Next Generation Geostationary Operational Environmental Satellite (GOES-R Series): A Space Segment Overview

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ABSTRACT

The next-generation National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES-R series) is currently being developed by NOAA in partnership with the National Aeronautics and Space Administration (NASA). The GOES-R series satellites represents a significant improvement in spatial, temporal, and spectral observations (several orders of magnitude) over the capabilities of the currently operational GOES-I/M series and GOES-N series satellite to be launched at the end of 2004.

The GOES-R series will incorporate technically advanced "third-generation" instruments and spacecraft enhancements to meet evolving observational requirements of forecasting for the era 2012-2025. The GOES-R instrument complement being developed includes an Advanced Baseline Imager (ABI), a Hyperspectral Environmental Suite (HES), a GEO Lightning Mapper (GLM), a Solar Imaging Suite (SIS) and a Space Environment In-Situ Suite (SEISS). Also, candidates for a number of GOES-R Pre-Planned Product Improvements (P^3Is) includes a Geo Microwave Sounder, a Coronagraph, a Hyperspectral Imager, and a Solar Irradiance Sensor.

Currently, the GOES-R space segment architecture is being evaluated as part of a GOES-R system End-to-End Architecture Study. The GOES-R notional baseline architecture is a constellation of two satellites (A-sat and B-sat) each nominally located at 75 degrees West longitude and at 135 degrees West longitude at geostationary altitude, 0 degrees inclination. The primary mission of the A-sat is to provide imaging from the ABI. The A-sat will also contain the SIS and the GLM. The primary mission of the B-sat is to provide sounding of the hemispherical disk of the earth from the HES. The B-sat also contains the SEISS. Both satellites have mesoscale capabilities for severe weather sounding or imaging.

This paper overviews the GOES-R Space Segment development including satellite constellation trade-off, improvements and differences between the current and future instrument and spacecraft capabilities, and technology infusion.

Keywords: GOES-R, ABI, HES, GLM, SIS, SEISS

1. INTRODUCTION

The GOES-R series era requirements for climatic, synoptic and mesoscale imaging and sounding data to support global forecasts and local warnings have evolved from the requirements of the current GOES-I/M series and GOES N series of satellites. The NOAA's National Weather Service (NWS) top priority requirements for the GOES-R series are for continuous, multi-spectral scale imagery data availability with improvements in temporal and spatial resolutions of the imagery and sounding data. In addition NWS require full coverage of weather events, i.e. the ability to obtain soundings through clouds where the current infrared capabilities are limited, and information on instantaneous rainfall rates. Lightning and low-light data are also required to aid forecasters in potential convection analyses, severe weather prediction and to discern fog and storm outflow boundaries respectively. The ocean and hazard support communities require higher-resolution imagery data to meet NOAA requirements for observations of coastal zone, hydrological phenomena, and certain atmospheric processes. In addition, improvements are required in the areas of solar and space environment sensing, data collection and data broadcast. Each of these requirement advances primarily concern the space segment of the GOES program.

2. MISSION OVERVIEW

There are four goals of the Geostationary Operational Environmental Satellite (GOES) system program:

A. Maintain reliable operational, environmental, and storm warning systems to protect life and property
B. Monitor the earth's surface, atmospheric conditions and space environmental conditions
C. Introduce improved atmospheric and oceanic observations and data dissemination capabilities
D. Develop and provide new and improved applications and products for a wide range of federal agencies, state and local governments, and private users

To accomplish these goals, the GOES-R series of geostationary satellites perform three major functions:

Environmental Sensing: Acquisition, processing and dissemination of atmospheric imaging and sounding data, along with solar and space environment (in-situ) data. The environmental sensing payload is composed of the following instruments.

- Advanced Baseline Imager (ABI)
- Hyperspectral Environmental Suite (HES)
- GEO Lightning Mapper (GLM)
- Solar Imaging Suite (SIS)
  - Solar X-ray Imager (SXI)
  - X-ray Sensor (XRS)
  - Extreme Ultraviolet Sensor (EUVS)
- Space Environment In-Situ Suite (SEISS)
  - Magnetospheric Particle Sensor (MPS)
  - Energetic Heavy Ion Sensor (EHIS)
  - Solar and Galactic Proton Sensor (SGPS)
  - Magnetometers (MAG)

Data Collection: Interrogation and receipt of data from earth surface-based data collection platforms and relay to the NOAA command and data acquisition stations. The space allocated resource for this function is the Data Collection System (DCS).

