Heliophysics

31 October 2013
Dave Chenette, NASA
Heliophysics Division Director

Agenda:

- **Recent Accomplishments, Program Updates, Current Status**
- **Heliophysics budget allocations and projections**
- **Future Planning and Status of Decadal Survey Implementation**
- **Upcoming Key Events/Issues**

2

HPD Objectives and Programs

Understand the sun and its interactions with Earth and the solar system

2014 SMD Science Plan for Heliophysics (draft)

Explorers

Smaller, Competed Flight Program

Research

Research tasks utilizing suborbital and existing assets plus theory and modeling

Solve the fundamental mysteries of Heliophysics: Explore the physical processes in the space environment from the sun to the Earth and throughout the solar system.

Understand the nature of our home in space: Advance our understanding of the connections that link the sun, the Earth, planetary space environments, and the outer reaches of our solar system.

Build the knowledge to forecast space weather throughout the heliosphere: Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Solar Terrestrial Probes

Strategic Mission Flight Program

Living With a Star

Strategic Mission Flight Program

3

Agenda:

- **Recent Accomplishments, Program Updates, Current Status**
- **Heliophysics budget allocations and projections**
- **Future Planning and Status of Decadal Survey Implementation**
- **Upcoming Key Events/Issues**

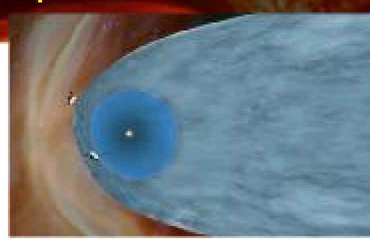
4

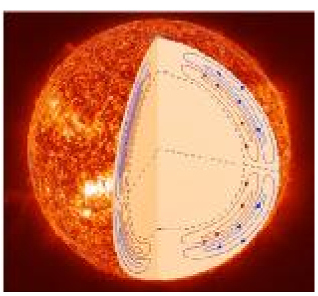
Heliophysics Press Highlights

Productive scientific community, significant public impact.

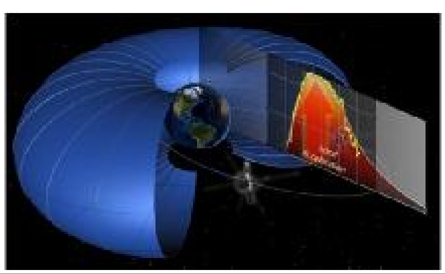
Recent Major Accomplishments – Science

Sept. 12, 2013 – Voyager 1 Embarks on a Historic Journey into Interstellar Space: Voyager 1 is officially the first human-made object to venture into interstellar space. New data indicate Voyager 1 has been traveling for about one year through the interstellar plasma. Voyager 2 is expected to exit in ~3 more years.





SDO Untangles the Motion Inside the Sun: Using the Helioseismic and Magnetic Imager (HMI) on NASA's Solar Dynamics Observatory, scientists have mapped out the flow of the material inside the sun. Recent results reveal a double layer of circulation, with two cycles of flow on top of each other

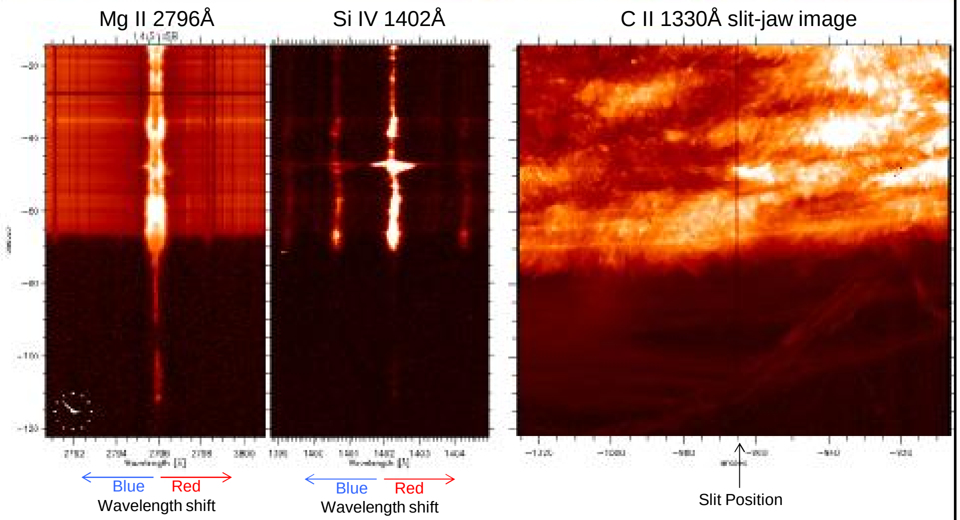


July 25, 2013 – Van Allen Probes Discover Particle Accelerator in the Heart of Earth's Radiation Belts: New results from the Van Allen Probes show that acceleration energy comes from within the belts themselves rather than a more global process.

6

Interface Region Imaging Spectrograph (IRIS)

