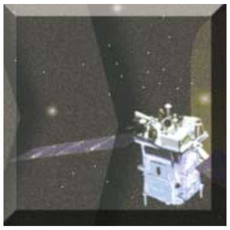


TIMED Launch Operations

Steven R. Vernon and Stanley F. Kozuch

Completion of all ground-based environmental testing of a spacecraft marks the start of the launch campaign. Launch operations are the hand-off point when the ground teams (design, development, assembly, and test) relinquish control and responsibility to the launch vehicle provider and Mission Operations Team that will actually operate the spacecraft in orbit. This article describes the TIMED launch operations, including shipment and transportation of the spacecraft and associated support hardware to the launch site, testing conducted at the Payload Processing Facility, launch vehicle integration operations, spacecraft system software and electrical testing, and preparation for launch.

INTRODUCTION

Launch operations typically start immediately after the completion of spacecraft environmental testing. For the TIMED (Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics) mission, the launch delay associated with the co-manifested Jason spacecraft considerably extended the time between environmental testing and shipment to the field for launch operations to approximately 18 months. The joint NASA/French Jason spacecraft delays forced the TIMED spacecraft into storage twice, once at APL and again at Vandenberg Air Force Base (VAFB).

Launch site operations officially commenced with the overland truck shipment of mechanical and electrical ground support equipment (GSE) to the VAFB launch site in Lompoc, California, approximately 1 week before shipment of the spacecraft. Early shipment and arrival of the GSE allowed personnel to clean the required equipment, organize the field office, establish the critical external communication links back to APL, and certify that the facility was ready to accept the spacecraft, thus meeting the program requirements for cleanliness. Once the facility was certified and the necessary support equipment and personnel were deemed ready, the program office was notified and the process for shipment of the TIMED spacecraft by military aircraft from APL to VAFB commenced. (Complete information on the TIMED mission, including participants, status, science, etc., may be found at http://www.timed.jhuapl.edu/mission/.)

SHIPMENT AND TRANSPORTATION

Shipment of the spacecraft began when it was loaded onto a flatbed, air-ride, low-deck truck at APL (Fig. 1) for over-the-road transportation to Andrews Air Force Base under security escort. A Maryland state–issued transportation waiver for oversized and critical loads requiring an escort dictated early morning transportation to avoid disruption to local traffic.

Figure 1. TIMED spacecraft shipment. The spacecraft (inside the container) is secured for land shipment to Andrews Air Force Base.

The spacecraft itself was protected from the elements and other hazards by a metallic shipping container. This container was under constant nitrogen purge supplied by boil-off of liquid nitrogen from dewars that accompanied the spacecraft at all times. It was instrumented to record shocks and incorporated externally readable gauges to measure the internal temperature, pressure, and humidity. Internal shock isolation mounts provided dynamic protection of the payload against jolts encountered during transportation and handling events.

All loading and transportation activities were controlled and overseen by a mechanical payload team that also accompanied the payload throughout its journey. Constant communication links were maintained via two-way radios and cell phones between the payload team and APL.

Upon arrival at Andrews, personnel inspected the cargo and ensured that the proper clearances and waivers had been approved and all hazardous materials were accounted for and labeled properly. Equipment and the spacecraft were then packaged onto cargo pallets for rapid loading onto a C-17 military aircraft. Figure 2 depicts the loading of the shipping container as viewed from inside the C-17.

Because of the requirement for continuous nitrogen purge, coupled with aircraft emergency contingency planning (e.g., unscheduled aircraft diversions due to weather or national emergencies, aircraft maintenance or mechanical problems encountered on the ground), it was determined that three dewars of liquid nitrogen totaling 1080 L be shipped with the TIMED spacecraft. This was calculated to cover at least 9.5 days at full flow rates. The large amount of liquid nitrogen required that the dewar pressure-relief safety burst-disk devices be plumed and vented to one of the overboard fittings located inside the C-17 aircraft. This was done to ensure crew safety should a rupture of a dewar burst disk occur in flight.

In addition to the onboard aircraft monitoring systems, the oxygen content of the cargo compartment was monitored at 30-min intervals by APL spacecraft personnel using portable oxygen monitors to ensure crew safety. During these monitoring activities, the nitrogen flow rates and purity of the purge system were also checked and the data recorded.

