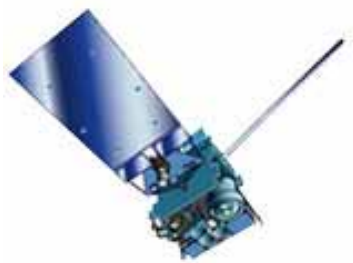
GOES-R Overview and Status

Tom Renkevens

NOAA's Satellite and Information Service



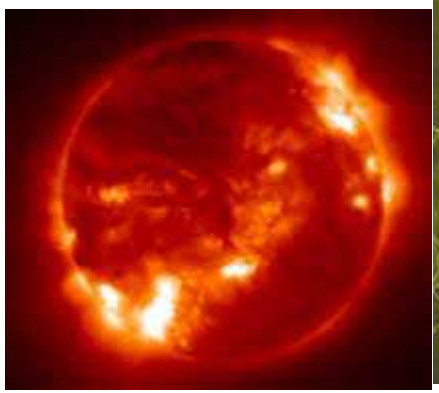
McIDAS Users Group – 2005
October 27, 2005

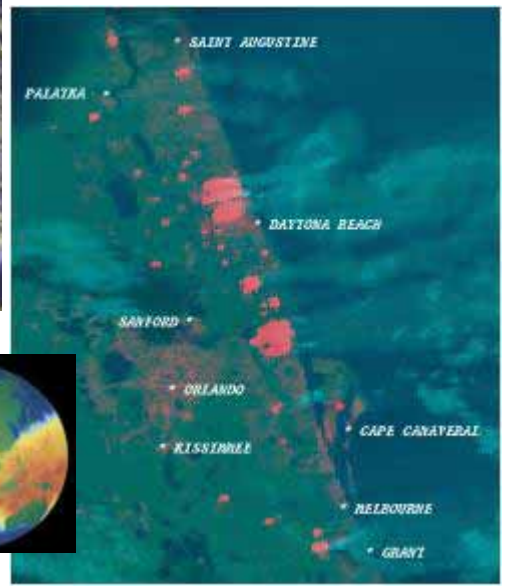
Outline

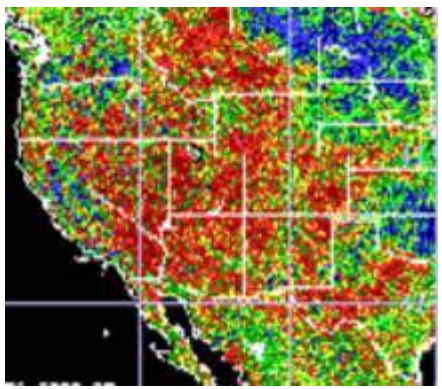
- Purpose
- GOES Background
- Requirements
- Instrument Summary
- Notional Architecture
- Algorithm Working Group
- Acquisition Process and Approach
- GOES-R Program Status
- Summary/Next Steps

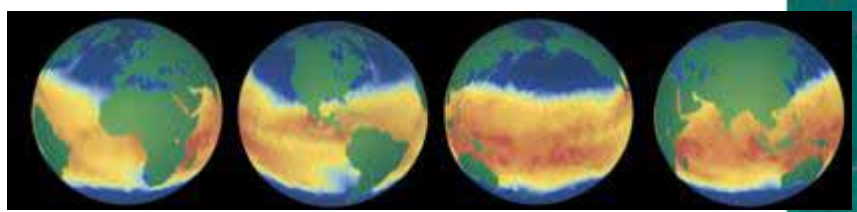
NOAA's Operational Environmental Satellites

NOAA provides observations of the atmosphere, ocean, land, and the sun



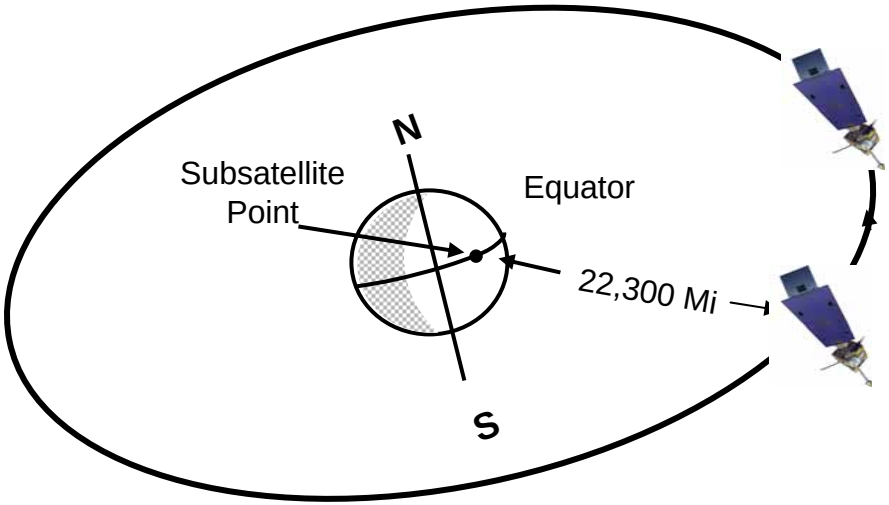




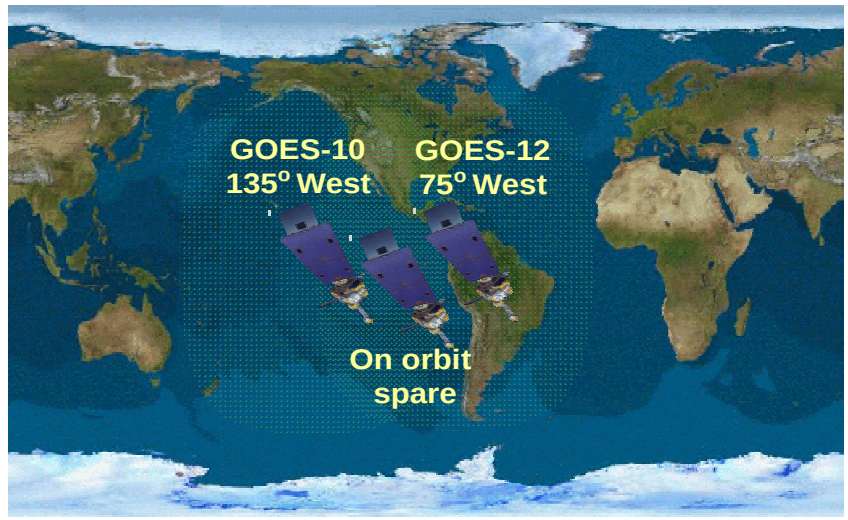


Geostationary Operational Environmental Satellite (GOES)

