

National Polar-orbiting Operational Environmental Satellite System (NPOESS)

An Introduction to NPOESS
presented at

ITSC 13
Sainte Adele, Canada

Hal J. Bloom
Integrated Program Office
Space Segment Manager

October 31st 2003

A Tri-agency Effort to Leverage and Combine Environmental Activities



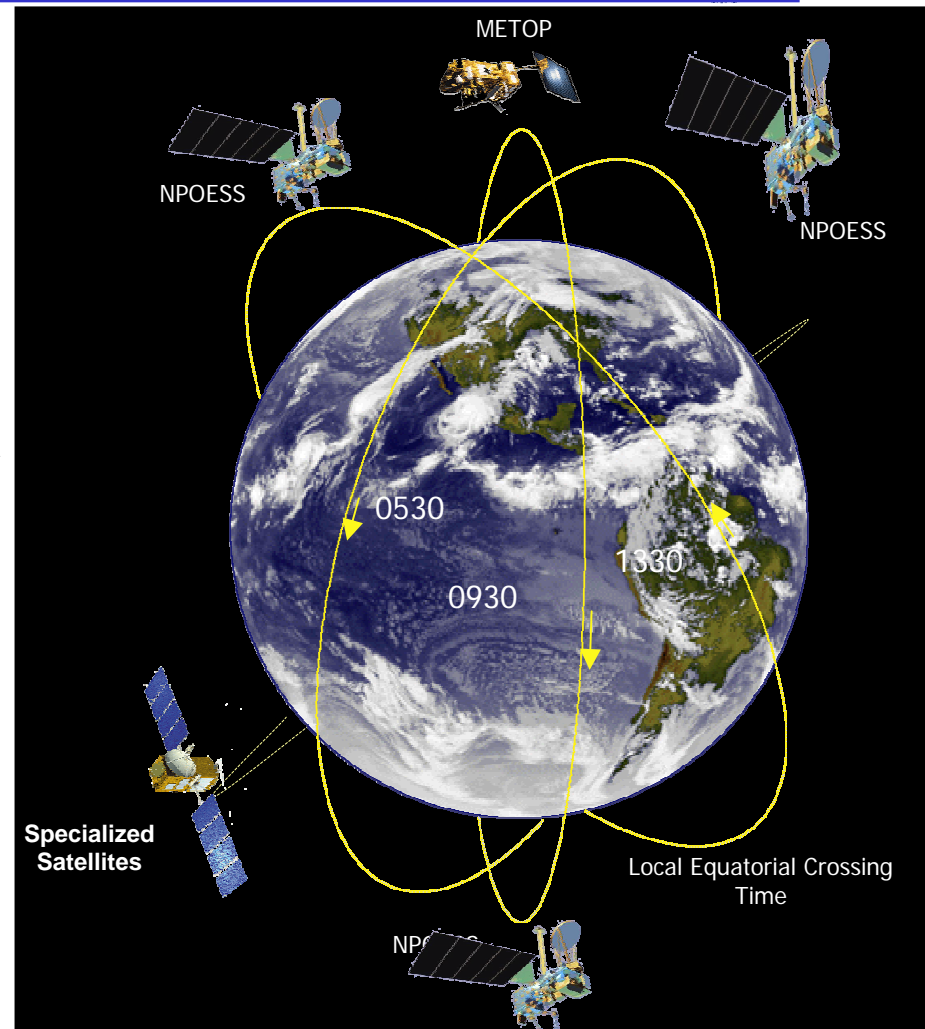
Mission

Provide a national, operational, polar-orbiting remote-sensing capability

Achieve National Performance Review (NPR) savings by converging DoD and NOAA satellite programs

Incorporate new technologies from NASA

Encourage International Cooperation



Saves as much as \$1.3B from the cost of previously planned separate developments

NPOESS EDR-to-Sensor Mapping

55 Product Sets [RDR, SDR, EDR]



☆ Atmospheric Vertical Moisture Profile	Cloud Top Pressure	Precipitable Water
☆ Atmospheric Vertical Temp Profile	Cloud Top Temperature	Precipitation Type/Rate
☆ Imagery	Downward Longwave Radiance (sfc)	Pressure (Surface/Profile)
☆ Sea Surface Temperature	Downward Shortwave Radiance(sfc)	Sea Ice Characterization
☆ Sea Surface Winds	Electric Field	Sea Surface Height/Topography
☆ Soil Moisture	Electron Density Profile	Snow Cover/Depth
Aerosol Optical Thickness	Energetic Ions	Solar Irradiance
Aerosol Particle Size	Geomagnetic Field	Supra-Thermal-Auroral Particles
Aerosol Refractive Index	Ice Surface Temperature	Surface Type
Albedo (Surface)	In-situ Plasma Fluctuations	Wind Stress
Auroral Boundary	In-situ Plasma Temperature	Suspended Matter
Auroral Energy Deposition	Ionospheric Scintillation	Total Water Content
Auroral Imagery	Medium Energy Charged Particles	Vegetation Index
Cloud Base Height	Land Surface Temperature	
Cloud Cover/Layers	Net Heat Flux	
Cloud Effective Particle Size	Net Solar Radiation (TOA)	
Cloud Ice Water Path	Neutral Density Profile	
Cloud Liquid Water	Color/Chlorophyll	
Cloud Optical Thickness	Ocean Wave Characteristics	
Cloud Particle Size/Distribution	Outgoing Longwave Radiation (TOA)	
Cloud Top Height	Ozone - Total Column/Profile	

	VIIRS (23)
	CMIS (19)
	CrIS/ATMS (3)
	OMPS (1)
	SES (13)
	GPSOS (2)
	ERBS (5)
	TSIS (1)
	ALTIMETER (3)
	APS (4)

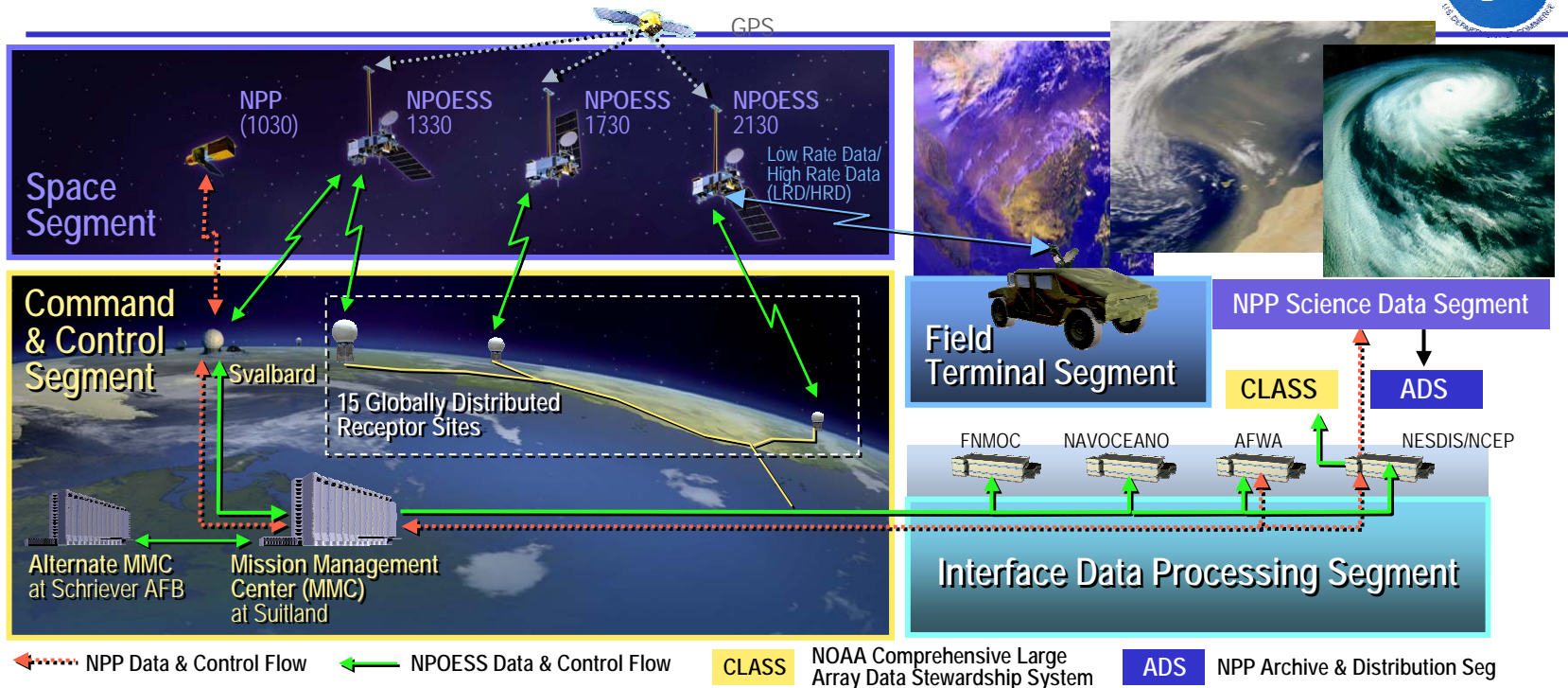
☆ Environmental Data Records (EDRs) with Key Performance Parameters

