GOES-R Overview and Status

Tom Renkevens
NOAA’s Satellite and Information Service

McIDAS Users Group – 2005
October 27, 2005
Outline

• Purpose
• GOES Background
• Requirements
• Instrument Summary
• Notional Architecture
• Algorithm Working Group
• Acquisition Process and Approach
• GOES-R Program Status
• Summary/Next Steps
NOAA provides observations of the atmosphere, ocean, land, and the sun.
Geostationary Operational Environmental Satellite (GOES)

Continuous operations since 1974:
- GOES I-M (8-12)* series currently operational since 1994
- GOES-N, O, P series under contract; GOES-N launch 2005
- GOES-R series early in development; first available for launch in 2012

* Note: satellites are labeled with letters on the ground and changed to numbers on-orbit
• The current satellites have finite lives and coverage will eventually end unless new satellites are procured
• Based on 5 year contracted life for GOES I-P, GOES-R must be procured in time for a September 2012 launch
GOES-R Supports DOC/NOAA Strategic Plan

- High priority program that is critical to NOAA’s ability to achieve outcomes set forth in Goal 3 of DOC Strategic Plan (observe, protect and manage the Earth’s resources to promote environmental stewardship)
  - Improve accuracy and timeliness of weather and water information
  - Increase understanding of climate variability and change
  - Improve protection, restoration, and management of coastal and ocean resources through ecosystem-based management
  - Support the nation’s commerce with information for safe, efficient, and environmentally sound transportation

- Mission need and program requirements are:
  - Consistent with President’s Management Agenda
    - Has clearly defined objectives (user driven)
    - Directly supports measurable outcomes (results oriented)
    - Promotes innovation through competition
  - Defined in GOES-R Program Requirements Document (GPRD)
  - Reviewed and validated by NOAA

- Link to NOAA Strategic Plan
  - [http://www.spo.noaa.gov/](http://www.spo.noaa.gov/)
GOES-R Provides Critical Products to the Nation

- Weather sentinel
  - Hurricanes
  - Severe storms
  - Flash floods
- Input to environmental models, forecasts and warnings
- Lightning mapping for thunderstorm detection and warning
- Winds and icing for aviation
- Solar and space monitoring for communication satellites, utility companies, and astronaut safety
- Sea surface temperature monitoring for fisheries, climate
- Harmful Algal Bloom detection for forecasting and warning of hazardous ocean conditions
- Other important products for environmental monitoring:
  - Air Quality
  - Snow, ice, and fog analysis
  - Volcanic ash detection
  - Fire and smoke detection
- Environmental data relay
- Search and rescue

GOES-R will provide >3X the number of products currently produced by GOES
Mapping Requirements To System Solutions

NOAA Users
- NWS
- OAR
- NOS
- NMFS
- NMAO
- PPI
- NESDIS

Other Users
- Ecosystems, Weather & Water, Climate, Commerce & Transportation

Requirements
- Aerosols
- Clouds
- Precipitation
- Atmospheric Profiles
- Atmospheric Radiance
- Atmospheric Winds
- Land
- Ocean
- Coastal Waters & Estuaries
- Space & Solar

Instruments
- Adv. Baseline Imager (ABI)
- Hyperspectral Environmental Suite (HES)
- Solar Imaging Suite (SIS)
- Space Env In-Situ Suite (SEISS)
- GOES Lightning Mapper (GLM)

Baseline Instruments
- Microwave Sounder/Imager
- Coronagraph
- Hyperspectral Imager
- Solar Irradiance Sensor