Continuous observations of the Western Hemisphere



Current operational philosophy is two satellites and a spare on orbit

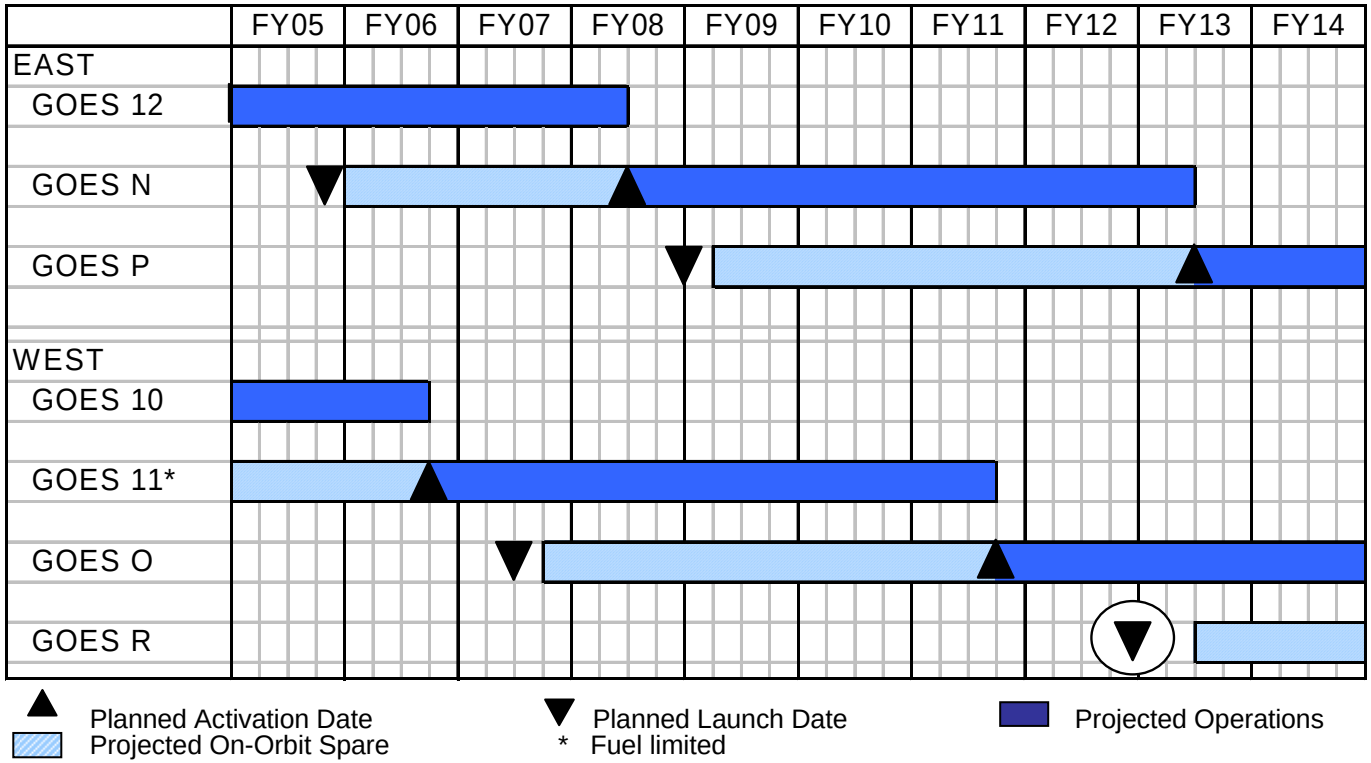


Continuous operations since 1974:

- 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

GOES Planned Launch and Operations Schedule



- 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

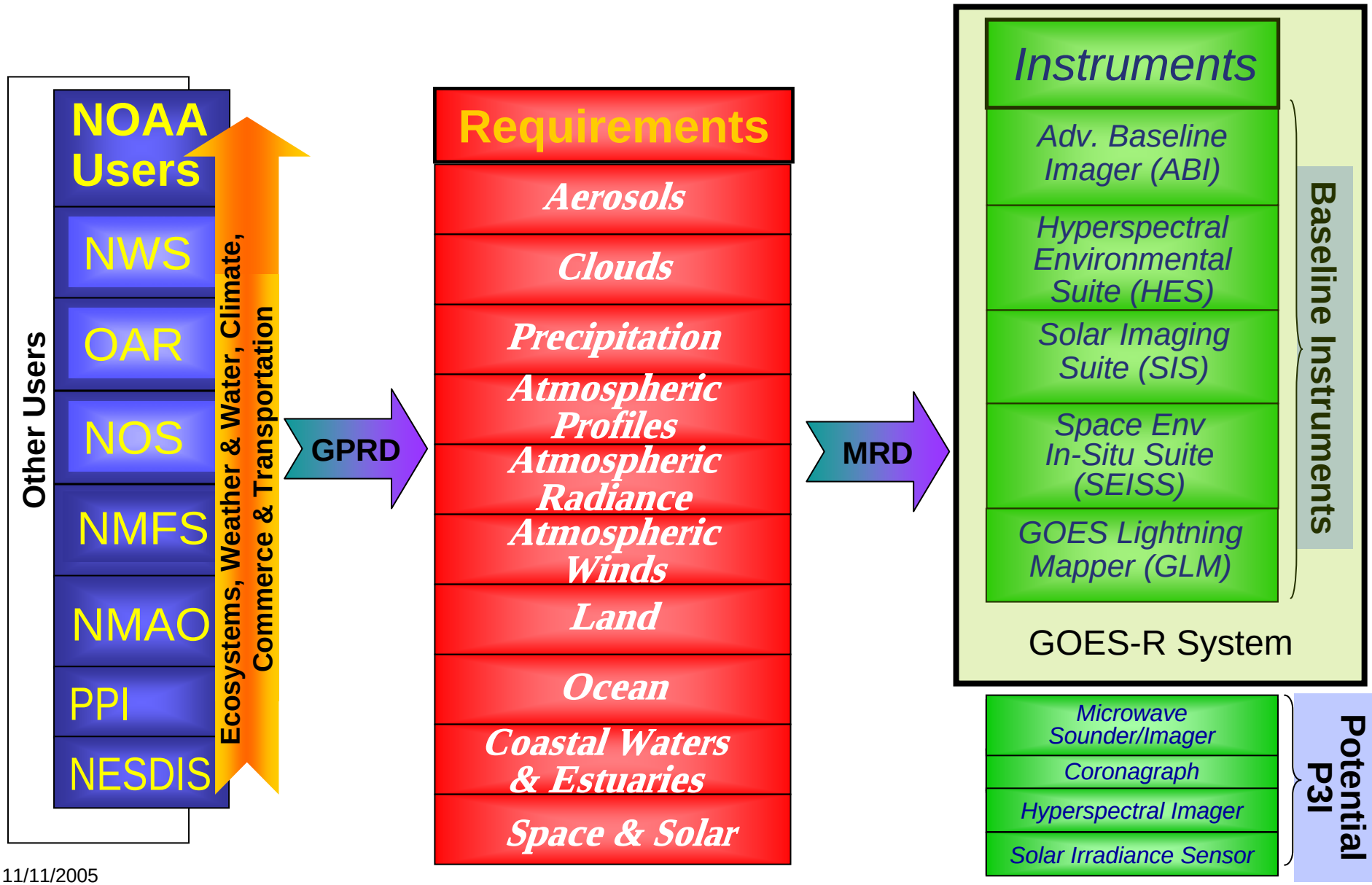
  - Link to NOAA Strategic Plan
    - http://www.spo.noaa.gov/
    - http://www.spo.noaa.gov/pdfs/NOAA%20Strategic%20Plan.pdf

