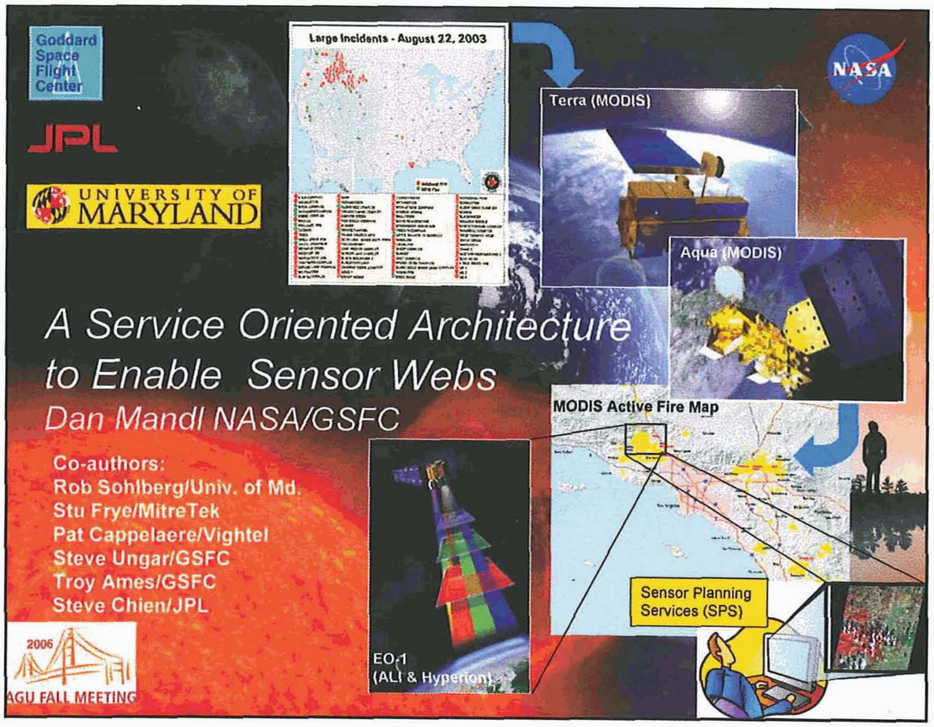


Introduction

- Lower cost of new Earth science products by:
  - Sharing open source science algorithms
  - Creating standard interfaces for tasking sensors via a service oriented architecture
  - Making sensor capabilities, data sources and algorithms discoverable on the Internet
  - Allowing users to create new algorithms out of existing algorithm components
- Enable rapid and cost-effective reconfiguration of new sensor webs via this architecture

