Goddard Space Flight Center

National Aeronautics and Space Administration

SensorWeb as an Enabling Step for Holistic Remote Sensing

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IS&T Colloquium
May 22, 2013

NASA • GSFC• JPL/Caltech • Ames

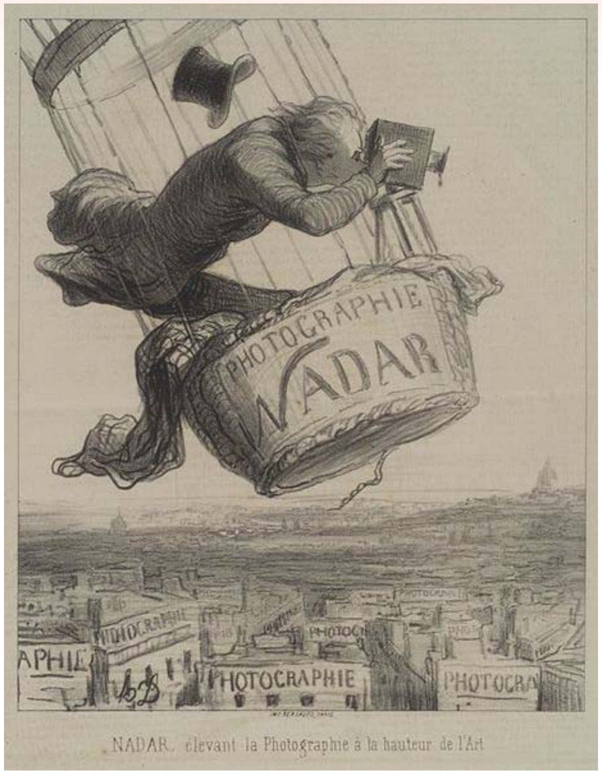
www.nasa.gov

"Integrating Sensors to Manage Earth Resources"

Remote Sensing Has Consequences

- Gallileo Galilei used the telescope to discover the four Jovian moons and the phases of Venus.
- Championed heliocentric view of solar system
- In 1615 put under permanent house arrest for his views

Early remote sensing



Published in *Le Boulevard*, 25 May 1862.

. **Gaspard-Félix Tournachon** (6 April 1820 – 23 March 1910) known as **Nadar**, became the first person to take aerial photographs in 1858 at 1200 feet in a balloon over Paris.

First SensorWeb – 1903 Bavarian Pigeon Corp

- Cameras were set to take pictures every 30 seconds while pigeons flew.

Why Are SensorWebs Important?

- Provides flexibility to user to customize data products rapidly
- Automatically cross triggers sensors using predictive models or automatically detected events
- Provides societal benefits for disaster management via early warning, rapid situational awareness and post disaster assessment
- Provides world wide access to sensor data, data visualization and data manipulation over the Internet
- Dramatically lowers cost for data access via the use of open standards
- Can be used to build lower cost remote sensing missions of the future missions

Definition

- A ***SensorWeb*** is a distributed system of sensing nodes (space, air or ground) that are interconnected by a communications fabric and functions as a single, highly coordinated, virtual instrument. It detects and dynamically reacts to events autonomously or semi-autonomously for scientific investigation, disaster management, resource management and environmental intelligence.

Vrydag 11 Maart 2011 Republikein 3

Nuwe skote klap in beldebat

• Dani Booysen

Reënkanse kwyn

• Dani Booysen

NCCI vra ekonomiese groei

• Francoise Steynberg

Donderdag 14 April 2011 Republikein 3

■ 'n Nasa-satellietbeeld van die Zambezirivier se vloedvlaktes in die Caprivi op 3 April.

Rampsyfers vandag onder die loep

• Dani Booysen

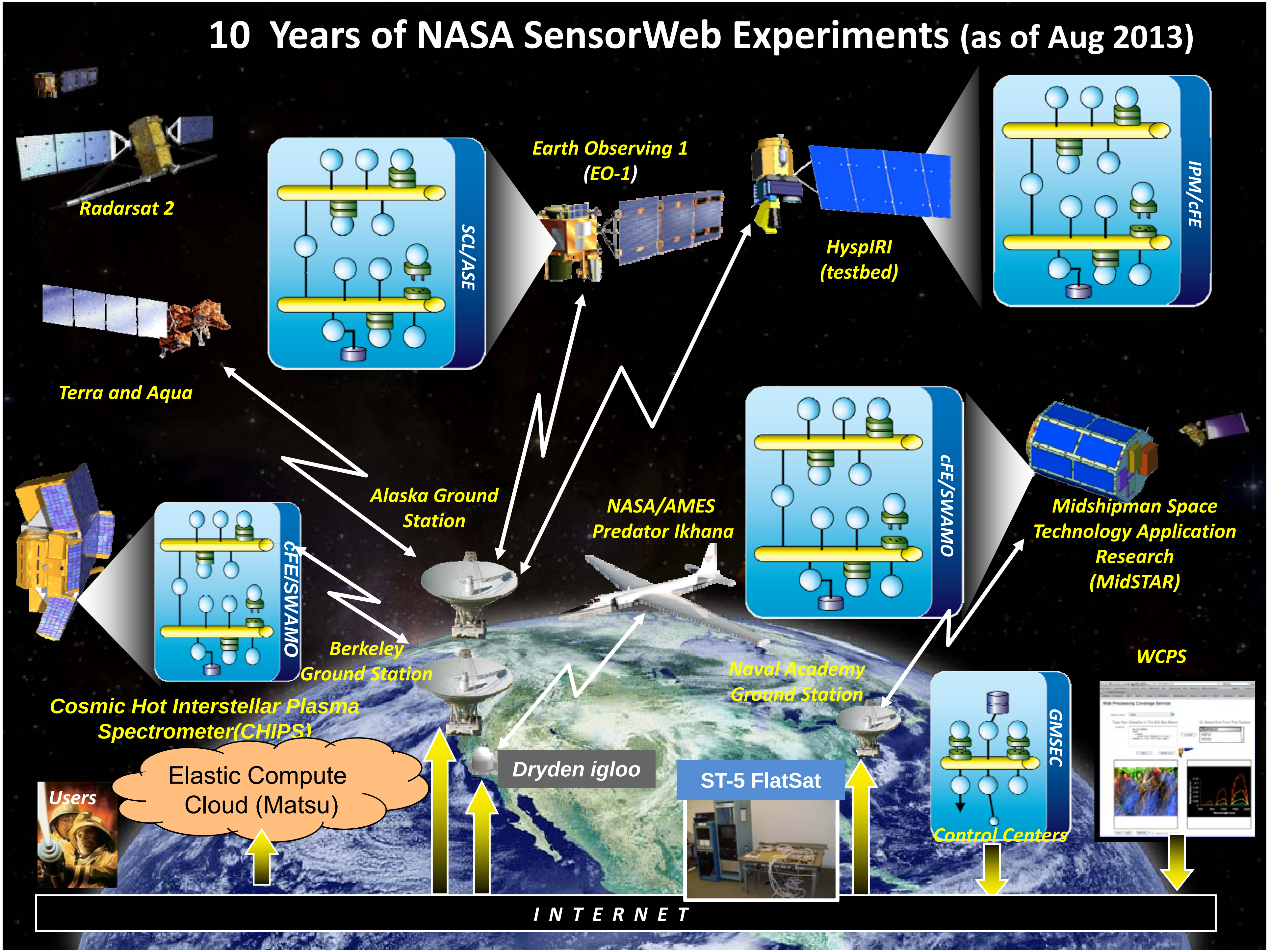
Difference From Constellations

- SensorWebs differ from terminology such as formation flying, virtual missions, ad-hoc constellations etc. in that the focus is primarily on the organization and flow of data via information technology for acquisition of sensor data; the processing of the data into data products and the distribution of the data products.
- SensorWebs can live on top of constellations or across a heterogeneous set of sensors from different constellations to create an ad hoc SensorWeb relationship.

Holistic Sensing (Dan's view from SensorWeb Perspective)

- Holistic ---need to consider observer and observation as a whole to optimize system
- Need to consider the breadth of factors affecting data acquisition and data product production
  - Access/control (open versus closed) and ease of access to sensors
  - Rapid customization
  - Do-it-yourself data product production and data fusion
  - Discovery
  - Complexity and managing complexity
  - Speed (e.g. turn around time)
  - Data volume – handling "Big Data" and data navigation and rapid product production (onboard multicore processors and cloud computing)
  - Composability (abstraction) – Levels of Interoperability
  - Learning and evolving SensorWebs (Model driven SensorWebs)

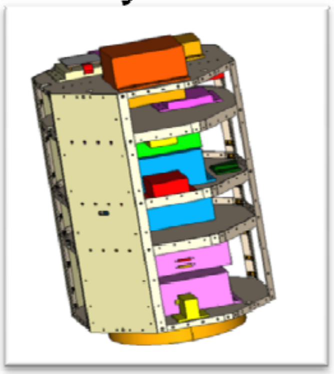
(Note: for this presentation, will go over selected examples in above list)

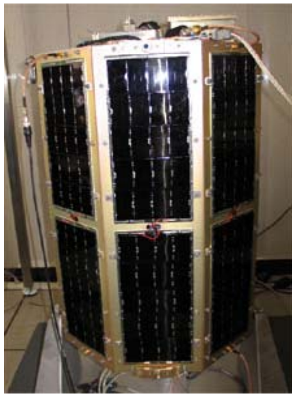


10 Years of NASA SensorWeb Experiments (as of Aug 2013)
Radarsat 2
Earth Observing 1
(EO-1)
SCL/ASE
HyspIRI
(testbed)
IPM/cFE
Terra and Aqua
Alaska Ground
Station
NASA/AMES
Predator Ikhana
cFE/SWAMO
Midshipman Space
Technology Application
Research
(MidSTAR)
CFE/SWAMO
Berkeley
Ground Station
Naval Academy
Ground Station
WCPS
Cosmic Hot Interstellar Plasma
Spectrometer(CHIPS)
GMSEC
Elastic Compute
Cloud (Matsu)
Dryden igloo
ST-5 FlatSat
Users
Control Centers
INTERNET

MidSTAR-1 Satellite

- Midshipman Space Technology Applications Research
  - US Naval Academy Small Satellite Program effort launched in March 2007
  - General-purpose satellite bus with Linux operating system
  - IP-in-space communication system
  - Operators (Keith Hogie (CSC) and Ed Criscuolo(CSC)) maintain satellite from Goddard Space Flight Center
  - Low-cost program launched through the DoD Space Test Program – Zero budget at this point (running as a ‘pet project’ by Keith and Ed)
  - MidSTAR is a single spacecraft under the command and control of a single satellite ground station at the US Naval Academy
  - US Naval Academy retains responsibility for S/C





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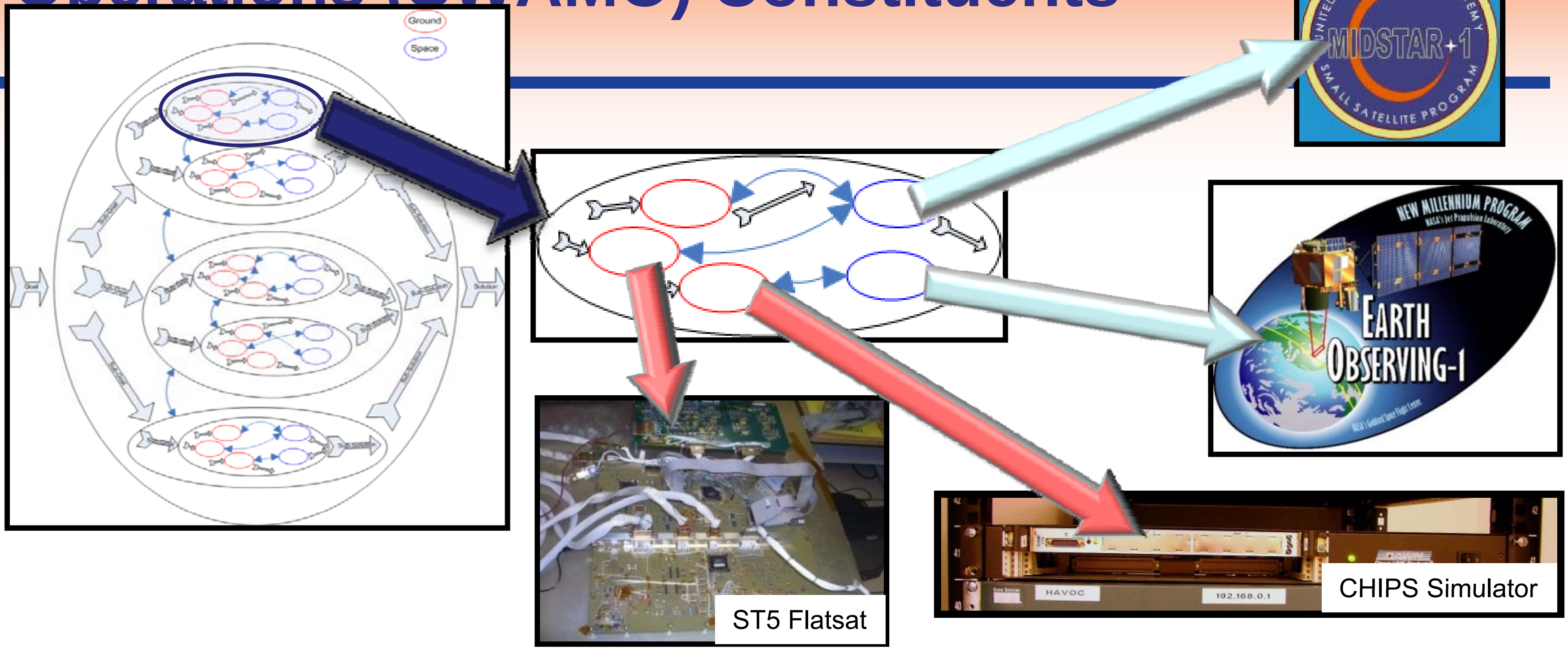
SensorWeb for Autonomous Mission Operations (SWAMO) Constituents



SWAMO is a Sensor Web enabling technology. It provides an intelligent infrastructure to support the dynamic planning for utilization of nodes within a Sensor Web.

Intelligent agents within the system encapsulate the models and interact with the planning system. Agents predict the effect of changes to the plan, and provide confidence as to feasibility and impact.

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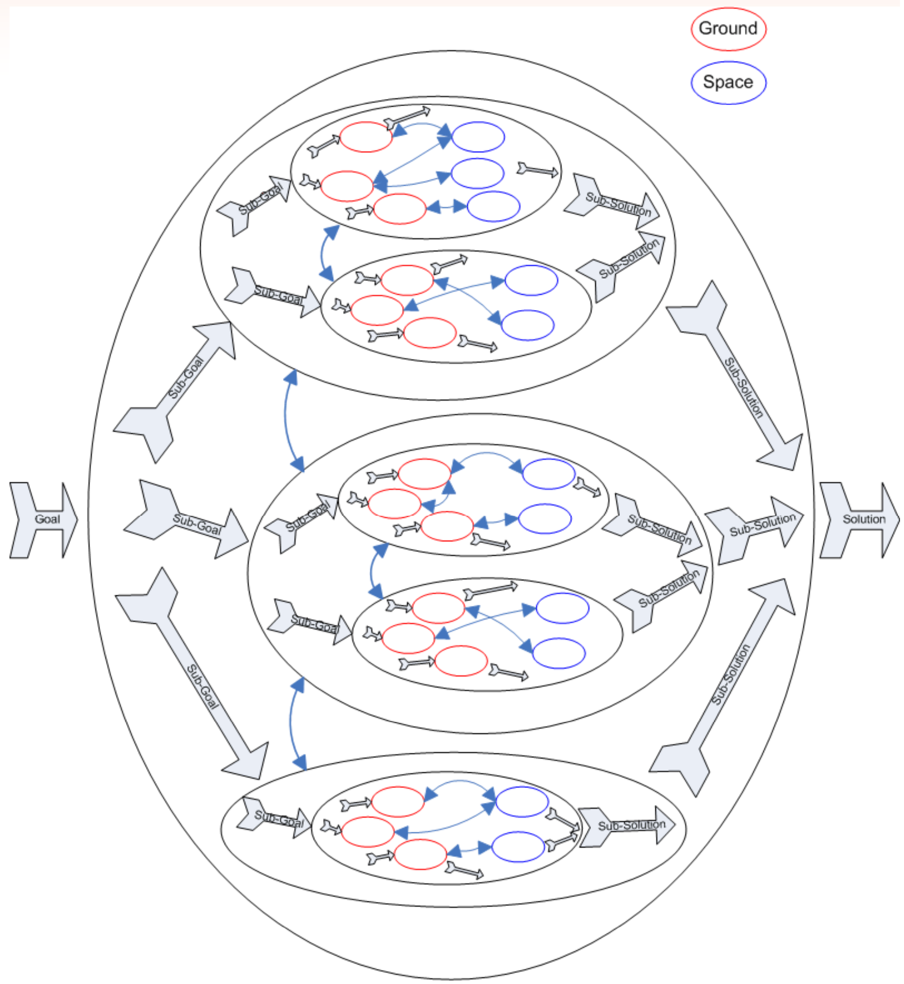
Sensor Web Concept in a Nutshell

A Goal is presented to a Sensor Web system. The system breaks the Goal down, as necessary, into more atomic, discrete sub-goals that are achievable by sub-systems known to the system. This break-down happens according to predefined, and well known rules, so that the inputs to the subsystems are appropriately provided.

This process happens recursively within subsystems and sub-subsystems, until the atomic sub-goal is directly resolvable.

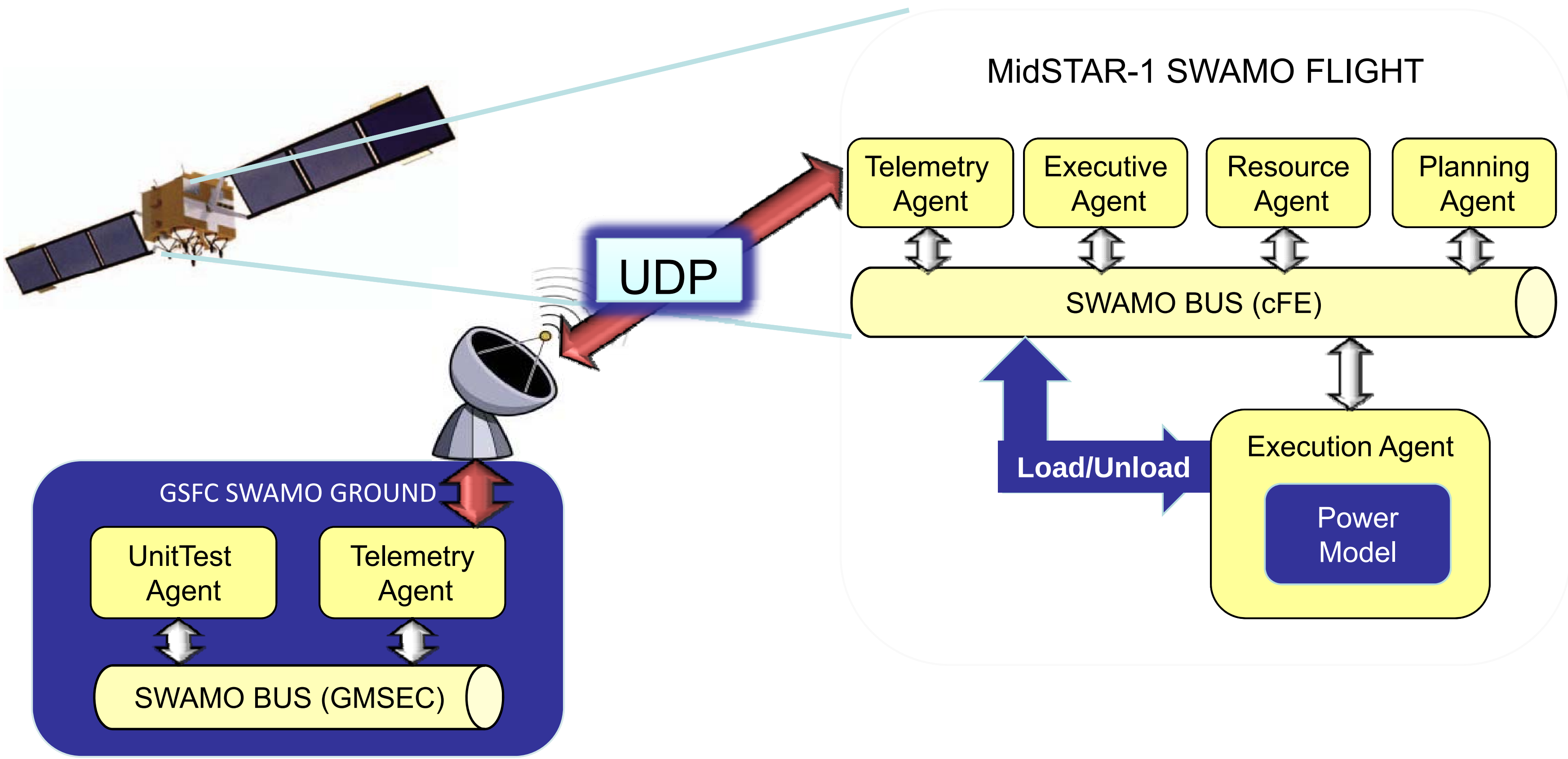
Sub-Goal Solutions are then repeatedly combined until the original Goal has a Solution.