Potential P3I

11/11/2005
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<th>GOES-R Observational Requirements</th>
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<td><strong>Aerosol Detection</strong></td>
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<tr>
<td><strong>Aerosol Particle Size</strong></td>
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<td><strong>Suspended Matter</strong></td>
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<td><strong>Volcanic Ash</strong></td>
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<td><strong>Aircraft Icing Threat</strong></td>
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<td><strong>Cloud Imagery</strong></td>
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<tr>
<td><strong>Cloud &amp; Moisture Imagery</strong></td>
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<td><strong>Cloud Base Height</strong></td>
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<td><strong>Cloud Layers / Heights &amp; Thickness</strong></td>
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<td><strong>Cloud Liquid Water</strong></td>
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<td><strong>Cloud Optical Depth</strong></td>
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<td><strong>Cloud Particle Size Distribution</strong></td>
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<td><strong>Cloud Top Phase</strong></td>
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<td><strong>Convection Initiation</strong></td>
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<tr>
<td><strong>Enhanced &quot;V&quot;/Overshooting Top Detection</strong></td>
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<td><strong>Hurricane Intensity</strong></td>
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<td><strong>Imagery: All-Weather / Day - Night</strong></td>
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<td><strong>Lightning Detection</strong></td>
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<td><strong>Low Cloud &amp; Fog</strong></td>
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<td><strong>Turbulence</strong></td>
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<td><strong>Visibility</strong></td>
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<td><strong>Geomagnetic Field</strong></td>
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<tr>
<td><strong>Dust/Aerosol</strong></td>
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<tr>
<td><strong>Probability of Rainfall</strong></td>
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<td><strong>Rainfall Potential</strong></td>
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<td><strong>Rainfall Rate</strong></td>
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<td><strong>Atmospheric Vertical Moisture Profile</strong></td>
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<td><strong>Capping Inversion Information</strong></td>
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<td><strong>Derived Stability Indices</strong></td>
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<td><strong>Pressure Profile</strong></td>
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<tr>
<td><strong>Total Precipitable Water</strong></td>
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<td><strong>Clear Sky Masks</strong></td>
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<td><strong>Radiance</strong></td>
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<td><strong>CO Concentration</strong></td>
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<td><strong>Ozone Total</strong></td>
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<td><strong>SO₂ Detection</strong></td>
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<td><strong>Derived Motion Winds</strong></td>
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<td><strong>Microburst Wind Speed Potential</strong></td>
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<td><strong>Fire / Hot Spot Imagery</strong></td>
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<td><strong>Flood / Standing Water</strong></td>
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<tr>
<td><strong>Land Surface (Skin) Temperature</strong></td>
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<tr>
<td><strong>Surface Albedo</strong></td>
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<td><strong>Surface Emissivity</strong></td>
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<tr>
<td><strong>Vegetation Fraction</strong></td>
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<tr>
<td><strong>Vegetation Index</strong></td>
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<tr>
<td><strong>Currents</strong></td>
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<tr>
<td><strong>Ocean Color</strong></td>
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<td><strong>Ocean Optical Properties</strong></td>
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<td><strong>Ocean Turbidity</strong></td>
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<td><strong>Sea &amp; Lake Ice / Displacement &amp; Direction</strong></td>
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<tr>
<td><strong>Sea &amp; Lake Ice / Age</strong></td>
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<tr>
<td><strong>Sea &amp; Lake Ice / Concentration</strong></td>
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<tr>
<td><strong>Sea &amp; Lake Ice / Extent &amp; Characterization</strong></td>
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<tr>
<td><strong>Sea &amp; Lake Ice / Extent &amp; Edge</strong></td>
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<tr>
<td><strong>Sea &amp; Lake Ice / Surface Temp</strong></td>
</tr>
<tr>
<td><strong>Sea &amp; Lake Ice / Motion</strong></td>
</tr>
<tr>
<td><strong>Sea &amp; Lake Ice / Thickness</strong></td>
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<tr>
<td><strong>Ice Cover / Landlocked</strong></td>
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<tr>
<td><strong>Snow Cover</strong></td>
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<tr>
<td><strong>Snow Depth</strong></td>
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<tr>
<td><strong>Sea Surface Temps</strong></td>
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<tr>
<td><strong>Energetic Heavy Ions</strong></td>
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<tr>
<td><strong>Mag Electrons &amp; Protons: Low Energy</strong></td>
</tr>
<tr>
<td><strong>Mag Electrons &amp; Protons: Med &amp; High Energy</strong></td>
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<tr>
<td><strong>Solar &amp; Galactic Protons</strong></td>
</tr>
<tr>
<td><strong>Solar Flux: EUV</strong></td>
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<tr>
<td><strong>Solar Flux: X-Ray</strong></td>
</tr>
<tr>
<td><strong>Solar Imagery: X-Ray</strong></td>
</tr>
</tbody>
</table>

- **ABI – Advanced Baseline Imager**
- **HES – Hyperspectral Environmental Suite**
- **SEISS – Space Env. In-Situ Suite**
- **SIS – Solar Instrument Suite**
- **GLM – GOES Lightning Mapper**
- **Magnetometer**
GOES-R Baseline Instruments to Meet User Requirements

- Advanced Baseline Imager (ABI)
  - Monitors and tracks severe weather
  - Images clouds to support forecasts

- Hyperspectral Environmental Suite (HES)
  - Provides atmospheric moisture and temperature profiles to support forecasts and climate monitoring
  - Monitors coastal regions for ecosystem health, water quality, coastal erosion, harmful algal blooms

