COLLEGE OF ENGINEERING
CLIMATE AND SPACE SCIENCES AND ENGINEERING
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Michael W. Liemohn · Professor

September 22, 2022

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 Science Mission Directorate (SMD) of the National Aeronautics and Space Administration (NASA), convened on 20-21 September 2022 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 of the members of HPAC participated. Specifically, those present were as follows:

- Aroh Barjatya (Embry-Riddle Aeronautical University)
- Rebecca Bishop (The Aerospace Corporation)
- Paul Cassak (West Virginia University)
- Matina Gkioulidou (Johns Hopkins University Applied Physics Laboratory)
- Larisa Goncharenko (Massachusetts Institute of Technology Haystack Observatory)
- James Klimchuk (NASA Goddard Space Flight Center)
- Therese Moretto Jorgensen (NASA Ames Research Center, vice chair)
- Michael Liemohn (University of Michigan, chair)
- Mari Paz Miralles (Smithsonian Astrophysical Observatory)
- Cora Randall (University of Colorado, Boulder)
- Kristin Simunac (St. Petersburg College)

Jennifer Kearns briefed the HPAC about the Government Performance and Results Act - Modernization Act (GPRAMA) process for 2022. The HPAC was tasked to lead the review of two of the SMD performance goals:

PG 1.2.1: 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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P.G. 1.2.6: 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 1.2.6, we were requested to assess NASA's performance on this subgoal:

Including 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.

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,

Michael W. Liemohn

GPRAMA Summary Statement for PG 1.2.1

PG 1.2.1: 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 determined in September 2022 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 this progress reported in FY22.

The 15 January 2022 epic eruption of the Hunga Tonga-Hunga Ha'apai volcano produced the largest explosion documented in the modern era. The eruption generated a broad range of atmospheric phenomena, including shock waves, sonic booms, tsunami waves, and a variety of gravity waves that circled the globe several times. Numerous anomalies were recorded around the world, reaching the upper thermosphere and ionosphere several hundred kilometers above the ground. For the next 12 hours, heat released from water and hot ash in the plume remained the largest individual source of atmospheric gravity waves worldwide. These waves traversed the entire globe and were observed to extend from the troposphere to the ionosphere by a suite of satellite and ground-based instruments, including the Atmospheric Infrared Sounder (AIRS) in the stratosphere and the Aeronomy of Ice in the Mesosphere (AIM) mission in the mesosphere. The Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED) satellite measured exceptionally large mesospheric gravity waves. The Global-scale Observations of the Limb and Disk (GOLD) images and Global Navigation Satellite System total electron content (GNSS TEC) maps show unique disturbance patterns in the ionosphere ~14,000 km away from the epicenter. These patterns are consistent with fluctuations in the winds seen by the Ionospheric Connection Explorer (ICON) after the passage of the volcano-induced waves. Many Tonga studies combine observations from multiple platforms and present an excellent example of the synergy between various NASA missions and ground-based observations, as well as synergy between NASA’s Earth Science and Heliophysics divisions.

A number of important discoveries were made about magnetic reconnection, a fundamental physical process that explosively releases energy stored in magnetic fields during solar flares, magnetic storms at Earth, and phenomena throughout the universe. NASA’s Magnetospheric Multiscale (MMS) mission influenced a theoretical study that solved a 60-year old mystery that explains how rapidly the reconnection process occurs. The satellites were also used to measure a hypothesized effect called anomalous resistivity for the first time, but it was found to play only a minor role in reconnection. Meanwhile, the Interface Region Spectrograph Imager (IRIS) observed solar surface emission produced during flares, and the pattern of emission is consistent with a recent model of how the reconnection energy release begins.

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Switchbacks, previously observed in the outer heliosphere, are kinks in the solar wind magnetic field that may be associated with substantial acceleration of plasma and enhanced turbulent energy transfer. *In situ* measurements from Parker Solar Probe recently revealed that switchbacks are much more prevalent closer to the Sun. Furthermore, imaging observations from Solar Orbiter indicate that switchbacks may be formed by interchange reconnection between the coronal loops of solar active regions and adjacent open-field regions. This discovery is important for understanding the origin of the slow solar wind.

NASA's Parker Solar Probe (PSP) is reaching closer to the Sun than any human-made object, and its orbit takes it near Venus to get into the right position to approach the Sun. On the way, it measures the ionosphere of Venus. PSP recently observed a plume of cold plasma escaping from Venus, and measured a significantly lower density than was observed by a previous mission at solar maximum. As these measurements were the first taken during solar minimum, these results suggest that Venus' ionosphere varies substantially over the 11-year solar cycle. This is important for understanding how Venus loses water and whether it was once habitable.

The committee voted ***unanimously*** *for a GREEN* rating.

GPRAMA Summary Statement for PG 1.2.6

P.G. 1.2.6: 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 2022 that NASA remained on track in its annual performance towards achieving this performance goal. Below are examples of the scientific progress reported in FY 2022. The studies highlighted in the GPRAMA PG 1.2.6 report directly address the extreme space weather events, including a terrestrial event with an extreme space weather impact. We would like to commend the HPD's strategic efforts to support targeted research and analysis activities that demonstrate significant progress towards PG 1.2.6. The growing constellation of observatories operated by HPD are providing more opportunities to test and validate forecasting tools as shown by the studies highlighted below.

A study combining data acquired both from a larger scale (THEMIS) and smaller scale CubeSat (ELFIN) NASA missions has revealed that interactions between energetic particles in near Earth space and a special type of plasma waves can result in fast precipitation of those energetic particles into the Earth's atmosphere. By incorporating the effects of those particular plasma waves and their occurrence rates, better radiation and atmospheric models can be attained, demonstrating the connection between space weather events and the lower atmospheric altitudes, even all the way down to the stratosphere.

NASA's Ionospheric Connection Explorer (ICON) made the first direct observation of the ionospheric dynamo in which lower atmospheric waves perturb the equatorial ionosphere. This confirmed the fundamental theoretical relationship between the circulation of neutral gas in a magnetic planetary ionosphere, including how the transfer of neutral gas motion to charged particles creates an electric field.

ICON's measurements, in conjunction with ESA's Swarm mission, were also crucial in observing the strong equatorial electrojet perturbations created by the Hunga Tonga volcano eruption. These combined observations highlight the significant impacts of extreme terrestrial events on space weather.

Determination of the near lunar environment, including dust lofting and surface charging which can impact technological systems, is needed as NASA pursues the goal of human exploration of the moon and Mars. A recent study utilizing data from the Acceleration, Reconnection, Turbulence and Electrodynamics (ARTEMIS) satellites determined that micrometeorite impacts, especially at dawn, can reduce the surface potential significantly. This effect can now be modeled, providing improved surface charging predictions that may be used for planning future lunar activities.

Opportunities to observe transients from multiple vantage points have been leveraged to make predictions and test forecasting models. For example, a flux rope observed by Parker Solar Probe (PSP) was later seen downstream at STEREO-A. The flux rope was compressed in radial extent due to a high-speed stream following the flux rope, but the overall magnetic structure agreed with the first observation. Radial alignment between Solar Orbiter and Earth provided an opportunity to test the predicted arrival of a solar wind disturbance downstream at Earth. Existing models have been combined to make predictions that are in reasonable agreement for near radial spacecraft alignments.

The committee voted ***unanimously*** *for a GREEN* rating.

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