

Integrating Orbital and Airborne Assets: SensorWeb Demonstrations During Western States Fire Mission 2007

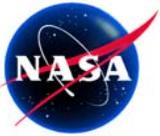
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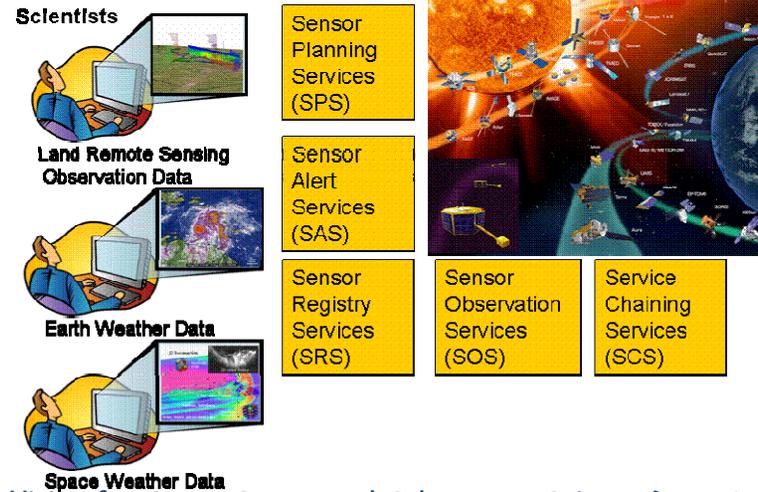


An Interoperable Sensor Architecture to Facilitate Sensor Webs in Pursuit of GEOSS

PI: Dan Mandl, GSFC

Objective

- Assist future Earth science needs for integrating multiple observations without requiring the end-user to have intimate knowledge of the sensors being used.
- Demonstrate and validate a path for rapid, low cost sensor integration, which is not tied to a particular system.
- Facilitate the United States contribution to the Global Earth Observation System of Systems by defining a common sensor interface protocol based upon emerging community standards.



Vision for Space Sensor and Subsequent Science Data Access Via Generic Web Services to Form Sensor Web

Approach

- Experiment with interoperability standards
- Demonstrate and specify the discovery process for available sensor resources
- Demonstrate and specify the ability to direct other sensors
- Demonstrate and specify the ability to specify how the available data should be delivered and combined

Co-I's/Partners

- Robert Sohlberg, Dr. C. Justice, Dr. J. Townshend / UMD
- Dr. Jeffrey Masek, Stuart Frye / NASA-GSFC
- Dr. Stephen Ungar, Troy Ames / NASA-GSFC
- Dr. Steve Chien, Daniel Tran / NASA-JPL
- Pat Cappelaere / Vighel
- Don Sullivan, Vince Ambrosia / NASA-ARC

Key Milestones

- Development of relevant science & operations concepts and scenarios (Done) June 2007
- 1st demonstration EO-1 "discoverable"/taskable via Internet and the use of SensorML & EO-1 Autonomy SW Sept 2007
- Augment demonstration 1 with GMSEC framework in testbed for 2nd demonstration June 2008
- Integration of SensorML, IRC, GMSEC, cFE and CHIPS or testbed into 3rd demonstration Mar 2009
- Full capabilities demonstration, 4th demo Sept 2009
- Ident. of Earth Science mission infusion targets Ongoing