Upon arrival at VAFB, the TIMED spacecraft and supporting hardware were off-loaded to flatbed trucks and transported to the Payload Processing Facility (PPF) located several miles from the aircraft runway.

PAYLOAD PROCESSING FACILITY

Site Selection

The remotely located PPF originally chosen by NASA/Kennedy Space Center (KSC) for the TIMED mission, based on a competitive procurement, was approximately 20 miles from the launch pad, Space Launch Complex (SLC)-2W. Selection was based on a requirements document produced by APL early in the program and the findings of several subsequent Ground Operations Working Group meetings involving Boeing, NASA, Vandenberg Range Safety, and APL. It soon became apparent that the initially selected NASA facilities at VAFB were inadequate to support a dual payload (i.e., Jason and TIMED) attach fitting mission. As a result, NASA/KSC instituted a competitive procurement between two available commercial PPFs. The APL requirements document served as a technical basis for contract bid evaluations and eventual award, which went to Spaceport Systems International (SSI).

Figure 2. Air Force C-17 loading operation. Air Force personnel direct the loading operations of the TIMED spacecraft within the shipping container for the flight to Vandenberg Air Force Base in Lompoc, California.

The SSI commercial PPF (Fig. 3)—the primary location at VAFB where the field crew, equipment, spacecraft, and field office were located—was designated as SLC-6W. It contained clean rooms, cranes, a multilayer insulation (MLI) fabrication area, storage for the GSE, office space, a precision cleaning station, forklifts, and a dewar storage refill station. Onsite testing laboratories, fabrication capabilities, and a metrology laboratory for tool and measurement calibration and certification were contracted out to various on-base facilities organizations as required.

The PPF was originally constructed for Space Shuttle payload integration and subsequent West Coast launch operations. Existing Boeing Delta-IV facility and launch pad modifications were ongoing near the PPF during the entire period in which the TIMED spacecraft was present, but these construction operations had no impact on the TIMED field operations.

Contamination Control

Once at the PPF, the TIMED spacecraft was moved inside, and the shipping container cover and outer contamination bag surrounding it were removed. The inner bag and shipping container base were cleaned, and the system was rolled into the high-bay clean room. After the entry doors were closed, the clean room was allowed time to stabilize to meet program requirements for temperature, humidity, and cleanliness. The mechanical team then removed the last bag and hoisted the spacecraft into the processing cell, mounting it to a work stand for testing and flight buildup. The processing cell doors were closed and sealed from the other facility clean areas to prevent cross contamination from operations of other payloads and tasks in preparation for launch vehicle (LV) mating.

SLC-6W, with its cranes, air handling and cleaning systems, power systems, communications systems, environmental controls, and monitoring systems, proved more than sufficient for the TIMED mission. Facility personnel responded instantly to any and all requests with creative and satisfactory solutions. Contamination control and cleaning teams performed with diligence, care, and complete respect for the security of the payload. Security, 24-h monitoring, separation of Jason and TIMED personnel and hardware, and access to the TIMED spacecraft and support equipment—both during times of activity and storage—were all under PPF personnel control.

The spacecraft underwent final mechanical assembly, installation of MLI, integration with the LV interface hardware and separation systems, and final software and system checkout while still at the PPF. After buildup and checkout were complete, the spacecraft system was readied for shipment to the launch pad. These operations and tests are detailed in the section below.

Figure 3. The PPF where the TIMED spacecraft was processed prior to transportation to the launch pad (top), and another view showing its proximity to the Pacific Ocean (bottom).

SPACECRAFT FLIGHT BUILDUP AND FINAL ASSEMBLY

The TIMED spacecraft was shipped with several nonflight instrument aperture protective covers in place, but minus critical power system components. In addition, the flight MLI with the final flight coating applied needed to be installed after most handling and assembly events were completed to keep from damaging the fragile thermal properties of the MLI and radiator coatings. The completion of all remaining tasks, preparations for flight, and verification of flight subsystems readiness are referred to as flight buildup and closeout activities.