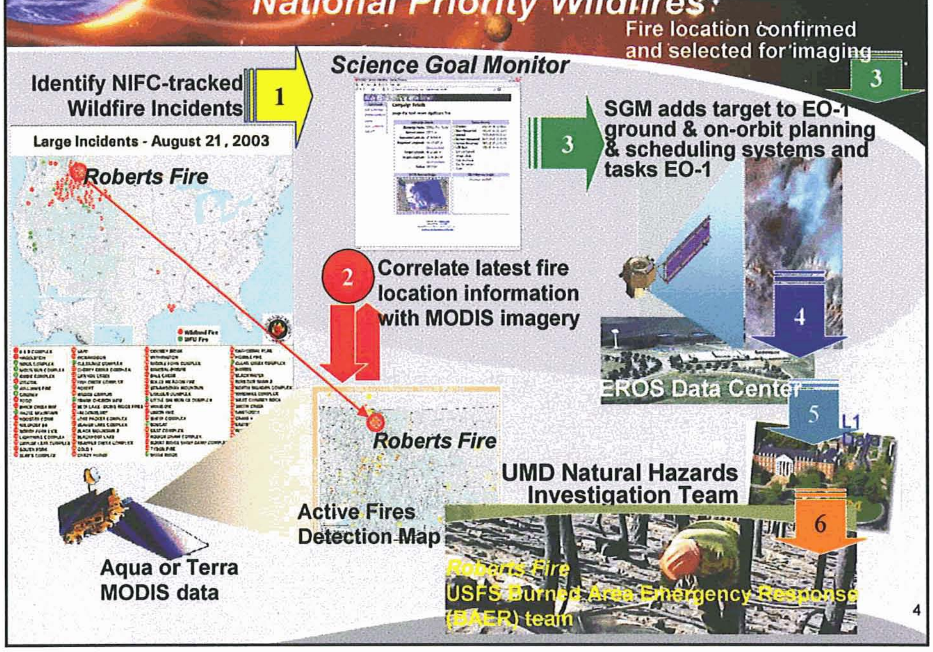
2

Current Way vs. New Way

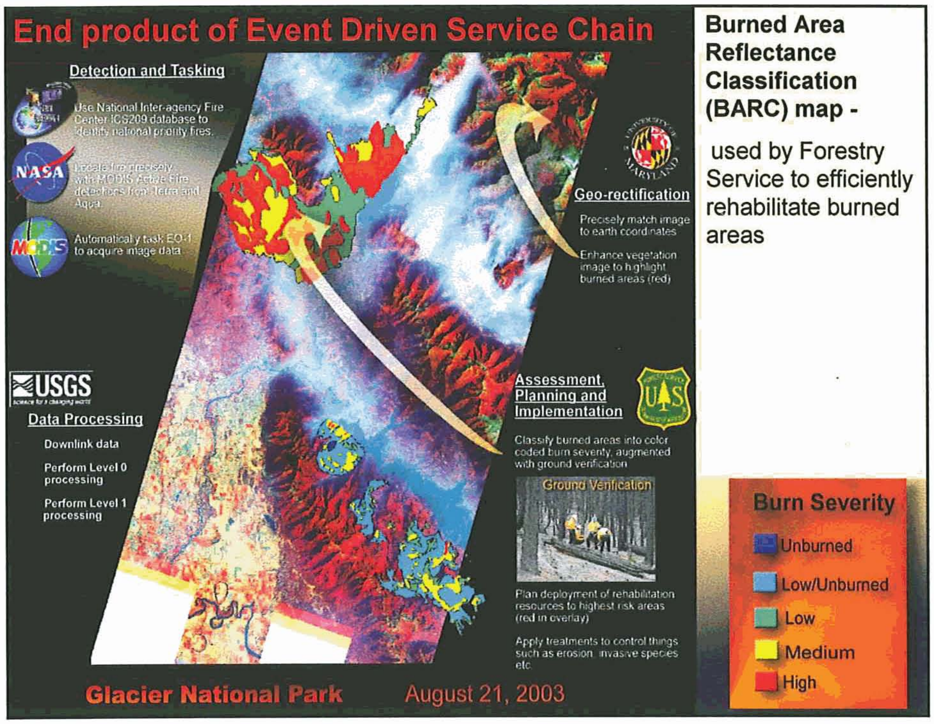
	Current Way	Vision for New Way
Method to develop new algorithms	Custom	Open source building blocks
Interoperability	Low	High
Time to create & implement new algorithms/service chains	Months	Minutes
Cost to create & implement new algorithms/service chains	High	Low
Data storage and transfer requirements	High: Store/archive and transfer all sensor data	Modest to Low: Filter and transfer only needed features; archive virtual products
Ease of finding and reusing existing algorithms	Difficult	Easy with automatic discovery