NPOESS Overview



- Contract was awarded on August 23, 2002 to Northrop Grumman Space Technology
- Contract consists of:
 - 6 satellites
 - Taking over all government instrument contracts
 - Buying all “leveraged” instruments
 - Integrating GFE instruments (ADCS and SARSAT)
 - Building and deploying all ground systems
 - C3 and data retrieval
 - Data processing hardware and software
 - Software for worldwide users
 - Operating system through IOC (2011)
 - with option to 2018

NPOESS Top Level Architecture



Data Quality

SMD/HRD
LRD

128 attributes above, 724 at, 7 below threshold

305 attributes above, 180 at, 0 below threshold

Data Latency

SMD
HRD/LRD

Threshold

Objective

Data Availability

Operational Availability



NPOESS Top Level Architecture



Data Quality

SMD/HRD
LRD

128 attributes above, 724 at, 7 below threshold
305 attributes above, 180 at, 0 below threshold

Data Latency

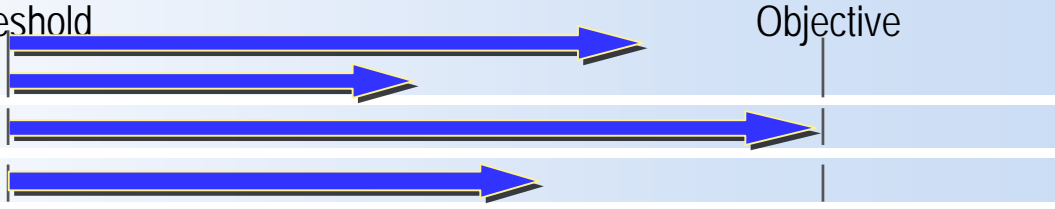
SMD
HRD/LRD

Threshold

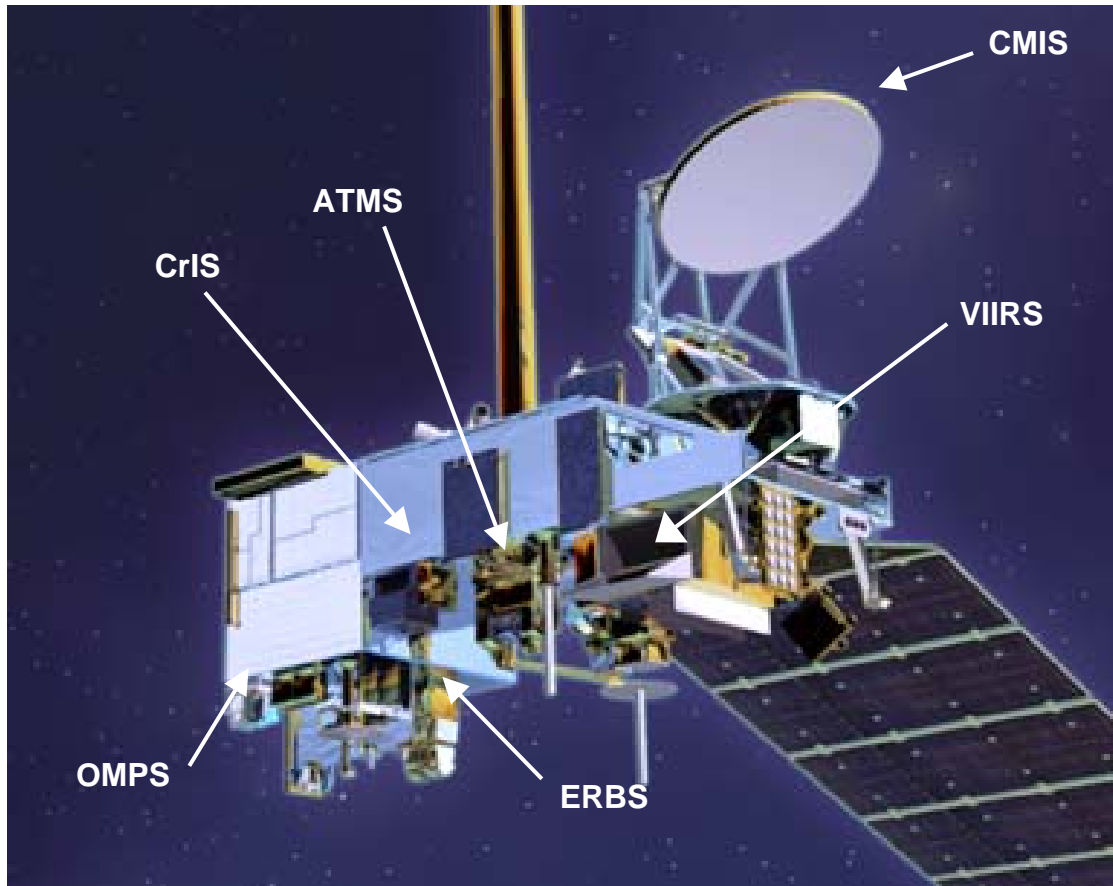
Objective

Data Availability

Operational Availability



NPOESS Satellite



NPOESS 1330 Configuration

Single satellite design with common sensor locations

- VIIRS - vis/IR imager
- CMIS - μ wave imager
- CrIS - IR sounder
- ATMS - μ wave sounder
- SESS - space environment
- GPSOS - GPS occultation
- OMPS - ozone
- ADCS - data collection
- SARSAT - search & rescue
- APS - aerosol polarimeter
- ERBS - Earth radiation budget
- SS - laser sensor
- ALT - altimeter
- TSIS - solar irradiance

	1330	1730	2130
VIIRS	X	X	X
CMIS	X	X	X
CrIS	X	X	X
ATMS	X	X	X
SESS	X		
GPSOS	X		
OMPS	X		
ADCS	X	X	
SARSAT	X	X	X
ERBS	X		
SS	X	X	X
ALT		X	
TSIS		X	