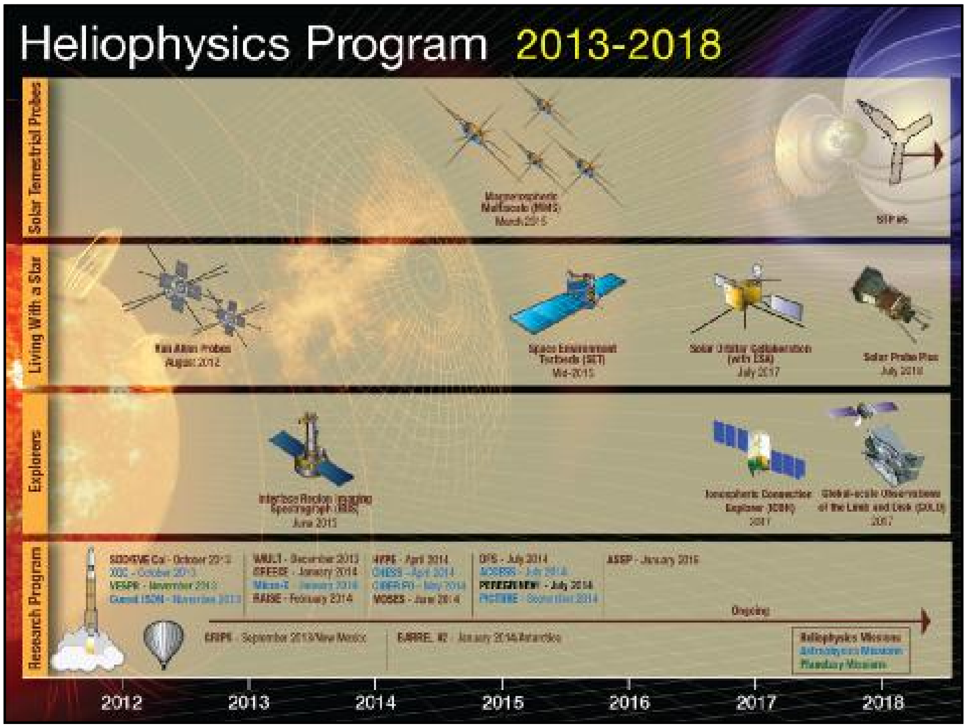
IRIS was successfully launched on June 27, 2013.



Spectacular images and simultaneous spectra reveal details of complex dynamics.
Official public release of mission data on 31 October 2013.

Heliophysics Programs
Recent Accomplishments and Updates

- Completed first **BARREL** balloon campaign in Antarctica in January 2013
  - 2nd flight scheduled for December 2013. Antarctic preparations underway.
- **IRIS** successfully launched 27 June, executing prime mission operations
- New Explorer selections: **ICON** and **GOLD** address key ITM physics
- **MMS** completed integration of all 4 instrument and spacecraft decks
  - Instrument integration and testing continues
  - Observatory #2 at NRL for thermal vacuum and thermal balance testing
- **Solar Orbiter Collaboration** completed successful Confirmation Review
  - ESA announced change in launch date from January to July 2017
  - Final Request for Launch Services Proposal released last May
    Proposals were received on 13 June and are under evaluation
- **Solar Probe Plus** in Phase B, on track for Jan 2014 PDR, March KDP-C
- Completed biennial **Senior Review** of operating missions
  - Begin termination of Cluster II. Wide-band only in FY14.
    Phase F closeout in FY15. No more funding starting in FY16.
- **SET-1** LRD delayed from no earlier than January 2014 to mid-2015.



Living With a Star/NSF Partnership for Collaborative Space Weather Modeling

Investment of $4.2 M/year for 5 years

PI	Institution	Title	Objective
Bob Schunk	Utah State	Physical Processes Governing Energy and Momentum Flows on Multiple Scales in Near-Earth Space Using a First-Principles-Based Data Assimilation System for the Global Ionosphere-Thermosphere-Electrodynamics	Ionosphere-Thermosphere modeling, forecast
Spiro Antiochos	GSFC	A Modular Capability for Community Modeling of Flares, CMEs and their Interplanetary Impacts	CME impacts
Nathan Schwadron	New Hampshire	Corona-Solar Wind Energetic Particle Acceleration (C-SWEPA) Modules	SEPs
Dusan Odstrcil	George Mason	Integrated Real-Time Modeling System for Heliospheric Space Weather Forecasting	ENLIL MHD propagation from Sun to Earth – operations
George Fisher	UC Berkeley	The Coronal Global Evolutionary Model	Coronal Modeling, CME formation
Tony Mannucci	JPL	Medium Range Thermosphere Ionosphere Storm Forecasts	Sun-to-mud modeling, ionosphere
Nagi Mansour	Ames	Integrated Global-Sun Model of Magnetic Flux Emergence and Transport	Solar subsurface modelling; prediction, forecasting
A. Bhattacharjee	Princeton	Integration of Extended MHD and Kinetic Effects in Global Magnetosphere Models	MHD modeling of magnetosphere

10

Heliophysics Summer School

Summer School, since 2007:

Total Students	190
International Students	82
U.S. Students	108
PhD Level	170
Masters Level	20

- Each year, ~35 graduate-level students are appointed from 13-15 different countries.
- Physics teachers of upper division undergraduate classes also invited to attend (in 2013).

11

2013 Jack Eddy Postdoctoral Awards

Stathis Ilonidis
Host Institution: Stanford University, Thomas Duvall
Project: Detection of Solar Active Regions Before They Emerge at the Surface and Improvement of Space Weather Forecasts

Bin Chen
Host Institution: New Jersey Institute of Technology, Dale Gary
Project: Coronal Magnetography: an Approach to Understanding Space Weather Drivers - Solar Flares and Coronal Mass Ejections

Antonia Savcheva
Host Institution: Harvard-Smithsonian Center for Atmospherics, Katharine Reeves
Project: Understanding Sigmoid Evolution and Eruption: From Formation to CME Propagation

Thiago Brito
Host Institution: LASP/University of Colorado, Scot Elkington
Project: The effect of drift orbit bifurcations on radiation belt particles in time dependent fields

- Established in 2009 to train next generation researchers in the emerging field of heliophysics
- 9 postdoctoral fellows have been awarded two-year appointments as of December 2012

