Coupled Ion Neutral Dynamic Investigation (CINDI)

Introduction

NASA is providing advanced instruments for an Air Force satellite that will study the elements that influence space weather near the Earth's equator in the ionosphere and thermosphere in outer space. NASA's Coupled Ion Neutral Dynamic Investigation (CINDI) instrument set will examine the winds in charged and neutral gases that can affect critical space assets such as the International Space Station and the Space Shuttle as they fly through them. In addition many of the communications and navigation signals that we depend upon, such as those from the Global Positioning System (GPS), must pass through this region and are affected by space weather events. The CINDI investigation will enhance the science objectives of the Communication/Navigation Outage Forecast System (C/NOFS) satellite undertaken by the Air Force Research Laboratory and the Space and Missile Command Test and Evaluation Directorate.

What is Space Weather?

Outer space, over 100 miles above the Earth's surface, is usually considered a vacuum but in fact has a density that is about one-one hundred billionth the density of air at the surface of Earth. This is the upper atmosphere, and it is made up of neutral and electrically charged particles. The very small neutral density is sufficient to produce a drag on space vehicles that orbit the Earth at this altitude. The charged particle density is sufficient to affect the path that radio waves follow through the region.

Space weather properties are similar to the climate and weather that we experience at the Earth's surface. The days of summer are quite different from the days of winter and days of calm can be followed by days of storms that may last a few hours or many days. They can occur on a large scale and permeate the entire region or occur on a smaller scale and be restricted to specific regions. The effects of space weather can include sudden increases of drag or damage to satellites, disruption of power grids on Earth, and dramatic reduction in the performance of critical communication and navigation systems.

Space storms can be produced by massive eruptions of electrically charged gas from the sun, called coronal mass ejections that collide with the Earth's magnetic field extending into space. They may also be produced by instabilities within the Earth's upper atmosphere, created by winds and special conditions that occur near the equator.

During the daytime, radiation from the Sun constantly maintains the ionosphere and thermosphere regions that are thus quite smooth and well behaved. But during the nighttime, the charged particles become suspended on the horizontal magnetic field and the region is unstable to overturning. Winds and waves in the lower atmosphere can produce ripples in the less dense plasma below that grow and rise through the higher density plasma above. The low-density plasma rises to the top of the region, much like air bubbles in water and scientists use the term equatorial plasma bubbles to describe these regions of low-density charged particles. The walls of these equatorial plasma bubbles are where the communication and navigation signals are corrupted. However, at the present time we do not know when these plasma bubbles will appear or how large a region they will occupy.

The CINDI Mission and Space Weather

Understanding when and where space weather events like plasma bubbles occur, how severe they will be and how long they will last is vitally important since interference from plasma bubbles affects GPS signals that pass through this region. Other types of radio signals that travel around the globe by reflecting between the Earth and the ionosphere are also affected by space weather. These signals are used for communication and navigation by a wide variety of commercial and government entities including the Federal Aviation Administration and search and rescue operations. Most of us are directly or indirectly dependent on the proper function of these space-based systems and it is imperative that we attempt to predict the times when such systems may not be reliable.

During the mission, CINDI will explore the winds in the upper atmosphere in greater detail than ever before. The winds in both the ionosphere and thermosphere are critical in triggering space weather events such as plasma bubbles.

CINDI can determine the conditions that exist just prior to the onset of plasma bubbles and how their evolution is related to these conditions. The CINDI mission will simultaneously explore the motions of the charged and neutral gases for the first time and will discover the differences in their behavior when plasma bubbles form and when they do not. This information will help explain the fundamental relationships between charged and neutral particles, allowing scientists to build a better forecast model for plasma bubbles for use in the Earth's environment and also in other planetary environments as well.

CINDI Instruments

The CINDI mission is comprised of two instruments that will measure the concentration and kinetic energy of the electrically charged particles (ions) and neutral particles in space as the satellite passes through them at the equator. The data gathered will be used to understand the various structures or boundaries of the plasma bubbles, and the different densities of ions in the ionosphere at the equator. These can interfere with radio signals between the Earth and spacecraft in orbit, thus causing errors in tracking and loss of valuable communication.

The two separate instruments on-board the satellite, the Ion Velocity Meter (IVM) and the Neutral Wind Meter (NWM), separately measure the ionized and neutral particles that exist in the ionosphere. Both instruments are mounted on the front of the spacecraft looking forward into the direction of the satellite's orbital motion. The satellite is traveling much faster than the particles are, so as the ions stream into the openings for the IVM, the instrument measures how fast they are going in the direction of the satellite's travel. The IVM also measures how fast the ions are traveling at right angles to the satellite's orbital motion. Subtracting out the satellite's speed from the first measurement and adding in the speeds in the two directions at right angles gives researchers a full three-dimensional measurement of the ion velocity   Measuring the total number of ions entering the IVM will tell what the ion density is at that point in space. Measuring the variations of the ion velocities over a short period of time will tell both the temperature of the ions and, their relative composition by elements.