TRL_{in} = 3
TRL_{9/30/07} = 4



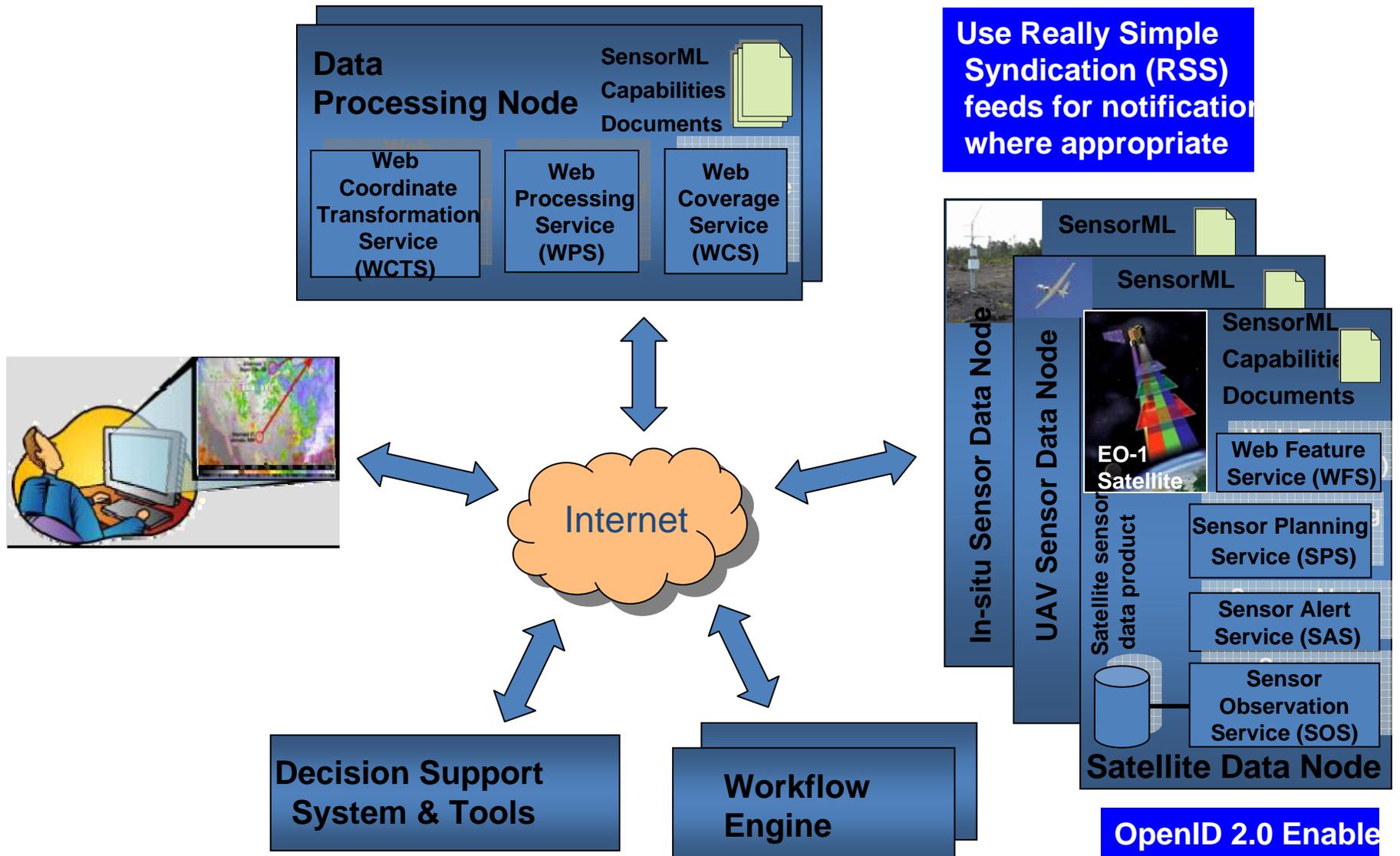
Overview

- Sensors are everywhere
- Disasters and natural phenomena can happen anywhere
- Develop process to interconnect world's sensors using the Internet, it's common tools such as browsers and the emerging Web 2.0 capabilities
- Facilitate cost reductions to produce customized science data products by an order of magnitude

Approach

- Identify investigation / potential targets
- Discover available sensor assets and algorithms over Internet
- Select or customize needed workflows and delivery methods
- Execute workflow automatically
- Making customized products via web “mash-ups”
- Deliver data to user desktop

Reference Architecture: Encapsulate Sensors and Data Processing with Web Services and OGC Standards



OGC Interface Terms

- SPS: Sensor Planning Service
- SOS: Sensor Observation Service
- WfCS: Workflow Chaining Service
- WPS: Web Processing Service
- WMS: Web Map Service
- WCS: Web Coverage Service
- WCS-T: Web Coverage Service - Transformation
- CSW: Catalog Services for the Web

Accomplishment Thus Far (1 of 2)

Sensor Web Services Established

JPL SPS

EO-1 Hyperion

EO-1 ALI

JPL SOS

EO-1 Hyperion L0

EO-1 Hyperion

EO-1 Hyperion

EO-1 Hyperion

EO-1 ALI L0

EO-1 ALI L1R

EO-1 ALI L1G

Geobliki WfCS

WfXML workflow engine

JPL WPS

Thermal classifier

Burn Index

Composite Browse

Fluvial classifier

Cloud classifier

Sulfur classifier

SWIL classifier

Fire fuel load classifier
(various, future)

Geobliki WPS

Vegetation Index (future)

Burn scar

Water classifier (future)

Rhodamine dye (future)

Snow & Ice (future)

Geobliki SPS

EO-1 Hyperion

EO-1 ALI

Geobliki SOS

EO-1 Hyperion L0

EO-1 Hyperion

EO-1 Hyperion L1R

EO-1 Hyperion

EO-1 ALI L0

EO-1 ALI L1R

EO-1 ALI L1G

Geobliki WMS

Fire maps

KML transform for
Google Earth

Accomplishment Thus Far (2 of 2)