12

Government Activity on Space Weather

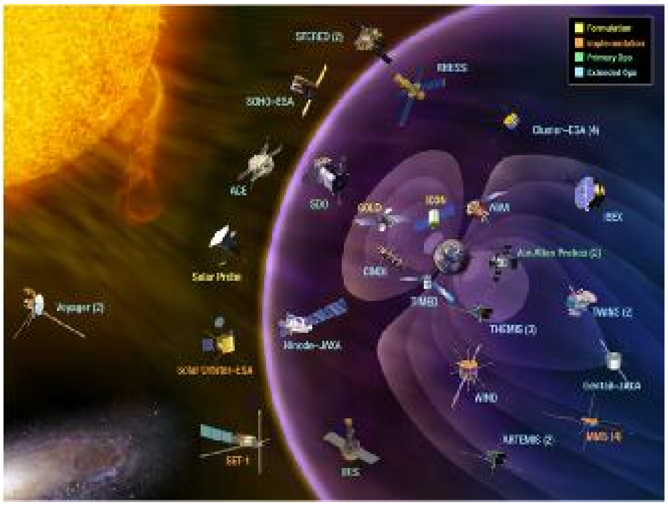
- 20 March 2013:
  - Senate Commerce, Science, and Transportation Subcommittee hearing on Assessing Space Threats, included space weather threats
- April 2013: OSTP Space Weather Report
  - Finds that federal agencies have deployed an effective mix of space-based and ground-based systems that are needed to support both operational space weather services and scientific research
- July 2013: FERC orders development of reliability standards for geomagnetic disturbances (GMD)
  - January 2014: Reliability standards that require owners and operators of the bulk power system to develop and implement operational procedures to mitigate geomagnetic disturbance effects consistent with reliable operation of the electric power grid
  - January 2015: Reliability standards that require initial and ongoing assessments of the potential impact of benchmark geomagnetic disturbances on both grid equipment and on the grid as a whole

Agenda:

- **Recent Accomplishments, Program Updates, Current Status**
- **Heliophysics budget allocations and projections**
- **Future Planning and Status of Decadal Survey Implementation**
- **Upcoming Key Events/Issues**

Heliophysics System Observatory

A fleet of spacecraft to understand the sun and its interactions with Earth and the solar system



- **Heliophysics has 18 operating missions (on 29 spacecraft):** **Voyager, Geotail, Wind, SOHO, ACE, Cluster, TIMED, RHESSI, TWINS, Hinode, STEREO, THEMIS/ARTEMIS, AIM, CINDI, IBEX, SDO, Van Allen Probes, IRIS**

  (Missions in red contribute to operational Space Weather.)

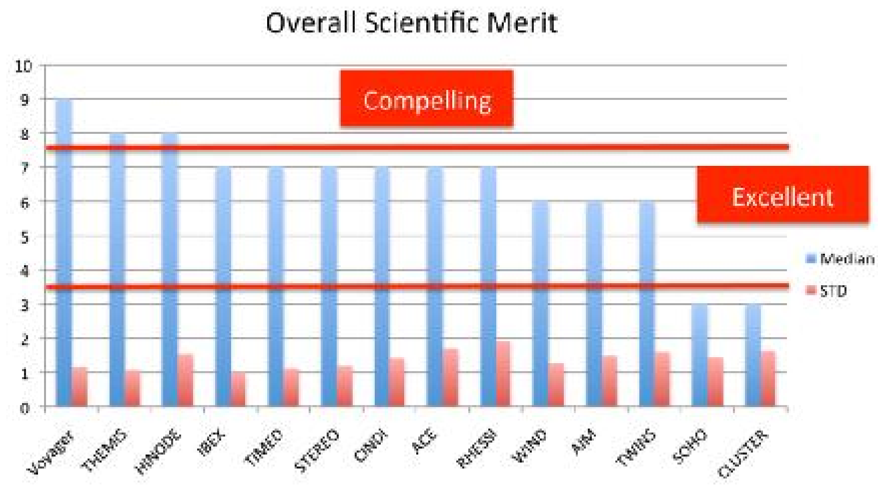
- **6 missions are in development:** **SET, MMS, SOC, SPP, ICON, and GOLD**

$5.5B total investment in Heliophysics space assets (excluding launch costs)
$68M annual operating budget (1.2% per year)

2013 Senior Review Findings

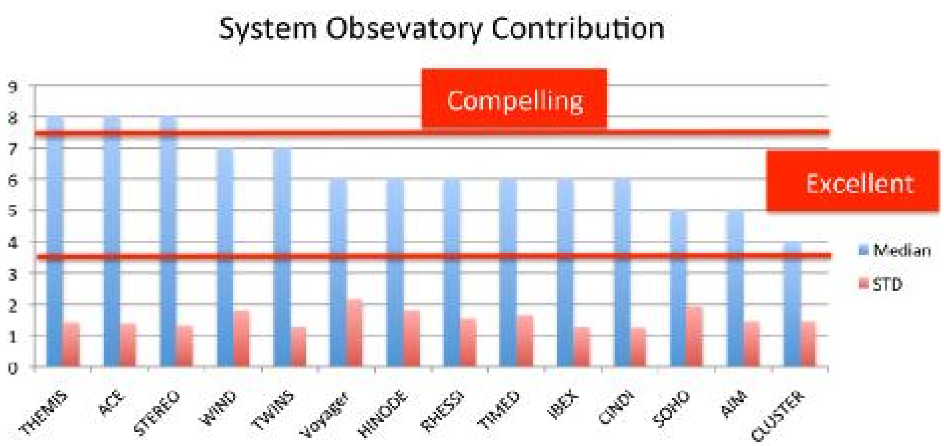
1) ACE and Wind are complementary missions and both should be supported as long as possible.
2) Cluster-II did not make a sufficiently compelling case for continued support (the panel believes that *possibly* funding the WBD team, the only fully-US team on the mission, may be justified);
3) STEREO and especially Hinode were noted to have larger budgets compared to the other missions in the portfolio, with unclear justification.
4) SOHO was determined to be less scientifically useful than before, but recognized that it has now become an operational space weather asset. The panel found that the SOHO mission should be removed from the MO&DA portfolio and funded outside of Heliophysics.
5) Voyager is extremely important and unique, but emphasis should be placed on making all the magnetometer data publically accessible.
6) THEMIS is to be applauded in its innovative approach to continued science ops, and their Prioritized Science Goal 1 (combining with MMS and Van Allen) was deemed very exciting.

