DATE: July 2, 2010

FROM: NASA Heliophysics Subcommittee
Chair: Dr. Roy Torbert, Univ of New Hampshire
Dr. David Alexander, Rice University
Dr. Stuart Bale, University of California, Berkeley
Dr. Jeffrey Forbes of the University of Colorado
Dr. Mary Hudson, Dartmouth College
Dr. Charles Kankelborg, Montana State University
Dr. Judith Karpen of the NASA Goddard Space Flight Center
Dr. Robert McPherron of University of California, Los Angeles
Dr. Richard Mewaldt, California Institute of Technology
Dr. Zoran Mikic, Predictive Science, Inc.
Dr. Ennio Sanchez of SRI International
Dr. Karel Schrijver of Lockheed Martin Advanced Technology Center
Dr. Harlan Spence, formerly Boston University, now Univ of New Hampshire
Dr. Charles Swenson, Utah State University
Dr. Leonard Strachan of the Harvard-Smithsonian Center for Astrophysics
Dr. Michelle Thomsen, Los Alamos National Laboratory
Dr. Allan Tylka, Naval Research Laboratory

TO: Dr. Wesley T. Huntress, NASA Advisory Council Science Committee

Dear Wes,

The Heliophysics Subcommittee (HPS) met at NASA Headquarters on June 30 and July 1, 2010. A total of 16 of the 17 members attended all or part of the meeting. The meeting agenda is attached to this letter.

Several new members to the subcommittee were welcomed: Drs. Jeffrey Forbes, University of Colorado; Judy Karpen, NASA Goddard Space Flight Center (GSFC); Ennio Sanchez, SRI International; Karel Schrijver, Lockheed Martin Advanced Technology Center; Leonard Strachan, Harvard-Smithsonian Center for Astrophysics; and Robert McPherron, University of California, Los Angeles.

NASA gave one specific charge to the subcommittee for this meeting. The subcommittee was asked to provide an assessment of Heliophysics science performance for FY2009. This assessment is used as input to the yearly Performance and Accountability Report (PAR) submitted as part of NASA's yearly Government Performance Results Act (GPRA) requirements. A significant portion of the meeting time was spent preparing this science assessment, which is included as an appendix to this letter.

In particular, the assessments were:

Outcome 3B1: Progress in understanding the fundamental physical processes of the space environment from the Sun to Earth. A motion was made and seconded for "green." Voting was: 16 in favor, 0 against, 0 abstentions. Passed.

Outcome 3B2: Progress in understanding how human society, technological systems, and the habitability of planets are affected by solar variability and planetary magnetic fields. A motion was made and seconded for "green." Voting was: 15 in favor, 0 against, 1 abstentions. Passed.

Outcome 3B3: Progress in developing the capability to predict the extreme and dynamic conditions in space in order to maximize the safety and productivity of human and robotic explorers. A motion was made and seconded for "yellow." The Subcommittee discussed the definitions of "green" and "yellow" and what the expectations and predictions were for this outcome. After substantial discussion, a vote was called on the motion for yellow. Voting was: 1 in favor, 15 against, 0 abstentions. The motion did not pass. A motion was made for "green." Voting was: 15 in favor, 0 against, 1 abstentions. Passed.

In other business, the Heliophysics division provided briefings on several topics: Heliophysics Division flight status, status of the Low Cost Access to Space (LCAS) programs, and a status of the Heliophysics Decadal Survey. Also, the subcommittee heard reports from the Solar & Heliosphere, Geospace, and Data & Computing MOWGs.

Other discussions included heliophysics science utilization of the ISS. It was noted that the Heliophysics community has three open opportunities to propose payloads to the ISS: Solar and Heliospheric SR&T Program call for proposals; Geospace SR&T Program call for proposals (proposals recently received); and Explorer Missions of Opportunity (final announcement to be released Fall 2010). These announcements offer an opportunity to gauge the scientific community's interest in the deployment of experiments on the ISS. The subsequent peer review process offers the most robust method of assessing scientific value.

No findings to be raised to the NAC Science Committee resulted from this meeting. The next meeting of the subcommittee will be held on September 20 and 21, 2010 at NASA Headquarters. Major topics at that meeting are expected to be (1) the relationship of the heliophysics virtual observatories to the major flight missions; and (2) the level of support for data analysis, theory and modeling in "systems science."

Respectfully Submitted,

[signature on original]

Roy B. Torbert, Chair

cc:
Edward Weiler, Associate Administrator, NASA Science Missions Directorate
Richard Fisher, Director, NASA Heliophysics Division
Jens Feeley, Executive Secretary, NAC Science Committee
Barbara Giles, Executive Secretary, NASA Heliophysics Subcommittee
Heliophysics Subcommittee

APPENDIX

HELIOPHYSICS DIVISION FY10 PERFORMANCE HIGHLIGHT

Sub-goal 3B: Understand the Sun and its effect on Earth and the solar system.

Responsible Mission Directorate: Science

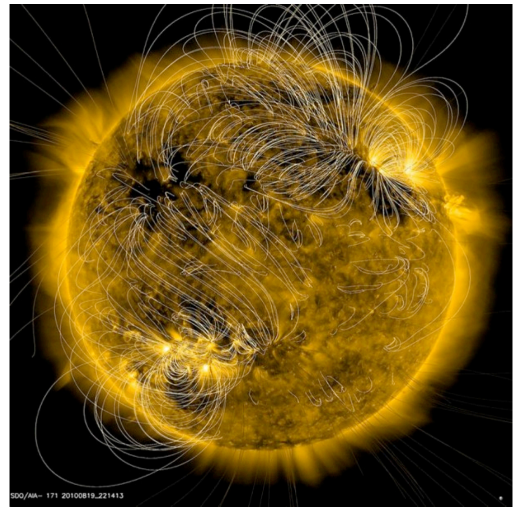
NASA explores the Sun's connection with, and effects on, the solar system to better understand the Earth and Sun as an integrated system, protect technologies at Earth, and safeguard space exploration. Our planet is immersed in an inherently hostile environment. Above the protective cocoon of Earth's atmosphere is a plasma environment composed of matter entwined with penetrating radiation and energetic particles. Our Sun's energy output, which varies on time scales from milliseconds to billions of years, can drive changes in our local space environment — affecting our magnetosphere, ionosphere, atmosphere, and disrupting terrestrial technology, including satellite communications, global positioning system applications, satellite orbital decay and international air transport operations.

