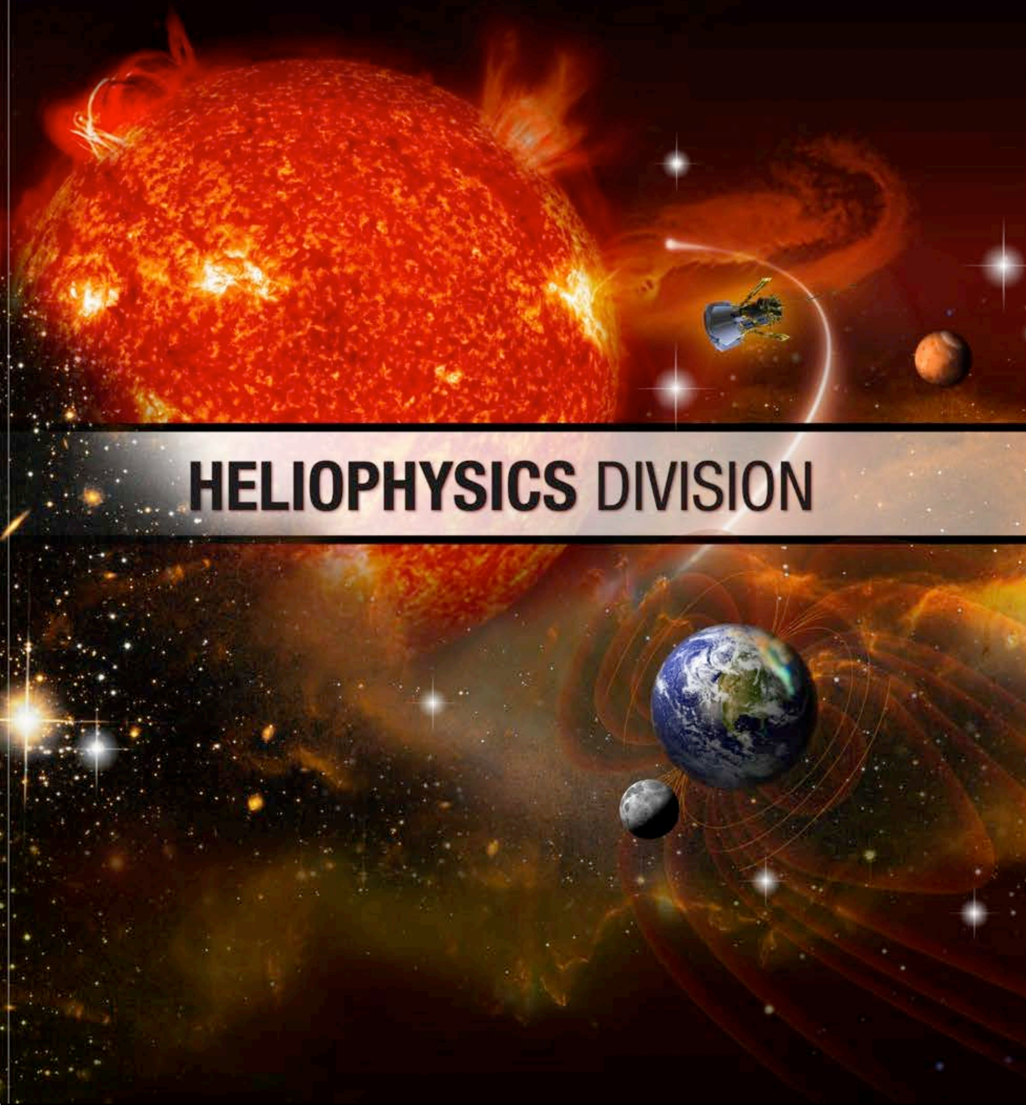
National Aeronautics and Space Administration



HELIOPHYSICS DIVISION

Heliophysics Overview
Ionospheric Effects Symposium
May 12, 2015
Elsayed Talaat

HPD Objectives and Programs

Solar Terrestrial Probes

SOLAR TERRESTRIAL PROBES

Strategic Mission
Flight Programs

Living With a Star

Strategic Mission
Flight Programs

Solve the fundamental physics 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

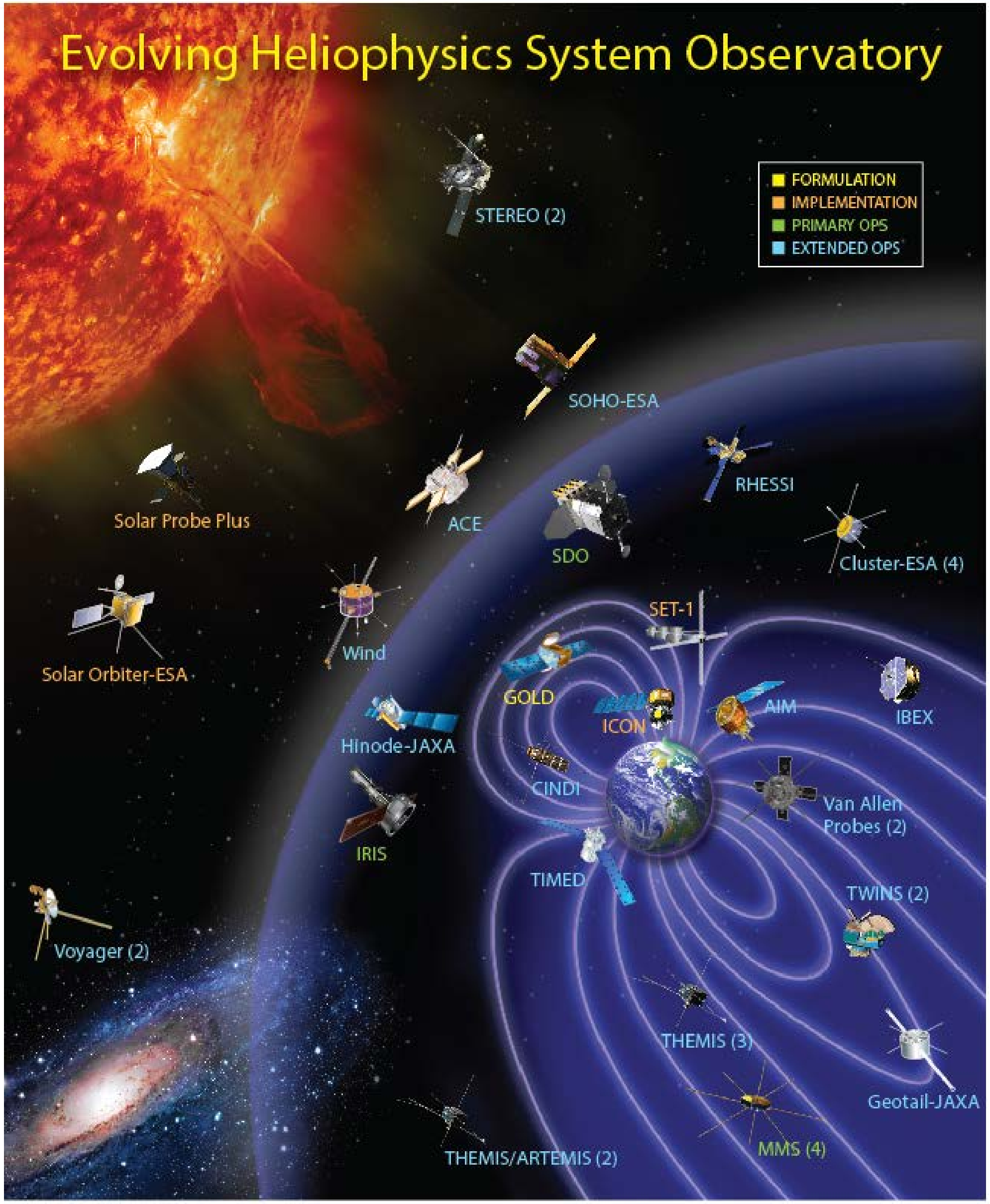
Smaller flight programs,
competed science topics,
often PI-led

Research

Scientific research projects
utilizing existing data plus
theory and modeling

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

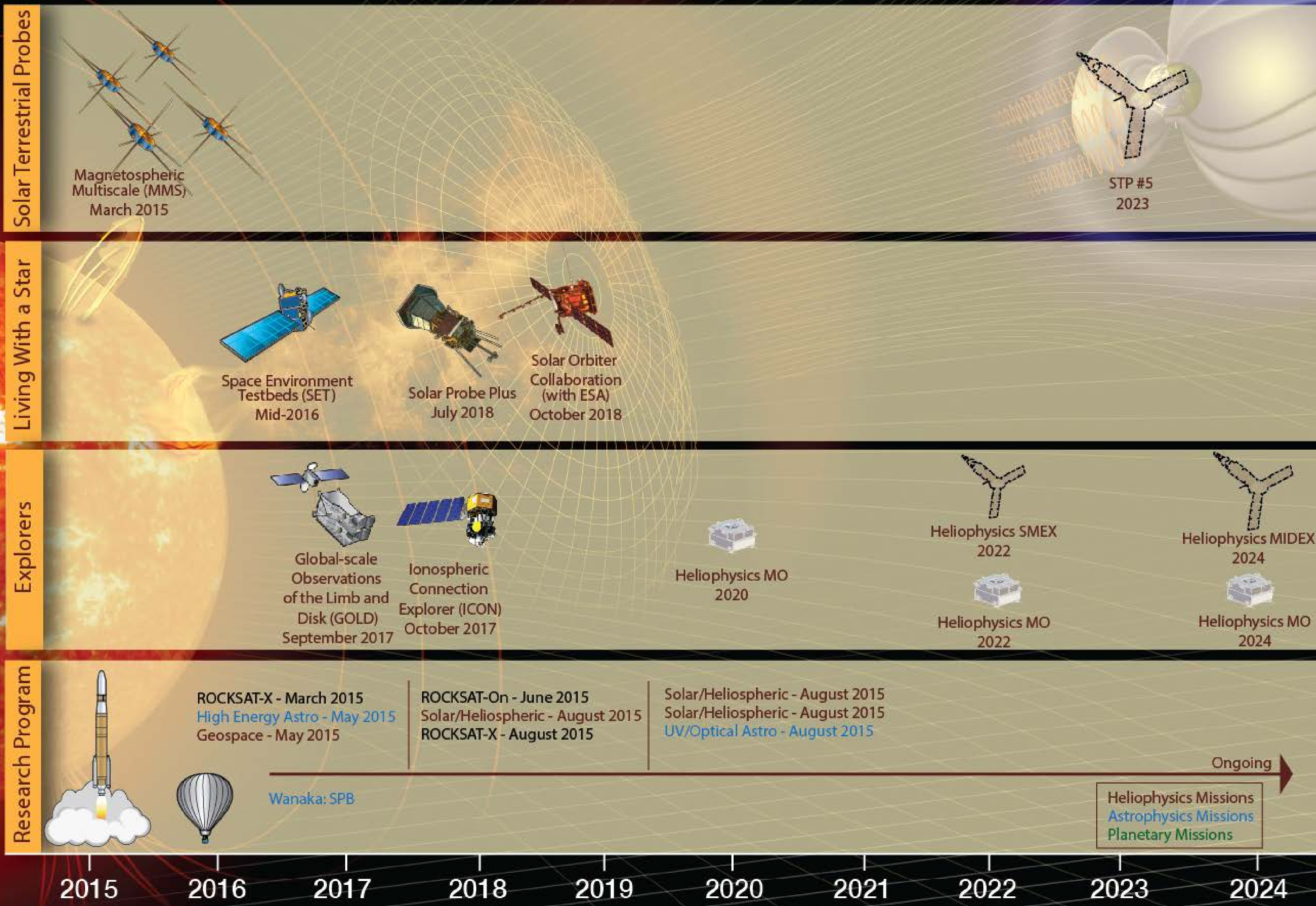


- **Heliophysics has 19 operating missions (on 33 spacecraft): Voyager, Geotail, Wind, SOHO, ACE, Cluster, TIMED, RHESSI, TWINS, Hinode, STEREO, THEMIS/ARTEMIS, AIM, CINDI, IBEX, SDO, Van Allen Probes, IRIS, MMS**
- **(Missions in red contribute to operational Space Weather.)**

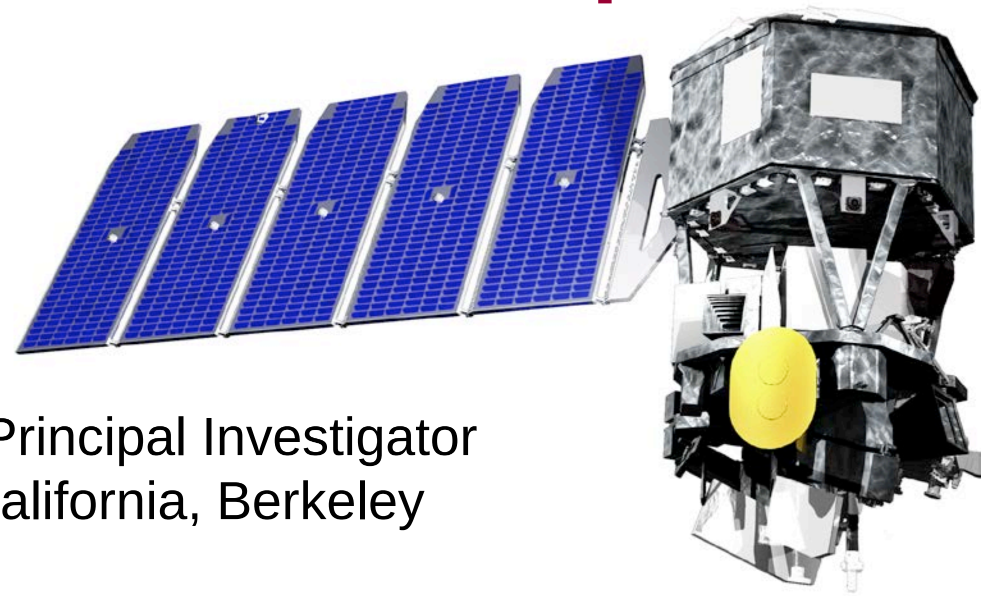
- **5 missions are in development: SET, SOC, SPP, ICON, and GOLD**

