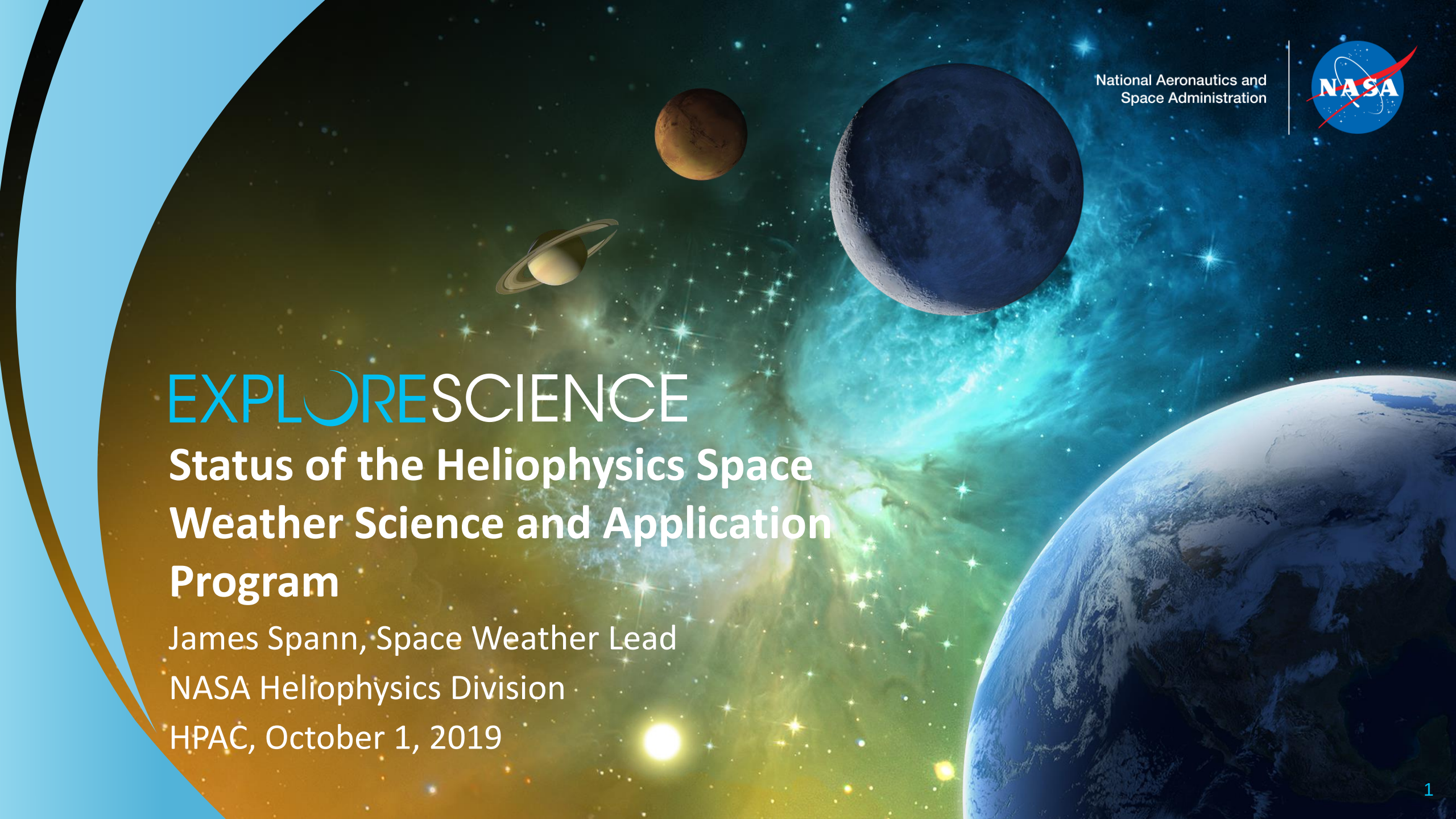
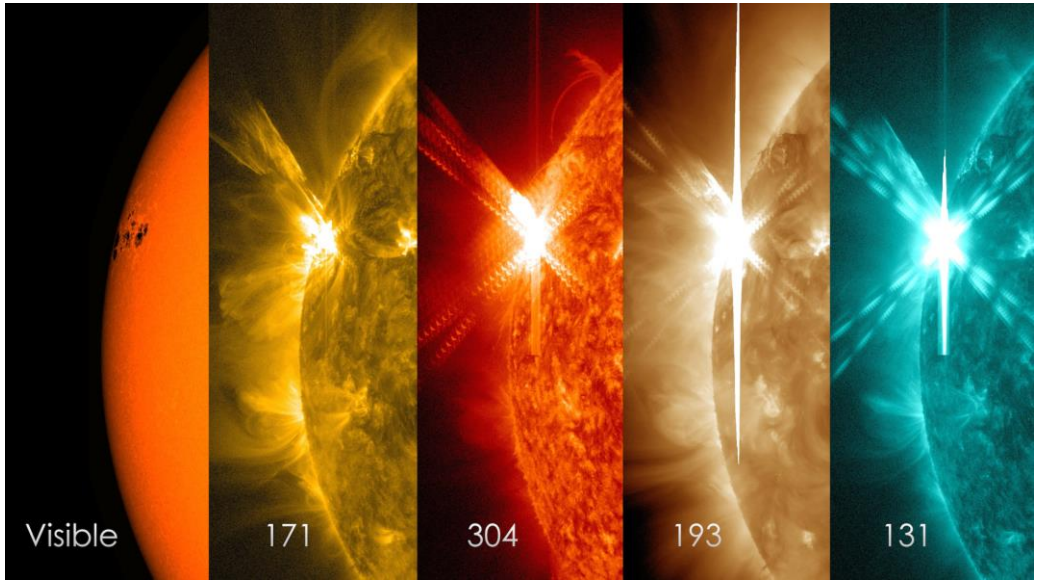


Status of the Heliophysics Space Weather Science and Application Program

James Spann, Space Weather Lead
NASA Heliophysics Division

HPAC, October 1, 2019

The Dawn of a New Era for Heliophysics



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

Explore uncharted territory**:** through pockets of intense radiation near Earth right to the Sun itself, and past the planets into interstellar space.