Sensor Web Services Established

Draper WPS

AFWA Cloud Cover

AMES WCS

Ikhana UAS hot pixels

AMES SPS

Ikhana UAS Wildfire Instrument

AMES WMS

Ikhana UAS Wildfire Images & Fire location maps

KML transform for Google Earth

Northrop Grumman

Smoke Model

GMU WCS

Hot Pixels

GMU WCS-T

Transform Hot Pixels for Map production

GMU WfCS

BPEL engine to execute workflow

SPOT-5 SPS

SPOT-5

WVHTF WfCS

Sensor Workflow Engine

ASTER SPS

ASTER

ASTER SPS

ASTER

MODIS WFS

MODIS Hot Pixels

Earth Science Gateway CSW

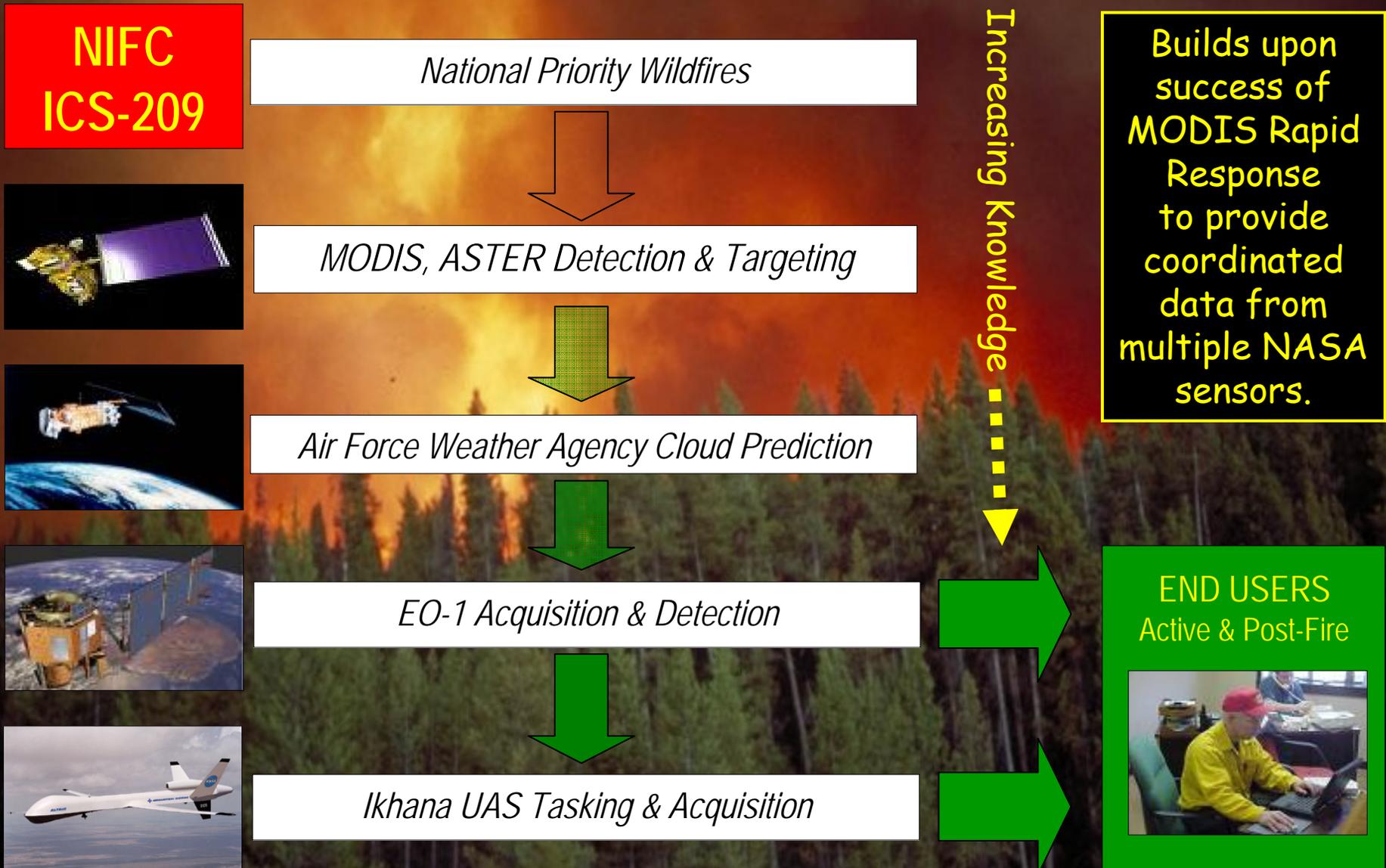
NASA data

Global Change Management Directory CSW

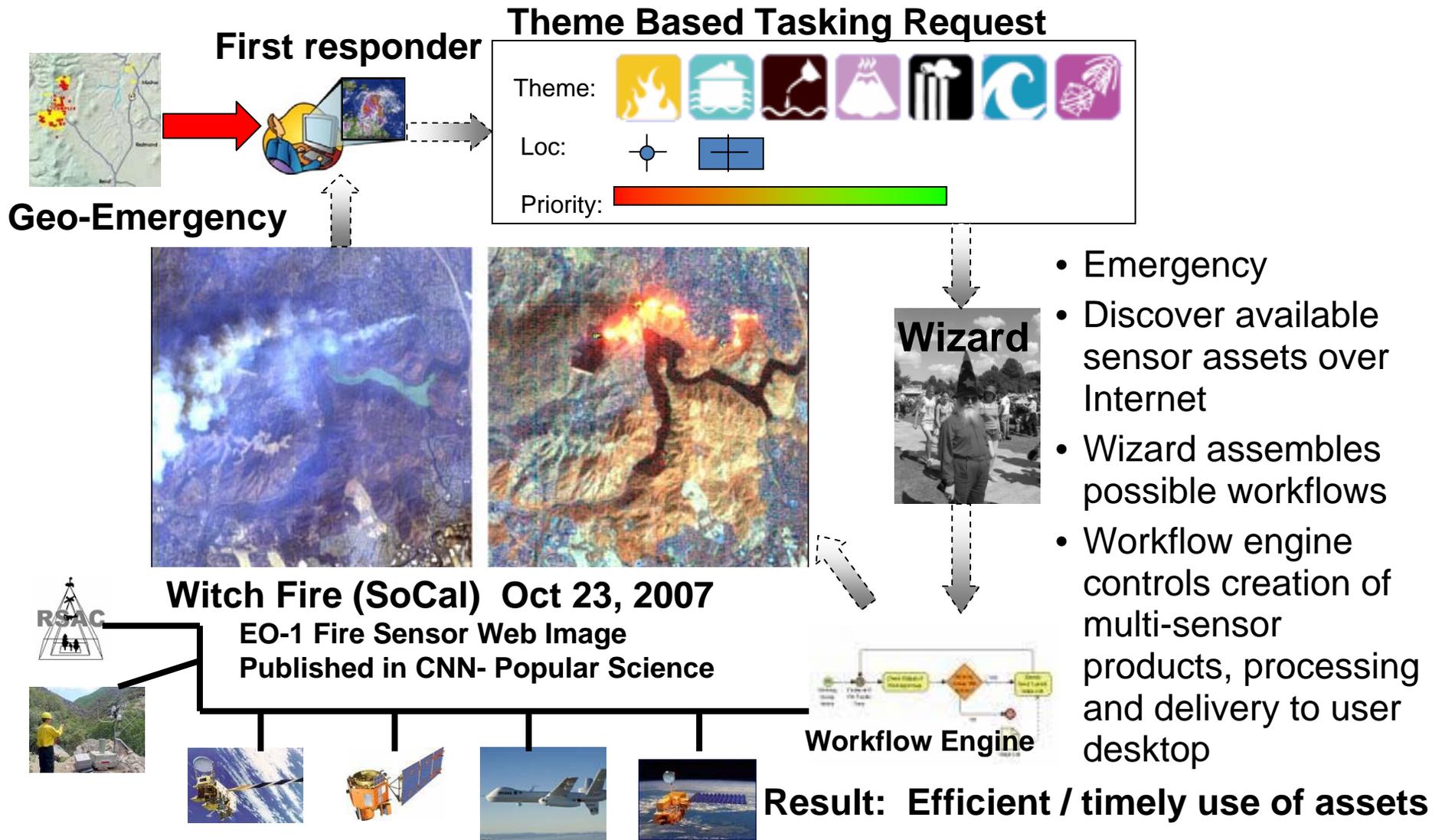
NASA data

Summer 2007 Wildfire SensorWeb Scenario

Utilizing MODIS, ASTER, EO-1 (ALI / Hyperion), and Ikhana UAS



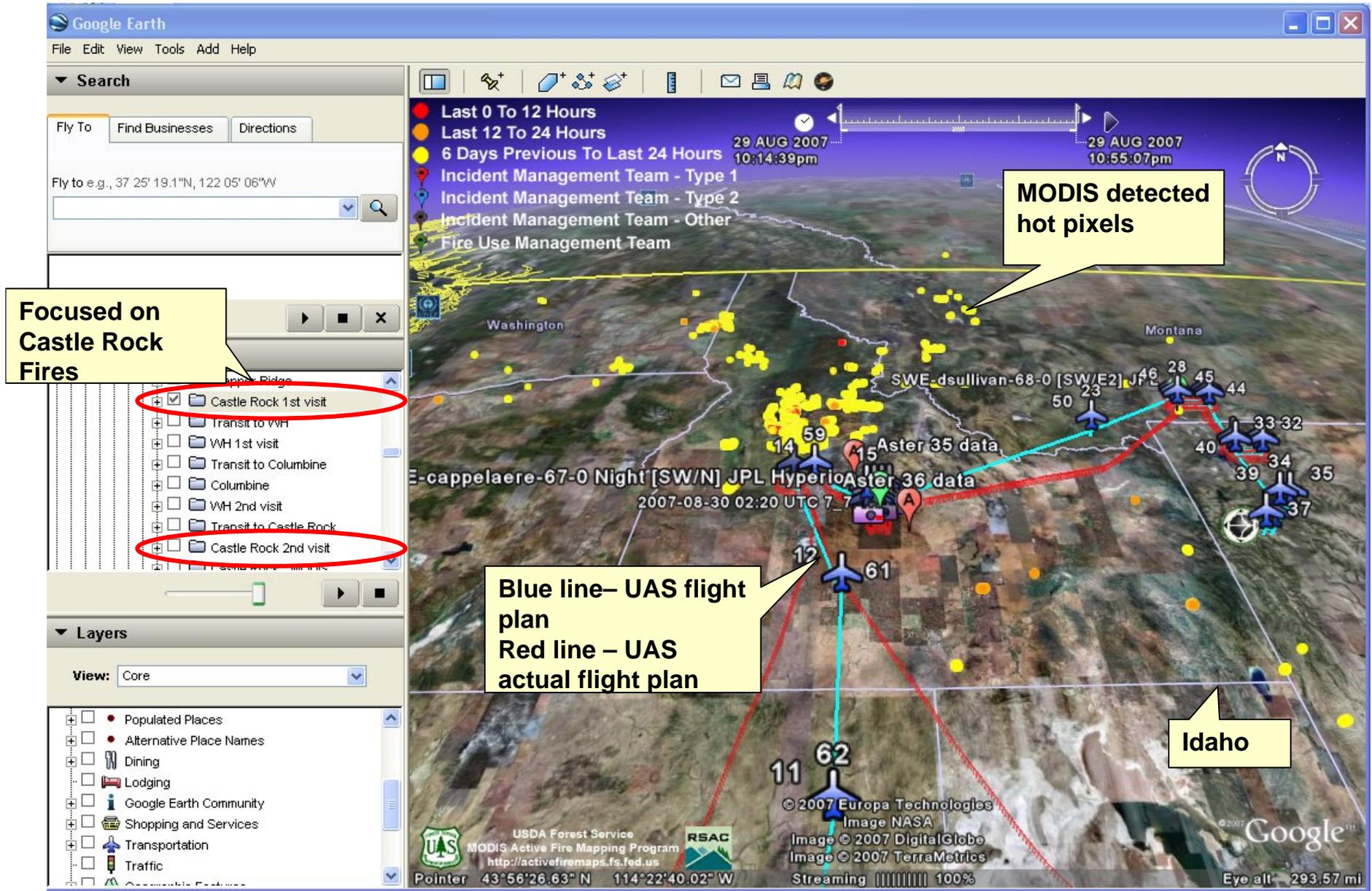
High Level Architecture for Fall 2007 Fire SensorWeb Demo



Date/Time	OGC Services Used	Description of Demo step
1. Monday, August 27, 2007	SPS	Trigger ASTER image for Wed/Thurs of Castle Rock fire in Idaho if ASTER can see targets in that timeframe
2. Wed, August 29, 2007 morning(Pacific)		Steve Wegener posts final UAS flight plan to Ames Collaborative Decision Environment (CDE) web page
