Heliophysics Division

Space Weather Strategy

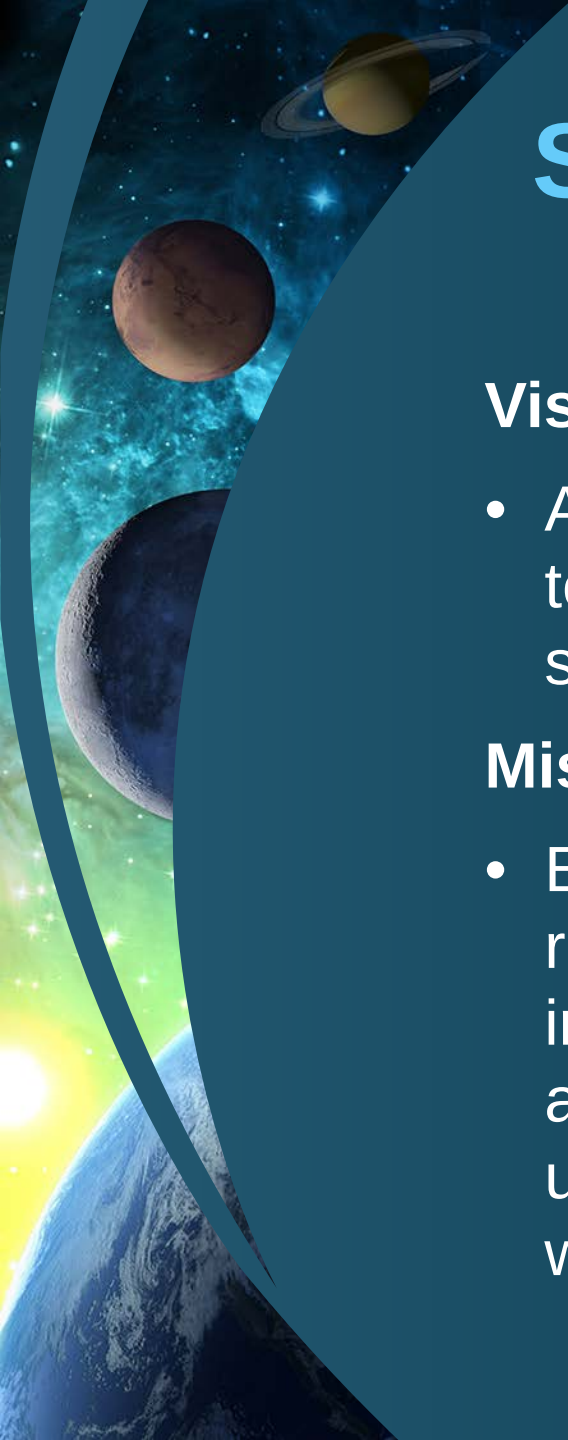
HPAC, June 30 – July 1, 2020

Heliophysics Space Weather Strategy

This strategy outlines the goals and objectives of NASA Heliophysics Division with respect to space weather. It is consistent with the goals and agency responsibilities articulated in the 2019 National Space Weather Strategy and Action Plan, as well as the Agency's efforts in human and robotic exploration.

Context

- Understanding space weather is the domain of Heliophysics. Space weather is the applied expression of Heliophysics. In Priority 1 of the 2020 NASA Science Plan, Strategy 1.4 pertains directly to space weather:
  - *Develop a Directorate-wide, target-user focused approach to applied programs, including Earth Science Applications, Space Weather, Planetary Defense, and Space Situational Awareness.*



Space Weather Strategy

Vision

- Advance the science of space weather to empower a technological society safely thriving on Earth and expanding into space.

Mission

- Establish a preeminent space weather capability that supports robotic and human space exploration and meets national, international, and societal needs by advancing measurement and analysis techniques, and by expanding knowledge and understanding for transitioning into improved operational space weather forecasts and nowcasts.

Goals

- NASA plays a vital role in space weather research by providing unique, significant, and exploratory observations and data streams for theory, modeling, and data analysis research, and for operations.
- NASA's contributions to observing and understanding space weather are critical for the success of the National and International space weather enterprise.
- NASA has a preeminent space weather capability through the pursuit of the following goals:

1. Observe

- Advance observation techniques, technology, and capability

2. Analyze

- Advance research, analysis and modeling capability

3. Predict

- Improve space weather forecast and nowcast capabilities

4. Transition

- Transition capabilities to operational environments

5. Support

- Support Robotic and Human Exploration

6. Partner

- Meet National, International, and societal needs consistent with Government directives

