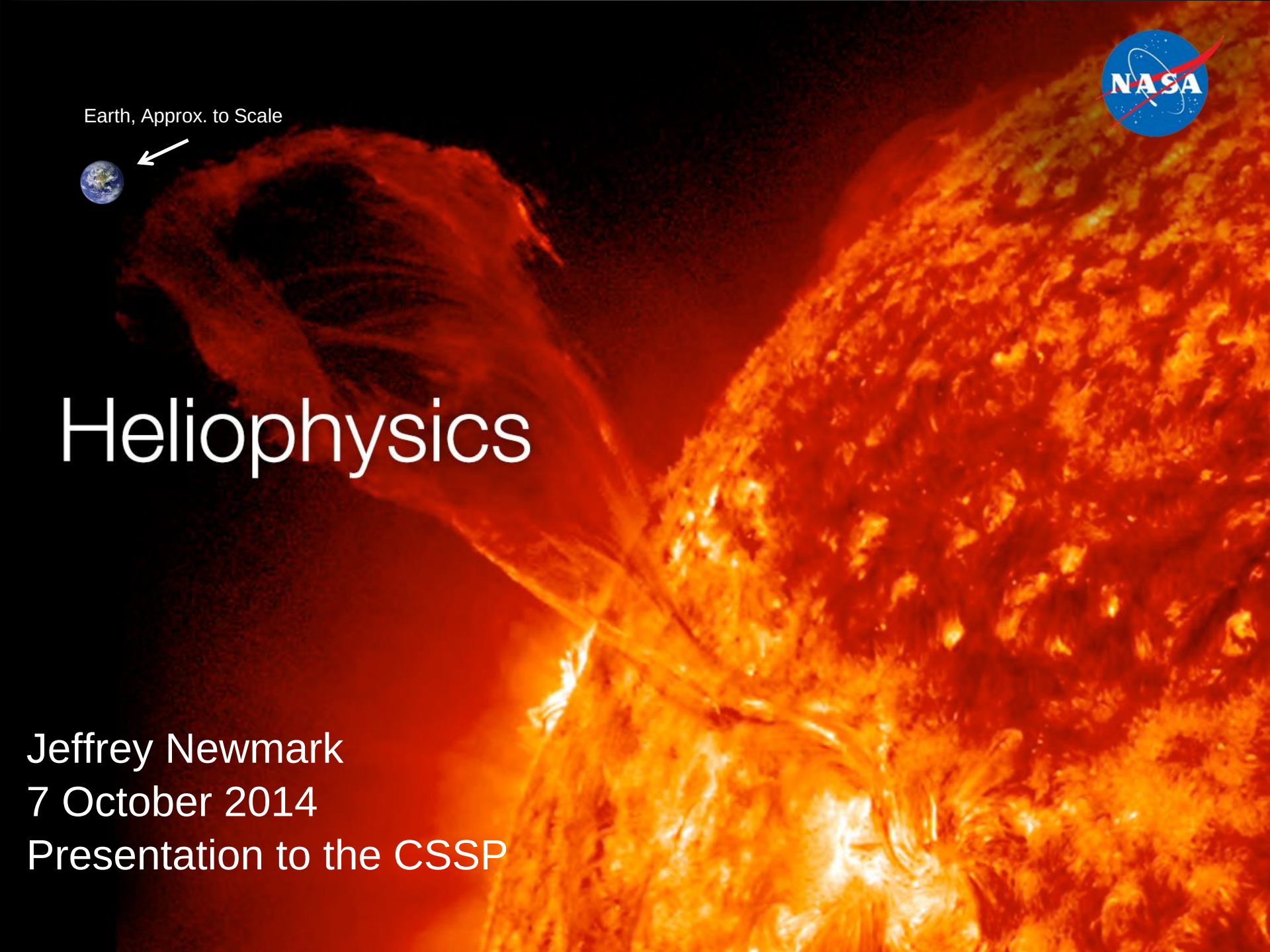


Heliophysics

Jeffrey Newmark

7 October 2014

Presentation to the CSSP

Topics for discussion

- **NASA's Heliophysics Division Objectives and Science**
- **Recent Accomplishments, Program Updates, Current Status**
- **Future Planning and Status of Decadal Survey Implementation**
- **Issues, Discussion**

HPD is Organized into Four Major Sections

Goal: Understand the Sun and its interactions with Earth and the solar system, including space weather

Solar Terrestrial Probes

Strategic Mission Flight Programs

Living With a Star

Strategic Mission Flight Programs

Solve the <u>fundamental physics</u> mysteries of heliophysics: Explore and examine the physical processes in the space environment from the sun to the Earth and throughout the 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.

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.

Explorers

Smaller flight programs, competed science topics, often PI-led

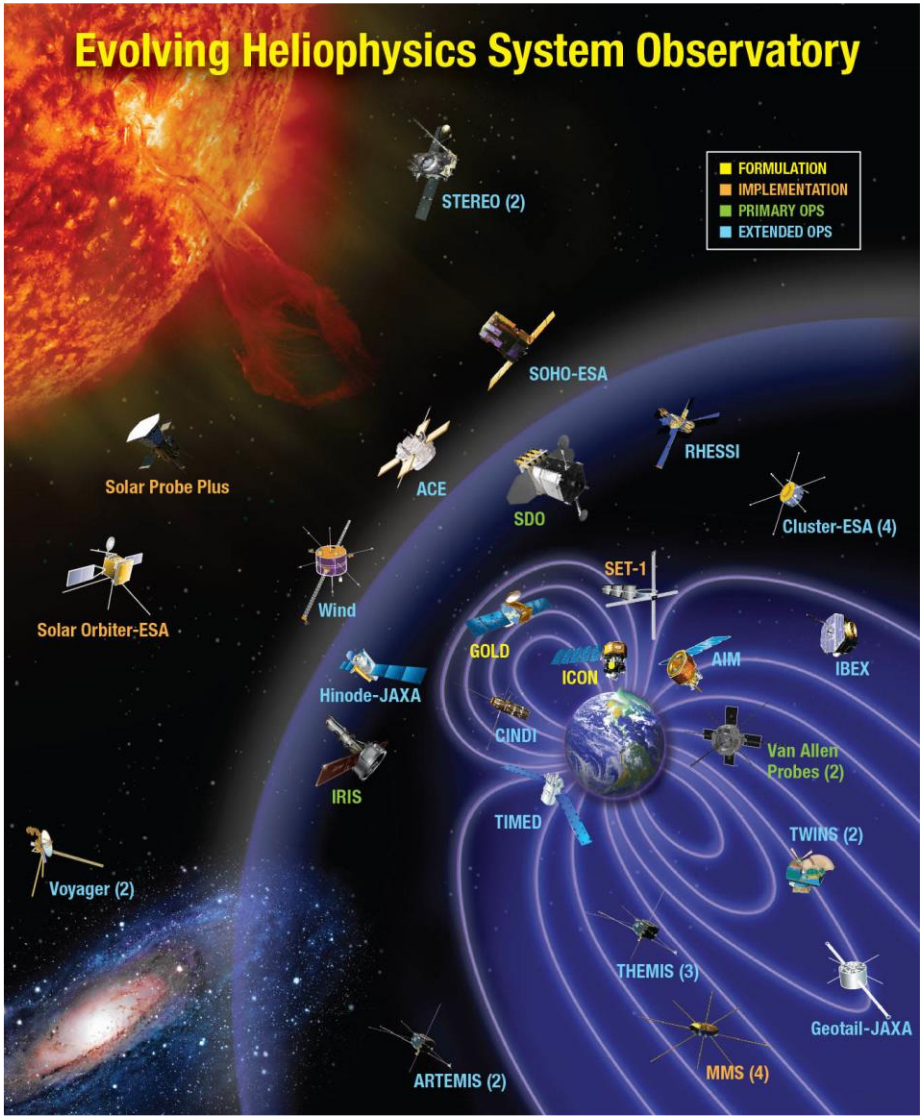
Research

Scientific research projects utilizing existing data plus theory and modeling

2014 SMD Science Plan for Heliophysics

Heliophysics System Observatory

A coordinated and complementary fleet of spacecraft to understand the Sun and its interactions with Earth and the solar system, including space weather