MMS Launch March 12, 2015 at KSC

Heliophysics Program 2015-2024

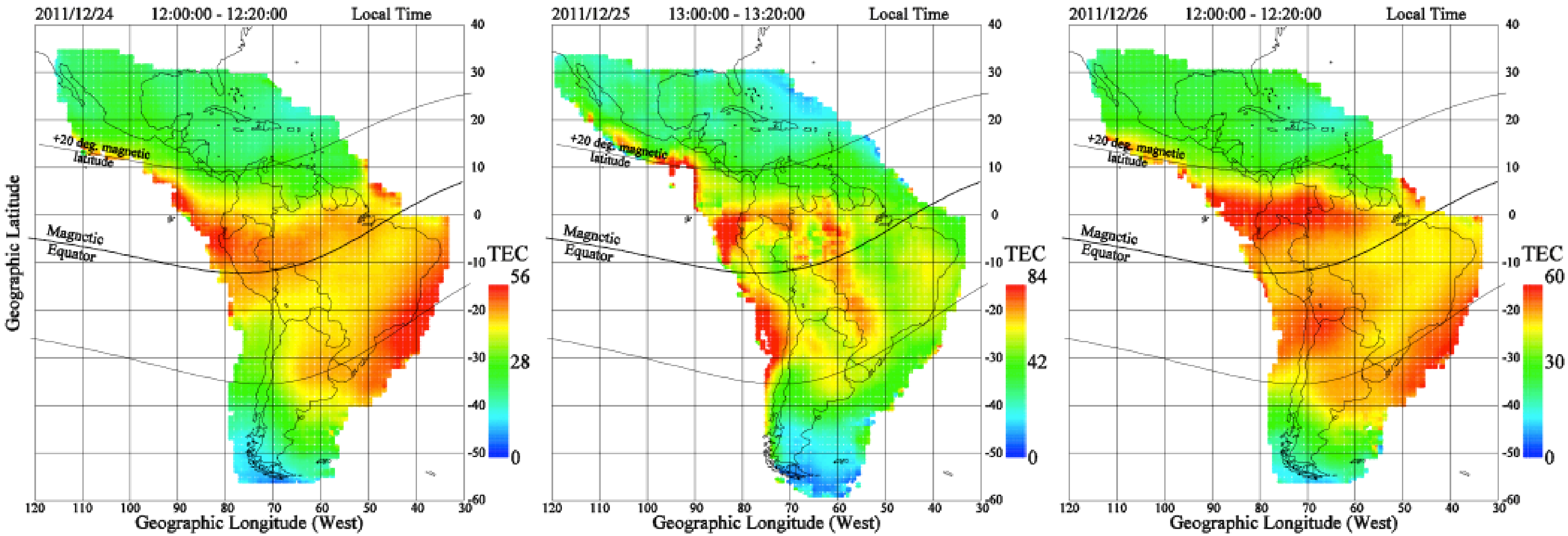


The Ionospheric Connection Explorer



Thomas Immel, Principal Investigator
University of California, Berkeley

Current knowledge cannot account for what is observed in Near-Earth space



- ❑ LISN Network TEC – PI Cesar Valladares, Boston College
- ❑ Outstanding day-to-day variability in equatorial ionosphere while Dst = 0 nT
- ❑ Cause unknown!

We continue to see behavior of the ionosphere that is completely unexpected.

ICON's Science Objectives require measurements of both drivers and responses

The Ionospheric Dynamo, driven by the neutral atmosphere, governs the motion of the plasma:

- We need to measure the **drivers**:

Neutral winds that carry the energy and momentum that drives the dynamo.

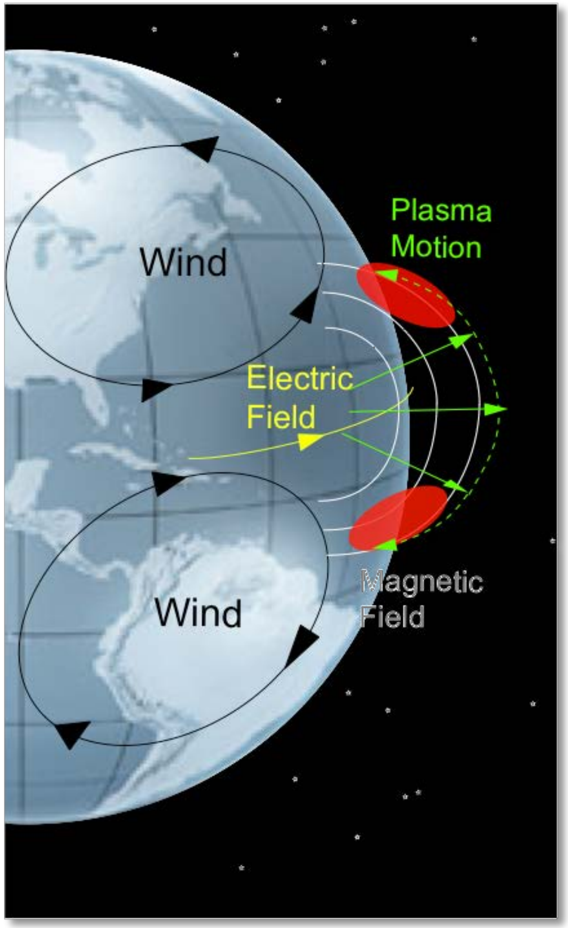
Composition of the atmosphere that controls the chemical production and loss rates of plasma.

Temperature of the atmosphere that reveals the atmospheric waves entering space from below.

- along with the **responses**:

Electric fields and **plasma motion**, both the result of the wind dynamo forcing.

Plasma density of the ionosphere, the combined result of solar production and plasma motion.

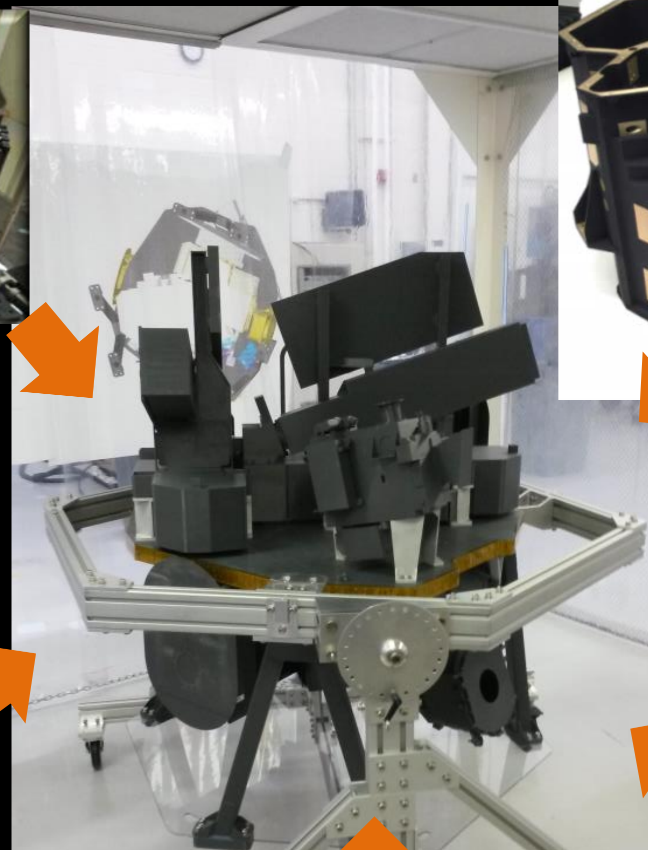


To understand the ionospheric dynamo, the drivers and response must be measured **at all relevant altitudes and at the same time.**

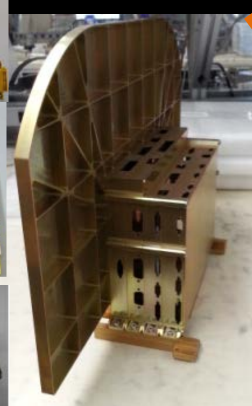
Payload

MIGHTI

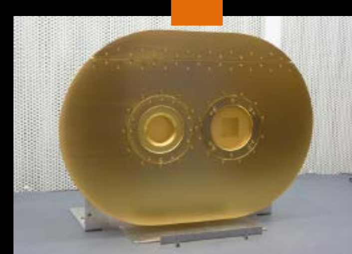
FUV



ICP

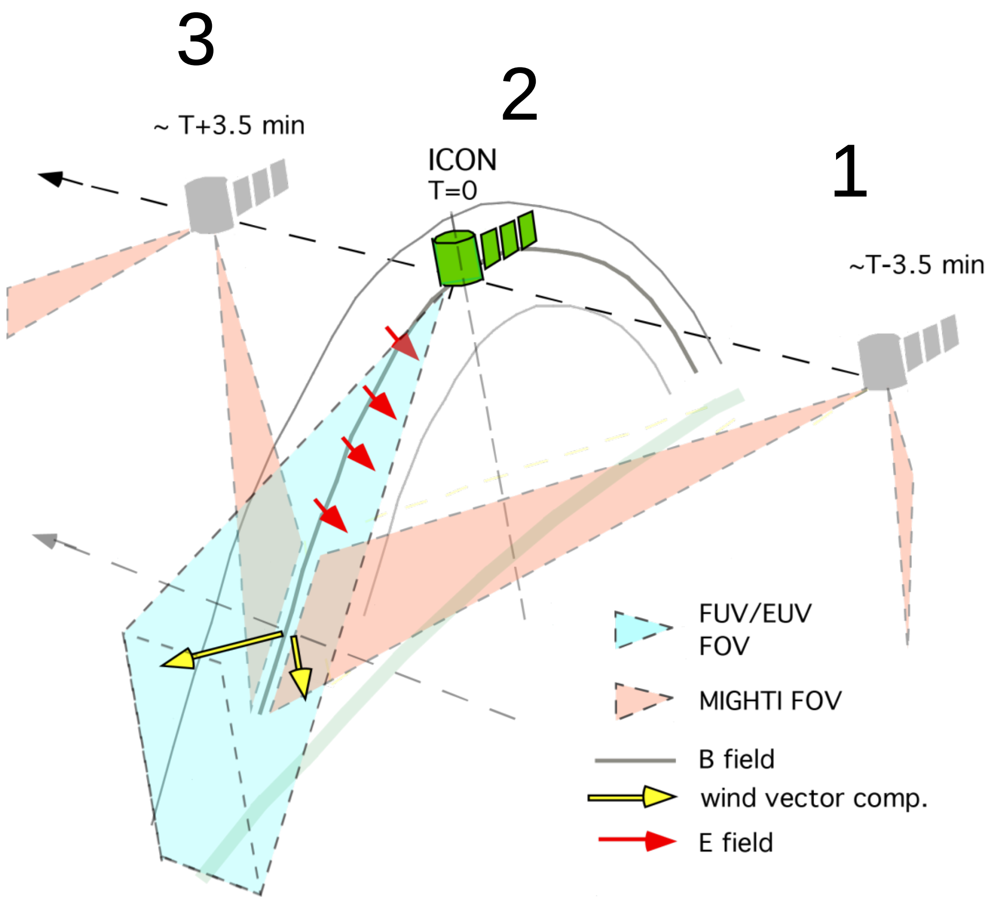


EUV



IVM

ICON makes complete measurements of equatorial geospace to address these objectives



ICON is illustrated at 1-2-3 consecutive positions (top). ICON optical measurements are limb viewing (bottom).

FUV and EUV instruments measure the thermospheric and ionospheric density and composition near the ICON's magnetic field line.

Fore- and aft-viewing MIGHTI measures vector wind components as a function of altitude ~7 minutes apart. In-situ ion velocity meter.

IVM measures local ion drift directly related to the perp. electric field (projected || along B field).

ICON
Ionospheric Connection Explorer

ICON

- ICON will be the first investigation of the drivers of variability in the dense plasma of the equatorial ionosphere using an innovative combination of remote sensing and in situ measurements

- Scientific performance of ICON has been preserved through detailed design.

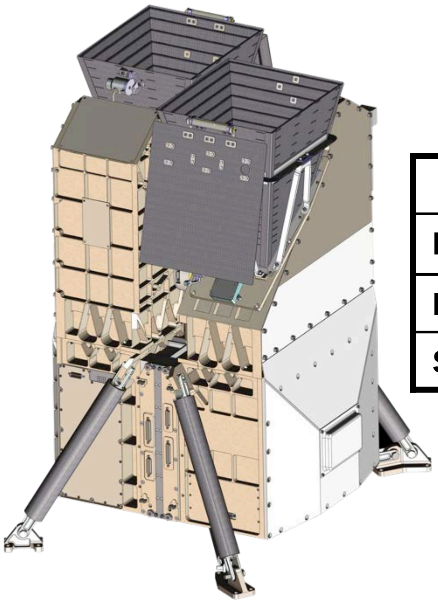
- Ready to move forward to final implementation and on to major scientific impact on-orbit!