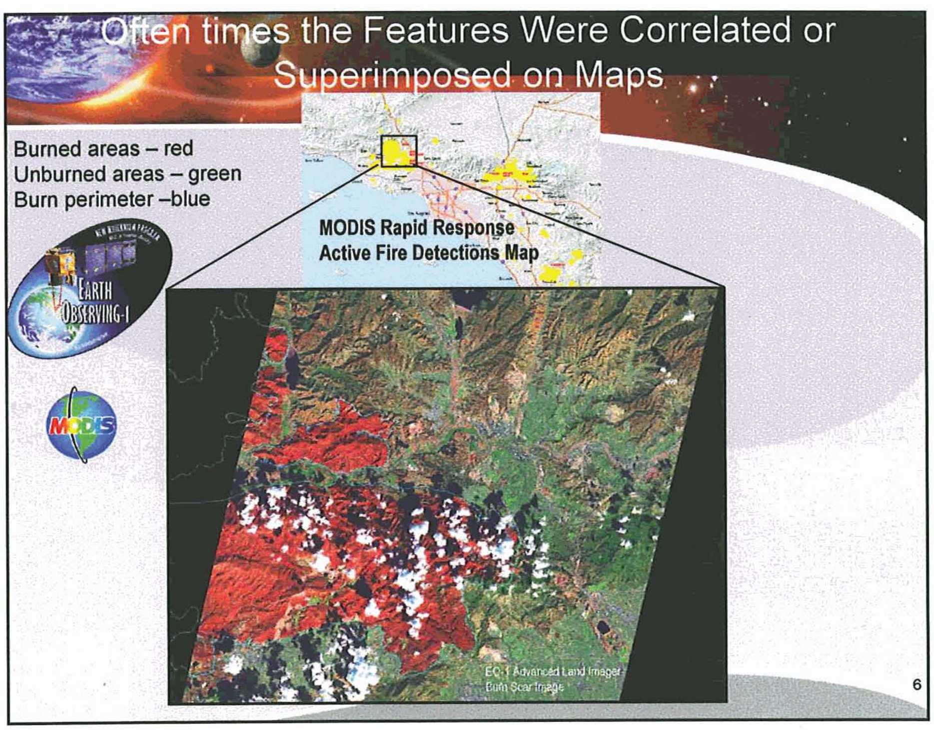
3

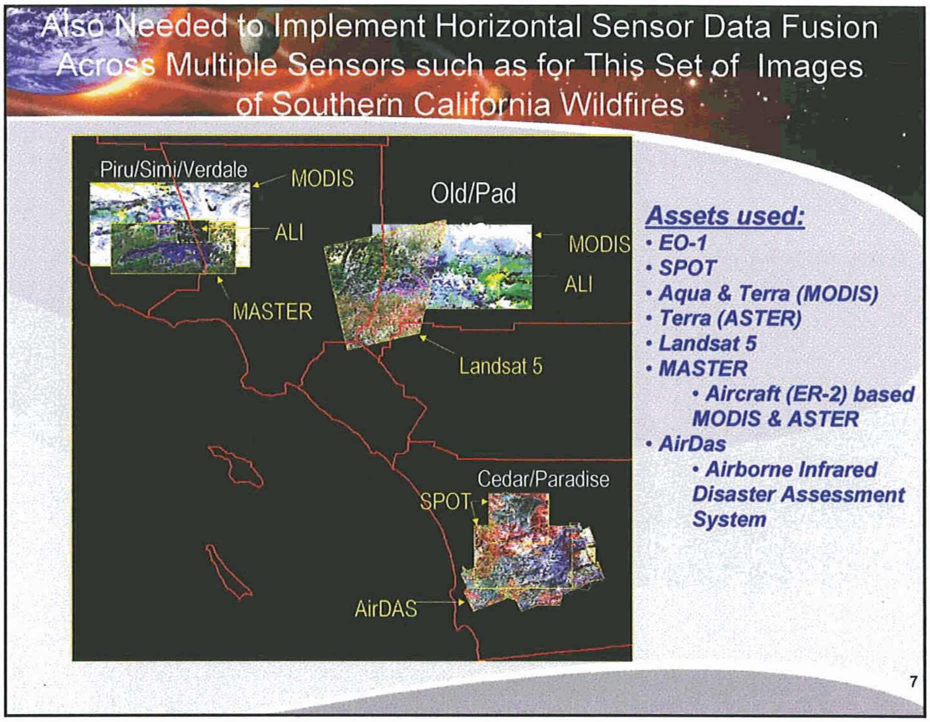
Our First Sensor Web Experiment with EO-1 National Priority Wildfires

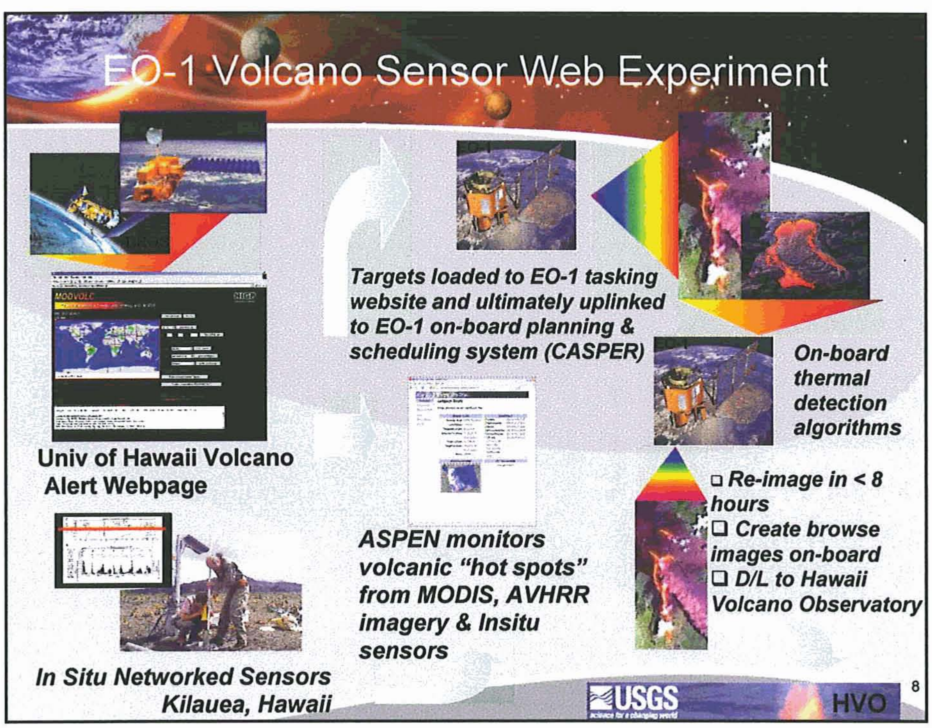


4


End product of Event Driven Service Chain
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
USGS
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
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
Burned Area Reflectance Classification (BARC) map -
used by Forestry Service to efficiently rehabilitate burned areas
Burn Severity
Unburned
Low/Unburned
Low
Medium
High


Often times the Features Were Correlated or Superimposed on Maps
Burned areas – red
Unburned areas – green
Burn perimeter –blue
EARTH OBSERVING-1
MODIS
MODIS Rapid Response Active Fire Detections Map
EO-1 Advanced Land Imager Burn Scar Image
6


Also Needed to Implement Horizontal Sensor Data Fusion Across Multiple Sensors such as for This Set of Images of Southern California Wildfires
Piru/Simi/Verdale
MODIS
ALI
MASTER
Old/Pad
MODIS
ALI
Landsat 5
Cedar/Paradise
SPOT
AirDAS
Assets used:
• EO-1
• SPOT
• Aqua & Terra (MODIS)
• Terra (ASTER)
• Landsat 5
• MASTER
• Aircraft (ER-2) based MODIS & ASTER
• AirDas
• Airborne Infrared Disaster Assessment System
7


EO-1 Volcano Sensor Web Experiment
Univ of Hawaii Volcano Alert Webpage
In Situ Networked Sensors Kilauea, Hawaii
Targets loaded to EO-1 tasking website and ultimately uplinked to EO-1 on-board planning & scheduling system (CASPER)
ASPEN monitors volcanic "hot spots" from MODIS, AVHRR imagery & Insitu sensors
On-board thermal detection algorithms
❑ Re-image in < 8 hours
❑ Create browse images on-board
❑ D/L to Hawaii Volcano Observatory
USGS
HVO
8