- 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

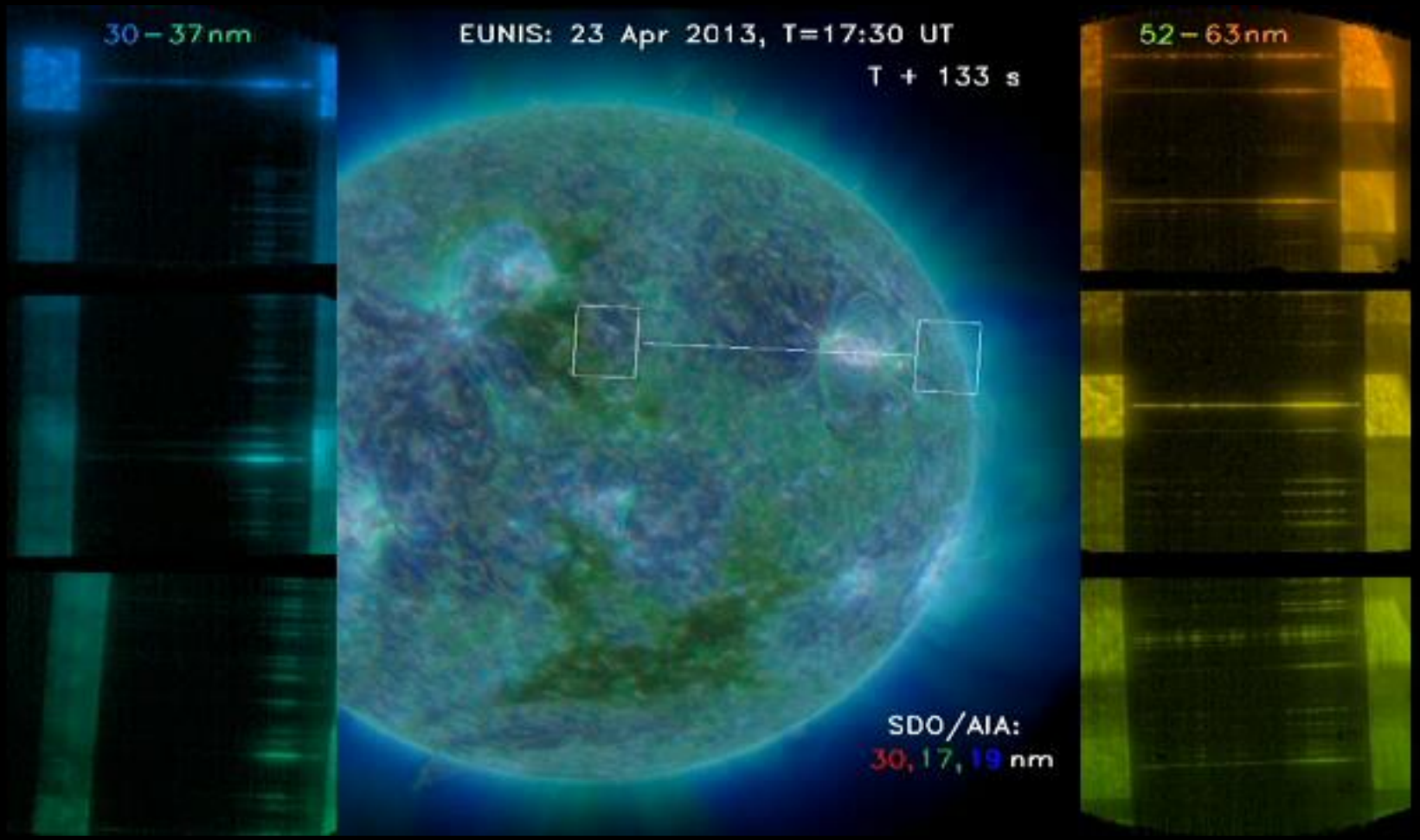
  (Missions in red contribute to operational Space Weather.)

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

Topics for discussion

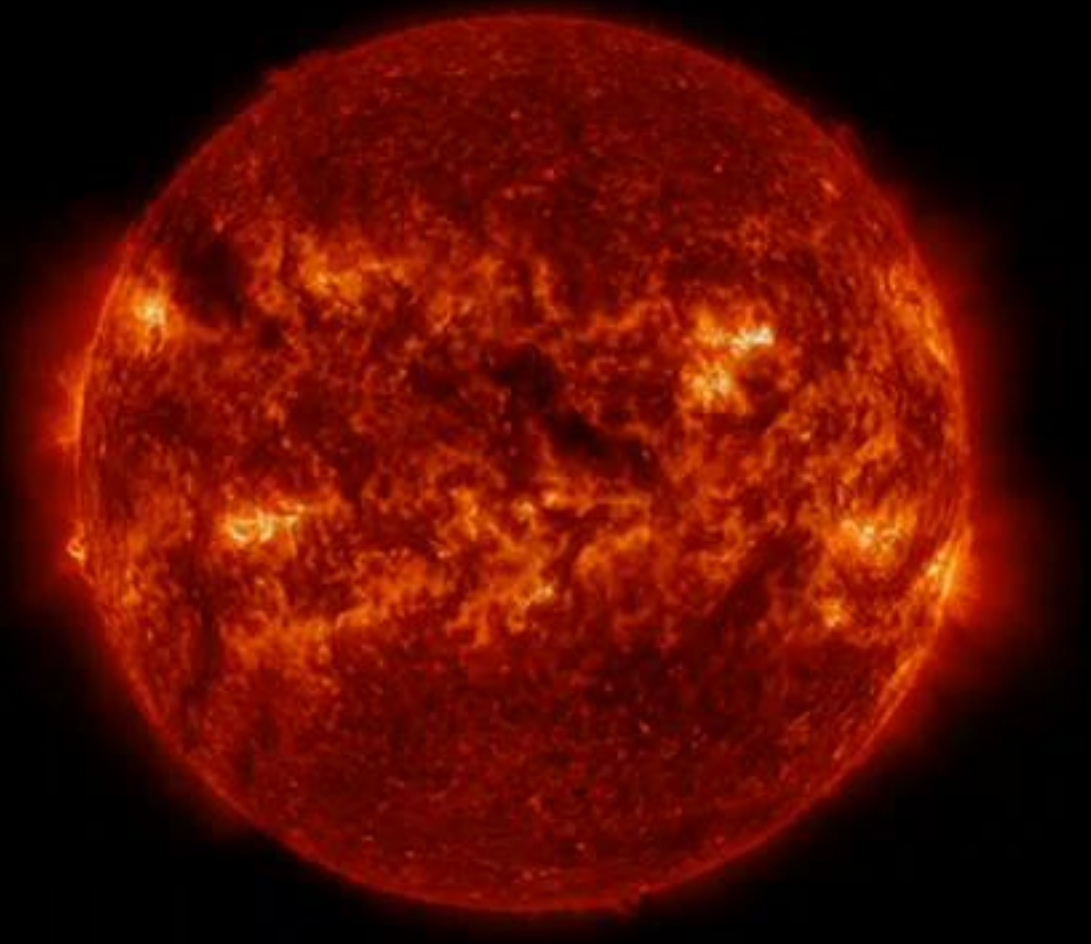
- **NASA's Heliophysics Division Objectives and Organization**
- **Recent Accomplishments, Program Updates, Current Status**
- **Future Planning and Status of Decadal Survey Implementation**
- **Issues, Discussion**

Solving the Mysteries of Coronal Heating



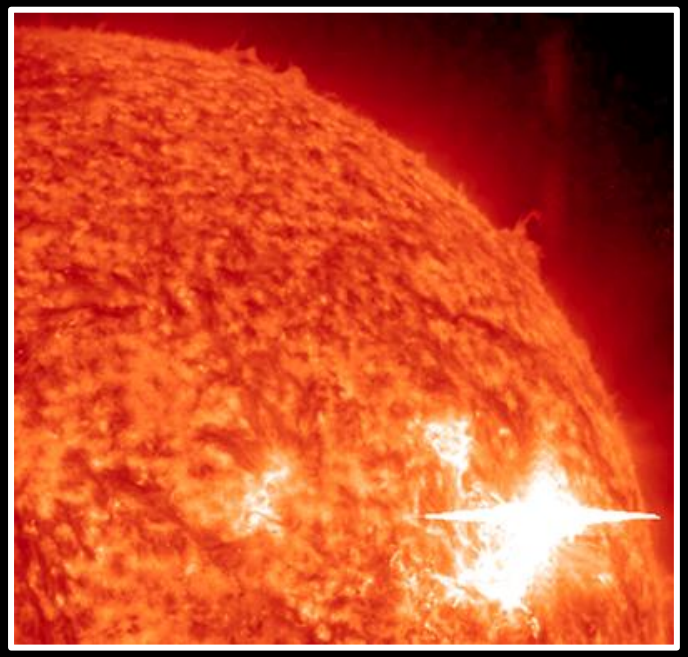
A NASA Sounding Rocket Provides the Best Evidence Yet For Coronal Heating Theory: EUNIS observations are consistent with only one current coronal heating theory: nanoflares!