NPOESS Payloads

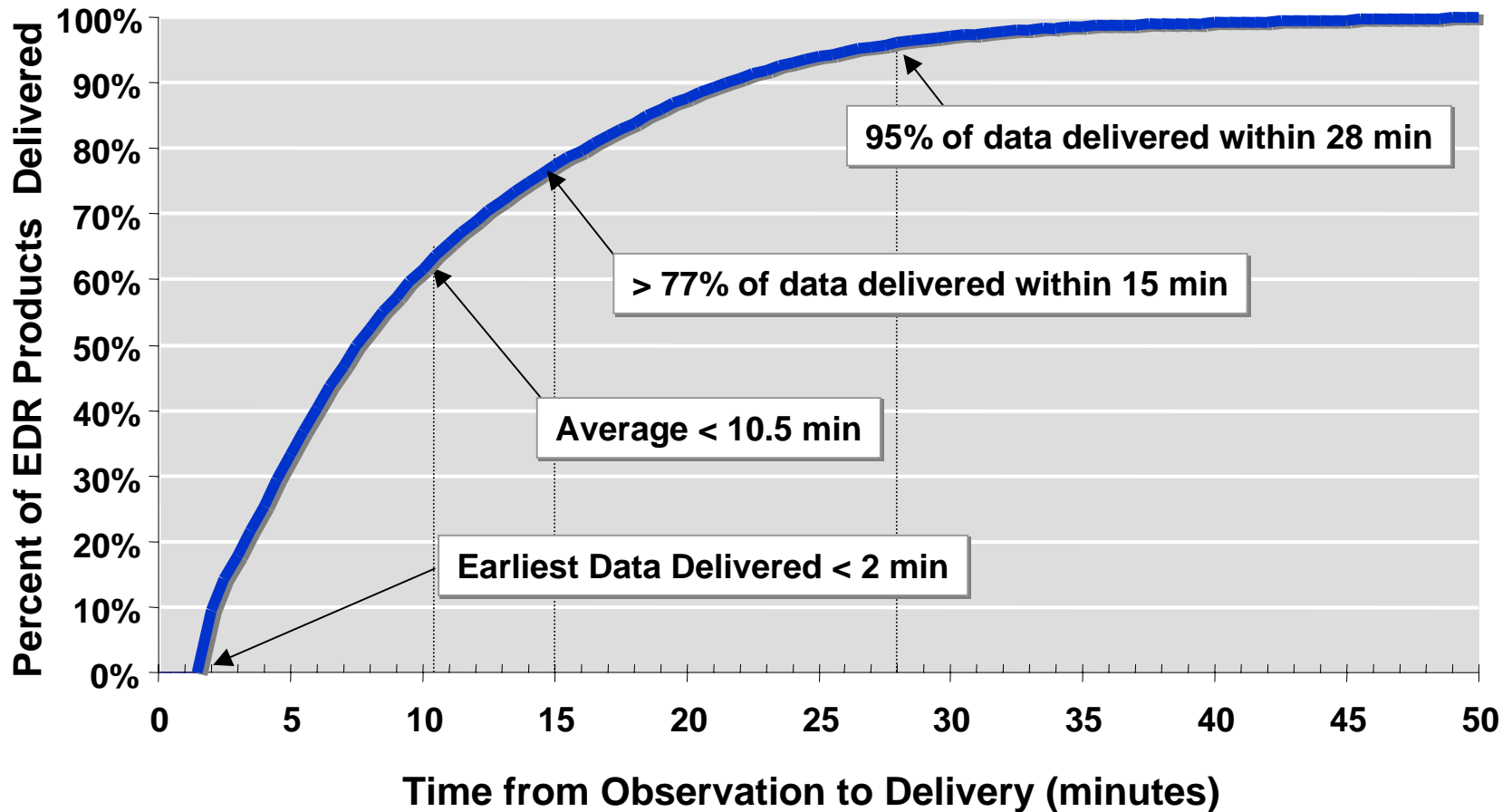


NPOESS Instruments	0530	0930	1330	METOP 0930	NPP 1030
<u>IPO Developed</u>					
Visible/IR Imager Radiometer Suite (VIIRS)*	X	X	X	X (AVHRR)	X
Cross-track IR Sounder (CrIS)*	←	X	X	X (IASI/HIRS)	X
Conical MW Imager/Sounder (CMIS)*	X	X	X		
Ozone Mapper/Profiler Suite (OMPS)			X	X (GOME)	X
GPS Occultation Sensor (GPSOS)			X	X (GRAS)	
Space Environmental Sensor Suite (SESS)			X	X (SEM)	
Aerosol Polarimetry Sensor (APS)		X			
<u>Leveraged</u>					
Advanced Technology MW Sounder (ATMS)*	←	X	X	X (AMSU/MHS)	X
ARGOS-Data Collection System (A-DCS)	X		X	X	
Search and Rescue (SARSAT)	X	X	X		
Earth Radiation Budget Sensor (ERBS)			X		
Total Solar Irradiance Sensor (TSIS)	X				
Radar altimeter (ALT)	X				
Survivability Sensor (SS)	X	X	X		
Advanced Scatterometer (ASCAT)				X	

NPOESS EDR Processing Timeline



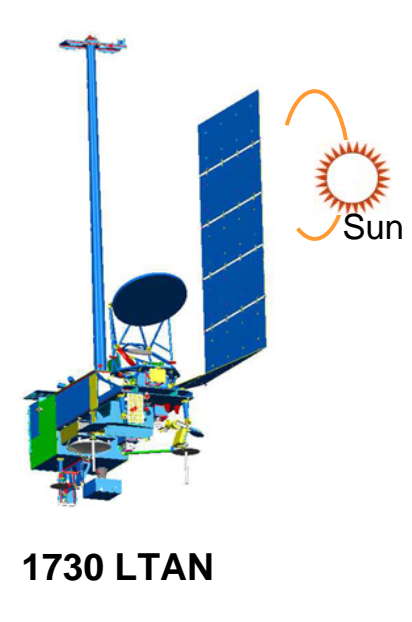
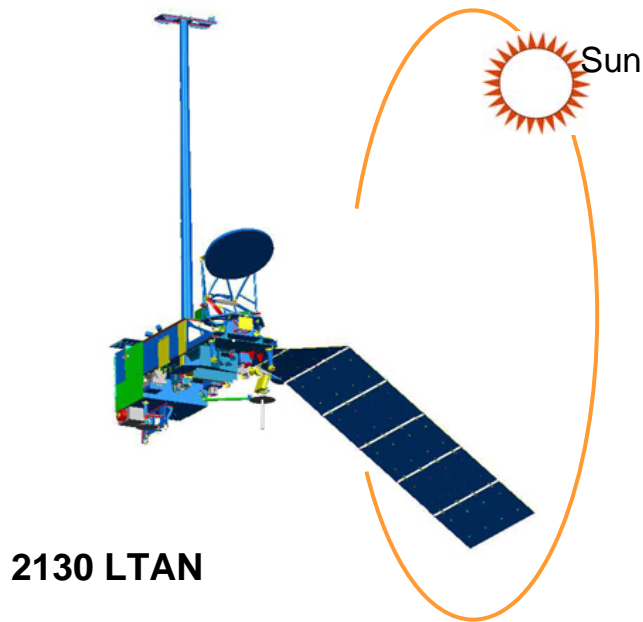
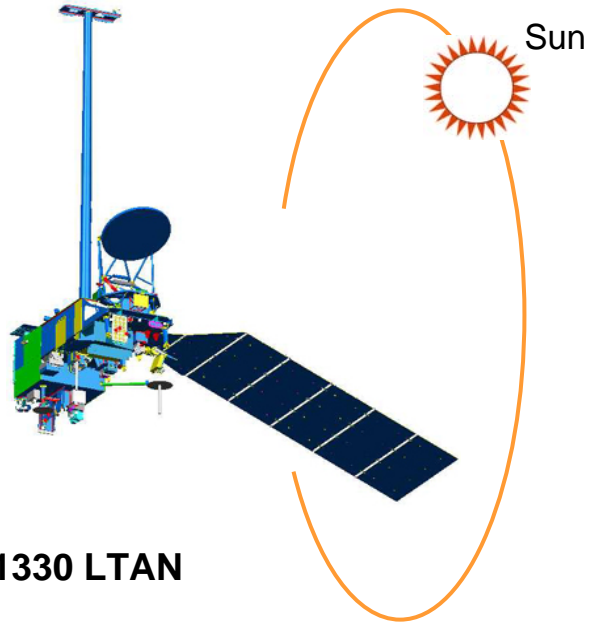
End-to-End EDR Latency



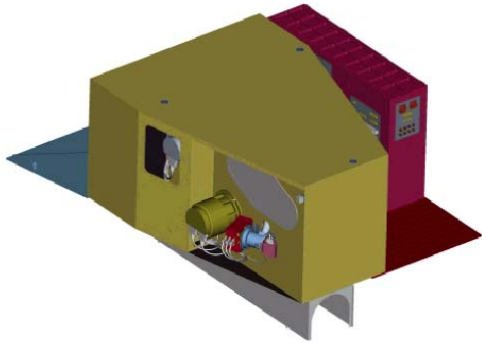
Single Satellite Solution



- Common spacecraft design for all three planes
- Common sensors in the same place for efficient integration and re-configuration

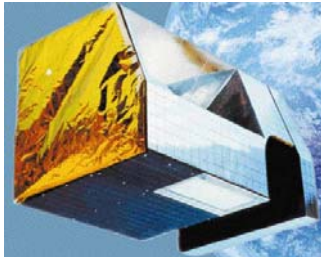


Development Sensor Highlights



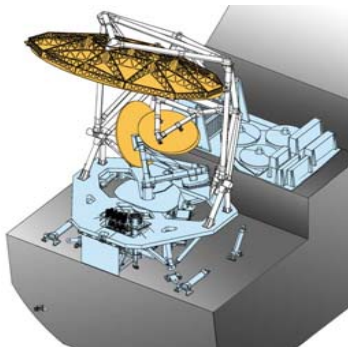
- **Visible/Infrared Imager Radiometer Suite (VIIRS)**
Raytheon Santa Barbara Research Center

- 0.4 km imaging and 0.8 km radiometer resolution
- 22 spectral bands covering 0.4 to 12.5 μm
- Automatic dual VNIR and triple DNB gains
- Spectrally and radiometrically calibrated
- EDR-dependent swath widths of 1700, 2000, and 3000 km



- **Cross-track Infrared Sounder (CrIS)** **ITT Fort Wayne**

- 158 SWIR (3.92 to 4.64 μm) channels
- 432 MWIR (5.71 to 8.26 μm) channels
- 711 LWIR (9.14 to 15.38 μm) channels
- 3x3 detector array with 15 km ground center-to-center
- 2200 km swath width



- **Conical Scanning Microwave Imager/Sounder (CMIS)**
Boeing Space Systems

- 2.2 m antenna
- RF imaging at 6, 10, 18, 36, 90, and 166 GHz
- Profiling at 23, 50 to 60, 183 GHz
- Polarimetry at 10, 18, 36 GHz
- 1700 km swath width

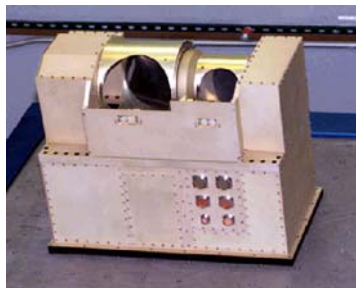
Development Sensor Highlights (cont.)