3. Wed, August 29, 2007 morning (Pacific)		EO-1 Geobliski (Cappelaere) and Draper (Kolitz) retrieve flight plan from CDE
4. Wed, August 29, 2007 morning (Pacific)	WFS	Geobliski computes targets from MODIS fire hot pixel map via the WFS interface and send targets to Draper (Kolitz)
5. Wed, August 29, 2007 afternoon (Pacific)		Draper (Kolitz) sends revised UAS flight plan to Ames (S. Wegener) - note: Draper sends update cloud predicts to Ames every 6 hours
6. Wed, August 29, 2007 afternoon (Pacific)		Draper send E-Mail to Geobliski with selected EO-1 target (screening for least cloudy) and occurring Wed night or Thurs morning
7. Wed, August 29, 2007 afternoon(Pacific)		EO-1 Geobliski SPS tasks EO-1 and bumps previously planned image for new image requested
8. Wed, August 29, 2007 2:00 pm (Pacific)		UAS takes off
9. Wed, August 29, 2007 evening (Pacific)	SPS	UAS detects first fire on way to Idaho and then automatically posts (D.Sullivan) new target request for EO-1 via Geobliski SPS
10. Thursday, August 30, 2007		EO-1 images target before UAS lands if selected targets are viewable in that time period
11. Aug 29 Sept 2	SOS, WPS, WCS-T, WMS, WFS	Post UAS and EO-1 Images