Flight buildup started when the mechanical team mounted the spacecraft to the work stand in the PPF clean room (processing cell #3), as noted earlier. The spacecraft was then connected to the electrical GSE, which had an active electrical interface with the spacecraft flight hardware.

TIMED was subjected to an electrical functional test to verify post-shipment performance, i.e., to confirm subsystem and instrument integrity after handling, storage, and transportation, or after exposure to environmental testing. This functional test was used to ensure that the spacecraft would operate nominally through all of its direct and cross-strapped electrical interfaces. As this was a nominal condition test, it did not subject the spacecraft to a wide range of test conditions for performance assessment.

After the successful completion of the functional test, a comprehensive performance test was conducted to verify performance specification parameters. As such, it tested the spacecraft to specification extremes under a wide range of scenarios designed to simulate on-orbit conditions, and included in its design the following most critical criteria:

- Verification of all command and data paths between components within the system
- Verification of all subsystem and instrument operational modes
- Evaluation of all flight hardware and flight software interfaces

Subsequent to the comprehensive performance test, an event-driven simulation was conducted on the spacecraft's primary and redundant components. This simulation initially had TIMED in a normal on-orbit configuration. An electrical GSE GPS simulator and a guidance and control (G&C) simulator (TIMED Attitude System Test and Integration Equipment [TASTIE]) provided inputs to the spacecraft to achieve the required simulation, which consisted of several simulated ground contacts as well as a yaw maneuver (see below). The intent of this event-based simulation was twofold: (1) to exercise intra-subsystem data transfer and communications as much as possible, and (2) to generate as many of the event-driven status flags as possible to exercise the responses from the respective spacecraft subsystems and instruments.

The yaw maneuver is a periodic event that needs to be performed on the spacecraft. The spacecraft precesses its orbit approximately 3° per day with respect to the Sun. After about 60 days, the Sun has traveled a full 180°. Eventually the spacecraft must perform a maneuver to allow the Sun to continue to travel on the hot side of the spacecraft. This maneuver is a 180° yaw of the spacecraft along the nadir line. The yaw maneuver is conducted near a beta = 0 orbit. It also is conducted in shadow to prevent inadvertent sunlight from shining on the cold side of the spacecraft during the maneuver.

At this point the spacecraft was in a configuration that enabled mission operations personnel to perform a Mission Operations Readiness Demonstration as well as a 96-Hour Readiness Demonstration. The former consisted of a simulated countdown, spacecraft separation, de-tumble, and early orbit station contacts. The 96-h test, which was started using TASTIE and solar array simulators, simulated a week in the life of TIMED and included spacecraft and instrument commanding during simulated station contacts. The simulation began when the spacecraft and instruments were finally put into the on-orbit configuration. Solid-state recorder dumps were executed at each contact, and all post-contact data processing and distribution activities were exercised.

In parallel to the system testing described above, preparations for solar array integration were ongoing. Before solar array installation, the wings were carefully opened and visually inspected to ensure that no solar cells were damaged after almost 1.5 years of storage and the subsequent shipping and handling events. Also in preparation for the spacecraft flight build, flight fuses housed in the Power Switching Unit, solar array junction boxes, and G&C Attitude Interface Unit were checked and installed in the Power Distribution Unit. In addition, flight batteries were removed from temperature-controlled storage and installed into the spacecraft in their final flight configuration.

Prior to final installation of the last spacecraft internal access panel, quality control, mechanical, and electrical teams independently verified that every connector, ground strap, fastener, and fitting was properly secured for flight. High-resolution photographs were taken to provide the "as-built" documentation required should any questions arise at a later date. The structural $-y$ access panel was then installed, and the solar arrays were assembled onto the spacecraft. The solar array pyrotechnic release devices were installed next, and final closeout of the spacecraft power system was completed. Additional closeout photographs were taken of items that would eventually be hidden by the MLI.

While the spacecraft system testing and closeout activities just described were being performed, instrument teams and subsystem lead engineering and science staff converged on the PPF and prepared their instruments and sensors for flight. Protective covers and high-voltage safing plugs were removed, and pyrotechnic deployment mechanisms were installed. Flight MLI installation was carried out as scheduling permitted.