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



GOES-R Observational Requirements

Aerosol Detection	Dust/Aerosol	Surface Albedo
Aerosol Particle Size	Probability of Rainfall	Surface Emissivity
Suspended Matter	Rainfall Potential	Vegetation Fraction
Volcanic Ash	Rainfall Rate	Vegetation Index
Aircraft Icing Threat	Atmospheric Vertical Moisture Profile	Currents
Cloud Imagery	Atmospheric Vertical Temperature Profile	Ocean Color
Cloud & Moisture Imagery	Capping Inversion Information	Ocean Optical Properties
Cloud Base Height	Derived Stability Indices	Ocean Turbidity
Cloud Layers / Heights & Thickness	Moisture Flux	Sea & Lake Ice / Displacement & Direction
Cloud Ice Water Path	Pressure Profile	Sea & Lake Ice / Age
Cloud Liquid Water	Total Precipitable Water	Sea & Lake Ice / Concentration
Cloud Optical Depth	Total Water Content	Sea & Lake Ice / Extent & Characterization
Cloud Particle Size Distribution	Clear Sky Masks	Sea & Lake Ice / Extent & Edge
Cloud Top Phase	Radiances	Sea & Lake Ice / Surface Temp
Cloud Top Height	Absorbed Shortwave Radiation	Sea & Lake Ice / Motion
Cloud Top Pressure	Downward Longwave Radiation	Sea & Lake Ice / Thickness
Cloud Top Temperature	Downward Solar Insolation	Ice Cover / Landlocked
Cloud Type	Reflected Solar Insolation	Snow Cover
Convection Initiation	Upward Longwave Radiation	Snow Depth
Enhanced "V"/Overshooting Top Detection	CO Concentration	Sea Surface Temps
Hurricane Intensity	Ozone Total	Energetic Heavy Ions
Imagery: All-Weather / Day - Night	SO_2 Detection	Mag Electrons & Protons: Low Energy
Lightning Detection	Derived Motion Winds	Mag Electrons & Protons: Med & High Energy
Low Cloud & Fog	Microburst Wind Speed Potential	Solar & Galactic Protons
Turbulence	Fire / Hot Spot Imagery	Solar Flux: EUV
Visibility	Flood / Standing Water	Solar Flux: X-Ray
Geomagnetic Field	Land Surface (Skin) Temperature	Solar Imagery: X-Ray

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

I-P Combined **I-M** **N-P** **R-Series**

Performance Capability	GOES I-M	GOES N-P	GOES R
Imaging			
Resolution - Visible	1 km	1 km	0.5 km
Resolution - IR	4 km	4 km	2 km
Full Disk Coverage Rate	30 min	30 min	5 min
# of Channels	5	5	16
Atmospheric Soundings			
Resolution	10 km	10 km	10 km / 4 km
Hourly Coverage	CONUS	CONUS	Full Disk @ 10 km resolution
Severe Weather Rapid Scan	No	No	Yes - 4km resolution CONUS
# of Channels	19	19	~1500
Coastal Water Monitoring	No	No	Yes - 300 m resolution
Solar Monitoring (SXI)	GOES-M only	Yes	Yes
Lightning Detection	No	No	Yes
Operate through Eclipse	No	Yes	Yes
Ground System Backup	Limited	Limited	Full
Archive and Access	Limited	Limited	Yes

The Advanced Baseline Imager (ABI)

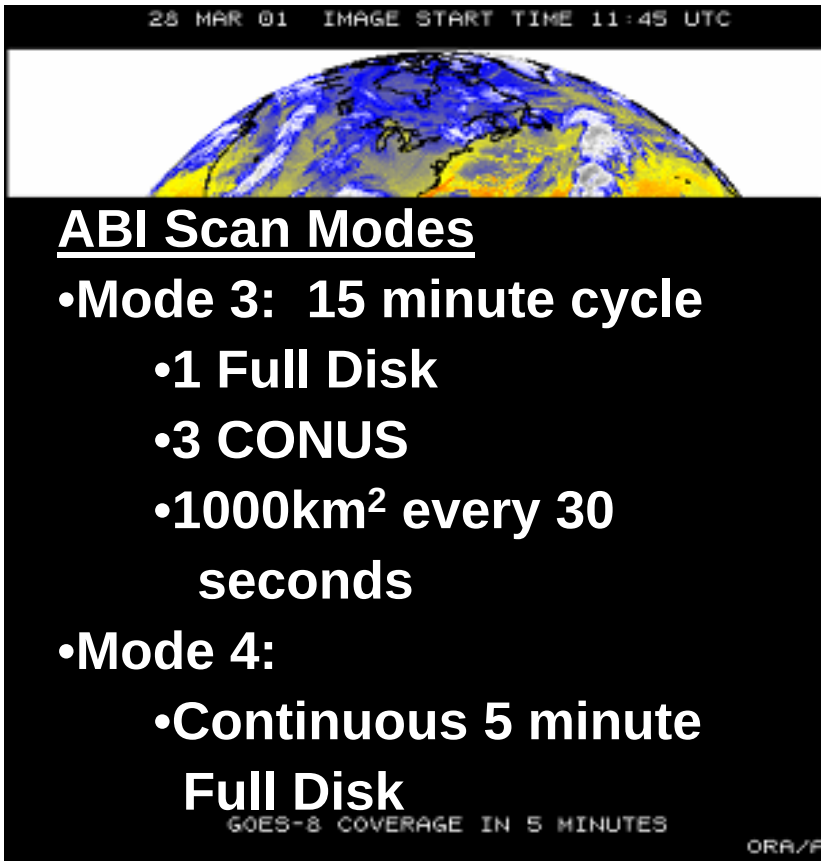
	ABI	Current
Spectral Coverage		
	16 bands	5 bands
Spatial resolution		
0.64 μm Visible	0.5 km	Approx. 1 km
Other Visible/nearIR	1.0 km	n/a
Bands (>2 μm)	2 km	Approx. 4 km
Spatial coverage		
Full disk	4+ per hour	Every 3 hours
CONUS	12 per hour	~4 per hour
Mesoscale	Every 30 sec	-
Visible		
On-orbit calibration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

