Overview of SMD's Mission Enabling Activities in NASA's Earth and Space Science Missions

Paul Hertz, Chief Scientist
Max Bernstein, Lead for Research
Marc Allen, AAA for Strategy, Policy, and International

NRC Study on Mission Enabling Activities in NASA Science Missions
January 22, 2009

Opening Message

- The SMD program is opportunity rich
  - Supports investigations from <$20K to large missions
- Up to half of the budget is mission enabling
  - ~50% of budget is mission development and mission operations
  - Mission enabling activities are embedded in every program
  - At least 25% of non-mission budget is technology development
- The program has evolved over 50 years to a balance between mission and mission enabling
  - The overall balance has been fairly stable over time
- The NASA science program is the only space science program in the world with an integral and substantial R&A program
  - It is arguably the best structured program for scientific exploration in space, of space, and from space

Role of Mission Enabling Activities

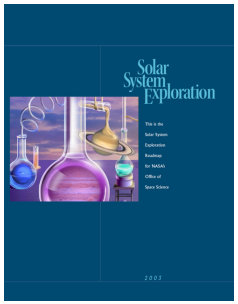
- Primary: Support NASA's science flight missions
  - New instrument development
  - Supporting ground-based and suborbital research
  - Theoretical investigations and modeling
  - Managing and providing access to data
  - Mission data analysis
  - Providing computing, curatorial, and research capabilities
- Also: Many other, broader societal benefits
  - Science to support public policy making, including Earth applications
  - Fundamental scientific breakthroughs
  - New technology with commercial spinoff value
  - Research that supports other Federal goals, including national security and climate change research
  - Science diplomacy (international cooperation) and national prestige
  - Strengthen U.S. universities and other research institutions
  - Develop U.S. technical and aerospace industrial base
  - Contribute to STEM education (K-12)
  - Promote citizen science literacy and intangible enrichment of understanding of the cosmos (public affairs and informal education)
  - Promote STEM workforce development

What is Mission Enabling

- Mission enabling activities include
  - Research activities including individual investigator-led and group investigations
  - Technology development activities
  - Suborbital projects including sounding rockets, scientific balloons, and airborne science
  - Calibration and validation activities, supporting field campaigns
  - Data archives, modeling, high-end computing, facilities and infrastructure, astromaterials curation
  - Science Teams (mission science teams, participating scientists, science working groups, science definition teams)

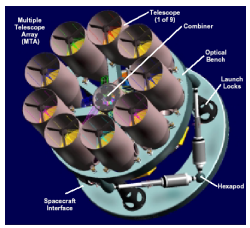
  ? Education/Public Outreach
  ? Earth science applications

Cycle of Discovery



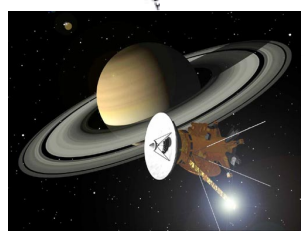
Committees & Academy

Legislation



Mission Enabling Technology

Missions

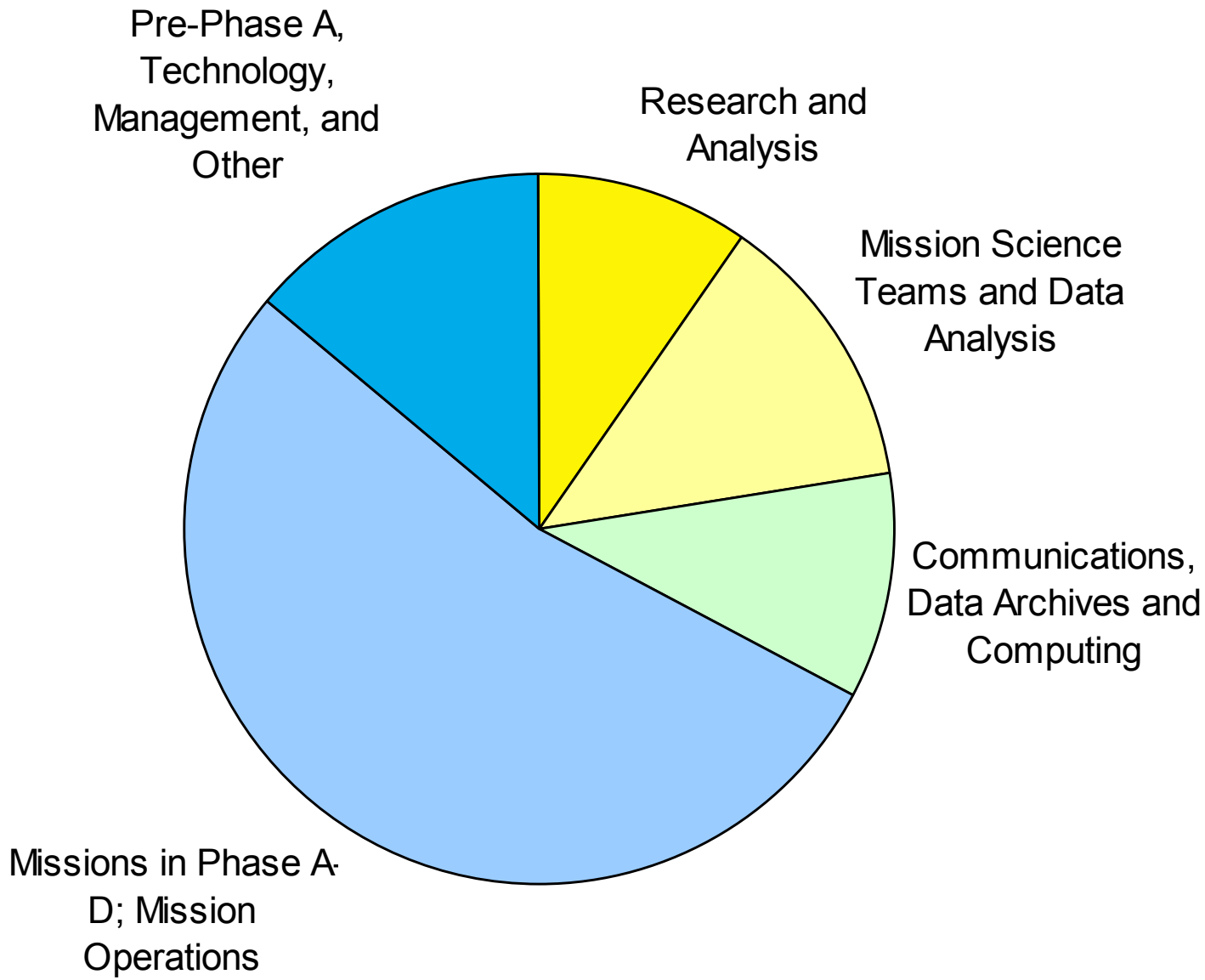


Education

Public

Mission Enabling Research

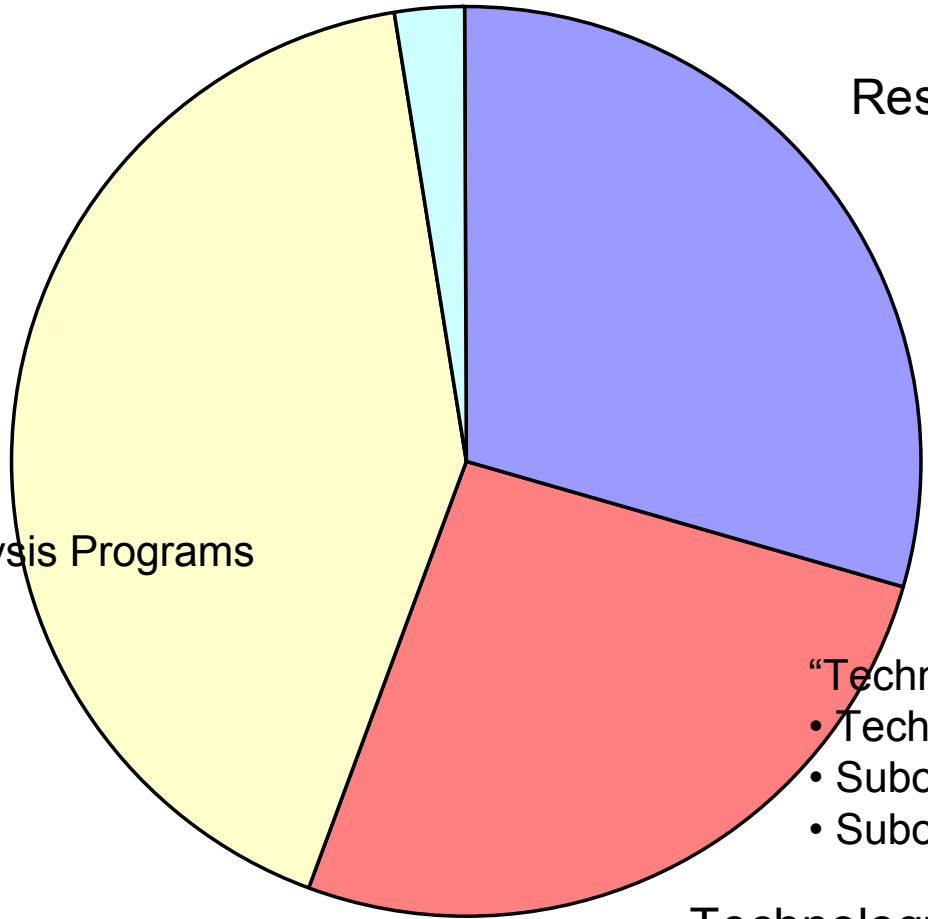
SMD FY09 Budget Approximate Breakout



FY08 Mission Enabling Budget

Total: $1025M

Does not include science teams, or focused technology development



"Applications" includes
- Earth science applications program

"Research" includes:
- Basic research
- Research facilities
- High-end computing

"Technology" includes
- Technology development
- Suborbital payloads/missions
- Suborbital capabilities

"Data" includes
- GO and Data Analysis Programs
- Data Systems
- Data Archives

Naming Names

- Investigator-led research activities have many names:
  - Research and Analysis (R&A)
  - Supporting Research and Technology (SR&T)
  - Data Analysis (DA) including Guest Investigator, Guest Observer, General Observer (GI or GO), or Data Analysis Program (DAP) opportunities
  - Research and Data Analysis (R&DA)
  - “Grant programs”

- NASA does not have “grant programs” per se
  - NASA has competitive science research programs
  - The objective is to advance NASA’s science objectives, not to issue grants
  - Grants are a procurement vehicle for universities and other proposing organizations

- Here “research” is often used instead of “mission enabling”

Managing SMD's Mission Enabling Activities

NASA's Strategic Goals

U.S. Space Exploration Policy

- To advance U.S. scientific, security, and economic interests through a robust space exploration program

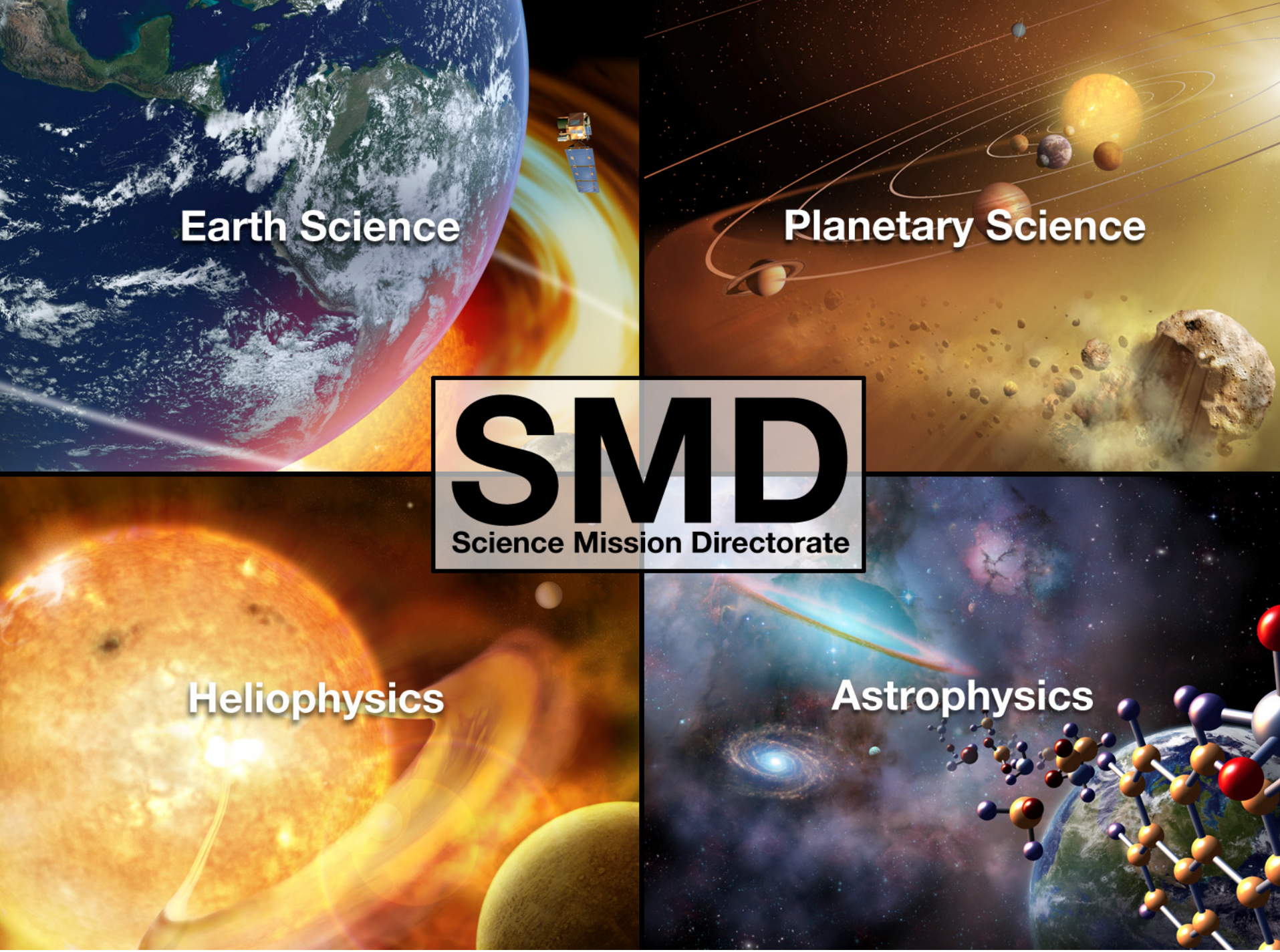
NASA's Mission

- To pioneer the future in space exploration, scientific discovery, and aeronautics research

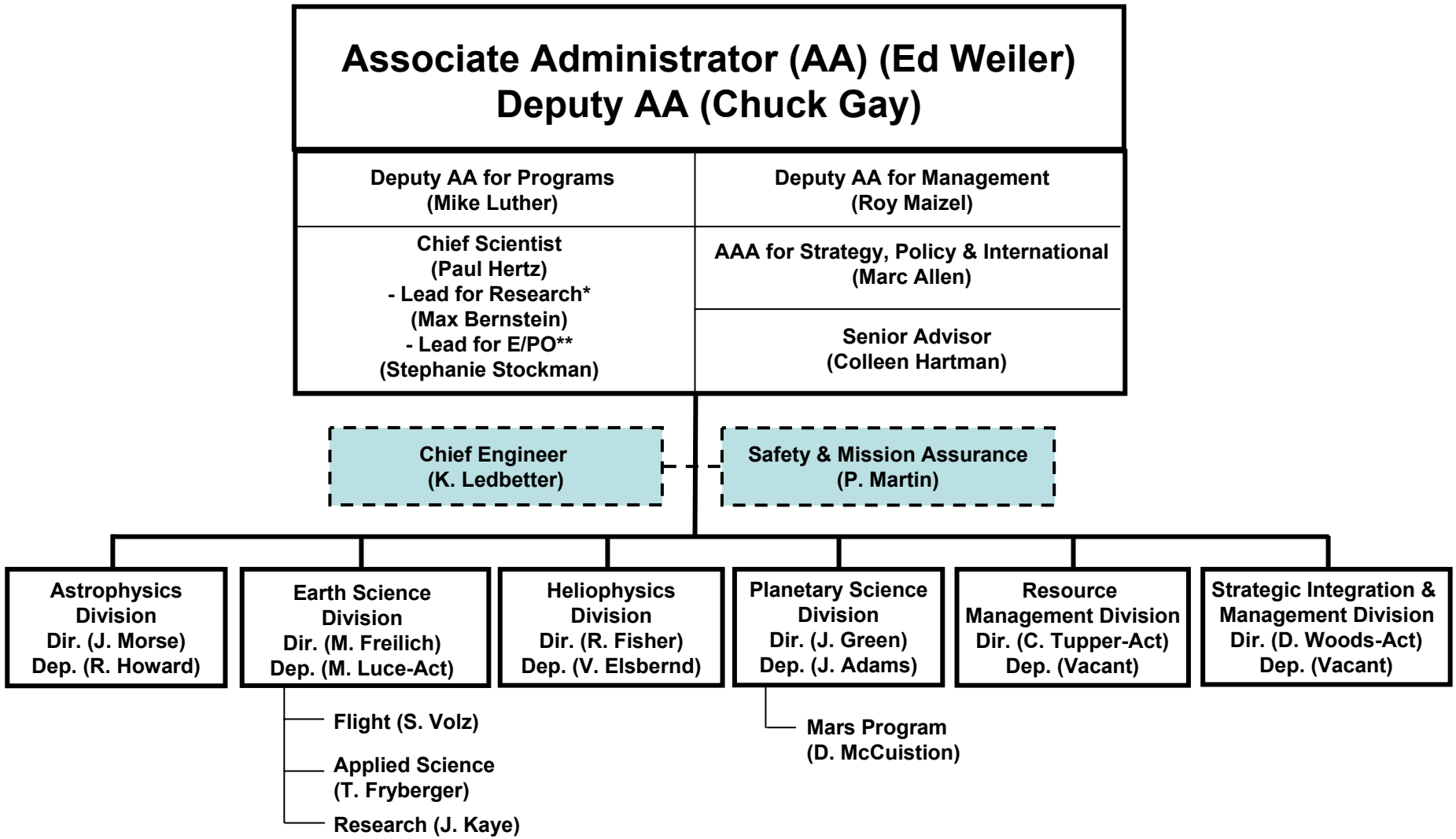
NASA's Strategic Goals in Science

- Study Earth from space to advance scientific understanding and meet societal needs.
- Understand the Sun and its effects on Earth and the solar system.
- Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space.
- Discover the origin, structure, evolution, and destiny of the universe, and search for Earth-like planets.

from the *2006 NASA Strategic Plan*


Earth Science
Planetary Science
SMD
Science Mission Directorate
Heliophysics
Astrophysics

SMD Organization

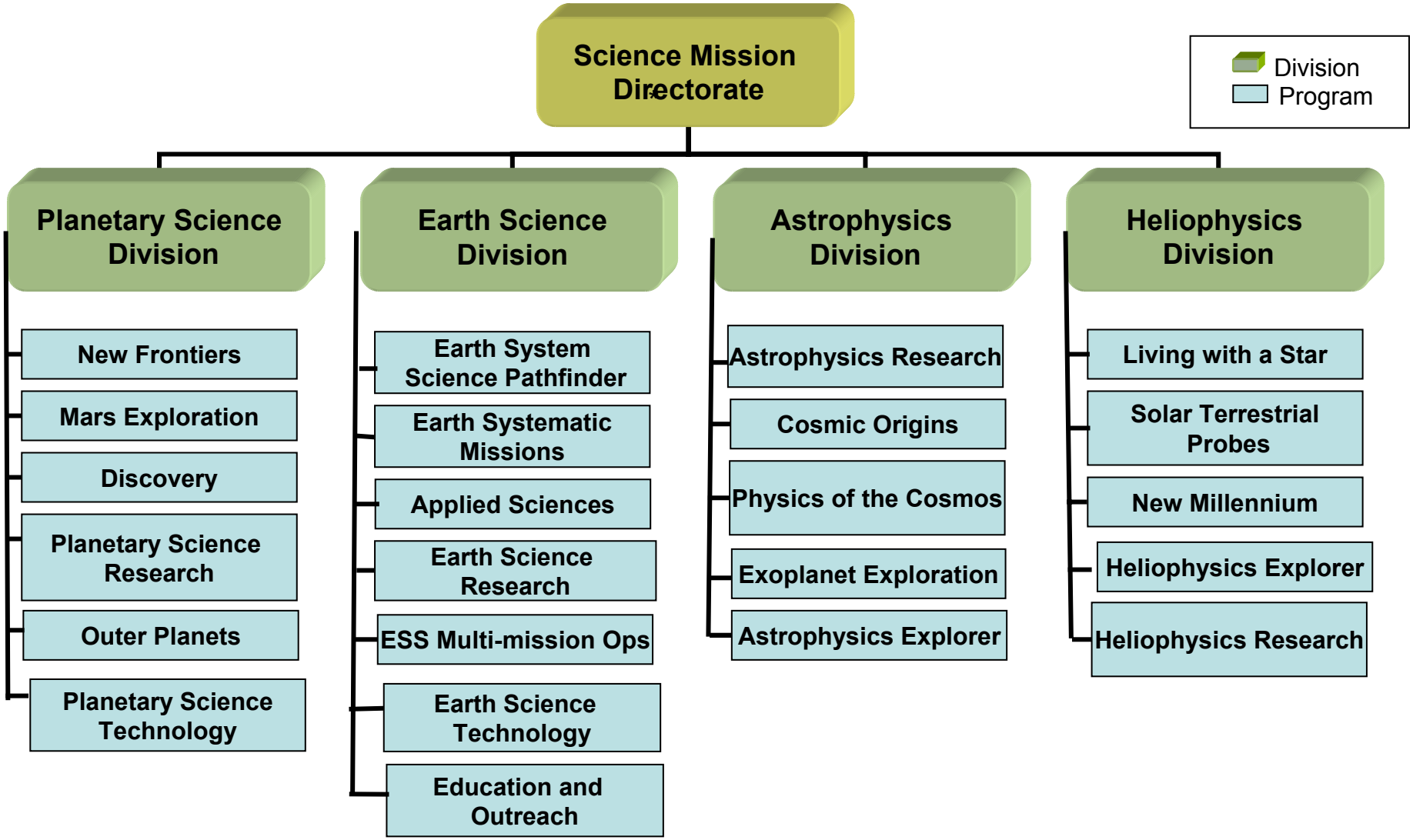


Blue dashed boxes denote individuals who report to other organizations, but support SMD

* = Co-located from Planetary Science Division
** = Co-located from Earth Science Division

Draft: January 12, 2009

SMD Programs



Total Missions / Spacecraft
91 / 102

Updated 8/8/08

Formulation 13 / 17

JPL 5
NuSTAR
JUNO
GRAIL
ExoMars
MAVEN# or TGE#

GSFC 8/12
LDCM
GPM
GPM Const
MMS (4)
RBSP (2)
SMEX (2012 or 2015)
SMEX (2012 or 2015)
NEXT (SXS)

MSFC 0

Implementation 22 / 18

JPL 11/9
Keck (1/0)
Herschel
Planck
LBTI (1/0)
Kepler
WISE
ST-7
OCO
Aquarius
M3
MSL

GSFC 10/9
HST-SM4(1/0)
JWST
GOES-O
GOES-P
NOAA-N´
Glory
NPP
SDO
IBEX
SET-1

DFRC 1/0
SOFIA(1/0)

Primary Ops 23 / 28

JPL 9
Spitzer
OSTM
Cassini
MRO
Rosetta
Phoenix
DAWN
EPOXI*
NExT*

GSFC 10/15
GLAST
Suzaku
Aqua
Aura
STEREO (2)
TWINS-A
THEMIS (5)
AIM
CINDI
TWINS-B

MSFC 3
Hinode
MESSENGER
New Horizons

LaRC 1
CALIPSO

Extended Ops 33 / 39

JPL 10/13
GALEX
Cloudsat
ACRIMsat
GRACE (2)
Jason-1
QuikSCAT
Voyager (2)
Mars Express
Mars Odyssey
MER (2)

GSFC 22/25
HST
Integral
RXTE
WMAP
XMM
SWIFT
SORCE
EO-1
ICEsat
Terra
TRMM
Landsat 7~
SeaWiFS`
Cluster-2 (4)
FAST

MSFC 1
Chandra

Astrophysics
Earth Science
Heliophysics
Planetary Science

In concept development:

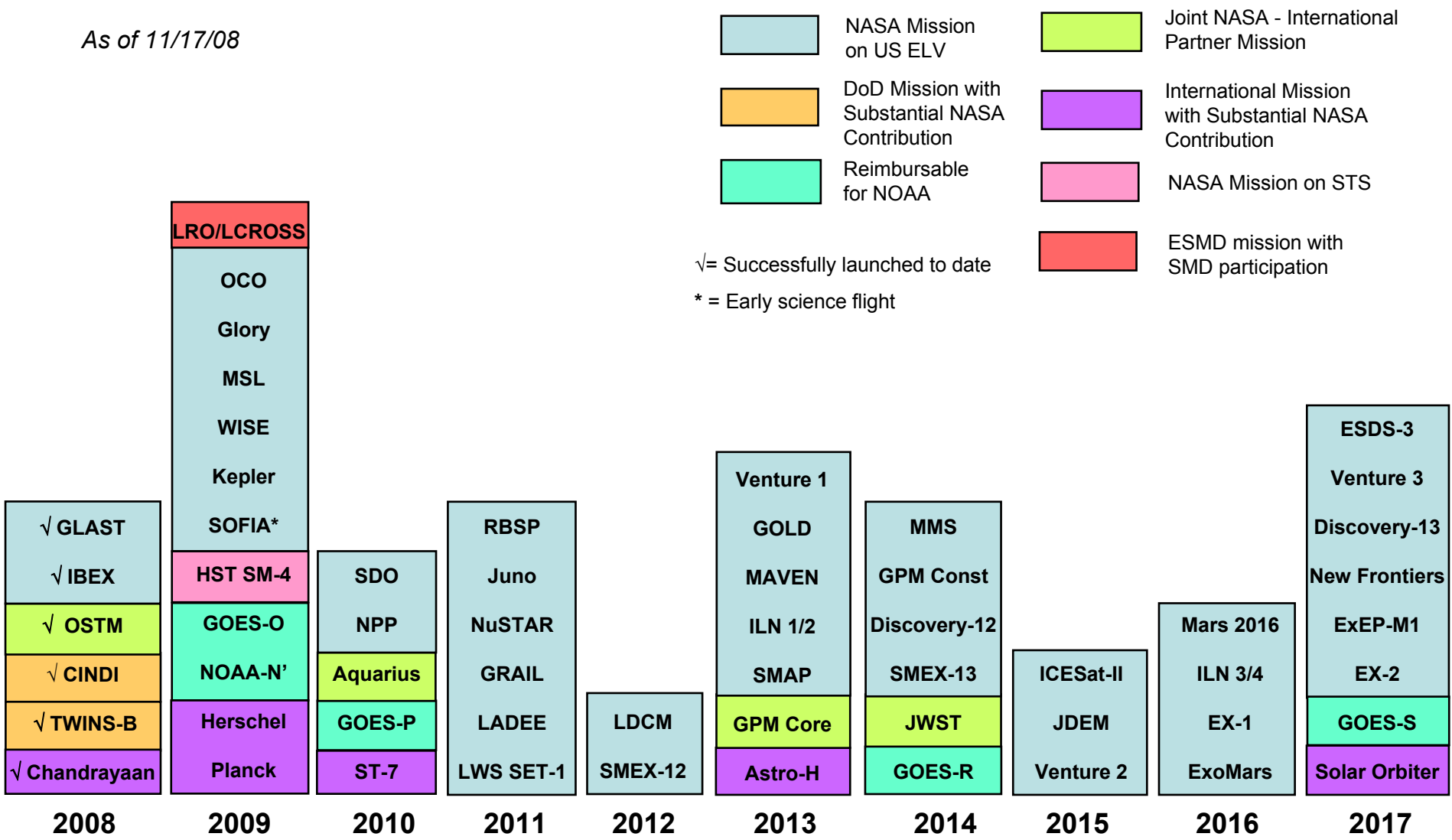
JDEM, SIM-Lite, LISA, Con-X, LADEE, ILN, OPF, SMAP, ICESat-II, Solar Probe +

RHESSI SOHO
TIMED TRACE
WIND ACE
GEOTAIL

Italics = US instruments on foreign mission
X / Y = # of missions / # of spacecraft
* New missions for Deep Impact and Stardust, respectively
KECK, LBTI, and HST-SM4 are mission projects but do not themselves add spacecraft
~ Operated by USGS; ` operated by commercial partner
# Mars Scout-2 mission; select one of two in mid-2008

NASA Science Mission Launches

As of 11/17/08



SMD's Principles

- Investment choices first consider scientific merit.
  - SMD will use open competition and scientific peer review as the primary means for establishing merit for selection of research and flight programs.
- Active participation by the research community outside NASA is critical to success.
  - SMD will engage the external science community in establishing science priorities, preparation and review of plans to implement those priorities, analysis of requirements trade studies, conduct of research, and evaluation of program performance.
- The pace of scientific discovery is fueled by prompt, broad, and easy access to research data.
  - SMD will ensure vigorous and timely interpretation of mission data by requiring that data acquired be made publicly available as soon as possible after scientific validation.

SMD's Principles

- Partnerships are essential to achieving NASA's science objectives.
  - Other nations and agencies are engaged in space and Earth science. NASA and SMD will partner with other national and international organizations to leverage NASA's investment and achieve national goals.
- Partnerships are essential to realizing relevant societal benefits from NASA's research.
  - Beyond increasing scientific understanding, many NASA programs produce results with practical societal benefits. NASA and SMD will forge partnerships with other U.S. Federal agencies to facilitate their use of NASA research data and science results in their operational products and services.
- The NASA mandate includes broad public communication.
  - SMD will convey the results and excitement of our programs through formal education and public engagement. SMD will seek opportunities to promote student interest in science, technology, engineering, and mathematics disciplines and careers.

SMD's Principles

- Sustained progress in advancing U.S. space and Earth science interests requires investments across a broad range of activities.
  - The range of activities include basic research to understand the scientific challenges, technology development to enable new capabilities, space mission development to acquire the vital new data, and supporting science and infrastructure systems to ensure delivery of high value scientific results to the science community and the general public.
  - NASA will consider the long-term sustainable health of the necessary scientific disciplines and communities that enable progress towards NASA's scientific objectives when determining the mix of research and mission investments.
  - NASA and SMD will maintain essential technical capabilities at the NASA Centers to plan for the future, lead strategic missions, and assist NASA sponsored community research and mission developments.

SMD's Principles

  - SMD will establish mission lines that enable competitive selection, funding, and management of classes of missions based upon the focus of the science outcome. Some missions are focused on specific science questions, and some missions are focused on providing foundational data sets that researchers will be using for decades to come. In the first case, PI leadership has proven to be a successful strategy for maintaining science focus and technical discipline. In the second case, strategic missions with guidance from a representative science team is more appropriate.
- The Nation looks to NASA for innovation in space.
  - SMD will accelerate the pace of scientific discovery through advanced technologies that will enable and enhance new space missions; shorten the mission development cycle; and speed the use of observation, model, and research results in the planning of future and the operation of current missions and systems.

