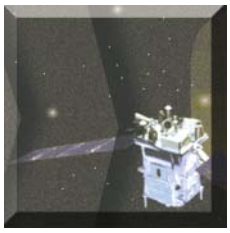

TIMED: From Concept to Realization

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The Earth is an island in the universe where life has developed and flourished. This has been possible because of the interaction between our nearest star, the Sun, which bathes the entire solar system in a dynamic outflow of energy, and the shielding provided by the Earth's magnetic field and atmosphere.

It is the goal of NASA's Sun-Earth Connection Division in the Office of Space Science to understand how the Sun, the region of space influenced by the Sun (the "heliosphere"), and planetary environs are connected in a single system. The primary vehicle for achieving this goal is the Solar Terrestrial Probes (STP) program, a series of strategic missions configured to study the fundamental physical processes associated with the Sun-heliosphere-Earth system. STP missions will provide critical knowledge to better understand the Sun's variability and the effects of that variability on the Earth's atmosphere.

The first Space Physics Strategic Implementation Study, conducted in 1990, placed the highest priority within the STP program on a mission to study the mesosphere/lower thermosphere/ionosphere (MLTI) region where the upper atmosphere interfaces with the near-Earth space environment. The Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED) mission evolved from this initial vision and is now using advances in remote sensing technology to study the influences of the Sun and humans on the MLTI, the least explored region of Earth's atmosphere. Other spacecraft have studied portions of this gateway region between Earth's environment and space, but TIMED is the first mission to obtain a global picture of it. Understanding the MLTI has important practical applications because its variability can impact communications, satellite tracking, and spacecraft lifetimes and materials. In addition, there is some evidence that changes occurring in the MLTI may be early indicators of global change.

The mission that was contemplated in the Strategic Implementation Study was conceived in the days of the "old" NASA, when missions involved increasingly more spacecraft (at least 6) and numerous instruments (≈15), equivalent to a "great observatory" for space physics with an estimated cost of $1 billion. But diminishing budget prospects almost immediately led to the first in a series of downsized expectations for the STP MLTI mission. At an Office of Space Science strategy meeting in the summer of 1991, the goal became more modest, i.e., a couple of spacecraft in the $300 to $400 million range. Detailed mission

studies continued; the TIMED mission study in 1992 envisioned two high-altitude spacecraft, with one spacecraft that would periodically dip into the lower regions of the atmosphere. Mission costs increased to as much as $450 million during this study.

An Announcement of Opportunity for TIMED science investigations was released in April 1992, and a new start would have been the next step for this mission concept. Within this same timeframe, however, a new NASA administrator came onboard with a vision of more smaller missions with shorter development times. This vision and pressure on the agency's budgets worked against a new start for the multiple spacecraft concept for TIMED. Responding to these pressures, NASA reduced available budget costs to the $100 million range. In the meantime, nine TIMED investigations had been selected in June 1993; only those investigations that clearly supported the primary science goals as defined by the Science Definition Team were chosen.

In parallel with the descoping of the TIMED program, NASA began discussions with APL about how to take advantage of the Laboratory's special expertise in developing small, cost-efficient mission concepts in support of TIMED's science objectives. As a result of these discussions, NASA asked APL in mid-1994 to establish a project to study the feasibility of TIMED as a single spacecraft with nine instruments. To further decrease costs, a descope in the number of instruments was considered. Using input from the Science Working Group, a special *ad hoc* science panel was convened to prioritize investigations and to suggest what a minimum TIMED mission should include. In June 1994, the panel reported its recommendations: the minimum set of investigations necessary to achieve the highest priority science consisted of a suite of four instruments that could be flown on a single spacecraft. In October 1994, on the basis of the panel's recommendations, NASA officially descoped the instruments from nine to four: the Global Ultra Violet Imager (GUVI), Sounding of the Atmosphere using Broadband Emission Radiometry (SABER), Solar Extreme Ultraviolet Experiment (SEE), and TIMED Doppler Interferometer (TIDI).

From this point on, detailed mission design proceeded on the four instruments, with APL starting Phase B in June 1996 and TIMED appearing as a new start in the FY1997 budget. A Preliminary Design Review and a Non-Advocate Review (NAR) were held in February 1997. Following the advice of the NAR, the NASA Headquarters Program Management Council recommended that implementation proceed, with launch targeted for January 2000. At this point TIMED was officially in Phase C/D, with a cost target for the development phase of $129 million. (Dave Grant, in his guest editorial, this issue, details some of the cost-efficiencies and innovative technologies used by APL that allowed the TIMED mission to become a reality.) A later decision was made to co-manifest TIMED on a Delta-II with another NASA payload, thus moving the launch date to May 2000. In October 1999, information was received that the co-manifested payload could not be ready for the May 2000 launch. This was the first of a number of slips in the readiness of the co-manifested payload that resulted in significant delays and cost increases for the mission.

TIMED launched successfully on 7 December 2001, and its official science mission began in January 2002. In the relatively short time since launch, the mission has already made great strides toward helping scientists learn more about the MLTI; in fact, TIMED met the minimum mission success criteria on 22 April 2002.

In addition to making excellent progress toward its primary goal—the much needed long-term characterization of the MLTI—TIMED is making significant contributions to studies of the dynamical response of the upper atmosphere to solar storms, providing the final link in the chain of processes connecting the Sun and Earth. TIMED is also producing some unexpected benefits; the GUVI instrument, for instance, is making comprehensive observations of the spatial extent and geographic distribution of equatorial plasma bubbles, which are sources of significant communication disturbances.

Follow-on STP missions that will build on TIMED's successes will provide both remote and *in situ* observations to help us better understand other aspects of the Sun-Earth connection. Future STP missions include Solar-B, Solar Terrestrial Relations Observatory (STEREO), Magnetospheric Multiscale, Geospace Electrodynamic Connections, and Magnetospheric Constellation. Each mission individually will yield exciting discoveries about various elements of the Sun-Earth connection, but together, their most important aspect is a synergy that will greatly improve our knowledge of the operation of the complex system connecting the Sun and Earth. These missions will enable us to view the Sun as never before possible and to better understand its impact on life on Earth and other planets.

THE AUTHORS

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