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# **Geostationary Operational Environmental Satellite- R Series (GOES-R) 2016**

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## ABSTRACT

This is a report on the first NOAA GOES-R satellite, launched on November 19<sup>th</sup>, 2016. This report will cover some of the details of the GOES-R project, as well as discuss the collaborations that made the project possible. This document will also detail some of the new satellite's capabilities including geostationary lightning detection, and space weather monitoring, and will focus on real-world application of such technology. Additionally, this report will list some of the current and projected GOES-R products, and the potential benefits if testing proves successful.

# 1. Introduction

The National Oceanic and Atmospheric Administration better known as NOAA, in collaboration with the National Aeronautics and Space Administration or NASA launched the first of the R-series GOES satellites into orbit on 19 November, of this year. The purpose of the GOES-R series was to provide “the nation’s next generation of geostationary weather satellites.” ([www.goes-r.gov](http://www.goes-r.gov)) This series would encompass four main enhancements in comparison to previous editions in the GOES family: better and faster data and imagery, lightning detection, space weather reporting, and search and rescue possibilities.

## 2. General Information

The first GOES-R satellite was successfully launched from Space Launch Complex 41 at Cape Canaveral Air Force Station, Florida on an Atlas V541 rocket on November 19<sup>th</sup>, 2016 at 6:42pm EST. The satellite which reached its orbit at about 22,300 miles (or about 36,000 km) above the earth on 29 November, 2016 and will now be referred to as GOES-16. GOES-R will be initially placed in a checkout location of 89.5°W.

### *a. Overview*

This satellite is the first in a series of four (-R, -S, -T, -U) satellites that will extend NOAA’s geostationary coverage until at least 2036. The name, GOES-R, stands for Geostationary Operational Environmental Satellite-R Series, and is soon to be the 16<sup>th</sup> operational geostationary weather satellite since the first GOES launched in 1975. The GOES-R project was given a lifecycle budget of \$10.83B spanning more than 30 years to

encompass the development, and operation of each of the four satellites. The budget was also to include all instruments, work in the ground segment, construction of a backup satellite station in West Virginia and upgrades to the existing NOAA Satellite Operations Facility (NSOF) in Maryland. Approximately \$6.1B had already been spent by the close of FY2015 (Bichell (2016)).

*b. Flight and Ground Segment Projects*

The GOES-R Program Office is located at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and is primarily managed by NOAA personnel. The program is also further broken down into two integrated (NOAA-NASA) project offices: the Flight Project and the Ground Segment Project. “The Flight Project oversees the development of the space segment of the mission, which consists of the spacecraft, the instruments, the launch vehicle, and the auxiliary communication payloads,”(GOES-R MISSION NOAA/NASA). The Ground Segment Project Office, on the other hand, handles various other things such as ground-based facilities (antenna sites), the software and hardware for command and control, data processing, and end-product distribution. The ground system will operate out of two primary locations, including the NSOF in Suitland, Maryland and the Wallops Command Data Acquisition Center (WCDAS) in Wallops, Virginia. The most notable function will be the generation of Level 1b and Level 2+ products for public dissemination. (See Table 1.)

### **3. Capabilities**

“GOES-R’s instruments will be capable of scanning the planet five times faster and with four times more resolution than any other satellite in our fleet. With these new

instruments and powerful new capabilities, GOES-R will strengthen NOAA's ability to issue life-saving forecasts and warnings and make the United States an even stronger, more resilient Weather-Ready Nation," declared NOAA Administrator Dr. Kathryn Sullivan. The GOES-R satellite will remarkably be introducing 6 new instruments, including the first operational geostationary lightning mapper, which will result in "34 new, or improved, meteorological, solar, and space weather products," (Barclay and Leslie (2016)).

*a. Enhanced Resolution and Data Capability*

One of the notable upgrades of this GOES model is its enhanced ability to provide high-resolution and timely imagery. Current editions of GOES satellites only produce imagery about every 30 minutes or so, leaving unmonitored gaps in rapidly developing weather phenomena. GOES-R will be able to provide new satellite imagery as frequently as every 30 seconds, which will enable forecasters to better monitor rapidly developing thunderstorms, and issues quicker warnings. The Advanced Baseline Imager, or ABI "will collect three times more data, provide four times better resolution and more than five times faster coverage than current GOES,"(Bichell (2016)). Some of the products GOES-R will provide include Cloud Top Height, Cloud Top Temperature, Derived Motion Winds, Derived Stability Indices, Radiances, Rainfall Rate, Sea Surface Temperature, and Snow Cover (GOES-R MISSION NOAA/NASA). (See Figure 1.) Additionally, the ABI will have 16 bands comprised of 2 visible, 4 near-infrared, and 10 infrared channels. NOAA made the comparison that these new images will be akin to "going from black-and-white TV to high definition overnight,"( Meyers (2016)).