Solving the Mysteries of Solar Flares

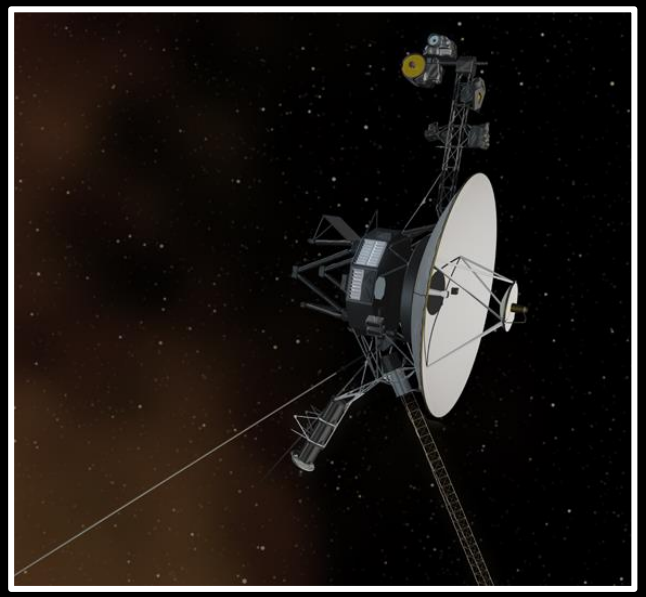


NASA Telescopes Coordinate Best-Ever Flare (X-Class) Observations

Solar-Heliosphere Interactions

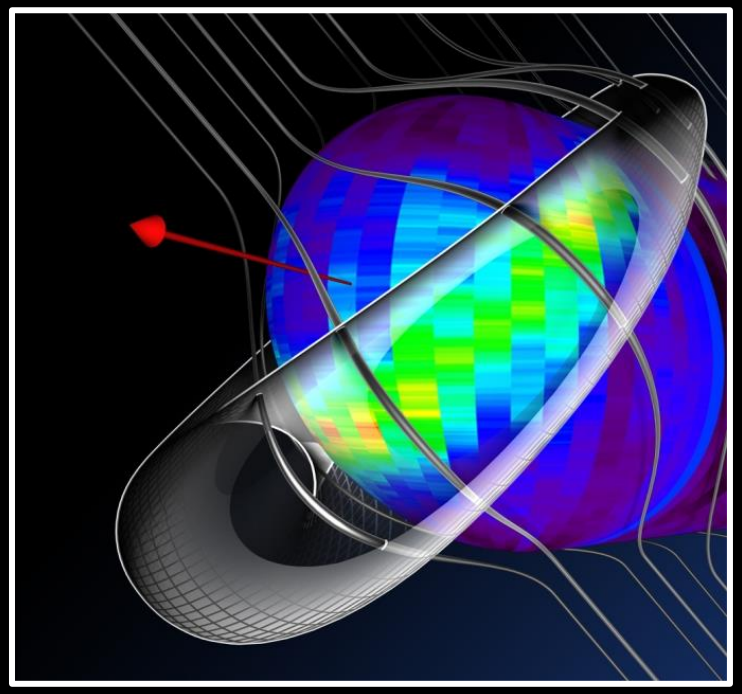


NASA STEREO and MESSENGER Measurements Open New Window Into High- Energy Processes on the Sun: *A solar flare on the far side of the sun on June 4, 2011 sent neutrons into space.* The lifetime for these neutrons is only ~15 minutes, so they *are rarely observed near Earth.*



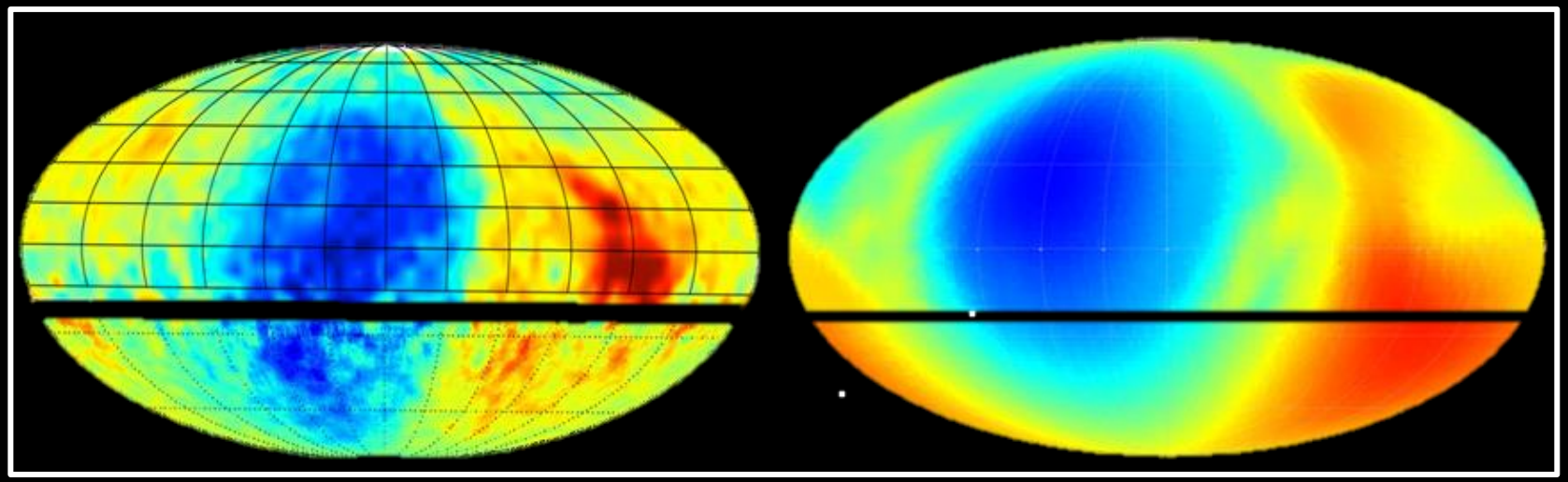
Voyager 1 Measures A Shock Wave from the Sun: *Voyager 1 has observed a series of three shock waves from the sun, supporting the conclusion that it had left the heliosphere.*

Interacting Magnetic Fields at the Interstellar Boundary

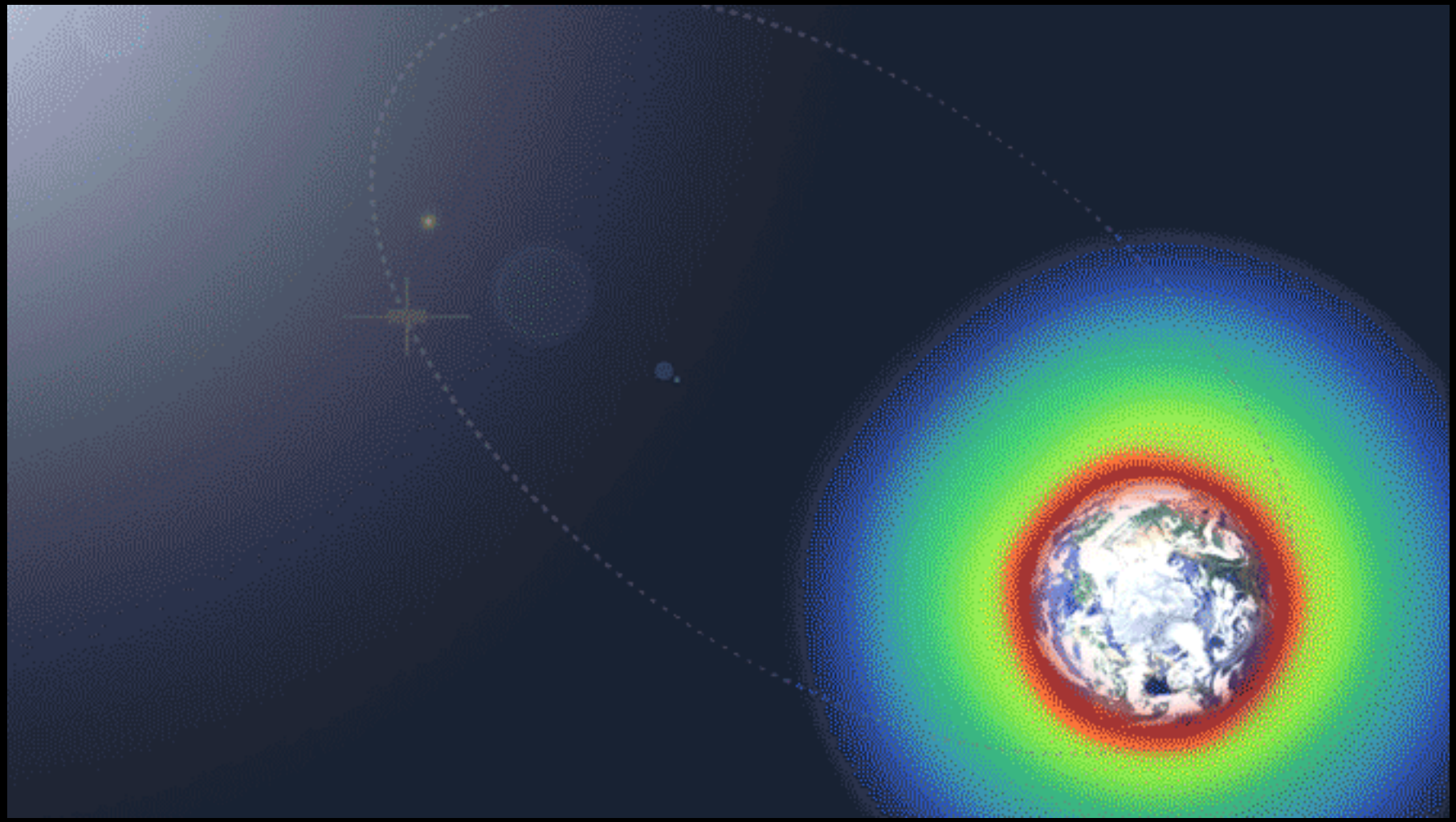


NASA's IBEX Helps Paint Picture of the Magnetic System Beyond the Solar Wind:
Combining observations of energetic cosmic ray particles with IBEX measurements show a magnetic field that is nearly perpendicular to the motion of our solar system through the galaxy.