1. Observe: Advance observation techniques, technology, and capability

1.1 Identify technologies and techniques for which enhanced or future investments would produce results that significantly and positively impact space weather understanding and prediction

1.2 Create opportunities to develop observation techniques and instrumentation

1.3 Establish and sustain recurrent flight cadence and supporting infrastructure opportunities for space weather instrumentation and missions

a. Develop and launch a NASA-led pathfinder mission that contributes significantly to the National space weather enterprise

1.4 Identify and implement the capability to ensure that real-time and latent data streams for space weather-relevant space observations are available

2. Analyze: Advance research, analysis and modeling capability

2.1 Identify analysis capabilities that would advance space weather understanding and prediction

2.2 Establish opportunities to support the development of improved data analysis and modeling capabilities

2.3 Work with NSF and other Federal agencies, and with international space agencies to advance research and analysis capabilities relevant to space weather

3. Predict: Improve space weather forecast and nowcast capabilities

3.1 Develop a structure and process that funnels basic research information to an applied focus

a. Create opportunities to use existing and past observations to develop improved forecast and nowcast capability

b. Create opportunities for the scientific community and the GSFC Community Coordinated Modeling Center to test and validate forecast and nowcast models that show promise for operational environments

c. Periodically assess the opportunity to capture new discoveries into forecasting and nowcasting models

4. Transition: Transition capabilities to operational environments

4.1 Create a pipeline that conveys the results and outputs of the NASA Heliophysics research and technology programs to a space weather proving ground environment where models and techniques are assessed

4.2 In coordination with NOAA, establish a testbed capability to transition forecasting and nowcasting models (SWPC) and transition observations and data streams (NESDIS)

4.3 Establish formal relationships between NASA and DoD, and with international space agencies, to exchange data and observation capabilities, and effectively transition data, improved forecasting and nowcasting capabilities, and improved observation techniques

5. Support: Support Robotic and Human Exploration

5.1 Advance the partnership between the Heliophysics Division and the Human Exploration and Operations Mission Directorate (HEOMD) to provide expertise on space environment conditions that enable the health and safety of astronauts beyond low-earth orbit

- a. Develop Earth-independent observational and model assessment capabilities needed for on-board space environment forecasting on long-duration crewed missions
- b. Identify opportunities to manifest space observation capabilities to improve forecasting of space environment in support of space exploration
  - i. Deliver Gateway HERMES payload and establish a Science Operation Center
  - ii. Establish a competed HERMES science team to conduct science investigations

5.2 Provide key real-time data streams to the Agency for forecasting, nowcasting, and anomaly resolution for robotic and crewed missions

6. Partner: Meet National and International needs consistent with U.S. Government directives

6.1 Secure the counsel of space weather expertise within the government, academia, commercial and private sector

- a. Seek advice of the NASA Heliophysics Advisory Committee (HPAC) on matters relevant to space weather
- b. Secure the results of a NASA focused gap analysis of space weather knowledge, observational and data capability, and forecasting and nowcasting capability
- c. Engage NASEM on matters relevant to space weather

6.2 Provide key real-time data streams to sister agencies for forecasting, nowcasting, and anomaly resolution

6.3 Continue active participation at the Executive level with OSTP

- a. Partner with other Federal Agencies to achieve the objectives of the National Space Weather Strategy and Action plan

6.4 Represent the U.S. in international space weather research fora to advance the global capability and enhance U.S. ability to meet its space weather needs

- a. Provide leadership to the UN COPUOS space weather activities
- b. Partner with international agencies to further the capability of space weather forecasting/nowcasting
  - i. Coordinate with ESA for NASA participation in the Lagrange Mission
  - ii. Coordinate with CSA for NASA participation in the Arctic Observation Mission
  - iii. Coordinate with other space agencies as the opportunity arises and is appropriate, to include the establishment of an International Agency Space Weather Coordination Group

