National Aeronautics and
Space Administration
Goddard Space Flight Center

Gravity Recovery and Climate Experiment (GRACE)

The Program

The first NASA Earth System Science Pathfinder (ESSP) mission to launch is the Gravity Recovery and Climate Experiment (GRACE). The GRACE mission will accurately map variations in the Earth's gravity field over its 5-year lifetime and the resulting improvements in precision of gravity measurements is expected to revolutionize our understanding of key climatological phenomena. The GRACE mission will have two identical spacecraft flying about 220 kilometers apart in the same polar orbit 500 kilometers above the Earth. The GRACE-twins are scheduled to launch in early 2002.

Mission Objectives

GRACE will be able to map the Earth's gravity fields by making accurate measurements of the distance between the two satellites, using GPS and a microwave ranging system.

It will provide scientists from all over the world with an efficient and cost effective way to map Earth's gravitational field with unprecedented precision and resolution. The results from this mission will reap benefits for numerous disciplines that rely on this data to study the Earth's climate.

GRACE should help scientists: track water movement on and beneath Earth's surface; track changes in ice sheets and in global sea level; study surface and deep ocean currents; and study changes in the solid Earth. GRACE will also collect data intended to yield more accurate profiles of atmospheric pressure, temperature and humidity, leading to improved weather forecasts.

GRACE 2002: A Scientific Geodesy

The distribution of mass over the Earth is non-uniform. GRACE will determine this uneven mass distribution by measuring changes in Earth's gravity field. The term mass is a way to talk about the amount of a substance in a given space, and is directly correlated to the density of that substance. For example, a container filled with a more dense material, like granite rock, has more mass than that same container filled with water. Because mass and density are directly related, there is also a direct relationship between density and gravity. An increase in density results in an increase in mass, and an increase in mass results in an increase in the gravitational force exerted by an object. Density fluctuations on the surface of the Earth and in the underlying mantle are reflected in variations in the gravity field. As the twin GRACE satellites pass over the Earth's surface, they sense these variations in density (the orbital motion of the satellites changes) and a gravity field map can thus be constructed.

Geodesy is the science dedicated to precise measurements of Earth's gravity field. The GRACE mission will render the gravity field (referred to as a geoid) with unprecedented precision and resolution. A more accurate geoid will increase the accuracy of satellite altimetry, synthetic aperture radar interferometry, and digital terrain models covering large land and ice areas—all used in remote sensing applications and in cartography. These techniques provide critical input to many scientific models used in oceanography, hydrology, geology and related disciplines and, for this reason the Earth Science community eagerly anticipates the GRACE launch.

In addition to the primary gravity measurement, the two Global Positioning Satellite (GPS) receivers on GRACE will be used to scan the Earth's limb and determine how much error is introduced into GPS measurements as the GPS signal passes through the atmosphere. This is done using a technique known as occultation, where the GPS receivers track refracted signals from the GPS satellites as they rise or set through the Earth's atmosphere and compare them to a non-occulting GPS satellite. Improvements to the accuracy of GPS measurements expected to result from these measurements will in turn improve the accuracy of soundings of key atmospheric parameters that serve as input into numerical weather prediction models.

Spacecraft and Systems

The GRACE Project is divided into the following five systems:

Satellite System

Jet Propulsion Laboratory (JPL) leads the development of the satellite system in partnership with Space Systems/Loral (SS/L) and Astrium GmbH (AGmbH).

Science Instrument System (SIS)

The SIS includes all elements of the inter-satellite ranging system, the GPS receivers and associated sensors such as the Star Cameras. This system also coordinates the integration activities of all sensors, assuring their compatibility with each other and the satellite.

Launch Vehicle System (LVS)

The LVS includes the ROCKOT launch vehicle, multi-satellite dispenser, personnel, test equipment and facilities for preparation, integration and launch of the satellites. The LVS is managed by the launch vehicle manager at Deutsches Zentrum für Luft und Raumfahrt (DLR) and supported by the JPL Project and its contractors.

Mission Operations System (MOS)

The MOS consists of facilities and resources of the German Space Operations Center (GSOC), tracking antennas at Weilheim and Neustrelitz, and other stations and facilities. These facilities are used to monitor and control the satellite, perform initial processing of the telemetry data, and deliver all data to the Science Data System for further processing and generating science products. Mission operations are conducted at the GSOC control center in Oberpfaffenhofen, Germany.

Science Data System (SDS)

The SDS functions include science data processing, distribution, archiving and product verification. The SDS is a distributed entity and managed in a cooperative approach by JPL and the University of Texas Center for Space Research (UTCSR) in the US and the GeoForschungsZentrum Potsdam (GFZ) in Germany.

