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Abstract

This report investigates the capability of the new Geostationary Operational Environmental Satellite-16 (GOES-16) satellite to display 16 channels of the electromagnetic spectrum, to produce images at a higher resolution at increased intervals, and to detect and display lightning. This report also discusses the main instrumentation aboard the new geostationary satellite and how it aids in creating accurate data collection, which in turn, produces quicker weather forecasts and warnings. The 16 different channels produced by the Advanced Baseline Imager aboard the new satellite are analyzed in detail as to the functions and wavelengths on which the channels operate. The image resolution and time intervals of the GOES-16 is compared to current geostationary satellites to distinguish the technological improvements fashioned on the new satellite. Lastly, the lightning detection feature of the Geostationary Lightning Mapper on the GOES-16 is examined to understand the benefits that the revolutionary technology places on the meteorological community.
The Capabilities of the Geostationary Operational Environmental Satellite-16 (GOES-16)

The introduction of the Geostationary Operational Environmental Satellites (GOES) in 1975 granted meteorologists and the public a near continuous view of the blue planet which human civilization designates as home. With Earth’s turbulent and hazardous weather systems, meteorologists gain vital information from the geostationary satellites to assist in weather forecasting, which in turn saves lives. By having a continuous imagery access of the world below, meteorologists piece together a greater knowledge of the Earth’s different climate conditions, while also having the ability to peer beyond Earth to study solar activity—space weather (GOES History).

The National Oceanic and Atmospheric Administration (NOAA) in partnership with the National Aeronautics and Space Administration (NASA) has developed, and launched 15 different geostationary satellites since 1975 with the purpose to better understand the Earth’s atmospheric conditions. The first three GOES satellites, GOES 1-3, only viewed the earth ten percent of the time, and it delivered information in two dimensions; while today NOAA operates GOES 13-15 which allows for continuous imagery with an added dimension to detect and pinpoint intense storms. Currently, GOES-13—referred to as GOES East—is positioned at 75 degrees west over the equator, while GOES-15—referred to as GOES West—is positioned at 135 degrees west over the equator. GOES-14 is in “on-orbit storage”, with all GOES 13 through 15 satellites being launched between the years 2006 and 2010 (GOES History). Now more than 40 years since the launch of the first Geostationary Operational Environmental Satellite, NOAA and NASA developed and launched the first next-generation geostationary weather satellite, the GOES-16, on November 19, 2016, thus ushering in a new era of improved weather imagery and data (GOES-16 Mission).
The GOES-16 Satellite

The Geostationary Operational Environmental Satellite-16 (GOES-16) is the first in a new series of GOES satellites to be launched into space. The GOES-R satellite—now referred to as GOES-16—made the leap into space on November 19, 2016 at 6:42pm EST aboard the Atlas V 541 launch vehicle (GOES-16 Spacecraft and Instruments). Currently, GOES-16 is orbiting and undergoing “post-launch checkout and validation” (GOES History), and the new satellite is scheduled to be permanently positioned at 75.2 degrees west—replacing GOES-13—in December of 2017. GOES-16 is designed to remain operational for ten years with an additional five years of on-orbit storage. While in orbit, the new satellite boasts some impressive features and new improvements from previous GOES satellite missions (GOES-16 Spacecraft and Instruments).

The instrumentation aboard GOES-16 varies from imagers to various sensors all of which assist in creating new capabilities and weather products that further the understanding of Earth and space. One of the main instruments on GOES-16 is the Advanced Baseline Imager (ABI), which allows the satellite to view the Earth with 16 spectral bands (GOES-16 Spacecraft and Instruments). The GOES website operated by NOAA and NASA state that the, “ABI improves every product from the previous GOES imager and introduces a host of new products.” (Advanced Baseline Imager). Also, the new and crucial imager allows for, “three times more spectral information, four times the spatial resolution, and more than five times faster temporal coverage than the previous system.” (Advanced Baseline Imager). In addition to the ABI, GOES-16 hosts the Geostationary Lightning Mapper (GLM), the Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS), the Solar Ultraviolet Imager (SUVI), the GOES-16 Magnetometer, and the Space Environment In-Situ Suite (SEISS). (GOES-16 Spacecraft and Instruments).
The Geostationary Lightning Mapper (GLM) is the first lightning mapper on a geostationary satellite and will be able to detect lightning such as in-cloud, cloud-to-cloud, and cloud-to-ground. The GLM will be discussed further in the “Lightning Detection” section. The Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS) detects solar irradiance and will be utilized to monitor solar flares that negatively affect many electrical systems such as power grids, different satellites, and communications. These sensors allow for advanced warnings in hopes to protect various systems. The Solar Ultraviolet Imager (SUVI) much like the EXIS will detect solar anomalies that can negatively impact the Earth and assist in issuing warnings. The SUVI is a telescope that observes the sun and helps further expand the knowledge and data of space weather. The GOES-16 Magnetometer measures the space environment magnetic field in the outer part of the magnetosphere. The charged particles in this magnetic field can pose a threat to spacecraft and humans in space, thus the GOES-16 Magnetometer will help issue warnings to such entities. One of the last major instruments aboard the GOES-16 is the Space Environment In-Situ Suite (SEISS). The SEISS is comprised of four sensors that will “monitor proton, electron, and heavy ion fluxes” which aid in the alerting of radiation hazards to satellites and spacecraft. Overall, NASA outfitted the GOES-16 with advanced instrumentation to passively observe and sense the Earth and the surrounding space—amplifying the satellite’s unique capabilities.