Strategically ***combine research from a fleet of carefully-selected missions*** at key locations to better understand our entire space environment.

To understand the interaction between Earth weather and space weather – ***protecting people and spacecraft****.*

Coordinate with other agencies to fulfill its role for the Nation enabling advances in ***space weather*** *knowledge and technologies*

Engage the public with research breakthroughs and citizen science

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

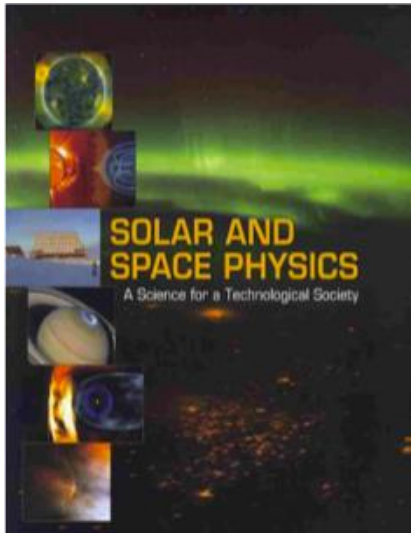
Space Weather Science and Application Program

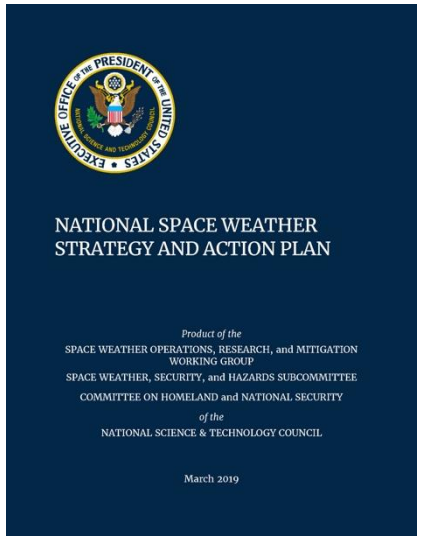
Space Weather Science and Application (SWxSA)

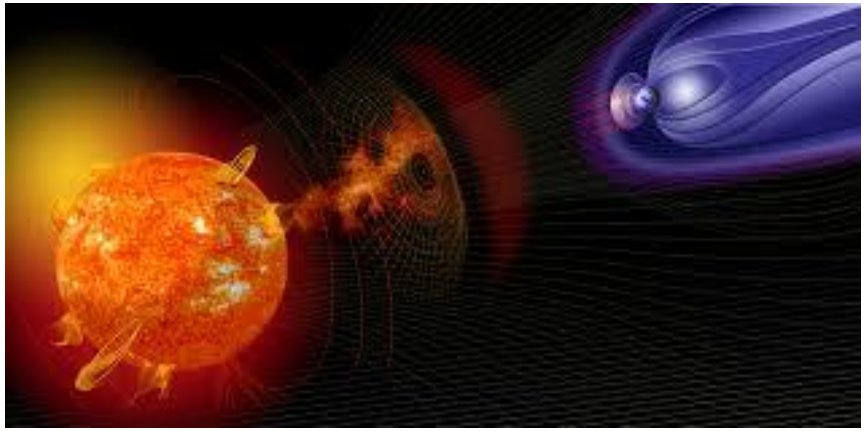
- A new program in the NASA Heliophysics Portfolio
- Totally integrated into and consistent with the goals, research investigations, missions, and technology of the NASA Heliophysics Division
- Does not impact the Heliophysics Division research and mission resources

Space Weather Science and Application (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. This progress is then applied to enable more accurate characterization and predictions with longer lead time
- Transition technology/techniques, tools, models, data, and knowledge from research to operational environments
- Focused on Artemis and National Space Weather Capability







Space Weather Science and Application **Update**

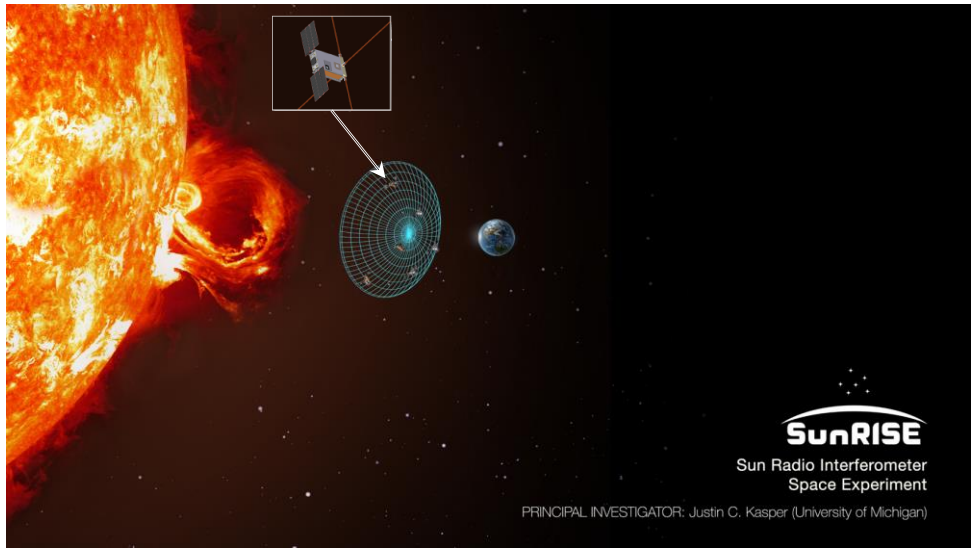
Space Weather Strategy: NASA, NOAA, OSTP, and OMB