- **Advanced Technology Microwave Sounder (ATMS)**

Northrop Grumman Electronics

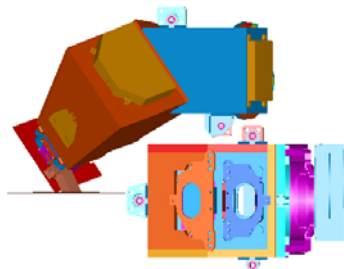
- CrIS companion cross track scan
- Profiling at 23, 50 to 57, 183 GHz
- Surface measurements at 31.4, 88, 165 GHz
- 1.1, 3.3, and 5.2 deg (SDRs resampled)
- 2300 km swath width



- **Ozone Mapping and Profiler Suite (OMPS)**

Ball Aerospace

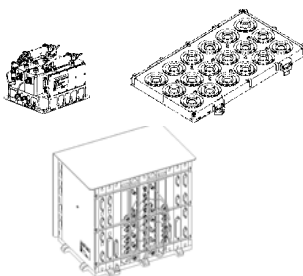
- Total ozone column 300 to 380 nm with 1.0 nm resolution
- Nadir ozone profile 250 to 310 nm with 1.0 nm resolution
- Limb ozone profile 290 to 1000 nm with 2.4 to 54 nm resolution
- Swath width of 2800 km for total column



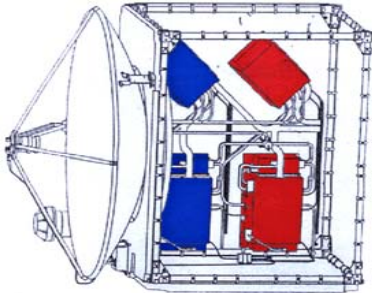
- **Global Positioning System Occultation Sensor (GPSOS)**

Saab Ericson

- RF receiver/processor of GPS signals at 1575.42 and 1227.60 MHz
- Velocity, anti-velocity and nadir views
- Ionospheric scintillation
- Tropospheric/stratospheric sounding



Leverage Sensor Highlights



- **Radar Altimeter (ALT)**

 - Alcotel**

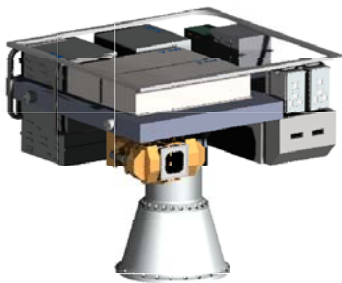
 - Measures range to ocean surface with a radar at 13.5 GHz
 - Corrects for ionosphere with 5.3 GHz radar
 - Corrects for atmosphere with CMIS water vapor measurements
 - Precise orbit determination with GPS



- **Earth's Radiation Budget Suite (ERBS)**

 - Northrop Grumman Space Technology**

 - Three spectral channels
 - Total radiation measurement 0.3 to 50 μm
 - Shortwave Vis and IR measurement 0.3 to 5 μm
 - Longwave IR measurement 8 to 12 μm

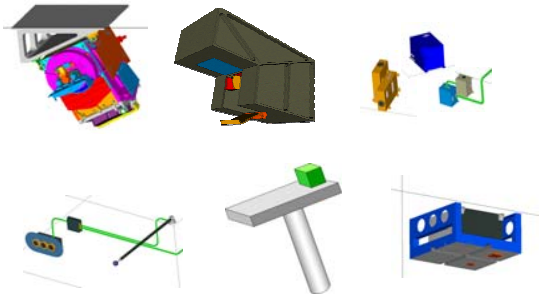


- **Total Solar Irradiance Sensor (TSIS)**

 - University of Colorado**

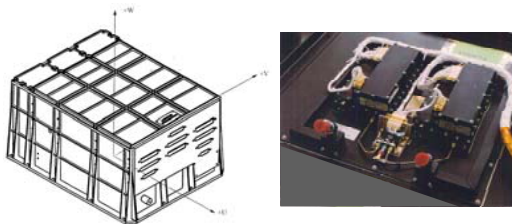
 - Two sensors for total irradiance (TIM) and spectral irradiance (SIM)
 - TIM measures total solar irradiance
 - SIM measures spectral irradiance 200 to 2000 nm
 - Pointing platform and sensor suite to be provided by CU LASP

Highlights of Other Sensors



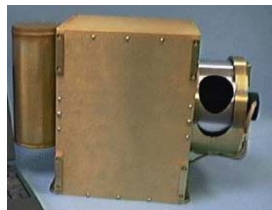
- **Space Environment Sensor Suite (SESS)**
Ball Aerospace

- Sensor suite collecting data on particles, fields, aurora, and ionosphere
- Suite includes a UV disk imager (BATC), EUV limb imager (BATC), charged particle detectors (Amptek/U. of Chicago), thermal plasma sensors (UTD), a magnetometer (MEDA), and a coherent beacon sensor (AIL)



- **Advanced Data Collection System (ADCS) and Search and Rescue Satellite-Aided Tracking (SARSAT)**

- “GFE” to NPOESS from France and Canada
- ADCS supports global environmental applications
- SARSAT collects distress beacon signals



- **Aerosol Polarimetry Sensor (APS)**
Raytheon Santa Barbara Research Center

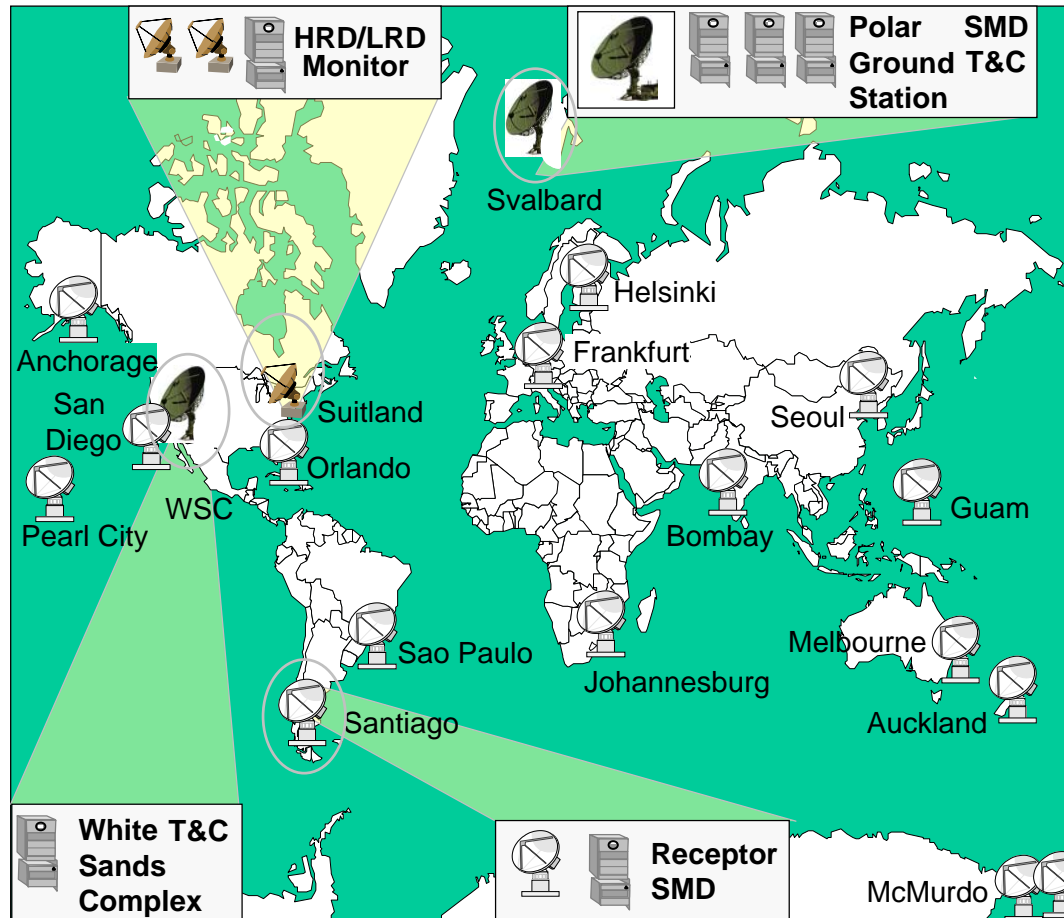
- Aerosol characterizations of size, single scattering albedo, aerosol refractive index, aerosol phase function
- Multispectral (broad, 0.4 to 2.25 μm)
- Multiangular (175 angles)
- Polarization (all states)

