Goddard SPACE FLIGHT CENTER

National Aeronautics and Space Administration

SensorWeb as an Enabling Step for Holistic Remote Sensing

Dan Mandl
Steve Ungar

IS&T Colloquium
May 22, 2013

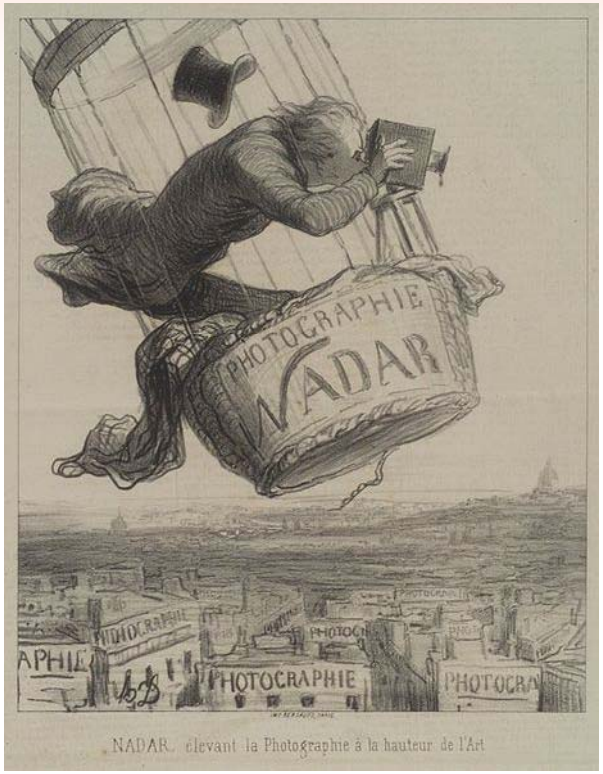
NASA • GSFC• JPL/Caltech • Ames

“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

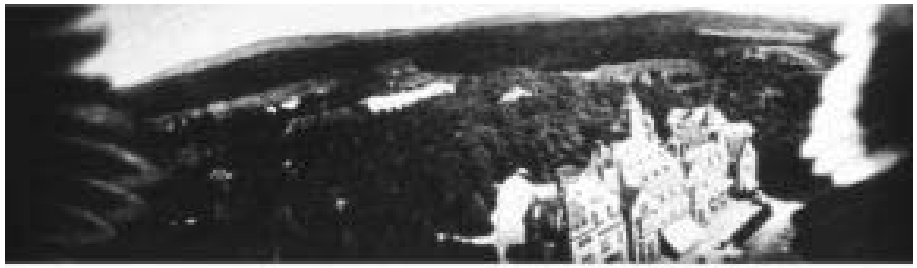
Early remote sensing



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

"DIT word nou regtig belaglik," het MTC-ginter die jongste skoot in 'n vuurwarm debat oor die Namibiese Kommunikasiekoerseunie (NCC) se opdrag oor die gebruikbaarheid van helpryse tussen selfoonverskaffers laat vlam.

"Ons is weer sleg, sal ons sekre Volvo's aan ander ontwerke se klikrate moet begin uitdeel ..." het woordvoerder Tim Ekandjo oor die bewerende neerslagtering van die beloerde gevat.

MTC bly sterk gehaat teen die monopolie gevolge van die telekommunikasiewaghond se besef vir die hoge grein opreepe en SMS's wat die flenoerskuffer aan sy ele klikrate hou. Mnr. Ekandjo het aanvrygings verweerp dat die MTC-bestuur se voorstel gespeelpel in die Asech-Asech pakket, in stryd met die NCC se opdrag is.

Na tien dae kon die beloerd volgens MTC nog net beloerkeur vanaf lés en Switch met 4% verhoog en verkeer na MTC met 2%. "Die beskuit gaan nie ons nodedingers bereenbied nie," het mnr. Ekandjo aangeneer.

"En ons het nog geen klikrate verhoe nie. Ons is ook vol rectrone dat dit nie gaan gebeur nie."

Mnr. Ekandjo het egter toegegee dat die syfers later kan verander. Volgens MTC se eerste 70% – 'n verhoe op sy deelnik gratis – 'n diens waarvan deelnemers mense

Volgens mnr. Ekandjo is die beloerd "vreemd" aan alle gein praktyk in die wereld. Om die beloeren in Kenia, waar 'n soortgelyke beskuit tot onbetaverdig pryswerkel gebe het as 'n sukses-resep te beskou, is volgens MTC 'n rampe in weerling.

Hoewel mnr. Ekandjo toegegee het dat die tarifverskuldig nodig was het die NCC-beskuit nie was as 'n ondersteek volgens MTC tog gevalle.

Die maatskappy staan by sy punt dat die beloerd belegginge kon ontwikkeling. Volgens mnr. Ekandjo sal dit egter "'n punt maande" neem om te sien hoe MTC se uitvolgkoms vir vierde generasie-tegnologie (4G) dalk gemaak gaan word.

"Ons het die beset reeds redelig gevolge op 1 Maart," het mnr. Ekandjo oor ondedingers se klagte gesê.

Die kenedyvoere van MTC se hongerde beroisningsaanstaark in die Hoëlstad is volgens mnr. Ekandjo "om die belange van verbruikers te beskerm". Die opsie om 'n interdik te bekom, is volgens MTC bloot laat vaar op grond van die NCC se advies dat gratis optreepe en SMS's nie ons gemak word tie.

"Ons klikrate is nie opgeskuif in hul eie rameerk nie," het mnr. Ekandjo gesê. "Indien dit so sou wees, sal ons ook nie kon kwyte is die sukses-syfers later kan verander. Volgens MTC se eerste 70% – 'n diens waarvan deelnemers mense

Reënkanse kwyn

• Dani Booysen

HOEWEL reëlvisie oor die naweek in die noordelike en sentrale gedeeltes van die land sal voorkom, gaan die intensiteit van reenvlae volgens die weerkantoor begin afneem.

Kuise op reën in die Suide bly steeds.

Droogtelande bly die eer hoogste vloedmaatskappy vir die Verre Noorde en newerheenwers langs die Okavangoriver van krag.

By Engela het waterhakke sindag aandvoo etyg, maar weer effekte rondom Okatana en Oshakati gebe het.

"Nog vir almal wie se blyplek onder water is, het al getrek nie," het mnr. Kingsley Keetman, die Namibiese Rooi Kruis se hoofcoordeer vir rampbestuur, gister per selfoon aan *Republikein* sê 'n vloedkamp op Ngoma in die Caprivi gesê.

Die nuwste inwoners van oorstroonde nedersettinge elders in die Zambezirivier se vloedvlaktes is egter volgens hom al in herwerdigingsentra by bynoorheid Schuylenaarsdweg, Kabbe en Luiene.

Sonar 3 000 mense is al in die Caprivi bereenig, waarvander 'n bereenede 2 000 skeedelanders. Die Rooi Kruis is egter nog besig om die inligting te verifieer.

Die grootste bedreiging vir verdere opdroog van die vloedwaters is donderbuie in die weerkantoor. Die hoogste lesings wat gisteroggend aangeteken is, was 9,4 mm by Bukspan en 3,4 mm op Gobabis.

Die Kuisrow was gister by Runtuna op 7,16 m nog 12 cm dieper. Volgens staatshidrolog Guido van Langenhove het die Kavadese Ruimteagentskap intussen aangetoon met satellietbeeld's van die huidige vloede in Noord-Namibië te neem en behoort die beelde vroeëagse beskikbaar te wees.

NCCI vra ekonomiese groei

• Francoise Steyaerg

DIE Namibiese Kamer van Handel en Nywerheid (NCCI) verwelkom die begroeting en woensdag die Regering aan om te fokus op hul

se pogings te ondersteun wat gerig is op ekonomiese groei en werkskepping. "Ons sal beslis ook kyk na die manier waarop die Geïntegreerde Ingryningsprogram

■ Die satellietfoto van Nasa wys die Angolese vloedvlaktes oos van die Kunenerivier se bokoe tussen Xangongo en Naulila op 7 Maart 2011. Die water in die oshanas vloei afwaarts na Namibië. (Foto verwerk deur Mo-cloud Kaijzeu, Namibiese Hidrologiese Dienste.)

Donderdag 14 April 2011 — Republikein — 3

FLOODING: CAPRIVI (ZAMBEZI RIVER)
SATELLITE IMAGERY: NASA EO1
03 APRIL 2011

PROCESSING: MCCI OUM KAIJEUU

Legend
Health Centers
Schools

ZAMBIA
NAMIBIA
BOTSWANA

Rampsyfers vandag onder die loep

• Dani Booysen

DIE voortgesette daling van watervlakke in die sentrale noorde sal waarskynlik die enigste goeie nuus wees by 'n nasionale indaba van belanghebbendes, wat vandag 'n omvattende verslag oor die gevolge van vanjaar se rekordvloede moet finaliseer.

Vroeër die week het die Verenigde Nasies (VN) se koördinerende kantoor in Windhoek die getal geraakte inwoners op sowat 220 000 mense in sewe streke geskat.

Beide die Okavango-, gister 8,38 m hoog op Rundu, en Zambeziriviere, 6,85 m hoog, styg steeds.

Suid van die grens met Angola het watervlakke by Engela met nog 4 cm na 1,33 m teruggesak. Die ebgety is stadiger in ander oshanas van die Cuvelai.

Op Oshakati het die gemiddelde lesing op 'n hoogte van 1,26 m anker gegooi.

Die vloede was 'n belangrike punt op die agenda van die Namibiese Kamer van Handel en Nywerheid (NCCI) toe die liggaam se direksie vroeg vandeesweek vergader het.

Volgens die NCCI se hoof uitvoerende beampte, mnr. Tarah Shaanika, het die raad sy kommer uitgespreek oor die land se klaarblyklike onvermoë om langtermynoplossings te vind wat die invloed van die waterslag doeltreffend tot die minimum sal beperk.

"Die vloede het verskriklike gevolge op ons ekonomie en die maatskaplike omstandighede waarin ons mense woon," sê die NCCI.

Ongeveer 1 000 sakeondernemings is volgens die kamer deur die vloede geskuit, terwyl ander nie ten volle sake kan doen nie.

Die vierde vloedslag in ewe veel jare beteken volgens die NCCI dat daar meer dringend na "durende oplossings" gesoek moet word.

Die Regering is versoek om die leiding te neem, terwyl die NCCI die ondersteuning van die privaatsektor sal mobiliseer.

Mnr. Shaanika het nog meer besighede aangemoedig om noodlenigingspogings finansieel of op ander maniere te ondersteun.

Vir vandag voorspel die weerkantoor enkele donderbuie in die noordweste en verspreide neerslae oor die sentrale binneland en in die Hardapstreek. Volgens me. Olga Tjiuzea bly die kanse op reën môre dieselfde oor die sentrale binneland en die suide, terwyl buie Saterdag en Sondag ook weer in die noordweste kan val.

Die 11 mm wat tot gisteroggend in en rondom Windhoek gemeet is, was die weerkantoor se hoogste amptelike reënsyfer vir die dag. Op Otjiwarongo het 2,2 mm geval, 1,5 mm op Opuwo en druppels by Okaukuejo, op Mariental en Oranjemund.

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

Foto: Namibiese Hidrologiese Dienste

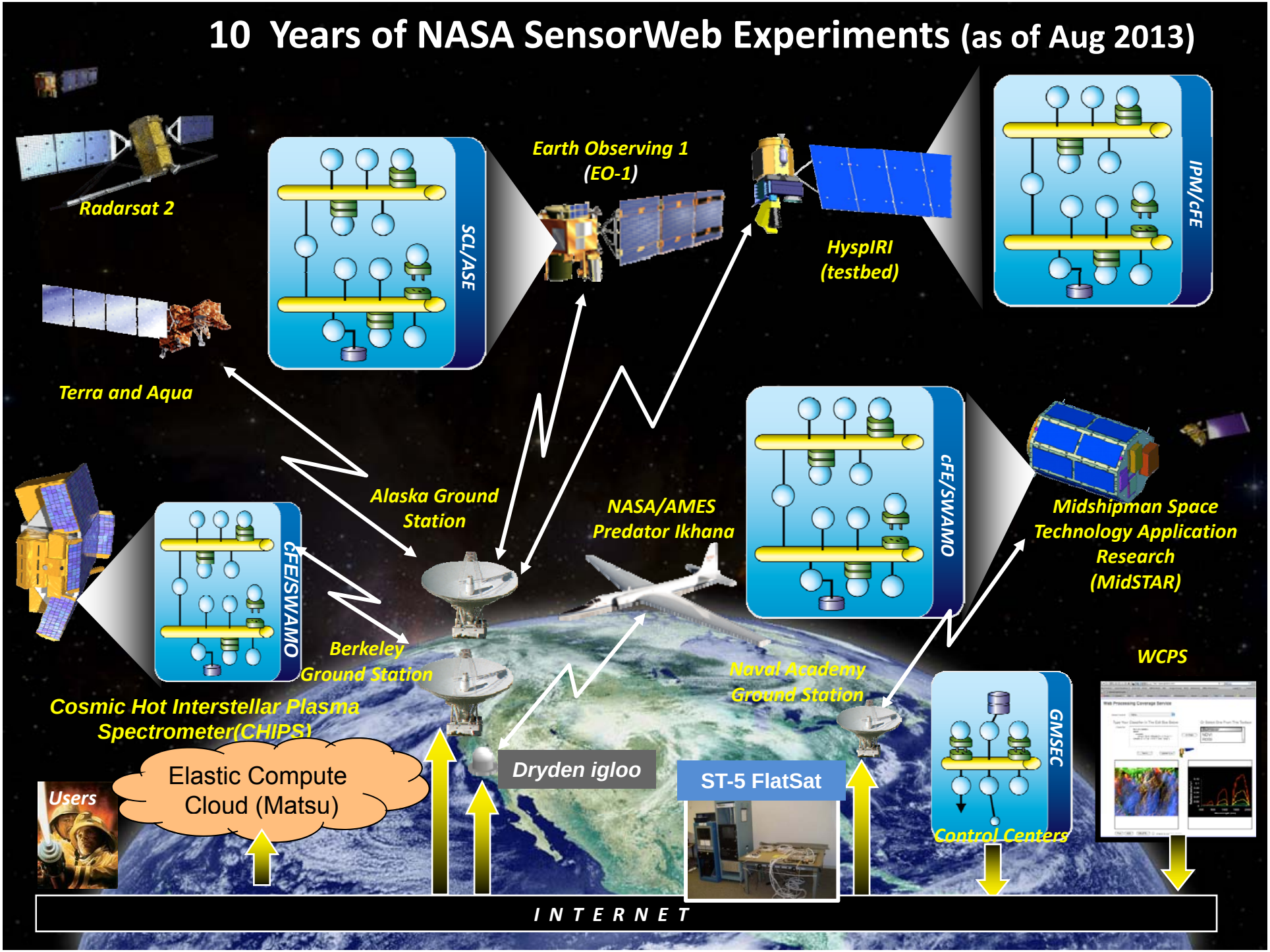
Difference From Constellations

- 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)

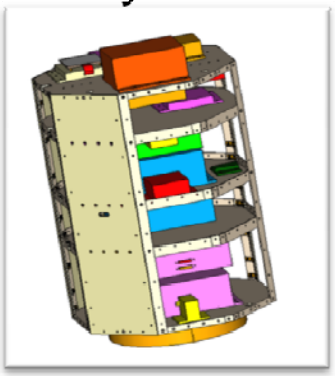
- Holistic ---need to consider observer and observation as a whole to optimize system
- Need to consider the breadth of factors affecting data acquisition and data product production
  - Access/control (open versus closed) and ease of access to sensors
  - Rapid customization
  - Do-it-yourself data 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)

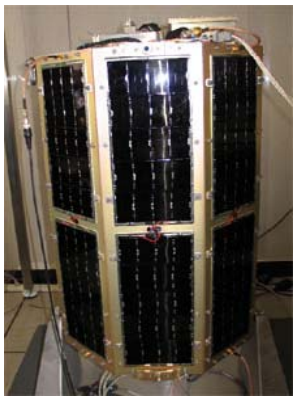
  (Note: for this presentation, will go over selected examples in above list)