- August 2, Strategic meeting held at GSFC
  - September-October, pilot test-bed process and architecture – considering cloud-based
  - Addresses objective #2 from National Space Weather Strategy and Action Plan
- Working Quad Agency MOU – adding DoD
  - Enables codified interaction with increased likelihood of resources
- Steve Hill is detailed to HQ from NOAA

Space Weather Mission of Opportunity under review:

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.



Space Weather Science and Application ROSES & SBIRs

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
  - 4-6 selections anticipated in October 2019

ROSES 2019 call released – no focus topic

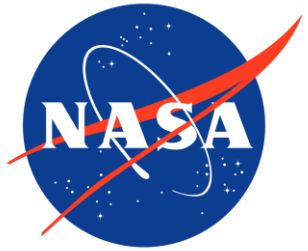
Small Business Innovation Research (SBIR) Program for Space Weather

- 2018 – Selected 2 Phase II
- 2019 – Selected 4 Phase I
- 2020 – Language for Call has been approved

Space Weather Science and Application **Ongoing Steps**

- Develop NASA Heliophysics Space Weather Science and Applications Implementation Plan
- Define transition framework and implement pilot test-bed with NOAA SWPC
  - Define process
  - Transition one or two test cases
  - Implement a mirror test-bed capability to enhance transitioning
- Develop with Human Exploration & Operations Mission Directorate (HEOMD) a lunar space environment capability to safeguard human and robotic explorers beyond low-earth-orbit
  - Participating in Lunar Gateway Payload Working Group
    - Responded to ‘Call for Information’ for Heliophysics and space weather payloads
    - Energetic particles and solar wind sensor package rated high to launch with the Power and Propulsion Element of Gateway Phase 1
- Define
  - Strategic instrument development for ESA L5 mission
  - Robust multipurpose space weather package for additional rideshare opportunities
- Secure counsel of community expertise
- 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