SWxSA Strategy by Goal		
Theme	**Goal**	**Objective**
1. Observe	Advance observation techniques, technology, and capability	1.1 Identify technologies and techniques for which enhanced or future investments would produce results that significantly and positively impact space weather understanding and prediction 1.2 Create opportunities to develop observation techniques and instrumentation 1.3 Establish and sustain recurrent flight cadence and supporting infrastructure opportunities for space weather instrumentation and missions 1.4 Identify and implement the capability to ensure that real-time and latent data streams for space weather-relevant space observations are available
2. Analyze	Advance research, analysis and modeling capability	2.1 Identify analysis capabilities that advance space weather understanding and prediction 2.2 Establish opportunities to support the develop improved data analysis and modeling capabilities 2.3 Work with NSF and other Federal agencies to advance research and analysis capabilities relevant to space weather
3. Predict	Improve space weather forecast and nowcast capabilities	3.1 Develop a structure and process that funnels basic research information to an applied focus
4. Transition	Transition capabilities to operational environments	4.1 Create a pipeline that conveys the results and outputs of the NASA Heliophysics research and technology programs to a space weather proving ground environment where models and techniques are assessed 4.2 In coordination with NOAA, establish a testbed capability to transition forecasting and nowcasting models (SWPC) and transition observations and data streams (NESDIS). 4.3 Establish formal relationships between NASA and DoD to exchange data and observation capabilities, and effectively transition data, improved forecasting and nowcasting capabilities, and improved observation techniques.
5. Support	Support Robotic and Human Exploration	5.1 Advance the partnership between the Heliophysics Division and the Human Exploration and Operations Mission Directorate (HEOMD) to provide expertise on space environment conditions that enable the health and safety of astronauts beyond low-earth orbit 5.2 Provide key real-time data streams to the Agency for forecasting, nowcasting, and anomaly resolution for robotic and crewed missions
6. Partner	Meet National, International, and societal needs consistent with Government directives	6.1 Secure the counsel of space weather expertise within the government, academia, commercial and private sector 6.2 Provide key real-time data streams to sister agencies for forecasting, nowcasting, and anomaly resolution 6.3 Continue active participation at the Executive level with OSTP 6.4 Represent the U.S. in international space weather research fora to advance the global capability and enhance U.S. ability to meet its space weather needs

SPACE WEATHER COUNCIL

Space Weather Council (SWC)

The NASA Heliophysics Division is establishing a Space Weather Council, a subcommittee to the Heliophysics Advisory Committee (HPAC).

- The Space Weather Council (SWC) is established as a means to secure the counsel of community experts across diverse areas, on matters relevant to space weather in support of the NASA Heliophysics Division (HPD).
- The SWC serves as a community-based, interdisciplinary forum for soliciting and coordinating community analysis and input and providing advice. It provides advice to the Heliophysics Advisory Committee (HPAC) of the NASA Heliophysics Division (HPD).
- The SWC shall report to and be responsive to actions levied by the HPAC. As appropriate, the SWC may seek scientific and programmatic input from the heliophysics and space weather communities at large on matters relevant to their actions.
- The SWC will support the Heliophysics Division Space Weather Science Application (SWxSA) objectives.

SPACE WEATHER RFI

Request for Information (RFI) for Space Weather Instruments and Missions for Science (SWIMS)

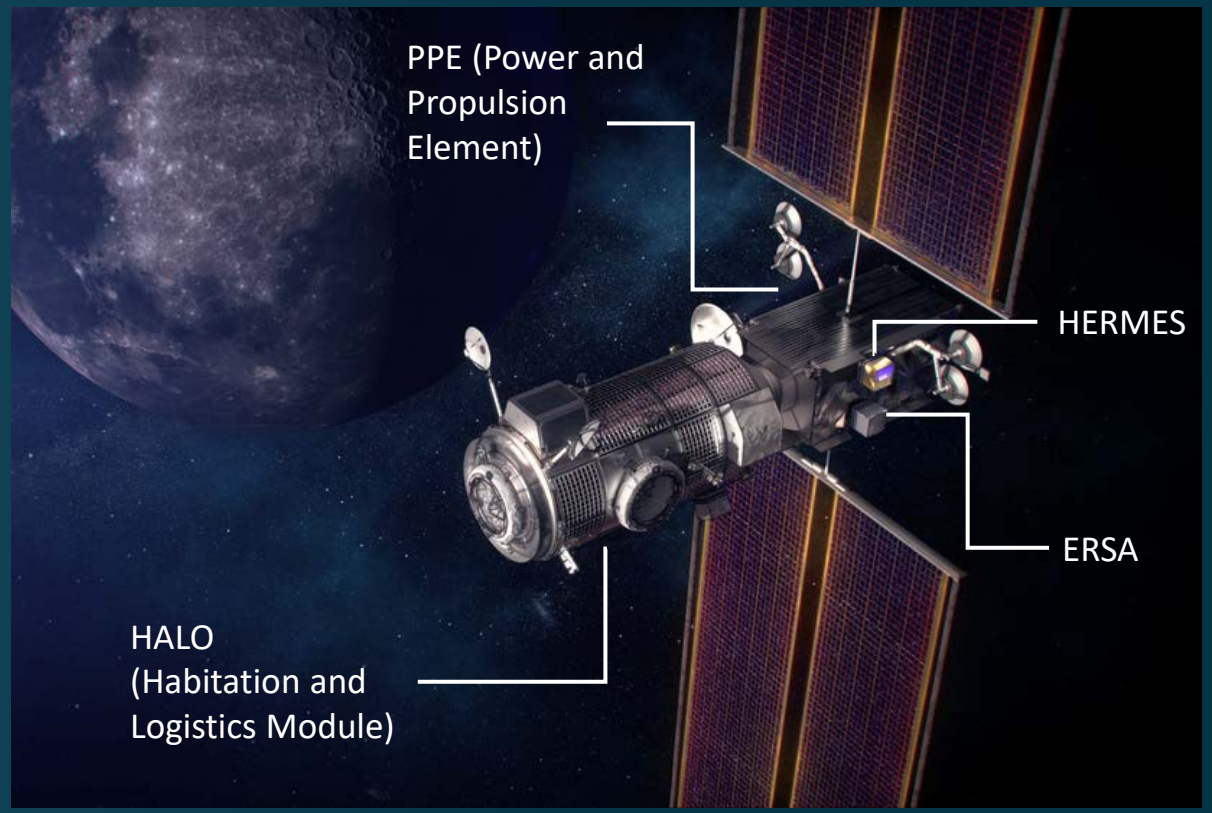
- NASA HPD is seeking information under this Request for Information (RFI) to assess community interest, concepts, and rough order of magnitude (ROM) cost for (1) small complete missions, (2) instrument suites, or (3) single instruments, that if flown in space would directly address space weather science and/or observational needs.
- The data collected through this RFI will be used by NASA to help inform future solicitations for instruments, instrument suites, or small complete missions that could be flown on secondary payload adapters or as hosted payloads on a satellite or other platform.
- Any of these options may be exercised as future Science Mission Directorate (SMD) Heliophysics missions or payloads.