- Solar Imaging Suite (SIS) and Space Environmental In-Situ Suite (SEISS)
  - Images the sun and measures solar output to monitor solar storms (SIS)
  - Measures magnetic fields and charged particles (SEISS)
  - Enables early warnings for satellite and power grid operations, telecom services, astronauts, and airlines

- Geostationary Lightning Mapper (GLM)
  - Detects lightning strikes as an indicator of severe storms
## GOES Evolution

### Imaging

<table>
<thead>
<tr>
<th>Performance Capability</th>
<th>GOES I-M</th>
<th>GOES N-P</th>
<th>GOES R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution - Visible</td>
<td>1 km</td>
<td>1 km</td>
<td>0.5 km</td>
</tr>
<tr>
<td>Resolution - IR</td>
<td>4 km</td>
<td>4 km</td>
<td>2 km</td>
</tr>
<tr>
<td>Full Disk Coverage Rate</td>
<td>30 min</td>
<td>30 min</td>
<td>5 min</td>
</tr>
<tr>
<td># of Channels</td>
<td>5</td>
<td>5</td>
<td>16</td>
</tr>
</tbody>
</table>

### Atmospheric Soundings

<table>
<thead>
<tr>
<th>Resolution</th>
<th>GOES I-M</th>
<th>GOES N-P</th>
<th>GOES R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hourly Coverage</td>
<td>CONUS</td>
<td>CONUS</td>
<td>Full Disk @ 10 km resolution</td>
</tr>
<tr>
<td>Severe Weather Rapid Scan</td>
<td>No</td>
<td>No</td>
<td>Yes - 4km resolution CONUS</td>
</tr>
<tr>
<td># of Channels</td>
<td>19</td>
<td>19</td>
<td>~1500</td>
</tr>
<tr>
<td>Coastal Water Monitoring</td>
<td>No</td>
<td>No</td>
<td>Yes - 300 m resolution</td>
</tr>
</tbody>
</table>

### Additional Features

<table>
<thead>
<tr>
<th>Solar Monitoring (SXI)</th>
<th>GOES-M only</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightning Detection</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Operate through Eclipse</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ground System Backup</td>
<td>Limited</td>
<td>Limited</td>
<td>Full</td>
</tr>
<tr>
<td>Archive and Access</td>
<td>Limited</td>
<td>Limited</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### The Advanced Baseline Imager (ABI)

<table>
<thead>
<tr>
<th>ABI</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spectral Coverage</strong></td>
<td></td>
</tr>
<tr>
<td>16 bands</td>
<td>5 bands</td>
</tr>
<tr>
<td><strong>Spatial resolution</strong></td>
<td></td>
</tr>
<tr>
<td>0.64 μm Visible</td>
<td>0.5 km Approx. 1 km</td>
</tr>
<tr>
<td>Other Visible/nearIR</td>
<td>1.0 km n/a</td>
</tr>
<tr>
<td>Bands (&gt;2 μm)</td>
<td>2 km Approx. 4 km</td>
</tr>
<tr>
<td><strong>Spatial coverage</strong></td>
<td></td>
</tr>
<tr>
<td>Full disk</td>
<td>4+ per hour Every 3 hours</td>
</tr>
<tr>
<td>CONUS</td>
<td>12 per hour ~4 per hour</td>
</tr>
<tr>
<td>Mesoscale</td>
<td>Every 30 sec -</td>
</tr>
<tr>
<td><strong>Visible</strong></td>
<td></td>
</tr>
<tr>
<td>On-orbit calibration</td>
<td>Yes No</td>
</tr>
</tbody>
</table>

[Link to AMS Article – Schmit et. al](#)
Increased Imaging Capability

5 Minute Coverage

GOES-I/P

ABI Scan Modes
• Mode 3: 15 minute cycle
  • 1 Full Disk
  • 3 CONUS
  • 1000km² every 30 seconds
• Mode 4:
  • Continuous 5 minute Full Disk

1/5 Disc

GOES-R

Full Disc
New complex requirements – Hyperspectral Design as opposed to 18 position filter wheel (GOES-I-P) which includes both, Sounding and Imaging Tasks

– Full Disk Sounding (DS) Task
  • IR Spatial resolution 10 km;
  • Spectral Range 3.7 - 15.4 micron (not continuous);
  • ~1500 channels;
  • 62º LZA coverage 60 min refresh rate
  • Vis Spatial resolution 1 km; Spectral Range 0.4 – 1.1 micron