After all closeout activities were completed, final cleaning, inspection, and certification of cleanliness were performed, and the TIMED spacecraft team officially notified the Boeing launch service provider that joint APL and Boeing LV integration operations were ready to commence.

LAUNCH VEHICLE INTEGRATION OPERATIONS

LV mating operations consisted of the following steps in order: flight payload adapter fitting (PAF), integration of the spacecraft into the dual payload adapter fitting (DPAF), Jason spacecraft integration, transportation canning and transport, and finally, LV integration. These steps are detailed below.

PAF Mating and Clamp-Band Installation

The spacecraft was now ready to be mated to the flight payload adapter, which consisted of a tensioned clamp-band that secured the spacecraft to the LV PAF. TIMED was hoisted above the APL work stand and transferred to the flight PAF assembly outside the processing cell. After centering the spacecraft over the flight PAF, the spacecraft was slowly lowered and mated to the PAF; multiple diameters and surfaces were mated to within a 0.002-in. clearance between parts in critical mounting surfaces. The flight PAF system provided the mounting interface for spacecraft electrical umbilical connectors, mission-unique liquid nitrogen purge connector, separation switches, battery AC system, push-off springs, and standard Boeing 37-in.-diameter clamp-band assembly.

Once the physical mate between the PAF and the spacecraft was accomplished, the clamp-band was installed under the direction of the installation engineer. Installation was accomplished by the slow and methodical tapping of the band with nonmetallic tipped hammers. The engineer monitored several strain gauges incorporated on the instrumented clamp-band to ensure that the loading was evenly distributed around the band. Once an even distribution of loading was accomplished, the band was declared ready for flight. Clamp-band loading for the TIMED spacecraft was 3200 ± 5 lbf tension in the band. After the required tension was achieved, the pyrotechnic-activated bolt cutters were installed. These devices cut the bolts in flight, thus releasing the tension in the band and allowing the spacecraft to separate from the LV. The fully assembled TIMED/PAF system is shown in Fig. 4. Note that the lift fixture bars are still attached for lifting and translating the completed TIMED/PAF assembly into the DPAF system.

Integration of the Spacecraft into the DPAF

The DPAF is a NASA-developed hardware system used for launching dual payloads from a single LV.

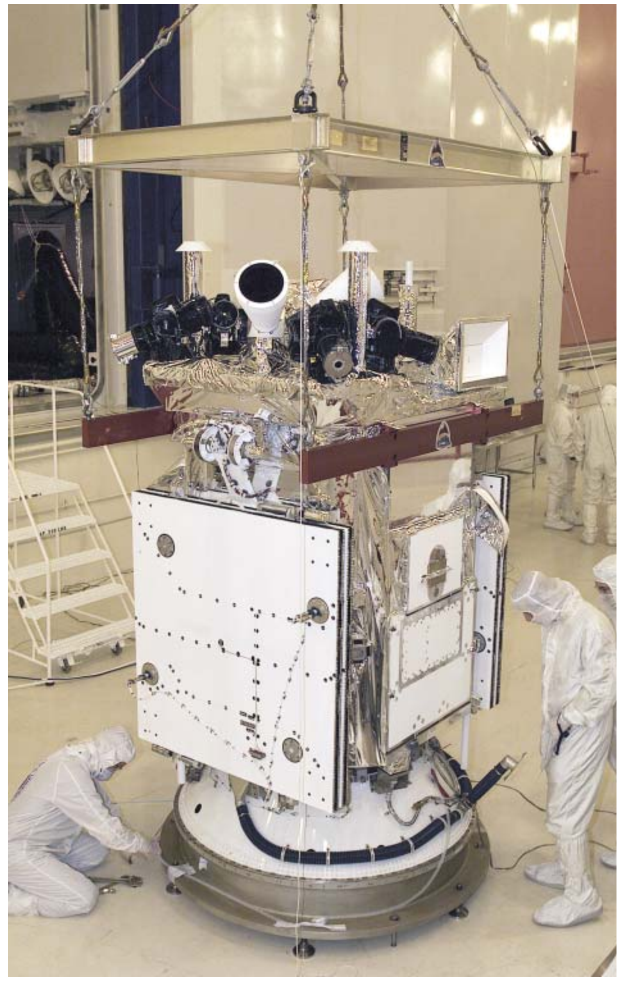


Figure 4. TIMED assembled to the flight payload adapter. The spacecraft in the launch configuration awaits integration into the dual payload adapter fitting launch vehicle system. The lifting fixture is still attached.

