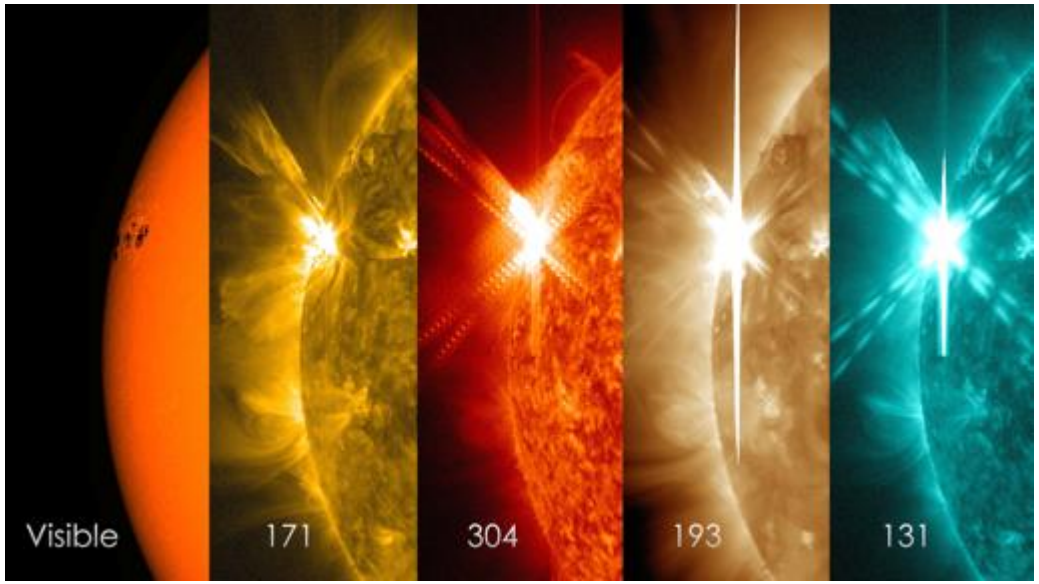
NASA Heliophysics Division Update

Heliophysics Advisory Committee
October 1, 2019

Dr. Nicola J. Fox

Director, Heliophysics Division
Science Mission Directorate

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 from 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.

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

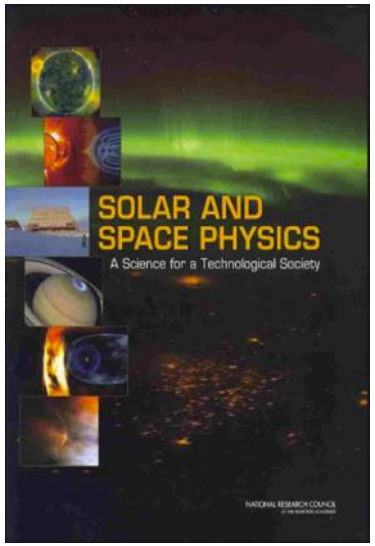
Develop the ***next generation*** of heliophysicists

Decadal Survey

Alignment with Decadal Survey Recommendations

NASA FY20 Presidential Budget Request	
R0.0 Complete the current program	Extended operations of current operating missions as recommended by the 2017 Senior Review, planning for the next Senior Review Mar/Apr 2020; 3 recently launched and now in primary operations (GOLD, Parker, SET); and 2 missions currently in development (ICON, Solar Orbiter)
R1.0 Implement DRIVE (Diversify, Realize, Integrate, Venture, Educate)	Implemented DRIVE initiative wedge in FY15; DRIVE initiative is now part of the Heliophysics R&A baseline
R2.0 Accelerate and expand Heliophysics Explorer program	Decadal recommendation of every 2-3 years; Explorer mission AO released in 2016 and again in 2019. Notional mission cadence will continue to follow Decadal recommendation going forward. Increased frequency of Missions of Opportunity (MO), including rideshares on IMAP and Tech Demo MO.
R3.0 Restructure STP as a moderate scale, PI-led flight program	IMAP mission (STP-5) selected in 2018 as a PI-led mission with an LRD in 2024
R4.0 Implement a large LWS GDC-like mission	GDC STDT report will be delivered to HPAC Oct 3, 2019; planning to kick off mission formulation immediately afterwards

Review of Progress Toward Implementing the Decadal Survey Vision in Solar and Space Physics: A Science for a Technological Society

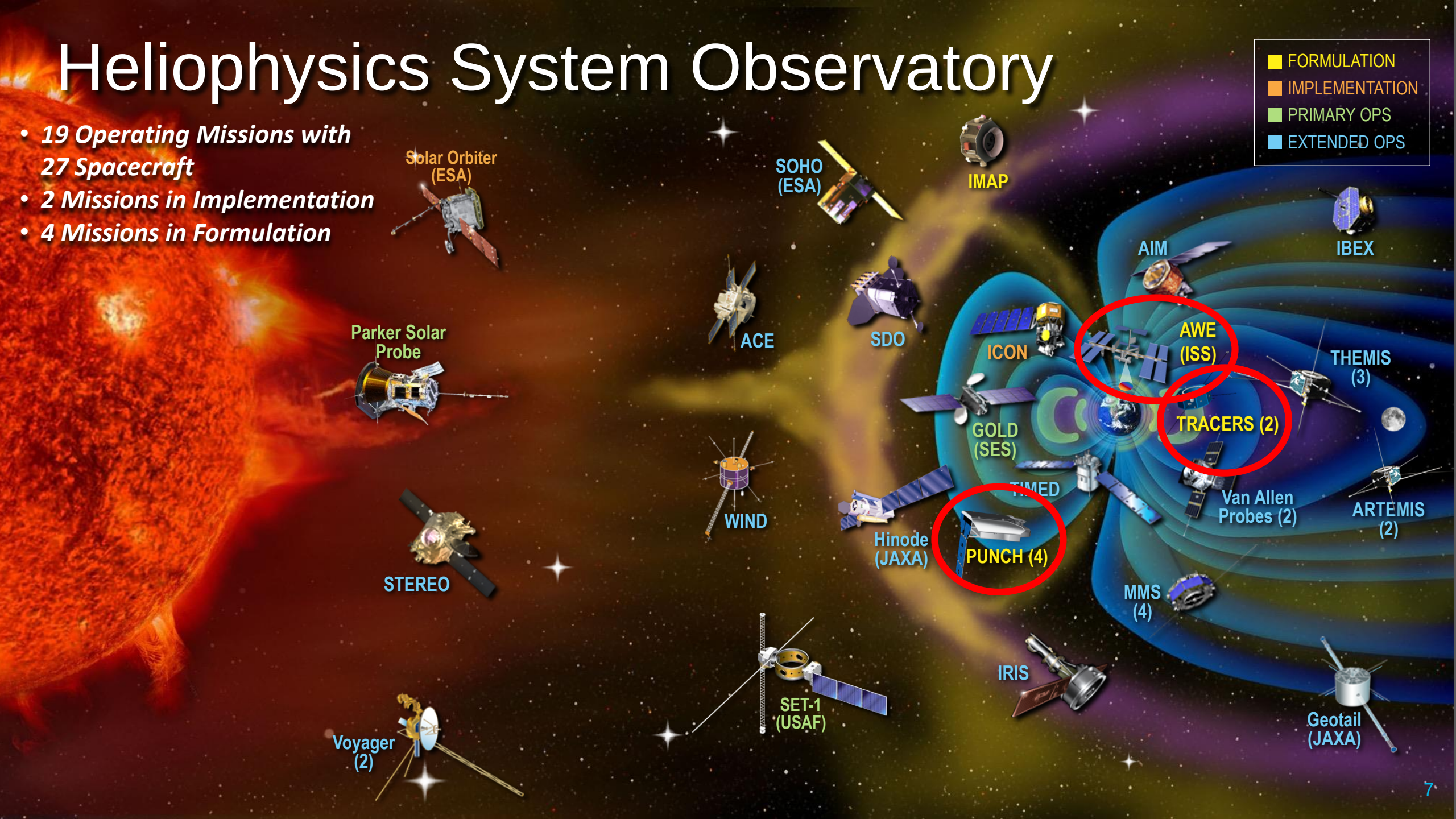


- The National Academies of Sciences, Engineering, and Medicine has convened an ad hoc committee to review the responses of NASA's Heliophysics program and NSF's Geospace program to the 2013 Decadal Survey, "Solar and Space Physics: A Science for a Technological Society."
- Assess the degree to which the Agencies' current programs address the strategies, goals, and priorities of the Decadal Survey
- Provide guidance about implementation of the recommended portfolio for the remaining years of the current decadal survey given actual funding levels
- Recommend any actions that could be taken to optimize the science value of the Agencies' programs including how to take into account emergent discoveries and potential partnerships

NEW Missions

Heliophysics System Observatory

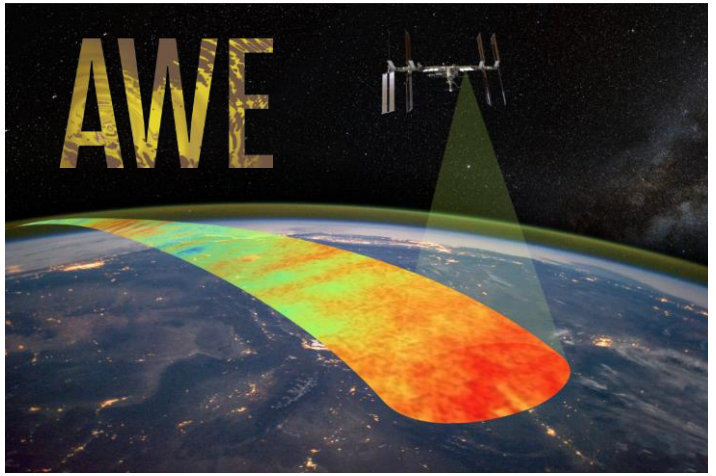
- *19 Operating Missions with 27 Spacecraft*
- *2 Missions in Implementation*
- *4 Missions in Formulation*



2016 Explorers MO Selections

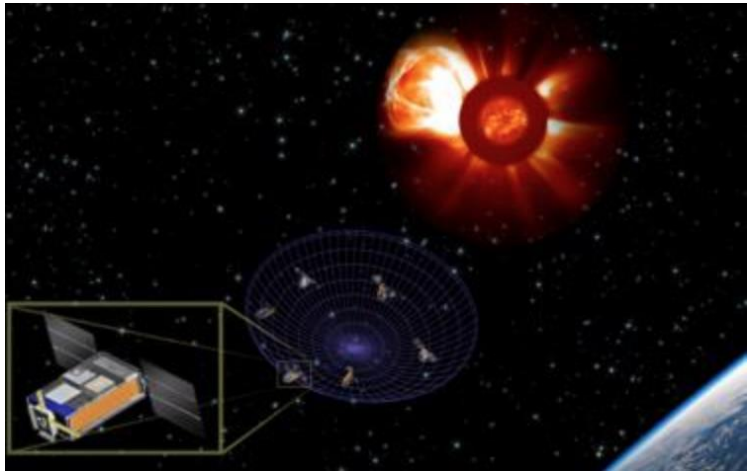
Atmospheric Waves Experiment (AWE)

- 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.
- **Principal Investigator:** Mike Taylor at Utah State University
- LRD NET Aug. 2022



Sun Radio Interferometer Space Experiment (SunRISE)

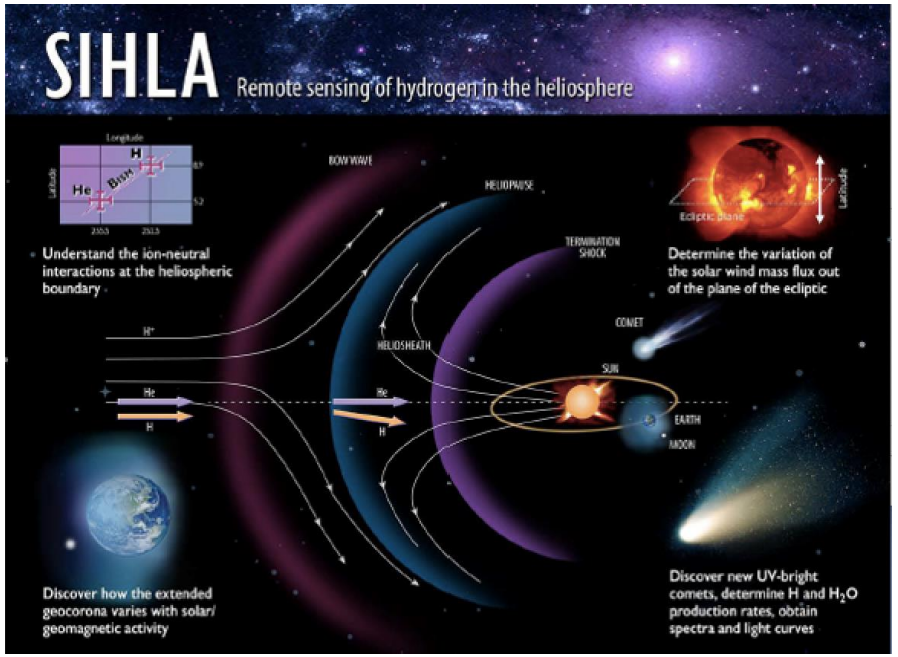
- Selected for a seven-month, $100,000 extended formulation study.
- SunRISE would be an array of six CubeSats operating like one large radio telescope to investigate how giant space weather storms from the Sun are accelerated and released into planetary space.
- **Principal Investigator:** Justin Kasper at the University of Michigan in Ann Arbor