– Severe Weather/Mesoscale (SW/M) Sounding Task
  • IR Spatial Resolution 4 km;
  • Spectral Range 3.7 – 15.4 micron (not continuous);
  • ~1500 channels
  • 1000 km x 1000 km refresh in 4 minutes
  • Vis Spatial Resolution 1 km

– Coastal Water (CW) Imaging Task
  • Vis Spatial Resolution 300 m
  • Spectral Range 0.4 – 1.1 micron
  • 14 channels
  • 3 hour refresh
Increased Coverage Rate

Much improved spatial coverage with the HES Sounder

Current GOES Sounder coverage in one hour

GOES-R HES Sounder coverage in one hour

Cloud Top Pressure
Improved Coastal Monitoring

GOES-8 loop from 1615 to 2345: This loop illustrates the changes that occur in the cloud field after the MODIS pass and the need to dynamically task HES.
Geostationary Lightning Mapper

- New Instrument
  - Severe Storm Warning Times
  - Lightning Danger Alerts
  - Disaster Team Response
  - Nitrogen Production
- Hemispheric Or CONUS Coverage
- Detects Total Strikes:
  In Cloud, Cloud To Cloud, And Cloud To Ground
  - Compliments Today’s Land Based Systems
- Parameters
  - 10 Km Spatial Resolution
    (1 Km Goal)
- Increased Coverage Over Oceans And Lands
  - Currently No Ocean Coverage, And
  - Limited Land Coverage In Dead Zones
Space Weather Instruments

Space Environmental In-Situ Suite (SEISS)

• Instruments:
  – Magnetospheric Particle Sensor (MPS),
  – Solar and Galactic Proton Sensor (SGPS)
  – Energetic Heavy Ion Sensor (EHIS)

• Measure: Proton, Electron, And Heavy Ion Fluxes

Solar Imaging Suite (SIS)

• Instruments:
  – Solar X-ray imager (SXI)
  – Solar X-ray sensor (XRS)
  – Extreme Ultraviolet Sensor (EUVS)

• Measure: Solar X-Ray Flux Magnitude, Solar EUV Flux, Coronal Hole Locations, Coronal Mass Ejections, Solar Flares

Magnetometers – Magnetic Field

Some GOES-R Improvements

– Medium Energy Radiation Environment Responsible For Spacecraft Charging
– Solar X-Ray Image Dynamic Range, Resolution, And Sensitivity
– EUV measurements for improved modeling of ionosphere and thermosphere

11/11/2005
Potential System Architectures

Consolidated Constellation

- All instruments on each satellite
- Lowest cost if every thing goes as planned

West
- ABI
- HES
- SIS
- SEISS
- GLM

East
- ABI
- HES
- SIS
- SEISS
- GLM

Distributed Constellation

- Instruments distributed over multiple smaller satellites
- Lower risk may offset higher planned cost

West
- ABI
- SIS
- SEISS
- HES
- GLM

East
- ABI
- SIS
- SEISS
- HES
- GLM

Flexible Constellation

- Can accommodate either configuration
- Flexibility may lower cost and risk

West
- ABI
- SIS
- SEISS
- HES
- GLM

East
- ABI
- SIS
- SEISS
- HES
- GLM
Communications

**AUX – Auxiliary Services**
LRIT--Low Rate Information transmission
EMWIN--Emergency Managers Wx Information Network
DCS--Data Collection System
SARSAT--Search and Rescue
NMAO – Airplane and Ship Service
GRB – GOES Rebroadcast

GOES-R will support improved AUX services
Higher Data Rates for LRIT, DCS
Communications System Overview

Space Segment

GOES-R Constellation

Ground Segment

Backup

NOAA Infrastructure

User Interface

Location: TBD

Product Requests

L1b, L2, SE Products

L1b, L2, SE Products

L0 Products (Backup)

CDAS
Wallops Is., VA

Primary

Telemetry

Space Environment Center,
Boulder, CO

Merged Processing

CLASS

Space Environment (SE) Products

Sensor data for: SIR, SDRS, NAG, P3I, Telemetry

Telemetry

MICROGRADATION

Downlink for Instrument Data

DCFR, LRT, EMWIN, NMAD AS

Downlink for Instrument Data, SARSAT

L1b, L2, SE Products

Product Requests

L0 Products (Backup)

MM, PG, PD
Location: TBD

Uplink for Command,
LRT, EMWIN, DCPI, ORB

Broadcast Downlink for:
GRB

Uplink for Command
LRT, EMWIN, DCPI, ORB

11/11/2005
Data Distribution Issues

- Prime Users:
  - NWS/NCEP, DoD, NESDIS, other NOAA, Foreign Governments, Academia, Private Sector

- Data Distribution Possibilities or Considerations:
  - Distribution methods for GFUL – All Level 1b products; Push/Pull
  - Development of a product generation (PG) system that will meet production processing timelines and product latencies.
  - Current methods of GVAR, NOAAPORT, McIDAS, Unidata IDD, Direct Readout

- Various Data Formats
  - GIF, Text, BUFR, GRIB, Binary, JPEG, NetCDF, and McIDAS files or replacement file formats.

