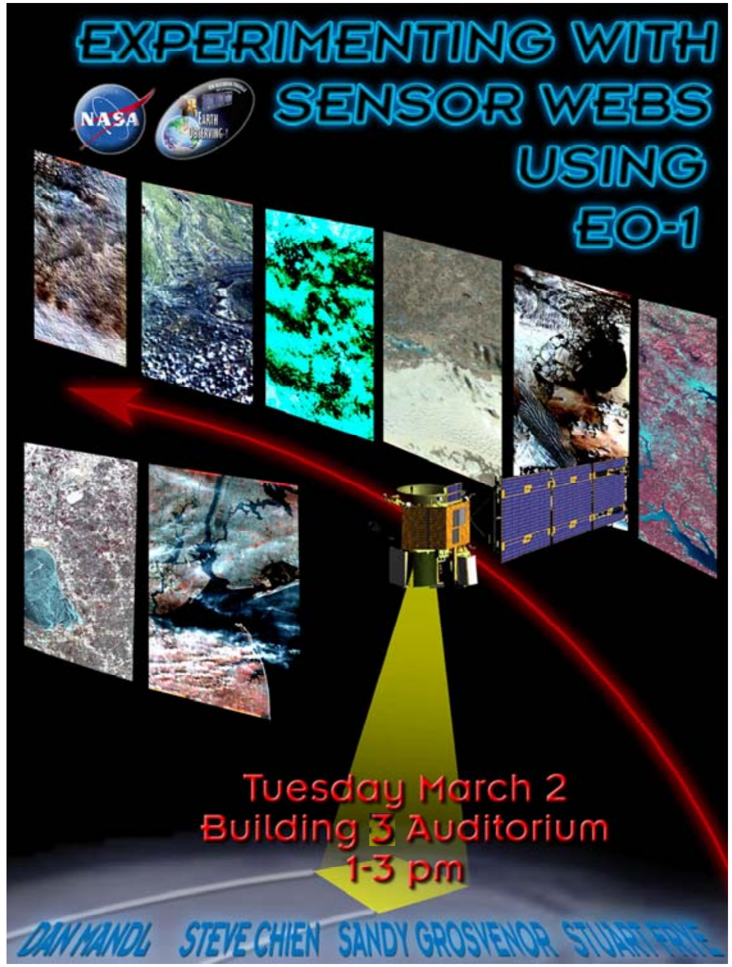
March 2, 2004



Dan Mandl, GSFC

Dr. Steve Chien/JPL

Sandra Grosvenor/SSAI/GSFC

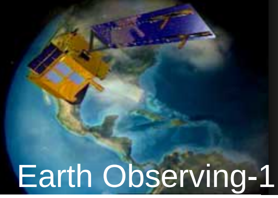
Stu Frye/Mitretek/GSFC

Agenda

- ***Dan Mandl***
  - *EO-1 Overview*
  - *Sensor Web overview*
  - *EO-1 Testbed activities*
- ***Steve Chien***
  - *Sensor webs experiments with floods and volcanoes*
  - *Continuous Activity Scheduling Planning Execution and Replanning (CASPER) system*
- ***Sandra Grosvenor***
  - *Science Goal Monitor*
- ***Stuart Frye***
  - *Warts, bumps and blemishes*

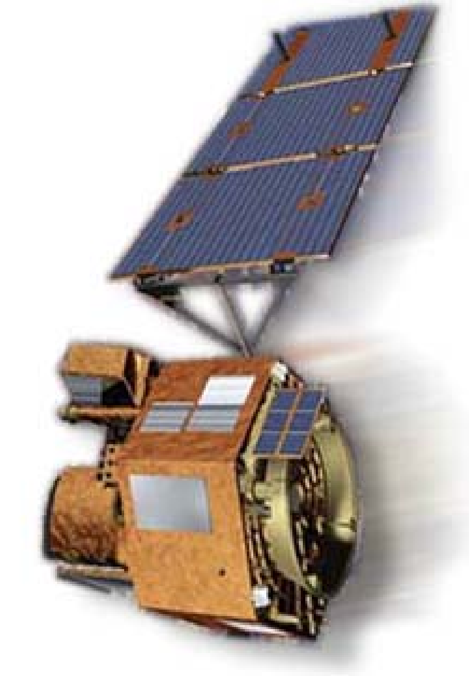
Introduction to EO1 Mission

- ***Key information:***
  - *Managed by GSFC*
  - *First Earth-Observing Mission sponsored by the New Millennium Program*
  - *A mission devoted entirely to the flight validation of 13 advanced technologies applicable to future land-imaging missions*
  - *Approved in March 1996 and launched in November 21, 2000*
  - *All technologies were flight-validated by December 2001 and EO-1 is now in an Extended Mission*
  - *Sufficient fuel to operate through at least September 2004*



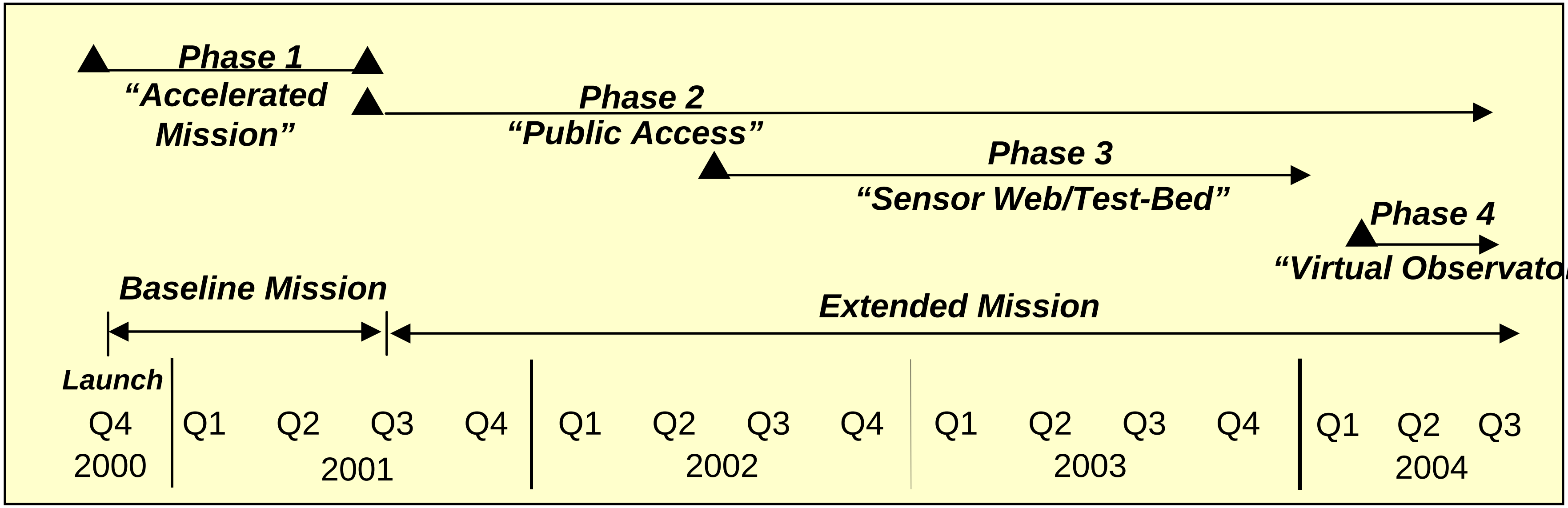
Introduction to EO1 Mission

- **_Payload:_**
  - ***Advanced Land Imager (ALI)***
    (visible, 30 m & 10m resolution)
  - ***Hyperion***
    (hyperspectral, 220 bands, 30m res.)
  - ***Atmospheric Corrector***
    (hyperspectral, 242 bands, 250m res.)
- **_Two Mongoose V CPU's (8 MIPS and 256 Mb RAM)_**
  - ***Flight control software on CDH CPU***
  - ***Autonomy software (including cloud cover detection software) on Wideband Advanced Recorder and Processor (WARP) Mongoose CPU***



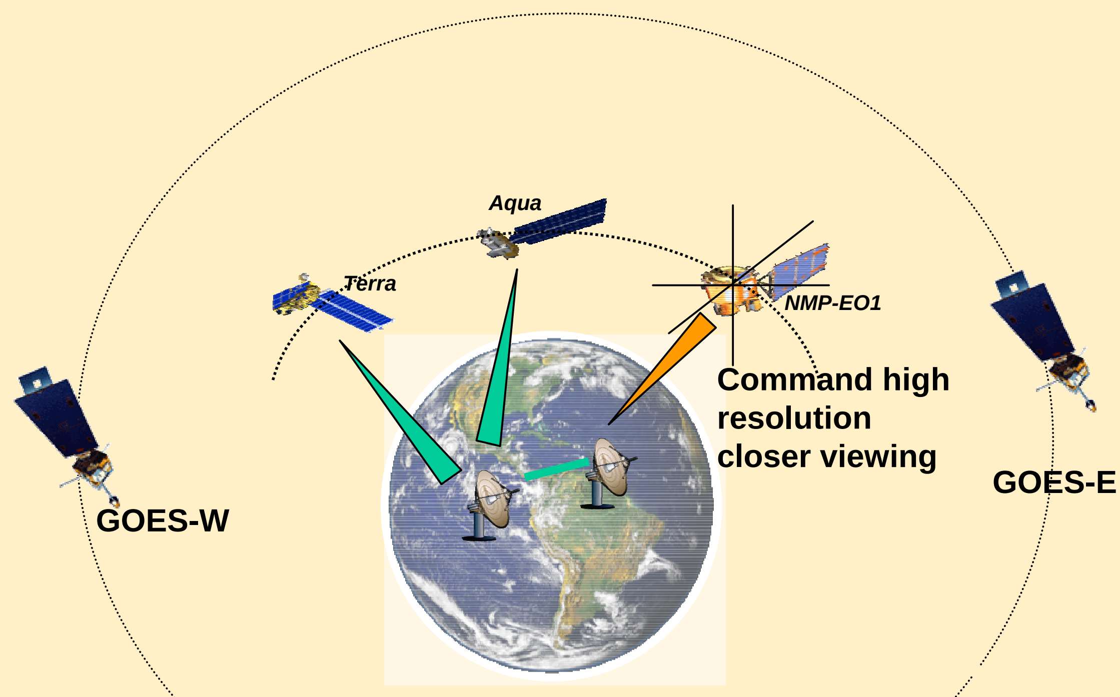
EO-1 Mission Phases

- ***After base mission, three more mission phases evolved as depicted in chart below***
- ***Sensor Web/Testbed phase is active now***
- ***Virtual observatory phase is the phase in which as much mission autonomy as possible will be implemented to reduce the cost as much as possible of running the EO-1 mission***
  - *Includes semi-autonomous tasking of EO-1*