ICON Ionospheric Connection Explorer

GOLD

Richard Eastes, Principal Investigator
University of Central Florida

Global-scale Observations of the Limb and Disk



Instrument Summary	
Mass	33 kg (CBE)
Power	53 W (CBE, AVG)
Size	51 × 55 × 69 cm^3

Imaging Spectrograph:

Two independent, identical channels

Wavelength range: 132 – 160 nm

Detectors: Microchannel plate, 2-D crossed delay line anode

Target Launch: Q4 - 2017

Hosted Payload on geostationary commercial satellite SES-14

Florida Space Institute (FSI)
University of Central Florida

PI: Richard Eastes

Project Coordinator: Andrey Krywonos

Laboratory for Atmospheric and Space Physics (LASP)
University of Colorado

Deputy PI: William McClintock

Project Manager: Michael Hackman

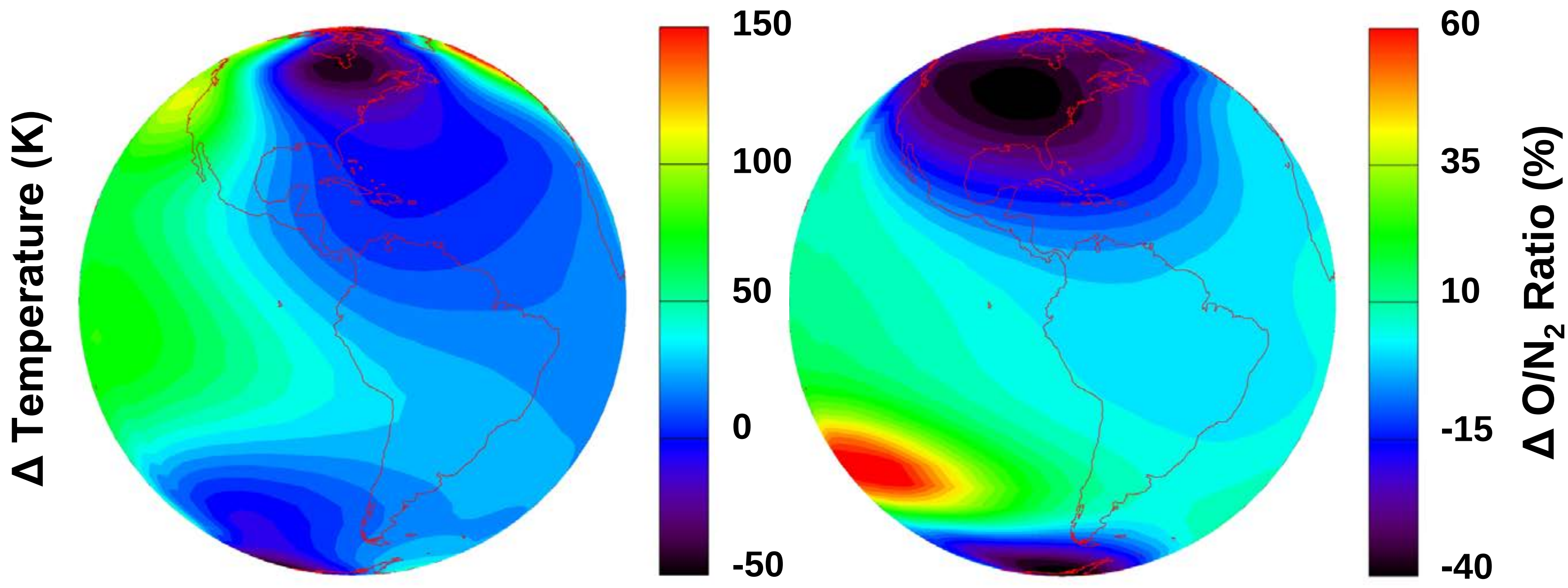
Observations:

- Disk maps of neutral temperature
- Disk maps of O/N_2 density ratio
- Limb scans (for temperature)
- Disk maps of peak electron density
- Stellar occultations

GOLD's Most Important Result

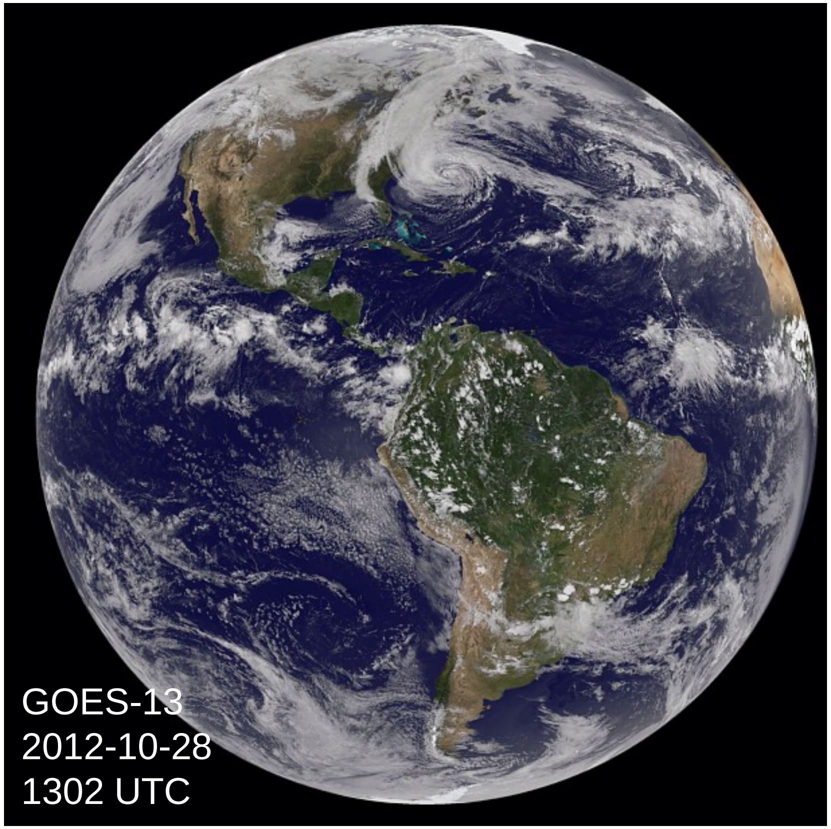
GOLD will discover how the upper atmosphere acts as a weather system

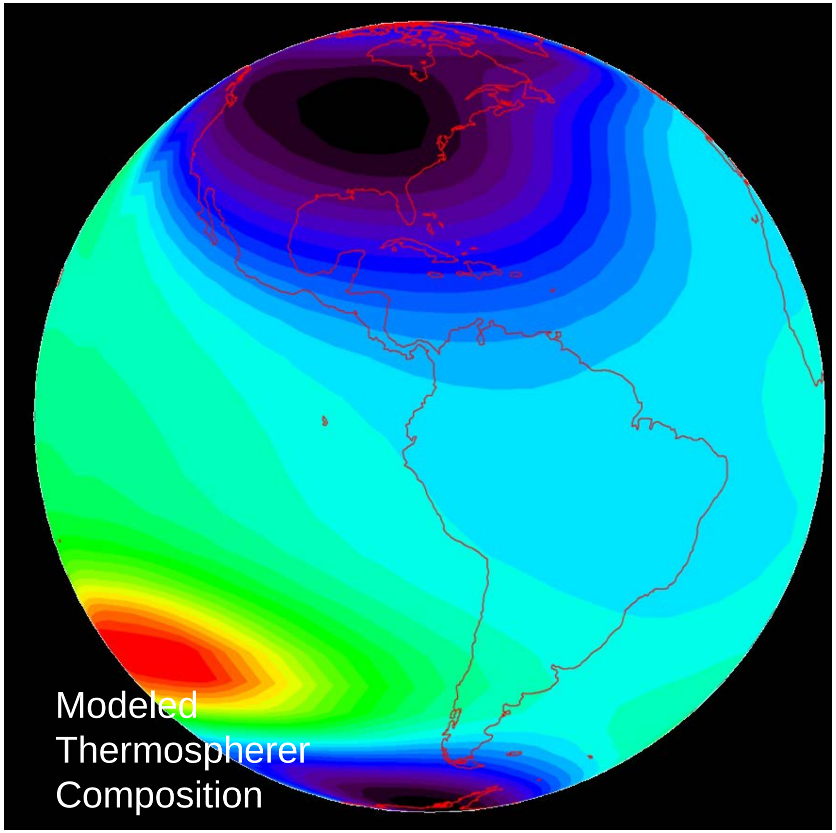
How do geomagnetic storms impact Earth's space environment?



Modeled changes in upper atmosphere during storm

The View from Geostationary Orbit

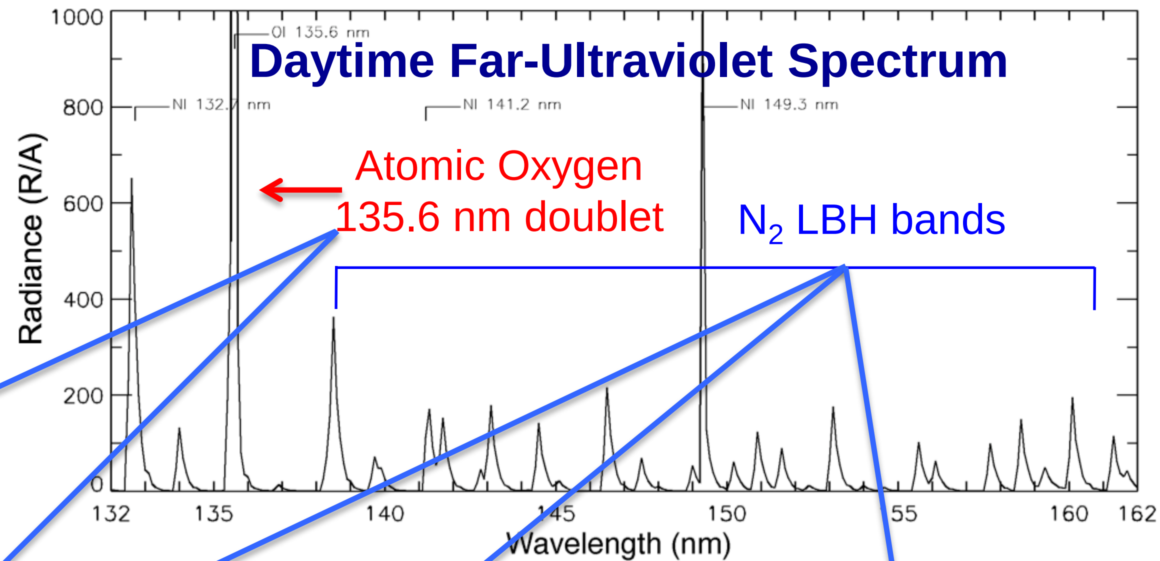




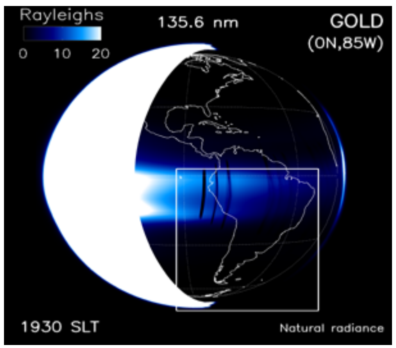
- **GOLD images the disk and limb from geostationary orbit**
- **Full images at 30-minute cadence**
- **GOLD measures the composition and temperature of the thermosphere**

GOLD Science Questions Determine Measurement and Analysis Approach

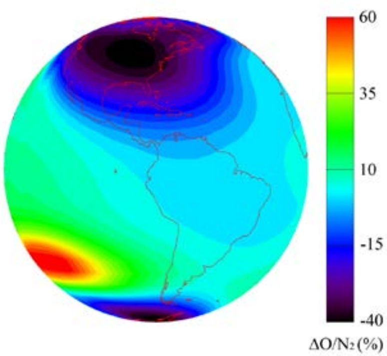
GOLD uses observations of O 135.6 nm and N_2 Lyman-Birge-Hopfield (LBH) emissions to address the science questions