HERMES and Gateway

Gateway: HERMES

NASA selects first two scientific investigations to fly on Gateway in support of Artemis

- The NASA space weather instrument suite, led by HPD, will observe solar particles and the solar wind. The second scientific investigation is a radiation instrument package, built by the European Space Agency.
  - NASA Suite: **HERMES** (Heliophysics Environmental and Radiation Measurement Experiment Suite)
  - ESA Suite: **ERSA** (ESA Radiation Sensors Array)
- **Program Office:** Living With a Start (LWS) Program, Explorers and Heliophysics Projects Division (EHPD), Goddard Space Flight Center (GSFC)
- This payload will enable meaningful science, support Artemis, and be forward looking to crewed missions to Mars.



Gateway: HERMES (cont.)

Coordinated System of Observations

- **Solar Energetic Particles (SEP) –** Improved understanding of the arrival location of the particles and the acceleration mechanism as the shocks pass by the lunar environment.
- **Solar Wind Structures –** Resolve 3D solar wind structures that will enable the ability to explore Galactic Cosmic Ray (GCR) variability across a compelling and interesting range of spatial and temporal scales needed to unravel these structures.
- **Magnetotail Dynamics –** Provide a synoptic view of the global energy input in the magnetosphere during storms and substorms, and how magnetic reconnection operates from a pristine location, unaffected by Earth's strong dipole.

Primary Payload

- **Miniaturized Electron pRoton Telescope (MERIT),** GSFC, Dr. Shrikanth Kanekal, Principal Investigator (PI)
- **Electron Electrostatic Analyzer (EEA),** GSFC, Dr. Daniel Gershman, PI
- **Solar Probe ANalyzers (SPAN)-A-ions,** University of California-Berkeley, Dr. Roberto Livi, PI
- **Fluxgate and Magneto-Inductive Magnetometers (MAG),** GSFC and University of Michigan-Ann Arbor, Dr. Eftyhia Zesta, PI, and Dr. Mark Moldwin, CO-I
- **Instrument Control Electronics (ICE),** GSFC Project Office
- **Integration Plate,** GSFC Project Office

Space Weather R2O2R

2017 O2R - Focus: Improve predictions of background solar wind, solar wind structures, and CMEs

NOAA Selections

No.	PI/ Institution	Title
21	Riley/Predictive Science Inc.	Metric-Based Assessment of a New Ambient Solar Wind Forecast Model incorporating Data Assimilation
4	Zhao/Stanford	Reliably Inferring the Sun's Far-Side Magnetic Flux for Operations Using Time-Distance Helioseismic Imaging