- Contents of GRB
  - Who decides?
  - Level 1b data vs Products

<table>
<thead>
<tr>
<th></th>
<th>GOES R</th>
<th>GOES I-P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument Data Downlink</td>
<td>132 Mbps</td>
<td>2.6 Mbps</td>
</tr>
<tr>
<td>Rebroadcast</td>
<td>&gt;17 Mbps (GRB)</td>
<td>2.1 Mbps (GVAR)</td>
</tr>
<tr>
<td>Level 1b</td>
<td>&gt;100 Mbps (GFUL)</td>
<td>2.1 Mbps (GVAR)</td>
</tr>
<tr>
<td>Level 2/3 Products</td>
<td>Approximately 1.5 Gbps</td>
<td>&lt; 4.7 Mbps</td>
</tr>
<tr>
<td>Product Latency</td>
<td>Real-time to 5 minutes (product dependent)</td>
<td>Real-time to TBS minutes</td>
</tr>
<tr>
<td>Number of Types of Products</td>
<td>&gt;160</td>
<td>41</td>
</tr>
<tr>
<td>CLASS Data Storage</td>
<td>Daily: 0.5 TB 7 year life: 1,100 TB</td>
<td>N/A</td>
</tr>
<tr>
<td>Temporary Storage</td>
<td>30 Days of raw data records, L0 and selected products</td>
<td>0 days</td>
</tr>
</tbody>
</table>
Algorithm Working Group

- ORA tasked by the GOES-R Program Office to assist with identification and mitigation of risk in the development and implementation of GOES-R scientific and operational product algorithms

- To augment their experience and expertise and prepare the user community for the future products, ORA is involving the scientific community through two activities
  
  - The GOES-R Risk Reduction (R3) activity, to develop, test, and evaluate GOES-R products, has commenced and provided early results
  
  - Algorithm Working Group (AWG) began October 2005 to
    
    • broker algorithms from among government, academic and commercial sources,
    
    • support the prototyping and demonstration of algorithm performance including algorithm/product meta-data generation techniques, standards, and formats,
    
    • provide algorithm software, test data sets, and benchmarks as potential solutions for the product generation functions, and
    
    • review and assess applicable GIRs
Integrating AWG and GOES-R3

- During PDRR and AO, the main purpose of the AWG is to review, demonstrate and recommend algorithms and processes for GOES-R, including development of simulated and proxy datasets needed for demonstrations

- A major component of the AWG is the GOES-R3 activity, the GOES-R3 key roles include
  - Providing an algorithm pipeline to the AWG.
  - Preparation and utilization of the GOES-R data and products for nowcasting and forecasting

- The AWG will assess algorithms from R3 and other sources (industry, other agencies, etc)

- The AWG will verify compliance of algorithms implemented by the System Prime

- AWG will lead cal/val definition and the sustained post-launch validation activity

- AWG will provide approach for transition from N-series to R-series products including overlap period
AWG will continue to develop and improve algorithms over the life cycle of GOES-R
Proposed Applications Teams

Algorithm Working Group

- Hydrology
- Ocean
- Imagery
- Soundings
- Winds
- Space Environment
- Clouds
- Land Surface
- Aviation
- Cryosphere
- Radiation Budget
- Aerosols / Air Quality / Atmos. Chemistry
- Lightning
System Architecture Study Phase completed upon successful Key Decision Point (KDP)-B
- Approval in October 2005

Program Definition and Risk Reduction (PDRR) Phase acquisition plan approved and solicitation released, proposal submitted, and reviewed
- Contract award expected by November 2005