10 Years of NASA SensorWeb Experiments (as of Aug 2013)
Radarsat 2
SCL/ASE
Earth Observing 1 (EO-1)
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
Cosmic Hot Interstellar Plasma Spectrometer(CHIPS)
Naval Academy Ground Station
WCPS
Elastic Compute Cloud (Matsu)
Users
Dryden igloo
ST-5 FlatSat
GMSEC
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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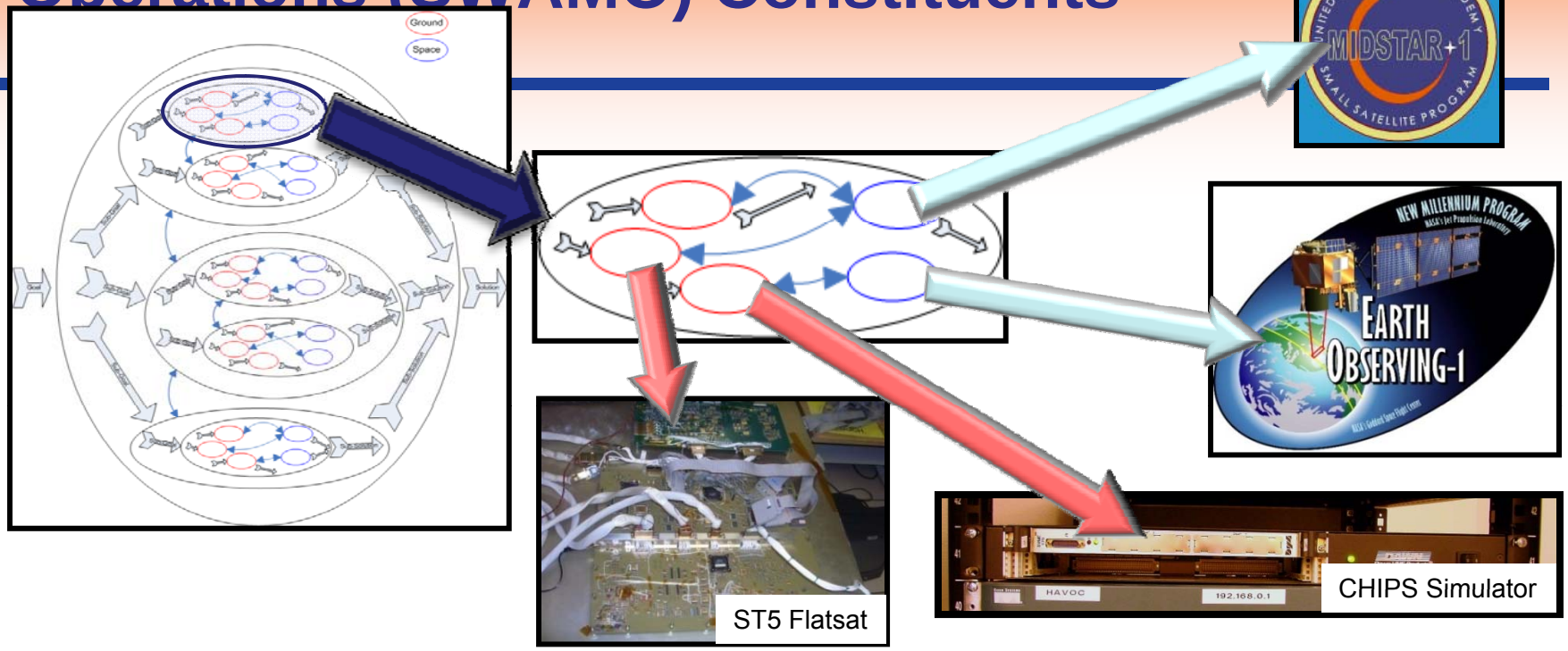
SensorWeb for Autonomous Mission Operations (SWAMO) Constituents



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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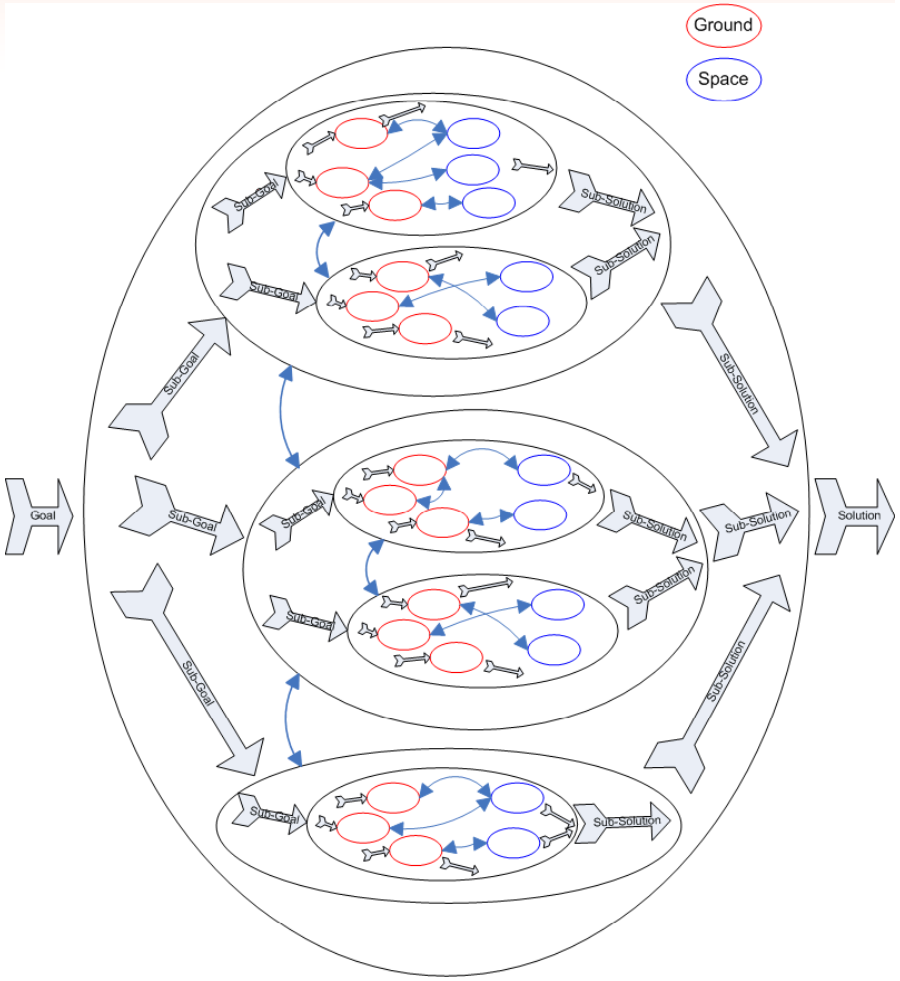
Sensor Web Concept in a Nutshell

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*



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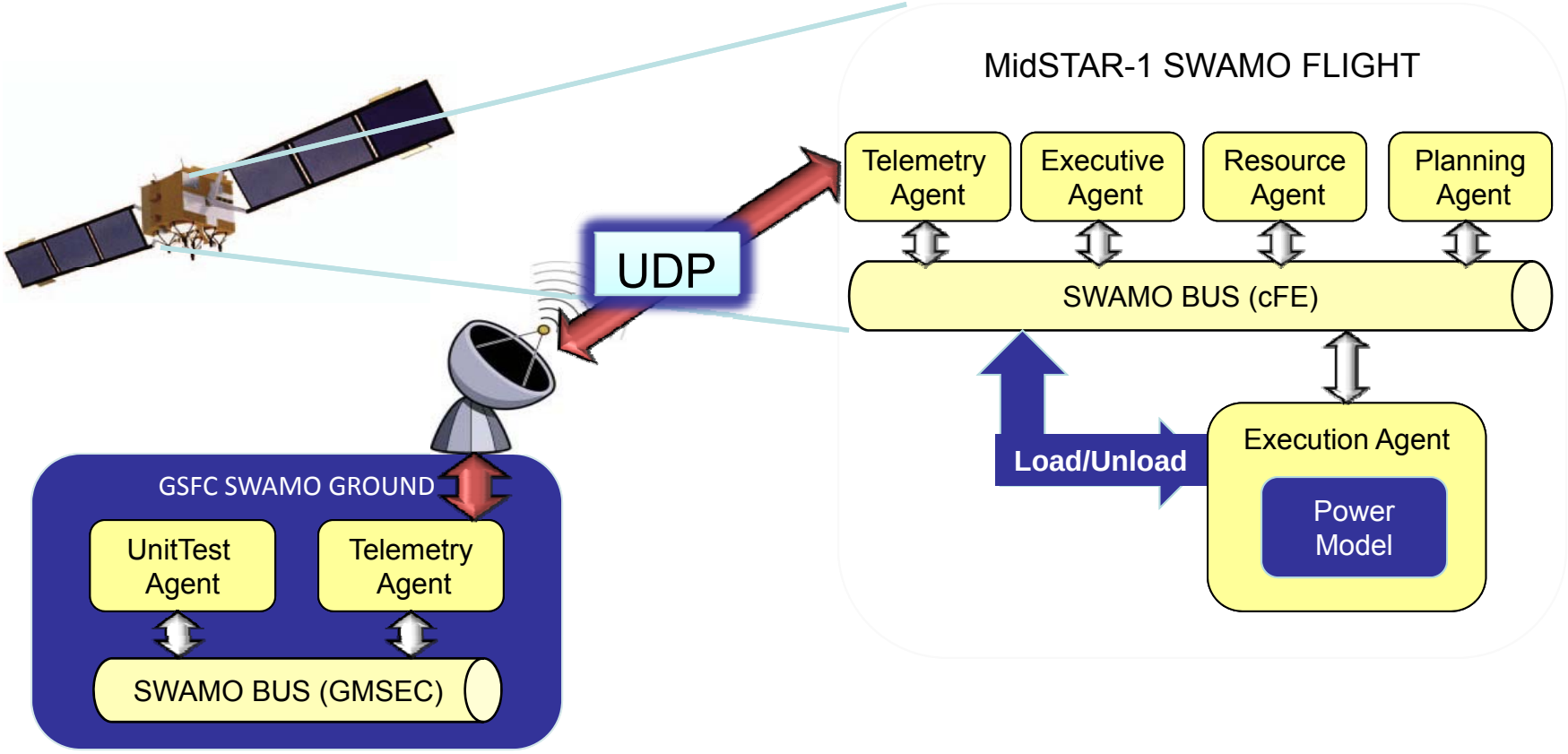
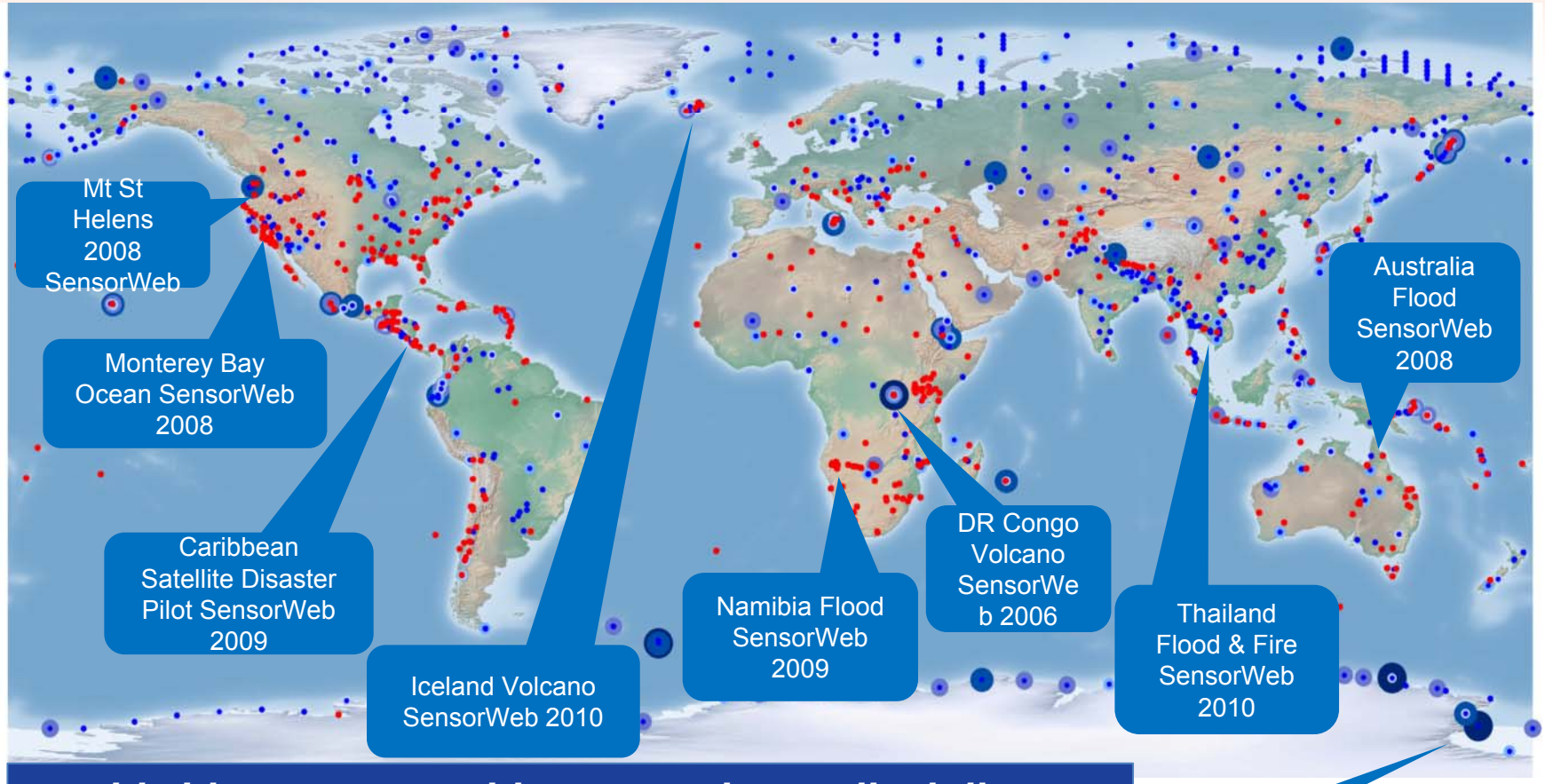
Delay Tolerant Network/SWAMO/MidSTAR-1

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)

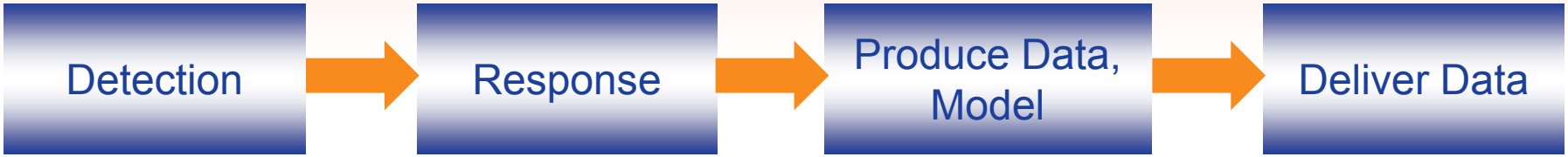


SensorWeb Images



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



(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

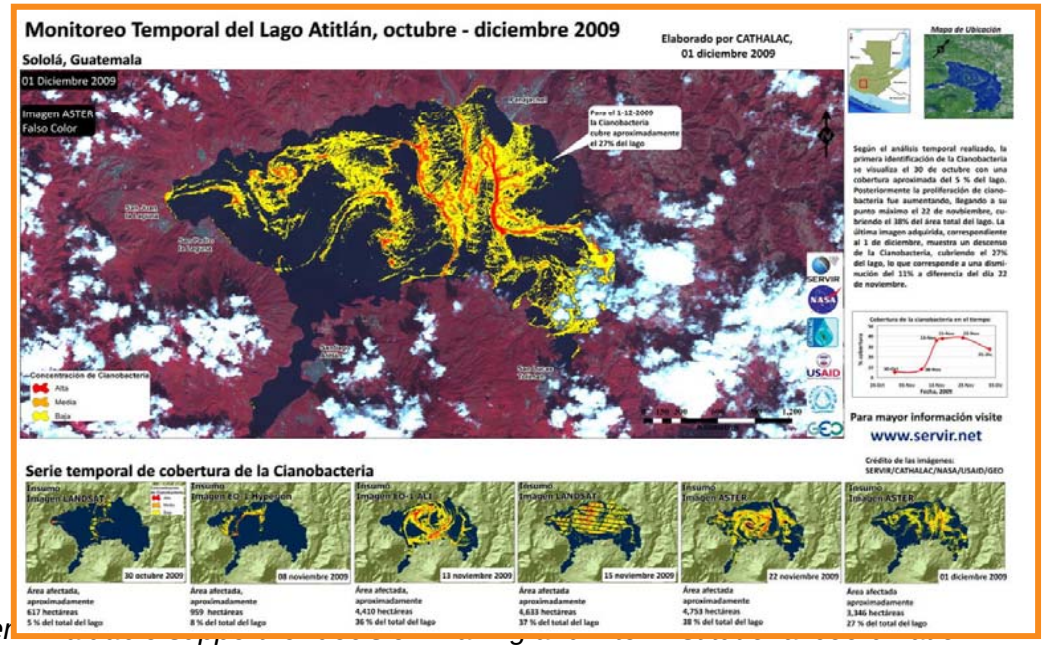
Total of seventeen (17) NTRs recorded for SensorWeb technologies

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)



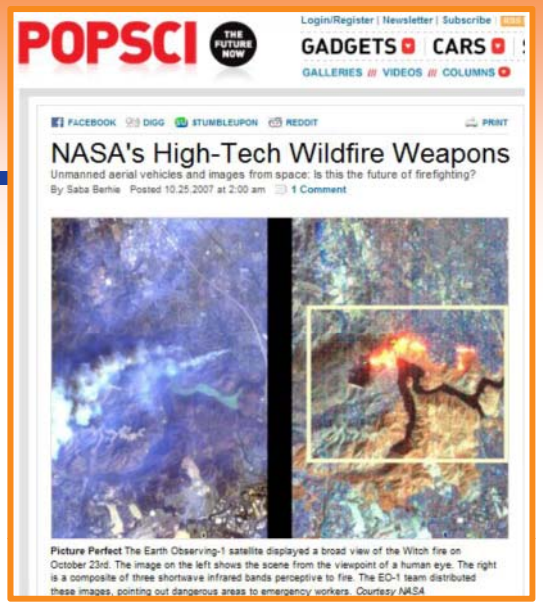
"The spatial analysis and studies through the satellite imagery (ASTER, EO-1 and Landsat) provided by CATHALAC through SERVIR have been [illegible] led by MARN to address these types of alerts and extreme events.