SMD's Principles are from the NASA Science Plan (*The Science Plan for NASA's Science Mission Directorate (2007-2016)*)

Structure of the SMD Research Budget

- Research is a part of everything we do, and it is a part of every budget line
  - NASA's budget is organized into Directorates, Themes/Divisions, Programs, Projects, and Activities
  - Every flight Program includes research activities for its missions in addition to development (including PI-led mission development and PI-led instrument development) and operations (including science operations and data processing): technology development, science teams, participating scientists and interdisciplinary scientists, data analysis, calibration and validation, research fellowships, etc.
  - Research Programs include non-flight projects and activities such as research and analysis (R&A), supporting research and technology (SR&T), suborbital projects (Airborne, Balloon, Sounding Rocket), data analysis (DA), general observers, archives, modeling, field campaigns, research facilities, computing, etc.
  - There is no set of budget lines that can provide the total SMD research budget

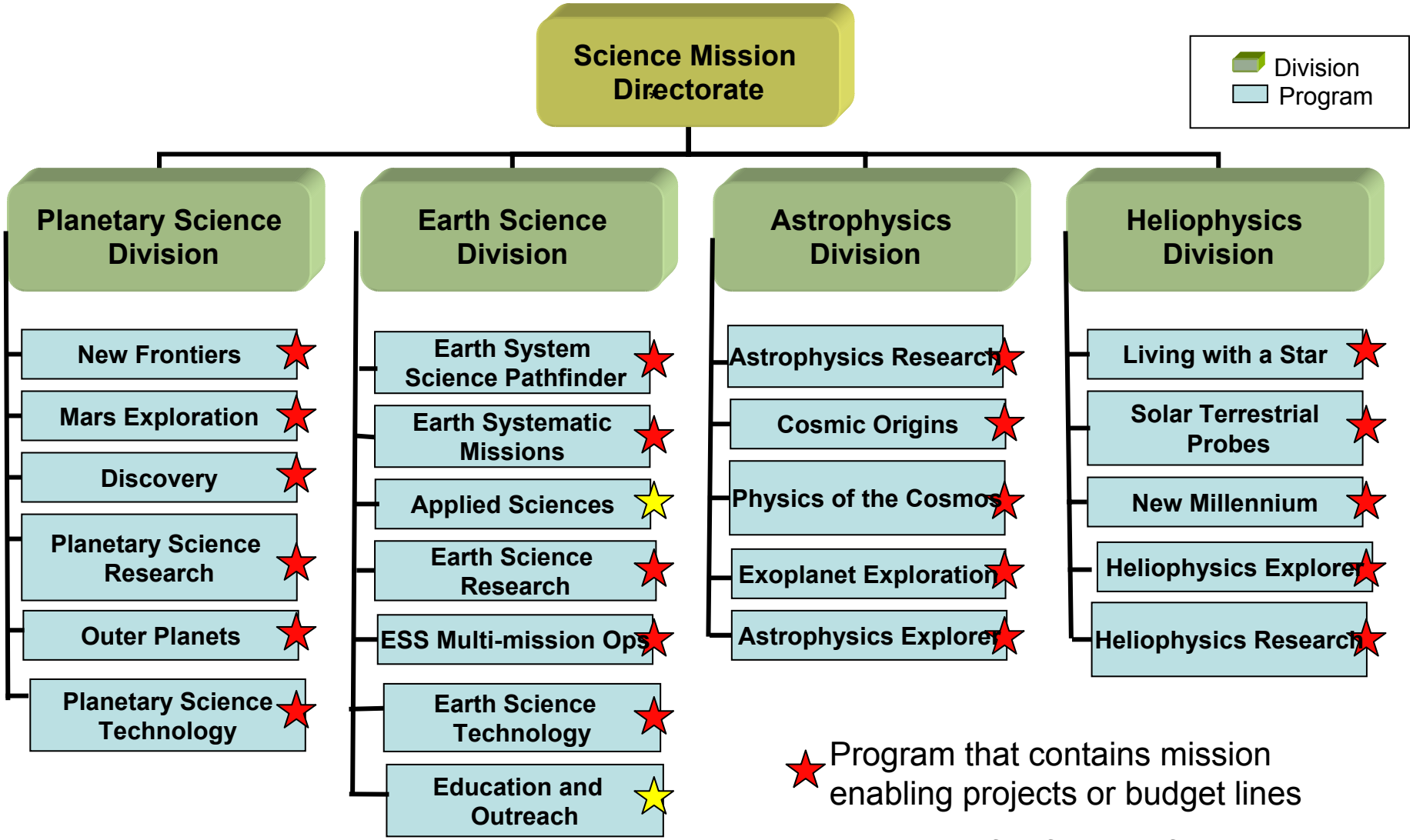
NASA FY09 President's Budget Request

	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
Total NASA	$16,231.0	$17,300.5	$17,610.7	$18,022.9	$18,457.0	$18,901.6	$19,355.4
Science	$4,609.9	$4,706.2	$4,441.5	$4,482.0	$4,534.9	$4,643.4	$4,761.6
Earth Science	$1,198.5	$1,280.3	$1,367.5	$1,350.7	$1,250.9	$1,264.4	$1,290.3
Planetary Science	$1,215.6	$1,247.5	$1,334.2	$1,410.1	$1,537.5	$1,570.0	$1,608.7
Astrophysics	$1,365.0	$1,337.5	$1,164.5	$1,122.4	$1,057.1	$1,067.7	$1,116.0
Heliophysics	$583.7	$590.9	$575.3	$598.9	$689.4	$741.2	$746.6
DSN / Ground Network	$247.2	$250.0					
Aeronautics Research	$593.8	$511.7	$446.5	$447.5	$452.4	$456.7	$467.7
Education	$114.1	$137.9	$112.1	$122.7	$120.4	$120.4	$120.4
Exploration Systems	$2,837.6	$3,143.0	$3,500.5	$3,737.7	$7,048.2	$7,116.8	$7,666.8
Constellation Systems	$2,114.7	$2,471.9	$3,048.2	$3,252.8	$6,479.5	$6,521.3	$7,080.5
Advanced Capabilities	$722.9	$671.1	$452.3	$484.9	$568.7	$595.5	$586.3
Space Operations	$5,093.5	$5,526.2	$5,774.7	$5,872.7	$2,900.1	$3,089.9	$2,788.5
Space Shuttle	$3,295.3	$3,266.7	$2,981.7	$2,983.6	$95.7		
International Space Station	$1,469.0	$1,813.2	$2,060.2	$2,277.0	$2,176.4	$2,448.2	$2,143.1
Space and Flight Support (SFS)	$329.2	$446.3	$732.8	$612.1	$628.0	$641.7	$645.4
Cross-Agency Support	$2,949.9	$3,242.9	$3,299.9	$3,323.9	$3,363.7	$3,436.1	$3,511.2
Agency Management and Operations	$971.2	$830.2	$945.6	$945.5	$939.8	$950.5	$961.3
Institutional Investments	$223.8	$319.7	$308.7	$331.7	$335.9	$330.4	$338.3
Congressionally Directed Items		$80.0					
Center Management and Operations	$1,754.9	$2,013.0	$2,045.6	$2,046.7	$2,088.0	$2,155.2	$2,211.6
Inspector General	$32.2	$32.6	$35.5	$36.4	$37.3	$38.3	$39.2

Structure of the SMD Budget

- Research is part of everything we do, and it is a part of every budget line
  - Budget is distributed as a component of every program and every project
  - Different divisions bookkeep their research budgets in different ways
    - E.g. Science teams can be embedded in individual flight projects or funded from a research project – some are R&A, some are not
    - E.g. Data analysis can be embedded in individual flight projects or funded from a research project – some are R&A, some are not
- Research is a “program line” in the NASA budget
  - R&A is only one “project” in the “program”
  - Mission operations
  - Data analysis
  - Suborbital projects
  - Data archives
  - Etc.

SMD Programs



★ Program that contains mission enabling projects or budget lines

☆ Depends of definition of mission enabling

Components of the SMD Research Budget

- "Standard" R&A
  - R&A project (each Division has one in its Research Program)
  - R&A embedded in flight programs (e.g. Mars, Living With a Star, Physics of the Cosmos)
  - Technology in a program (Earth Science Technology) or distributed
- Data analysis (other than traditional R&A)
  - General Observer/Guest Investigator programs
  - Archival data analysis programs
  - Mission or program specific data analysis programs
  - Data archive, virtual observatory, etc.
- Science Teams (other than traditional R&A)
  - PI teams for missions and instruments selected through AO
  - Additional team members selected through competition
    - Science teams, participating scientists, interdisciplinary scientists, science working group members, etc.

Structure of the SMD Research Budget

Other Mission Enabling Activities (all discussed later)

Earth Science

- EOS Science
- Mission Science Teams
- Airborne Science
- Data Systems
- High-End Computing
- Technology Development

Planetary Science

- Mission Science Teams
- Planetary Data System
- Astromaterials Curation

Heliophysics

- Mission Science Teams
- Sounding Rockets
- Research Range
- Data and Modeling Centers

Astrophysics

- Guest Observer Programs
- Mission Science Teams
- Scientific Balloons
- Data Centers

Earth Science applications and Education/Public Outreach are not discussed

Structure of the SMD Research Budget

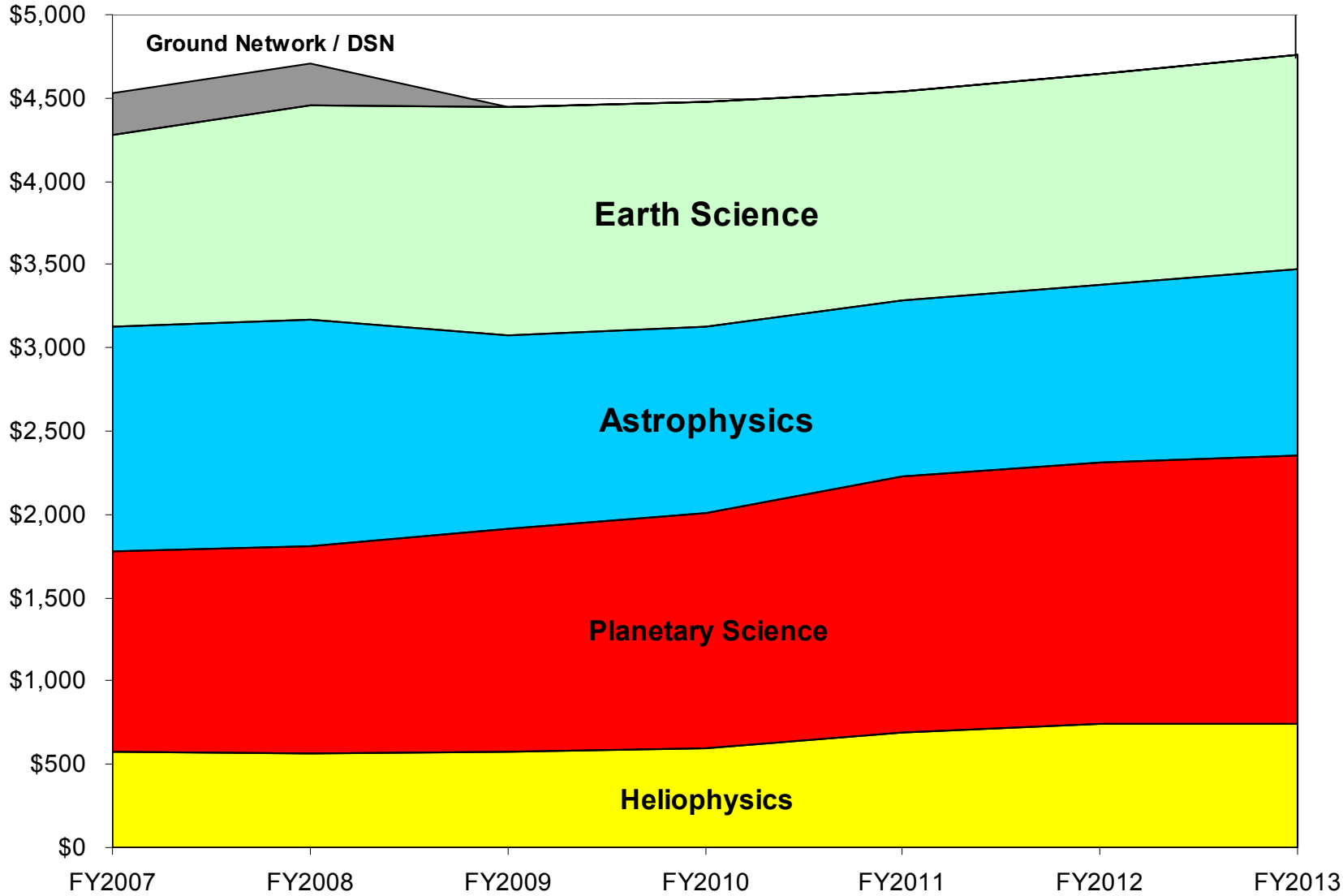
- Flagship missions enable NASA to meet science objectives
- Significant community funding is associated with large missions**
  - Hubble Space Telescope: Development of instruments provided over $1.2B to 10 instrument teams; Observing enabled 6510 GO grants over 15 years providing $283M to 4138 investigators, 1323 postdocs, 1852 grad students.
  - Earth Observing System missions provided $1.6B in funding over 14 years to 781 investigators, 112 postdocs, 159 grad students for algorithm development, IDS investigations, cal/val investigations.
  - Spitzer Space Telescope: Science operations provided $100M to 318 investigators over 6 years for science team and general observers.
  - Cassini: Science operations provided $200M over 9 years to 125 investigators, 120 postdocs and grad students for science development and data analysis.
  - Chandra: ~$100M over 10 years to 2446 GO grants.
- All funding is peer reviewed and selected through AOs, NRAs, Calls for Proposals (observing), or unsolicited but peer reviewed proposals.

** Data (except Chandra) is from a 2005 snapshot and has not been updated.

Structure of the SMD Research Budget

- Rationale
  - Initiatives for new programs (e.g., Mars Exploration, Living With a Star, Beyond Einstein, etc.) are correctly described as complete programs including flight missions, the technology to enable them, the mission operations and data analysis to reap their benefits, and the basic research necessary to leverage their data into science advances
  - Isolating research into a single budget line gives the false impression to outside observers that research is separate from flight missions rather than being an integral part of the Nation benefiting from NASA's flight missions
  - NASA's science goals, objectives, and metrics are based on science results not mission milestones; it is appropriate to link the budget necessary to realize these goals, objectives, and metrics to the appropriate program
  - There are many examples of the value of this approach

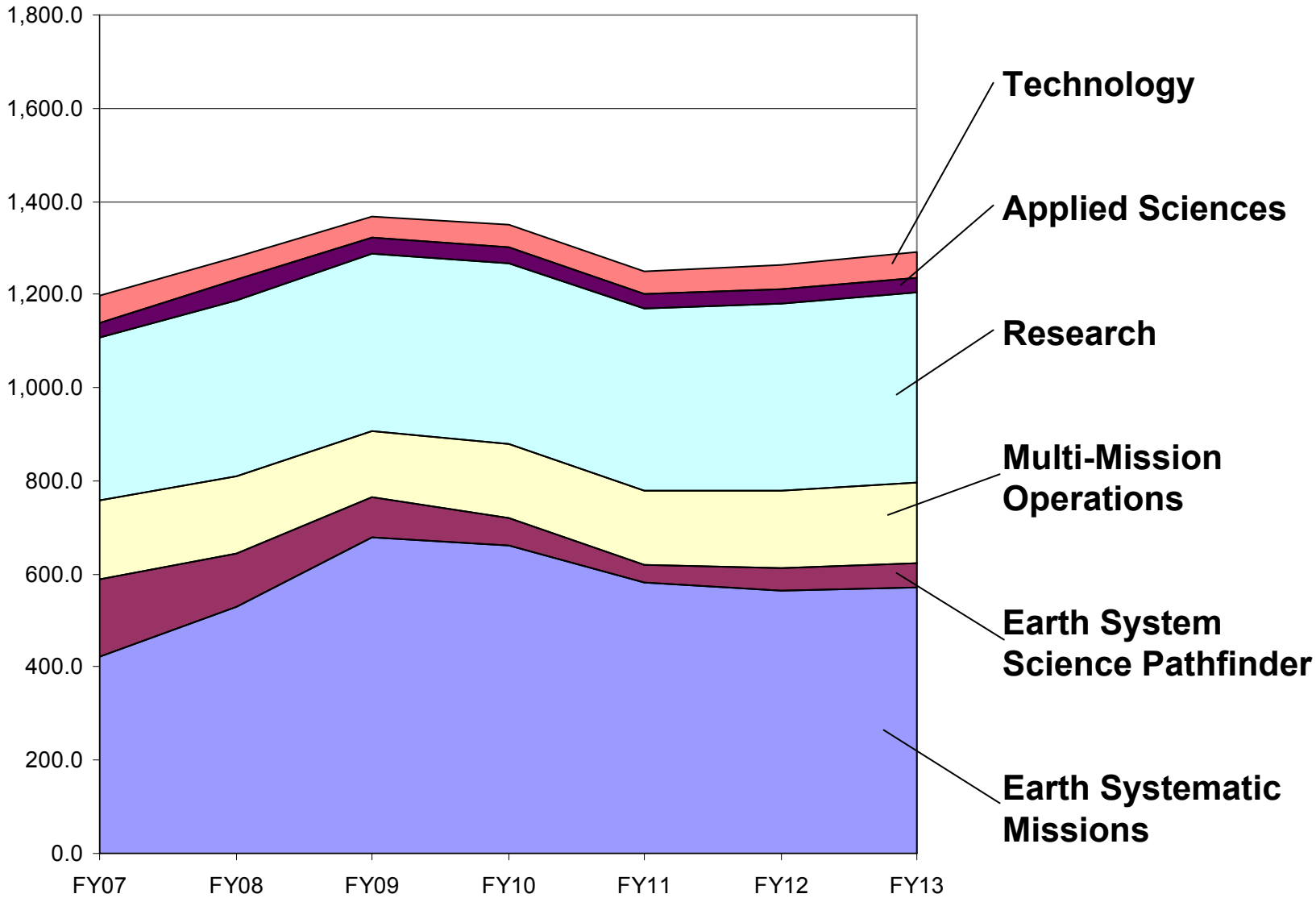
FY09 President's Request by SMD Division



Earth Science Program Content

	FY07	FY08	FY09	FY10	FY11	FY12	FY13
FY09 President's Budget	1,198.5	1,280.3	1,367.5	1,350.7	1,250.9	1,264.4	1,290.3
Earth Systematic Missions	420.9	530.1	677.9	661.5	583.2	563.6	569.6
GPM	23.8	74.4	125.8	161.7	129.8	140.0	113.3
Glory	91.8	35.2	29.7	9.1	9.8	2.7	
LDCM	45.9	133.0	139.4	127.1	96.0	11.3	2.7
NPP	47.3	70.0	94.4	52.2	8.6	8.9	9.2
OSTM	42.8	27.5	8.0	7.8	7.7	7.3	7.3
Decadal Survey Missions	0.6	33.0	103.2	116.2	150.0	250.2	290.7
Other Missions and Data Analysis	168.7	157.0	177.4	187.5	181.2	143.1	146.3
Earth System Science Pathfinder (ESSP)	167.9	113.8	88.6	58.8	37.4	50.0	54.9
OCO	84.8	35.6	25.4	9.0	1.4		
Aquarius	62.4	48.6	33.8	27.9	5.1	4.0	2.9
Other Missions and Data Analysis	20.6	29.6	29.4	21.9	30.8	46.0	52.0
Earth Science Multi-Mission Operations	168.0	167.8	140.5	159.1	157.9	166.5	170.9
Earth Science Research	349.5	375.8	380.6	388.2	390.6	400.7	409.3
Research and Analysis	232.6	243.3	245.7	254.0	255.5	260.3	266.5
Computing and Management	91.3	103.1	104.9	104.7	107.3	110.1	111.8
Airborne Science	25.6	26.0	26.3	25.7	24.0	26.4	27.0
Near Earth Object Observations		3.4	3.7	3.8	3.8	3.9	4.0

FY09 Budget Proposal: Earth Science



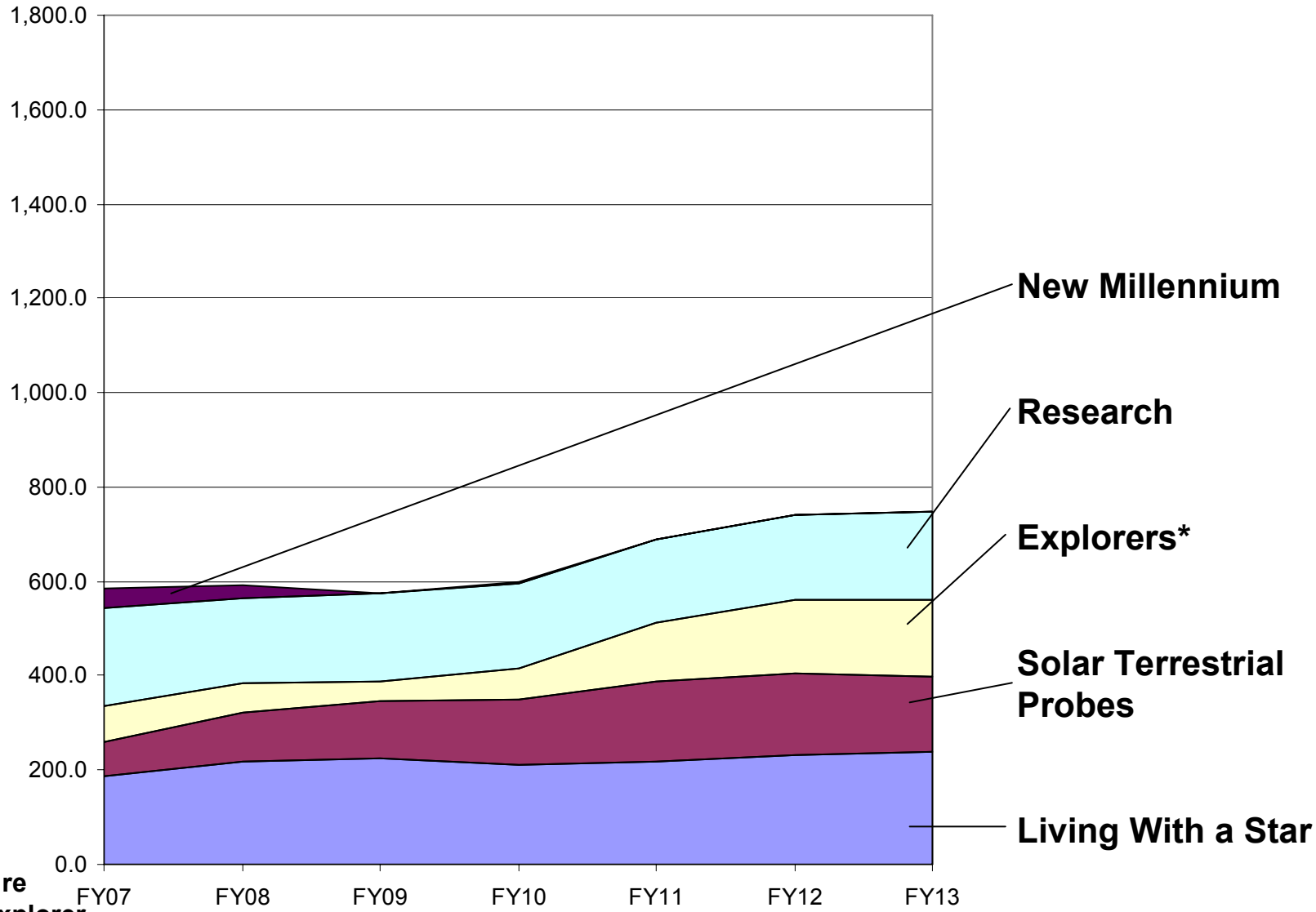
Structure of the SMD Earth Science Budget
(FY09 President's Request)

- Earth Science
  - Earth Systematic Missions
    - OSTM, GPM, Glory, LDCM, NPP
    - Decadal Survey Missions
    - Other Missions and Data Analysis — mission enabling
  - Earth System Science Pathfinder
    - OCO, Aquarius
    - Other Missions and Data Analysis — mission enabling
  - Earth Science Multi-mission Activities — mission enabling
  - Earth Science Research
    - Research and Analysis — mission enabling
    - Computing and Management — mission enabling
    - Airborne Science — mission enabling
    - Near Earth Object Observations — [to Planetary in FY10]
  - Applied Sciences
  - Earth Science Technology
    - Advanced Technology Initiatives — mission enabling
    - Instrument Incubator — mission enabling
    - Advanced Info Systems Technology — mission enabling

Heliophysics Program Content

	FY07	FY08	FY09	FY10	FY11	FY12	FY13
FY09 President's Budget	583.7	590.9	575.3	598.9	689.4	741.2	746.6
Living with a Star	188.6	217.1	223.8	212.0	216.6	232.8	237.5
SDO	144.0	90.0	24.1	14.8	14.6	15.5	14.7
Geospace RBSP	12.9	77.7	154.4	154.7	113.4	57.9	15.8
BARREL		0.8	0.9	3.9	2.4	2.0	2.1
Solar Probe Lite		13.9		3.4	40.1	74.2	106.3
Other Missions and Data Analysis	31.7	34.7	44.4	35.2	46.2	83.2	98.6
Solar Terrestrial Probes	71.8	105.9	123.1	137.5	171.4	172.6	161.5
MMS	31.1	73.2	94.6	116.0	149.3	148.8	137.5
Other Missions and Data Analysis	40.7	32.7	28.5	21.5	22.0	23.9	24.1
Heliophysics Explorers	74.4	61.0	41.3	66.8	125.1	156.0	160.1
IBEX	45.1	30.8	9.5	6.9	1.0		
Future Missions	1.5	8.4	16.5	40.9	105.8	135.7	139.2
Other Missions and Data Analysis	27.8	21.8	15.3	19.1	18.4	20.3	20.9
Heliophysics Research	208.0	181.2	184.8	180.3	175.3	179.8	187.5
Research and Analysis	32.5	30.9	33.9	35.9	38.9	39.6	40.5
Sounding Rockets	31.9	30.2	45.1	47.3	48.9	49.7	51.8
GSFC Building Support	30.0	20.0	12.0	12.0			
Operating Missions / Data / Modeling	113.6	100.1	93.8	85.1	87.6	90.5	95.2
New Millenium	40.8	25.8	2.3	2.2	1.1		

FY09 Budget Proposal: Heliophysics



* includes future astrophysics explorer missions

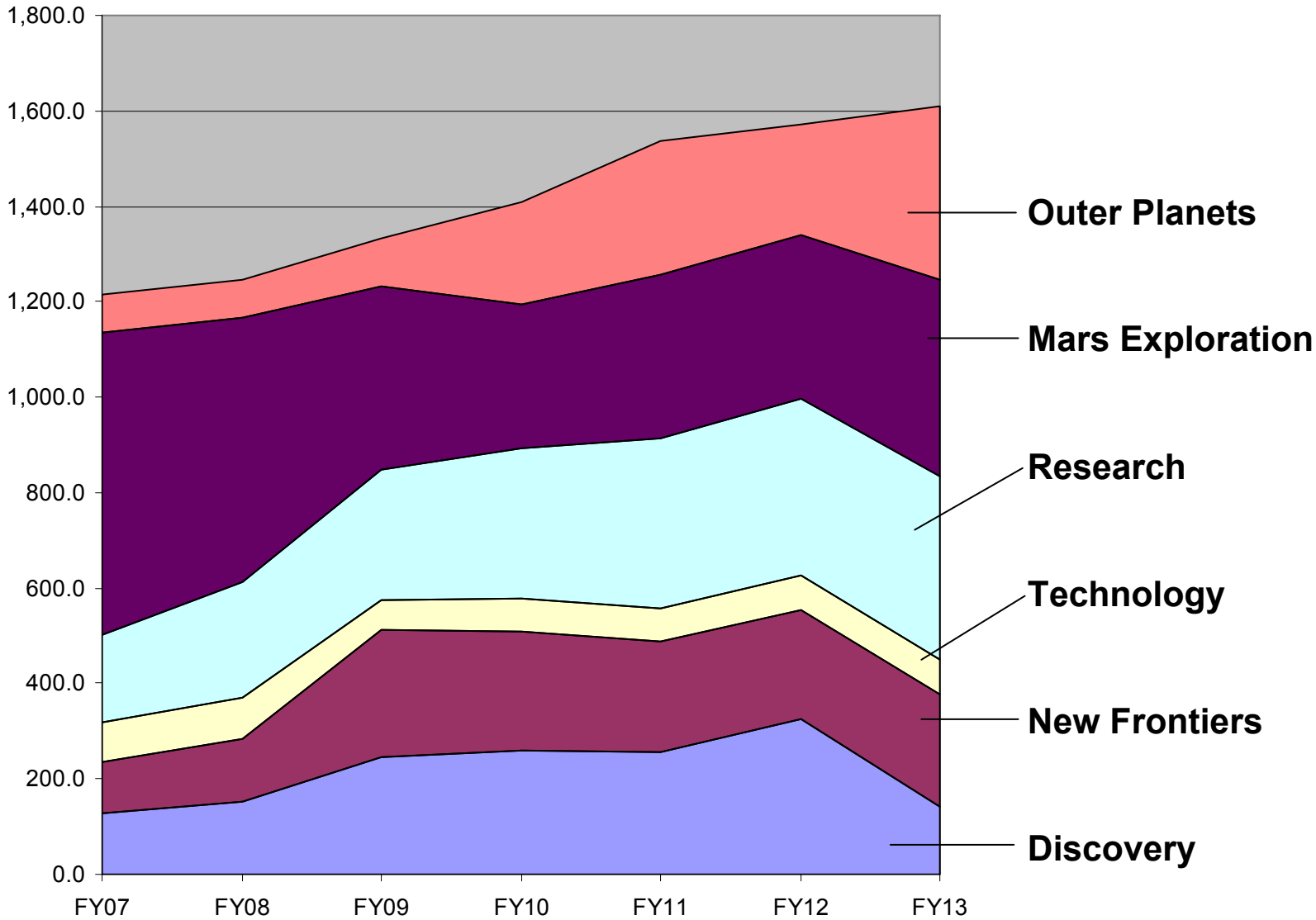
Structure of the SMD Heliophysics Budget
(FY09 President's Request)

- Heliophysics
  - Living With a Star
    - SDO, RBSP, Solar Probe, BARREL
    - Other Missions and Data Analysis — mission enabling
  - Solar Terrestrial Probes
    - MMS
    - Other Missions and Data Analysis — mission enabling
  - Heliophysics Explorer
    - IBEX
    - Other Missions and Data Analysis — mission enabling
  - Heliophysics Research
    - Research and Analysis — mission enabling
    - Sounding Rockets — mission enabling
    - ACE, Operating Missions and Data Analysis
    - Research Range — mission enabling
    - GSFC Building
  - New Millennium
  - Near Earth Networks // Deep Space Mission Systems

Planetary Science Program Content

	FY07	FY08	FY09	FY10	FY11	FY12	FY13
FY09 President's Budget	1,215.6	1,247.5	1,334.2	1,410.1	1,537.5	1,570.0	1,608.7
Discovery	128.3	153.0	247.0	258.3	256.0	326.1	140.5
Discovery Future	13.1	52.1	50.4	49.1	65.4	239.8	90.7
GRAIL		35.1	122.4	122.8	113.1	24.9	5.7
M3	6.6	2.6	2.7	2.6	0.5		
Discovery Research	11.9	10.0	18.8	16.5	15.7	16.9	17.3
Operating Missions and Data Analysis	96.8	53.2	52.6	67.3	61.3	44.6	26.8
New Frontiers	106.6	132.2	263.9	250.3	232.3	227.7	236.9
Juno	87.8	108.3	245.0	225.2	168.0	14.4	17.8
Other Missions and Data Analysis	18.8	23.9	19.0	25.1	64.3	213.3	219.1
Technology	84.8	84.8	64.9	69.3	69.6	71.3	73.0
Planetary Science Research	181.9	242.1	270.8	315.8	355.6	373.2	382.6
Research & Analysis	111.7	123.6	142.4	145.1	150.4	155.2	159.0
Outer Planet Mission Studies		4.2					
Lunar Science Research		22.7	105.0	122.0	140.0	150.0	151.9
Operating Missions and Analysis	20.4	19.1	19.5	21.4	22.2	22.3	22.7
Education and Directorate Management	49.8	72.4	3.9	27.4	43.1	45.7	49.0
Mars Exploration	634.9	553.5	386.5	299.6	344.5	341.1	413.8
MSL 2009	416.8	305.5	223.3	69.0	54.6	37.6	
Scout 2013	5.3	57.7	6.7	68.5	152.5	170.7	121.8
JPL Building Support	26.8	13.4					
Mars R&A	14.2	27.4	24.9	25.9	26.7	27.1	27.5
Operating Missions and Data Analysis	171.8	149.4	131.6	126.2	90.5	69.9	69.3
Mars Next Decade				10.0	20.2	35.8	195.2
Outer Planets	79.0	81.9	101.1	216.7	279.4	230.6	362.0
Cassini	79.0	81.9	81.8	81.5	75.3	10.0	10.0
Outer Planets Flagship			19.3	135.2	204.1	220.6	352.0

FY09 Budget Proposal: Planetary Science



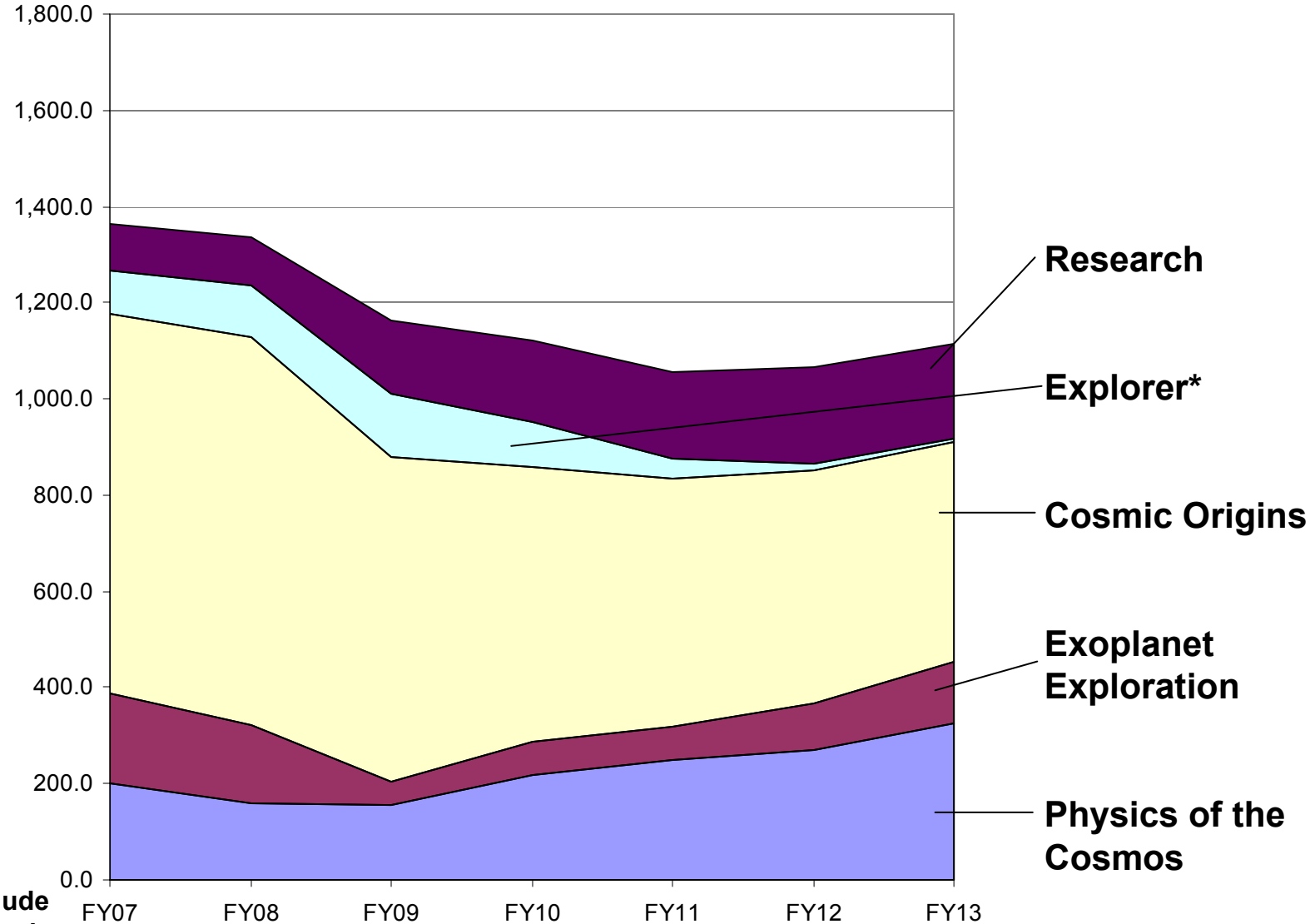
Structure of the Planetary Science Budget
(FY09 President's Request)