Acquisition and Operations (A&O) Phase acquisition plan and approach for KDP C/D under development
## GOES-R Master Schedule

|-------------|------|------|------|------|------|-----------|------|------|-----------|
| **Instrument Contracts**  
(NASA/GSFC contracts) | | | | | | | | | |
| **System Architecture Studies**  
(12 x industry contracts) | | | | | | | | | |
| PDRR solicitation release | | | | | | | | | |
| PDRR proposal evaluation | | | | | | | | | |
| **Key Decision Point B** | | | | | | | | | |
| **Program Definition & Risk Reduction (PDRR)** | | | | | | | | | |
| System Requirements Review | | | | | | | | | |
| System Concepts Review | | | | | | | | | |
| Interim Preliminary Design Review | | | | | | | | | |
| **Key Decision Point C/D** | | | | | | | | | |
| **Acquisitions and Operations** | | | | | | | | | |
| Launch readiness | | | | | | | | | |

**Instruments**

**Key Decision Point B (KDP-B)**

**Key Decision Point C/D (KDP-C/D)**

**Acquisition & Operations (A&O)**

**Instrument contracts transition to system prime contract**
Fourth GOES-R Users’ Conference

• Planned for May 1-3 2006:
  – Location: Omni Interlocken Hotel in Broomfield, CO
  – Focus on User Readiness

– For more info:
  • [http://www.osd.noaa.gov/announcement/index.htm](http://www.osd.noaa.gov/announcement/index.htm)
  • Link to Draft Agenda
Summary

– The **great amount of information** from the GOES-R series will offer both a **continuation of current products and services**, and provide **improved or new capabilities**.

– Major improvements in GOES-R means
  • major task in preparing for the change

– NOAA plans to continue working with user communities to ensure user readiness
Selected Additional Information

NOAA GOES-R Page – Links to CONOPS, GPRD, MRD
  • https://osd.goes.noaa.gov/

NOAA/NESDIS OSD Page – Links to GOES Users’ Conference
  • http://www.osd.noaa.gov/

NASA Industry Day – Links to Instrument Documentation
  • http://goespoes.gsfc.nasa.gov/goesr_industry.htm

ABI Research at CIMSS
  • http://cimss.ssec.wisc.edu/goes/abi/

HES Research at CIMSS
  • http://cimss.ssec.wisc.edu/goes/hes/

ABI Documentation from NASA:
  • http://goespoes.gsfc.nasa.gov/abihome.htm

GOES and MODIS Galleries:
  • http://cimss.ssec.wisc.edu/goes/misc/interesting_images.html
  • http://www.ssec.wisc.edu/~gumley/modis_gallery/
# Performance Comparison with GOES N-P

<table>
<thead>
<tr>
<th>Observational Parameter</th>
<th>GOES R</th>
<th>GOES N-P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medium and High Energy Electrons and Protons</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of energy bands</td>
<td>Electrons: 10 bands plus 1 integral channel&lt;br&gt;Protons: 7 Bands</td>
<td>Electrons: 5 bands and 3 integral channels with threshold of .6,2 and 4 MeV&lt;br&gt;Protons: 12 bands</td>
</tr>
<tr>
<td>Spatial Coverage</td>
<td>5 directions</td>
<td>9 directions</td>
</tr>
<tr>
<td><strong>Low Energy Electrons and Protons</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement Range</td>
<td>Electrons: 30 eV – 30 keV&lt;br&gt;Protons: 30 eV – 30 keV</td>
<td>N/A</td>
</tr>
<tr>
<td>Number of energy bands</td>
<td>15 bands</td>
<td>N/A</td>
</tr>
<tr>
<td>Spatial Coverage</td>
<td>5 directions</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Solar and Galactic Protons</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement Range</td>
<td>1 MeV – 500 MeV; &gt; 500 MeV</td>
<td>350 - &gt; 700 MeV</td>
</tr>
<tr>
<td>Number of energy bands</td>
<td>10 bands, 1 integral band &gt; 500 MeV</td>
<td>10 bands, 1 integral band for &gt; 700 MeV</td>
</tr>
<tr>
<td>Spatial Coverage</td>
<td>2 directions</td>
<td>2 directions</td>
</tr>
<tr>
<td><strong>Energetic Heavy Ions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement Range</td>
<td>10 – 200 MeV / nucleon, 4 mass groups: He, C-N-O, Ne-S, and Fe</td>
<td>He (Alpha particles) only: 1 - &gt; 425 MeV / nucleon</td>
</tr>
<tr>
<td>Number of energy bands</td>
<td>5 bands</td>
<td>7 bands, 1 integral band for &gt; 850 MeV</td>
</tr>
<tr>
<td>Spatial Coverage</td>
<td>1 direction</td>
<td>2 directions</td>
</tr>
</tbody>
</table>