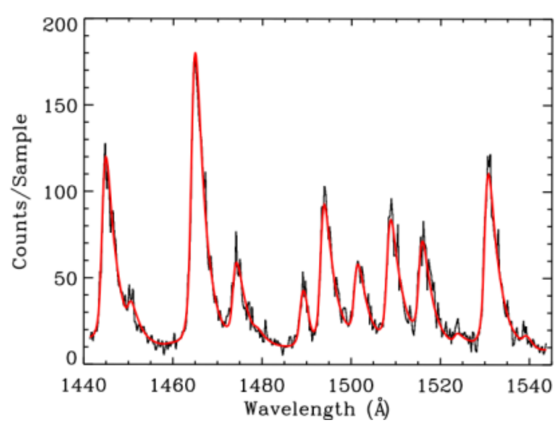
N_e from O^+ recombination emission



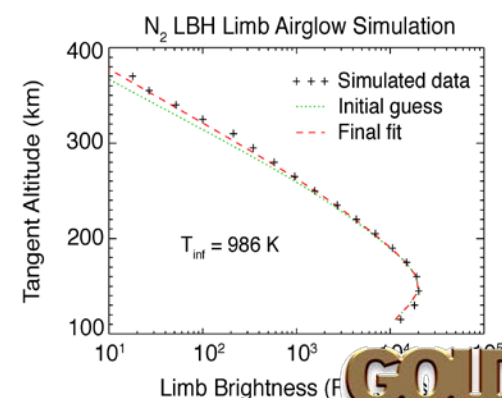
O/N_2 composition from intensities



Temperature (disk) from band shapes

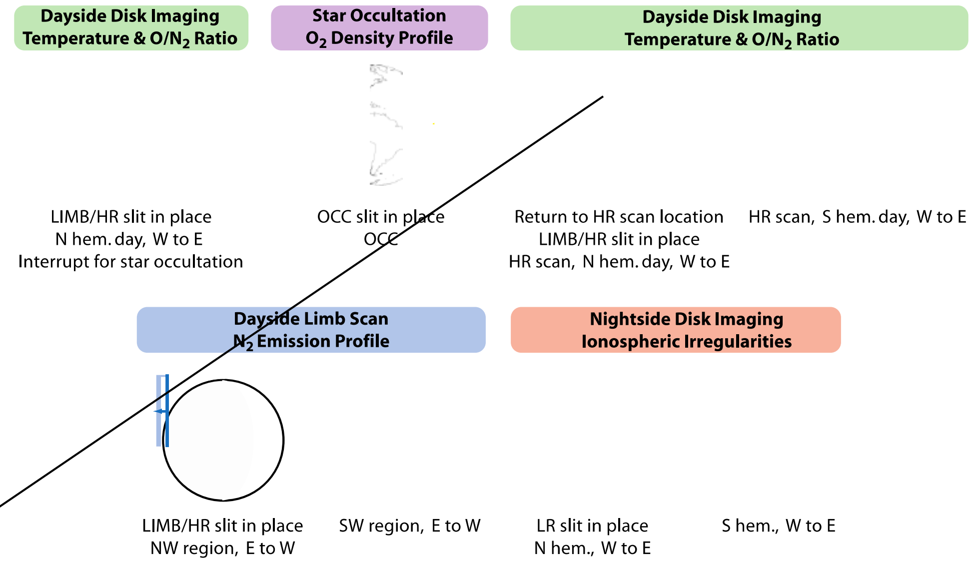


T_{EXO} from limb profiles

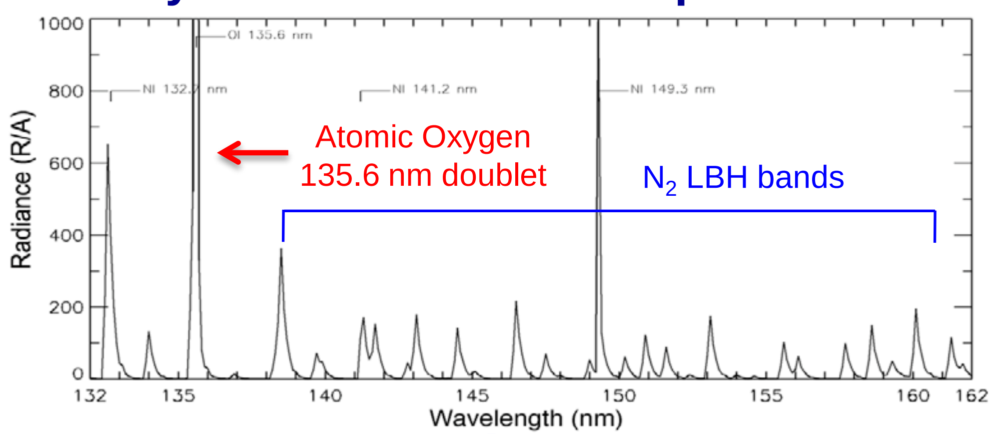


GOLD Uses Whiskbroom Imaging to Build Spatial-Spectral Image Cubes

Telescope equipped with a scan mirror images the T-I system onto the slit of an imaging spectrograph. The limiting resolution is ~ 50 km.



Daytime Far-Ultraviolet Spectrum



The spectrograph records spectra as a function of slit height at each point on the disk.

Airbus DS wins SES-14

Feb 16th, 2015

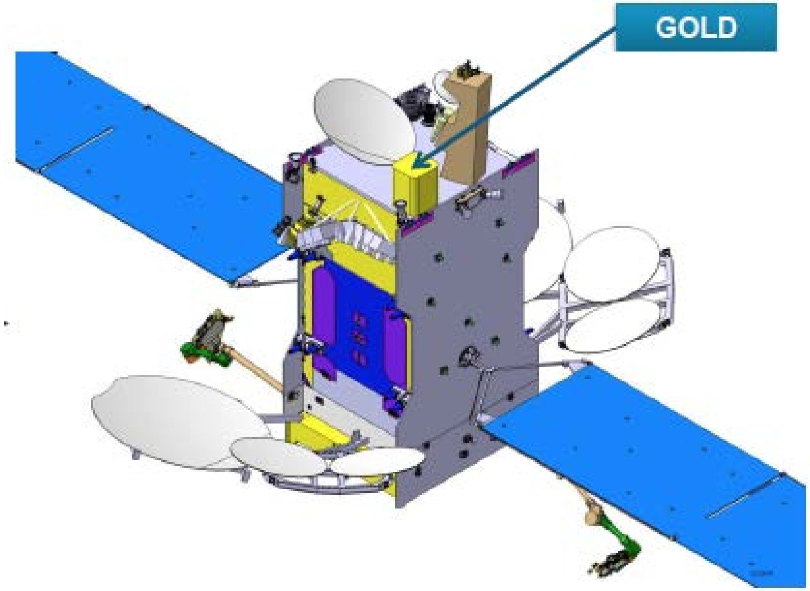
38 Eurostar 3000 satellites launched

- 7 on orbit with electric propulsion (EP) for station keeping
- 5 with EP in production
  - 2 use EP for station keeping
  - 3 use EP for orbit raising and station keeping

Eurostar 3000 satellites in development for SES

- SES-10 (67° W) – 2016 launch
- SES-11 (105° W) – 2016 launch
- SES-12 (95° E) – 2017 launch
- SES-14 (47.5° W) – Q4 2017 launch

SES-6 Launched June 3, 2013



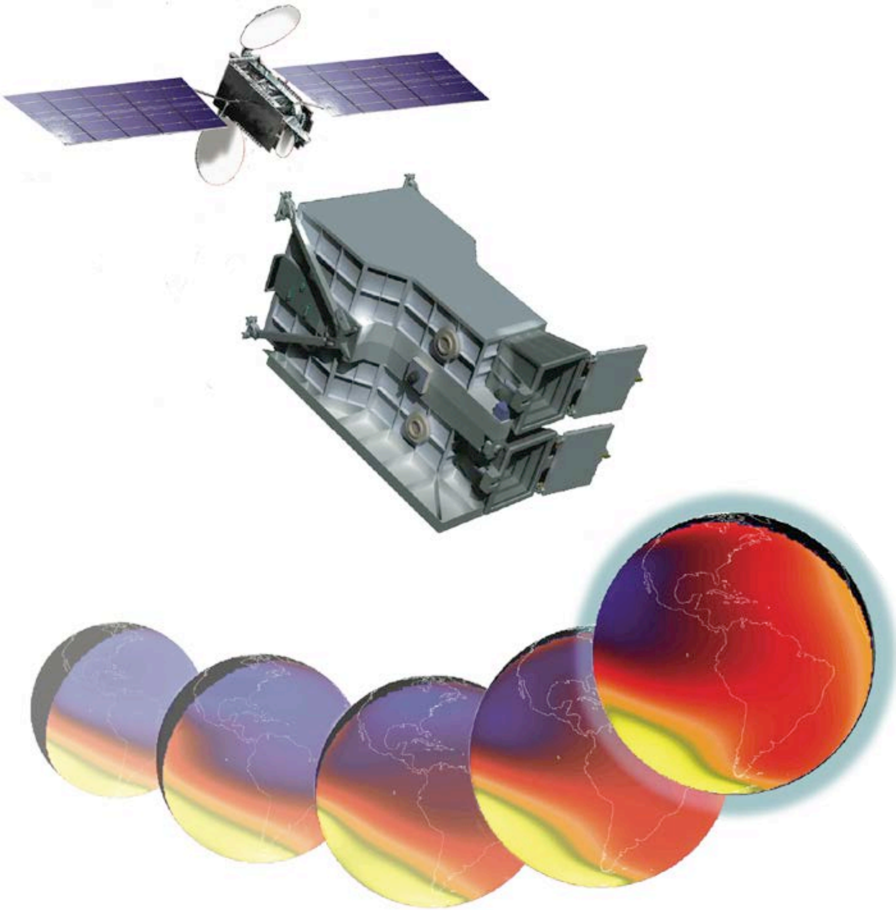
SES-14 Launch 2017 (All EP)

Imaging the Boundary Between Earth and Space

GOLD Mission of Opportunity will study how space around Earth responds to the Sun and the lower atmosphere.

GOLD will make unprecedented images of Earth's response.

GOLD FUV imager launches in 2017.

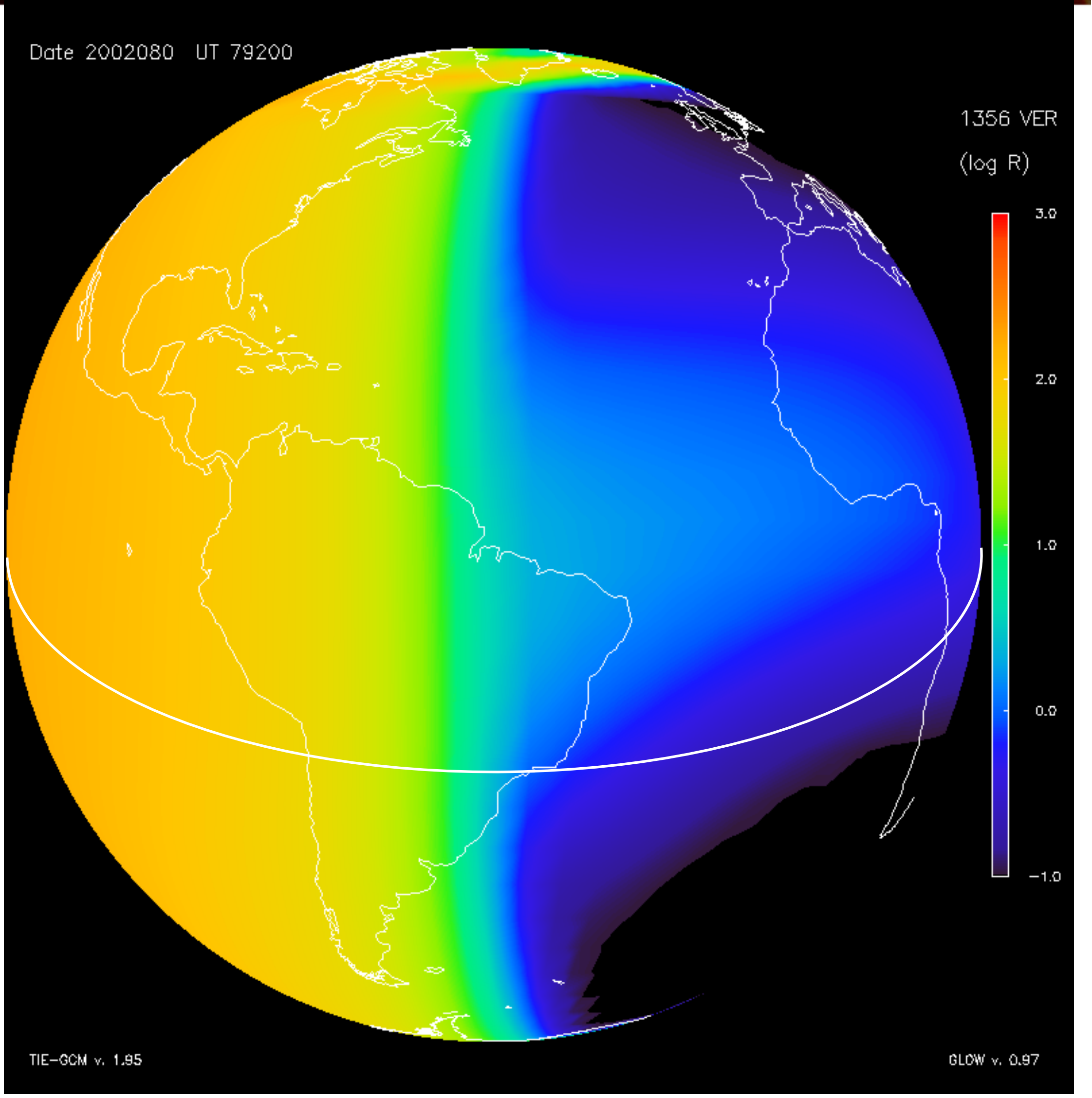


ICON and GOLD in the Big Picture

- ❑ Wind and temperature imaging, day and night with 1 minute cadence or better.
- ❑ In situ, high-precision plasma measurements, combined with North or South facing views.
- ❑ Daytime ionospheric emission profiles with highest possible S/N.

All these measurements in the FOV of the geosynchronous imaging GOLD mission every 90 minutes.

Truly an outstanding combination and an opportunity for discovery.