Evolution Towards Integrated Observations

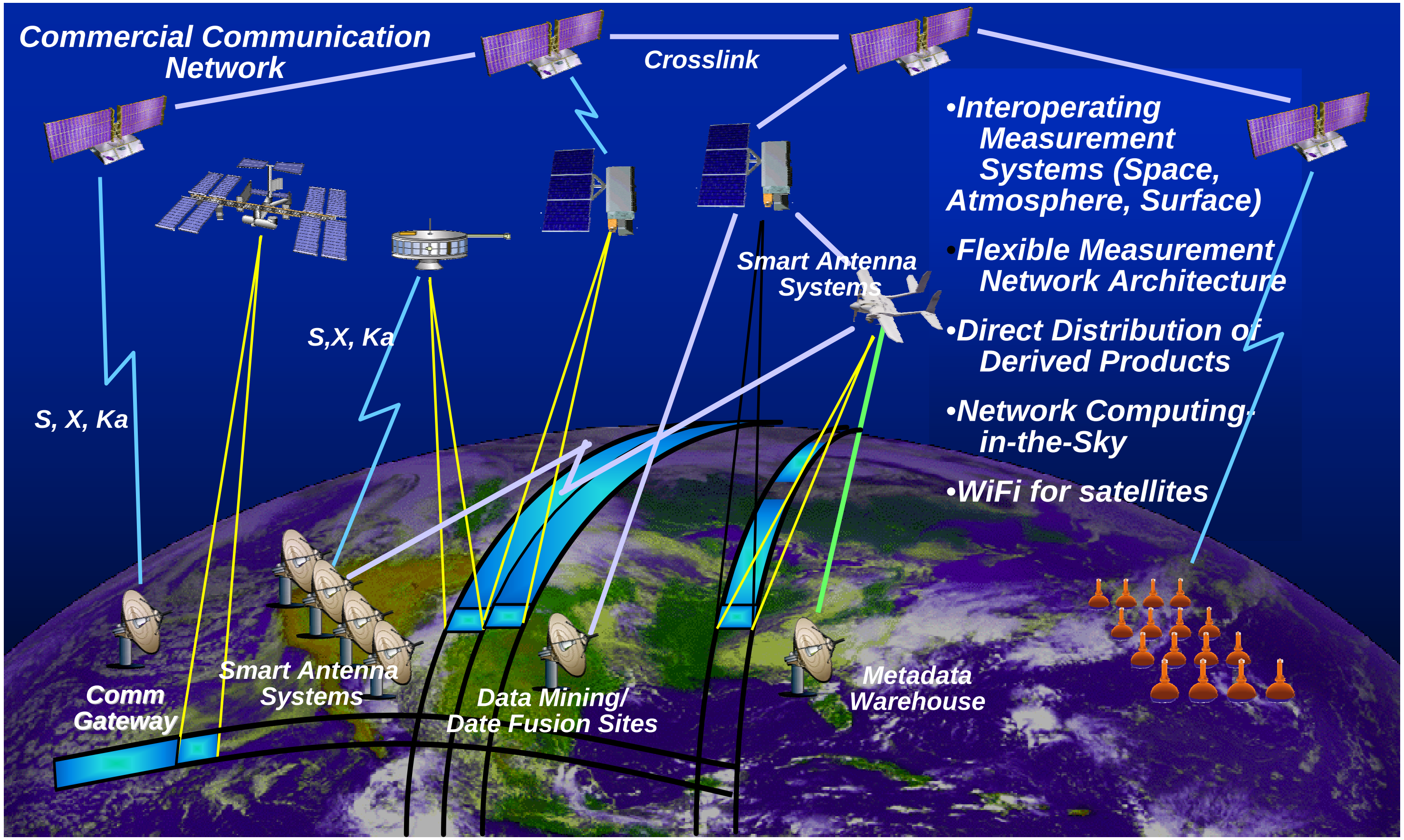
Today:
“Stovepiped”
Observing Systems

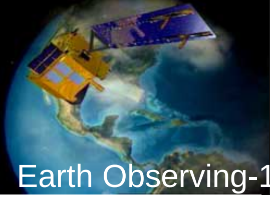


Near Term: Evolution Towards Distributed Space Systems for Integrated Observations

The Future: A Vision for a Globally Integrated Sensor Web Observing System

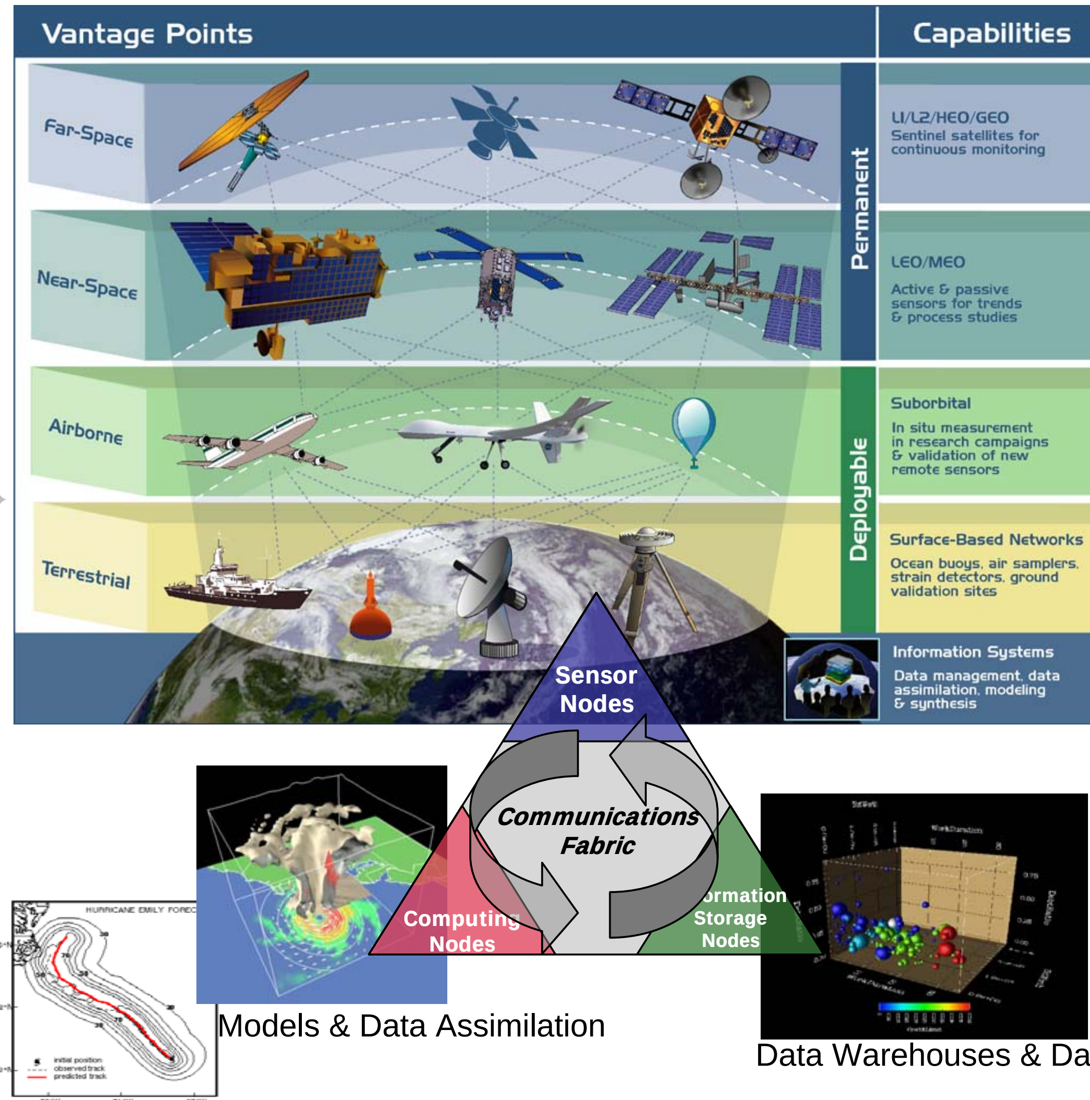
A sensor web is a coherent set of distributed "nodes", interconnected by a communications fabric, that collectively behave as a single, dynamically adaptive, observing system.





Sensor Web Nodes & Interactions

March 2, 2004



Models & Data Assimilation

Data Warehouses & Data Mining

Slide by Steve Talabac/586

Benefits of Sensor Web Dynamic Measurement Techniques and Adaptive Observing Strategies

- ***Event driven observations***
  - ***Improved system response (to catch transient events)***
- ***Model-driven observations***
  - ***Improved predictive capability***
- ***Intelligent data collection***
  - ***Improve efficiency of resource utilization***
- ***Sensor data fusion***
  - ***Improved science integration***

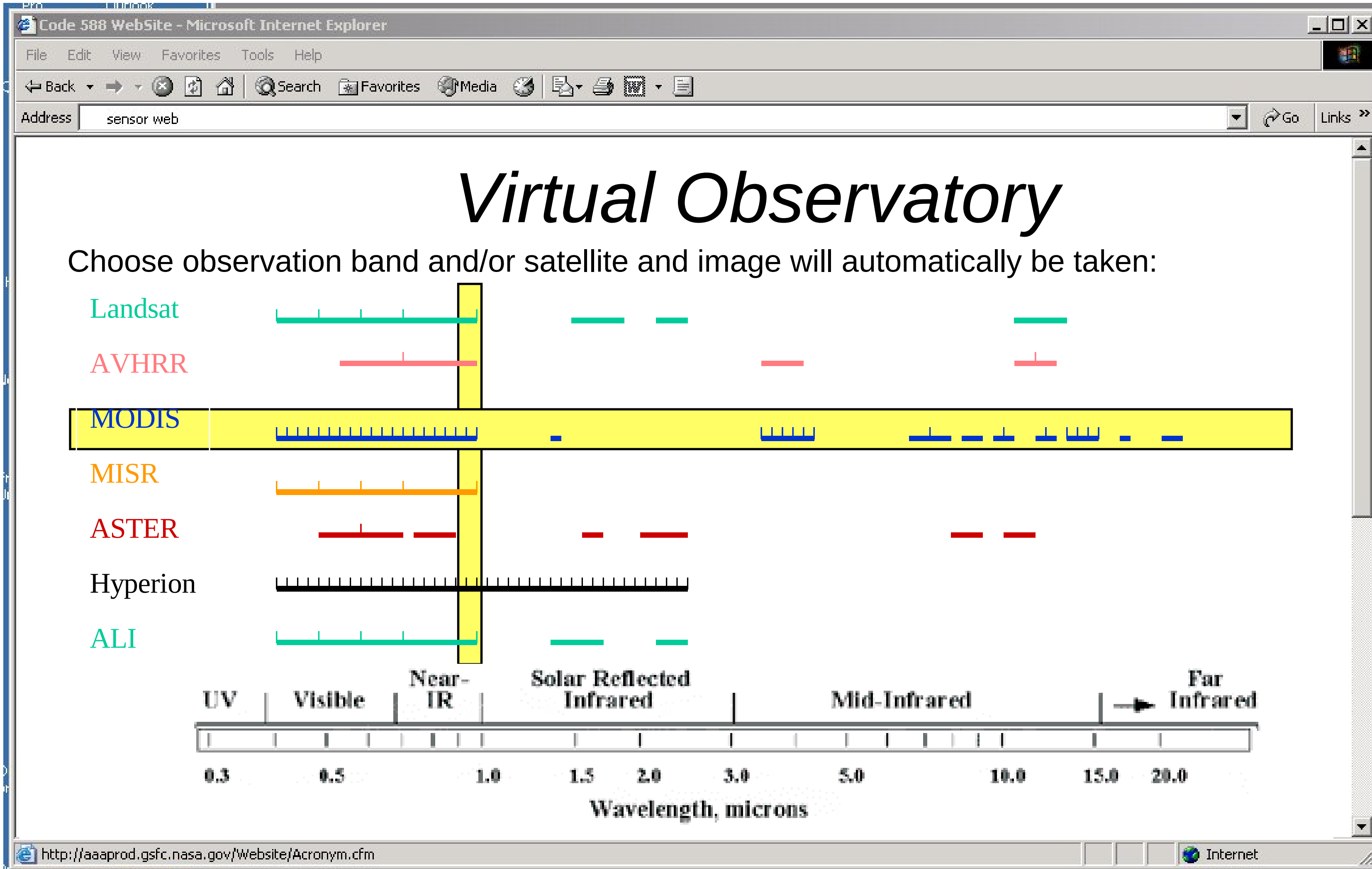
Experimenting with Following Capabilities

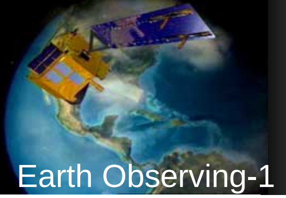
(Under categories of event driven sensor webs and intelligent data collection)

- ***Automatic science product generation***
  - ***Archives***
  - ***Tasking "ad hoc" set of satellites automatically***
- ***Ad Hoc constellations***
  - ***Capability to rapidly combine data from heterogeneous sets of satellites on-orbit and other instrumentation such as in-situ instruments to create new science products not originally planned***
  - ***"Ad hoc" constellation planning and scheduling for the sensor webs***
    - *Capability to rapidly reconfigure and schedule different groupings of "ad hoc" satellites*
    - *"Ad hoc" constellation planning and scheduling hidden from user*
- ***User specifies high level goals and system takes care of details***
  - ***Virtual observatory***
- ***Make use of existing assets***
- ***Enable radiometric crosswalk***
  - ***Ability to rapidly mosaic and fill in images with different satellites and instrumentation***

Sensor Web Vision

How we’d like it to be!