Pre-Planned Product Improvement (P3I) EDR Candidates



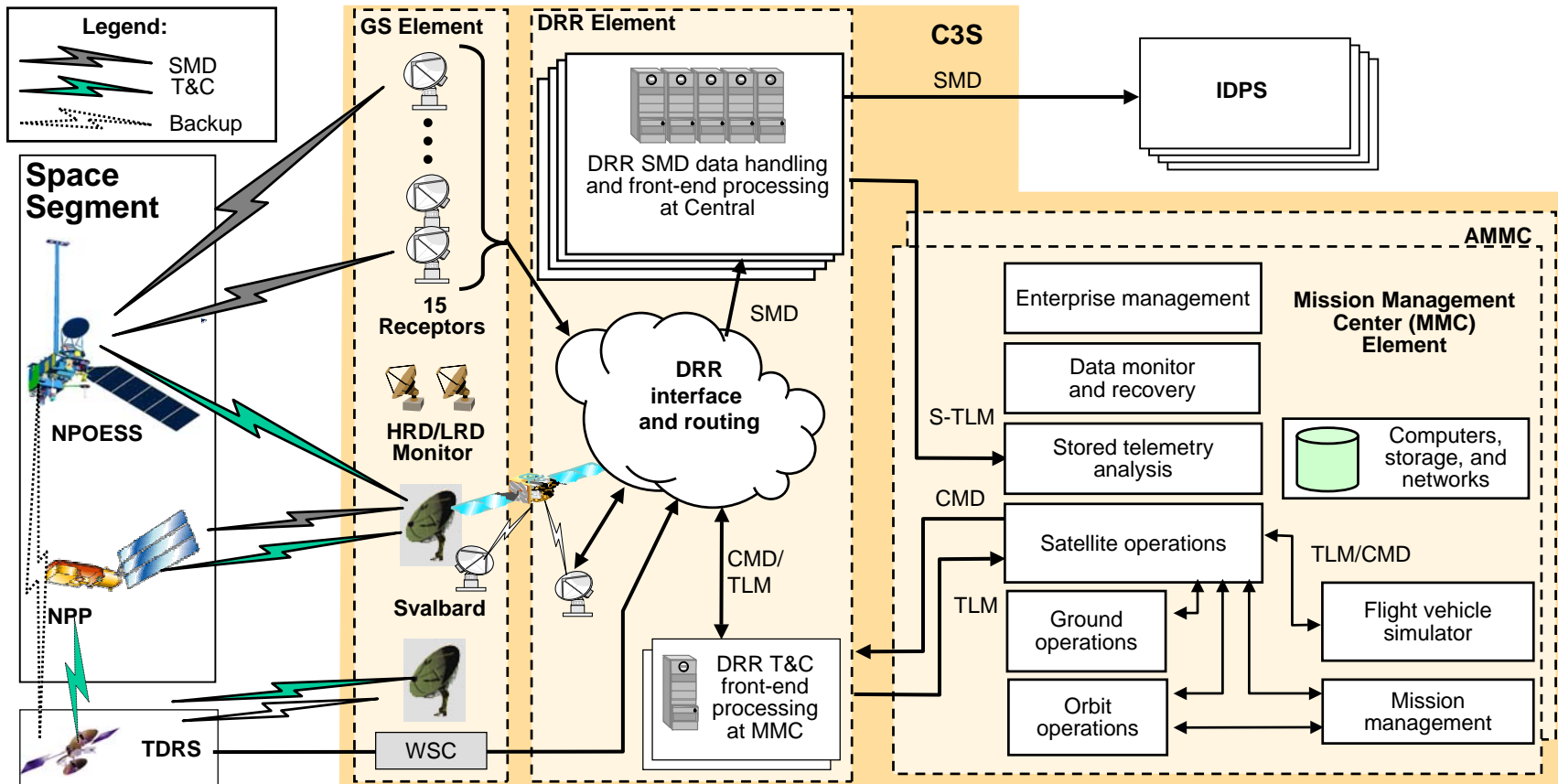
**Tropospheric winds
Neutral winds
All weather day/night imagery
Coastal sea surface winds
Ocean wave characteristics
Surf conditions
Oil spill location
Littoral current
CH4 column
CO column
CO2 column
Optical background
Sea and lake ice
Coastal ocean color
Bioluminescence potential
Coastal sea surface temperature
Sea surface height coastal
Bathymetry
Vertical hydrometeor profile
Salinity**

C3S Ground Station Element



SMD Receptors and T&C Ground Stations provide automated, schedule-driven connectivity to the Space Segment

C3S Segment Design



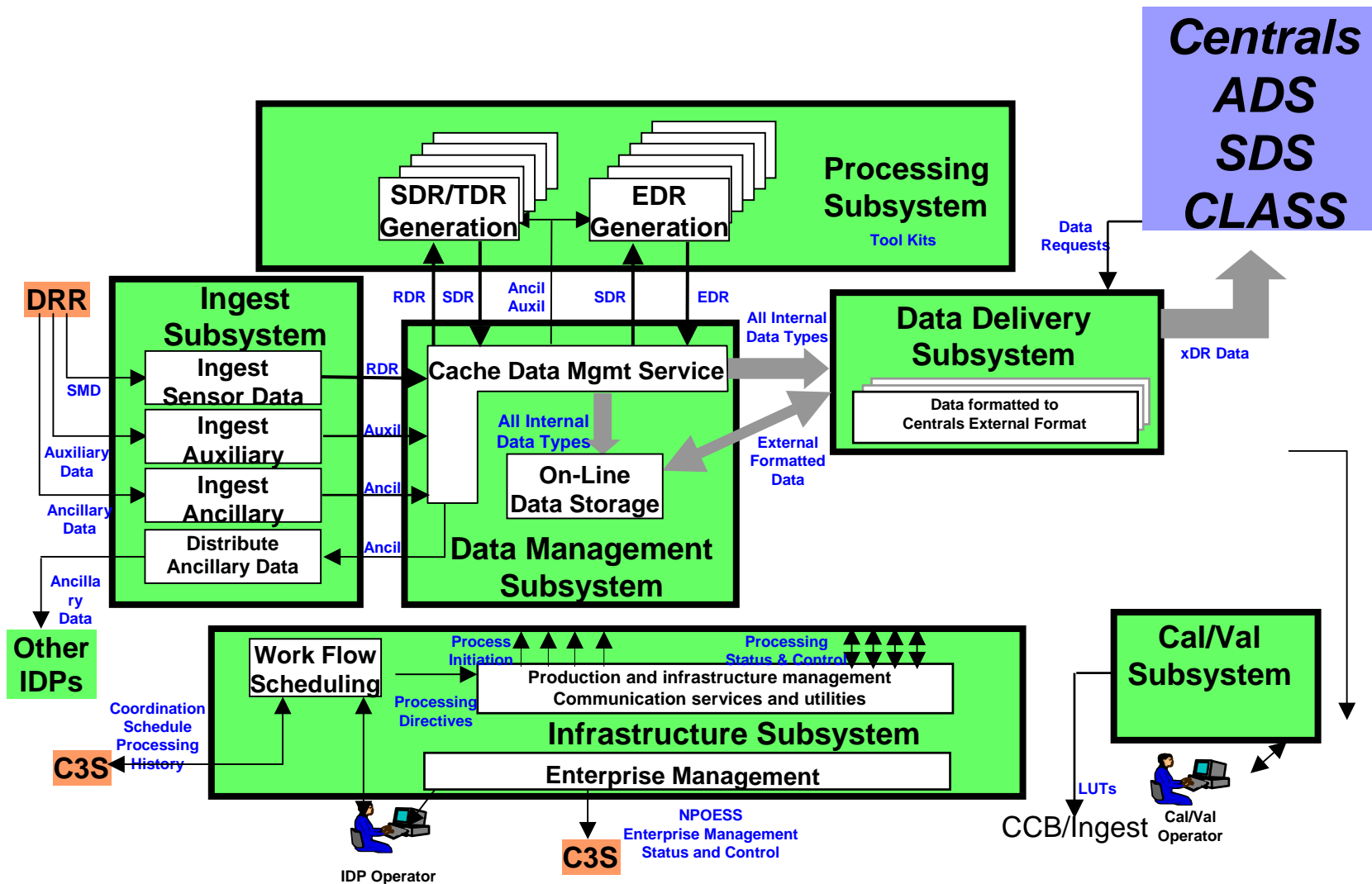
SafetyNet C3S provides low-cost, reliable, and timely data delivery with the flexibility needed for low-cost system growth and technology insertion

IDPS Segment Approach



- **High performance computing hardware**
 - Each Central has a complete system (IDP) that will generate all products within required latencies
 - Each IDPS or Central contains an Operations string, an Integration and Test (I&T) string, and shared disk arrays (RAID)
 - Operations string carries 100% reserve capacity and additional availability processors
 - I&T string can be used for integration and test of new software, support for technology insertion, parallel operations, failover, and algorithm development
- **Modular, workflow managed software**
 - Receives multiple data streams from C3S, processes data into RDRs, SDRs, TDRs, and EDRs, packages products into form useful for Centrals, and delivers requested products to end users
 - Centrals have control over what products are created, which ancillary data sets are used, and how products are delivered
- **Same software is used in field terminals**
 - Will be made available worldwide via download from the internet

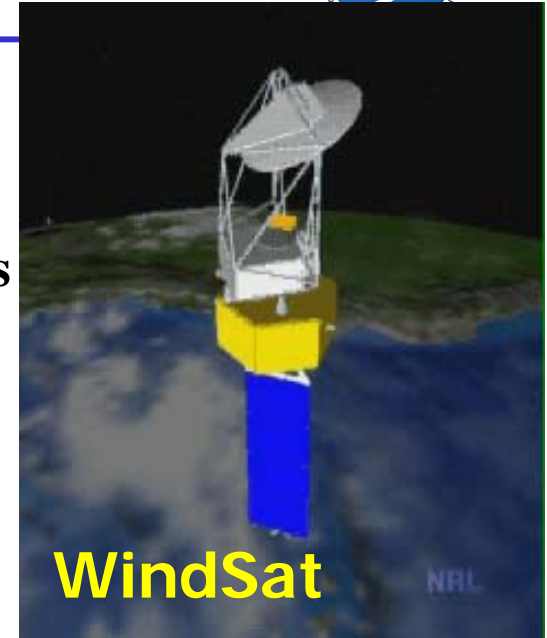
IDPS Functional Diagram



Risk Reduction



- Validate technological approach to remote sensing
- Early delivery of NPOESS data to users
- Sensor demonstrations on non-operational platforms
 - Lower risk to operational users
 - Lower risk of launch delays due to operational schedule
- Share cost & risk among agencies