- Planetary Science
  - Discovery
    - GRAIL, MMM, Future Missions
    - Discovery Research — mission enabling
    - Operating Missions and Data Analysis — mission enabling
  - New Frontiers
    - Juno
    - Other Missions and Data Analysis — mission enabling
  - Technology — mission enabling
  - Planetary Science Research
    - Research and Analysis — mission enabling
    - Lunar Science Research — mission enabling
    - Operating Missions and Analysis — mission enabling
    - Education and Directorate Management [for SMD]
  - Mars Exploration
    - MSL, MAVEN, JPL Building
    - Mars Research and Analysis — mission enabling
    - Operating Missions and Data Analysis — mission enabling
  - Outer Planets — mission enabling

Astrophysics Program Content

	FY07	FY08	FY09	FY10	FY11	FY12	FY13
FY09 President's Budget	1,365.0	1,337.5	1,164.5	1,122.4	1,057.1	1,067.7	1,116.0
Physics of the Cosmos	201.3	159.0	157.0	219.8	249.0	271.1	326.0
GLAST	88.9	33.3	23.2	23.3	24.1	24.9	24.9
Herschel	11.7	14.5	27.2	17.4	17.6	17.5	16.4
Planck	6.8	8.0	9.4	8.9	6.6	6.5	6.5
JDEM		3.7	8.5	63.0	83.0	109.0	125.0
LISA	6.5	5.1	5.7	15.9	18.7	26.7	35.0
Constellation-X	8.3	5.4	8.3	12.0	16.8	15.9	42.0
Other Missions and Data Analysis	79.1	89.0	74.9	79.3	82.1	70.6	76.2
Exoplanet Exploration	184.7	162.6	48.1	67.7	68.4	96.4	126.2
SIM	30.4	54.1					
Kepler	121.8	78.9	25.2	14.9	13.9	12.6	8.8
Future Exoplanet Missions	1.0	1.1	6.6	41.7	44.0	72.0	107.5
Other Missions and Data Analysis	31.5	28.5	16.3	11.2	10.5	11.7	9.9
Cosmic Origins	790.9	807.3	674.4	571.1	515.4	485.6	458.5
James Webb Space Telescope	398.6	448.3	371.9	311.1	265.1	236.1	194.9
Hubble Space Telescope	279.5	228.5	154.9	125.6	114.7	94.8	93.9
SOFIA	38.9	62.1	72.8	72.8	57.0	58.8	60.6
Spitzer	73.8	68.4	71.7	15.9	10.3	3.2	3.3
Astrophysics Future Missions			3.0	45.8	68.3	92.7	105.8
Astrophysics Explorer	89.2	106.4	132.6	93.3	43.3	11.7	6.4
WISE	54.1	71.8	65.2	13.0	5.2	1.6	
NuSTAR			43.5	57.8	31.0	6.8	6.4
Operating Explorers	35.1	34.6	23.9	22.5	7.1	3.2	
Astrophysics Research	98.9	102.2	152.3	170.4	181.0	203.0	198.9
Research and Analysis	52.2	50.3	61.4	65.4	69.3	72.6	77.5
Balloons	22.2	22.8	24.6	26.7	28.8	32.4	33.2
Other Missions and Data Analysis	24.5	29.1	66.3	78.4	82.9	97.9	88.2

FY09 Budget Proposal: Astrophysics



*** does not include future astrophysics explorer missions**

Structure of the SMD Astrophysics Budget
(FY09 President's Request)

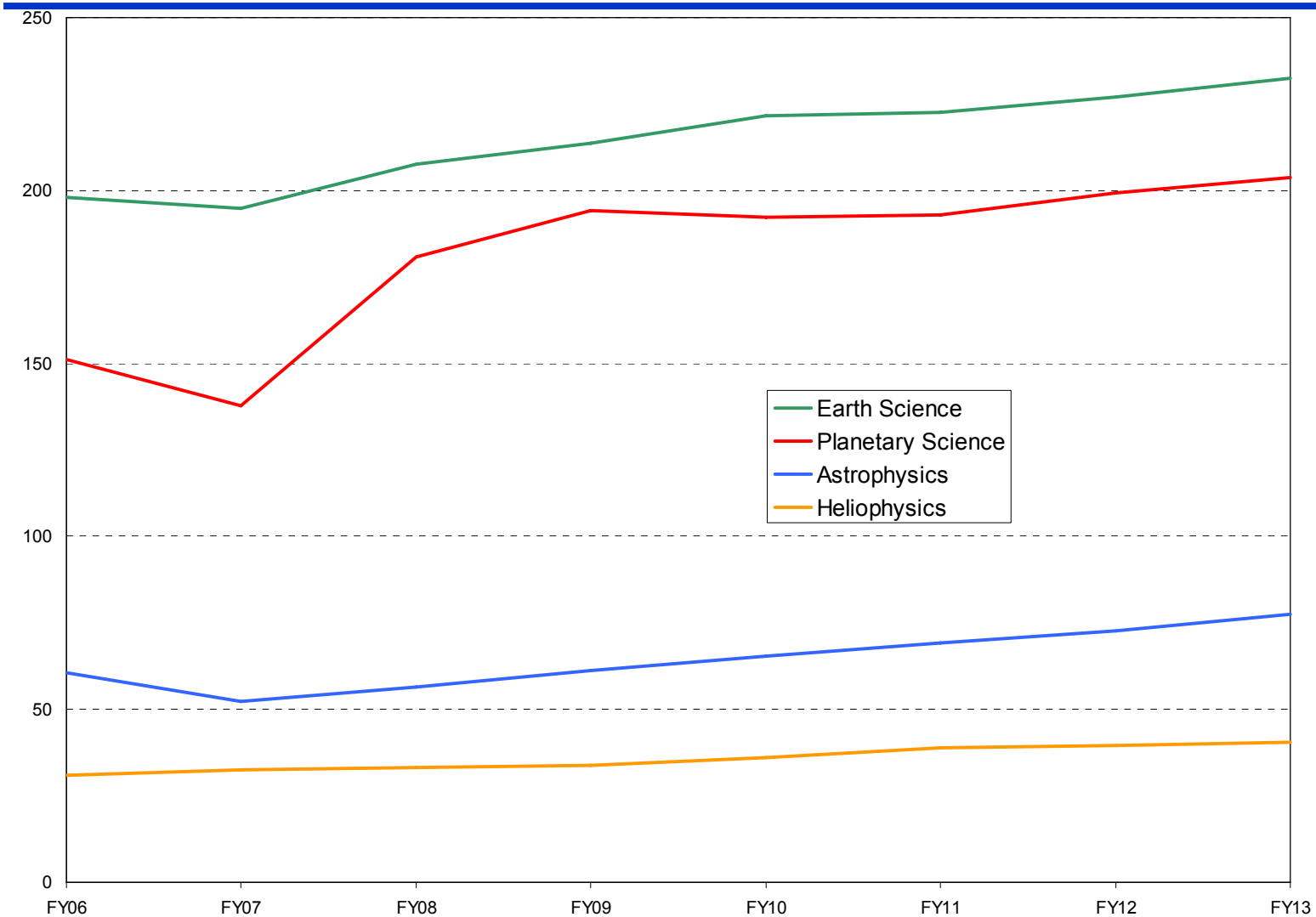
- Astrophysics
  - Astrophysics Research
    - Research and Analysis — mission enabling
    - Balloon Project — mission enabling
    - Operating Missions and Data Analysis — mission enabling
  - Cosmic Origins
    - Hubble, JWST, SOFIA, Spitzer
    - Astrophysics Future Missions — mission enabling
  - Physics of the Cosmos
    - Fermi, JDEM, Herschel, Planck
    - Chandra, Other Missions, and Data Analysis — mission enabling
  - Exoplanet Exploration
    - SIM, Kepler
    - Other Missions and Data Analysis — mission enabling
  - Astrophysics Explorer
    - WISE, NuSTAR
    - Operating Missions and Data Analysis — mission enabling

SMD Mission Enabling Budget

"Standard" Research	FY07	FY08	FY09
Earth Science	152	153	168
Heliophysics	62	61	67
Planetary Science	138	192	209
Astrophysics	66	72	76
Other Mission Enabling			
Earth Science	371	359	341
Heliophysics	64	66	79
Planetary Science	16	16	16
Astrophysics	105	107	124
SMD Total	972	1,025	1,080

- Notes
  - "Standard Research" is the competed research programs (R&A, SR&T, etc.)
  - Other Mission Enabling does not include mission science teams, pre-phase A technology, communications, management
  - "Standard Research" includes Earth science applications

SMD "Subset" R&A Budgets (FY06-FY13)



"Subset" R&A is a subset of R&A selected by the budget office based on the budget line's name. It is not "standard" research.

SMD "Subset" R&A Budgets (FY06-FY13)

	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13
Astrophysics	61	52	56	61	65	69	73	78
Earth Science	198	195	208	214	222	223	227	232
Heliophysics	31	32	33	34	36	39	40	41
Planetary Science	151	138	181	194	192	193	199	204
SMD Total	441	417	478	503	515	524	538	554

"Subset" R&A is a subset of R&A selected by the budget office based on the budget line's name. It is less than "standard" research. It includes:

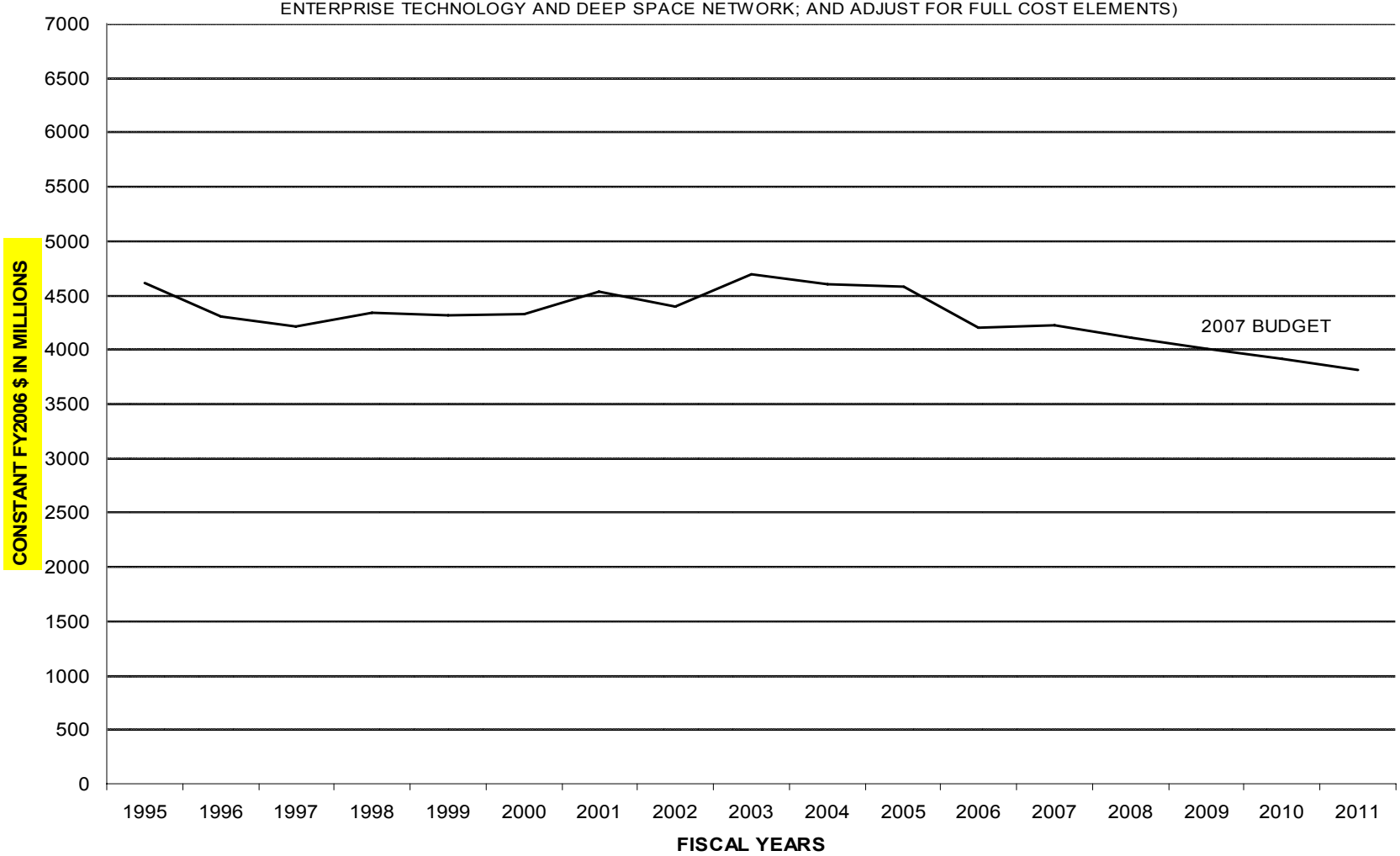
Earth Science R&A
Earth Science interdisciplinary science
Space Geodesy (satellite laser ranging)
Heliophysics R&A
Planetary Science R&A
Mars R&A
Discovery R&A
Astrophysics R&A
Astrophysics SR&T (new in FY09)

History of Research Policy and Funding

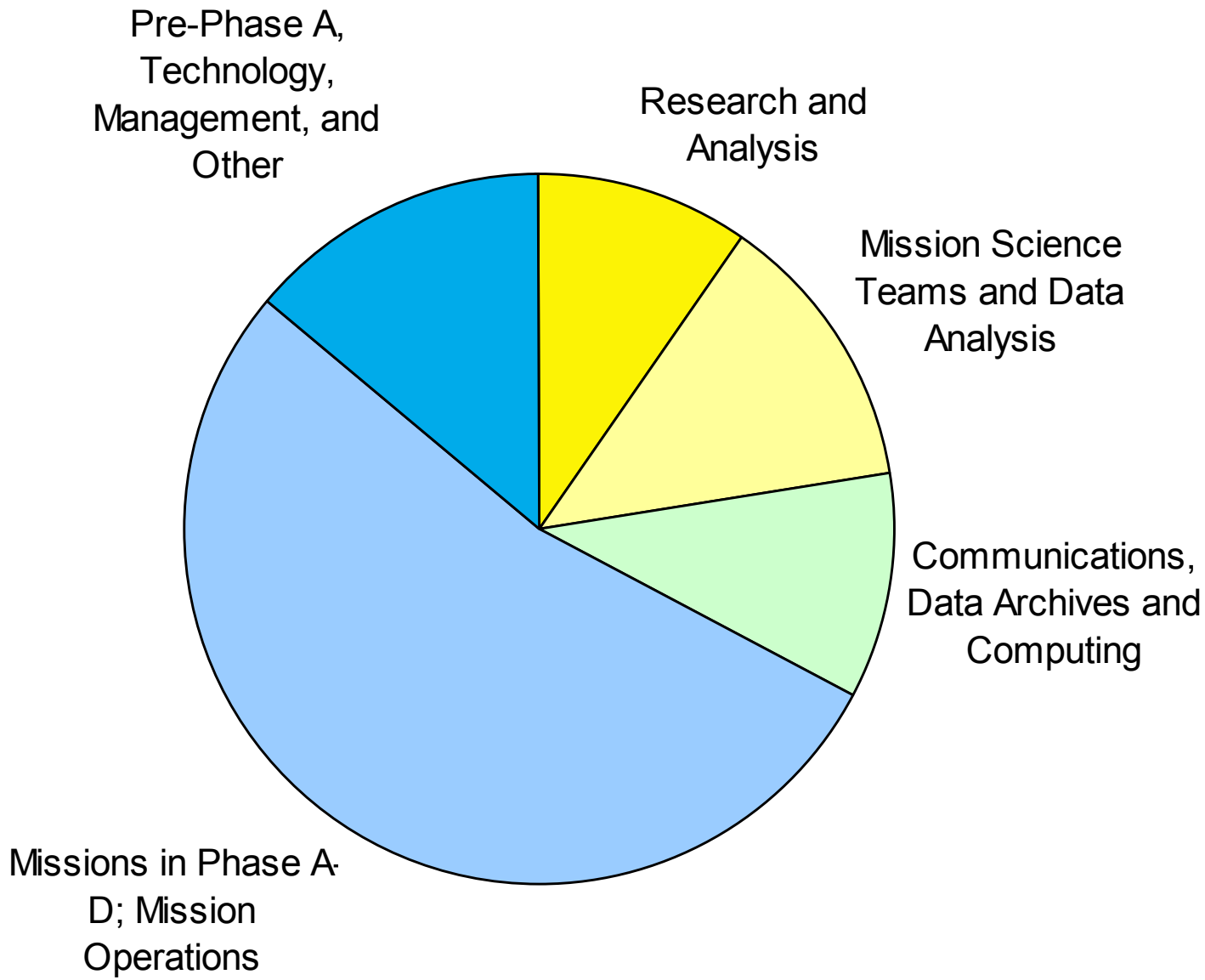
- The biggest changes come from Agency reorganization
  - Splitting of Code S, Code U, and Code Y
  - Elimination of Code R
  - Merging of Code S and Code Y
  - Full cost accounting
  - Reorganizing Code S and then SMD
- Policy changes over the years include:
  - External peer review (rather than internal review by NASA)
  - Solicited proposals (rather than unsolicited proposals)
  - Competitive selections (rather than case-by-case selections)
  - Selecting investigations (rather than block funding)
  - Full cost accounting (rather than base funding to Centers)
  - Research institutes for planetary, astrobiology, lunar
  - Science institutes for Hubble, Chandra, Spitzer
  - Annual calls for 1/3 of program (rather than triennial calls for total)
  - Four year awards (rather than three years)
  - Grouping of disciplines into program elements

SMD 95-06 ACTUALS AND FY 2007 BUDGET

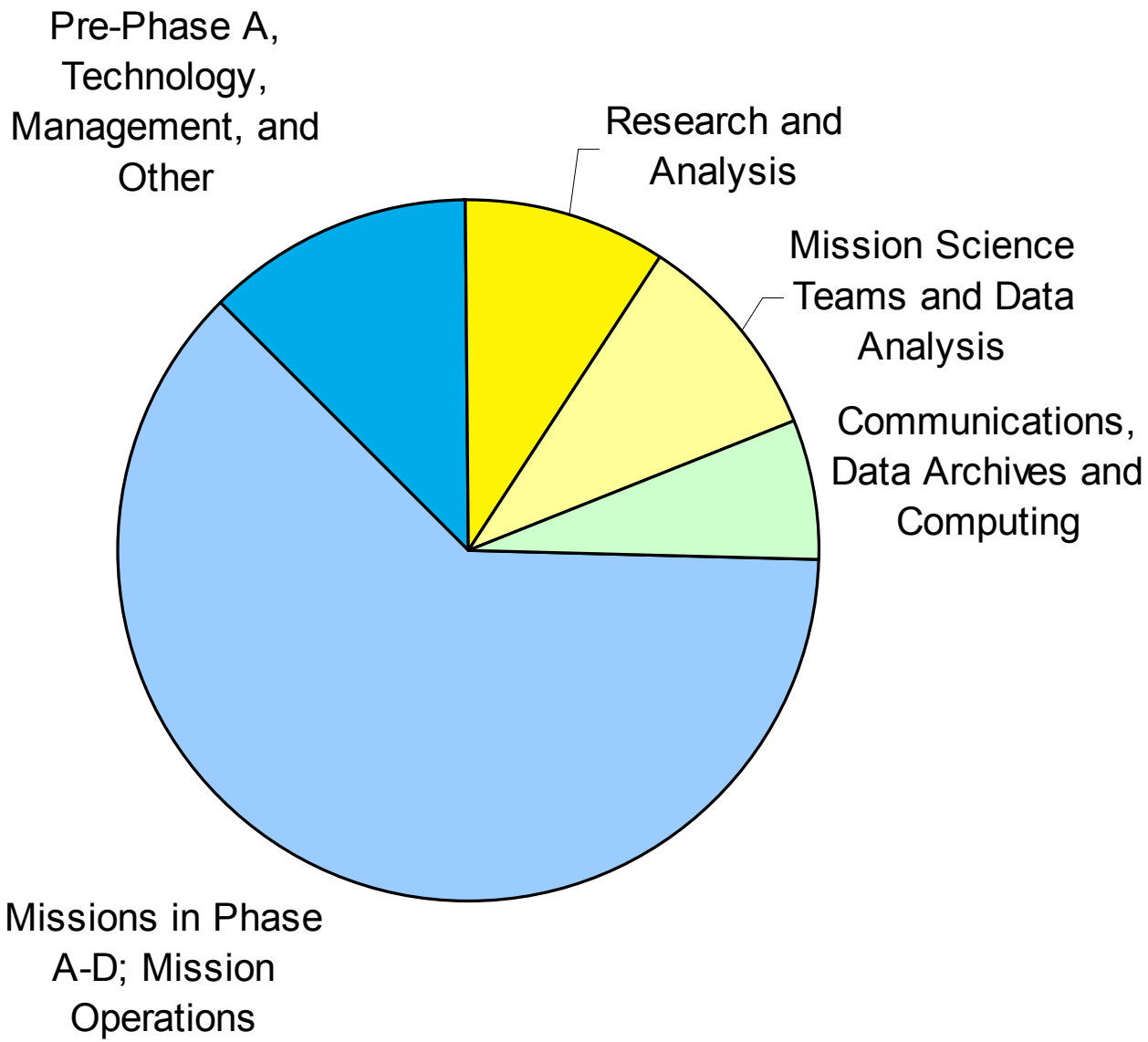
(NORMALIZED TO INCLUDE ELV'S IN ALL YEARS; TO REMOVE JIMO, NUCLEAR PROPULSION, LUNAR EXPLORATION, CROSS ENTERPRISE TECHNOLOGY AND DEEP SPACE NETWORK; AND ADJUST FOR FULL COST ELEMENTS)



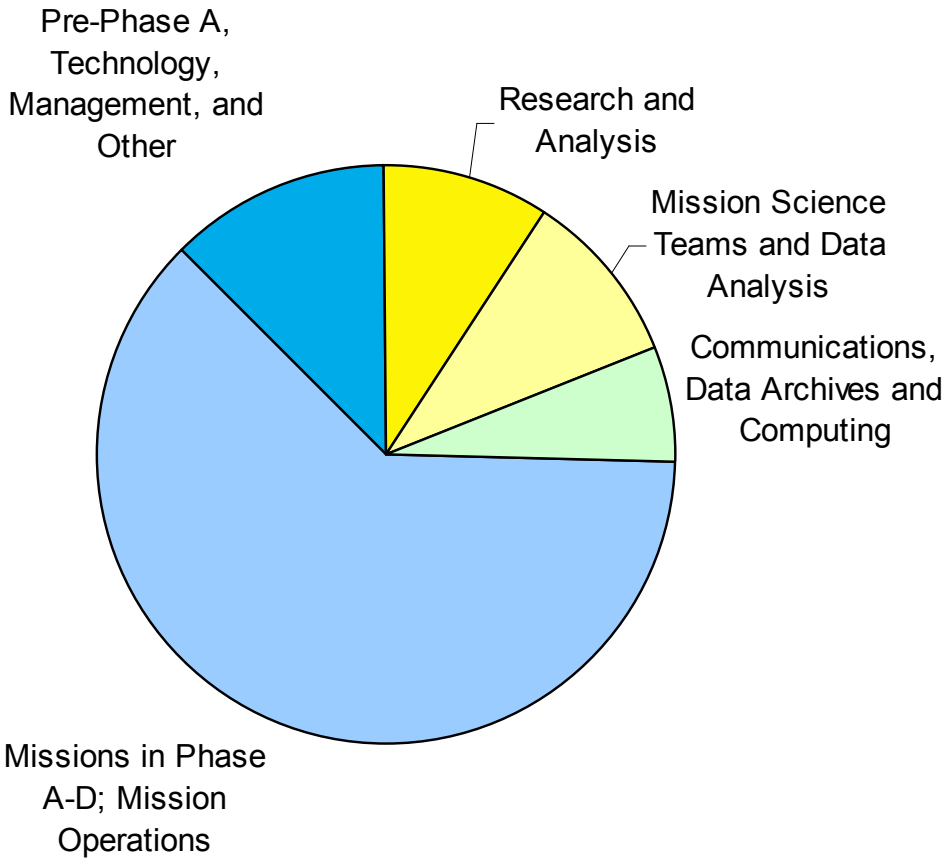
SMD FY09 Budget Approximate Breakout

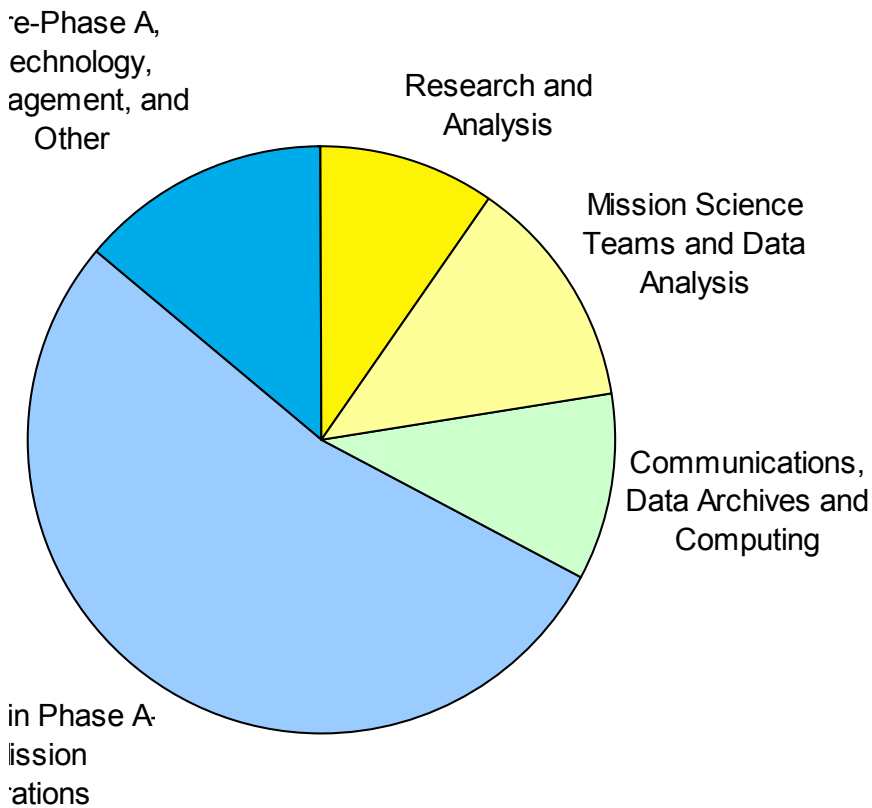


OSSA FY90 Budget Approximate Breakout



OSSA FY90 and SMD FY09 Budget Approximate Breakouts

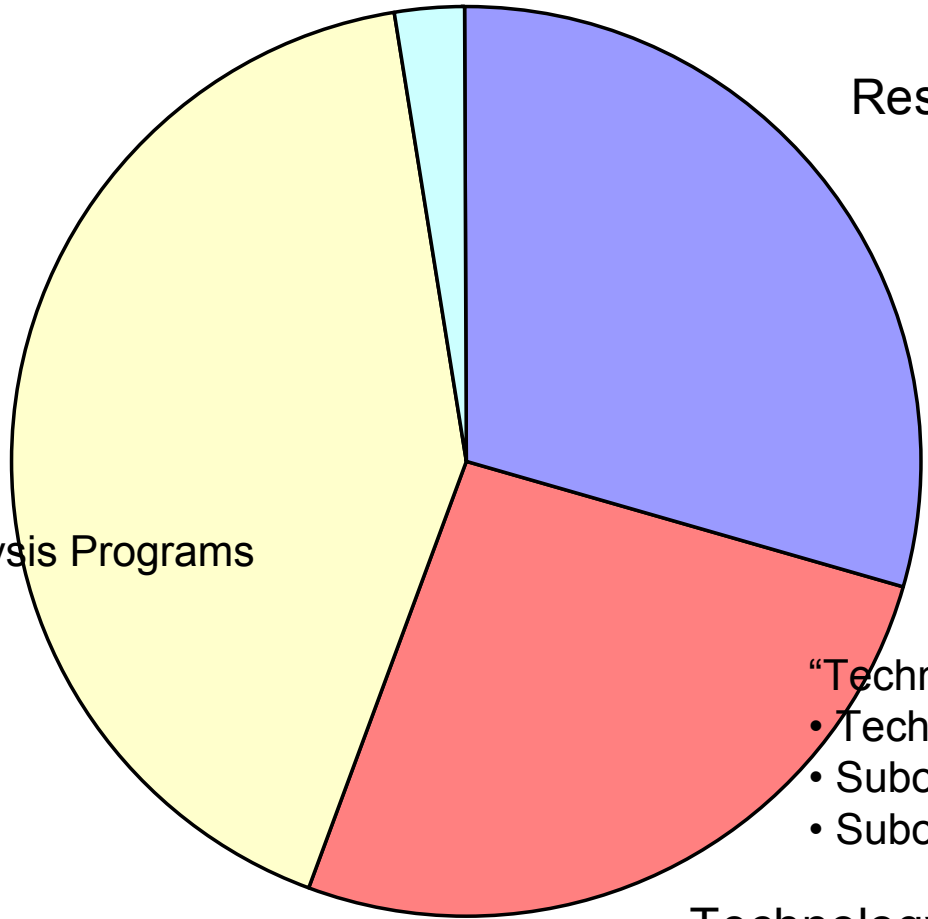




FY08 Mission Enabling Budget

Total: $1025M

Does not include science teams, or focused technology development



"Applications" includes
- Earth science applications program

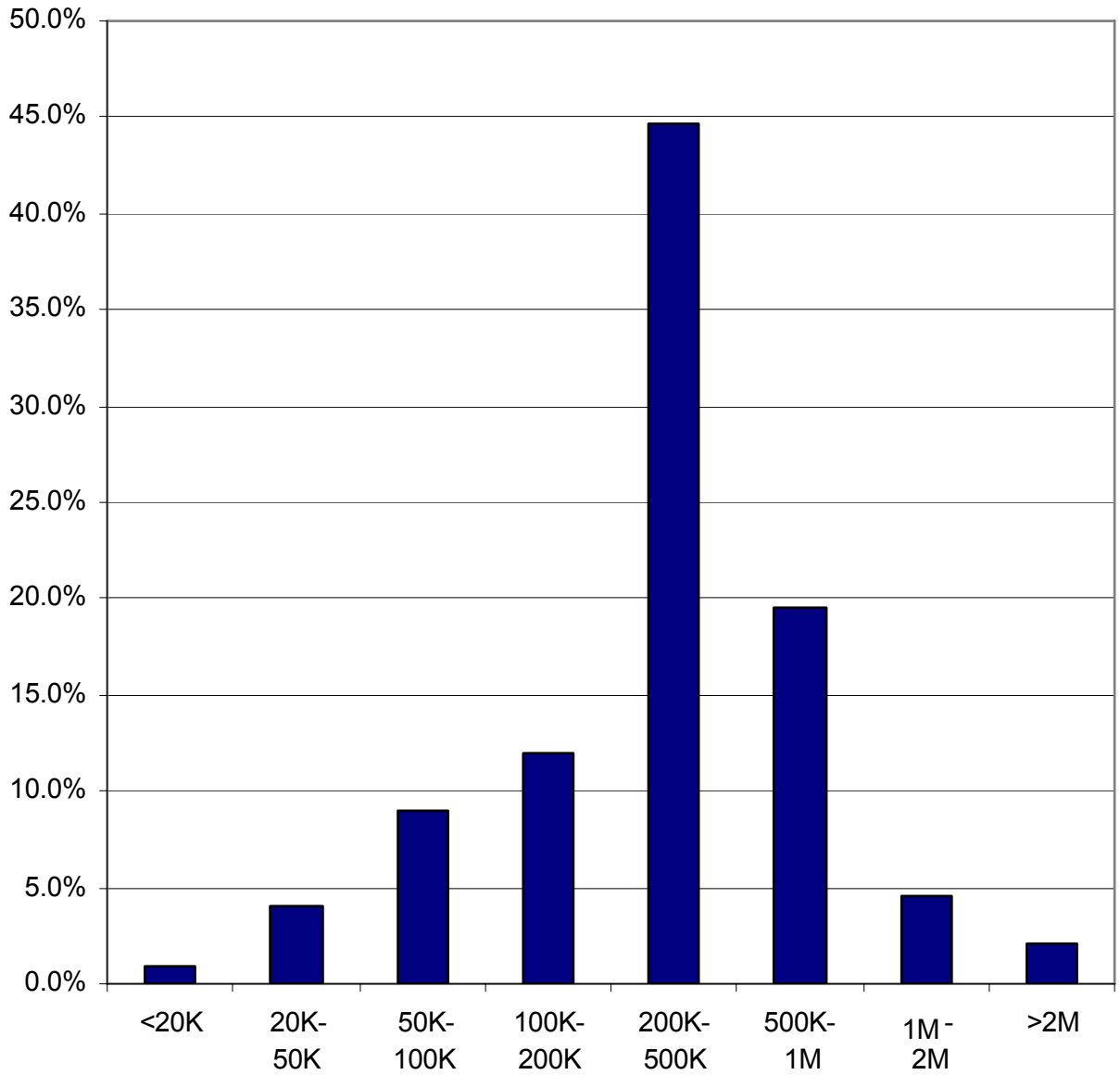
"Research" includes:
- Basic research
- Research facilities
- High-end computing