Below: IBEX observations (left) support models of cosmic rays entering the heliosphere (right) – blue represents fewer rays.

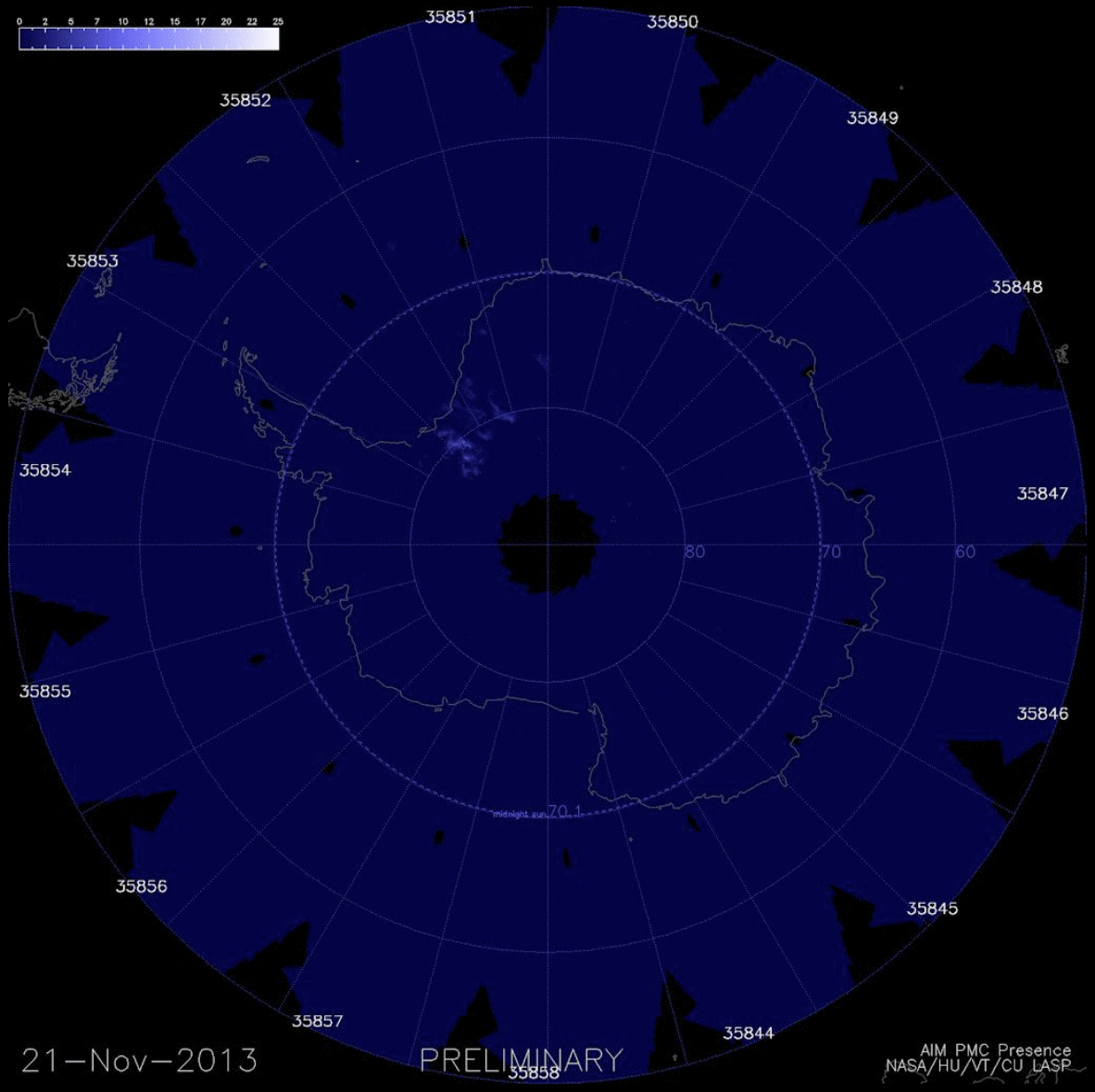


Interacting Magnetic Fields Near Earth



NASA's THEMIS discovers a process that protects Earth from space weather events

Our Near-Space Environment



Unexpected Teleconnections in Noctilucent Clouds (NLCs):

AIM observations of NLCs revealed teleconnections in Earth's atmosphere that link weather and climate.

Our Near-Space Environment

NASA Sounding Rocket Launches Into Aurora Over Alaska: Launched into the heart of an aurora. Combined with an array of ground-based imagers to take measurements of the particles and electric fields within the aurora.

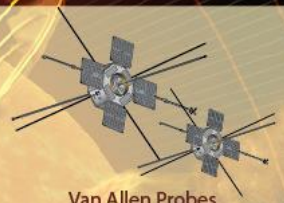
Heliophysics Program 2012-2020

Solar Terrestrial Probes

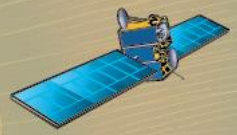
Magnetospheric Multiscale (MMS)
March 2015

STP #5

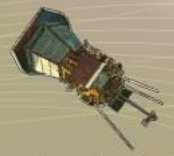
Living With a Star



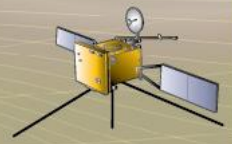
Van Allen Probes
August 2012



Space Environment Testbeds (SET)
Mid-2016

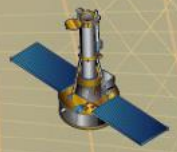


Solar Probe Plus
July 2018

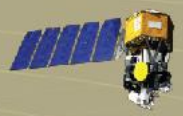


Solar Orbiter Collaboration (with ESA)
October 2018

Explorers



Interface Region Imaging Spectrograph (IRIS)
June 2013



Ionospheric Connection Explorer (ICON)
June 2017

Global-scale Observations of the Limb and Disk (GOLD)
September 2017

Research Program

Solar/Heliospheric - September 2014
Solar/Heliospheric - November 2014
Geospace - November 2014
Geospace - November 2014
Solar/Heliospheric - December 2014
UV/Optical Astro - January 2015
PEREGRINE#1 - January 2015
Geospace - January 2015
Geospace - January 2015
Geospace - January 2015

HySICS - August 2014 / WFF

Ongoing

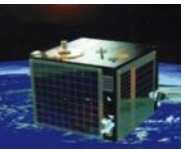
Heliophysics Missions
Astrophysics Missions
Planetary Missions

2012 2013 2014 2015 2016 2017 2018

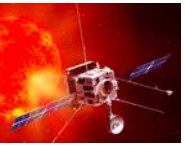
Living With a Star (LWS) and Solar Terrestrial Probes (STP)

Living With a Star:

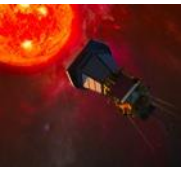
• **Balloon Array for RBSP Relativistic Electron Losses (BARREL):**
BARREL is a balloon-based mission to augment the measurements of the Van Allen Probes mission. Launch: BARREL #1 January 2013, BARREL #2 December/January 2014 - Completed



• **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: Mid-2016

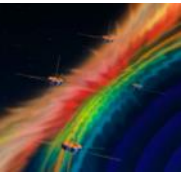


• **Solar Orbiter Collaboration (SOC):**
SOC will unravel how solar transients alter the plasma and magnetic field structure of the inner heliosphere and measure the solar polar magnetic fields. Launch: NLT Oct. 2018 (July 2017)



• **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: July 2018

Solar Terrestrial Probes:



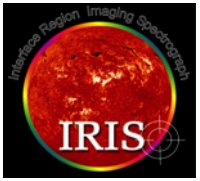
• **Magnetospheric Multiscale (MMS):**
The MMS mission will use Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection. Launch: March 12, 2015

STP #5

• **Solar Terrestrial Probe #5 (tbd): NET FY17**

Explorer Program and Low-Cost Access to Space

Explorers Program:



• **Interface Region Imaging Spectrograph (IRIS): Launched in June 2013**
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 Explorers Selected in Spring 2013**
ICON (full mission) and GOLD (Mission of Opportunity) will study the ionosphere and how it is coupled to and affected by the magnetosphere and sun above and the atmosphere below

•**Future Explorer AOs: based on the President's FY15 budget request, AO ~FY17**

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 19 NASA suborbital launches in 2013

The Sounding Rocket Program completed 12 NASA suborbital launches in 2014

Heliophysics Key Milestones

Key Decision Points

October 2014	ICON KDP-C
~Jan. 2015	GOLD KDP-C
March 12, 2015	MMS Launch Readiness Date
March 2015	SPP CDR
July 2018	SPP Launch Readiness Date
October 2018	SOC Commitment Date

Solicitations

February 2015	ROSES NRA
February 2016	ROSES NRA

The next Heliophysics Explorer solicitation anticipated no earlier than FY2017.