Credit: University of Colorado at Boulder

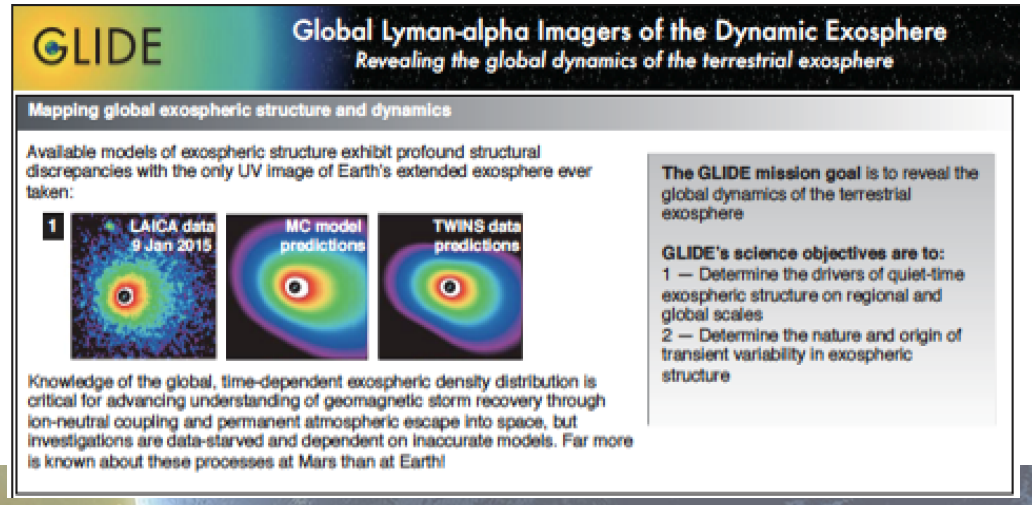
2018 STP Science MOs to ride with IMAP

Two missions selected (Aug 13) for nine-month concept studies; down-selection in 2020



Spatial/Spectral Imaging of Heliospheric Lyman Alpha (SIHLA)

- would focus on mapping the velocity and distribution of the solar wind helping to resolve our understanding of what drives structure in the solar wind and heliopause.
- **Principal Investigator:** Larry Paxton at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland.



Global Lyman-alpha Imagers of the Dynamic Exosphere (GLIDE)

- would gather ultraviolet light emitted from hydrogen at a high rate, with a view of the entire exosphere.
- **Principal Investigator:** Lara Waldrop at the University of Illinois at Urbana-Champaign

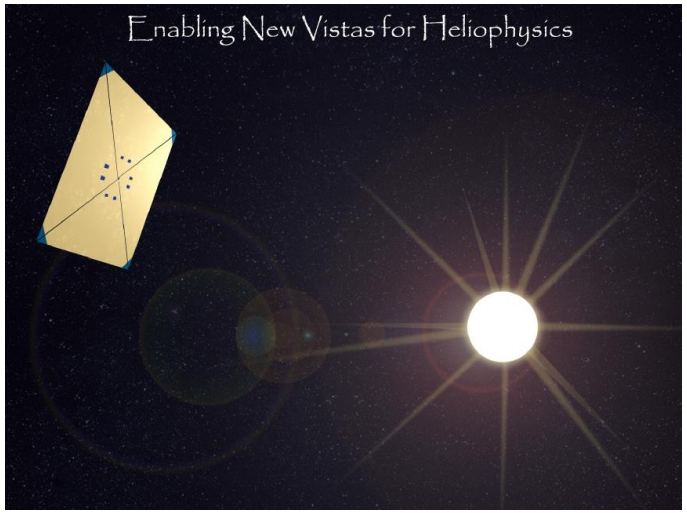
LRD Oct 2024

2018 STP Technology Demonstration MOs

Two missions selected (Aug 15) for nine-month concept studies; down-selection in 2020.

Science-Enabling Technologies for Heliophysics (SETH)

- Demonstrate technologies in two areas:
  1. Deep space small satellite optical communications; and
  2. Solar energetic neutral atom (ENA) detector that detects X-rays and energetic charged particles as well.
- **Principal Investigator:** Antti Pulkkinen at NASA's Goddard Space Flight Center in Greenbelt, Maryland



Solar Cruiser

- Designed to mature solar sail technologies and demonstrate a novel solar coronagraph for SmallSat applications.
- 1666m^2 solar sail would be the largest ever flown
- **Principal Investigator:** Les Johnson at NASA's Marshall Space Flight Center in Huntsville, Alabama

LRD Oct 2024

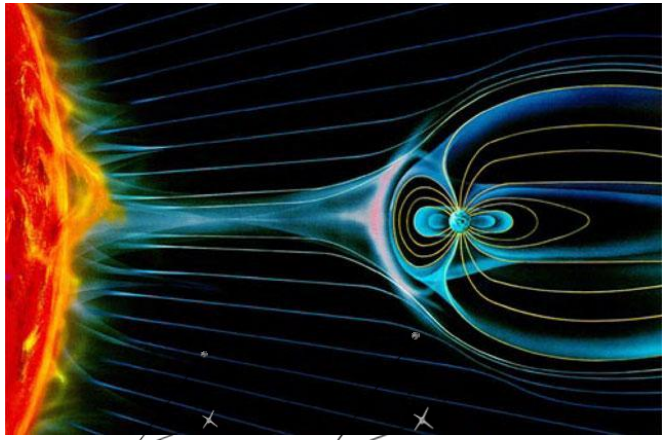
Explorers AO 2016 SMEX Selections

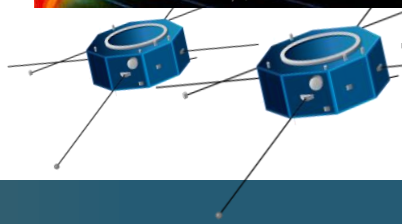
Polarimeter to Unify the Corona and Heliosphere (PUNCH)

- Focuses directly on the Sun's corona, and how it generates the solar wind
- Image and track the solar wind as it leaves the Sun.
- Track coronal mass ejections to better understand their evolution and develop new techniques for predicting such eruptions
- Composed of four suitcase-sized satellites
- **Principal Investigator:** Dr. Craig Deforest at Southwest Research Institute

Tandem Reconnection and Cusp Electrodynamics Reconnaissance Satellites (TRACERS)

- Observe particles and fields at the Earth's northern magnetic cusp region and study how magnetic fields around Earth interact with those from the Sun.
- First space mission to explore this process in the cusp with two spacecraft, providing observations of how processes change over both space and time.
- **Principal Investigator:** Craig Kletzing at University of Iowa





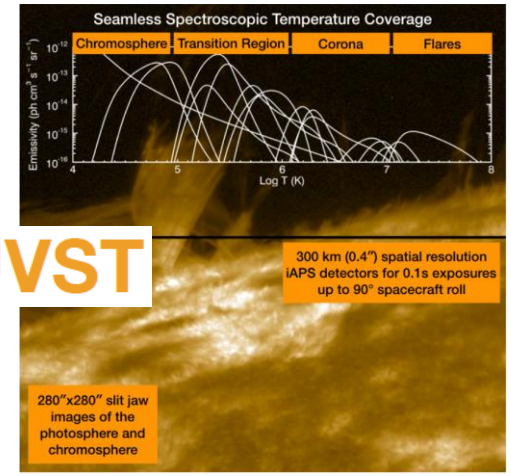
TRACERS

LRD NLT Aug 2022

"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" – Thomas Zurbuchen

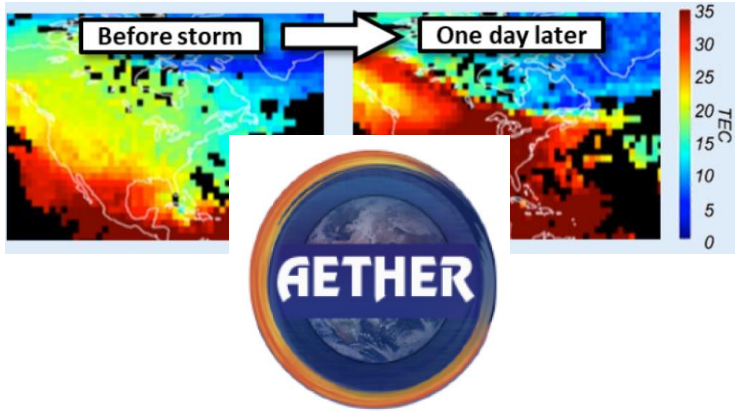
3 Explorers Missions of Opportunity to Advance Understanding of Heliophysics

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



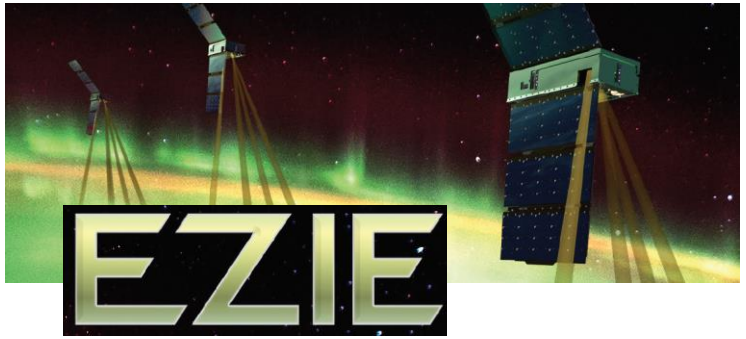
Extreme Ultraviolet High-Throughput Spectroscopic Telescope (EUVST) Epsilon Mission

- 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.

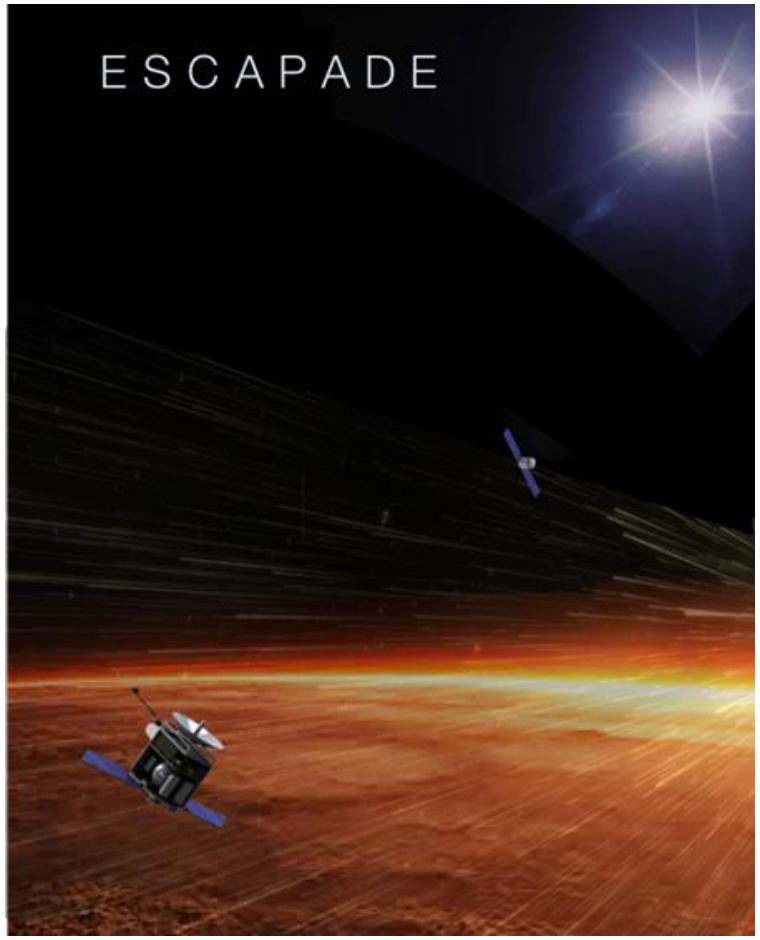


Electrojet Zeeman Imaging Explorer (EZIE)

- 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.