The 16 Channels

The GOES-16 is unlike previous GOES satellites in that the imager aboard the GOES-16—the Advanced Baseline Imager (ABI)—has 16 bands (channels) of spectral coverage, whereas previous imagers only incorporated five bands—a tremendous leap in imaging. The 16 channels on the ABI include two visible channels, four near-infrared channels, and ten infrared...
THE CAPABILITIES OF THE GOES-16

Channels, thus making the ABI produce 65 percent of the GOES-16 mission data (Advanced Baseline Imager). Channels 1 and 2 make-up the visible channels of the ABI. Channel 1 is nicknamed “Blue” Band and it has an approximate central wavelength of 0.47 micrometers. This channel will be utilized to view various aerosols in the atmosphere such as dust, haze, and smoke, which will assist in monitoring air quality. Channel 2 is nicknamed “Red” Channel due to the approximate central wavelength of 0.64 micrometers being closer to the red part of the visible spectrum. The “Red” Channel shares resemblance to the visible channel on the current GOES satellites in that the “Red” Channel’s primary objective is to depict clouds such as fog, low-level clouds, and high-level clouds (ABI Bands Quick Information Guides).

Channels 3-6 on the ABI are designated as the near-infrared bands for GOES-16. Channel 3 has an approximate central wavelength of 0.86 micrometers and will primarily be used to detect daytime cloud cover as well as to calculate a normalized difference vegetation index, thus the nickname of the channel is the “Veggie” Channel. Channel 4 is called the “Cirrus” Channel and has a central wavelength of 1.37 micrometers. This channel detects and is sensitive to high, thin cirrus clouds and the channel will help differentiate high clouds. Channel 5’s primary purpose is for ice and snow discrimination as well as total cloud cover estimation and cloud-top phase. Channel 5 is nicknamed the “Snow/Ice” Channel and has a central wavelength of 1.61 micrometers. The final near-infrared band is Channel 6 of the ABI—“Cloud Particle Size” Channel. This channel’s 2.24 micrometer wavelength will be able to estimate the size of cloud particles, thus the nickname (ABI Bands Quick Information Guides).

The final ten infrared channels of the ABI are Channels 7-16 on GOES-16. Channel 7, “Shortwave Window” Channel, has a central wavelength of 3.9 micrometers and assists in the identification of fires, volcanic ash, low clouds and urban heat islands. Channel 8, “Upper-Level
Water Vapor” infrared, has a wavelength of 6.2 micrometers and will be primarily be used for atmospheric feature detection—such as jet stream identification, hurricane forecasting, and turbulence detection. Channel 9, “Mid-Level Water Vapor” Band, has a central wavelength of 6.9 micrometers, serves the same purpose as Channel 8 except focused on the middle of the troposphere. Channel 10, “Low-Level Water Vapor” Channel, and serves to monitor water vapor features in the mid to low-levels of the troposphere with the central wavelength being 7.3 micrometers (ABI Bands Quick Information Guides).

Continuing with the infrared channels of the ABI, Channel 11, known as “Cloud-Top Phase” Channel, has a wavelength of 8.4 micrometers, and detects cloud phase and type as well as sulfur dioxide in the atmosphere. Channel 12, “Ozone” infrared, will provide atmospheric dynamics near the tropopause and can give indications of clear-air turbulence. Channel 13, “Clean” longwave infrared window band, will improve atmospheric moisture corrections as well as cloud particle size estimation due to this channel being less sensitive to water vapor with a wavelength of 10.3 micrometers. Channel 14, known as the longwave infrared window band, has a central wavelength of 11.2 micrometers, and helps determine cloud features for forecasting and analysis. Channel 15, “Dirty” longwave infrared window channel, can distinguish differences with other longwave infrared windows in low-level moisture estimations and air particulates with a central wavelength of 12.3 micrometers. The last channel of the ABI is Channel 16, known as the “Carbon Dioxide” longwave infrared band, which is used for mean air temperature estimation and cloud differentiation by having a central wavelength of 13.3 micrometers. The GOES-16 utilizes three times as many channels compared to previous GOES satellites for better data accumulation, which in turn leads to improved forecasting and knowledge of the atmosphere (ABI Bands Quick Information Guides).
Higher Resolution and Intervals