Management

GRACE is a joint partnership between the National Aeronautics and Space Administration (NASA) in the United States and DLR in Germany. The Principal Investigator is from UTCSR and the Co-Principal Investigator is from the GFZ. JPL has responsibility for the Project Management and Project Science of GRACE. Goddard Space Flight Center maintains responsibility for Mission Management.

The ESSP Program

The GRACE Mission will be the inaugural flight of NASA's Earth System Science Pathfinder Program (ESSP). A component of NASA's Earth Science Enterprise (ESE), the ESSP missions are intended to address unique, specific, highly-focused scientific issues and provide measurements required to support Earth science research.

The ESSP missions are an integral part of a dynamic and versatile program consisting of multiple Earth system science space flights. The ESSP program is characterized by relatively low- to moderate-cost, small- to medium-sized missions that are capable of being built, tested and launched in short-time intervals. These missions are capable of supporting a variety of scientific objectives related to Earth science, including the atmosphere, oceans, land surface, polar ice regions and solid Earth. Investigations include development and operation of remote sensing instruments and the conduct of research investigations using data from these instruments. Subsequent launches are planned over the next few years.

For the Classroom: Modeling GRACE

The primary gravity measurement is made by recording changes in the speed and distance between the two GRACE satellites. The two satellites fly in formation over the Earth and the precise speed of each satellite and the distance between them is constantly communicated via a microwave K-band ranging instrument. As the gravitational field changes beneath the satellites—correlating to changes in mass of the surface beneath—the orbital motion of each satellite is changed. This change in orbital motion causes the distance between the satellites to expand or contract and will be measured using the K-band instrument. From this, the fluctuations in the Earth's gravitational field can be determined.

Materials needed

5-20 magnets of varying strengths, cardboard or foam board, magnetic wand, spring scale, two ring stands, rod, 2 clamps, grid of graph paper marked in 5 cm squares, and masking tape.

Procedure

1. Set up two ring stands. Attach each end of the rod to a ring stand so it is suspended between the two ring stands. Attach the spring scale from the rod so the scale slides freely on the rod. Attach the magnetic wand to the spring scale and adjust the height so that the scales and wand hang freely. Record the starting weight in Newtons.
2. Tape the grid of graph paper to the top of the card or foam board.
3. On the desktop, between the ring stands, place 5 to 20 magnets of varying strengths, randomly in a space slightly smaller than the size of the foam board.
4. Place the card or foam board on top of the magnets and tape all around the sides.
5. Distribute graph paper to each student the same size of the card or foam board.
6. Slowly slide the spring scale/magnetic wand over each column of the graph paper. For each grid, have students record observed changes in the spring scale. Move the ring stand so the scale/magnetic wand covers the next column of the foam board until the entire board has been mapped.

Questions

- What was the starting weight in Newtons? This represents the mass with standard gravity.
- For each grid reading that is different from the starting weight, subtract this standard gravity reading. Divide this number by the starting weight. This represents the percent change in gravity. Negative values will represent less gravity than the standard. Positive values show an increase in gravity.
- Where does the model's gravity increase? Decrease?
- On Earth, what types of things might account for an increase or decrease in gravity?

GRACE will obtain a gravity field map by looking at how the Earth's mass varies from place to place on the surface as the twin satellites pass over. Mass and gravity are positively correlated—that is to say an increase in mass relates to an increase in the gravitational force exerted. Mass is also related to the density and amount of materials located in any one place.

Extension

1. Using four equal sized containers, fill the first with rocks, second with water, third with plastic bag of air, and fourth with sand.
2. Weigh each container and record the weight.

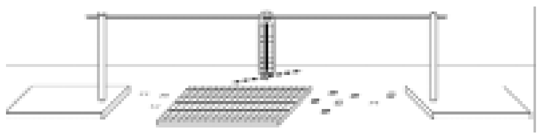
Questions/Analysis

- Which container weighed the most? The least?
- Based on the demonstrations would you expect the Earth's gravitational pull to be constant?
- Describe geographic features on earth that will cause GRACE to detect changes in gravity.

Discuss with students

- Scales may read in pounds or kilograms but weight in the metric system is correctly recorded in Newtons.
- The difference between acceleration due to gravity and the gravitational force.
- Difference between gravity field and magnetic field.
- Why models are used in science.

For more information on the ESSP Program, visit http://essp.gsfc.nasa.gov/
For more information on GRACE, visit http://www.csr.utexas.edu/grace/



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