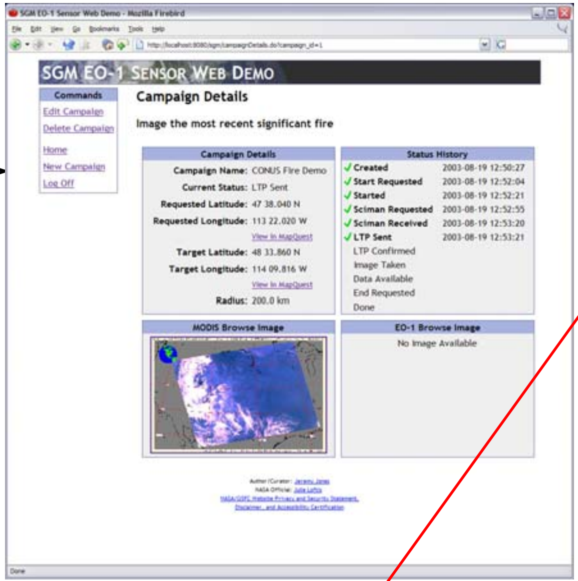




Example of Recent Sensor Web Experiment, National Priority Wildfires, Performed 8-21-03

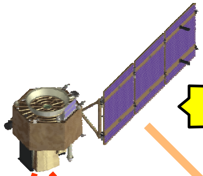
March 2, 2004

1 Large wild fires tracked by National Interagency Fire Center (NIFC)

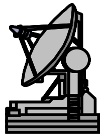


3 After ascertaining that the Robert fire is at lat 48.564 long -114.163, EO-1 is tasked to take closer high resolution look

4 SGM causes MOPSS, CMS, CASPER (ground version) to task EO-1 via command load

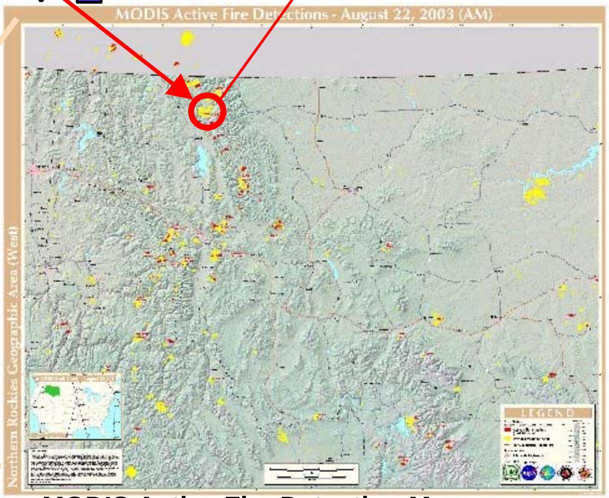


5 and causes EO-1 to downlink the image to EROS Data Center (EDC) at Sioux Falls

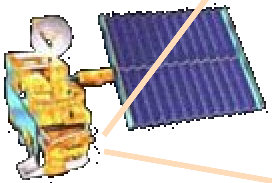


6 EDC performs L0 and L1 processing and FTP's image to Natural Hazards investigators at UMD.

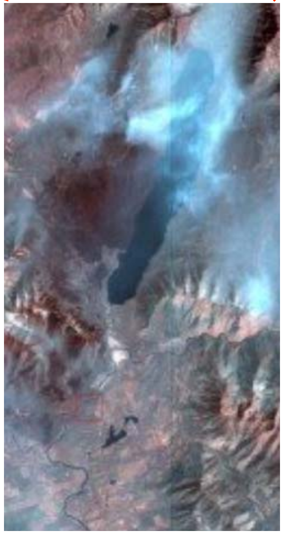
2 SGM correlates selected wildfire (25 Robert) to exact present location using data from Rapid Fire workstation in MODIS Instrument Center which is updated every 5 minutes



MODIS Active Fire Detection Map

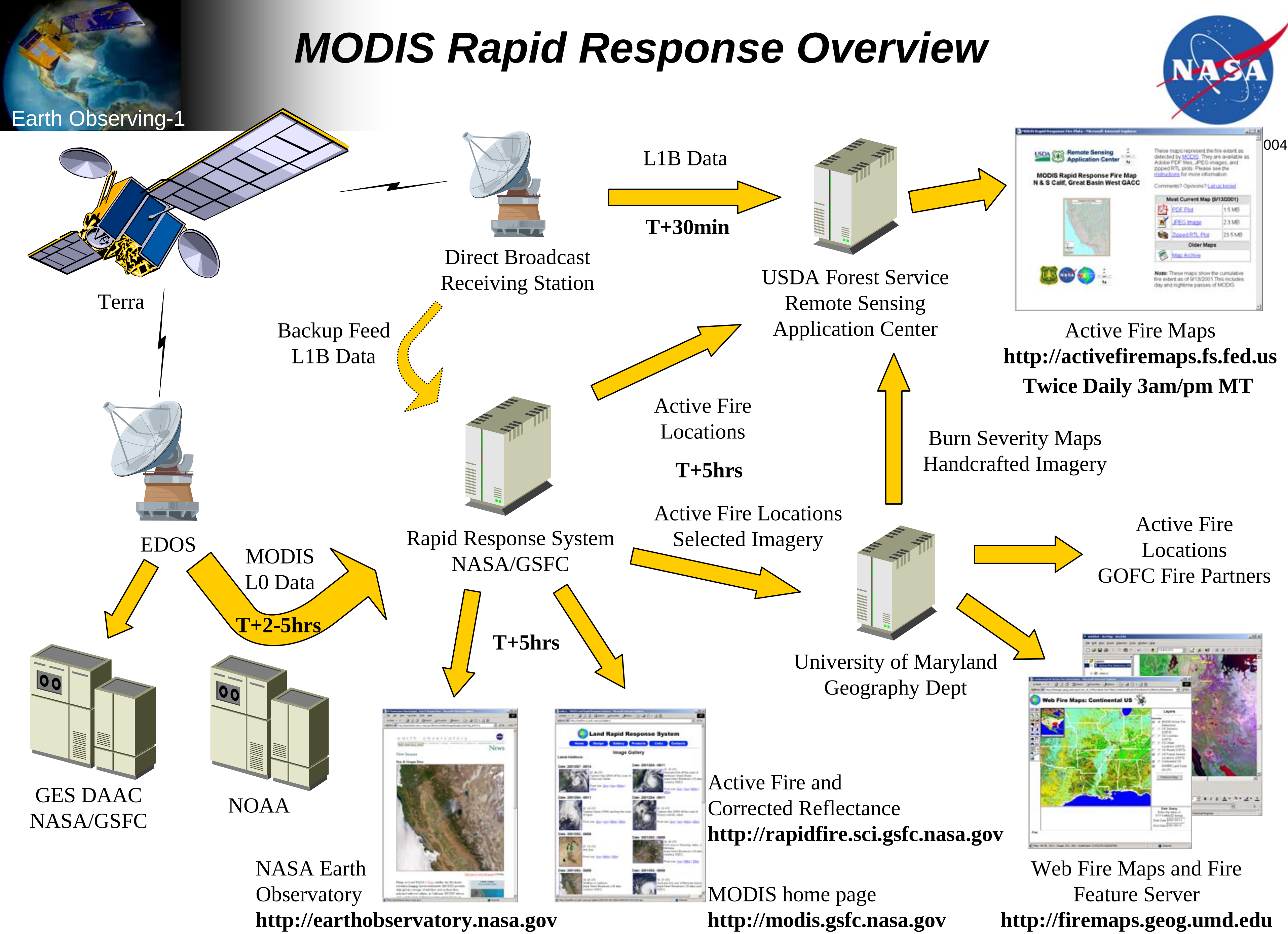


MODIS Instrument on Terra or Aqua



7 UMD team transforms image into ERDAS format and FTP's file to USFS/Salt Lake City where burn extent product is derived. Result is sent to BAER team at Robert Fire.

MODIS Rapid Response Overview



EO-1 Wildfire Sensor Web Experiment

Detection and Tasking

Use National Inter-agency Fire Center ICS209 database to identify national priority fires.

Locate fire precisely with MODIS Active Fire detections from Terra and Aqua.

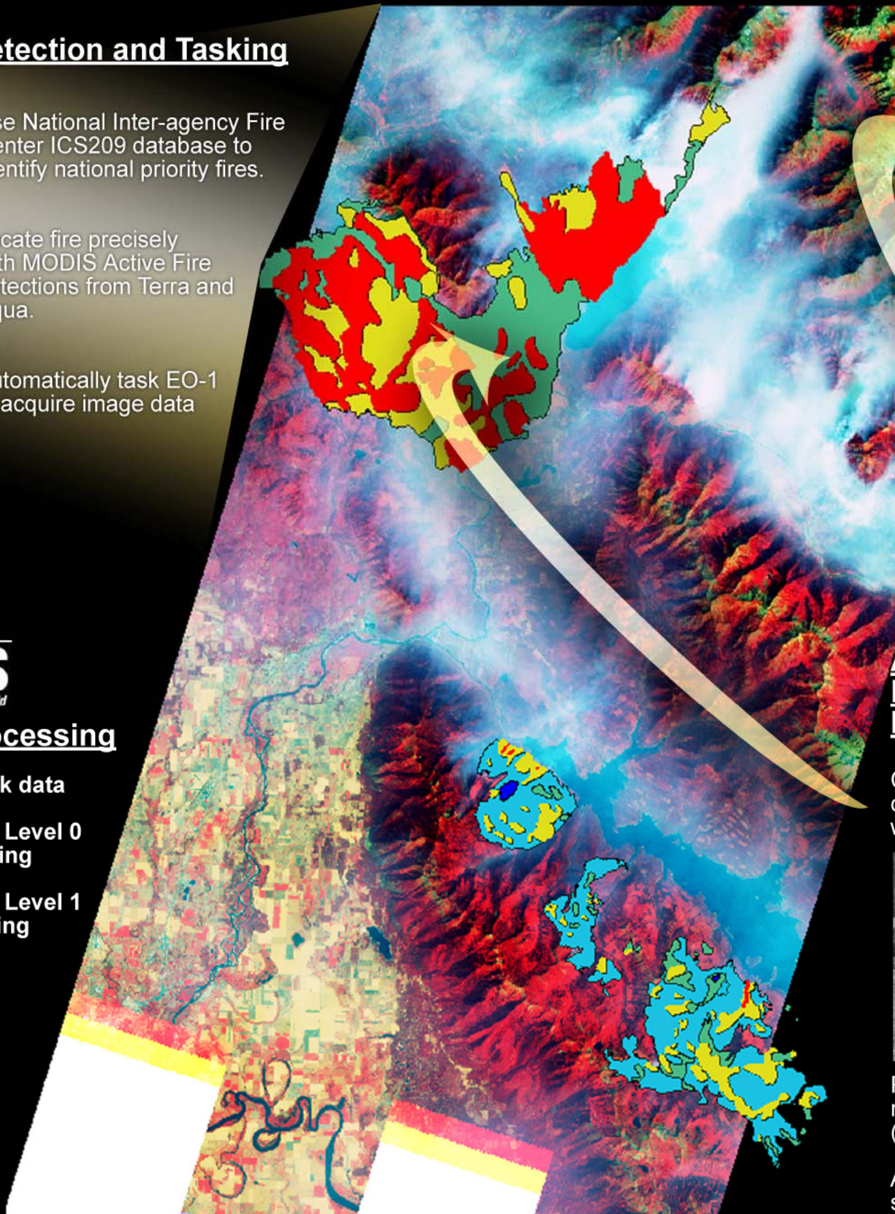
Automatically task EO-1 to acquire image data

Data Processing

Downlink data

Perform Level 0 processing

Perform Level 1 processing



Geo-rectification

Precisely match image to earth coordinates

Enhance vegetation image to highlight burned areas (red)

Assessment, Planning and Implementation

Classify burned areas into color coded burn severity, augmented with ground verification

Plan deployment of rehabilitation resources to highest risk areas (red in overlay)

Apply treatments to control things such as erosion, invasive species etc.