Fire Sensor Web Demo Aug 27-30 2007

Ikahana UAS, EO-1 (Hyperion & ALI), Terra/Aqua (MODIS & ASTER)



Fire Sensor Web Demo Aug 27-30 2007

Zoom in - 1

The screenshot displays the Google Earth interface with a focus on fire sensor data. The left sidebar contains the Search, Places, and Layers panels. The main map area shows a satellite view of a region in Idaho, with a large black rectangular area representing the field of view of a satellite. This area is overlaid with a grid of red lines and contains several satellite icons with associated timestamps and labels. A yellow callout box points to the top-left corner of this area, indicating the field of view of the EO-1 ALI sensor. The map also shows numerous yellow circular markers representing fire sensors, with a legend on the left identifying their time ranges and management team types. The bottom status bar provides coordinates, elevation, and other technical details.

Search

Fly To: Find Businesses Directions

Fly to e.g., 37 25' 19.1"N, 122 05' 06"W

Places

- Trapper Ridge
- Castle Rock 1st visit
- Transit to WH
- WH 1st visit
- Transit to Columbine
- Columbine
- WH 2nd visit
- Transit to Castle Rock
- Castle Rock 2nd visit
- Castle Rock MODIS

Layers

View: Core

- Populated Places
- Alternative Place Names
- Dining
- Lodging
- Google Earth Community
- Shopping and Services
- Transportation
- Traffic

Legend

- Last 0 To 12 Hours
- Last 12 To 24 Hours
- 6 Days Previous To Last 24 Hours
- Incident Management Team - Type 1
- Incident Management Team - Type 2
- Incident Management Team - Other
- Fire Use Management Team

Map Labels

- Idaho
- Aster 35 data
- 2007-08-30 02:55 UTC 17_17
- SWE-cappelaere-67-0 Night [SW/N] JPL Hyperion
- 2007-08-30 02:43 UTC 14_14
- Aster 36 data
- 2007-08-30 02:20 UTC 7_7
- © 2007 Eūropa Technologies
- USDA Forest Service
- MODIS Active Fire Mapping Program
- http://activefiremaps.fs.fed.us
- RSAC
- Image © 2007 TerraMetrics
- Pointer 43°54'34.53" N 114°22'42.30" W elev 7911 ft Streaming 100%
- Eye alt 55.63 mi

Callout Box: EO-1 ALI field of view on 1st image requested. Hyperion contained within ALI field of view

Fire Sensor Web Demo Aug 27-30 2007

Zoom in - 2

Google Earth interface showing a fire sensor web demo. The map displays a network of red lines representing sensor paths and blue airplane icons with numbers (15, 18, 19, 54, 51, 22, 16, 57, 56, 17, 20, 53, 21, 52). A yellow callout box points to a specific sensor image on the map with the text "One of the UAS instrument images superimposed on landscape".

Search bar: Fly To Find Businesses Directions

Places list:

- GeoBliki Article
- SWE-cappelaere-67-0 Night [SWNI]
- SWE-cappelaere-67-0 Night [SWNI]
- JPL All
- GeoBliki Article SWE-cappelaere-67-0 Night [SWNI] JPL
- Aug3007_0119_17_17
- 2007-08-30 02:55 UTC 17_17
- Aug3007_0119_9_9
- 2007-08-30 02:27 UTC 9_9

Layers:

- Populated Places
- Alternative Place Names
- Dining
- Lodging
- Google Earth Community
- Shopping and Services
- Transportation
- Traffic

Status bar: Pointer 43°39'49.83" N 114°27'38.08" W elev 6735 ft Streaming 100% Eye alt 13.37 mi

Fire Sensor Web Demo Aug 27-30 2007

Zoom in – 3 – Hyperion WPS & WCS-T hot pixel classification

The screenshot displays the Google Earth interface with several key components:

- Search Panel:** Includes a search bar and options for "Fly To", "Find Businesses", and "Directions".
- Places Panel:** Lists various data layers, with "Hot Pixel coverage" circled in red. Other items include "JPL WPS thermalapprox1g output created from EO-1 Hyperion Bands: 110, 150, 210, 213" and "SWE-cappelaere-67-0 Night [SW/N] JPL Hyperion".
- Layers Panel:** Shows a "View: Core" dropdown and a list of map layers such as "Global Awareness", "roads", "3D Buildings", "borders", "Populated Places", "Alternative Place Names", "Dining", and "Lodging".
- Map Area:** Displays a satellite view of a forested region with red and cyan grid lines. A legend in the top right corner lists time-based and team-based filters: "Last 0 To 12 Hours", "Last 12 To 24 Hours", "6 Days Previous To Last 24 Hours", "Incident Management Team - Type 1", "Incident Management Team - Type 2", "Incident Management Team - Other", and "Fire Use Management Team". A blue airplane icon is positioned over the map with the numbers "20" and "53" nearby. A yellow callout box points to a specific hot pixel detection.
- Bottom Panel:** Contains logos for the USDA Forest Service, MODIS Active Fire Mapping Program, REAC, and NASA. It also displays coordinates (Pointer 43°38'41.65° N 114°27'40.48° W), elevation (6487 ft), and other technical details.

