



EXPLORESCIENCE

NASA Vision for Implementation of the Heliophysics Space Weather Science and Applications Program

James Spann, Space Weather Lead

NASA Heliophysics Division

SWEF, June 26, 2019

The Dawn of a New Era for Heliophysics

Heliophysics Division (HPD), in collaboration with its ***partners***, is poised like never before to:

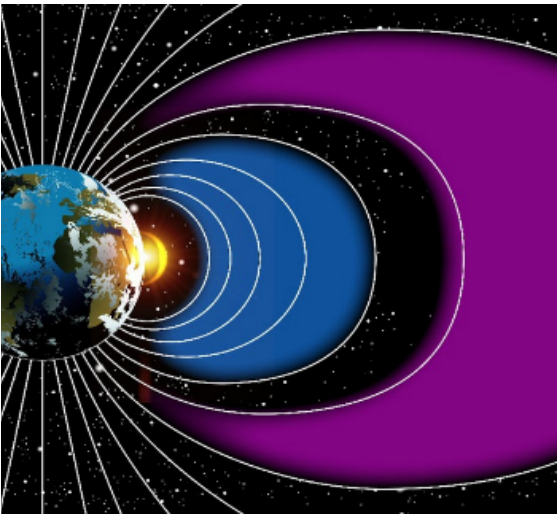
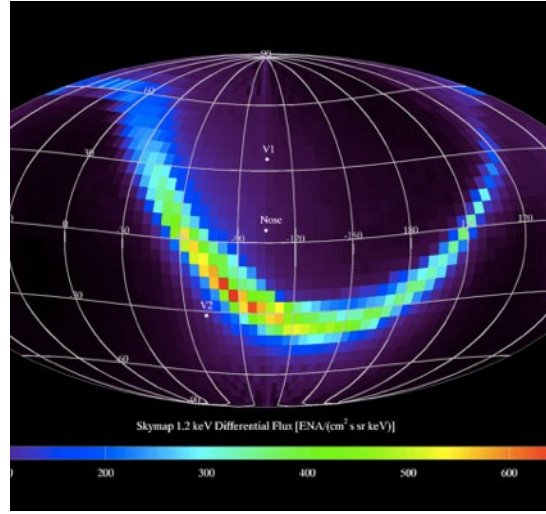
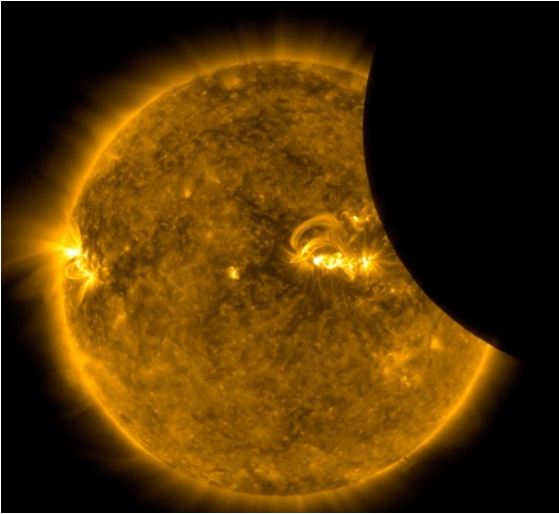
Strategically advance understanding of solar and space physics, make ***amazing discoveries***

Augment the Helio fleet with ***new missions*** and a robust ***suborbital*** program

Fulfill its role for the Nation enabling advances in ***space weather***

Engage the public with science knowledge and citizen science

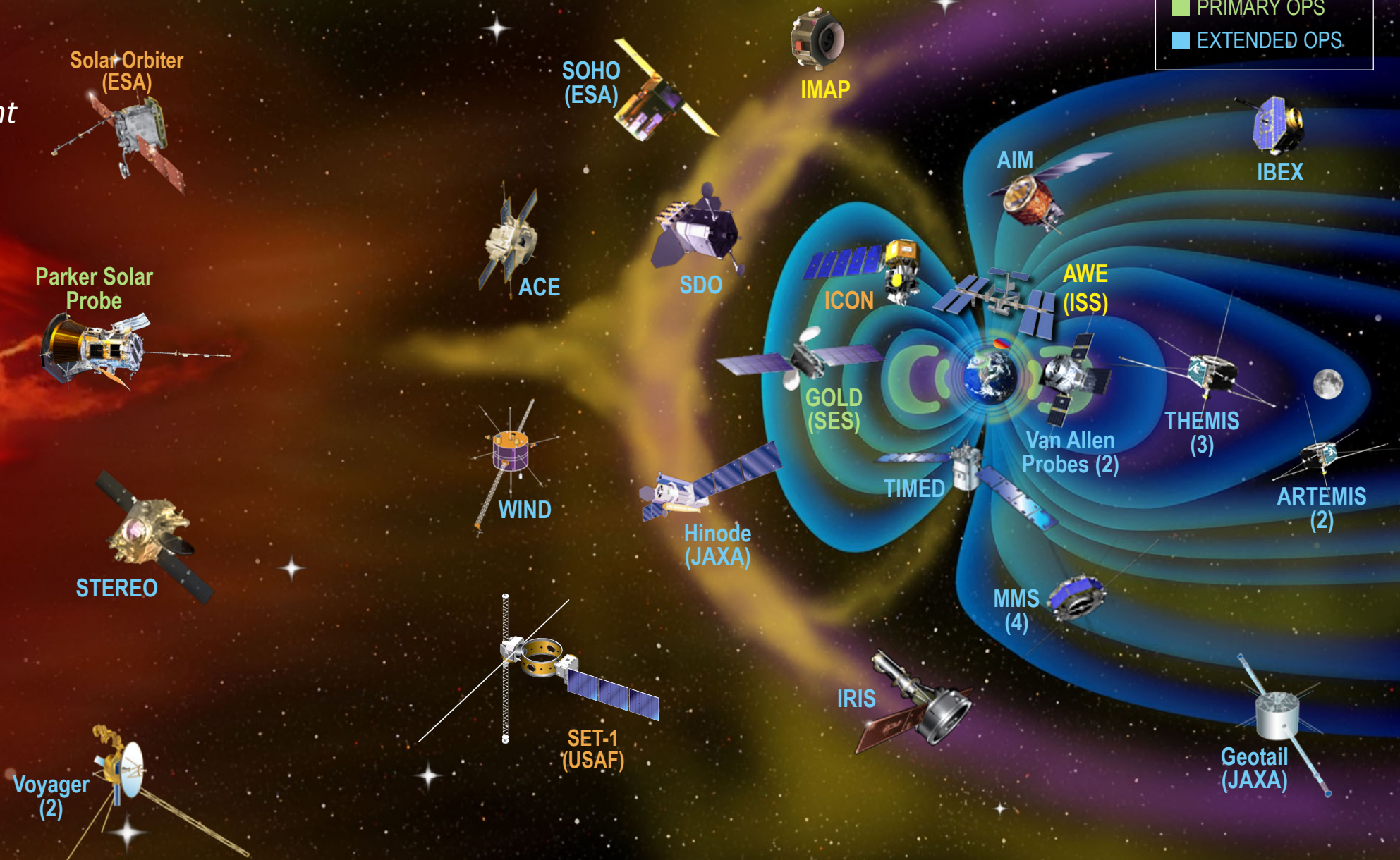
Develop the ***next generation*** of heliophysicists



Heliophysics System Observatory

■ FORMULATION
■ IMPLEMENTATION
■ PRIMARY OPS
■ EXTENDED OPS

- 18 Operating Missions with 26 Spacecraft
- 3 Missions in Development
- 1 Mission in Formulation
- 1 Mission of Opportunity in Formulation



The background of the slide is a composite image of space. The top half features a dark blue and black space filled with numerous small, bright stars and a prominent, wispy blue nebula on the right side. The bottom half is a gradient of orange and yellow, also filled with stars and a faint, glowing greenish-yellow nebula. A light blue horizontal band runs across the middle, containing the title text.