The scholarly journal *Satellite Today* writes that GOES-16 is, “already providing valuable imagery around current hurricanes, such as Harvey and Irma,” and that GOES-16 is, “becoming an even more critical asset for weather forecasting.” (Materion's optical filters to improve weather forecasting on GOES 16). The technological improvements of the imager aboard GOES-16 has allowed for improved image resolution and quicker scan intervals, which supersede previous GOES satellites by drastic amounts. The comparison of visible spatial resolution between the current GOES satellites and the new GOES-16 is approximately 1 kilometers to 0.5 kilometers respectfully. The infrared spatial resolution between the current GOES satellites and GOES-16 is 4 kilometers to 2 kilometers respectfully. Since the new geostationary satellite’s imager produces images with double the resolution than previous satellites, meteorologists can better differentiate cloud features and interpolate larger amounts of data (Advanced Baseline Imager).

Not only is the image quality improved, but meteorologists also receive the images faster than with previous technology. For instance, GOES-16 can produce a Western Hemisphere image every fifteen minutes and an image of the United States every five minutes; whereas current satellites are scheduled to produce full disk images three times an hour and images of the United States every 15 minutes. Also, GOES-16 can produce mesoscale images at a faster rate than current GOES imagers. The journal *Satellite Today* states that GOES-16 can update meteorologist with, “critical information about severe weather events…, as fast as 30 seconds, five times faster than previous technology.” (NOAA releases first GOES 16 image). Overall, the capability of GOES-16 to produce high resolution images at quicker intervals is remarkable, and on January 23, 2017 GOES-16 released the first images from the ABI—22,300 miles above the
Earth (NOAA releases first GOES 16 image). The images produced by GOES-16 are breathtaking as seen in figures 1 and 2 below, which can be found on www.goes-r.gov. (Images: Data and Imagery).

*Figure 1. (Images: Data and Imagery)*
Figure 2. (Images: Data and Imagery)

**Lightning Detection**

The GOES-16 lightning detection capability is the first for GOES satellites, and NOAA reports that the new Geostationary Lightning Mapper (GLM) gives, “National Weather Service forecasters richer information about lightning that will help them alert the public to dangerous weather.” (Flashy First Images Arrive from NOAA’s GOES-16 Lightning Mapper). Per the GOES-16 website, the GLM is a, “single-channel, near-infrared optical transient detector that can detect the momentary changes in an optical scene, indicating the presence of lightning.” (Instruments: Geostationary Lightning Mapper). Basically, the GLM is constantly looking for lightning flashes, and differentiates types of lightning such as in-cloud, cloud-to-cloud, and cloud-to-ground. The GLM also records the frequency of lightning, and the location of the
discharge, which can be utilized to determine the stages of thunderstorm development (Instruments: Geostationary Lightning Mapper).

The GLM improves safety around the world by allowing for greater coverage and quicker issuance of weather hazard warnings. Currently, thunderstorms that develop over the ocean pose a threat to aviation and maritime travel due to the lack of lightning detection. With the GLM, detection over the Pacific becomes more accurate, thus creating precise weather products and making travel safer over distant waters. Also, with the lightning detection equipment, GOES-16 can detect an increase in lightning activity, which could lead to severe weather hazards such as tornadoes and flash floods caused by severe thunderstorms. With this new advanced notice, meteorologist will be able to issue warnings quicker to the affected areas, hence increasing safety. In addition, lightning is a main ignition source for wildfires, thus the GLM will aid the firefighters in determining possible areas that are under threat of possible fire (Flashy First Images Arrive from NOAA’s GOES-16 Lightning Mapper). Overall, the addition of the new GLM to GOES-16 provides meteorologists and the public with revolutionary data, which will ultimately increase safety around the Earth (Instruments: Geostationary Lightning Mapper).

**Conclusion**

The Geostationary Operational Environmental Satellite-16 presents the public with new views of the Earth’s weather and atmosphere—accelerating the knowledge of the world humans deem home. The added components and instruments of GOES-16 places the new series of GOES satellites above and beyond the current geostationary satellites. With the capability of displaying a greater number of channels, at a higher resolution with greater frequency, and the added lightning detection, GOES-16 is proving to be a “game changer” when it comes to data collection and interpolation—forging a safer world (GOES-16 Mission).
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