NASA Selections

No.	PI/ Institution	Title
7	Hickman/LANL	Optimizing the Source Surface and Interface Radii in WSA using Data Assimilation
5	Wang/NRL	Using Magnetograms and Coronal Imaging Observations to Improve Space Weather Predictions
8	Odstrcil/GMU	Improving the Prediction Accuracy of CME Arrivals in the WSA-ENLIL-Cone Model
2	Kirk/Catholic Univ	Evaluating and Validating Heliospheric Models Against Data and Each Other
14	Merkin/JHU	Data-driven Time-Dependent Model of the Inner Heliosphere
18	Barnes/NRA	Global Boundary Magnetic Field Optimization to Improve Solar Wind Model Predictions
11	Berger/CU	Improving Magnetic Field Boundary Conditions for Solar Wind Forecast Models
19	Kim/Univ. of Alabama	A Higher-Accuracy Model of the Heliosphere with Improved Background Solar Wind and Coronal Mass Ejections

2018 O2R - Focus: Improve specifications and forecasts of the energetic particle and plasma encountered by spacecraft

No.	PI/ Institution	Title
3	Li/UC Boulder	Quantitative forecasts and specifications of outer radiation belt electrons based on solar wind conditions
4	Green/Space Hazards	Specifying High-altitude Electrons using Low-altitude LEO Systems
6	Chen/LANL	A Neural Network Based Predictive Model for MeV Electrons inside Earths Outer Radiation Belt
7	Bortnik/UCLA	A machine learning based specification and forecast model of the inner magnetospheric radiation environment
8	Jordanova/LANL	Data-driven Specification of the Near-Earth Space Environment
10	Murphy/UMD College Park	An ARIMAX model of radial diffusion for space weather forecasting
13	Sorathia/APL	Data-Augmented Forecasting Model for near-Earth Relativistic Electron Intensities
16	Fok/GSFC	Advanced Particle and Plasma Environment Specification Model for Spacecraft Impacts
19	Sazykin/Rice	Development of a Predictive Inner Magnetosphere Model for Space Weather

2018b O2R - Focus: Improve forecasts of solar energetic particles and heavy ions

Proposal	PI/Institution	Title
3	Falconer/University of Alabama, Huntsville	Automated All-Clear Forecasting of Fast-Rising SPEs
5	Dayeh/Southwest Research Institute	Forecasting energetic particle and heavy-ion enhancements at 1 AU: A machine-learning, data intensive approach
7	Linker/Predictive Science	Integrated MHD-Focused Transport Modeling of Solar Particle Events
8	Zhang/Florida Institute of Technology	Prediction of Solar Energetic Particle Radiation Based on Measurements of Solar Eruption and Photospheric Magnetic Field
10	Szabo/NASA Goddard Space Flight Center	Solar Energetic Particles and Interplanetary Type III Bursts
11	Nitta/Lookheed Martin Advanced	Building a Solar Energetic Particle Forecast Model Using Spatial Properties of Solar Eruptions
12	Engell/NextGen Federal System	Forecasting solar particle events with SPRINTS

2019 O2R - Focus: open call

13 proposals selected - announcement notice is eminent

2020 O2R - Focus: Ionospheric Disturbances & Satellite Drag

Step 1 proposals due 12/16/2020, Step 2 due 02/17/2021

2019 NSF-NASA Space Weather Quantification of Uncertainties

Final proposals selection in progress - announcement notice is eminent

Small Business Innovative Research (SBIR)

Proposal	PI/Institution	Title
SBIR 2018 Phase 2	Meaghan Marsh / Predictive Science, Inc.	Interactive Tool for Modeling Multiple Solar Eruptions
SBIR 2018 Phase 2	Kent Tobiska/Space Environment Technologies, LLC	Automated Radiation Measurements for Aerospace Safety - Dual Monitor (ARMAS-DM)
SBIR 2019 Phase 2	Pete Riley / Predictive Science, Inc.	An Extensible Tool for Estimating Space Weather Benchmarks
SBIR 2019 Phase 2	Jesse Woodroffe / Quantitative Scientific Solutions, LLC	Geoelectric Field Forecasting with Machine Learning: A Data-Driven, Ensemble-Based Capability for Hazard Mitigation
SBIR 2019 Phase 2	Janet Green / Space Hazards Applications, LLC	A Tool for Defining Solar Particle Access to the Magnetosphere (SPAM) for Satellite Anomaly Attribution: PhaseII
SBIR 2020 Phase 1	8 proposals recommended	Under review at HQ

Next Steps

- Establish a Space Weather Council as a subcommittee to HPAC
- Release the Request for Information (RFI) for Space Weather Instruments and Missions for Science (SWIMS)
- Develop a space weather implementation plan
- Establish a NASA SWxSA team to serve as a sounding board and implementation team
- Conduct a space weather science and measurement gap analysis