COLLEGE OF ENGINEERING
CLIMATE AND SPACE SCIENCES AND ENGINEERING
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September 21, 2020

Dr. Nicola Fox, Heliophysics Division Director
National Aeronautics and Space Administration
Heliophysics Division
300 E Street, SW
Washington, DC 20546-0001

Dear Dr. Fox:

The Heliophysics Advisory Committee (HPAC), an advisory committee to the Heliophysics Division (HPD) of the National Aeronautics and Space Administration (NASA), convened on 21 September 2020 via Webex virtual connection. The undersigned served as Chair for the meeting with the support of Dr. Janet Kozyra, HPAC Designated Federal Officer (DFO), of NASA-HPD.

All but one of the members of HPAC participated. Specifically, those present were as follows: Vassilis Angelopoulos (University of California, Los Angeles), Rebecca Bishop (The Aerospace Corporation), Paul Cassak (West Virginia University), Darko Filipi (BizTek International LLC), Lindsay Glesener (University of Minnesota), Larisa Goncharenko (Massachusetts Institute of Technology (MIT) Haystack Observatory), George Ho (Johns Hopkins University Applied Physics Laboratory), Lynn Kistler (University of New Hampshire), Tomoko Matsuo (University of Colorado Boulder), William H. Matthaeus (University of Delaware), Mari Paz Miralles (Smithsonian Astrophysical Observatory), Cora Randall (University of Colorado, Boulder), and me. The only one absent was James Klimchuk (NASA Goddard Space Flight Center), who had another NASA HQ commitment today.

Also in attendance for the first half of the meeting were representatives from the Earth Science Advisory Committee and the Planetary Science Advisory Committee, Drs. Marshall Shepherd and Conor Nixon, respectively.

Dr. Michael New briefed HPAC on the new GPRAMA performance goals, including the interdisciplinary nature of the goals this year. Jennifer Kearns briefed the HPAC about GPRAMA process for 2020.

The HPAC was tasked to lead the review of two of the SMD performance goals:

PG 1.1.1. NASA shall demonstrate progress in exploring and advancing understanding of the physical processes and connections of the Sun, space, and planetary environments throughout the Solar System.

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PG 1.1.6. NASA shall demonstrate progress in developing the capability to detect and knowledge to predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Also, specifically within PG 1.1.6, we were requested to assess NASA's performance on this subgoal:

To include specific consideration/rating for progress in advancing scientific understanding of background solar wind, solar wind structures, and coronal mass ejections, which can be integrated into key models used to predict the arrival time and impact of space storms at Earth.

Resulting from substantial deliberation, all present voted unanimously for a "green" rating for both of these performance goals, finding "expectations for the research program fully met in context of resources invested." The specific summary text generated by HPAC for each of the performance goals can be found below.

Finally, during the open discussion portion of the meeting, we talked with Dr. Jim Spann of HQ about the composition of the membership of the Space Weather Council.

We thank the HPD staff for providing source material with highlights from the NASA-supported missions and research projects. This was most helpful in our assessment of the performance goals for the GPRAMA review. We welcome any requests from NASA Heliophysics Division for clarification or elaboration on our findings.

Sincerely yours,

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PG 1.1.1	NASA shall demonstrate progress in exploring and advancing understanding of the physical processes and connections of the Sun, space, and planetary environments throughout the Solar System.

The Heliophysics Advisory Committee (lead), Planetary Advisory Committee, and Earth Science Advisory Committee determined in September 2020 that NASA has demonstrated progress in its annual performance towards exploring and advancing understanding of the physical processes and connections of the Sun, space, and planetary environments throughout the Solar System. Below are examples of scientific progress reported in FY 2020.

The Global-scale Observations of the Limb and Disk (GOLD) mission enabled significant progress in understanding the effects of solar and atmospheric variability on Earth's thermosphere and ionosphere. Researchers using GOLD suggested a physical pathway for planetary wave coupling in the atmosphere-ionosphere system via planetary wave-modulated tides causing multi-day oscillations in electron density. GOLD observed a reduction in the ratio of atomic oxygen to molecular nitrogen during the break-up of the polar vortex in the stratosphere in early 2019, revealing a connection between the weather of the polar stratosphere and the weather of the thermosphere. Simulations of long-term trends of the atmosphere using TIMED/SABER data showed that vertical temperature profiles are an important signature of global climate change and are critical to monitor globally and continuously. The Aeronomy of Ice in the Mesosphere (AIM) Explorer identified a previously unreported Sun-Earth connection that short-term variability in solar emission produces a variation in mesospheric gravity waves.

Numerical simulations demonstrated that acoustic waves at the interface between the ocean and the atmosphere produced by offshore earthquakes can reach as far as the upper atmosphere (70 kilometers up and higher), where they can be detected as variations in airglow. Such waves can be detected more rapidly than tsunamis, potentially providing a new approach for tsunami early warning systems.