In 2010, NASA launched the Solar Dynamics Observatory (SDO). The observatory is returning images that confirm an unprecedented new capability for scientists to understand our sun's dynamic processes. The images show never-before-seen detail of material streaming outward and away from sunspots. Others show extreme close-ups of activity on the sun's surface revealing how the solar magnetic field is generated in the solar interior and how its structure evolves in the solar atmosphere.

Measurements from the CINDI investigation have unexpectedly shown that Earth's ionosphere contracted far more than expected during this recent solar minimum. This results from the compound effects of an unusual lull in solar activity, combined with enhanced radiative cooling at the upper reaches of our atmosphere due to elevated CO_2 levels produced by human-related activities near Earth's surface. This effect means that orbital debris will have a longer residence time in orbit than would have otherwise been expected.

The extended solar minimum has also allowed the highest intensity of galactic cosmic rays of the space era to impact our atmosphere, with intensities as much as 20% greater than during previous solar minima. Studies of the radiation dose resulting from the enhanced 2009 cosmic ray intensities suggest that it may be necessary to re-think how much radiation shielding astronauts take with them on deep-space missions.

There is also important new information for understanding the motion of our Sun and solar system through the Milky Way galaxy. The Voyager and IBEX mission have discovered a strong, tilted local interstellar magnetic field in the area of deep space just outside our solar system and report that this interstellar magnetic field is stronger than expected and oriented so as to press inward more strongly in the southern hemisphere than in the north. Understanding the boundary between our solar system and the interstellar environment beyond is important because it is this boundary that shields the inner solar system, and so our Earth, from the majority of harmful galactic cosmic rays emanating from deep space.

This image, taken on August 20, 2010 by the Solar Dynamics Observatory, shows that the Sun's corona is threaded with a complex network of magnetic fields. Some field lines are closed, not releasing solar wind, and some lines show open fields, letting solar wind escape. Understanding these magnetic fields is important because it is thought that solar storms and flares, which can affect us here on Earth, result from changes in the structure and connections of these fields. The SDO images show that the corona is a seething cauldron of superheated gases and intense magnetic fields that are constantly on the move. We now realize that the corona changes on every time scale at which it has ever been observed.	

HELIOPHYSICS SUBCOMMITTEE FULL REPORT TO FY10 PERFORMANCE ASSESSMENT

<u>Sub-goal 3B: Understand the Sun and its effect on Earth and the solar system.</u>

Theme Description: Heliophysics explores the Sun's connection with, and effects on, the solar system to better understand the Earth and Sun as an integrated system, protect technologies at Earth, and safeguard space exploration.

Our planet is immersed in an inherently hostile environment. Above the protective cocoon of Earth's atmosphere is a plasma environment composed of matter entwined with penetrating radiation and energetic particles. Our Sun's energy output, which varies on time scales from milliseconds to billions of years, forms an immense structure of complex magnetic fields. Inflated by the solar wind, this colossal bubble of magnetism, known as the heliosphere, stretches far beyond the orbit of Pluto. This solar influence can drive changes in our local space environment — affecting our magnetosphere, ionosphere, atmosphere, infrastructure on the Earth's surface, and potentially our climate.

Heliophysics is the study of the variable Sun and its interactions with the planets and structures of the solar system. It seeks to understand influences throughout the solar system but, in particular, the connection to the Earth and the Earth's extended space environment. The science of Heliophysics provides cultural and intellectual research benefits and the application of the new research results also provide economic benefit for modern society.

It is a bold enterprise to strive to understand the vast and seemingly invisible connections that govern the environment within our solar system. But with new understanding in this area it is possible to forecast the highly variable conditions that affect our planet and through which human and robotic space explorers must travel.

To achieve Sub-goal 3B, Heliophysics Theme researchers will study the Sun, the heliosphere, the local interstellar medium, near-Earth space and atmosphere, and all planetary space environments as elements of a single, interconnected system. Using a group of robotic science spacecraft to form an extended network of sensors, the missions address problems such as solar variability, the responses of the Earth and other planets to such variability, and the interaction of the heliosphere with the galaxy.

This constellation of over a dozen satellites, denoted the Heliophysics System Observatory, recently has provided unprecedented wide-ranging coverage of the Sun and Heliosphere during the deepest solar minimum of the space age. Key links in the magnetically connected chain have been forged, from the most detailed measurements of the Sun's meridional flow -- the conveyor belt carrying magnetic field from the equator to the poles -- to the first observations of the "ground state" of Earth's atmosphere and ionosphere. At the same time, advances in computational capabilities and hardware have yielded complex models with ever increasing realism and closure with data. This timely convergence of assets has enabled Heliophysics to make great strides toward understanding and predicting space weather and the space environment.

Benefits

As society becomes increasingly dependent on technologies that are affected by space weather, our vulnerabilities become more obvious. A report issued in December 2008 by the Space Studies Board of the U.S. National Academies addressed the impacts of space weather events on human technologies. The report, “Severe space weather events — Understanding societal and economic impacts,” estimates that the economic cost of a severe geomagnetic storm could reach U.S. $1– $2 trillion during the first year, and have a recovery period of 4–10 years. These long recovery times would result from damage to large power transformers and other necessary but hard-to-replace facilities.

Partnerships are NASA’s preferred method for assisting NOAA to satisfy the national need for space weather knowledge and observations. Presently, this is accomplished with the existing fleet of NOAA satellites and a number of NASA scientific satellites. Space weather “beacons” on NASA spacecraft provide real-time science data to space weather forecasters. Examples include ACE measurements of interplanetary conditions from L1, CME alerts from SOHO, and STEREO beacon images of the far side of the Sun. NASA cooperates with other agencies to enable new knowledge in this area and to measure conditions in space critical to both operational and scientific research.