Key factors are: *Autonomic planning, defined and discoverable interfaces,* and *Web Services*

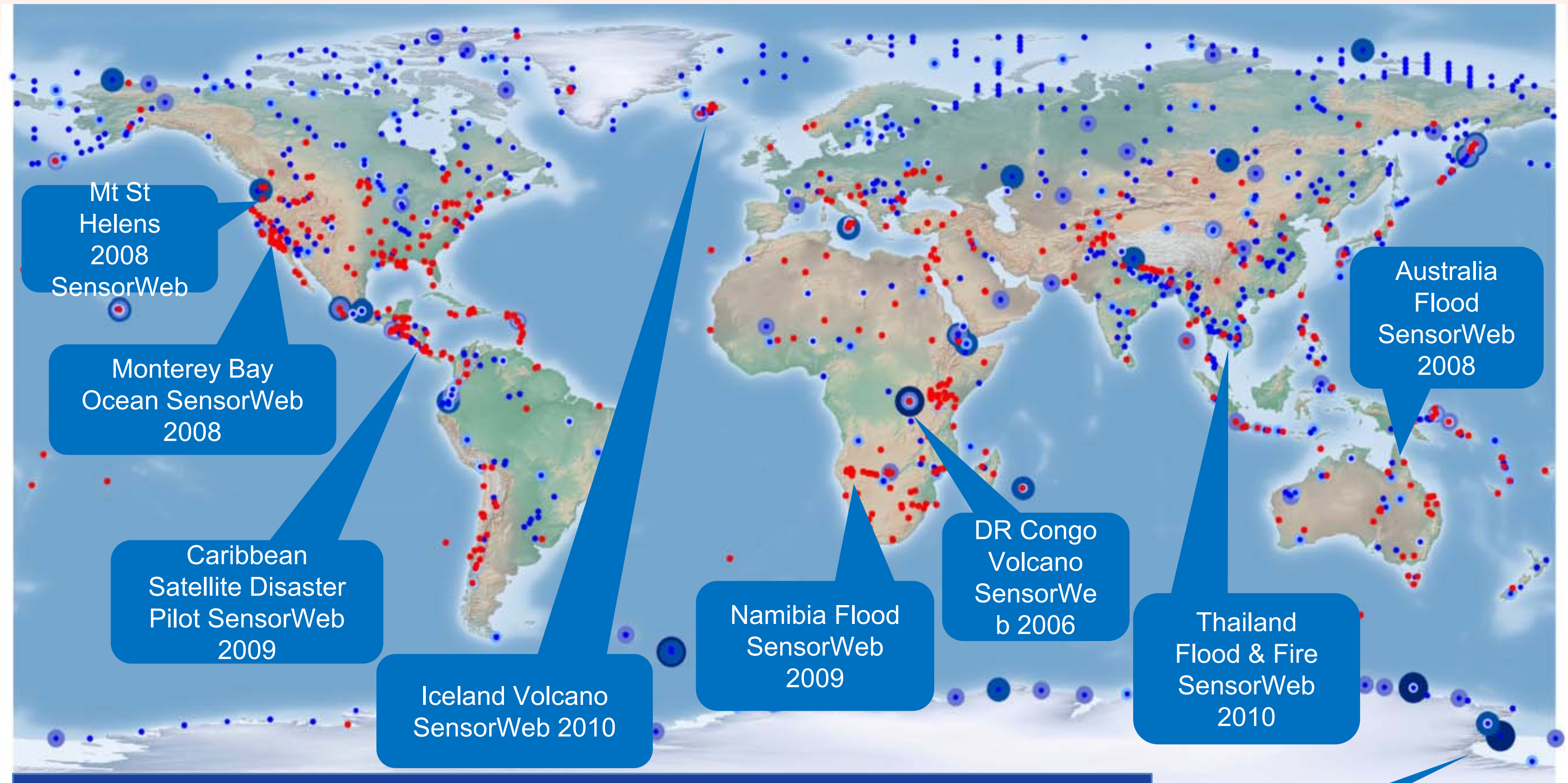


Delay Tolerant Network/SWAMO/MidSTAR-1

The goal of this Use Case from the SWAMO point of view is to demonstrate the SWAMO capability to dynamically load an agents on-board a flight asset via a request from a SWAMO agent on the ground. Even though not demonstrated on a science platform, it is a valuable function for science data processing (dynamically configure classifier models in real-time)



SensorWeb Images



Worldwide coverage with many science disciplines flooding, oceanography, volcanology, forestry,… Nearly 10,000 SensorWeb Images as of 5/20/11

Multiple Software Technologies for SensorWebs Documented in NASA Technology Reports

Detection → Response → Produce Data, Model → Deliver Data

(1) Detection	(2) Response/Tasking	(3) Produce Data	(4) Deliver Data
Volcano Monitor SO_2 Detectors JPL-45445	Campaign Manager GSC-16267-1	EO-1 Sensor Observation Service GSC-16272-1	OGC Pub/Sub Basic GSC-16270-1
MODIS-based Flood Detection, Tracking and Response (SVM, decision tree)(3) JPL-48149	Campaign Manager Client GSC-5027514	Weka to WCPS Translator GSC-16274-1	
Multisource Autonomous Response for Volcanoes JPL-48148 (2)	EO-1 Sensor Planning Service 0.3 GSC-16271-1	Web Processing Service (WPS) software framework JPL-45998	
Change based satellite monitoring using broad coverage targetable sensors JPL-48147	Identity Management Service GSC-16268-1	Web Coverage Processing Service GSC-1627531	
	EO-1 Sensor Planning Service 2.0 JPL-48142	Autonomous Hyperspectral Data Processing/Dissemination JPL-48123 (4)	
		Flood Dashboard GSC-16275-1	

SensorWeb Reference Architecture GSC-5025286

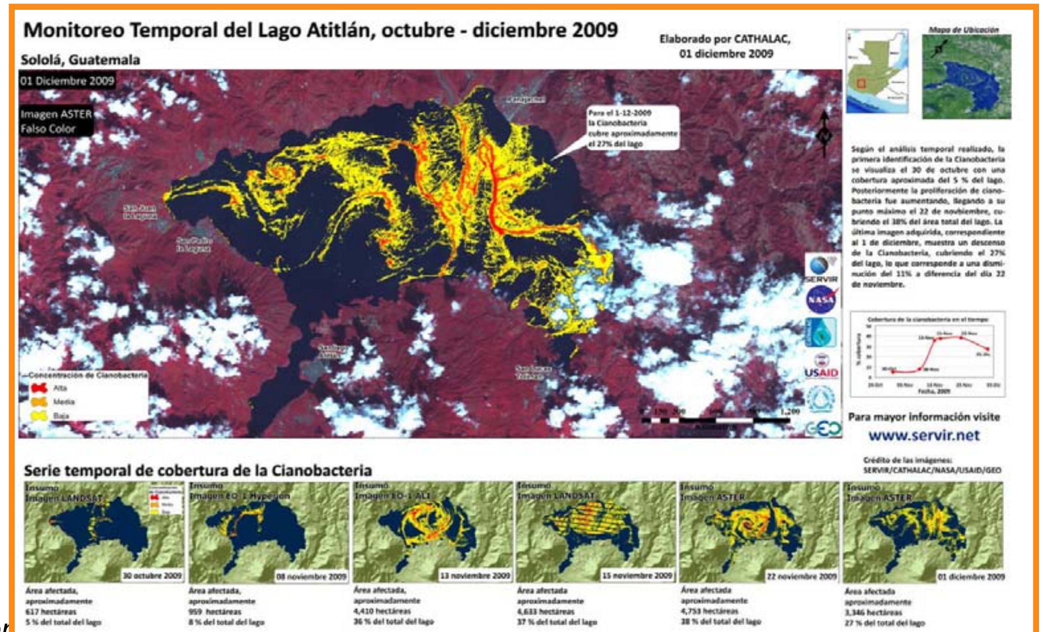
Total of seventeen (17) NTRs recorded for SensorWeb technologies

SensorWeb for Health Related Issues
Cyanobacteria Outbreak on Lake Atitlan

"The EO-1 data provided through SensorWeb for a cyanobacteria outbreak affecting Lake Atitlan even made it to the front page of Guatemala's widely read Prensa Libre newspaper in November 2009. The data provided was and is still being used to advise the Guatemalan Ministry of Environment on actions that should be taken with regards to the Lake's contamination, as approximately two hundred thousand Guatemalans use the Lake for both drinking water and recreation."

– Emil A. Cherrington
Manager, Division of Applied Research and Development, CATHALAC

- Water quality in Lake Atitlan is of such importance that the Guatemalan Government is implementing a $350M USD program to mitigate the problem. (Time Magazine 11/29/2009)

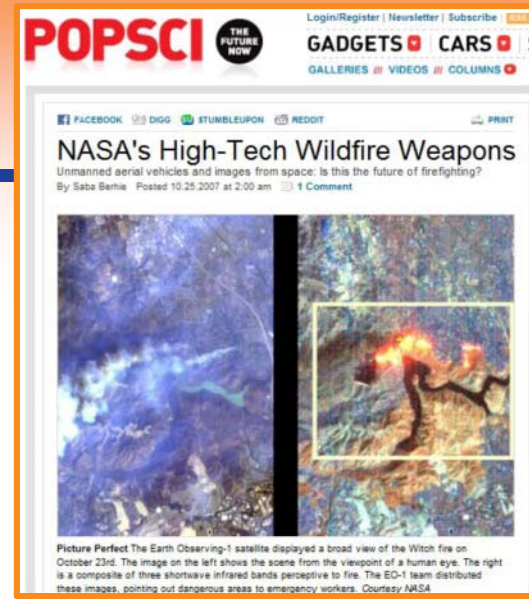


"The spatial analysis and studies through the satellite imagery (ASTER, EO-1 and Landsat) provided by CATHALAC through SERVIR have been invaluable support for decision making and inter-institutional coordination led by MARN to address these types of alerts and extreme events.

– Luis Armando Zurita Tablada
Vice Minister of the Environment, Guatemala

Fire SensorWeb Experiments with U.S. Forest Service

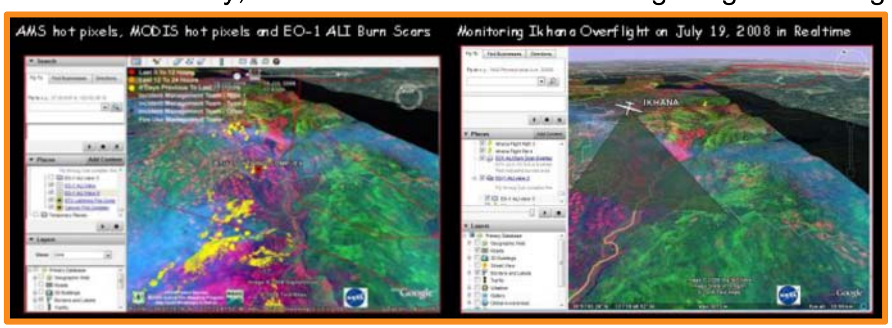
From 2003 to 2009, SensorWeb team conducted a variety of experiments to identify how best to inject SensorWeb technology into assisting Forest Service to manage large wildfires and assist decision makers. This involved interoperating satellite sensors and an Unmanned Aerial System sensors to produce useful data products to assist U.S Forest Service emergency managers.



Detect: National Fire Interagency Center (NIFC) large fire map and MODIS daily hot pixel maps acted as triggers
Respond: Trigger EO-1 and Unmanned Aerial System (UAS) images automatically to take a detailed look
Product Generation: Active fire maps, burn scar maps
Delivery: Experimented with various web based delivery such as mash up displays and RSS feeds

"An exciting aspect of the SensorWeb capability is the ability to automatically image, process and deliver higher resolution satellite imagery products online with little effort."

-Everett Hinkley, Forest Service Remote Sensing Program Manager



Namibia Flood Early Warning SensorWeb

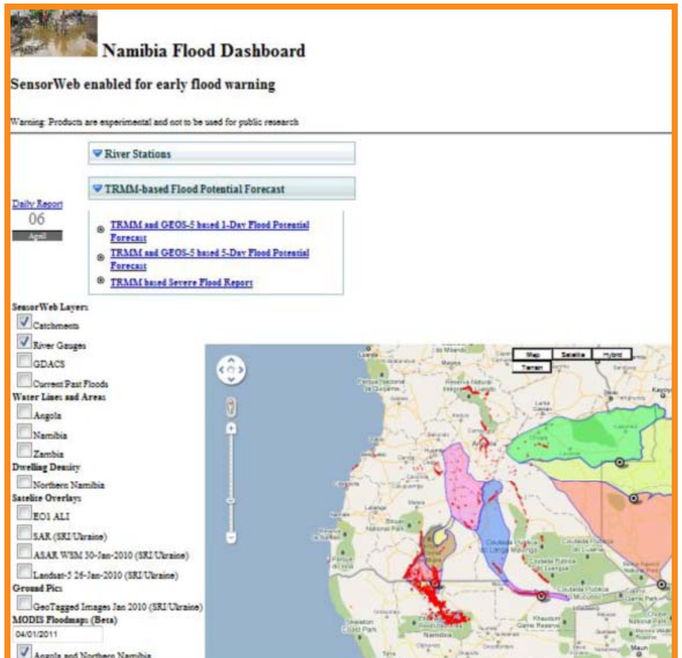
In 2009, 2010 and 2011, record floods hit Namibia with as much as ¼ of the population of 2 million affected by the floods, along with hundreds of deaths and millions in property damage. SensorWeb technology is being integrated to help Department of Hydrology implement a Flood Early Warning system to save lives and property.

Detect: TRMM rainfall estimate monitored upstream, AMSR-E based Riverwatch used to monitor river widths, daily MODIS flood extent maps

Respond: Trigger EO-1 and Radarsat imagery based on detection of triggers

Product Generation: MODIS daily flood extent overlays, EO-1 flood extent overlays, river gauge plots

Delivery: Aggregated data layers on Flood Dashboard



"This is to reiterate and stress support and enthusiasm for ongoing efforts during the past two years to integrate SensorWeb components for use by us and other flood disaster response workers and institutions."

– Guido Van Langenhove, Head of Namibia Department of Hydrology

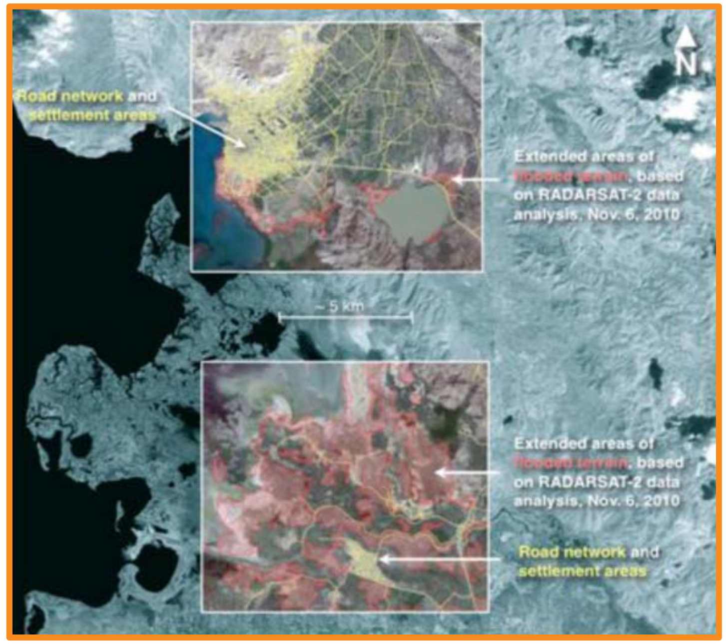
Caribbean Satellite Disaster Pilot

The 2010 hurricane season in the Caribbean was an active year and had more than 20 named storms. High resolution observations from NASA and CSA satellites were triggered to provide images for near real time assessment to regional centers. This provided national authorities with situational awareness. SensorWeb technology is becoming an integral part of disaster and emergency management and is being evaluated for incorporation into regional protocols for response and recovery.

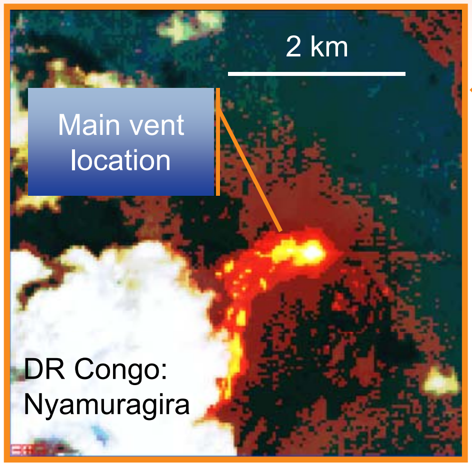
Detect: Hurricane landfall and precipitation predictions from the Caribbean Institute of Meteorology and Hydrology, Flood model 1 day forecast using TRMM, AMSR-E, and other satellite inputs, daily MODIS flood detection maps, web inputs from national partners
Respond: Trigger EO-1 and Radarsat imagery and generate flood maps for local and regional collaborators
Product Generation: Daily flood extent overlays from MODIS, EO-1. and Radarsat that cover 3 hurricanes (Earl, Nicole, Tomas) for Haiti, Jamaica, St Lucia, and Virgin Islands
Delivery: Aggregated and custom processed data layers on open cloud platform accessible on the internet

"*I applaud the SensorWeb Toolbox development team because they have created a real-world capability that has connected satellite earth observation data to the local users …which leads to saving lives and property in the developing world.*"

– Daniel E. Irwin, Director of NASA's SERVIR Program

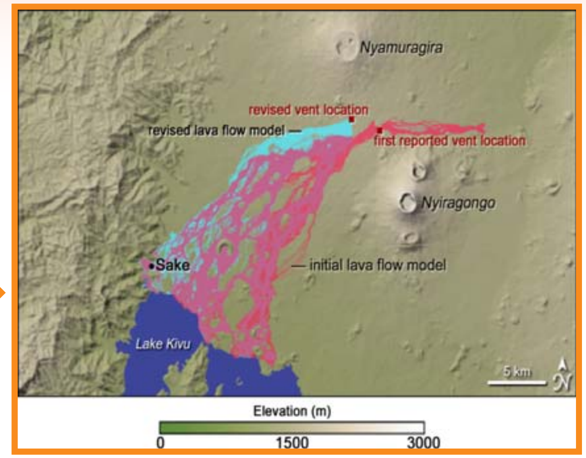


Volcano SensorWeb



EO-1 Hyperion SWIR image of destructive lava flows at Nyamuragira, DR Congo, 4 Dec 2006.

This vital data acquisition allowed pinpointing of the vent and enabled accurate modeling of likely lava flow direction.



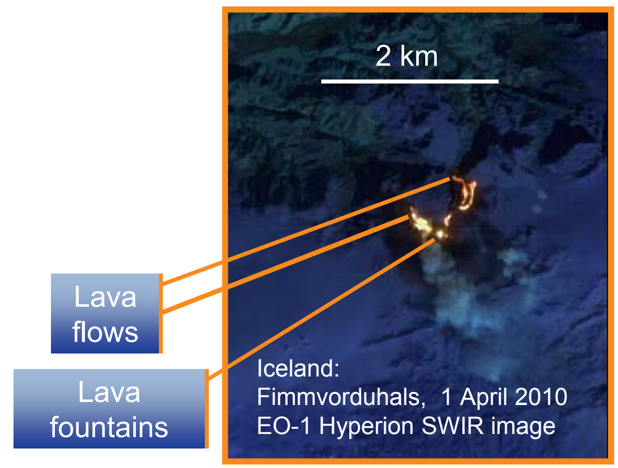
"This was a stunning demonstration of the capability of an autonomous system to obtain and provide vital information during a volcanic emergency."
- Gari Mayberry, Geoscience Advisor, USAid

Alert: Uses alerts from multiple sources (*in situ* sensors, MODIS, AFWA, VAAC, et al.)

Response: Alerts are used in a prioritized fashion to trigger follow up targeted satellite observations.

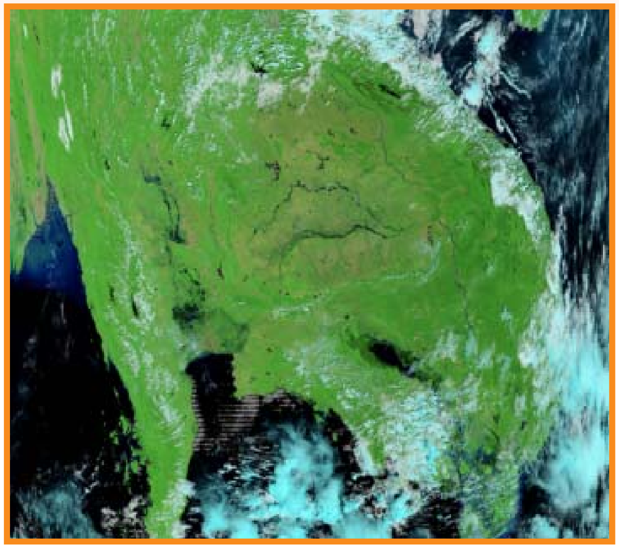
Product Generation & Delivery: Rapid data processing, thermal maps, modeling of eruption parameters, and posting to end users.

SensorWeb now includes in-situ sensor monitoring of Icelandic volcanoes: http://en.vedur.is/earthquakes-and-volcanism



A. G. Davies / JPL

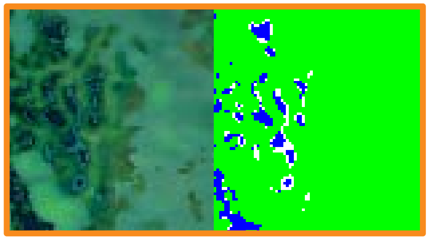
Thailand Flood SensorWeb



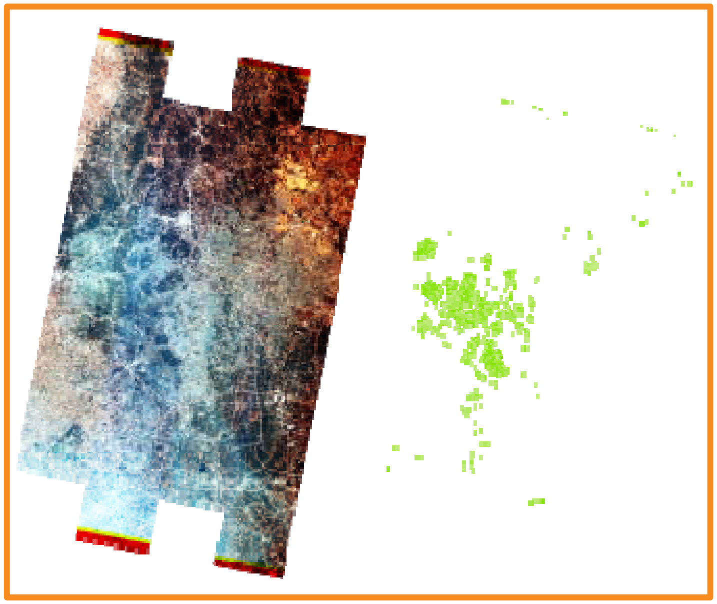
MODIS 28 Nov 2010 Imagery of Thailand Flooding (band 7-2-1)
Est. damage over $1.67B USD [CNN], Oct–Nov 2010

"The Thailand Flood SensorWeb provides a unique capability to detection, monitoring, response, and mitigation of flooding in Thailand"
Dr. Royol Chitadron, Director, HAII
Thailand

- **Detect:** Pull 2x daily RAPIDFire subsetted MODIS data, support Vector Machine Learning (SVM) & band ratio methods of classifying gauging reaches against baseline dry scores
- **Respond:** Earth Observing 1 autonomously responds to acquire more detailed imagery
- **Product Generation & Delivery:** Data and flood products electronically delivered to Thailand Hydro Agro Informatics Institute (http://www.haii.or.th)



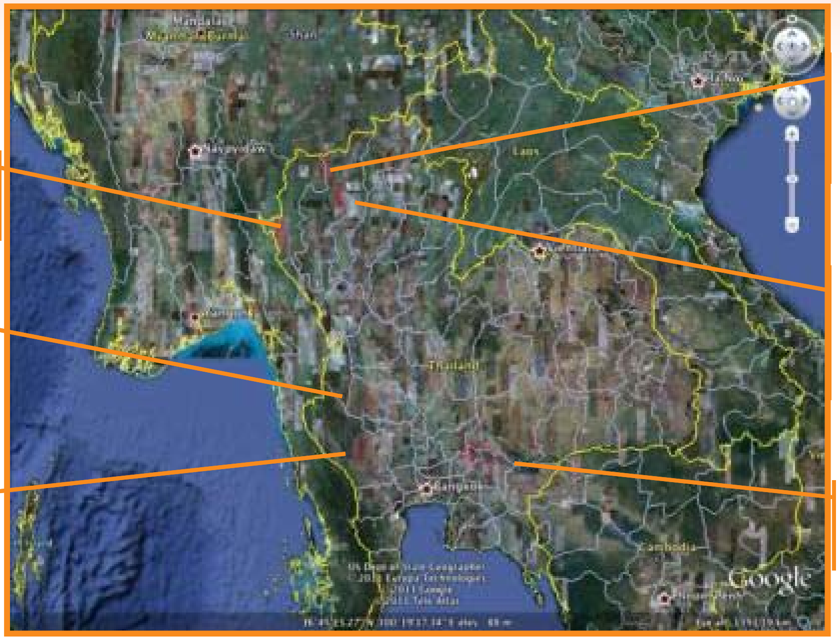
Detect:
(L) MODIS imagery of Bang Pla Ma from 20 Jan 2011
(R) Classified surface water extent from MODIS image



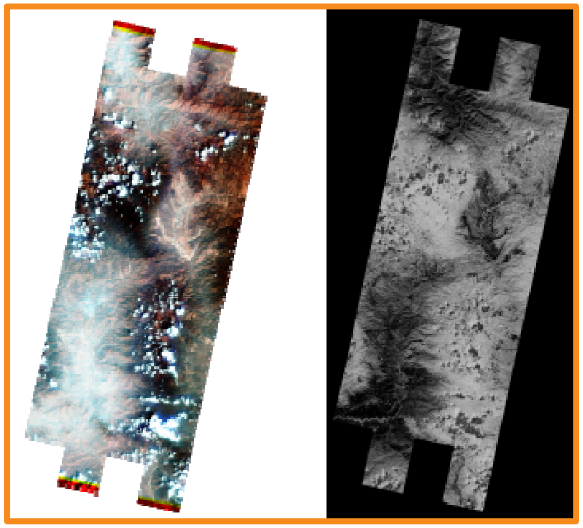
Respond → Generate → Deliver
(L) ALI imagery of Bang Pla Ma from 21 Jan 2011
(R) Classified surface water extent from ALI image

S. Chien / JPL

Thailand Fire Sensorweb



Color image (L) & Normalized Burn Ratio (R) product of Huay Nam Dang acquired 4 March 2011 in response to active fire alert



Detect: Uses FIRMS MODIS-based fire detection system to monitor National Heritage Areas and Wildlife Sanctuaries

Respond: Alerts are used in a prioritized fashion to trigger follow-up targeted satellite observations by EO-1.

