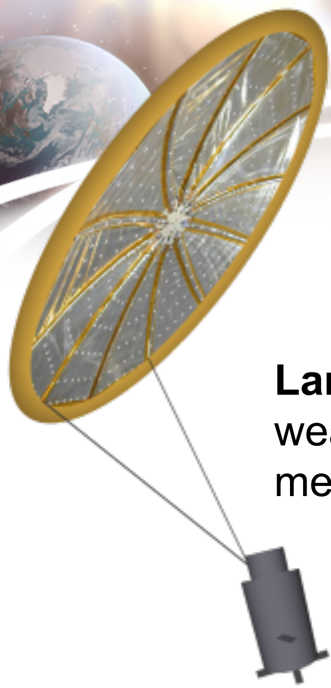


The ***HyperAngular Rainbow Polarimeter HARP-CubeSat*** will validate a technology required by the Aerosol-Cloud-Ecosystem (ACE) mission concept and prove the capabilities of a highly-accurate, wide-FOV, hyperangle, *imaging polarimeter* in three wavelenghts and no moving parts for characterizing aerosol and cloud properties.
- J. V. Martins, University of Maryland, Baltimore County

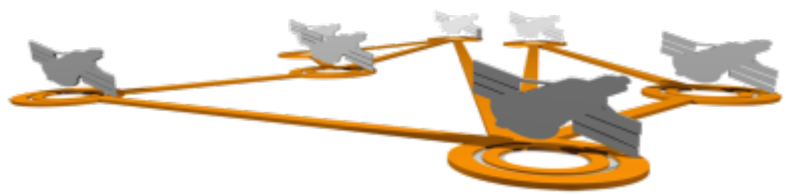
Key Technology Challenges



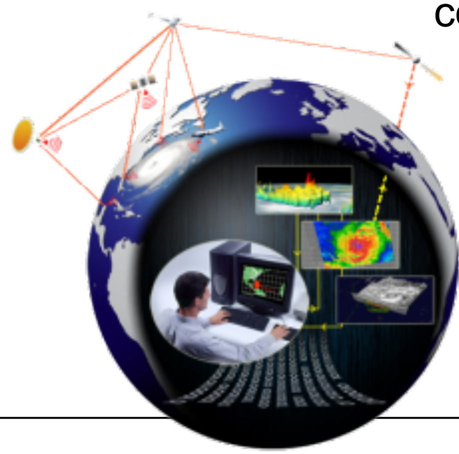
Active Remote Sensing Technologies to enable atmospheric, cryospheric and earth surface measurements



Large Deployables to enable future weather, climate and natural hazards measurements



Intelligent Distributed Systems using advanced communication, on-board processors, autonomous network control, data compression, and high density storage



Information Knowledge Capture through 3-D visualization, holographic memory and seamlessly linked models.

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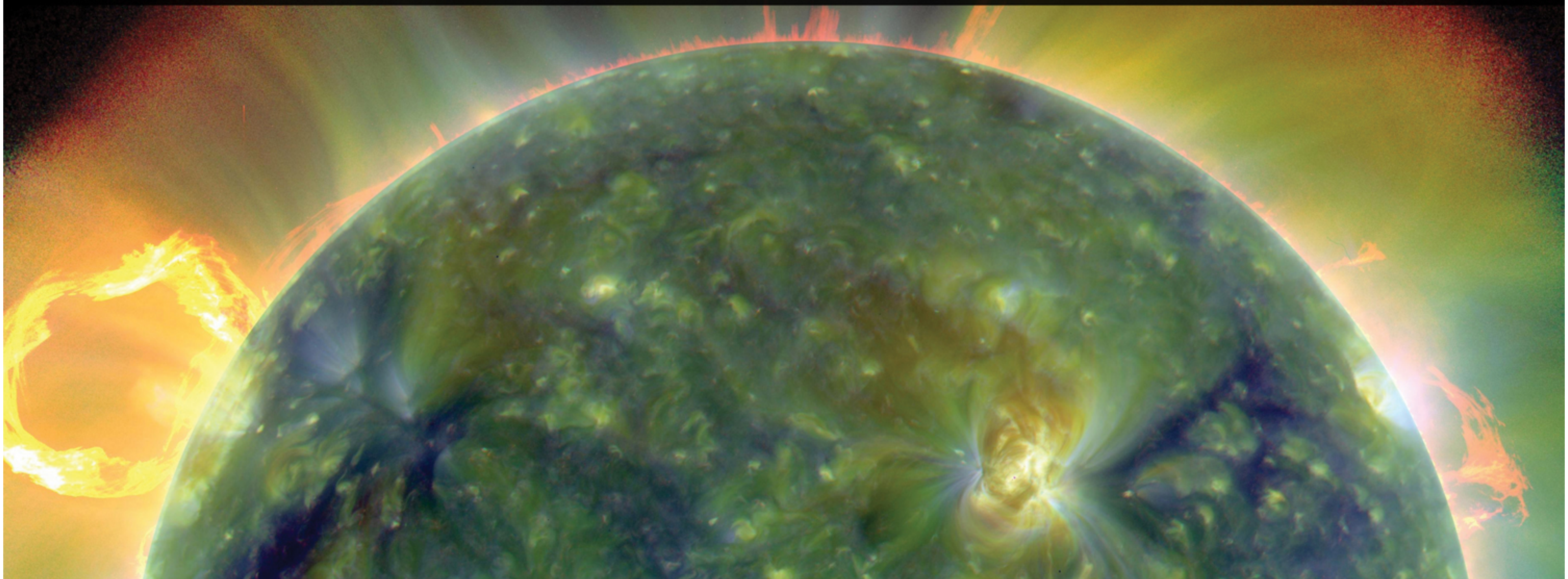

Heliophysics

Heliophysics

Heliophysics goal: Understand the Sun and its interactions with the Earth and the solar system

- Open the Frontier to Space Environmental Prediction: Understand the fundamental physical processes of the space environment – from the Sun to Earth, to other planets, and beyond to the interstellar medium.
- Understand the Nature of Our Home in Space: Understand how human society, technological systems, and the habitability of planets are affected by solar variability interacting with planetary magnetic fields and atmospheres.
- Safeguard the Journey of Exploration: Maximize the safety and productivity of human and robotic explorers by developing the capability to predict the extreme and dynamic conditions in space.

Heliophysics Priorities

The highest priority Heliophysics technology 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 imagers with 1° or better angular resolution.

Ulta-thin foils for improved sensitivity at lower energies in composition analyzers.

CubeSat subsystems such as RF, power, ACS, and thermal to enable a broader range of Heliophysics missions.

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Conclusion

- A focused, science-driven approach
- Peer-reviewed process
- Open, competitive program
- Frequent solicitations ensure current approaches and create regular, multiple opportunities for PI's
- Technologies selected for eventual infusion by principal investigators and mission managers
- Currently funded technologies are providing state-of-the-art instruments, components, and information systems capabilities for a wide range of science measurements

For more info:
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George Komar @ GSFC for Earth
Bill Stabnow @ HQ for Heliophysics
Billy Lightsey @ MSFC for Astrophysics