



The GOES-O Spacecraft

Geostationary Operational Environmental Satellite (GOES)-O represents a continuation of the newest generation of environmental satellites built by Boeing for the National Oceanic and Atmospheric Administration (NOAA) under the technical guidance and project management of NASA's Goddard Space Flight Center, Greenbelt, MD. GOES satellites provide the familiar weather pictures seen on many United States television newscasts every day. The GOES imaging and sounding instruments (built by ITT) feature flexible scans for small-scale area viewing in regions of the visible and infrared spectrum allowing meteorologists to improve short-term forecasts. GOES provides nearly continuous imaging and sounding, which allow forecasters to better measure changes in atmospheric temperature and moisture distributions and hence increase the accuracy of their forecasts. GOES environmental information is used for a host of applications, including weather monitoring and prediction models, ocean temperatures and moisture locations, climate studies, cryosphere (ice, snow, glaciers) detection and extent, land temperatures and crop conditions, and hazards detection. The GOES-O&P Imagers have improved resolution in the 13 micrometer channel from 8 km to 4 km. The finer spatial resolution allows an improved cloud-top product, height of atmospheric motion vectors and volcanic ash detection. GOES-O continues the improved image navigation and registration, additional power and fuel lifetime capability, space weather, solar x-ray imaging, search and rescue, and communication services as provided on GOES-13.

On January 28, 1998, the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) awarded a contract to

Hughes Space and Communications (now Boeing), in El Segundo, California, for the manufacture, launch and delivery on-orbit of up to four advanced environmental monitoring Geostationary Operational Environmental Satellites (GOES) and delivery of associated ground system elements. The procurement of the GOES-N series was an extension of a program designed to primarily provide continuous monitoring of the Earth's weather systems and the near earth space environment. The new spacecraft of the GOES-N Series will be used to continue and enhance the environmental monitoring and communications functions of the GOES-I thru M (GOES-8 thru 12) series of NOAA operational spacecraft.

The basic contract provides for two spacecraft, GOES-N & O. NOAA decided to only exercise the option for a third GOES-P satellite with all three using the expendable launch vehicle Delta IV (4,2) with two solids for additional on orbit fuel savings. The first satellite, GOES-N (now called GOES-13 in orbit) was successfully commercially launched by Boeing, with a Federal Aviation Administration launch license on May 24, 2006. GOES-O will carry government furnished ITT built Imager and Sounder instruments to provide regular measurements of the Earth's atmosphere, cloud cover, ocean temperatures, and land surfaces. GOES-O has a government furnished Solar X-ray Imager built by Lockheed Martin of Palo Alto, CA. Space Environment Monitor instruments were part of the Boeing spacecraft contract and were built by Science Applications International Corporation (built the magnetometers) in Columbia, Maryland, and Assurance Technology Corporation (formerly GE Panametrics) in Carlisle, Massachusetts. Assurance Technology built the high energy, electron, and proton particle sensors and the new extreme ultraviolet solar monitoring instrument. Significant portions of the GOES-NOP Series satellite support ground system are provided by Integral Systems, Inc., of Lanham, Maryland.

In 2006, the GOES-O spacecraft completed construction and spacecraft level thermal-vacuum testing. GOES-O will be shipped to Cape Canaveral by a USAF C-17 aircraft on March 2, 2009, and will be processed at the Astrotech Space Operations, Inc. facility in Titusville, Florida starting on March 3, 2009. GOES-O will be processed for launch similar to how GOES-N was. GOES-N was transported to the Delta IV Space launch Complex 37 and hoisted and mated to the Delta IV as shown in the photo gallery images at this web site.

The multimission GOES-NOP Series of satellites will be a vital contributor to weather, solar, and space operations and future science improvements with weather prediction and remote sensing. The GOES-NOP Series will aid severe storm warnings, resource management, search and rescue, emergency managers, and likely lead to additional advances in environmental sciences and multifaceted data applications of remotely sensed phenomena. GOES-NOP data will add to the global climate change databases of knowledge, embracing many civil and government environmental forecasting organizations that work to benefit people everywhere and help save lives every day.