Data Broadcast: Continuous relay of meteorological data to distributed users, independent of other system functions and relay of distress signals from aircraft or marine vessels to search and rescue ground stations. The specific resources on the spacecraft that perform these functions are:

- GOES Data Rebroadcast (GRB)
- Low Rate Information Terminal (LRIT)
- Emergency Manager's Weather Information Network (EMWIN)
- Search and rescue (SAR)

3. SPACE SEGMENT OVERVIEW

The GOES-R space segment consists of a constellation of one or more satellites each nominally located at 75 degrees West longitude (East location) and at 135 degrees West longitude (West location) at geostationary altitude, 0 degrees inclination. The satellite consists of the spacecraft bus, the instrument payloads and the auxiliary communication services payloads. Table 1 shows the key GOES-R mission requirements

Mission Orbit	GEO 75ºW and 135ºW longitude (and possible 105ºW for reduced ops)
Inclination	±0.5º
Launch Vehicle	EELV Medium
Launch Date	2012
Constellation Size	1 spacecraft cluster at each Orbital Slot
System Availability	>0.82
Mission Lifetime	Data and products until year 2030
Spacecraft Lifetime	15 years (10 operational, after 5 years on-orbit spare)

Table 1. GOES-R Mission Requirements

3.1 Consolidated vs. Distributed Architecture

The GOES-R Space Segment architecture definition is currently being evaluated by industry as part of a NOAA Broad Agency Announcement for GOES-R End-to-End Architecture Study. Two primary architectures that are being considered are the Consolidated Architecture, and NOAA Notional Baseline Architecture (Distributed) shown in Figures 1 and 2 respectively.

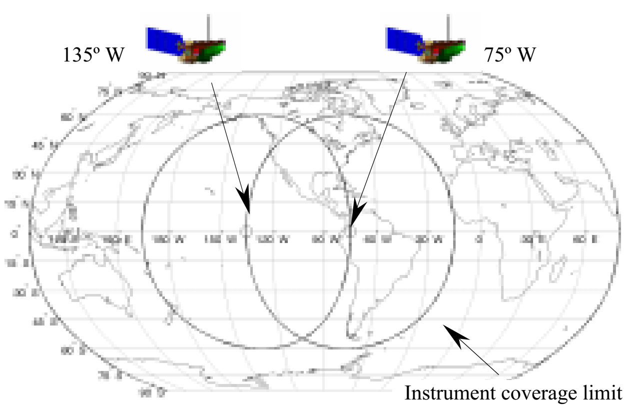

Figure 1: Consolidated Architecture

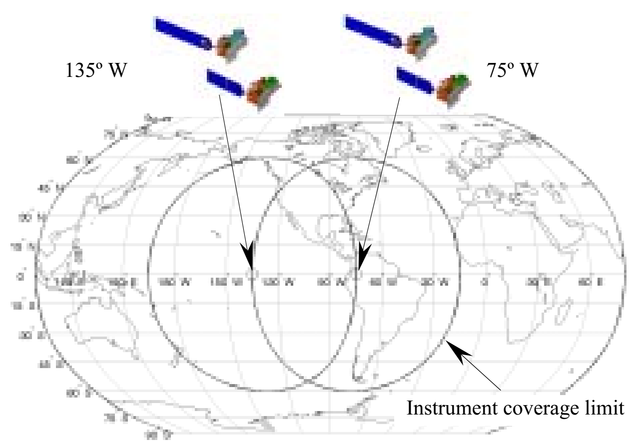

Figure 2: Distributed Architecture

The Consolidated Architecture uses a constellation of two satellites, one per each prime operational position (East and West). All instruments and communication services are included in each satellite. This architecture is similar to the current GOES I-P satellites.