The next Solar Terrestrial Probes solicitation anticipated no earlier than FY2017.

Solar Probe Plus: First Voyage to a Star

Description: Spacecraft in a highly eccentric elliptical orbit with a minimum perihelion of 9.5 Solar Radii (~4 million miles). Solar Probe Plus will employ a combination of in-situ measurements and imaging to achieve the mission's primary scientific goal: to understand how the Sun's corona is heated and how the solar wind is accelerated.

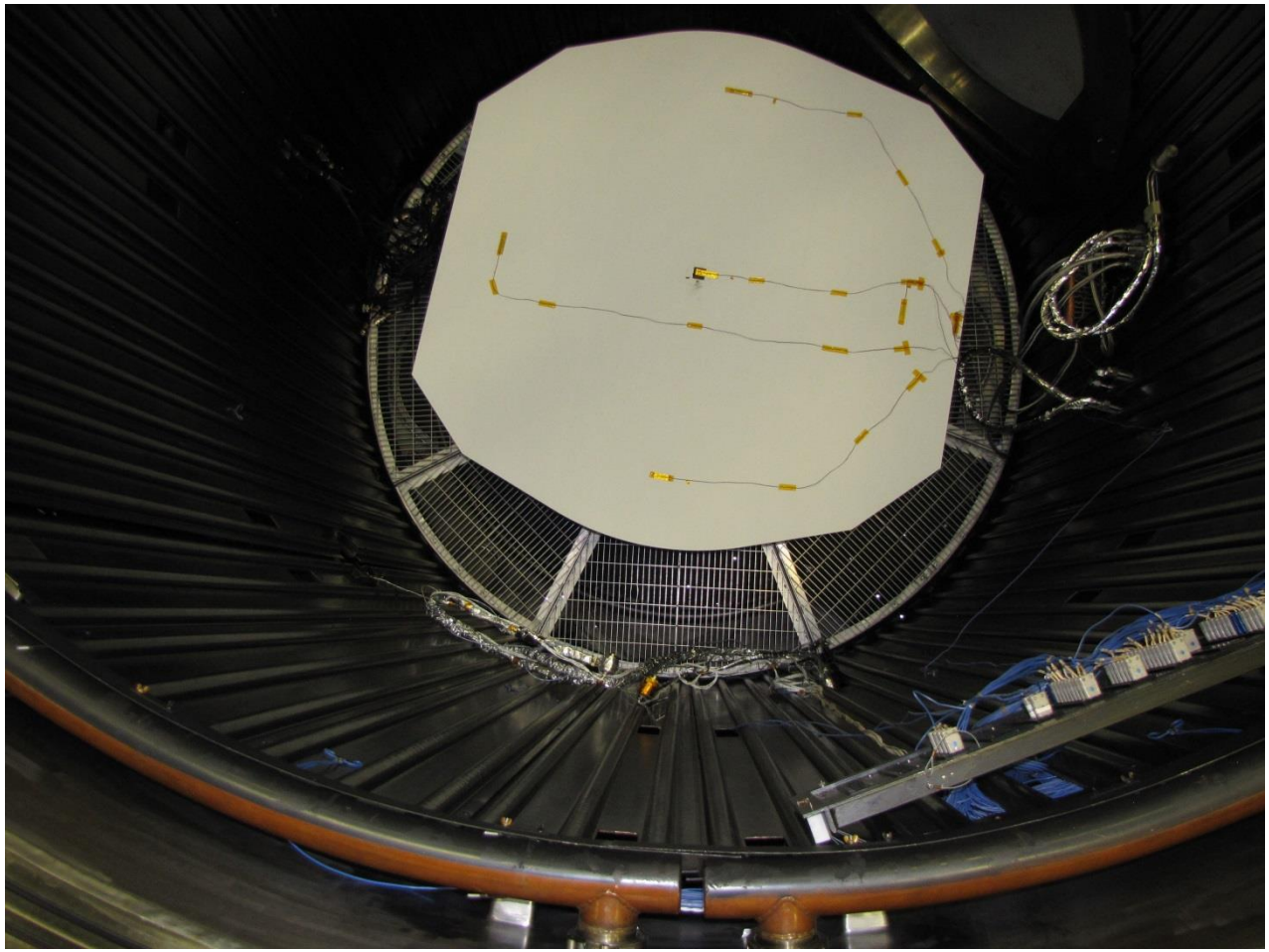
Milestones:

- KDP-C March, 2014 – Confirmed
- Thermal Protection System reach TRL 6
- CDR March, 2015
- LRD July, 2018

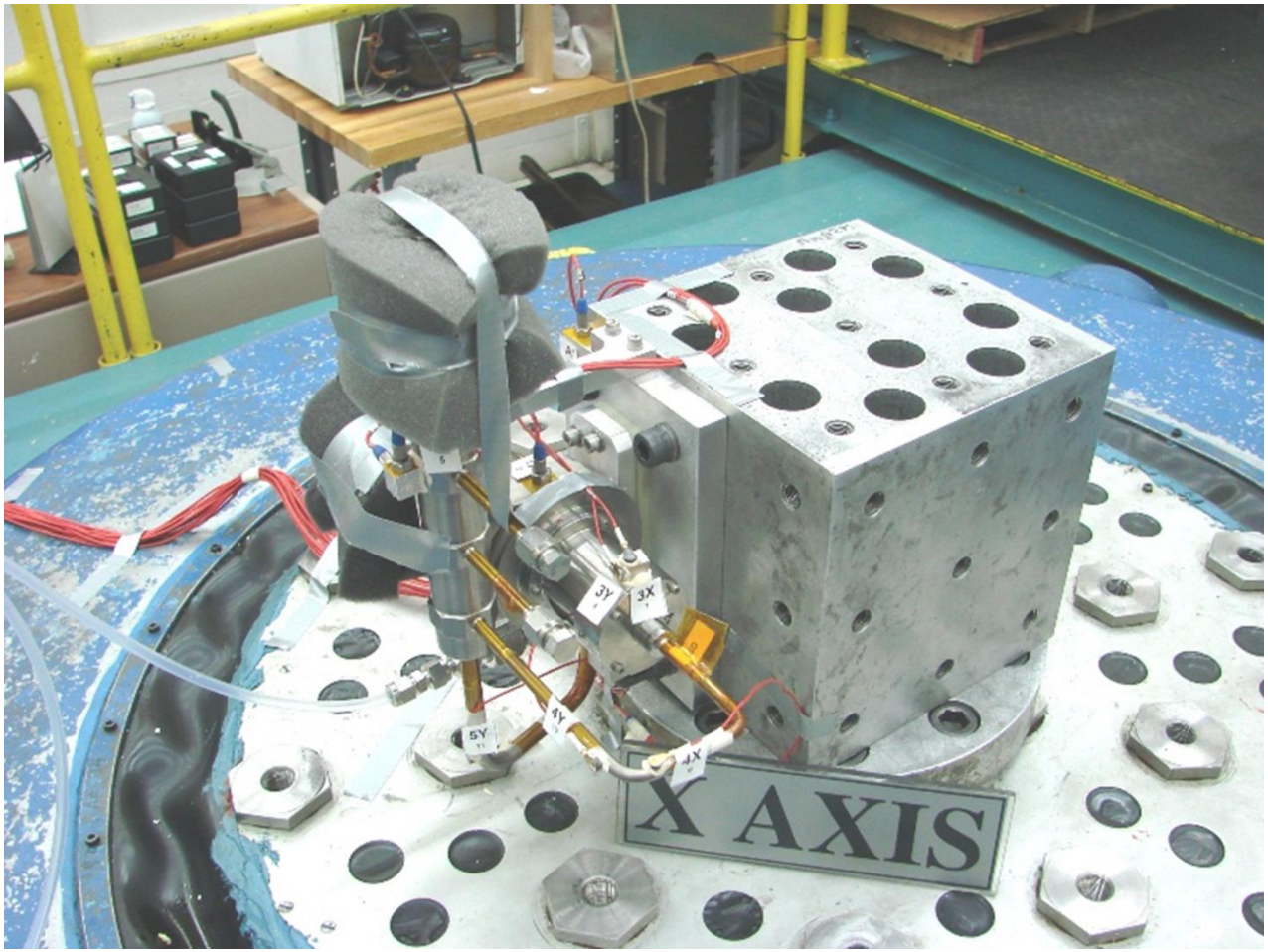
Recent Accomplishments:

- *Cooling System:* Successfully completed random vibration portion of the pump life test
- ***RF:*** **Held X-band Engineering Design Review**
- ***Avionics:*** **Held design review for the Redundant Processor Module DCDC Converters**
- ***Software:*** **Conducted flight software Critical Design Review**
- *Mechanical:* Made progress on the S/C separation interface to the LV/upper stage during TIM with KSC
- ***Propulsion:*** **Held Propulsion Subsystem Peer Review at Aerojet-Rocketdyne**
- ***Fields:*** **Completed thermal testing of the antennas; thermal models correlated well**
- *SWEAP:* Completed SPC SEM Faraday sensor unit single solar encounter period simulation test
- *WISPR:* Completed QM drawings for the baffles; released drawings for door mechanism procurement
- *ISIS:* EPI-Hi received prototype L0 and L1 detectors from Micron Semiconductor

TPS in GSFC Chamber for Cold Thermal Cycling



Solar Array Cooling System Pump Qual Vibration Testing

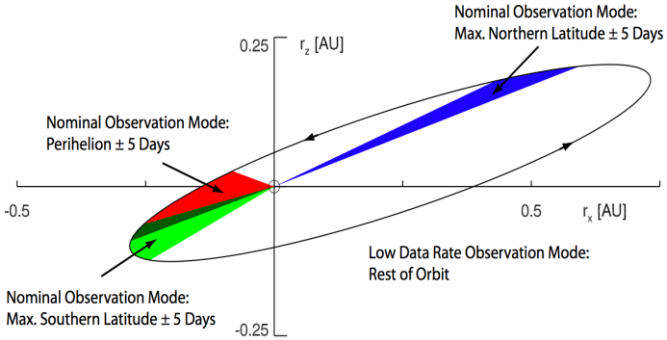


Solar Orbiter Collaboration

Status as of: 8/1/14

Current LRD: July 2017, Commitment for October 2018.