TIMED is the second mission to employ this system. TIMED engineers worked closely with NASA and Boeing during the development of the DPAF since the driving requirements for all anticipated uses of the DPAF system were completely enveloped by the TIMED mission requirements. The TIMED DPAF system also incorporated two mission-unique hardware items: (1) a zero tip-off rate ($T = 0$) purge system interface, and (2) a $T = 0$ dual battery radiator cooling system. These two new development items have also contributed to Delta-II capability increases and enhancements.

The intent of the DPAF system design was to decouple the designs of the two payloads during the spacecraft development cycle and thus provide a structurally independent means to accommodate each and minimize their interaction. The upper spacecraft, for example, does not affect structural loading of the lower spacecraft since the DPAF is a structural element that transmits the loads of each respective spacecraft into the LV.

The DPAF mechanical system is primarily a set of structures made from composite materials to reduce weight and is derived from a similar application on the Arianne LV, also for dual-manifested payloads. The TIMED spacecraft was encapsulated within the DPAF, with the Jason payload occupying the upper position (Fig. 5). In flight, the deployment sequence started with separation of Jason from the system, followed by deployment of the upper DPAF and then the TIMED spacecraft. The TIMED liquid nitrogen purge flowed continuously through the DPAF buildup process until launch. In addition, the $T = 0$ cooling system was running during battery charging operations while TIMED was encapsulated within the DPAF until transportation to the pad. After TIMED was mated, contamination bagging was installed to prevent debris generated during Jason operations from impacting the TIMED cleanliness requirements.

Jason Spacecraft Integration

The Jason spacecraft followed a PAF integration process similar to that of TIMED and was then fueled and assembled onto the upper half of the DPAF. Once TIMED was fully encapsulated, facility cleanliness requirements were relaxed to lower 100,000 levels from the 10,000 level owing to lower Jason cleanliness requirements. TIMED maintained higher cleanliness requirements while inside the DPAF via DPAF external contamination bagging, positive-pressure AC supplied to the battery radiators inside the DPAF, and the constant liquid nitrogen purge of the spacecraft.

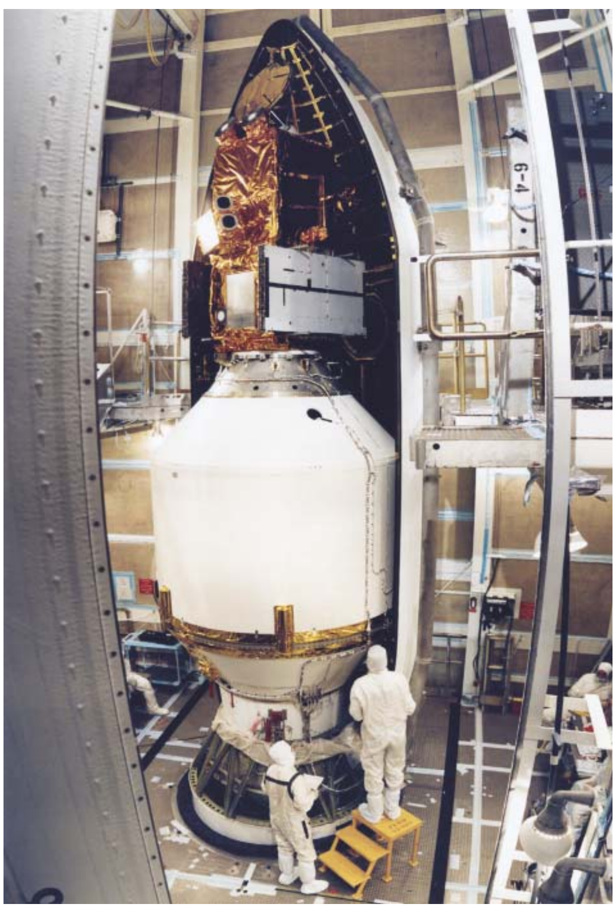


Figure 5. Fairing encapsulation. The first half of the launch vehicle fairing is installed around the payload. TIMED is located within the large white cylinder, and the NASA/Jason spacecraft is located in the upper section of the fairing.