International Partners

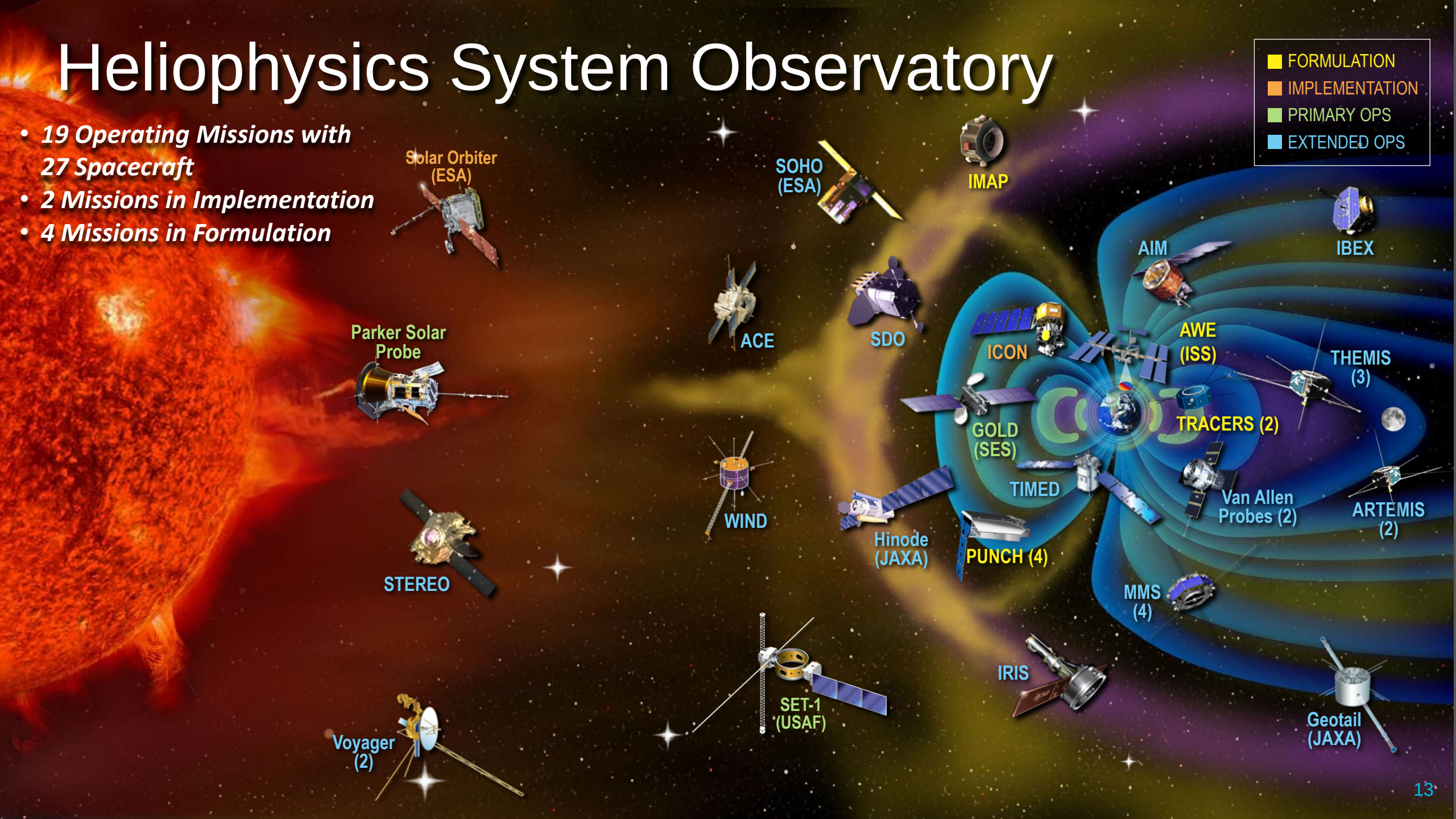
International Partners

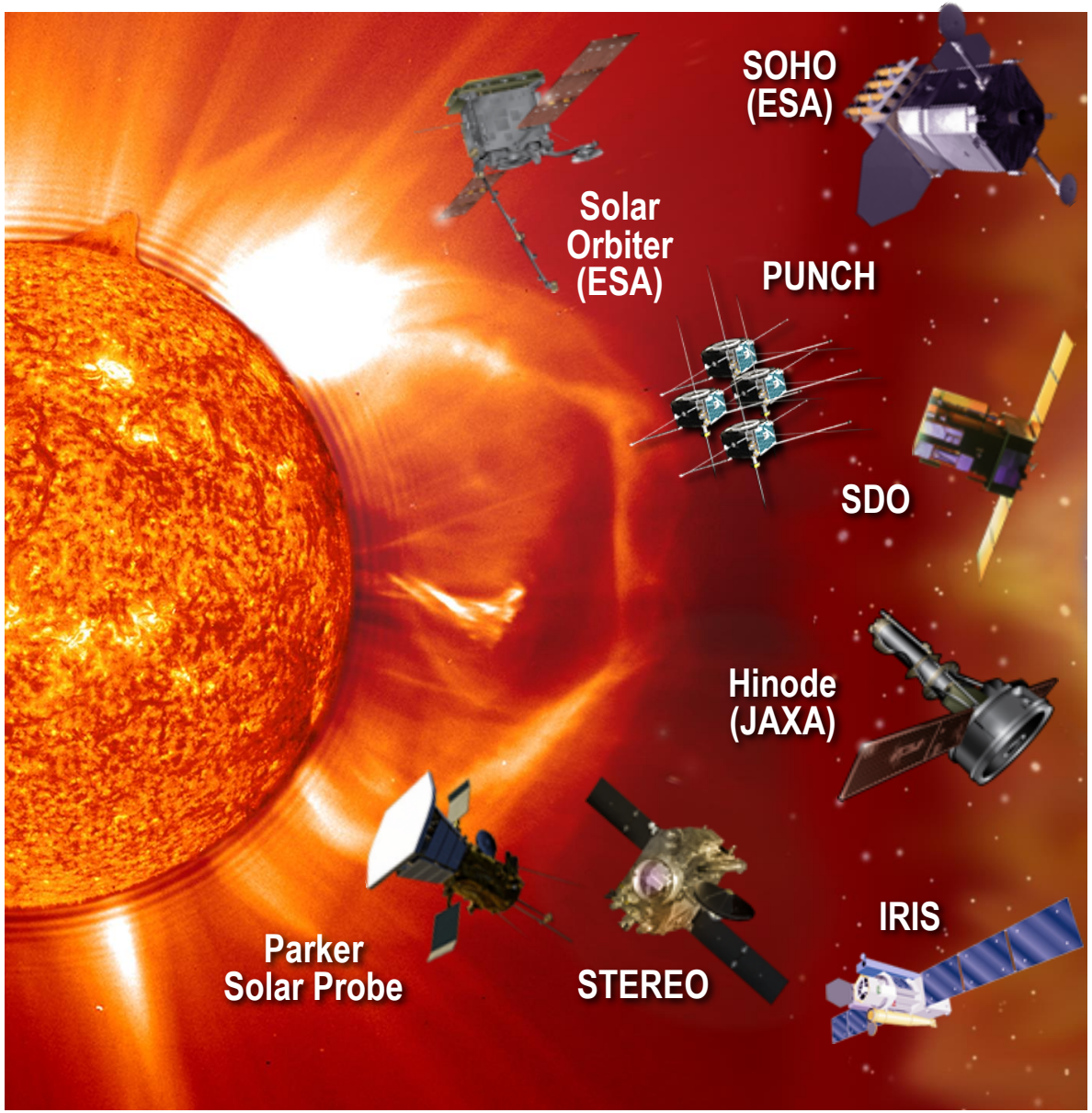
Partner	Mission(s)/Campaigns/Models
Austrian Aeronautics and Space Agency	THEMIS, MMS
Belgium – University of Liege, Belgian Federal Science Policy Office (BELSPO)	ICON, SOC, Parker
Brazilian Space Agency (AEB)	Van Allen, **SPORT**
CNES, Centre National d'Études Spatiales	STEREO, MMS, LWS/SETI, SOC, Parker, SET, SOHO, THEMIS, WIND
CBK, Space Research Centre PAN, Polish Academy of Sciences	GLObal solar Wind Structure (GLOWS) instrument on IMAP
CONAE, National Commission on Space Activities of the Argentine Republic for Cooperation in Solar and Space Physics	Van Allen
CSA, Canadian Space Agency	THEMIS
Academy of Sciences of the Czech Republic – Institute of Atmospheric Physics	Van Allen
DLR, Deutsches Zentrum für Luft- und Raumfahrt	STEREO, THEMIS, Parker, sounding rocket campaigns
ESA, European Space Agency	SOHO, SOC
ISRO, Indian Space Research Organisation	Aditya-1 mission collaboration, space weather modeling, long-term strategic collaboration focus areas
JAXA, Japan Aerospace Exploration Agency	Hinode, MMS, Geotail, **CLASP and CLASP-2 Sounding Rockets missions**, **EUVST**
KASI, Korea Astronomy and Space Science Institute	Van Allen, SDO, KASI Geomagnetic Storm Forecast Model, **SNIPE, BITSE, CODEX, IMAP I-ALIRT**
Norway Space Center	IRIS
Roscosmos, Russian Academy of Sciences	SDO, STEREO, WIND, Hi-C Sounding Rocket Mission
Swedish National Space Board	MMS
Swiss Space Office, University of Bern	STEREO, SOC, IBEX
UKSA, United Kingdom Space Agency	Hinode, STEREO, LWS/SETI, SOC, SET