Glacier National Park August 21, 2003

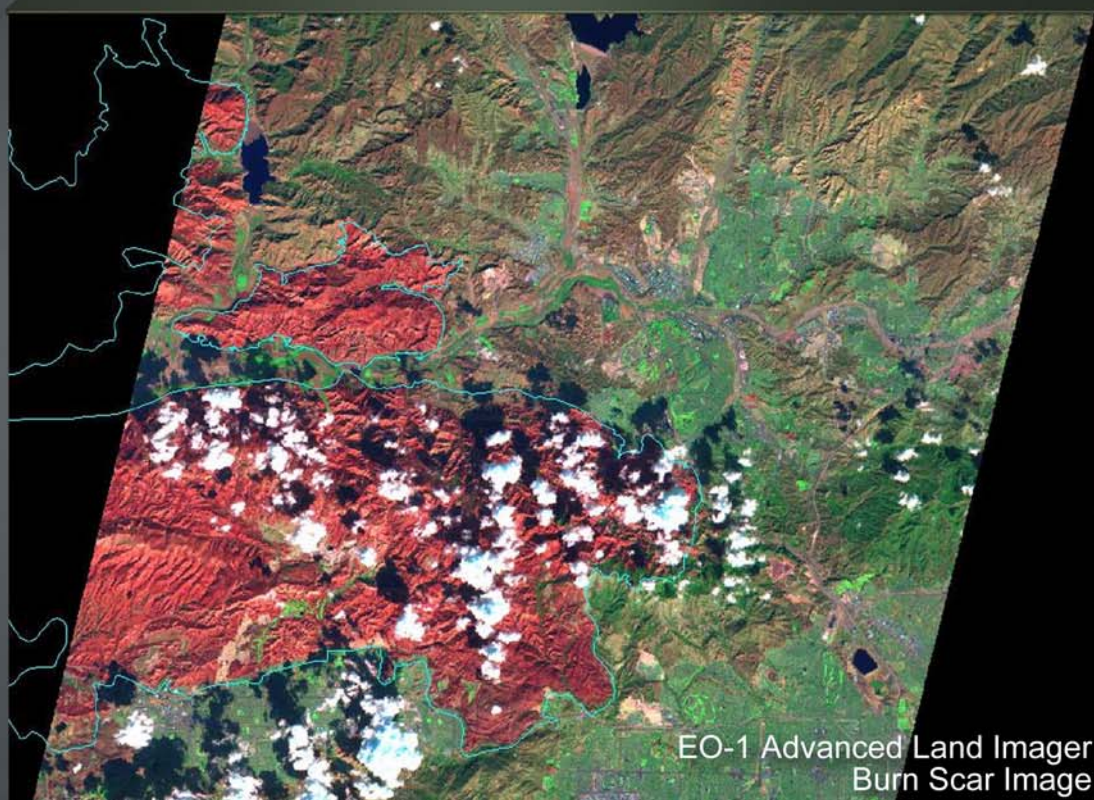
Two Burned Area Reflectance Classification (BARC) map overlays are shown on top of Advanced Land Imager (ALI) data taken semi-autonomously by the EO-1 Sensor Web. The EO-1 image request was generated automatically based on fire location triggers detected by MODerate-resolution Imaging Spectro-radiometer (MODIS) Instruments onboard Terra and Aqua satellites. The upper left Overlay is the BARC map for the Robert fire and the lower right. Overlay is the BARC map for the Middle Fork Complex fire. The overlays were created by the Forest Service Burn Area Emergency Response teams to identify areas at high risk and to contract rehabilitation treatments. Satellite data such as this assists in efficient use of resources.

Burn Severity

- Unburned
- Low/Unburned
- Low
- Medium
- High

Wildfire SensorWeb

MODIS Rapid Response
Active Fire Detections

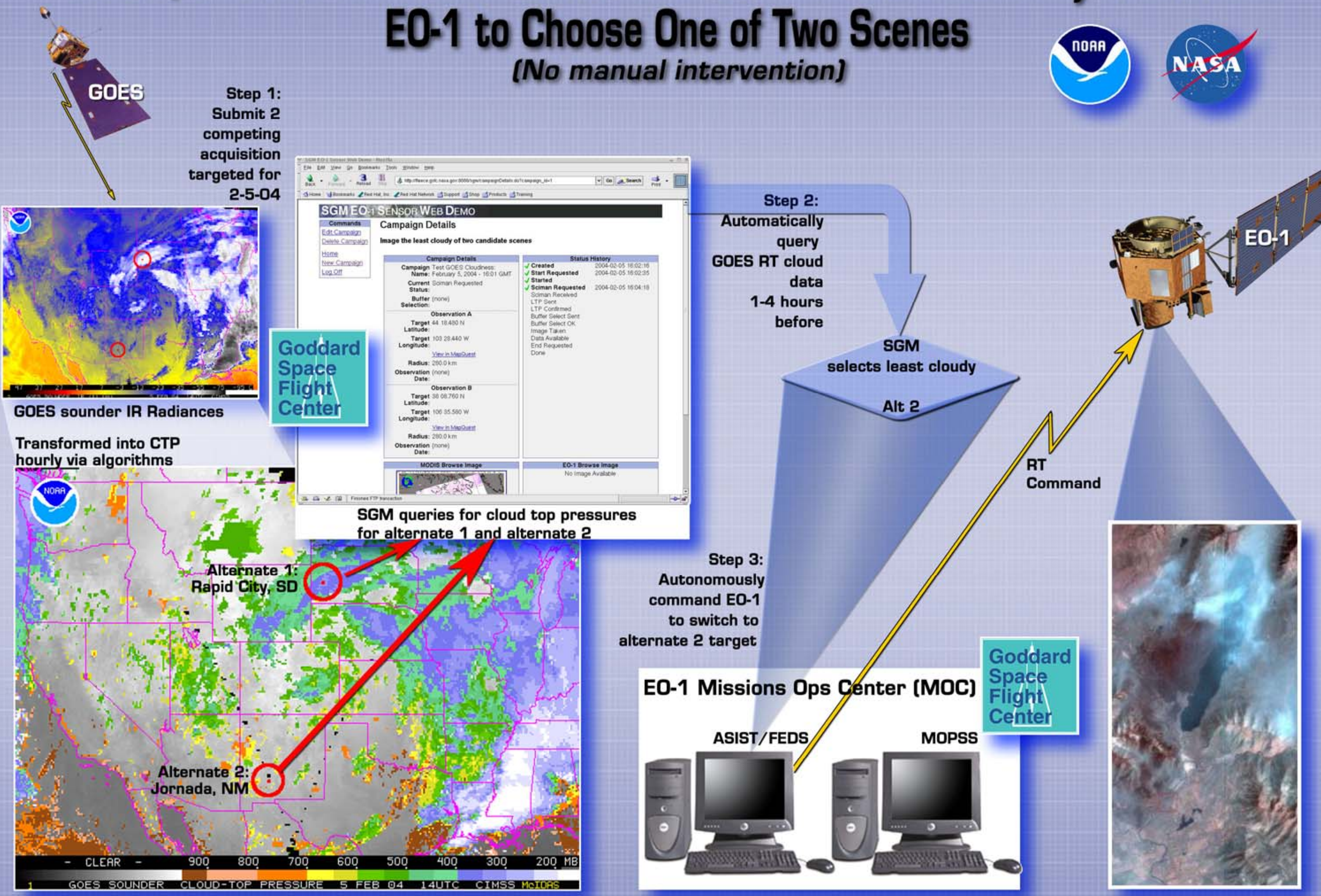


EO-1 Advanced Land Imager
Burn Scar Image

On 11-2-03, the NASA Wildfire SensorWeb was employed to collect data on the burn scars resulting from the Simi Valley, Val Verde and Piru fires in Southern California. MODIS active fire detections for the duration of the event were used to target an acquisition by the ALI and Hyperion instruments onboard EO-1. Such data are employed by the USDA Forest Service for Burned Area Emergency Response mapping. BAER maps are used to target high risk areas for erosion control treatments. In this image, burned areas appear **red** while the unburned areas appear **green**. The **blue** burn perimeter vector is based on ground data.

NOAA/NESDIS GOES Real-Time Cloud Product Automatically Commands EO-1 to Choose One of Two Scenes

(No manual intervention)

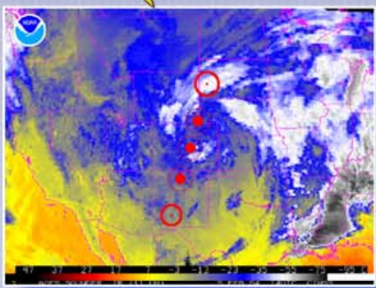


Cloud Top Pressure (CTP) Derived from the GOES-East and GOES-West Sounders Hourly (10 km pixels) on 2-5-04 at 9:00 am EST

NOAA/NESDIS GOES Real-Time Cloud Product Automatically Commands EO-1 to Choose One of N Scenes

(Choice of targets is made onboard EO-1 by CASPER)

Step 1: Submit n competing acquisition targeted

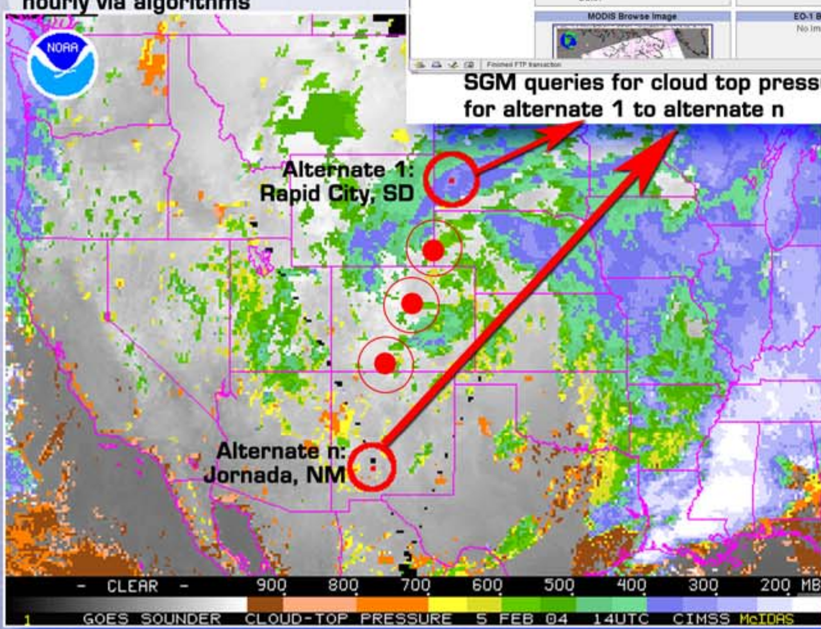


GOES sounder IR Radiances

Transformed into CTP hourly via algorithms

Goddard Space Flight Center

SGM queries for cloud top pressures for alternate 1 to alternate n



Cloud Top Pressure (CTP's) derived from the GOES-East and GOES-West Sounders hourly (10 km pixels)

Step 2: Automatically query GOES RT cloud data 1-4 hours before overflight

Step 3: Uplink n CTP's to EO-1

Cloud Top Pressures for each target

CASPER selects least cloudy alternate

JPL

EO-1 Missions Ops Center (MOC)

Goddard Space Flight Center

CASPER = (Continuous Activity Scheduling Planning Execution and Replanning) system

Targeted EO-1 Sensor Web Experiments

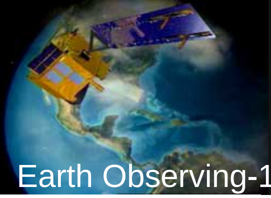
March 2, 2004

Target	*Space sensors*	*Ground Sensors*	*Coordination*	*Partners*	*Status*
Wildfires	***EO-1 (ALI, Hyperion), Terra/Aqua (MODIS)***	***N/A***	***SGM and/or ASE***	***GSFC, JPL, UMD, USFS,NOAA***	***ongoing***
Floods	***Quickscat, Terra/Aqua (MODIS), EO-1***	***Delin's Gnd Sensorweb***	***SGM and/or ASE***	***JPL,GSFC Dartmouth Flood Observatory***	***ongoing***
Volcanoes	***MODIS, GOES, ASTER, EO-1***	***TBD***	***SGM and/or ASE***	***GSFC, JPL, Univ. of Hawaii***	***ongoing***
Algal Blooms	***EO-1***	***Seahorse***	***SGM and/or ASE***	***GSFC, ARL (Univ. of Penn.)***	***future***
Dust storms	***EO-1, TBS***		***SGM and/or ASE***	***JPL, GSFC, NRL***	***future***