Heliophysics Budget FY16 Overview

Favorable Budget: Showing first real growth in a Decade

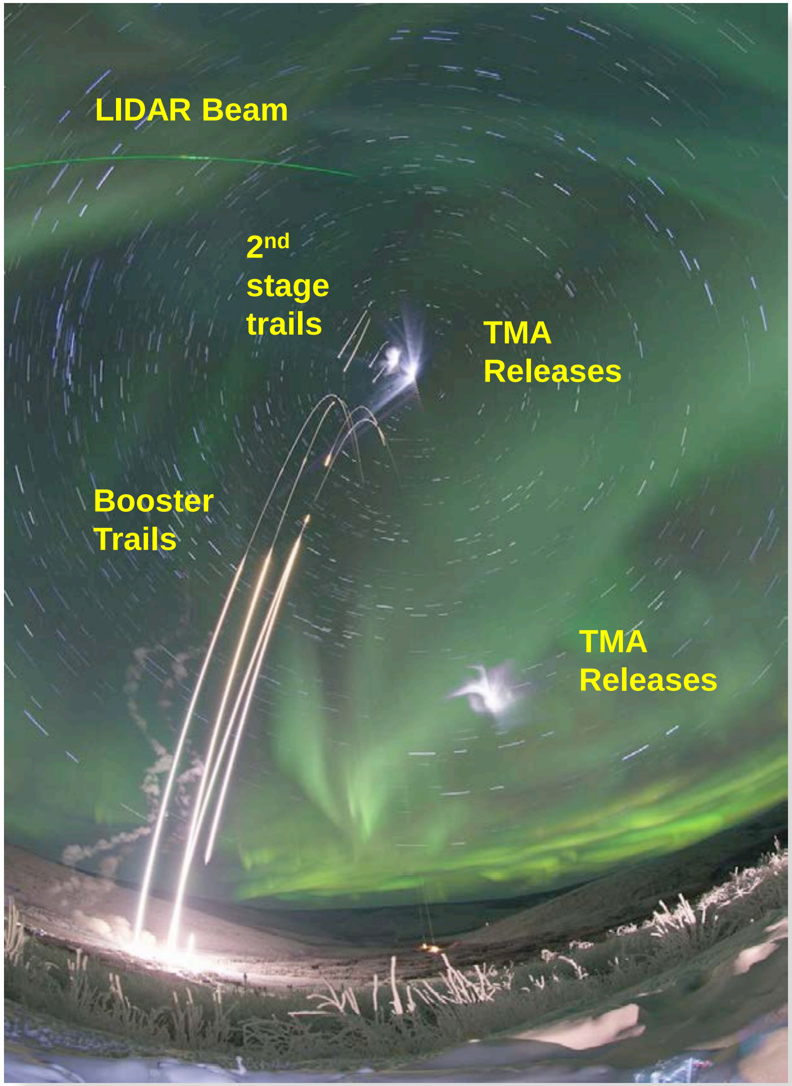
($M)	2016	2017	2018	2019	2020
Heliophysics	$651	$685	$698	$708	$722

- Meets our requirements - No surprises
- Augmentation fully implements DRIVE wedge
- Provides requested resources for current program

Sounding Rockets - Poker Campaign

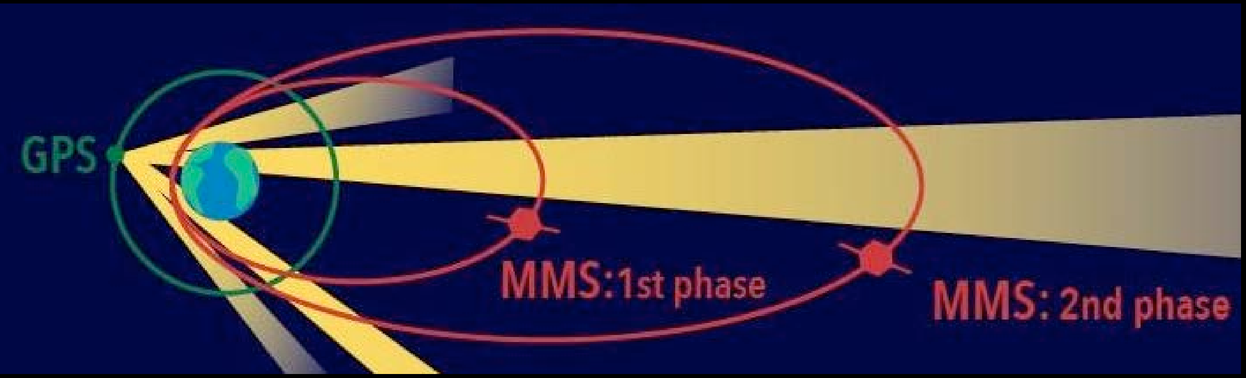
- **4 Rocket Salvo – Campaign January 13-25**
  - **Collins** /Mesospheric-Lower Thermosphere Turbulence Experiment (MTeX) - Terrier-Improved Malemute vehicles (2 ea)
  - **Larsen** / MIST / Mesospheric Inversion-layer Stratified Turbulence Experiment - Terrier-Improved Orion vehicles (2 ea)

- **Launch sequence** - After 12 nights of counting the necessary combination science and weather conditions finally occurred and all four rockets were launched as planned
  - One each Collins and Larsen rockets were launched one minute apart
  - Approximately 33 minutes later the second pair of rockets launched one minute apart
- **Mission Results**
  - Success - All four rockets flew well with no anomalies. All four payloads (support systems & experiments) functioned as planned.

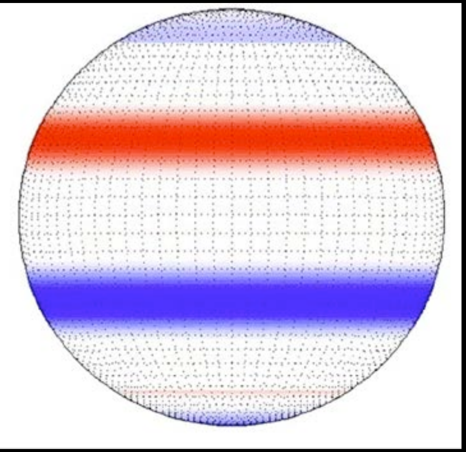


Heliophysics Science Highlights

April 2015

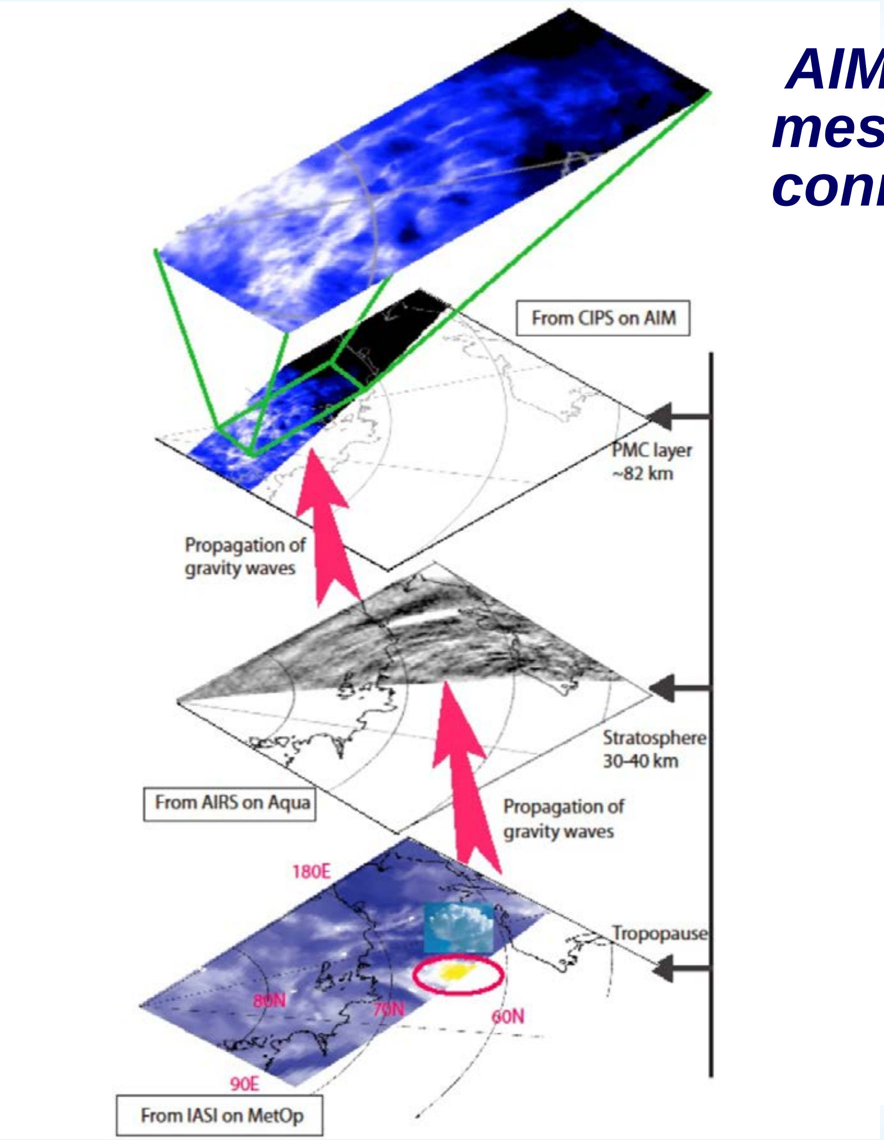


MMS Navigation System Setting Records: The onboard navigation tool on the MMS spacecraft had never before flown on a spacecraft with an orbit traveling so far from Earth. In the month and a half since launch, the MMS Navigator system has set the record for the highest GPS use in space!



Seasonal Year-Long Cycles Seen on the Sun: The solar activity cycle peaks approximately every 11 years. New research shows evidence of a shorter time cycle as well, with activity waxing and waning over the course of about 330 days. These quasi-annual variations in solar storms are driven by changes in bands of strong magnetic field located in each solar hemisphere.

Small Solar Eruptions Can Have Profound Effects on Unprotected Planets: On Dec. 19, 2006, the sun ejected a small, slow-moving puff of solar material. Four days later, this sluggish CME was powerful enough to rip away dramatic amounts of oxygen out of Venus' atmosphere and send it out into space, where it was lost forever. Learning why a small CME had such a strong impact may have profound consequences for understanding what makes a planet hospitable for life.



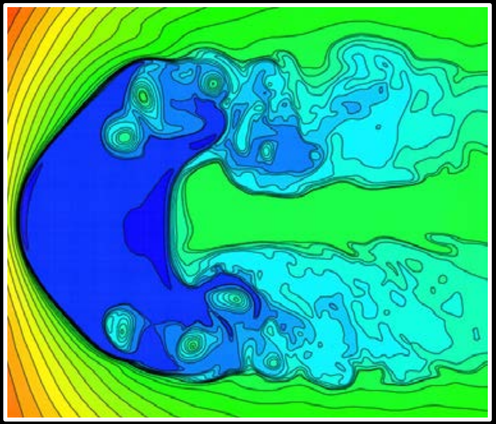
AIM, Aqua and IASA show upper mesosphere to troposphere connections

Upper tropospheric cloud disturbances occurring ~8 miles above the surface are traced through the atmosphere to the edge of space at ~50 miles altitude using three satellite instrument systems:

IASI/NetOp,
AIRS/Aqua
AIM/CIPS.

Heliophysics Science Highlights

May 2015

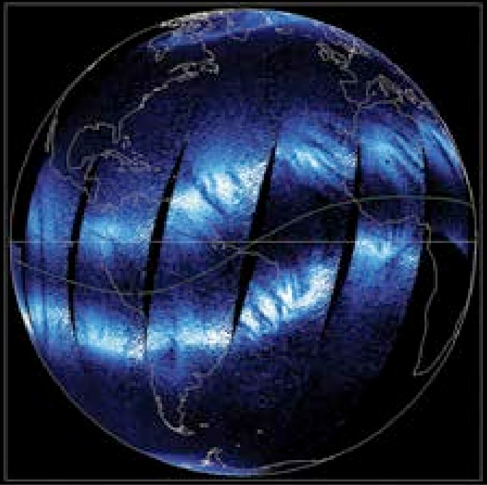


NASA-Funded Study Finds Two Solar Wind Jets in the Heliosphere:

New research suggests the heliosphere is actually dominated by two giant jets of material shooting backwards over the north and south poles of the sun, which are confined by the interaction of the sun's magnetic field with the interstellar magnetic field. These curve around in two—relatively short – tails toward the back. The end result is a heliosphere that looks a lot more like a crescent moon than a comet.

NASA's SDO Celebrates 5th Anniversary:

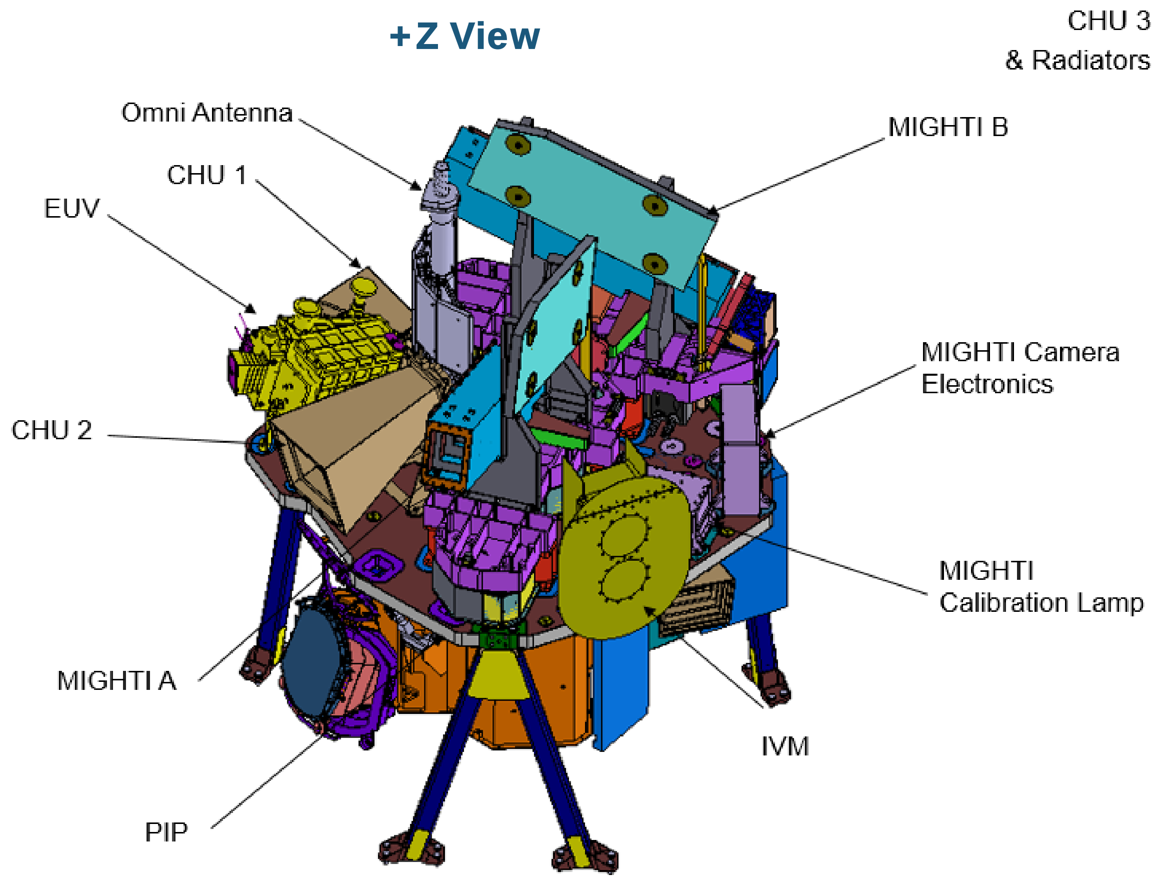
February 11, 2015 marked five years in space for NASA's Solar Dynamics Observatory or SDO, which provides incredibly detailed images of the Earth-facing side of the sun 24 hours a day. SDO has provided an unprecedentedly clear picture of how massive explosions on the sun grow and erupt ever since its launch and recently returned its 100-millionth image.