Product Generation & Delivery: Imagery & burn severity products electronically delivered to National Park, Wildlife and Plant Conservation Department of Thailand (NPWPCD; http://www.dnp.go.th)

"We are currently using the system to monitor fire activity in six critical areas of Thailand."

– Director General, National Park, Wildlife and Plant Conservation Department of Thailand

S. Chien / JPL

Significance to Technology/Applications

- Detection, Response, Workflow automation technologies have been documented in 70 publications and presentations (including 20 peer reviewed publications)
  - Detection
    - Advances the state of the art and state of the practice in automated interpretation of satellite imagery and in use for automated workflow chaining services for data processing and interpretation. See Doubleday et al. 2011 AI/Space, Chien et al. 2011 IGARSS.
  - Response
    - Advances the state of the art in routine use of automated re-tasking of assets. See Chien et al. 2010 SpaceOps, i-SAIRAS.
    - Advances the state of the art and state of the practice in semi-automated and automated integrated control of space, air, marine, and fixed sensor assets. See Schofield et al. EOS 2010, Chien et al. i-SAIRAS 2008.
  - Data product generation and delivery
    - Advances the state of the art and state of the practice in use of workflow services for automated product generation and delivery

Significance to Science/Applications

- Hydrology—SensorWeb brings together more data sources (4+ satellites, in-situ, models) more rapidly (within hours from acquisition) to enable more precise modeling
- Forestry—SensorWeb integrates more data sources & automates product generation & delivery to lower barrier for use
- Volcanology—SensorWeb allows rapid response to acquire more satellite data (> 500 in FY10, total of 1000's of scenes)
- Oceanography—SensorWeb enables synergistic combination of space with in-situ data from gliders, floaters, ships, and autonomous underwater vehicles

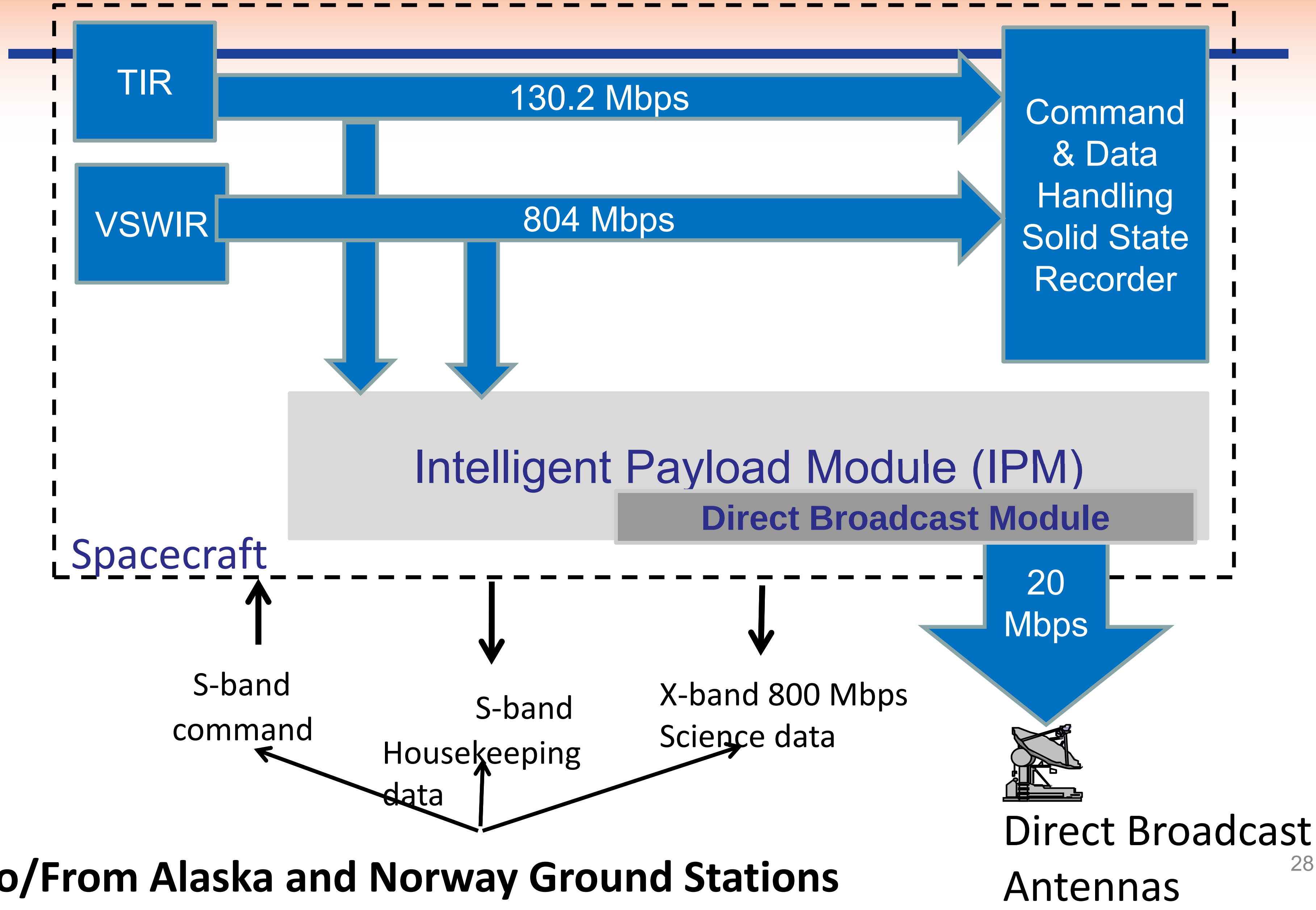
Steve's Presentation Here

- Add Science perspective

Need Right Tool for the Job

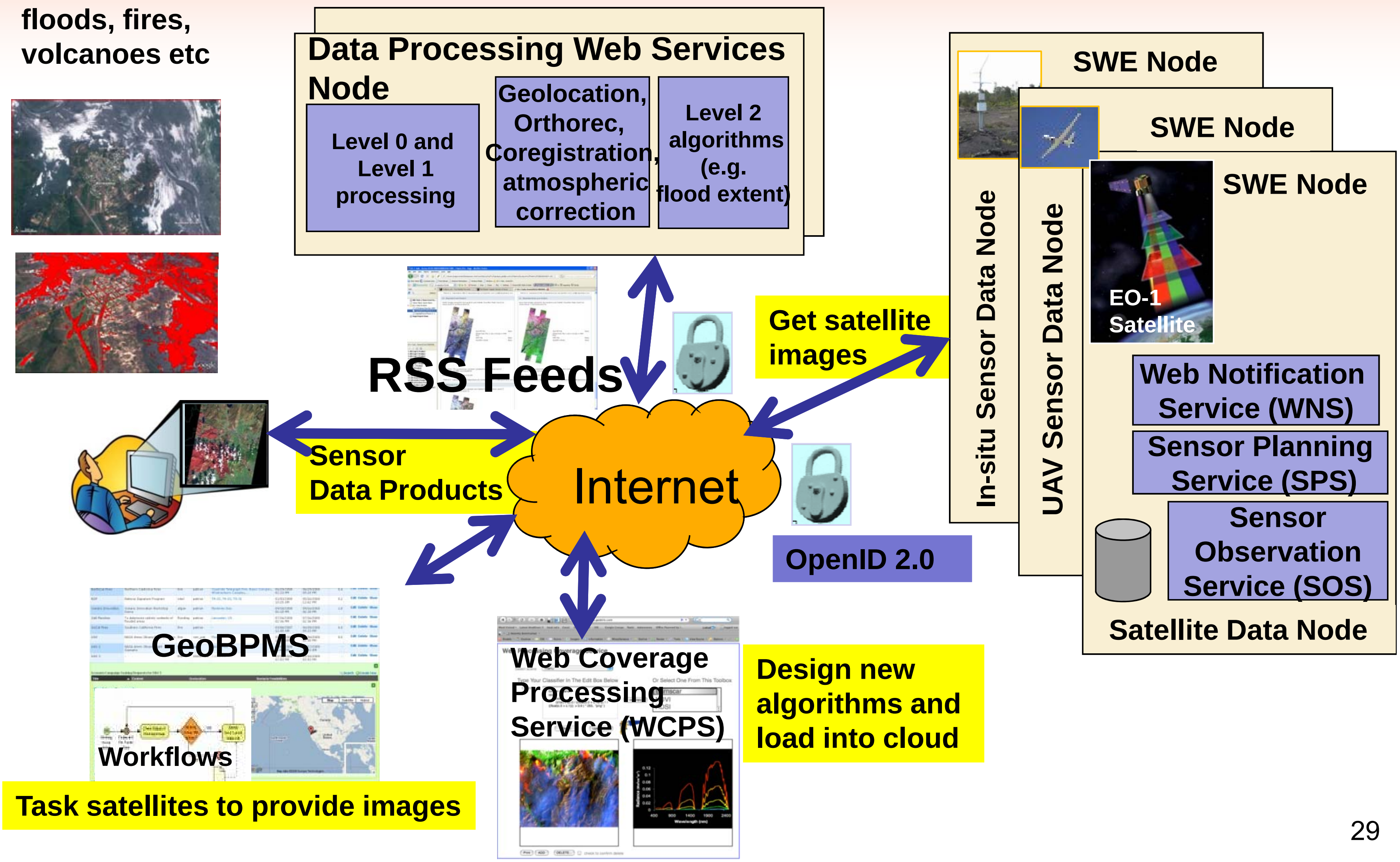
- Use SensorWeb software to get right tool for the job

Original HyspIRI Low Latency Data Flow Operations Concept (Intelligent Payload Module)



SensorWeb High Level Architecture

Sensors, Algorithms and Models Wrapped in Web Services Provide Easy Access to Sensor Data and Sensor Data Products



Add Cloud Computing

Technologists
NASA Investigators
Disaster Responders

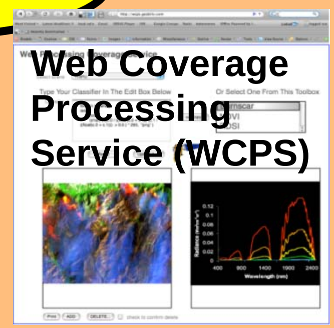
Matsu Cloud

http server

Level 1R and Level 1G Processing for ALI & Hyperion

Co-registration with Landsat GLS

Web Coverage Processing Service (WCPS)



Starlight 100 Gigabit Ethernet Exchange

Hyperion and ALI Level 0 Processed data from GSFC, building 3 server

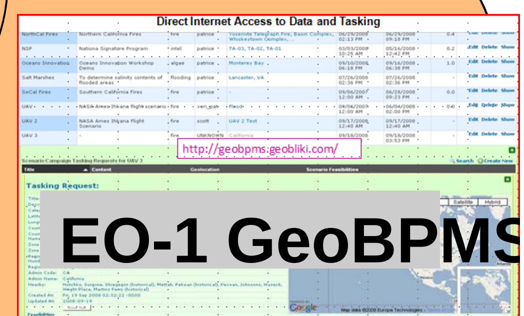
Atmospheric Correction for ALI & Hyperion

Namibia Flood Dashboard

Multi year data product archive

Matsu Cloud
- •Eucalyptus/Open Stack-based Elastic Cloud SW
- •300+ core processors
- •500+ Tbytes of storage
- •10 Gbps connection to GSFC
  - being upgraded to 100 Gbps (Part of OCC)
- •Hadoop Tiling/MapReduce/Accumulo
- •Supplied by Open Cloud Consortium
- •Open Science Data Cloud Virtual Machines & HTTP server to VM's

Joyent Cloud

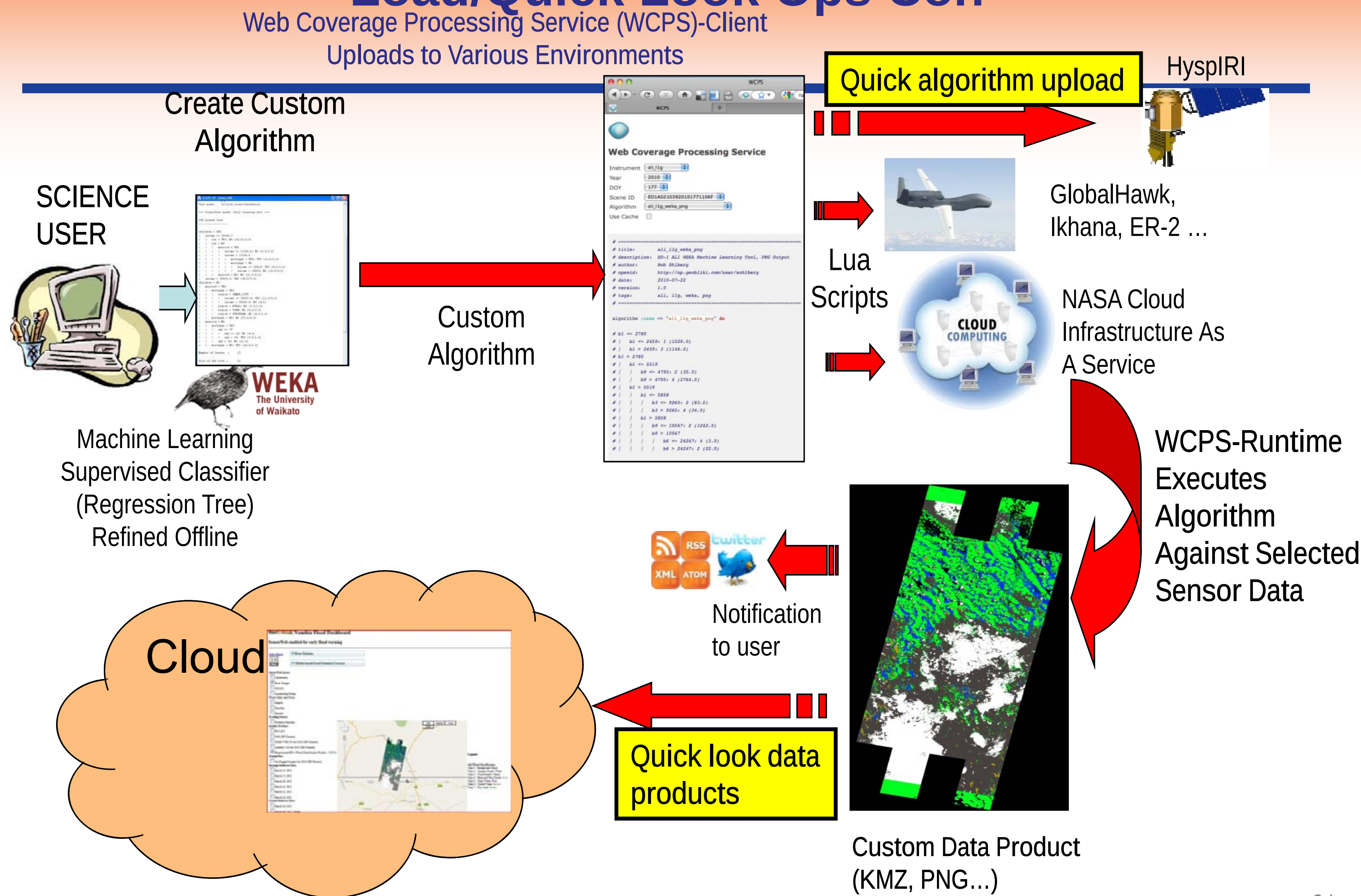


EO-1 GeoBPMS

EO-1 GeoBliki

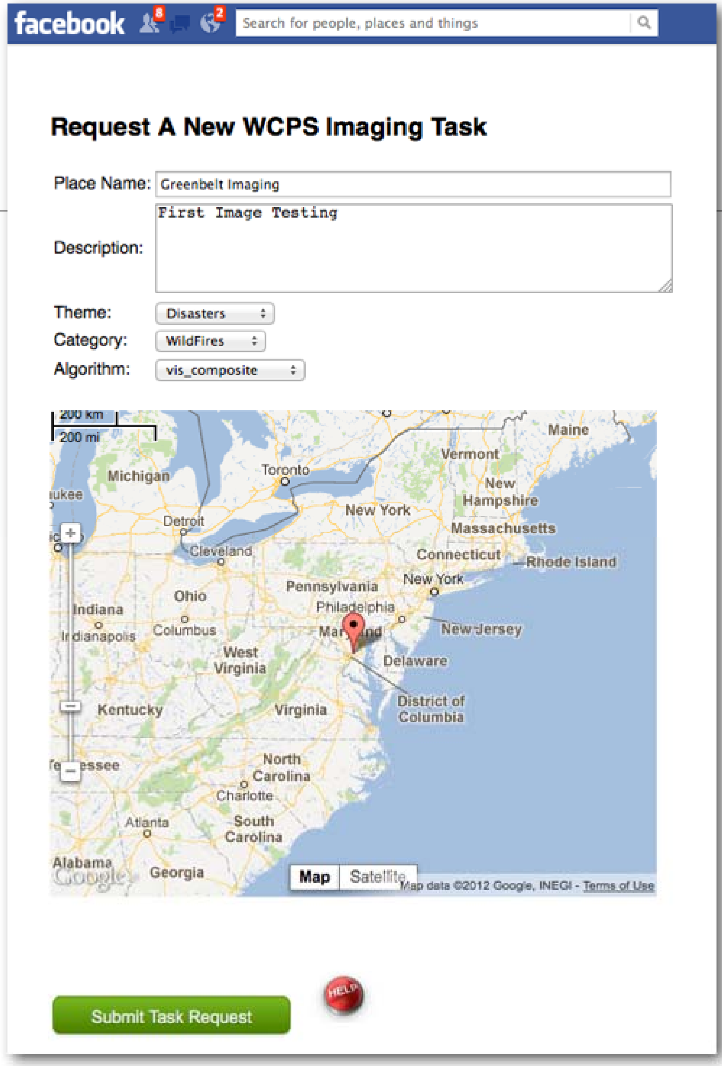
Joyent Cloud
- •Ruby on Rails
- •3 processors
- •3 Tbytes of storage