How We Would Like to Do It

- The previous slides depicted a sensor webs that operated in slow motion and were manpower intensive to coordinate images and assemble finished science products
- The following slides are how we would like to do this same or similar processes
  - Discovery of data availability and algorithm availability
  - Automatic tasking of sensors
  - Easy specification of algorithm service chain
  - Automatic execution of service chain
  - Automatic delivery of finished science product to desktop
- First experiments being conducted under auspices of Opengeospatial Consortium (OGC) Webservices Phase 4 (OWS-4) testbed

9

User Shielded From Details By Services

- Sensor Planning Service (SPS) details or capability and availability of sensor (whether in-situ or on-orbit) and provides automatic means for user to task sensor
- Sensor Observation Service (SOS) provides observation data to user
- Web Processing Service (WPS) classified desired features
- Web Coverage Service (WCS) places features on map provided by Web Map Service (WMS)
- Language such as SensorML used to self-describe sensor capabilities and availability, thus enabling discovery of services
- Other services as depicted on next slide fill in the architecture to allow the general array of services to work together

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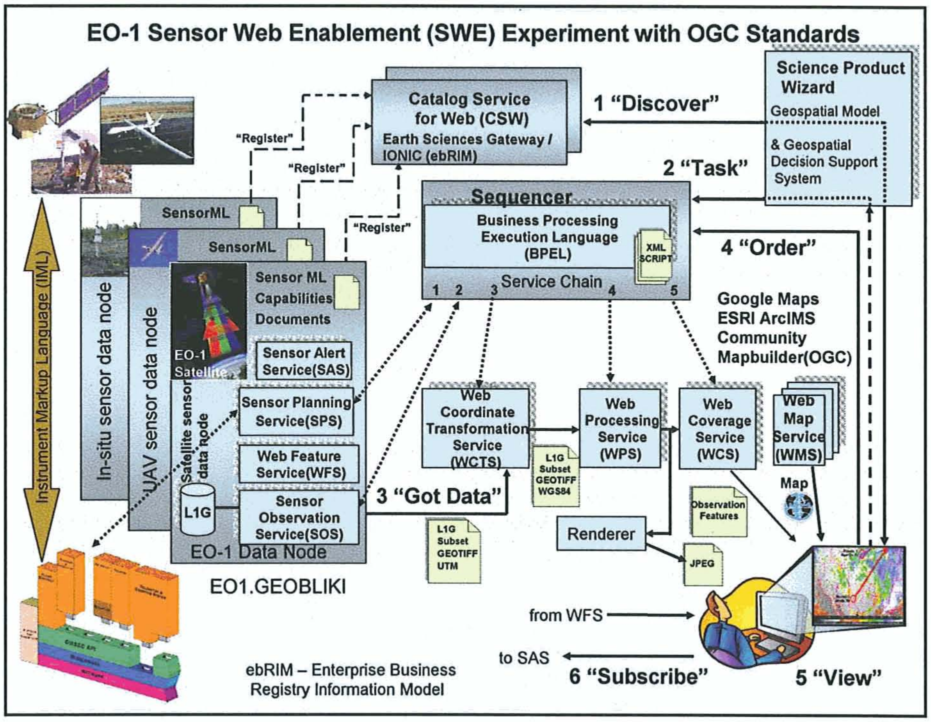
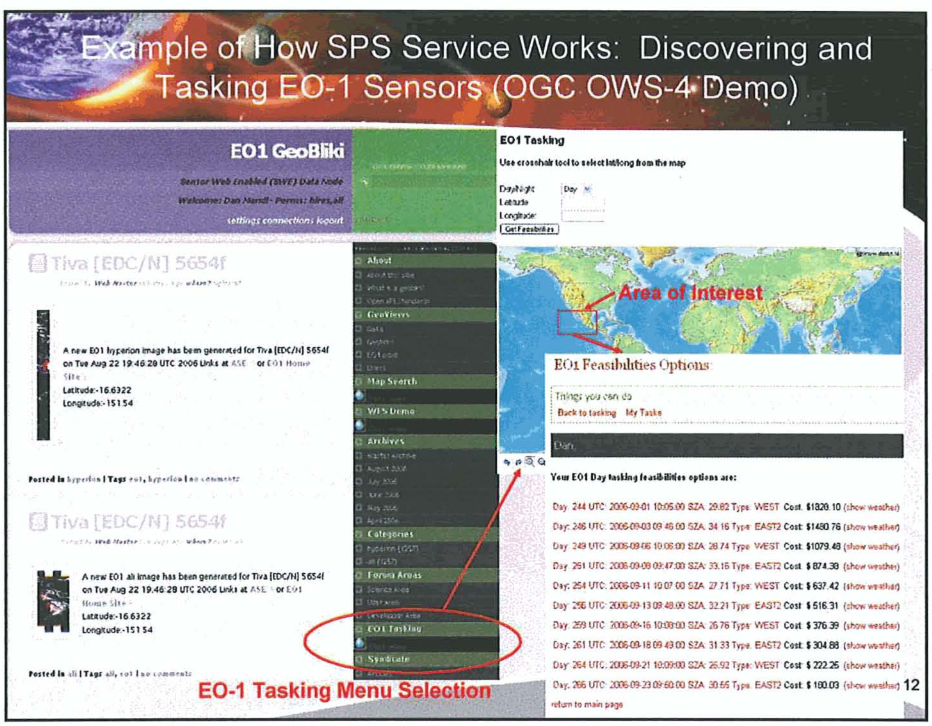