An advanced attitude control system using star trackers, a spacecraft optical bench, and improved Imager and Sounder mountings provides enhanced instrument pointing

performance for improved image navigation and registration to better locate severe storms and other events important to the NOAA National Weather Service and all of us. NASA Goddard Space Flight Center (GSFC) and the NOAA National Environmental Satellite, Data and Information Service (NESDIS) have set a higher standard of location accuracy for the GOES-NOP series, including data picture element (pixel) location to approximately two kilometers from geosynchronous orbit of about 35,780 km (22,233 miles) above the Earth's surface. For more information on the GOES-13 improvements to image navigation and registration (INR) being achieved please refer to the paper at the following web site: <http://ams.confex.com/ams/pdfpapers/135921.pdf> . The paper reports that GOES-13 image navigation and registration performance is "more than 100% improved over the previous generation of GOES satellites and very close to next generation (GOES R) performance specifications". A movie loop comparison between GOES-12 and GOES-13 is found at the web site: <http://cimss.ssec.wisc.edu/goes/blog/archives/date/2006/12>. A comparison there of visible channel images centered over northeastern Minnesota on December 25, 2006, shows the improvement in navigation accuracy with the new GOES-13 satellite. Surface features (such as frozen/snow-covered interior lakes, and the Lake Superior shoreline) appear to have significantly less image-to-image movement on GOES-13 versus GOES-12. This improved navigation will allow for better accuracy of satellite products such as satellite derived winds or atmospheric motion vectors. The GOES-NOP enhanced INR quality of service is further improved by the integrated systems ability to operate through eclipses and improved recovery after station-keeping maneuvers and yaw flips. GOES-13 Imager and Sounder NOAA science testing was conducted in 2006 and a NESDIS Technical Report is available from the following web site: http://rammb.cira.colostate.edu/projects/goes_n/.

GOES-P is in ground storage at Boeing, in El Segundo, California and will undergo a second thermal vacuum test in the year ahead. GOES-P should be ready for a December 31, 2009, launch.

Imager

The Serial Number 09 GOES-O Imager satisfies the NOAA primary mission imagery requirements and was built and tested at ITT in Fort Wayne, Indiana. It is similar to the GOES-N Imager and was delivered to Boeing by NASA/GSFC and integrated onto GOES-O. Like the GOES-N Imager the SN09 Imager has evolutionary improvements incorporated to reduce single point failures; improve launch vehicle environments flexibility; added thermal shields to the secondary mirror structure to remove health and safety concerns relating to scanning operations during eclipse periods; and takes advantage of cooler operational set points for infrared detectors provided by the spacecraft accommodation clearer view of and improved thermal radiation to space. The Imager blackbody dwell time increased from 0.2 to 2 seconds as compared to the GOES-12 Imager and this helps reduce potential image striping. The GOES-O&P Imagers have improved resolution in the 13 micrometer channel from 8 km to 4 km. This finer spatial resolution allows an improved cloud-top product, height of atmospheric motion vectors and volcanic ash detection. The first official GOES-13 visible full disk image was taken

on June 22, 2006 and is located at this web site.

Sounder

The Serial Number 09 GOES-O Sounder was built and tested at ITT in Fort Wayne, Indiana and satisfies the NOAA atmospheric sounding multi-spectral mission visible and infrared sensing requirements. It was delivered to Boeing by NASA/GSFC and integrated onto GOES-O. The GOES-NOP Sounders have likewise incorporated low risk evolutionary improvements to improve channel to channel coregistration; add thermal shields to the secondary mirror structure to remove health and safety concerns relating to scanning operations during eclipse periods; reduce single point failures; improve launch vehicle environments flexibility; and take advantage of cooler operational set points for infrared detectors provided by the spacecraft accommodation clearer view of and improved thermal radiation to space.

Solar X-ray Imager

The GOES-NOP Solar X-Ray Imager (SXI) contract was awarded in 1997 to Lockheed Martin Advanced Technology Center in Palo Alto, California for two firm flight models with options and associated ground support equipment and services. Three units have been successfully delivered and integrated for flight on the GOES-NOP Series of spacecraft. The first official GOES-13 SXI image was taken on July 6, 2006, and is located at this web site. The GOES-13 SXI experienced an anomaly on December 5, 2006, after looking at a strong solar flare longer than recommended. An exceptionally active solar region 930 rotated onto the solar disk at a time when solar cycle 23 was theoretically approaching minimum levels. On December 5, 2006, at 10:18 UT region 930 generated an X9 flare. Region 930 continued to generate flares over the ensuing two weeks and resultant ion storms were also recorded by GOES. The GOES-13 SXI sustained damage to several pixels of its CCD detector while observing this X9 flare event. The source of the damage was the large X-ray flux of the flare convolved with the observing sequence. The susceptibility of the SXI CCD detector to radiation damage was not well understood or adequately operationally constrained. Eight lines of pixels across the CCD are damaged and are unlikely to fully recover. Operational constraints and updates to on-board observing sequence software should enable the SXI to continue its mission without further damage to its detector. The impact on observations and predictioning is being assessed as new sequence software and operational constraints are developed. Ground algorithms will be developed to minimize the appearance of the 'lost' lines through interpolation or other means. Corrective actions have been implemented in operational constraints and automated fault protection software is being developed to prevent such an anomaly from occurring in the future and extend the life of the SXI CCD detector arrays. For further information contact Dr. Steven Hill (Steven.Hill@noaa.gov)

with NOAA's Space Weather Prediction Center or see GOES-13 and other SXI solar images at http://sxi.ngdc.noaa.gov/sxi_greatest.html.