Space Weather Science and Applications

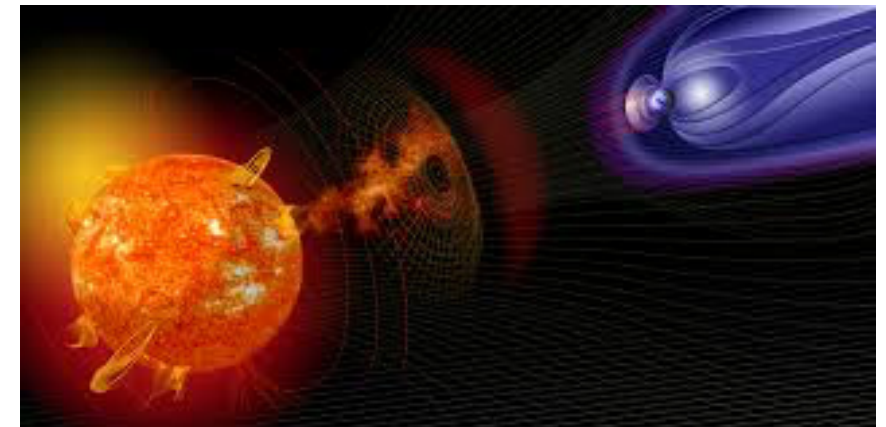
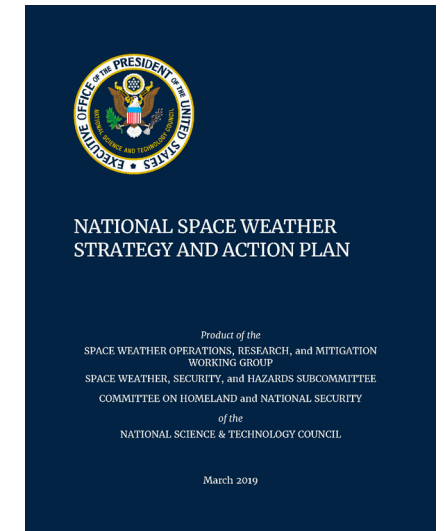
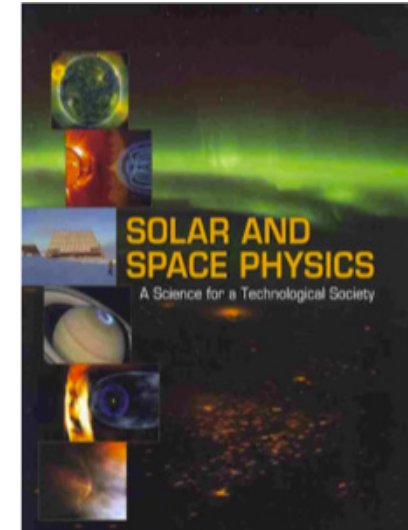


Space Weather Science and Applications (SWxSA)

- A new program in the NASA Heliophysics Portfolio
- Totally integrated into and consistent with the goals, research investigations, missions, and technology of the NASA Heliophysics Division
- Does not impact the Heliophysics Division research and mission resources

Space Weather Science and Applications (SWxSA)

- Establishes an expanded role for NASA in space weather science under single budget element
 - Consistent with the recommendation of the NRC Decadal Survey and the OSTP/SWORM 2019 National Space Weather Strategy and Action Plan
- **Competes** ideas and products, **leverages** existing agency capabilities, **collaborates** with other agencies, and **partners** with user communities
- Distinguishable from other heliophysics research elements in that it is specifically focused on investigations that significantly advance understanding of space weather and then apply this progress to enable more accurate characterization and predictions with longer lead time
- Transition tools, models, data, and knowledge from research to operational environments



Space Weather Science Applications

3 calls were made between ROSES 2017 and ROSES 2018 in Space Weather Operations-to-Research (SWO2R)

- 8 selections made for ROSES 2017 SWO2R
 - Focus: Improve predictions of background solar wind, solar wind structures, and CMEs
- 9 selections made for ROSES 2018 (1) SWO2R
 - Focus: Improve specifications and forecasts of the energetic particle and plasma encountered by spacecraft
- ROSES 2018 (2) SWO2R selections upcoming:
 - Focus: Improve forecasts of solar energetic particles and heavy ions
- ROSES 2019 SWO2R step 1/2 proposals due December 2019/February 2020

Small Business Innovation Research (SBIR) Program for Space Weather

- 2018 - Selected two Phase 2 proposals
- 2019 –Phase 1 proposals in review

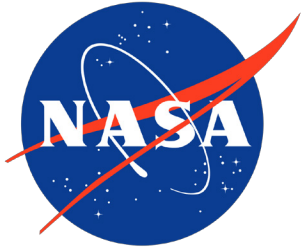




Ongoing Steps for SWxSA

- Develop the NASA Heliophysics Space Weather Science and Applications Strategic Plan
- Develop with Human Exploration & Operations Mission Directorate (HEOMD) a lunar space environment capability to safeguard human and robotic explorers beyond low-earth-orbit
- Explore options for
 - Strategic instrument development
 - Robust multipurpose space weather package for rideshare opportunities
- Secure counsel of community expertise through the Heliophysics Advisory Committee
- Work in concert with the OSTP Space Weather Operations, Research, and Mitigation (SWORM) Working Group and in accordance to the 2019 National Space Weather Strategy and Action Plan (NSW-SAP)

Interagency Partners



NASA-NOAA (MOU):

- Collaboration between GSFC/CCMC and NOAA/SWPC on space weather modeling capability
- Collaboration between JSC/SRAG and NOAA/SWPC
- Co-funding O2R proposals
- Accommodation for SWFO mission on IMAP launch

NASA-NSF (MOU):

- Coordinating ICON & GOLD opportunities (joint NASA mission GI and NSF CEDAR solicitations)
- Consulted on solicitation design for Science Centers

- Co-funding CCMC

- New opportunity focused on Computational Aspects of Space Weather

NASA-NSF-NOAA (MOU):

- Pilot O2R research activity, MOU

NASA-USGS:

- NASA collaborating with USGS to enable Magneto-Telluric Survey in southwest

NASA-NSF-NOAA-DoD (in work):

- Preparing Quad-Agency MOU focused on Space Weather

The background of the slide is a composite of two cosmic images. The top half features a dark space filled with numerous small, distant stars and a prominent, wispy blue nebula on the right side. The bottom half shows a similar starry field but with a large, vibrant orange and yellow nebula on the left, transitioning into a greenish-blue nebula on the right. A solid light blue horizontal band runs across the middle of the slide, serving as a backdrop for the title.