Equally important, our local space environment provides a convenient venue for studying the plasmas that make up most of the visible universe. Under the control of magnetic fields, plasmas organize into galactic jets, radio filaments, supernova bubbles, accretion disks, galactic winds, stellar winds, stellar coronas, sunspots, heliospheres, magnetospheres, and radiation belts. Studies of our local space environment provide knowledge relevant to remote astrophysical plasma systems that are inaccessible to direct study.

Risks to Achieving Sub-goal 3B

Of primary concern for the Heliophysics Division is the increased cost and the reduced availability of Expendable Launch Vehicle (ELV) options. Over the course of the last decade, the Delta II has been the workhorse for SMD, its loss leaving only costlier ELVs (Delta IV, Atlas V) for many of the missions identified in the NASA Science Plan. NASA is aggressively exploring options to maintain a vital Heliophysics flight program. Rising mission costs also present a risk, as the reduced mission frequency impacts the systems approach to Heliophysics.

Outcome 3B.1: Progress in understanding the fundamental physical processes of the space environment from the Sun to Earth, to other planets, and beyond to the interstellar medium.

Major Activities / Accomplishments / Impediments

NASA launched the Solar Dynamics Observatory (SDO) on February 11, 2010 and the observatory is returning images that demonstrate an unprecedented capability for scientists to understand our sun's dynamic processes. The images show never-before-seen detail of material streaming outward and away from sunspots. Others show extreme close-ups of activity on the sun's surface. The spacecraft also has made the first high-resolution measurements of solar flares in a broad range of extreme ultraviolet wavelengths. SDO scientists will study how the solar magnetic field is generated in the solar interior, detail its structure in the solar atmosphere, and provide key observations for the understanding of the solar cycle.

The Magnetospheric Multiscale (MMS) mission has completed its critical design review (CDR) and is finishing final design prior to the start of integration and testing. MMS is a four-spacecraft mission to study magnetic reconnection, providing better understanding of this primary process by which energy is transferred from the solar wind to Earth's magnetosphere.

Instrument selections were completed for the Solar Probe Plus mission. Solar Probe Plus will fly into the Sun's atmosphere (or corona), for the first time. Coming closer to the Sun than any previous spacecraft, Solar Probe Plus will employ a combination of in situ measurements and imaging to understand how the Sun's corona is heated and how the solar wind is accelerated.

Major Scientific Findings or Discoveries

IBEX and Voyager Reveal a Strong, Tilted Local Interstellar Magnetic Field. A portion of the gas from interstellar space is thought to flow into our inner solar system undeflected by the Sun's magnetic field, although they should be affected by solar radiation pressure and collisions. In turn, solar wind plasmas emanating from the Sun should be deflected as they press outward against the local interstellar medium surrounding our sun's heliosphere. New measurements from IBEX show that much of the hydrogen and oxygen gas from interstellar space are relatively quickly lost on their journey toward the inner solar system due to collisions with solar wind plasmas. New Voyager measurements show that the interstellar magnetic field is stronger than previous estimates and is oriented so as to press inward more strongly in the southern hemisphere where Voyager 2 is located than in the north where Voyager 1 is located. These results are important for understanding the motion of our star and solar system through the Milky Way galaxy and the implications that has for the long-term galactic environment of our planet.

References:

E. Möbius et al., Science 326, 969 (2009)

Opher, M., F. A. Bibi, G. Toth, J. D. Richardson, V. V. Izmodemov, and T. I. Gombosi, Nature 462, 24 (2009).

The Sun and Humankind Conspire to Contract the Ionosphere

NASA's CINDI (Coupled Ion-Neutral Dynamics Investigation) instrument was launched aboard the Air Force Communication/Navigation Outage Forecast System (C/NOFS) satellite on April 16, 2008. The C/NOFS space weather mission was designed to explore disturbances in Earth's ionosphere that can result in a disruption of navigation and communication signals. However, during its first year of operation CINDI unexpectedly unveiled an ionosphere that occupied far less vertical extent than expected. This unusual observation results from the compound effects of an extreme lull in solar activity, combined with a smaller long-term neutral density decrease revealed by four decades of satellite drag observations. The latter is due to enhanced radiative cooling of the upper atmosphere due to elevated CO2 levels produced by human-related activities near Earth's surface. These observations also lead to the prediction that orbital debris will have a longer residence time in orbit than previously thought.

References:

Heelis, R. A., et al., "Behavior of the O+/H+ transition height during the extreme solar minimum of 2008," Geophys. Res. Lett., doi:10.1029/2009GL038652, 2009.

Emmert , J. T., J. L. Lean, and J. M. Picone (2010), Record-low thermospheric density during the 2008 solar minimum, Geophys. Res. Lett., 37, L12102, doi:10.1029/2010GL043671.

The dynamic nature of the Sun's lower atmosphere

The solar atmosphere has been shown to be far more dynamic than previous observations had suggested. Very high resolution imaging and spectroscopy by the instruments on the Hinode spacecraft revealed that the solar atmosphere is permeated by a variety of waves, fast flows, and jets, that are embedded in magnetic fields on all scales. Hinode has shown that the relentless overturning gas flows of the solar convection, occurring on scales from hundreds to tens of thousands of kilometers, drag the magnetic field around in a chaotic motion that leads to a wide variety of impulsive and explosive upsets of the solar atmosphere, often in the form of jets that thrust up gases at high speeds (20-800 km s^{-1}) that are well in excess of the ambient sound speed. Many of these jets are driven by impulsive release of magnetic energy through a form of magnetic field reconnection. The observation of these jets on a wide range of spatial scales provides insight into the various jet formation mechanisms and the impact of these jets on the layers of the higher solar atmosphere, the Sun's corona that is millions of degrees hotter than its 5,000 K photosphere. The fastest, most fleeting of these ubiquitous jets were shown to contain so much energy and material that they contribute a substantial fraction of heating and mass flux requirements of the corona.

