

# TIMED

**Thermosphere · Ionosphere · Mesosphere ·  
Energetics and Dynamics**



*A NASA Mission to Explore One of the Last Frontiers  
in Earth's Atmosphere*

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# **T**hermosphere **I**onosphere **M**esosphere **E**nergetics and **D**ynamics

## **A Guide to the Mission, the Spacecraft and the Mission Team**

*The TIMED mission is sponsored by the National Aeronautics and Space Administration's (NASA) Science Mission Directorate, Washington, D.C., and is managed by the NASA Goddard Space Flight Center's Solar Terrestrial Probes Program Office, Greenbelt, Md. The Johns Hopkins University Applied Physics Laboratory, in Laurel, Md., designed, built and is operating the spacecraft and leading the project's science effort during the mission.*

**TIMED Mission Web Site — [www.timed.jhuapl.edu](http://www.timed.jhuapl.edu)**

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# Introduction

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For centuries, scientists have realized that Earth's natural environment is greatly impacted by the abundance of solar energy striking the Earth from a constantly changing sun. Over the last few years, they have begun to realize that human activities are also playing a role in changing our environment.

By studying portions of Earth's atmosphere, scientists believe global change is occurring, primarily due to variations in the sun's cycle and from the release of gases, such as methane and carbon dioxide, into our atmosphere from human-induced activities. Despite signs of global change, scientists haven't had a benchmark against which future variations in Earth's upper atmosphere can be globally compared, analyzed or predicted because there are still portions of this solar-terrestrial chain, including regions within Earth's atmosphere, that are poorly understood.

The TIMED (Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics) mission, launched on December 7, 2001, is studying the influences of the sun and humans on the least explored and understood region of Earth's atmosphere – the Mesosphere and Lower Thermosphere/Ionosphere (MLTI). The MLTI region is a gateway between Earth's environment and space, where the sun's energy is first deposited into Earth's environment. TIMED is focusing on a portion of this atmospheric region located approximately 40-110 miles (60-180 kilometers) above the surface.

In a society increasingly dependent upon satellite technology and communications, it is vital to understand the variability within this critical region of our atmosphere so scientists can predict its effects on communications, satellite tracking, spacecraft lifetimes, degradation of spacecraft materials and on the reentry of piloted vehicles. TIMED's study of space weather

will help scientists gain a better understanding of the dynamics of this gateway region.

A comprehensive global study of the MLTI region has never before been accomplished. Ground-based instruments can only observe a small portion of the upper atmosphere located over an observation site. This region is too high for balloons to reach. Sounding rockets (rockets that fly into the upper atmosphere for just a few minutes before falling back down) can only provide a brief snapshot of the MLTI region's activity near the rocket.

Other spacecraft have studied portions of the MLTI region, but TIMED is the first mission to obtain a global picture of it, which scientists need to better understand our upper atmosphere.

The TIMED mission is establishing a baseline against which future studies of changes within this region can be compared and analyzed.

The TIMED spacecraft is observing this relatively unexplored frontier from its 388-mile (625-kilometer) circular orbit around the Earth. Employing advances in remote-sensing technology, the spacecraft's instrument suite will work with a worldwide network of ground-based observation sites to obtain an unprecedented set of comprehensive global measurements of the region's temperature, pressure, wind and chemical composition, along with its energy inputs and outputs.

The TIMED spacecraft is the first mission in NASA's Solar Terrestrial Probes Program, and is part of the Heliophysics Great Observatory – a collection of NASA's sun-Earth-focused missions.

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***TIMED will study the least explored and understood region of Earth's atmosphere.***

# Mission

## Launch and Orbit

The TIMED spacecraft was boosted into its 388-mile (625-kilometer) circular orbit around the Earth (inclined 74.1 degrees from the equator) aboard a Delta II launch vehicle from the Western Range at Vandenberg Air Force Base, Calif., on Dec. 7, 2001.

The Delta II 7920-10 is a medium-lift, two-stage, liquid-propellant rocket built by The Boeing Company. The 1,294-pound (587-kilogram) TIMED spacecraft was launched aboard a Delta II with the Jason-1 spacecraft. The second of the two spacecraft jettisoned from the rocket, TIMED reached its orbit 2 hours, 5 minutes after launch.

## Mission Operations

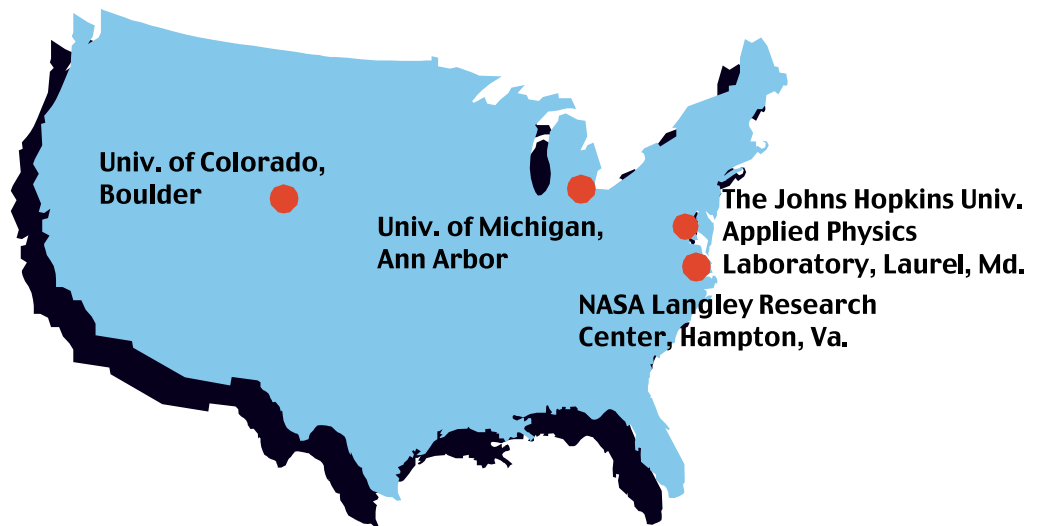
The TIMED mission utilizes an innovative mission operations system consisting of a combination of the spacecraft, instruments, ground system and the supporting science and engineering teams. This system, combined with TIMED's interdisciplinary approach, lowers mission costs while enhancing science return.

TIMED's interdisciplinary approach brings together worldwide experts over a wide range of disciplines to carry out the mission. Each of the four instrument Principal Investigators, or PIs, has direct control of their instruments and experiments via Payload Operations Centers situated at four locations across the country.