The Distributed Architecture uses a constellation of one "A" satellite and one "B" satellite for each of the orbital locations (East and West) for the total of four satellites. The primary difference between the "A" and "B" satellites is that "A" carries ABI, while "B" carries HES. The remaining payloads and communication services are distributed between the two satellites so as to maintain a rough balance in terms of mass, power, and data rate. The notional baseline architecture accommodates the Advanced Baseline Imager (ABI), Solar Imaging Suite (SIS) and GOES Lightning Mapper (GLM) on the A Satellite and Hyperspectral Environmental Suite (HES) and the Solar Environmental In Situ Suite (SEISS) on the B Satellite and the GOES communication services on both. The distributed architecture provides the same functions as a single consolidated satellite.

The advantage of the distributed architecture over the consolidated architecture is that it provides simpler instrument accommodation, greater programmatic flexibility, and improved satellite performance. The major disadvantage of the distributed architecture is the increased cost due to launch cost of 8 vs. 4 satellites and due to increase in spacecraft hardware and spacecraft processing cost. In order to normalize two architectures a new metric has to be defined that takes into consideration each architecture's strengths. This measure of effectiveness has to take into account the technical and programmatic flexibility as well as procurement and operational costs. A concept of cost of a virtual satellite per orbital slot per year is introduced. This approach can effectively evaluate distributed and consolidated architectures, as long as respective architectures can "put together" a virtual satellite in the proper orbital slot. To perform the evaluation each element (spacecraft bus and primary instruments) of the virtual satellite is assigned a probability of success over the lifetime. For example: the virtual satellite comprised from distributed architecture will be a A Sat and a B Sat; for consolidated architecture, a single satellite or two consolidated satellites with functioning primary instruments (ABI on one and HES on another spacecraft). To make a consolidated architecture spacecraft "act" like A or B Sat of distributed architecture the satellite communication subsystems has to be design in such manner that two consolidated satellites would not interfere with each other in the same orbital slot. To complicate these scenarios one also needs to consider possible reduced operational capability, when there is only one HES or ABI and this single instrument is placed in the middle (105ºW) orbital position. A detailed probabilistic analysis is being performed using Monte Carlo method of solving this Systems Engineering problem. The results of this cost/benefit analysis are being used to determine the best value architecture for the GOES-R system.

3.2 Environmental Sensing Payload

The GOES-R series will incorporate technically advanced "third-generation" instrument enhancements to meet evolving observational requirements of forecasting for the era 2012-2030. The GOES-R instrument complement being developed includes Advanced Baseline Imager (ABI), Hyperspectral Environmental Suite (HES), GEO Lightning Mapper (GLM), Solar Imaging Suite (SIS) and Space Environment In-Situ Suite (SEISS). The GOES-R will generate high volume data and products (150+) as compared with only 42 products on GOES-N. These enhanced products results from the increase in the number of spectral bands observed, spatial resolution, temporal resolution, and radiometric accuracy of the imagery and sounding data. Table 2 shows the comparison between the GOES-N and GOES-R instrument complement.

3.2.1 Advanced Baseline Imager (ABI)

The Advanced Baseline Imager (ABI) is a multi-channel, visible through infrared, passive imaging radiometer. The ABI will provide sixteen spectral channels compared to five channels on the current GOES I/P series imager. This increase will allow more comprehensive monitoring of atmospheric conditions such as aerosol concentration, cirrus cloud location, and cloud properties. ABI will also provide data products with a spatial resolution of at least half the current imager, down to 0.5 km in the visible band. With its high temporal coverage, full disk every 5 minutes, and ability to continue operations around local midnight, ABI will provide continuous and timely monitoring of weather. This is further augmented by ABI's ability to revisit a specified 1000 kilometer region every 30 seconds to track severe weather.

3.2.2 Hyperspectral Environmental Suite (HES)

The Hyperspectral Environmental Suite (HES) is marked improvement for the GOES-R in the 2012 timeframe. Although the detailed HES parameters will be studied by industry under the formulation phase of the HES, the instrument specifications represent an enormous improvement over the current sounder. The HES coverage rate will be about five times faster than the current sounder. Consequently, regular coverage of the sounder can extend over an area that is much larger than the CONUS. The number of sounder spectral channels will also increase from 18 IR bands to about 1500 IR bands. A visible band with 10 times finer spatial resolution than the IR will detect clouds.