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

Fire SensorWeb Experiments with U.S. Forest Service

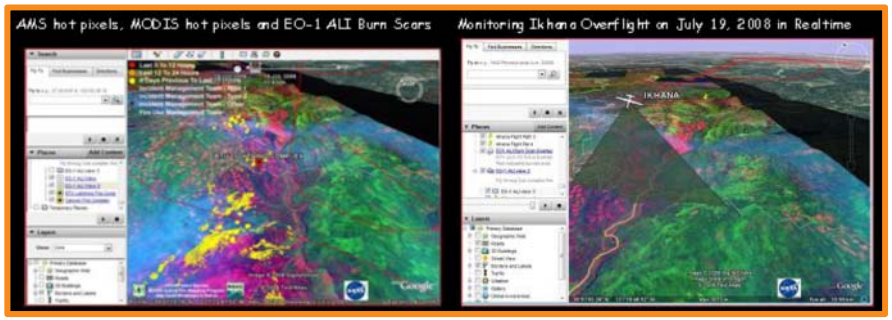
From 2003 to 2009, SensorWeb team conducted a variety of experiments to identify how best to inject SensorWeb technology into assisting Forest Service to manage large wildfires and assist decision makers. This involved interoperating satellite sensors and an Unmanned Aerial System sensors to produce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

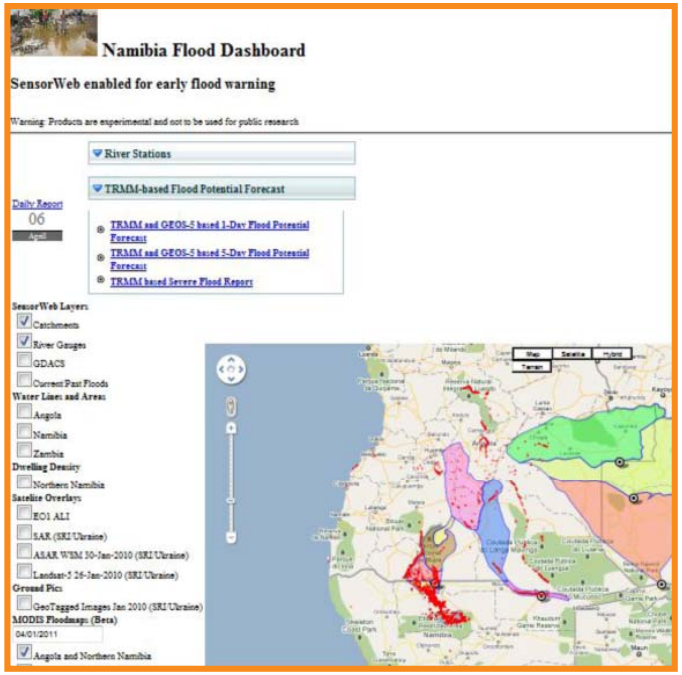
Respond: Trigger EO-1 and Radarsat imagery based on detection of triggers

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



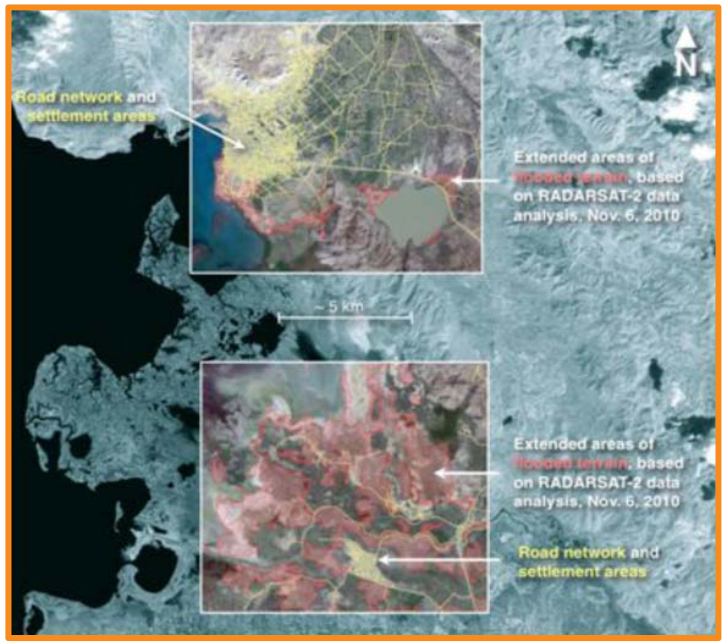
Caribbean Satellite Disaster Pilot

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

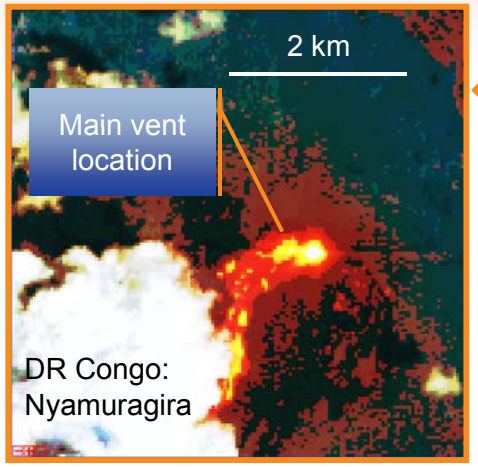
"*I applaud the SensorWeb Toolbox development team because they have created a real-world capability that has connected satellite earth observation data to the local users …which leads to saving lives and property in the developing world.*"

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



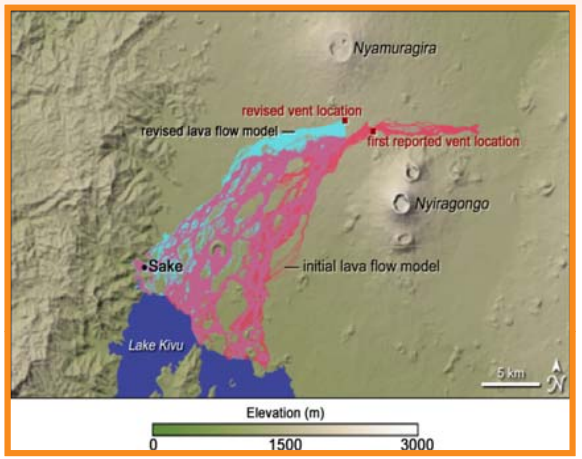
S. Frye/SGT/GSFC

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.



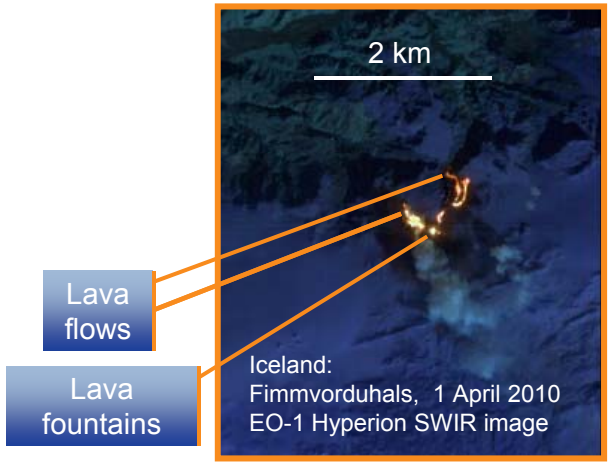
"This was a stunning demonstration of the capability of an autonomous system to obtain and provide vital information during a volcanic emergency."
- Gari Mayberry, Geoscience Advisor, USAid

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.

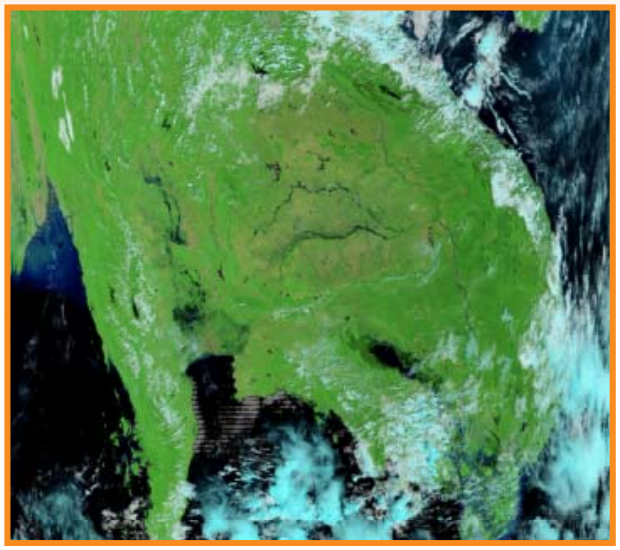
Product Generation & Delivery: Rapid data processing, thermal maps, modeling of eruption parameters, and posting to end users.

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



A. G. Davies / JPL

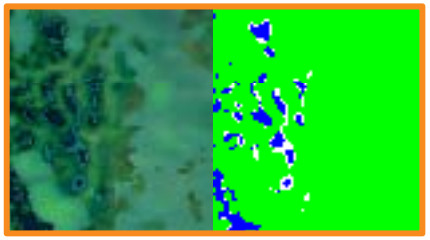
Thailand Flood SensorWeb



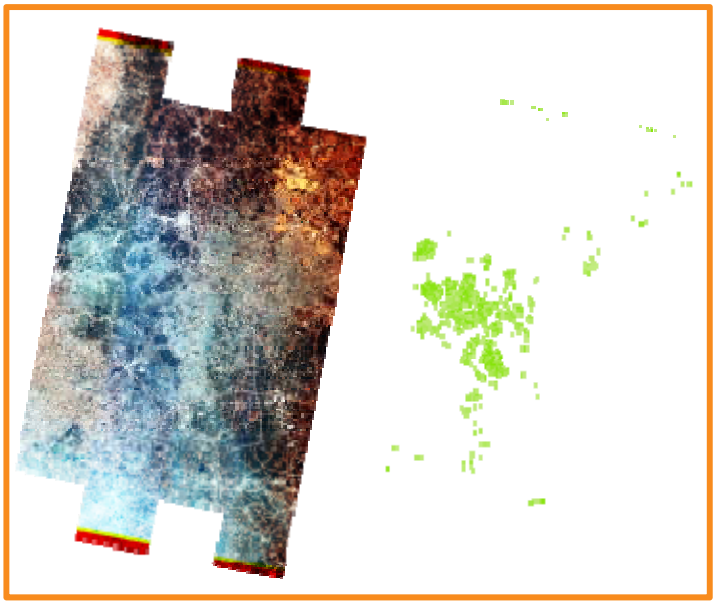
MODIS 28 Nov 2010 Imagery of Thailand Flooding (band 7-2-1)
Est. damage over $1.67B USD [CNN], Oct–Nov 2010

"*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)



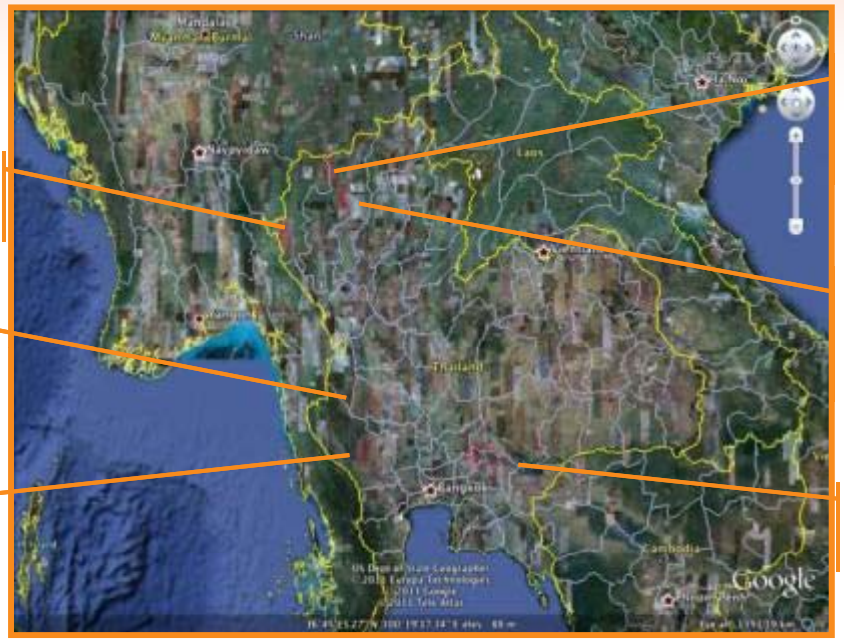
Detect:
(L) MODIS imagery of Bang Pla Ma from 20 Jan 2011
(R) Classified surface water extent from MODIS image



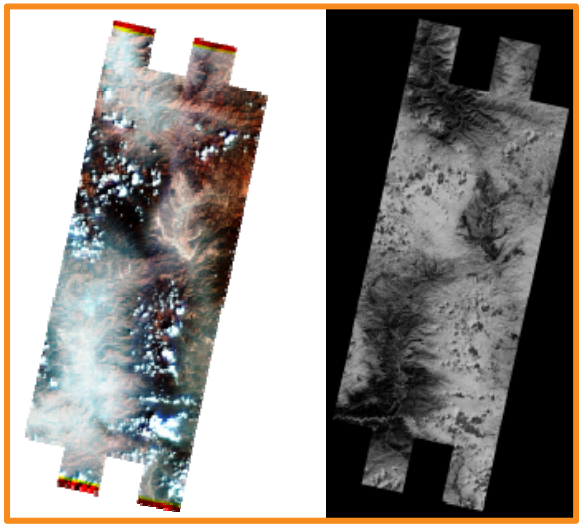
Respond → Generate → Deliver
(L) ALI imagery of Bang Pla Ma from 21 Jan 2011
(R) Classified surface water extent from ALI image