SGM = Science Goal Monitor

ASE = Autonomous Sciencecraft Experiment (includes CASPER)

CASPER = Continuous Activity Scheduling, Planning Execution and Replanning (software)



Related Sensor Web Tasks Using EO-1 as a Testbed

March 2, 2004

On-board Processing

On-board Cloud Cover Detection Validation complete

Hyperspectral Compression WG
- *On-board data mining*
- *On-board intelligent image compression*
- *Working group*

End-to-End Communications

Preliminary EO-1 Autonomy Experiment
- *On-board planning*
- *On-board feature detection*
- *Dynamic SW Bus*

Smart Antenna
- *Ground phased array*
- *"Cell tower" com to sat*

Autonomous Coordination

Science Goal Monitor(SGM)
- *Semi-autonomous coordination of imaging*

Livingstone On-board Model Based Diag Tool
- *Autonomous anomaly diagnosis and recommendations*

Operational Testbed

Autonomous Science Experiment(ASE)
- *Migration of ST6 onto EO-1*

EO-1, Terra, Aqua Sensor Web Demo 1 & 2
- *Uses MODIS inst center to detect fires and volcanoes*
- *Uses SGM/ASE to coord image collect with various levels of autonomously*

EO-1/ Gnd Sensor Sensor Web
- *Sensors similar to ones at Huntington Botanical Garden trigger EO-1 image*

Intelligent Distributed Spacecraft Technology Testbed

Funded by ESTO | ***Funded by NMP*** | ***Funded by IS*** | ***Proposed activity***

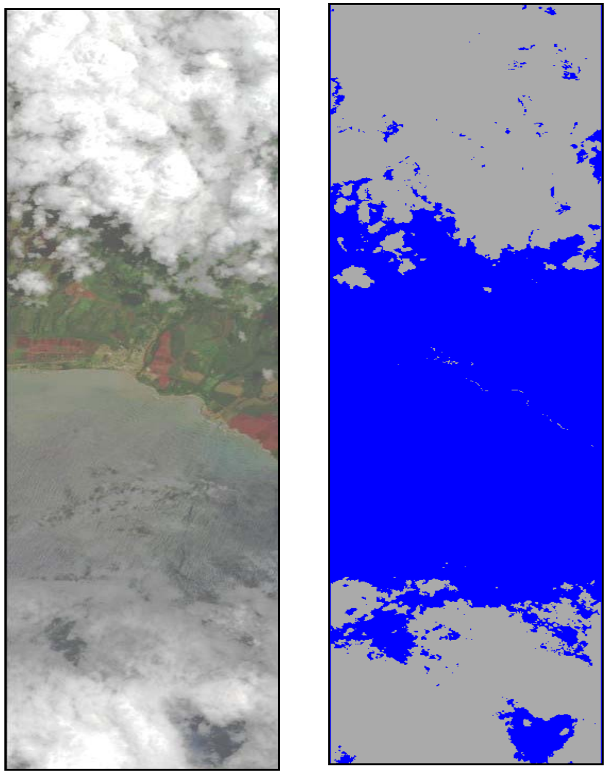
Partially funded – rest of task proposal submitted to CICT IS NRA

Onboard Cloud Cover Assessment

- *Flight validated an onboard cloud cover detection algorithm and determine the performance that is achieved on the Mongoose V*
  - ***Used Hyperion sensor measurements***
  - ***Algorithm developed by MIT / Lincoln Lab***
- *Final onboard cloud cover assessment of an EO-1 8 second (.75 Gbyte) Hyperion scene (taken March 4, 2003, El Mhamid) was expected to take hours but instead took less than 30 minutes*
- *Streamlined algorithm by:*
  - ***Performing level 0 on all data and then selecting the needed 6 bands***
  - ***Converted level 0 data to radiance (level 1R) one scan line (256 pixels) at a time***
  - ***Performed pixel by pixel cloud assessment***
- *Determined that we could perform onboard cloud assessment faster with the following capabilities:*
  - ***Subsampling of raw data (can get close to same results without processing all data)***
  - ***User defined area of interest within image and only process that portion***
  - ***Direct access to science recorder***
  - ***Cloud assessment algorithm can be expanded since we had more margin than expected***
- *For 20 test cases on ground, performed cloud assessment within 5% for major test cases, final validation underestimated 5-10%*

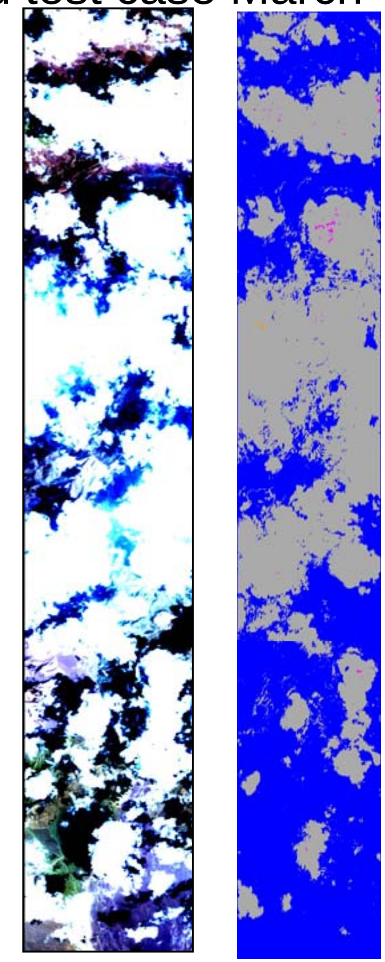
Onboard Cloud Cover Assessment

First onboard test case March 4, 2003



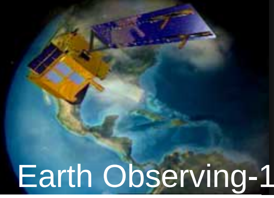
Cheyenne, Wy

Performed simulated cloud assessment on ground with real image



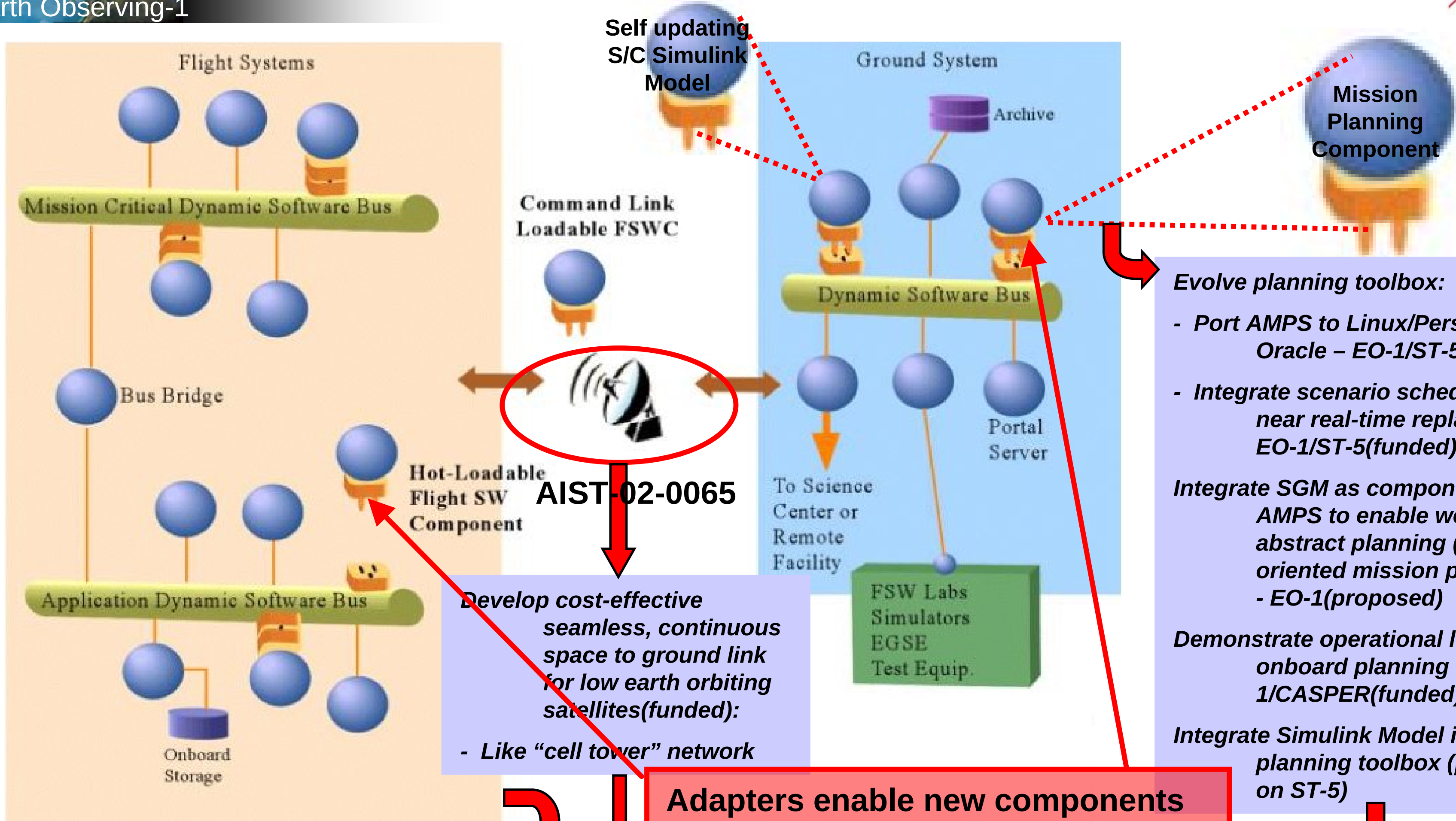
El Mahmid: Path 201 Row 39

Algorithm produced a cloud amount value of 47.1% for this scene



Key Technology to Enable Sensor Web Framework: Middleware to enable “plug and play”! (GMSEC)

March 2, 2004



Develop cost-effective seamless, continuous space to ground link for low earth orbiting satellites(funded):

- Like “cell tower” network

Evolve planning toolbox:

- Port AMPS to Linux/Personal Oracle – EO-1/ST-5(funded)
- Integrate scenario scheduler for near real-time replanning – EO-1/ST-5(funded)

Integrate SGM as component of AMPS to enable web based abstract planning (goal oriented mission planning) - EO-1(proposed)

Demonstrate operational loadable onboard planning tool-EO-1/CASPER(funded)

Integrate Simulink Model into planning toolbox (proposed on ST-5)

Adapters enable new components to be easily plugged-in, Gnd & S/C

Evolve “plug and play” flight SW capability:

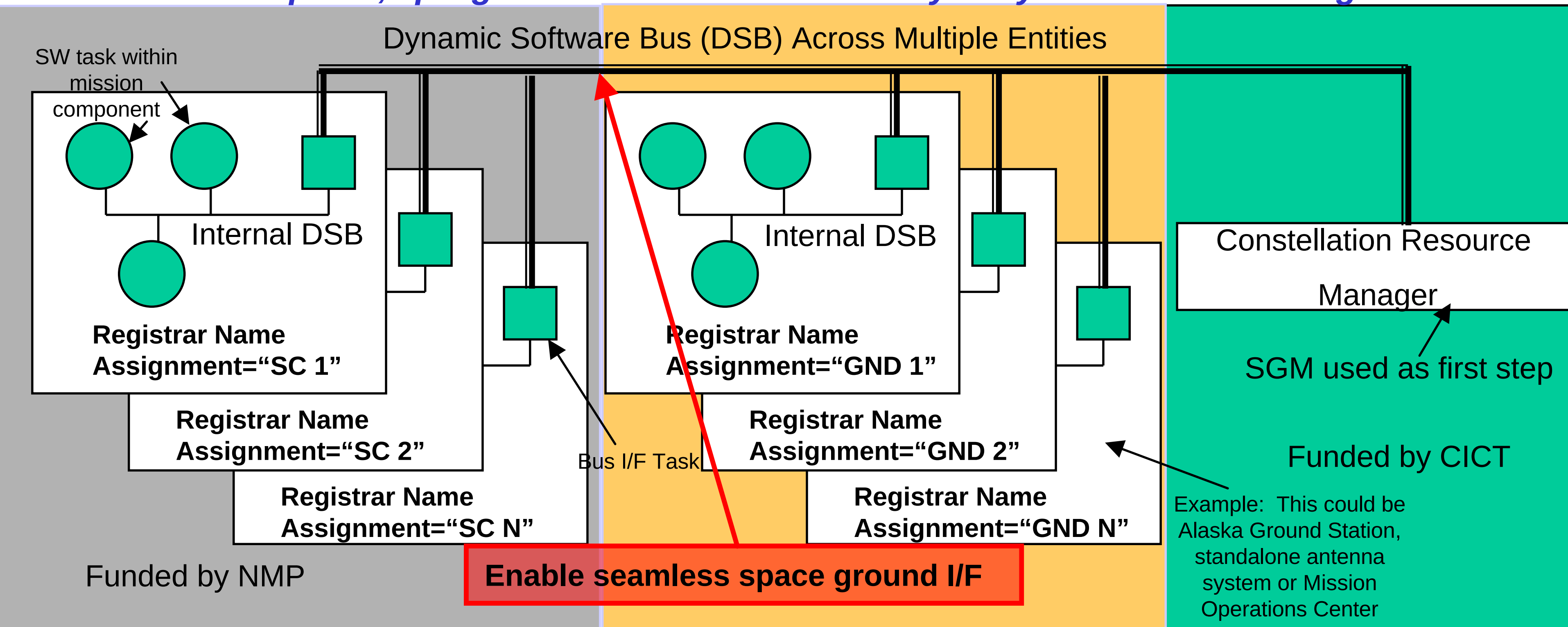
- Easily loadable new flight SW functionality – EO-1/CASPER –(funded, ongoing)
- Demonstrate “hot” plug and play flight SW through command link – proposed for EO-1, then LISA
- Build spec for flight SW “plug” – target LISA and Con-X to make operational (like USB for Flight SW)
- Establish flight SW reuse library – in process by Flight SW Branch (in process Flight SW Branch)

Target is to enable Sensor Web framework:

- Distributed collaborative planning components achieve goals with increasing autonomy

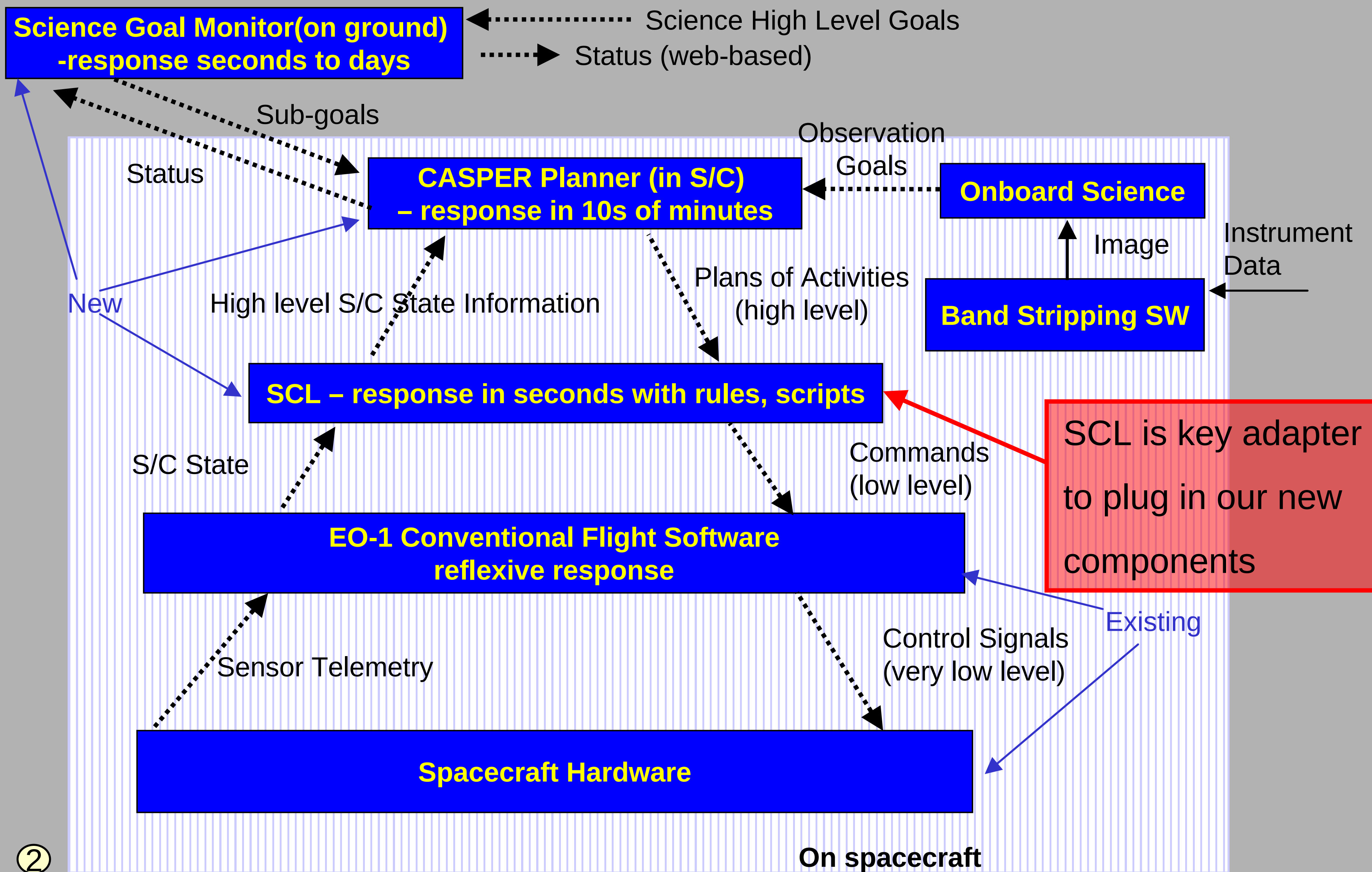
Target Mission Messaging Architecture

- ***Create seamless messaging system across constellation/mission components using Dynamic Software Bus (DSB) & IP***
  - *Multi-protocol*
  - *Easy integration of heritage components to create "ad hoc" constellations*
  - *Components send each other messages similar to internet (URL) by knowing registered name, details taken care of by system*
  - *Once in place, "progressive" mission autonomy easy to create and integrate*



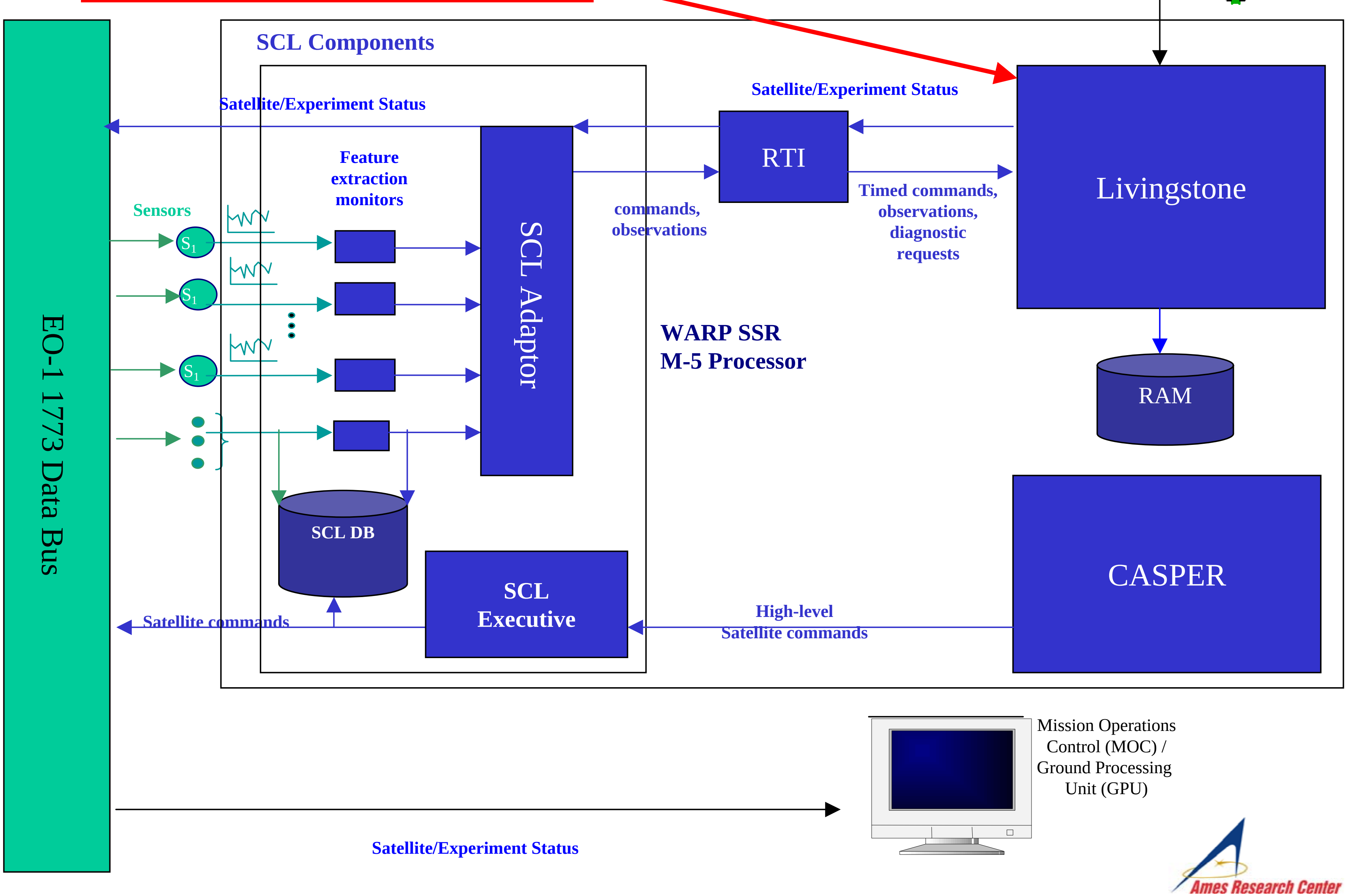
Example of how we are attempting to tie together Onboard and ground planning and scheduling tools

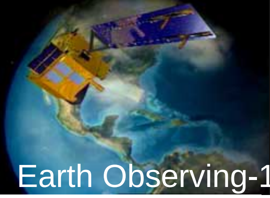
Earth Observing-1



2

An Onboard Plug-in Model-Based Diagnostic Tool to be used on EO-1





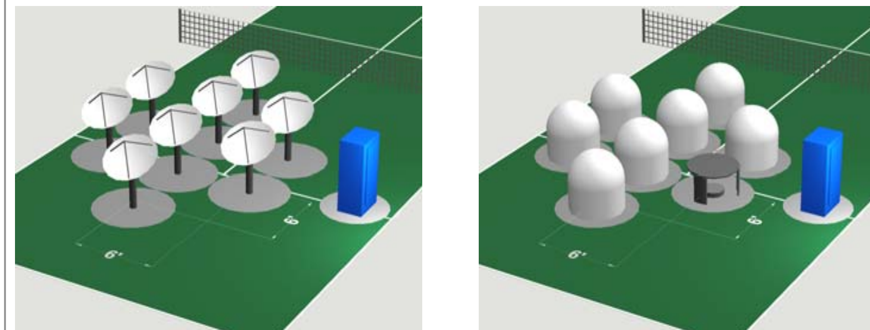
WiFi for Satellites (Smart Antennas)

March 2, 2004

PI: Dan Mandl, NASA/GSFC, Code 584

Description and Objectives

- *Validate new antenna technologies that either used separately or in combination lower cost to purchase, maintain and operate ground antennas in the X and Ka-band for low earth orbiting satellites*
- *Key objectives include increased reliability by eliminating moving parts, simultaneous users on one antenna system, wider and more flexible total coverage than present GN coverage, auto-detect of satellites entering the field –of-view of antennas and auto-adjust of Gain over Noise Temperature (G/T) depending on needed gain to receive data from satellite*



Conceptual Antenna System Architecture based on small dishes (left) and alternative concept based on Space Fed Lens Array (right), placed on backdrop of tennis court to visualize size.