LV: Atlas V 411



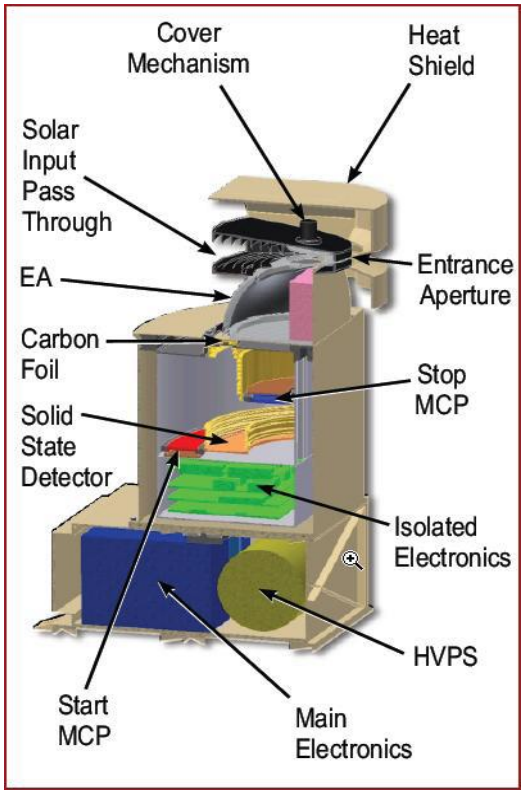
HIS Instrument (SwRI, San Antonio)

- ESA/IRAP **screening** and qualification of the RZ677 **glass version of the High Voltage Opto-Diode (HVOD)** continued, with a target completion date of December 2014.
- RFP in process for SwRI to develop and peer review a paper **design concept for a replacement HVPS** in the event that the IRAP HVPS cannot be flight qualified, with a target completion date of September 2014.
- **Modular Time of Flight (ToF)** mechanical design concept **Peer Review completed**. Action Items are being worked and reported to SOC.
- ASIC Single Event Effects (SEE) radiation testing was successfully completed at Texas A&M University.

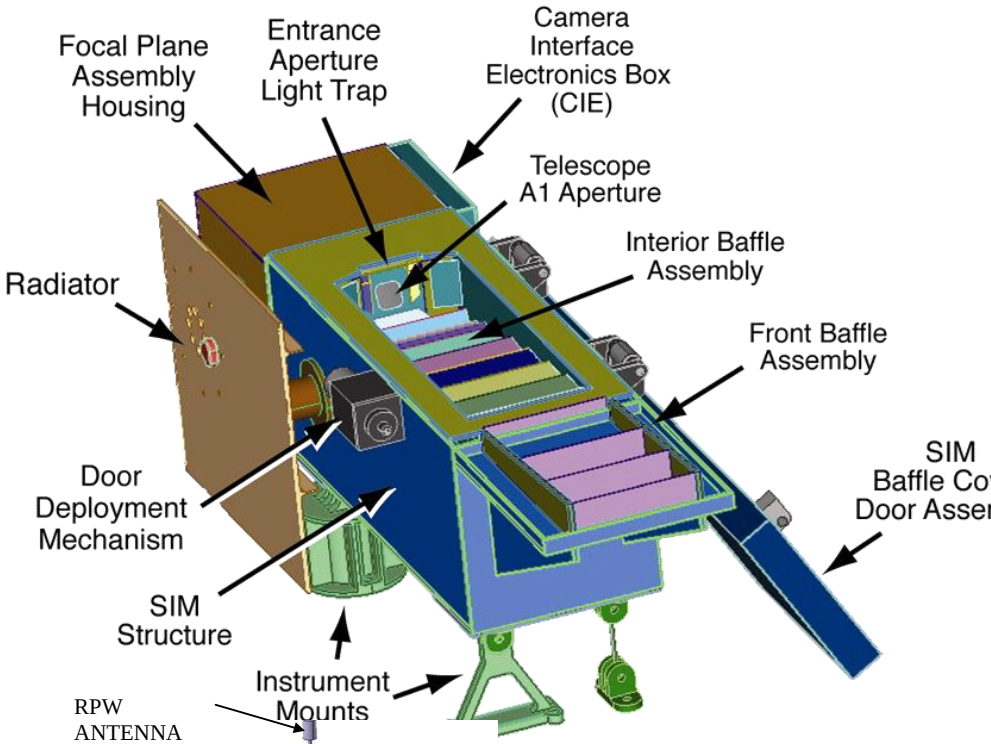
SOLOHI Instrument (NRL, Washington, D.C.)

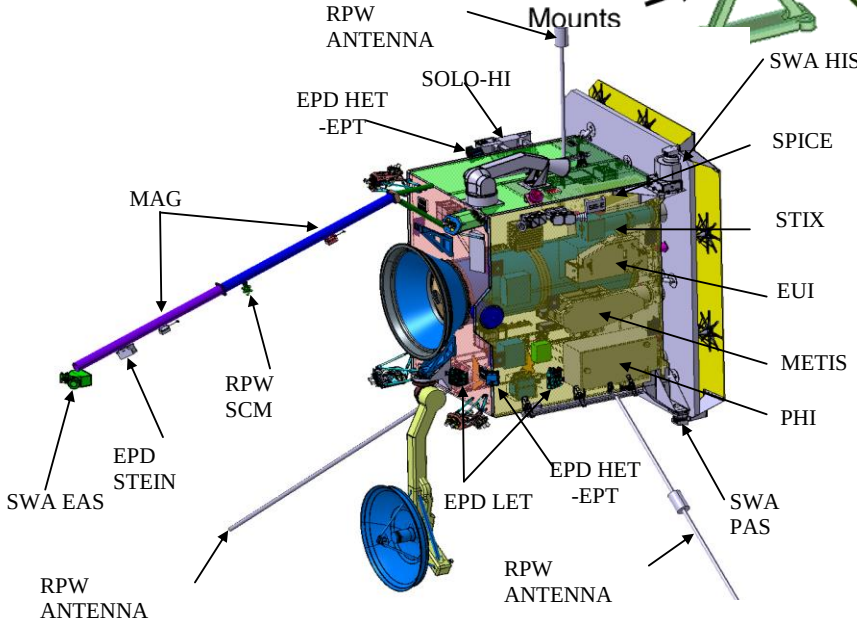
- Focal Plane Assembly Telescope QM in vibration testing now and TVAC testing planned for September. Delay in assembly of FPA Telescope QM due to design change in thermal isolation. An additional thermal isolator is required, which was learned while updating the thermal correlation model using results from STM testing.
- Lens Barrel Assembly telescope alignment on FPA Qualification Model(QM) is complete.
- **Discussions with ESA regarding straylight impingement around the solar shield continue with good results**. Risk could closed soon.
- **Electrical Model(ELM) has been assembled**. The ELM documentation was submitted to ESA for review and the Test Readiness Review was held 27 June. ELM testing is planned for August.
- Life Model Mechanism deployments and long term stowed test for mechanisms are completed.
- The FM detector interface boards(DIBs) have been populated and coated and have been sent to detector group(SRI) for integration with flight detectors.