Link to AMS Article – Schmit et. al

Increased Imaging Capability

5 Minute Coverage

GOES-I/P

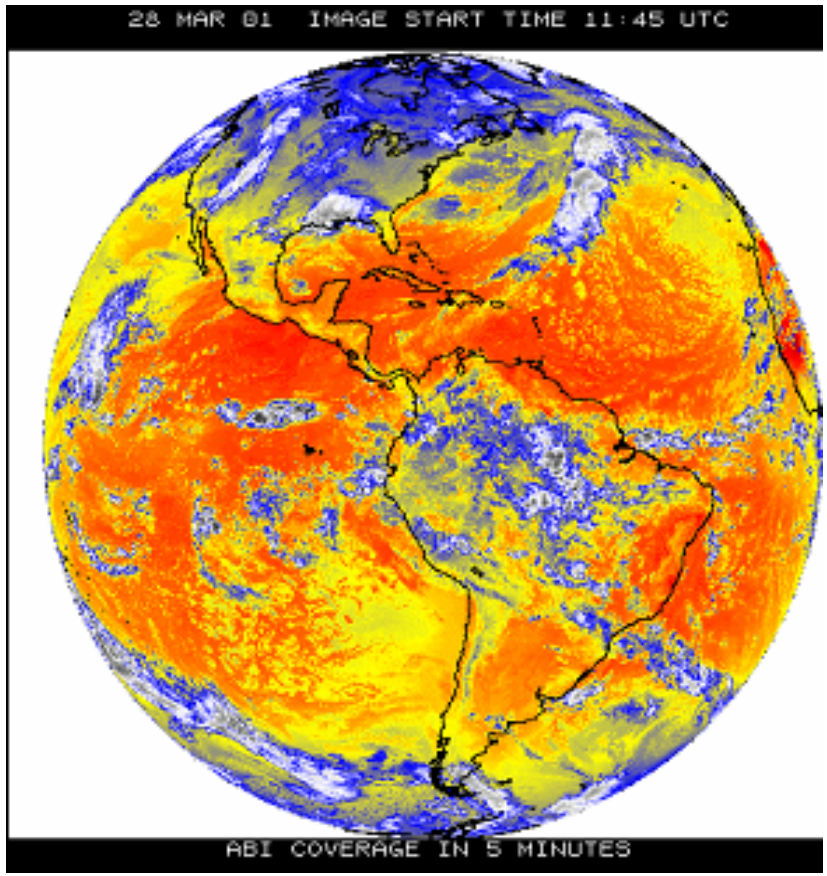


ABI Scan Modes

- Mode 3: 15 minute cycle
  - 1 Full Disk
  - 3 CONUS
  - 1000km^2 every 30 seconds
- Mode 4:
  - Continuous 5 minute Full Disk

1/5 Disc

GOES-R



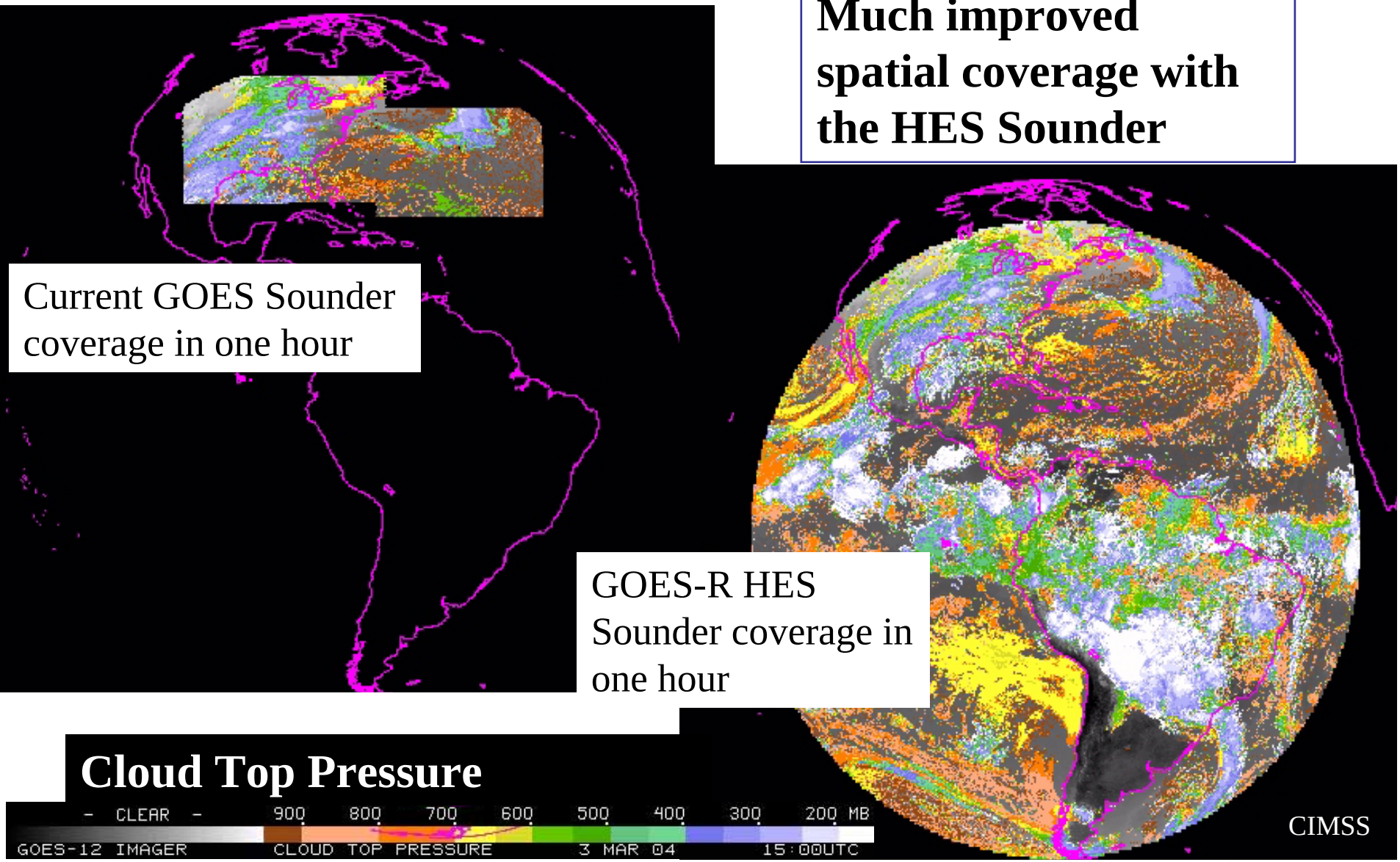
Full Disc

Hyperspectral Environmental Suite (HES)