*b. Geostationary Lightning Mapper (GLM)*

The GLM or Geostationary Lightning Mapper is GOES-R's most notable new feature. The GLM detects lightning on earth by using a high-speed camera which can sense rapid increases in light levels on a pixel-size scale. Lightning detection is important in meteorology because increased lightning activity almost always accompanies severe weather. The intent is that forecasters will be able to utilize this information compared with ground-based lightning systems (which detect cloud-to-ground lightning with a much higher accuracy than in-cloud lightning) to build a complete description of the lightning activity. By doing this, forecasters will be better able to detect potential (or ongoing) thunderstorms and issue more advanced warnings and maximize safety. This GLM can detect both in-cloud, and cloud-to-ground lightning and GOES-R will be the first satellite to carry an operational GLM in space.

*c. Space Weather Reporting*

Yet another impressive capability of the new GOES-R satellite is space weather monitoring. According to Rodney Vierick, a physicist with NOAA's Space Weather Prediction Center, there are 3 types of space weather: photons, protons, and plasma. Vierick notes that proton radiation (which takes roughly half an hour to reach the earth) "may be the biggest challenge... to humans." Solar flares, however small they may appear from the earth's surface can actually have a huge impact here at home. When fluxes in radiation (such as that spewed from a solar flare) reach the earth's atmosphere, they can have devastating consequences. "It's a billion tons of material traveling a million miles an hour," said Vierick. Potential consequences include lost communications, bends in radio frequency signals or even skewed GPS locations, and anything that falls within the electrical grid is potential victim. A massive solar storm in

1859 left enough electricity in the air to set telegraph offices from Cuba to India on fire. Extreme radiation can also reduce the lifetime of Low Earth Orbiting (LEO) satellites by depositing large amounts of energy into the upper atmosphere, and causing increased drag (GOES-R MISSION NOAA/NASA). Because of this, GOES-R will provide solar flux monitoring which will aid in protecting these important communication and navigation systems by giving increased notice of potential solar storms, and provide crucial information regarding satellite orbit.

#### *d. Search and Rescue Provisions*

All previous editions of GOES since GOES-I have included a Search and Rescue subsystem to detect distress signals broadcast on Emergency Locator Transmitters or more commonly, transponders. These transponders are often carried on general aviation aircraft, aboard marine vessels, and sometimes by individuals such as hikers and climbers. “A dedicated transponder on each GOES detects and relays signals to a Search and Rescue Satellite-Aided Tracking (SARSAT) ground station. The difference is the GOES-R’s transponder can operate at lower uplink powers than its predecessors, making it able to detect even weaker beacon signals. The information will be routed through a Rescue Coordination center and help will then be dispatched to the location of the distress call. SARSAT is an international program which has helped to save more than 39,000 lives worldwide, since its implementation in 1982.

## **4. Collaborations**

### *a. “Group Effort”*

Not surprisingly, the GOES-R project was not a single-group accomplishment. In fact, numerous organizations had a hand in the development and launch of the GOES-R



program. A team at Lockheed-Martin based outside of Denver and headed by Tim Gasparrini, was responsible for the design, creation, and testing of both the satellites and spacecraft. The team was also responsible for developing the Geostationary Lightning Mapper and Solar Ultraviolet Imager instruments. When asked of the project, Gasparrini had this to say, “In the first six months of operation for GOES-R, it will return more data than all of the previous geostationary satellites of the U.S. combined. Think of it as a quantum leap for weather forecasting.” The Harris Corporation played a huge role in mission success as they provided the ABI, GOES-R’s primary antenna system, and instrument source. Others played a role in providing smaller aspects such as sensors. The Laboratory for Atmospheric and Space Physics supplied the Extreme Ultra-violet and X-Ray Irradiance Sensor, while Assurance Technology procured the Space Environment In-Situ Suite (Barclay and Leslie (2016)).

*b. The Proving Ground*

The Proving Ground was established to simulate GOES-R products so that they could be tested and evaluated before its launch. These products would be generated by combining currently available GOES data with higher resolution data provided by instruments on polar-orbiting satellites and by synthetic modeled data. The official website for the NOAA/NASA GOES-R states that the Proving Ground is a “collaborative effort between the GOES-R Program Office, NOAA Cooperative Institutes, a NASA center, NWS Weather Forecast Offices, NCEP National Centers, and NOAA testbeds across the country. Some of the goals of the Proving Ground include, “training forecasters to use new products, identifying different utilities of each product, identifying weaknesses or errors with each product, and user-feedback development,”( GOES-R MISSION NOAA/NASA).

