NEWS

Problems With Weather Satellite Program Raise Concerns

PAGE 206

A major U.S. weather and environmental satellite program has gone over budget and is years behind schedule mostly due to poor management oversight, the U.S. Department of Commerce inspector general testified at an 11 May hearing before the U.S. House of Representatives Science Committee.

The National Polar-orbiting Environmental Satellite System (NPOESS) is a set of six satellites that are intended to replace weather satellites currently used by the U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of Defense (DOD). As of March 2005, the program was to be completed for $6.8 billion, and the first satellite launch take place in 2009.

However, the first launch is now not expected to occur until 2012, and DOD estimates that completing the program in its original configuration could cost NOAA and the U.S. Air Force—which split the cost of the program equally—$13.8 billion.

U.S. Department of Commerce Inspector General Johnnie Frazier told the committee that there were two major issues that were responsible for the NPOESS program becoming so behind schedule and over budget. First, the program's oversight committee—comprised of top NOAA, DOD, and NASA officials—missed opportunities for review that could have put the program back on track, and they did not challenge optimistic reports that minimized the impact that problems with the development of a major sensor would have on the program. Second, the contractor for NPOESS was awarded excessive incentive fees even as the program became more behind schedule and over budget. This practice does not give the contractor any incentive to improve progress, Frazier said.

Frazier said that NPOESS needs regular, independent reviews of the program status, and that the award fee structure for the contractor should be reviewed and revised.

NOAA Administrator, Vice Admiral Conrad Lautenbacher, Jr., said that he and the other members of the oversight committee had already improved the speed and transparency of oversight, and put in a more independent layer of review, as well as replaced top program managers. "I am a big proponent of learning from past errors, and I am working very hard to ensure NPOESS gets back on track and stays on track," he said.

Committee chair Rep. Sherwood Boehlert (R-N.Y.) said, "It is absolutely vital that the NPOESS program succeed. NPOESS will provide our 'eyes in the sky' for both civilian and military weather forecasting, and we cannot afford to be stumbling around blind."

In a 15 May letter to U.S. President George W. Bush, the ranking members of the Science Committee, Rep. Bart Gordon (D-Tenn.), and the Subcommittee on Environment, Technology, and Standards, Rep. David Wu (D-Ore.), called for the replacement of Lautenbacher and the Deputy Undersecretary for Oceans and Atmosphere, General John Kelly, Jr. They wrote, "The economic consequences and perhaps even the public health consequences of failure to fix the NPOESS situation are too dire for us to fail. However, we are convinced that this program will not succeed with the current leadership in place at NOAA."

Scott Smullen, deputy director for NOAA public affairs, said that NOAA officials are perplexed by this move as NOAA and DOD have already implemented or are in the process of implementing all of the recommendations in the inspector general's report.

The NPOESS program is currently undergoing a mandatory DOD review, which was triggered last year when estimates for the cost of the program exceeded its original baseline budget by more than 25 percent. A decision, which could leave the program significantly scaled back, is due by 6 June (see *Eos 87*(15), 2006).

—SARAH ZIELINSKI, Staff Writer

MEETINGS

Global Aspects of Magnetosphere-Ionosphere Coupling

PAGE 207

The near-Earth space environment is a complex, ever-changing system of magnetized plasmas whose behavior has a profound impact upon our technology-dependent society. The recent 2006 Yosemite Workshop examined the interaction of these plasmas from a systems-level perspective, focusing on how the Earth's magnetosphere and ionosphere are physically coupled together into a single global system.

The most dynamic behavior of the magnetosphere-ionosphere (MI) system comes ultimately from the Sun. Solar wind pressure confines the Earth's magnetic field to a comet-shaped cavity called the magnetosphere. Solar wind energy input initiates a large-scale convective flow in the magnetosphere, and often triggers geomagnetic storms that dramatically alter the near-Earth plasma environment.

At the inner edge of the magnetosphere, solar ultraviolet rays ionize the Earth's upper atmosphere, producing a permanent population of plasma called the ionosphere, at an altitude of a few hundred kilometers. The interface between the ionosphere and magnetosphere is the site of a two-way interaction involving mass, momentum, and energy. Many different plasmas inhabit the MI system, with an assortment of density, temperature, and behavior.