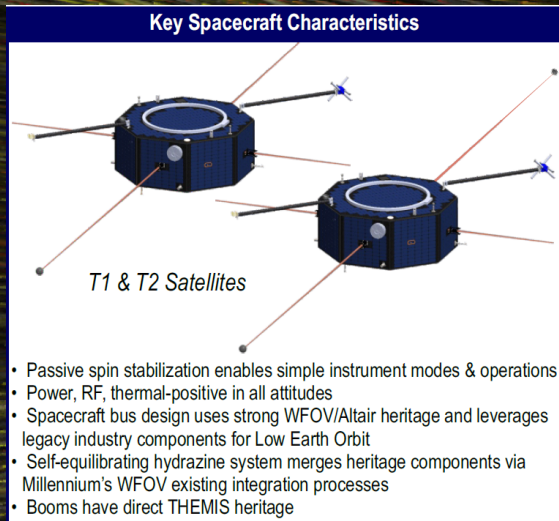
Missions



2016 SMEX Selections

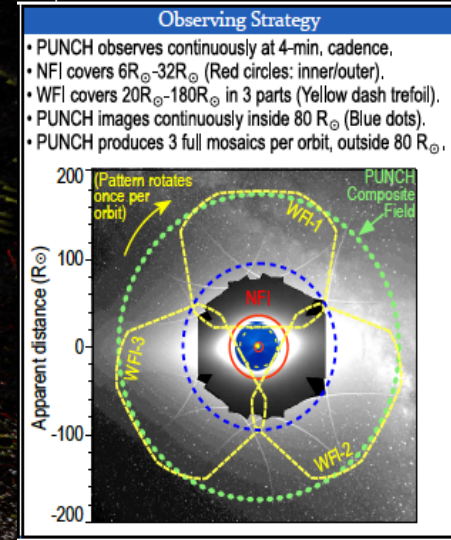
TRACERS

Tandem
Reconnection and
Cusp
Electrodynamics
Reconnaissance
Satellites



PUNCH

Polarimeter to Unify
the Corona and
Heliosphere



“We carefully selected these two missions not only because of the high-class science they can do in their own right, but because they will work well together with the other heliophysics spacecraft advancing NASA’s mission to protect astronauts, space technology and life down here on Earth,” said Thomas Zurbuchen, associate administrator for the Science Mission Directorate at NASA Headquarters in Washington.

Enhanced and Tandem Beacon Experiment (E-TBEx)

Launch Vehicle: Falcon Heavy

Rideshare: w/Space Test Program-2 multi-manifest launch – total of 23 satellites

Launch Site: Cape Canaveral

LRD: NET June 24, 2019

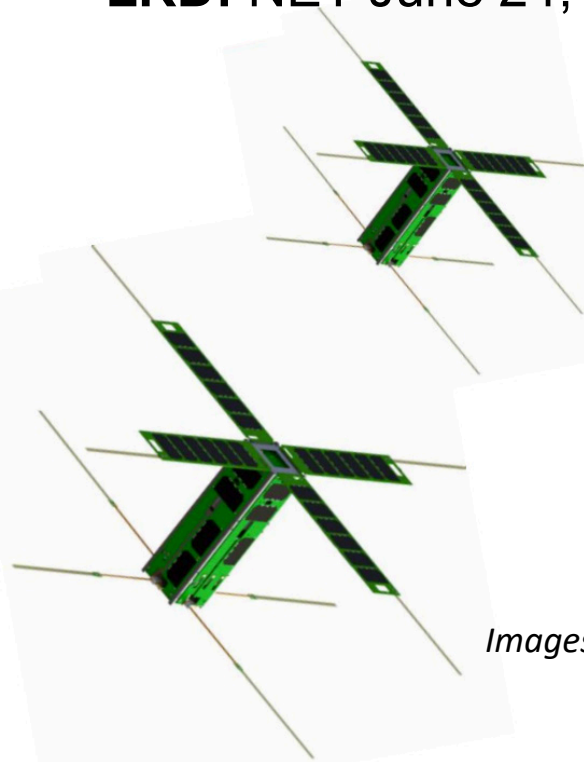
Principal Investigator: Ronald Tsunoda
(SRI/University of Michigan)

Description:

- Pair of 3U CubeSats each carrying tri-frequency radio beacons
- Measures how radio signals can be distorted by large bubbles that form naturally in the Earth's charged upper atmosphere
- Tracks how the ionosphere disrupts signals by monitoring, from the ground, beacon tones transmitted from eight orbital locations: the six COSMIC-2 spacecraft (NOAA) and the twin E-TBEx CubeSats (NASA)

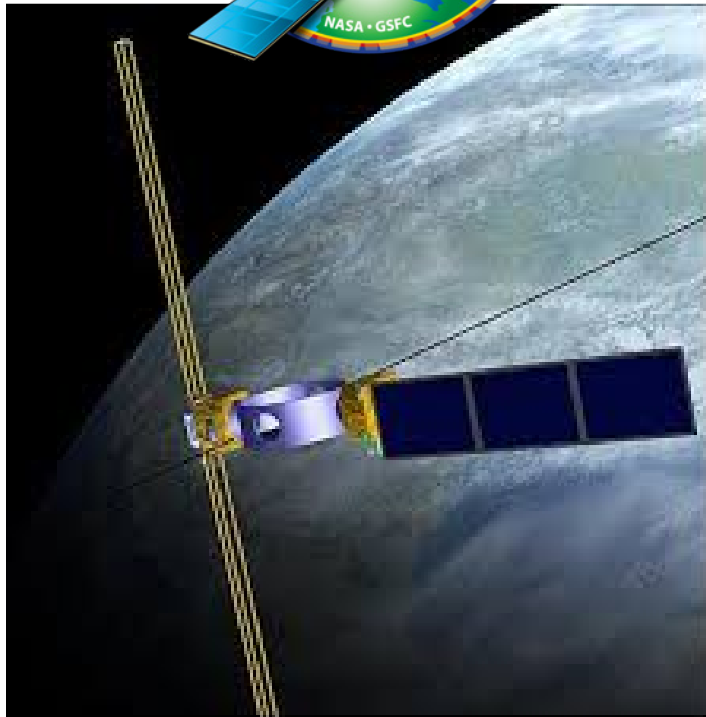
Impact:

- These bubbles interfere with communications and GPS in large regions near Earth's magnetic equator