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

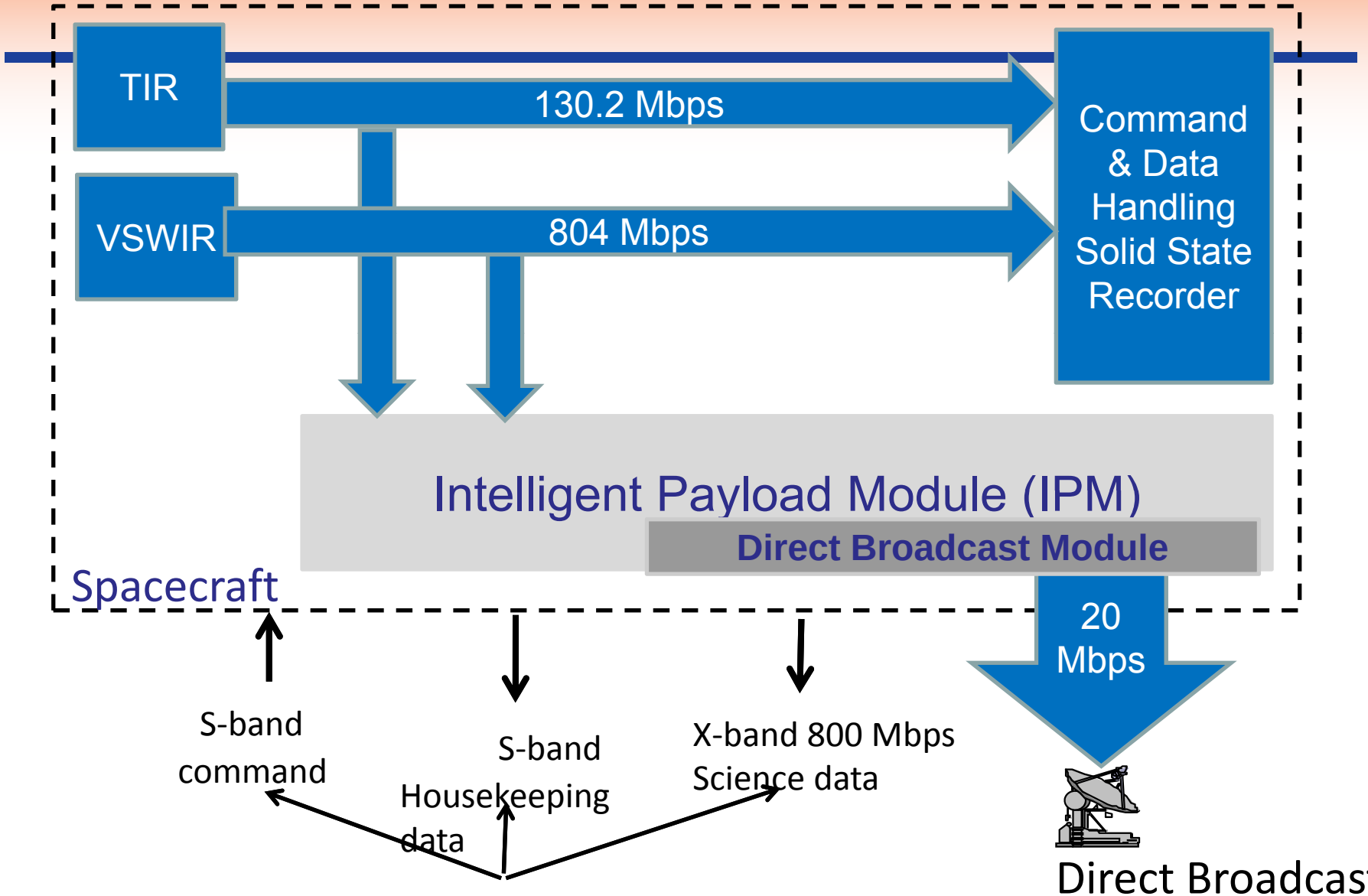
Steve's Presentation Here

- Add Science perspective

Need Right Tool for the Job

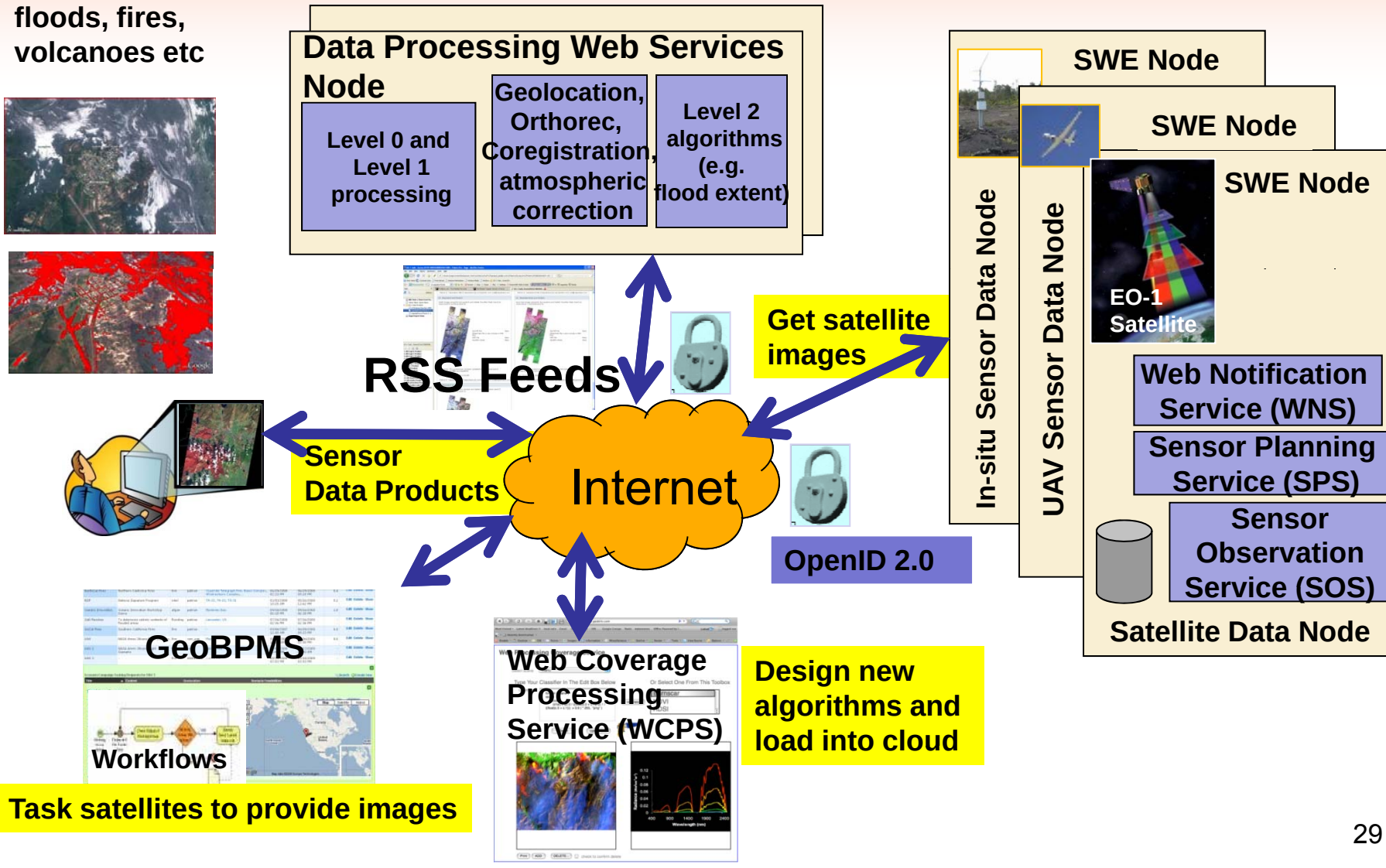
- Use SensorWeb software to get right tool for the job

Original HysplRI 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

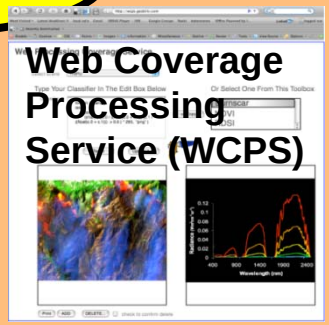
Matsu Cloud

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

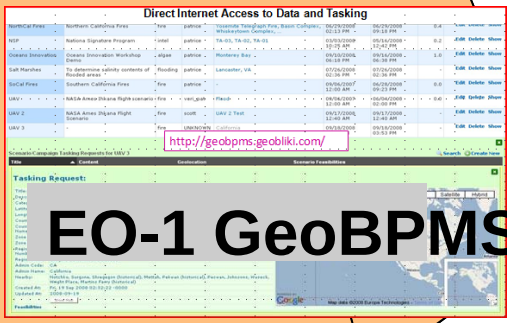
Atmospheric Correction for ALI & Hyperion

Namibia Flood Dashboard

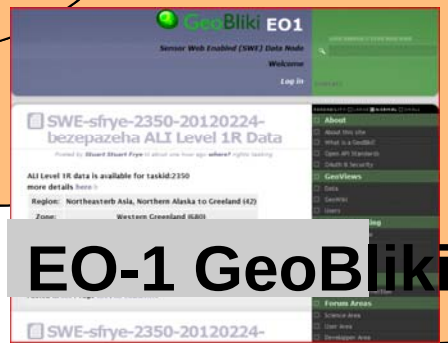
Multi year data product archive

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

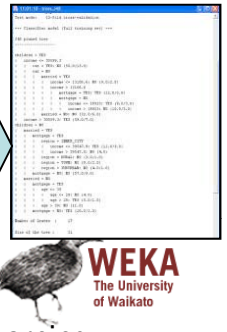
Joyent Cloud
- Ruby on Rails
- 3 processors
- 3 Tbytes of storage

Experimental Intelligent Payload Module Quick Load/Quick Look Ops Con

Web Coverage Processing Service (WCPS)-Client
Uploads to Various Environments

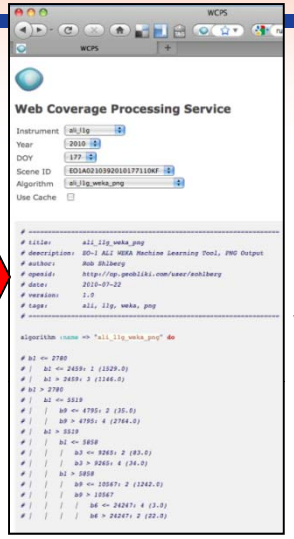
Create Custom Algorithm

SCIENCE USER



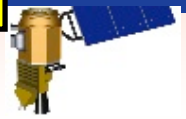
Machine Learning Supervised Classifier (Regression Tree) Refined Offline

Custom Algorithm



Quick algorithm upload

HyspIRI

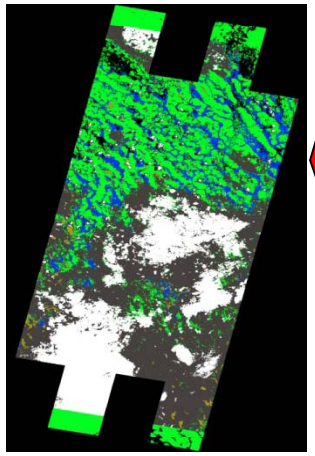


GlobalHawk, Ikhana, ER-2 …

Lua Scripts

NASA Cloud Infrastructure As A Service

WCPS-Runtime Executes Algorithm Against Selected Sensor Data

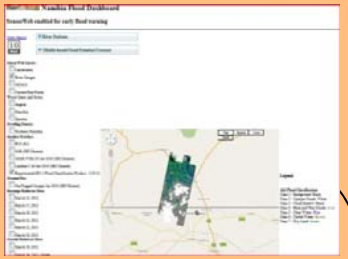


Custom Data Product (KMZ, PNG…)

Quick look data products

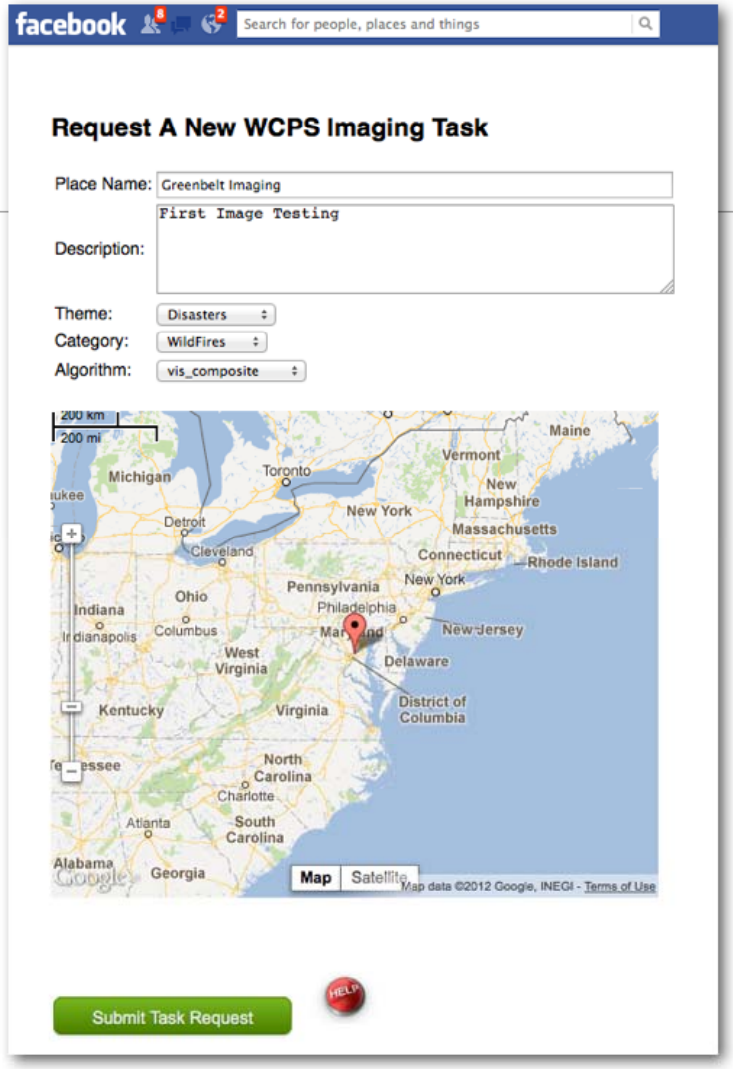
Notification to user

Cloud



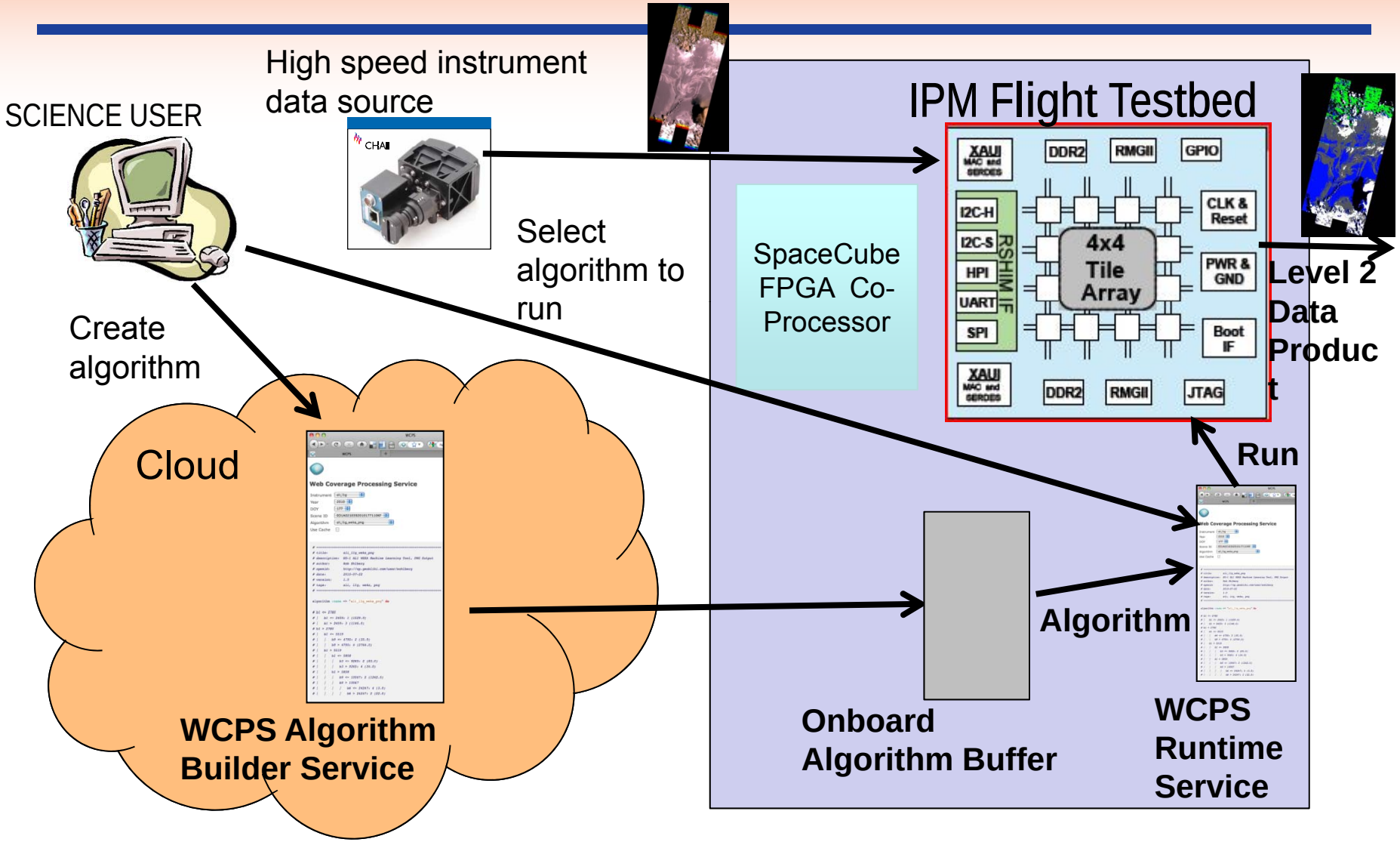
Use GeoSocial API on Facebook to Task IPM