Instrument		GOES N	GOES R	
Imager	Performance	5 channels, 1 to 4km GSD, 25 min FD, 56 urad Nav	16 channels, 0.5 to 2km GSD, 5 min FD, 28 urad Nav	ABI
Imager	Resources	137 kg, 200W, 2.5 Mbps, 1.05 m^3	275 kg, 450W, 60 Mbps, 3.279 m^3	
Sounder	Performance	19 channels, 10 km GSD, 75 min CONUS, 280 urad Nav	~1000 channels, 10km GSD, 60 min 62º LZA, 52 urad Nav	HES
Sounder	Resources	148 kg, 155W, 0.038 Mbps, 1.05 m^3	280 kg, 550W, 64 Mbps, 5.083 m^3	
Coastal Waters	Performance	N/A	14 channels, 0.3 km GSD, 3 hr coastal scan, 8 urad Nav	
Open Ocean[#]	Performance	N/A	7 channels, 4 km GSD, 3 hr 62 LZA, 52 urad Nav	
SXI[‡]	Performance	0.6 to 6.0 nm, 1 image/min, 37% Encircled energy at 10"	0.6 to 10.0 nm, 3 images/min, 37% Encircled energy at 7"	SIS
	Resources	33.1 kg, 80W, 100 Kbps, 0.0942 m^3	60kg, 130W, 2.8 Mbps. 0.083 m^3	
SEM	XRS	2 bands from 0.05 to 0.8nm	Same	
	EUV	5 bands from 10 to 126 nm	8 bands in 5-127 nm range	
	Energetic Particle Sensors	Electrons: 0.03 to 4MeV, 5 bands, 9 dir's, 33 sec Protons*: 0.08 to 700 MeV, 12 bands, 9 dir's, 33 sec Alphas: 1 to 425 MeV/nucleon, 7 bands, 2 dir's, 33 sec Solar/Galactic: 350 to 700 MeV, 10 bands, 2 dir's, 33 sec	Electrons: 30eV to 4MeV, 25 bands, 5 dir's, 30 sec Protons: 30eV to 1MeV, 7 bands, 5 dir's, 30 sec Ions (4 types): 10 to 400 MeV/nuc, 7 bands, 1 dir, 5 min Solar/Galactic: 1 to 500MeV, 10 bands, 2 dir's, 1 min	SEISS
	Resources	46 kg, 82W	42kg, 92W, 300 bps, 0.085 m^3	
Magnetomete[†]	Performance	+/- 400 nT Range, 1.0 nT accuracy, 8.5m boom	+/- 400nT Range, 1.0 nT accuracy	
	Resources	Included in S/C	Included in S/C	
Lightning Mapper	Performance	N/A	10km GSD, 70-90% probability of detection	GLM
	Resources	N/A	38 kg, 160W, 200 Kbps, 0.11 m^3	
Coronagraph[#]	Performance	N/A	0.5 to 0.8 um, 1 to 4.25º FOV, 50" resolution,15min	
	Resources	N/A	34 kg, 60W, 1.0 Mbps, 0.057 m^3	

Note: The resources for Coastal Waters and Open Ocean are included in HES/Sounder. Likewise XRS and EUV resources are included in SIS/SXI.
[†]Range is for Earth's magnetic field. GOES I-M had +/- 1000 nT range to account for large S/C field which the boom on GOES-N eliminated.
[‡]Had to estimate encircled energy for GOES-N SXI in order to compare performance to GOES-R specification.
*GOES-N spec was for 0.03 MeV, however 0.08 MeV was what could be achieved for low end of range.
[#]Optional Instrument