"Technology" includes
- Technology development
- Suborbital payloads/missions
- Suborbital capabilities

"Data" includes
- GO and Data Analysis Programs
- Data Systems
- Data Archives

Current R&A Snapshots

Current R&A Snapshots



Distribution of award sizes

Snapshot from RAPTOR

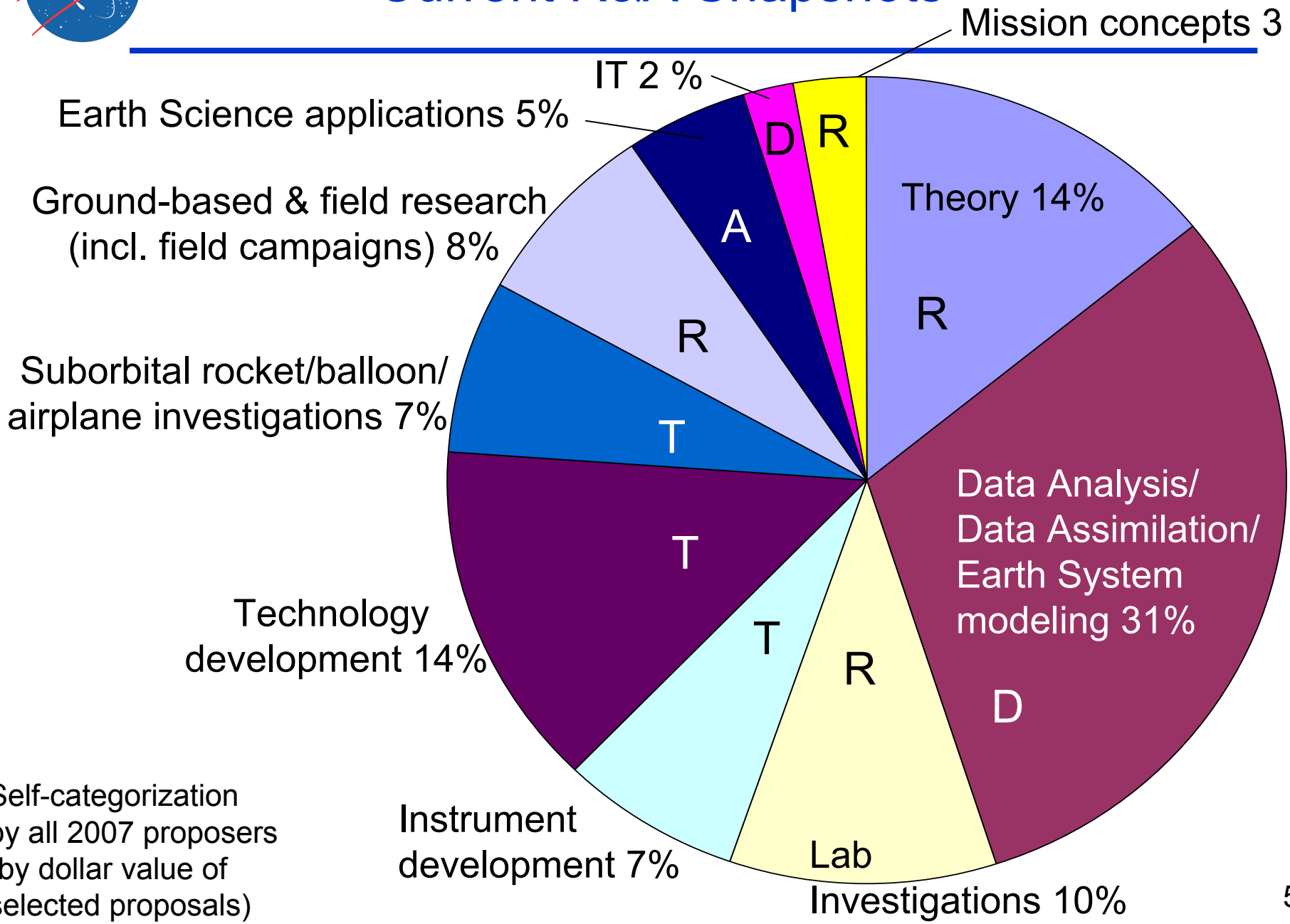
Total award (cumulative over period of performance)

Based on ~5000 SMD awards active in FY07 and FY08

Includes all types of awards (grants, Center funding, interagency transfers, etc.)

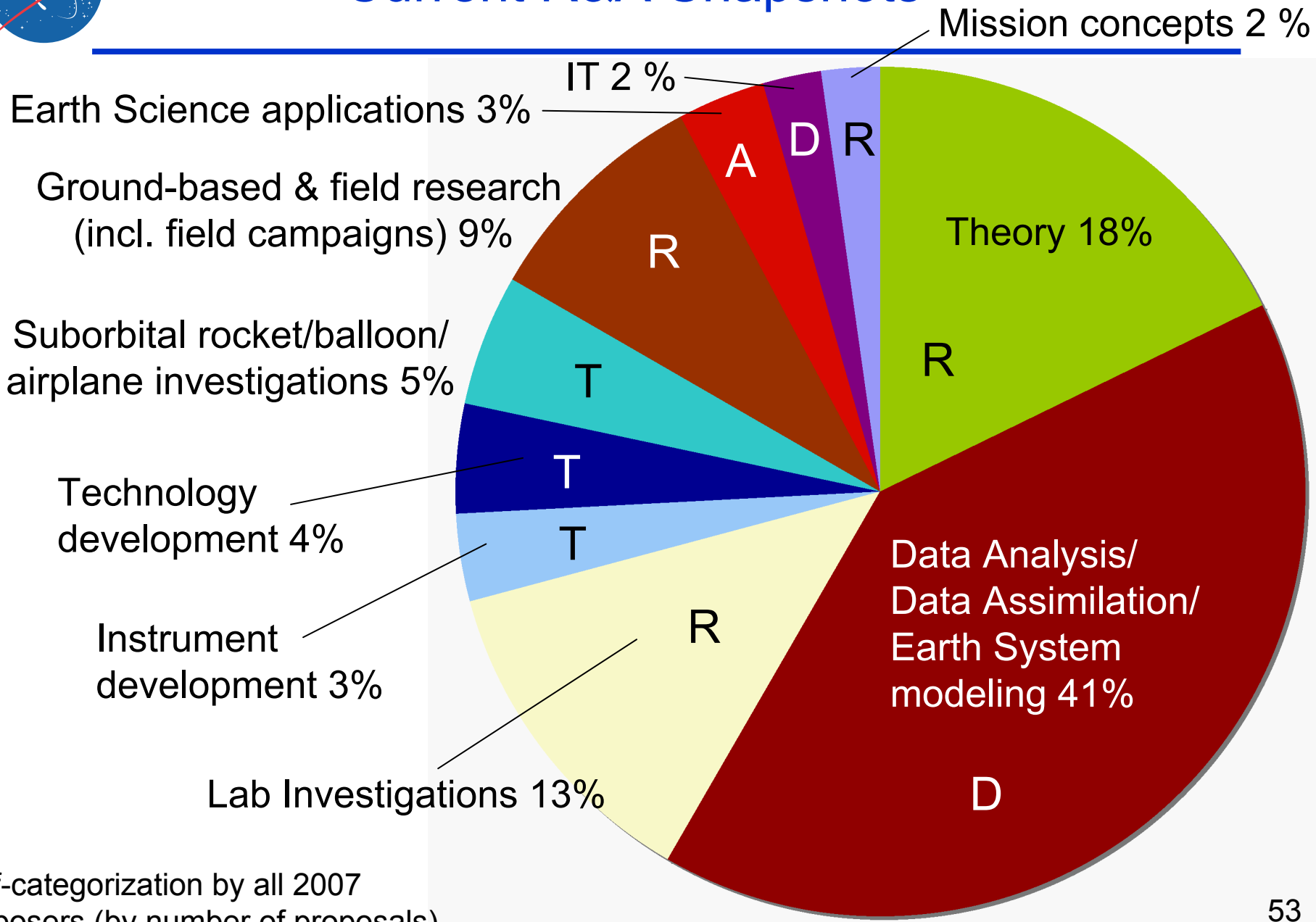
Does not include astrophysics GO programs

Current R&A Snapshots



Self-categorization by all 2007 proposers (by dollar value of selected proposals)

Current R&A Snapshots



Self-categorization by all 2007 proposers (by number of proposals)

Current R&A Snapshots

Categories for proposer self-categorization

1. Theory/Computer modeling [R]
2. Data Analysis/data assimilation/Earth System modeling (including Guest Observer Activities) [D]
3. Laboratory investigations (incl. sample analysis, physical simulations, and determination of physical parameters) [R]
4. Instrument development (incl. basic and advanced space and suborbital Instrumentation [T]
5. Technology development (incl. tech & subsystems for space and suborbital) [T]
6. Technology development applicable to space nuclear/electric propulsion [T]
7. Suborbital rocket/balloon/airplane investigation [T]
8. Ground-based field research in support of NASA Missions (incl. astro observations, field research, field campaigns) [R]
9. Earth System Science applications and decision support [A]
10. Development/application of information technology/data and information systems and tools [D]
11. Development of future mission concepts [R]

R = “research”, [T] = “technology”, [D] = “data”, [A] = “applications”

Current R&A Snapshots

- Ratio of funding to NASA Centers vs. universities and other institutions
  - Based on 2007 actuals as reported through the NASA financial system
  - Includes 14 R&DA "projects" (5 Earth, 9 Space) with total funding of $486M selected as representative of total R&DA funding

	SMD	Earth	Space
NASA Centers (including JPL)	33%	46%	23%
Other Government Agencies**	7%	6%	7%
Universities, etc.	60%	48%	69%
Fraction of total SMD funding	100%	43%	57%

** Only NASA provides funds to other agency labs and FFRDCs; NSF, DOE, USGS, NOAA, etc. do not.

Current R&A Snapshots

- Investigator turnover rates
  - Based on a canvass of SMD program officers
  - Includes 30 program elements with selections in 2007 or 2008 that resulted in the selection of 755 proposals
  - Definition of turnover rate used is the fraction of newly selected PIs who are not currently the PI of an existing award (terminating or continuing) in that same program element

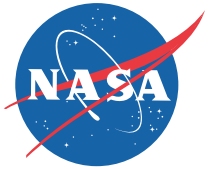
	Programs	Sample Size	Turnover Rate
Earth Science	13	292	61%
Heliophysics	7	182	74%
Planetary Science	8	187	52%
Astrophysics*	3	101	67%
SMD Total	31	762	63%

Range of turnover rates among program elements is 19% to 100%

* excludes GO programs – Turnover rate for small GO programs is ~47% (4 // 234)

Current R&A Snapshots

- Graduation data about how many or how often R&A investigators become flight mission PIs
  - As far as we can tell, all flight mission PIs have been R&A investigators
  - But there are very few flight mission PIs and a lot of R&A investigators, so the graduation rate is very small
  - R&A investigators: 1000 new selections each year, turnover rate is 69%, so over a 10 year period there are up to 6900 R&A investigators
  - Flight mission PIs: ~4 missions per year, ~5 mission/instrument PIs per mission, so over a 10 year period there are ~200 flight mission PIs
  - Therefore graduation rate is ~~3%



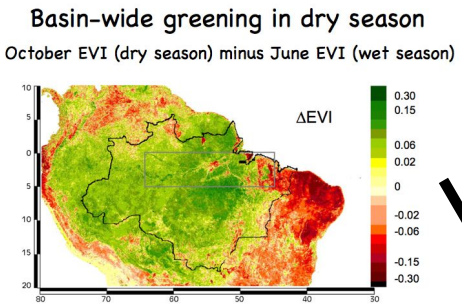
Earth Science

- Research
- Airborne Science
- Data Systems
- Modeling
- High-End Computing
- Technology Development

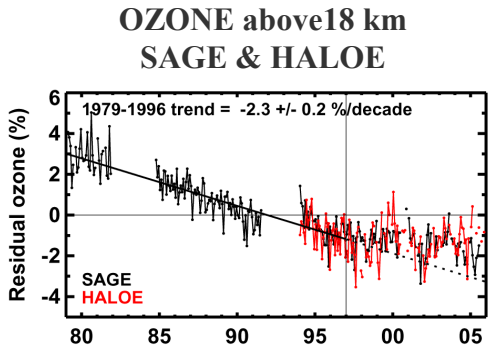
Structure of the SMD Research Budget (FY09 President's Request)

- Earth Science
  - Earth Systematic Missions
    - OSTM, GPM, Glory, LDCM, NPP
    - Decadal Survey Missions
    - Other Missions and Data Analysis — mission enabling
  - Earth System Science Pathfinder
    - OCO, Aquarius
    - Other Missions and Data Analysis — mission enabling
  - Earth Science Multi-mission Activities — mission enabling
  - Earth Science Research
    - Research and Analysis — mission enabling
    - Computing and Management — mission enabling
    - Airborne Science — mission enabling
    - Near Earth Object Observations — [to Planetary in FY10]
  - Applied Sciences
  - Earth Science Technology
    - Advanced Technology Initiatives — mission enabling
    - Instrument Incubator — mission enabling
    - Advanced Info Systems Technology — mission enabling

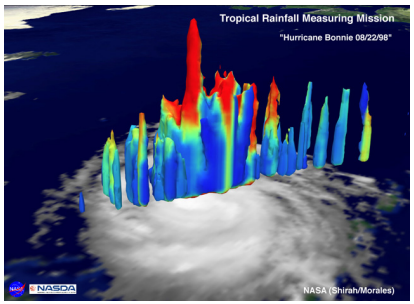
Earth Science Division Focus Areas



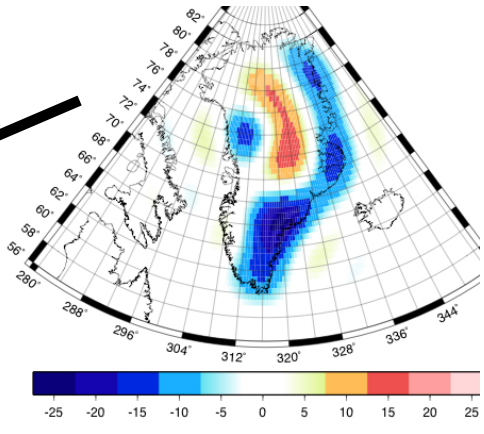
Atmospheric Composition



Carbon Cycle and Ecosystems

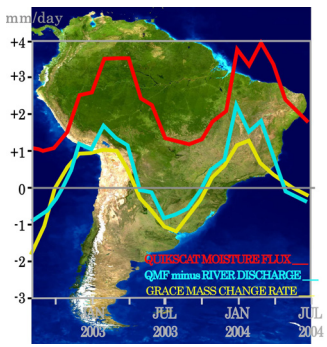


Climate Variability and Change

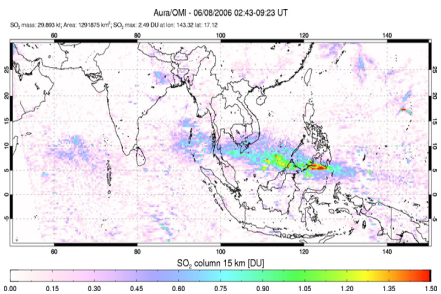


Weather

Water and Energy Cycle



Earth Surface and Interior



Research Program Objectives

- Advance knowledge of the Earth as a system through development and analyses of remotely sensed data, in situ and airborne measurements, and modeling
- Expand and demonstrate utility of NASA and related spaceborne mission data through measurement-focused investigations and development of advanced products
- “Mainstream” spaceborne Earth Observation products to encourage broad use by non-remote sensing experts
- Identify important yet tractable future problems and missions given expert knowledge of both science and technology state-of-the-art
- Identify key future areas of technology development to address presently intractable problems
- Provide a community of researchers that can support transition of new knowledge to applications (Applied Sciences) and prediction/operations (inter-agency)

Research Program Structure

- Research and Analysis - mainly individual investigator competed activities, organized predominantly around scientific disciplines [799]*
- Mission Science Teams - support for investigators affiliated with individual satellite missions or groups of closely related missions [392]*
- Interdisciplinary Science - includes calibration/validation for space-based measurements and interdisciplinary science, as well as EOS project science office [219]*
- Airborne Science - includes operation of aircraft platforms and investments to support bringing new capability into NASA airborne science programs
- High End Computing - includes investment in supercomputing capability (esp. at GSFC) to support community and infrastructure needed for its use
- Education and Public Outreach - includes graduate student fellowships, New Investigator Program, and public outreach activities (e.g., GLOBE)

*Task Count in RAPTOR approximates # investigations

Research Program Content

- R&A includes several basic areas
  - Laboratory investigations - especially spectroscopy, kinetics, and photochemistry
  - Surface-based measurement networks
  - Airborne and balloon-based measurements, including field campaigns
  - Integrated analysis of satellite data, including analysis of multiple data sets
  - Process model development and testing
  - Regional/global model development, testing, and application

R&A "Disciplines" and Science Focus Areas

R&A Discipline			**Science Focus Area**			
P = Primary, **S = Secondary**	Atmospheric Composition	Climate Variability & Change	Carbon Cycle & Ecosystems	Global Water and Energy Cycle	Weather	Earth Surface & Interior
Upper Atmosphere Research	**P**	S				
Tropospheric Chemistry	**P**	S	S	S	S	
Radiation Sciences	**P**	S		S	S	
Atmospheric Chemistry Modeling & Analysis	**P**	S	S	S		
Modeling and Analysis	S	**P**	S	S	S	
Physical Oceanography		**P**		S	S	
Cryospheric Science		**P**		S	S	S
Terrestrial Ecology	S	S	**P**	S		
Land Cover Land Use Change	S	S	**P**	S	S	S
Ocean Biology and Biogeochemistry	S	S	**P**	S		
Biodiversity*		S	**P**			
Terrestrial Hydrology		S	S	**P**	S	S
Atmospheric Dynamics	S	S		**P**	S	
Research-Operations Transition Activities	S	S			**P**	
Space Geodesy		S		S		**P**
Earth's Planetary Interior						**P**
Geohazards	S	S		S		**P**

*Nascent Program

Example of Scientific Integration

- Issue: Documenting changes in global sea level, being able to understand those changes, and predict their future evolution
- Contributing Program Elements:
  - R&A Disciplines
    - Physical Oceanography
    - Terrestrial Hydrology
    - Cryospheric Science
    - Space Geodesy
    - Modeling and Analysis
  - Instrument Teams
    - Jason (global sea level)
    - ICESat (ice sheet thickness)
    - GRACE (ice mass, stored water)
    - ASTER (glacier extent)
    - AMSR-E (SST/upper ocean heat content)
  - Airborne Science
    - Lidar flights for ice thickness studies
  - Interdisciplinary Science

Earth Science Research - FY08-FY13

(in $M)	FY08	FY09	FY10	FY11	FY12	FY13
Total Earth Science Competed Research	**411.9**	**400.0**	**399.8**	**404.4**	**415.3**	**421.8**
Core Earth Science Research*	**304.2**	**320.8**	**328.9**	**329.6**	**338.7**	**346.7**
Research and Analysis	125.5	136.9	144.4	146.4	149.8	153.5
EOS Science	57.4	62.3	62.6	61.5	62.3	63.7
HECC	38.9	41.9	42.8	43.8	44.8	45.9
Airborne Science	33.1	26.3	25.7	24.0	26.4	27.0
Scientific Computing	18.5	18.9	18.4	18.6	19.4	19.9
Space Geodesy/SLR	11.3	14.4	14.5	14.6	15.0	15.1
Global Modeling & Assimilation Office	10.3	10.1	10.4	10.6	11.3	11.6
Near Earth Object Observations	3.3	3.7	3.8	3.8	3.9	4.0
Ozone Trends Science	2.9	3.2	3.2	3.1	2.4	2.5
Carbon Cycle Science	2.2	2.3	2.3	2.3	2.4	2.5
Mission Science Guest Investigator	0.8	0.8	0.8	0.9	1.0	1.0
Earth Science Competed Science associated with Operating Missions*	**91.8**	**63.5**	**55.1**	**58.8**	**60.5**	**58.6**
AQUA	18.4	11.5	6.8	8.0	8.2	8.4
AURA	22.9	7.2	7.2	7.3	7.5	7.7
CALIPSO	3.1	2.8	2.9	2.9	3.0	3.1
CloudSat	2.9	2.9	3.0	3.1	3.1	3.2
GRACE	2.4	3.0	3.0	3.1	3.2	3.2
AQUARIUS	-	-	1.0	2.5	2.5	2.5
OCO	-	1.0	2.5	2.5	2.5	2.5
ICESAT I	4.6	2.5	2.5	2.5	2.5	-
OSTST		2.5	1.2	1.1	1.1	0.7
OVWST	6.5	4.7	4.8	4.7	4.8	4.8
Precipitation Science Team	11.9	8.3	7.5	7.6	7.7	7.9
NPP		5.8	5.9	5.6	6.3	6.3
TERRA	19.1	11.3	6.8	7.9	8.1	8.3
Other Research Related	**15.9**	**15.6**	**15.8**	**16.0**	**16.1**	**16.5**
Fellowships and New Investigators	8.0	8.2	8.2	8.3	8.4	8.6
Earth Science Education & Outreach Activities	7.9	7.5	7.6	7.6	7.7	7.9

* Source: FY2009 President's Budget Submit for FY09-FY13 and latest approved Operating Plan for FY08

R&A Budget Breakdown

Focus Area	Program	FY09 Funding $M
Carbon Cycle/Eco.	Terrestrial Ecology	14.0
Carbon Cycle/Eco.	Ocean Bio. & Biogeochem.	8.2
Carbon Cycle/Eco.	Land Cover/Land Use Change	7.6
Carbon Cycle/Eco.	Biodiversity	0.9
Clim. Var. Change	Modeling, Anal., & Pred.	9.7
Clim. Var. Change	Phys. Oceanography	9.3
Clim. Var. Change	Cryospheric Sci.	6.0
Atmos. Comp.	Upper Atm. Res.	12.3
Atmos. Comp.	Trop. Chem.	7.8
Atmos. Comp.	Atmos. Chem. Mod. & Anal.	6.7
Atmos. Comp.	Radiation Sci.	7.3
GWEC	Terrestrial Hydrology	10.7
GWEC	Atmospheric Dynamics	4.6
Weather	Res. Ops. Trans.	2.6
Earth Surf. & Int.	Earth Surf. & Int.	10.3
N/A	X-Cutting and Mgmt. Directed	18.9
Total		136.9

Competed Mission Science Teams

Mission(s)	Last Competed	FY09 Funding $M
Terra	FY06	11.3
Aqua	FY06	11.5
Aura	FY07	7.2
ICESat	FY05	2.5
OSTST	FY07	2.5
OVWST	FY05	4.7
Precipitation	FY06	8.3
NPP	FY06	5.8
GRACE	FY06	3.0
GNSS	FY06	1.0
Cloudsat	FY05	2.9
CALIPSO	FY05	2.8
Glory (SAG)	FY07	0.5
TOTAL		64.0

ESD Research Solicitation History

Area	Sub-Area	ROSES 05	ROSES 06	ROSES 07	ROSES 08
Research	Atmospheric Composition	Atmospheric Composition (Satellite Data Analysis, Kinetics)	Atmospheric Composition: TC-4 (FC); Ground-Networks; Modeling and Analysis	Atmospheric Composition: Aura Science Team; Glory Science Advisory Group; ARCTAS (FC)	Atmospheric Composition: Laboratory Research; Surface, Balloon, and Airborne Observations
	Climate Variability and Change	ICESat/Cryosat; OVWST	International Polar Year	Physical Oceanography, OSTST; Cryospheric Science	Modeling, Analysis, and Prediction; Physical Oceanography; Ocean Salinity Science Team
	Carbon Cycle and Ecosystems	LBA (FC); NACP; Ocean Biology and Biogeochemistry; Terrestrial Ecology and Biodiversity	Ocean Biology and Biogeochemistry	LCLUC, Carbon Cycle Science; Terrestrial Ecology; Ocean Biology and Biogeochemistry	Terrestrial Ecology, LCLUC, Ocean Biology and Biogeochemistry, Biodiversity
	Global Water and Energy Cycle	LCLUC; Cloudsat/CALIPSO; Terrestrial Hydrology; NEWS	Precipitation Science	NEWS; Terrestrial Hydrology	NEWS/ Water Quality
	Weather	NASA African Monsoon Multidisciplinary Analyses (FC)		Wind Lidar Science	Hurricane Science Research
	Earth Surface and Interior	Earth Surface and Interior	GRACE Science Team	Earth Surface and Interior; EarthScope: The InSAR and Geodetic Imaging Component (new)	Advanced Concepts in Space Geodesy
	Interdisciplinary, Cross-Cutting	Remote Sensing Science	Interdisciplinary Research in Earth Science; Earth System Science Research; GNSS Remote Sensing Science Team	Airborne Instrument Technology Transition (new); Space Archaeology (new); Accelerating Operational Use of Research Data (new)	
Applied Sciences		Decision Support		Decision Support through Earth Science Research Results	Through Earth Science Research Results; Earth Sciene Applications
Data		ACCESS	ACCESS;MEaSUREs	ACCESS	
Technology		ACT, AIST		IIP	AIST, ACT
E/PO		Program in Earth Science	International Polar Year EPO	Program in Earth Science	

Proposal History: ROSES 07

Program Category	Element	# Prop. Submitted
R&A/Carbon Cycle	Land Cover/Land Use Change	77
R&A/Carbon Cycle	Carbon Cycle Science	113
R&A/Carbon Cycle	Terrestrial Ecology	59
R&A/Carbon Cycle	Ocean Bio & Biogeochem	8
R&A/Climate Var & Change	Cryospheric Science	53
R&A/Global Water & Energy Cyc	NASA Energy & Water Cycle	47
R&A/Global Water & Energy Cyc	Terrestrial Hydrology	49
MST/Atmos Comp	Aura Science Team	76
MST/Atmos Comp	Glory Sci. Adv. Group	12
R&A/Atmos Comp	ARCTAS	73
R&A/Weather	Wind Lidar Science	13
R&A/X-Cutting	Accel. Op. Use Res. Data*	16
R&A/Earth Surface & Interior	Earth Surface & Interior	60
R&A/Earth Surface & Interior	Geodetic Imaging	18
R&A/X-Cutting	Airborne Instr. Tech. Trans.*	36
R&A/X-Cutting	Space Archaeology*	16
Appl. Sci.	Decision Support	125
Education & Public Outreach	New Investigator Program	78
Data	ACCESS	31
Technology	Inst. Incubator Program	71
TOTAL		1125

* New R&A Program Element in ROSES 07

Proposal History: ROSES 08

Program Category	Element	# Prop. Submitted
R&A/Carbon Cycle	Land Cover/Land Use Change	63
R&A/Carbon Cycle	Terrestrial Ecology	77
R&A/Carbon Cycle	Ocean Bio & Biogeochem	50
R&A/Carbon Cycle	Biodiversity*	54
R&A/Climate Var & Change	Modeling, Analysis, and Prediction	152
R&A/Climate Var & Change	Physical Oceanography	26
R&A/Global Water & Energy Cyc	Rem. Sensing Water Qual.	16
R&A/Atmos Comp	Atmos. Comp. Lab Res.	49
R&A/Atmos Comp	Atmos. Comp. Field Obs.	55
R&A/Weather	Hurricane Science Research	52
Appl. Sci.	Decision Support	148
Appl. Sci.	Feasibility Studies	79
Appl. Sci.	Gulf of Mexico	69
Technology	Adv. Component Tech.	87
Technology	Adv. Information Syst. Tech.	103
Mission Science Team	ICESat II Science Def. Team	39
Mission Science Team	SMAP Science Def. Team	44
TOTAL		1163

* New R&A Program Element in ROSES 08

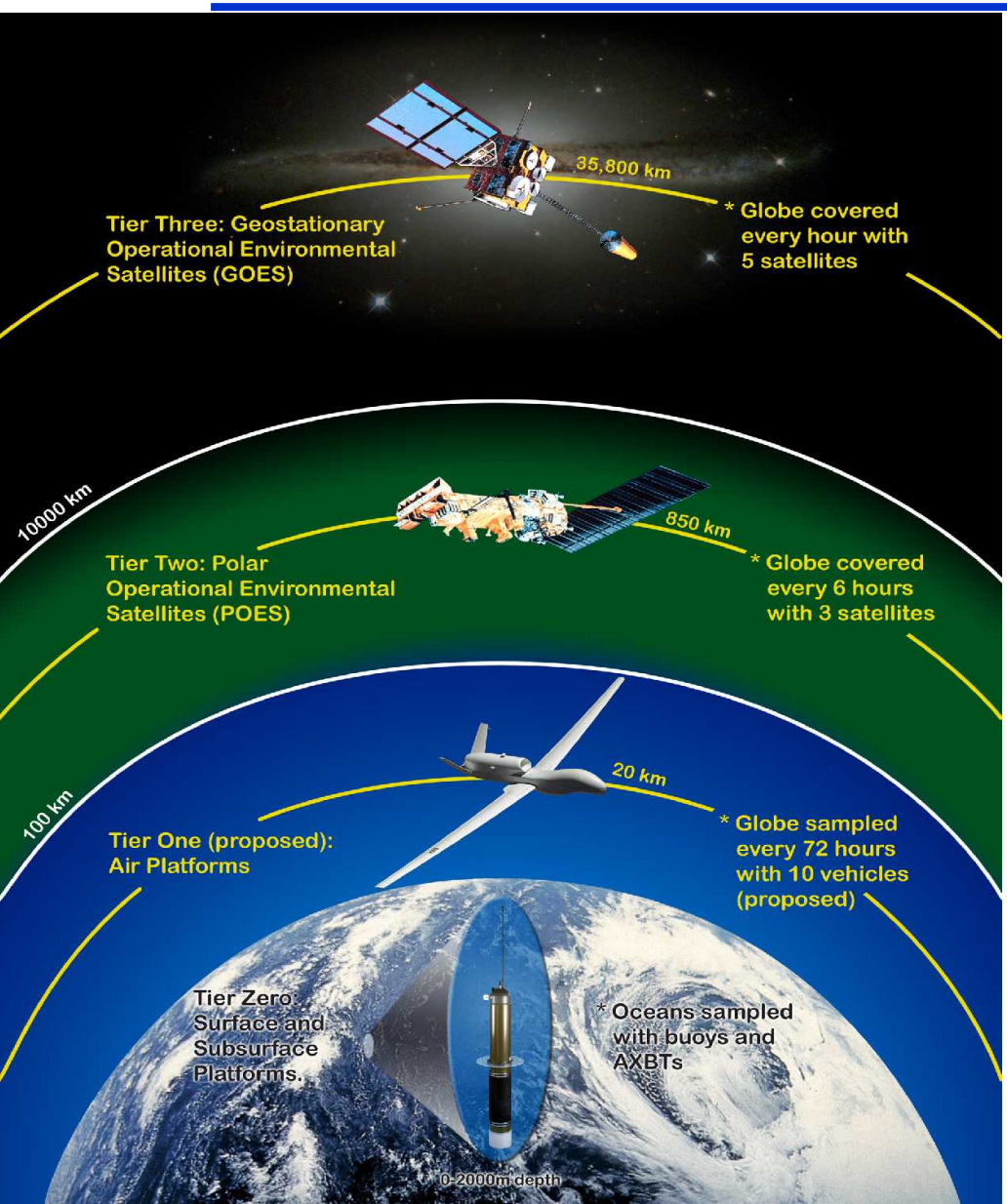
Earth Science ROSES Statistics

- ROSES generates significant “proposal traffic”
  - 2006: 1048 proposals from 13 elements
  - 2007: 1125 proposals from 22 elements
  - 2008: 1163 proposals from 17 elements
- Overall success rate is changing slowly
  - 2006: 37%, 2007: 34%, 2008: 31% (2008 is incomplete)
- Success rates between elements can vary enormously
- Have made limited use of “two-step” approach to reduce number of full proposals

FY08 R&A Field Program Highlights

- GasEx - Ongoing (late Feb - early April) Interagency field program aboard NOAA ship Ron Brown quantifying atmosphere-ocean gas exchange processes in poorly sampled Southern Ocean, providing unique cal/val opportunity for NASA and other satellites, as well as input into carbon cycle models
- ARCTAS - multi-aircraft (DC-8, P-3, B-200), multi-deployment (spring, summer) campaign studying transport of trace gases and particulate matter to Arctic and their chemical and radiative impacts (including role of Boreal fires). Supports IPY.
- AMISA - DC-8 flying in Arctic to study radiative issues associated with Arctic sea ice and overlying atmosphere; coordinated with Swedish ship-based measurements. Supports IPY.
- NOVICE - WB-57 experiment this summer to provide test platform for numerous instruments (ARC, LaRC, NOAA/ESRL, Harvard) mainly in atmospheric composition focus area.