Experimental Intelligent Payload Module Quick Load/Quick Look Ops Con



Use GeoSocial API on Facebook to Task IPM

IPM Tasking



VIGHTEL IRAD

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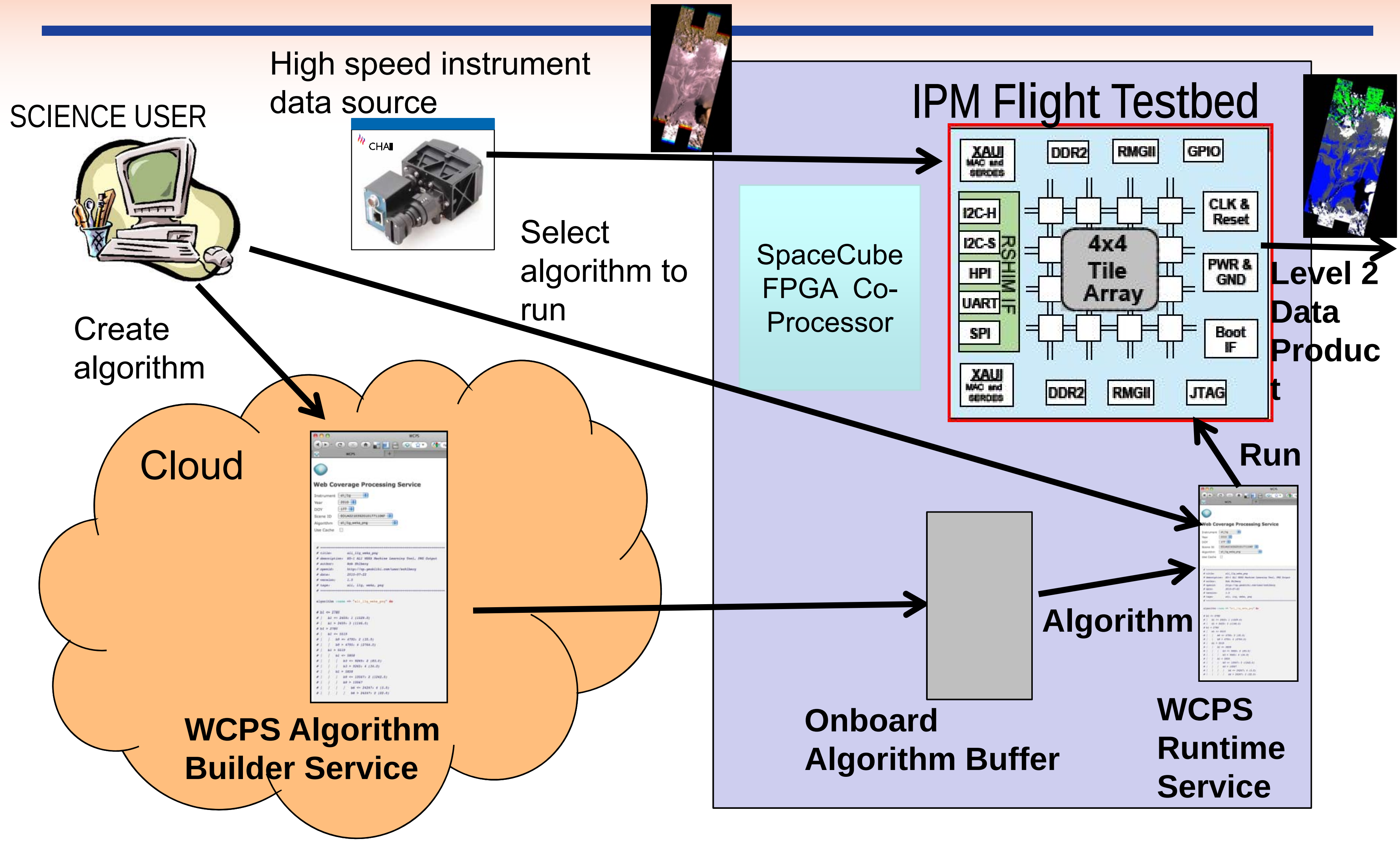
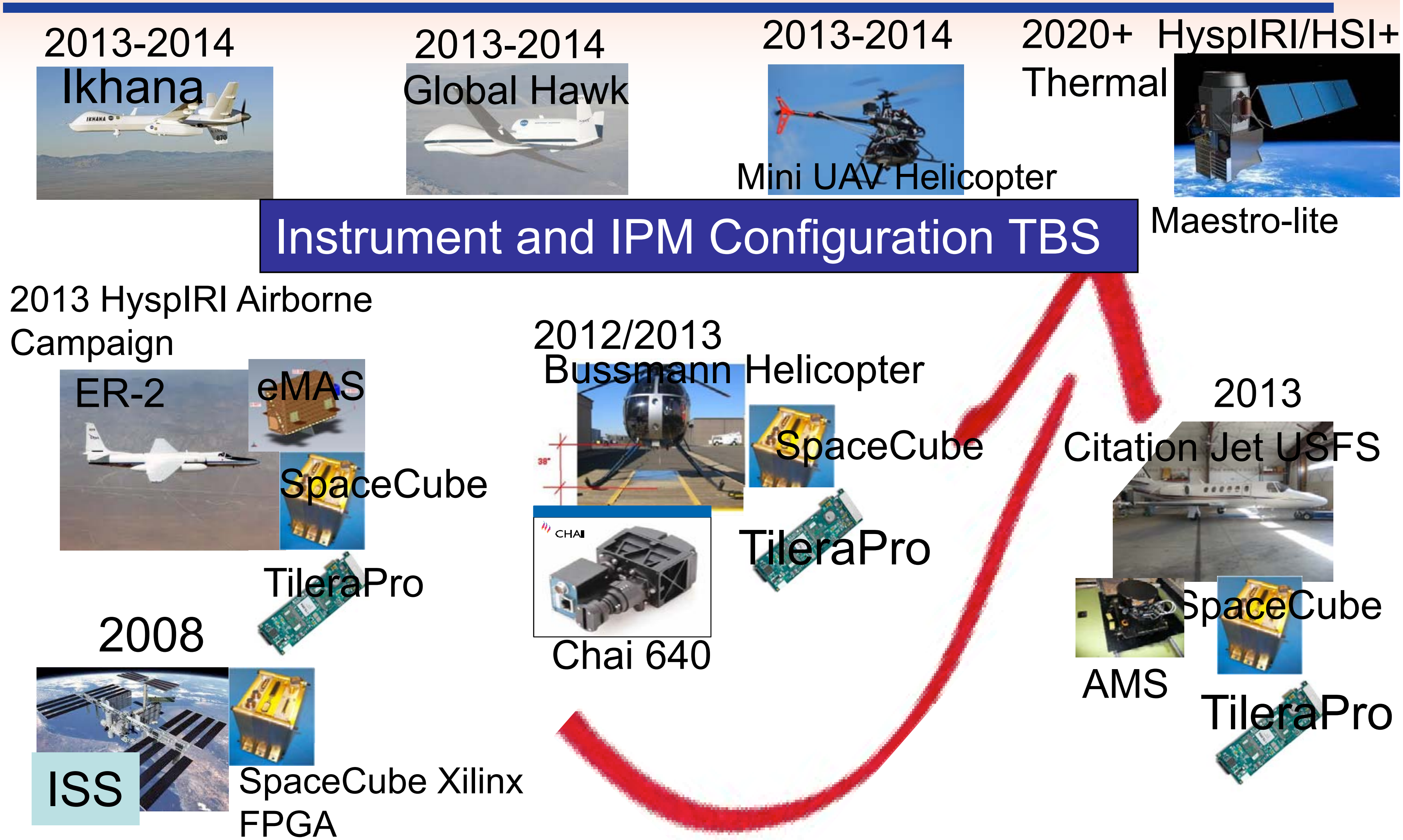
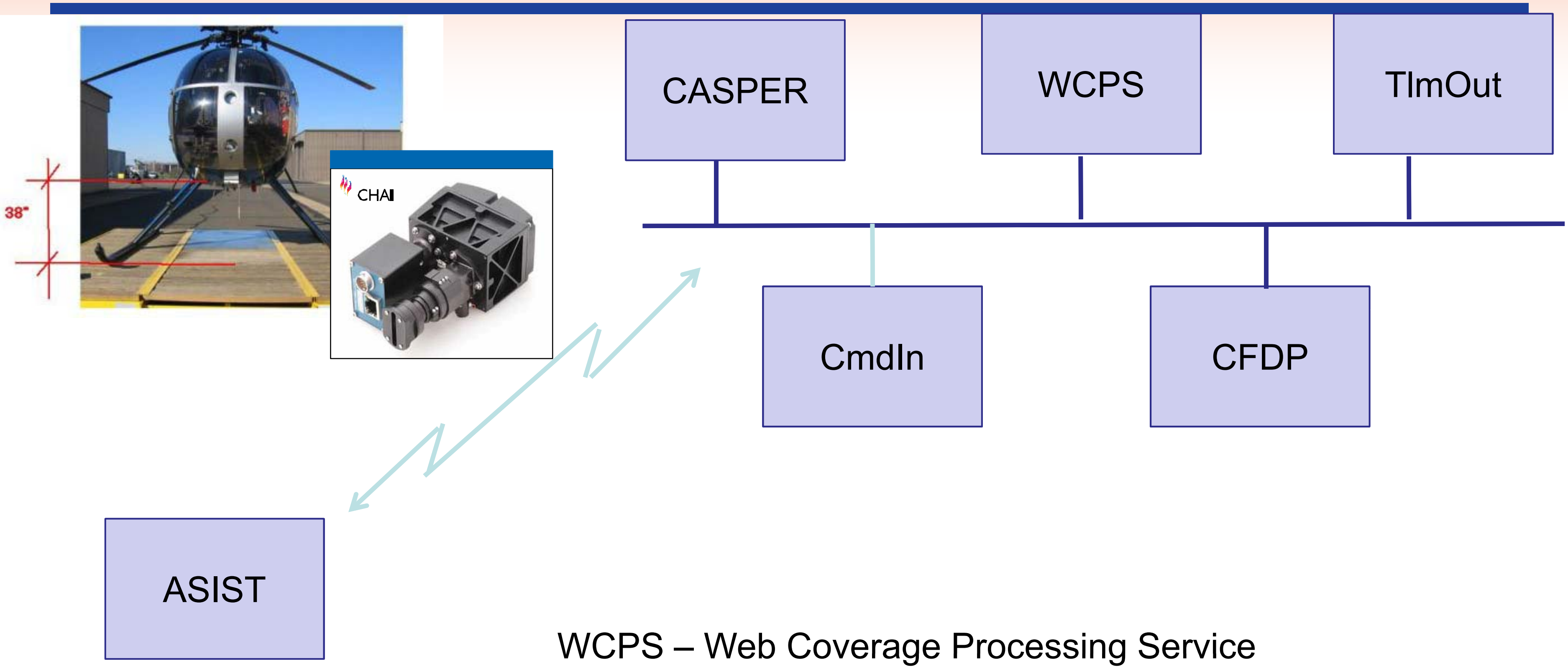
Top Level IPM Ops Concept

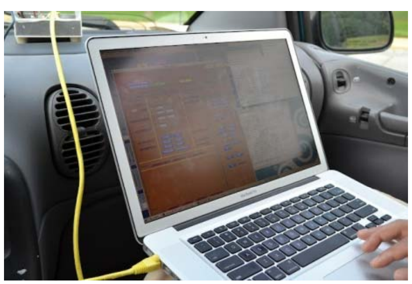


Roadmap for IPM Flight Opportunities



Flight & Ground Architecture Using Operational SW Components



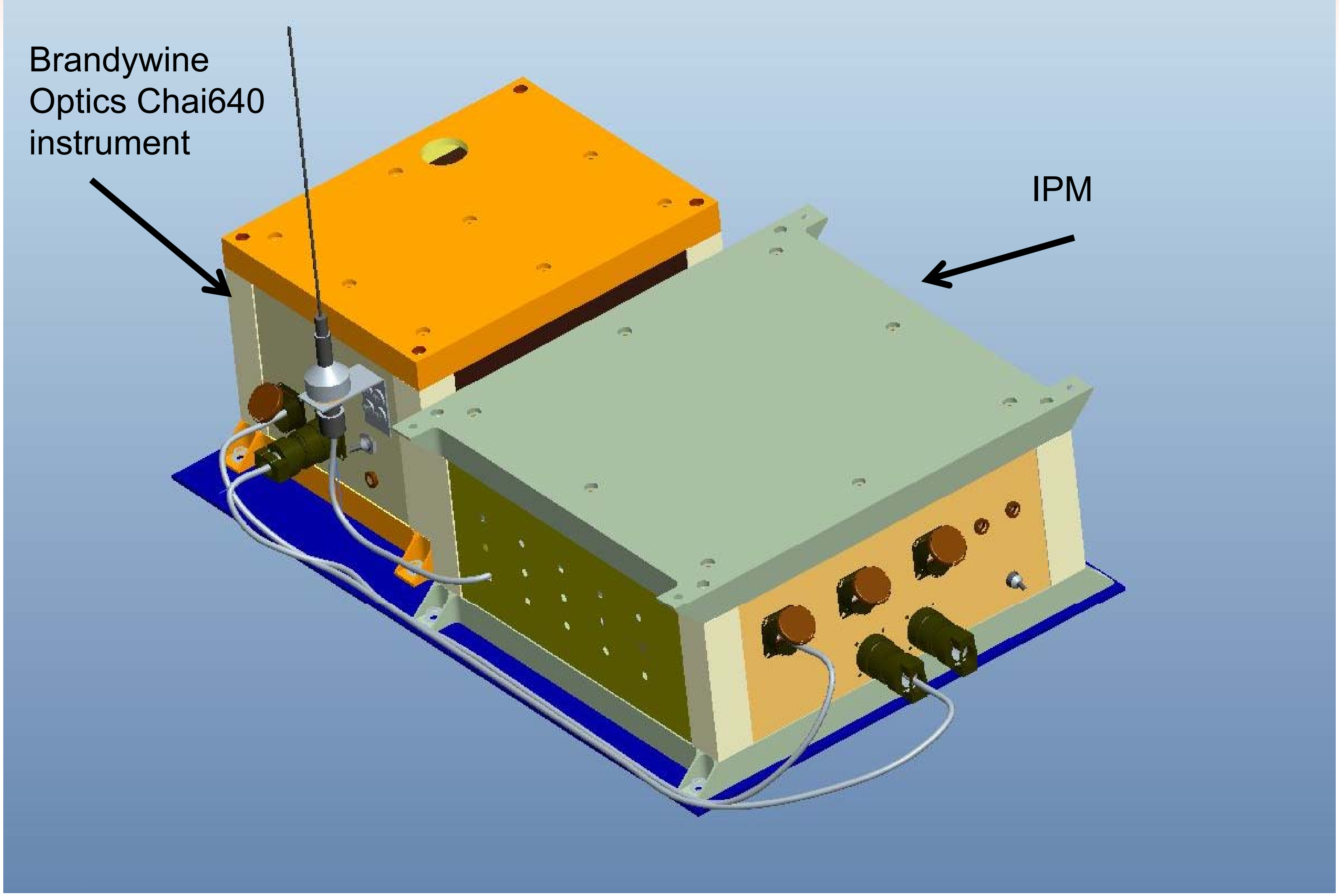


WCPS – Web Coverage Processing Service
CmdIn – Command Ingest
TlmOut – Telemetry Output
CASPER - Continuous Activity Scheduling Planning Execution and Replanning system
CFDP - CCSDS File Delivery Protocol
ASIST - Advanced Spacecraft Integration and System Test Software

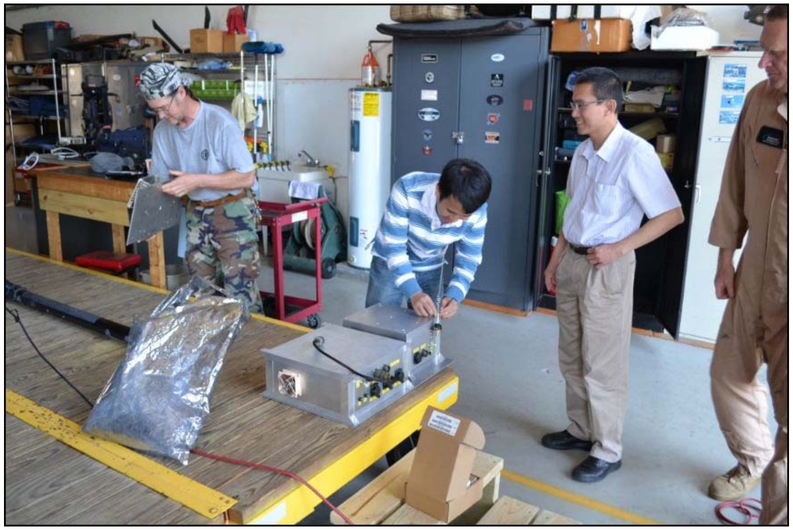
First Calibration Test with Chai V640 Imaging Spectrometer Instrument (5/16/13)

Visible image constructed from test data

Intelligent Payload Module Assembly with Chai640



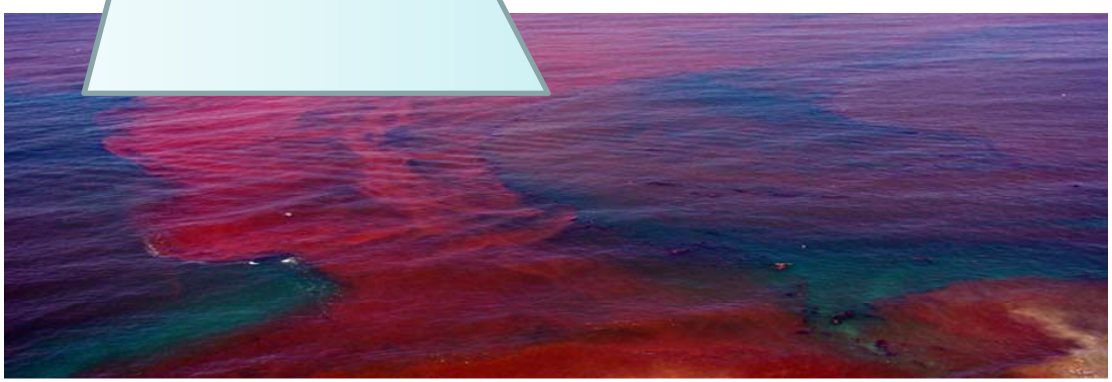
Beginning Integration Process on Helicopter



Sample Operational Scenario: Detection of Harmful Algal Blooms with Rapid Map Downlinked to Validation Team on Ground

Realtime map with following processing steps:
- ✓Radiance to reflectance conversion
- ✓Atmospheric Correction
- ✓Geocorrection/Co-registration
- ✓Classification

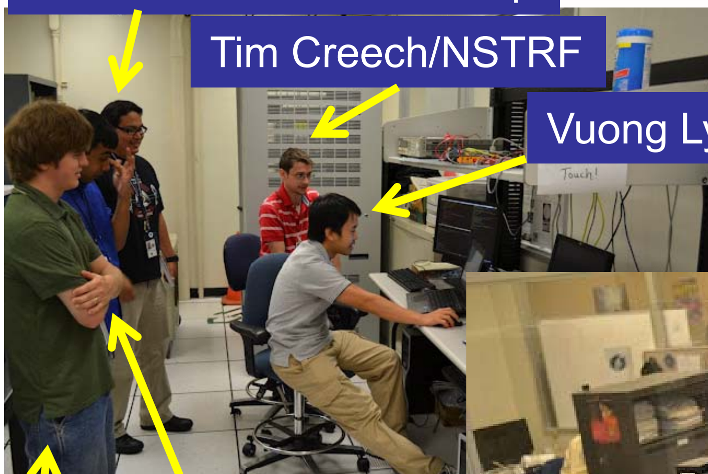
Downlink to Ipad



Harmful Algal Bloom

Validation team in boat being directed to location by rapid map product

Intelligent Payload Module (IPM) Prototype without Box



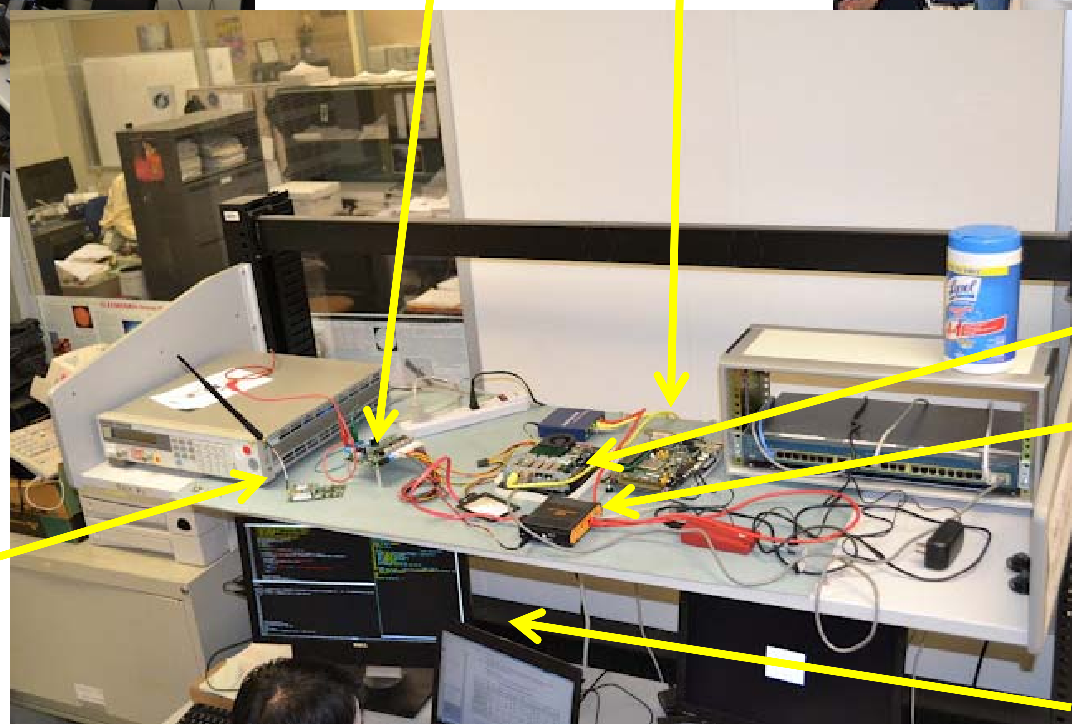
Joshua Bronston/581 coop

Tim Creech/NSTRF

Vuong Ly/583

Neil Shah/581 summer intern

Matt Handy/583



Power supply

SpaceCube board

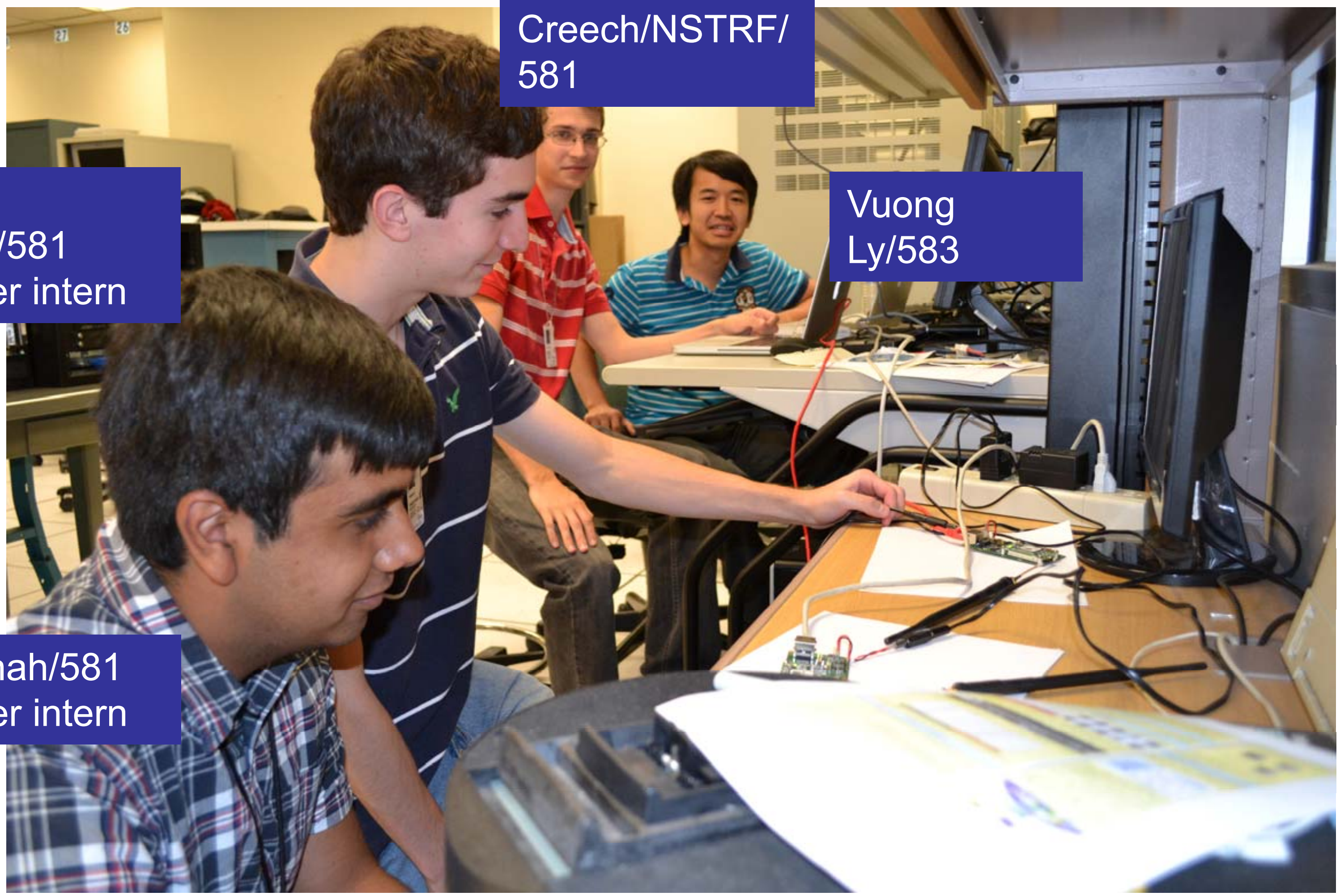
Tilera board

Dream plug (processor)