Images from CubeSat Workshop Apr 2018

Space Environment Testbed (SET-1) Mission



Mission Line: Living With a Star

Launch Vehicle: Falcon Heavy

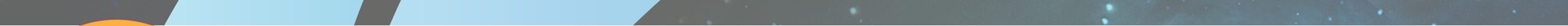
Launch Site: KSC

LRD: June 24, 2019

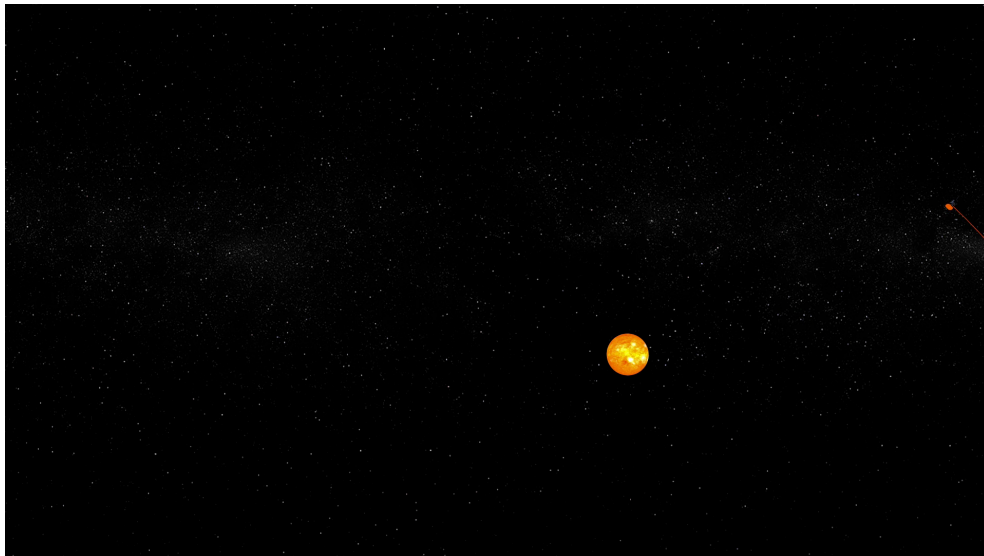
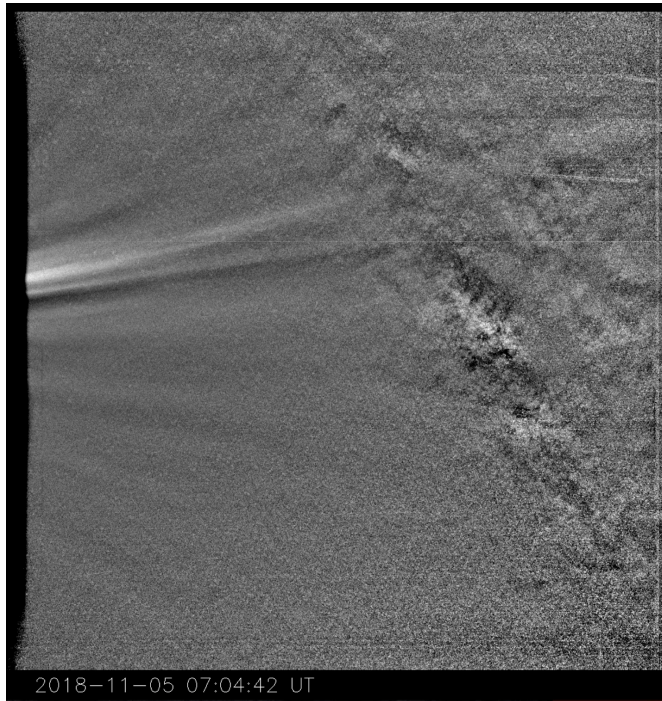
Observatory: SET-1 hosted payload on Air Force Research Laboratory (AFRL) Demonstration and Science Experiments (DSX) spacecraft

Description:

- Define the mechanisms for induced space environment and effects
- Reduce uncertainties in the definitions of the induced environment and effects on spacecraft and their payloads
- Improve design and operations guidelines and test protocols so that spacecraft anomalies and failures due to environmental effects during operations are reduced



WISPR image from Nov 5, 2018 showing a complex streamer structure being obscured by the Milky Way

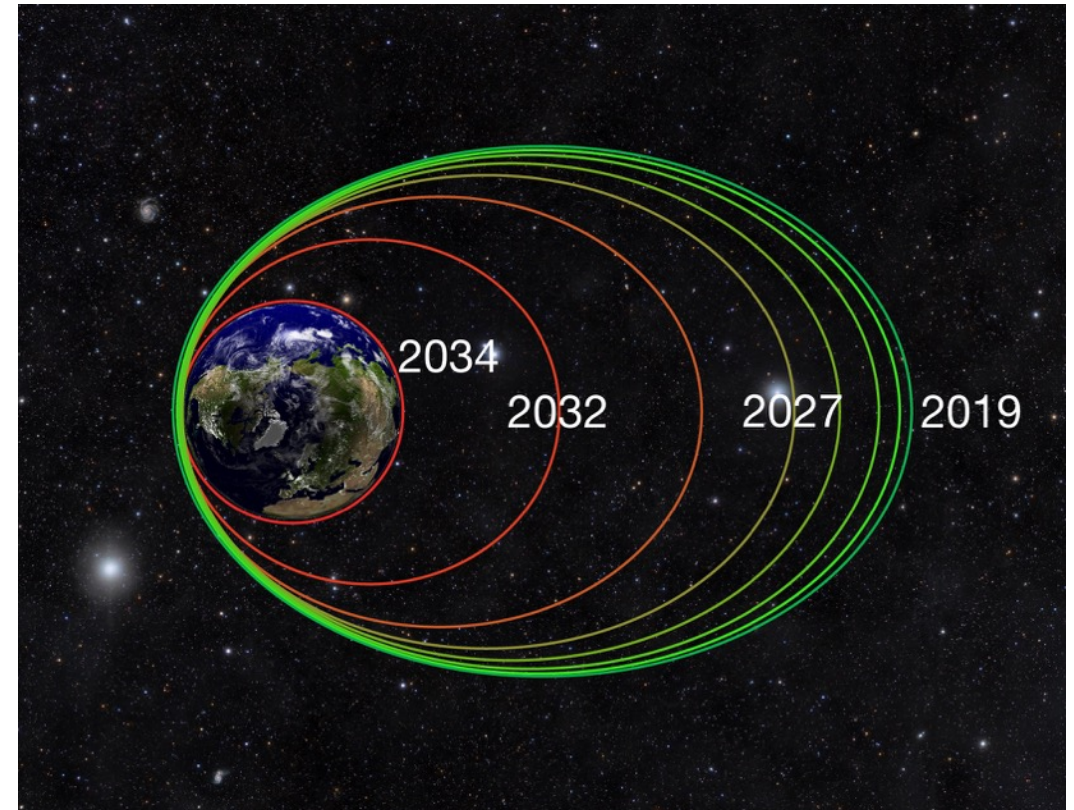


Parker Solar Probe

- First Solar Encounter performed Oct 31–Nov 11 2019
 - Minimum perihelion of $\sim .17$ AU occurred on Nov. 5, and max speed of 213,200 mph
- Second Solar Encounter performed Mar 30–Apr 10 2019
 - Minimum perihelion occurred on Apr. 4
- Data from orbit 1 and 2 downlinked in April 2019
- Perihelion #3: September 1, 2019
- **Data release: November 2019**
- Venus Flyby #2: December 26, 2019
- Perihelion #4: January 29, 2020
 - Minimum perihelion of ~ 0.13 AU with max speed of 224,200 mph
- Parker performance sufficiently characterized to reduce the RF margin as well as increase instrument on time and data production.