Table 2. GOES N – GOES-R Comparison

The HES will perform three threshold tasks and the possibly one goal task. The minimum tasks are: Disk Sounding, Severe Weather/Mesoscale Sounding, and Coastal Waters Imaging. The goal task is Open Ocean Imaging. The sounding tasks sense the thermal emitted IR radiation from 4.4 microns to 15.4 microns with a spectral resolution on the order of 1.0 cm-1. The ground sampling distance (GSD) at nadir for the Disk Sounding task is 10km and the GSD for the Severe Weather/Mesoscale sounding task is 4km. The Disk Sounding task has the capability to sound the full disk in approximately 90 minutes. The Severe Weather/Mesoscale task will perform sounding in less than 5 minutes a region of 1000km by 1000km. The Coastal Waters Imaging task senses reflected solar radiation in 14 channels from 0.4 microns to 1.0 microns with spectral resolution on the order of 10nm. The GSD at nadir for the Coastal Waters task is 300m. Coastal water images extend 400km from the shore and the HES must scan either the West or East Coast images every 3 hours. The Open Ocean Imaging task uses the same bands as the Coastal Waters task, however the GSD at nadir is 4km. The HES is not required to perform both sounding tasks simultaneously, however the Coastal Waters task must be performed simultaneously with either sounding task.

3.2.3 Geostationary Lightning Mapper (GLM)

The Geostationary Lightning Mapper (GLM) will observe the Earth in geosynchronous orbit and detect lightning over the full-disk. This includes cloud-to-cloud as well as cloud-to-ground lightning. At least 70% of events as short as one millisecond are to be detected with less than 5% false alarms. Because of clouds, satellites see lightning diffused over wide areas. For this reason, the required horizontal resolution is only 10 km.

Lightning sensors have flown in low-Earth (LEO) orbit but not yet in geosynchronous orbit. Continuous GLM observation will allow the use of lightning to predict convective storms, including tornados. The GLM will probably be similar to earlier LEO instruments which used the 0.7774 micron oxygen emission associated with lightning. Those instruments used refractive optics, interference filters, silicon CCDs and real-time event detection electronics.

3.2.4 Solar Imaging Suite (SIS)

The GOES-R Solar Imaging Suite (SIS) will monitor the solar EUV (extreme ultraviolet) and X-ray output. The SIS consists of a solar X-ray sensor (XRS), an extreme ultraviolet sensor (EUVS) and a Solar X-ray imager (SXI). The GOES-R XRS will detect the beginning, duration, and magnitude of solar X-ray flares, monitoring two wavelength bands: 0.05 - 0.4 nm, and 0.1 - 0.8 nm similarly to GOES-N. The GOES-R EUVS will monitor the solar EUV flux in the 5 - 127 nm range as compared to the 10 – 126 nm range for GOES-N.

The GOES-R Solar X-Ray Imager (SXI) will provide full-disk solar images at high cadence in the soft X-ray to EUV wavelength range to locate coronal holes for geomagnetic storm forecasts, detect and locate flares for forecasts of solar energetic particle (SEP) events related to flares, and monitor changes in the corona for flare forecasts. The GOES-R SXI will monitor solar X-rays in the 0.6 to 10.0 nm wavelengths at a rate equivalent to 3 images/min with 37% encircled energy within 7 arc seconds, as compared to the GOES-N 0.6 to 6.0 nm wavelengths at a rate of 1 image/min with 37% encircled energy within 10 arc seconds.

3.2.5 Space Environment In-Situ Suite (SEISS)

The GOES-R SEISS will provide real-time measurements of the charged particle environment in geosynchronous orbit. The SEISS will monitor geomagnetically trapped electrons and protons; electrons, protons, and heavy ions of direct solar origin; and galactic background particles. The sensors are designated as the magnetospheric particle sensor (MPS) the energetic heavy ion sensor (EHIS), and the solar and galactic proton sensor (SGPS). Electrons will be measured on GOES-R over the range of 30 eV to 4 MeV as on GOES-N. Protons will be measured on GOES-R over the range 30 eV to 500 MeV and over 500 MeV as compared to the GOES-N measurement range of 80 KeV to 700 MeV. GOES-R will measure four solar ion mass groups: He, C-N-O, Ne-S, and Fe; by comparison, GOES-N only alpha particles.

Similarly to GOES-N, the GOES-R magnetometer will measure the earth's geomagnetic field at geosynchronous orbit in three-axes, providing information on the general level of geomagnetic activity and current systems in space. This information facilitates the detection of magnetopause crossings and sudden magnetic storm commencements, and detection of sub storms.

