

James J. Gurka
NOAA/ NESDIS, Office of Systems Development,
Silver Spring, Maryland, U.S.A.

Timothy J. Schmit
NOAA/ NESDIS, Office of Research and Applications,
Madison, Wisconsin, U.S.A.

1. GOES-R SATELLITE ARCHITECTURE: NOTIONAL BASELINE

In order to meet the requirements, documented by the GOES user communities, the instruments designated for the GOES-R notional baseline include an Advanced Baseline Imager (ABI), a Hyperspectral Environmental Suite (HES), a Lightning Mapper, and advanced space and solar observing instruments. These instruments will first be launched in 2012.

The Advanced Baseline Imager is a state of the art, 16-channel imager covering 6 visible to near-IR bands (0.47, 0.64, 0.86, 1.38, 1.61, and 2.26 μm), and 10 infrared (IR) bands (3.90 μm to 13.3 μm). Spatial resolutions are band dependent, 0.5 km at nadir for broadband visible, 1.0 km for near IR and 2.0 km for IR. The ABI will scan the Full Disk (FD) in approximately 5 minutes.

The HES is a multi channel imager and sounder instrument suite with three threshold tasks. HES will provide high-spectral resolution Hemispheric Disk Soundings (DS) and Severe Weather Mesoscale (SW/M) soundings and Coastal Waters (CW) imaging. HES DS provides 10 km IR resolution from 3.7 μm to 15.4 μm with a one-hour refresh rate of the full disk, 62° local zenith angle. SW/M will cover a 1000 x 1000 km square in 4 minutes, at 4 km resolution for IR. HES CW task will provide at least 14 channels covering 0.4 μm to 1.0 μm , with a 300 m resolution and a 3-hour refresh rate. Coastal Waters are defined as the 400 km zone adjacent to CONUS.

Additional capabilities include an improved Space Environment Monitor, a Solar X-Ray Imager, and direct user services, such as Search and Rescue (SAR), and a Data Collection System (DCS). This paper will focus on the planned instrument capabilities of the GOES-R Series, the space system architecture, and how the new capabilities

will complement the future Global Observing System to meet the documented user needs.

The present notional baseline for the GOES-R series calls for a distributed architecture, with two satellites (A-Sat and B-Sat) in the eastern slot (approximately 75 deg. West) and two in the west (approximately 135 deg. West). Each A-Sat will host an ABI, a Solar Imaging Suite (SIS), a GOES Lightning Mapper (GLM), and services, including Data Collection System (DCS), Search and Rescue (SAR), Low Rate Information Transmission (LRIT), and Emergency Managers Information Network (EMWIN). Each B-Sat will host a HES, a Space Environmental In-Situ Suite (SEISS) and services. The current schedule is shown in Figure 1.

More information on GOES-R is available from the Third GOES-R Users' Conference, that was held in Broomfield Colorado from May 10 to 13, 2004, with approximately 340 participants from government, the private sector, academia and the international community. The goals of the conference were: (1) to inform GOES users on the status for the GOES-R constellation, instruments and operations; (2) to refine potential user applications for data and products from the GOES-R series; (3) to seek ways to help the user communities prepare for GOES-R; (4) to address user and societal benefits of the GOES-R series as an integral part of the Global Observing System; and (5) to continue to improve communication between NOAA and the GOES User communities. These goals were well realized, because many recommendations were made that NOAA will consider as it approaches deployment of the new series.

More information can also be found at:
The GOES-R Users Conference.

<ftp://ftp.osd.noaa.gov/Goes-R/>

NASA Goddard page:

http://goes2.gsfc.nasa.gov/goesr_industry.htm

* Corresponding author address: James J. Gurka,
Office of Systems Development, Silver Spring,
Maryland; email: James.Gurka@noaa.gov