Van Allen Probes Begin Final Phase of Exploration

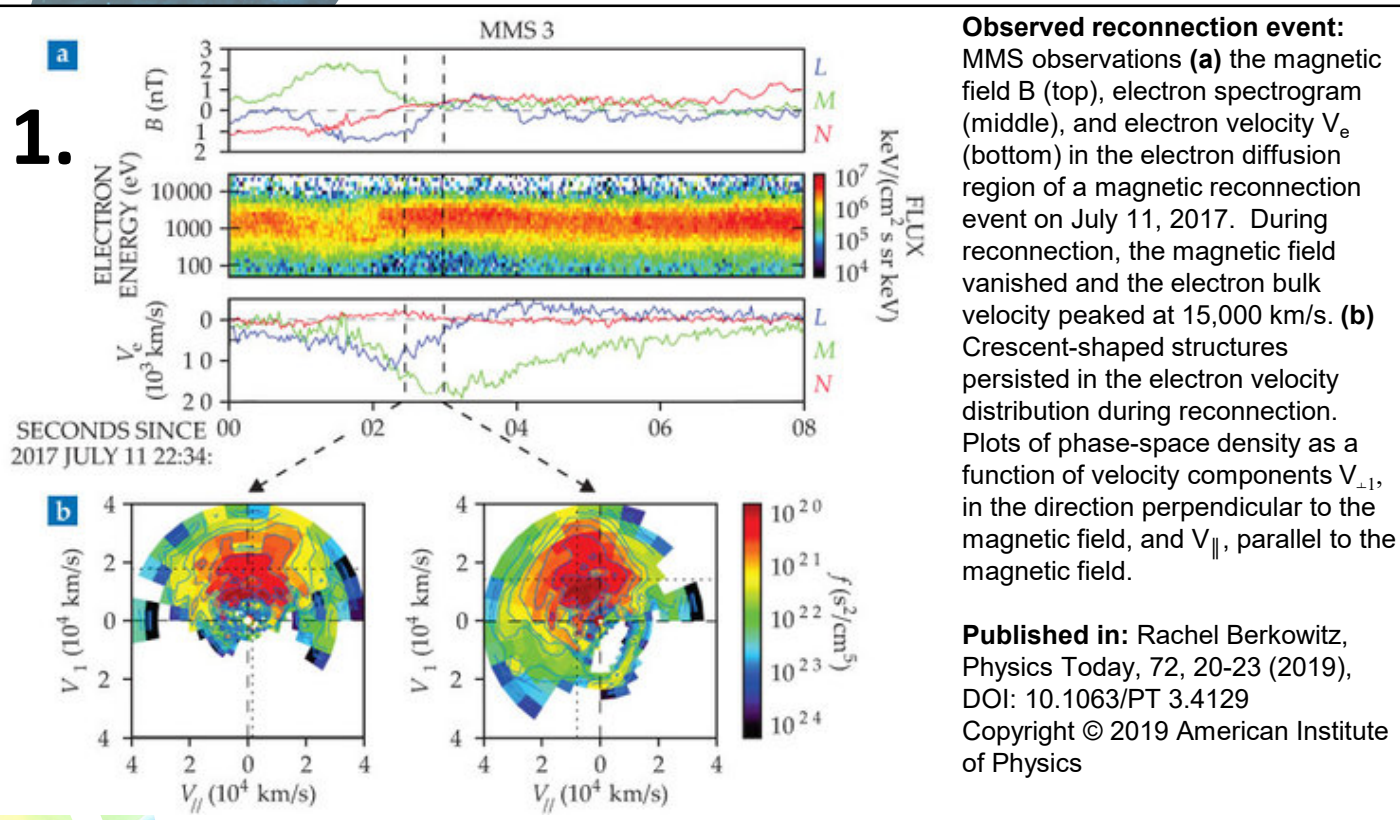
- On Feb. 12, 2019, Spacecraft B of the Van Allen Probes began a series of orbit descent maneuvers to bring its perigee just under 190 miles closer to Earth, from about 375 miles. Spacecraft B began descent Mar. 11-22
- This new orbit positions the spacecraft for an eventual re-entry into Earth's atmosphere in about 15 years.
- Launched in 2012, the Van Allen Probes have been orbiting Earth for the past 6.5 years, flying repeatedly through the Van Allen radiation belts.



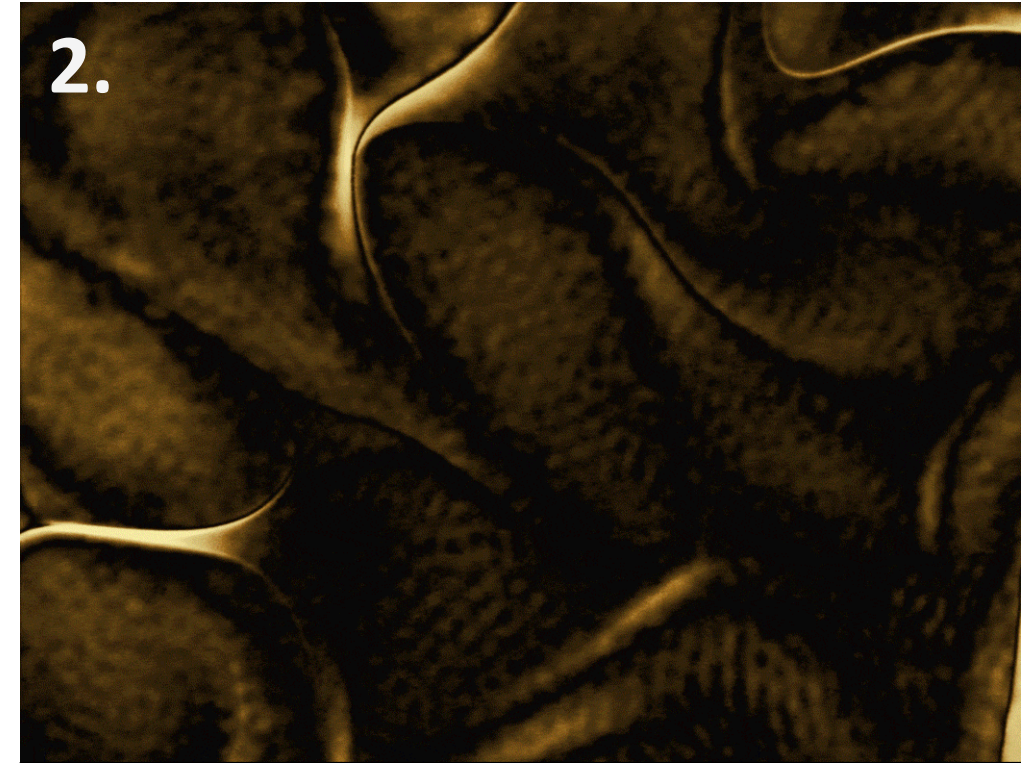
Above: After performing de-orbit maneuvers in February and March 2019, the Van Allen Probes' highly elliptical orbits will gradually tighten over the next 15-25 years as the spacecraft experience atmospheric drag at perigee, the point in their orbits closest to Earth. **Credits: Johns Hopkins APL**

MMS: Magnetic Reconnection

1.