Solar Orbiter Heliospheric Imager (SoloHI)



HEAVY ION SENSOR (HIS)





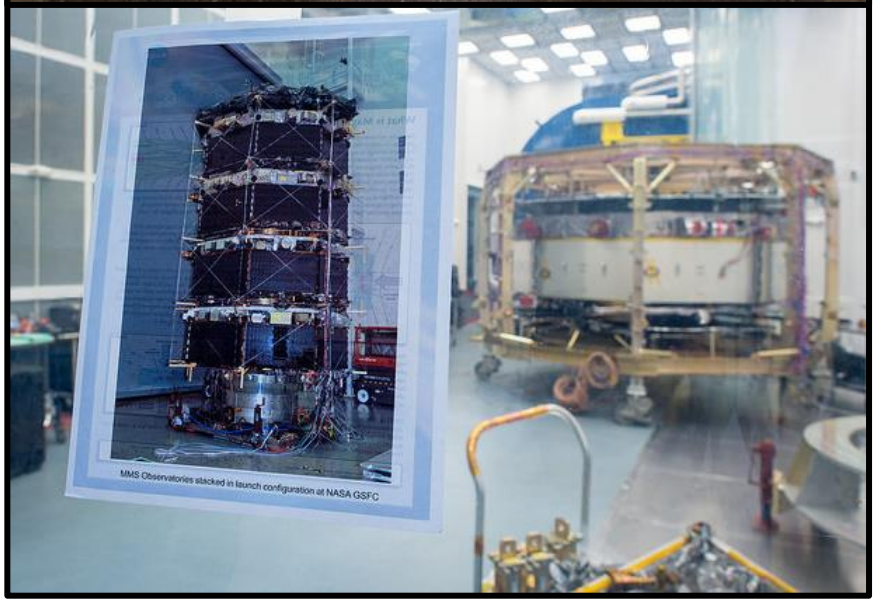
MMS Significant Progress Highlights

- **LAUNCH: March 12, 2015**
- **Observatory #3 in thermal-vacuum testing completed at NRL!**
  - No problems or issues with the Observatory.
  - High voltage instrument testing accomplished in spite of struggles with vacuum levels.
- **Observatories #1,#2, & #4 having post environmental test closeout, deployments, and clean-up work performed.**
  - Observatory #1 and #2 to risk-reduction acoustics on 8/11 and 8/16
- All SDPs now reinstalled
  - Deployment stoppages (recoverable) of spare unit (SN7) during UNH testing being investigated
- All FPI instruments now integrated.
- **All Navigators have been repaired and reintegrated.**
- SMD DPMC convened 6/27/2014 and recommend/approved MMS replan for March 2015 launch.
- Launch Day Simulation (MRT14) performed using all four Observatories.

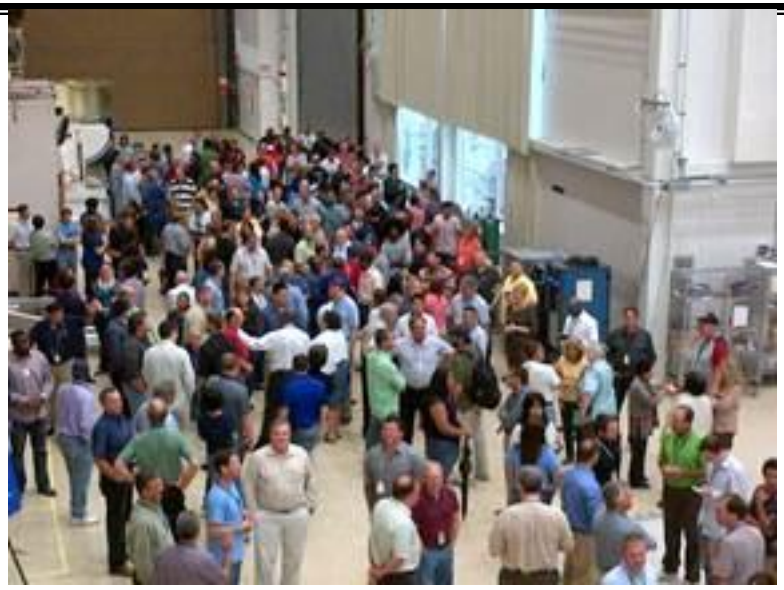
NASA Administrator Visits MMS Spacecraft at the Naval Research Lab

August 4, 2014

Above: NASA Administrator Charles Bolden with MMS Project Manager Craig Tooley outside the Naval Research Lab cleanroom where Observatory #3 had just completed environmental testing.
Credit: NASA



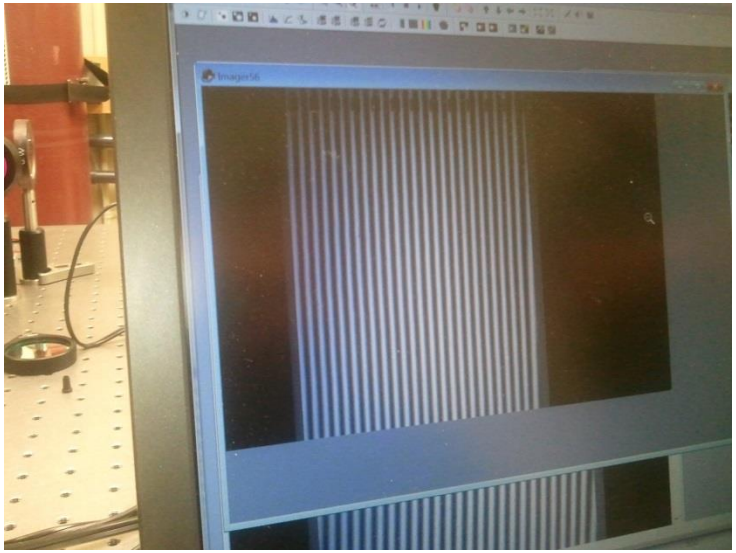
MMS



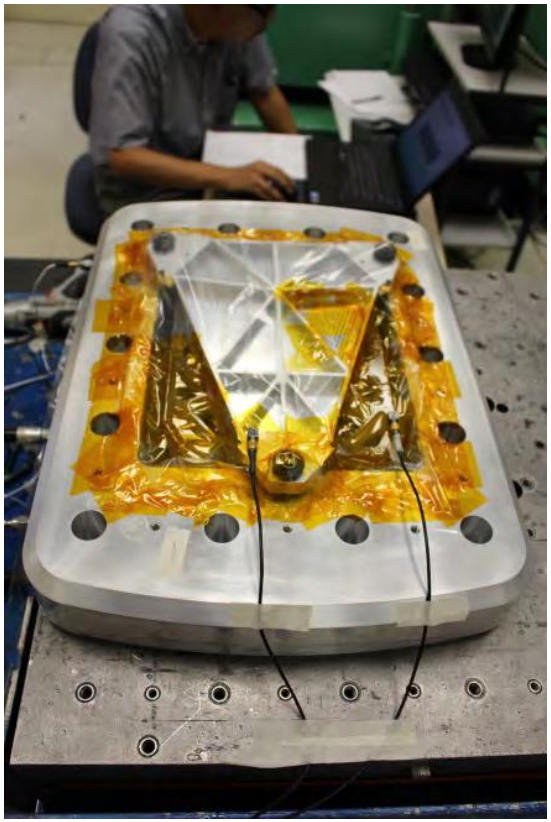
http://www.youtube.com/watch?v=qTZYY18Qagw

ICON Hardware

- MIGHTI Instrument – completed EM and achieved fringe contrast



- FUV Instrument – M2 mirror mount vibrated successfully



Heliophysics Flight Program Highlights

Upcoming Key Events

- **ICON –** KDP-C TBD
- **GOLD** – Mission PDR TBD
- **MMS –** PSR planned Oct 22-24
- **MMS** – ORR/FRR Nov 18-21
- **HELIO Senior Review 2015** - Draft Call for Proposals ~9/16/2014

Sounding Rockets

- **Hall –** 8/28/14 (Conde Precursor –
  - Partial success)
- **Vourlidas** – 9/30/14 (Successful)

Program Implementation Review (PIR)

- **Explorer, LWS, STP PIR** October 16-17, 2014

Research

Helps ensure the vigor, vitality, and high quality of HPD research.

- The **Research Program** is essential to the scientific productivity of HPD
  - Operations and data analysis for extended missions
  - Annual research proposal opportunities open to the entire scientific community
  - The “mortar” that binds individual missions to form the Heliophysics System Observatory
- Leverages NASA’s investment in the HSO for large impact at low cost
  - Enables and funds heliophysics theory and modeling (deeper understanding)
  - Enables contributions from outside of core mission teams (community breadth)
  - Enables cross-mission, correlative, and “system” research (technical breadth)
  - Funds technology development, data sharing (development and infrastructure)
  - Funds Low-Cost Access to Space and rocket program infrastructure (diversify)
- Supports applications of heliophysics science to space weather prediction
  - Community Coordinated Modeling Center (CCMC)
  - Space Weather Research Center (SWRC)
  - Model testing, verification, and validation for transition to operations at NOAA/SWPC

We are committed to increasing the Research fraction of the budget per the recommendations of the 2013 Decadal Survey.