Transportation Canning and Transport

After Jason/TIMED payload assembly, the stack was placed in a protective transportation container for overland travel to the launch pad and subsequent LV mating. Transport started at 12:00 midnight and ended with payload arrival at the pad at approximately 5:00 a.m. Night transportation satisfied several and often conflicting technical requirements more easily than daytime transportation. For example, actual travel speed was limited to 5 mi/h because of range safety concerns and to keep the dynamic environment during transport within acceptable limits for the payload stack. Also, nighttime temperatures on the California coast are quite stable, and maximum wind-loading limits are usually not exceeded. In addition, the payload had to be ready for hoisting operations to commence at daybreak.

Launch Vehicle Integration

The first order of business at daybreak was to assemble the payload and LV teams for a briefing to outline responsibilities and review procedures and the schedule for the day's activities. The teams then went on to the launch pad to start operations. Since the TIMED continuous purge requirement for the payload necessitated personnel support and interactions during lifting and mating operations, members of the APL/TIMED mechanical team become an integral part of the Boeing-led LV assembly and integration team rather than observers.

During hoisting operations, LV personnel performed crane checkouts, assembled the proper tools and equipment, and opened the required doors on the Mobile Service Tower (MST) so that the payload could transition inside to the top of the tower. In addition, the payload team prepared the purge line for trouble-free lifting of the payload stack. This involved laying out 200 ft of purge line, assigning personnel to handle the hose during the lift, and visual inspection to provide advanced warning of possible problems not directly observed by participants because of sight restrictions. The lifting of the payload could not be compromised by disturbances such as entangled lines, winds, or tipping of the payload owing to hose entanglements. TIMED field crew members were also assigned to the upper levels of the MST to assist in hose handling operations as the payload transitioned to within the tower.

A final roll call was taken before payload/LV mating began to ensure that all personnel and equipment were in place and that winds were measured and determined to be within acceptable ranges. The operation continued flawlessly. Within an hour of the first crane movement, the payload was inside the protected confines of the MST and was being mated to the LV. The outside doors were closed, with a feed-through opening providing for the purge hose. When the payload was mated, the hoisting purge line was replaced with the existing LV purge line previously certified and tested clean. Next, the MST level occupied by the payload was sealed and cleaned. Personnel access and clothing requirements were then controlled to more rigorous levels to ensure cleanliness of the payload environment.

From this point in the process, access to the TIMED payload was limited because of its proximity within the DPAF. Nevertheless, since the TIMED cleanliness requirements drove the cleanliness requirements of the mission, TIMED personnel were present for all significant operations (e.g., transportation container removal, payload contamination bag removal, LV fairing installation) up to launch.

SYSTEM-LEVEL TESTING

To facilitate remote testing of the TIMED spacecraft at the APL Mission Operations Center, several pieces of electrical GSE were relocated, e.g., the Blockhouse Control Unit was moved to the Delta-II SLC-2W electrical equipment building, and the Delta Tower Interface Unit was moved into the Delta-II fixed umbilical tower junction box. These moves enabled spacecraft electrical testing on the launch pad.

Before mating the combined TIMED and Jason spacecraft to the Delta-II LV, an electrical "safe-to-mate" verification was conducted from the TIMED Blockhouse Control Unit in the SLC-2W electrical equipment building to the Delta-II LV TIMED spacecraft umbilical connectors. Use of the TIMED spacecraft simulator enabled all electrical signal interfaces to be verified from the Blockhouse Control Unit to the umbilical connectors prior to mating and powering up the TIMED spacecraft through LV harnessing.

Once the Jason and TIMED spacecraft were installed on the Delta-II LV and their respective umbilical interfaces connected, the TIMED spacecraft flight batteries were continuously "trickle-charged" through launch from a battery-charge power supply located in the Blockhouse Control Unit. During the trickle-charge process, air-conditioning flowed through a separate direct air-conditioning duct within the Delta-II LV to maintain battery cooling until just prior to launch.