2.



Video: Illustration of microscale magnetic turbulence. Flashes indicate magnetic reconnection triggered when field lines cross and intense electric currents (bright regions) are formed. This represents the discovery of electron magnetic reconnection without ion coupling in Earth's turbulent magnetosheath. Authors T. D. Phan, J. P. Eastwood, [...]W. Magnes
<https://doi.org/10.1038/s41586-018-0091-5>

3.

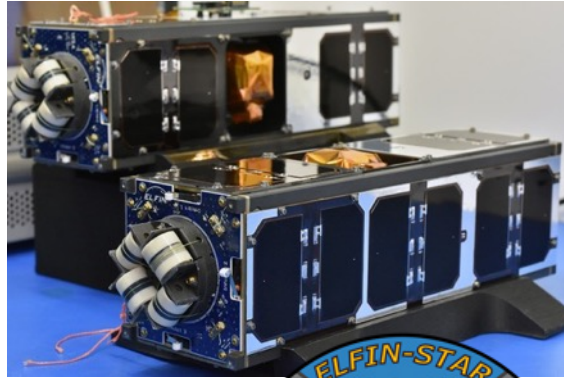
Recently, a powerful method for mapping the position the magnetic reconnection electron diffusion region using the MMS high-resolution 3-D magnetic field observations was developed. This paves the way for studying the elusive and small reconnection site without having to pass directly through it.

<https://doi.org/10.1002/2016JA022788>

Suborbital Highlights



G-CHASER, short for Grand Challenge Student Rocket launched Jan 13, 2019, Andøya Space Center, Norway, PI Koehler



Electron Loss and Fields Investigation with Spatio-Temporal Ambiguity Resolving (ELFIN-STAR) launched Sep 15, 2018, with ICESat-2 Vandenberg Air Force Base, PI Angelopoulos



Balloon Array for Radiation belt Electron Losses (BARREL), launched Dec 9, 2018, McMurdo Station Antarctica, PI Millan

HPD Suborbital Program

- 2018: 22 NASA missions + 4 reimbursable missions; 3 CubeSats; 4 balloon investigations
- 2019: 19 NASA missions + 2 reimbursable missions; 3 CubeSats

Grand Challenge

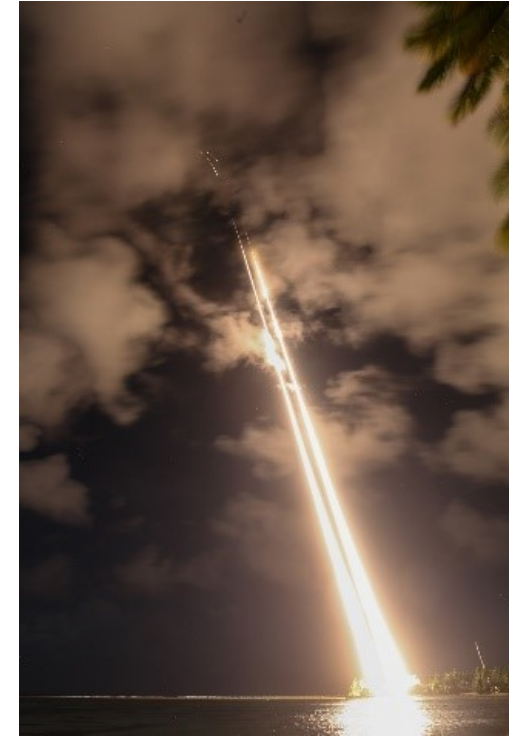
- 5 of 9 missions launched so far

Upcoming campaigns:

- 4 Astrophysics missions targeting Summer 2020 launch windows

Suborbital Campaigns

- **Waves and Instabilities from a Neutral Dynamo (Too-WINDY)**
 - Two rockets will study equatorial spread F, or ESF, which are disturbances that occur after sunset at latitudes near the equator in part of the ionosphere known as the F region, and can interfere with radio communication, navigation and imaging systems and pose a hazard to technology and society that depends on it.
 - Launched: Jun. 19, 2019, Marshall Islands
- **RockOn!**
 - RockOn! is a workshop intended to be an introductory flight opportunity to provided exposure to, and spark interest in, space based science missions.
 - Launched: Jun. 20, 2019, Wallops Flight Facility
- **RockSat-X**
 - The RockSat-X carries student developed experiments and is a follow on mission to RockOn and RockSat-C.
 - Launch: Aug. 12, 2019, Wallops Flight Facility



Waves and Instabilities from a Neutral Dynamo-2 (Too-WINDY) successfully launched from Roi Namur, Kwajalein Atoll, Marshall Islands on June 19, 2019

Upcoming CubeSat Missions

E-TBEx – The Enhanced Tandem Beacon Experiment is a pair of 3U CubeSats each carrying tri-frequency radio beacons. It measures how radio signals can be distorted by large bubbles that form naturally in the Earth's charged upper atmosphere. It tracks how the ionosphere disrupts signals by monitoring, from the ground, beacon tones transmitted from eight orbital locations: the six COSMIC-2 spacecraft (NOAA) and the twin E-TBEx CubeSats (NASA). June 2019

SORTIE: The Scintillation Observations and Response of The Ionosphere to Electrodynamics is a scientific investigation mission on a 6U CubeSat to advance understanding of ionospheric irregularities and the roles of various drivers in their formation in order to improve predictive capabilities. October 2019

OPAL – The Oxygen Photometry of the Atmospheric Limb is a 3U CubeSat experiment designed to study temperature fluctuations in the lower thermosphere by focusing on remote optical observations of atmospheric temperatures. October 2019

LLITED: The Low-Latitude Ionosphere/Thermosphere Enhancements in Density Mission consists of two 1.5U CubeSats that will make simultaneous thermosphere/ionosphere measurements of the Equatorial Temperature and Wind Anomaly (ETWA) and the Equatorial Ionization Anomaly (EIA) to investigate the coupling between the two features. 2020

Upcoming CubeSat Missions

petitSat: The Plasma Enhancement in The Ionosphere-Thermosphere Satellite is a scientific investigation 6U CubeSat mission designed to provide in-situ measurements of plasma density, 3D ion drift, as well as ion and neutral composition. It will determine the conditions under which Medium-Scale Traveling Ionosphere Disturbances (MSTIDs) generate large plasma enhancements, which can interfere with radio waves used for communication and navigation. 2020