To examine global aspects of MI coupling, the workshop brought together a diverse group of space physicists with interests in ionospheric, magnetospheric, and thermospheric physics. Together, they examined the rich and complex physical interconnection among the various plasmas and gases, with emphasis on understanding how all these parts respond to and are affected by the Sun and solar wind as one great 'system of systems.' The informal character of the meeting encouraged discussion across disciplines and areas of concentration, and much progress was made toward developing a more integrated picture of the near-Earth space environment.

Electromagnetic Coupling and Plasma Motion

One of the clearest examples of global MI coupling is the electromagnetic feedback that occurs between the ionosphere and the ring current, a warm (several to hundreds of kilo electron volts) plasma that encircles the Earth at several Earth radii. Global images have confirmed that strong sunward plasma convection during geomagnetic storms contracts and intensifies the nightside ring current. This produces a clear, characteristic signature in magnetometers on the Earth's surface, and also sets up an electrical current linking the ring current (RC) and ionosphere (I), generating strong electric potentials that modify the very convection that caused the RC-I current system to form. Several speakers at the Yosemite workshop emphasized that even after decades of investigation, critical details of this feedback phenomenon, such as how long it takes to set up this current system and under what conditions it is most effective, are still not fully understood. These speakers mentioned that ionospheric conductivity plays a vital role in controlling the strength of the RC-I generated potentials, yet it has not been empirically characterized in sufficient detail.

Several talks at the Yosemite workshop highlighted how space plasma convection has a very concrete effect on technology. For example, signals from numerous Global Positioning System (GPS) satellites are routinely used to determine a location on Earth. During geomagnetic storms, the dayside low-latitude ionosphere convects northward, forming dense plumes of plasma that extend over the United States and Canada. These plumes can bend or scatter GPS signals, causing location errors comparable in size to football fields, creating a potential hazard to GPS users such as airplanes or planned automated car navigation systems. Accurate plasma convection models, if achievable, have the potential to mitigate the dangers of this space weather effect by providing a forecast of likely GPS errors to users. Many talks at the Yosemite meeting emphasized the progress that has been made in improving storm-time convection models. A recurring point throughout the meeting was that a major weakness in convection models is the contribution from neutral wind effects, especially (but not limited to) geomagnetically quiet periods.

Mass Coupling

Direct exchange of particles between the magnetosphere and the ionosphere occurs on a continuous basis. The most dramatic consequences of this exchange are in the auroral zones. There, energetic electrons precipitate into the atmosphere, producing the aurora. At the Yosemite workshop, results were shown that highlight new understanding in the relationship between the auroras in the Northern and Southern Hemispheres, and how Alfvén waves (a fundamental magnetohydrodynamic wave in plasmas) can provide up to one watt per square meter of power to the aurora. This auroral precipitation causes heating of the atmosphere and the outflow of ionospheric ions (hydrogen and oxygen). These ions populate the Earth's magnetosphere and have a significant and immediate impact on the dynamics of the magnetosphere. Previous observations, limited in spatial coverage, have suggested that outflow was limited to high latitudes and strongest on the morning side. New global imaging observations presented at the meeting show that the outflow is global in nature, with a broad extent in local time and latitude, and is strongest on the dayside.

Magnetosphere-Ionosphere-Thermosphere Coupling

It is becoming increasingly obvious that the systems-level picture of plasma convection must be extended to include consideration of the motion of the thermosphere, the 'neutral wind.' Thermospheric winds (both disturbance-driven and diurnal) may play a larger role than previously thought, coupling the motions of neutral gases and plasmas of the ionosphere-thermosphere (IT) system. For example, for many years it has been known that IT coupling can cause the mid-latitude ionosphere to lag behind the rotation rate of the Earth [*Blanc and Richmond*, 1980; *Wand*, 1983; *Heelis and Coley*, 1992]. However, not until global imaging of the plasmasphere was there any discussion about how this IT coupling effect might in turn lead to subcorotation of the plasmaspheric portion of the mid-latitude magnetic flux tubes [*Sandel et al.*, 2003; *Burch et al.*, 2004].

Results from the meeting indicate that space weather scientists have much to learn about when and where the magnetosphere is significantly affected by subcorotation and other IT coupling effects. Previously, the effects of neutral winds have been thought to be important only during periods of geomagnetic quiet. New results from the meeting strongly advocate the inclusion of coupling between the upper atmosphere and magnetosphere into global models of magnetospheric convection.