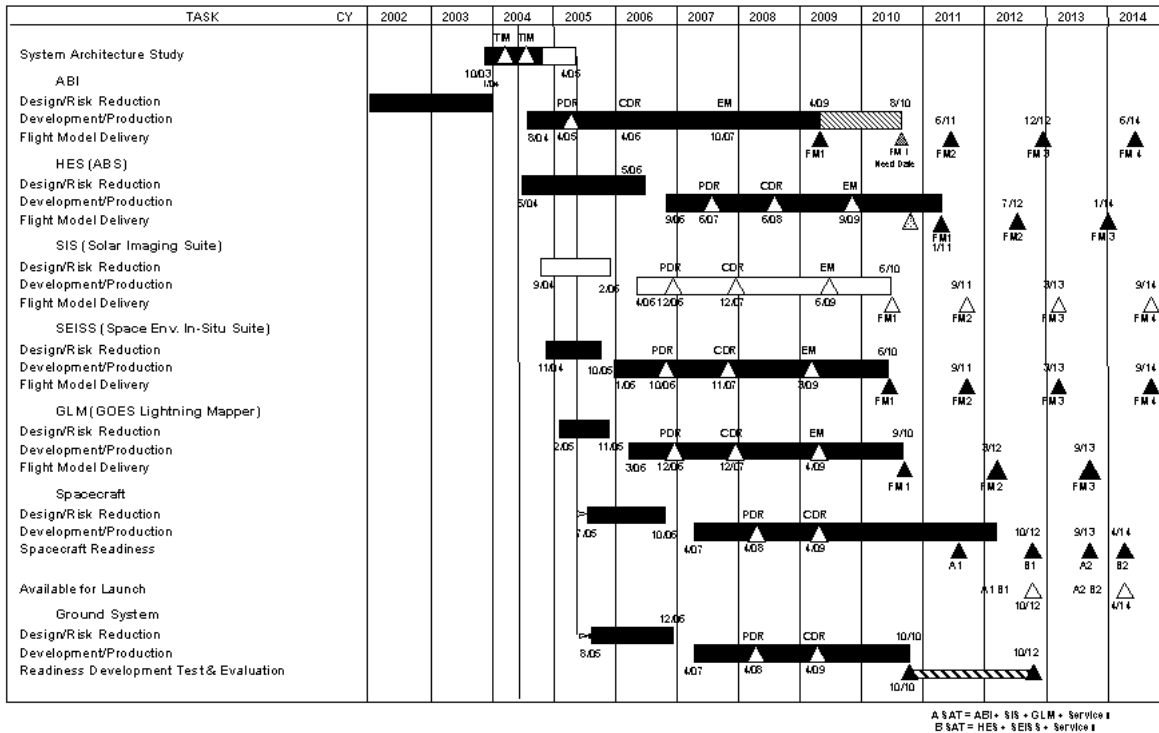


Figure 1. Current GOES-R program schedule.

2. ADVANCED BASELINE IMAGER (ABI)

The ABI represents an exciting expansion in geostationary remote sensing capabilities. The ABI addresses the needs of the GOES user communities by increasing spatial resolution (to better depict a wider range of phenomena), by scanning faster (to improve temporal sampling and to scan additional regions) and by adding spectral bands (to enable new and improved products). Every product that is being produced from the current GOES Imager will be improved with data from the ABI (Schmit et al, 2004, Schmit et al, 2005). The ABI will improve the spatial resolution from nominally 4 to 2 km for the infrared bands and 1 to 0.5 km for the 0.6 μ m band, 2 km for the 1.38 μ m, and 1 km for the other visible/near-IR bands. There will be a five-fold increase of the coverage rate. The ABI expands the spectral band number to 16; five are similar to the 0.6, 4, 11, and 12 μ m windows and the 6.5 μ m water vapor band on the current GOES-8/11 imagers. The additional bands are a visible band at 0.47 μ m for aerosol detection and visibility

estimation, a visible band at 0.86 μ m for the detection of aerosols and vegetation; a near-infrared band at 1.38 μ m to detect very thin cirrus clouds; a snow/cloud-discriminating 1.6 μ m band; the 2.26 μ m band will be used for particle size, vegetation and cloud properties/screening, hot spot detection, and moisture determinations; mid-tropospheric water vapor absorption bands centered at approximately 7.0 and 7.34 μ m to track atmospheric motions; an 8.5 μ m band to detect volcanic dust clouds containing sulfuric acid aerosols and cloud phase; the 9.6 μ m band for monitoring total column ozone; the 10.35 μ m band to derive low-level moisture and cloud particle size; and the 13.3 μ m band useful for determining cloud top heights and effective cloud amounts. The channel selection for the ABI is a balance of heritage with existing GOES bands (on the imager and sounder), consistency with bands on other satellites (both in geostationary and polar-orbits) and the relationship between which information will be derived from the advanced high-spectral resolution sounder. A comparison of some current versus future imager attributes are listed in Table 1.

Table 1. Comparison of the current and future geostationary imagers. It should be noted that the instrument noise values for ABI are specifications, while those from the GOES Imager are on-orbit measurements.