3.3 Auxiliary Communication Services

In addition to supporting environmental sensing payloads, GOES carries an array of UHF, S-band, L-band antennas to support the following auxiliary communication services.

3.3.1 Data Collection

The GOES Data Collection System (DCS) collects near-time environmental data from more than 19,000 data collection platforms located in remote areas where normal monitoring is not practical. The DCS receives data from platforms on ships, aircraft, balloons and fixed sites. These data are used to monitor seismic events, volcanoes, tsunami, snow conditions, rivers, lakes, reservoirs, ocean data, forest fire control, meterorological and upper air parameters. The GOES-R DCS is similar to GOES-N.

3.3.2 Data Broadcast

GOES Rebroadcast (GRB): The GOES rebroadcast (GRB) is a communication service that provides processed mission data to the user community. Raw data from the environmental sensors is processed into calibrated navigated data sets at the receive site. The processed data is then uplinked to GOES for broadcast to users within view of the satellite. The current GRB baseline is just under 24 Mbps, which is more than an order of magnitude increase over GOES-N GVAR.

Low Rate Information Terminal (LRIT): The low rate information terminal (LRIT) transmission is a communication service provided through a transponder onboard the GOES satellite. The LRIT service evolves from the current WEFAX system which provides a wide dissemination of GOES imagery and other data at the relatively low information rate of 128 kbit/s. The LRIT has a requirement to upgrade the user information rate to 256 kbit/s, technically making it a high rate system in accordance with EUMETSat convention.

Emergency Manager's Weather Information Network (EMWIN): The emergency manager's weather information network (EMWIN) transmission is a communication service provided though a transponder onboard the GOES satellite. EMWIN is a suite of data access methods that make available a live stream of weather and other critical information to Local Emergency Managers and the Federal Emergency Management Agency (FEMA).

Search and Rescue (SAR): The Search and Rescue (SAR) subsystem onboard the GOES satellite is a dedicated transponder that detects 406 MHz distress signals transmitted by Emergency Locator Transmitters (ELT) carried on aircraft, Emergency Position-Indicating Radio Beacons (EPIRB) aboard marine vessels, and Personal Locator Beacons (PLB) used in land-based applications. The distress signals are relayed by the GOES satellite to a ground station located within the field-of-view of the satellite. The information is then passed to a mission control center and ultimately to a rescue coordination center from where help is dispatched.

3.4 Spacecraft Bus

The spacecraft bus architecture is being evaluated as part of the GOES-R End-to-End Architecture Study. The spacecraft bus design assumes a commercial-type bus with space heritage. The spacecraft design and functionality for the consolidated and distributed are similar and scaled to meet the payload requirements. A common spacecraft bus design is assumed for the distributed spacecraft. Table 3 shows the GOES-R payload mass, power, and data rate budget for the consolidated and distributed spacecraft design.

	Consolidated Sat	**Distributed A Sat**	**Distributed B Sat**
Payload			
Mass (kg)	860	530	490
Power (W)	2000	1280	1200
Data Rate (Mbps)	140	70	70

Table 3. GOES-R Payload Mass, Power, Data Rate Budget

The spacecraft structure provides mechanical support and alignment for all flight equipment and instruments throughout the life of the mission. The spacecraft will provide a nadir-pointed deck for an instrument optical bench to which all nadir facing instruments (ABI, HES, GLM), star tracker, and stellar inertial reference unit are mounted. The nadir deck also provides an interface for the communication service module. The spacecraft will also provide a sun-pointing platform for the SIS instruments. The sun-pointing platform will be mounted on the solar array with a second axis of rotation perpendicular to the rotation of the solar array to accommodate seasonal variations of solar looking instruments. The body-mounted SEISS instruments are mounted on the spacecraft zenith deck with a clear field of view to space. In addition, the magnetometer instrument will require a deployable boom. A possible payload layout of the consolidated spacecraft is shown in Figure 3.