As part of the pad electrical checkout, the TIMED spacecraft was subjected to a "pad-abbreviated" functional test to verify that its subsystems and instruments had survived the activities associated with its transport to the pad and the mating operations at the pad. A complete TIMED spacecraft electrical functional test at the pad was not performed because TIMED was enclosed in the DPAF, which prohibited the installation of stimulators and hat couplers. The functional test was tailored to accommodate all launch pad testing constraints. No TIMED spacecraft RF testing or instrument high-voltage power turn-on was performed while the spacecraft was on the LV. Commanding and telemetry monitoring of TIMED during all pad activities was done via hard-line interfaces.

Two special tests were performed in support of the Boeing Delta-II LV preparations for launch. The first was the Delta-II LV flight program verification test which required the TIMED spacecraft to be powered in the launch configuration while the Delta-II LV simulated its countdown and flight boost phase operations. The second test was the Delta-II power-on stray voltage test. This test required the TIMED spacecraft to be powered on with all subsystems that were to be turned on from the Delta-II LV ordnance installation through the flight boost phase.

FINAL COUNTDOWN TO LAUNCH

A TIMED spacecraft countdown test was performed in conjunction with the Boeing Delta-II flight program verification test. TIMED subsystem and instrument personnel participated in this launch rehearsal before Boeing personnel performed their Delta-II verification test. The launch rehearsal activities emulated an actual countdown, with activities beginning 11 h before the simulated launch time. Voice communications were established, spacecraft subsystems were set up in their launch configurations, spacecraft power was switched from the electrical GSE Blockhouse Control Unit to internal spacecraft battery power, and go/no-go checklist confirmations were performed.

Five days prior to the TIMED spacecraft launch, the two-piece fairing (Fig. 5) was installed and G&C parameter blocks were loaded into the spacecraft's two Attitude Interface Units and two Attitude Flight Computers. These blocks contained numerical constraints used by the G&C flight software and included alignment matrices for the attitude sensors and actuators, torque rod control set, processor control, and controller gains. Most of the parameters consisted of constants used in controlling algorithms to point the spacecraft and determine the attitude. After the parameters were loaded, they were dumped and then verified against expected values that were matched to the load script values. After verification, the loaded parameters were copied to nonvolatile memory in the respective G&C processors.

Along with the G&C parameter block loads, the two flight GPS Navigation System (GNS) processors were loaded with updated GNS "almanacs" (i.e., long-term, low-accuracy representations of the GPS ephemeris used for initial acquisition of the GPS signal). The almanac ephemeris parameters were then used to calculate the Doppler and visibility of each GPS satellite in the constellation. The receiver's current rough estimates of time and position appeared as parameters in the calculation. This information was used to define how to correlate with the incoming GPS signals, i.e., which pseudo-random noise codes and Doppler shifts should be used.

Four days before launch, Boeing personnel conducted a Jason/TIMED Flight Readiness Review to support Boeing Delta-II LV second-stage propellant loading and to obtain concurrence to proceed with LV second-stage fuel loading.

Three days prior to launch, NASA personnel conducted a mission management rehearsal at the Vandenberg Mission Directors Center. The objective here was to give launch managers an opportunity to practice their role during a simulated countdown and to familiarize themselves with the countdown procedure, communications network, and operation of their console. It also gave the team a chance to practice readiness polling which would occur before significant milestones in the launch countdown.

Two days prior to the Jason/TIMED launch, NASA personnel conducted a Launch Readiness Review at Vandenberg. This was the final management review of all systems supporting launch prior to entering the countdown. All actions assigned in previous readiness reviews have to be closed at this review; if not, a Delta Launch Readiness Review is typically scheduled prior to entering the countdown. Authority is given to the launch team by the launch manager to enter the countdown as scheduled if all elements of the team report "go" when polled by the launch manager at the close of the meeting.

The MST rollback from the fixed umbilical tower occurred the night before launch. An APL presence was requested by Boeing to ensure that the payload environment and purge were maintained properly during these operations and to react quickly should the need arise. Figure 6 depicts the LV as seen from the MST during rollback.