The GOES-13 SXI entrance filter is degrading in orbit and an improved entrance filter design was developed in the last year. New SXI entrance filters were space qualified and were installed on the GOES-O SXI instrument to better assure NOAA's ability to meet newer SXI observing goals over the minimum 5 years of SXI required operations in orbit.

Space Environment Monitor

The main GOES-NOP Space Environment Monitor (SEM) subcontract was awarded by Boeing in 1998 to GE Panametrics (now Assurance Technology Corporation) in Carlisle, Massachusetts. The contract includes instrument packages to be flown on each of the spacecraft in the series and includes *in situ* measurements of the magnetic and particle environments as well as remote measurement of the integrated X-ray emission and the extreme ultraviolet (EUV) spectra of the Sun. These units have all been delivered and integrated for flight on the GOES-NOP spacecraft. The two GOES-O magnetometers were provided by Boeing subcontract to Science Applications International Corporation (SAIC) in Columbia, Maryland. To provide stable magnetic field measurements independent of the spacecraft field, dual magnetometers are near the end of a deployable boom that is more than 8 meters long. The GOES-N SEM instruments have all been activated and the EUV and the X-ray Sensor (XRS) appropriately responded to the M2 level solar flare that was observed on July 6, 2006. The XRS instrument experienced a failure on November 5, 2006, that appears to be due to a random part failure. That same suspect part is not used in the GOES-O&P XRS instruments plus additional confidence testing has been done to better assure adequate part reliability.

Launch and Orbit Raising

GOES-N was launched from Cape Canaveral Air Force Station Space Launch Complex (SLC) 37B on a Boeing Delta IV (4,2) using a 4 meter fairing common booster core configuration, with two solid strap on motors, on May 24, 2006, at 6:11 pm EDT. The GOES-O Delta IV was erected on February 25, 2009, and the two solid rockets will be attached the following week. The use of the Delta IV upper stage Pratt & Whitney supplied RL10B engine performing a third burn to get to orbit saves fuel on the spacecraft, and helps achieve at least 13.5 years of fuel lifetime (nominally 5 years of on orbit storage and 5 years of operations). The Delta IV provided GOES-N an initial orbit of approximately 3,576 x 18,994 nmi at 12 degrees inclination. A series of spacecraft liquid apogee motor (LAM) firings was subsequently done to bring the spacecraft to geosynchronous orbit of approximately 22,233 miles (35,780 km). GOES-N successfully completed the necessary Liquid Apogee Motor Firings to get to geosynchronous orbit near 90 degrees west longitude and as of June 4, 2006, at 2:46 am EDT became GOES-13. The solar array was fully deployed as were the magnetometer boom, Imager and Sounder optical port covers and cooler doors, and the SXI. On Friday, June 2, 2006, the

first command was sent from Wallops Virginia to GOES-N. The NOAA Wallops Command and Data Acquisition Station became the prime ground station on Sunday morning, June 4, 2006. GOES-O is expected to go through a similar launch and orbit raising plan.

The GOES-O post launch testing is expected to be reduced from that done for GOES-N since some capabilities have already been fully demonstrated on GOES-13. After successful post-launch checkout near 90 degrees west longitude by a coordinated Boeing, NASA, NOAA, GOES-O integrated Government and Industry team, from the NOAA Satellite Operations Control Center (SOCC) at the new NOAA Satellite Operations Facility (NSOF) in Suitland, Maryland, the satellite will be placed in an on-orbit storage mode at 105 degrees west longitude so that it can more rapidly replace a failure of any of the other operational GOES.

GOES N,O,P Enhancement Summary

- GOES N,O,P have an improved Image Navigation and Registration (INR) system that uses star trackers to provide precision image navigation and registration information for use with the Imaging and Sounding data products. This improves knowledge of exactly where severe weather events are located.
- A stable optical bench is provided to isolate thermal deformations of the spacecraft from the Imager and Sounder instruments.
- A data product improvement is provided with the development of the digital Low Rate Image Information Transmission (LRIT) system for distribution of data Products that were distributed in an analog WEFAX format in the previous generation of GOES-I/M satellites. The LRIT system permits the transmission of data products consistent with the World Meteorological Organization (WMO) and permits the distribution of more National Weather Service (NWS) information at a higher data rate to the NOAA data user community.
- The Data Collection System (DCS) is enhanced with the addition of 300 and 1200 bps Data Collection Platforms (DCPs) that use 8-PSK modulation and a higher power satellite transponder so that more DCPs can use the link at the same time.
- The power subsystem is improved with the use of a single panel solar array that contains high-efficiency dual-junction gallium-arsenide solar cells. A nickel-hydrogen battery is provided to permit the satellites to operate during the eclipse periods.
- A new Solar X-Ray Imager (SXI) developed by the Lockheed Martin Advanced Technology Center permits the observation and collection of solar data products.
- A dedicated transponder is provided to support the Emergency Manager's Weather Information Network (EMWIN) data product service.
- The Satellite design life time has improved from 7 to 10 years, and the expected propellant lifetime has increased to 13.5 years.
- The GOES-N,O,P command data rate increased to 2,000 bps, as compared to a data rate of 250 bps for the previous generation of GOES-I/M satellites.