Approach

- Explore three technologies; adaptive beamforming using Digital Signal Processing (DSP) as backend and Space Fed Lens and Reflectarray as front end
- Manipulate following parameters to minimize cost: aperture size, number of apertures, aperture efficiency and selection of beam forming algorithm

Co-I's/Partners

- Dr. Mary Ann Ingram, Georgia Institute of Technology
- Dr. Felix Miranda, Dr. Richard Lee, Dr. Robert Romanofsky, Dr, Afroz Zaman, Glenn Research Center
- Dr. John Langley, Saquish Group

Schedule and Deliverables

3/15/04 – Complete S-Band antenna demo using DSP

3/15/05- Complete X-Band antenna demo using DSP/SpaceFed Lens

3/15/06 – Complete X-band antenna demo using DSP/Reflectarray & if possible, Ka-Band antenna demo using DSP

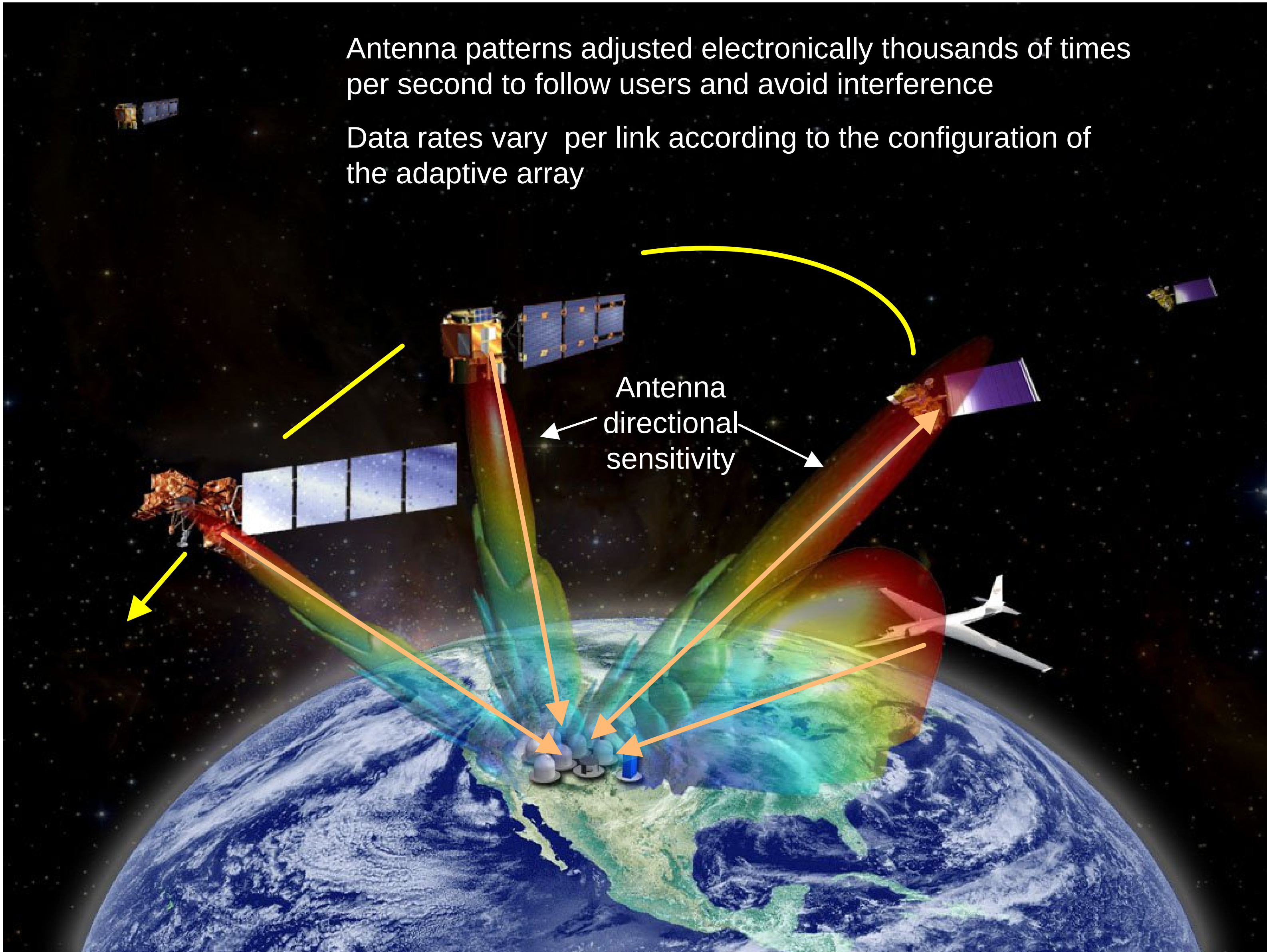
Application/Mission

- EO-1 and similar missions that have S, X and Ka-Band communications

$TRL=4_{in}$

Ongoing research to use Smart Antennas to shape antenna patterns to enable efficient use of the space to ground communications spectrum for constellations.

Vision for Smart Antennas for Satellites

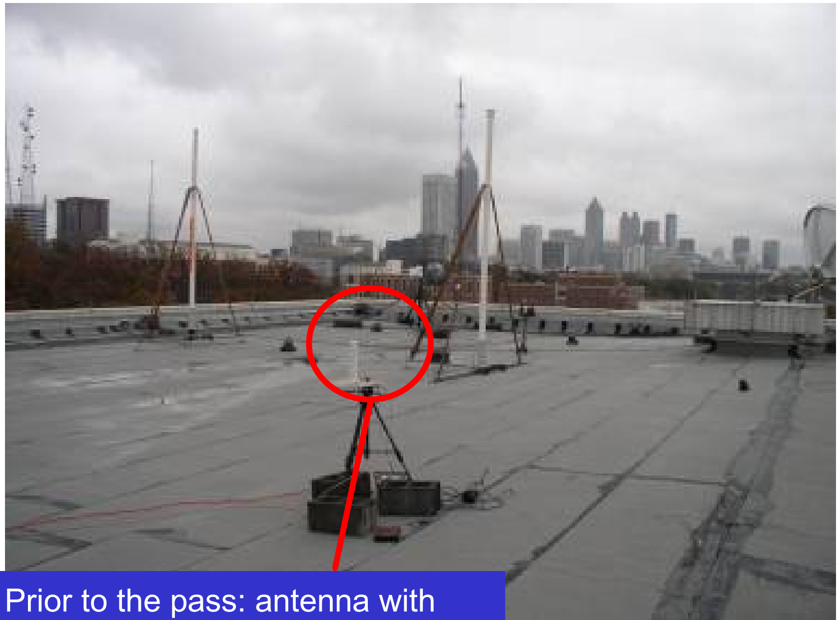


Georgia Tech Task: Initial Setup of Test Element for Smart Antenna in July 2003

- ***Helical antenna element being setup for pass with EO-1 in July 2003***
- ***Final test for year 1 will be four element system, adaptively combining the signal to enable capturing S-Band data from EO-1***
  - ***Year 2 will work with X-Band data***
  - ***Year 3 will work with Ka-Band data if possible***

Earth Observing-1

Georgia Tech:Successful Smart Antenna Tests at Georgia Tech 11-19-03 and 11-25-03

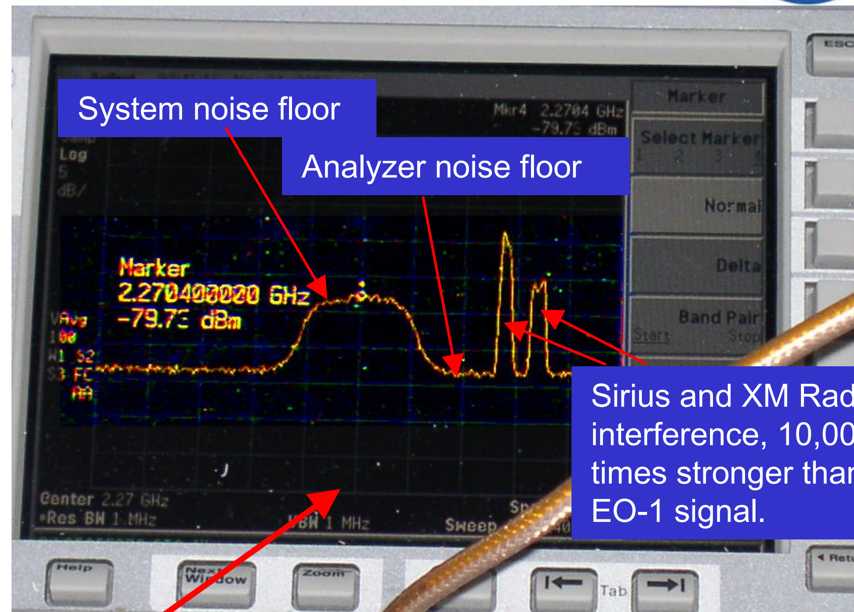


1. Prior to the pass: antenna with cement blocks to prevent it from blowing over. Atlanta skyline in the background. The antenna had a significant vertical wobble (ground plane) due to wind.

2. Students observing EO-1 signal spectrum.

3. Prior to pass, checking spectra of know interference.

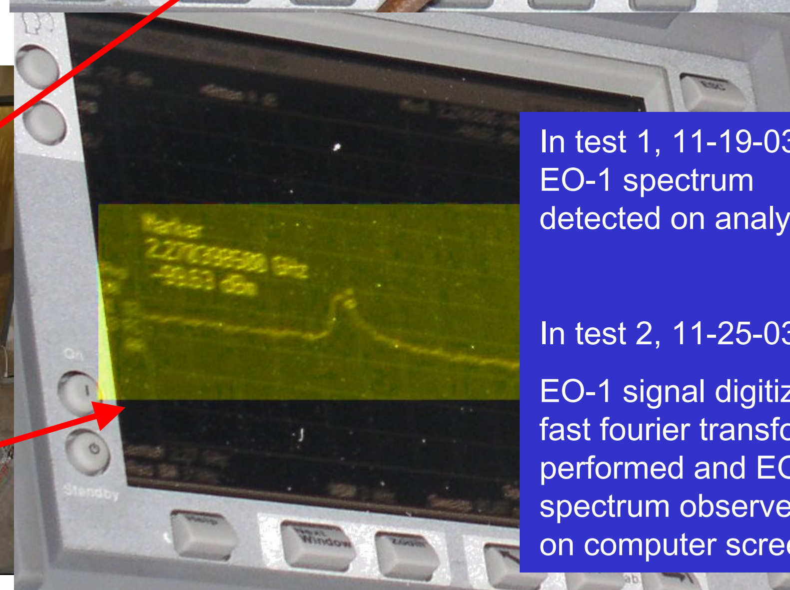
4. Detected EO-1 spectrum during pass



System noise floor

Analyzer noise floor

Sirius and XM Radio interference, 10,000 times stronger than EO-1 signal.