EO-1 hot pixel detection from WPS & WCS-T Hyperion hot pixel classification output

Fire Sensor Web Demo Aug 27-30 2007

Zoom in – 4 – Easy retrieval of actual Hyperion and ALI images

The screenshot displays the Google Earth web interface. On the left, the 'Search' and 'Places' panels are visible. The 'Places' panel shows a tree view with the following items:

- [-] SWE-cappelaere-67-0
 - [+] Hot Pixel coverage
 - JPL WPS thermalapprox1g output created from EO-1 Hyperion Bands: 110, 150, 210, 213
 - [+] SWE-cappelaere-67-0 Night [SW/N] JPL Hyperion
 - [GeoBliki Article SWE-cappelaere-67-0 Night \[SW/N\]](#)
 - .JPL
 - [+] SWE-cappelaere-67-0 Night [SW/N] JPL Ali
 - [GeoBliki Article SWE-cappelaere-67-0 Night \[SW/N\] J](#)

The 'Layers' panel shows various map layers, with 'View: Core' selected. The main map area displays a satellite view with a grid of red and cyan lines. A legend in the top right corner lists categories: Last 0 To 12 Hours, Last 12 To 24 Hours, 6 Days Previous To Last 24 Hours, Incident Management Team - Type 1, Incident Management Team - Type 2, Incident Management Team - Other, and Fire Use Management Team. A popup window titled 'SWE-cappelaere-67-0 Night [SW/N] JPL Hyperion' is open, containing the following text:

[GeoBliki Article SWE-cappelaere-67-0 Night \[SW/N\] JPL](#)

A new EO1 hyperion image has been generated for SWE-cappelaere-67-0 Night [SW/N] JPL on Fri Aug 31 04:53:39 UTC 2007 Links at [ASE](#) or [EO1 Home Site](#)
Latitude: 43.6546
Longitude: -114.458

Directions: [To here](#) - [From here](#)

A yellow callout box points to the popup window with the text: 'Tabs with latitude/longitude of center of EO-1 images along with hyperlinks to retrieve full image'. The bottom status bar shows coordinates: 43°38'41.65" N 114°27'40.48" W, elevation 6487 ft, and a 100% zoom level.

Fire Sensor Web Demo Aug 27-30 2007

Zoom in – 5 – Overlays of UAS & EO-1 fire perimeter classification

Search

Fly To: Find Businesses Directions

Fly to e.g., Tokyo, Japan

Places

- Sensor Derived Fire Perimeters
 - Current Mission
 - Previous Missions
 - 08-29-2007 - 2nd mission
 - Castle Rock 1st visit
 - 2007-08-30 02:17 UTC 6_6
 - 2007-08-30 02:26 UTC 8_8
 - 2007-08-30 02:27 UTC 9_9
 - 2007-08-30 02:29 UTC 10_10
 - 2007-08-30 02:30 UTC 11_11
 - 2007-08-30 02:31 UTC 12_12

Layers

View: Core

- Featured Content
- Global Awareness
- roads
- 3D Buildings
- borders
- Populated Places
- Alternative Place Names
- Dining
- Lodging

Legend

- Last 0 To 12 Hours
- Last 12 To 24 Hours
- 6 Days Previous To Last 24 Hours
- Incident Management Team - Type 1
- Incident Management Team - Type 2
- Incident Management Team - Other
- Fire Use Management Team

Map Labels

- 56 17
- 20
- SWE-cappelaere-67-0 Night [SV]
- 2007-08-30 09:10 UTC 23_24
- 7-08-30 08:10 UTC 8_9
- 2007-08-30 02:40 UTC 13_13
- 2007-08-30 07:56 UTC 5_6

Callout Box

Fire perimeters as derived from:
Yellow: UAS 1st visit
Purple: UAS 2nd visit
Orange: EO-1 Hyperion

USDA Forest Service
MODIS Active Fire Mapping Program
<http://activefiremaps.fs.fed.us>

© 2007 Europa Technologies

Pointer 43°37'09.99" N 114°29'55.88" W elev 7005 ft Streaming 100% Eye alt 40820 ft

Fire Sensor Web Demo Aug 27-30 2007

Zoom out – 6 – Find contemporaneous ASTER data

The screenshot displays the Google Earth interface with several key elements:

- Search Panel:** Includes a search bar and filters for "Fly To" (Find Businesses, Directions) and "Fly to e.g., Tokyo, Japan".
- Places Panel:** A red circle highlights the "Aster" folder, which contains "Aster 36 data" and "Aster 35 data".
- Layers Panel:** Shows various map layers like "Global Awareness", "roads", "3D Buildings", "borders", "Populated Places", "Alternative Place Names", "Dining", and "Lodging".
- Main Map:** Displays a satellite view of a forested area with numerous red and blue markers. A yellow callout box points to the map with the text: "Zoom out and go to link with ASTER contemporaneous image collect".
- Info Window:** A white window titled "Aster 36 data" is open, showing a link to "ASTER Expedited LEVEL 1 Data" and three small satellite images. It also includes "Directions: To here - From here".
- Map Labels:** Various labels are visible on the map, including "Aster 35 data", "Aster 36 data", and "SWE-cappelaere-67-0 Night [SW/N] JPL Hyperion".
- Status Bar:** At the bottom, it shows coordinates (43°45'56.37" N, 114°08'40.30" W), elevation (8153 ft), and a scale of 54.08 miles.