- The GOES-N,O,P telemetry data rate improved to provide data at either 4,000 or 1,000 bps, as compared to the 2,000 bps data rate on the previous generation of GOES-I/M satellites.
- An optional operational “yaw flip” capability and procedure was developed on the GOES-N,O,P Program to permit optimum performance of the Imager and Sounder radiation coolers. The procedure permits operation of the Imager and Sounder detectors at a lower temperature and results in lower noise performance of the instruments.
- The Space Environment Monitoring (SEM) subsystem is enhanced by the addition of the Extreme Ultraviolet (EUV) sensor, Energetic Proton, Electron, and Alpha particle Detector (EPEAD), the Magnetospheric Electron Detector (MAGED), the Magnetospheric Proton Detector (MAGPD) and dual magnetometers on a 27.9 foot (8.5 meter) long boom. The Energetic Particle Sensors are improved on GOES-N,O,P to provide coverage over an extended energy range and with improved directional accuracy.
- The communications services are tailored to comply with modern national and international requirements.
- Potential reduction in striping in the image is achieved due to increasing the Imager’s scan-mirror dwell time during the blackbody calibration process from 0.2 seconds to 2 seconds.
- Health and safety concerns related to scanning operations during eclipse periods have been removed because thermal shields have been added to the secondary mirror structure elements for the Imager and Sounder instruments.
- There will be no GOES-I/M era “boom snap” problem on the GOES-N,O,P satellites since the effect was due to the shadow of the magnetometer boom crossing the solar sail boom and a solar sail boom is not used with the GOES-N,O,P satellite design.

Additional GOES-N Series Satellite Information

The linked PDF document titled “NOAA GOES-NOP -- The Next Generation” contains more top level information on the GOES history, mission, services, payloads, and GOES-NOP improvements. The “GOES-N Data Book” has more spacecraft and mission detailed information and is also available in PDF from this web site above for download or downloaded by section from the outstanding GOES Project Science web site at: <http://goes.gsfc.nasa.gov/text/goes.databookn.html>. The GOES-N Mission Booklet prepared by Boeing, in PDF form above, is a very good overview of the GOES-N mission and the expected performance from the Delta IV launch vehicle. If more timely information is needed, the NOAA GOES Program Manager, is Steve Kirkner at 301-286-1943 (email: Steve.Kirkner@noaa.gov) and the NOAA GOES-N Series Technical Acquisition Manager is Thomas M. Wrublewski at 301-286-3119 (email: Thomas.M.Wrublewski@noaa.gov). A two page GOES-O satellite and launch vehicle overview is available for download in PDF form above. The GOES-O Data Book is being prepared by Boeing and should be available prior to the GOES-O launch.

GOES-O Major Milestones:

Event	Date
GOES - O LV on Stand	Wednesday, 2/25/09
GOES - O Spacecraft Ships to Cape (arrives 3/3/09)	Tuesday, 3/3/09
GOES – O Mission Readiness Review (MRR) @GSFC	Thursday, 3/5/09
GOES O Safety Mission Success Review @ NASA HQ	Thursday, 3/19/09
GOES – O Operations Mission Dress Rehearsal	Monday, 3/23/09
GOES -O MRB at NASA HQ	Friday, 3/27/09
GOES- O Fairing Encapsulation	Wednesday, 4/8/09
GOES - O Delta IV Wet Dress Rehearsal	Wednesday, 4/8/09
GOES – O Launch Site Readiness Review	Tuesday, 4/14/09
GOES - O Transport to Launch Pad 37	Wednesday, 4/15/09
GOES-O Flight Readiness Review (FRR)	Tuesday, 4/21/09
GOES- O Mission Dress Rehearsal	Wednesday, 4/22/09
GOES- O Launch Readiness Review (LRR)	Monday, 4/27/09
GOES- O Launches with 6:24 p.m. to 7:24 p.m. EDT window	Tuesday, 4/28/09
GOES – O Engineering Handover Review	Friday, 5/22/09
GOES – O Acceptance Review EHD+150 Days	Monday,10/19/09