Solid state disk

Freewave Radio Transceiver & Antenna

Testing Freewave Radio



Tim Creech/NSTRF/581

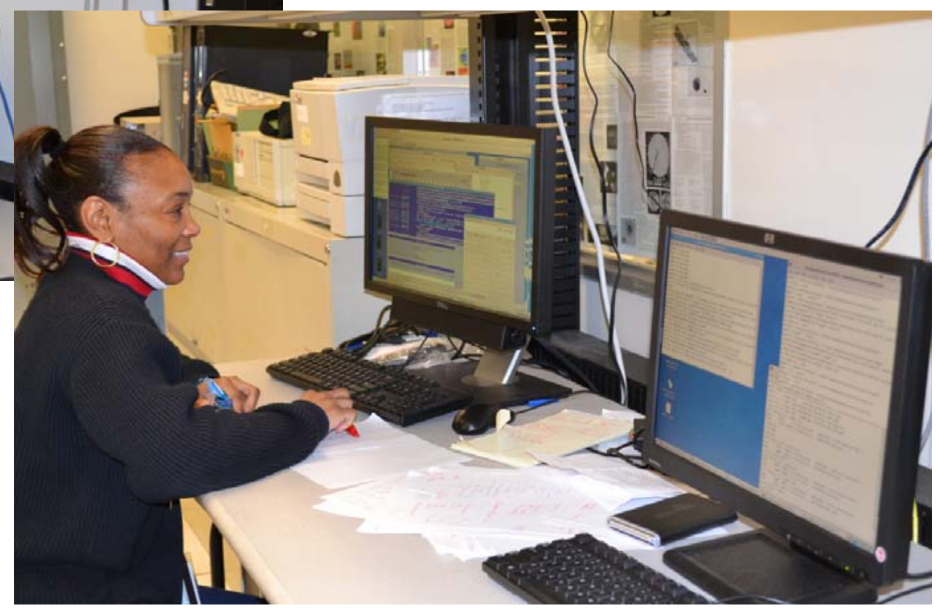
Chris Flatley/581 summer intern

Vuong Ly/583

Neil Shah/581 summer intern

IPM Testbed with Tilera Acting as Proxy for Maestro & Maestro-lite Board (building 23)

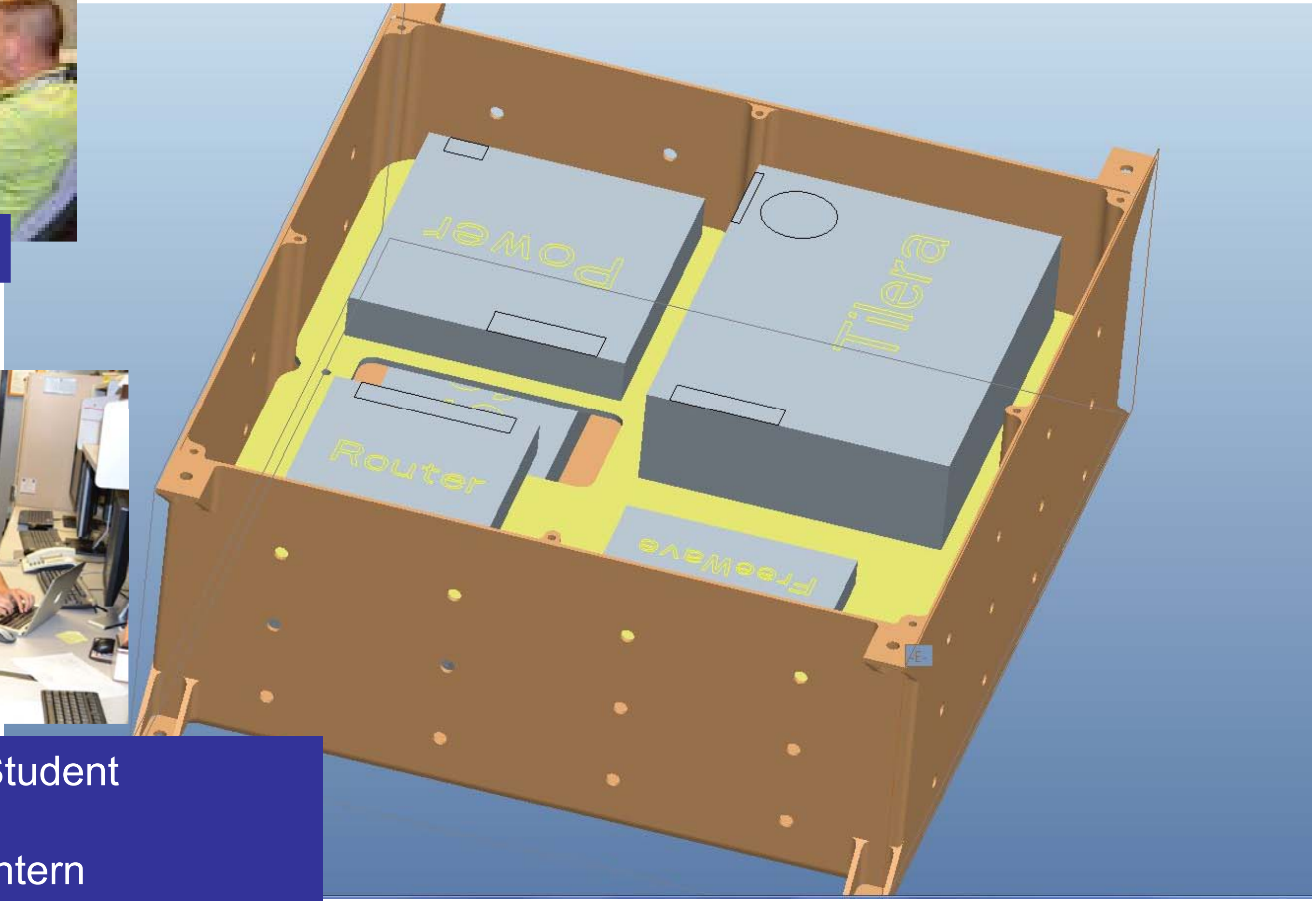
Above: Vuong Ly/583 (Ground System SW Branch) standing front of IPM testbed holding a SpaceCube board.
Right: Tawanda Jacobs/582 (Flight SW Branch) working on integration of cFE onto IPM testbed.



Designed Box with Pro-E to House IPM Components

Mike Flick/SES

Mike Mandl/UMCP Student
Mike Flick
Neil Shah/Summer Intern
Chris Flatley/Summer Intern



Plan to Mount IPM to Helicopter for Tests Under AIST ESTO Research Grant

Vibration isolation mount for helicopter

Mike Mandl/UMCP student

Chris Flatley/581 Summer intern

Joshua Bronston/581

Mike Flick talking to Bussmann Aviation technician

Steve Bussmann/Bussmann Aviation

Unmanned Aerial System Jellyfish Monitoring Mission with IPM (Univ. of Catalunya)

Area of interest: Delta del Ebre south of Barcelona. Multiple Australian jellyfish being increasingly detected.

First test mission: Late summer 2012

Initial low-altitude mid-altitude images successfully acquired.

http://www.youtube.com/watch?v=Uam7-thvM80

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Namibia Flood Dashboard - Main Page

Namibia Flood Dashboard

SensorWeb enabled for early flood warning

Daily Report

Janua
31

Daily Bulletin:

HYDROLOGICAL SERVICES NAMIBIA – DAILY FLOOD BULLETIN 30 JANUARY 2013

Rains returned to central northern Namibia. NMS reported 25.4 mm for Okahao and 15.4 mm for Oshikango, and Ms Nancy Robson gave 7 mm for Odibo. Satellite images showed also good rains in the headwater of Kavango and Kunene rivers, and higher flows may be building up to reach Namibia next week. The Zambezi River is further rising at Katima Mulilo, but more slowly now. The forecast is still for 5.50 m by 10 February, which would be the normal seasonal floodlevel that is usually reached by the beginning of April.

View Complete Current Bulletin
View Bulletin Records
Search Bulletin Records
New Bulletin

Configure Layers
Upload Layer

River Stations

SensorWeb Layers

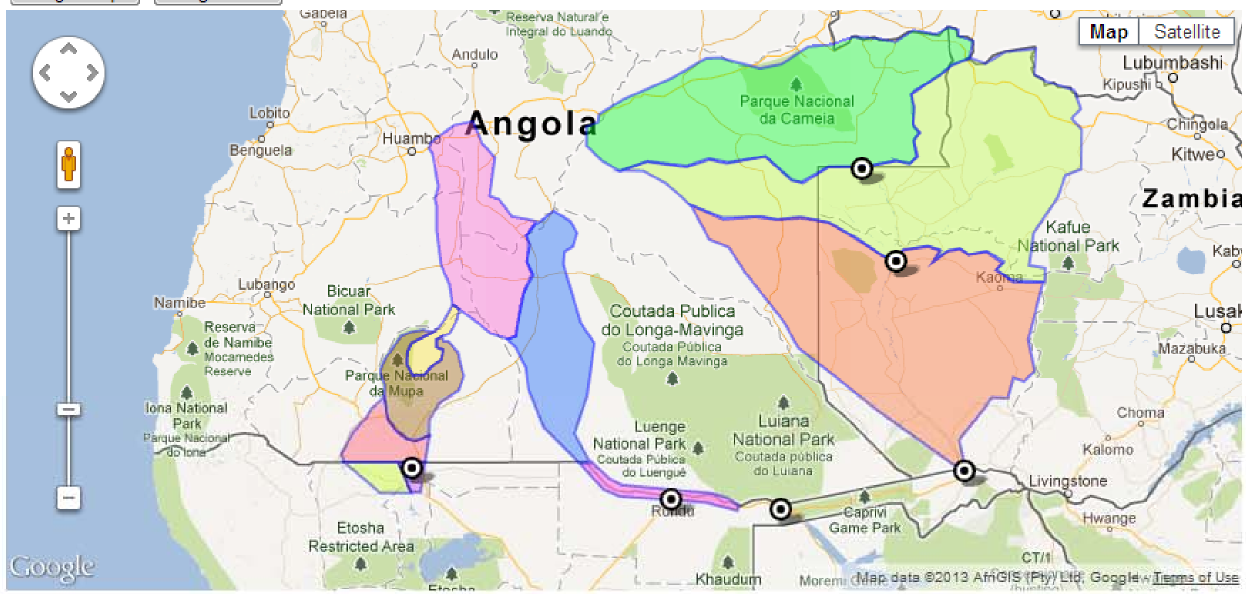
Water Lines and Areas

Google Maps
Google Earth

Namibia Flood Dashboard -Geospatial Display (The Big Map)

- River Stations
- SensorWeb Layers
- Water Lines and Areas
- Satelite Overlays
- Ground Pics
- Kavango Radarsat Data
- Cuvelai Radarsat Data
- TRMM Rainfall Accumulation and Flood Forecast
- Global Scene Counts
- MODIS Floodmaps
- Infrastructure
- ALI Flood Classification

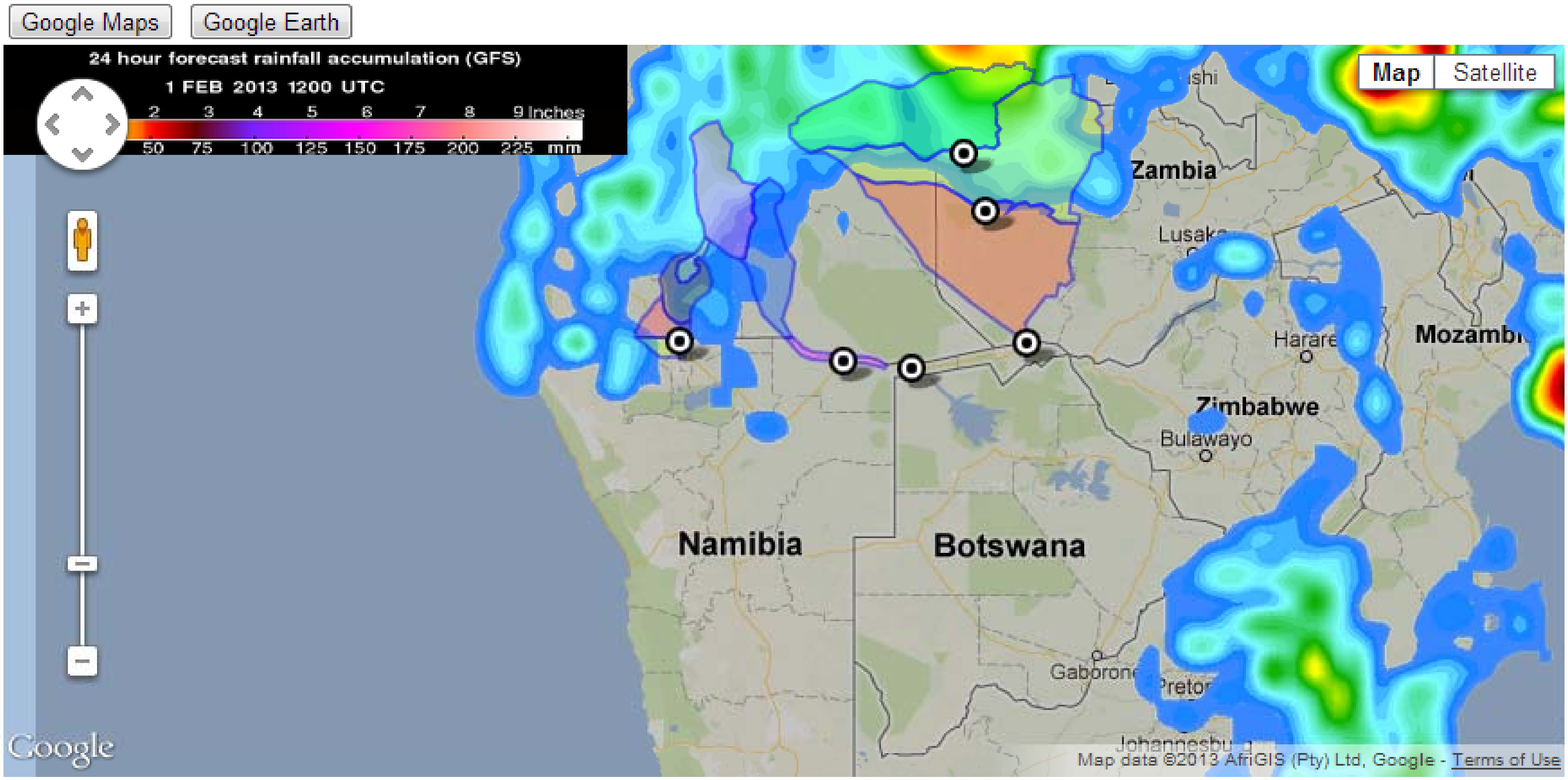
Google Maps | Google Earth



Legend:

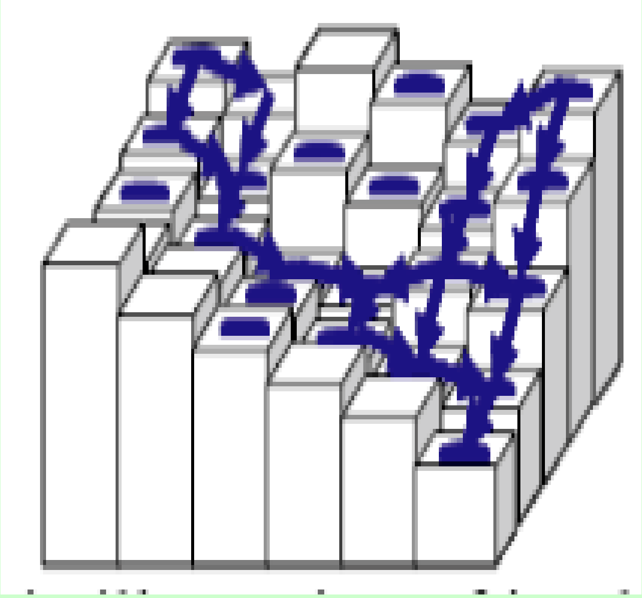
ALI Flood Classification	Class 1 - Background:	Class 2 - Opaque Clouds:	Class 3 - Cloud Shadow:	Class 4 - Haze and Thin Clouds:	Class 5 - Clear Water:	Class 6 - Turbid Water:	Class 7 - Dry Land:

TRMM Rainfall



NASA/ Oklahoma University CREST Cell-based Water Balance Model

Cell-to-Cell Flow Routing



Storage = (Precip. — ET) + (Inflow – Outflow) - Infiltration

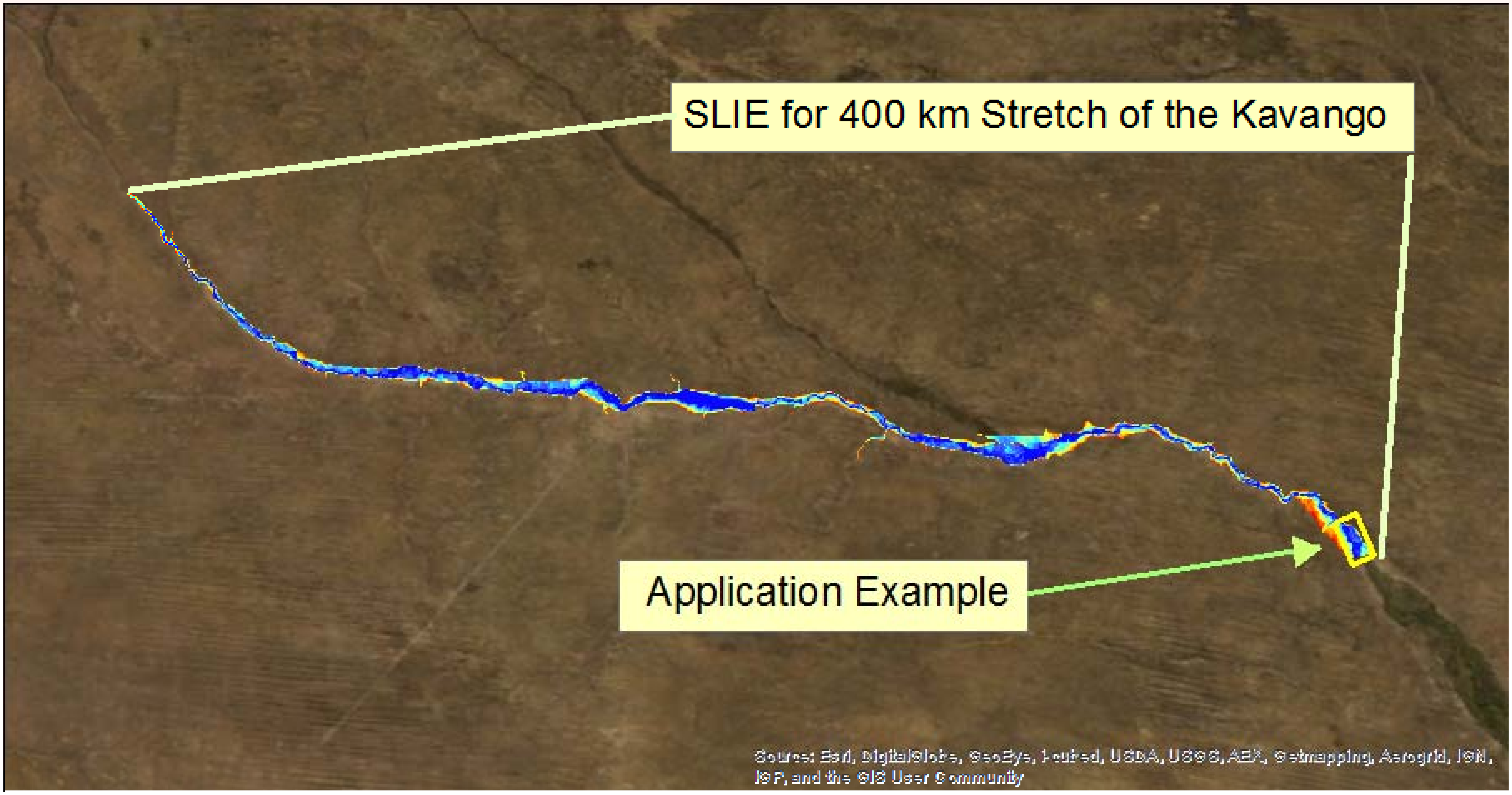
Step I: Rainfall-infiltration Partitioning (Distributed and Time-variant)

Step 2: Flow Routing using Macro-scale Cell-to-Cell Algorithm

Step 3: Flood Inundation Mapping

Segmented Library of Inundation Extents (SLIE)