EO-1 Sensor Web Enablement (SWE) Experiment with OGC Standards
Catalog Service for Web (CSW)
Earth Sciences Gateway / IONIC (ebRIM)
1 "Discover"
Science Product Wizard
Geospatial Model
& Geospatial Decision Support System
"Register"
"Register"
"Register"
2 "Task"
Sequencer
Business Processing Execution Language (BPEL)
XML SCRIPT
4 "Order"
Service Chain
1 2 3 4 5
SensorML
SensorML
Sensor ML Capabilities Documents
Instrument Markup Language (IML)
In-situ sensor data node
UAV sensor data node
Satellite sensor data node
EO-1 Satellite
Sensor Alert Service(SAS)
Sensor Planning Service(SPS)
Web Feature Service(WFS)
Sensor Observation Service(SOS)
L1G
EO-1 Data Node
EO1.GEOBLIKI
Google Maps
ESRI ArcIMS
Community
Mapbuilder(OGC)
Web Coordinate Transformation Service (WCTS)
Web Processing Service (WPS)
Web Coverage Service (WCS)
Web Map Service (WMS)
L1G Subset GEOTIFF WGS84
Map
3 "Got Data"
Observation Features
Renderer
L1G Subset GEOTIFF UTM
JPEG
from WFS
to SAS
6 "Subscribe"
5 "View"
ebRIM – Enterprise Business Registry Information Model


Example of How SPS Service Works: Discovering and Tasking EO-1 Sensors (OGC OWS-4 Demo)
EO1 GeoBliki
Sensor Web Enabled (SWE) Data Node
Tiva [EDC/N] 5654f
Tiva [EDC/N] 5654f
EO1 Tasking
Use crosshair tool to select lat/long from the map
Area of Interest
EO1 Feasibilities Options
Your EO1 Day tasking feasibilities options are:
EO-1 Tasking Menu Selection
12

Target EO-1 User Scenario for OWS-4

- Department of Homeland Security (DHS) analyst requests satellite imagery in disaster area to validate potential site. Catalog returns EO-1 as possible source via Catalog Services for the Web (CSW).
- Access to high resolution EO-1 data is granted based on user/role permission
- No data is available, so satellite tasking is required and achieved (at no cost to DHS via SPS service).
- Analyst is notified via instant message that Hyperion/ALI data products are available. High resolution imagery is retrieved via SOS, WCS and WFS services.

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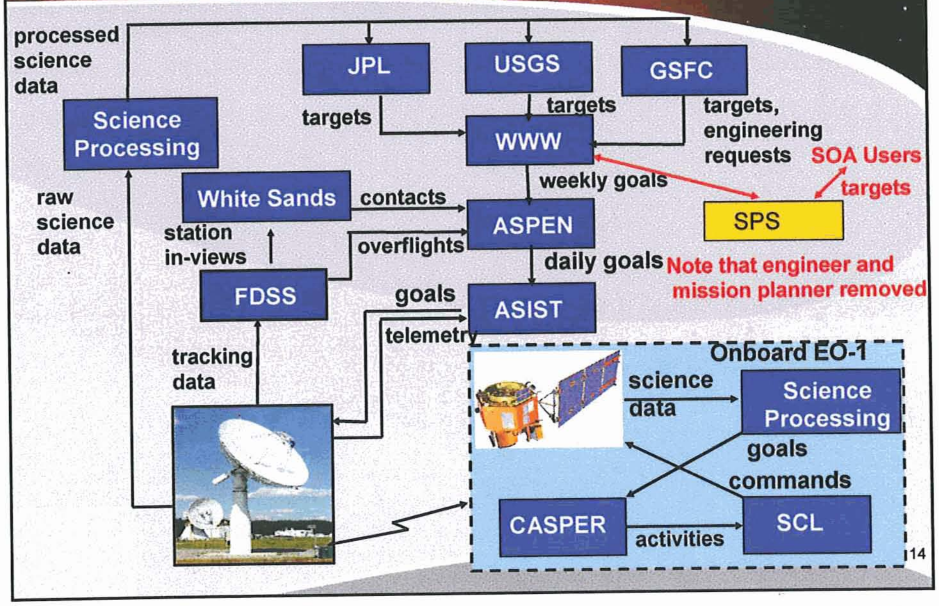
The Architecture Behind the SPS for EO-1



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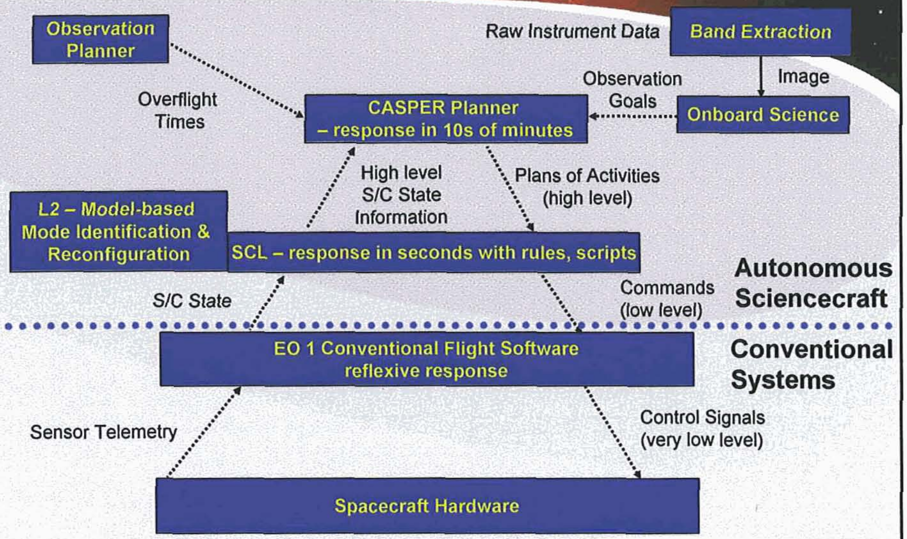
Architecture That Drives SPS Includes Onboard Intelligent Software



