An Updated Status of the Experiments with Sensor Webs and OGC Service Oriented Architectures to Enable Global Earth Observing System of Systems (GEOSS)

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Agenda

• Introduction
• Problem
• Basic service oriented architecture approach
• Series of experiments
• Next experiments
• Conclusion
Introduction

- Sensor Web – a collection of sensors (space/terrestrial) nodes and computational nodes (e.g. models) connected by a communication fabric which act as a cohesive whole.
- Global Earth Observing System of Systems
  - International agreement signed by 67 nations to create interoperable earth observing assets
- Experiments with sensor webs and service oriented architectures
  - 10 satellites, UAV, in-situ sensors, models, emulators, web processing nodes
  - Instant “ad-hoc” sensor webs
  - Open Geospatial Consortium standards
  - On-demand science

Problem

- How to make existing sensors, models, emulators compatible with future assets integrated into sensor web
  - Standards evolve
  - Retrofit of old systems expensive
  - New systems continue to evolve
- Would like the following capabilities while seamlessly integrating old and new components into sensor web
  - 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
Service Oriented Architecture as an Approach

1. Register service and methods to access
2. Request service class
3. Service information and access info
4. Open service
5. Perform or provide service

- Single interface standard not required
- Supports multiple hardware and software architectures simultaneously
- Service consumer only has to know how to interface to registry
- Registry contains all pertinent information of how services are provided

Example with Web Services

Front end of service "Generic request"
"I want a package delivered" Service Aggregator

Back end "plug-ins to fulfill service"
Each service executed differently but looks same to user.

- Discovery of services enabled via Internet search tools
- Details of service implementation hidden to simplify user access
- Scalability enabled because new services can be easily plugged in
- Obsolescence prevention because new services can be easily plugged in and removed in real-time
- Fault tolerant because user can locate and connect to alternative service
Basic Concept

- Encapsulate sensors, models and emulators with software agents
  - Hide details
- Provide seamless space/ground messaging capability such as via Internet and sensor-based message bus
- Add registries to enable users to discover components and how to use them automatically

Series of Experiments
Often times the Features Were Correlated or Superimposed on Maps

Burned areas – red
Unburned areas – green
Burn perimeter – blue

MODIS Rapid Response
Active Fire Detections Map

Also Needed to Implement Horizontal Sensor Data Fusion Across Multiple Sensors such as for This Set of Images of Southern California Wildfires

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
EO-1 Volcano Sensor Web Experiment – With Goal-Oriented Operations Implemented as Pre-step to SQA

Univ of Hawaii Volcano Alert Webpage

In Situ Networked Sensors Kilauea, Hawaii

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

The Architecture Used to Transform EO-1 into Goal-Oriented Operations

processed science data

Science Processing

raw science data

White Sands

station in-views

FDSS

tracking data

JPL

targets

USGS

targets

GSFC

targets, engineering requests

WWW

weekly goals

ASPIEN

daily goals

ASIST

goals, telemetry

On-board EO-1

Science Processing

goals commands

Casper

activities

SCL
Moving Models Onboard CHIPS Satellite Under cFE to Demonstrate Mobile Agents

- Mobile agent – autonomous software module that can easily be moved around a network
- Mission operations models running on ground transformed into mobile agents
  - Worked with Solid State Recorder agent (model) first
- Adapter built to make compatible with both GMSEC and Core Flight Executive (cFE)
- Demonstrated capability to transfer software running on ground to S/C with minimal effort
- Demonstrates beginning step to transform missions from central control to distributed control via self-managing software

One of Three Experiments Conducted by UMBC Undergraduate Class 12-14-05

EO-1 Advanced Land Imager (ALI) Image of UMBC Campus
Experiment with UMBC Undergraduates
Class 12-14-05

Picture of Experiment Day
Sensor network class, Dr. Younis, Vuong Ly and Dan Mandl
Sensor mote layout & atrium where experiment conducted (inset)

Mini-rover in action
Baltimore Sun reporter
Mini-rover autonomously finding broken sensor node (part of Emergency Response UMBC project team)

Reference Architecture for an Inter-Operable Sensor Web

Requested data from sensor data nodes or data processing nodes via internet

Web Map Service
"Thin" Web Client
Workflow Editor
Geospatial Processing Models
Optimizer Scheduler
Installation Service
Check Workflow Feasibility

Catalog Service for Web (CSW)
(Product Features and Service Capabilities)