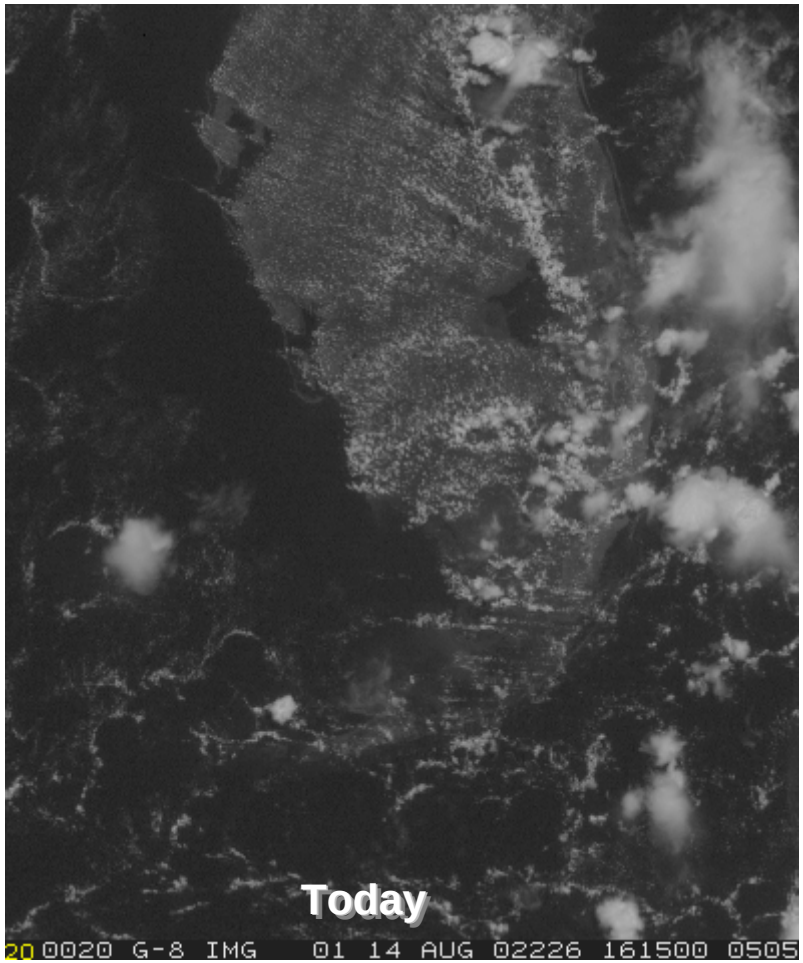
- New complex requirements – Hyperspectral Design as opposed to 18 position filter wheel (GOES-I-P) which includes both, Sounding and Imaging Tasks
  - Full Disk Sounding (DS) Task
    - IR Spatial resolution 10 km;
    - Spectral Range 3.7- 15.4 micron (not continuous);
    - ~1500 channels;
    - 62º 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