Wave-Particle Interactions

MI and inter-region plasma coupling is central to the behavior of warmer plasmas, the ring current, and the radiation belts, the latter being intense zones of very energetic (on the order of megaelectron-volt) particles that encircle the Earth. Certain types of plasma waves (e.g., Alfvén waves, and chorus, a whistler-mode plasma wave) can feed energy into the ring current and radiation belts through local heating and radial transport [*Elkington et al.,* 2004; *Horne et al.,* 2005]. The resulting radiation belt intensifications are hazardous to satellites and astronauts.

The outcome of such intensifications can range from communication disruption, to reduced lifetime or complete loss of spacecraft in extreme cases. There is a balance between sources and losses of radiation belt particles, with other types of plasma waves that are enhanced during disturbed times (e.g., hiss, a broad-band whistler emission, and electromagnetic ion cyclotron (EMIC) waves, generated by gyration of magnetized ions), which can deplete the warm plasmas by scattering them into the Earth's atmosphere [*Summers and Thorne,* 2003; *Thorne et al.,* 2005]. Results presented at the meeting indicate that the slot region separating inner and outer electron belts, which is mostly devoid of energetic electrons, may be largely controlled not by strong losses (which take several days to affect the global population), but by the absence of strong acceleration mechanisms that can act much more quickly.

The distribution and generation of all these waves depend upon the background plasma density, temperature, composition, and motion, all of which are only incompletely known. There was a general consensus among meeting participants that solving this problem will require much better models of the various waves that control the radiation belts.

Future Progress

Understanding the Earth's space environment has become of critical importance as people become increasingly reliant upon navigation and communications capabilities afforded by satellites. And as people strive to achieve a permanent presence in space, this environment will take center stage.

The Yosemite workshop made it evident that future progress will require better communication among those studying the magnetosphere, ionosphere, and thermosphere than has traditionally been the case. The delay in appreciating the cause of plasmaspheric corotation lag is one striking example of the communication gap that must be bridged, but there are many other examples. In the past, those studying different components of the larger system have not always worked together. Though past efforts have yielded a much fuller understanding of the workings of the components of the system, it is essential that scientists continue this progress by understanding how the different components of the system link together at the global level. The Yosemite workshop's cross-disciplinary, systems-level approach is one way to achieve this goal.

The 2006 Yosemite Workshop was held 7–10 February in Yosemite National Park, Calif. For more information, see http://yosemite2006.space.swri.edu

Acknowledgments

We are indebted to C. Kempe for her tireless and indispensable efforts coordinating the workshop, and to the program committee members, who endured numerous teleconferences to bring the successful mix of experts together. We thank M. Hudson and R. Strangeway for useful input to this report. We are deeply grateful to all scientists who attended, presented, debated, and discussed at the sessions, upholding the Yosemite tradition that a meeting can be scientifically productive and fun.

References

Blanc, M., and A. D. Richmond (1980), The ionospheric disturbance dynamo, *J. Geophys. Res., 85,* 1669–1686.

Burch, J. L., J. Goldstein, and B. R. Sandel (2004), Cause of plasmasphere corotation lag, *Geophys. Res. Lett., 31,* L05802, doi:10.1029/2003GL019164.

Heelis, R. A., and R. J. Coley (1992), East-west ion drifts at midlatitudes observed by Dynamics Explorer 2, *J. Geophys. Res., 97,* 19,461–19,469.

Sandel, B. R., J. Goldstein, D. L. Gallagher, and M. Spasojevic (2003), EUV observations of the structure and dynamics of the plasmasphere, *Space Sci. Rev., 109,* 25–46.

Wand, R. H. (1983), Seasonal variations of lower thermospheric winds from the Millstone Hill incoherent scatter radar, *J. Geophys. Res., 88,* 9227–9241.

—JERRY GOLDSTEIN, Southwest Research Institute, San Antonio, Texas; MARIA SPASOJEVIC, Stanford University, Stanford, Calif.; STEPHEN FUSELIER, Lockheed-Martin Corporation, Palo Alto, Calif.; E-mail: jgoldstein@swri.edu