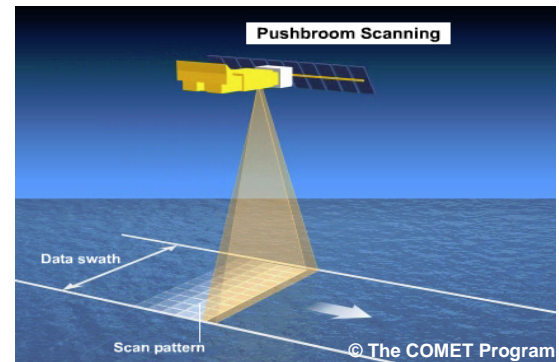




On April 1, 1960, NASA launched TIROS-1, a 270-pound device equipped with television cameras and transmitters. Hours later, the first television pictures from space were broadcast on Earth. Today, Earth is orbited by hundreds of observational satellites that monitor atmospheric, surface and even subsurface conditions. Earth observation through satellites is a form of *remote sensing*, the process of sensing or measuring something which the observer is not directly contacting. Remote sensing ranges from Magnetic Resonance Imaging (MRI) at the doctor's office to simple things like observing the text and pictures on your computer monitor.

### What Can Satellites Detect?

- Atmospheric water vapor and temperature
- Precipitation
- Stratospheric ozone levels
- Land and sea surface temperatures
- Sea water chlorophyll concentrations
- Forest biomass and vegetation conditions (e.g., leaf water content, important for drought monitoring)
- Land, sea ice and snow cover
- Sea surface and tropospheric winds
- Tropospheric aerosols (e.g. dust and volcanic ash)
- Groundwater levels



Above: The *pushbroom scanner* sensing array uses a line of scanners that take measurements to construct a digital “microcosm” of surface conditions.

### Types of Satellite Remote Sensing

Satellite-based remote sensors are classified by the electromagnetic frequencies they sense and whether they sense these frequencies passively or actively. Among the frequencies of most importance for Earth observations are those in the ultraviolet, visible, infrared and microwave regions of the electromagnetic spectrum.

**Passive Remote Sensing:** Passive remote sensing involves observing reflected or emitted radiation from sources such as the Sun and Earth. Different types of objects on Earth (roads, trees, water, etc.) absorb and reflect different portions of the spectrum. Each object has a *spectral reflectance signature*. Satellites can sense these respective signatures as well as their *intensity values*, or the quantity of photons in the given wavelength band. Images of portions of the Earth's surface are usually gathered in a digital format. Images are constructed using pixels, with each pixel having a *location address* corresponding to a geographic coordinate. Passive remote sensing from satellites includes: *optical remote sensing*, measurements of visible and near infrared radiation used to observe the objects that our eyes can see; *ultraviolet remote sensing*, used to monitor ozone and sulfur dioxide in the atmosphere; *infrared remote sensing*, used to measure atmospheric, land and sea surface temperatures (as well as to detect forest fires); and *microwave remote sensing*, used to measure sea ice, land ice, vegetation and other components of the Earth system. Variations in the Sun's output are currently measured by the Active Cavity Radiometer Irradiance Monitor (ACRIMSAT), launched in 1999.

**Active Remote Sensing:** This type of sensing uses equipment that actively transmits electromagnetic energy, as well as equipment that measures these same waves after they have bounced off the object being sensed. One of the most common pieces of equipment used in active sensing from satellites is the Synthetic Aperture Radar (SAR), which sends out microwave pulses. Based on the time it takes the microwaves to return to the spacecraft (microwaves travel at the speed of light), the angle at which they return and changes in spectral bands, Earth's surface properties such as the slope, roughness, soil moisture content and vegetation structure can be determined. The longer the wavelength used, the more penetration the waves have (longer wavelengths are more useful for observing forests with different vegetation layers) but the less surface detail they reveal (shorter wavelengths are better for measuring ocean and ice conditions). Lasers are also used in active sensing. ICESat, launched in 2003, uses the Geoscience Laser Altimeter System (GLAS), which emits 40 laser pulses per second. As with other altimeters, the time it takes the photons to return to the spacecraft is used to measure variations and changes in the underlying topography, with the emphasis for ICESat being the Earth's ice masses.

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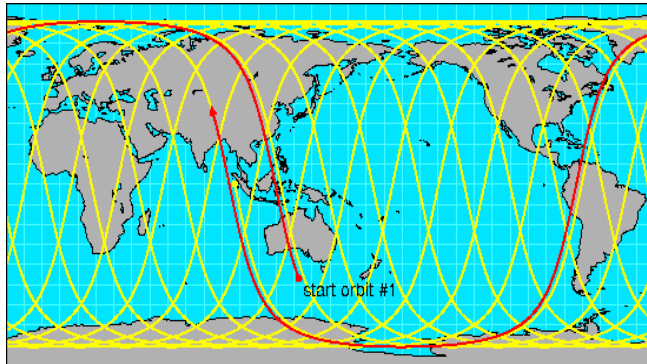
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## Types of Orbits

Different types of orbits are used for different monitoring purposes. A satellite's orbital *period* is the time it takes the satellite to orbit the Earth one time. The *ground track* is the path on the Earth's surface the satellite traces as it orbits above. As the image below shows, some orbital patterns have different ground tracks covered during different periods. The *repeat cycle* is the time interval that passes before the satellite begins to repeat its series of ground tracks. Some common orbital types are:

- **Geostationary Orbits:** The most commonly used orbital type for weather forecasting, geostationary orbits have ground tracks that are parallel to the equator with orbital periods matching the period of Earth's rotation (24 hours) and thus appear stationary (always above the same location on Earth). In order to keep this 24-hour period, these satellites must remain at relatively high altitudes. The Geostationary Operational Environmental Satellite (GOES), for example, orbits at an altitude of over 22,300 miles. This distance enables the satellite instruments to monitor a large portion of the Earth's surface continuously.
- **Near-Polar Orbits:** These types of orbits follow a ground track that is at a slight angle relative to the Earth's axis of rotation and are at lower altitudes (typically several hundred kilometers). These orbits pass close to the poles and can observe most of the Earth's surface in a repeat cycle (several days to weeks).
- **Sun-Synchronous Orbits:** These are near-polar orbits that are synchronous with the sun, meaning that the satellite passes over a given location at the same local solar time each day. This enables the satellite to make repeat measurements at the same level of solar illumination and track seasonal changes.



Above: A schematic view of the track of a near-polar sun-synchronous orbit. The repeat cycle is the time it takes the satellite to follow all the yellow lines. Image UCAR.

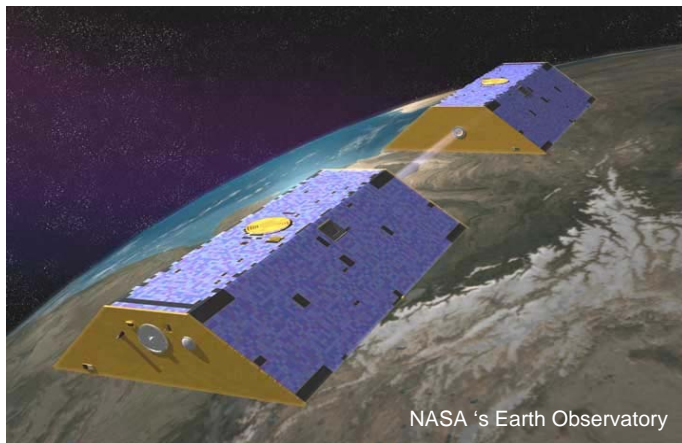
## Examples of Satellites

**AQUA:** Aqua, launched in 2002, was the first satellite of NASA's Afternoon Constellation, commonly known as the A-train. The A-train is dedicated to better understanding Earth's water cycle. Aqua has six different types of sensors and is used to measure many atmospheric, ocean and land variables, including ocean algal conditions.

**GRACE:** A twin set of satellites, the Gravity Recovery and Climate Experiment (GRACE), launched in 2002, detects changes in Earth's gravity field. Such changes have been used to estimate fluctuations in the ice content on Antarctica and Greenland, as well as groundwater depletion in northern India.

**TERRA:** The first of NASA's major Earth Observing System (EOS) satellites, Terra (launched in 1999) is a multi-national and multi-disciplinary endeavor. It provides data on the state of the atmosphere, land and oceans, and scientists are using these data to examine how these variables relate to solar radiation and each other.

**CLOUDSAT:** Another member of the A-Train constellation, CloudSat (launched in 2006) was developed jointly by NASA and the Canadian Space Agency. It transmits millimeter wavelength microwave radiation to detect raindrop-sized particles, measuring cloud moisture content and improving rain and snow prediction. These measurements are particularly important as clouds are among the most profound yet least understood aspects of current climate prediction.



Above: An artist's depiction of the GRACE satellites.

## **More Information**

### **The COMET Program**

- COMET's Microwave Remote Sensing education modules - <http://www.meted.ucar.edu/topics/satellite.php>
- COMET's Environmental Satellite Resource Center - <http://www.meted.ucar.edu/esrc/>

### **NASA**

- NASA's Earth Observatory Home Page - <http://earthobservatory.nasa.gov/>
- NASA's Earth Observing System Resources for Scientists - [http://eosps0.gsfc.nasa.gov/eos\\_homepage/for\\_scientists/index.php](http://eosps0.gsfc.nasa.gov/eos_homepage/for_scientists/index.php)
- Information on NASA's satellite constellation - <http://climate.nasa.gov/missions/>
- Global Climate Change at NASA's Jet Propulsion Laboratory - <http://www.jpl.nasa.gov/earth/>
- NASA's Remote Sensing Tutorial - <http://rst.gsfc.nasa.gov/>
- The Goddard Earth Sciences Data and Information Services Center - <http://daac.gsfc.nasa.gov/>
- Track NASA's Satellites - <http://science.nasa.gov/realtime/>

### **NOAA**

- NOAA's "Remote Sensing: An Overview" - <http://www.csc.noaa.gov/products/nchaz/htm/ccap5.htm>
- NOAA's Office of Satellite Operations - <http://www.oso.noaa.gov/>

### **Centre for Remote Imaging, Sensing and Processing, National University of Singapore**

- "Principles of Remote Sensing," a tutorial by Dr. S.C. Liew - <http://www.crisp.nus.edu.sg/~research/tutorial/rsmain.htm>

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