Doschek, G. A., Landi, E., Warren, H. P., & Harra, L. K. 2010, ApJ, 710, 1806
Martınez-Sykora, J., Hansteen, V., DePontieu, B., & Carlsson, M. 2009, ApJ, 701, 1569
McIntosh, S. W., & De Pontieu, B. 2009, ApJ, 706, L80
De Pontieu, B, McIntosh, S., Hansteen, V., Schrijver, C., Astrophysical Journal Letters 701, 1 (2009)

Computer experiments reveal how sunspots can form from magnetic field rising to the Sun's surface.

The most spectacular manifestation of magnetic fields on the Sun's surface is in the form of sunspots, which result from buoyant magnetic flux bundles emerging from the solar interior into the solar atmosphere. The formation and evolution of sunspots, which have field strengths comparable to those used in magnetic resonance imaging devices but are often larger than Earth in diameter, are often associated with solar eruptions that affect space weather in the near-Earth environment. Recent observations from the Solar Optical Telescope (SOT) onboard the Hinode spacecraft have unveiled the intricate dynamics of sunspot formation in unprecedented detail.

By performing state-of-the-art numerical simulations of emerging magnetic field bundles incorporating as much of the real-world physical processes as the computers were capable of, solar researchers were able, for the first time, to mimic various observational properties of how sunspots form and evolve. In particular, the supercomputer experiments reveal how magnetic fields ascend through the uppermost layers of the solar interior, how they expand in the process of erupting onto the surface as a collection of magnetic fragments, and how these fragments subsequently undergo a large-scale organization to form sunspots. With the simulation results now matching the formation of sunspots in the observable layers of the Sun, the computer enables us to study the otherwise invisible phenomena that happen before the magnetic field reaches the surface. Understanding of emerging magnetic regions will also help us use observations from NASA's Solar Dynamics Observatory to forecast when sunspots may appear on the solar surface, and which kinds of space weather effects may follow.

Cheung, M., Schuessler, M., Tarbell, T., Title, A.: Astrophysical Journal 687, 137 (2008).
Cheung, M., Rempel, M., Title, A., Schuessler, M; Astrophysical Journal, 2010 (in press):
http://adsabs.harvard.edu/abs/2010arXiv1006.4117C

The solar wind heats as it expands: Cluster, Wind, and STEREO scientists determine the nature of turbulent heating in the solar atmosphere.

The solar wind consists of electrons and ions ejected from the sun, moving supersonically at millions of miles per hour. This hot wind expands into space, dragging and twisting the Sun's magnetic field out from the solar atmosphere. The wind is also hotter than it should be, and for decades researchers have puzzled over the wind's structure and the unknown source of energy that heats it. Using data from the joint ESA-NASA Cluster mission and NASA's Wind mission, it has been confirmed that the solar wind is heated by fluctuations known as kinetic Alfvén Waves; as the wind expands, it generates these microscale Alfvén waves. These waves have significant electric fields which efficiently transfer wave energy to the plasma by a physical process known as Landau damping. The STEREO and Cluster results also show that this wave turbulence in the solar wind has three-dimensional structure consistent with the evolution of turbulent eddies into a spaghetti-like mess of magnetic fields. The consequences for how energetic charged particles from the sun and from the galaxy move through such a structured medium have yet to be determined.

References:
F. Sahraoui, M.L. Goldstein, P. Robert, Yu. V. Khotyaintsev, Evidence of a cascade and dissipation of solar wind turbulence at electron gyroscale, Phys. Rev. Lett., http://link.aps.org/abstract/PRL/v102/e231102, DOI: 10.1103/PhysRevLett.102.231102,
S. D. Bale, J. C. Kasper, G. G. Howes, E. Quataert, C. Salem, D. Sundkvist, Magnetic fluctuation power near pressure anisotropy instability thresholds in the solar wind, Phys. Rev. Lett., 103, 21, 211101, 2009
J. Podesta, Dependence of Solar-Wind Power Spectra on the Direction of the Local Mean Magnetic Field, Astrophys. J., 698, 986, 2009.
Y. Narita, K.-H. Glassmeier, F. Sahraoui, M.L. Goldstein, Wave-vector dependence of magnetic-turbulence spectra in the solar wind, Phys. Rev. Lett., 104, 171101, http://link.aps.org/doi/10.1103/PhysRevLett.104.171101, 2010.

The Earth's Extended Atmosphere is Shaped by the Solar Wind: The neutral atmosphere of the Earth has long been known to extend into space by a distance that falls exponentially with little dependence on sun angle. New data from the TWINS (Two Wide-angle Imaging Neutral-atom Spectrometers) mission, however, reveals a strong day-night asymmetry in the density of this atmospheric shell called the geocorona. The data has revealed a newly found "geotail" feature: an extended region of enhanced atmospheric density stretching tail-like in the direction opposite to the sun. The shape of the geotail depends upon solar wind pressure. When solar wind pressure has been high for 1-2 days, this atmospheric windsock is visibly compressed on the dayside and more tail-like on the nightside. Further analysis will characterize this effect with respect to solar cycle, season, and space storm activity.

Reference:
Zoennchen, J. H. and U. Nass and G. Lay and H. J. Fahr (2010), 3D-Geocoronal hydrogen density derived from TWINS Ly-alpha-data, Ann. Geophys., submitted.

Identifying the Particle Acceleration Region of a Solar Flare

Solar flares are amongst the most energetic phenomena in the solar system, releasing vast amounts of energy in a few minutes while heating the local solar atmosphere to greater than 40 million degrees and accelerating particles to relativistic speeds. Understanding the fundamental physical processes that occur in solar flares provides unique insight into similar energetic processes in the Universe. Recent, hard X-ray and microwave observations of coronal hard X-ray emission in partially disk-occulted solar flares by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) and the Nobeyama Radioheliograph, respectively, have indicated the presence of high energy electrons (~80 keV) high in the solar corona. The source of the high-energy emissions is located ~6000 km above where the post-flare thermal loops eventually form in a region of low ambient density. These observations clearly establish that the above-the-loop emission is purely non-thermal in nature little evidence of direct heating. The lack of hot plasma suggests the source is produced by a mechanism that accelerates all available electrons and is, therefore, a direct observation of the acceleration region itself. The study of particle acceleration sources in the corona is crucial in gaining an understanding of fundamental physical processes that occur during solar flares and in astrophysical regimes throughout the Universe.