IPM Tasking



5

Top Level IPM Ops Concept



Roadmap for IPM Flight Opportunities

2013-2014
Ikhana

2013-2014
Global Hawk

2013-2014

Mini UAV Helicopter

2020+ HyspIRI/HSI+
Thermal

Maestro-lite

Instrument and IPM Configuration TBS

2013 HyspIRI Airborne Campaign

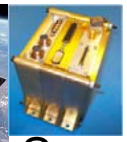
ER-2

eMAS

SpaceCube

TileraPro

2008



ISS

SpaceCube Xilinx FPGA

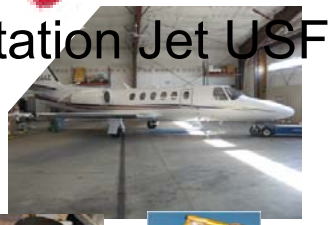
2012/2013
Bussmann Helicopter

SpaceCube

TileraPro

Chai 640

2013
Citation Jet USFS

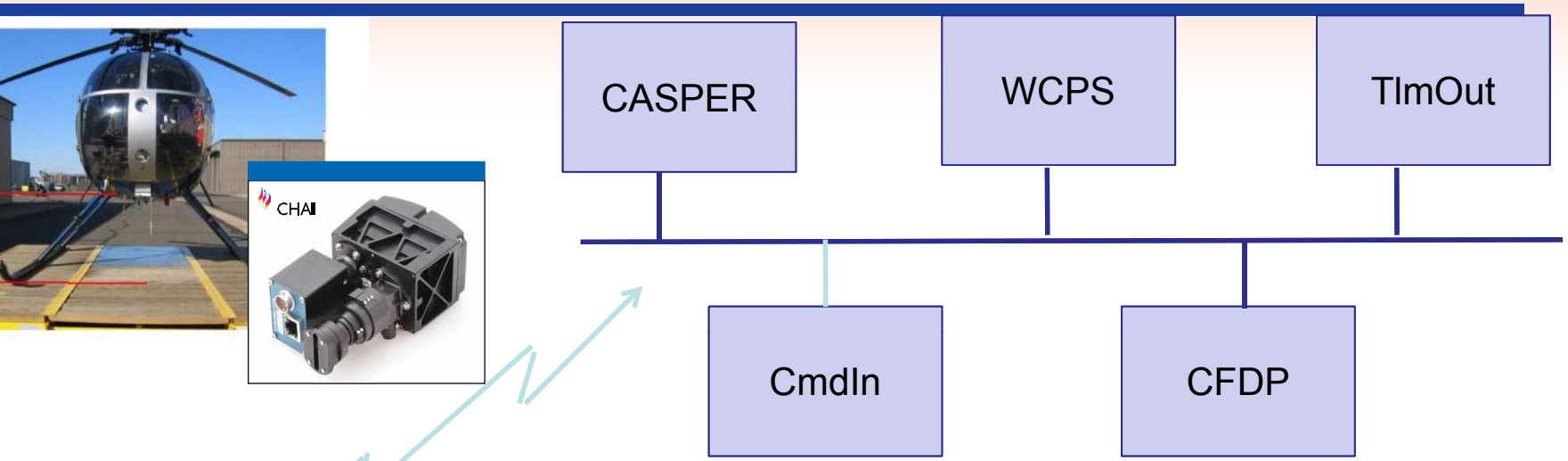


AMS

SpaceCube

TileraPro

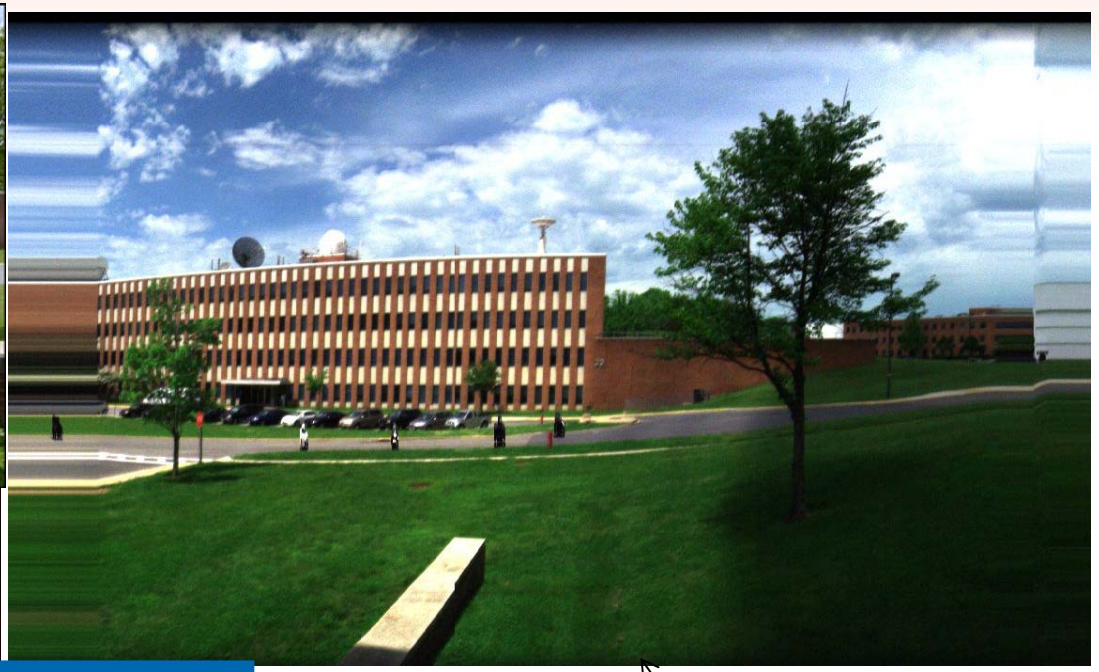
Flight & Ground Architecture Using Operational SW Components



ASIST

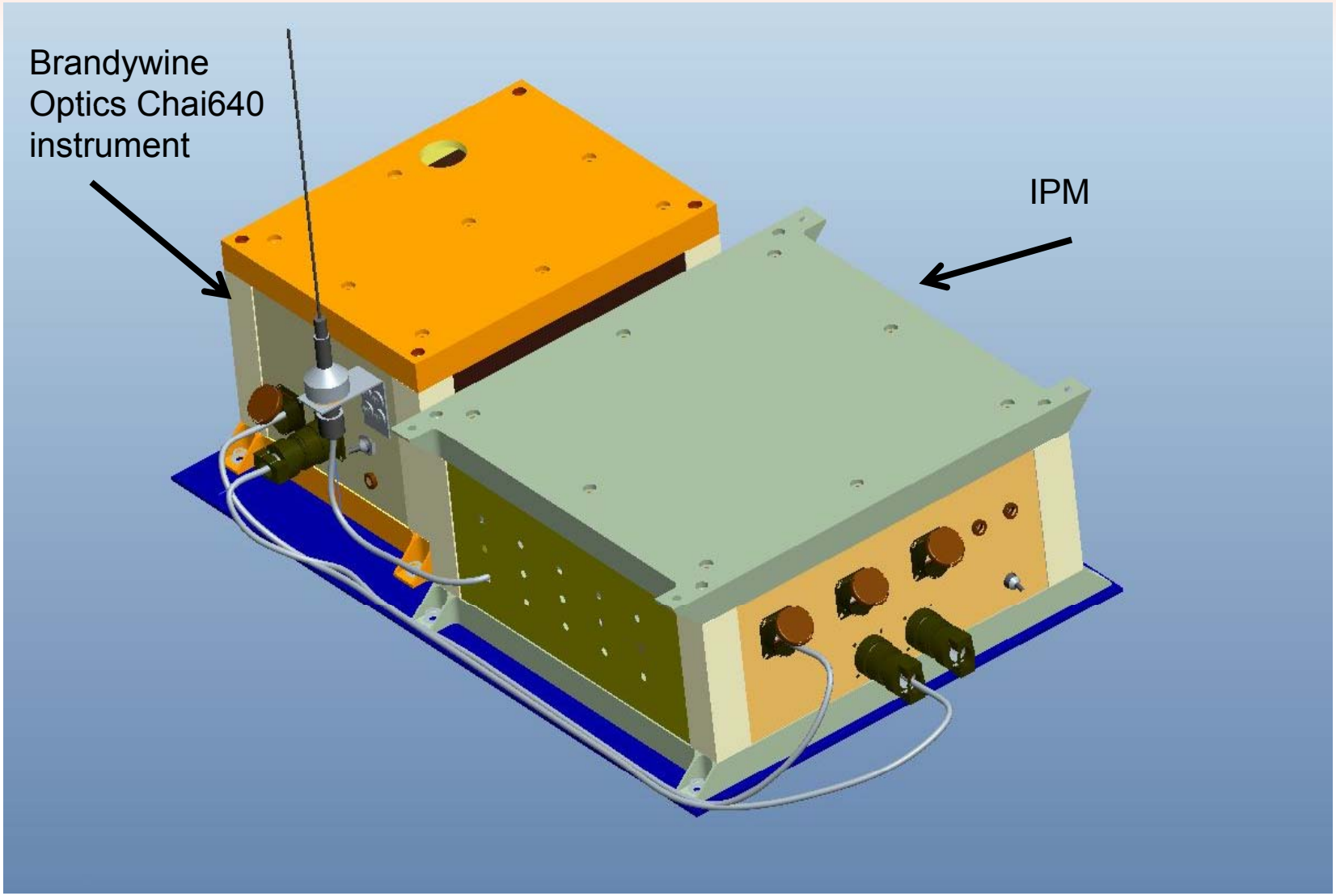
WCPS – Web Coverage Processing Service
CmdIn – Command Ingest
TlmOut – Telemetry Output
CASPER - Continuous Activity Scheduling Planning Execution and Replanning system
CFDP - CCSDS File Delivery Protocol
ASIST - Advanced Spacecraft Integration and System Test Software

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



Visible image constructed from test data

Intelligent Payload Module Assembly with Chai640



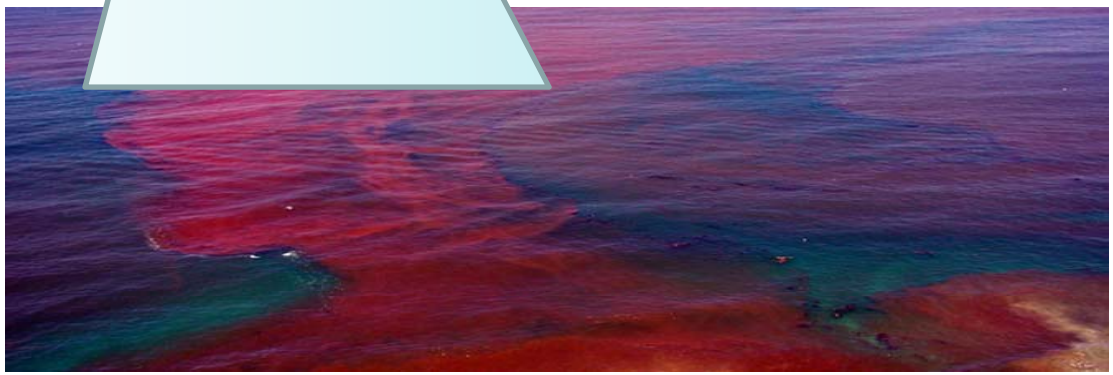
Beginning Integration Process on Helicopter

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

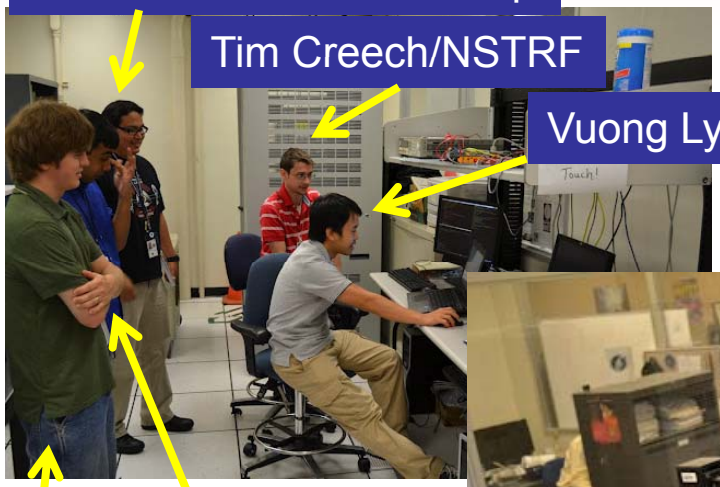
Downlink to Ipad

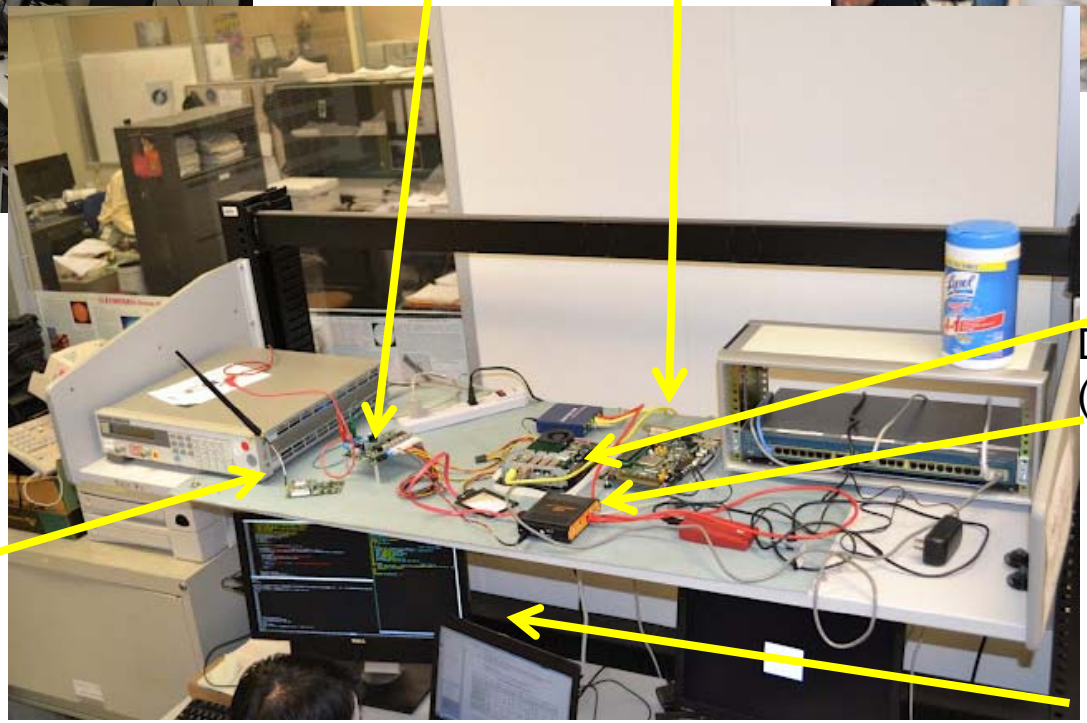
Validation team in boat being directed to location by rapid map product