Approximately 14 h from launch, a favorable weather briefing allowed the countdown to proceed. The procedure included a sequential list of activities to be performed during the launch countdown and steps to be performed in the event of unscheduled countdown interruptions and recycle operations. These countdown activities began 11 h before the scheduled liftoff from SLC-2W. Voice communications were established among engineers at APL, VAFB, and the ground support networks prior to spacecraft turn-on. The Mission Operations Center at APL controlled the computerized countdown procedure.

Figure 6. The night before launch. The Delta-II launch vehicle for the TIMED mission as viewed from the Mobile Service Tower after tower rollback, approximately 8 h prior to launch.

The TIMED spacecraft was initially powered up using ground power supplied in the Blockhouse Control Unit at the Vandenberg electrical equipment facility. Engineers at APL spent the next 5 h performing spacecraft "aliveness" tests and final flight configurations of their respective subsystems and instruments to ensure readiness for launch. The configurations were completed 4 h before expected liftoff. During this entire period, the flight batteries were constantly cooled, trickle-charged, and boost-charged, as required, to maintain maximum storage energy capacity.

At approximately 7 min before launch, the TIMED spacecraft power was switched from Blockhouse Control Unit power supplies to the spacecraft's internal flight batteries. At 4 min to launch, all TIMED subsystem and instrument personnel were polled one last time to verify that their respective areas met the established go/no-go criteria.

The Jason/TIMED spacecraft payload was successfully launched on 7 December 2001 at 7:07:35 PST from the VAFB SLC-2W facility.

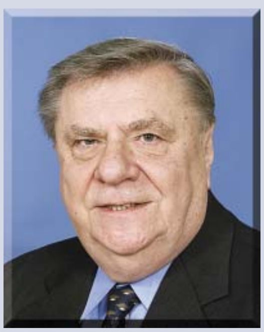
CONCLUSION

Of significant importance to the TIMED program was that the majority of the field tests and the TIMED spacecraft launch operations were entirely controlled from the TIMED Mission Operations Center at APL. The advantage of this ground system capability eliminated the need for subsystem and instrument personnel to travel out to the field site (VAFB) for extended periods of time to support testing, thereby eliminating costly travel time and per-diem expenses. Another significant advantage of this ground system configuration was that the Mission Operations Center was immediately ready to support post-launch operations since the ground hardware and software were common in supporting both field and flight operations.

ACKNOWLEDGMENTS: The authors wish to acknowledge the contributions of all Spaceport Systems International (SSI) payload processing personnel, and in particular Melony Schuyler, for their excellent support prior to and after arrival of the TIMED spacecraft at Vandenberg. Also, the Boeing Delta-II team personnel, and in particular Bill Sobczak and Kevin Shrewsbury, are to be commended for keeping things on schedule and assisting the TIMED team throughout launch vehicle integration. We are completely indebted to John Demko from NASA/Vandenberg, especially for his support starting several years prior to launch and continuing well after.

THE AUTHORS

STEVEN R. VERNON is a Senior Professional Staff engineer in the APL Space Department. He graduated from The Johns Hopkins University in 1992 with a bachelor's degree in mechanical engineering. He has led the development efforts of numerous APL mechanical systems including sensors, deployment devices, and structures for space applications. Previous lead assignments have included the MSX instrument section, Cassini INCA sensor, and TIMED spacecraft mechanical system. Mr. Vernon's current assignments are the New Horizons (Pluto) Project mechanical engineer and launch vehicle interface engineer for the mission. He is an American Institute of Aeronautics and Astronautics senior member and consultant via the AIAA to the National Reconnaissance Office for launch vehicle and payload integration. His e-mail address is steven.vernon@jhuapl.edu.



STANLEY F. KOZUCH received a B.S. degree in electrical engineering from the Pennsylvania State University in 1963. Before joining APL in 1994, he supported integration and testing of such NASA spacecraft programs as LANDSAT and the Space Telescope. Mr. Kozuch is a Senior Professional Staff engineer in the Space Department's Integration and Operations Group and supervisor of the Space Integration and Test Section. While at APL, he has served as an integration and test engineer on the Delta series, MSX, and NEAR spacecraft. Mr. Kozuch also served as the lead integration and test engineer on the TIMED program and is presently acting in that same capacity on the New Horizons Program. His e-mail address is stanley.kozuch@jhuapl.edu.