Senior Review Rankings (1 of 2)



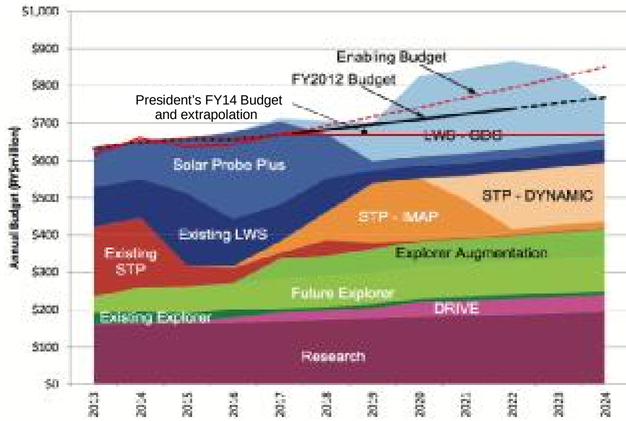
17

Senior Review Rankings (2 of 2)



18

Decadal Survey Budget Assumptions



- Heliophysics budget and program plan by year and category from 2013 to 2024. (Figure 6.1 from 2012 Decadal Survey, page 6-2)
- President's FY14 budget (solid red line) added, assuming no growth beyond 2018.
- Final FY13 Appropriations totaled $589.7M

19

Changes since President's FY13 Budget

Budget Authority Dollars	BY(2013)	BY (2014)	BY + 1 (2015)	BY+ 2 (2016)	BY+ 3 (2017)	BY+ 4 (2018)
Heliophysics FY13 President's Budget	**$647.0**	**$643.0**	**$636.7**	**$638.3**	**$661.6**	
Sequester Reduction	(30.6)					
FY13 Operating Plan Reductions	(13.9)					
SMD Administrative and CS FTE labor	3.6	3.0	2.0	3.9	3.1	
Strengthen NASA Institutional Capabilities		(7.4)	(7.3)	(7.3)	(7.4)	
GEMS FY12 Offset to Astrophysics		(24.3)				
CubeSats		5.0	5.0	5.0	5.0	
Explorer Future Missions		1.7				
STEM Reductions		(3.1)	(3.3)	(3.0)	(3.0)	
Directed R&T		35.9				
Heliophysics Final FY13 Budget	**$606.3**					
Heliophysics FY14 President's Budget		**$653.7**	**$633.1**	**$636.8**	**$664.3**	**$664.6**
Less Admin & Directed R&T*	(16.6)	(44.1)	(9.9)	(13.5)	(18.1)	(20.1)
Net Heliophysics Budget	**$589.7**	**$609.6**	**$623.2**	**$623.3**	**$646.2**	**$644.5**
FY2013 Heliophysics Expenditures	**$589.7**					

*These budgets support SMD shared activities not specific to Heliophysics. Greyed entries represent notional estimates.

20

Agenda:

- Recent Accomplishments, Program Updates, Current Status
- Heliophysics budget allocations and projections
- Future Planning and Status of Decadal Survey Implementation
- Upcoming Key Events/Issues

21

Heliophysics and DS Recommendations

- **NASA's Commitment (Our HPD Commitment):**
  Achieve as much of the DS priorities as possible, given current budget constraints.

- **Guiding principles:**
  (1) focus resources on the most important and highest quality research,
  (2) utilize the full range of flight opportunities: sounding rockets, cubesats, hosted payloads, etc., and be flexible, to achieve the highest-priority science objectives,
  (3) protect and enhance the core Research and Analysis program,
  (4) seek synergies and partnerships for maximum leverage of scarce resources.

- **Top DS priority: Complete the current program, including ICON and GOLD**
  - Execute on our commitments to the science community and to the taxpayers
  - Manage risks and opportunities as responsible custodians of public trust

- **Support the community to achieve the highest-priority recommendations**
  We must find ways to maximize our current resources and sustain heliophysics science in this restricted budgetary environment. Our ability to understand the Heliophysics System is of growing importance to the science community, to NSF and NASA, and to our Nation. Publicizing program science results and discoveries to an increasingly broad audience will help the public understand why heliophysics is so important.

22

Heliophysics Assets Addressing Decadal Priorities

DECADAL SURVEY HELIOPHYSICS SCIENCE GOALS FOR THE NEXT DECADE*	CURRENT HELIOPHYSICS SYSTEM OBSERVATORY MISSIONS	HELIOPHYSICS MISSIONS IN DEVELOPMENT	DECADAL RECOMMENDATIONS
- Determine the origins of the sun's activity and predict the variations in the space environment	IRIS, SDO, STEREO, Hinode, RHESSI, ACE, SOHO, Wind	Solar Orbiter, Solar Probe Plus	DRIVE initiative, Augmented Explorer Program, New Starts: None
- Determine the dynamics and coupling of Earth's magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs	BARREL, Van Allen Probes, CINDI, TWINS, AIM, TIMED, Cluster, Geotail, Wind, ACE, THEMIS	MMS, ICON, GOLD	DRIVE initiative, Augmented Explorer Program, New Starts: GDC, DYNAMIC, MEDICI
- Determine the interaction of the sun with the solar system and the interstellar medium	IBEX, STEREO, ACE, SOHO, Wind, Voyager	Solar Orbiter, Solar Probe Plus	DRIVE initiative, Augmented Explorer Program, New Starts: IMAP
- Discover and characterize fundamental processes that occur both within the heliosphere and throughout the universe	IRIS, Van Allen Probes, SDO, THEMIS/ARTEMIS, STEREO, Hinode, IBEX, RHESSI, Cluster, ACE, SOHO, Wind, Voyager	MMS, Solar Orbiter, Solar Probe Plus	DRIVE initiative, Augmented Explorer Program, New Starts: IMAP, GDC, DYNAMIC, MEDICI