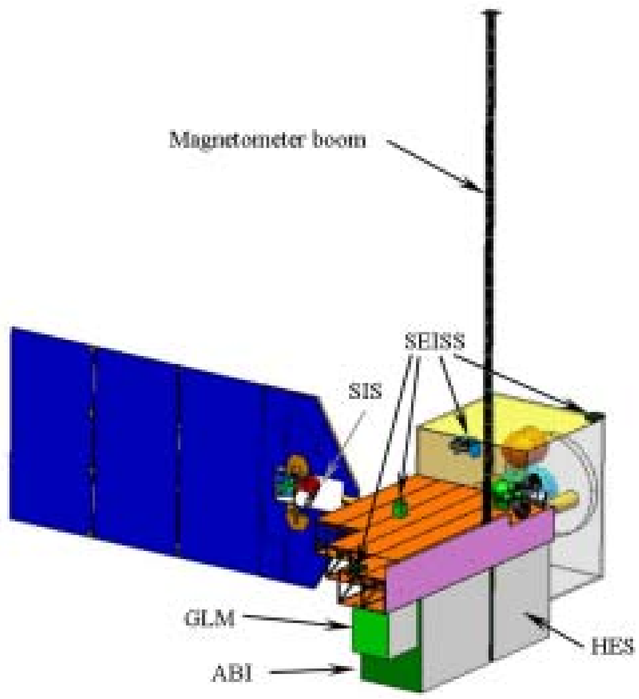

Figure 3: Payload Layout

Image Navigation and Registration (INR) is a set of image quality metrics pertaining to the location errors of instrument pixels in processed data. Navigation is absolute location accuracy, and registration is relative location accuracy within an image, between subsequent frames, and between spectral channels. GOES INR performance requirements have been tightened over the generations. For example, the navigation accuracy requirement for GOES I–M is 112 micro radians, or 4 km at nadir; for GOES N–Q, it is 56 micro radians (2 km), and for GOES–R, it will be 28 micro radians (1 km). It is the instrument's responsibility to meet the required INR requirements given the INR related spacecraft requirements shown in Table 4. This is a major departure from previous GOES where spacecraft contractor was responsible for the overall INR. To meet such tight requirements a number of techniques to stabilize spacecraft to instrument interface are envisioned: predicted torques with the feed forward, passive damping, and motion compensation.

Attitude Control	270 μ rad
Attitude Knowledge	60 μ rad
Attitude Stability	300 μ rad peak-to-peak over 60 sec. 60 μ rad/sec. below 15 sec.
Attitude Jitter	frequency dependant linear acceleration Requirement: 0.4 to 1.4 mg's
Orbit Knowledge	300 meters

Table 4. INR-related Spacecraft Requirements

Although the design of the attitude control system (ACS) will be performed by the spacecraft contractor, it is likely that the ACS will include star trackers and gyros for attitude sensing, reaction wheels for nominal zero momentum three-axis control, and propulsion for momentum management. The spacecraft configuration may or may not be balanced with respect to solar radiation pressure, depending on instrument cooling requirements and the operational decision of whether or not to baseline a semiannual yaw flip. The orbit knowledge requirements may drive the spacecraft to use GPS or a ranging implementation with multiple ground stations. A propulsion system will be used to maintain the spacecraft within specified orbital parameters. The propulsion technology and operational concept for orbit and momentum maintenance are currently under study by industry. The goal is to achieve an environment where instruments can continuously operate within INR specification during station-keeping and momentum unloading operations.

The on-board data system for the GOES-R spacecraft departs from the way heritage GOES spacecraft handle science, health, safety, and command data. To accommodate the higher data rate SpaceWire point-to-point interface is specified as a standard interface to communication between spacecraft and all instruments. The GOES-R spacecraft is implementing a Packet Telemetry and Telecommand system compliant with Consultative Committee for Space Data Systems (CCSDS) recommendations. In addition, the instrument compliment generates significantly larger volumes of science data at much higher rates than the heritage spacecraft, and lossy and lossless compressions are utilized to lower data rates to more manageable rates (it is approximately 2 to 10 times data rate reduction will be achieved). In addition to packet telemetry, modern error detection and correction codes (e.g. LDPC and Turbo codes) are being considered for high data rates. These error correction codes along with advanced modulation techniques like GMSK will save power and spectrum while delivering superior performance.