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Other Targeted Activities

- Add NASA/Ames Unmanned Aerial System (UAS) to sensor web with services (see next two slides)
- Add a standardized set of sub-services to enable the SPS to be reconfigured in a plug and play manner
- Use Instrument Markup Language (IML) to control various sensors
- Create a variety of WPS as standard services from the already available onboard classifiers used on EO-1 such as thermal, clouds, floods, ice, etc.
- Demonstrate ease of tasking and coordination of multiple assets via SPS's

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12-Channel Wildfire Scanner Specifications

Channel 1:	0.42 - 0.45 um
Channel 2:	0.45 - 0.52 um
Channel 3:	0.52 - 0.60 um
Channel 4:	0.60 - 0.62 um
Channel 5:	0.63 - 0.69 um
Channel 6:	0.69 - 0.75 um
Channel 7:	0.76 - 0.90 um
Channel 8:	0.91 - 1.05 um
Channel 9:	1.55 - 1.75 um
Channel 10:	2.08 - 2.35 um
Channel 11:	3.60 - 3.79 um (VIIRS M12)
Channel 12:	10.26 -11.26 um (VIIRS M15)

FOV: 42.5 or 85.9 degrees (selectable)
IFOV: 1.25 mrad or 2.5 mrad (selectable)
Spatial Res.: 3 – 50 meters (altitude dependant)


General Atomics Altair UAS

Also compatible with the GA Mariner, Predator-B & Cessna Caravan C208.

- Targeting input from NIFC, MODIS Rapid Response, and GOES.
- Onboard, real-time geolocation and product generation for both imagery and fire detects.
- Browse and fire detects available via Google Earth interface within ca. 4 minutes.
- Cal/Val coordination with MODIS Land Team and CEOS-LPV.
- Activities in plan with AIST PIs for SensorWeb implementation in concert with MODIS and EO-1.

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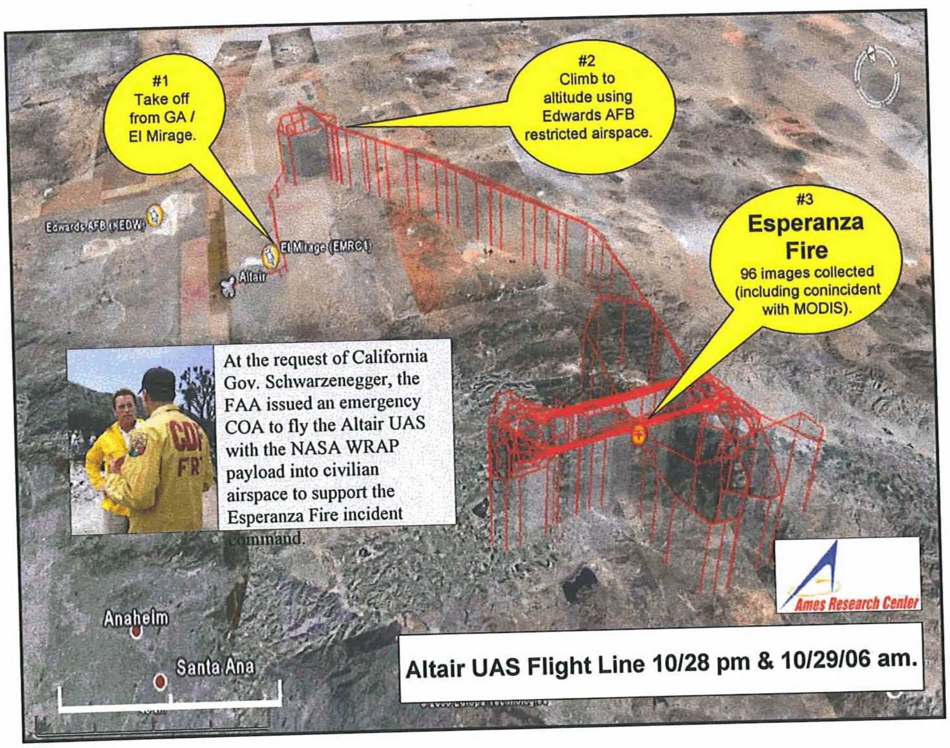


Conclusion

- Integrating sensors with open source, interoperable reusable science services facilitates the vision of Global Earth Observing System of Systems
- Creating these open services, lowers the cost of performing science analysis and creating new methods
- With the OGC or similar standards, any set of sensors can become a virtual sensor web
- Data volume is greatly reduced since only virtual products stored and desired products produced on-demand