This interdisciplinary approach is possible, in part, due to the spacecraft's autonomous design. The spacecraft can carry out many functions on its own, including sensing its position,

orientation and orbit, and react accordingly. Since a more autonomous spacecraft is easier to operate, the spacecraft and its instruments can be controlled from separate locations.

## TIMED Payload Operations Centers



TIMED's Payload Operations Centers are located at: The Johns Hopkins University Applied Physics Laboratory (APL), Laurel, Md. (Global Ultraviolet Imager); NASA Langley Research Center, Hampton, Va. (Sounding of the Atmosphere using Broadband Emission Radiometry); the University of Colorado in Boulder (Solar Extreme Ultraviolet Experiment); and at the University of Michigan in Ann Arbor (TIMED Doppler Interferometer).

This approach is quite different from traditional spacecraft operations. Typically, instrument PIs submit requests for measurements they want to make, which must be balanced with other spacecraft activities including daily maintenance operations and positioning of the spacecraft. But TIMED's design helps avoid potential conflicts between PI requirements and other spacecraft operations. TIMED's instruments won't interfere with one another nor will daily spacecraft maintenance operations interfere with data collection activities.

TIMED's interdisciplinary approach enables a low-cost data collection process with a fast turnaround of data products. The PI institutions send commands daily to the TIMED Mission Operations Center located at APL, where instructions for the instruments and the spacecraft are combined and uplinked to the spacecraft once a day.

## Data Management

### Spacecraft Instruments

Similar to its mission operations approach, TIMED employs a unique distributed data management system, where spacecraft instrument teams individually process data, generating products for distribution, from their respective Payload Operations Centers. This approach is unique compared to traditional space science missions and to most remote-sensing programs.

Traditionally, space science missions maintain one central data center, which has full control of the data – from downloading it from the spacecraft to processing, archiving and distributing data products. This approach typically requires larger staffs working around-the-clock shifts.

But within TIMED's distributed data management system, the Mission Data Center (part of the Mission Operations Center) is responsible for downlinking raw data from the satellite and then sending it, via direct links, to processors at each of the remote Payload Operations Centers. These centers process their instrument's raw data and turn it into data products that can be used by the public, and scientific and educational communities. Due to TIMED's more efficient data management system, the Mission Data Center and remote data processing sites operate with one shift per day.

Once a remote site completes a data product, a notice is sent to the Mission Data Center indicating that the product is available for distribution. The Mission Data Center maintains a central catalog of TIMED data products, which incorporates query capabilities and a Web-based interface so the public, science teams

and educational communities can quickly and easily retrieve products from the remote sites via TIMED's Web site ([www.timed.jhuapl.edu](http://www.timed.jhuapl.edu)).

In addition to saving program dollars by reducing staff sizes and the number of daily shifts, TIMED's distributed data management approach enables rapid turnaround of data products available for distribution. Total turnaround time – from the spacecraft acquiring data to development of a final product and its distribution online – is within 54 hours. Traditionally, a mission could take up to several days or weeks to get similar products distributed.

### Collaborative Investigators

In addition to TIMED's instrument Principal Investigators and interdisciplinary scientists, the TIMED team includes a set of collaborative investigators jointly funded by TIMED and the National Science Foundation's Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) program.

Data products created by the collaborative investigators are also reflected in TIMED's central catalog, which can be queried from TIMED's Web site. Collaborative investigators have the option of archiving their own data and maintaining a Web site (accessible via a link from TIMED's Web site) or their data can be managed by CEDAR. Like the remote Payload Operations Centers, CEDAR sends catalog information to the Mission Data Center regarding any collaborative investigators' data products they manage.

### Costs

The initial cost for the 2-year mission – for the TIMED spacecraft, its instruments and the launch vehicle – was approximately \$193 million. An additional \$42 million was set aside for mission operations, ground-based operations and data analysis during the first two years.

In 2003, the mission was extended by NASA for three additional years of operations and data analysis, followed by an additional year of data analysis in 2007. In 2006, TIMED was extended again with operations and data analyses through 2010.

# TIMED Mission Operations Concept

## TIMED Spacecraft

- Receives and processes commands for each instrument
- Instruments perform experiments
- Stores instrument data for later transmission to Mission Data Center

- Receives and processes spacecraft commands
- Performs spacecraft operations
- Stores spacecraft telemetry for later transmission to Mission Data Center

## Mission Operations Center

Laurel, Md.

- Receives raw instrument and spacecraft data from spacecraft
- Sends raw instrument data to Mission Data Center for later retrieval by Payload Operations Centers
- Assesses spacecraft health

- Develops operations plan
- Develops spacecraft commands
- Receives instrument commands directly from each Payload Operations Center
- Uplinks instrument and spacecraft commands to spacecraft

## Payload Operations Centers

• Ann Arbor, Mich. • Boulder, Colo. • Hampton, Va. • Laurel, Md.

- Retrieve raw instrument data from Mission Data Center
- Assess experiment results

- Plan experiments
- Develop instrument commands
- Send instrument commands to Mission Operations Center for uplink



# Science Objectives

The science objective of the TIMED mission is to understand the MLTI (Mesosphere and Lower Thermosphere/Ionosphere) region's basic pressure, temperature and wind that result from the transfer of energy into and out of this region.

Located approximately 40-110 miles (60-180 kilometers) above the Earth's surface, the MLTI region is sensitive to external influences from the sun above and atmospheric layers below it. Its chemical and thermal balance can change rapidly due to naturally-occurring and/or human-induced changes to the energy contained within this region.