Kansas Applied Remote Sensing Program (KARS) - The University of Kansas

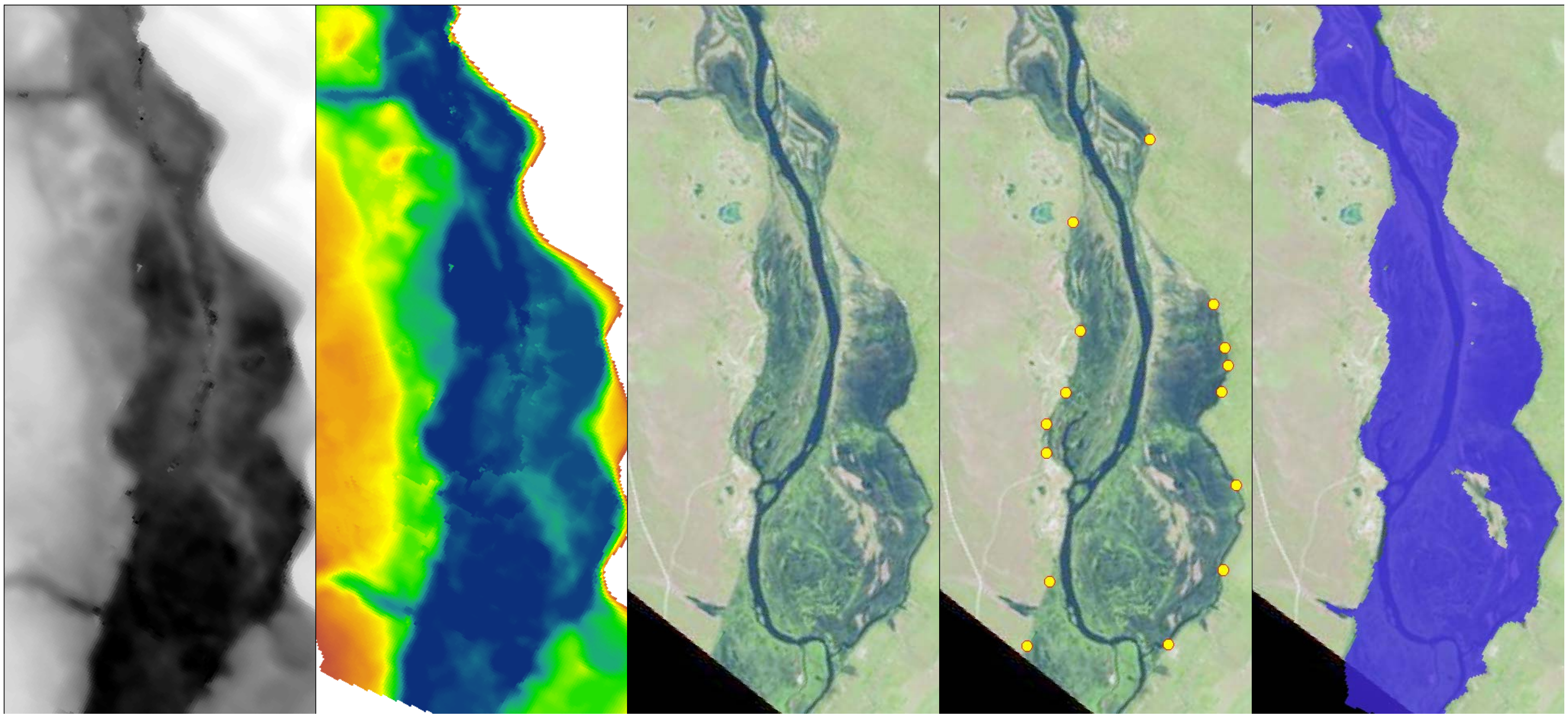


More info: kevindobbs@ku.edu

Segmented Library of Inundation Extents (SLIE)

Kansas Applied Remote Sensing Program (KARS) - The University of Kansas

Use Best Available DEM	Produce **SLIE** for **Full Range** of Flood Levels (in advance)	Example: May 2000 Flooding Kavango - (Landsat)	SLIE Selectors :**GPS, Image Point Extraction, Stream Gauge, GFDS**	Select Corresponding Library Elements to Produce Flood Map

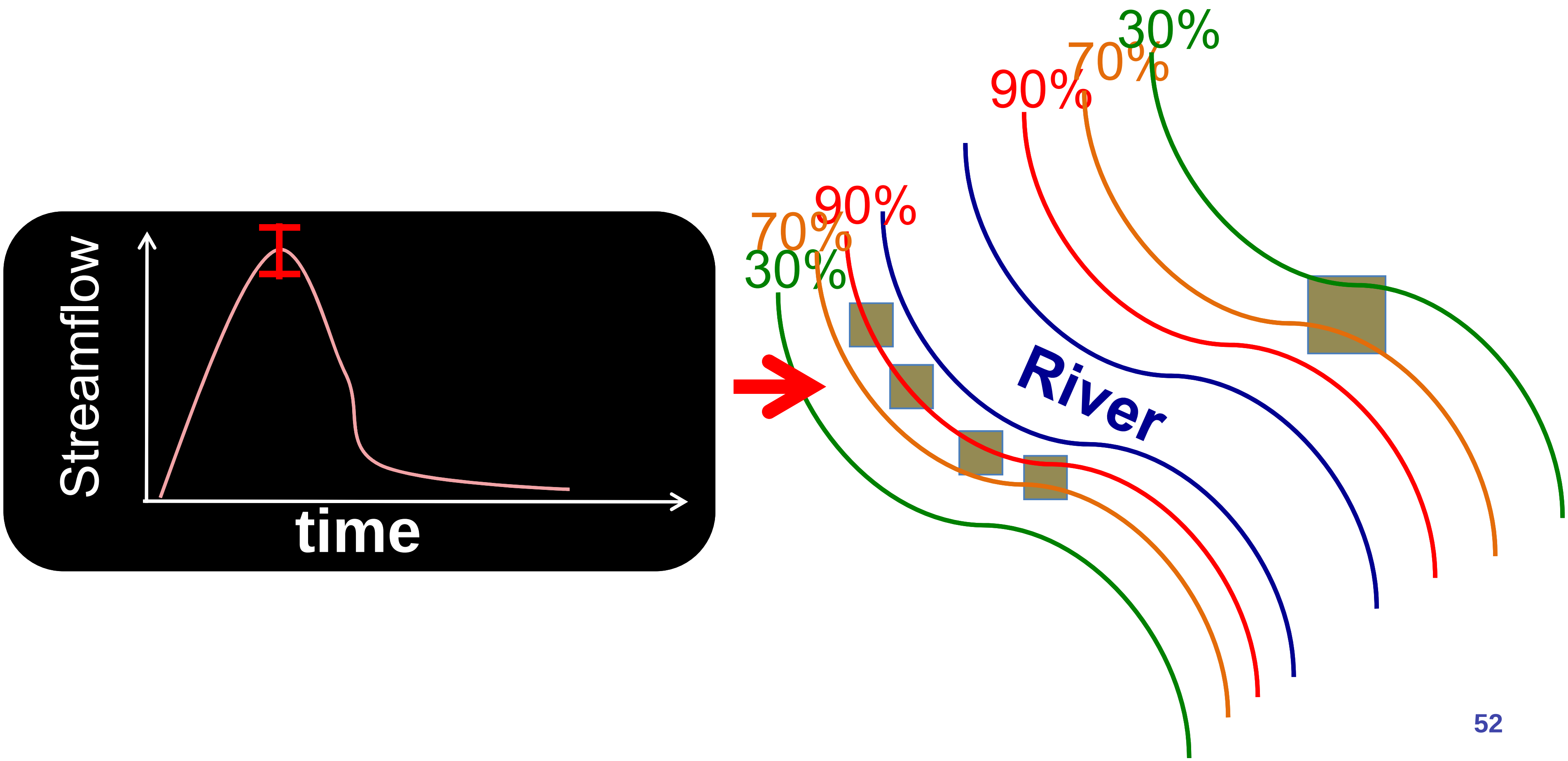


Approximately 6 x 15 km Lower Kavango	Automated Parallel Processing Over Large Areas to Produce Library		Example of Image Point Extraction (or Simulated GPS Points)	Actual Extent Layer Produced from Points – **Rapid Turnaround Time**

More info: kevindobbs@ku.edu

End Goal!

- Use historical Moderate Resolution Imaging Spectroradiometer (MODIS), Radarsat, and Earth Observing-1 (EO-1) Water Level Maps to relate **Hydrologic Model Streamflow** to **Spatial Extent of Flooding**.



Timeline of Initial Activities Related to Namibia Early Warning Flood Project

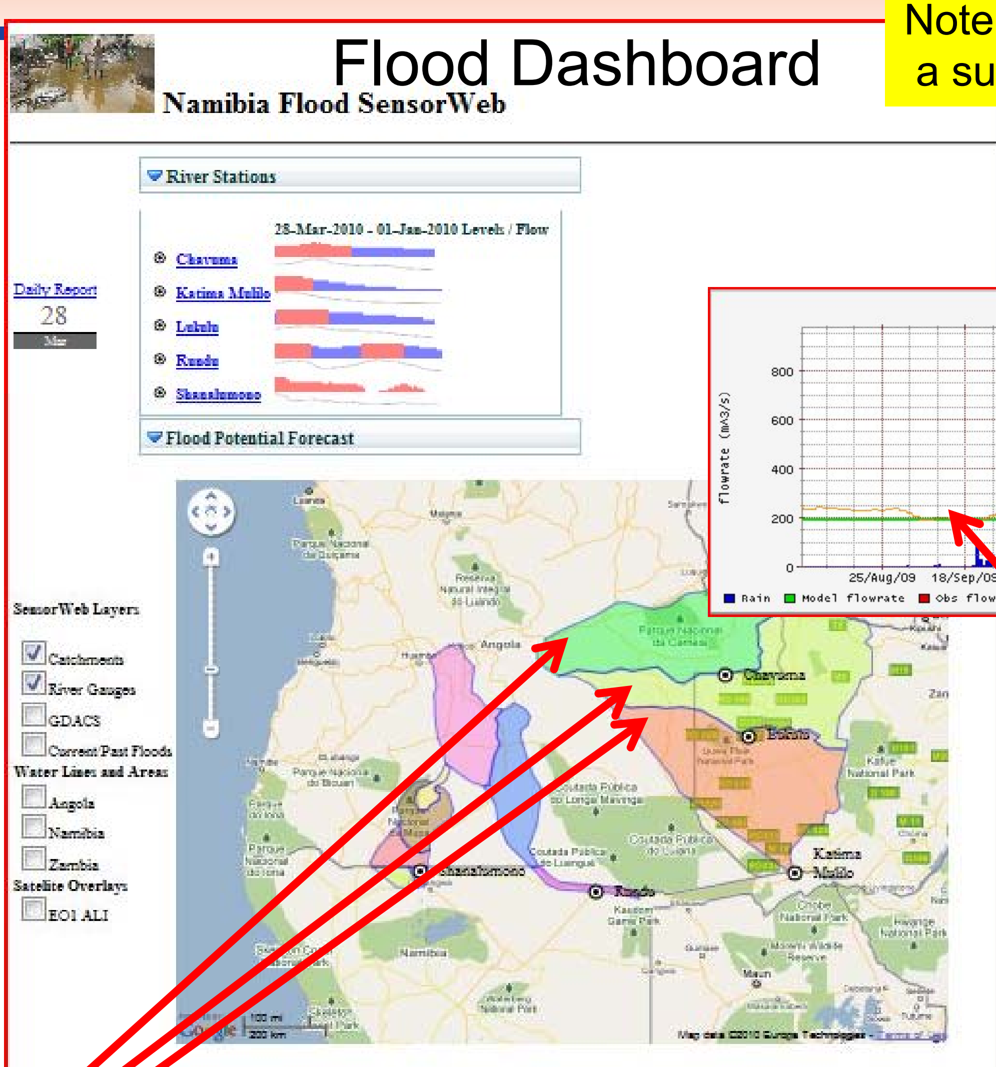
Coordination Meetings at UN in Bonn Germany 2009

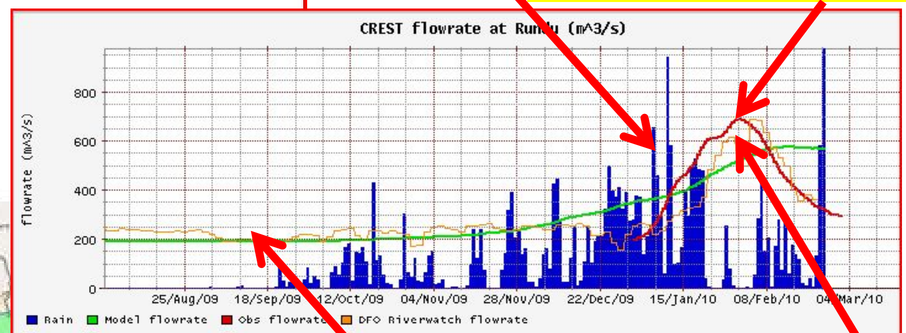
Flood SensorWeb Workshop Held in Windhoek, Namibia in January 2010

Front Row: left to right, Gail D. Mathieu, U.S. Ambassador to Namibia, John Mutorwa, Minister of Ministry of Agriculture, Watery and Forestry (MAWF) and Kari Egge, UN Resident Coordinator in Namibia

The following agencies contributed to establish an international expert team and sent representatives to this field mission:
European Commission, Joint Research Center (JRC), Italy; German Aerospace Center (DLR), Germany; German Technical Cooperation (GTZ), Windhoek, Namibia; International Institute for Geo-Information Science and Earth Observation (ITC), University of Tuente,
The Netherlands; National Aeronautics and Space Administration (NASA), US; NOAA / National Environmental Satellite Data and Information Service (NESDIS),US; Ukraine Space Research Institute (USRI), Ukraine; UNESCO; United Nations Resident Coordinator, Namibia; United Nations Office for Outer Space Affairs (UNOOSA), Austria/Germany; and World Meteorological Organisation (WMO).

2010 Initial Experiment to Correlate Remotely Sensed Rain Upstream with Flood Wave Downstream





Note blue bars (TRMM data) indicating a surge of rainfall upstream

Then a flood wave appears downstream at Rundu river gauge days later (gauge data)

Early CREST Model trying to predict flood wave (Green)

Riverwatch Model trying to predict flood wave (Orange) Better than CREST based on AMSR-E

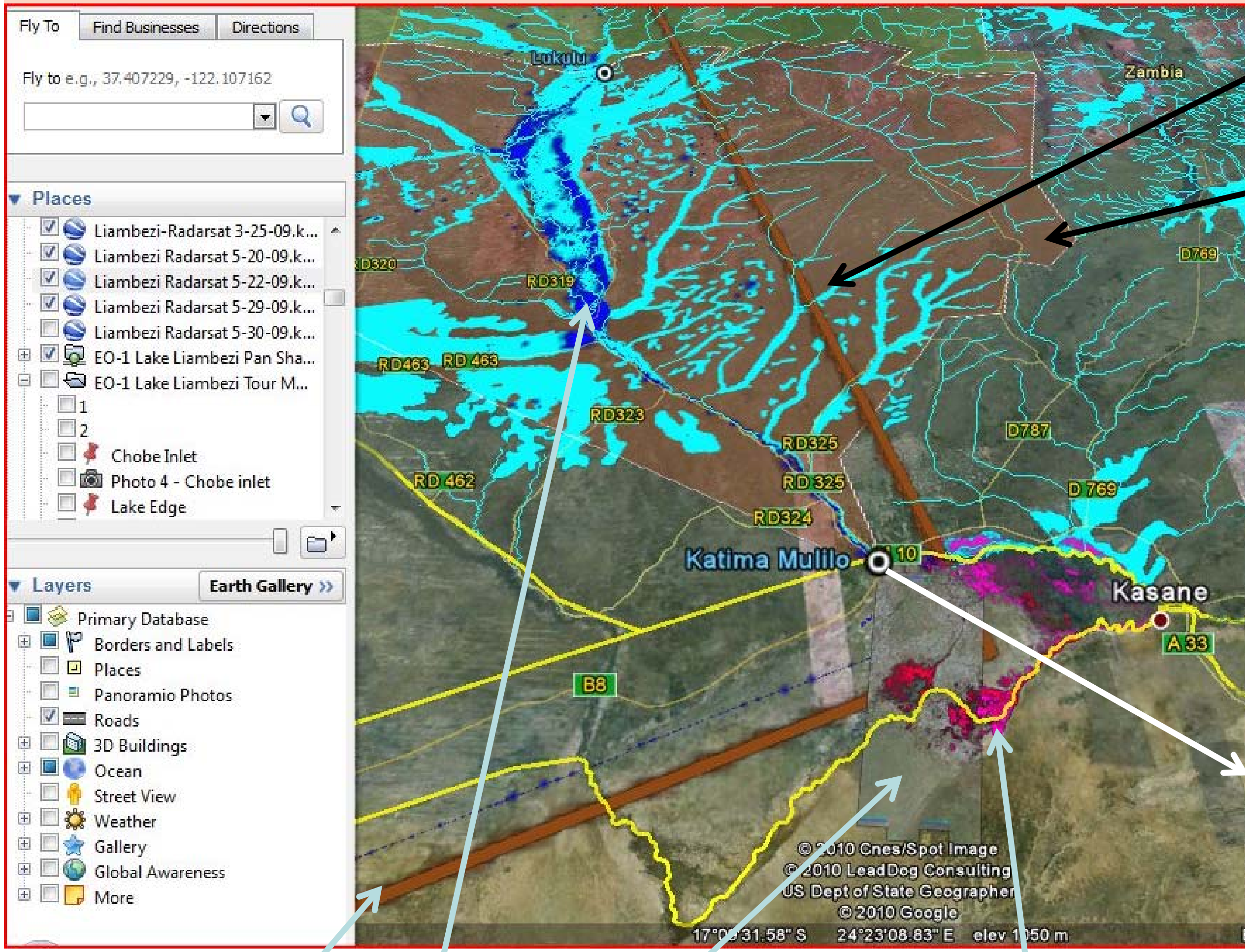
Zambezi basin consisting of upper, middle and lower catchments

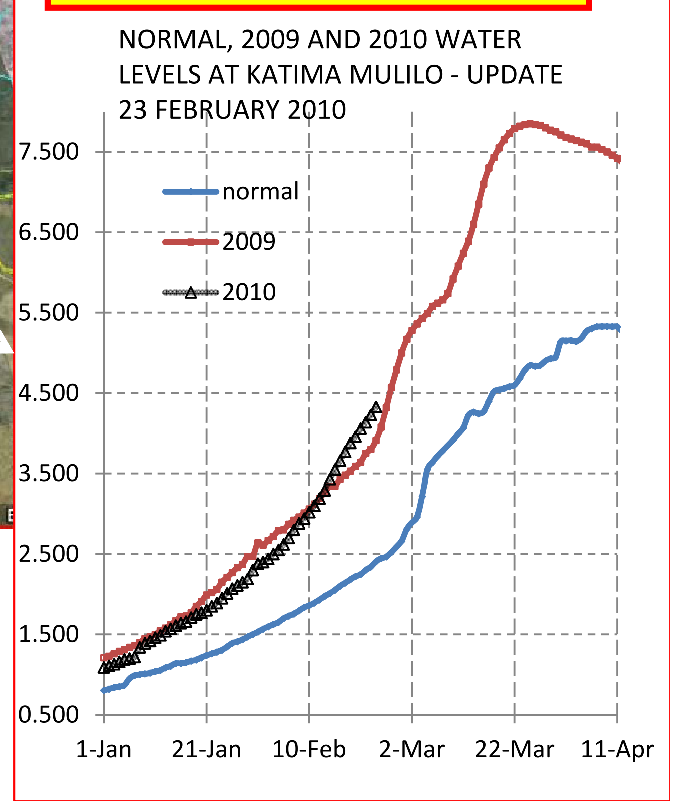
Early Look at Inundation Extent Related to River Height

Zambia water lines from old database

Lower Zambezi catchment

Multiyear river gauge measurements





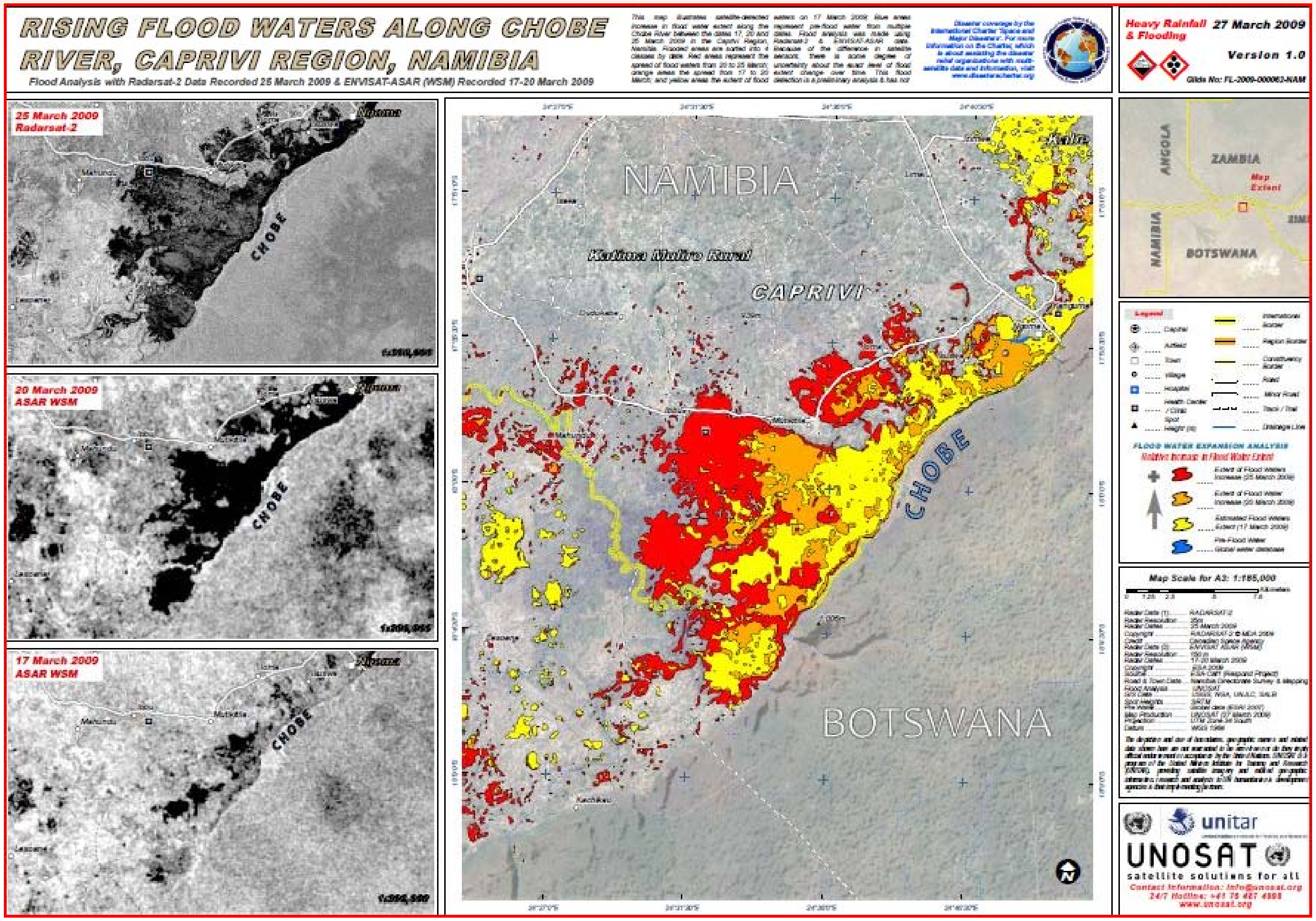
Envisat swath

Envisat Data March 2009

EO-1 Data March 2009

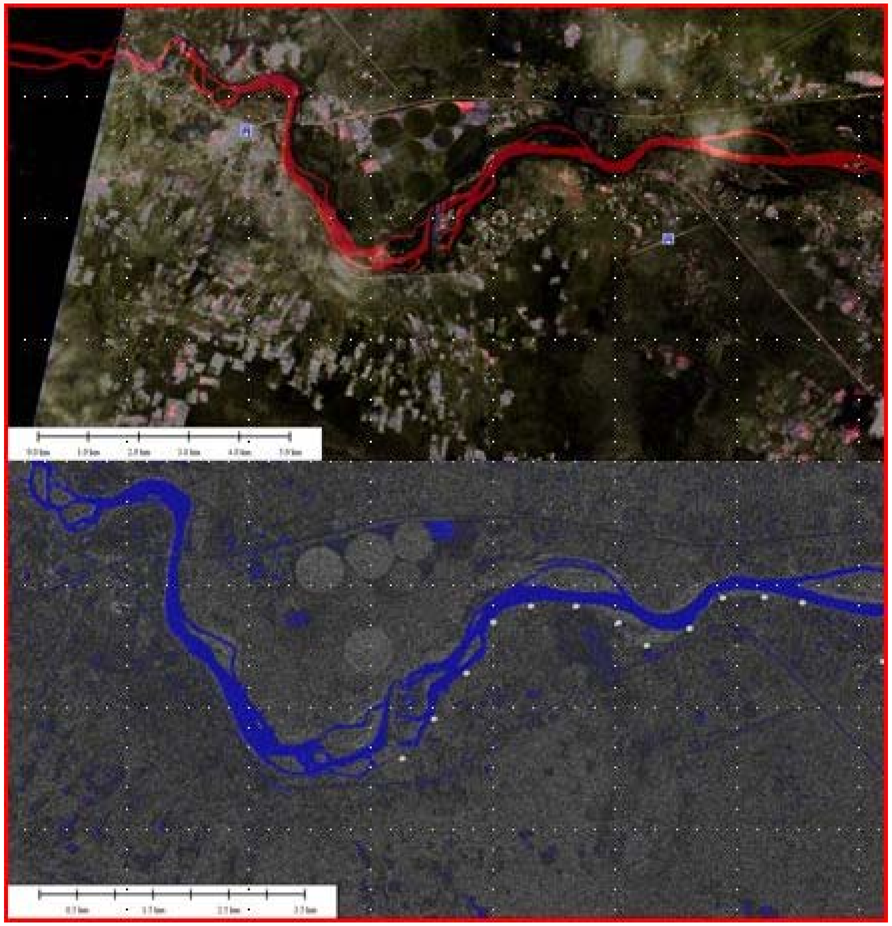
Radarsat Data March 25, 2009

Unosat Flood Time Sequence In March 2009 in Caprivi when Katima Mulilo River Gauge Above 7.5 M



Vision is to generate similar product automatically when floods predicted and pair them with river gauge measurements

Repeat Process with Namibia Data Gathered January 2012 Radarsat, EO-1 and Ground GPS



McCloud Katjizeu (orange) Dept. of Hydrology compares GPS readings of control point with Univ. of Namibia students for mapping exercise.