Krucker, S. et al., 2010, ApJ, 714,1108.

FY2010 Annual Performance Goals	FY05	FY06	FY07	FY08	FY2009	FY2010
APG 10HE01 Demonstrate progress in understanding the fundamental physical processes of the space environment from the Sun to Earth, to other planets, and beyond to the interstellar medium. Progress will be evaluated by external expert review,	5SEC9 Blue None 5SEC12 Blue 5SEC13 Green	6ESS11 Green 6ESS12 Green 6ESS14 Green 6ESS15 Green	7ESS13 Green	8HE01 Green	9HE01 Green	**GREEN 16 to zero**
APG 10HE2 Develop missions in support of this Outcome, as demonstrated by completing the Magnetospheric Multiscale (MMS) Spacecraft Critical Design Review (CDR)	None	None	7ESS15 Red	8HE02 Green	9HE02 Green	10HE02 Green
APG10HE3 Develop missions in support of this Outcome, as demonstrated by completing the Geospace Radiation Belt Storm Probes Critical Design Review (CDR)	5SEC4	6ESS18	7ESS16 Green	8HE04 Green	9HE03 Green	10HE03 Green
APG10HE4 Develop missions in support of this Outcome, as demonstrated by the award of Solar Probe instrument contracts..						10HE04 Green now???
APG10HE5 Conduct flight program in support of this outcome, as demonstrated by achieving mission success criteria for Hinode, THEMIS, and IBEX.						10HE05 Green

Outcome 3B.2: Progress in understanding how human society, technological systems, and the habitability of planets are affected by solar variability and planetary magnetic fields.

Major Activities / Accomplishments / Impediments

The Radiation Belt Storm Probes (RBSP) mission has completed its critical design review (CDR) and has been approved to proceed into implementation activities. RBSP is a two-spacecraft mission to investigate how populations of relativistic electrons and ions in space are formed or changed in response to the variable inputs of energy from the Sun.

Major Scientific Findings or Discoveries

Ice Clouds Near the Edge of Space

The AIM mission provided major advances in understanding the relationship between Noctilucent Clouds and the environment in which they form. Noctilucent Clouds are mysterious clouds that form on the edge of space, 50 miles above the Earth over the summer pole. The Aeronomy of Ice in the Mesosphere (AIM) mission has revealed the sudden response of cloud formation to temperature excursions below the frost point, much like the turning on of a geophysical light bulb. Cloud brightness and occurrence respond dramatically to even very small changes in the surrounding temperature. Moreover, AIM has confirmed that it is the change in temperature, as opposed to a change in the abundance of the background water vapor that controls the seasonal onset of cloud formation. Water vapor does appear to play an important role in governing the subsequent behavior of the clouds, however, because its availability limits the amount of ice that can be formed. The AIM scientists have also been able to show that when the mesospheric temperature and water vapor abundances are known, a number of important features of the clouds can be modeled and from this a predictive capability can be developed. A dramatic new finding is that the clouds reveal that the Earth's lower and upper atmospheres constitute a globally coupled system; noctilucent clouds in one hemisphere's mesosphere, on occasion, respond directly to wind speeds in the opposite hemisphere's stratosphere 20,000 km away. This global scale coupling takes place through wave interactions that have become the focus of intense study.

References:
Russell III, James M., Pingping Rong, Scott M. Bailey, Mark E. Hervig, and Svetlana V. Petelina, The relationship between the Summer Mesopause and Polar Mesospheric Cloud Heights, J. Geophys. Res., in press, May, 2010.
Hervig, M.E., L.L. Gordley, M. Stevens, J.M. Russell, and S. Bailey, Interpretation of SOFIE PMC measurements: Cloud identification and derivation of mass density, particle shape, and particle size, J. Atmos. Solar-Terr. Phys., doi:10.1016/j.jastp.2008.07.009, 2009.
Chandran, A., D. W. Rusch, A. W. Merkel, S. E. Palo, G. E. Thomas, M. J. Taylor, S. M. Bailey, and J. M. Russell III (2010), Polar Mesospheric Cloud structures observed from the CIPS experiment on the AIM spacecraft: Atmospheric gravity waves as drivers for longitudinal variability in PMC occurrence, J. Geophys. Res., doi:10.1029/2009JD013185, in press, Accepted 22 January 2010.
Karlsson, B., C.E. Randall, S. Benze, M. Mills, V.L. Harvey, S.M. Bailey, J.M. Russell III, Intra-seasonal variability of polar mesospheric clouds due to inter-hemispheric coupling, Geophys. Res. Lett., VOL. 36, L20802, doi:10.1029/2009GL040348, 2009.

The Interstellar Boundary Explorer (IBEX) has provided the first global views of the protective boundary that surrounds our solar system and shields it from the harmful radiation in the galactic medium. The maps are made by collecting particles known as Energetic Neutral Atoms (ENAs), which are created by the collisions of solar wind particles with the inflowing interstellar gas. The maps show a remarkably bright and narrow "ribbon" of ENAs not predicted by any model or theory. The observations indicate a blunt termination shock that is wide in longitude and flattened latitudinally. The origin of this ribbon is still debated, but it appears to show the imprint of the galactic magnetic field, which shapes and controls the global heliosphere. The Voyager missions continue these discoveries with direct sampling of the most distant plasmas ever measured. For example, the supersonic solar wind was expected to be abruptly slowed when encountering our solar system's interface with the intergalactic wind, forming a termination shock. Voyager 2 has discovered however, that ions in the solar wind bounce back and forth across the shock formation, slowly gaining speed as they drain energy from the supersonic wind. So many ions were extracting energy from the solar wind in fact, that the solar wind had slowed by twenty percent before the final shock boundary, resulting in a weaker shock than expected. These results show that the interaction between our solar system and the interstellar medium has remarkable structure and dynamics. The results have already changed our understanding about our solar system's home in the galaxy, how galactic cosmic rays reach the Earth, and how the environments surrounding other stars may or may not influence the possibility of the existence of habitable planets in other solar systems.