** Heliophysics Research and Analysis, Theory, and Modeling address all goals*

Heliophysics Division Strategy (preliminary)

- **Execute on our commitments for the current programs.**
  - Plan for and allocate program funding at the 70% joint confidence level
  - Manage program development risks and opportunities pro-actively
  - Fund operating missions per the Senior Review
  - Continue formulation and technology development for SPP
    - Achieve a successful SPP mission confirmation in 2014
- **Implement the Decadal Survey DRIVE recommendations**
  - Grow the Research and Analysis Program as a fraction of total budget
  - Maintain commitments for announced awards and near-term programs
  - Be flexible and innovative in adapting to budget realities
- **Grow Heliophysics Explorer mission cadence to DS recommendation**
  - Allocate sufficient funding for future Heliophysics Explorer selections
- **Support and facilitate the heliophysics community to demonstrate the importance of heliophysics science and its value to society**
- **Overall objective: Deliver the best possible science program within the budget and following the recommendations of the 2012 Decadal Survey**

Decadal Survey Research Recommendations

Recommendations	Science	DS Cost Estimate
0.0 Complete the current Program	Support the existing program elements that constitute the Heliophysics Systems Observatory (HSO) and complete missions in development (RBSP, IRIS, MMS, SOC, SPP).	Assumes no cost growth for any of these elements
1.0 DRIVE (Diversify, Realize, Integrate, Venture, Educate)	Strengthen observational, theoretical, modeling, and technical advances with additional R&A capabilities: small satellites; MO&DA funding, science centers and grant programs; instrument development	Program rebalance: move up to ~$33M/yr into Research
2.0 Accelerate and expand Heliophysics Explorer Program	Launch every 2-3 years, alternating SMEX & MIDEX with continuous Missions of Opportunity.	Program rebalance: move $70M/yr extra into Explorers
3.0 Restructure STP line as a moderate scale, PI-led flight program. Implement three mid-scale missions.	Mission 1: Understand the interaction of the outer heliosphere with the interstellar medium; includes L1 space weather observations Mission 2: Understand how space weather is driven by lower atmosphere weather. Mission 3: Understand how the magnetosphere-ionosphere-thermosphere system is coupled and responds to solar forcing.	$520M per mission in FY12$; launches in 2021, 2025, 2029
4.0 Start another LWS mission by the end of the decade.	Mission 4: Study the ionosphere-thermosphere-mesosphere system in an integrated fashion.	$1B mission, Launch 2024

Notes: 1) Recommendations listed above are top level, each contains a number of sub-elements
2) Recommendations are listed in priority order, pending budget constraints
3) Recommendations are separable by Agency, only NASA Recommendations are listed here

25

Roadmap and Decadal

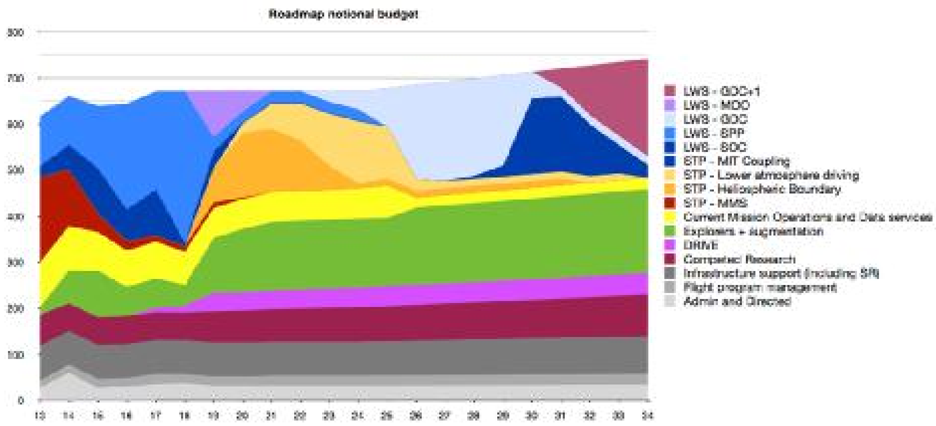
HELIOPHYSICS

- Heliophysics Roadmap will be released Winter 2013/2014
- Follows vision and priorities of 2012 Heliophysics Decadal Survey
  - Acknowledges need for flexibility in achieving science targets due to significant budget pressures and uncertainties
- Roadmap and Decadal both assume current missions in formulation and development are the top priority
  - These current missions will require the total available budget until FY18
- The President's FY14 budget was developed before the release of the 2012 Heliophysics Decadal Survey

26

Roadmap 20 Year Budget Plan and Priorities

HELIOPHYSICS



Heliophysics budget and program plan by year and category.
This is the budget plan provided to guide the Roadmap.

27

Agenda:

- **Recent Accomplishments, Program Updates, Current Status**
- **Heliophysics budget allocations and projections**
- **Future Planning and Status of Decadal Survey Implementation**
- **Upcoming Key Events/Issues**