Airborne Science Program



Program Objectives:

Satellite Calibration and Validation

Provide best value methods to perform the cal/val requirements for Earth Observing System satellites

New Sensor Development

Provide best value methods to reduce risk for new sensor concepts and algorithm development prior to committing sensors to spacecraft

Process Studies

Facilitate best value to acquire high spatial/temporal resolution focused measurements that are required to understand small atmospheric and surface structures which generate powerful Earth system effects.

Next Generation NASA Scientist and Engineer Development

Facilitate the development of our future NASA workforce by maturing our PI's, Project Scientist, Instrument Engineers, science management. Airborne programs typically last 12 to 24 months and as compared to satellite going years to decades on one project.

Airborne Science Program Operations

Core Airborne Systems: Subsidized User fee

ER-2, WB-57, DC-8, P-3, G-III





New Technology Airborne Systems: Subsidized to No User fee

Global Hawk, Sierra, Over the Horizon Communications,
Payload Portability between aircraft and centers - standards


Catalog Airborne Systems: Full cost User fee

B-200 (LaRC, DOE, etc), S-3 (GRC), Learjet (GRC), Twin Otter, Caravan, Aerosonde, etc

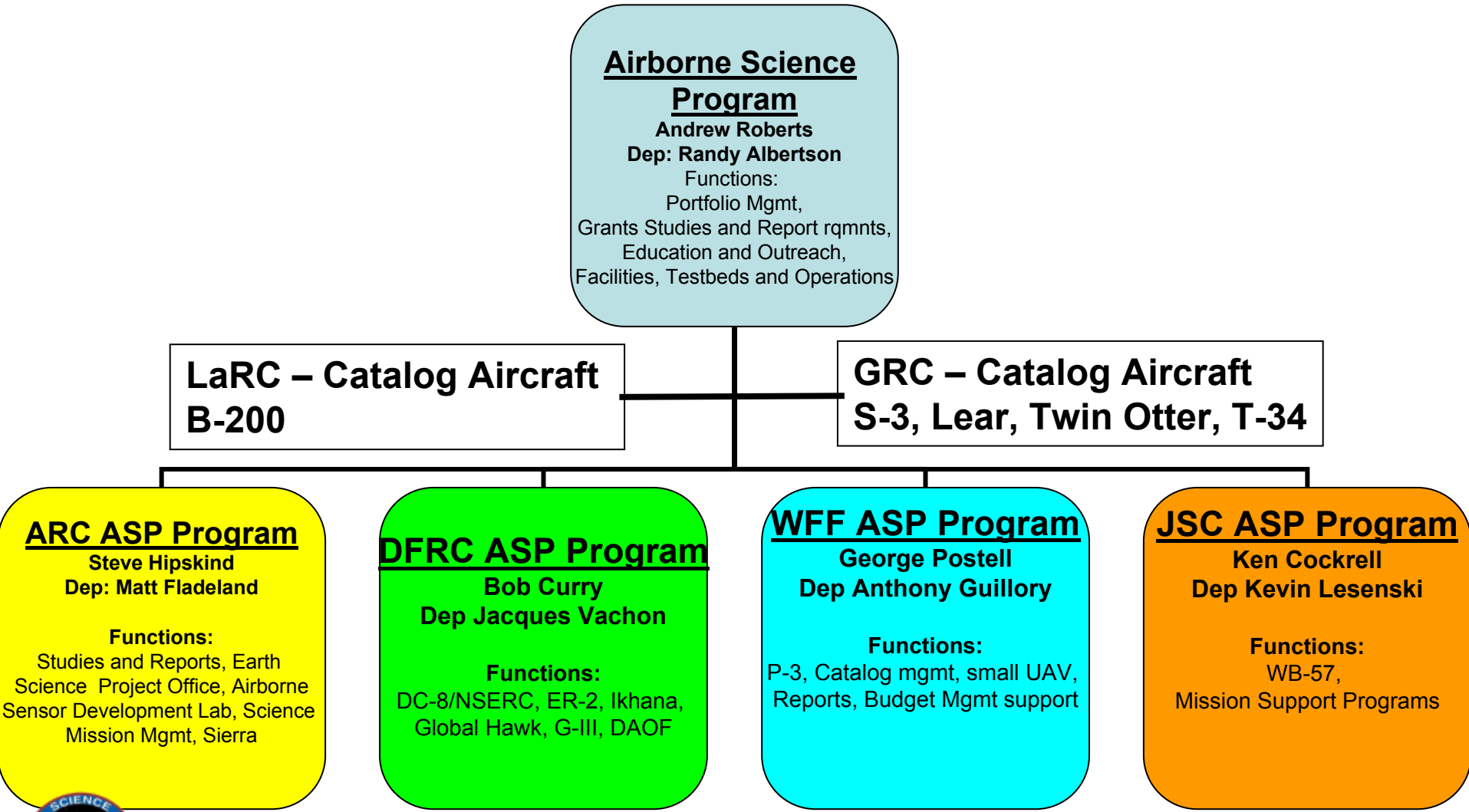


Airborne Sensor Facility, Mission/Campaign Management

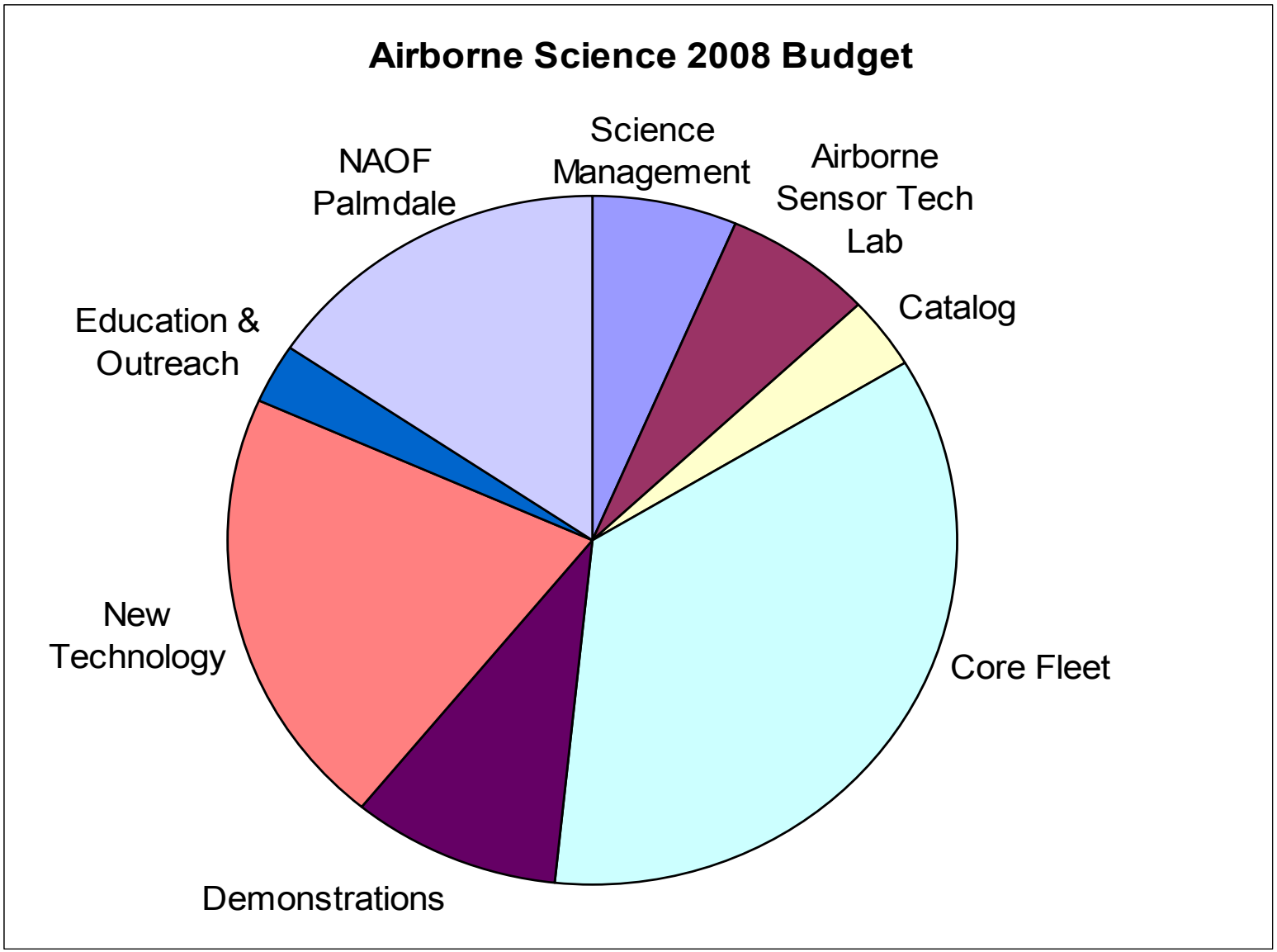
Over 50 aircraft available to the Program

2005-2008 Airborne Campaigns

Airborne Science Program



Airborne Science 2008 Budget



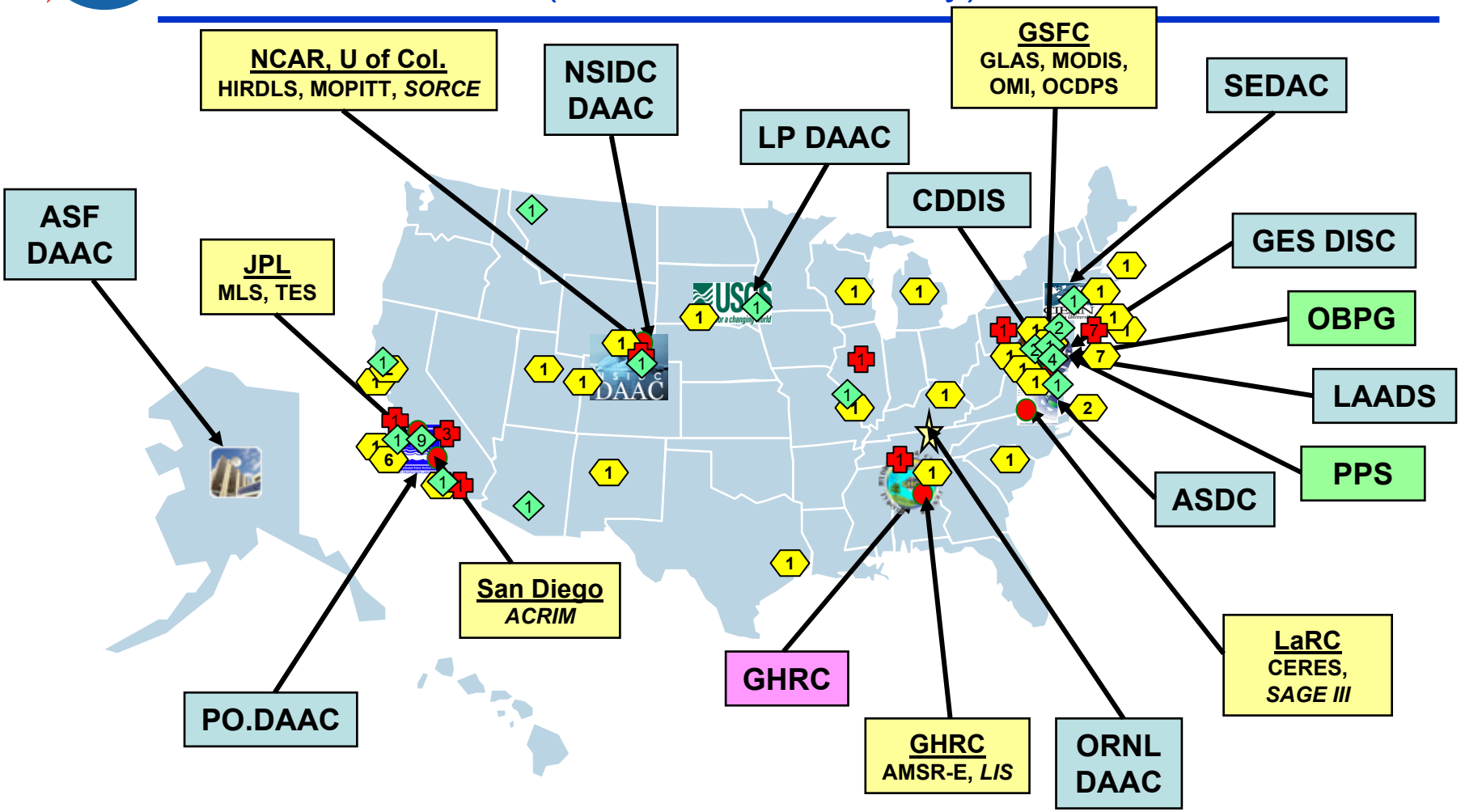
Airborne Science Budget

	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13
Airborne Science	29.1	25.6	33.1	26.3	25.7	24.0	26.4	27.0

In addition there is about $8M/yr in User fees and Mission Peculiar Costs

Earth Science Data Systems

(Core and Community)



KEY

EOSDIS Data Centers	Related Data Providers	Measurement-based Systems	Science Investigator-led Processing Systems (SIPSs)

Core

41 REASoN 29 MEaSUREs 17 ACCESS

Community

Earth Science Data Systems Programs

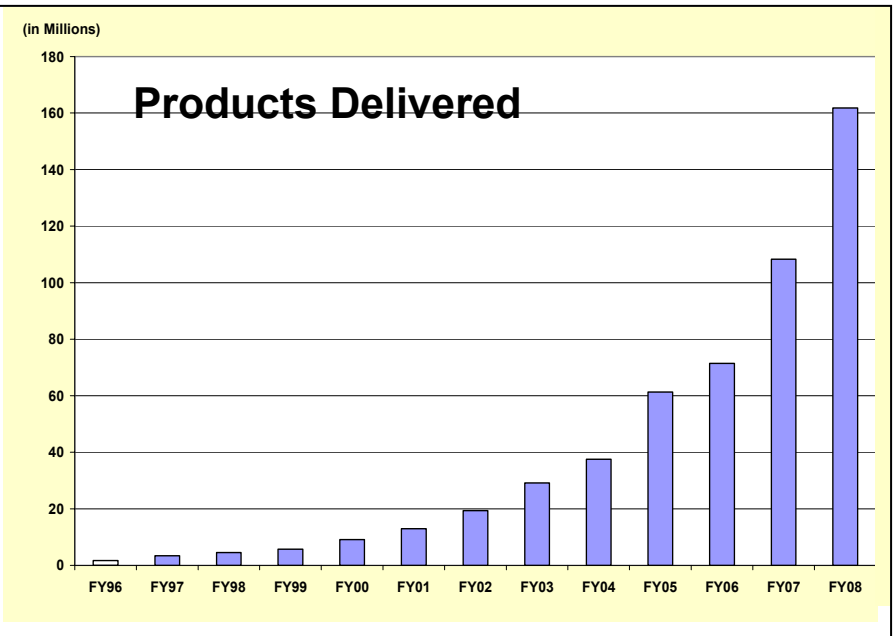
CORE	COMMUNITY
Projects Subject to Programmatic Review	Projects Competitively Selected
Substantive NASA Oversight	'Light Touch' Oversight w/Significant Community Involvement
Tight Integration of Data System Tools, Services and Functions	Community-based Tools and Services Loosely-Coupled
Employ Well Established Information Technologies	Employ 'Edgy' or Emerging Technologies

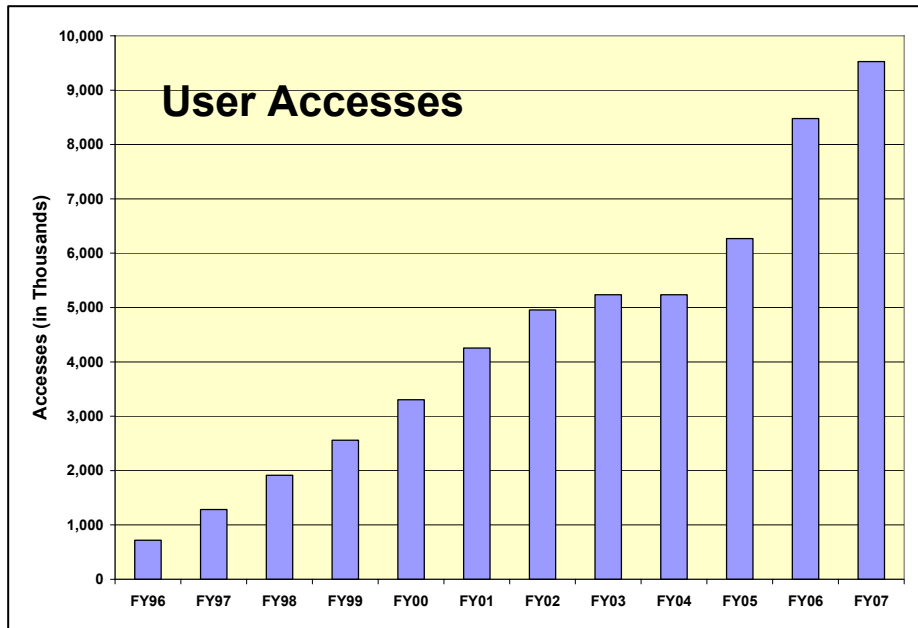
EOSDIS Key Metrics

EOSDIS Metrics (Oct 1, 06 to Sept 30, 07)	
Unique Data Products	>2700
Distinct Users at Data Centers	~3.0M
Daily Archive Growth	3.2 TB/day
Total Archive Volume	4.9 PB
End User Distribution Products	>100M
End User Daily Distribution Volume	4.2 TB/day

Cost: $112M/yr to $121M/yr

ESDIS Project Supports		
Science System Elements	Data Centers	11
	SIPS	14
Interfaces	Interface Control Documents	41
Partnerships	US	8
	International	18
Missions	Science Data Processing	7
	Archiving and Distribution	51
	Instruments Supported	75



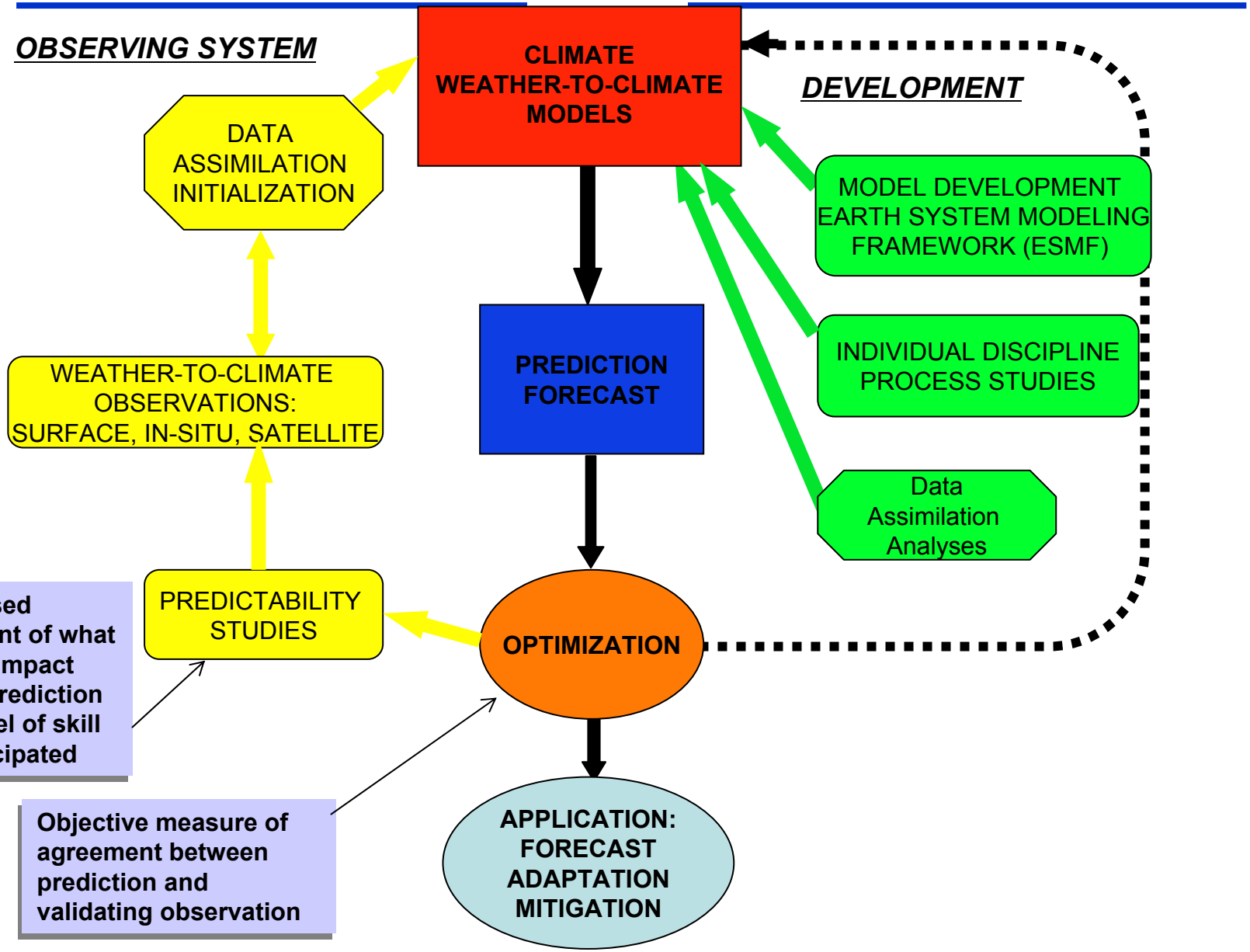


Data-Oriented Competitive Research Programs

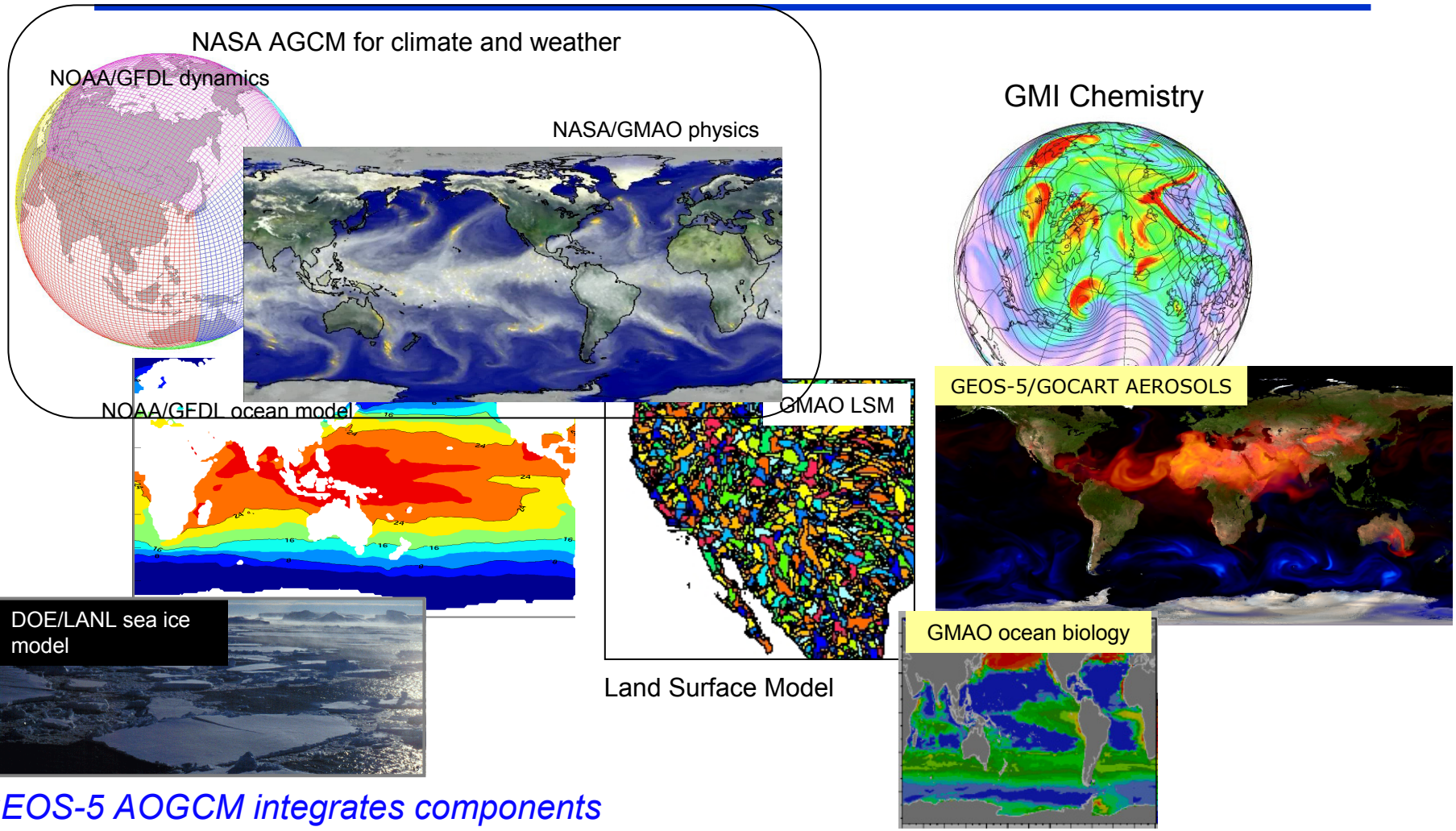
- MEaSUREs: Making Earth System data records for Use
  - Provide Earth science data products and services driven by NASA's Earth science goals and contributing to advancing Earth system "missions to measurements" concept.
  - Bring together expertise in multiple instrument characterization and calibration, data processing, science-based product generation and distribution, science tools, and interactive relationships with the broader science community.
  - Initial MEaSUREs solicitation focused on the creation of Earth System Data Records (ESDRs), including Climate Data Records. 29 of 86 proposals were selected in 10/07 (~$15/year)
- ACCESS: Advancing Collaborative Connections.
  - Enhance and improve existing components of the distributed and heterogeneous data and information systems infrastructure that support NASA's Earth science research goals.
    - … increase the interconnectedness and reuse of key information technology software and services in use across Earth system science investigations.
    - … enable the freer movement of data and information within a distributed environment of providers and users, and the exploitation of needed tools and services to aid in improvements of Earth science data access and data usability.
  - A 2007 call resulted in 30 proposals of which 10 were selected for funding (~$3.5M/year).

NASA Earth System Model

Development/Improvement for Forecast/Prediction



NASA Earth System Model Example



GEOS-5 AOGCM integrates components from different sources using ESMF - a systems engineered structure, allowing collaborative exchange of model elements

With assimilation components and satellite data
⇒ science + future mission design

High-End Computing (HEC) Program

Mission Objective: Plan and provision high-end computing systems and services to support NASA's mission needs. Operate and manage these HEC resources for the benefit of Agency users, customers and stakeholders.

Key Science Products:

- Production of reanalysis products
- Modeling and analysis products

System Components:

- Compute: Modeling and data processing
  - columbia – 89 TFlops SGI Altix
  - Pleiades – 516 TFlops SGI Altix-ICE
  - explore – 7 TFlops SGI Altix BX2
  - discover – 77 TFlops IBM & Linux Networx
- Storage: Model data archives
- Networks: Transportation of science data
- Services: Data visualization, computational performance tuning, & code scaling and porting

'Pleiades' & 'columbia'
ARC/HECC

'explore' & 'discover'
GSFC/NCCS

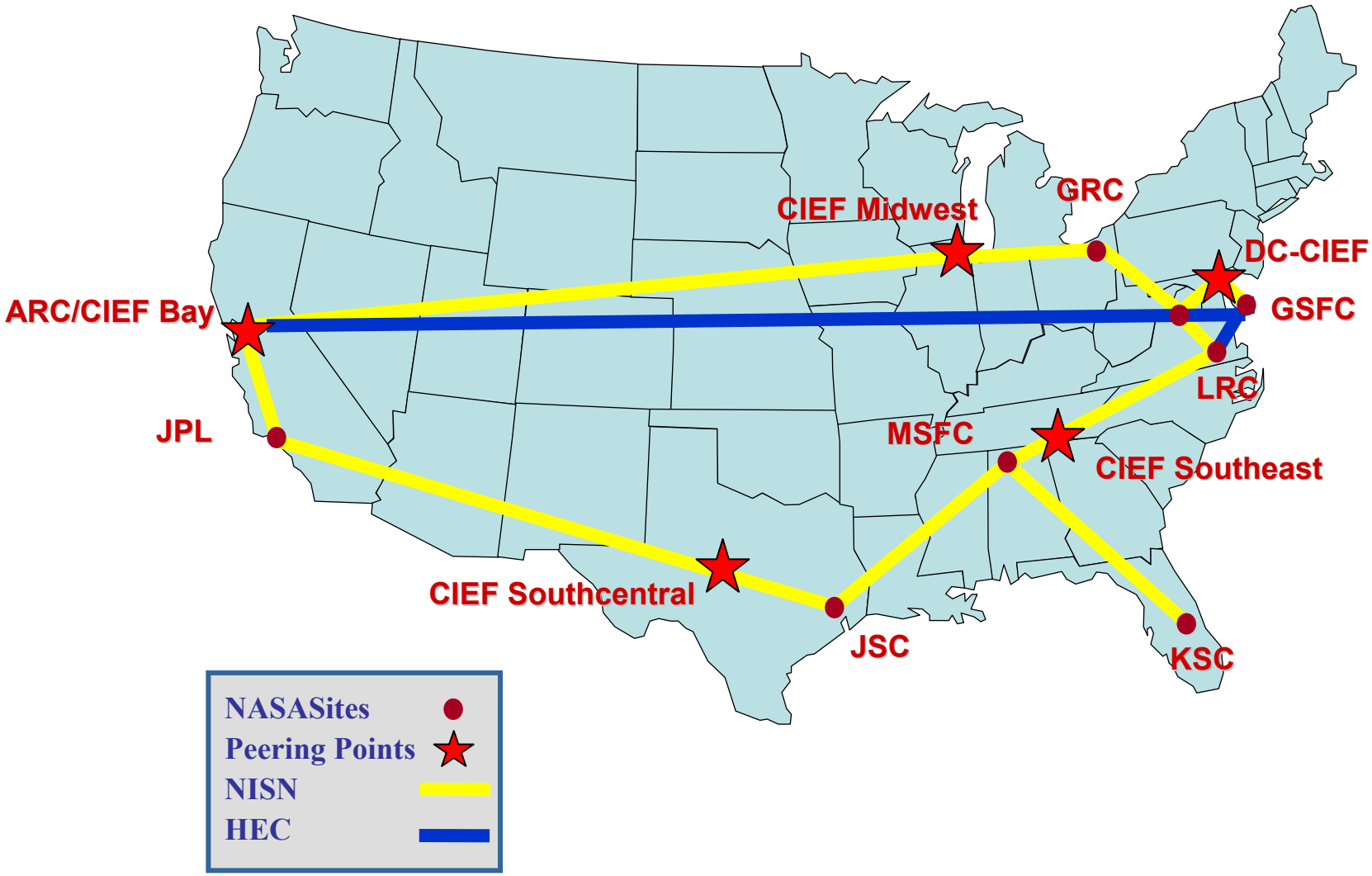
Mission Description:

Mission Life: *Ongoing/Upgrade and refresh routinely and also scheduled to changing requirements*

Projects: ARC/HECC Cost: (FY09) $*42*M GSFC/NCCS Cost: (FY09) $*19*M

* HECC project is an Agency investment managed by SMD

High Speed Network



High-End Computing Budget

	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13
Scientific Computing	15.3	18.9	18.5	18.9	18.4	18.6	19.4	19.9
High-End Computing Capability	35.7	38.9	38.9	41.9	42.8	43.8	44.8	45.9
Total	48.8	57.9	57.4	60.8	61.2	62.3	64.2	65.8

FY05 - FY07 Actuals // FY08 Current Op Plan // FY09 – FY13 President's Budget Submit

Budget is approximately:

- 1/3 operations
- 1/3 maintenance
- 1/3 system refresh

High-end computing @ ARC
Scientific computing is @ GSFC

SMD PI-led projects late-2008 snapshot:
268 projects

- 136 with allocation only at ARC/NAS
- 84 with allocation only at GSFC/NCCS
- 42 with allocation at both

- 131 Earth Science
- 43 Heliophysics
- 41 Planetary Science
- 48 Astrophysics

Earth Science Technology Development

Science driven, competed, actively managed, dynamically communicated

Competitive, peer-reviewed proposals enable selection of best-of-class technology investments

Risks are retired before major dollars are invested: a *cost-effective approach* to technology development and validation

This approach has resulted in:

- a portfolio of emerging technologies that will enhance and/or enable future science measurements
- a growing number of infusion successes:
  - technologies are infused into: science campaigns, instruments, ground systems and missions
  - infusion is by competitive selection by science investigators or mission managers, not the technology program

Implementation - Program Elements

Observational Technologies: 9 Solicitations (5-IIP, 4-ATI/ACT)

- **Advanced Technology Initiatives (ATI) -** provides for concept studies and development of component and subsystem technologies (Advanced Component Technology (ACT) Program) for instruments and platforms
- **Instrument Incubator Program (IIP) -** provides new instrument and measurement techniques, including lab development and airborne validation

Information Systems Technologies: 5 Solicitations

- **Advanced Information Systems Technologies (AIST) -** provides innovative on-orbit and ground capabilities for the communication, processing, and management of remotely sensed data and the efficient generation of data products and knowledge. Includes data manipulation, and visualization of very large, highly distributed remotely sensed data sets consistent with modeling needs

Directed Technology Efforts:

- NASA **Laser Risk Reduction Program** (LRRP) and Airborne Repeat Pass Interferometric Synthetic Aperture Radar (**UAVSAR)**

Progress to Date

In the ten years ESTO has existed, fourteen competitive research solicitations have been developed and issued, requesting everything from components and information technologies to instruments

- Over 440 Projects Completed to Date (through FY08)
  - Principal Investigators from more than 100 different organizations – academia, industry, national labs, and NASA centers – located in 32 states
  - More that 69% advanced at least 1 technology level (TRL) over their course of funding
  - Over 33% of projects have been infused into missions/campaigns
  - Over 41% of projects have a path identified for infusion
- Current portfolio contains 132 active / recently awarded research projects, with more than 350 co-investigators.
- Many new measurement capabilities have been enabled.