References:
D. J. McComas et al., Science 326, 959 (2009)
S. A. Fuselier et al., Science 326, 962 (2009)
J. Heerikhuisen et al., Astrophys. J. Lett. 708, 2, L126 (2010)
H. O. Funsten et al., Science 326, 964 (2009)
N. A. Schwadron et al., Science 326, 966 (2009)

Richardson, J. D., Stone, E. C., Kasper, J. C., Belcher, J. W., and R. B. Decker, Geophysical research Letters 36, l10102 (2009).
Florinski, V., Decker, R. B., le Roux, J. A., and G. P. Zank, Geophysical Research Letters 36, L12101 (2009).

TWINS resolves mystery about the anisotropy of the terrestrial ring current:
It has been known for nearly a century that the ring current produced by the westward drift of proton and oxygen ions in the radiation belts is asymmetric with the largest ground effects near the dusk meridian. More recently images of the ring current produced by energetic neutral ions showed that the brightest ring current emissions occur a little past midnight suggesting that the peak pressure of the ring current might be at this location. This disagreement between the two sets of observations was perplexing and cast doubt on our understanding of the currents responsible for the ground magnetic perturbations. The TWINS (Two Wide-angle Imaging Neutral-atom Spectrometers) has resolved this discrepancy. Near midnight the ions have low energy and are drifting slowly. As they drift toward dusk they gain energy. Low energy protons produce brighter emissions while more energetic protons produce a stronger current. Thus both observations are correct but have different interpretations and implications for the Earth's near space environment.

References:
Brandt, P. C. and D. Bazell and J. Redfern and P. Valek and J. P. McFadden and E. C. Roelof and A. T. Y. Lui and D. J. McComas (2010), Simultaneous TWINS and THEMIS Observations of the Spatial, Spectral and Pitch-Angle Ion Distributions of the Ring Current, J. Geophys. Res., submitted.
Perez, J. D. and E. W. Grimes and J. Goldstein and D. J. McComas and P. Valek (2010), Ion Intensity from TWINS ENA Images: Two Eyes are Better than One, J. Geophys. Res., doi:10.1029/2010JA015426, submitted.
Brandt, P. C:son, S. Ohtani, D. G. Mitchell, M. -C. Fok, E. C. Roelof, and R. Demajistre, Global ENA observations of the storm mainphase ring current: Implications for skewed electric fields in the inner magnetosphere, Geophys. Res. Lett., 29(20), 1954, doi:10.1029/2002GL015160, 2002.
Buzulukova, N., M.-C. Fok, J. Goldstein, P. W. Valek, D. J. McComas, and P. C. Brandt, Ring current dynamics in modest and strong storms: Comparative analysis of TWINS and IMAGE/HENA data with CRCM, J. Geophys. Res., doi:10.1029/2010JA015292, submitted, 2010.

Advances in identifying the events leading to auroral explosions. The aurora is a global phenomenon that brightens the region of the upper atmosphere known as the ionosphere. During a geomagnetic storm this often occurs suddenly over an oval shaped area centered around the poles, creating intense electric currents that can damage infrastructure in space and on the ground. Such conditions are driven by enhanced solar wind magnetic field and speed. The explosive change in auroral brightness (the substorm) is a direct consequence of dynamic processes happening in the Earth's distant magnetosphere, approximately 100,000 miles above the surface of the Earth. A long-standing problem in magnetospheric physics is the identification of the cause of the explosive phase of the auroral substorm known as expansion phase. Recently, ground and space observations from the THEMIS mission have been used to define the sequence of events conducive to the onset of the expansion phase. Prior to onset, a fast-moving knot of aurora in the Earth's ionosphere has been seen to move equatorward until it reaches a dimly-lit curtain of pre-existing aurora stretching from east to west across the midnight sky. The equatorward-moving aurora is the atmospheric footprint of a jet of energized plasma that moves Earthward from deep space, while the dimly-lit curtain originates from plasma raining down from the inner magnetosphere, approximately 20,000 miles above the surface of the Earth. Once the jet reaches this inner boundary, it triggers the substorm and produces the dramatic brightening of the aurora. Further THEMIS observations have determined the width of one of these deep space jets and determined how it triggered the substorm. The plasma jet, with a width equivalent to the diameter of the Earth, slammed into the inner magnetosphere, generating vortices on either side of the plasma jet. The vortices became the source of electric currents that flowed down to the Earth's ionosphere, thus generating auroral brightening. One interpretation of the observations suggests that the initial brightening is caused by a burst of magnetic energy converted to fast flows in the distant magnetosphere and that the expansion is the consequence of instability of the near Earth environment. Alternate interpretations have suggested that the initial brightening maps to a second region closer to the Earth and that it is not possible to distinguish the difference in the ground data with current methods. Resolution of this argument will depend on advances of ongoing model development of the tail field of the Earth's magnetosphere.

References:
Nishimura, Y. and L. Lyons, Press Conference, Fall Meeting of the American Geophysical Union, San Francisco, California, December 2009.
Nishimura, Y., L. Lyons, S. Zou, V. Angelopoulos, and S. B. Mende, Substorm triggering by new plasma intrusion: THEMIS all-sky imager observations, J. Geophys. Res., doi:10.1029/2009JA015166, in press (accepted 1 April 2010).
Lyons, L. R., Y. Nishimura, Y. Shi, S. Zou, H.-J. Kim, V. Angelopoulos, C. Heinselman, M. J. Nicolls, and K.-H. Fornacon, Substorm triggering by new plasma intrusion: Incoherent-scatter radar observations, J. Geophys. Res., doi:10.1029/2009JA015168, in press (accepted 30 March 2010).
Panov, E., R. Nakamura, and W. Baumjohann, Press conference, European Geophysical Union Meeting, Vienna, Austria, May 2010.
Panov, E. V., R. Nakamura, W. Baumjohann, V. Angelopoulos, A. A. Petrukovich, A. Retinò, M. Volwerk, T. Takada, K.-H. Glassmeier, J. P. McFadden, and D. Larson, Multiple overshoot and rebound of a bursty bulk flow, Geophys. Res. Lett., 37, doi:10.1029/2009GL041971, 2010.
Farr, N. L., Using a global magnetohydrodynamic model to determine the start of the substorm recovery phase, Ph.D. thesis, University of Colorado, 2010.
Farr, N. L., D. N. Baker, and M. Wiltberger, Complexities of a 3-D plasmoid flux rope as shown by an MHD simulation, J. Geophys. Res., 113, A122202, doi:10.1029/2008JA013328, 2008.