Escape, Plasma Acceleration and Dynamics Explorers (EscaPADE)



Selection Date: Jul 8, 2019

Principal Investigator: Robert Lillis, University of California, Berkeley

Observatory: Dual observatories rideshare hosted on Psyche mission

Instruments:

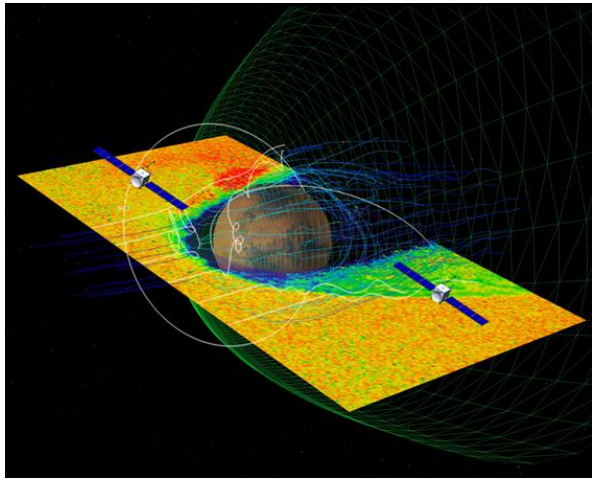
- EscaPADE Magnetometer (EMAG)
- EscaPADE Electrostatic Analyzer (EESA)
- EscaPADE Langmuir Probe (ELP)

With unprecedented two-point plasma measurements, ESCAPADE will untangle temporal from spatial variability and definitively map out the transfer of energy and momentum that leads to ion and sputtering escape, enabling a much more reliable extrapolation of escape rates to early Mars.

LRD Aug 2022

HELIOPHYSICS

Planetary Science
New Worlds, New Discoveries



PSYCHE

NASA Selects 12 New Lunar Science, Technology Investigations

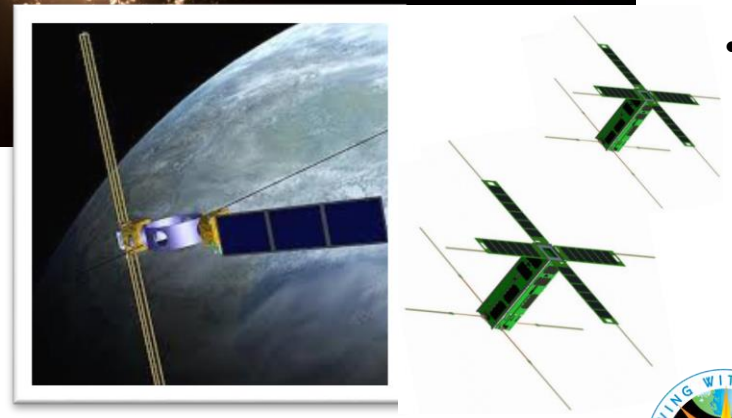
The selected investigations will go to the Moon on future flights through NASA's **Commercial Lunar Payload Services (CLPS)** project and the NASA Exploration Campaign.

The following three missions support heliophysics science objectives:

1. **The Lunar Surface Electromagnetics Experiment (LuSEE)**
   - LuSEE will integrate flight-spare and repurposed hardware from the **Parker Solar Probe** FIELDS experiment, the **STEREO**/Waves instrument, and the MAVEN mission to make comprehensive measurements of electromagnetic phenomena on the surface of the Moon.
   - Principal Investigator: Stuart Bale of University of California, Berkeley
2. **The Lunar Environment heliospheric X-ray Imager (LEXI)**
   - LEXI will capture images of the interaction of Earth’s magnetosphere with the flow of charged particles from the Sun, called the solar wind.
   - Principal Investigator: Brian Walsh of Boston University
3. **Lunar Demonstration of a Reconfigurable, Radiation Tolerant Computer System**
   - Lunar Demonstration of a Reconfigurable, Radiation Tolerant Computer System aims to demonstrate a radiation-tolerant computing technology. Due to the Moon's lack of atmosphere and magnetic field, radiation from the Sun will be a challenge for electronics. This investigation also will characterize the radiation effects on the lunar surface.
   - Principal Investigator: Brock LaMeres of Montana State University, Bozeman

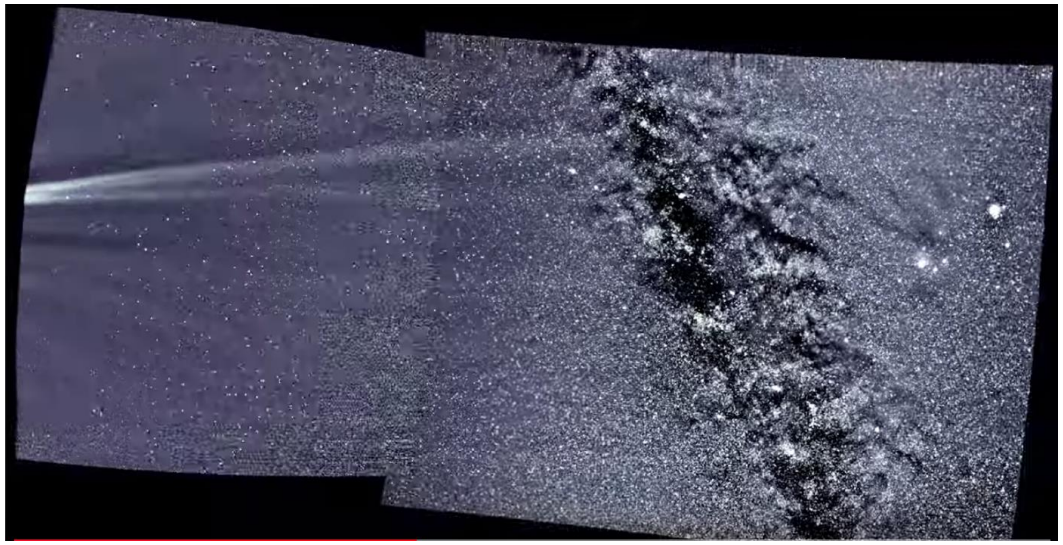
Missions in Operation: Highlights

SET-1 and E-TBEx Launch Aboard Falcon Heavy

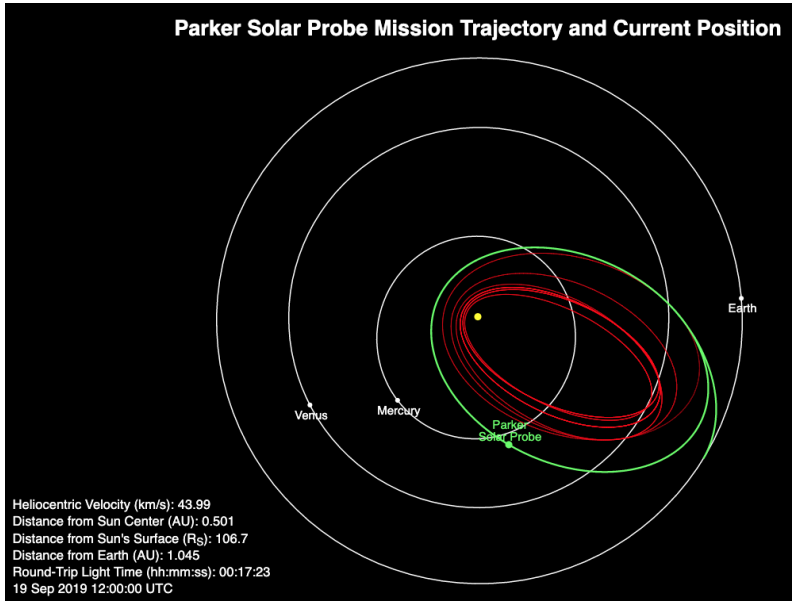


Above: SpaceX Falcon Heavy rocket carrying 24 satellites as part of the Department of Defense's Space Test Program-2 (STP-2) mission launches from Launch Complex 39A at NASA's Kennedy Space Center in Florida Tuesday, June 25, 2019.

- **Space Environment Testbed-1 (SET-1)** hosted payload on Air Force Research Laboratory (AFRL) Demonstration and Science Experiments (DSX) spacecraft
  - 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
- **Enhanced and Tandem Beacon Experiment (E-TBEx)**
  - 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



Above: Parker Solar Probe's WISPR instrument saw the solar wind streaming past during the spacecraft's first solar encounter in Nov 2018.
Credits: NASA/Naval Research Laboratory/Parker Solar Probe



Parker Solar Probe

Parker one-year on orbit – August 12, 2019

- First, Second, and Third Solar Solar Encounters complete
- Perihelion #3: September 1, 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.

Parker Solar Probe science results will be published in a Nature Special Edition coming this fall!

Van Allen Decommissioning

Van Allen Probes (VAP) successfully conducted a combined Decommissioning Review and Disposal Readiness Review on July 11 for both spacecraft.

- **Spacecraft B:**
  - Jun 20: East-West precession maneuver performed and approximately half the planned distance was reached
  - Jul 19: remaining passivation activities were completed
- **Spacecraft A:**
  - Aug 29 East-West precession maneuver performed but planned distance was not reached
  - Early October earliest passivation

Above: Mission controllers John Eichstedt and Janis Flynn (seated, center), prepare to send the command from Johns Hopkins APL's 60-foot satellite dish to spacecraft B that will end its operations after seven years of scientific discovery.

HPD at a Glance: Operating Missions

Mission	Launch Date	Phase	Extension	M-3	M-2	M-1	Cur. M.	Remarks
Voyager 1 + 2	8/20/1977	Extended	9/30/2021					
Geotail	7/24/1992	Extended	9/30/2021					
Wind	11/1/1994	Extended	9/30/2021					
SOHO	12/2/1995	Extended	9/30/2024					
ACE	8/27/1997	Extended	9/30/2021					
TIMED	12/7/2001	Extended	9/30/2021					
Hinode	9/23/2006	Extended	9/30/2021					
STEREO	10/25/2006	Extended	9/30/2021					
THEMIS+Artemis	2/17/2007	Extended	9/30/2021					
AIM	4/25/2007	Extended	9/30/2021					
IBEX	10/19/2008	Extended	9/30/2021					
SDO	2/11/2010	Extended	9/30/2021					
Van Allen	8/30/2012	Extended	9/30/2021					VAP-B decommissioned Jul 19, VAP-A failed to complete Aug 29 maneuver due to loss of fuel
IRIS	6/27/2013	Extended	9/30/2021					
MMS	3/12/2015	Extended	9/30/2021					
GOLD	1/25/2018	Prime	10/17/2020					
Parker	8/12/2018	Prime	9/30/2025					Completed 3rd Solar Encounter on Sep 7. Solar Probe Cup anomaly during solar encounter #3.
SET-1	6/25/2019	Prime	7/1/2020					Currently powered-off, s/c problems prevent completion of commissioning

Mission proceeding to meet science requirements

Area of concern - possible reduction in capability

Significant problem – possible or probable loss of mission

Mission Decommissioned

Senior Review 2020

Overview:

- Conducted every 3-years to maximize scientific return within finite resources
- Typically proposals provide new science objectives for their operating mission

Modifying Senior Review

- To allow for a more strategic approach to the HSO
- There will be two proposal options moving forward (science investigation or HSO infrastructure)

Benefit to Community:

- HSO is based on more strategic decisions
- Long-lived missions are relieved of the need to develop new and compelling science justifications
- HSO retains long baseline measurements beneficial to Heliophysics community

***More details to come in the upcoming Senior Review presentation**

Future Missions & Opportunities

Ionospheric Connection Explorer (ICON)

Launch Vehicle: Pegasus XL rocket

Launch Site: Cape Canaveral

LRD: October 9, 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*: Ferry Flight from VAFB to CCAFS on Oct 1*

Solar Orbiter Collaboration (with ESA)

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

Launch Site: Cape Canaveral

LRD: February 5, 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:

- Aims to make significant breakthroughs in our understanding both of how the inner heliosphere works, and of the effects of solar activity on it.
- 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.