The NWM measures the velocity of the neutral particles. Even though the ions and neutral particles are in the same place, they are not necessarily moving in the same direction or at the same speed. The neutral particles are affected the most by the Earth's gravity pulling them down, but also from the pressure of the surrounding particles pushing them up and sideways. These same forces affect the ions, but since they are electrically charged, the local magnetic and electric fields are also pushing the ions around. The only time the ions and the neutrals interact is when they collide with each other, and this further changes the directions of both their motions. When the ions and neutrals collide a lot, then they are said to be strongly "coupled" to one another, Hence, the term "coupled" in the name of the CINDI Investigation.

By measuring the motions of the ions and neutrals, we can study the variations or the structure of the ionosphere. Studying these structures we can see how they change at different local times of the day, how they change from day to day, how they change with the season, and how they change as a result of solar storms like CMEs. Eventually scientists will gather enough information to understand and predict the formation and movements of these structures. And since these structures can interfere with the radio signals traveling between the Earth and satellites further out, they can begin to forecast when these outages will occur and how severe they will be. These findings will further advance the study and prediction of space weather, similar to our ability to predict weather events on Earth.

CINDI will discover the role of ion-neutral interactions in the generation of small and large-scale electric fields in the Earth's upper atmosphere. Ion-neutral interactions are a key process in controlling the dynamics of all planetary atmospheres and their understanding is important to describing the electrodynamic connections between the Sun and the Upper Atmosphere.

Mission Team

The Coupled Ion-Neutral Dynamics Investigation (CINDI) is a NASA sponsored Mission of Opportunity conducted by the University of Texas at Dallas (UTD). NASA's Explorer Program at Goddard Space Flight Center, Greenbelt, Md, manages the CINDI mission. The Explorer's Program provides frequent flight opportunities for world-class scientific investigations from space within heliophysics and astrophysics.

The Principal Investigator for this mission is Prof. Rod Heelis of the UTD Space Sciences Center. The Center will provide open access to the CINDI data for the science community.

The CINDI investigation is carried out as an enhancement to the science objectives of the Communication/Navigation Outage Forecast System (C/NOFS) satellite undertaken by the Air Force Research Laboratory and the Space and Missile Command Test and Evaluation Directorate.

This program will utilize satellite and ground-based data to develop and evaluate a real-time system for forecasting the presence of radio scintillation caused by equatorial ionospheric plasma structure. The C/NOFS satellite will provide measurements of ionospheric electric fields and particle drifts, the total plasma density and radio diagnostics. In addition the CINDI instruments will provide measurements of the 3-D neutral winds and ion drifts. During that time the CINDI science investigations will be undertaken and will provide essential input to real-time specification and prediction models being developed by C/NOFS. This synergistic relationship optimizes the productivity and resources for the CINDI mission.

Pegasus XL Launch Vehicle
The Pegasus XL was developed as an inexpensive way of launching small payloads into space. The rocket specializes in carrying satellites and experiments that weigh up to 1,000 pounds into low-Earth orbit. With the body of an oversize model rocket and tail of an airplane, the Pegasus has three solid-fuel rocket motors and a rather unique and economical way of lifting off.

Pegasus' first leap into space is actually aboard Orbital Science's L-1011 "Stargazer" jet. The Pegasus starts its mission secured to the belly of the L-1011, where it's carried to the planned launch altitude. Using the Stargazer again and again saves money by eliminating the need for a first stage motor to lift each Pegasus off of the ground.

One of Pegasus' greatest benefits is its ability to be launched from practically anywhere in the world. Every Pegasus flight starts with the rocket locked to the underside of the Stargazer. The jet takes off and requires about one hour to fly to the rocket's launch altitude of 39,000 feet. At that height, the Pegasus is released and allowed to freefall for about five seconds. Then the first stage motor fires and accelerates the rocket to over 5,000 miles per hour.

After 76 seconds, the first stage motor burns out and the vehicle briefly coasts before igniting its second stage rocket at the 97-second mark. Nearly 10 minutes later, the Pegasus has exhausted its stage two and three motors, reached a top speed of nearly 17,000 mph, and climbed to an altitude of 460 miles. Following the boost phase of the flight, the spacecraft will separate from the Pegasus and glide off to begin its mission.

The C/NOFS spacecraft will be launched into an equatorial orbit that ranges from 250 to 530 miles (400 to 850 kilometers) in altitude and it is scheduled to collect data for two years.

Websites for more information:

NASA's CINDI Web site
http://www.nasa.gov/mission_pages/cindi/index.html

CINDI Web site at the University of Texas at Dallas
http://cindispace.utdallas.edu/

CINDI Educational and Public Outreach website http://cindispace.utdallas.edu/education/