FY 2010 Annual Performance Goals	FY05	FY06	FY07	FY08	FY2009	
APG 10HE2 Develop missions in support of this Outcome, as demonstrated by completing the Magnetospheric Multiscale (MMS) Spacecraft Critical Design Review (CDR)	None	None	7ESS15 Red	8HE02 Green	9HE02 Green	10HE02 Green expected
APG10HE3 Develop missions in support of this Outcome, as demonstrated by completing the Geospace Radiation Belt Storm Probes Critical Design Review (CDR)	5SEC4	6ESS18	7ESS16 Green	8HE04 Green	9HE03 Green	10HE02 Green
APG10HE4 Develop missions in support of this Outcome, as demonstrated by the award of Solar Probe instrument contracts..						10HE04 Now Green??
APG 9HE6 Demonstrate progress in understanding how human society, technological systems, and the habitability of planets are affected by solar variability and planetary magnetic fields. Progress will be evaluated by external expert review.	5SEC8 Green 5SEC11 Green	6ESS10 Green 6ESS13 Green	7ESS19 Green	Green	9HE06 Green	**GREEN 15 to 0, 1 abstain**
APG 10HE7 Conduct flight program in support of this outcome, as demonstrated by achieving mission success criteria for THEMIS.						10HE07 Green

Outcome 3B.3: Progress in developing the capability to predict the extreme and dynamic conditions in space in order to maximize the safety and productivity of human and robotic explorers.

Major Activities / Accomplishments / Impediments

The Solar Dynamics Observatory (SDO) was successfully launched in February 2010 to become the first Living with a Star (LWS) mission and the newest component of the Heliosphysics Great Observatory. SDO carries three instruments that will be used to study the origins of the magnetic field in the solar interior, the evolution of the magnetic field in the corona, and the variability of the sun's extreme ultraviolet (EUV) emissions. A downlink data rate of 1.5 Terabytes per day allows high time cadence, full disk images of the sun to be obtained in multiple wavelength bands at a maximum rate of one image every 10 seconds. This unprecedented capability is expected to produce significant advances in our ability to predict space weather and its impacts on human and robotic explorers throughout the heliosphere.

Major Scientific Findings or Discoveries

Cosmic Rays Hit Space Age High as the Solar Magnetic Field hits Space Age Low
In order for galactic cosmic rays to enter the heliosphere, they must make their way through the Sun's magnetic field that is carried out by the solar wind. The interplanetary magnetic field deflects most cosmic rays away from the inner heliosphere. During the extended period of minimum solar activity, culminating in late 2009, the Advanced Composition Explorer (ACE) recorded the highest intensity of galactic cosmic rays of the space era, with intensities as much as 20% greater than during previous solar minima. The 2009 intensities are consistent with studies of radioactive isotopes that are made by cosmic rays hitting the upper atmosphere, including Carbon-14 stored in tree rings and Beryllium-10 stored in ice cores. These studies show that the cosmic-ray intensity during the space era has been lower than in past centuries. The primary reason that cosmic rays had greater access to the inner heliosphere during 2009 was that the Sun's magnetic field (and therefore the interplanetary magnetic field) was weaker than in previous solar minima of the space age. Studies of the radiation dose resulting from the enhanced 2009 cosmic ray intensities suggest that it may be necessary to re-think how much radiation shielding astronauts take with them on deep-space missions.

References:
Science at NASA, September 29, 2009,
http://science.nasa.gov/science-news/science-at- nasa/2009/29sep_cosmicrays/
R. A. Mewaldt et al., submitted.
N. A. Schwadron, A. J. Boyd, K. Kozarev, M. Golightly, H. Spence,
L. W. Townsend, and M. Owens, Space Weather, Space Weather, 8, S00E04,
doi:10.1029/2010SW000567, 2010

Understanding an unusually long solar cycle. In the outer third of the Sun, energy is transported by convective motions akin to those of water boiling in a pot. The approximate 11-year solar activity cycle is believed to be driven by compact elements of magnetic field moving through what is called the “convection zone.” New results by researchers using data from the Solar and Heliospheric Observatory (SOHO) have found a distinctive signature that may explain why the current solar cycle has been so long. The method works by examining variations in the meridional flow (a poleward surface wind) of strong magnetic field elements in the sun’s photosphere. Measurements of the flow pattern were made from 1996 to 2010 and the research shows that one component of the surface flow velocity has remained at a nearly constant and high value throughout the recent extended (2008-2009) solar minimum. At the same point in the cycle for the previous solar minimum in 1996 the surface velocity of this poleward wind would have already started to decrease in magnitude. The fact that the surface flow speed is still high supports the surface flux transport models which predict that faster surface flow speeds lead to weaker polar magnetic fields and hence, a longer solar minimum. This differs from some earlier flux transport dynamo models which suggest that variations in the surface flow speeds produce different results for the magnetic field strength at the poles.

REFERENCES:

Hathaway, D.H. and Rightmire, L., Variations in the Sun’s Meridional Flow over a Solar Cycle, 2010, Science, 327, 1350. DOI: 10.1126/science.1181990

Dikpati, M. and Gilman, P.A., Simulating and Predicting Solar Cycles Using a Flux-Transport Dynamo, 2006, ApJ, 649, 498. DOI: 10.1086/506314

Schrijver, C.J. and DeRosa, M.L., Photoshperic and Heliospheric Magnetic Fields, 2003, Solar Phys., 212, 165. DOI: 10.1023/A:1022908504100

Advances in Predicting the Terrestrial Impact of Solar Eruptions: Observations from widely-separated spacecraft have spurred progress in the development of more realistic and more reliable numerical models of interplanetary coronal mass ejections (CMEs) and solar energetic particle (SEP) events. These efforts, which will ultimately contribute to predictive space-weather capabilities, include (1) using the stereo viewing capability from the two Solar TErrestrial RElations Observatory (STEREO) spacecraft to derive the direction and speed of CMEs, thereby improving prediction of arrival times at Earth, where they can initiate geomagnetic storms; (2) using Wind and the STEREO observations to model how solar-wind streams govern evolution of magnetic topology during transit from the Sun; (3) modeling large-scale CME-driven shocks to predict how SEP time-intensity profiles vary with source location and reflect structure in solar-wind streams; (4) improved modeling of SEP access to Earth’s atmosphere and effects on space systems.