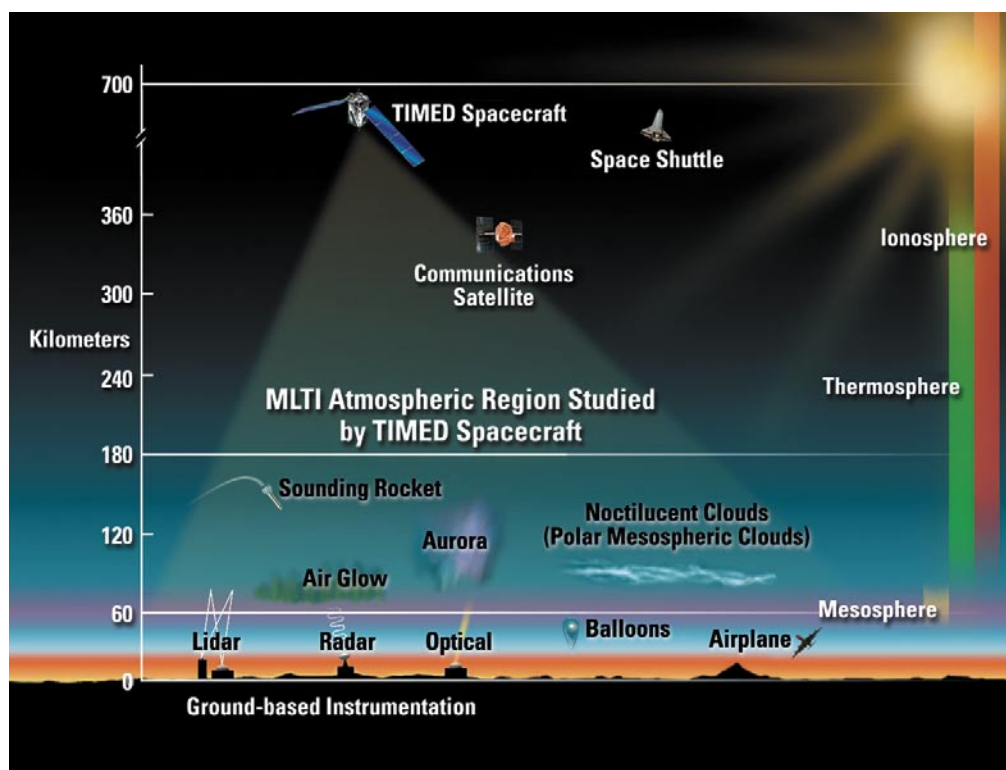
Human-induced changes in the lower atmosphere can have a significant impact on Earth's upper atmosphere. When released, gases, such as carbon dioxide (from burning fossil fuel) and

chlorofluorocarbons (from Freon, cleaning solvents and/or aerosol propellants), are transported to high altitudes within the upper atmosphere where they ultimately affect its chemistry and composition.

Particles and energy emitted from the sun also alter Earth's upper atmosphere when deposited into the MLTI region. These components change this region's energy input and balance, affecting its chemistry and temperature. Since Earth's upper atmospheric regions are connected to the lower portion of the atmosphere where we live, scientists need TIMED to help them better understand the connections between these atmospheric regions.

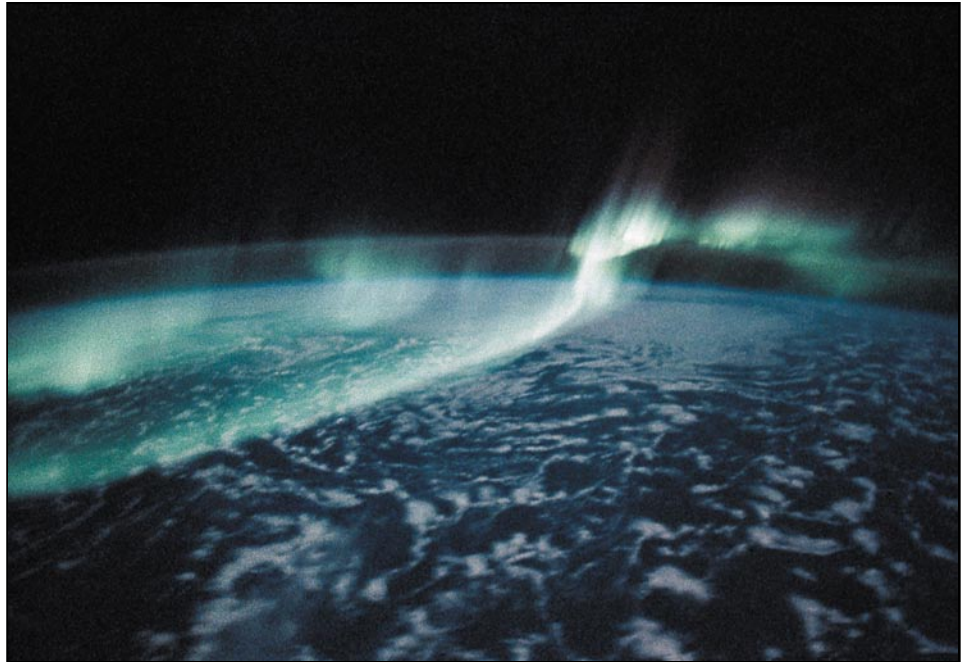
The MLTI region is an area of transition where many important processes change dramatically.

It's where energetic solar radiation is absorbed, energy input from the aurora maximizes, intense electrical currents flow and upward propagating waves and tides break. With all of these volatile processes taking place within the MLTI region, some scientists believe it is acting as an early indicator of global change. One example, some scientists say, is the increasing occurrence of noctilucent clouds at latitudes closer to the equator.



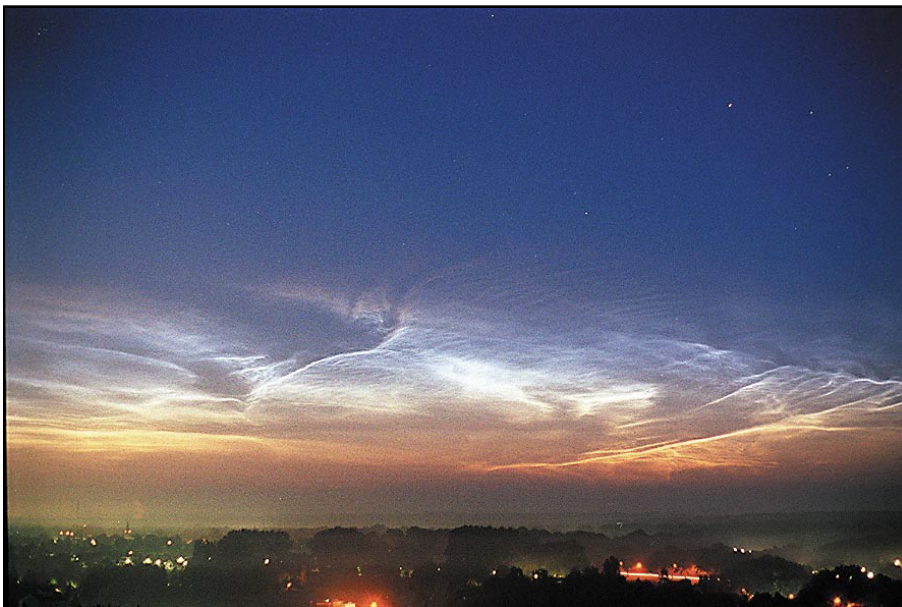
*The TIMED spacecraft, located 388 miles (625 kilometers) above the Earth's surface, studies the MLTI atmospheric region using advances in remote sensing. Ground-based systems, balloons and sounding rockets can only study small portions of this region. But together, TIMED and a worldwide network of ground-based observation sites are obtaining an unprecedented set of comprehensive global measurements of this region.*