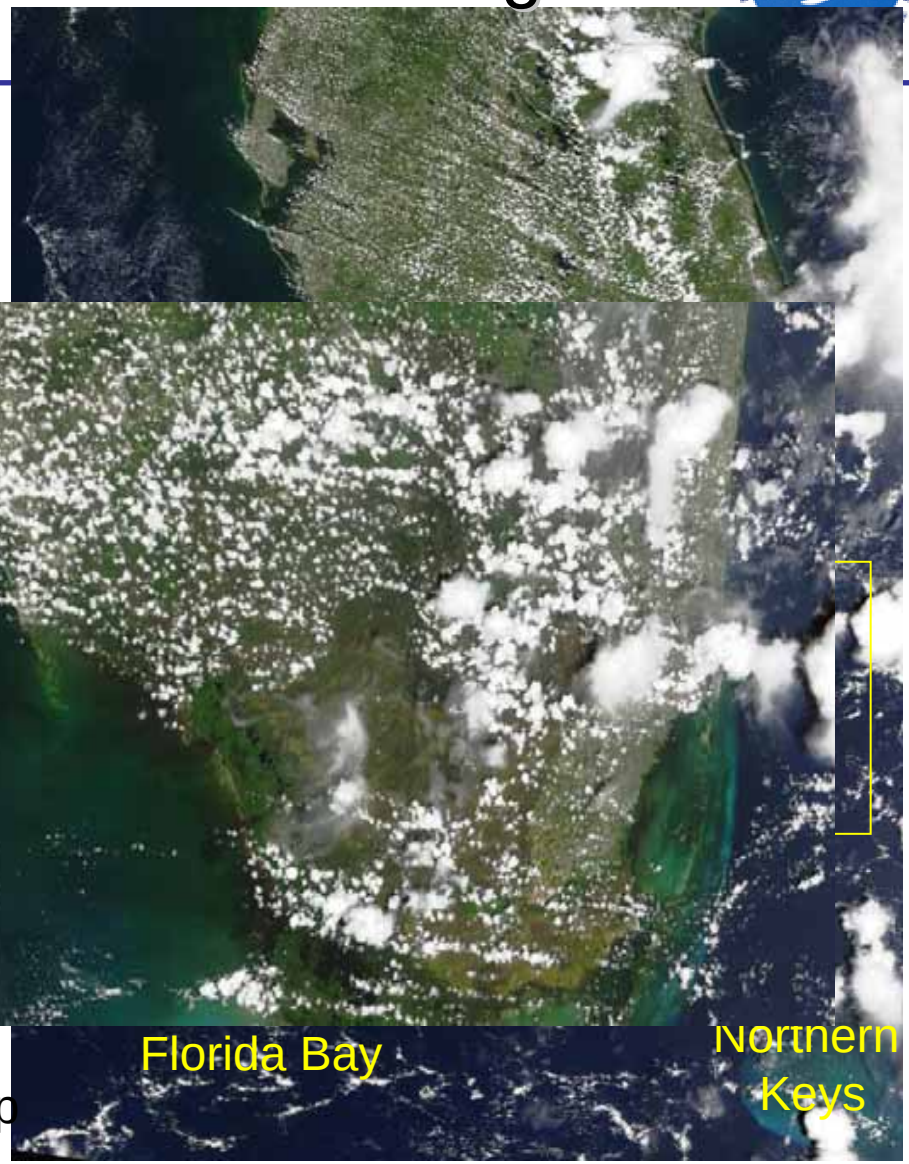
Increased Coverage Rate

Much improved spatial coverage with the HES Sounder



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

Simulated GOES-R

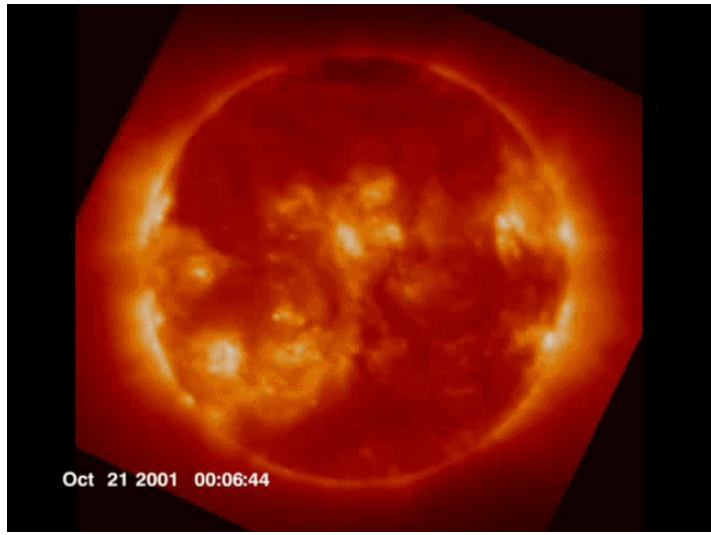
Geostationary Lightning Mapper

- 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

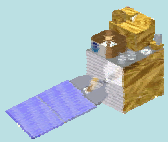
Some GOES-R Improvements

- 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

Potential System Architectures

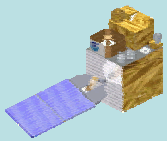
Consolidated Constellation

West



ABI
HES
SIS
SEISS
GLM

East

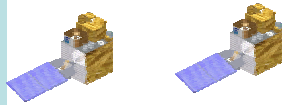


ABI
HES
SIS
SEISS
GLM

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

Distributed Constellation

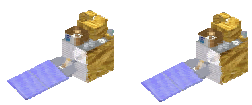
West



ABI
SIS
SEISS

HES
GLM

East



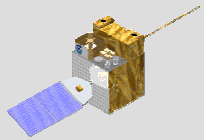
ABI
SIS
SEISS

HES
GLM

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

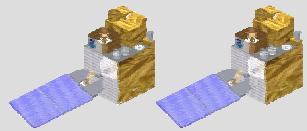
Flexible Constellation

West



ABI
HES