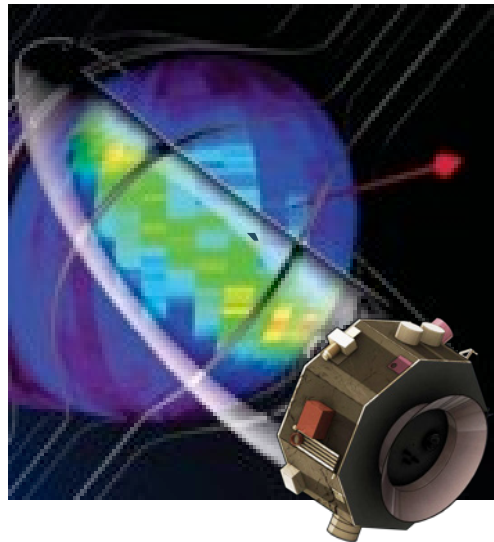
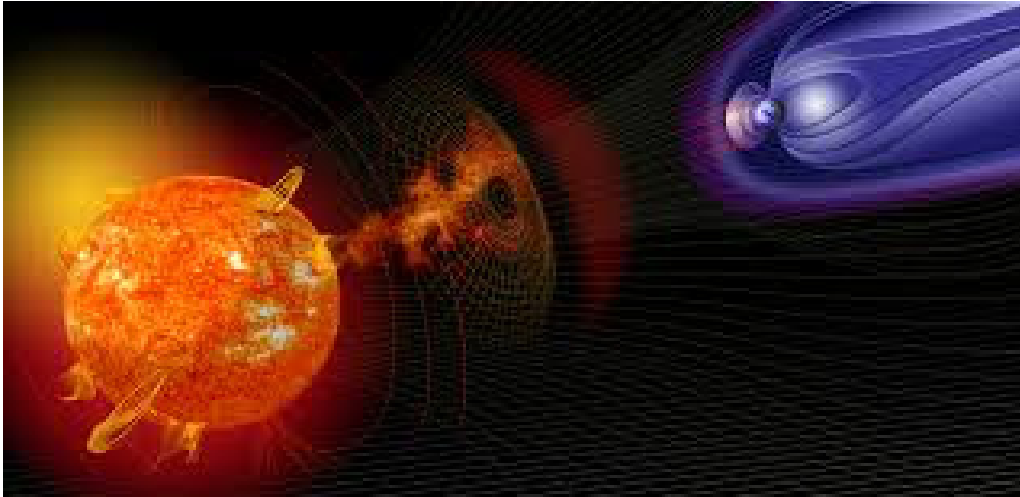
SPORT: The Scintillation Prediction Observations Research Task is a US-Brazil mission using a 6U CubeSat with six remote and in situ instruments, that seeks to understand the pre-conditions under which ionospheric variability develops that leads to scintillation of RF signals. 2020

LAICE: The Lower Atmosphere/Ionosphere Coupling Experiment is a 6U CubeSat with four sensors to remotely observe gravity wave signatures in the mesosphere, while simultaneously observing in-situ plasma and neutral gravity wave-induced fluctuations at LEO altitudes. The observations will be correlated with tropospheric storm data from weather satellites in an attempt to trace the probable origins of the waves, and to better determine their global distribution. 2020 – NSF/NASA

The background of the slide is a composite image of space. The top half features a dark blue and black nebula with bright, star-like points of light. The bottom half is a gradient of orange and yellow, also filled with numerous small, bright stars. The word "Summary" is centered in a white, sans-serif font.

Summary

It is a Great Time to be a Heliophysicist!



- HPD launched its most ambitious mission ever to touch the Sun (Parker), and the first NASA instrument aboard a commercial satellite (GOLD)
 - both within budget and on schedule
- New Missions of Opportunity selected and solicited
- Blazing a trail with enhanced ride share program
- Established the genesis of a Space Weather Science and Applications (SWxSA) in collaboration with sister federal agencies, academia, and industry
- Fully funded Decadal-proposed DRIVE initiative with provisions for early career, technology, diverse elements
 - Equals a very healthy R&A program!
- Instituted a strategic approach following the Decadal Survey recommendations
- Unique opportunity to study the Sun and its effects throughout the Heliosphere

The background of the slide is a cosmic image featuring a blue nebula in the upper right and an orange nebula in the lower left, with a light blue gradient band across the center.

Backup



Heliophysics Opportunities

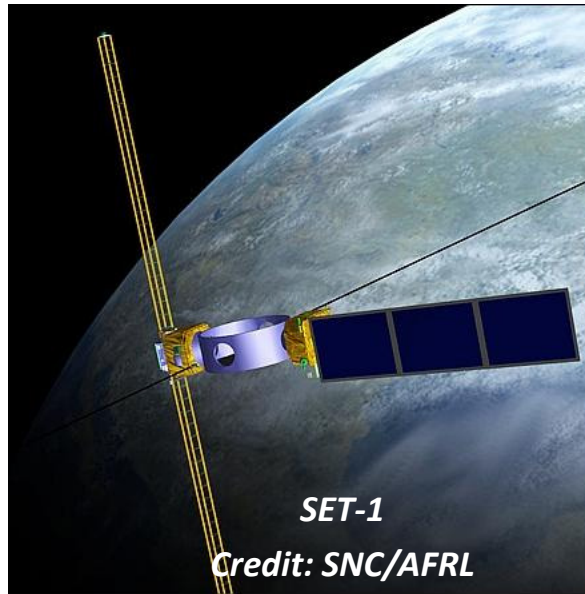
- Within the **SALMON AO** released Aug. 7, 2018, were two Program Element Appendices (PEAs) for Missions of Opportunity (MOs):
 - Proposals received Nov. 30
 - Science MO cost cap \$55M
 - Science MO small complete mission (SCM) cost cap \$75M to ride on ESPA ring
 - Technology Demonstration MO SCM cost cap \$65M to ride on ESPA ring
- **MIDEX 19**
 - Draft AO release date: May 2019
 - Final AO release date: June 30, 2019
 - PI managed Cost Cap: \$250M



Geospace Dynamics Constellation

- Decadal Survey identified GDC as next LWS large strategic mission:
 - “...provide the first simultaneous, multipoint observations of how the ionosphere-thermosphere system responds to, and regulates, magnetospheric forcing over local and global scales...”
- Science and Technology Definition Team convened in May 2018
 - Discussions are limited to the science objectives and measurement requirements; no instrument-specific or mission implementation details
 - Study report expected to be delivered July 2019
- LRD anticipated NET 2029

Future Rideshare Opportunities



- SMD has embraced Rideshare opportunities as a standard practice to maximize mass to orbit
 - Enabling additional opportunities for science community
- SMD has finalized a Rideshare policy
- Rideshare opportunities on IMAP ESPA Grande
 - Science MO SCM & Technology Demonstration MO SCM
 - NOAA Space Weather Forward Observatory
 - If there are open ESPA ports after the above missions are accommodated, they will be offered to other SMD investigations under new Rideshare Policy.
- In support of rideshare, HPD is developing a mission-unique ESPA Systems Interface Specification

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Future Missions & Opportunities

Ionospheric Connection Explorer (ICON)



Mission Line: Explorers

Launch Vehicle: Pegasus XL rocket

Launch Site: Cape Canaveral

LRD: NET 3rd Quarter 2019

ICON Principal Investigator: Tom Immel (UC Berkeley)

Description:

- ICON will study the frontier of space: the dynamic zone high in our atmosphere where terrestrial weather from below meets space weather above.
- In this region, the tenuous gases are anything but quiet, as a mix of neutral and charged particles travel through in giant winds.
- These winds can change on a wide variety of time scales -- due to Earth's seasons, the day's heating and cooling, and incoming bursts of radiation from the sun.