Noctilucent clouds are thin, luminous clouds located at extremely high altitudes (50 miles, or 80 kilometers, above the surface) and are visible only against a twilight sky. They usually form at latitudes closer to the poles (50-60 degrees in both hemispheres), but are now beginning to appear in locations closer to the equator (as low as 40 degrees north latitude), which scientists say is unprecedented. Scientists believe this implies that the upper atmospheric regions, which TIMED is studying, are getting colder. TIMED is providing significant information that will help scientists find out why such a



*Auroras occur within the MLTI region of Earth's atmosphere, which TIMED is studying.*

phenomena is occurring at lower latitudes and what effects it might have on lower altitudes where we live.



*Noctilucent clouds, as the name implies, are clouds that shine at night. They are found at much higher altitudes (approximately 50 miles or 80 kilometers) than most clouds (9 miles or 15 kilometers). Photo courtesy of Oscar van der Velde.*

TIMED is employing advances in remote-sensing technology to globally observe this relatively unexplored frontier from space, making direct measurements of the MLTI region's various energy inputs and outputs and acquiring measurements of its wind, density and temperature profiles. These measurements are providing critical empirical data to help scientists better understand this region's energy balance. TIMED is establishing a baseline for future investigations of the MLTI region, providing a basis for early warning of global change.

# Spacecraft

TIMED is the first spacecraft to study the MLTI region on a global basis and the first mission to provide a baseline for future investigations of this region. It was designed for a primary mission, but operations have been extended by NASA until 2010. TIMED is studying the MLTI region, using advances in remote-sensing technology, from its orbit located approximately 388 miles (625 kilometers) above the Earth's surface.

The key criterion driving the design of the TIMED spacecraft was to lower mission operations costs while enhancing science return by enabling TIMED's instruments to operate at their full capacity around-the-clock. Several technological innovations are incorporated into TIMED's design providing a more efficient and inexpensive spacecraft that's easier to use. Several of these technological developments can enhance future science and commercial endeavors.

## Increased Autonomy

The TIMED spacecraft is designed to be highly autonomous – able to carry out certain functions on its own – which results in more efficient spacecraft operations. It has a number of sensors to monitor many variables including its position, the amount of sunlight falling on its arrays, its temperature and power, and react accordingly. Just as an automobile monitors its oil supply and engine temperature, and switches on a light to alert the driver when there's a problem, the TIMED spacecraft is smart enough to monitor many of its own functions, take some corrective actions and alert Mission Operations personnel when a problem occurs. TIMED's ability to make the best use of its onboard resources makes the spacecraft easier and less expensive to operate.

## Onboard Orbit Determination

One key difference between TIMED and most conventional spacecraft is TIMED's ability to determine its own orbit using a Global Position-

ing System (GPS) receiver located onboard the spacecraft.

Most spacecraft detect their orbits from ground-based crews, who uplink position information to the spacecraft using time-based predictions regarding the spacecraft's position and its data collection opportunities.

To more accurately determine and relay the spacecraft's position to ground-based crews, TIMED automatically feeds its GPS data into an onboard model containing a special filter (Kalman filter), which averages out errors that are sometimes experienced by GPS systems used onboard spacecraft. This is the first time such a filter has been incorporated into a GPS system for onboard orbit determination.

The spacecraft's ability to determine its orbit helps reduce mission life-cycle costs. The conventional time-based method of operations requires many people working from multiple ground stations worldwide to gather the information downlinked from the spacecraft, which is then routed to an operations center. TIMED, however, requires only one ground station – located at TIMED's Mission Operations Center at APL – which reduces the personnel and facility costs.

## Event-based Commanding

For the first time, a space mission is using GPS to drive its mission operations – a cornerstone of the low-cost operations approach incorporated into the TIMED mission.

Because the TIMED spacecraft has a GPS receiver onboard, scientists can use a mode of operations known as event-based commanding, which enables a more simplified, reliable and cost-effective approach. With GPS onboard, the spacecraft knows its position at all times and can trigger events based on its position. For example, the spacecraft can be instructed to turn on its transmitter when it flies over the ground station; or to change the mode of instrument number one to mode B when it flies over the North Pole.

The traditional time-tagged method used by most spacecraft, however, tries to predict what time certain things will happen and issues spacecraft commands based on a timeline developed around those expectations.

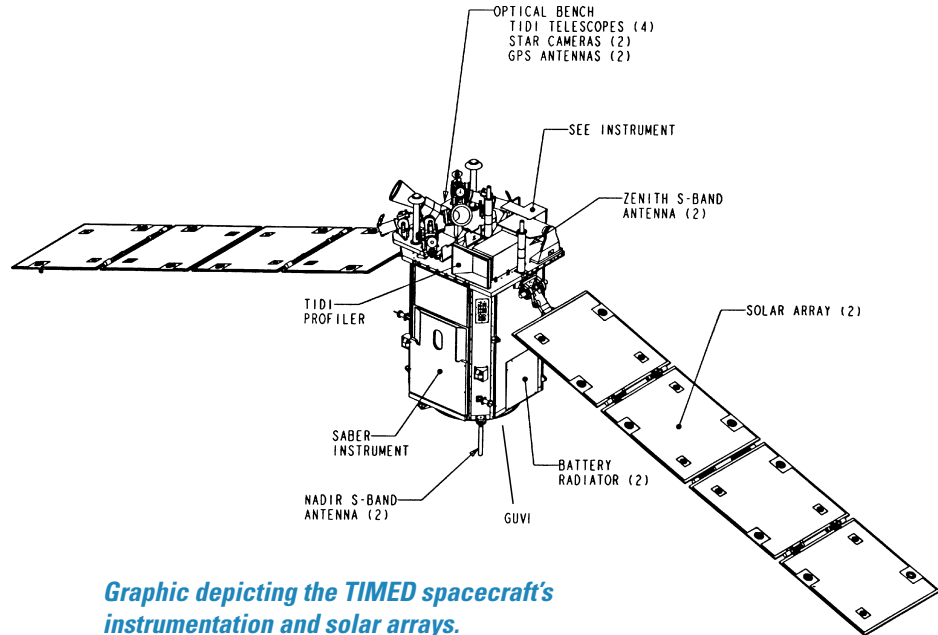
For example, if you give someone directions to the nearest convenience store based on a timeline rather than on landmarks, you would give them instructions like: drive north on state Route 12 for 40 seconds, turn right in 30 seconds, make a left turn in 10 seconds, and then turn right into the parking lot in another 5.5 seconds. Just as several drivers could make errors finding the convenience store using this approach, so too, can missions using the time-based commanding methods of operations.