28

FY14 Program Accomplishments

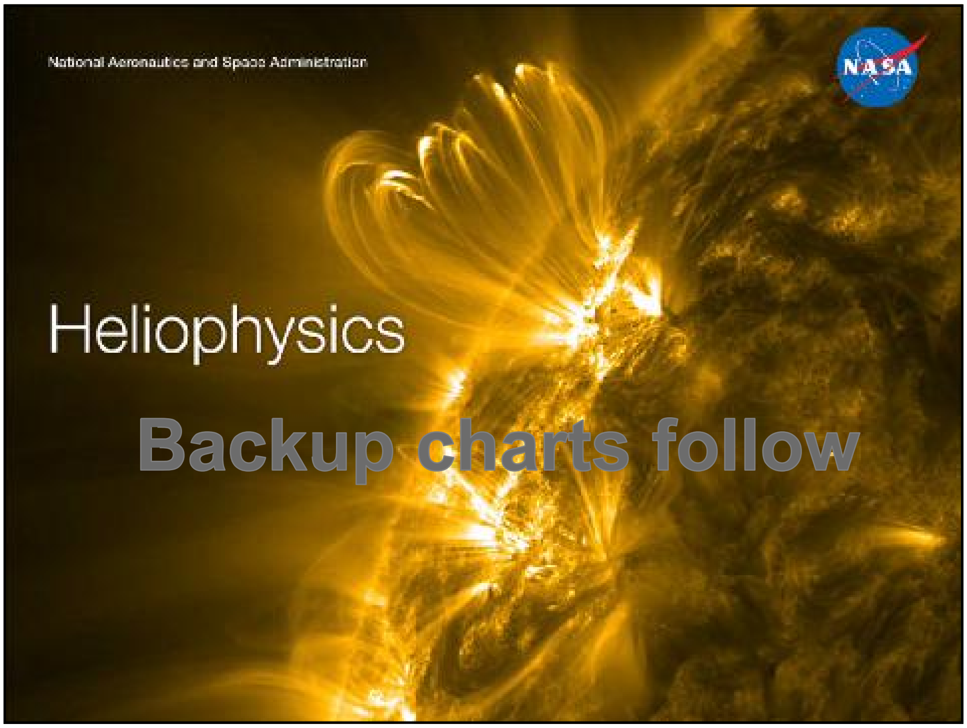
- **BARREL**: Balloon campaign #2, Antarctica, in December 2013/January 2014
- **MMS:** Complete observatory integration and testing
  - Successful Pre-ship Review and Operational Readiness Reviews
  - Ship to launch site for successful launch in 2014
- **SPP:** Retire technology development risks, transition formulation to development.
  - Successful mission PDR in January 2014
  - KDP-C Confirmation Review in March 2014
- **SOC:** SoloHI and HIS instrument Critical Design Reviews
  - Launch vehicle procurement and contact award
- **GOLD:** Successful System Requirements Review in January 2014
  - Preliminary Design Review in September 2014
- **ICON:** Successful System Requirements Review in December 2013,
  - PDR in April 2014, Confirmation Review in May 2014
- **R&A:** Enable compelling science addressing key problems in heliophysics

29

Where is the Heliophysics Division Going?

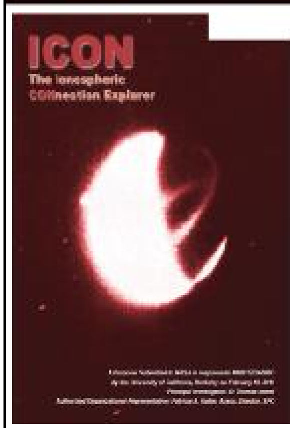
- **NASA's SMD Heliophysics Division Mission Statement (preliminary draft version):** Use the 2012 Heliophysics Decadal Survey and the Roadmap (soon to be released) as the foundation to foster the next decade of heliophysics research, and to apply its scientific discoveries to provide direct benefits both to the science of space weather and, through its study of fundamental processes and coupled systems, NASA and space science overall.
- **Approach to implementing the Heliophysics Decadal Survey recommendations**
  - Heliophysics Roadmap will define a detailed implementation plan for the Decadal Survey, including technology development requirements
  - Perform on our commitments to complete the current program on time and on budget
  - Strengthen our Research and Analysis, MO&DA, and Technology Programs
  - Plan for more frequent, lower cost missions: Expand Explorers and Missions of Opportunity
  - Commence development of the highest priority Strategic Program (STP, LWS) science targets as soon as possible: Outer heliosphere remote sensing, Geospace coupling
- **Continue to build our understanding of heliophysics (the sun and its interaction with the Earth and solar system) and the science of space weather**

30



Ionospheric Connection Explorer

Neutral-Ion Coupling in the Upper Atmosphere



ICON employs a single spacecraft traveling eastward and continuously imaging the thermosphere and ionosphere.

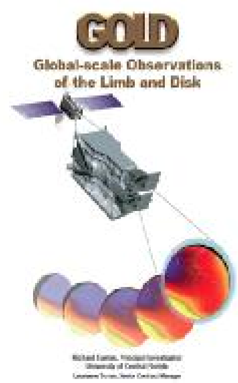
Ionospheric Connection Explorer (ICON)
Thomas Immel, PI, University of California, Berkeley

ICON will explore the boundary between Earth and space – the ionosphere – to understand the physical connection between our world and the immediate space environment around us. This region, where ionized plasma and neutral gas collide and react exhibits dramatic variability that affects space-based technological systems like GPS.

The ionosphere has long been known to respond to “space weather” drivers from the sun, but recent NASA missions have surprised us in showing this variability often occurs in concert with weather on our planet. ICON will compare the impacts of these two drivers as they exert change on the space environment that surrounds us.

32

Global-scale Observations of the Limb and Disk (GOLD)



GOLD will address how the ionosphere and the top layers of the atmosphere respond to geomagnetic storms, solar radiation, and upward propagating tides.

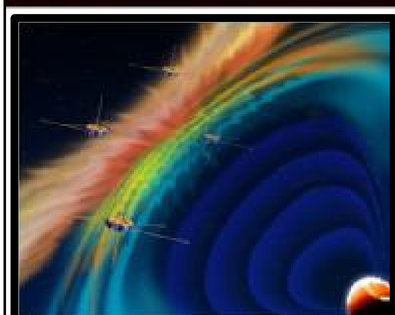
Global-scale Observations of the Limb and Disk (GOLD) Richard Eastes, PI, University of Central Florida. The instrument will be hosted on a commercial communications satellite from SES-GS.