Georeferenced photos enable Rob Sohlberg/Univ. of Maryland to train classifier algorithm to detect presence of water in grassy marsh lands from satellite data.

Explored Socioeconomic Assessment

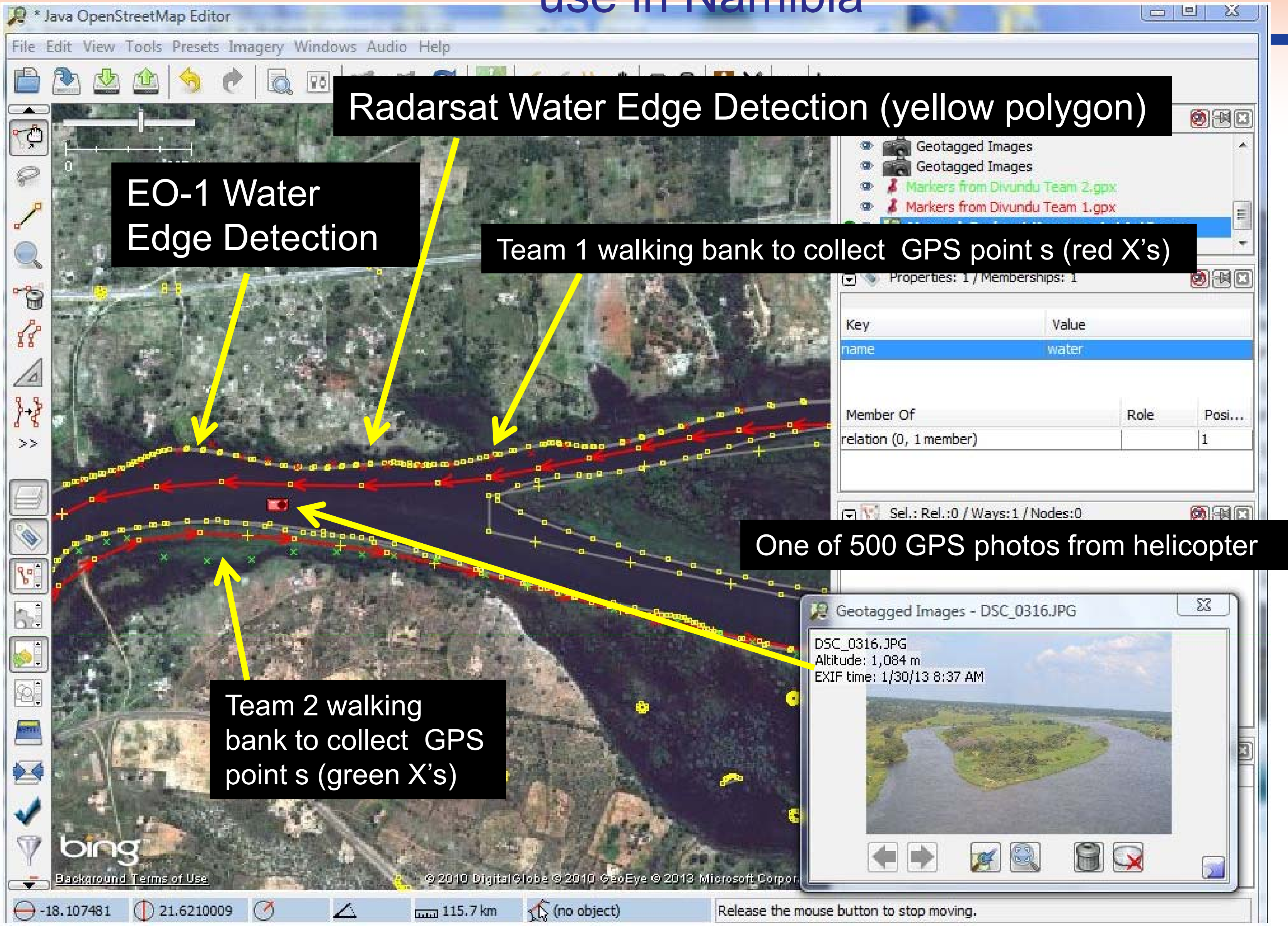
Left to Right: Matt Handy (NASA), Reinhold Kambuli (NDH), Village Resident, Dr. Julie Silva(UMD), John Moyo(Local Guide)

Preliminary visits to flood prone villages to gauge community interest in participating in socioeconomic surveys and assess familiarity and perceptions of radio flood forecasts.

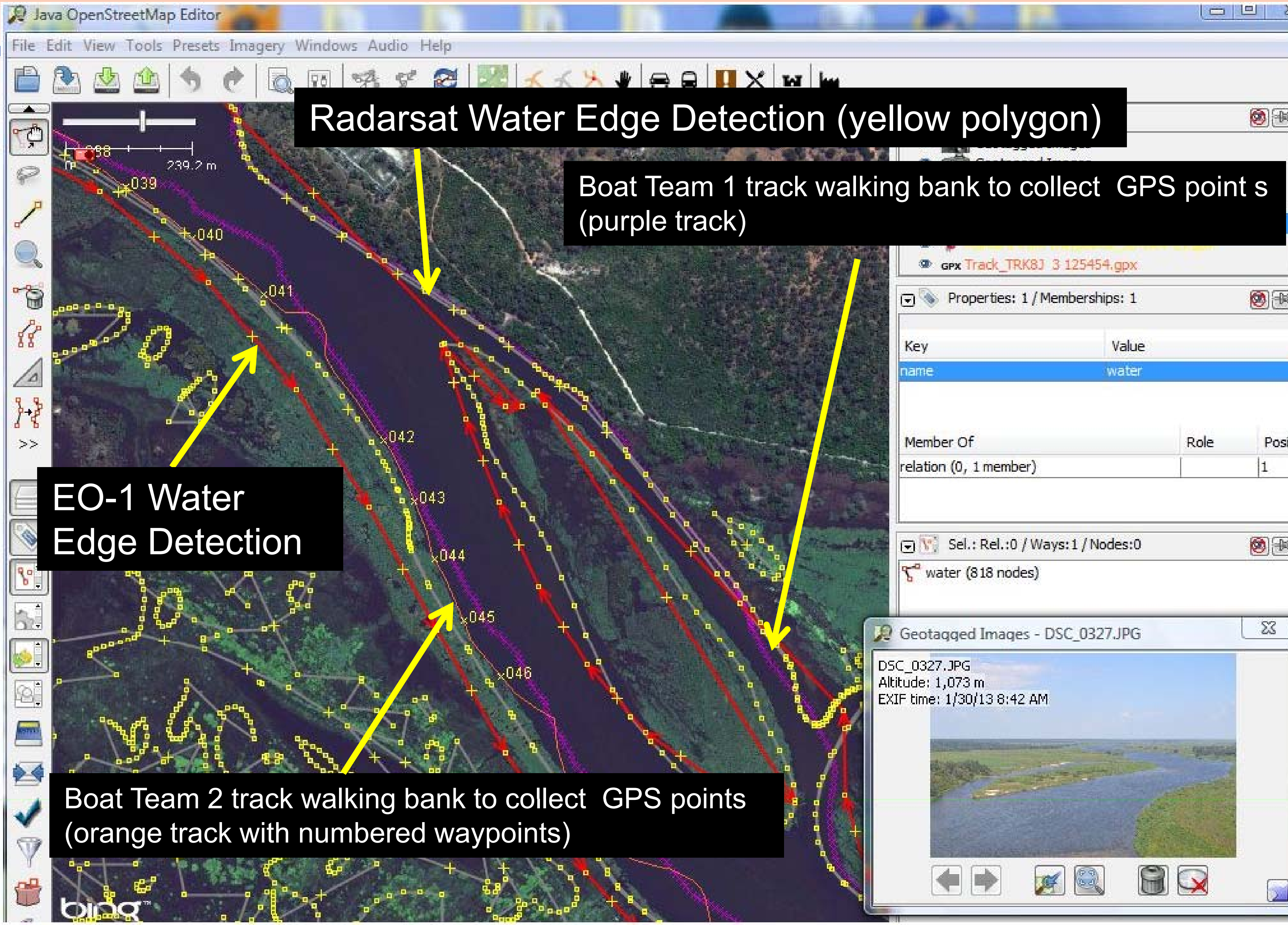
Flooding and Impacts on Local Livelihoods

Villager shows flood damage and impact during team site assessment

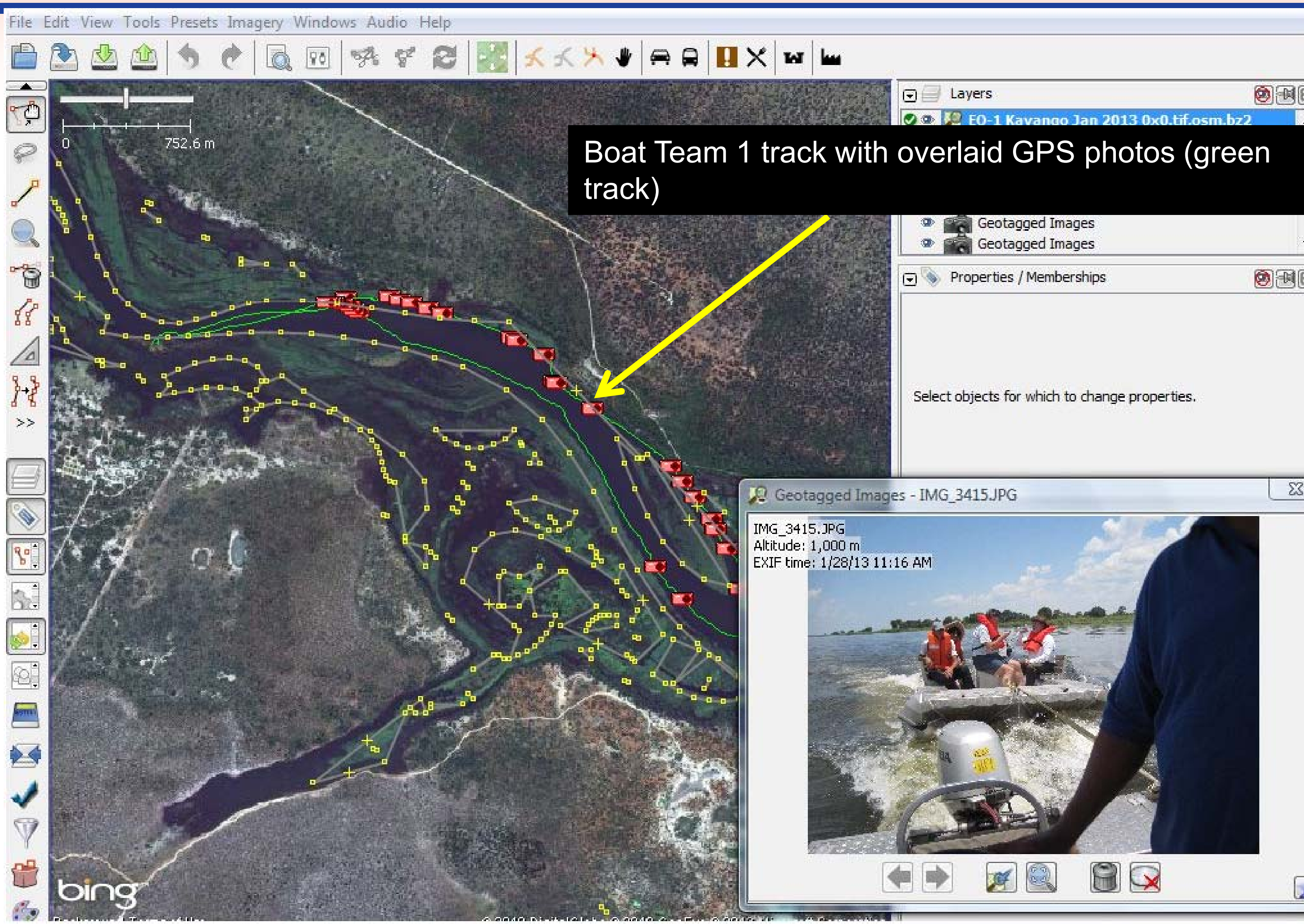
Conducted field exercises around Kavango river in 2012 and 2013 to train in country hydrologist and research methods to use in Namibia



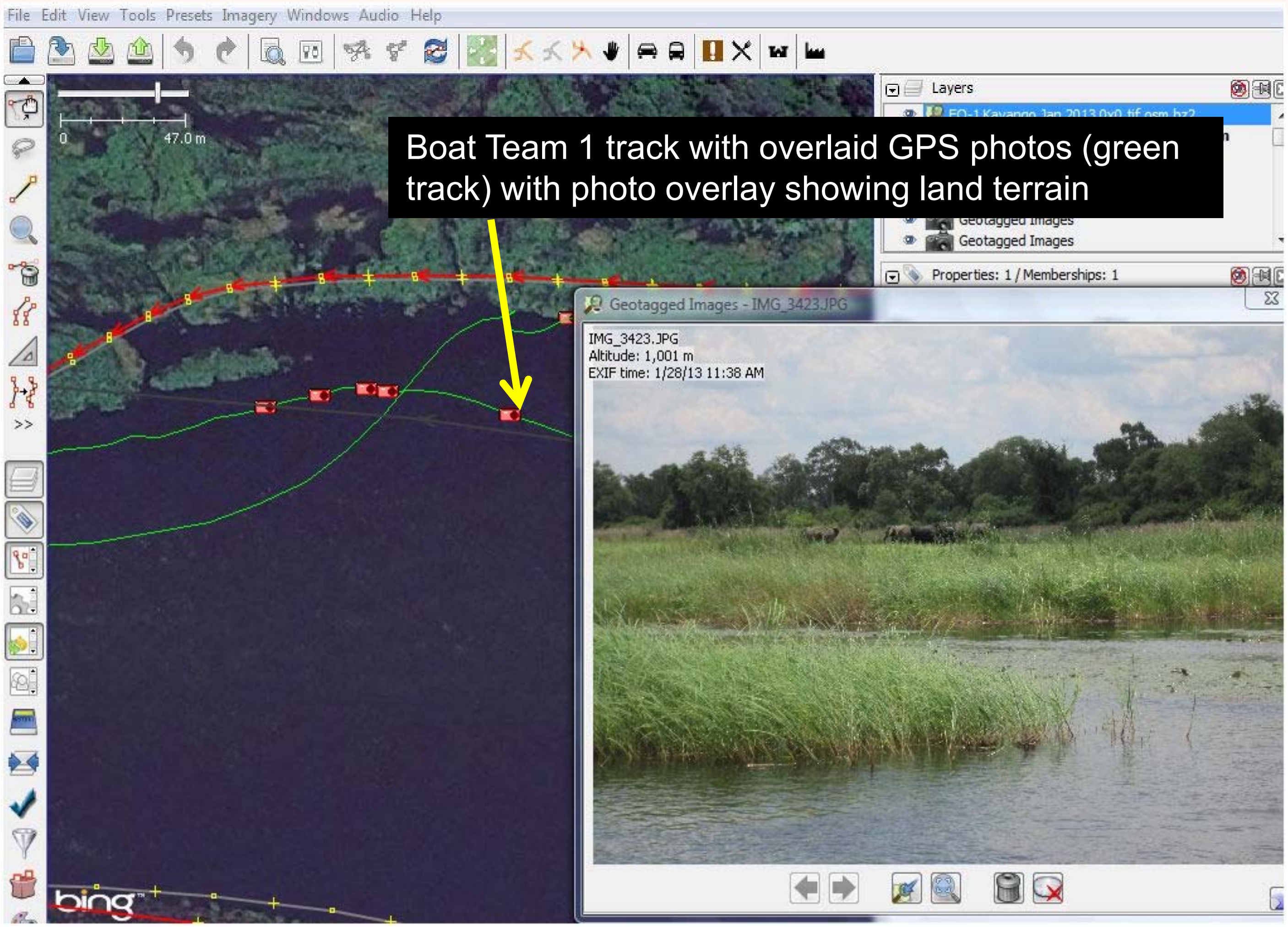
Integrated Water Edge Detection Display with Boat GPS Measurements, GPS located photos, Radarsat/EO-1 water edge detections



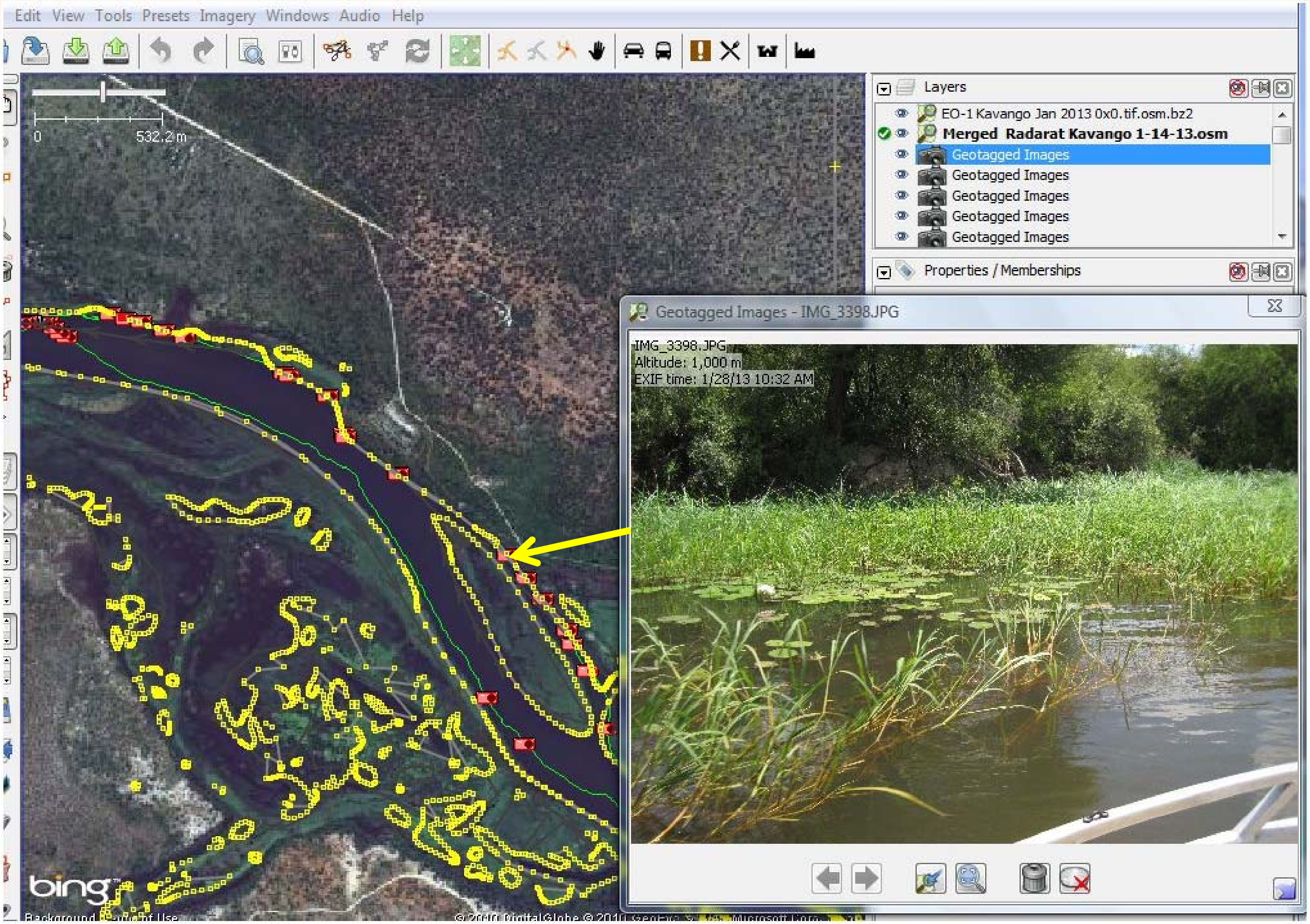
GPS photos Overlaid on Boat Track



GPS Photo Shows Terrain Type Overlaid on Boat Track (geotagged elephants!)