Next Step*: Qualification Acceptance Review Oct 15*

Interstellar Mapping and Acceleration Probe (IMAP)

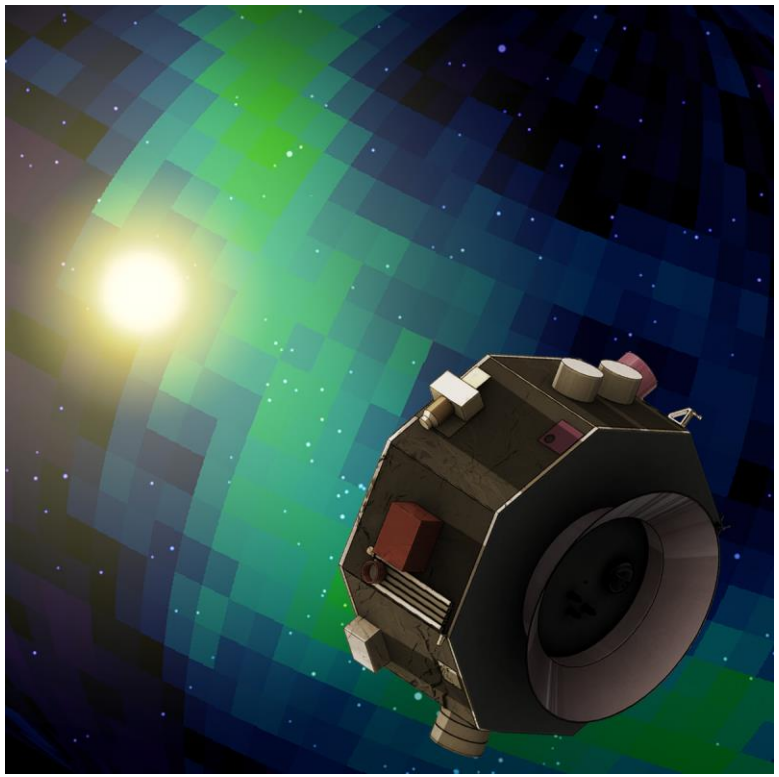


Photo: *NASA artist concept of IMAP observing the IBEX Ribbon*

Selected: June 1, 2018

LRD: October, 2024

Project Scientist: David McComas, 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 energetic neutral atoms and dust streaming to Earth from the edge of interstellar space.
- Investigate the acceleration of particles in the heliosphere and beyond.
- 10 scientific instruments
- Investigating possible accommodation of a Tech Demo

Rideshare opportunities on the ESPA Grande:

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

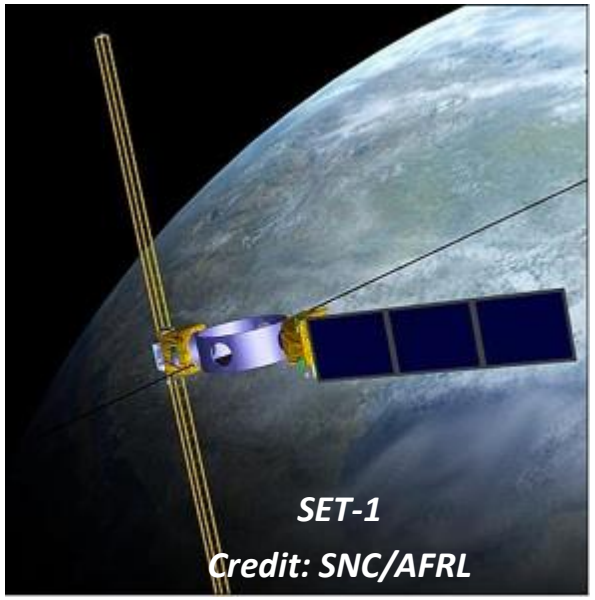
Geospace Dynamics Constellation (GDC)

- Decadal Survey identified GDC as the next Living With a Star (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 recommendations
  - Final report will be debriefed at this meeting
- Changes since FY20 Budget: LRD NET 2026

Explorers MIDEX19

- Draft AO release date: May, 2019
- Final AO release date: July 2, 2019
- Step-1 proposals due: September 30, 2019
- PI managed Cost Cap: $250M

Ability to take advantage of any future Rideshare opportunity



- SMD has embraced Rideshare opportunities as a standard practice to maximize mass to orbit
  - Enabling additional opportunities for science community
- SMD has developed a rideshare policy and a policy team to develop standard rideshare processes
- Rideshare opportunities on IMAP ESPA Grande
  - Science MO SCM & Technology Demonstration MO SCM
  - NOAA Space Weather Follow On
  - 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

Agile Responses to Short-Notice Rideshare Opportunities: Request for Community Input

The Heliophysics Division asked the National Academies Committee on Solar and Space Physics (CSSP) to prepare a short report discussing possible elements of a program with the flexibility and agility to respond to such emergent rideshare opportunities.

The CSSP received community input, in particular with regards to the following topics:

1. Kinds of solar and space physics science that would be enabled by an agile response to rideshare opportunities, at locations that would provide global perspectives, unique views, or continuous coverage, among others;
2. Types of payloads that are suited to rideshare opportunities, because they are scientifically valuable in single or multiple locations and rapidly deployable with short development times or that can be shelved until a launch becomes available;
3. Considerations for the development and implementation of a new HPD program that would allow agile responses to future short-notice rideshare opportunities.

Report is due October 1 to CSSP

Next steps: Community workshop on Rideshare, February 25-27 hosted by JHU/APL

Heliophysics Strategy

HPD Strategic Working Groups

To drive innovation within the upcoming Heliophysics Division's (HPD) Decadal Survey strategy, HPD formed 8 strategic working groups (SWG). The SWGs have outlined their high-level strategic objectives below. Across the working groups, three key themes have emerged as priorities for HPD: maximize the impact of HPD missions and research, ensure the sustainable management and innovative expansion of HPD science, and diversify the future of the science community.

Archives

- Assess, restructure, and modernize the HPD Archives

Citizen Science

- Develop and implement the HPD Citizen Science policy and strategy

Communications

- Enhance coordination between HPD, the science community, and the public

Mission Size Mix

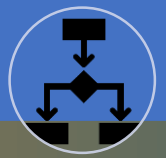
- Assess the optimal mix of future mission sizes in the HPD portfolio

Research & Analysis

- Assess the R&A program's strategic balance and effectiveness in supporting the HPD community

STP and LWS

- Better define and distinguish the goals and objectives of STP and LWS mission lines



Space Weather

- Define overarching strategy for the Heliophysics Space Weather and science applications program

Technology

- Define technology strategy to enable advances in Heliophysics science

Heliophysics Vision 2050 Workshop

- **HQ-enabled, community-led workshop to lay the groundwork for the next Decadal Survey**
  - Short-, medium-, and long-term science goals and objectives
  - Technology, modeling, and other infrastructure/capabilities to enable those science investigations
- **Part of Division pre-Decadal preparation**
  - Based upon the idea of the Planetary Science Vision 2050, but modified to meet Heliophysics Division needs
  - Create a strategic framework that the community can leverage to provide background and context for their Decadal white papers
  - Focus community attention on work in the next decadal to enable potential missions in later decades
- **Community announcements in the near future**
  - Description of the workshop, schedule, and expected output
  - Solicitation for community organizers

Investments in Future Heliophysics Leaders

Opportunities

- 6 current Jack Eddy Fellows
- 12 Future Investigators in NASA Earth and Space Science and Technology (FINESST) in 2019
- 11 selections for ROSES18 Early Career Investigator Program (ECIP)
- 24 early career professionals participated in Frontier Development Lab in 2019
  - 6 teams (4 early career, 2 domain experts, 2 computer/AI experts)

Collaboration with IMAP mission

- Heliophysics Future Leaders Program
  - Scientists are paired with diverse and high-achieving grad students and post-docs
- Student Collaboration CubeSat Development
  - University of New Hampshire teaming with Howard University

Summer Schools

- 35 students participated in Heliophysics Summer School 2019 hosted in Boulder, CO
- HPD mission formulation summer school at JPL, coming 2020

Sounding Rockets

- RockSat-X
  - 100+ students, launched Aug 12, 2019
- RockOn 2019
  - 88 students; launched Jun 20, 2019

Heliophysics Summer School 2019, Boulder, CO

RockOn 2019

NASA Heliophysics Summer Seminar

- HPD is enlisting JPL to create a new Heliophysics-oriented Summer Seminar based upon the Planetary Science Summer Seminar (PSSS)
- Participants selected from the Heliophysics community, both science and engineering disciplines
  - post-docs, recent PhDs, doctoral candidates
- Participants will learn
  - the formulation of achievable science objectives and the Level-1 requirements that flow down from them
  - the NASA mission life cycle
  - roles of scientists and engineers in a mission environment; and
  - mission design interconnectedness and trade-offs

Heliophysics HQ Interns

Abigail Kimber

Georgia Technology University, rising Junior

- *Created instrument catalog using Heliophysics missions*
- *Sources include instrument papers, instrument websites, and cost information from SOMA*

Sam Holloway

Virginia Tech, rising Junior

- *Created CubeSat/Small Sat catalog for Heliophysics missions*
- *Developed poster and presented at Small Satellite Conference in Logan, Utah from August 3-8*