Missions, and relevance to SWxSA

Heliophysics System Observatory

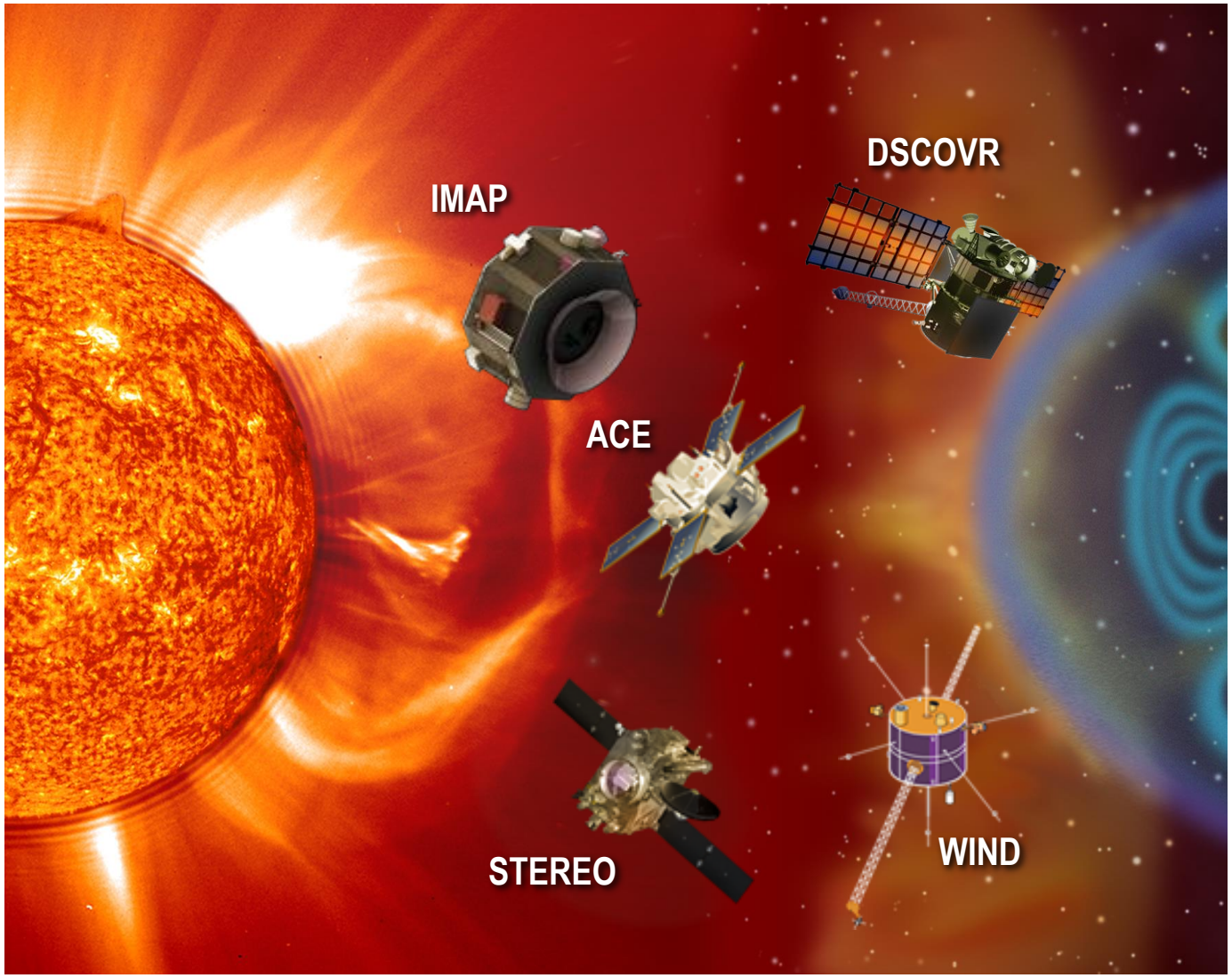
- *19 Operating Missions with 27 Spacecraft*
- *2 Missions in Implementation*
- *4 Missions in Formulation*





Eyes on the Sun

- Parker Solar Probe (8/12/2018)
- Solar Orbiter (ESA/NASA) (LRD Feb 2020)
- Polarimeter to Unify the Corona and Heliosphere (PUNCH) (LRD Aug 2022)
- Solar Dynamics Observatory (SDO) (2/11/2010)
- Solar TErrestrial RElations Observatory (STEREO) (10/25/2006)
- Hinode (JAXA/NASA) (9/23/2006)
- Interface Region Imaging Spectrograph (IRIS) (6/27/2013)
- Solar and Heliospheric Observatory (SOHO) (ESA/NASA) (12/2/1995)