Next Step: *Awaiting launch*

Solar Orbiter Collaboration (with ESA)



Mission Line: Living With Star

Launch Vehicle: U.S. provided Atlas-V 411

Launch Site: Cape Canaveral

LRD: Feb. 2020

Solar Orbiter Collaboration Project Scientist: Chris St. Cyr

U.S. Provided Instruments:

- HIS (Heavy Ion Sensor), part of SWA, and SoloHI (Heliospheric Imager)

Description:

- Solar Orbiter aims to make significant breakthroughs in our understanding both of how the inner heliosphere works, and of the effects of solar activity on it.
- The spacecraft will take a unique combination of measurements: in situ measurements will be used alongside remote sensing close to the Sun to relate these measurements back to their source regions and structures on the Sun's surface.

Interstellar Mapping and Acceleration Probe (IMAP)

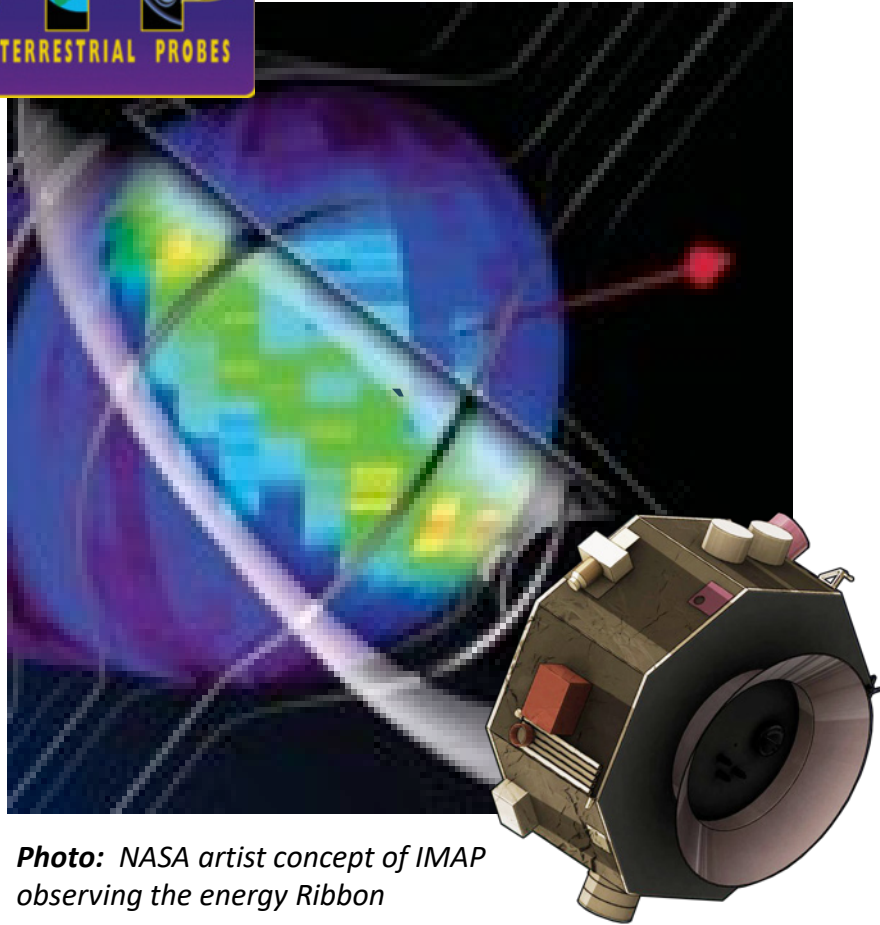
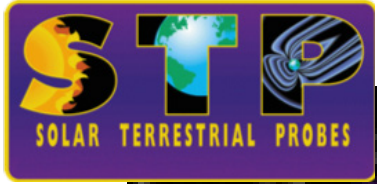


Photo: NASA artist concept of IMAP observing the energy Ribbon

Mission Line: Solar Terrestrial Probes; selected June 1, 2018

LRD: October 2024

Project Scientist: David McComas of Princeton University

- Project Management and Mission Operations Center at Johns Hopkins University's Applied Physics Laboratory in Laurel, Maryland

Orbit: L1 Lagrangian point

Description:

- Sample, analyze, and map particles streaming to Earth from the edge of interstellar space.
- Investigate the generation of cosmic rays in the heliosphere and beyond.
- 10 scientific instruments
- Investigating possible accommodation of a Tech Demo ins

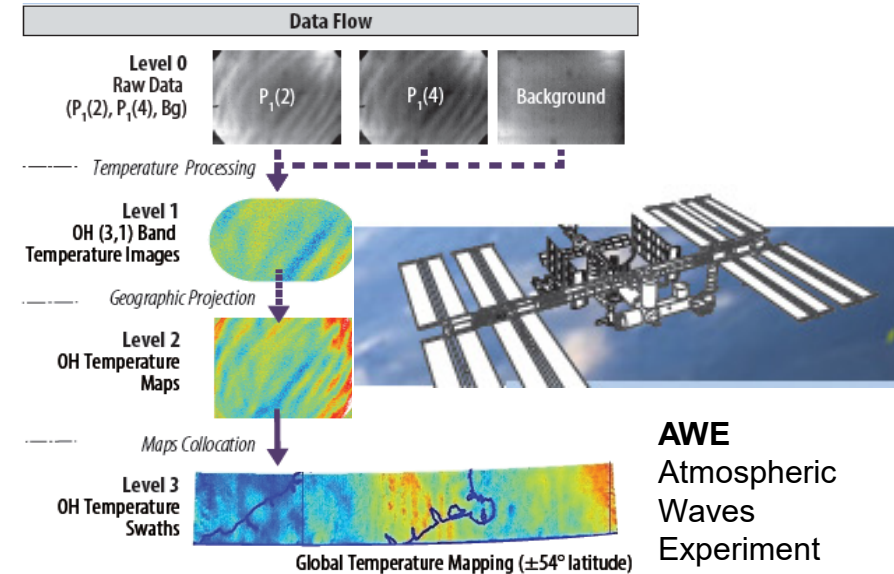
Rideshare opportunities on the ESPA Grande:

- Competitive Missions of Opportunity including Tech Demo and Science
- NOAA Space Weather Follow-On L-1

2016 Explorers Mission of Opportunity Selections

Atmospheric Waves Experiment (AWE)

- Attached to the exterior of the ISS, AWE will focus on airglow to determine what combination of forces drive space weather in the upper atmosphere.
- LRD NET Aug. 2022



Sun Radio Interferometer Space Experiment (SunRISE)

- Selected for a seven-month, \$100,000 extended formulation study.
- SunRISE would be an array of six CubeSats operating like one large radio telescope to investigate how giant space weather storms from the Sun are accelerated and released into planetary space.

