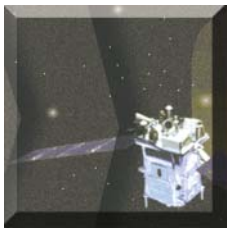

TIMED Technology Advances: Guest Editor's Introduction

David G. Grant

On 7 December 2001, a Boeing Delta-II 7920-10 launch vehicle lifted the Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED) spacecraft into a 625-km circular orbit from Space Launch Complex 2 at Vandenberg Air Force Base, California. This launch event was the culmination of more than 4 years of intense technical and scientific effort by APL and its collaborating partners and signaled the onset of 5 years of scientific data collection and 6 years of analysis.

This issue of the *Technical Digest* begins with an article by Mellott and Elsbernd, who describe NASA's Solar Terrestrial Probes Program and its first basic science mission: TIMED. The primary purpose of TIMED is to gain an understanding of the mesosphere, lower thermosphere/ionosphere (MLTI) region of the atmosphere where the enormous energy output of the Sun first interacts with the Earth's environment. The MLTI is the gateway region between the Earth and space that extends from roughly 60 to 180 km in altitude. Because the MLTI is too high for balloon studies and too low for *in situ* satellite measurements, it is largely unexplored; only occasional rocket flights have produced scientific data in this region.

A suite of four remote sensing instruments on TIMED now provides scientists a unique opportunity to make comprehensive, long-term measurements in the MLTI region. TIMED is instrumented to measure critical state parameters including temperature, winds, electron density, and chemical composition, as well as solar energy input. These data will allow high-fidelity modeling of the region and quantification of global and seasonal variability, and, in particular, will shed light on global energy dynamics. While the Sun's impact on the MLTI region is the principal scientific interest, the impact of man on the region is being measured as well. Of special importance are the baseline scientific data TIMED is collecting in support of future environmental studies of the atmosphere to deduce changes due to man. In addition to basic science studies, TIMED also has a significant practical relevance to space weather, spacecraft dynamics, and telecommunications.

At the onset of the TIMED mission, NASA delegated complete responsibility for mission success to APL. In this all-encompassing role, the Laboratory's duties include overall

mission design; end-to-end system engineering; the design, development, integration, and test of the spacecraft; and technical management of the instrument payload. Also delegated were the design and development of a suitable mission operations center and science operations center to support post-launch data collection and dissemination through the APL ground station. NASA named APL's Jeng-Hwa (Sam) Yee to be the TIMED Project Scientist, a role usually held by a NASA scientist. In this capacity, Sam chairs the TIMED Science Working Group and is responsible to NASA for achieving all TIMED mission-level science objectives. An overview of the basic science mission of TIMED is given in the article by Yee.

The TIMED spacecraft was certified for operation on 22 January 2002. Since then it has been collecting data in its primary science data-gathering mode greater than 98% of the time. Early science results were presented at the 2002 Spring Meeting of the American Geophysical Union in Washington, DC, and were very well received. Especially noteworthy were results associated with a major solar event that occurred on 21 April 2002, whose impact on the Earth system was captured by the TIMED instrument suite. This event and other significant results are discussed in an article on TIMED's "first light" by Talaat, Yee, et al.

An overview of the TIMED spacecraft is provided in an article by Kusnierkiewicz, and its suite of science instruments is detailed in an article by Yee, Talaat, et al. The ground system, mission operations team, mission systems engineering, and system architecture are detailed in a further article by Kusnierkiewicz. The TIMED launch campaign, including the shipment and transportation of the spacecraft to the Payload Processing Facility, launch vehicle integration, final testing, and launch preparations, is described in an article by Vernon and Kozuch.

In response to mission technical requirements, the TIMED program provided an opportunity to introduce several new and important technologies. The spaceborne GPS Navigation System (GNS) was developed for the TIMED spacecraft and is described in an article by Devereux, Asher, Heins, Chacos, Kusterer, and Linstrom. Spacecraft orbital elements, position (i.e., latitude, longitude, altitude), velocity, and UTC (Universal Time Coordinated) are derived on TIMED from the GPS constellation. The GNS also facilitates "event-based" commanding. In this concept, the occurrence of significant orbital events such as terminator crossings, ground station contacts, and the point at which a critical Sun angle is reached are predicted onboard via the GNS. This information is communicated to spacecraft subsystems and instruments where requisite commands are generated. Event-based commanding eliminates the need to analyze, uplink, and downlink the mass of navigation and timing data needed for mission management. It's all done onboard. The GNS subsystem on TIMED is based on a custom integrated circuit, believed to be the most complex of its kind ever developed at APL.

The first flight units of an integrated electronics module (IEM) were developed for TIMED, as indicated in the article by Marth. The IEM is a packaging concept in which spacecraft subsystems are developed on multilayer boards and are integrated into a single chassis, similar to computer boards. This results in substantial savings in weight and volume over the traditional box-and-harness approach. On TIMED, the RF communications, GNS, and command and data handling subsystems were designed into an IEM configuration. Advanced versions of the TIMED IEM have since been designed for several deep space missions being developed at APL (i.e., CONTOUR, STEREO, MESSENGER, and New Horizons).

APL engineers also addressed the problem of high mission operations cost, the bane of many a good mission, as described in an article by Harvey. From the outset, a single-shift mission operations concept was the TIMED paradigm. Onboard solid-state recorders and downlink telemetry rates are sized to handle a 24-h single-contact-per-day data collection cycle. Further, by designing a robust, highly autonomous spacecraft, essentially free from spacecraft and/or instrument deconfliction requirements, and by using event-based commanding, the need to provide a "standing army" in the Mission Operations Center to manage limited spacecraft resources or to accommodate conflicting requirements has been eliminated. The TIMED spacecraft is designed so that all of the instruments can be commanded into any of their respective operating modes at any time without regard to the state of the other instruments or the spacecraft. This greatly simplifies mission planning.

The TIMED ground system was developed to allow science teams to operate their instruments from Payload Operations Centers (POCs) located at their home institutions. Instrument commands are communicated via the Internet from their POCs to a centralized Mission Operations Center at APL. These commands are packaged with spacecraft commands and other instrument commands and are then communicated to the spacecraft from the APL ground station. Likewise, science downlink telemetry is collected and sorted in the APL Science Data System and communicated via the Internet to the instrument POCs for processing. The spacecraft has been operated successfully in this manner since launch. The TIMED ground system has proven to be an extremely efficient and cost-effective approach to on-orbit spacecraft management. A description of the ground system and mission operations is given in an article by Rodberg, Knopf, Lafferty, and Nylund.

Education and public outreach continues to be a major component of the TIMED program and is

described in an article by Beisser, Goldberg, and Marren. The scope of this effort is geared toward students (with special emphasis on the disadvantaged), teachers, and the general public.

The TIMED mission has met or surpassed our greatest expectations. The scientific productivity of TIMED has been truly remarkable. As a result of this success, NASA has extended the mission and operations and data gathering phase for an additional 3 years (through the 2nd quarter of 2007) and the scientific data analysis phase through the end of 2007.

Complete information on the TIMED mission, including participants, status, science, etc., may be found at http://www.timed.jhuapl.edu/mission/.

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