Data from the Van Allen Probes mission, which has made unprecedented measurements of the dynamics of Earth's radiation belts, has revealed that human activity can cause charged particles to be ejected from the radiation belts. Radio waves from high-powered, ground-based transmitters used to communicate with submarines also propagate into space. They scatter low-energy electrons in a localized region a distance of one Earth radius above Earth's surface. The effect of the waves is clearly visible, and important in quantitatively assessing the impacts of different loss processes.

The Magnetospheric Multiscale (MMS) mission, which consists of four satellites orbiting in a tighter formation than any previous satellite mission, was used in conjunction with the Japanese Arase satellite to show that oxygen ions flowing out of both the nightside aurora and the dayside cusp reach the near-Earth plasma sheet during the main phase of geomagnetic storms, where they become the source for ions that cause strong disturbances in Earth's magnetic field during the storms. Also, MMS observations near the bow shock between the Sun and Earth were used to verify a prediction that the most energetic particles gain their energy via a distortion of magnetic structures and subsequent scattering of the particles.

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The Parker Solar Probe (PSP) mission, which has gotten closer to the Sun than any previous human-made object, is expected to see the plasma making up the solar wind corotate with the Sun once it is close enough to the Sun. Though PSP has not yet traversed within the predicted distance of corotation, it observed strong sporadic flows in the corotating direction, and numerous regions where the magnetic field changes directions ("switchbacks") and jets of plasma. This suggests that the transition to corotating flow dominated by the interplanetary magnetic field is more turbulent than expected, and that PSP is getting near the transition point.

In other planetary environments, observations from the Mars Atmosphere and Volatile Evolution (MAVEN) mission were used to show that the most significant contribution to the loss of material from Mars' moon Phobos predominantly came from ions that previously escaped the atmosphere of Mars. This is the first moon in the solar system found to be affected by atmospheric escape, which could have implications for exoplanets orbiting closely to their stars. Also, it was found that the variations in the east-west flow of Venus' atmosphere at low latitudes are caused by the two-fold variation in its albedo (reflectance), which changes how much heat the atmosphere absorbs from the Sun. Simulations showed that the neutral sodium in Mercury's exosphere precipitates via the magnetospheric cusps of both hemispheres, explaining the double peak pattern previously seen in observations. At Earth's Moon, high reflectance regions called "lunar swirls" were found to be associated with plasma interacting with magnetic anomalies, and maps of the flow patterns of protons from the solar wind around lunar craters were produced, which is important for the study of weathering of the lunar surface.

The committee of 15 people voted **unanimously** for a **GREEN** rating.

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PG 1.1.6	NASA shall demonstrate progress in developing the capability to detect and knowledge to predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

The Heliophysics Advisory Committee determined in September 2020 that NASA remained on track in its annual performance towards achieving this performance goal. Below are examples of the scientific progress reported in FY 2020.

Understanding the nature of solar flare trigger mechanisms is key to improving space weather prediction capabilities. Hinode and Solar Dynamics Observatory (SDO) observations, in combination with modeling, provide strong evidence for the onset mechanism of flares. The intrusion of flux at the Sun's surface leads to instabilities in the overlaying coronal magnetic fields, resulting in a rapid release of energy through magnetic reconnection.

A unique and creative technique was developed utilizing acoustic wave information derived from the SDO and STEREO missions as well as ground-based observations to infer far-side solar structures. Up to now our ability to detect the formation of structures on the far-side of the Sun has been limited. This new technique enables far-side mapping of the Sun without the necessity of deploying satellites to that area. This will facilitate early detection of potential extreme events that impact Earth.

There has been a significant improvement in our ability to identify precursors to solar flares. By utilizing a deep neural network analysis of Interface Region Imaging Spectrograph (IRIS) high resolution spectral data, researchers are now able to identify pre-flare spectra ~35 minutes prior to the flare onset with 80% accuracy. This is a major step forward in forecasting flares and will provide a new avenue of investigation and forecasting.

Through observations from Time History of Events and Macroscale Interactions during Substorms (THEMIS), with support from Geostationary Operational Environmental Satellite(s) (GOES) and other observations from the NASA Heliophysics fleet, new insights into how and where energy is released during intense geomagnetic storms were obtained. Magnetic reconnection converts magnetic to particle energy and drives space currents, which in turn can disrupt electrical power line transmission. It was found that magnetic reconnection events occur closer to Earth, and the conditions conducive to reconnection are more common, than previously thought. The knowledge gained will enable improved modeling of storm-time energy release and its effects on space currents and ground disturbances.

In addition to the above examples, the committee was charged with providing a focused examination of the progress related to the topic of extreme solar events that cause changes in the solar wind structure. This was accomplished by developing creative and unique mapping techniques, through international collaboration using historical NASA datasets, and data obtained through new missions such as Parker Solar Probe (PSP). There has been significant progress made in both the understanding, observation capability, and forecasting of drivers and sources influencing solar wind structures. The progress wasn't due to any one mission or data

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type but utilized many different NASA assets and collaborations in creative ways. It really demonstrates NASA optimally utilizing a well-rounded portfolio to produce results.

The committee of 13 people voted **unanimously** for a **GREEN** rating.

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