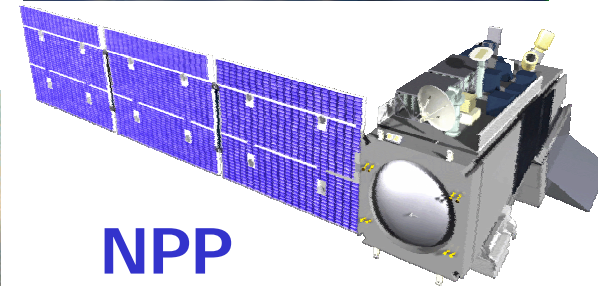


WindSat

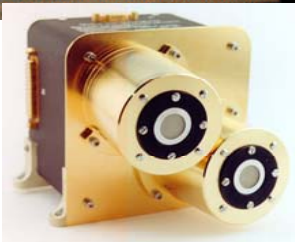
NASA ER2 / NAST



Proteus



NPP



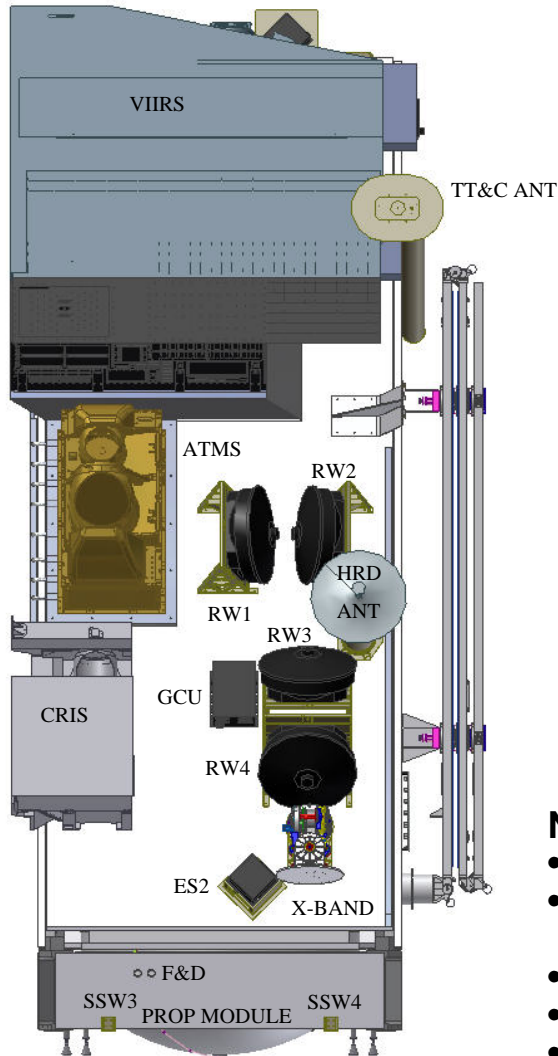
DIDM

SOLSE

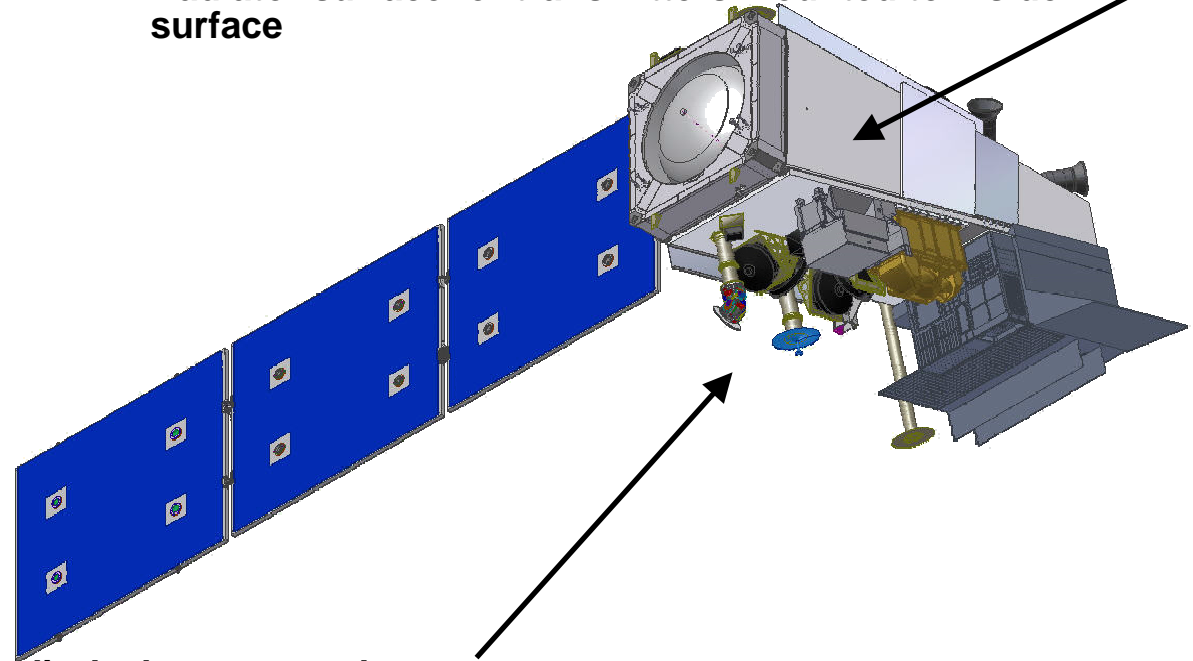


LORE

NPP Instruments Accommodation



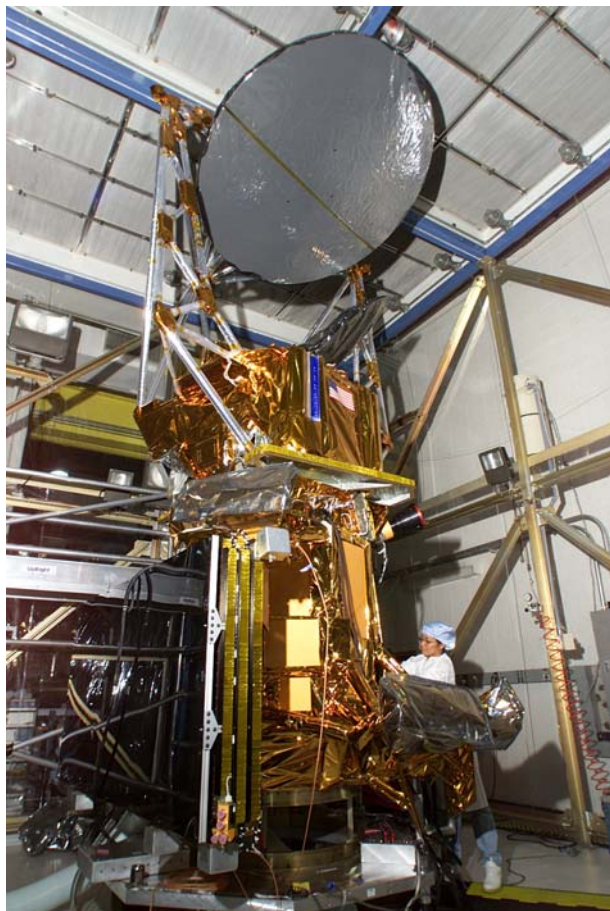
- Spacecraft “COLD” +Y panel accommodates:
- Instrument cooler FOVs
 - Heat pipe cold plates for ATMS and VIIRS EM
 - Radiator surface for transmitters mounted to inside surface



- Nadir deck accommodates:
- Instruments (ATMS, CrIS, VIIRS, OMPS and potentially CERES)
 - Nadir coverage antennas (X-band high gain, nadir CMD/TLM, HRD Earth Coverage)
 - Reaction wheels
 - Earth sensor assemblies
 - Star tracker support structure mounts to inside of nadir deck near VIIRS interface