Using the traditional time-tagged operational method, commands have to be uploaded for each orbit throughout the day, which requires around-the-clock shifts in the Mission Operations Center. But with event-based commanding, a set of commands used for each orbit is uploaded only once and used over and over again. This helps reduce overall mission operations costs by reducing the number of shifts needed to upload commands to the spacecraft on a daily basis.

With event-based commanding, TIMED is helping pave a new way of operating future scientific and commercial spacecraft.

## Integrated Electronics Module (IEM)

The TIMED program is using an innovative technology called the Integrated Electronics Module (IEM), which enables smaller, lighter



*Graphic depicting the TIMED spacecraft's instrumentation and solar arrays.*

and more compact spacecraft to be launched on smaller launch vehicles.

The complex circuitry of most conventional spacecraft is housed on multiple circuit cards within multiple boxes. Typically, one box is used for each separate function that the spacecraft has to perform electronically.

The TIMED program has reduced each box to one or two cards and all cards have been placed within one box. TIMED's Integrated Electronics Module does the job of 10-12 separate boxes used on conventional missions. This key technology will enhance future space missions by helping create smaller, lighter and more compact spacecraft.

## GPS Navigation System

One of the key subsystems contained within the IEM is the APL-developed GPS Navigation System (GNS), which autonomously generates, in real time, highly accurate estimates of TIMED's position, velocity and time. GNS will permit the realization of TIMED's event-based commanding mission operations concept, which was selected to reduce program life-cycle costs.

TIMED's GNS provides critical system functions for the mission, including onboard autonomous navigation, time recovery, position-based event detection, autonomous onboard orbit propagation and future event predictions. This newly developed system can be optimally applied for other low-earth- and/or medium-earth-orbiting missions.

## Peak Power Tracker

As sunlight falls on a spacecraft's solar arrays, the arrays convert solar energy into electricity, which powers the spacecraft. Gallium arsenide solar panels alone, like those used on TIMED, are approximately 18-20 percent efficient in converting energy into electricity.

TIMED's Peak Power Tracker allows more efficient use of a spacecraft's solar arrays by loading them in the most efficient manner so peak power will be flowing from the arrays into the spacecraft. This means a spacecraft can fly with the smallest panels possible for the amount of power required to operate the spacecraft. This technique can be used on other missions to reduce overall spacecraft weight and provide more efficient solar array power utilization.

## Instruments

TIMED's science payload consists of a tightly focused set of four instruments – the minimum set necessary to achieve the highest priority TIMED science.

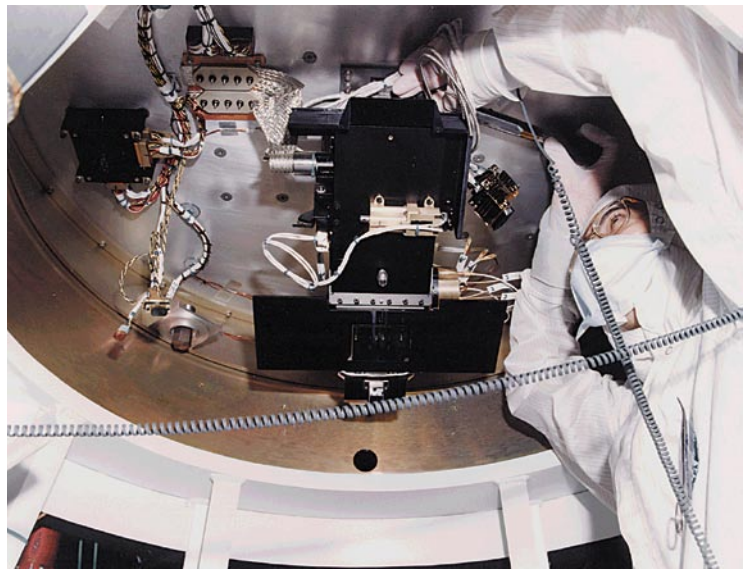
The science payload is allowing scientists to look, for the first time in detail, at composition changes in the upper atmosphere; acquire unique measurements of atmospheric cooling as gases radiate energy back into space; measure the primary energy that's deposited into the MLTI region; and measure the speed and direction of wind in this region.

TIMED's four instruments are the:

- Global Ultraviolet Imager (GUVI);
- Sounding of the Atmosphere using Broadband Emission Radiometry (SABER);
- Solar Extreme Ultraviolet Experiment (SEE);
- TIMED Doppler Interferometer (TIDI).

### Global Ultraviolet Imager (GUVI)

The GUVI instrument is designed to observe the glow of the Earth's upper atmosphere in ultraviolet light so scientists can better understand the properties of this atmospheric region. The upper atmosphere is known to respond to both external influences, such as solar variations, and internal motions originating in the atmosphere near the Earth's surface.



*The GUVI instrument is being integrated with the TIMED spacecraft.*

GUVI is used to determine energy inputs from the sun into a region of the upper atmosphere where ultraviolet light ionizes the atoms and molecules. This area of Earth's atmosphere is home to the aurora and electrical currents that heat the upper atmosphere during magnetic storms. It's where radio waves are reflected

back to Earth making long-distance radio communication possible.

GUVI, a spatial-scanning far-ultraviolet spectrograph, will globally measure the composition and temperature profiles of the MLTI region, as well as its auroral energy inputs. GUVI is looking at sources of far-ultraviolet light originating in the Earth's upper atmosphere, such as the aurora, and will count individual particles of light, or photons, emitted by the atmosphere. GUVI is the first instrument sensitive enough to look, in detail, at composition changes in the upper atmosphere.