Topics for discussion

- **NASA's Heliophysics Division Objectives and Organization**
- **Recent Accomplishments, Program Updates, Current Status**
- **Future Planning and Status of Decadal Survey Implementation**
- **Issues, Discussion**

Key Budget Consequences for Heliophysics

- The Heliophysics budget request for FY15 is increased over FY14
  - Net of administrative items: $609.8 in FY14, to $613.9 in FY15
- The budget sustains long-standing HPD programs
  - Research & Analysis, operating mission support is essentially constant
- The budget covers the Agency Baseline Commitment cost for SPP
  - Baseline commitment for launch in 2018. No impact to research budget.
- It maintains the July 2017 launch date for Solar Orbiter
- It supports MMS through launch.
- It funds both ICON and GOLD for launches in 2017
- We will continue to implement the DRIVE initiative
  - Small satellites: Addressed with CubeSat budget line item (success)

Decadal Survey Research Recommendations

Recommendations	Science	Cost
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 augmentation, LCAS augmentation, science centers and grant programs; instrument development	Program rebalance: move up to **~$33M/yr** into Research by 2022
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

Heliophysics Division DS Implementation

- **Execute on our commitments for the current programs:**
  - MMS, Solar Orbiter, Solar Probe Plus, ICON, and GOLD
  - Manage program development risks and opportunities pro-actively
  - Fund operating missions per the 2013 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
  - Expand and leverage partnerships with NSF, NOAA/SWPC, and others
- **Grow Heliophysics Explorer mission cadence to DS recommendation**
- **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 2013 Decadal Survey**

Decadal Survey Implementation

Priority	sub	Recommendation	Objective	Status
0		Complete the current program		
	0.1	Van Allen Probes	on orbit	Baseline Mission Completed
	0.2	BARREL	completed	Data analysis underway for publications
	0.3	IRIS	on orbit	Mission Success achieved
	0.4	MMS	LRD March 2015	In System I&T
	0.5	Solar Orbiter	LRD July 2017 (Oct. 2018)	In Implementation
	0.6	Solar Probe Plus	LRD August 2018	In Implementation
1		Implement the DRIVE initiative		
	1.1	NASA tiny-satellite grants program	$9M/yr more	$1M/yr HPD share of CubeSat line
	1.2	Permanently augment MO&DA support	$10M/yr more	HPD #1 strategic objective
	1.3	Directed guest investigator program as %-age of mission	2% of mission	HPD strategic Objective
	1.4	Laboratory plasma astrophysics and spectroscopy	$2M/yr more	Ongoing, Coordinate with Astrophysics
	1.5	Coordinate programs across agencies	continue	Coordinate with NSF, NOAA, DoD, others
	1.6	Heliophysics science centers		Ramp up to ~$8M/yr
	1.7	Consolidate technology funding, including constellations	up to $4M/yr	
	1.8	Educate	continue	Summer schools, Fellowships, E&C
2		Accelerate and expand the Heliophysics Explorer program	$70M/yr more	Next A/O NET FY17, 6-year cadance
3		Restructure STP as a moderate-scale, PI-led line		Under Study
	3.1	IMAP-like		
	3.2	DYNAMIC-like		
	3.3	MEDICI-like		
4		LWS Geospace Dynamics Constellation		

Heliophysics Roadmap

- The Roadmap is the community-generated document to guide NASA HPD's implementation of the Decadal Survey's recommendations
- Closely follows vision and priorities of 2013 Heliophysics Decadal Survey
  - In context of funding for HPD in President's FY15 budget
  - Recognizes and acknowledges need for flexibility in achieving science targets due to significant budget pressures and uncertainties
- Current missions in formulation and development remain the top priority
  - These current missions will require the total available budget until FY18
- NASA planning for longer-term future will depend on:
  - ✓ President's FY15 budget
  - President's FY16 budget, expected to be released in Feb/Mar 2015
  - Expeditious completion and timely launch of MMS by early 2015
  - Expeditious completion and timely launch of SPP by early 2018
  - ✓ Continued outstanding results and public recognition of heliophysics value

Topics for discussion

- **NASA's Heliophysics Division Objectives and Organization**
- **Recent Accomplishments, Program Updates, Current Status**
- **Future Planning and Status of Decadal Survey Implementation**
- **Issues, Discussion**

Where is the Heliophysics Division Going?

NASA's SMD Heliophysics Division Mission Statement (Why we exist… Not our Agency Objective):

Vision: Committed to creating a world in which our technological society benefits from understanding the sun, the space environment, and our place in the galaxy

Mission Statement: Empower the community to advance our understanding of Heliophysics and reap the benefits through science missions and enabling technology and research

- **Approach to implementing Decadal Survey recommendations**
  - Heliophysics Roadmap defines our 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
    - President's FY15 budget supports Solar Probe Plus launch in 2018
  - Strengthen our Research and Analysis, MO&DA, and Technology Programs
    - Work towards rebalancing research program (DRIVE) as recommended by the Decadal Survey
  - Plan for more frequent, lower cost missions: Expand Explorers and Missions of Opportunity
    - CubeSat line started in FY14, next Heliophysics Explorer A/O likely in FY2017
  - Commence development of the highest priority Strategic Program (STP, LWS) science targets, consistent with the budget and with Research and Explorer priorities

- **Continue to build our understanding of heliophysics (the sun and its interaction with the Earth and the solar system, including space weather)**

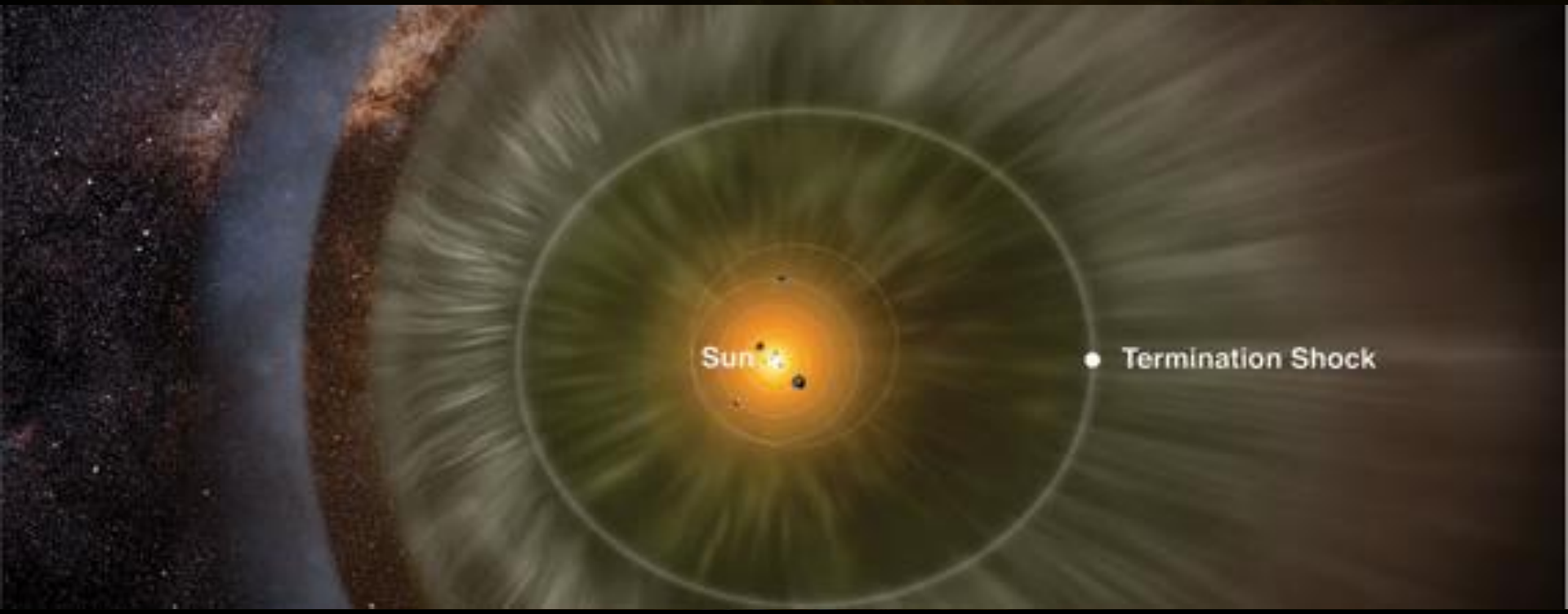
Discussion Topics: STP

- STP Program Future – Science implementation strategy- Focused vs. very loosely coupled mission line?
- The goal of the STP program is to understand the physical processes that determine the mass, momentum, and energy flow in the solar system from the Sun to planetary bodies including Earth.
- The STP program develops missions and technology to address fundamental science questions about the physics of space plasmas and the flow of mass and energy through the solar system. STP program objectives are:
  - To describe the system behavior of the magnetic variable star, our sun, and its interaction with the entire solar system;
  - To understand the critical physics that link the sun, Earth, heliosphere, and the interstellar medium; and,
  - To understand the processes and dynamics of the magnetosphere-ionosphere-upper atmosphere system, the near space electromagnetic plasma environment surrounding the Earth.
  - To develop and mature instrumentation and mission technologies with the potential of advancing STP science.

Discussion Topics: Research and Analysis

- Current portfolio balance of strategic (directed) versus open
  - Current Elements: LWS TR&T, R&A (Supporting Research, Theory, LCAS, ITD, LNAPP), Guest Investigator, cubesats, Data environments
  - DRIVE Initiative: Science Centers (Grand Challenges), smallsats, enhancements of existing elements

National Aeronautics and Space Administration



Questions?

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*