Glossary

BPEL – Business Processing Execution Language

DSS -- Decision Support System

ebRIM -- Enterprise Business Registry Information Model

SOS – Sensor Observation Service

CSW – Catalog Services For the Web

SPS – Sensor Planning Service

GMSEC – Goddard Mission Services Evolution Center

WCS – Web Coverage Service

IML – Instrument Markup Language

WCTS – Web Coordinate Transformation Service

SAS – Sensor Alert Service (Pub/Sub)

WFS – Web Feature Service

WMS – Web Map Service

WPS – Web Processing Service

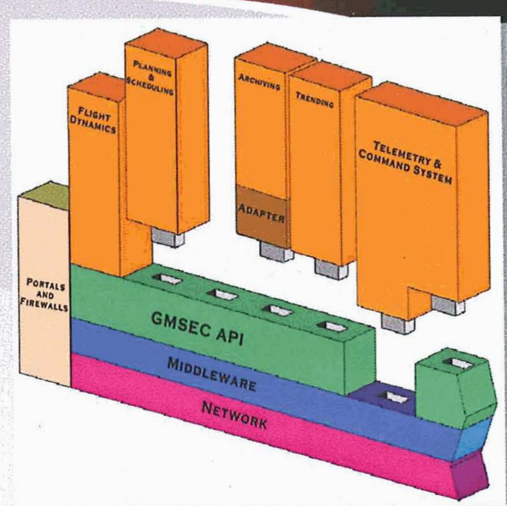
Backup Slides

21

Underlying "Plug and Play" Message Bus Architecture-- Goddard Mission Services Evolution Center (GMSEC)

GMSEC architecture provides a scalable and extensible ground and flight system approach

- Standardized messages formats
- Plug-and-play components
- Publish/Subscribe protocol
- Platform transparency
- ST5 first mission to be totally GMSEC compliant



More info at:
http://gmsec.gsfc.nasa.gov

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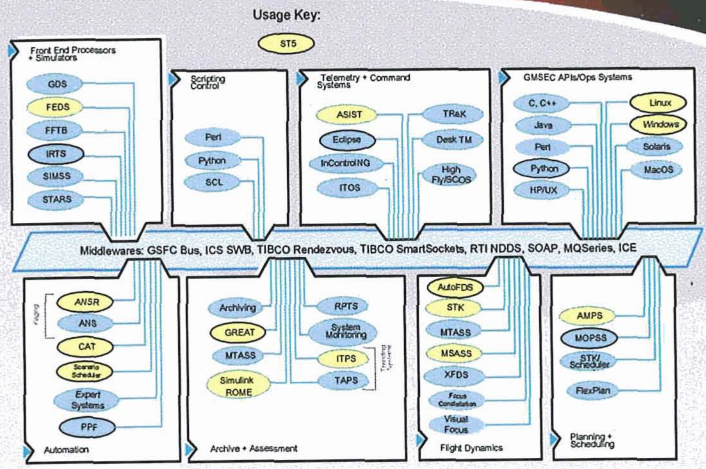
Example of Rapid Mission Configuration Using GMSEC Interoperable Catalog Components



GMSEC approach gives users choices for the components in their system. The ST-5 mission rapidly selected key components from the GMSEC catalog.

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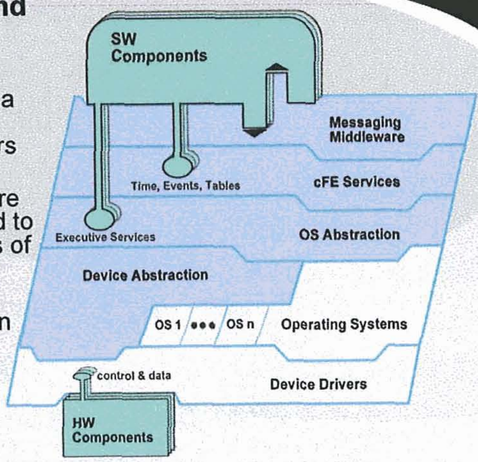
Core Flight Executive (cFE), an Extension for GMSEC for Flight SW

cFE provides a framework that simplifies the development and integration of applications

- Layered Architecture – software of a layer can be changed without affecting the software of other layers
- Components communicate over a standard message-oriented software bus, therefore, eliminating the need to know the details of the lower layers of inter-networking.
- Software components can be developed and reused from mission to mission.
- Developed by Flight SW Branch at GSFC
- To be used on LRO
- More info at: http://gmsec.gsfc.nasa.gov



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Advantages of SOA for Space Sensors

- Networked standardized interface connections, loosely coupled
  - Components connected at run-time
- Enables discovery of services
- Hides details of how service performed (encapsulated implementation)
- Fault tolerant
  - Since connection occurs at run-time, if service not available, a component can find or "discover" an alternative service and if unavailable, can connect to another instance of the service if available
  - Troubleshooting is easier because information is provided at component and services level
- Highly reusable
  - Standardized, networked "plug and play" interfaces
- Scalable
  - Interactions between services and clients independent of location and numbers
- Sustaining engineering for constellation simplified
  - Can initiate new instance of service or alternative service and then disconnect old services

Taken from: Hartman, Hoebel; "Lightweight Service Architectures for Space Missions", SMC-IT 2006, Pasadena, Ca