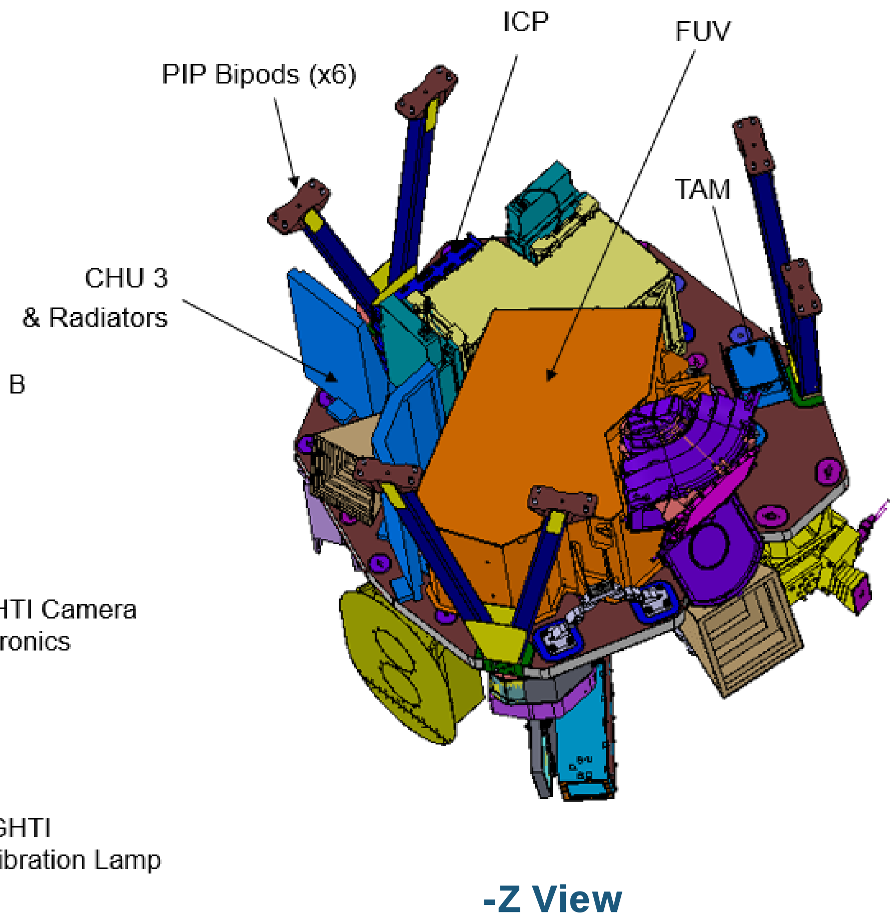


Study of Ionospheric 'Froth' May Improve GPS Communications:

A new study on irregularities in the ionosphere compares turbulence in the auroral region to that at higher latitudes, and provides insights that could have implications for the mitigation of this disturbance. The size of the irregularities in the plasma gives researchers clues about their cause, more turbulence means larger disturbances to radio signals.

ICON Payload System Description

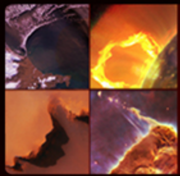




ICON and GOLD Status Update

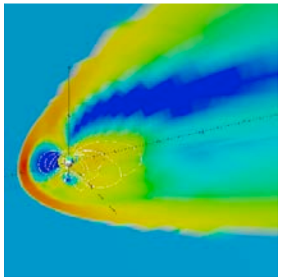
- *Ionosphere Connection Explorer (ICON)*
  - PI: Thomas Immel (University of California, Berkeley)
  - Institutions: U. of California, Berkeley; Naval Research Lab.; U. of Texas, Dallas; U. of Illinois; U. of Colorado; Astra, National Center for Atmospheric Research; Johns Hopkins Univ. Applied Physics Lab.; Orbital Space Corp.
- PDR – Jul 8-10, 2014
- KDP-C – Oct 28, 2014
- CDR – Mar 18, 2015
- LRD – Jun, 2017

- *Global-scale Observations of the Limb and Disk (GOLD)*
  - PI: Richard Eastes (University of Central Florida)
  - Institutions: U. of Colorado; National Center for Atmospheric Research; SES-Government Solutions; National Oceanic and Atmosphere Association; Computational Physics
- PDR – Dec 9-11, 2014
- KDP-C – Mar 5, 2015
- CDR – Jul 21, 2015
- LRD – Oct, 2017

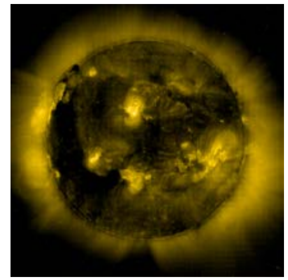


Weather in the Thermosphere-Ionosphere

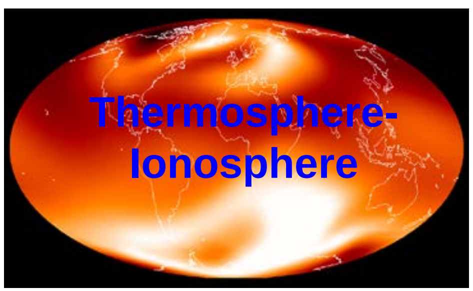
Forcing from Above



1. How do geomagnetic storms alter the temperature and composition structure of the thermosphere?

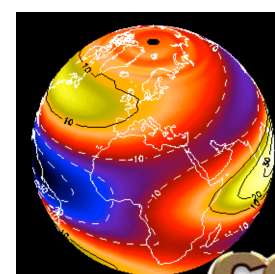


2. What is the global-scale response of the thermosphere to solar extreme-ultraviolet variability?



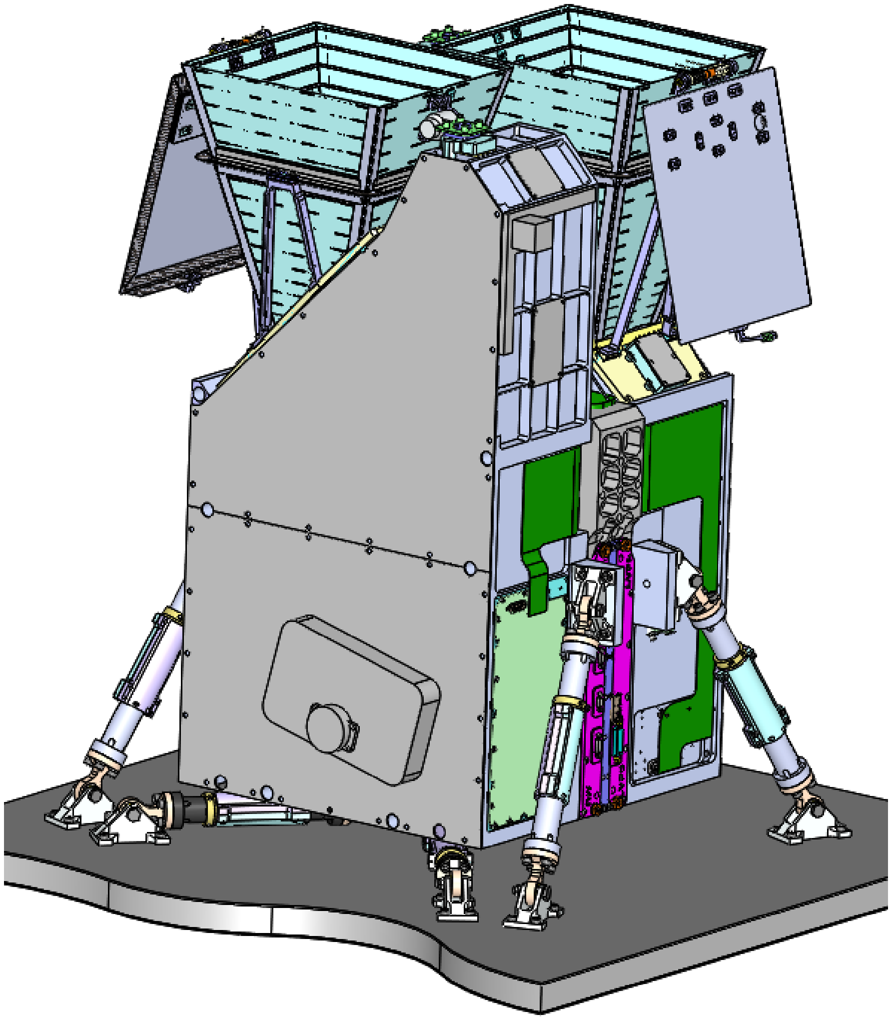
4. How does the nighttime equatorial ionosphere influence the formation and evolution of equatorial plasma density irregularities?

3. How significant are the effects of atmospheric waves and tides propagating from below on thermospheric temperature structure?



Forcing from Below

GOLD Configuration Enables Simultaneous Measurements of Composition and Temperature



Two imaging spectrometers, which independently image the limb and disk, and a single processor packaged in one housing

CU/LASP's planetary exploration experience provides the foundation for GOLD's implementation

- Cassini: Ultraviolet Imaging Spectrograph
- Messenger: Mercury Atmospheric and Surface Composition Spectrometer
- MAVEN: IUVS

Observations:

- Disk maps of $T_{neutral}$ and O/N_2 density ratio (dayside)
- T_{exo} from limb scans (dayside)
- Disk maps of N_e maximum (nightside)
- O_2 density by occultations

Earth's Space Weather Affects Satellite Based Systems

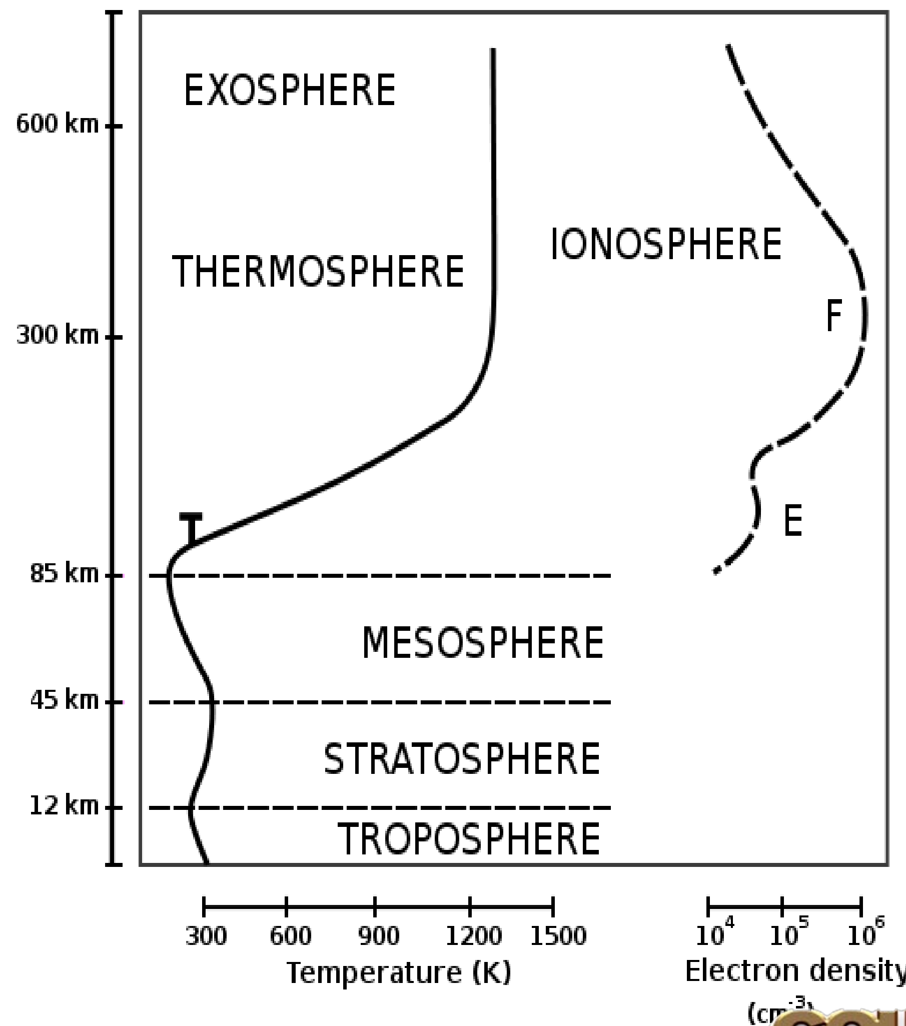
Space weather change in an hour can be almost 10 times greater than weather changes we see on Earth