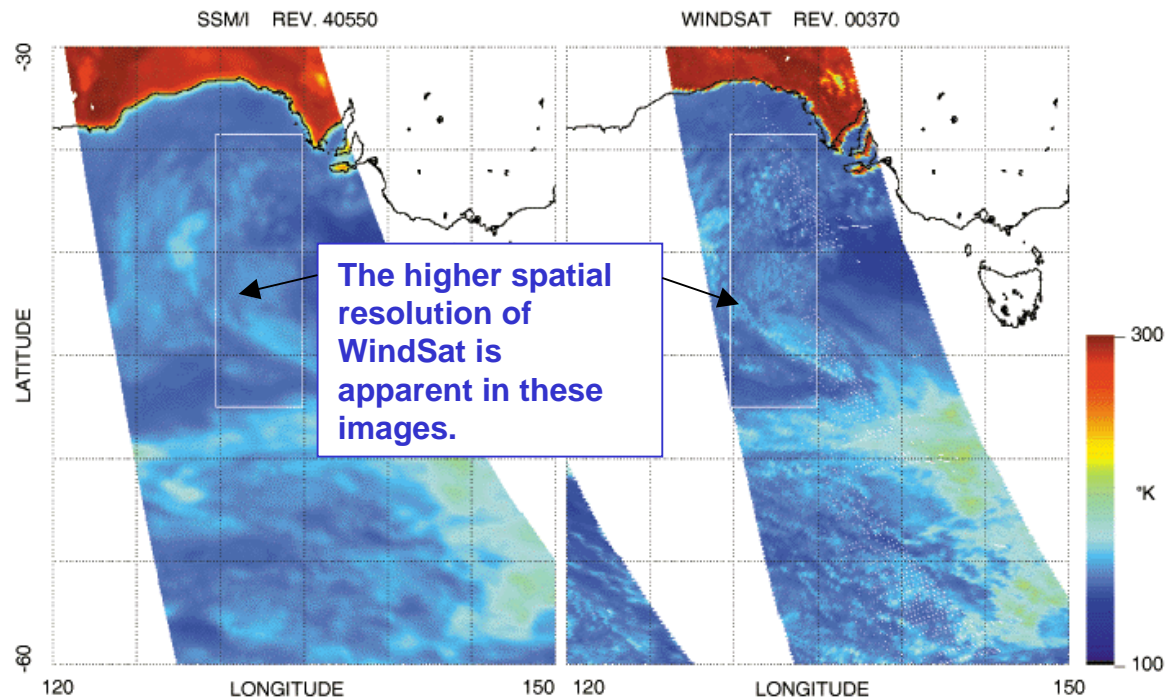
WindSat / Coriolis

NPOESS CMIS Risk Reduction

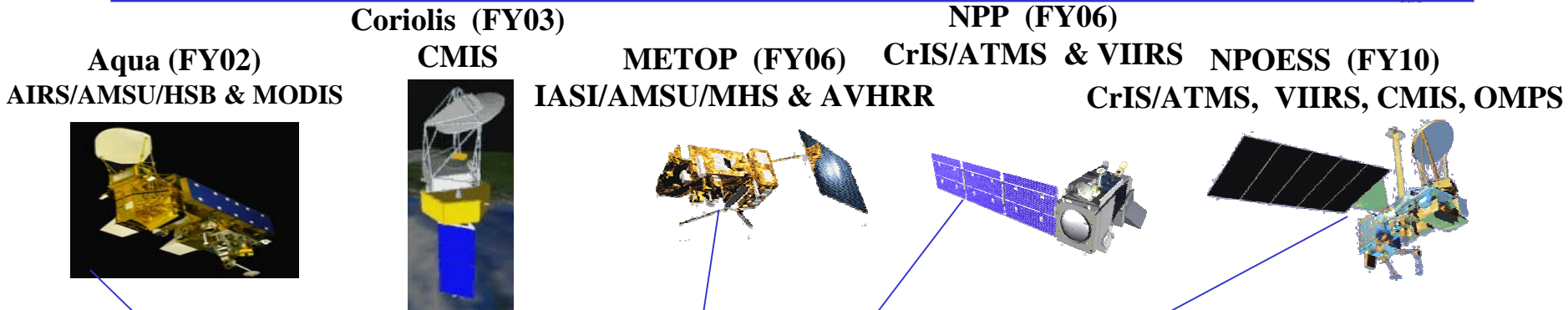


WindSat TDR to SSM/I Brightness Temperature 37 GHz Horizontal Polarization

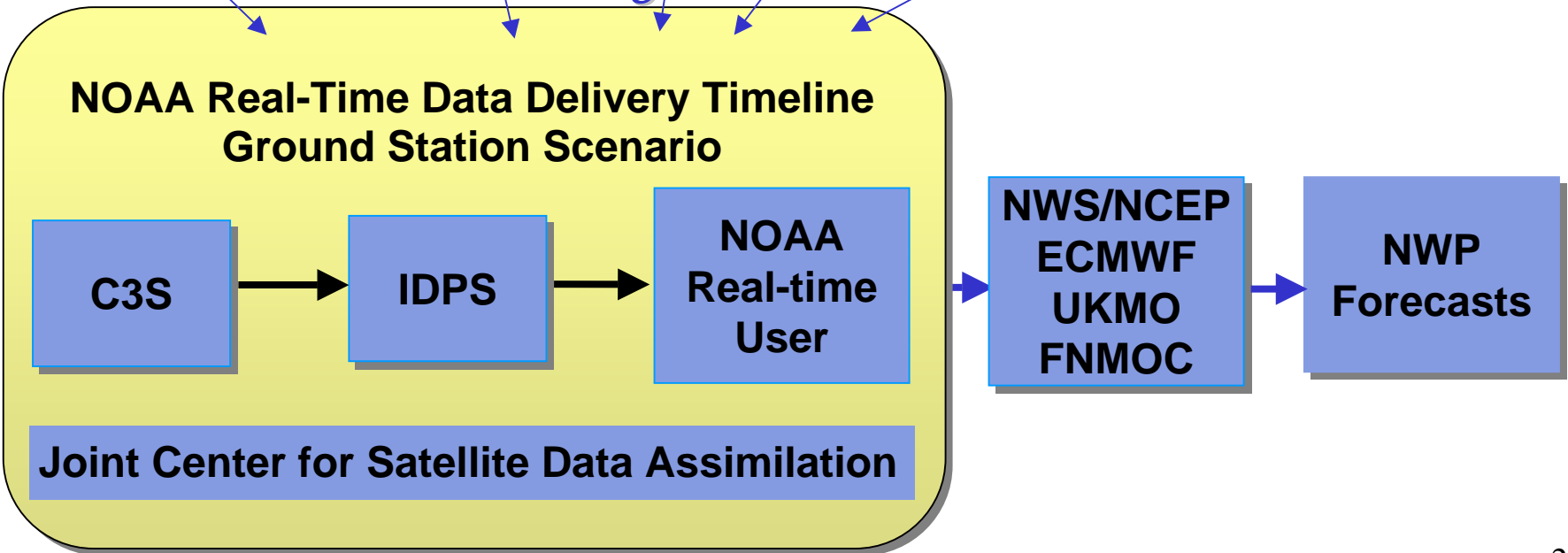
SSM/I 37H & WINDSAT 37.0H TDR COMPARISONS