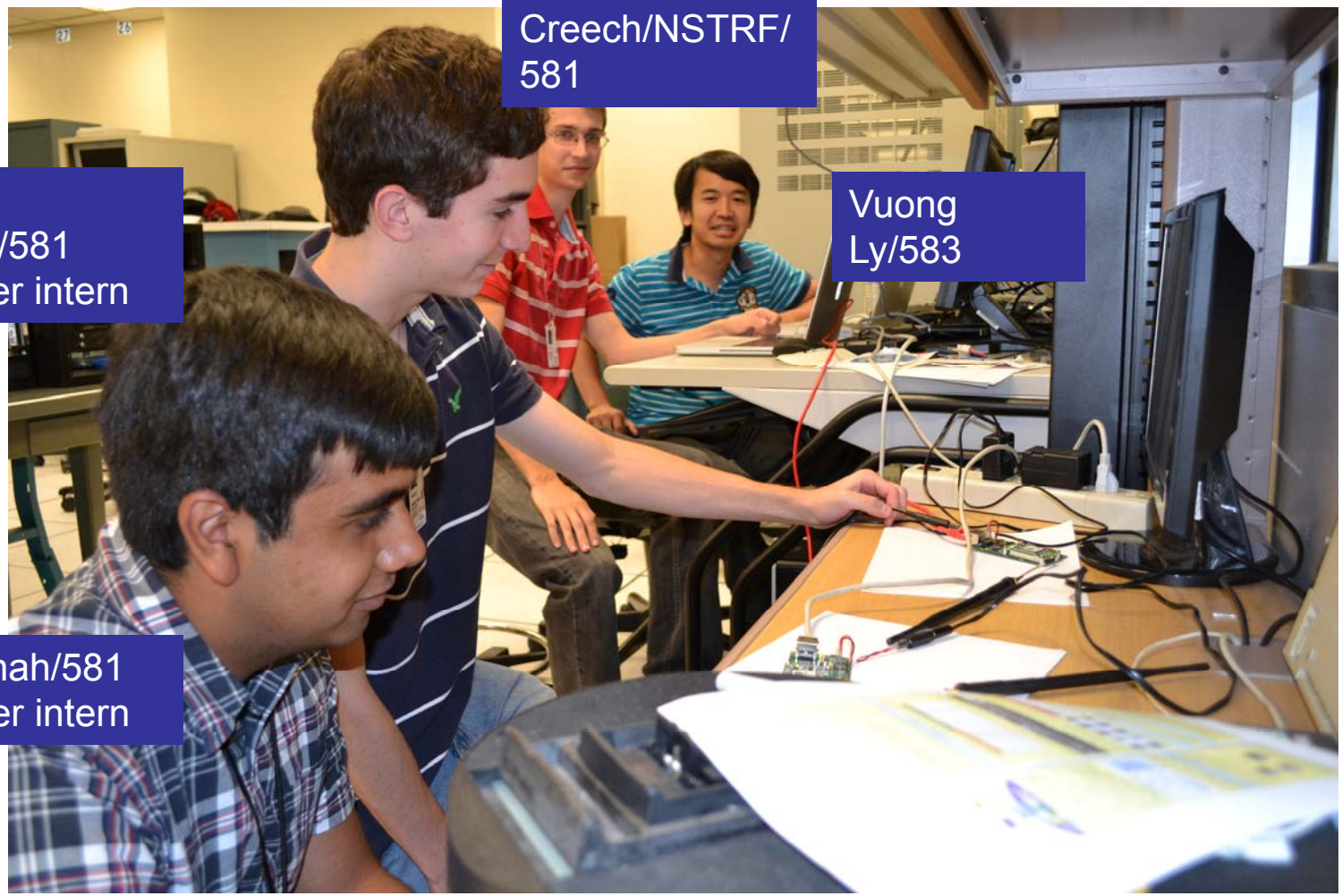
Harmful Algal Bloom

Intelligent Payload Module (IPM) Prototype without Box

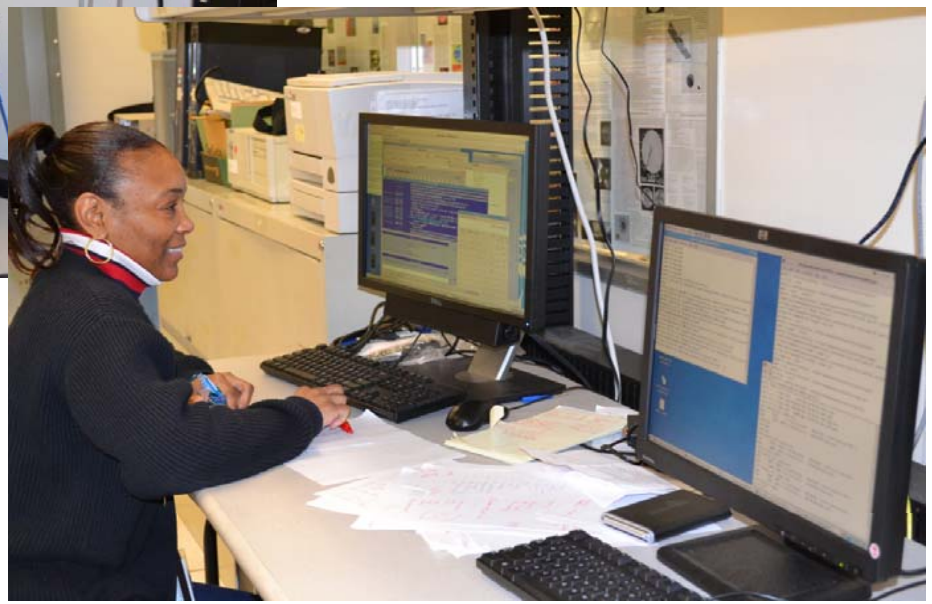




Testing Freewave Radio



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

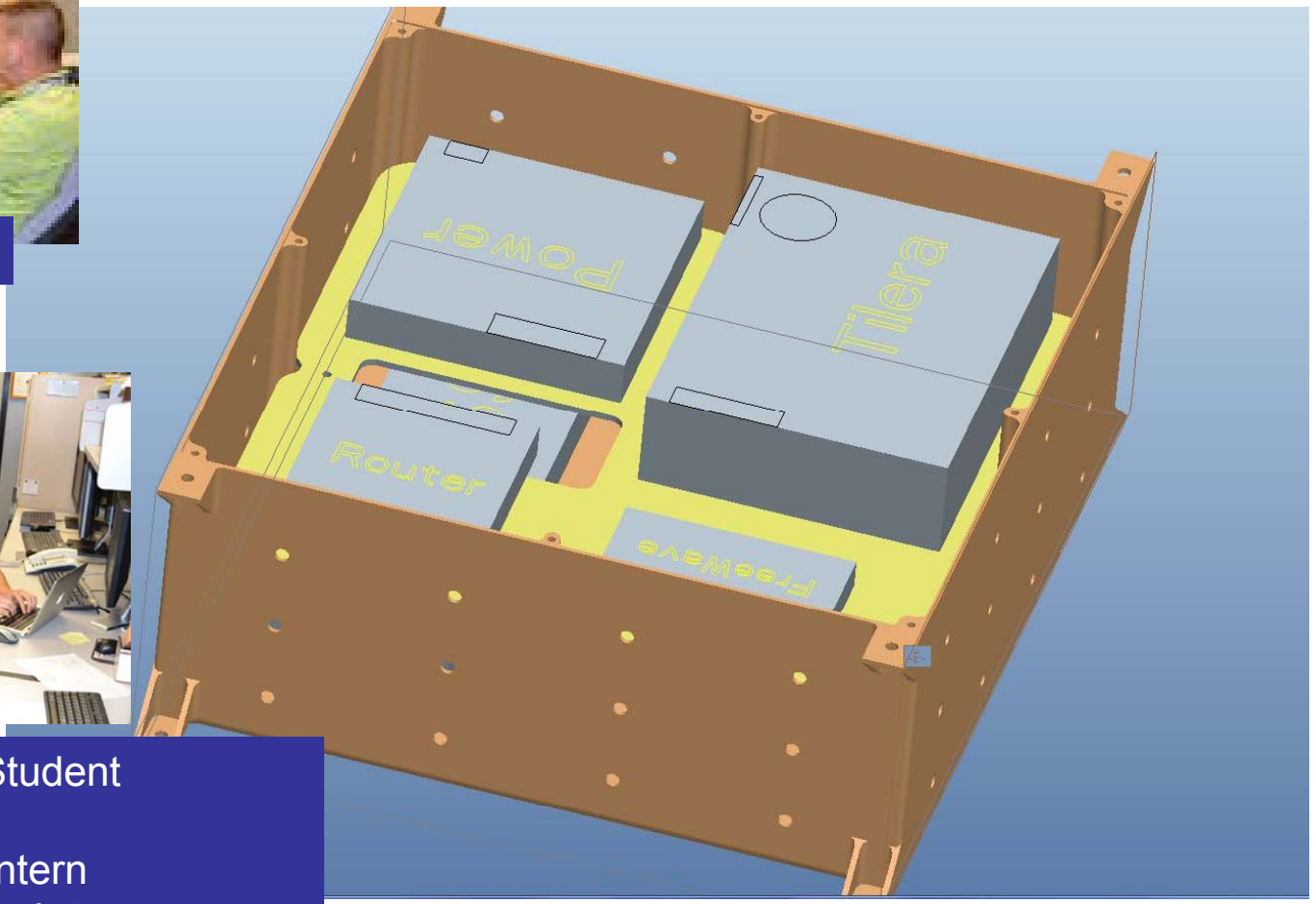


Above: Vuong Ly/583 (Ground System SW Branch) standing front of IPM testbed holding a SpaceCube board. Right: Tawanda Jacobs/582 (Flight SW Branch) working on integration of cFE onto IPM testbed.

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

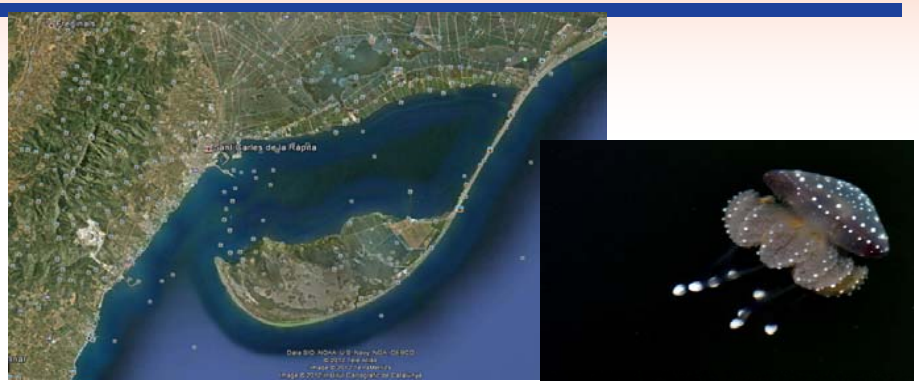
Chris Flatley/581 Summer intern

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

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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

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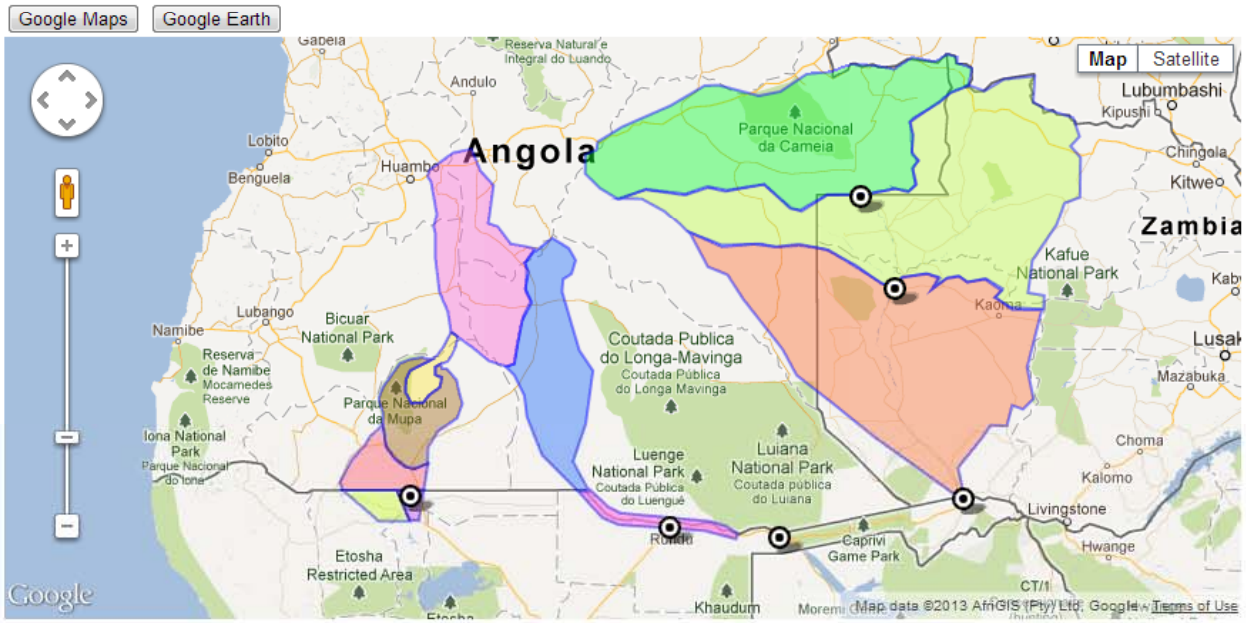
Namibia Flood Dashboard -Geospatial Display (The Big Map)

- 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

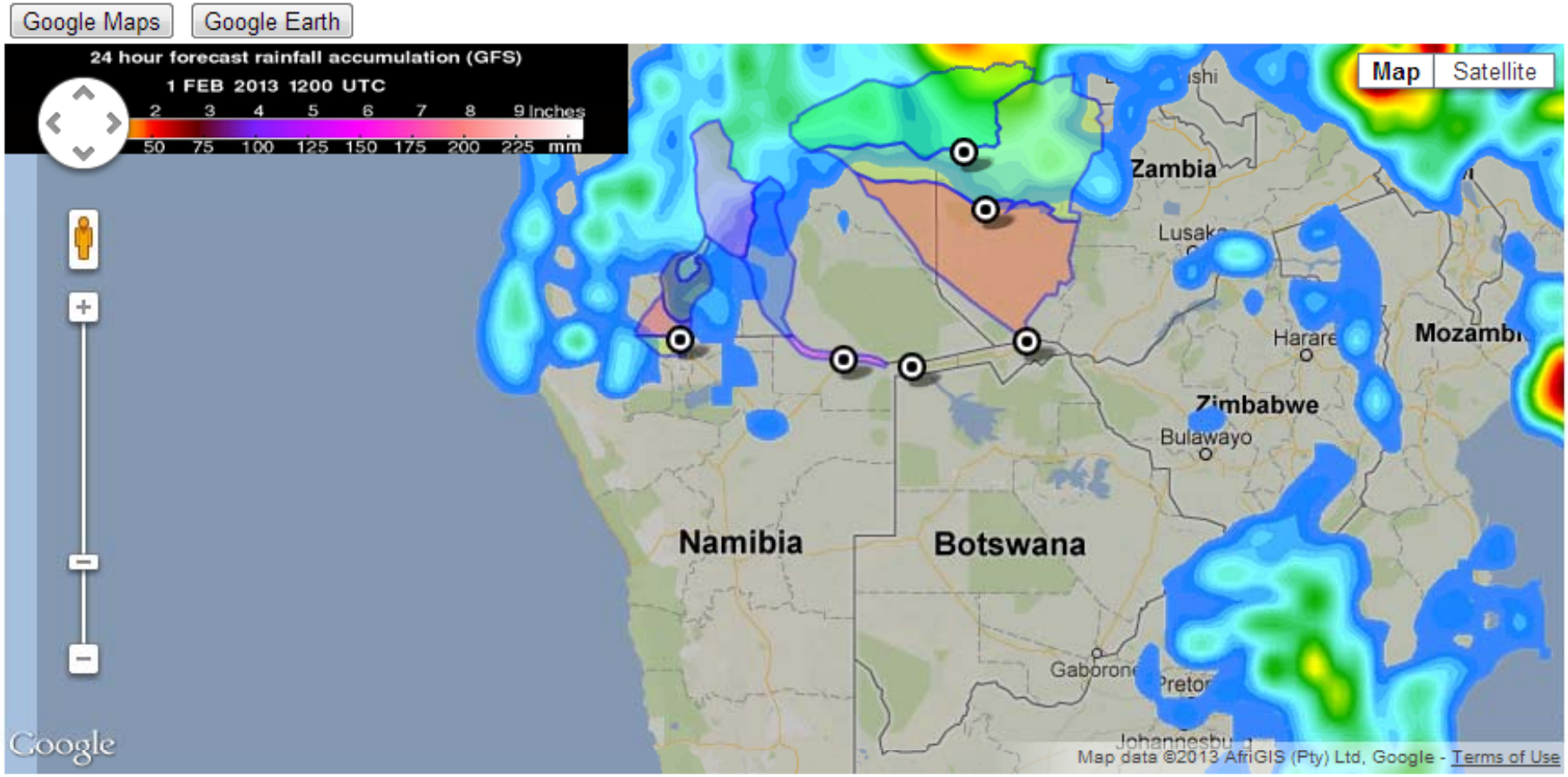


Legend:

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:

47

TRMM Rainfall



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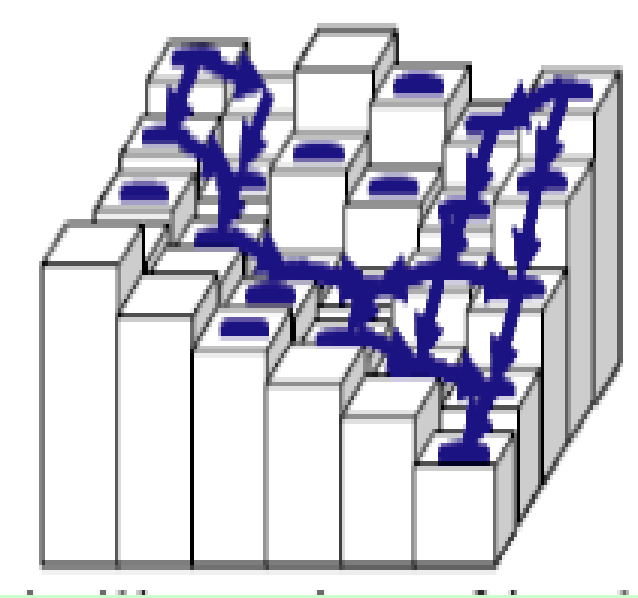
NASA/ Oklahoma University CREST Cell-based Water Balance Model

Cell-to-Cell Flow Routing



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

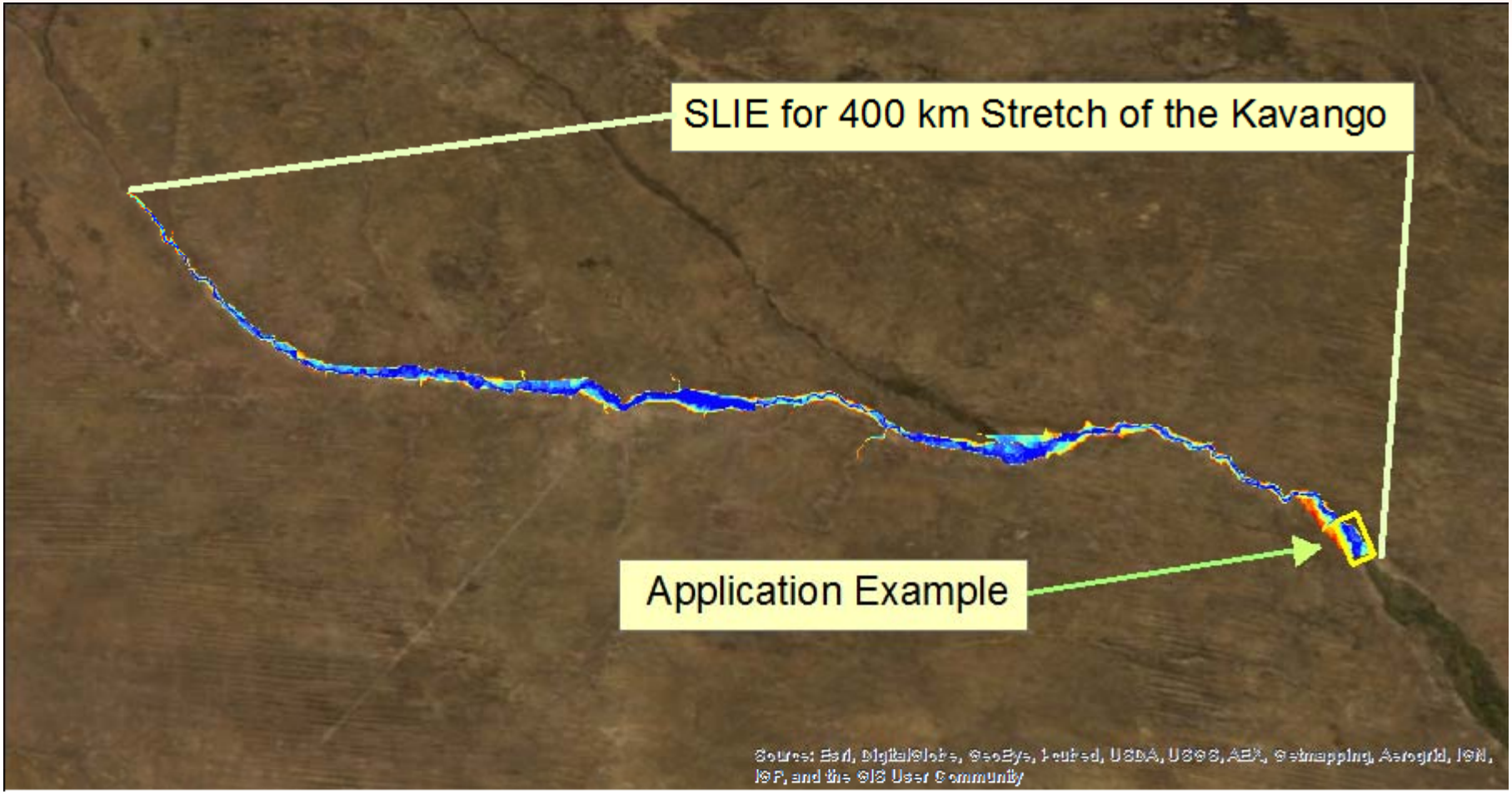
Step I: Rainfall-infiltration Partitioning (Distributed and Time-variant)

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

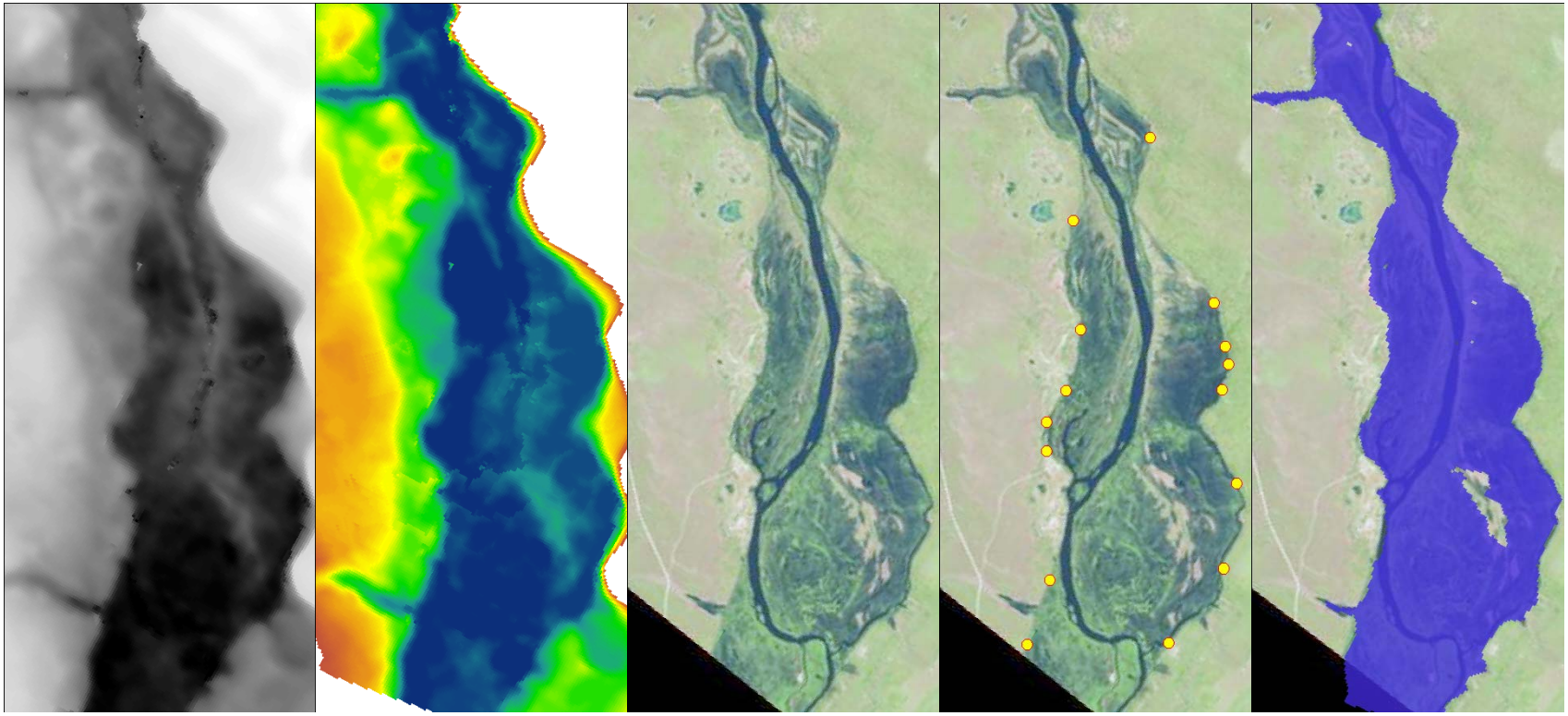
Use Best Available DEM

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

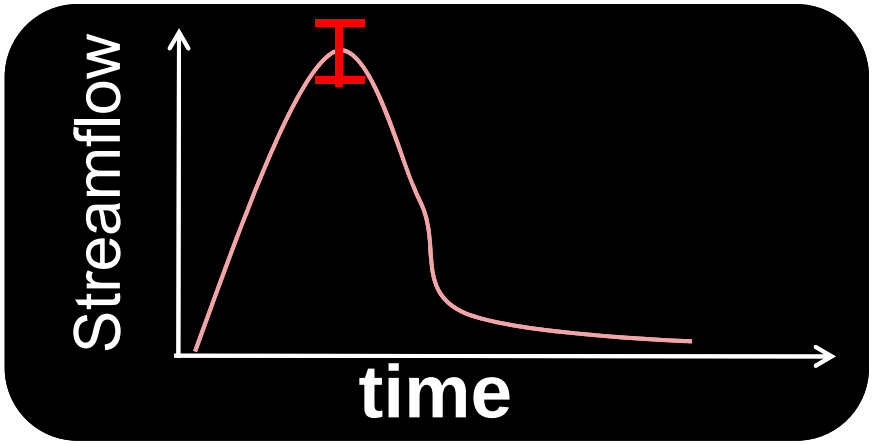
Example of Image Point Extraction (or Simulated GPS Points)

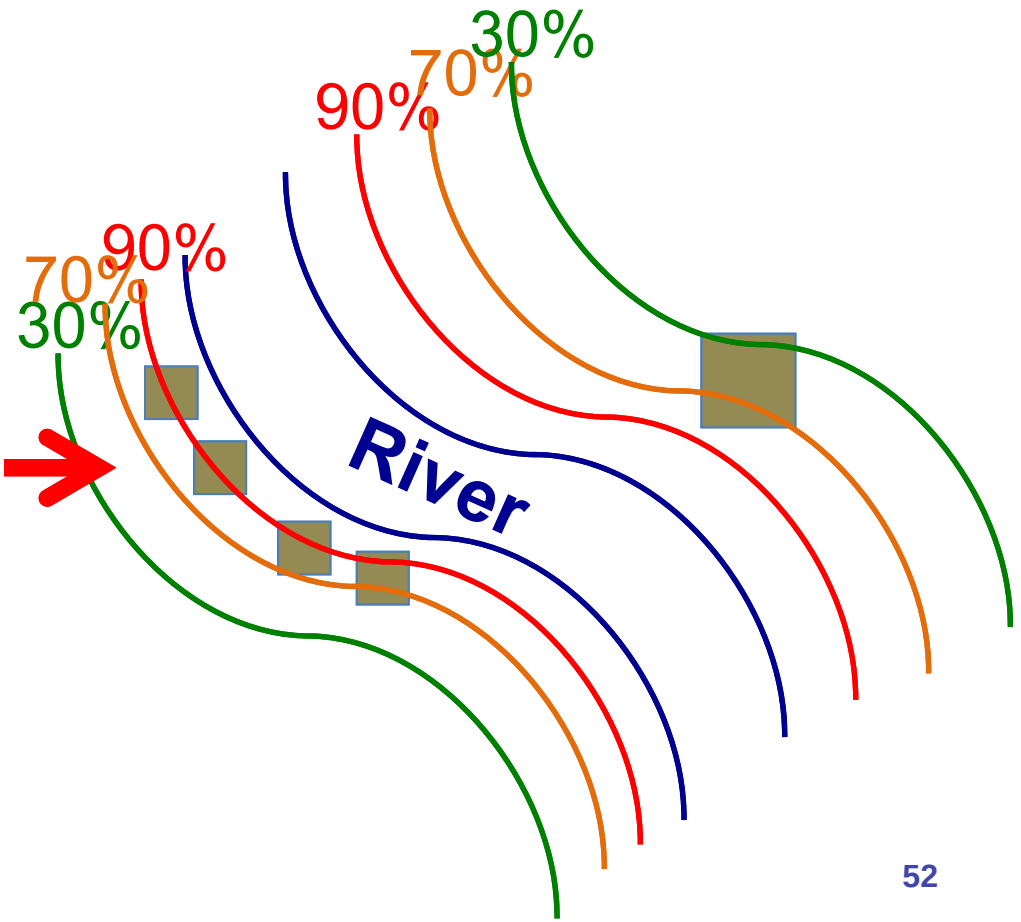
Actual Extent Layer Produced from Points – **Rapid Turnaround Time**

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

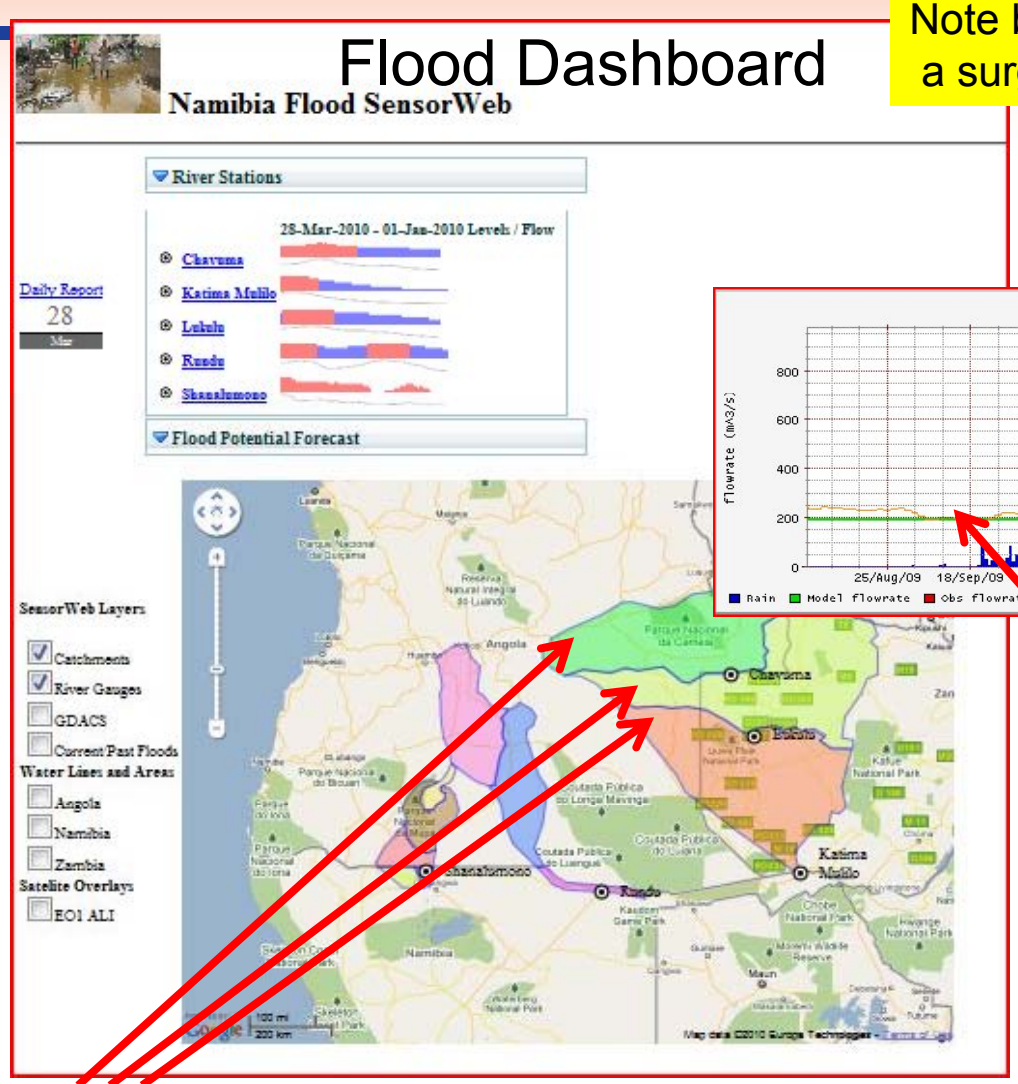
Coordination Meetings at UN in Bonn Germany 2009