Parameter	Current GOES Imager	Future GOES Imager	Comments
Number of Visible bands	1	3	Cloud cover, plant health and surface features during the day, etc.
Number of Near IR bands	0	3	Cirrus clouds, Low cloud/fog and fire detection, etc.
Number of Infrared bands	4	10	Upper-level water vapor, clouds, SO ₂ , SST, etc.
Coverage Rate	25 minutes for full disk	15 minutes for full disk, plus CONUS images every 5 minutes	ABI is approximately five times faster
Noise (at 300K) in the IR window	0.15K	0.10K	No correction has been made for the larger FOV of the current GOES imager compared to that of the ABI
Spatial resolutions of the 0.6 um visible band	Approximately 1 km	0.5 km	At the sub-satellite point
Spatial resolutions of the infrared bands	Approximately 4-8 km	2 km	At the sub-satellite point
Low-light capabilities	No	Yes	

3. HYPERSPECTRAL ENVIRONMENTAL SUITE (HES)

The Hyperspectral Environmental Suite will consist of either a single instrument or multiple instruments that can perform at least three tasks. These tasks include disk sounding (DS), Severe Weather/ mesoscale (sounding), and coastal waters imaging. In the disk sounding mode, the HES will have the capability to provide hourly coverage of the area within 62 deg. of the satellite local zenith angle with a 10 km footprint. In the severe weather/ mesoscale task, HES can provide coverage of a 1000 km by 1000 km area every 4 minutes, with a 4 km footprint. For more information on HES Soundings, see Li et.al, 2004.

The coastal waters imaging function will be capable of providing coverage of the coastal zone within 400 km of the continental U.S. coast every 3 hours with a footprint size of 300 m. HES will be

able to provide coastal waters imaging simultaneously with either the DS task or the SW/M, but will not be able to perform the DS and SW/M at the same time.

In each of the three tasks, HES will have the flexibility to provide coverage as described above or to look at smaller areas at more frequent intervals. It will also have the flexibility to change between DS and SW/M tasks, and to change coverage areas almost instantaneously. Furthermore, while the coverage capacity is defined by the 62 degrees from local zenith angle within one hour, the HES will be capable of providing useful soundings out to at least 65 degrees from local zenith.

The HES atmospheric sounding function will provide observations in clear skies approaching radiosonde quality. It will be capable of: 1) providing an accurate three-dimensional picture of atmospheric water vapor: 2) determining atmospheric motions much better by

discriminating more levels of motion and assigning heights more accurately; 3) distinguishing between ice and water cloud and identifying cloud particle size; 4) providing a 4 km field of view for better viewing between clouds and near cloud edges; 5) providing accurate land and sea surface temperatures and characteristics by accounting for emissivity effects; 6) distinguishing atmospheric constituents with improved certainty, including volcanic ash, ozone, and possibly methane; and 7) detecting atmospheric inversions.

The GOES-R Sounder will be a very flexible instrument that can provide routine coverage of the near full disk every hour with 10 km horizontal resolution (disk sounding mode), or provide more frequent coverage of smaller areas (1000 x 1000 km in 4 minutes) with 4 km horizontal resolution. The latter will be used when there is the potential for explosive development of severe thunderstorms, hurricanes, or severe winter storms. It can also be used in over areas where the numerical models have low confidence (targeted observations). The GOES-R sounder products will provide valuable information for Nowcasting in the forecast offices and for input into numerical models. In the 2012 time frame, the horizontal resolution of numerical models will be approaching 1 km globally with continuous data assimilation. GOES-R sounders will be the only source of temperature and moisture profiles that will meet the temporal and spatial resolution requirements of future NWS global, regional and mesoscale numerical forecast models. The HES-IR will be able to provide higher spectral resolution observations (on the order of 1 cm^{-1} , compared to 20 cm^{-1} on today's broadband sounders) with spatial resolutions of between 4 and 10 km. More details are listed in Table 2. Following are examples of HES sounder capabilities and applications that offer distinct advantages over the present filter-wheel GOES Sounders.

Spatial Coverage: Due to a 5 times faster coverage rate, the HES will allow MUCH improved spatial coverage. The current GOES sounder only scans the CONUS and some surrounding oceans, while GOES-R will be able to cover the land and ocean regions within 62 degrees of satellite sub-point in one hour.

Vertical moisture information: Due to its high spectral resolution, the HES will provide a three dimensional picture of water vapor as never before from geostationary orbit.

Nowcasting: The HES together with improved numerical models, will improve the nowcasting (forecasts out to a few hours) applications due to its improved detection of atmospheric moisture and stability.

Numerical Weather Prediction: Global and regional numerical models will use HES data due to its improved vertical resolution and better spatial coverage. Improved surface emissivity will lead to more radiances assimilated over land.