In test 1, 11-19-03: EO-1 spectrum detected on analyzer

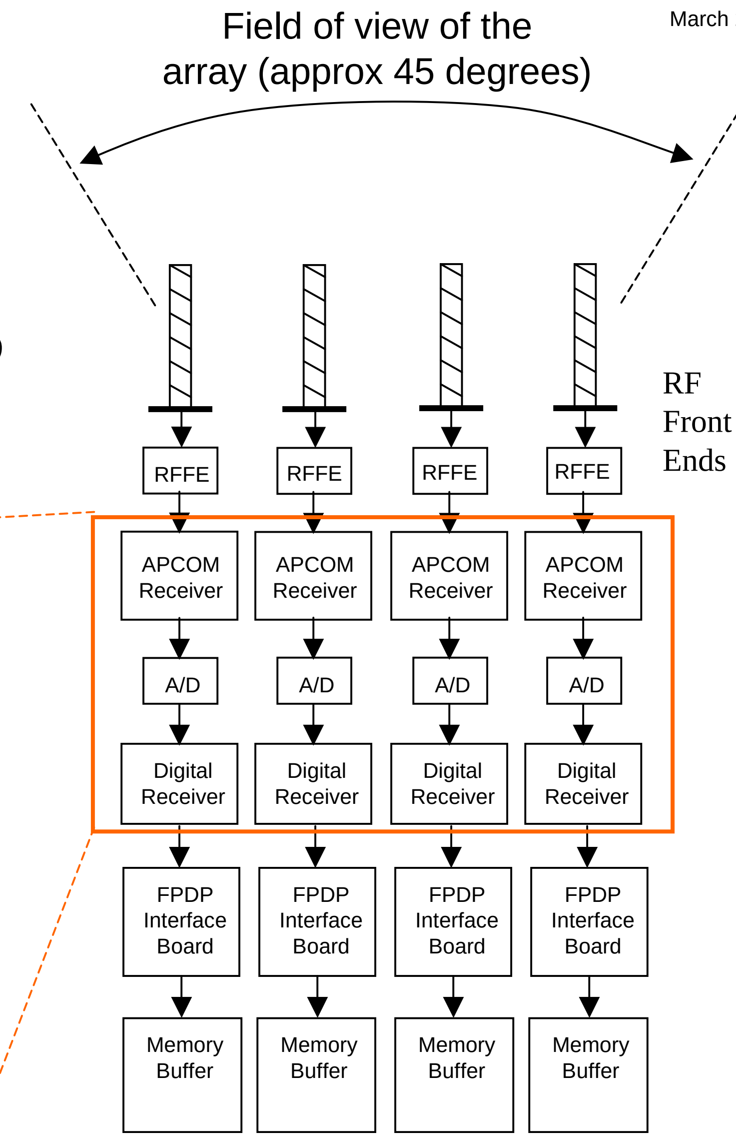
In test 2, 11-25-03:

EO-1 signal digitized, fast fourier transform performed and EO-1 spectrum observed on computer screen.

Target Full Test System to be Built by Georgia Tech by End of First Year

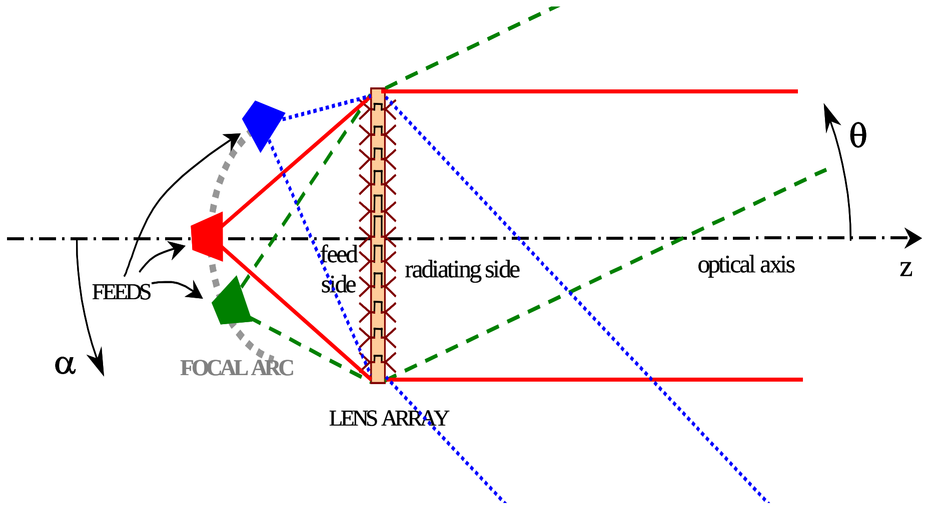
- ***Card cage holds APCOM receivers, A-to-D converters, and digital down-converters***

Card cage



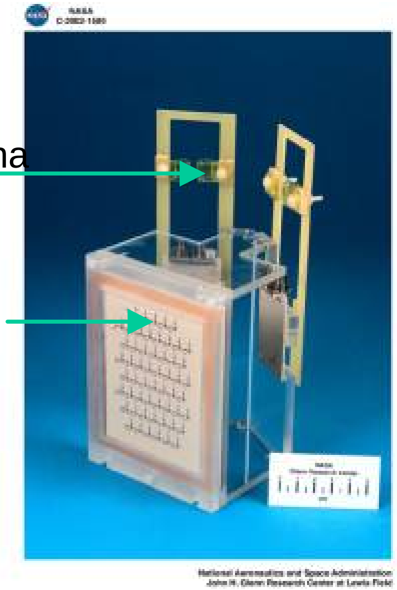
How it will probably look on roof at Georgia Tech

Space Fed Lens Element Being Developed at Glenn Research Center

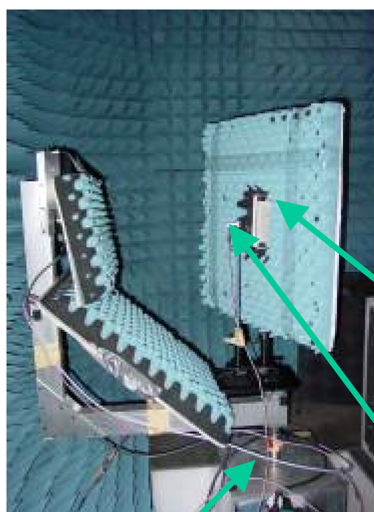


Feed antenna

Lens



Ka-band dual-beam space-fed lens array



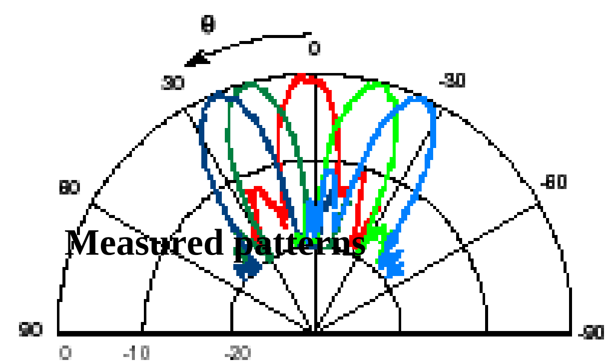
Lens array

Feed antenna

Rotating stage

Test setup

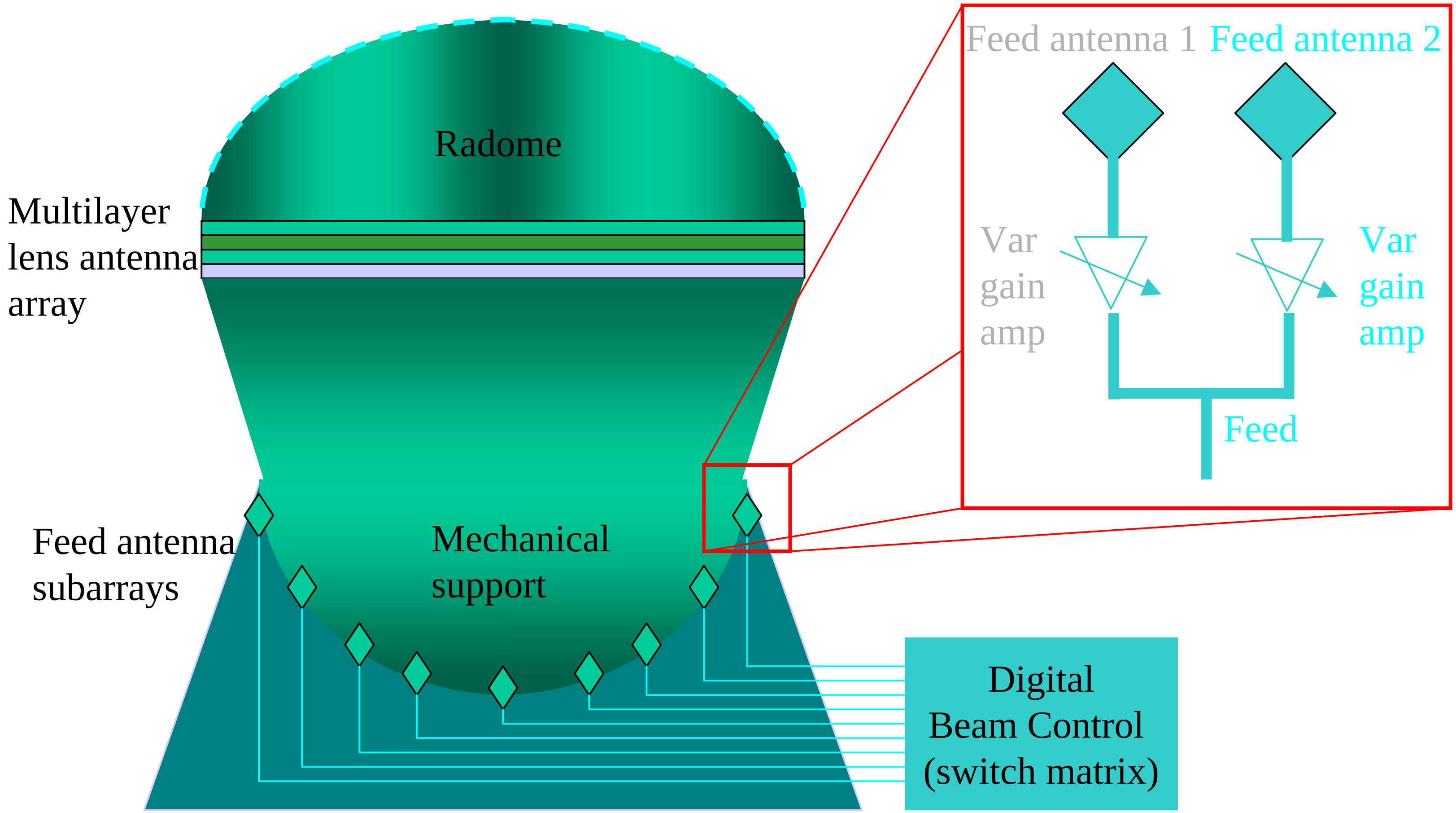
26.7 GHz



Measured patterns

GLENN RESEARCH CENTER
at Lewis Field

How Space Fed Lens Element Will Look

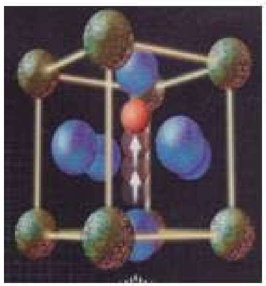


Another Element Being Developed at Glenn: Reflectarray

Ground Hybrid Phased Array

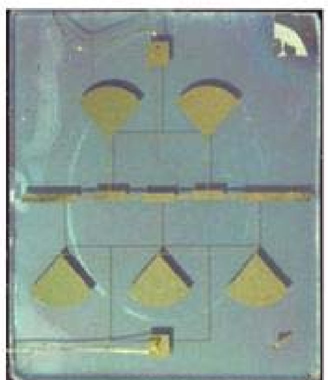
GRC GLENN RESEARCH CENTER at Lewis Field

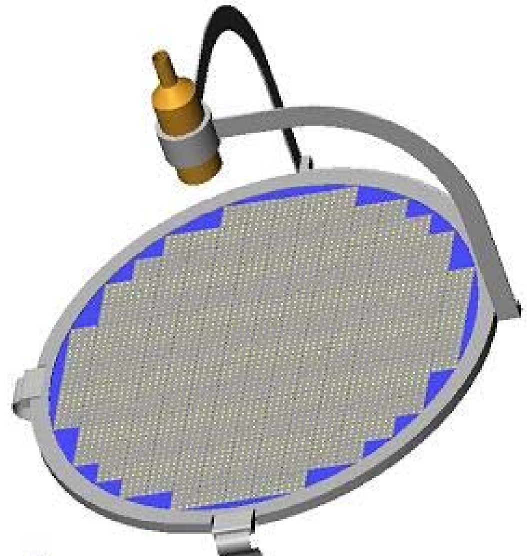
Ferroelectric Reflectarray Antenna



$Ba_xSr_{1-x}TiO_3$ Crystal

Thin Film
Phase Shifter





~500 Element Reflectarray

Principle Investigator: R. Romanofsky