Fire Sensor Web Demo Aug 27-30 2007

Move to Yellowstone National Park – 7 – Find fire and trigger EO-1

Google Earth

File Edit View Tools Add Help

Search

Fly To Find Businesses Directions

Fly to e.g., Tokyo, Japan

Places

- WH 1st visit
- 2007-08-30 04:03 UTC 25_25
- 2007-08-30 04:05 UTC 26_26
- 2007-08-30 04:07 UTC 27_27
- 2007-08-30 04:20 UTC 32_32
- 2007-08-30 04:22 UTC 33_33
- 2007-08-30 04:28 UTC 34_34
- 2007-08-30 04:29 UTC 35_35
- Transit to Columbine

Layers

View: Core

- Global Awareness
- roads
- 3D Buildings
- borders
- Populated Places
- Alternative Place Names
- Dining
- Lodging

Legend:

- Last 0 To 12 Hours
- Last 12 To 24 Hours
- 6 Days Previous To Last 24 Hours
- Incident Management Team - Type 1
- Incident Management Team - Type 2
- Incident Management Team - Other
- Fire Use Management Team

Yellowstone National Park

Image © 2007 DigitalGlobe
© 2007 Europa Technologies

USDA Forest Service
MODIS Active Fire Mapping Program
<http://activefiremaps.fs.fed.us>

RSAC

NASA

Google

Pointer 45°11'43.42" N 110°34'20.40" W elev 8523 ft Streaming 100% Eye alt 39.11 mi

Fire Sensor Web Demo Aug 27-30 2007

Zoom in – 8 – Find fire and trigger EO-1

Search

Fly To: Find Businesses Directions

Fly to e.g., Tokyo, Japan

Places

- Sensor Derived Fire Perimeters
- Current Mission
- Previous Missions
 - 08-29-2007 - 2nd mission
 - Castle Rock 1st visit
 - Transit to WH
 - WH 1st visit
 - 2007-08-30 04:03 UTC 25_25
 - 2007-08-30 04:05 UTC 26_26
 - 2007-08-30 04:07 UTC 27_27
 - 2007-08-30 04:20 UTC 32_32
 - 2007-08-30 04:22 UTC 33_33
 - 2007-08-30 04:28 UTC 34_34
 - 2007-08-30 04:29 UTC 35_35
 - Transit to Columbine
 - Columbine

Layers

View: Core

- Featured Content
- Global Awareness
- roads
- 3D Buildings

Map Legend

- Last 0 To 12 Hours
- Last 12 To 24 Hours
- 6 Days Previous To Last 24 Hours
- Incident Management Team - Type 1
- Incident Management Team - Type 2
- Incident Management Team - Other
- Fire Use Management Team

Map Labels

24 49

46 27

45 28

2007-08-30 04:22 UTC 33_33

SWE-dsullivan-68-0 [SW/E2] JPL

SWE-dsullivan-68-0 [SW/E2] JPL

Callout Box:

UAS finds fire and automatically triggers EO-1 image which occurs a day later. No hot pixels on EO-1 classification therefore fire gone.

Image © 2007
© 2007 Europa Technologies

USDA Forest Service
MODIS Active Fire Mapping Program
<http://activefiremaps.fs.fed.us>

RSAC

NASA

Google

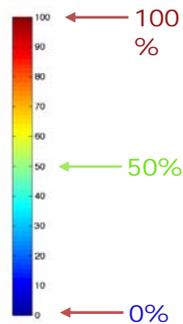
Pointer 45°12'33.21" N 110°34'20.38" W elev 6972 ft Streaming 100% Eye all 19.97 mi

Sample cloud coverage prediction used to select least cloudy targets for EO-1 & UAS

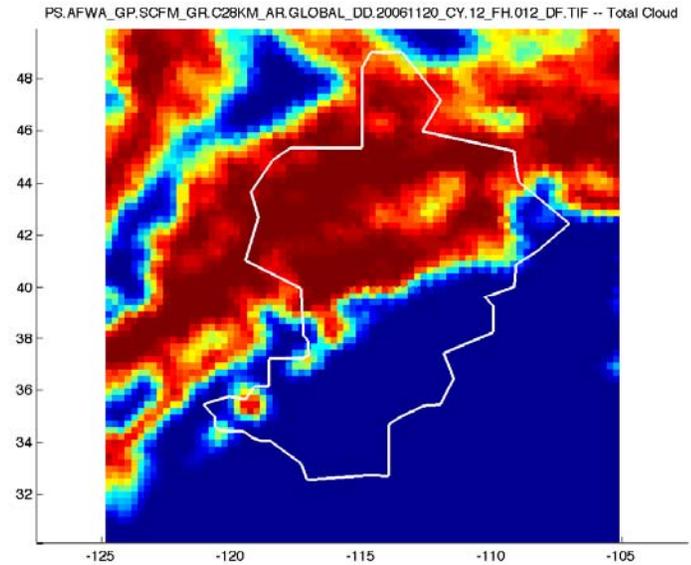


Flight Corridors with Predicted Total Cloud Cover Provided to UAS to Optimize Flight Path

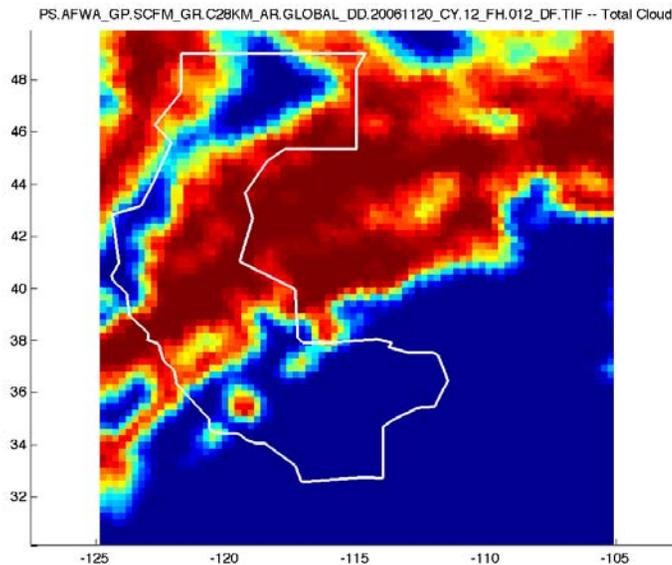
An Example using AFWA Stochastic Cloud Forecast Model Data converted to GeoTIFF