SIS
SEISS
GLM

East



ABI
SIS
SEISS

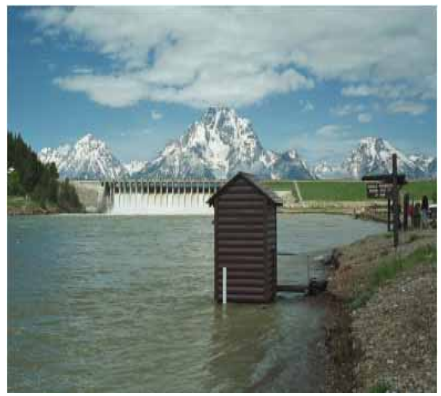
HES
GLM

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

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

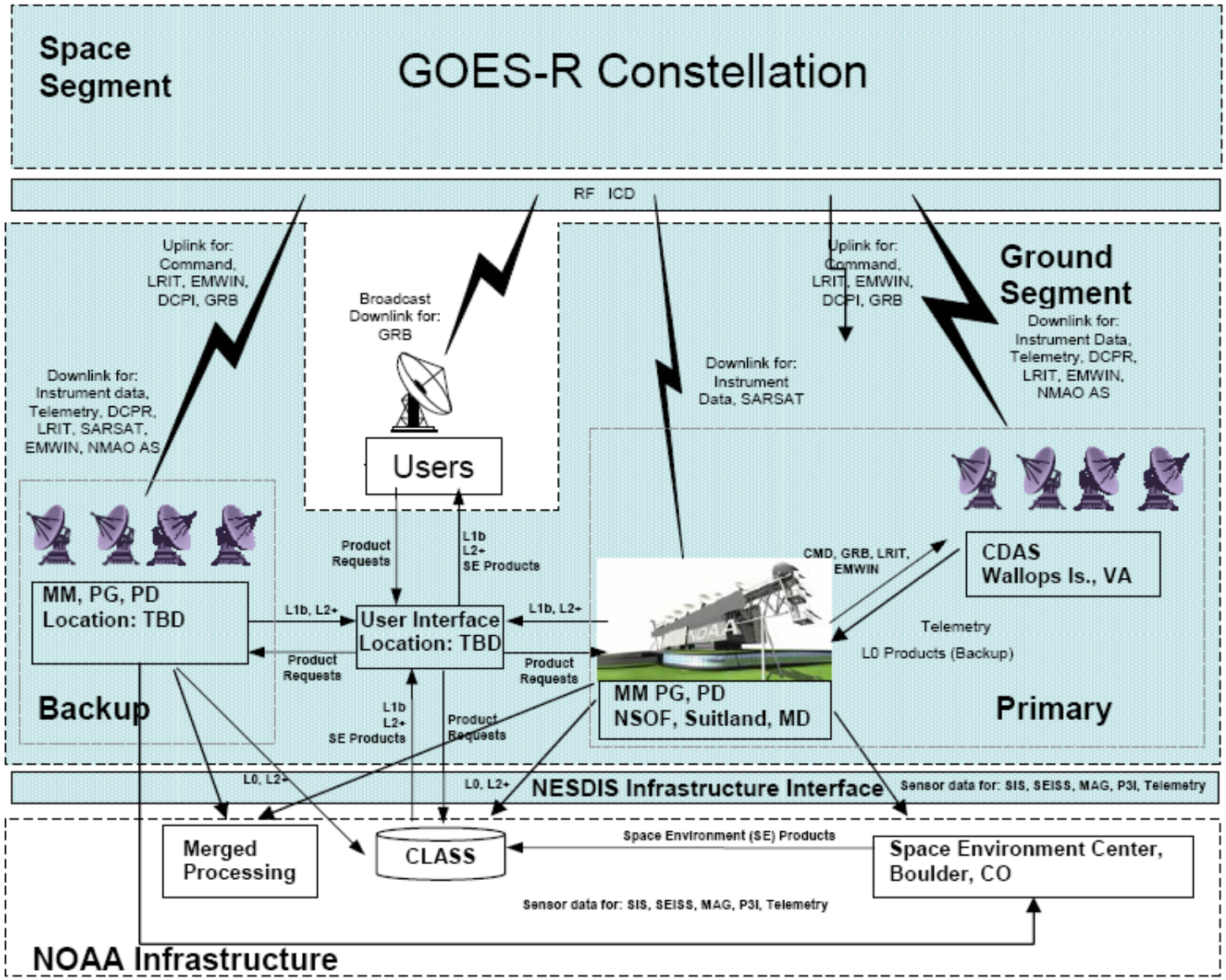


http://water.usgs.gov/nsip/

GOES-R will support improved AUX services

Higher Data Rates for LRIT, DCS

Communications System Overview



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

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

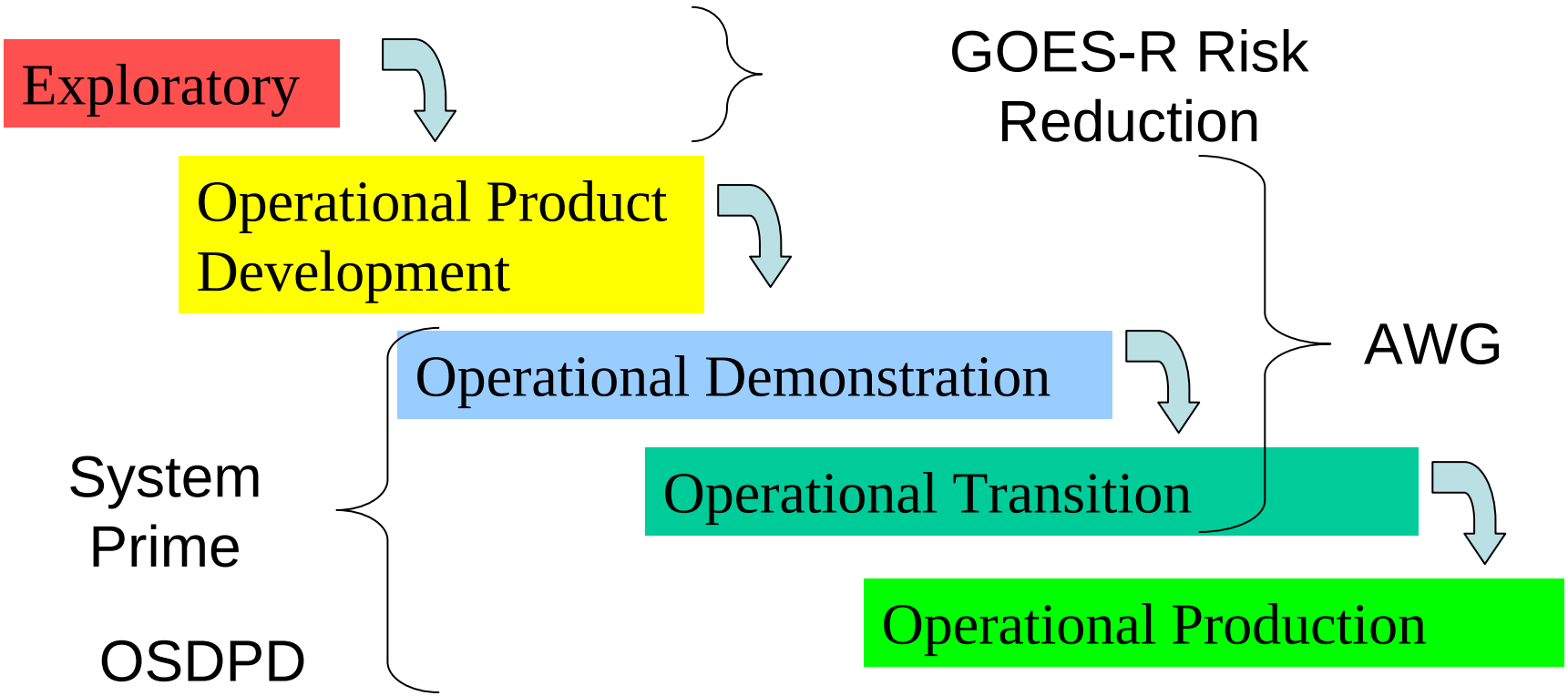
Algorithm Working Group

- 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

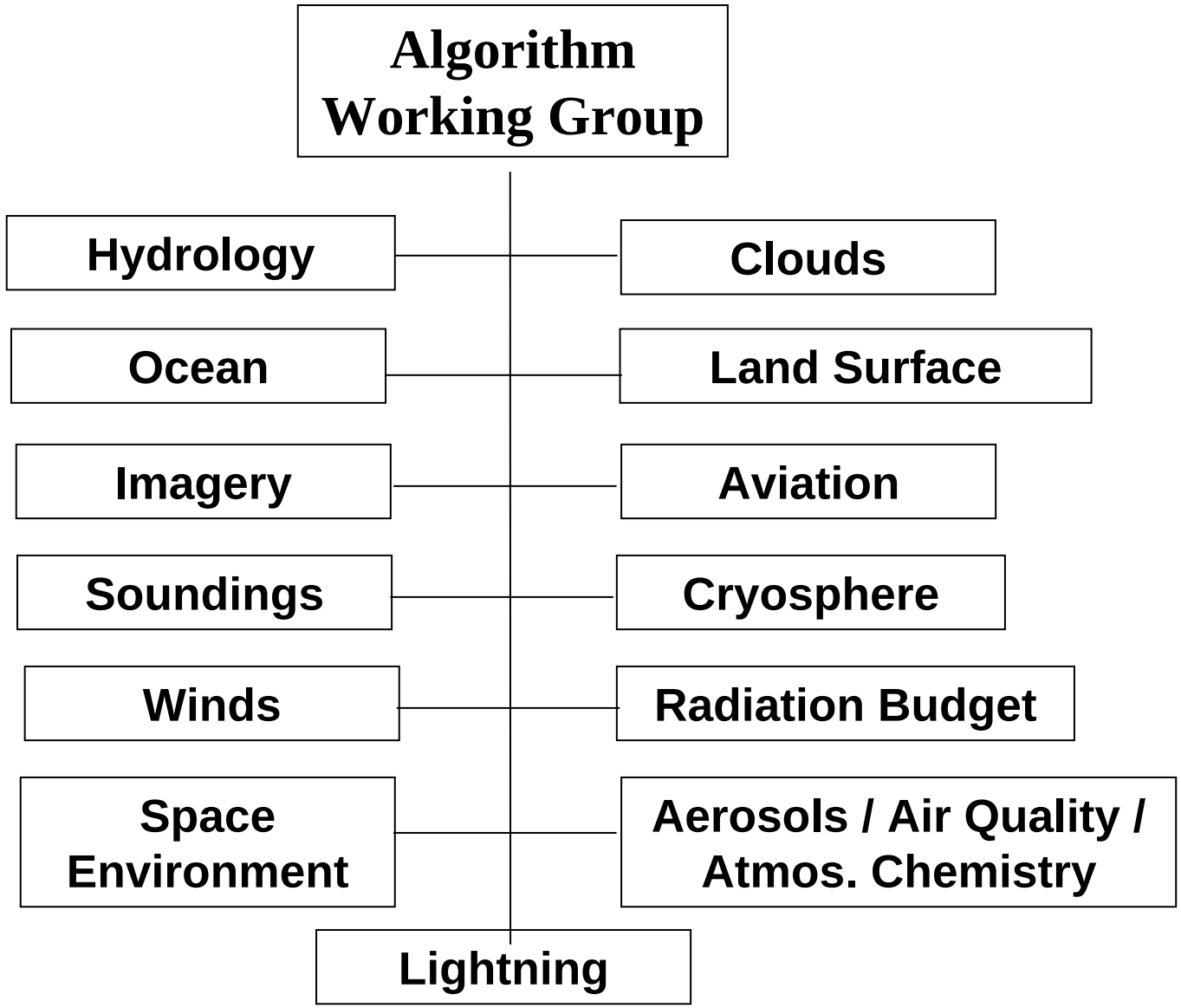
- During PDRR and AO, the main purpose of the AWG is to review, demonstrate and recommend algorithms and processes for GOES-R, including development of simulated and proxy datasets needed for demonstrations
- A major component of the AWG is the GOES-R3 activity, the GOES-R3 key roles include
  - Providing 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