GUVI is globally scanning the MLTI region looking for aurora and other sources of ultraviolet light every 1.5 hours – the time it takes to complete an orbit cycle. During each orbit cycle, GUVI is acquiring day, night and auroral observations. Its very sophisticated, sensitive optical devices will enable scientists to see extremely minute amounts of light from space, for the first time, and create images of the upper atmosphere's composition changes.

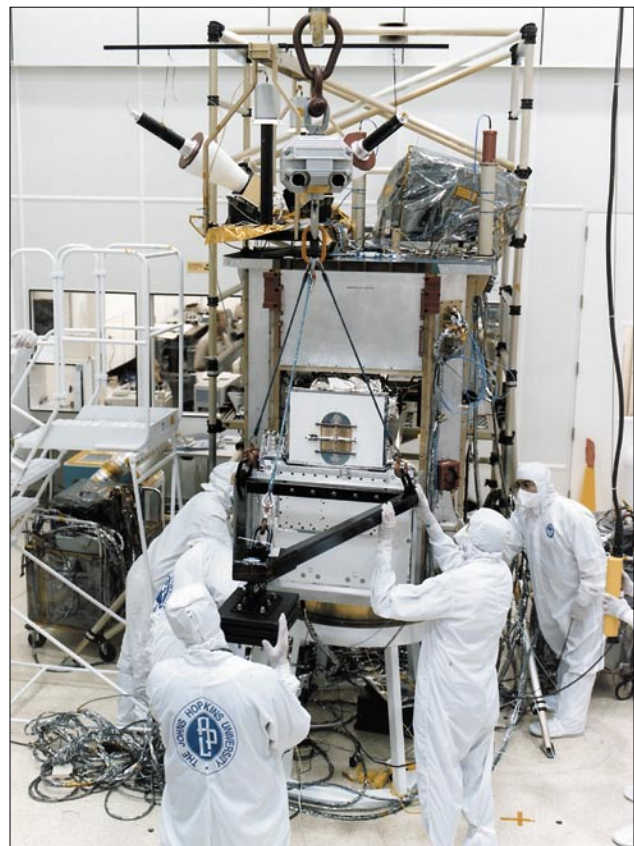
### **Sounding of the Atmosphere using Broadband Emission Radiometry (SABER)**

SABER is an instrument, known as a multi-channel infrared radiometer, designed to measure heat emitted by the atmosphere over a broad altitude and spectral range.

SABER's primary science objectives are to explore the MLTI region to determine its energy balance; atmospheric structure (how temperature, density and pressure vary with altitude); chemistry (variations of key gases in the oxygen and hydrogen families); and the movement of air, or dynamics, between atmospheric regions (lower to higher altitudes, pole to equator, and east-west direction). It is also measuring global temperature profiles and sources of atmospheric cooling, such as the "air glow," which occurs when energy is radiated back into space.

The technique that SABER is using on TIMED to sound, or make measurements in, the atmosphere has never before been used to study the MLTI region in such detail. Once every 58 seconds, SABER scans up and down the Earth's horizon collecting data over an altitude range from approximately 112 miles (180 kilometers) down to the Earth's surface. It measures the vertical distributions of elemental constituents, such as ozone, water vapor, carbon dioxide, and nitrogen and hydrogen gases, as well as temperature.

Over the course of one orbit, SABER observes polar regions in one hemisphere to high latitudes in the opposite hemisphere. Over the course of a day, SABER makes measurements covering 15 longitude bands. During the course of the mission, the instrument will assemble a global picture of how the MLTI region is chang-



*The SABER instrument is being placed onto the TIMED spacecraft.*

ing with latitude, longitude, altitude and time.

SABER's observations are opening up a new area in the field of radiation balance. It is acquiring measurements in a range of the atmosphere where the radiation and chemistry are much different than in the lower atmospheric regions due to molecules being more sparse and less active.

SABER is the first instrument to measure the global-scale distribution of carbon dioxide concentrations within the MLTI region. Carbon dioxide, a greenhouse gas that's transported to Earth's upper atmosphere from the ground level where it's produced, results from natural emissions, burning fossil fuel needed for heating, electric power generation and a host of other industrial processes. SABER is measuring nitric oxide emissions, which scientists now believe is one of the primary gases responsible for the cooling of the upper atmospheric regions that TIMED is studying.

### **Solar Extreme Ultraviolet Experiment (SEE)**

SEE is comprised of a spectrometer and a suite of photometers designed to measure solar ultraviolet radiation – the primary energy that's deposited into the MLTI atmospheric region. Examples of solar ultraviolet radiation that SEE is focusing on are solar soft X-rays (which contain less energy than a traditional X-ray you would get in a doctor's office), extreme-ultraviolet and far-ultraviolet radiation.

The primary objectives of the SEE instrument are to study the solar ultraviolet irradiance – how much it varies and how it affects the atmosphere; how much it heats the atmosphere and changes its composition; and to understand



*A member of the SEE team prepares the instrument for integration with the spacecraft.*

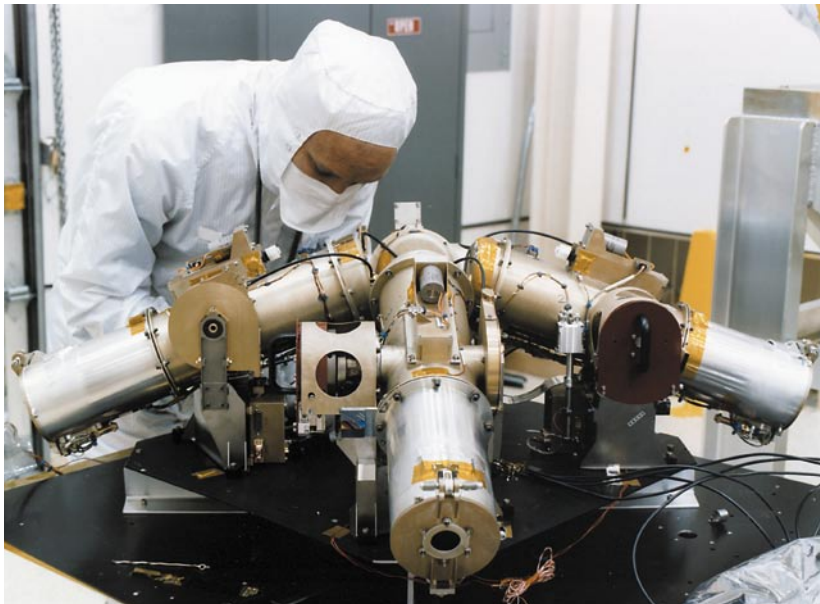
and establish an index of the solar variabilities so scientists can understand the solar ultraviolet changes occurring in this region, even after the TIMED mission is over.