Early Career Investigator Program (ECIP) – ROSES18

Haihong Che
University of Alabama, Huntsville

Michael Hartinger
Space Science Institute

Seth Dorfman
Space Science Institute

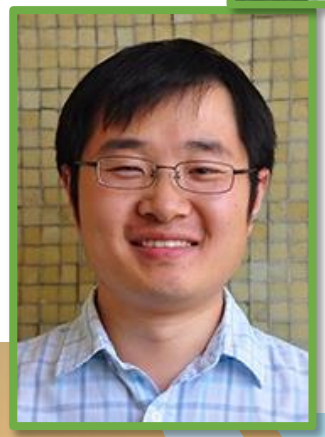
McArthur Jones
Naval Research Lab

Weichao Tu
West Virginia University

Christina Kay
Catholic University of America

Maria Kazachenko
University of Colorado, Boulder

Solar
Helio
Mag
ITM



Xiangning Chu
University of Colorado, Boulder

Kristopher Klein
University of Arizona

Raluca Ilie
University of Illinois, Urbana-Champaign

Reka Winslow
University of New Hampshire, Durham

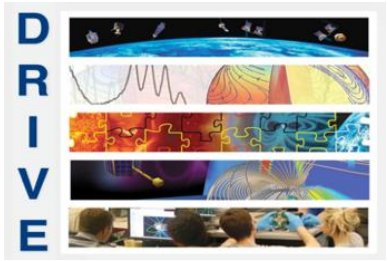
Research

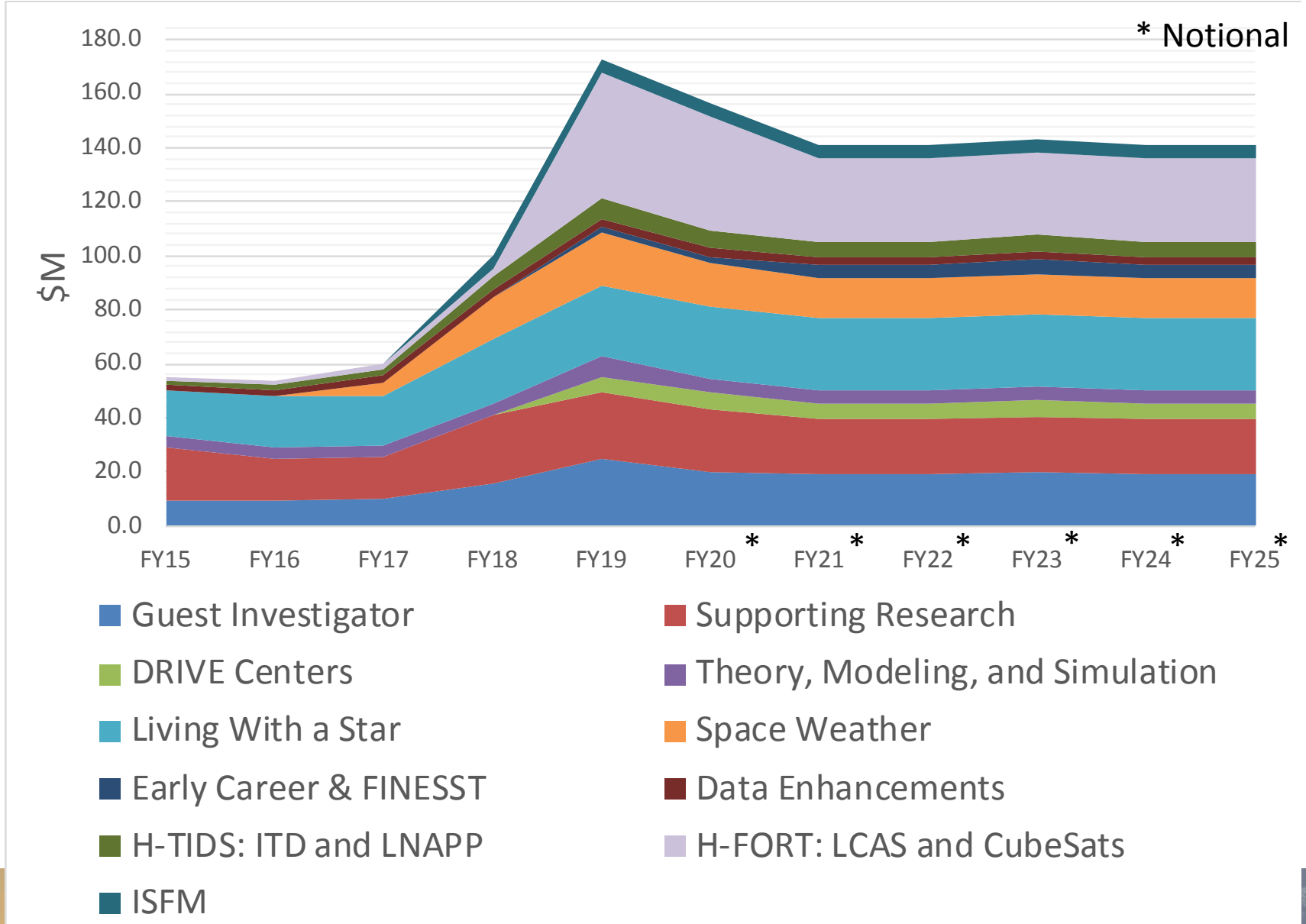
Internal Scientist Funding Model (ISFM) Progress

- ISFM is directed work that can best be done or only be done at NASA Centers
- Results accomplished through ISFM enhance the value of Agency funds by allowing NASA civil servant scientists to work on research that is substantial, strategic, forward leaning, and focused and enabling them to more fully engage with the broader scientific community
- All directed work is externally reviewed
- Teams from first year include:
  - Connecting the corona to solar wind structure and magnetospheric impact using modeling and remote and in situ observations
  - Understanding coronal heating and the solar spectral irradiance
  - Magnetic energy buildup and explosive release in the solar atmosphere
- ISFM results represented in GPRAMA 2019 source material

"The ISFM structure has allowed us to amplify our collaborations with the external community, since we are no longer in competition with them." – First year team

Fully Implemented DRIVE Initiative

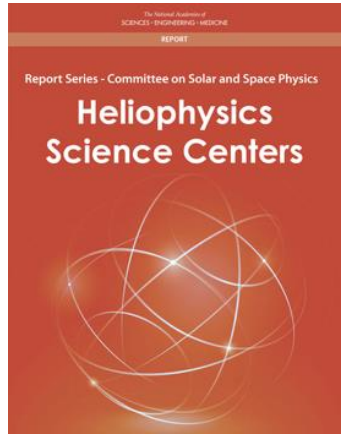




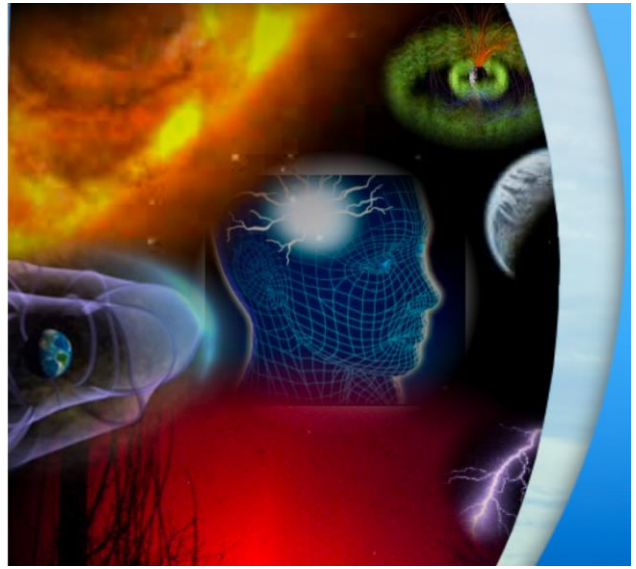
- DRIVE initiative is now part of the Heliophysics R&A baseline
- Space Weather is in addition to this baseline
- 1st ever Heliophysics DRIVE Science Centers kicking off in 2019

DRIVE Science Centers (DSC)

Report Series: Committee on Solar and Space Physics: Heliophysics Science Centers, 2017



- Received 39 proposals
- Collaboration with NSF
- Solicitation included several quotes on diversity:
  - “The characteristics of a successful DSC, include:” “creative, substantive activities aimed at enhancing education, diversity, and public outreach” and “a talented, diverse, multi/inter/trans-disciplinary, and fully integrated team to execute the research program.”



Living With a Star (LWS) Program

Overall Status:

- Continue using LPAG to provide community perspective on various issues related to LWS, including future ROSES Focused Science Topics
  - LPAG met in July 2019
- Maintaining LWS Institutes, Summer Schools, and Postdoctoral Program
- Plans for international collaboration:
  - Parker Solar Probe includes international science Co-Investigators
  - Solar Orbiter with ESA collaboration, LRD in Feb 2020
  - International participation in the GDC project is under discussion

LWS Opportunities in ROSES

- ROSES 19: Five Focus Science Topics (FSTs)
- ROSES 20:
  - Strategic Capabilities with five-year awards
  - Tools and Methods with a topic on AI applications
  - Additional FSTs

Heliophysics Research: ROSES 18

	ROSES Element				Proposal Due Date	Notify Date	Days Since Received	# Proposals received	# Proposals selected	% selected
2018	HGIO		Guest Investigators Open		6/15/2018	10/25/2018	132	142	37	26%
	HTIDS	ITD & LNAPP	Technology and Instrument Development for Science	Instument Technology Development & Laboratory Nuclear, Atomic, and Plasma Physics	7/20/2018	12/20/2018	153	74	13	38%
		LCAS		Low Cost Access to Space	7/20/2018	2/11/2019	206		9	
		R&T Prime		Research and Technology Prime (>$3.5M)	4/30/2019	8/27/2019	119		3	
	HDEE		Data Environment Enhancements		7/20/2018	12/20/2018	153	4	4	100%
	SWO2R		Space Weather Operations to Research		8/3/2018	10/23/2018	81	19	9	47%
	HSR		Supporting Research		9/7/2018	4/1/2019	206	168	33	20%
	ECIP		Early Carreer Investigator Program		9/21/2018	4/1/2019	192	51	12	24%
	LWS Science		Living With a Star Science		5/9/2019			104		
	SWO2R-2		Second Space Weather Operations to Research		5/16/2019			12		
	DRIVE Centers		Phase I DRIVE Centers		6/20/2019			39		

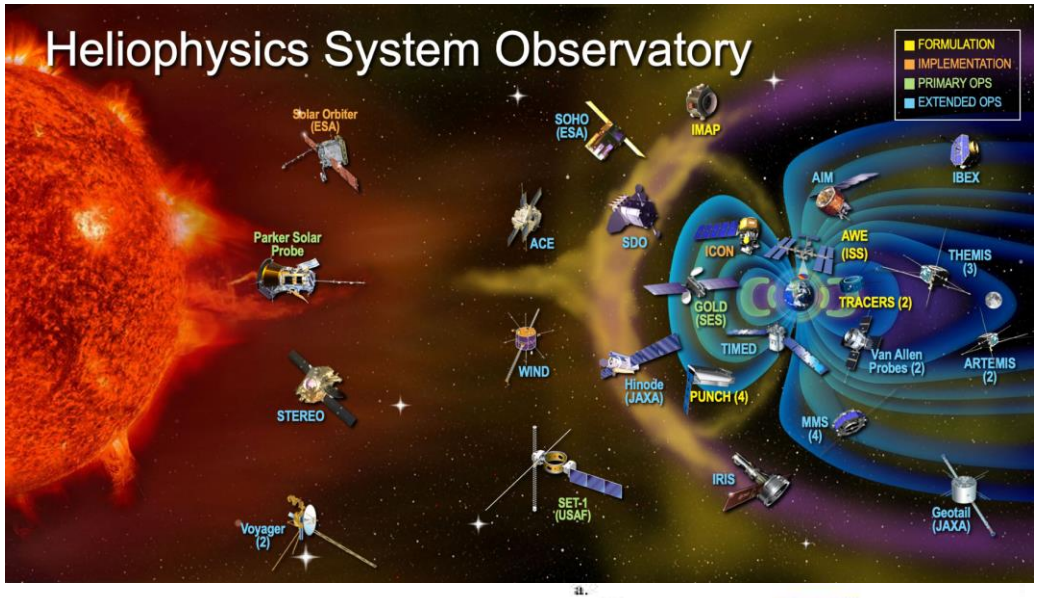
- **HITDS, HSR and ECIP were impacted by the shutdown.**
- **LWS 2018 review just completed, selections in preparation.**
- **SWO2R-2 review in process.**
- **DRIVE review in October.**

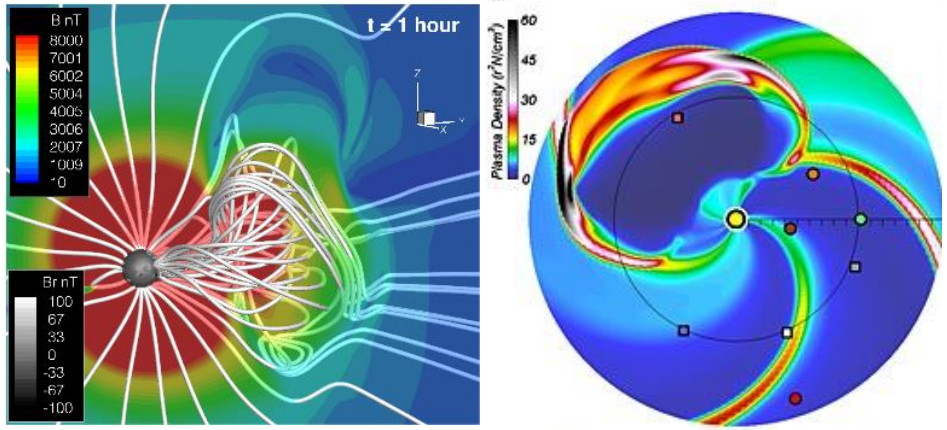
Heliophysics Research: ROSES 19

	ROSES Element		Proposal Due Date	Notify Date	Days Since Received	# Proposals received	# Proposals selected	% selected
2019	HDEE	Data Environment Emphasis	6/20/2019			15		
	HGIO	Guest Investigators Open	7/17/2019			128		
	HSODS	Heliophysics System Observatory Data Support	8/15/2019			6		
	HTIDS	Technology and Instrument Development for Science	8/28/2019			31		
	HSR	Supporting Research	10/18/2019					
	HFORT	Flight Opportunities for Research and Technology	11/1/2019					
	TMS	Theory, Modeling, Simulation	12/3/2019					
	OHGI	Outer Heliosphere Guest Investigator	12/3/2019					
	SWO2R	Space Weather Applications Operations 2 Research	2/13/2020					
	LWS Science	Living With a Star Science	2/27/2020					

- **HSODS review in process.**

Three new R&A ROSES 2019 Programs





Heliophysics System Observatory Connect

- Diverse interdisciplinary teams working together to use the HSO as an end-to-end system.
- Coordinated observations of Parker Solar Probe with currently operating space missions and ground-based observatories; and observatories not yet launched.

Heliophysics System Observatory Data Support

- Targeting ground based solar observatory data; a subset of HSO Connect
  - Received 6 proposals

Outer Heliosphere Guest Investigators

- Focused on analysis of data from Voyager, IBEX, other space assets to study the outer heliosphere.
  - Step-2 proposals due Dec 3, 2019

Volunteer for a Proposal Review Panel!