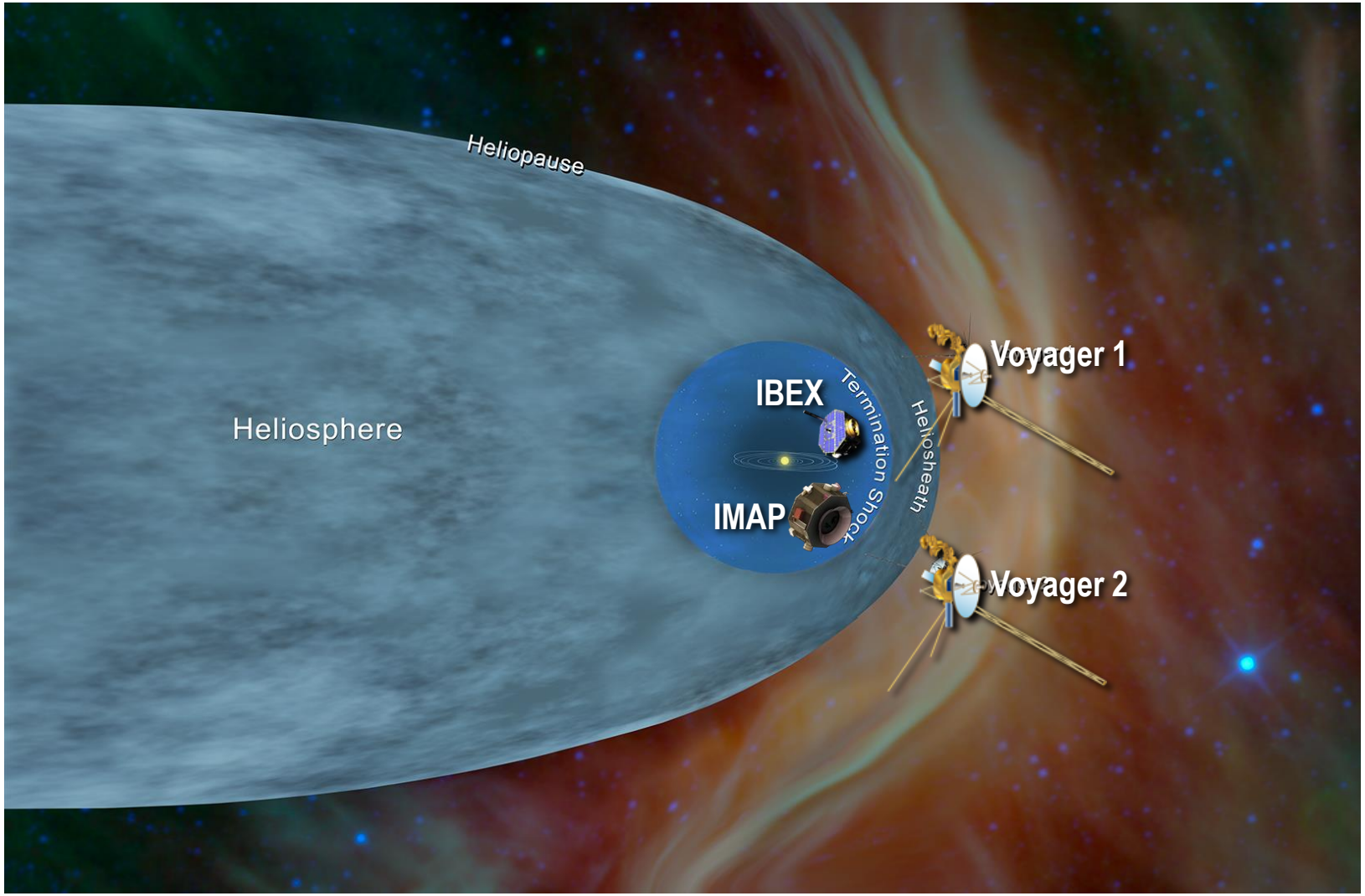


Sailing in the Solar Wind

- Interstellar Mapping & Acceleration Probe (IMAP) LRD 10/2024
- Deep Space Climate Observatory (DSCOVR) (2/11/2015)
- Advanced Composition Explorer (ACE) (8/27/1997)
- Solar TErrestrial RElations Observatory (STEREO) (10/25/2006)
- Wind (11/1/1994)

Guardians of the Magnetosphere & Ionosphere

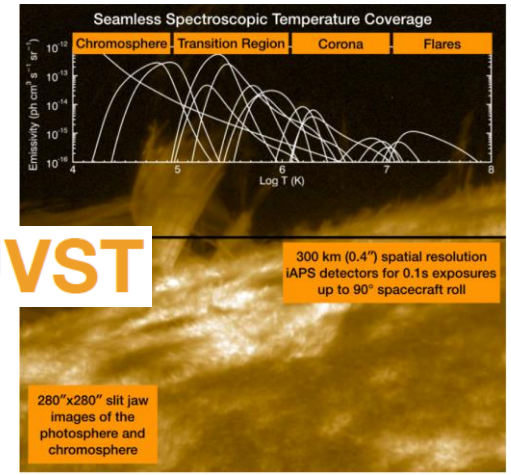
- Global-scale Observations of the Limb and Disk (GOLD) (1/25/2018)
- Magnetospheric Multiscale Mission (MMS) (3/14/2015)
- Van Allen Probes (8/30/2012)
- Aeronomy of the Ice in the Mesosphere (AIM) (4/25/2007)
- Time History of Events and Macroscale Interactions in Substorms (THEMIS) (2/17/2007)
- Thermosphere Ionosphere Mesosphere and Dynamics (TIMED) (12/7/2001)
- Geotail (JAXA-lead) (7/24/1992)
- Solar Environment Testbeds-1 (SET-1) LRD 6/22/2019
- Ionospheric Connection Explorer (ICON) LRD 2019
- Atmospheric Wave Experiment (AWE) LRD 8/2022
- Tandem Reconnection & Cusp Electrodynamics Reconnaissance Satellites (TRACERS) (LRD Aug 2022)



To infinity & beyond!