References:

Liu, Y., Davies, J.A., Luhmann, J.G., Vourlidas, A., Bale, S.D., and Lin, R.P. 2010, Geometric Triangulation of Imaging Observations to Track Coronal Mass Ejections Continuously Out to 1 AU, ApJ, 710, L82, DOI: 10.1088/2041-8205/710/1/L82

Thernisien, A., Vourlidas, A., and Howard, R.A., Forward Modeling of Coronal Mass Ejections Using STEREO/SECCHI Data, 2009, Solar Phys., 256, 111. DOI: 10.1007/s11207-009-9346-5

Farrugia, C. J., D. B. Berdichevsky. C. Moestl, M. A. B. Galvin, M. Leitner, M. A. Popecki, K. D.C. Simunac, A. Opitz, B. Lavraud, A. M. Veronig, M. Temmer, J. G. Luhmann, and J.-A., Sauvaud, Multiple, distant (40 deg azimuthal spread) in situ observations of a magnetic cloud and a corotating interaction region complex, J. Geophys. Res., submitted, 2010.

Luhmann, J.G. et al., Cone model-based SEP event calculations for applications to multipoint observations, ASR 46, 1-2, 2010.

Kress, B. T.; Mertens, C. J.; Wiltberger, M, Solar energetic particle cutoff variations during the 29–31 October 2003 geomagnetic storm, Space Weather, Vol. 8, No. 5, S05001, 10.1029/2009SW000488

Liu, Y., Davies, J.A., Luhmann, J.G., Vourlidas, A., Bale, S.D., and Lin, R.P. 2010, Geometric Triangulation of Imaging Observations to Track Coronal Mass Ejections Continuously Out to 1 AU, ApJ, 710, L82, DOI: 10.1088/2041-8205/710/1/L82

Thernisien, A., Vourlidas, A., and Howard, R.A., Forward Modeling of Coronal Mass Ejections Using STEREO/SECCHI Data, 2009, Solar Phys., 256, 111. DOI: 10.1007/s11207-009-9346-5

FY2009 Annual Performance Goals	FY05	FY06	FY07	FY08	FY2009	FY2010
APG 10HE03 Develop missions in support of this Outcome, as demonstrated by completing the Geospace Radiation Belt Storm Probes Confirmation Review	5SEC4	6ESS18	7ESS16 Green	8HE04 Green	9HE03 Green	10HE03 Green
APG 9HE08 Demonstrate progress in developing the capability to predict the extreme and dynamic conditions in space in order to maximize the safety and productivity of human and robotic explorers. Progress will be evaluated by external expert review.	15.1 Green	3B.3 Green	Green	Green	9HE08 Green	**GREEN vote: 14 Green to 1 yellow, 1 abstain**

Heliophysics Subcommittee Meeting
June 30 - July 1, 2010
MIC-3 (Room 3H46)

ver 5: 29 June 2010

Wednesday, June 30

8:30	Subcommittee Room Open	
9:00	Welcome, overview of agenda, introduction of new members	Roy Torbert, HPS Chair
9:15	News from the NAC and NAC Science Committee	Roy Torbert, HPS Chair
9:30	Heliophysics Division Overview	Richard Fisher, NASA HQ
10:00	Flight Program Status	Victoria Elsbernd, NASA HQ
10:15	BREAK	
10:30	Status of the LCAS Programs:	
	Program Overview	Cheryl Yuhas, NASA NQ
	Sounding Rockets	Philip Eberspeaker, Wallops Flight Facility
11:30	Discussion	Subcommittee
NOON	LUNCH IN ROOM: Bob McPherron: Summary of the Aspen Global Change Conference	
1:00	Senior Review of Operating Missions	Jeffrey Hayes, NASA HQ
1:15	MOWG Reports (15 min each)	
	Solar & Heliosphere MOWG	Jim Klimchuk, NASA GSFC
	Geospace MOWG	Larry Kepko, NASA GSFC
	Data & Computing Working Group	Aaron Roberts, NASA GSFC
2:00	Heliophysics Science Performance Assessment, input for the FY2009 NASA PAR – Overview	Barbara Giles, NASA HQ
2:15	Heliophysics Science Performance Assessment, input for the FY2009 NASA PAR – Review and Assignments	Subcommittee
3:15	BREAK	
3:30	Subcommittee input to the NAC Science Committee: ISS Science	Subcommittee
4:00	Discussion, including future meeting dates, potential agenda topics, action items	Subcommittee
5:30	END OF DAY	
7:00	Group Dinner, tbd, email Barb with preferences	

Heliophysics Subcommittee Meeting
June 30 - July 1, 2010
MIC-3 (Room 3H46)

ver 5: 29 June 2010

Thursday, July 1

8:00	Subcommittee Room Open	
8:30	Review of agenda and work products	Roy Torbert, HPS Chair
9:00	Heliophysics Decadal Survey Update	tbd
9:30	Discussion	Subcommittee
10:00	BREAK	
10:15	Heliophysics Science Performance Assessment, input for the FY2009 NASA PAR – Final Work and Voting	Subcommittee
NOON	LUNCH IN ROOM	
1:00	Heliophysics Science Performance Assessment, input for the FY2009 NASA PAR – Final Work and Voting Continued	Subcommittee
2:00	Subcommittee work session	Subcommittee
2:45	Debrief with Heliophysics Division Director	Richard Fisher, NASA HQ Subcommittee
3:15	**ADJOURN**	