- We rely on community participation to help with the R&A program's review panels – and we have a full schedule each year.
- This is your chance to see the process in action and provide feedback.
- The Senior Advisor for Research and Analysis (SARA) or SMD Lead for Research helps with the solicitation process; please click the link to the right and volunteer for a proposal review panel.

https://science.nasa.gov/researchers/volunteer-review-panels

Data Management

- Focus group reviewing current state of Heliophysics archives and determining future needs around:
  - Data Curation (greater than 50 years)
  - Open Source Code and algorithms
  - Accessibility and interoperability between data and models
  - Machine Learning/Artificial Intelligence to enable new science
  - High End Computing needs for modeling
- Exploring public-private-partnerships (PPP), with Amazon Web Services on viability of collocating data and analysis code on a Cloud with possibility of ML/AI application
- Assess the division's ability to serve and make public peer-reviewed publications funded by NASA, reference Executive Order and OMB Memorandum M-13-13 *"Making Open and Machine Readable the New Default for Government Information"*

Solar Data Analysis Center

Technology

Heliophysics Technology Development

ROSES 18: (**HTIDeS**)

Laboratory Nuclear, Atomic, and Plasma Physics (LNAPP)

Instrument and Technology Development (ITD)

R&T Flight (Higher TRL: in-line with NPR7120.8)

- Split Low Cost Access to Space (LCAS) into CubeSats and LCAS (all suborbitals)
- non-prime proposals (≤$3.5M)

R&T Flight Prime – proposals received (>$3.5M)

- Mandatory formulation study with down-select

ROSES 19

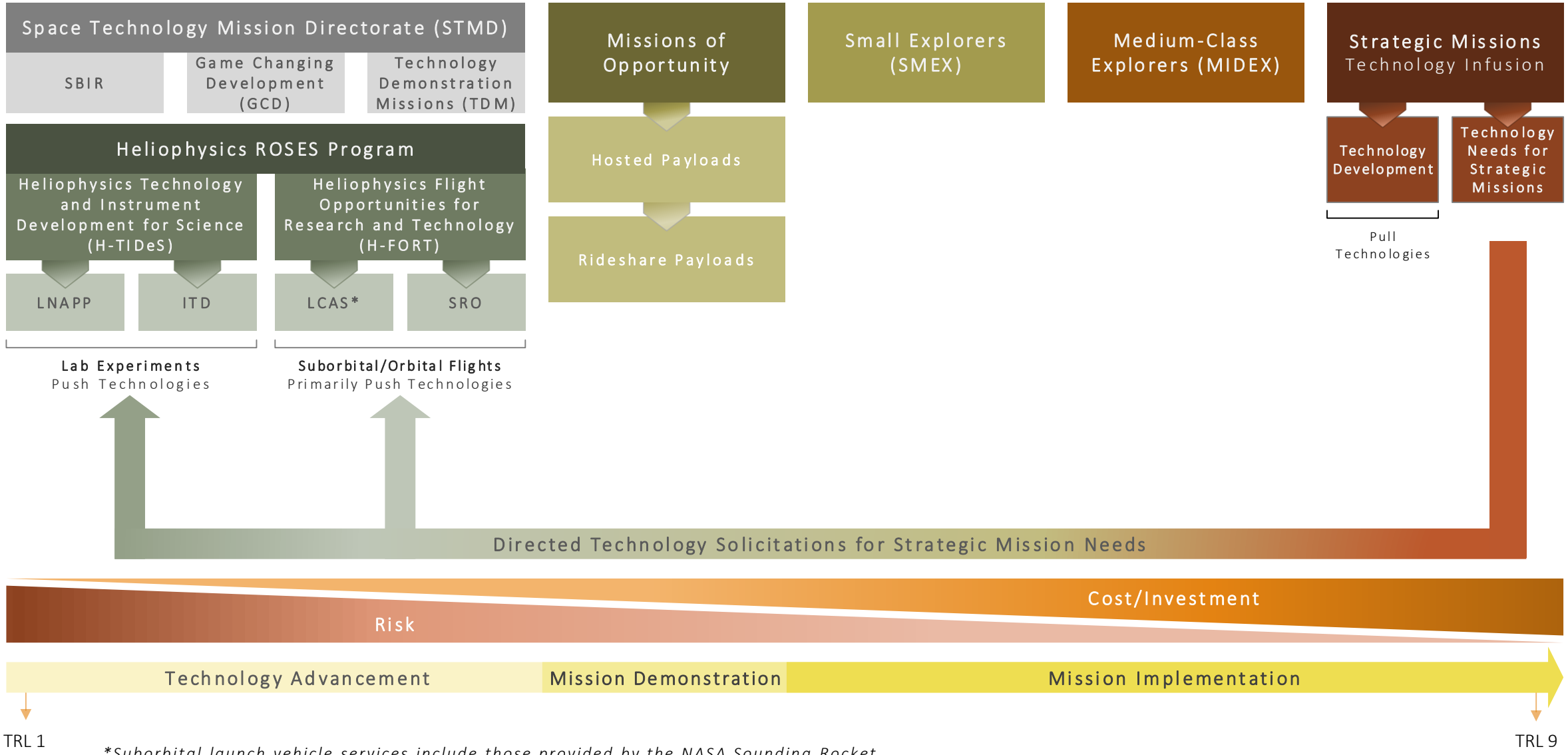
HTIDeS: Heliophysics Technology and Instruments Development for Science (Lower TRL)

- LNAPP
- ITD

H-FORT: Flight Opportunities for Research and Technology (Higher TRL: in-line with 7120.8)

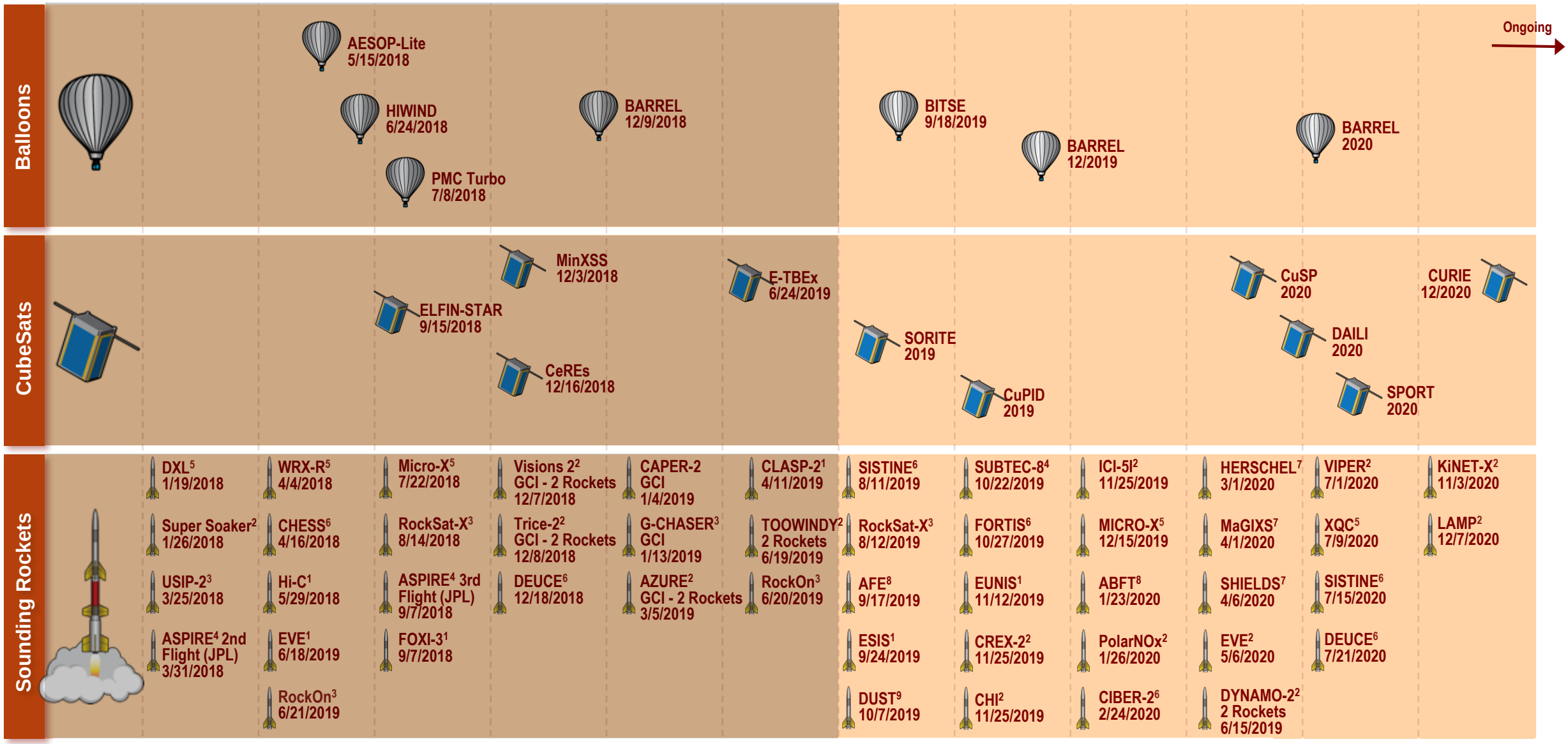
- LCAS
- SmallSats and Rideshare Opportunities (SRO)

Heliophysics Division Technology Strategy to Enable Science



**Suborbital launch vehicle services include those provided by the NASA Sounding Rocket Program Office (SRPO), overseen by the Heliophysics Division*

Heliophysics Suborbital & CubeSats (2018-2021)



Suborbital & CubeSats Highlights: Providing low cost access to cutting edge research

***ELFIN-STAR**, 2-3U CubeSats, launched Sep 15, 2018, with ICESat-2 Vandenburg Air Force Base, PI Angelopoulos (Earth Magnetospheric Particle Precipitation)*

***CLASP-2** launched April 11, 2019, White Sands Missile Range, PI McKinzie (Solar Chromospheric Magnetic Fields)*

***BITSE** launched Sep 18, 2019, Ft. Sumner, NM, PI Gopalswamy (Solar Coronal Temperature and Velocity)*

HPD Suborbital Program

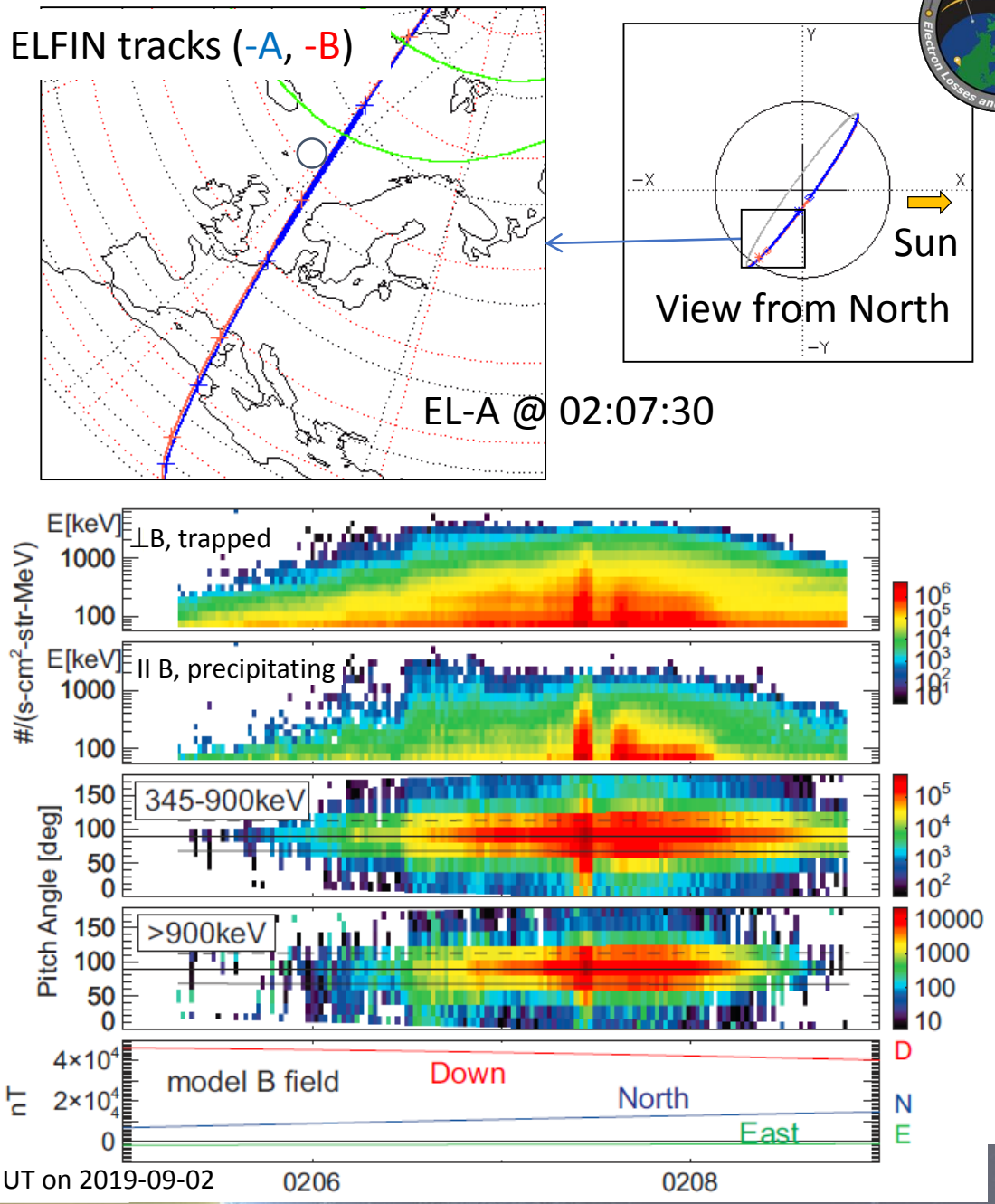
- 2018: 22 NASA missions + 4 reimbursable missions; 3 CubeSats; 4 balloon investigations
- 2019: 8 NASA missions launched as of Sep 5, 8 additional NASA missions planned for 2019 + 1 reimbursable mission (DoD); 3 CubeSats; 2 balloon investigations
- 2020: 14 NASA mission planned + 2 reimbursable missions; 4 CubeSats; 1 balloon investigation