Earth Science Technology Funding: FY08-FY13

Program	FY08	FY09	FY10	FY11	FY12	FY13
ATI	$7.9	$8.3	$9.0	$9.5	$9.7	$9.9
IIP	$23.4	$25.9	$28.2	$28.0	$28.8	$29.5
AIST	$11.7	$11.9	$12.0	$12.7	$13.0	$13.0
Total	**$43.0**	**$46.1**	**$49.2**	**$50.2**	**$51.5**	**$52.4**

Heliophysics

- Research including technology development
- Sounding Rockets
- Research Range
- Modeling and Data Centers

Structure of the SMD Research Budget (FY09 President's Request)

- Heliophysics
  - Living With a Star
    - SDO, RBSP, Solar Probe, BARREL
    - Other Missions and Data Analysis — mission enabling
  - Solar Terrestrial Probes
    - MMS
    - Other Missions and Data Analysis — mission enabling
  - Heliophysics Explorer
    - IBEX
    - Other Missions and Data Analysis — mission enabling
  - Heliophysics Research
    - Research and Analysis — mission enabling
    - Sounding Rockets — mission enabling
    - ACE, Operating Missions and Data Analysis — mission enabling
    - Research Range — mission enabling
    - GSFC Building
  - New Millennium
  - Near Earth Networks // Deep Space Mission Systems

Research Competed Elements

- **Solar and Heliophysics SR&T**
  - Solar Magnetic Fields and Helioseismology
  - Solar Activity
  - Solar X- and gamma-ray
  - UV/Optical
  - IR/Sub-mm/Radio
  - Heliospheric Physics
  - Solar Wind
  - CME and Solar System Response
  - Advanced Tools and Techniques* (new)
- **Geospace SR&T**
  - Inner and Outer Magnetosphere
  - Ionosphere
  - Mesosphere and Thermosphere
  - Instrument Development
- **Low Cost Access to Space**
  - Solar and Helio SR Payloads
  - Geospace SR Payloads
- **Heliophysics Theory Program**

- **LWS Targeted R&T**
  - *Focused Science Teams 2004-08*

Examples

  - CME Constraints
  - Response of atmosphere to solar XUV
  - Magnetic connection between photosphere and corona
  - Predict IMF at L1
  - Extreme Space Weather
  - Ionosphere-Magnetosphere Plasma redistribution
  - Solar origins of irradiance variations
  - Solar wind heating and acceleration
  - Solar wind entry & transport in magnetosphere
  - Sensitivity of climate to solar forcing
  - Global electrodynamics in ionosphere

  - *Strategic Capabilities 2005-08*

Examples

  - Integrated Model of Atmosphere and Ionosphere
  - Comprehensive Magnetosphere - Ionosphere Model
  - 3D Model of Solar Active Region
  - Earth-Moon-Mars Radiation Model

The LWS TR&T Program

- LWS is a systematic, goal-oriented research program targeting those aspects of the Sun-Earth system that affect life and society.
- The TR&T component of LWS is to provide the theory, modeling, and data analysis necessary to enable an integrated, system-wide approach to LWS science.

TR&T Supports:

- Focused Science Teams
- Strategic Capabilities
- Cross-cutting Workshops
- Summer Schools

Selection for ROSES 2007
- 161 proposals submitted; 50 selected (success ratio: 1/3.2) for TR&T
- Proposal selection March 2008, funding completed June/July 2008
- Partnership with Planetary Division - one Focus Topic
- 3 workshops/summer schools selected

ROSES 2008
- ~ $5M available
- NOI due September 17, 2008.
- Proposals due October 19, 2008.
- Announcements ~March 19, 2009.

- TR&T >100
  - 5 FT (4 years)
  - II/TM (3 years)
- SC <10 (5 years)
- C/NOFs proposals >20

The Guest Investigator Program

- MO&DA for currently operating missions
- Guest Investigator Program
  - Includes special calls (e.g. C/NOFS, STEREO)
- SEC Data and Modeling Services
  - SDAC and VSO,
  - SPDF (e.g. CDAWeb, OMNIWeb, etc.),
  - CCMC
  - New VxOs
  - Resident Archives
- Multimission Operations Project at GSFC
  - Concentrates on control center functions and flight dynamics
  - Sustain operations and flight dynamics infrastructure
  - Promote new operations tools and architectures
  - Supports all Space-Science operations at GSFC

Heliophysics Research Budget

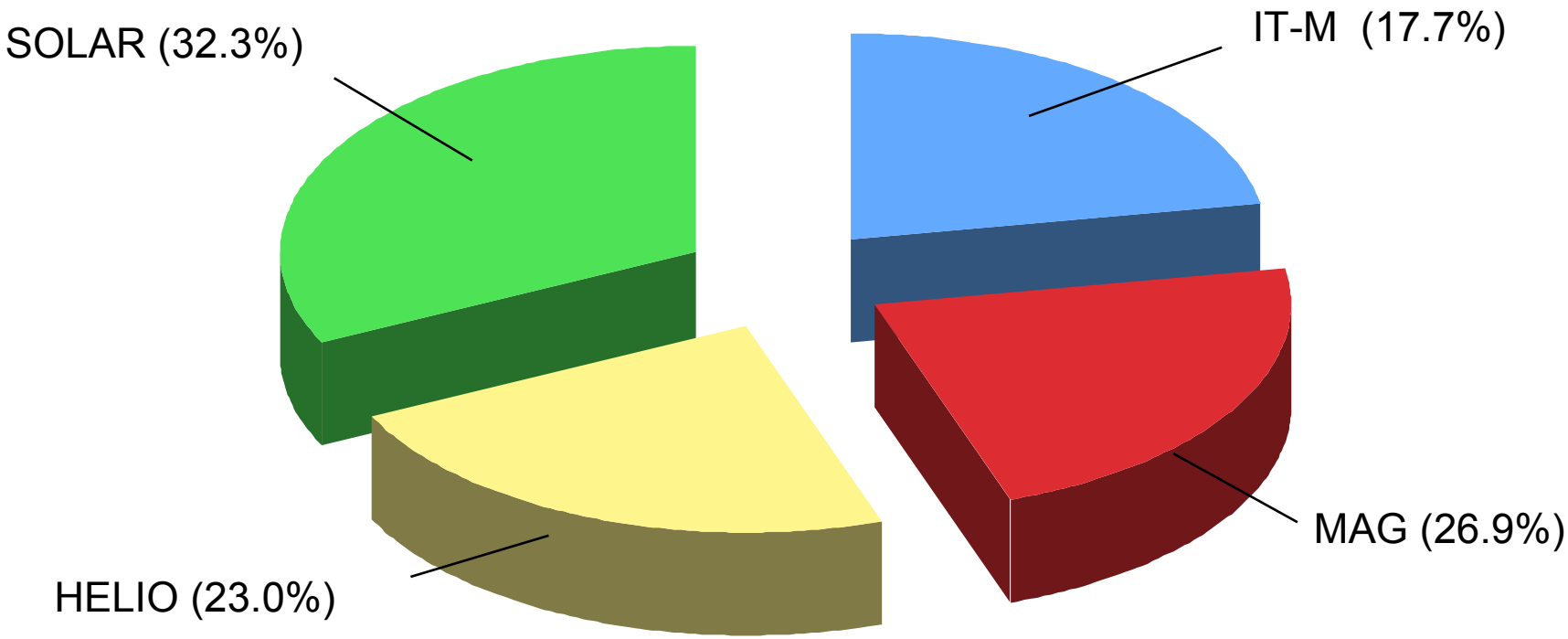
For *FY2007*, the following aggregates the competed research budget, including Low Cost Access to Space (LCAS - Sounding Rocket Payloads)

- "SR&T" $50.2 M
  - Solar-Heliosphere SR&T
  - Geospace SR&T
  - Heliophysics Theory
  - LWS Target Research and Technology
- Guest Investigator Program $11.5 M
  - Geospace GI Program
  - Solar and Heliospheric GI Program
- Data and Computing $14.0 M
  - Applied Information Research Program (AISRP)
  - VXOs, and Theory Modeling and Data Services
- Mission Science Teams (other than "Heliophysics R&A") $15.0 M
  - PI teams for missions and instruments selected through AO
  - Additional team members selected through competition
    - Participating scientists, interdisciplinary scientists, science working group members, etc.
- Extended Missions research and data analysis funding* $17.8 M

Total Heliophysics Competed **$108.5 M**

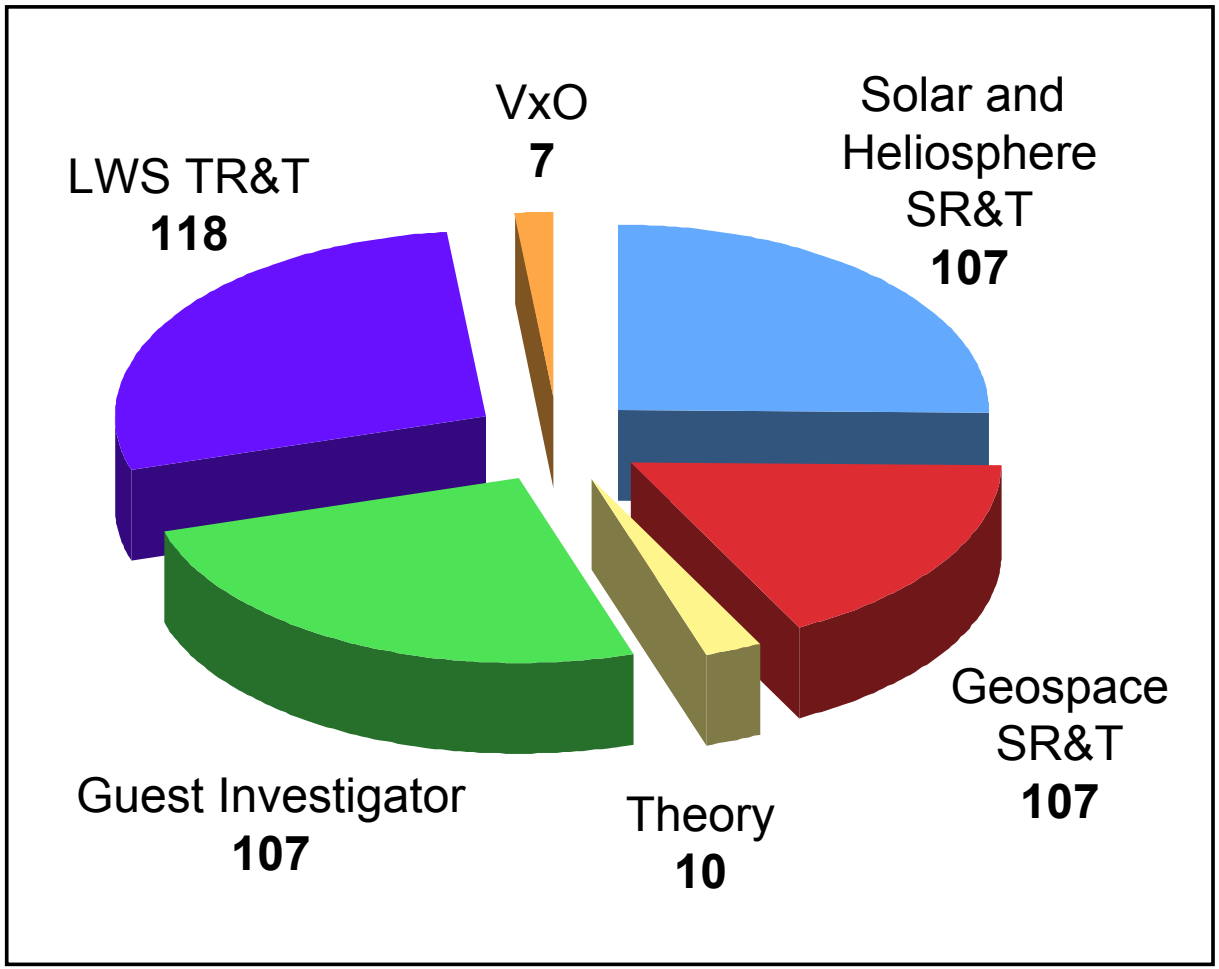
* FY08 planning number - competed via Senior Review Process every two-three yrs.

Heliophysics Balance in SR&T



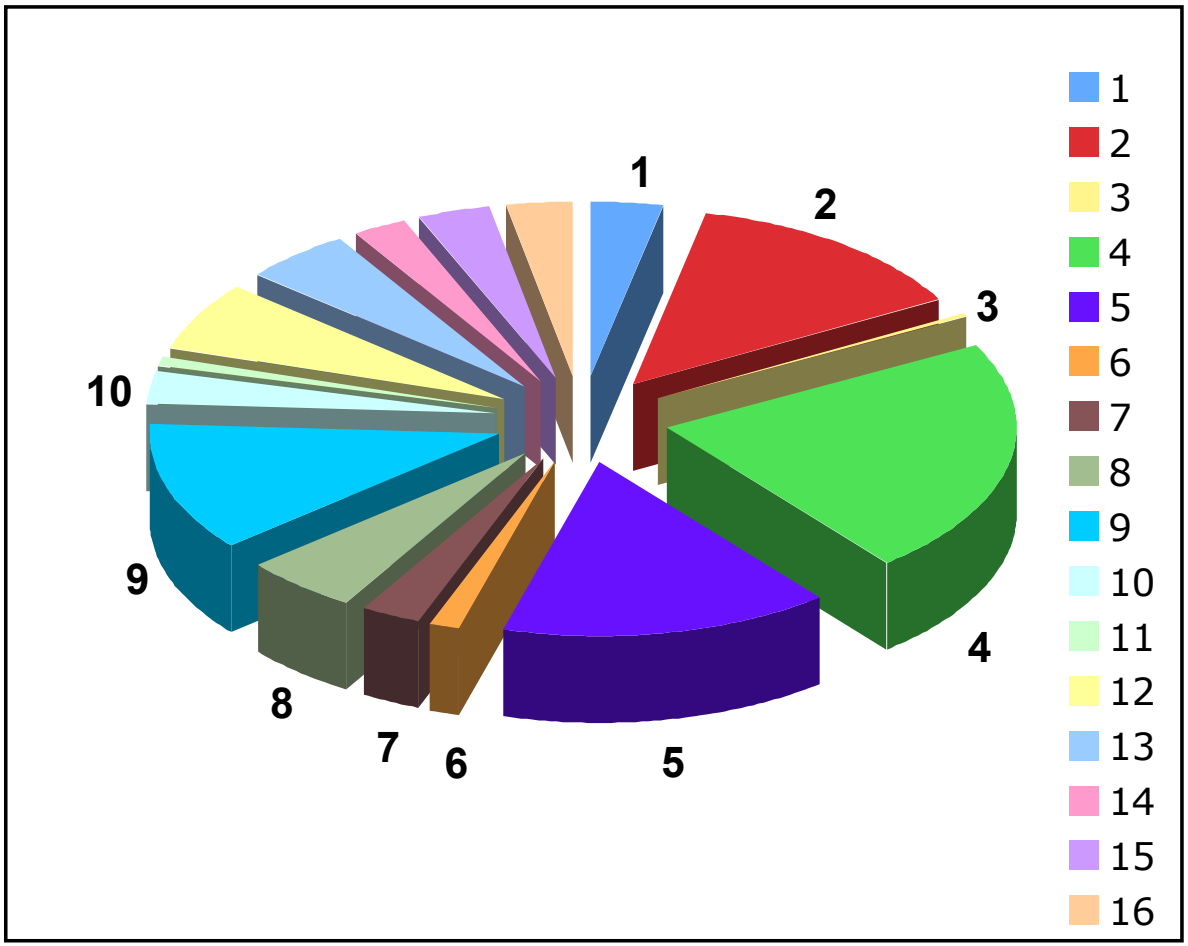
Proposals selected FY2005 - 2007

Proposals by Science Program



421 funded proposals through FY07

Mission Ops & Data Analysis (Est.) 2008



Prime Ops

AIM	2.6 $M
THEMIS	11.1
IBEX	0.1
STEREO	17.7
Hinode	12.4
CINDI	1.1
TWINS	2.3
Voyager	4.3
SOHO	9.6
Wind	2.5
Geotail	0.6
Cluster II	5.1
ACE	4.1
Fast	1.9
Trace	2.7
Rhessi	2.5

Extended Ops

Characterization of FY07 Competed Elements

ELEMENT	Win RATE	Avg. AWARD ($K)	New Awards ($M)
GI program			
GI-Geospace	34%	90.9	4.3
GI-S&H	30%	92.9	5.2
Geospace SR&T (w/LCAS)			
Geo-SR&T	26%	157.3	
HP Theory Program	35%	417.1	3.9
Solar-Heliospheric SR&T (w/LCAS)			
S-H SR&T	13%	90.7	2.8
LWS – TRT	28%	110.0	3.9
ASIRP, Data, Computing, and Models			
ASIRP-A	N/A	N/A	3.4
ASIRP-H	15%	136.4	3.2
VxO	50%	85.2	2.1
Grand Aggregate	25%	140.2	22.3

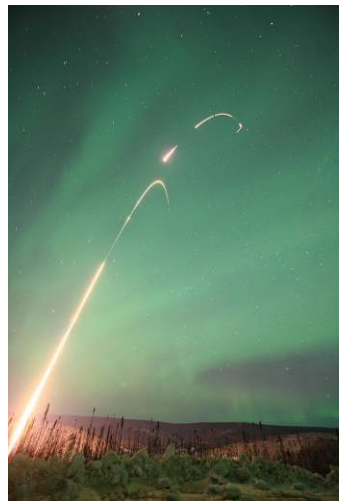
* Partial data available

Heliophysics Funding History

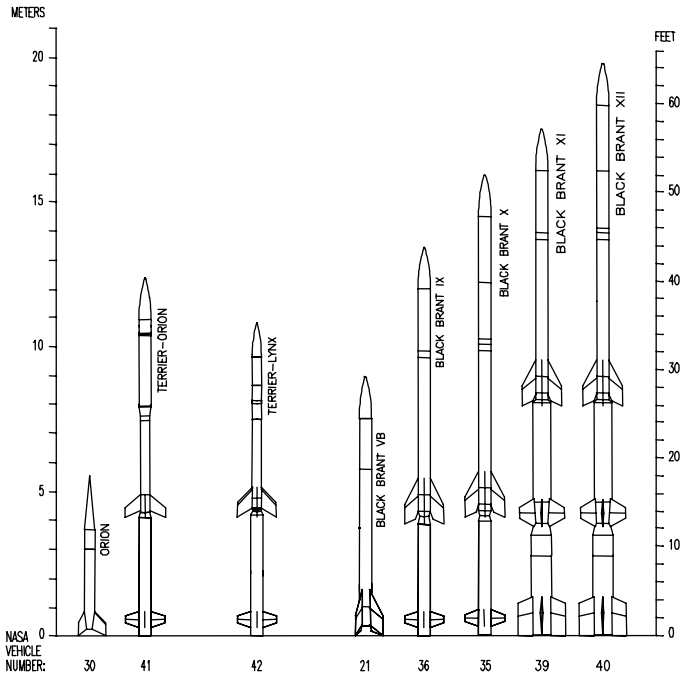
	FY07 Final Released Amt	FY08 Final Released Amt	FY09 Projected Amounts
Geospace Science	12,904,693	13,166,536	13,326,601
Solar and Heliospheric	15,806,893	15,666,522	15,869,190
Space Physics Theory	3,806,414	4,120,942	4,259,209
LWS TR&T	17,672,359	17,406,000	19,687,000
SR&T Total	50,190,359	50,360,000	53,142,000
Guest Investigator	11,651,000	10,923,605	14,053,000
AISRP + NSSDC	9,940,000	9,730,000	10,300,000
VxO	2,111,304	3,143,000	3,702,000
SEC Data & Modeling	2,000,000	2,000,000	2,000,000
Data & Computing Total	14,051,304	14,873,000	16,002,000
Total	75,892,663	76,156,605	83,197,000

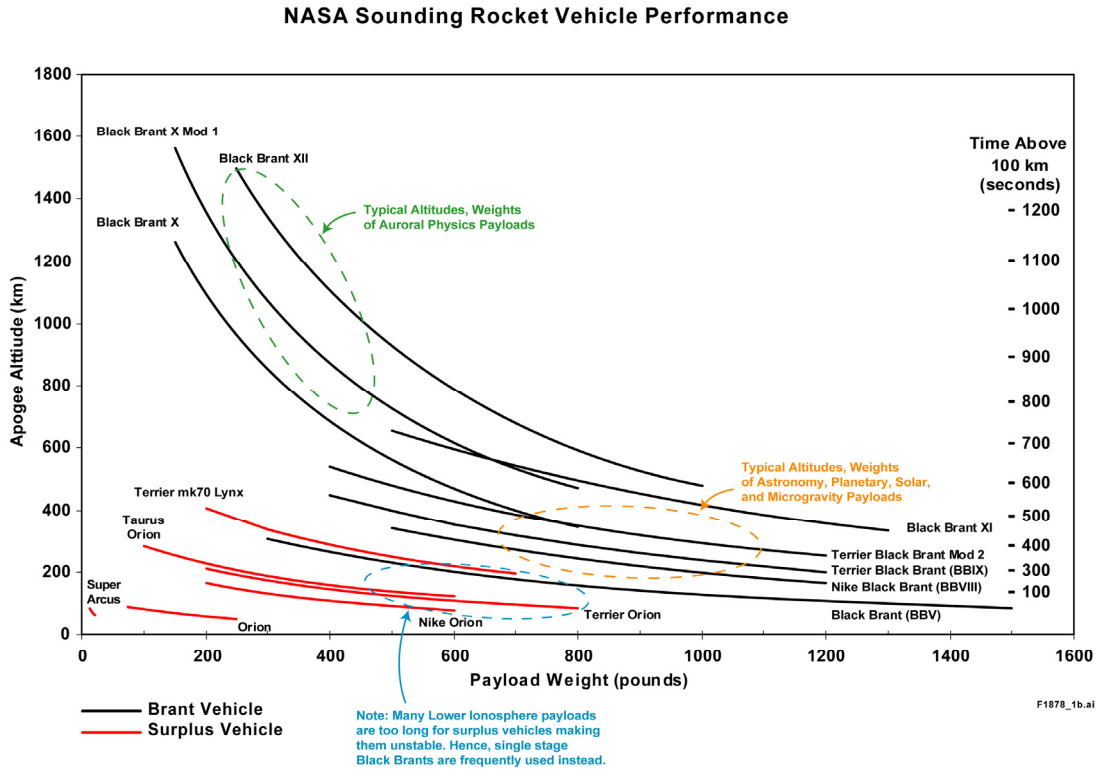
NASA Sounding Rocket Program

- NASA is the custodian of the national capability for custom, sub-orbital rockets technology, payloads and remote field operations.
- The capabilities of the sounding rocket program are drawn upon by a diverse science community, the Department of Defense and Industry for a variety of purposes.
- Key Characteristics:
  - Low-cost, responsive aerospace activity
  - Support diverse launch locations
  - Fly payloads from 80 to over 1500 km in altitude
  - Support small to large payloads (10 to 1500 lb)
  - Construct complex, custom-payloads with attitude control, complex deployments and telemetry
- The Sounding Rocket Program supports the research facilities, infrastructure, and rocket operations only; range services and payloads are separately funded.
- Program Objectives: Provide suborbital launch vehicles, payload integration, and field operations to support low-cost access to space for:
  - scientific investigations in geospace, solar physics, and astronomy;
  - technology development of vehicle systems;
  - development & test of future space-based measurement concepts and sensors.
- Mission Rate: 20-24 rocket flights per year. Auroral campaigns to polar regions (Alaska or Norway) once per year.



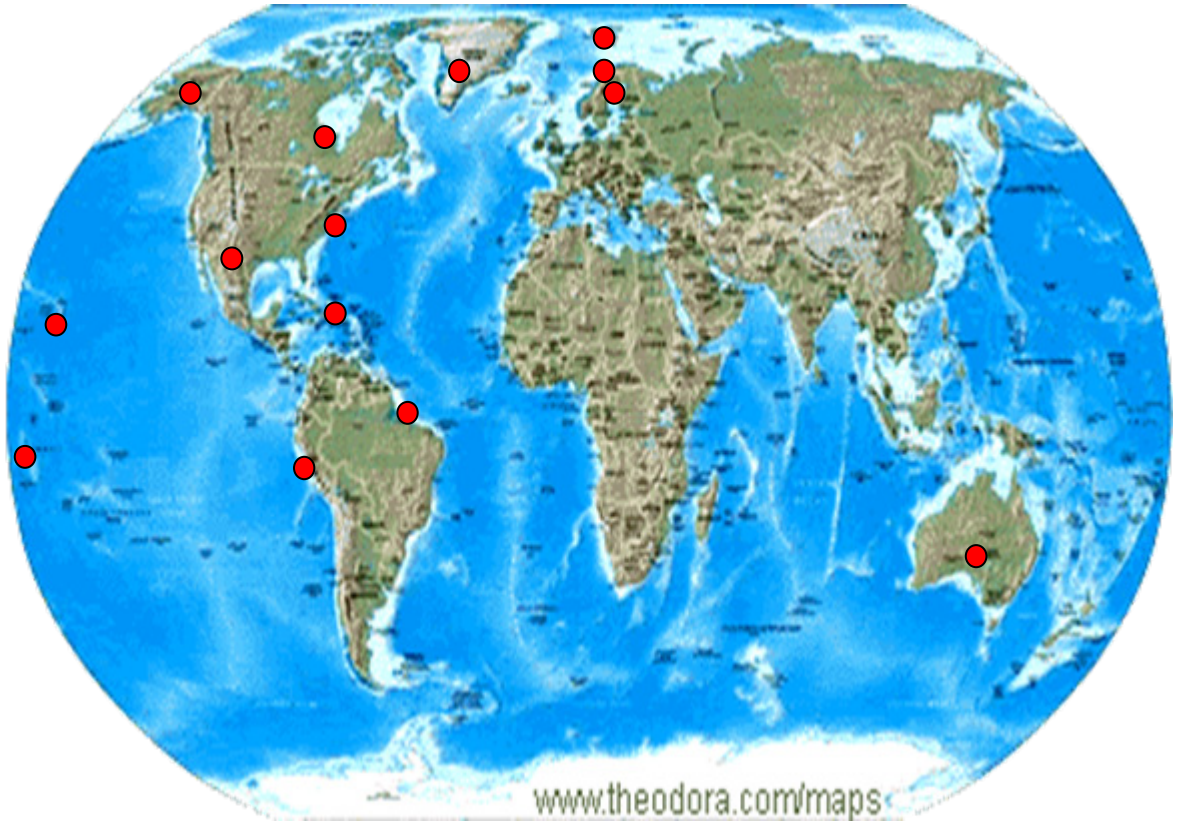
NASA Suborbital Sounding Rockets





- Stable of 8 vehicles covering max altitudes from 100-1500km, using various motor combinations (Terrier, Black Brant, etc)
- Sounding rocket vehicles are composed of military surplus and commercially available rocket motors
- Vehicle selection is based on payload weight and scientific requirements

World-Wide Operations



Norway – within the auroral oval, availability of down range observation sites, and access to unique instrumentation

Australia – observation of the southern sky and large land area to support special trajectories and recovery

Sweden – Favorable ionospheric conditions

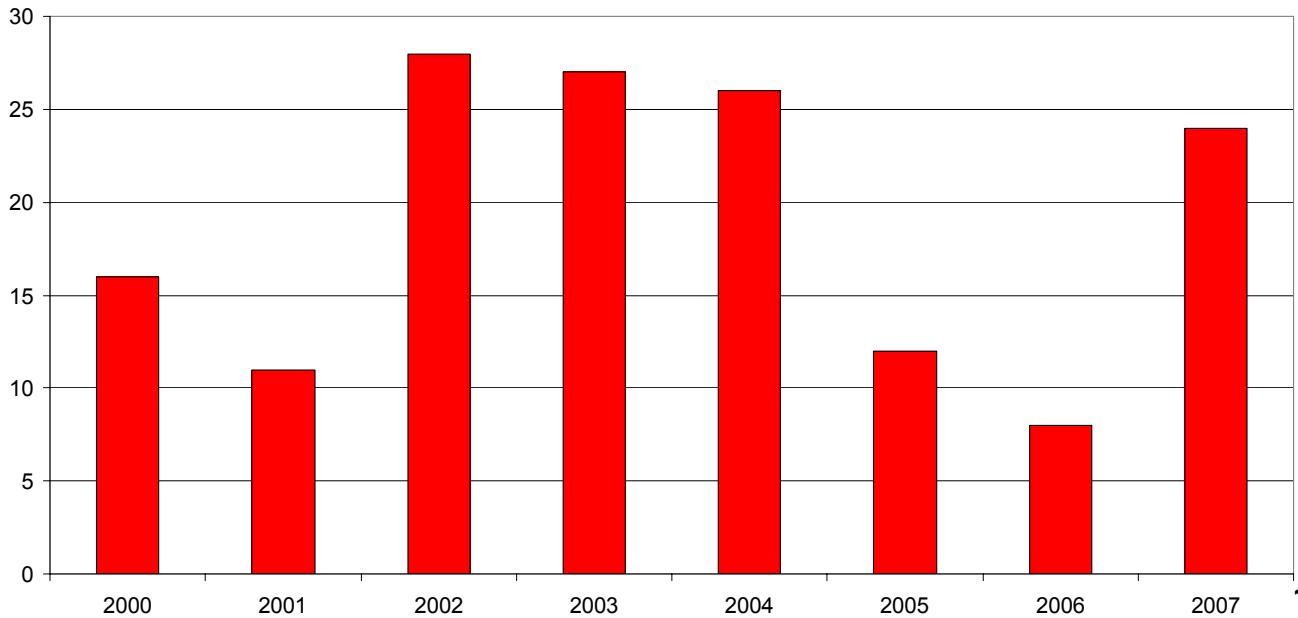
Kwajalein – close to the magnetic equator

Because many scientific investigations rely on in-situ measurements, launch operations must be conducted from sites around the world.