*c. Improvements since GOES-1*

Early GOES satellites (A-C) in the mid 1970s were spin-stabilized and this allowed the optical lens to only view the earth about 10% of time. Furthermore, these satellites only had reporting capabilities in two dimensions. At the time, GOES were unable to detect cloud thickness, moisture content or even temperature variation in the vertical direction, all common products used in meteorology today. It was not until 1980s that these satellites possessed the capability to provide vertical profiles, which gave forecasters a more accurate image of intensity, and thus the extent of storms, however these satellites were still spin-stabilized and resolution was poor. It was not until 1994, when GOES-I was released and three-axis stabilization was implemented that satellite imagery saw a giant leap in quality. This technology also contained separate optics for imaging and sounding, which meant that both could run simultaneously. The satellites could also now temporarily suspend their normal scans, and concentrate on smaller areas where rapidly developing storms may be occurring, which improved short-term forecasting. GOES-R will mark the first big technological advances since the launch of GOES-I. GOES-R will have more spectral channels, higher resolution, and provide substantially faster coverage than any of the former GOES satellites. It will also include a GLM, and improved monitoring of solar fluxes, making it a ‘quantum leap forward for weather forecasting’ and a universally powerful means of data-reporting.

# 5. Figures and Tables

Table 1.

(GOES-R MISSION NOAA/NASA)

Figure 1.

BASELINE PRODUCTS	FUTURE PRODUCTS
<p><b>Advanced Baseline Imager (ABI)</b></p> <ul style="list-style-type: none"> <li>• Aerosol Detection (Including Smoke and Dust)</li> <li>• Aerosol Optical Depth (AOD)</li> <li>• Clear Sky Masks</li> <li>• Cloud and Moisture Imagery</li> <li>• Cloud Optical Depth</li> <li>• Cloud Particle Size Distribution</li> <li>• Cloud Top Height</li> <li>• Cloud Top Phase</li> <li>• Cloud Top Pressure</li> <li>• Cloud Top Temperature</li> <li>• Derived Motion Winds</li> <li>• Derived Stability Indices</li> <li>• Downward Shortwave Radiation: Surface</li> <li>• Fire/Hot Spot Characterization</li> <li>• Hurricane Intensity Estimation</li> <li>• Land Surface Temperature (Skin)</li> <li>• Legacy Vertical Moisture Profile</li> <li>• Legacy Vertical Temperature Profile</li> <li>• Radiances</li> <li>• Rainfall Rate / QPE</li> <li>• Reflected Shortwave Radiation: TOA</li> <li>• Sea Surface Temperature (Skin)</li> <li>• Snow Cover</li> <li>• Total Precipitable Water</li> <li>• Volcanic Ash: Detection and Height</li> </ul> <p><b>Geostationary Lightning Mapper (GLM)</b></p> <ul style="list-style-type: none"> <li>• Lightning Detection: Events, Groups &amp; Flashes</li> </ul> <p><b>Space Environment In-Situ Suite (SEISS)</b></p> <ul style="list-style-type: none"> <li>• Energetic Heavy Ions</li> <li>• Magnetospheric Electrons &amp; Protons: Low Energy</li> <li>• Magnetospheric Electrons &amp; Protons: Med &amp; High Energy</li> <li>• Solar &amp; Galactic Protons</li> </ul> <p><b>Magnetometer (MAG)</b></p> <ul style="list-style-type: none"> <li>• Geomagnetic Field</li> </ul> <p><b>Extreme Ultraviolet and X-ray Irradiance Suite (EXIS)</b></p> <ul style="list-style-type: none"> <li>• Solar Flux: EUV</li> <li>• Solar Flux: X-ray Irradiance</li> </ul> <p><b>Solar Ultraviolet Imager (SUVI)</b></p> <ul style="list-style-type: none"> <li>• Solar EUV Imagery</li> </ul>	<ul style="list-style-type: none"> <li>• Absorbed Shortwave Radiation: Surface</li> <li>• Aerosol Particle Size</li> <li>• Aircraft Icing Threat</li> <li>• Cloud Ice Water Path</li> <li>• Cloud Layers/Heights</li> <li>• Cloud Liquid Water</li> <li>• Cloud Type</li> <li>• Convective Initiation</li> <li>• Currents</li> <li>• Currents: Offshore</li> <li>• Downward Longwave Radiation: Surface</li> <li>• Enhanced "V" / Overshooting Top Detection</li> <li>• Flood/Standing Water</li> <li>• Ice Cover</li> <li>• Low Cloud and Fog</li> <li>• Ozone Total</li> <li>• Probability of Rainfall</li> <li>• Rainfall Potential</li> <li>• Sea and Lake Ice: Age</li> <li>• Sea and Lake Ice: Concentration</li> <li>• Sea and Lake Ice: Motion</li> <li>• Snow Depth (Over Plains)</li> <li>• SO<sub>2</sub> Detection</li> <li>• Surface Albedo</li> <li>• Surface Emissivity</li> <li>• Tropopause Folding Turbulence Prediction</li> <li>• Upward Longwave Radiation: Surface</li> <li>• Upward Longwave Radiation: TOA</li> <li>• Vegetation Fraction: Green</li> <li>• Vegetation Index</li> <li>• Visibility</li> </ul>

(GOES-R MISSION NOAA/NASA)

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