Upcoming campaigns:

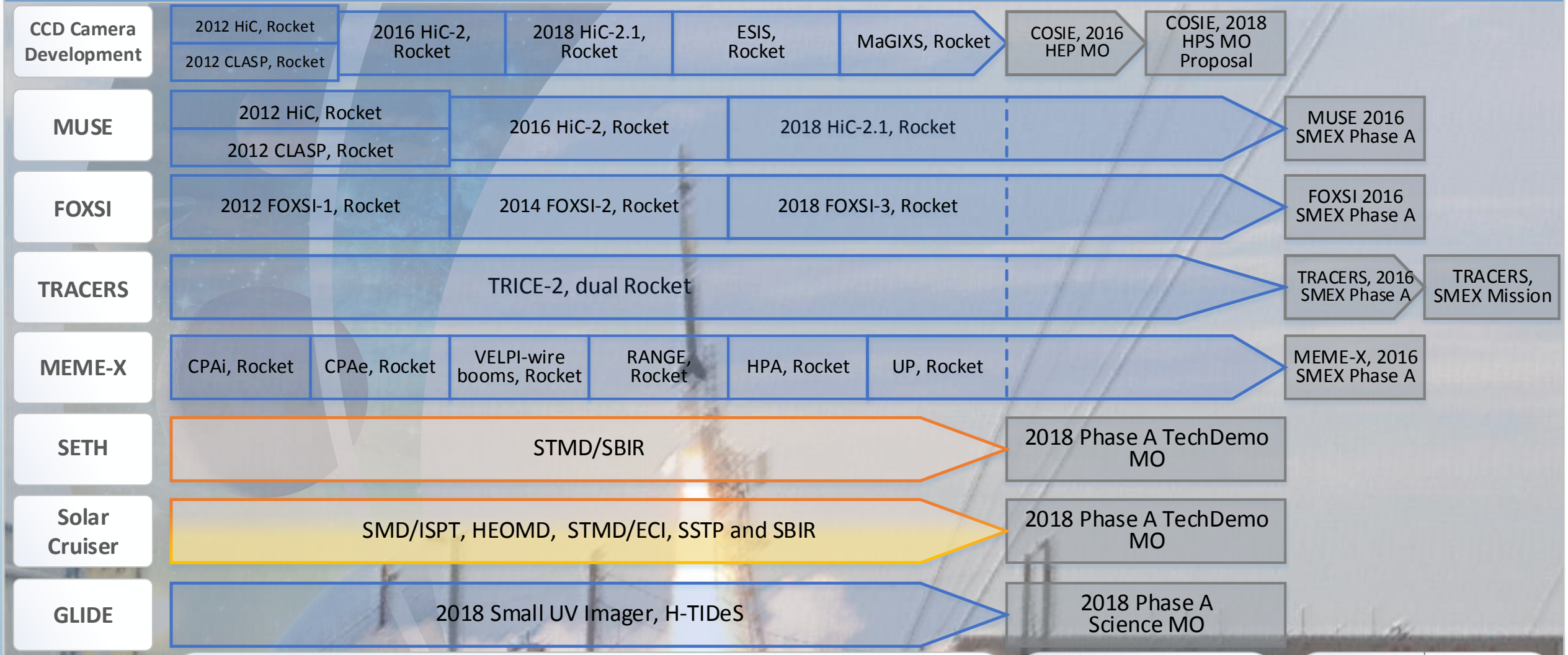
- 4 Astrophysics missions targeting May 2020 launch window using new launch location – Australia

ELFIN captures the first pitch-angle resolved relativistic electrons precipitating to the atmosphere

- The scattering of such electrons has been theorized to be due to electromagnetic ion cyclotron waves at the equator.
- ELFIN set-out to detect the pitch-angle spectra of the electrons just prior to their loss, to determine if they have the theoretically expected pitch-angle and energy spectral signatures.
- Shown are trapped and precipitating electron energy spectra from 50 keV to 6 MeV, and pitch angle spectra at ~500keV and ~1MeV. All clearly show the presence of precipitation from 50keV to 1.5 MeV.
- These and similar spectra to be collected over the next 1.5 years together with models will definitively answer whether EMIC waves are responsible for the scattering or if other waves (e.g., whistlers) may be also contributing to the scattering.



Heliophysics Technology Infusion Examples

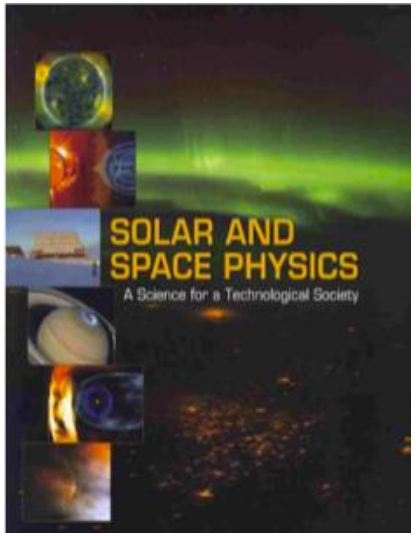


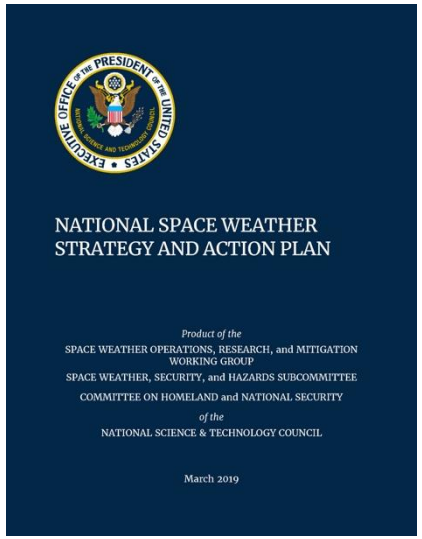
*"Sounding rockets are an **ideal** technology development arena: Higher risk tolerance encourages innovation; rapid development cycles and frequent flight rates permit iteration; build experienced and coherent teams, train future instrument, mission, and scientific leaders"; Doug Rowland*

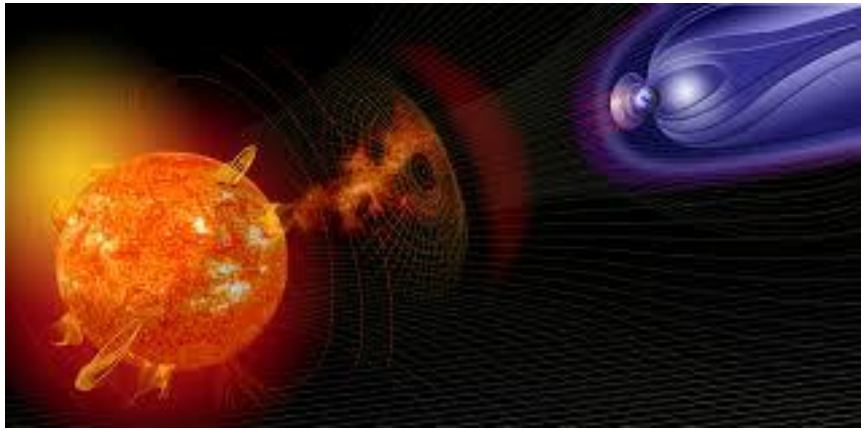
Space Weather

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







Space Weather Science and Applications Update

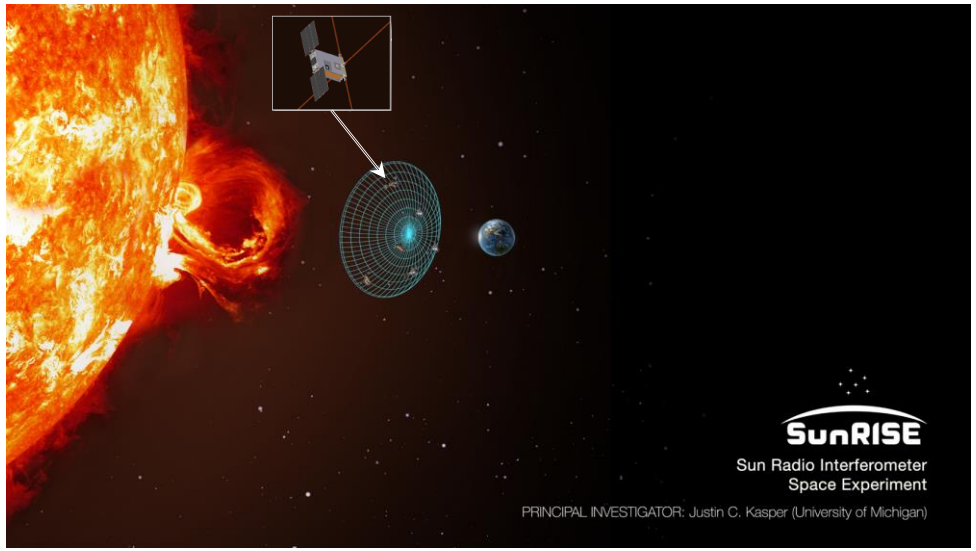
Space Weather Strategy: NASA, NOAA, OSTP, and OMB

- 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 Applications 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