Clouds. Simulations and real data have shown that cloud-top properties are improved with high spectral data. This is especially the case for thin clouds. The HES will be able to distinguish between ice and water cloud-tops and identify cloud particle sizes.

Winds. By tracking retrieved profiles, HES will provide improved analyses of winds by discriminating more levels of motion and assigning heights more accurately. The current Sounder provides relatively coarse vertical resolution.

Aerosols, CO and trace gases. The current GOES has no skill for determining CO. HES will be able to distinguish atmospheric constituents with improved certainty; these include volcanic ash, ozone, and possibly methane plus other trace gases. Simulations have also shown improved ozone detection from high-spectral resolution measurements. The high spectral measurements may also allow a few vertical layers to be retrieved (the current sounder can only retrieve the total ozone amount).

Climate. With proper spectral coverage, a geo-HES can be used as an inter-calibrator to inter-compare various instruments. The current sounder cannot be used due to its low spectral resolution and poor spatial coverage.

Table 2. Comparison of the current and future geostationary sounders.

Parameter	Current GOES Sounder	Future GOES Sounder	Comments
Number of Visible bands	1	1	Cloud cover
Number of Infrared bands	18	Approximately 1500	Moisture and temperature retrievals, cloud-top information, ozone, etc.
Coverage Rate	40 minutes for CONUS	60 minutes for full sounding disk	GOES-R is approximately five times faster
Temperature Accuracy	2 K	1 K	
Relative Humidity Accuracy	20%	10%	
Vertical Resolution	Approximately 3 km	1 km	
Spatial resolutions of the infrared bands	Approximately 8-10 km	Approximately 4-8 km	At the sub-satellite point

While the ABI represents an exciting expansion in geostationary remote sensing capabilities, it will not be operating alone. Where appropriate, the ABI will be used in concert with the GOES-R high-spectral resolution sounder, the HES (Hyperspectral Environmental Suite). The ABI high spatial resolution data will help flag sub-pixel clouds in the HES infrared measurements (Li et al, 2004a), while the high spectral resolution HES measurements will offer an improved surface emissivity for determining skin temperatures from ABI data as well improved cloud heights estimates, especially for thin clouds (Li et al., 2004b).

A Cost Benefit Analysis study showed combined annual marginal economic benefits from ABI and HES are greater than \$500 M annually (in 2002 dollars). This is projected when considering a few key representative economic sectors (agriculture, aviation, electric power and natural gas generation, recreational boating, and trucking). The cost benefit study is on-line at: http://www.osd.noaa.gov/goes_R/docs/GOES-R_CBA_Final_Jan_9_2003.pdf.

4. GOES LIGHTNING MAPPER (GLM)

The GLM will provide information to identify growing, active, and potentially destructive thunderstorms over land as well as ocean areas.

Two primary advantages of the proposed lightning mapper on GOES over ground based systems, is that it will be able to detect total lightning flash rate (cloud to cloud and cloud to ground) rather than just cloud to ground flashes, and it will be able to detect lightning over ocean rather than just over land. Research (Goodman et.al. 1988; Williams et.al. 1989) indicates that GLM measurements could provide vital information to help the operational weather, aviation, disaster preparedness, or fire communities in a number of areas: 1) improvement in tornado and severe thunderstorm lead times and false alarm reduction; 2) more reliable warning of lightning ground strike hazards; 3) improvements in the initialization of numerical weather prediction models by better identification of deep convection; 4) improved routing of commercial, military, and private aircraft over oceanic regions where observations of thunderstorm intensity are scarce; 5) improved ability to monitor intensification or de-intensification of storms during radar outages, or where radar coverage is poor, such as in mountainous areas; 6) better short range forecasts of heavy rainfall and flash flooding; 7) ability to monitor the intensification of tropical cyclones, which is often accompanied by increased eyewall lightning activity; and 10) updates of lightning climatology within the GOES field of view.

5. SUMMARY

The great amount of information from the GOES-R series will both offer a continuation of current product and services, but also allow for improved or new capabilities. These products, based on validated requirements, will cover a wide range of phenomena. This includes applications relating to: weather, climate, ocean, coastal zones, land, hazards, solar and space. The geostationary perspective offers a rapid refresh rate and constant viewing angles. The Advanced Baseline Imager (ABI), the Hyperspectral Environmental Suite (HES), the Geo Lightning Mapper (GLM), the space and solar instrument suites (Solar Imaging Suite (SIS) and the Space Environment In-Situ Suite (SEISS) on GOES-R will enable much improved monitoring compared to current capabilities.

6. ACKNOWLEDGEMENTS

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