The current GOES spacecraft computer is significantly less powerful with limited flight software capabilities. The advent of flight computers like the PowerPC and R6000 class provides on-board resources that allow for non-deterministic science and telemetry data collection, management, and transmission. In addition, modern networking protocols and processes can be implemented on the spacecraft. Many of these technical innovations are possible due to such a huge increase in data volume, which require a complete departure from GOES I-P heritage systems.

The payload communication subsystem provides the capability to transmit raw Sensor Data (SD) directly to the Command and Data Acquisition Station (CDAS) ground station located at Wallops Island, receive the processed mission data uplink from Wallops Island, and transmit that uplink via a broadcast mode (GRB) to all in-view ground users. The GOES-R SD rate of 140 Mbps is a factor of 47 times that of GOES-N data rate. The SD will be sent to the ground via X-band. Due to the increased volume of data from the GOES-R payload, rebroadcast of the full set of that data cannot be accomplished on the current GOES L-band 12MHz bandwidth allocation. The GOES-R system has the capability to rebroadcast 24 Mbps of the required data using 8PSK modulation and 7/8 Turbo coding or equivalent for specified 12 MHz bandwidth. Alternate means to provide the full GOES rebroadcast (GFULL) by ground network and/or commercial communication satellite is under investigation. The GOES-R auxiliary communication services for LRIT, EMWIN, SAR and DCP are similar to GOES-N. Figure 4 shows the GOES-R notional communication architecture.

The Electrical Power Subsystem design assumes a planar single-wing array, with multi-junction GaAs/Ge solar cells and lightweight Al honeycomb panels. Energy storage will be based on Li-ion batteries with energy density of 100 W-h/kg, maximum depth of discharge (DOD) of 60%. The spacecraft will provide a regulated 28 V bus to the instruments.

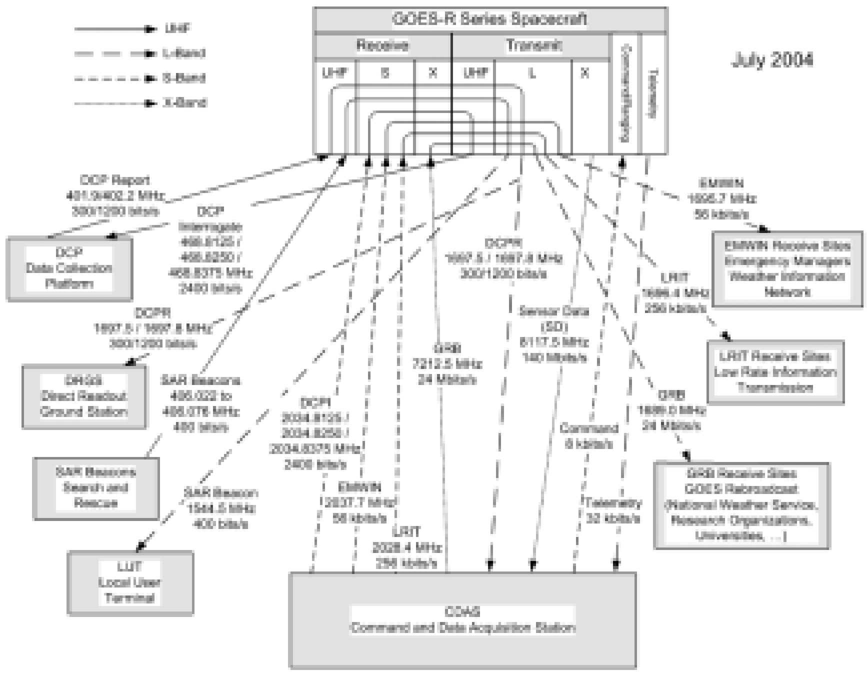

Figure 4. GOES-R Notional Communication Architecture

4.0 SCHEDULE

The near term schedule for GOES-R is very active. In the next three months the Project will make the selection for ABI implementation contractor, as well as SIS and SEISS study phase contractors. The HES instrument's three vendors have begun a formulation phase contract that will last for two years. And finally, the spacecraft and GLM contracts are being prepared for the formulation phase to be released at the end of 2004 or early 2005.