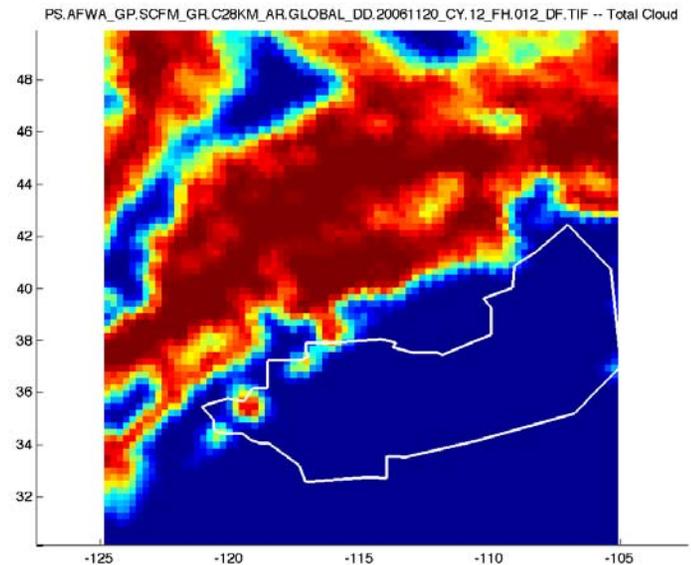
Corridor B



Corridor A



Corridor C

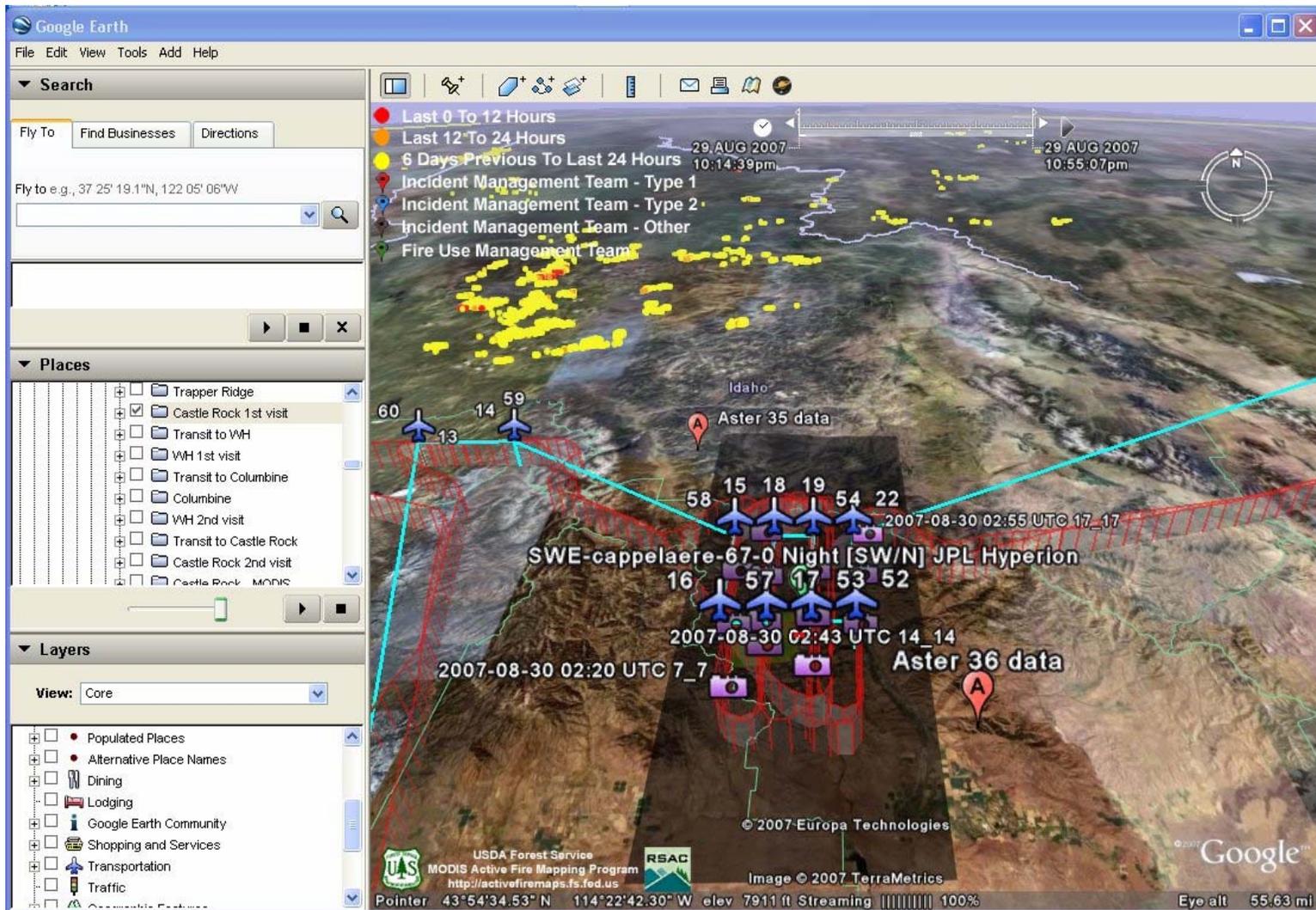


Wildfire SensorWeb: The Movie

3 minute version

Fire SensorWeb Experiments During 2007

- Funded by NASA Earth Science Technology Office AIST grant.
- Coordinated observations using ALI, Hyperion, MODIS, ASTER and Ikhana UAS.
 - Delivery via an OGC compliant web interface.
 - Deployed during South California Fire Siege.
 - Planned deployments for 2008.



Future Plans in Fire Science and Applications

NASA LARGE FIRE CAMPAIGN 2009

Science Goals:

- Characterize the integrated release of energy from large fires.
- Quantify the effect of flaming vs. smoldering combustion on fluxes.
- Use ground based measurements to calibrate remote sensing data.
- Support validation of satellite fire products.
- Determine when fire becomes unstable and exhibits extreme fire behavior.

Provide robust data set to community for subsequent analysis