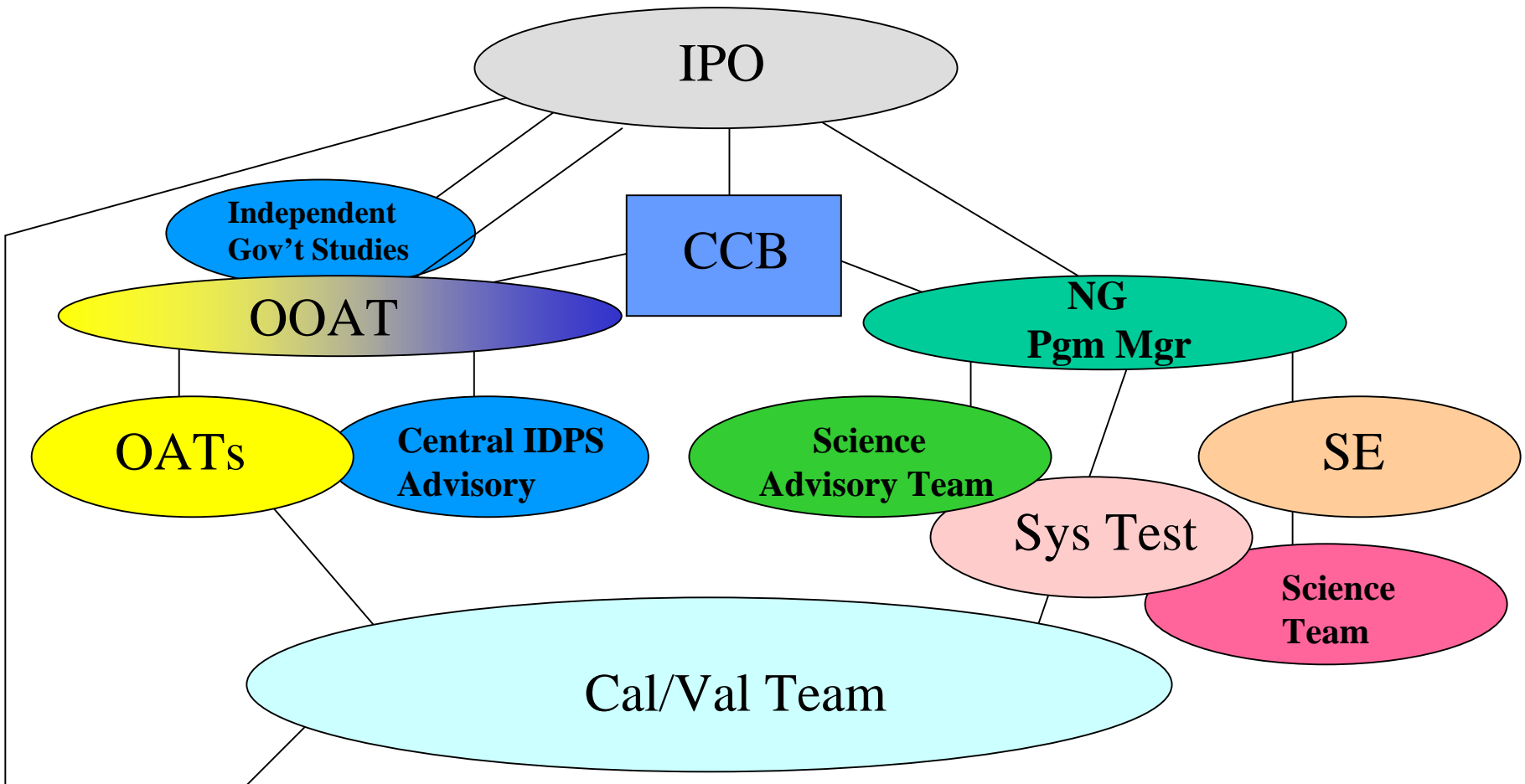
Real-Time Operational Demonstrations



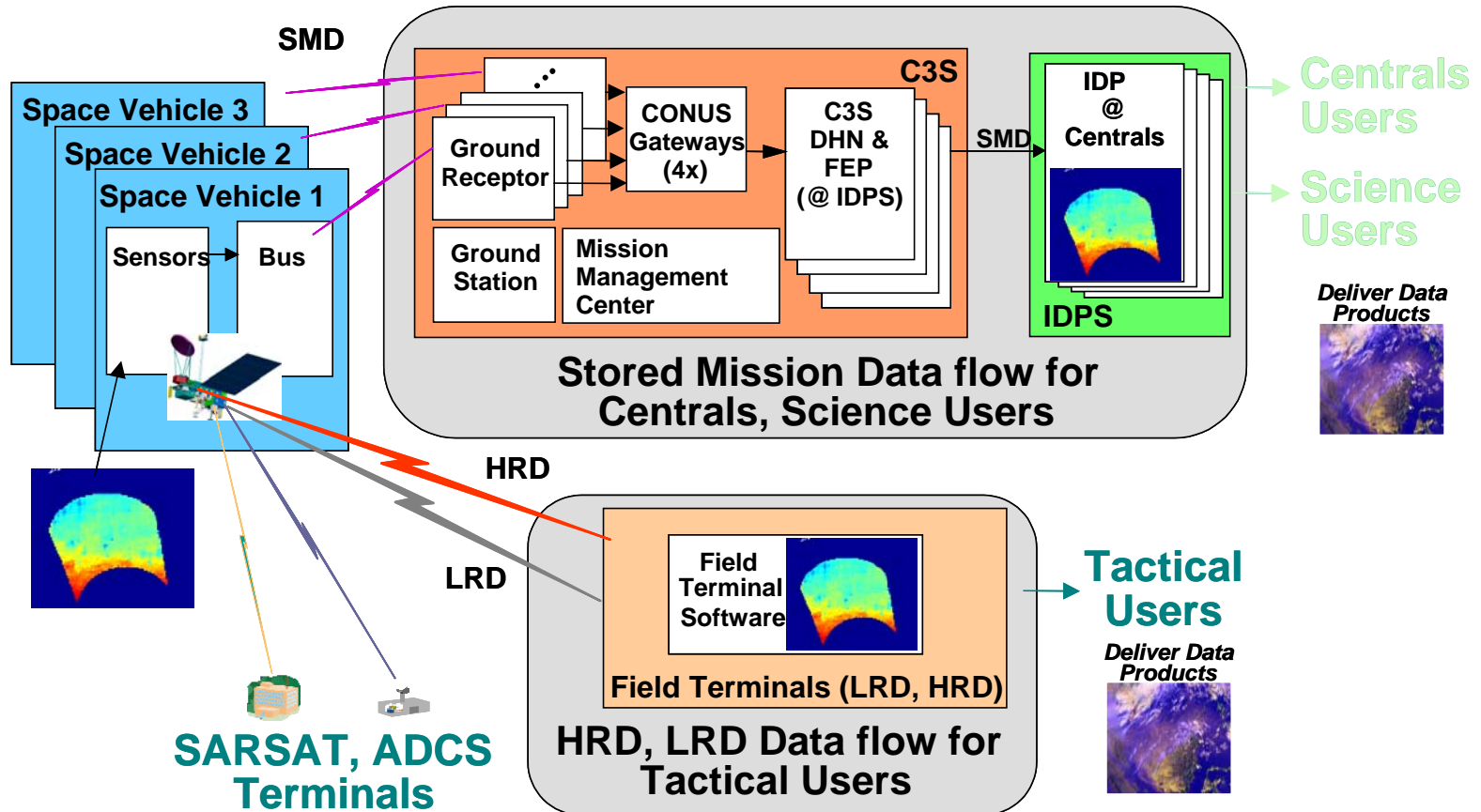
Use of Advanced Sounder Data for Improved Weather Forecasting/Numerical Weather Prediction



Science Support is an Integral Part of NPOESS Program



Field Terminals are an integral part of NPOESS



What is NPOESS planning?



- **NPOESS responsible for building software and terminal specifications, but not for building terminals**
 - NPOESS will publish specifications and design trade information for users
 - NPOESS will make certified software available on the program website for download by anyone desiring to use it
- **NPOESS will deliver data to users world-wide in accordance with US national data policy**
 - Data will be downlinked openly around the world at no cost to receivers
 - Capability for data encryption/data denial exists for national defense needs
 - Denial can be done on a world-wide or geographic basis
- **NPOESS calls the world-wide users “field terminals” (to differentiate from the Weather Centrals)**

Field Terminal Procurement Specification

Link Parameters



<u>Parameter</u>	<u>NPOESS HRD</u>	<u>NPOESS LRD</u>
Carrier Frequency	7812 MHz or 7830 MHz <i>command selectable</i>	1706 MHz
Max Occupied Bandwidth	30.8 MHz	8.0 MHz
Channel Data Rate*	40 Mbps	7.76 Mbps
Ground Aperture Size	≤ 2.0 meters	1.0 meters
Minimum Elevation Angle	5.0 degrees	5.0 degrees
Data Quality	128 attributes above, 724 at, 7 below threshold 305 attributes above, 180 at, 0 below threshold	
SMD/HRD		
LRD		
Data Latency	Threshold	Objective
SMD		
HRD/LRD		

* Includes all CCSDS overhead, Reed-Solomon forward error correction, and convolutional encoding



LRD Environmental Data Records (28 EDRs)

☆☆	Atmospheric Vert Moisture Profile	Cloud Top Pressure	Precipitable Water
☆☆	Atmospheric Vert Temp Profile	★ Cloud Top Temperature	Precipitation Type/Rate
☆☆	Imagery	Downward Longwave Radiance (sfc)	Pressure (Surface/Profile)
☆☆	Sea Surface Temperature	Downward Shortwave Radiance(sfc)	Sea Ice Characterization
☆☆	Sea Surface Winds	Electric Field	Sea Surface Height/Topography
☆☆	Soil Moisture	Electron Density Profile	Snow Cover/Depth
★	Aerosol Optical Thickness	Energetic Ions	Solar Irradiance
	Aerosol Particle Size	Geomagnetic Field	Supra-Thermal-Auroral Particles
	Aerosol Refractive Index	Ice Surface Temperature	Surface Type
★	Albedo (Surface)	In-situ Plasma Fluctuations	Surface Wind Stress
	Auroral Boundary	In-situ Plasma Temperature	Suspended Matter
	Auroral Energy Deposition	Ionospheric Scintillation	Total Water Content
	Auroral Imagery	Medium Energy Charged Particles	Vegetation Index
★	Cloud Base Height	★ Land Surface Temperature	
★	Cloud Cover/Layers	Net Heat Flux	
★	Cloud Effective Particle Size	Net Solar Radiation (TOA)	
	Cloud Ice Water Path	Neutral Density Profile	
★	Cloud Liquid Water	Ocean Color/Chlorophyll	
★	Cloud Optical Thickness	★ Ocean Wave Characteristics	
	Cloud Particle Size/Distribution	Outgoing Longwave Radiation (TOA)	
★	Cloud Top Height	Ozone - Total Column/Profile	

VIIRS	23
CMIS	19
CrIS/ATMS	3
OMPS	1
SES	13
GPSOS	2
ERBS	5
TSIS	1
ALT	3
APS	4

☆☆ EDRs with Key Performance Parameters

★ High Priority EDRs

★ Lower Priority EDRs

Integrated Program Office

Web sites



NPOESS Websites

- <http://www.npoess.noaa.gov>
- <http://npoesslib.ipo.noaa.gov/>
(electronic bulletin board)