Flight History Since 2000 (FY)

Site	2000	2001	2002	2003	2004	2005	2006	2007
Wallops	6	5	7	11	4	4	3	5
WSMR	7	6	8	6	7	5	4	5
Poker	3	-	11	7	-	3	-	10
Kwajalein	-	-	-	-	14	-	-	-
Norway	-	-	2	1	1	-	1	4
Sweden	-	-	-	2	-	-	-	-
	16	11	28	27	26	12	8	24

Science payloads only

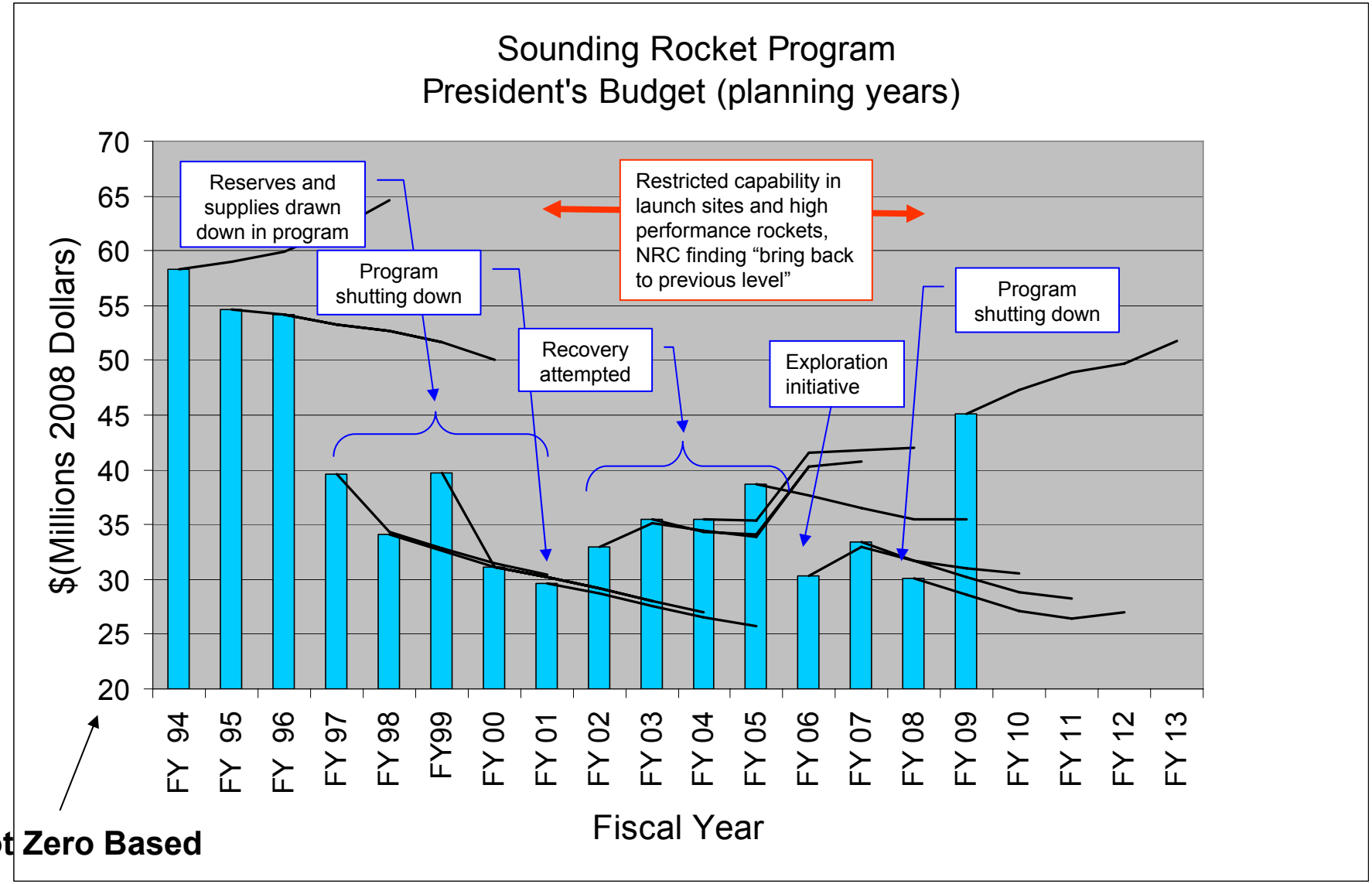


FY09 Sounding Rocket Program Cost Elements

The following table depicts the major cost elements for the NASA Sounding Rocket Program for FY09. This budget is consistent with the need to recover from previous cost reduction actions as well as meeting the projected flight rate.

Program Element	Cost
Civil Service Labor	$ 3.6M
Contractor Labor	$ 16.9M
Rocket Motor Procurements (Brant & Nihka)	$ 6.0M
Hardware Inventory Replenishment	$ 1.0 M
FY09 Mission Hardware Procurements	$ 4.8 M
FY09 Mission Support Systems Refurbishment & Analysis	$ 1.5 M
Logistics, Travel, System Development & Misc	$ 5.9 M
White Sands and Poker Range Support Contracts (fixed and variable costs)	$ 3.6 M
Other Support Contracts (Indian Head, WICC, CSC, etc)	$ 1.9 M
TOTAL	**$ 45.1 M**

Sounding Rocket Program Budget History



Research Range

Wallops Flight Facility's Research Range is a unique national resource enabling flexible, low-cost space access, in-flight science, and technology research for all of NASA and the Nation.

It is the only Launch Range that NASA owns.

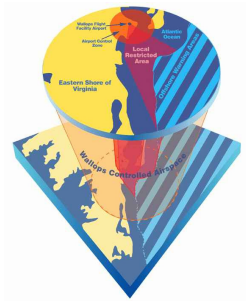
- Enabling Science from Earth to Orbit and Beyond
  - Vehicle Development and Risk Reduction Missions
    - Proof of Concept Missions and Technology Testing
      - Partnered with Mission Directorates and Centers

Components of the Research Range

- Tracking, Telemetry & Command Instrumentation:
  - Radar systems
  - Telemetry systems
  - Command/Destruct Systems
  - Video Tracking/Recording
  - Radio, intercom and voice circuits
  - Weather measurement & assessment
- Mobile Systems
  - All TT&C instrumentation packaged in mobile vans for deployment worldwide.
- Range Control Center
- Airspace and Airfield Services
  - WFF controlled airspace R-6604
  - 3 major + 1-UAV-dedicated runways
  - Air traffic control tower
- Facilities and Launchers (funded separately)
  - Spacecraft processing & hazardous processing facilities
  - Vehicle integration bay
  - Simulation & Test labs
  - Launch control blockhouse
  - ELV launcher & gantry
  - 20K and 50K launchers

Tracking Radar

Mobile Range Systems



WFF-controlled airspace

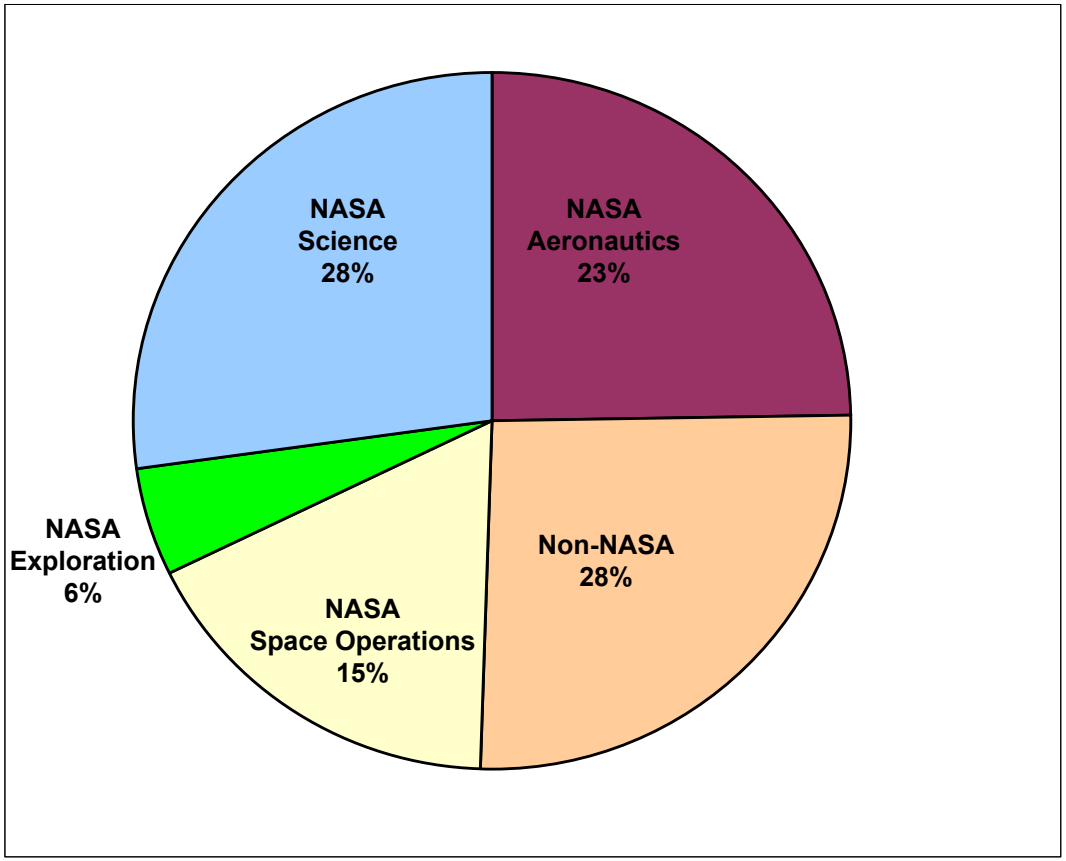
Range Control Center

Launchers

Hazardous Processing Facility

Research Range Annual Usage

Complexity-weighted Annual Average Usage



Average Annual Usage Events

ELV Support from WFF	1-2
Field Campaigns	1-2
Suborbital-class Rockets	7
Small Rockets	20
Shuttle Launch	1-2
Orbital Tracks (ISS/STS)	389
UAVs / Drop Models	143
Aircraft Tests	144
Ground System Tests	30
DoD Targets	24
DoD Gun Tests	3
Other Tests	20

884 total events (~680 NASA Events)
Airspace Activated 189 days in 2006

Research Range & Sounding Rocket Program Budget

			FY07	FY08	FY09	FY10	FY11	FY12	FY13
Research Range			17.5	17.4	18.3	19.2	18.6	19.2	19.6
Sounding Rockets			31.9	33.6	45.1	47.3	48.9	49.7	51.8

Sounding Rocket Payloads**	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13
Heliophysics	4	4	6	7	7				
Astrophysics	?	?	12	13	15				

** included in Division SR&T budgets

Data Archives & Modeling Centers

- Heliophysics Data and Model Consortium
  - Set up in FY09 to manage the new infrastructure for Heliophysics data archiving and access
  - Budget of $3.6M in FY09, slated to grow to ~$4M/year in next few years
  - Decisions on directions, etc. are made by an Implementation Working Group consisting of representatives of the various HDMC components

HDMC Supported Activities

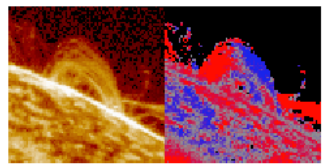
- **Discipline specific Virtual Observatories** ("VxOs") to uniformize access to all data from each subdiscipline (e.g. Magnetospheric Physics) (~$2.3M/yr for a total of ~7 groups in the current building phase, to decrease with maturity; solar is funded currently through SDAC.)
- **Data Restoration projects** (retrieve old data, make any data more compatible with new architectures) (~$300K/yr; fluctuates, but relatively stable for now.)
- **Resident Archives** to continue serving mission data after a mission ends but its data are still widely used (~$350K/yr, expected to grow as more missions end, with somewhat balancing decreases due to moves to Final Archives as specific dataset use declines.)
- **Value added services** to make VxOs and archives more effective (e.g., event-based and visual searches, format independent data readers and plotting tools) (~$450K/yr; to be balanced with and combined with core VxO services)

Heliophysics Data Centers at GSFC

Space Physics Data Facility

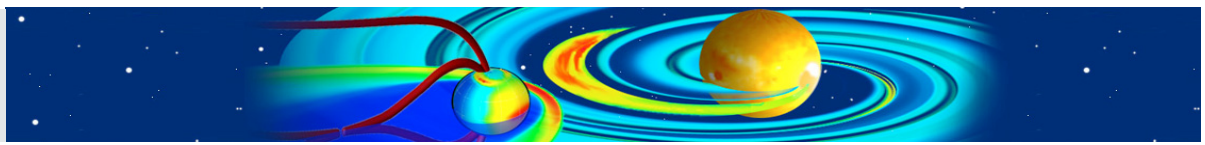
- Final multi-mission active archive for Space Physics Data
- Holder and maintainer of an active inventory of all HP data
- provider of easily used orbit data
- maintainer and developer of CDF (becoming defacto standard for space physics)
- provider of active mission data by arrangement with missions

Solar Data Analysis Center

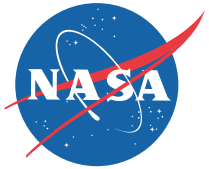


- Provider of access to HP solar physics data
- Final active archive for solar physics data
- maintainer of SolarSoft analysis tools
- coordinator of the Virtual Solar Observatory effort
- primary or secondary provider of active mission data for a number of current missions

Community Coordinated Modeling Center



- Coordinating center for HP models in all areas.
- Provides runs on request, help with models, online and desktop analysis tools, and a catalogued archive of previous runs.
- In conjunction with other agencies, works to advance models to provide an operational space weather prediction capability.



Planetary Science

- Research including technology development and data analysis
- Planetary Data System
- Astromaterials Curation
- Research and Support Facilities

Structure of the SMD Research Budget (FY09 President's Request)

- Planetary Science
  - Discovery
    - GRAIL, MMM, Future Missions
    - Discovery Research — mission enabling
    - Operating Missions and Data Analysis — mission enabling
  - New Frontiers
    - Juno
    - Other Missions and Data Analysis — mission enabling
  - Technology — mission enabling
  - Planetary Science Research
    - Research and Analysis — mission enabling
    - Lunar Science Research — mission enabling
    - Operating Missions and Analysis — mission enabling
    - Education and Directorate Management [for SMD]
  - Mars Exploration
    - MSL, MAVEN, JPL Building
    - Mars Research and Analysis — mission enabling
    - Operating Missions and Data Analysis — mission enabling
  - Outer Planets — mission enabling

Structure of Planetary R&A

Basic Research	Focused Research	Mission Data Analysis and Participating Scientists	Technology Development
Planetary Geology & Geophysics	Planetary Protection	Planetary Mission Data Analysis	Propulsion and Power
Cosmochemistry	Planetary Major Equipment	Lab Analysis of Returned Samples	Planetary Instruments
Planetary Atmospheres	Mars Fundamental	Mars Data Analysis & Mars PS	Mars Instruments & Technology
Planetary Astronomy	Near-Earth Objects	MESSENGER, Dawn & Venus PS	Astrobiology Instruments & Analogs
Origins of Solar Systems	Lunar Research & NASA Lunar Science Institute	Lunar Recon Orbiter PS	Lunar Sorties & Analogs
Astrobiology-Exobiology & NASA Astrobiology Institute	Outer Planets	Jupiter and Cassini Data Analysis	
Research programs for post docs, graduate & undergrad students		SALMON PS	

Planetary Missions and Focused Research

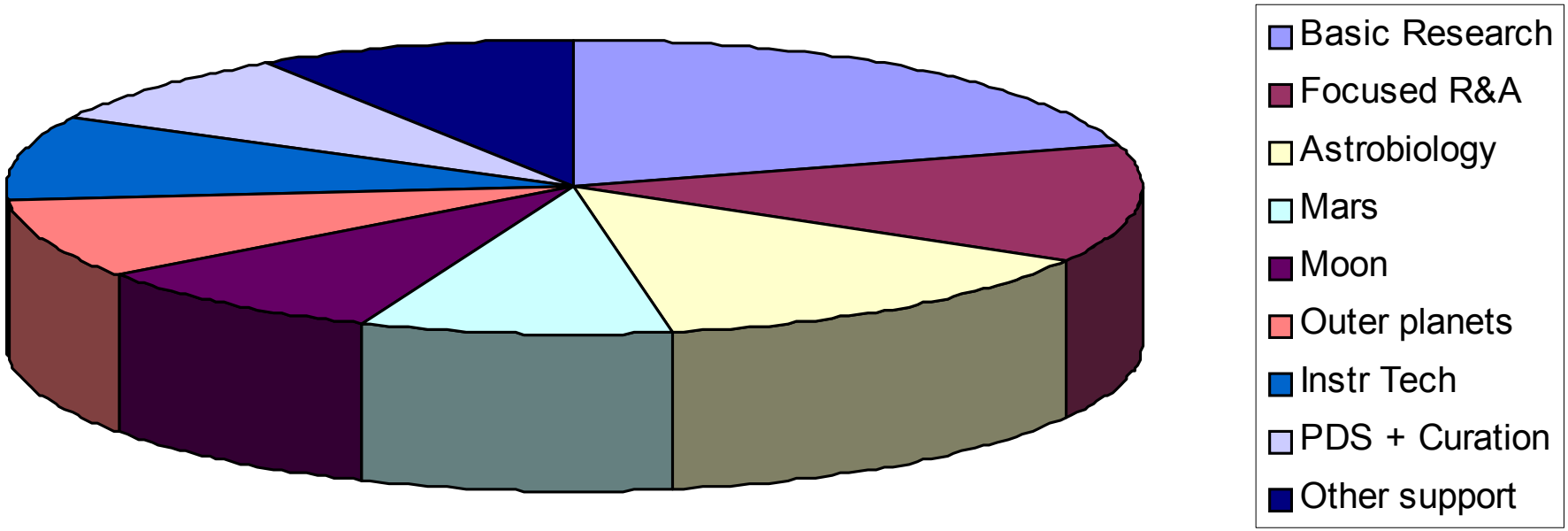
Solar System Body	Missions	Data Analysis & Participating Scientists	Focused Research	Applied Research & Technology
Sun	Genesis, Ulysses, Voyager	LARS (SRLIDAP)		
Mercury & Venus	Mariner 10, Magellan, **MESSENGER**, ***Venus Express***, *Bepi-Columbo*	MESSENGER PS, Venus Express PS		Venus SDT
Moon	Apollo, Clementine, Prospector, ***M3***, LRO, LCROSS, GRAIL, LADEE, ILN	LASER, LRO PS	LASER, NLSI	LASER, MMAMA, NLSI, ILN SDT
Mars	MPF, MGS, **Odyssey, MER, *Mars Express***, **MRO**, Phoenix, MSL, MAVEN, *ExoMars*	MDAP, Mars PS	MFRP, AB/EXO, NAI	MIDP, MTP
Asteroids & Comets	NEAR, Stardust, Deep Impact, **Stardust NExT, Dawn, EPOXI**, **WISE, *Rosetta, Hayabusa, NEOsat***	LARS (SRLIDAP), Dawn PS		NEOO
Outer Planets	Voyager, Gallileo, **Cassini, New Horizons,** Juno	OPR, JDAP, CDAP	OPR, AB/EXO, NAI	OPF SDT

Underline - past
Bold - operating
Italics - foreign
Normal - in development

Planetary R&A Overview

ROSES	FY07	FY08	FY09
Mars R&A	**$14,158**	**$19,936**	**$24,938**
Mars Fundamental Research			
Mars DAP			
Discovery Research	**$11,881**	**$13,556**	**$18,816**
Sample Return Lab Inst & DAP			
Discovery DAP & Stardust DAP			
MESSENGER Participating Scientists			
Planetary R&A	**$79,256**	**$93,537**	**$92,657**
Planetary Geology & Geophysics			
Cosmochemistry			
Planetary Astronomy			
Planetary Atmospheres			
Planetary Instruments			
Origins of Solar Systems			
Planetary Protection			
Outer Planets Research			
New Horizons & Jupiter DAP			
Cassini Data Analysis Program			
Astrobiology	**$32,414**	**$40,033**	**$49,724**
ASTEP			
ASTID			
NASA Astrobiology Institute			
Astrobiology: Exo and Evo			
Lunar Research	**$0**	**$18,487**	**$22,800**
Lunar Sortie Science Opportunity			
LRO Participating Scientist Program			
Lunar Advanced Science & Exploration Research			
NASA Lunar Science Institute			
Total Planetary Research	**$137,708**	**$185,549**	**$208,935**

Planetary R&A FY08 Budget Balance



Basic Research is cross-cutting;
Astrobiology is minus technology

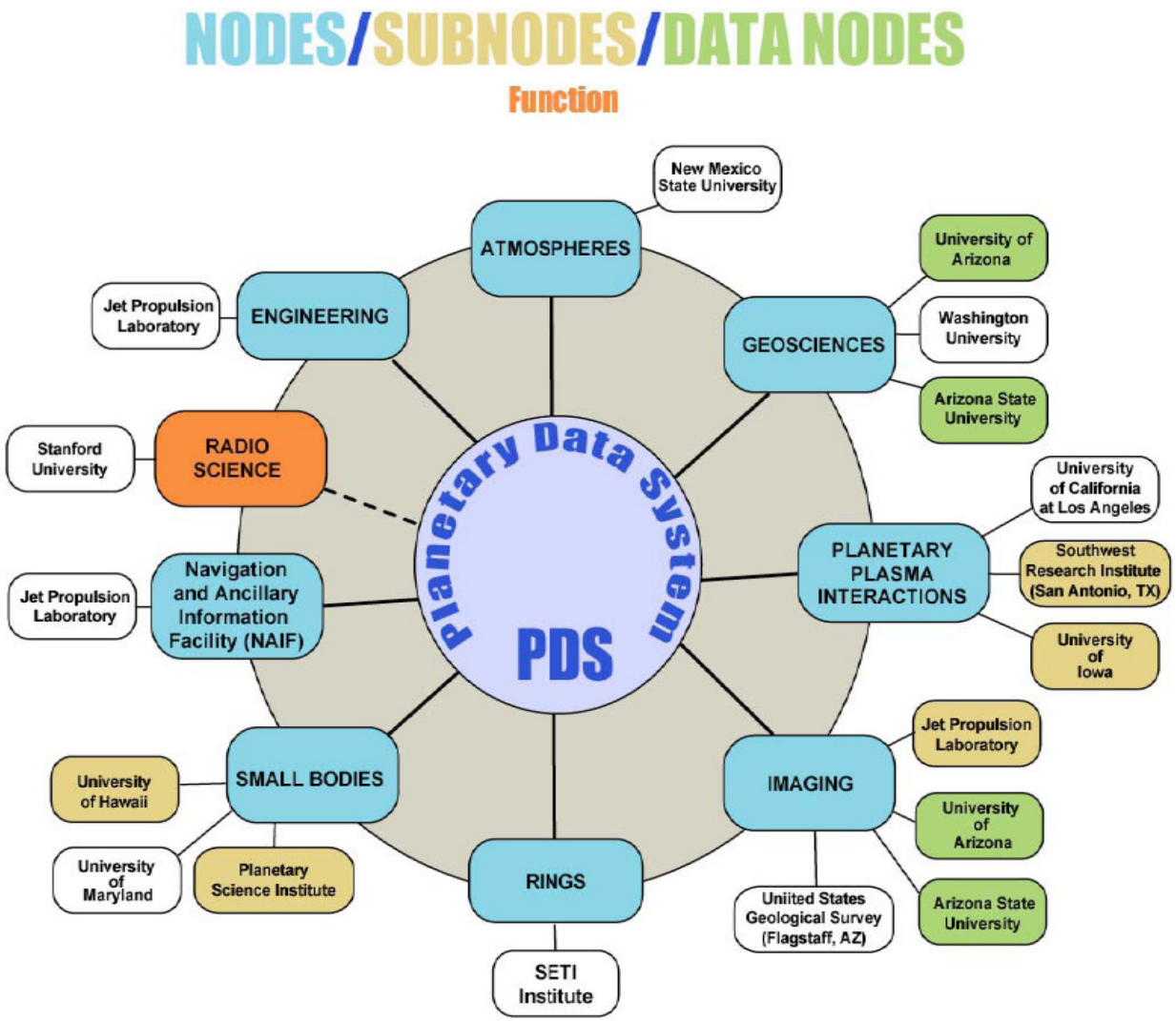
Recent Proposal Statistics

FY	Program	proposals	selected	
2008	Astrobiology Science & Technology for Exploring Planets	54	7	13%
2007	Astrobiology Science and Technology Instrument Developn	97	17	18%
2007	Astrobiology: Exobiology and Evolutionary Biology	113	33	29%
2008	Cassini Data Analysis	61	20	33%
2008	Cosmochemistry	68	31	46%
2008	Jupiter Data Analysis	40	14	35%
2007	Lunar Advanced Science and Exploration Research	162	43	27%
2007	Mars Data Analysis	78	33	42%
2008	Mars Fundamental Research	95	21	22%
2008	NASA Lunar Science Institute	33	7	21%
2008	Near Earth Object Observations	15	4	27%
2008	Origins of Solar Systems	94	30	32%
2007	Outer Planets Research	120	29	24%
2008	Planetary Astronomy (PAST)	46	18	39%
2008	Planetary Atmospheres (PATM)	81	30	37%
2008	Planetary Geology and Geophysics	114	28	25%
2007	Planetary Instrument Definition and Development	115	15	13%
2007	Planetary Mission Data Analysis	30	15	50%
2008	Sample Return Laboratory Instruments and Data Analysis	28	15	54%
		1444	410	28%

Planetary Data System

- PDS is the official planetary science data archive for the NASA SMD Planetary Science Division
- PDS is chartered to ensure that planetary data are archived and available to the scientific community
- PDS is a distributed system designed to optimize scientific oversight in the archiving process
- Science nodes focus on data ingestion, distribution, and supplier and user interaction
- Support nodes focus on infrastructure, basic development and cross-discipline support

Planetary Data System Organization



Astromaterials Curation (@JSC)

- Responsible for physical curation and security of all NASA Astromaterials, including those from future missions
- Curation tasks includes:
  - Documentation, preservation, preparation and distribution for research and display
  - Preserving the physical and environmental security in JSC Curation Labs
  - Developing and implementing detailed procedures on curation and security
- Curation facilities and team
  - Special clean rooms for each collection
  - Highly trained curators and technicians

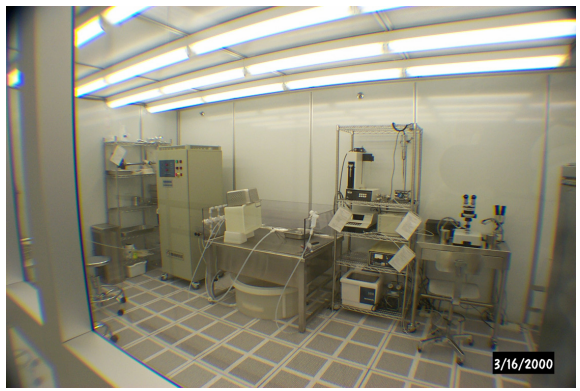
Astromaterials Curation Facilities

JSC Curation Building

Lunar Lab

Meteorite Lab

Cosmic Dust Lab



Genesis Lab

Stardust Lab

Planetary Research Support

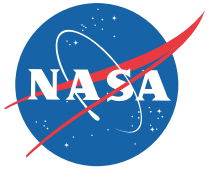
- Planetary Data System (PDS) mission data archive
  - Management Node at GSFC
  - 2 Support nodes at JPL [Engineering and Navigational & Ancillary Information (NAIF)]
  - 6 Distributed Science nodes [Atmospheres, Geosciences, Imaging, Planetary Plasma Interactions (PPI), Planetary Rings, Small Bodies]
- Astromaterials Curation (@JSC) returned sample archive
  - Apollo Lunar Samples
  - Meteorites from Antarctica
  - Cosmic Dust from Stratosphere
  - Genesis Solar Wind
  - Stardust Comet Coma

Support Task	FY07	FY08	FY09
Astromaterials Curation	$4.187M	$5.072M	$4.712M
Planetary Data System	$11.408M	$10.606M	$11.176M

Research and Support Facilities

- Lunar and Planetary Institute (LPI, Houston)
- InfraRed Telescope Facility (IRTF, Hawaii)
- Regional Planetary Image Facilities (RPIF)
  - 9 U.S.
  - 8 foreign
- Planetary Cartography (USGS, Flagstaff)
- RELAB (reflectance spectroscopy, Brown U.)
- Vertical Gun Lab (ARC)
- Planetary Aeolian Lab (ARC)

- Budgets are part of the Planetary R&A line



Astrophysics

- Research including technology development
- Guest Observer Programs
- Scientific Balloons
- Astrophysics Data Centers

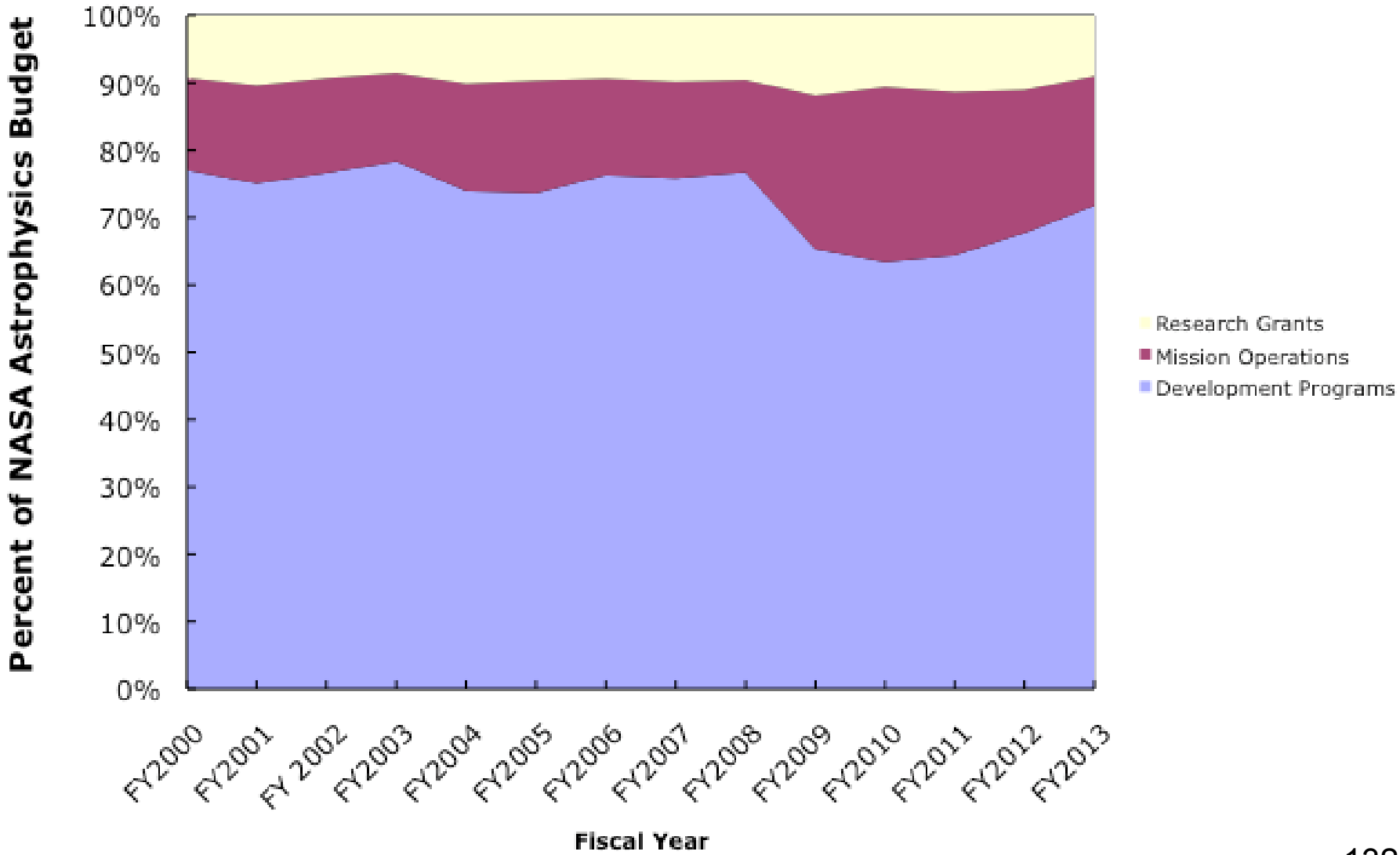
Structure of the SMD Research Budget (FY09 President's Request)

- Astrophysics
  - Astrophysics Research
    - Research and Analysis — mission enabling
    - Balloon Project — mission enabling
    - Operating Missions and Data Analysis — mission enabling
  - Cosmic Origins
    - Hubble, JWST, SOFIA, Spitzer
    - Astrophysics Future Missions — mission enabling
  - Physics of the Cosmos
    - Fermi, JDEM, Herschel, Planck
    - Chandra, Other Missions and Data Analysis — mission enabling
  - Exoplanet Exploration
    - SIM, Kepler
    - Other Missions and Data Analysis — mission enabling
  - Astrophysics Explorer
    - WISE, NuSTAR
    - Operating Missions and Data Analysis — mission enabling

Astrophysics Program Descriptions

- Astrophysics Research
  - The supporting research & technology component develops new detectors and technologies for use in future major missions; balloons and rockets advance the readiness of the technologies and perform science observations; laboratory astrophysics measures properties of matter in conditions approximating astrophysical situations; theory and data analysis transform data into knowledge and knowledge into the questions & technology that drive future missions
- Cosmic Origins - *How the Universe evolved from the Big Bang to people*
  - Discover how matter clumped into large-scale filaments and structures to form the cosmic web for the formation of galaxies and clusters of galaxies; how they evolved into the galaxies of stars, gas and dust that we see today; how stars and planetary systems form within the galaxies.
- Physics of the Cosmos – *Explore the fundamental nature of the Universe*
  - Explore the nature of space, time, energy and matter; the behavior of fundamental particles and forces of nature (dark matter, dark energy); the processes that shape the structure and composition of the Universe as a whole (the Big Bang and accelerated expansion of the Universe).
- Exoplanet Exploration - *The search for life elsewhere in the Universe*
  - Determine the frequency of planetary systems and measure the properties of stars that harbor planets, the percentage of terrestrial and larger planets that are in or near the habitable zone of a wide variety of stars and measure their orbits, search for evidence of life on those planets
- Astrophysics Explorer
  - Small PI-led astrophysics missions selected for innovative science and to fill the scientific gaps between the larger missions