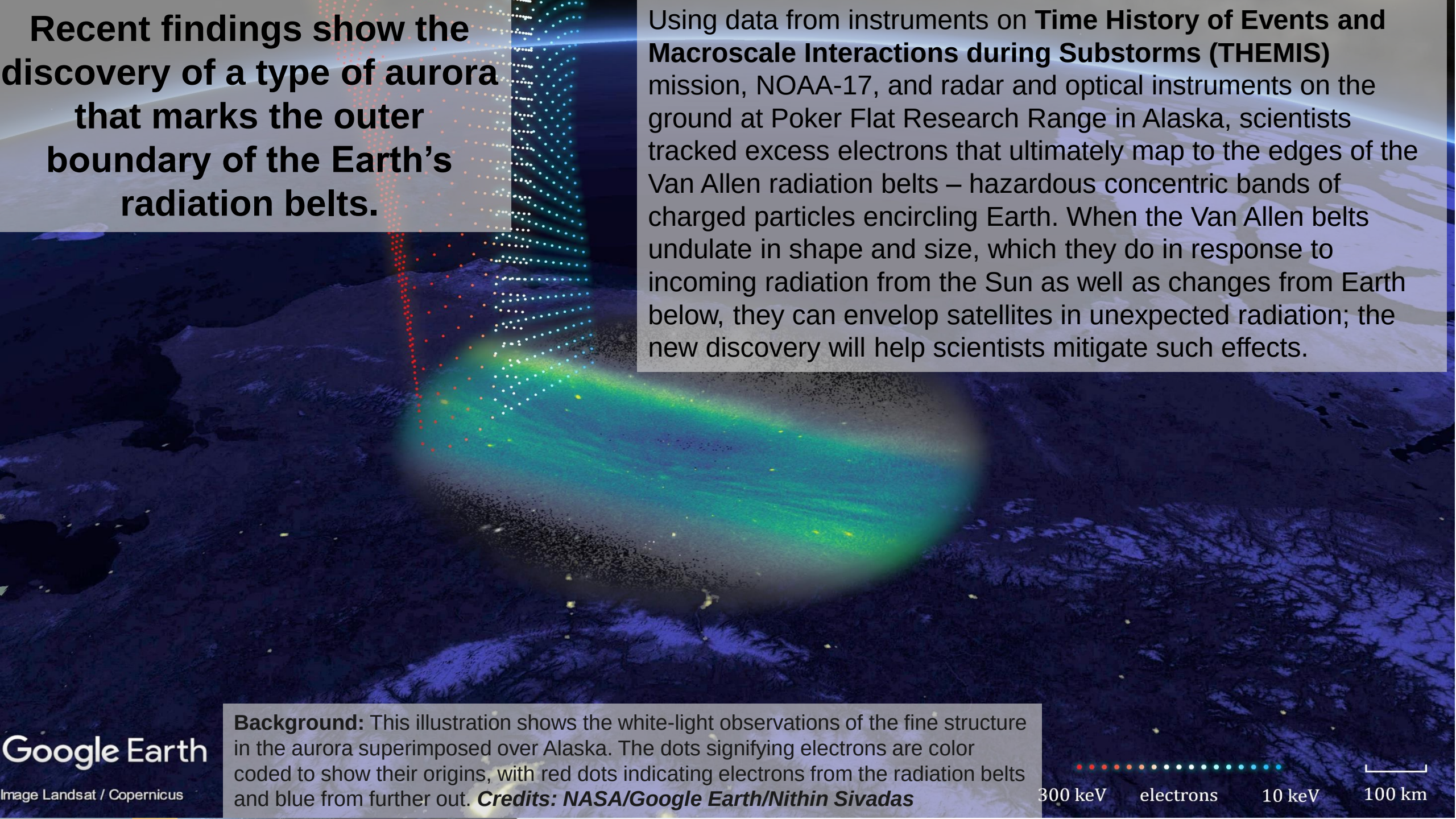
- 2018 – Selected 2 Phase II
- 2019 – Selected 4 Phase I
- 2020 – Language for Call has been approved

Space Weather Science and Applications 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 a lunar space environment capability with Human Exploration & Operations Mission Directorate (HEOMD) 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
- 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)

Recent findings show the discovery of a type of aurora that marks the outer boundary of the Earth's radiation belts.

Using data from instruments on **Time History of Events and Macroscale Interactions during Substorms (THEMIS)** mission, NOAA-17, and radar and optical instruments on the ground at Poker Flat Research Range in Alaska, scientists tracked excess electrons that ultimately map to the edges of the Van Allen radiation belts – hazardous concentric bands of charged particles encircling Earth. When the Van Allen belts undulate in shape and size, which they do in response to incoming radiation from the Sun as well as changes from Earth below, they can envelop satellites in unexpected radiation; the new discovery will help scientists mitigate such effects.

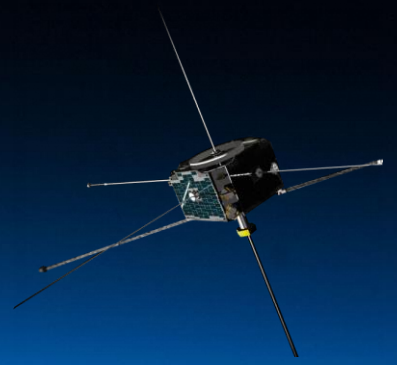


Background: This illustration shows the white-light observations of the fine structure in the aurora superimposed over Alaska. The dots signifying electrons are color coded to show their origins, with red dots indicating electrons from the radiation belts and blue from further out. ***Credits: NASA/Google Earth/Nithin Sivadas***

THEMIS-ARTEMIS gains insight on the Moon's environment

The Moon actually possesses a very tenuous atmosphere. Ionization of this atmosphere, primarily by sunlight, creates a lunar ionosphere roughly one million times more tenuous than that of the Earth.

When the Moon passes through the near vacuum of the geomagnetic tail of the Earth each lunar month around full Moon, the lunar-derived charged particle density becomes comparable to the ambient value, and the presence of the lunar ionosphere can affect its surroundings. This can lead to better characterization of the lunar environment in anticipation of future human exploration of our closest planetary body.



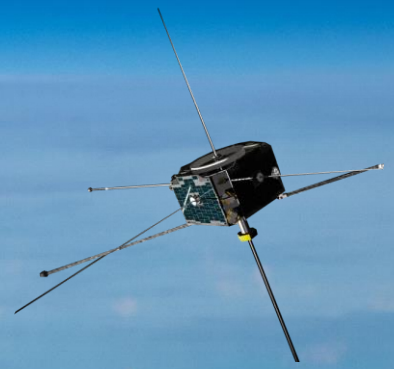


Photo Credit: NASA/Johnson

Cross Collaborations

Intra- and Interagency Partners

Planetary:

- Co-selected LWS grants; joint ROSES Juno Participating Scientist Program
- EscaPADE mission

Astrophysics:

- Joint “Impact of Stellar Properties on the Habitability of Exoplanets” research opportunity

NASA-NOAA (MOU):

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

NASA-NSF:

- 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:

- Pilot O2R research activity, MOU signed

NASA-USGS

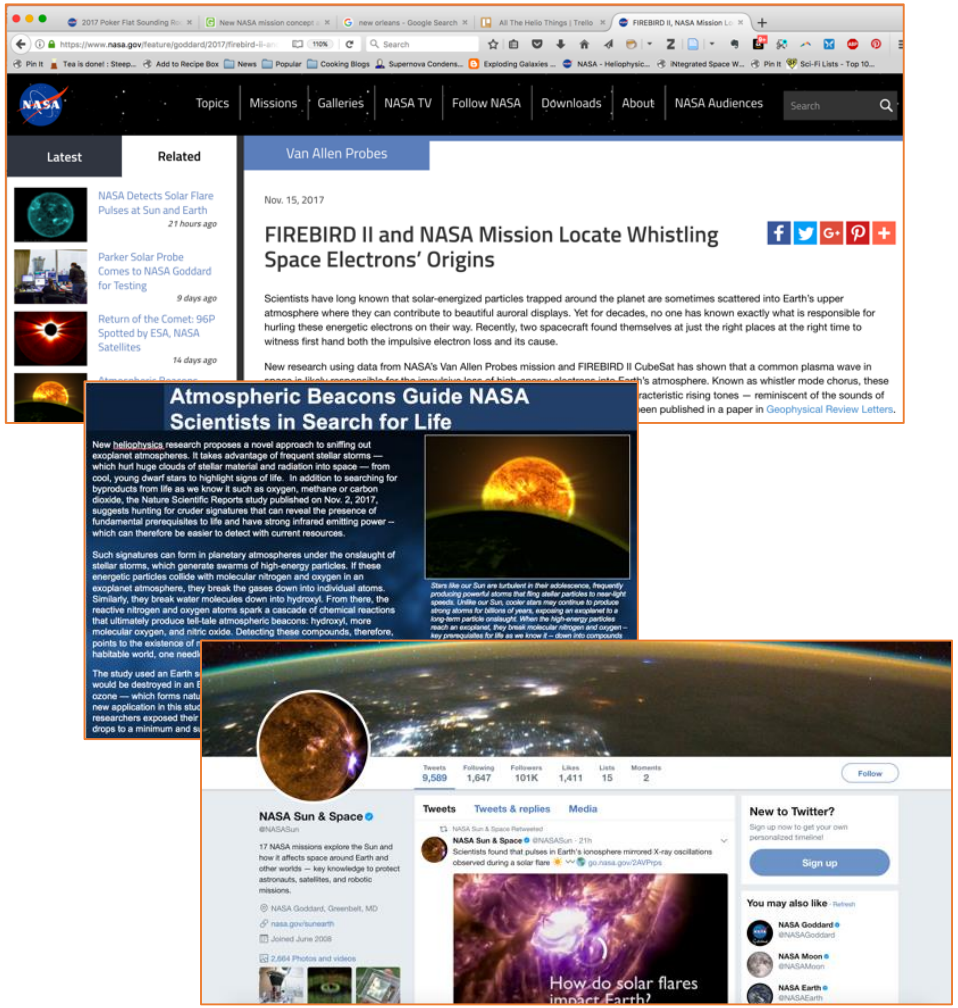
- NASA collaborating with USGS to enable Magneto-Telluric Survey in southwest

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

Summary

HELIO CONNECTS through Science

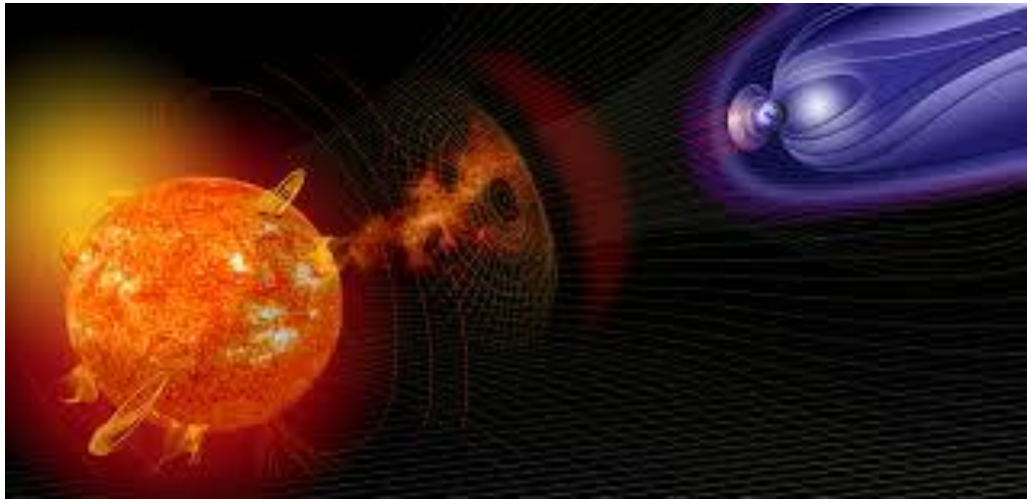


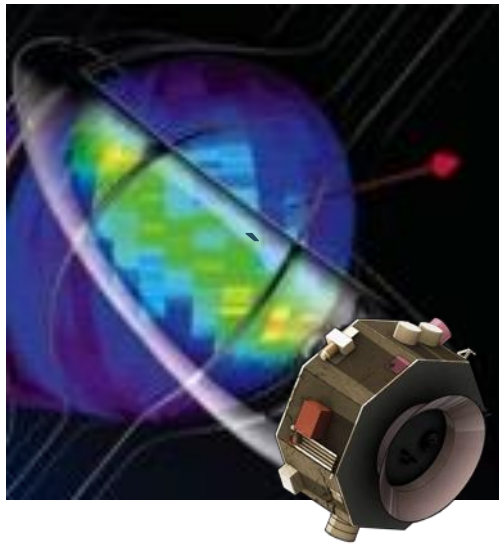
We want to share your research with others at NASA, with the community, with the public and with the media! But we need your help…

- Please let NASA's heliophysics communications team know about:
  - Upcoming papers
  - Upcoming mission events (i.e., testing, anniversaries, records broken)
  - Outreach events: school visits, press interviews, stakeholder interactions, etc.
  - Submit at: bit.ly/SubmitHelioScience
- We can feature your research via numerous outlets:
  - With NASA leadership: weekly and monthly updates
  - With the community: newsletters (sign up for it here)
  - With the public
    - Internet: NASA.gov/sunearth and blogs.nasa.gov/sunspot
    - Social media: @NASASun and facebook.com/NASASunScience
    - Imagery: Videos, visualizations, infographics (https://svs.gsfc.nasa.gov/Gallery/NASAsHeliophysicsGallery.html)
  - With the media: Press releases and press briefings

Let us know at: bit.ly/SubmitHelioScience

It is a Great Time to be a Heliophysicist!





- The Heliophysics Division is poised like never before to:
- Capitalize on our unique opportunity to study the Sun and its effects throughout the Heliosphere
- Augment the Heliophysics fleet with new, innovative missions, a robust suborbital program, and an enhanced ride share program
- Make research and technology investments to enable science, e.g. interstellar probe, solar sails
- Develop the next generation of Heliophysicists and engage the public with science knowledge
- Fulfill our responsibility for the Nation enabling advances in space weather
- Play a critical role in Exploration supporting the Artemis mission
- Lean forward for success in the next decade

#HelioRocks