This Mission of Opportunity will fly an ultraviolet (UV) imaging spectrograph on a geostationary satellite to measure densities and temperatures in Earth's thermosphere and ionosphere. The goal of the investigation is to address an overarching question in heliophysics science: What is the global-scale response of the thermosphere and ionosphere to geomagnetic storms, solar radiation, and forces from the lower atmosphere?

Measurements from GOLD will be used, in conjunction with sophisticated models of the terrestrial thermosphere and ionosphere, to revolutionize our understanding of the space environment.

33

Magnetospheric Multiscale (MMS)



Fit check of FPI sensors on deck of Vehicle #1

The MMS mission will use Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection, a fundamental plasma-physical process that converts magnetic energy into heat and the kinetic energy of charged particles.

These processes — magnetic reconnection, particle acceleration, and turbulence — occur in all astrophysical plasma systems but can be studied in situ only in our solar system and most efficiently in Earth's magnetosphere, where they control the dynamics of the geospace environment and play an important role in space weather.

34

Solar Orbiter Collaboration (SOC)

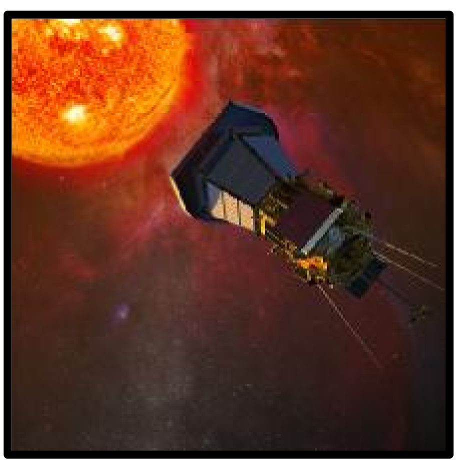
NEWS of 8 Oct 2011: ESA selects Solar Orbiter as first M-class mission

Solar Orbiter probe will pass closer to the sun than any previous mission, approaching 26 million miles from the sun's fiery surface to sample the solar wind shortly after it is ejected. The spacecraft will also include remote sensing imaging instruments to observe the sun's corona and the solar atmosphere.

Solar Orbiter will unravel how the sun influences the solar system by determining the origins and causes of the supersonic solar wind, the sun's magnetic field, and massive eruptions from disturbances on the sun's surface.

35

Solar Probe Plus (SPP)



Solar Probe Plus will fly to less than 10 solar radii (R_s) of the Sun,"walking in" from 35 R_s over 24 orbits.

Solar Probe Plus will approach as close as 9 solar radii from the surface of the Sun, repeatedly sampling the near-Sun environment. By directly probing the solar corona, this mission will provide essential knowledge and understanding of coronal heating and of the origin and acceleration of the solar wind, critical questions in heliophysics that have been ranked as top priorities for decades.

By making the first direct, *in situ* measurements of the region where some of the most hazardous solar energetic particles are energized, Solar Probe Plus will make a fundamental contribution to our ability to characterize and forecast the radiation environment in which future space explorers will work and live.

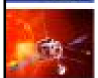
36

Living With a Star (LWS) and Solar Terrestrial Probes (STP)

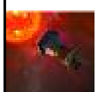
Living With a Star:

• Balloon Array for RBSP Relativistic Electron Losses (BARREL):
BARREL is a balloon-based mission to augment the measurements of the Van Allen Probes mission. Launch: BARREL #1 January 2013, BARREL #2 December/January 2014

• Space Environment Testbeds (SET):
SET will perform flight and ground investigations to characterize the space environment and its impact on hardware performance in space. Launch: August 2015

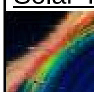


• Solar Orbiter Collaboration (SOC):
SOC will unravel how solar transients alter the plasma and magnetic field structure of the inner heliosphere and measure the solar polar magnetic fields. Launch: No earlier than 2017



• Solar Probe Plus (SPP):
SPP will approach as close as 9.5 solar radii from the surface of the Sun, repeatedly sampling the near-Sun environment. By directly probing the solar corona, this mission will provide essential knowledge. Launch: No earlier than 2018

Solar Terrestrial Probes:



• Magnetospheric Multiscale (MMS):
The MMS mission will use Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection. Launch: No later than March 2015

STP #5

• Solar Terrestrial Probe #5:
Understand the interaction of the outer heliosphere with the interstellar medium; includes L1 space weather observations

6

37

Explorer Program and Low-Cost Access to Space

Explorers Program:

• Interface Region Imaging Spectrograph (IRIS):
IRIS will contribute to our fundamental understanding of the solar energy transport, will increase our ability to forecast space weather, and will provide an archetype for all stellar atmospheres.

• Future Explorer Selection Spring 2013
ICON (full mission) and GOLD (Mission of Opportunity) Selected to enter into Phase B

•Future Explorer AOs: based on the Presidents FY14 budget, AO ~FY16

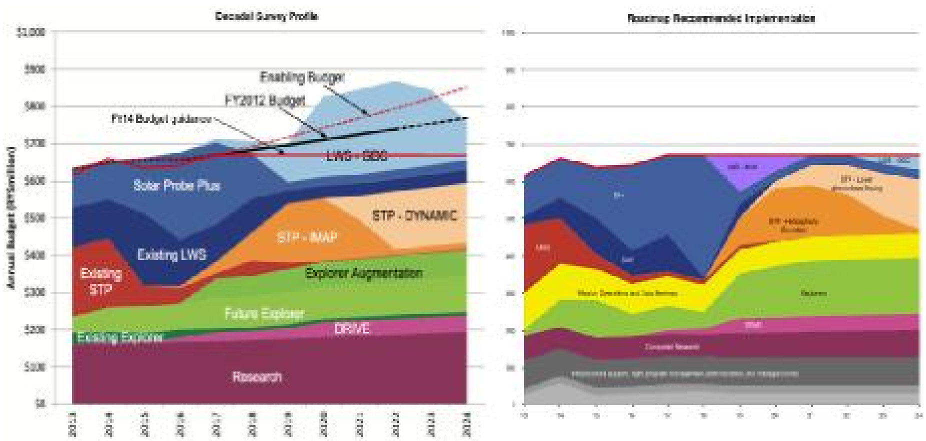
Low Cost Access to Space:

- Both the Geospace and Solar and Heliospheric programs include Low Cost Access to Space (LCAS) components. **LCAS investigations are distinguished from other Research Program efforts in that the achievement of their objectives requires access to space.** The program offers a variety of methods including standard and long-duration balloons, sounding rockets, commercial reusable suborbital research rockets, cubesats, and sounding rocket-class payloads flown as secondary payloads or on other flights of opportunity.
- These programs fulfill three critical elements: executing intrinsically meritorious science investigations; advancing the technology readiness levels of future space flight detectors and supporting technologies; and preparing future leaders of NASA space flight missions such as junior researchers, students, and engineers.

The Sounding Rocket Program completed 21 NASA suborbital launches, supporting 11 science investigations, 3 technology demonstration/test vehicles, and 2 educational projects.

38

Decadal Survey Future Enabling Budget Assumptions for Research Recommendations



President's FY2014 Budget Request Heliophysics Budget Details (1 of 3)

	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018
				(FY15-18 estimates are notional)			
Heliophysics	**644.8**		**653.7**	**633.1**	**636.8**	**664.3**	**664.6**
Heliophysics Research	166.7		195.7	163.0	167.5	172.1	174.1
Heliophysics Research and Analysis	32.9		33.5	33.9	34.0	33.9	33.9
Sounding Rockets	52.3		51.6	53.7	53.0	53.0	53.0
Research Range	20.1		21.0	21.3	21.6	21.7	21.7
Other Missions and Data Analysis	61.3		89.6	54.2	58.8	63.5	65.5
CubeSats			5.0	5.0	5.0	5.0	5.0
Voyager	5.3		5.3	5.3	5.5	5.4	5.4
SOHO	2.0		2.2	1.9	1.9	1.9	1.9
Wind	2.0		2.2	2.2	2.2	2.2	2.2
CLUSTER-II	2.5		1.2	1.2	1.2	1.2	1.2
Geotail	0.2		0.2	0.2	0.2	0.2	0.2
SOLAR Data Center	0.7		1.0	1.0	1.0	1.0	1.0
Data & Modeling Services	3.8		3.2	3.2	3.0	3.0	3.0
Space Physics Data Archive	1.4		2.0	2.0	2.0	2.0	2.0
Guest Investigator Program	10.4		8.2	7.2	8.0	8.0	8.0
Community Coordinated Modeling Center	2.0		1.5	1.4	1.4	1.4	1.4

(continued on next slide)

President's FY2014 Budget Request
Heliophysics Budget Details (2 of 3)

	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018
				(FY15-18 estimates are notional)			
Heliophysics Research Other Missions and Data Analysis (cont'd)							
Science Data & Computing	1.7		2.1	2.0	2.0	2.0	2.0
Space Weather Research to Operations			0.3	0.4	0.4	0.4	0.4
Space Science Mission Ops Services	10.1		11.0	11.3	11.6	11.7	11.7
Directed Research & Technology	13.5		37.8	3.4	6.9	11.4	13.3
Science Planning and Research Support	5.7		6.3	6.5	6.6	6.7	6.8
Living with a Star	196.3		216.2	277.7	332.6	353.9	374.4
Solar Probe Plus	52.6		104.8	137.1	229.3	213.5	329.7
Solar Orbiter Collaboration	19.7		55.5	97.3	68.2	100.0	6.7
Other Missions and Data Analysis	124.0		55.8	43.3	35.1	40.5	38.0
Van Allen Probes (RBSP)	86.1		13.8	8.4			
Solar Dynamics Observatory (SDO)	16.7		14.1	9.5	9.5	9.5	9.5
BARREL	1.6		1.5	0.3			
LWS Space Environment Testbeds	0.5		0.6	0.1			
LWS Science	15.0		17.2	17.5	17.5	17.5	17.5
LWS Program Mgmt and Future Missions	4.0		8.7	7.5	8.1	13.4	10.9

41

President's FY2014 Budget Request
Heliophysics Budget Details (3 of 3)

	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018
				(FY15-18 estimates are notional)			
Solar Terrestrial Probes	216.0		146.6	68.7	48.9	50.1	27.9
Magnetospheric Multiscale (MMS)	194.6		120.9	39.5	20.2	12.3	2.7
Other Missions and Data Analysis	21.4		25.8	29.2	28.7	37.8	25.2
STEREO	9.0		9.5	9.5	9.6	9.6	9.6
Hinode (Solar B)	8.2		8.3	8.3	8.5	8.5	8.5
TIMED	3.0		2.7	2.7	2.7	2.6	2.5
STP Program Mgmt and Future Missions	1.4		5.2	8.6	7.9	17.1	4.6
Heliophysics Explorer Program	65.8		95.2	123.7	87.9	88.2	88.2
Heliophysics Explorer Future Missions	3.8		65.7	99.8	67.6	64.5	67.5
Interface Region Imaging Spectogr (IRIS)	39.1		8.4	1.0			
THEMIS	6.0		4.2	4.2	4.2	4.2	4.2
Interstellar Boundary Explorer (IBEX)	1.6		3.7	3.4	3.4	3.4	3.4
Aeronomy of Ice in Mesophere (AIM)	3.0		3.0	3.0	3.0	3.0	3.0
ACE	3.7		3.0	3.0	3.0	3.0	3.0
RHESSI	1.9		2.0	2.0	2.1	2.1	2.1
CINDI	1.0		0.9	0.2	0.0		
TWINS	1.0		0.6	0.6	0.6	0.6	0.6
Heliophysics Explorer Program Mgmt	4.7		3.7	6.4	4.1	7.4	4.4

42