- Voyager 1 & 2 (9/5/1977 & 8/20/1977)
- Interstellar Mapping & Acceleration Probe (IMAP) LRD 8/2024
- Interstellar Boundary Explorer (IBEX) (10/19/2008)

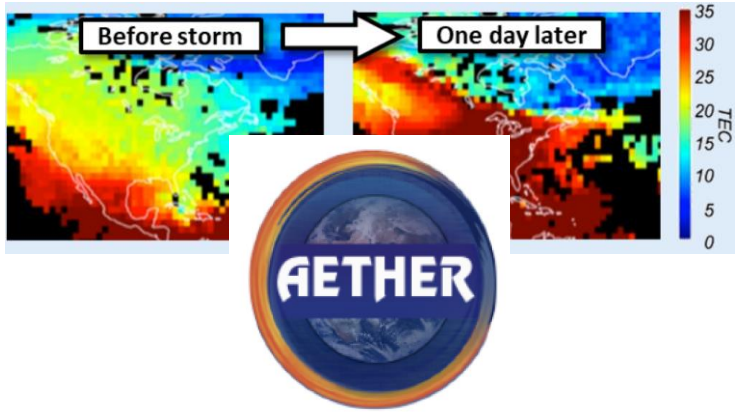
3 Explorers Missions of Opportunity to Advance Understanding of Space Weather



Three missions selected (Sep 3) for nine-month concept studies; down-selection in 2020.

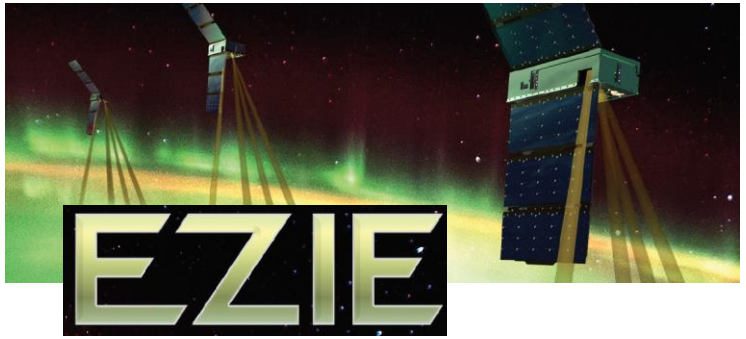
Extreme Ultraviolet High-Throughput Spectroscopic Telescope (EUVST) Epsilon Mission

- EUVST would observe simultaneously, for the first time and over a wide range of the lower solar atmosphere, how magnetic fields and plasma interact.
- Instrument to fly on JAXA's Solar-C mission
- **Principal Investigator:** Clarence Korendyke at the U.S. Naval Research Laboratory in Washington, D.C.



Aeronomy at Earth: Tools for Heliophysics Exploration and Research (AETHER)

- AETHER would explore the ionosphere-thermosphere system and its response to geomagnetic storms from a position aboard the International Space Station.
- **Principal Investigator:** James Clemmons at the University of New Hampshire in Durham.



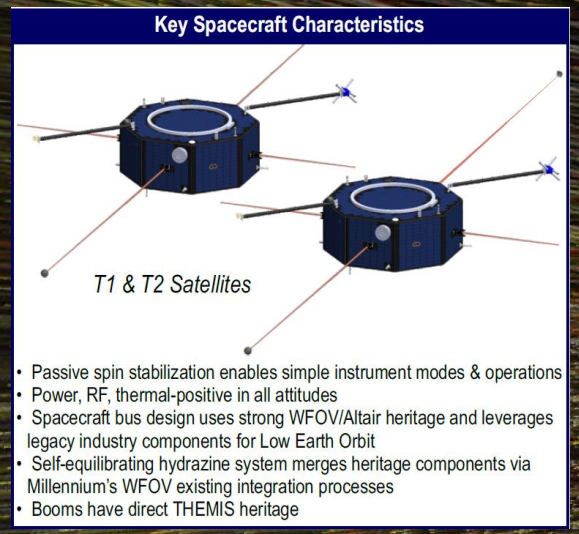
Electrojet Zeeman Imaging Explorer (EZIE)

- EZIE would focus on an electric current known as the auroral electrojet, which circles through the atmosphere around 60 to 90 miles above Earth, near the poles.
- **Principal Investigator:** Jeng-Hwa Yee at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland.

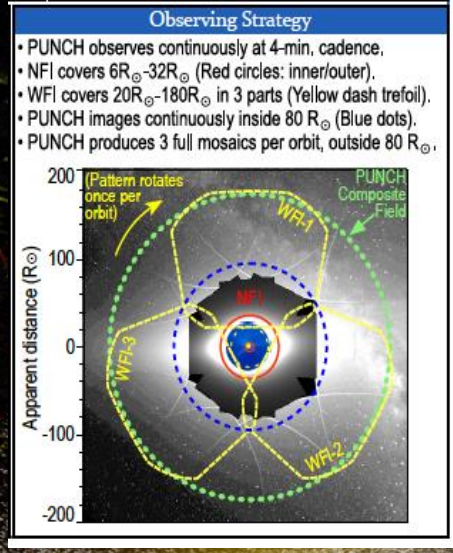
Each potential mission has a separate launch opportunity and time frame.