Temperatures can change by 100's of degrees

Densities can change by an order of magnitude

Space weather changes the ***thermosphere*** and ***ionosphere***

These changes affect radio frequency propagation (GPS, radar, etc.) between the Earth and space



Heliophysics Presidents FY16 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Heliophysics Research	185.1	--	**158.5** ★	168.5	202.1	207.6	208.4
Living with a Star	212.5	--	**343.0**	387.3	399.9	212.6	103.3
Solar Terrestrial Probes	143.3	--	**50.5**	37.6	41.8	133.3	189.2
Heliophysics Explorer Program	100.2	--	**98.9**	91.9	54.1	154.5	221.3
Total Budget	**641.0**	--	**651.0**	**685.2**	**697.9**	**708.1**	**722.1**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

★ Decrease only due to non-Heliophysics components, i.e. DR&T, SMD-wide activity

Heliophysics FY16 Budget Top Level

FY16 Budget provides resources to allow for:	**DS Recommendation**
Funds currently operating missions per upcoming April 2015 Senior Review	0.0
Fund Missions in development (~$3.5B investment):	0.0
• Proceed with MMS for an LRD of Mar 2015 ✔	
• Proceed with SOC for LRD Oct 2018	
• Proceed with SPP development for LRD Jul 2018	
• Proceed with ICON development for LRD Oct 2017	
• Proceed with GOLD development for LRD Sep 2017	
Fund missions entering extended operations (Van Allen, IRIS, SDO)	0.0
Competed PI research award program, current (~$63M) + DRIVE augmentation (~$40M) + program growth	1.0
Maintain viable sounding rocket/Wallops research range program for the benefit of SMD	1.0
Utilize mission wedge for future missions	2.0, 3.0

Heliophysics Research Program

Research Program has strong growth in all of its elements beginning in FY16 and in notional future budgets.

- Highest priority: Significant funding wedge for DRIVE implementation
  - Growth in Research & Analysis (includes LCAS, Instrument & Technology Development, Theory, etc.), Guest Investigator, LWS Targeted Research & Technology
- As in the past, Research Program contains elements that are Science Mission Directorate (SMD) pass-throughs, i.e. bookkeeping for non-Heliophysics funds. These include “Science Planning and Research Support” and “Directed Research and Technology.” The latter had a significant decrease, but no decrease to “Heliophysics” research budget since these are funds for other SMD activities.
- Sounding Rocket Program Office budget had no decrease. This budget line funds the infrastructure part of the program, changes reflect planned multi-year phasing of budget allocations, i.e., shifting from FY16 to FY15 of some funds to meet procurement needs.

Heliophysics Explorer Program

- Second priority
- Budget reflects strong growth in notional out-year budgets.
- Notional budget future years projects funding for the launch of ICON and GOLD, as well as the beginning development of new Explorer missions.

Heliophysics Strategic Mission Lines: LWS/STP

The FY16 budget fully funds the missions in development, and shows a healthy budget for future missions in the notional out-years.

- Third Priority

- Near-term budget reflects planned phasing of missions in development (MMS, SOC, SPP).

- Given the size of these missions relative to our total budget, the Strategic missions lines (STP, LWS) are not flat. Rather, funding levels are set at mission Confirmation and allocated as required.

ROSES 2015 Update

The information below is now available through NSPIRES.

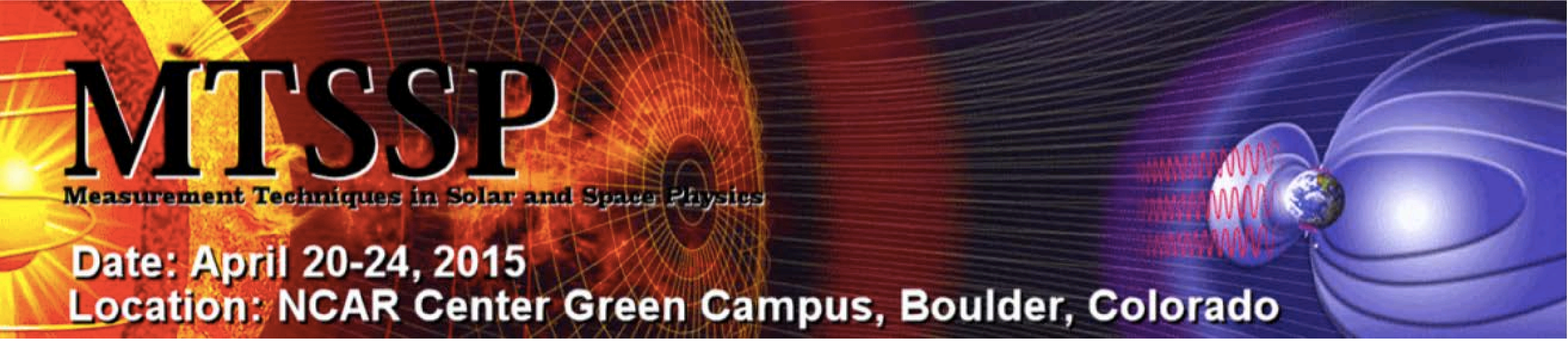
- **Two-Step Process**
  - All Heliophysics ROSES Solicitations Will Continue Utilizing the Two-Step Process
  - Encourage/Discourage Process Successful in ROSES14 H-GI, H-SR
  - **H-GI, H-SR: Encourage/Discourage in Step 1**. Three-Page Step-1 Proposals Required
  - **H-LWS, H-TIDeS and H-IDEE Step-1**: Single-Page, Team Fixed, **Compliance Check Only**
- **Duplicate Proposals: Risk Noncompliance**

ROSES 2015 Program Elements

- **Guest Investigator (H-GI)**
  - Open- primary emphasis is the analysis of data from currently-operating missions of the Heliophysics System Observatory (HSO)
- **Supporting Research (H-SR)**
  - Highest priority will be proposals that use data from current or historical NASA spacecraft together with theory and/or numerical simulation to address Heliophysics Decadal Survey goals
- **Living With a Star (H-LWS)**
  - Strategic Capabilities not competed
  - Cross-disciplinary proposals
  - Focus Topics, VarSITI,
- **Technology and Instrument Development for Science (H-TIDeS)**
  - Low Cost Access to Space
  - Instrument and Technology Development
  - Laboratory Nuclear, Atomic, and Plasma Physics
- **Grand Challenge Research (H-GCR)**
  - Currently Fully Subscribed. Not Competed in ROSES15.
- **Infrastructure and Data Environment Enhancements (H-IDEE)**
  - Only Data Environment Enhancements, no infrastructure. Heliophysics Data Services CAN: Solicited Outside ROSES

Where is the Heliophysics Division Going?

- **Summary**
  - 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 FY16 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 FY2016, STP 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)**
- **Congrats to George Doschek and Jonathan Cirtain for their prizes!**



- Goals:
  (a) identify techniques and technology to advance Decadal Survey
  (b) survey and document remote and *in situ* measuring techniques
- Four focus areas: particles, fields, photons, ground-based
- 220 participants, 192 talks, 76 posters, 26 students
- Four-volume publication plan: Space Science Reviews in 2016
- Jointly sponsored by NASA Heliophysics and NSF Geospace
- Convened by James Spann (MSFC) and Thomas Moore (GSFC)
- Enthusiastic response demonstrates solar and space physics community cohesion and solidarity in pursuit of Heliophysics Decadal Survey science objectives through the development of NASA space missions and NSF research programs.
- Meeting details: https://mtssp.msfc.nasa.gov

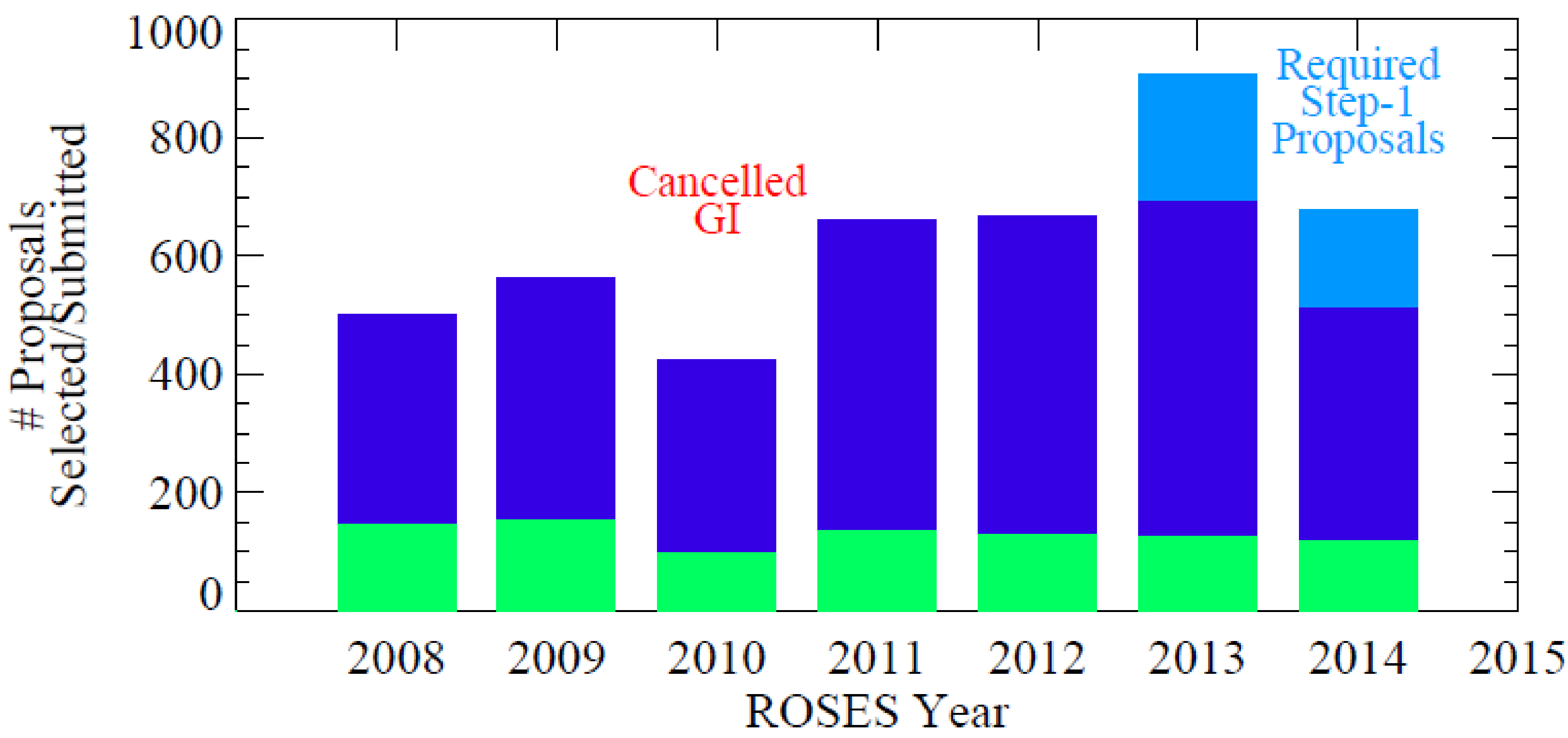
Tell us about interesting results before they are published!

Heliophysics - Our Dynamic Space Environment: Science and Technology Roadmap for 2014-2033