SEE observes the sun about three minutes per orbit while the sun is in full view. When possible, it will view the sunset through the atmosphere, which will help scientists determine the atmosphere's density. Data collected from SEE's observations of the sun shows where the solar energy, or radiation, is coming from as a function of wavelength and how each wavelength varies with time.

A device known as a soft X-ray photometer was developed to provide SEE scientists with the most precise measurements of the spectral region containing soft X-rays – the least understood and most difficult part of the solar spectral region to measure. Developed initially for SEE, these X-ray photometers are now being developed for ground-based plasma experiments.

### **TIMED Doppler Interferometer (TIDI)**

TIDI is globally measuring the wind and temperature profiles of the MLTI region. It is determining, on a global basis, the speed and direc-



*TIDI's telescopes are prepared for placement onto the spacecraft.*

tion of wind in the atmosphere by measuring tiny changes in the color of light emitted from individual chemical constituents in the atmosphere, such as atomic oxygen, molecular oxygen, oxygen-hydrogen and sodium. Similar to how the change in pitch from a passing ambulance's siren helps determine its speed, scientists are using changes in color of light emitted by atmospheric particles to determine atmospheric wind speed and direction.

TIDI employs a spectrally-resolving optical element to determine the color, or wavelength, of light to a tremendously high degree of precision. Its high sensitivity and precise observations are accomplished by four telescopes looking simultaneously in perpendicular directions – two in front of the satellite at 45 degrees and two in the opposite direction at 135 degrees.

TIDI measures wind at a few meters per second, and like all of the instruments onboard the spacecraft, TIDI's continuous data collection enables it to make the best possible use of available light in the atmosphere.

## Collaborative Investigators

NASA and the National Science Foundation (NSF) jointly sponsored a program that enabled the TIMED science team to closely collaborate with other members of the scientific community studying the MLTI region. This program took advantage of the synergy between ground- and space-based instruments and of the scientific contributions made by data assimilation and modeling.

Providing ground-based data complementary to that provided by the TIMED satellite was one of the most significant contributions

made by the collaborative investigators' program. The participating ground stations played a key role in helping mission scientists clarify time and location ambiguity in data acquired by the satellite.

Many of the effects the spacecraft observe change with location and time. For example, if TIMED flies over a mountain range at 4 p.m. and records a change in wind, scientists will want to know if the change is due to the time of day (more air movement in daytime as the sun warms the earth; less at night when the ground is cooler) or the location (air travels up a mountain range rather than across flat land). The spacecraft needs a second point, such as the ground-based observations, to differentiate between time and location to help determine the cause for such a change in measurements.

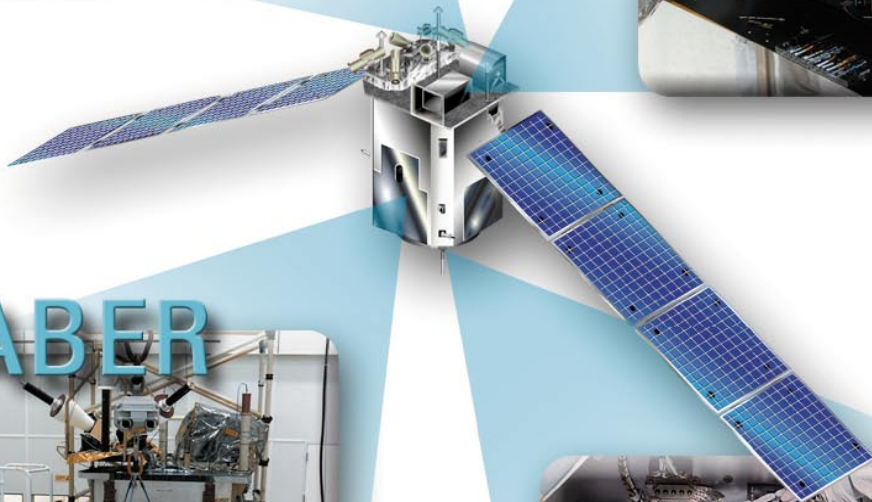
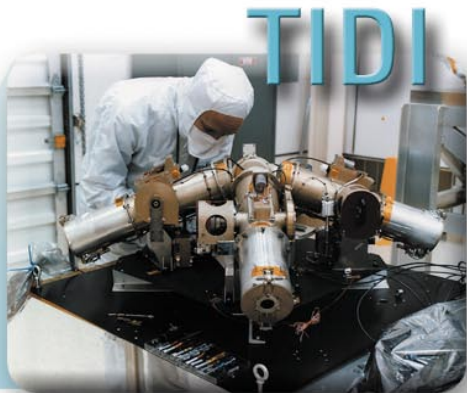
The ground-based participants observed some, but not all, of the same phenomena the satellite observed within the MLTI region, such as the aurora, wind and some temperature and composition changes. But the satellite is the only way to obtain global coverage of the MLTI



region since the number and location of ground stations are limited and each can only provide a single data point. Together, however, the spacecraft and ground stations collaborated to

unravel variations in the data regarding time and location to ensure the TIMED mission provides the most accurate data possible.

*Graphic showing the location of the four instruments onboard the TIMED spacecraft.*



# Mission Management and Science Team Leads

## NASA TIMED Mission Management

Solar Terrestrial Probes Program Executive.....	Charles Holmes (HQ)
Solar Terrestrial Probes Program Manager.....	Don Carson (GSFC)
Program Scientist.....	Craig Pollock (HQ)
Mission Director.....	Robert Sodyano (GSFC)
Project Scientist.....	Richard Goldberg (GSFC)

## APL TIMED Project Management

Space Department Head.....	Rob Strain
Programs Manager.....	Ted Mueller
Project Manager.....	David Grant
Project Scientist.....	Jeng-Hwa (Sam) Yee
Mission System Engineer.....	David Kusnierkiewicz
Ground System Lead Engineer.....	Elliot Rodberg
Data System Manager.....	Stu Nyland
Mission Operations Manager.....	William Knopf