Astrophysics Budget Split (FY00-FY13)



Astrophysics Research Budget

- For FY2008, the following aggregates the competed Astrophysics research budget excluding flight hardware development
  - "Standard" Astrophysics R&A $72M
  - Mission Guest Observer $70M
  - Mission Science Teams ~ $60M
    - PI teams for missions and instruments selected through AO
    - Additional team members selected through competition
    - Participating scientists
    - Interdisciplinary scientists
    - Science working group members
  - Total Astrophysics research and data analysis funding ~ $200M

Astrophysics SR&T Elements

- $72M in FY2008
- Astronomy & Physics Research & Analysis ($39M)
  - Categories of Investigations
    - Suborbital Investigations
    - Detector Development
    - Supporting Technology (Optics, Coatings, Coronagraphs, …)
    - Laboratory Astrophysics
    - Ground-based
  - Disciplines
    - Particle Astrophysics
    - Gamma-Ray
    - X-ray
    - UV/Optical
    - IR/Sub-mm/Radio
- Astrophysical Theory & Fundamental Physics ($11M)
- Origins of Solar Systems ($3M)
- Astrophysics Data Analysis Program ($15M)
- Strategic Mission Concept Studies ($4M)

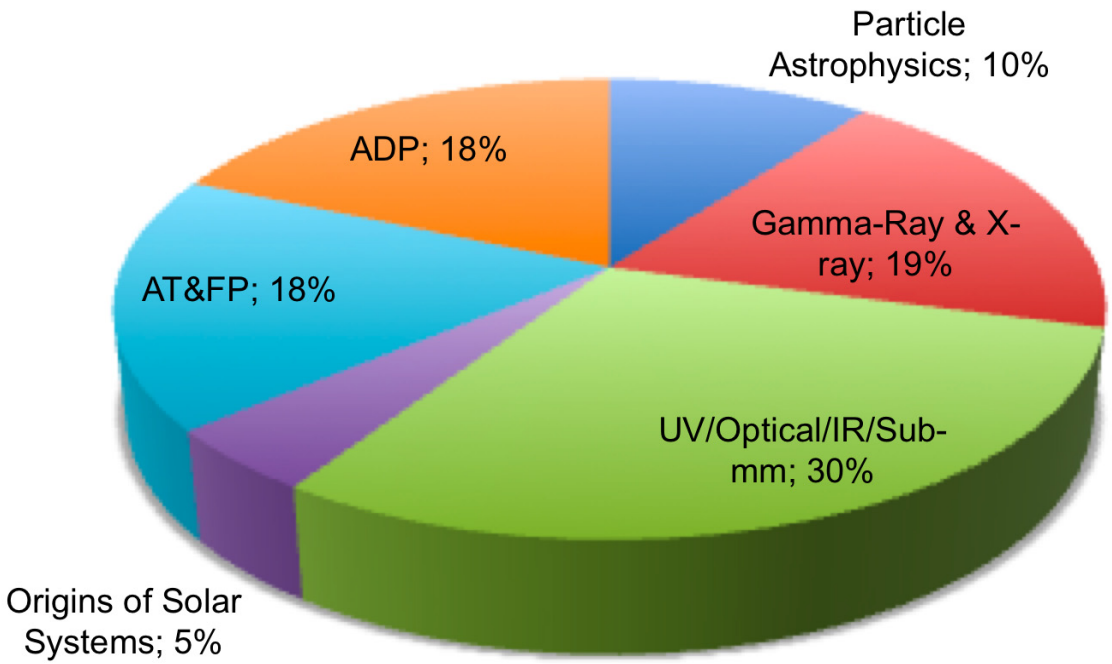
Astrophysics Statistics

ROSES-2007

	Proposals	Selected	Win Rate
SR&T [1]	559	150	27%
GO [2]	530	187	35%
Total	1089	337	31%

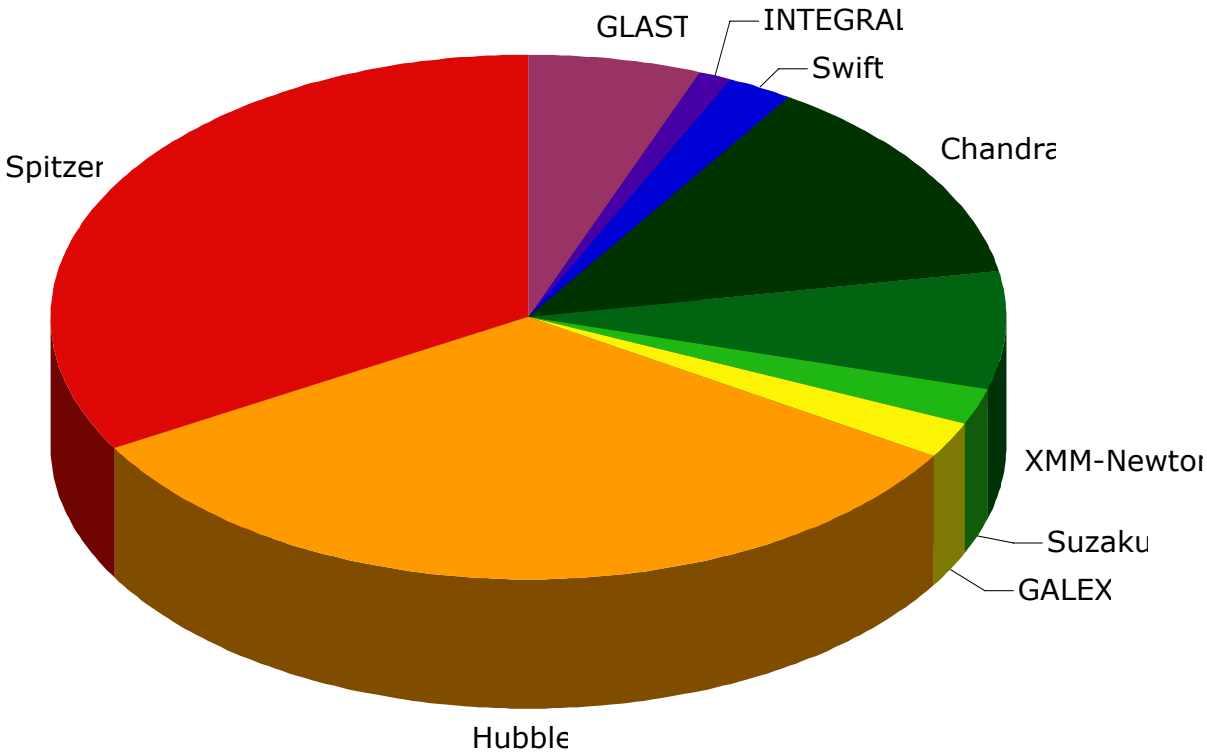
[1] APRA, ATFP, ADP, Orig SS
[2] GALEX, GLAST, Kepler, Suzaku, Swift

Astrophysics FY08 SR&T Snapshot



Total FY08 Funding $65M

FY08 Astrophysics Mission GO Funding



Total FY08 Funding $70M

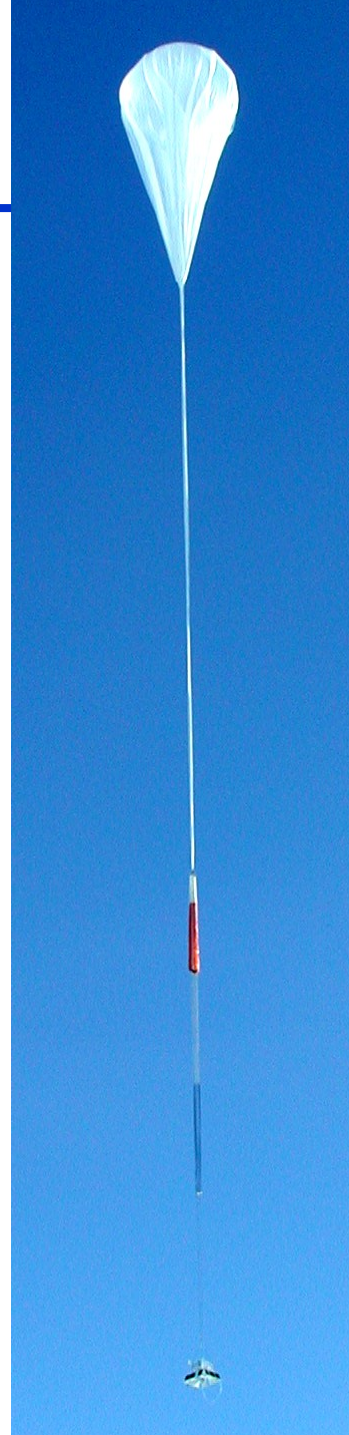
Astrophysics Funding History

	FY04 Actuals	FY05 Actuals	FY06 Actuals	FY07 Actuals	FY08 Guideline	FY09 Targets
Particle Astro	$ 8,248,000	$ 7,670,887	$ 8,543,526	$ 6,971,071	$ 7,396,076	$ 7,600,000
High Energy Astro	$ 14,548,000	$ 13,693,202	$ 14,779,227	$ 12,131,980	$ 12,421,315	$ 14,700,000
UV/Opt	$ 8,643,000	$ 7,919,208	$ 6,486,966	$ 5,158,608	$ 5,647,661	$ 6,300,000
IR/Sub-mm	$ 11,766,000	$ 10,822,918	$ 15,363,712	$ 12,146,210	$ 13,297,713	$ 14,800,000
Other	$ 1,019,000	$ 854,085	$ 337,664	$ 931,616	$ 559,020	$ 500,000
APRA Total	$ 44,224,000	$ 40,960,300	$ 45,511,095	$ 37,339,485	$ 39,321,785	$ 43,900,000
Orig SS	$ 4,209,000	$ 3,871,613	$ 4,149,617	$ 3,673,163	$ 3,441,703	$ 2,900,000
ATFP	$ 7,860,000	$ 7,363,285	$ 10,245,457	$ 10,106,352	$ 10,859,512	$ 12,200,000
ADP/LTSA	$ 16,986,000	$ 15,700,000	$ 15,188,960	$ 14,615,000	$ 14,513,000	$ 14,800,000
Astrophysics Core R&A	$ 73,279,000	$ 67,895,198	$ 75,095,129	$ 65,734,000	$ 68,136,000	$ 73,800,000
TPF/FS	$ 2,000,000	$ 2,000,000	$ -			
BEFS	$ 4,000,000	$ 3,000,000	$ 2,000,000	$ -	$ -	
ASMCS			$ -		$ 3,938,000	$ 2,000,000
TOTAL R&A	$ 79,279,000	$ 72,895,198	$ 77,095,129	$ 65,734,000	$ 72,074,000	$ 75,800,000
Hubble	$ 25,421,259	$ 26,493,569	$ 26,200,000	$ 25,000,000	$ 22,300,000	$ 24,700,000
Chandra	$ 9,500,000	$ 9,200,000	$ 10,100,000	$ 10,000,000	$ 11,800,000	$ 11,800,000
Spitzer	$ 22,025,000	$ 20,000,000	$ 21,000,000	$ 25,500,000	$ 20,000,000	$ 20,000,000
GLAST	$ -	$ -	$ -	$ -	$ 4,500,000	$ 8,000,000
WISE	$ -	$ -	$ -	$ -	$ -	$ -
Kepler	$ -	$ -	$ -	$ -	$ -	$ 1,300,000
Herschel	$ -	$ -	$ -	$ -	$ 2,500,000	$ 11,600,000
GALEX	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 1,800,000	$ 2,000,000	$ 2,000,000
RXTE	$ 900,000	$ 900,000	$ 900,000	$ 800,000	$ -	$ -
Suzaku	$ -	$ -	$ 1,700,000	$ 1,700,000	$ 1,000,000	$ 1,000,000
Swift	$ -	$ 1,000,000	$ 1,000,000	$ 1,500,000	$ 1,800,000	$ 1,500,000
XMM	$ 5,500,000	$ 5,500,000	$ 5,800,000	$ 5,500,000	$ 5,700,000	$ 5,700,000
INTEGRAL	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 900,000	$ 1,000,000	$ -
WMAP	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL GO	$ 66,346,259	$ 66,093,569	$ 69,700,000	$ 72,700,000	$ 72,600,000	$ 87,600,000
	Last normal R&A	$7M R&A cut	smaller R&A cut	15% R&A cut	Partial recovery	More R&A recovery

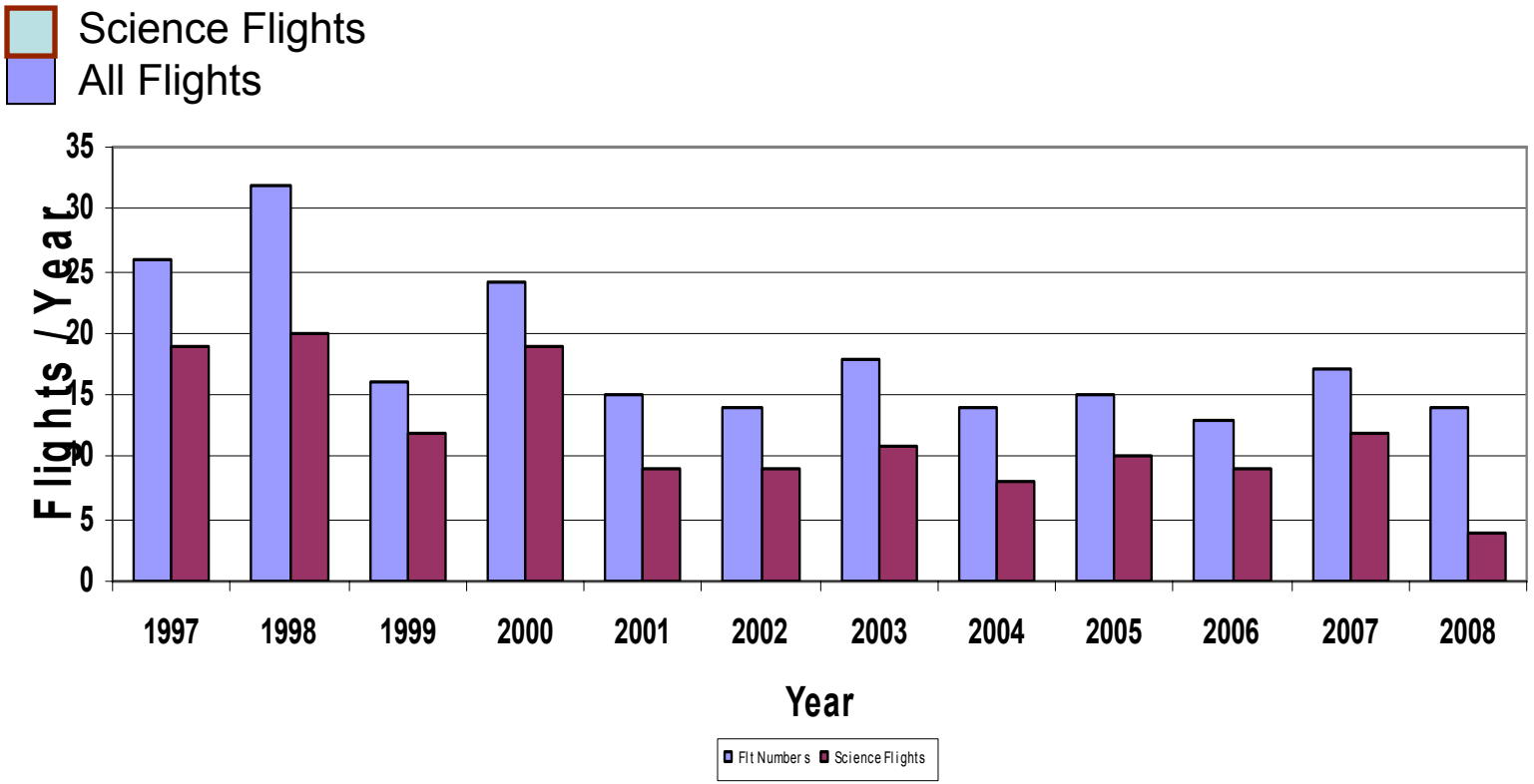
- Considering R&A Senior Review to assess balance between R&A elements/programs
- GO Funding is approximate

Scientific Balloon Project

- Balloon flight operations are managed by the Balloon Program Office (BPO) at the Wallops Flight Facility.
  - The flights are conducted by the staff of the Columbia Scientific Balloon Facility, a government owned, contractor-operated facility located in Palestine, Texas. The Physical Science Laboratory of New Mexico State University operates the facility under a competitive contract to the Wallops Flight Facility.
  - The BPO flies the SMD payloads, Upper Atmospheric Research Program payloads not flown on aircraft (which dominates that program), plus a few reimbursable payloads.
- Balloon payloads are competitively selected via ROSES NRA's.
- Balloon science flights are dominated (~ 85%) by Astrophysics with the rest (~15%) covering Heliophysics, Earth Science, and reimbursable flights.

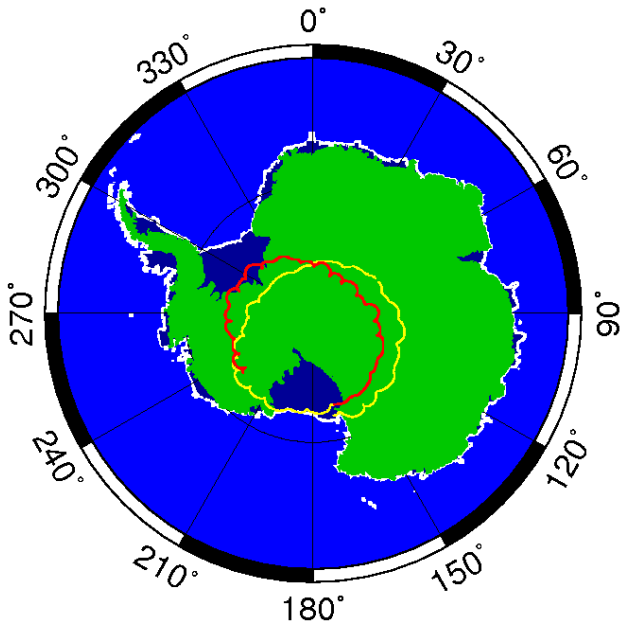


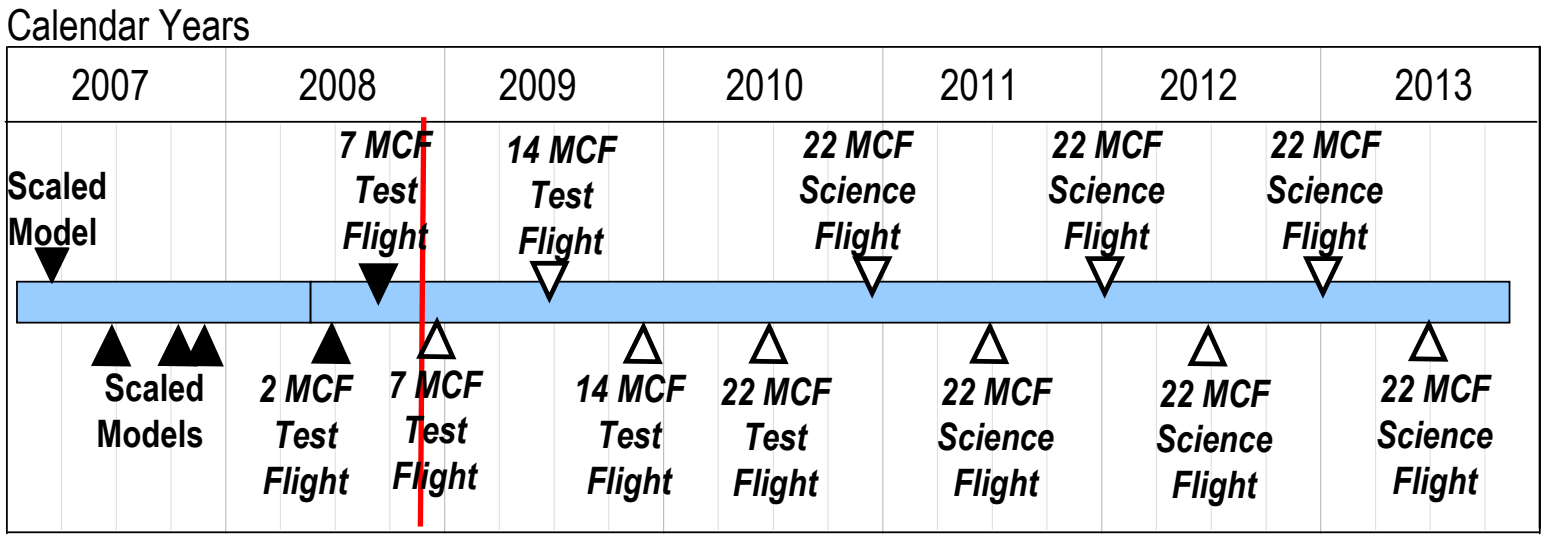
Balloon Flight Rates



Status of Super-Pressure Ballooning

- Test of 7 MCF super-pressure balloon currently flying in Antarctica
- Test flight of 14 MCF balloon from Sweden to Canada planned for July 2009
- Super-Pressure balloons enable mid-latitude flights comparable to Antarctic flights
- They also enable 100-day (aka ULDB) flights at any latitude (trajectory modification)





Balloon Project Budget

	FY07	FY08	FY09	FY10	FY11	FY12	FY13
Balloon Project	22.2	24.0	24.6	26.7	28.8	32.4	33.2

Balloon Payloads**	FY07	FY08	FY09	FY10	FY11	FY12	FY13
Heliophysics	4	5	7				
Astrophysics	12	13	15				

** included in Division SR&T budgets

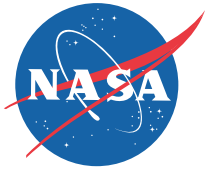
Astrophysics Data Centers

Science Archive Centers

- Archive permanently raw (level-0) and processed (level-1) data;
- Create advanced, higher-level data sets ready for science analysis.
  - High Energy Astrophysics (HEASARC @ GSFC)*: Swift, Fermi, Suzaku, INTEGRAL, XMM-Newton, Chandra, Beppo SAX, RXTE, ASCA, Rosat, Ginga, CGRO, EXOSAT, HEAO1-3, COS B, NuStar
  - Microwave Background (LAMBDA @ GSFC)*: WMAP, COBE, IRAS, SWAS
  - Ultraviolet & Optical (MAST @ STScI): GALEX, Hubble, FUSE, EUVE, IUE, UIT, HUT, ORFEUS, WUPPE, DSS, Kepler, JWST
  - Infrared & Submillimeter (IRSA @ JPL): IRAS, 2MASS, MSX, SWAS, ISO, Spitzer, WISE, Planck, (Herschel)

*HEASARC and LAMBDA have merged beginning in April 2008.

- The organization of the data centers by wavelength is a natural way to curate different data sets using the shared expertise at the respective data centers, enabling successful archival research.



Astrophysics Data Centers

Astrophysics Databases

- Astrophysics Data System (ADS @ SAO): Digital library with about 7.4M records indexed (astronomy: 1.6M; physics: 4.8M; arXiv preprints: 0.5M); provides abstracts, full papers, and literature citations.
- Simbad (Strasbourg, SAO): Basic data, cross-identifications, and bibliography for over 4.3M objects outside the Solar system.
- NASA Extragalactic Database (NED @ JPL): Basic data across all wavelengths, cross-identifications, bibliography , and redshifts (1.4M) for over 10M objects outside the Milky Way (plus 150M objects from SDSS DR6 added in late 2008).
- NASA Star and Exoplanet Database (NStED @ JPL): Data from space-based (MOST, Corot, Kepler) and ground-based telescopes related to the identification and characterization of exoplanets.

Virtual Astronomical Observatory (VAO)

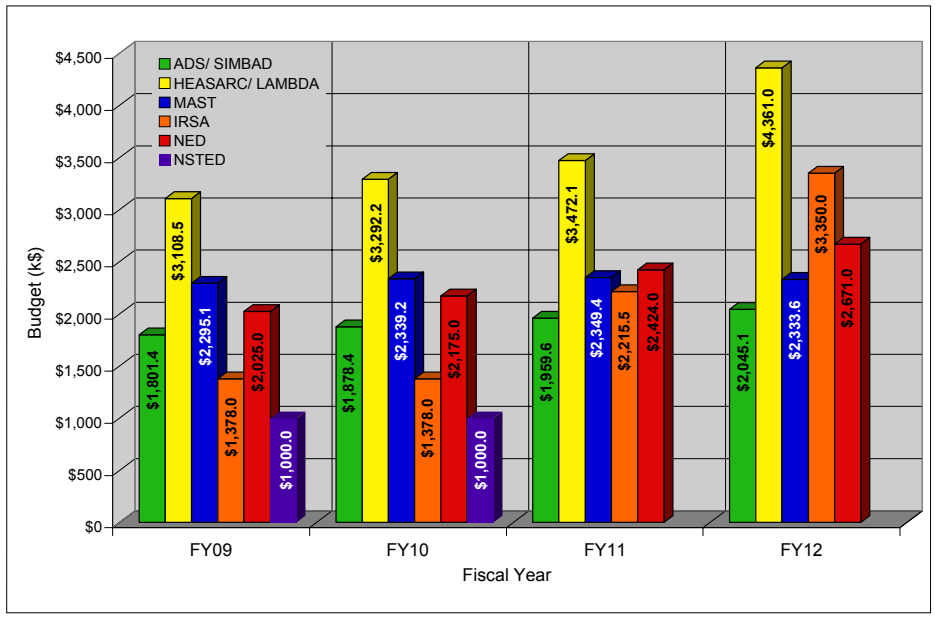
- National facility supported by NSF and NASA to find, enable access and use astronomy data from around the world. NASA archive centers provide the core of archived data to the VAO.

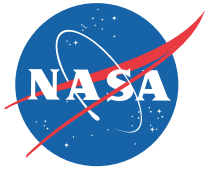
ADCAR Budget

(Astrophysics Data Curation and Archives)

Data Centers & Activities	FY 08	FY 09	FY 10	FY 11	FY 12
ADS/Simbad	$1,330.0	$1,801.4	$1,878.4	$1,959.6	$2,045.1
HEASARC/Lambda	$3,205.0	$3,108.5	$3,292.2	$3,472.1	$4,361.0
MAST	$1,550.0	$2,295.0	$2,339.0	$2,349.4	$2,333.6
IRSA	$1,378.0	$1,378.0	$1,378.0	$2,215.5	$3,350.0
NED	$1,925.0	$2,025.0	$2,175.0	$2,424.0	$2,671.0
NStED		$1,000.0	$1,000.0		
E/PO	*	$210.0	$220.0	$250.0	$280.0
ADCAR/VAO	$917.0	$108.1	$2,076.4	$896.4	-$32.7
Total	**$10,305.0**	**$11,926.0**	**$14,359.0**	**$13,567.0**	**$15,008.0**

* In FY08, E/PO was included in the Centers budget

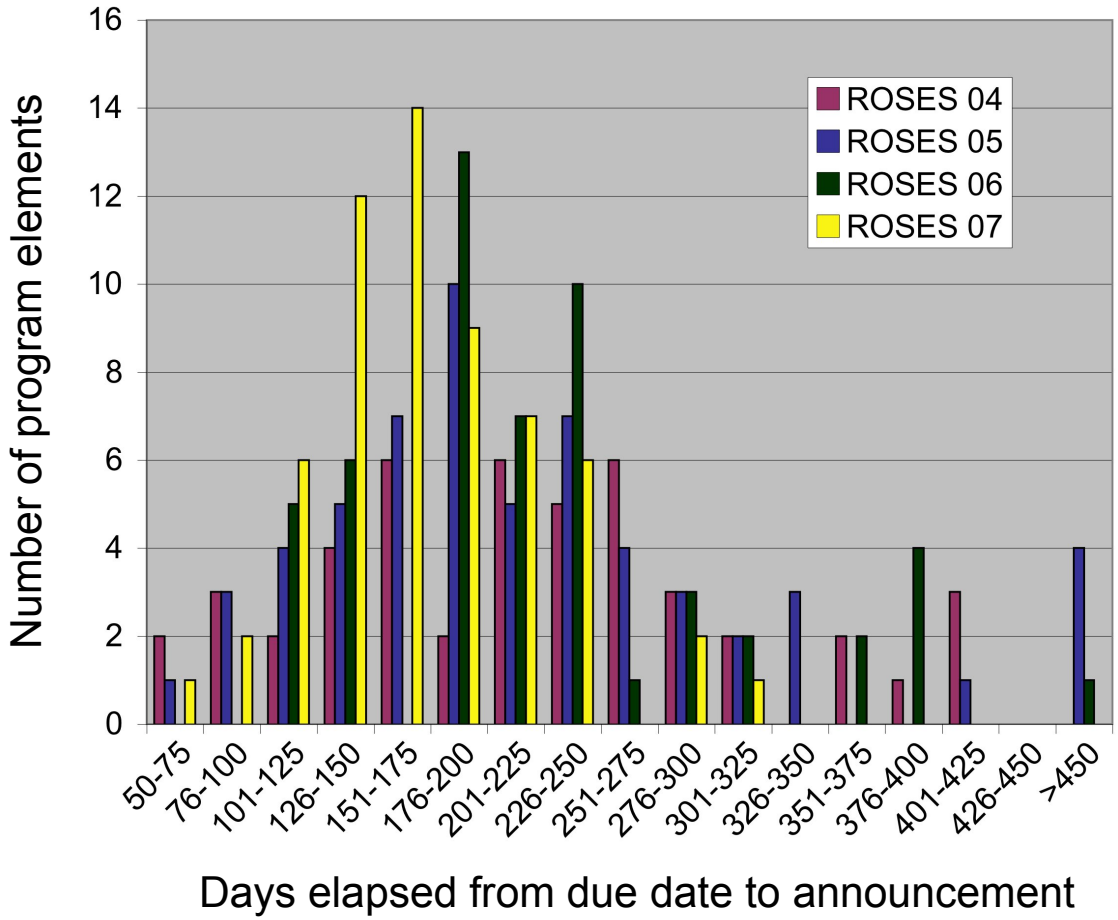




Back to SMD

SARA Web Page

- Lots more data at http://nasascience.nasa.gov/researchers/sara



Division Diversity in Research Practices

- Standing discipline solicitations or targeted solicitations
- Division roll-ups or individual discipline calls
- Community data analysis in the mission budget or in the research budget
- Selection and recompetition of mission science teams
- Role of mission science teams
- Establishment and management of data archives
- Management of suborbital programs including scheduling flights and funding payloads
- Role of interdisciplinary investigations
- Role and management of large scale modeling efforts
- Existence of other funding agencies

SMD's Research Management

- Research management is driven by several natural cycles: budget development, development of ROSES, selections
  - Requirements set in NPR 7120.8 and SMD Mgmt Handbook
- Annual budget cycle
  - Review portfolio status, accomplishments, and needs
  - Strategic decisions on balance between missions and research
  - Determine overall research budget
  - See research portfolio target budgets
- ROSES development
  - Review portfolio stats and needs
  - Determine solicitation strategy
  - Assign budgets for new awards
- Proposal selections
  - Consider science merit (from peer review)
  - Consider programmatic needs (future missions, unique opportunities, portfolio balance, high risk research)

Previous NRC Recommendations

- NRC has provided diverse recommendations on mission enabling activities in numerous recent reports, e.g.,
  - Grading NASA's Solar System Exploration Program (2008)
  - Assessment of the NASA Astrobiology Institute (2008)
  - The Scientific Context for the Exploration of the Moon (2007)
  - Performance Assessment of NASA's Astrophysics Program (2007)
  - Life in the Universe: An Assessment of U.S. and International Programs in Astrobiology (2003)
  - All four of the decadal surveys (2001 to 2007)
  - Supporting Research and Data Analysis in NASA's Science Programs: Engines for Innovation and Synthesis (1998)

- The current study should reconsider these and highlight high priority topics that remain areas of concern

Some Observations

- NASA is a mission agency
  - Drives need for targeted individual investigations rather than core support
  - “NASA funds projects not people”
- Missions are necessary
  - A decreasing flight rate is not a stable long term strategy
- There are too many proposal opportunities
  - Resulting in too many proposals requiring too many reviewers
  - Resulting in more proposal writing and lower selection rates without changing the total funding to the community
- In a flat budget environment, a growing community cannot be supported
  - The appropriate amount of community funding leads to an appropriately sized community

Final Statements

- The SMD program is opportunity rich
  - Supports investigations from <$20K to large missions
- Up to half of the budget is mission enabling
  - ~50% of budget is mission development and mission operations
  - Mission enabling activities are embedded in every program
  - At least 25% of non-mission budget is technology development
- The program has evolved over 50 years to a balance between mission and mission enabling
  - The overall balance has been fairly stable over time
- The NASA science program is the only space science program in the world with an integral and substantial R&A program
  - It is arguably the best structured program for scientific exploration in space, of space, and from space