SensorML
SensorML Capabilities
Documents

Data Processing Node
Web Coordinate Transformation Service (WCTS)
Web Processing Service (WPS)
Web Coverage Service (WCS)

Installation Service
Decision Support System & Tools

Concrete Workflow Engine

Execute
UAV Sensor Data Node
Satellite Data Node
GMSEC
IRC
Analysis/Simulation

Register
Discovery
Register
Next Wildfire Sensor Web Scenario
Utilizing MODIS, DMSP, EO-1, and Ikhana UAS

NIFC ICS-209
National Priority Wildfires

Increasing Knowledge

MODIS Detection & Targeting

DMSP Cloud Prediction

EO-1 Acquisition & Detection

Ikhana UAS Tasking & Acquisition

RAWS
Local WX

END USERS
Infrared Interpreter
Fire Behavior Analyst
Plans Chief

5 missions over 6 weeks
mid-July - end of August 2007

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

WRAP Wildfire Research and Applications Partnership

12-Channel Wildfire Scanner Specifications
Channel 1: 0.42 - 0.45 um
Channel 2: 0.48 - 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: 3.80 - 3.79 um (VIIRS M12)
Channel 12: 10.28 - 11.25 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 dependent)

• 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.
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
- With the OGC or similar standards, old and new assets can interoperable cost-effectively
Glossary

DSS – Decision Support System
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
Architecture That Drives SPS Includes Onboard Intelligent Software

- Observation Planner
- CASPER Planner: response in 10s of minutes
- Plans of Activities (high level)
- L2 - Model-based Mode Identification & Reconfiguration
- S/C State Information
- SCL - response in seconds with rules, scripts
- EO 1 Conventional Flight Software: reflexive response
- Sensor Telemetry
- Spacecraft Hardware
- Raw Instrument Data
- Observation Goals
- Band Extraction
- Image
- Onboard Science
- Commands (low level)
- Control Signals (very low level)

Integrated Goal-Oriented Planning Flow for EO-1

- Science Alerts
- Scientists
- Science Campaigns
- Science Event Manager: Processes alerts and Prioritizes response observations
- Observation Requests
- EO-1 Flight Dynamics: Tracks, orbit, overflights, momentum management
- ASPEN: Schedules observations on EO-1
- Updates to onboard plan
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

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

The 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.

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-17 2006, Pasadena, CA
Key Capabilities Implemented to Enable EO-1 Sensor Webs & Support "Backend" of SPS

- On-board science processing, classification and autonomous decision making
- Science data products generated on-board and validated by autonomous science algorithms
- Clouds
- Thermal
- Snow/Ice
- Floods
- Ice breakup
- El-Nino

- New targets integrated into schedule
- Triggered observations and new targets from the ground sorted and integrated into schedule
- Tape transfer of data converted to high speed electronic transfer and automated product generation
- Raw Data Dump

- Automated load generation
- Automated real-time upload
- Automated maneuver and image generation for individual targets
- Broadcast algorithm results

- Monitors ground sensors
- Monitors MODIS direct broadcasts
- Screens GDIS / DMSP data for least cloudy alternate targets
- System Management
- Spacecraft Health and Safety

User interface auto-sorts and prioritizes testing requests and uploads goal files for upload

Various EO-1 Sensor Web Experiments Conducted

- EO-1 responds to triggers and has onboard triggers for snow, water, gas, land, thermal and clouds
- MODIS (Sara and Doug) used to detect hot spots for fires, volcanoes
- Also used for flood detection
- MODPAC (lists of Hawaii) - MODIS
- Darnuths Flood Observatory
- DOD/DMSP used for cloud screening near real-time

Ground:
- MOPS: Mission Operations Planning and Scheduling System (GSC)
- SIRM: Science Risk Monitor (GSC)
- ASPEN: Planning & scheduling (JPL)
- EPIC: Earth Phenomena Observing System - Cloud screening (JPL)

On-board:
- ASE: Autonomous Senorcraft Experiment (JPL)
- Livelong (Renee) - On-board diagnostic tool

Communication infrastructure:
- Cellular based architecture for spacecraft using phased array antennas (RSFC/JRC, Ga Tech, Univ. of Colorado)

Triggers

Onboard & Ground Tools

Uses

Fires rehabilitation

Volcano eruption detection & assessment

Flood assessment

Ice breakup change detection

Cloud screening