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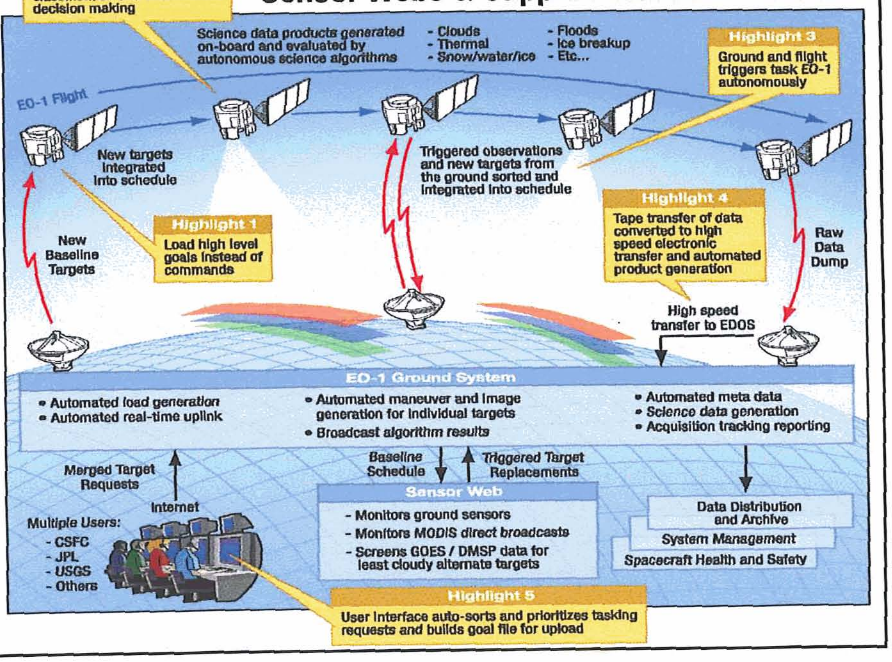
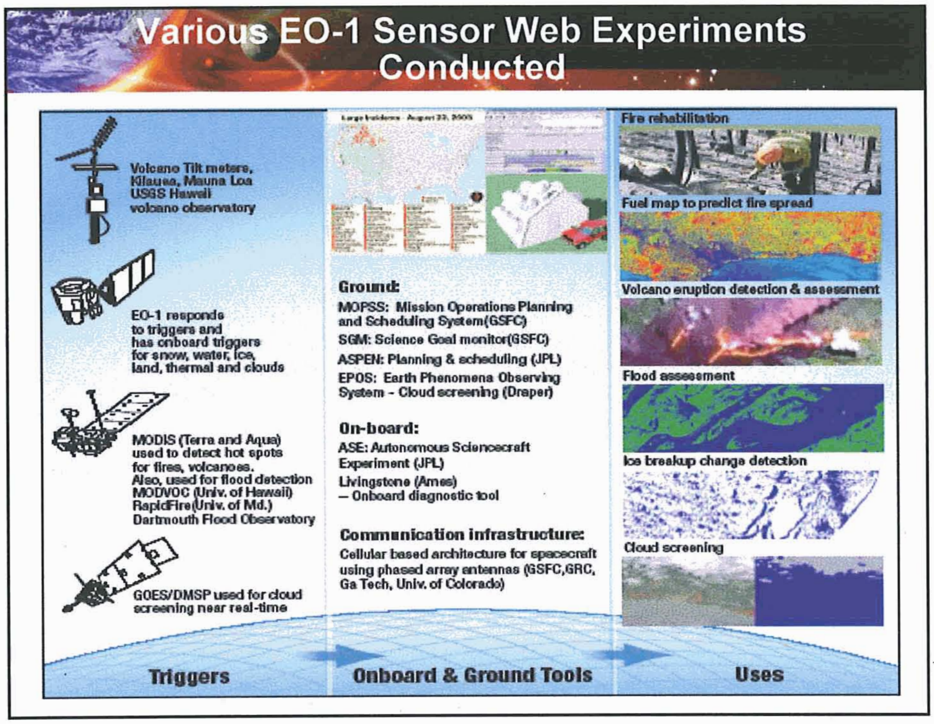
Key Capabilities Implemented to Enable EO-1 Sensor Webs & Support "Backend" of SPS




Various EO-1 Sensor Web Experiments Conducted
Volcano Tilt meters, Kilauea, Mauna Loa USGS Hawaii volcano observatory
EO-1 responds to triggers and has onboard triggers for snow, water, ice, land, thermal and clouds
MODIS (Terra and Aqua) used to detect hot spots for fires, volcanoes. Also, used for flood detection MODVOC (Univ. of Hawaii) RapidFire(Univ. of Md.) Dartmouth Flood Observatory
GOES/DMSP used for cloud screening near real-time
Ground:
MOPSS: Mission Operations Planning and Scheduling System(GSFC)
SGM: Science Goal monitor(GSFC)
ASPEN: Planning & scheduling (JPL)
EPOS: Earth Phenomena Observing System - Cloud screening (Draper)
On-board:
ASE: Autonomous Sciencecraft Experiment (JPL)
Livingstone (Ames) – Onboard diagnostic tool
Communication infrastructure:
Cellular based architecture for spacecraft using phased array antennas (GSFC,GRC, Ga Tech, Univ. of Colorado)
Fire rehabilitation
Fuel map to predict fire spread
Volcano eruption detection & assessment
Flood assessment
Ice breakup change detection
Cloud screening
Triggers
Onboard & Ground Tools
Uses