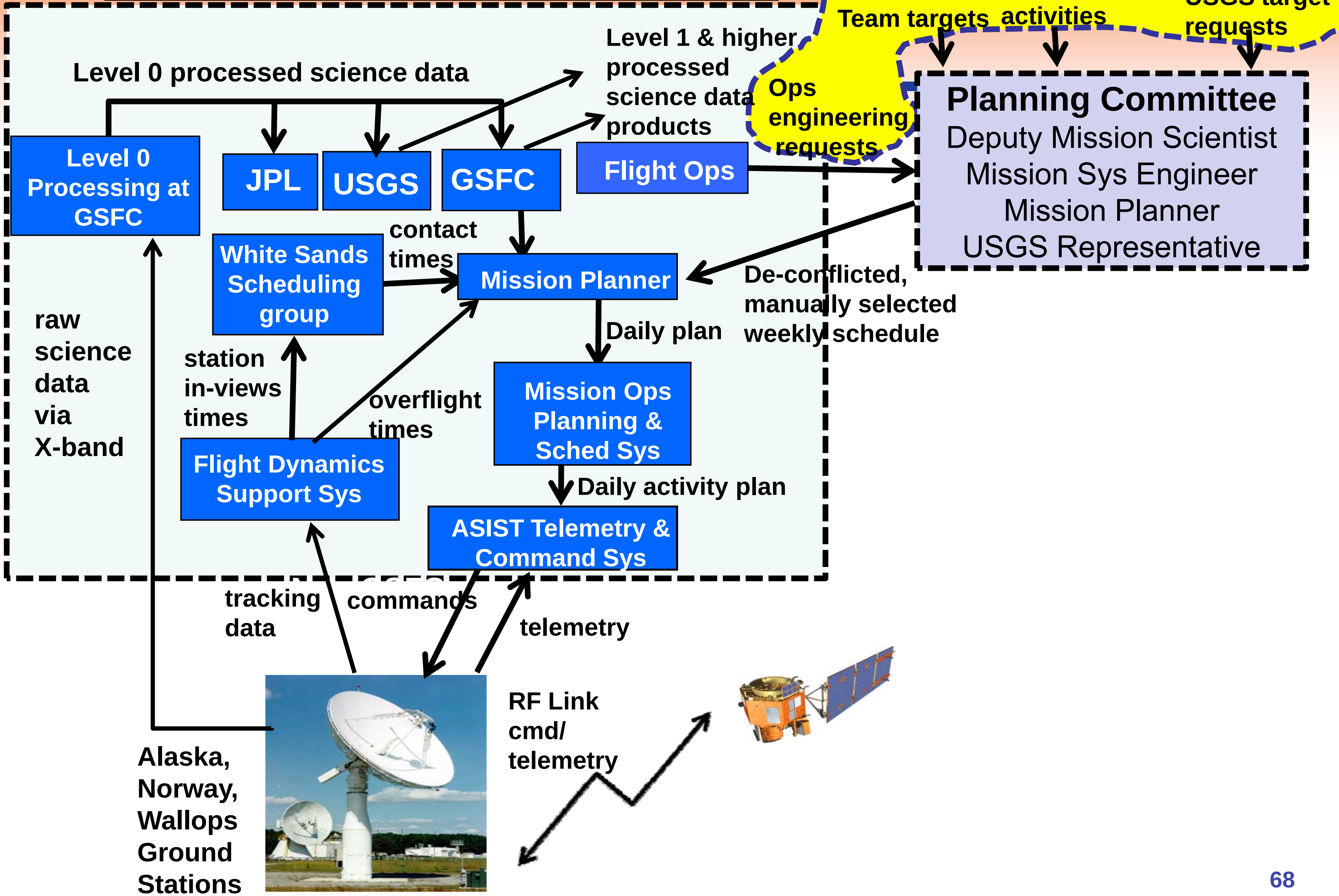


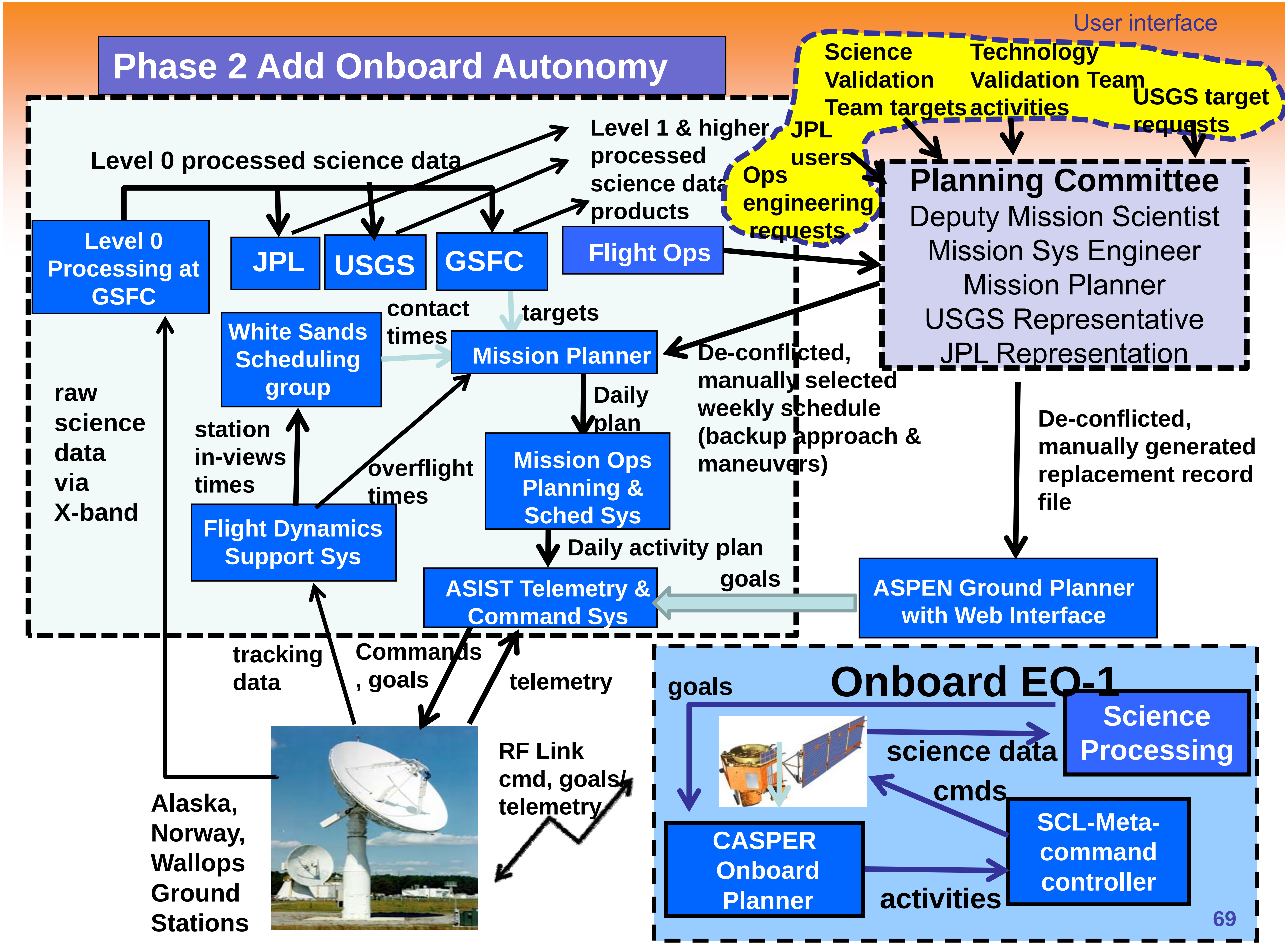
GPS Photo Shows Terrain Type Overlaid on Boat Track and Radarsat/EO-1 Water Detection

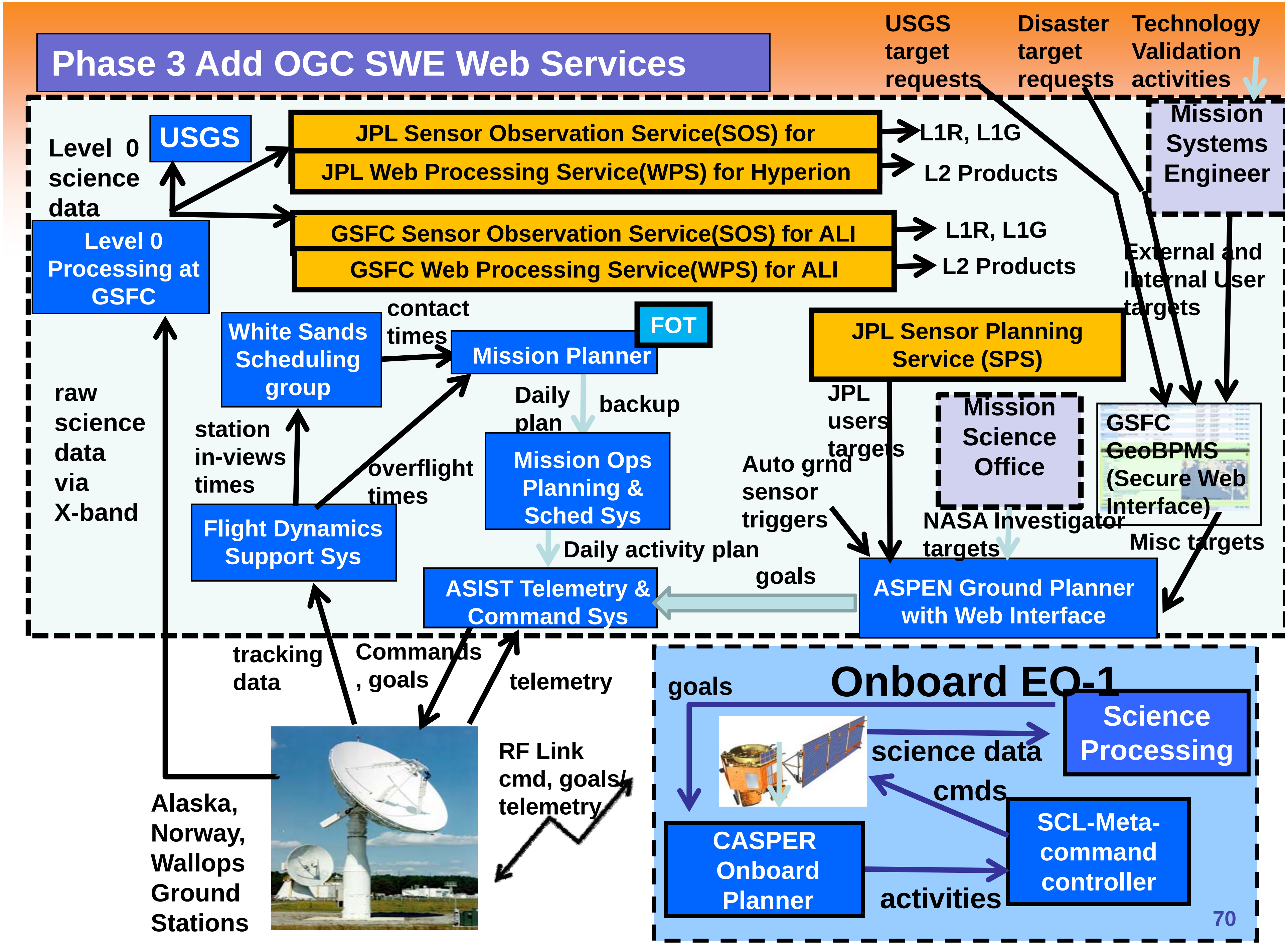


Backup

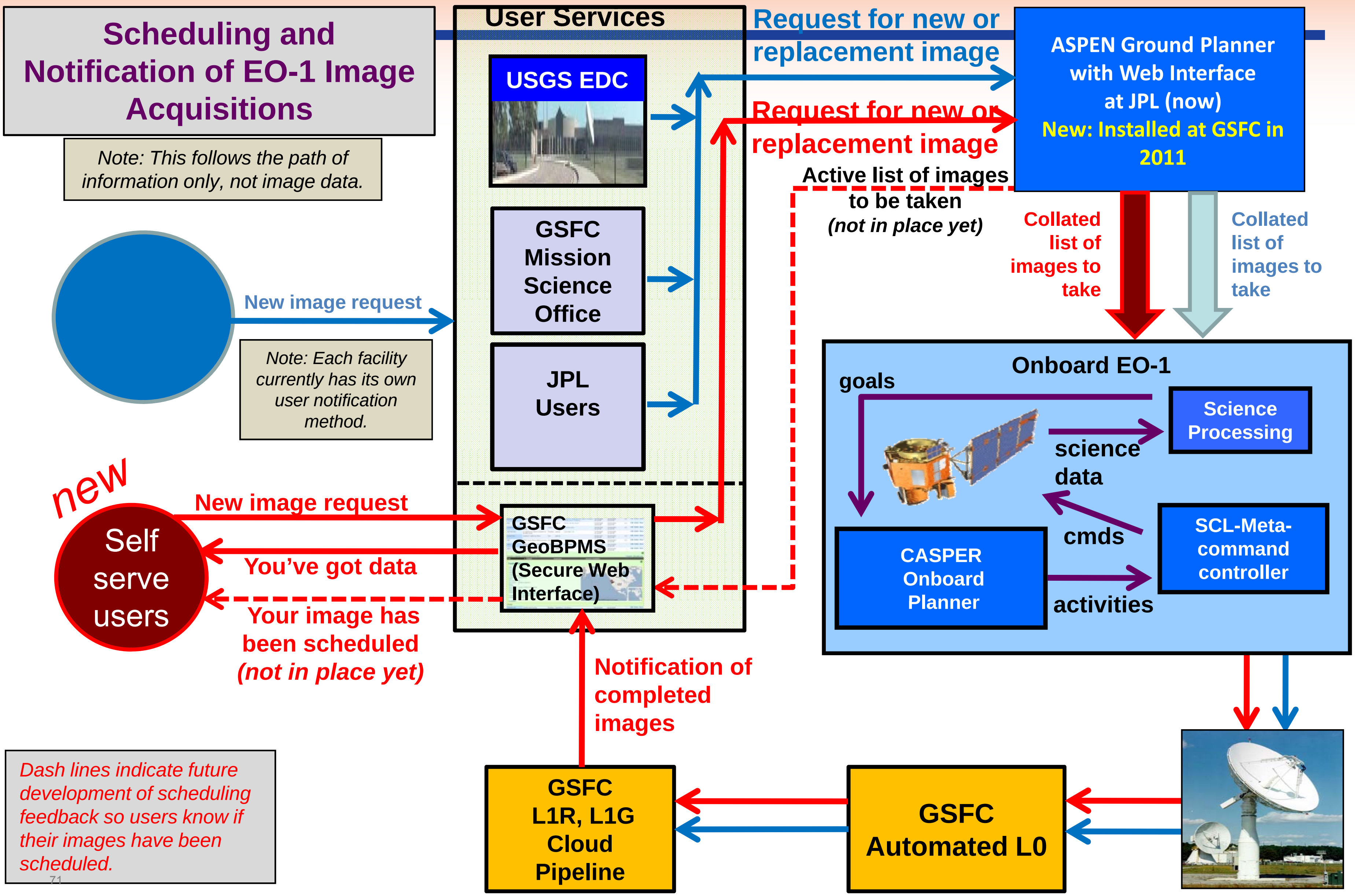
Phase 1 Standard Ops Architecture




Phase 2 Add Onboard Autonomy
User interface
Science Validation Team targets
Technology Validation Team activities
USGS target requests
JPL users
Ops engineering requests
Planning Committee
Deputy Mission Scientist
Mission Sys Engineer
Mission Planner
USGS Representative
JPL Representation
Level 0 processed science data
Level 1 & higher processed science data products
Level 0 Processing at GSFC
JPL
USGS
GSFC
Flight Ops
White Sands Scheduling group
contact times
targets
Mission Planner
De-conflicted, manually selected weekly schedule (backup approach & maneuvers)
Daily plan
raw science data via X-band
station in-views times
overflight times
Mission Ops Planning & Sched Sys
Flight Dynamics Support Sys
Daily activity plan
goals
ASIST Telemetry & Command Sys
De-conflicted, manually generated replacement record file
ASPEN Ground Planner with Web Interface
tracking data
Commands, goals
telemetry
RF Link cmd, goals/ telemetry
Alaska, Norway, Wallops Ground Stations
Onboard EO-1
goals
Science Processing
science data
cmds
CASPER Onboard Planner
SCL-Meta-command controller
activities
69


Phase 3 Add OGC SWE Web Services
USGS target requests
Disaster target requests
Technology Validation activities
Mission Systems Engineer
Level 0 science data
USGS
JPL Sensor Observation Service(SOS) for
JPL Web Processing Service(WPS) for Hyperion
L1R, L1G
L2 Products
Level 0 Processing at GSFC
GSFC Sensor Observation Service(SOS) for ALI
GSFC Web Processing Service(WPS) for ALI
L1R, L1G
L2 Products
External and Internal User targets
raw science data via X-band
White Sands Scheduling group
contact times
FOT
Mission Planner
JPL Sensor Planning Service (SPS)
JPL users targets
Mission Science Office
GSFC GeoBPMS (Secure Web Interface)
station in-views times
overflight times
Daily plan
backup
Mission Ops Planning & Sched Sys
Auto grnd sensor triggers
NASA Investigator targets
Misc targets
Flight Dynamics Support Sys
Daily activity plan
goals
ASIST Telemetry & Command Sys
ASPEN Ground Planner with Web Interface
tracking data
Commands, goals
telemetry
Onboard EO-1
goals
Science Processing
science data
cmds
RF Link cmd, goals/ telemetry
Alaska, Norway, Wallops Ground Stations
CASPER Onboard Planner
SCL-Meta-command controller
activities
70

Detail of Phase 3 – User Services



Phase 4 Add Cloud Computing

Technologists
NASA Investigators
Disaster Responders

Starlight 100 Gigabit Ethernet Exchange

Hyperion and ALI Level 0 Processed data from GSFC, building 3 server

Matsu Cloud

http server

Level 1R and Level 1G Processing for ALI & Hyperion

Co-registration with Landsat GLS

Web Coverage Processing Service (WCPS) to enable users to customize Level 2 products

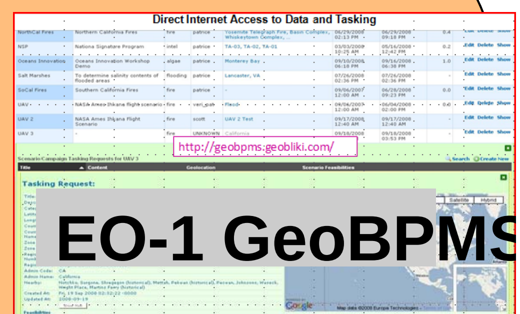
Atmospheric Correction for ALI & Hyperion

Multi year data product archive

Matsu Cloud
- Eucalyptus/Open Stack-based Elastic Cloud SW
- 300+ core processors
- 500+ Tbytes of storage
- 10 Gbps connection to GSFC
  - being upgraded to 100 Gbps

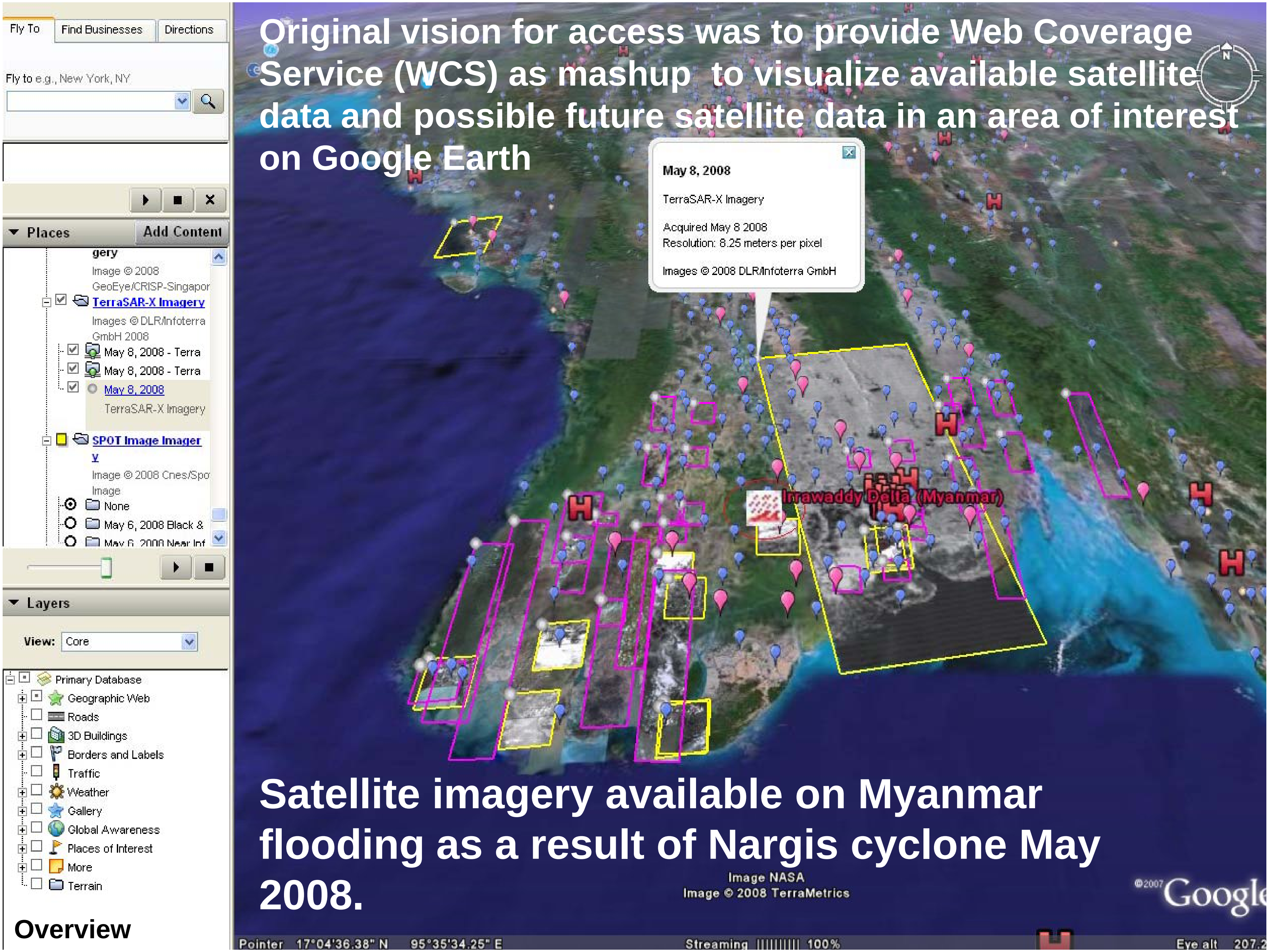
(Part of OCC)
- Hadoop Tiling/MapReduce/Accumulo
- Supplied by Open Cloud Consortium
- Open Science Data Cloud Virtual Machines & HTTP server to VM's

Joyent Cloud



Joyent Cloud
- Ruby on Rails
- 3 processors
- 3 Tbytes of storage

Original vision for access was to provide Web Coverage Service (WCS) as mashup to visualize available satellite data and possible future satellite data in an area of interest on Google Earth



Satellite imagery available on Myanmar flooding as a result of Nargis cyclone May 2008.

Overview

NASA