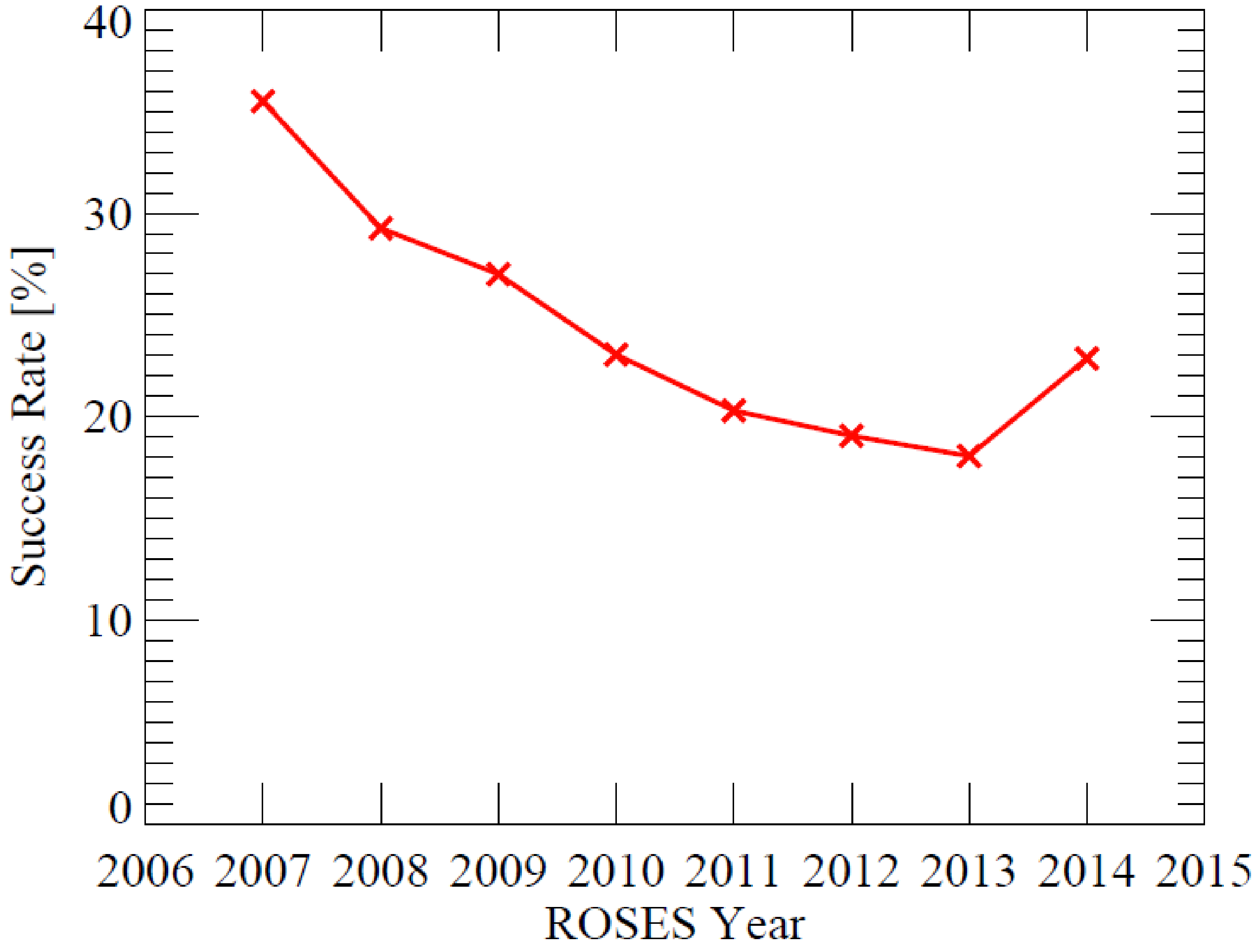
http://science.nasa.gov/heliophysics

Backup

ROSES: Research Proposal Submission Stats



Updated ROSES Proposal Success Rates



HELIOPHYSICS RESEARCH

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Research Range	21.8	--	**21.6**	21.7	21.7	21.7	21.7
Sounding Rockets	53.4	--	**48.3**	53.3	59.0	61.1	63.1
Heliophysics Research and Analysis	33.5	--	**34.0**	33.9	48.9	53.9	53.9
Other Missions and Data Analysis	76.4	--	**54.6** ★	59.6	72.5	71.0	69.7
Total Budget	**185.1**	--	**158.5**	**168.5**	**202.1**	**207.6**	**208.4**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

★ Decrease only due to non-Heliophysics components, i.e. DR&T, SMD-wide activity

Living with a Star

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Solar Probe Plus	121.4	179.2	**230.4**	226.5	323.7	100.4	25.2
Solar Orbiter Collaboration	39.4	31.5	**62.9**	112.2	19.3	42.8	2.3
Other Missions and Data Analysis	51.7	--	**49.7**	48.7	56.9	69.4	75.9
Total Budget	**212.5**	--	**343.0**	**387.3**	**399.9**	**212.6**	**103.3**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

Solar Terrestrial Probes

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Magnetospheric Multiscale (MMS)	120.9	52.4	**30.1**	17.5	10.8	0.0	0.0
Other Missions and Data Analysis	22.4	--	**20.4**	20.1	31.0	133.3	189.2
Total Budget	**143.3**	--	**50.5**	**37.6**	**41.8**	**133.3**	**189.2**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

Heliophysics Explorer Program

FY 2016 Budget

	Actual	Enacted	Request	Notional			
Budget Authority (in $ millions)	**FY 2014**	**FY 2015**	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**
ICON	59.8	61.0	**49.8**	48.0	9.0	4.5	1.3
Other Missions and Data Analysis	40.4	--	**49.2**	43.9	45.1	150.1	220.0
Total Budget	**100.2**	--	**98.9**	**91.9**	**54.1**	**154.5**	**221.3**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

Heliophysics President's FY16 Budget

	Op Plan	Enacted		Notional			
	FY14	FY15	FY16	FY17	FY18	FY19	FY20
Heliophysics	**641.0**		**651.0**	**685.2**	**697.9**	**708.1**	**722.1**
Heliophysics Research	185.1		158.5	168.5	202.1	207.6	208.4
Heliophysics Research and Analysis	33.5		34.0	33.9	48.9	53.9	53.9
Sounding Rockets	53.4		48.3	53.3	59.0	61.1	63.1
Research Range	21.8		21.6	21.7	21.7	21.7	21.7
Other Missions and Data Analysis	76.4		54.6	59.6	72.5	71.0	69.7
CubeSat	5.0		5.0	5.0	5.0	5.0	5.0
Voyager	5.4		5.7	5.6	5.6	5.6	5.5
SOHO	2.2		2.2	2.2	2.2	2.2	2.2
WIND	2.2		2.2	2.2	2.2	2.0	2.0
Geotail	0.5		0.2	0.2	0.2	0.2	0.2
CLUSTER-II	0.6						
Space Science Mission Ops Services	10.9		11.5	11.5	11.5	11.6	11.9
Solar Data Center	1.0		1.0	1.0	1.0	1.0	1.0
Data & Modeling Services	3.1		2.8	2.8	2.8	3.0	3.0
Community Coordinated Modeling Center	2.0		2.0	2.0	2.0	2.1	2.1
Space Physics Data Archive	2.0		2.0	2.0	2.0	2.0	2.0
Guest Investigator Program	8.1		10.5	10.3	19.2	24.3	22.7
Science Planning and Research Support	6.3		6.6	6.7	6.8	6.8	6.8
Heliophysics Directed R&T	27.2		2.9	8.0	11.9	5.3	5.3

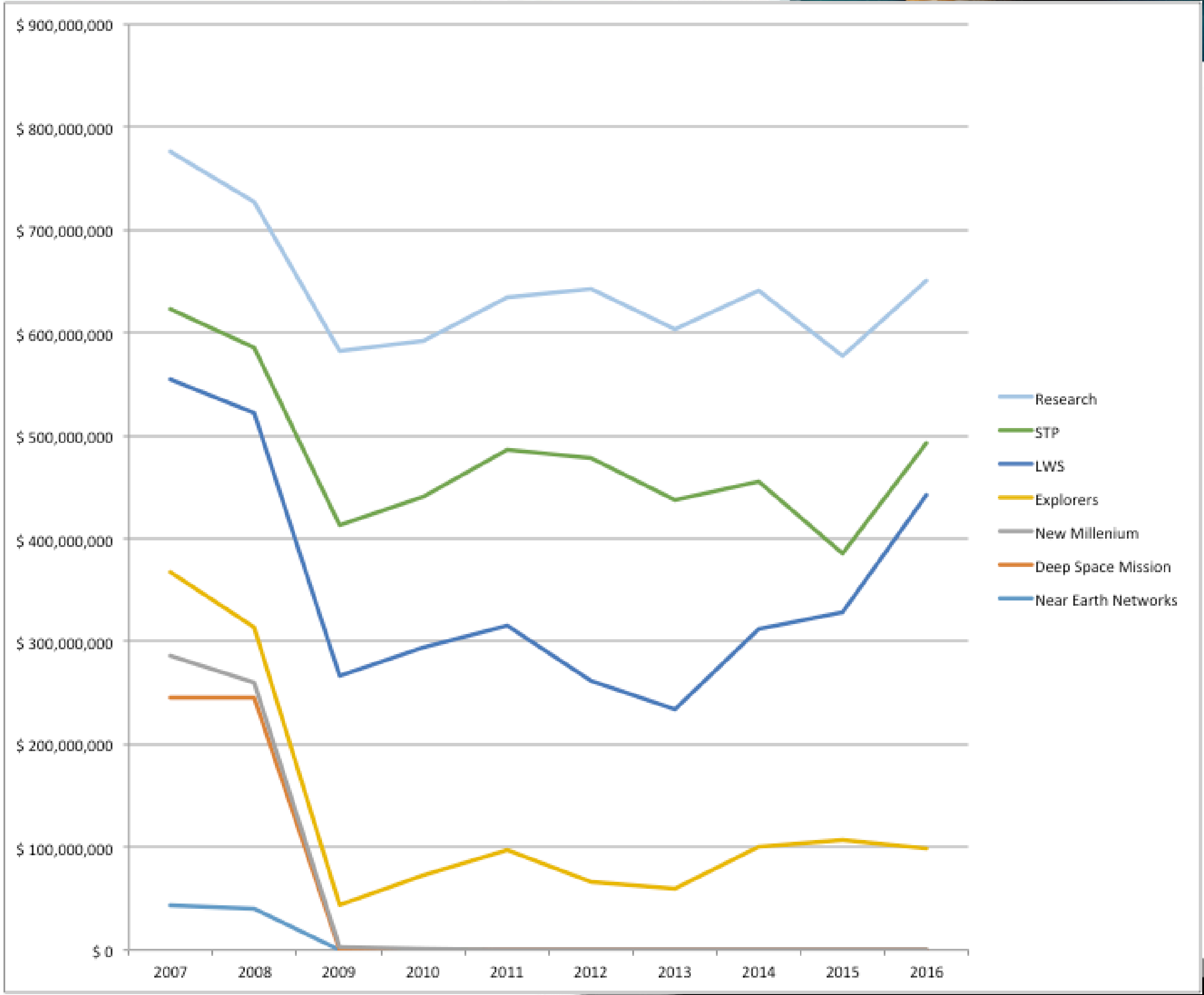
Heliophysics President's FY16 Budget (cont'd)

	Op Plan	Enacted		Notional			
	FY14	FY15	FY16	FY17	FY18	FY19	FY20
Living with a Star	212.5		343.0	387.3	399.9	212.6	103.3
Solar Probe Plus	121.4	179.2	230.4	226.5	323.7	100.4	25.2
Solar Orbiter Collaboration	39.4	31.5	62.9	112.2	19.3	42.8	2.3
Other Missions and Data Analysis	51.7		49.7	48.7	56.9	69.4	75.9
Van Allen Probes (RBSP)	10.8		15.5	14.3	14.0	14.0	10.0
Solar Dynamics Observatory (SDO)	14.8		9.5	9.5	9.5	9.5	9.5
LWS Space Environment Testbeds	0.6		0.4	0.4			
BARREL	1.5						
LWS Science	18.2		17.5	17.5	25.5	30.5	29.5
Program Management and Future Missions	5.9		6.7	6.9	7.8	15.3	26.8
Solar Terrestrial Probes	143.3		50.5	37.6	41.8	133.3	189.2
Magnetospheric Multiscale (MMS)	120.9	52.4	30.1	17.5	10.8		
Other Missions and Data Analysis	22.4		20.4	20.1	31.0	133.3	189.2
STEREO	9.5		9.5	9.5	9.5	9.5	9.5
Hinode (Solar B)	8.0		7.3	7.0	7.0	7.0	7.0
TIMED	2.9		2.7	2.6	2.5	2.5	2.5
Program Management and Future Missions	2.0		1.0	1.0	12.0	114.4	170.2

Heliophysics President's FY16 Budget (cont'd)

	Op Plan	Enacted		Notional			
	FY14	FY15	FY16	FY17	FY18	FY19	FY20
Heliophysics Explorer Program	100.2		98.9	91.9	54.1	154.5	221.3
ICON	59.8	61.0	49.8	48.0	9.0	4.5	1.3
Other Missions and Data Analysis	40.4		49.2	43.9	45.1	150.1	220.0
GOLD	9.4		17.5	14.8	8.6	2.8	0.7
IRIS	8.6		7.7	7.7	7.0	7.0	6.5
THEMIS	5.4		4.6	4.5	4.5	4.5	4.5
Interstellar Boundary Explorer (IBEX)	3.6		3.4	3.4	3.4	3.4	3.4
Aeronomy of Ice in Mesophere	3.0		3.0	3.0	3.0	3.0	3.0
ACE	3.0		3.0	3.0	3.0	3.0	3.0
RHESSI	2.1		1.9	1.9	1.9	1.9	1.9
TWINS	0.6		0.6	0.6	0.6	0.6	0.6
CINDI	0.9		0.6	0.3	0.2		
Heliophysics Explorer Future Missions					4.0	115.2	187.2
Heliophysics Explorer Program Management	3.8		6.8	4.7	8.9	8.7	9.1

Long Term Budget



Decadal Survey Summary for NASA (in order of priority)

1. **Complete implementation of missions that are currently selected**; maintain cost and schedule commitments. This includes RBSP (renamed Van Allen Probes), MMS, Solar Probe Plus, Solar Orbiter, along with IRIS and other already selected Explorers.
2. **Initiation of the DRIVE program** as an augmentation to the existing enabling research program. The DRIVE components provide for operation and exploitation of the Heliophysics System Observatory for effective research programs. The community must be equipped to take advantage of new innovative platforms.
3. **Execution of a robust Explorer program** with an adequate launch rate, including missions of opportunity (MOOs). The cadence should be accelerated to accomplish the important science goals that do not require larger missions and to provide access to space for all parts of the discipline.
4. **Launch of strategic missions in the reinvigorated STP line and in the LWS line** to accomplish the committee's highest-priority science objectives. This includes first the notional IMAP investigation and then DYNAMIC and MEDICI in the STP program and GDC as the next larger-class LWS mission.

Decadal Survey Decision Rules (in recommended order)

1. Missions in the STP and LWS lines should be reduced in scope or delayed to accomplish higher priorities.
2. If further reductions are needed, the recommended increase in the cadence of Explorer missions should be scaled back, with the current cadence maintained as the minimum.
3. If still further reductions are needed, the DRIVE augmentation profile should be delayed, with the current level of support for elements in the NASA research line maintained as the minimum.