## Science Working Group

### INSTRUMENT PRINCIPAL INVESTIGATORS

Global Ultraviolet Imager (GUVI).....	Andrew Christensen, The Aerospace Corporation
Sounding of the Atmosphere using Broadband Emission Radiometry (SABER).....	James Russell III, Hampton University
Solar Extreme Ultraviolet Experiment (SEE).....	Thomas Woods, University of Colorado
TIMED Doppler Interferometer (TIDI).....	Timothy Killeen, National Center for Atmospheric Research

### INTERDISCIPLINARY INVESTIGATORS

Jeffrey Forbes.....	University of Colorado
David Fritts.....	Colorado Research Associates/Northwest Research Associates
Janet Kozyra.....	University of Michigan
Hans Mayr.....	NASA Goddard Space Flight Center
Anne Smith.....	National Center for Atmospheric Research
Stanley Solomon.....	National Center for Atmospheric Research

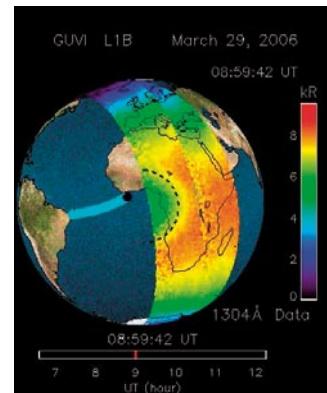
# Mission News

## APL-Led TIMED Mission Extended for Second Time

The TIMED community will have the opportunity to further its studies of Earth's atmosphere when the mission begins an extended campaign in October 2006 with operations and data analysis continuing through 2010.

## Two APL-built Instruments Observe Recent Total Solar Eclipse

APL space scientists got a first-hand look at what happens to Earth's atmosphere when the sun was abruptly "turned off" during the March 29, 2006, total solar eclipse.



## Atmospheric Study Shows Similarities in Sun's Effects on Earth and Mars

An APL TIMED scientist takes a closer look at how the sun's energy, which varies during its rotation, affects the atmosphere of Earth and Mars.

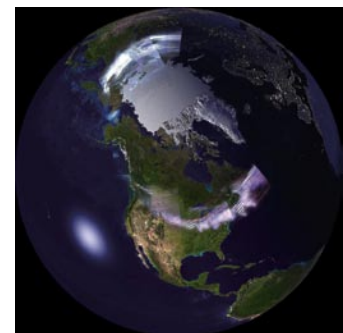
## TIMED Sees Unusual Light Show

Auroral lights are rarely seen in Maryland, but northern skies as far south as Alabama glowed brightly with red and green hues Nov. 4–8, 2004, when the sun shot at least five coronal mass ejections toward Earth.



## TIMED Weathers Record-setting Solar Flares in 2003 Spacecraft Healthy, Observes Earth's Response to Strong Solar Storms

The TIMED spacecraft weathered some of the strongest solar storms on record with all systems operating nominally, collecting data during one of the stormiest periods of solar activity on record.

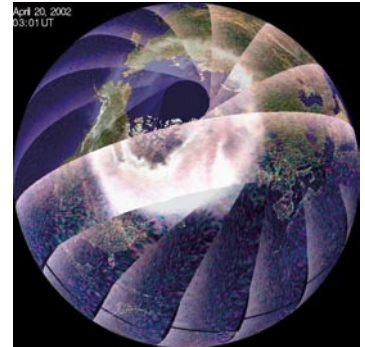


## TIMED Mission Extended for Future Studies

NASA extended the TIMED mission for another three years of operations and data analysis beginning in January 2004, followed by an additional year of data analysis in 2007 to be conducted after orbital operations are completed.

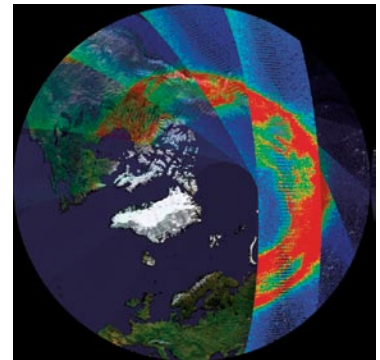
## TIMED Celebrates 1-Year Launch Anniversary

On Dec. 7, 2002, at the American Geophysical Union Conference, TIMED scientists celebrated the mission's 1-year launch anniversary by presenting a variety of scientific results, which included data depicting Earth's response to this year's major solar storms. TIMED data showcased was part of the aeronomy community's first in-depth look at critical elements in the sun-Earth chain.



## TIMED Watches April 2002 Solar Storms

The TIMED spacecraft observed our atmosphere's response to a series of strong solar storms, providing the critical link between the physical processes connecting the Sun and Earth.



## TIMED Launch Successful

The TIMED spacecraft was launched on December 7, 2001 at 7:07 a.m. PST (10:07 EST) out of Vandenberg Air Force Base, Calif., aboard a Delta II launch vehicle with the Jason-1 spacecraft. The second of the two spacecraft jettisoned from the rocket, TIMED reached its orbit 2 hours, 5 minutes after launch and began its 2-year exploration of one of the last frontiers in Earth's upper atmosphere.



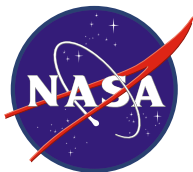
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# NASA's Heliophysics Division

The Heliophysics Division, within NASA's Science Mission Directorate, manages science flight programs that carry out the exploration of the sun, its effects on the planets within the solar system, and space environmental conditions and their evolution. Specifically, it seeks to understand the transfer of energy from the sun to the Earth, and the interaction of solar plasma and radiation with Earth, the other planets and the galaxy.

The Solar Terrestrial Probes (STP) Program in the Heliophysics Division focuses on specific scientific areas required to advance our fundamental understanding of the sun-solar system connection. STP missions will focus on studying the sun and Earth as an integrated system using a blend of in situ and remote-sensing observations, often from multiple platforms. The major goals of the STP program are aligned with the Heliophysics Division's science goals and objectives which include: (1) understanding the changing flow of energy and matter throughout the sun, heliosphere and planetary environments, and (2) exploring the fundamental physical processes of plasma systems in the solar system.

TIMED is the first mission within NASA's Solar Terrestrial Probes Program, and is part of the Heliophysics Great Observatory – a collection of NASA's sun-Earth-focused missions. APL also designed, built and operates the twin STEREO (Solar Terrestrial RElations Observatory) spacecraft, the third in the STP mission series, which were launched on Oct. 25, 2006 (<http://stereo.jhuapl.edu>.)



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