GOES-R Product Generation Development

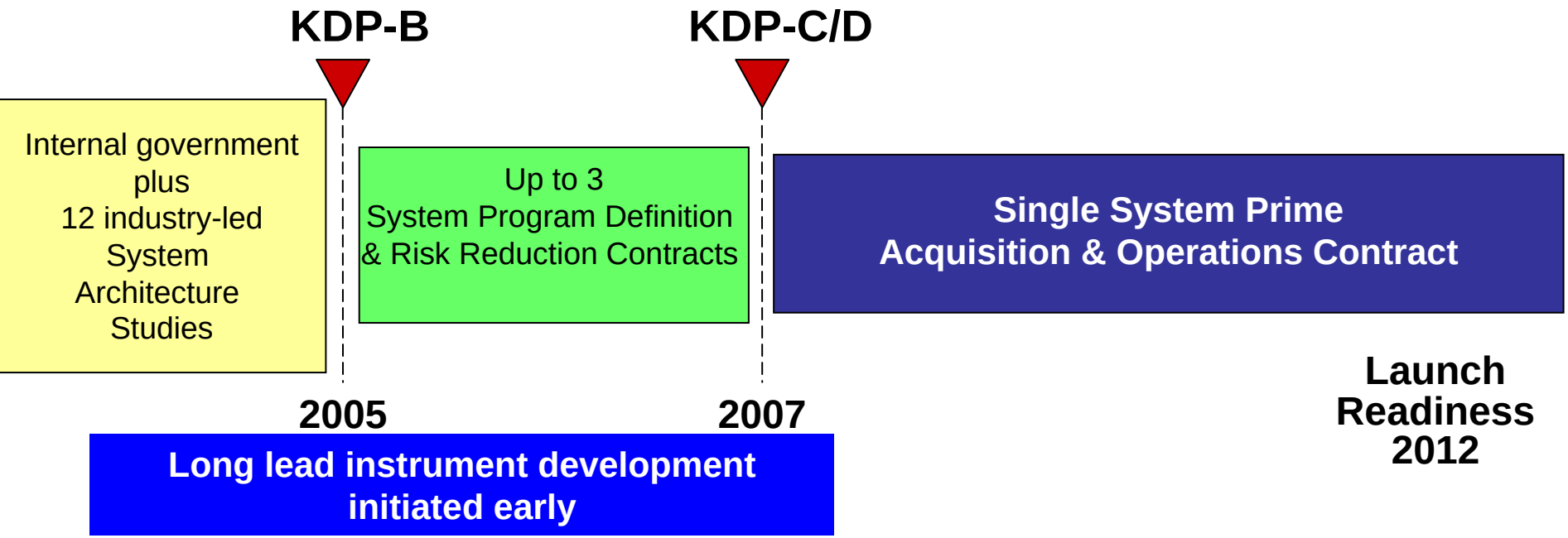


AWG will continue to develop and improve algorithms over the life cycle of GOES-R

Proposed Applications Teams

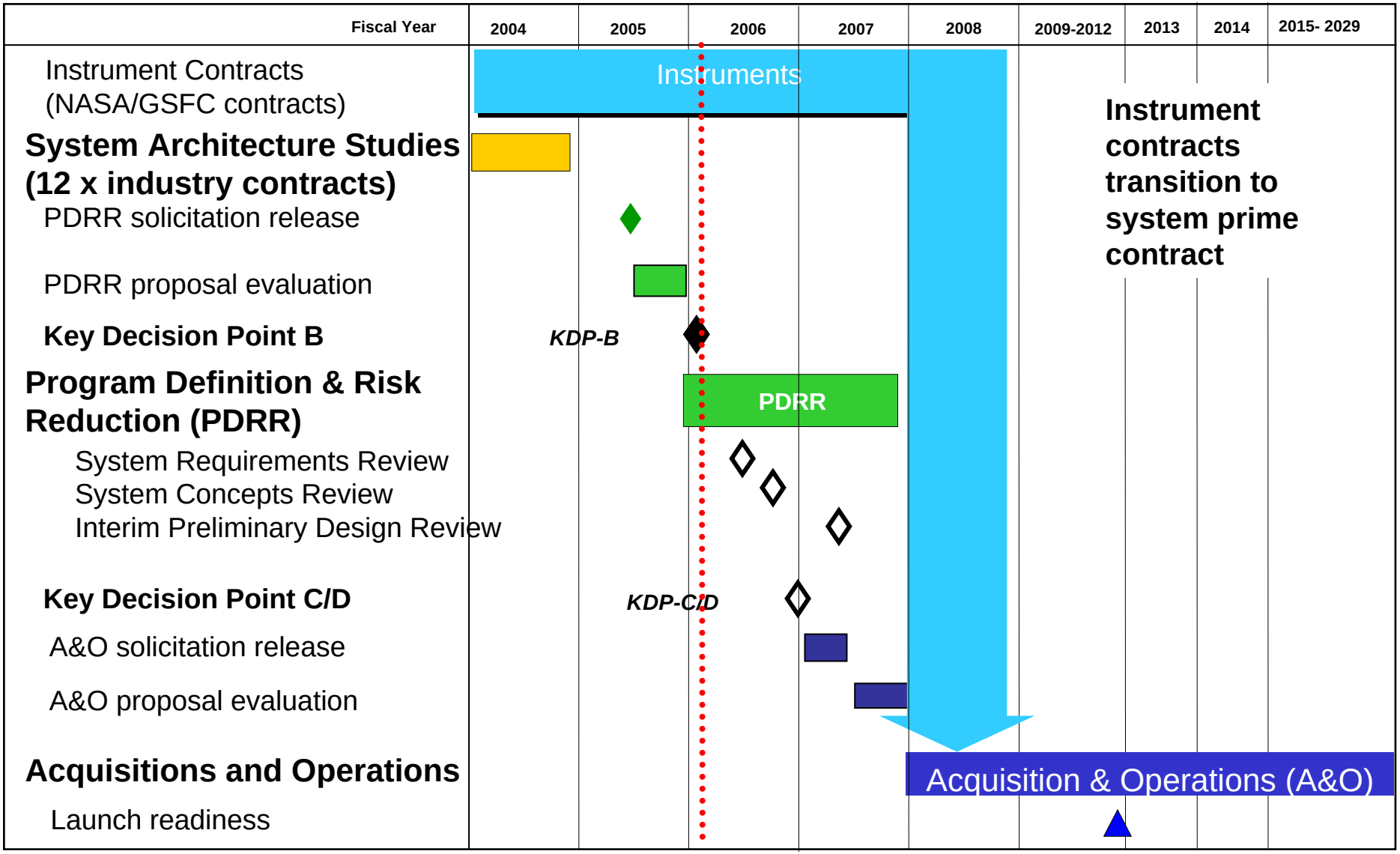


GOES-R Acquisition Life Cycle Phases



- 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



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*
    - *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

Observational Parameter		GOES R	GOES N-P
Medium and High Energy Electrons and Protons	Measurement Range	Electrons: 30 keV - 4 MeV Protons: 80 keV - 1 MeV	Electrons: 30 keV - 4 MeV Protons: 80 keV - >700 MeV
	Number of energy bands	Electrons: 10 bands plus 1 integral channel Protons: 7 Bands	Electrons: 5 bands and 3 integral channels with threshold of .6,2 and 4 MeV Protons: 12 bands
	Spatial Coverage	5 directions	9 directions
Low Energy Electrons and Protons	Measurement Range	Electrons: 30 eV – 30 keV Protons: 30 eV – 30 keV	N/A
	Number of energy bands	15 bands	N/A
	Spatial Coverage	5 directions	N/A
Solar and Galactic Protons	Measurement Range	1 MeV – 500 MeV; > 500 MeV	350 - > 700 MeV
	Number of energy bands	10 bands, 1 integral band > 500 MeV	10 bands, 1 integral band for > 700 MeV
	Spatial Coverage	2 directions	2 directions
Energetic Heavy Ions	Measurement Range	10 – 200 MeV / nucleon, 4 mass groups: He, C-N-O, Ne-S, and Fe	He (Alpha particles) only: 1 - > 425 MeV / nucleon
	Number of energy bands	5 bands	7 bands, 1 integral band for > 850 MeV
	Spatial Coverage	1 direction	2 directions