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.

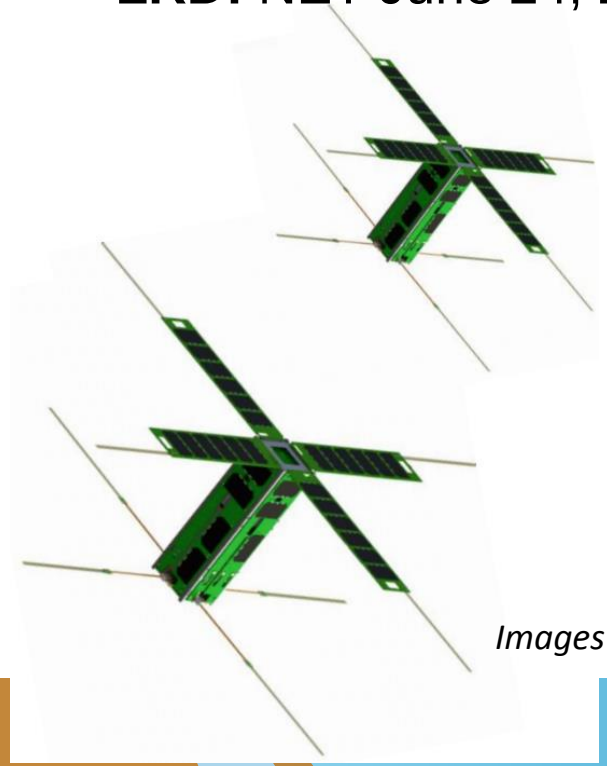
Enhanced and Tandem Beacon Experiment (E-TBEx)

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



Images from CubeSat Workshop Apr 2018

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

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

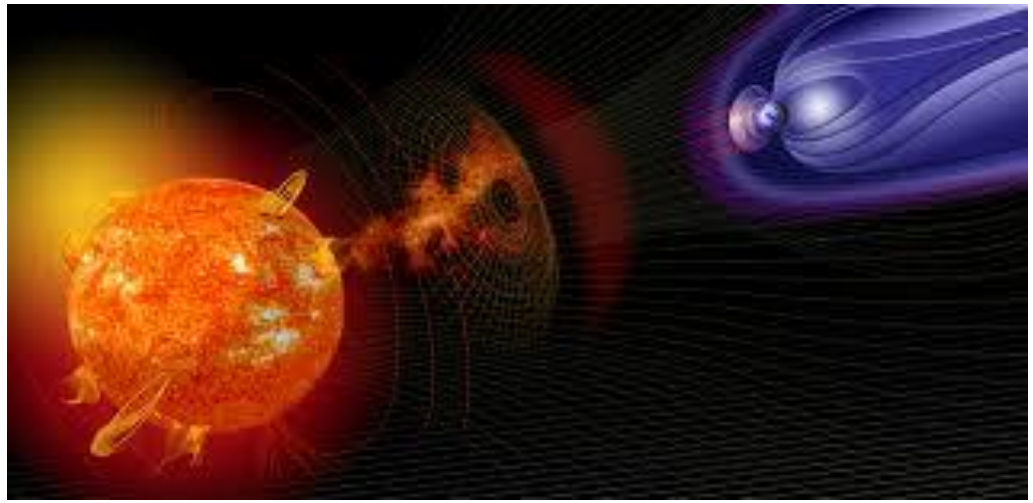
petitSat: The Plasma Enhancement in The Ionosphere-Thermosphere Satellite is a scientific investigation 6U CubeSat mission designed to provide in-situ measurements of plasma density, 3D ion drift, as well as ion and neutral composition. It will determine the conditions under which Medium-Scale Traveling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

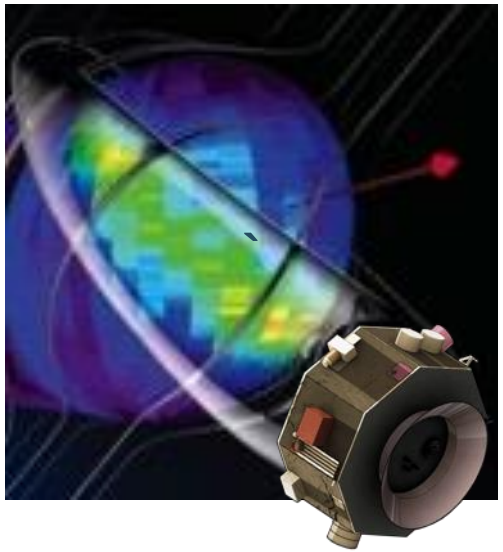
SPORT: The Scintillation Prediction Observations Research Task is a US-Brazil mission using a 6U CubeSat with six remote and in situ instruments, that seeks to understand the pre-conditions under which ionospheric variability develops that leads to scintillation of RF signals. 2020

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 probably origins of the waves, and to better determine their global distribution. 2020 – NSF/NASA

Summary

It is a Great Time to be a Heliophysicist!





- Strategically advance understanding of solar and space physics, make amazing discoveries
  - Build innovative missions to achieve this goal
- Fulfill its role for the Nation enabling advances in space weather
  - Committed to working with other agencies to implement Space Weather
- Critical role in Exploration
  - Support HEOMD in deep space - the Moon and beyond