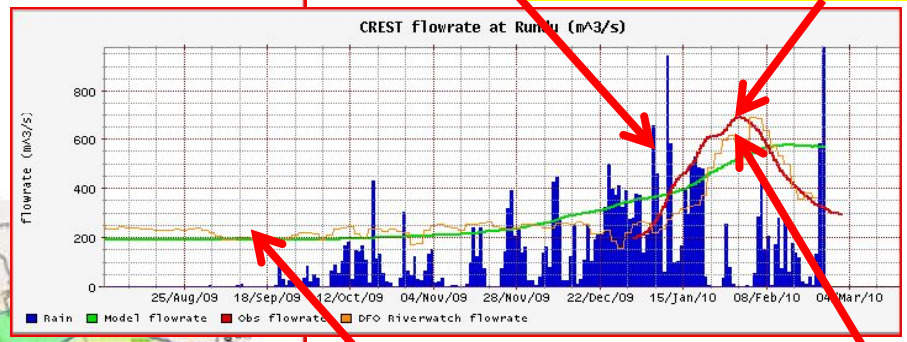
Flood SensorWeb Workshop Held in Windhoek, Namibia in January 2010

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

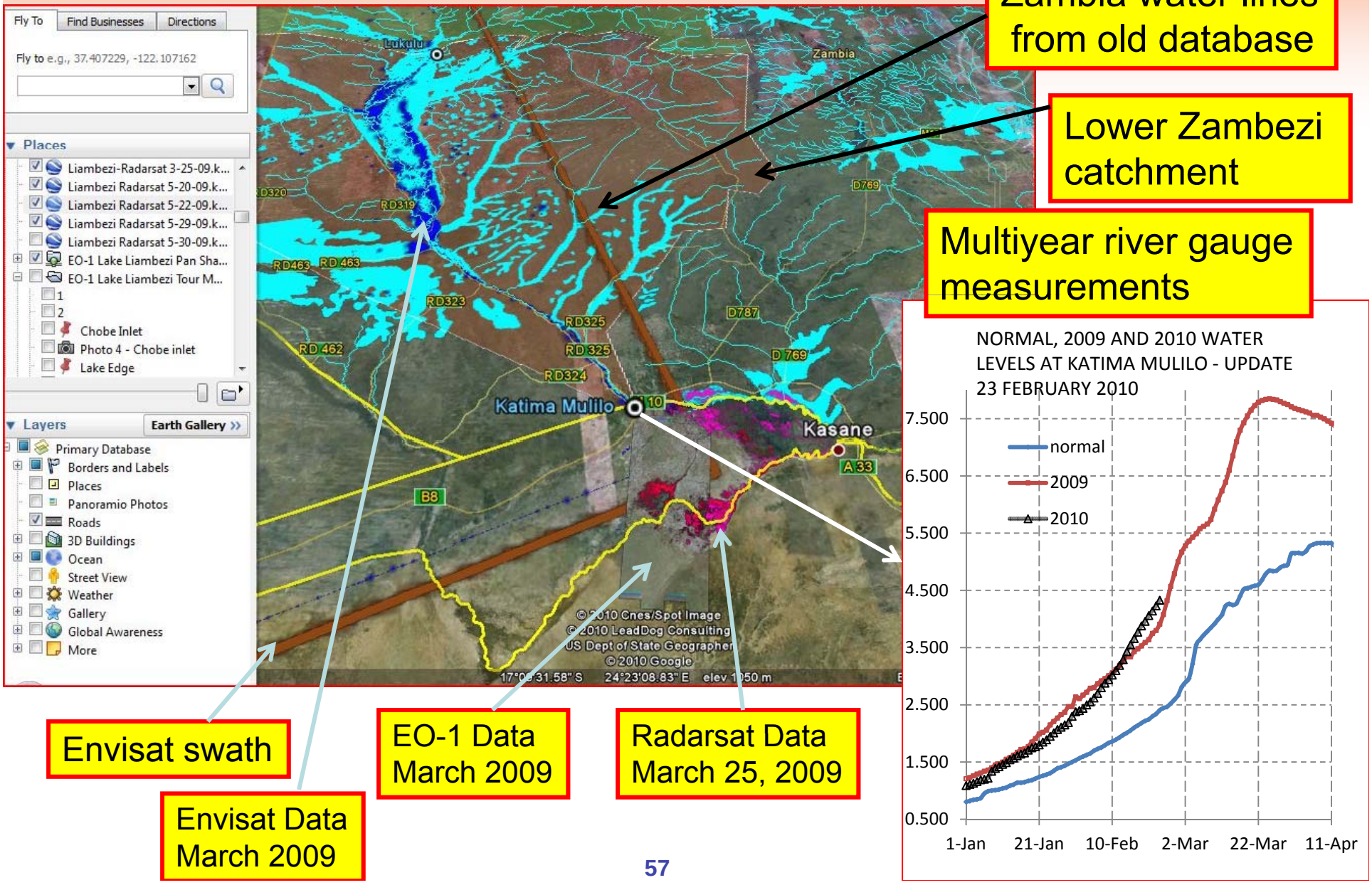
Then a flood wave appears downstream at Rundu river gauge days later (gauge data)

Early CREST Model trying to predict flood wave (Green)

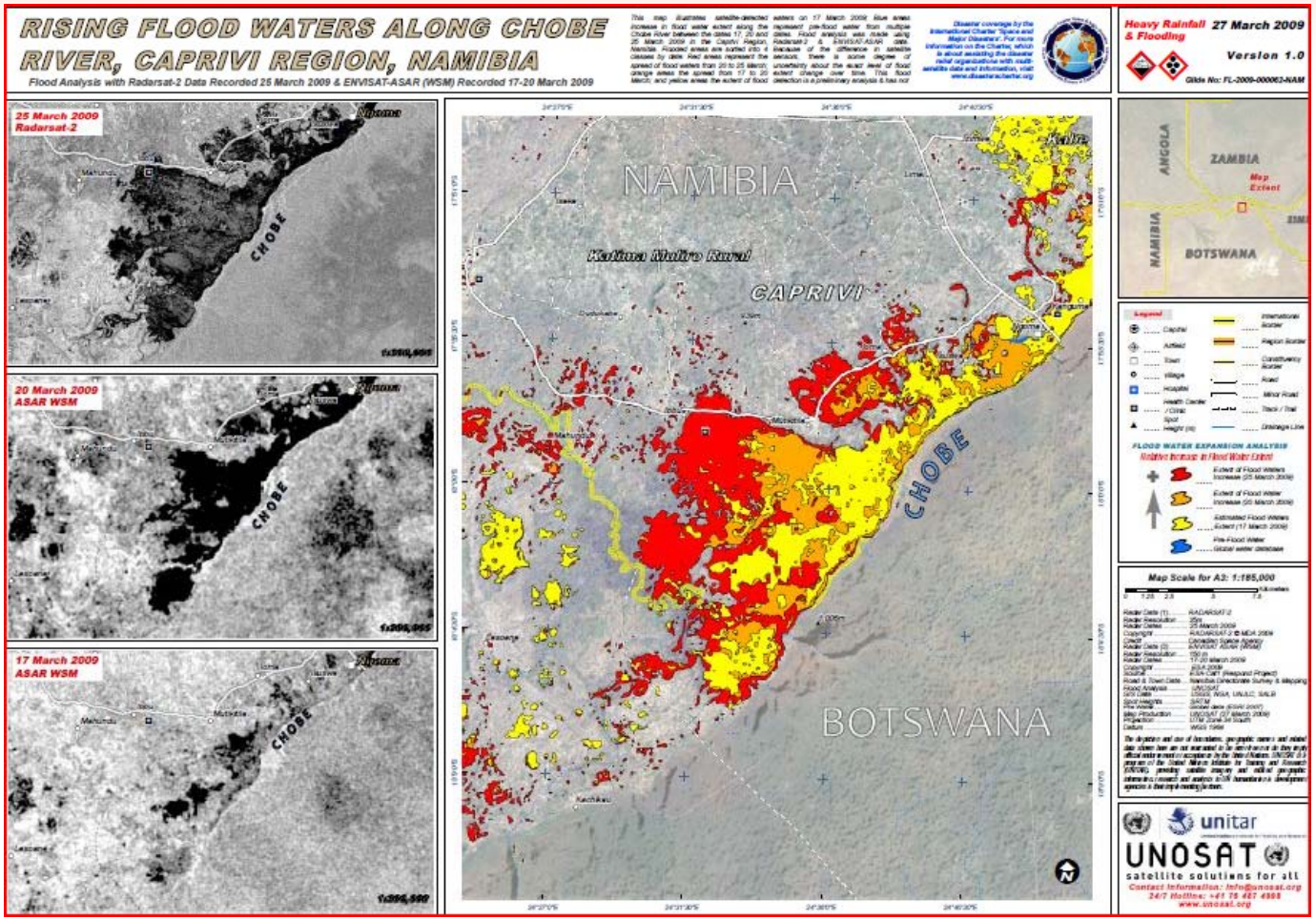
Riverwatch Model trying to predict flood wave (Orange) Better than CREST based on AMSR-E

Zambezi basin consisting of upper, middle and lower catchments

Early Look at Inundation Extent Related to River Height

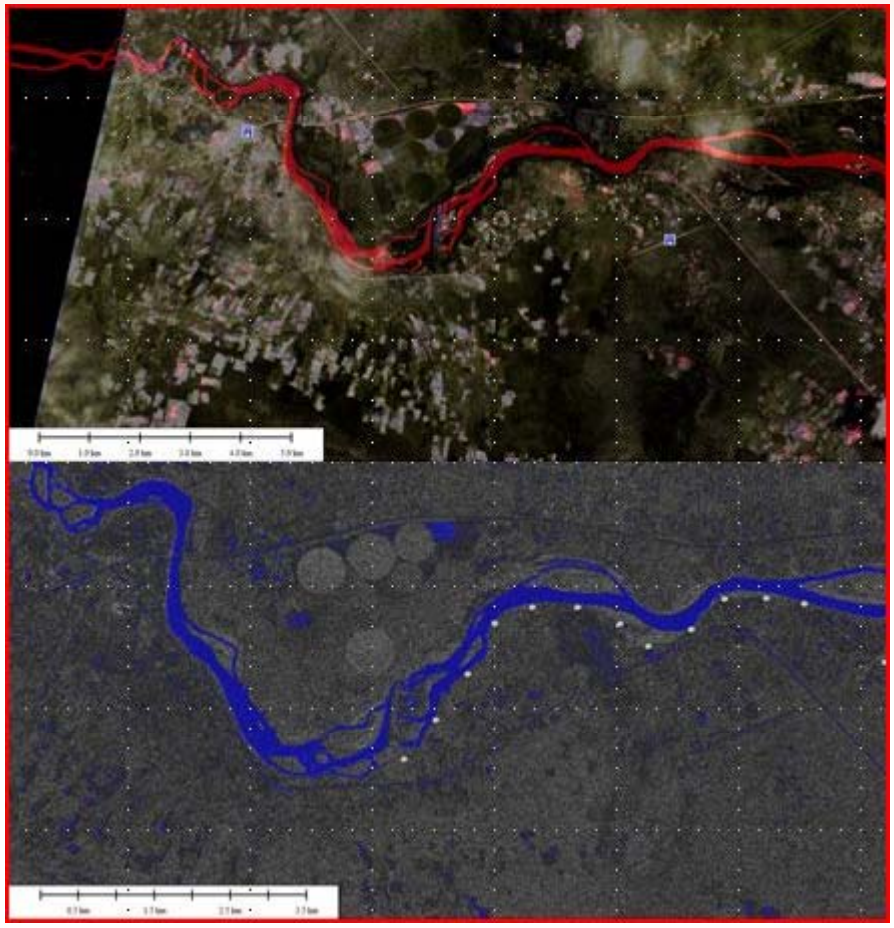


Unosat Flood Time Sequence In March 2009 in Caprivi when Katima Mulilo River Gauge Above 7.5 M



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

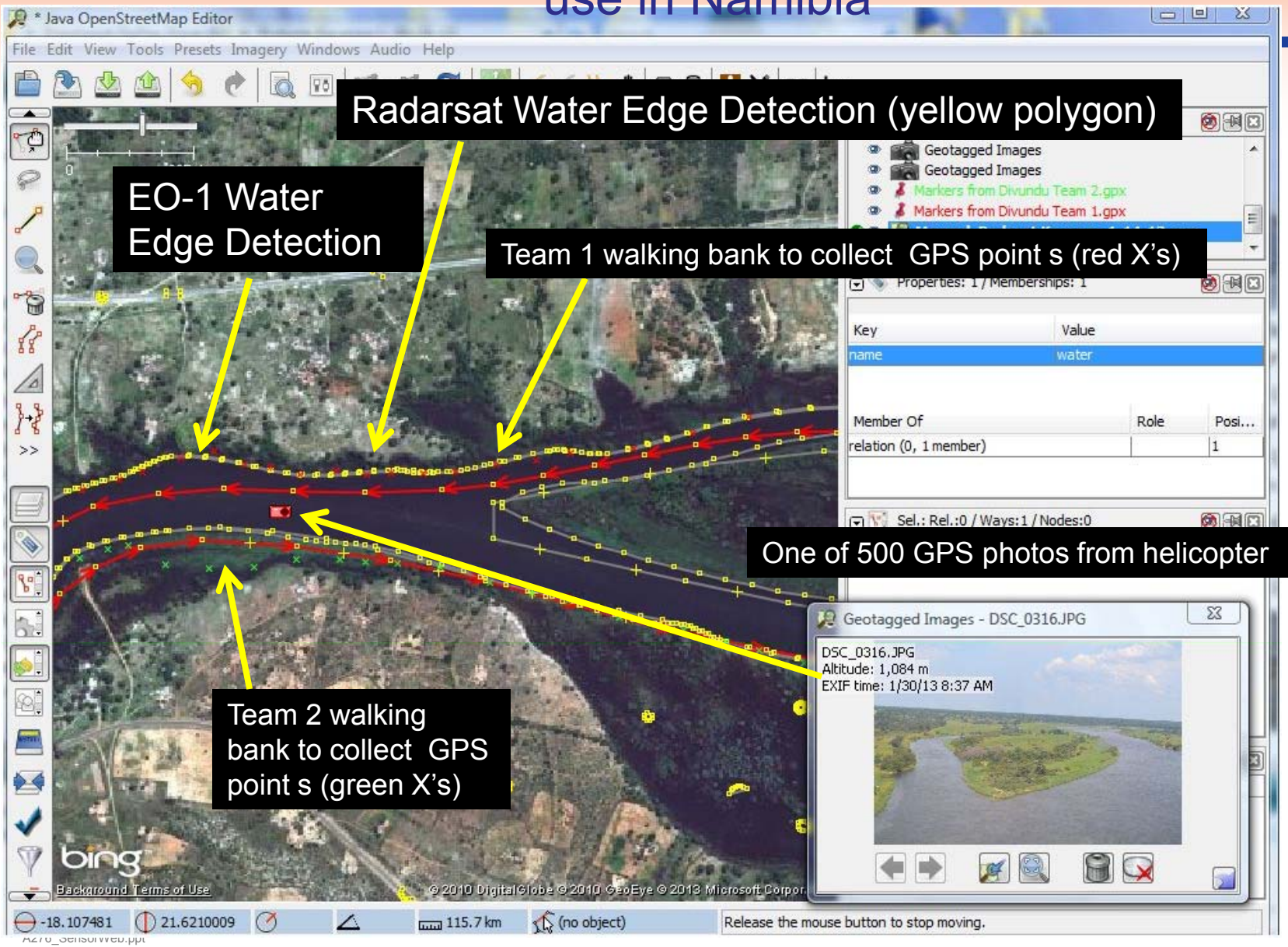
Left to Right: Matt Handy (NASA), Reinhold Kambuli (NDH), Village Resident, Dr. Julie Silva(UMD), John Moyo(Local Guide)

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

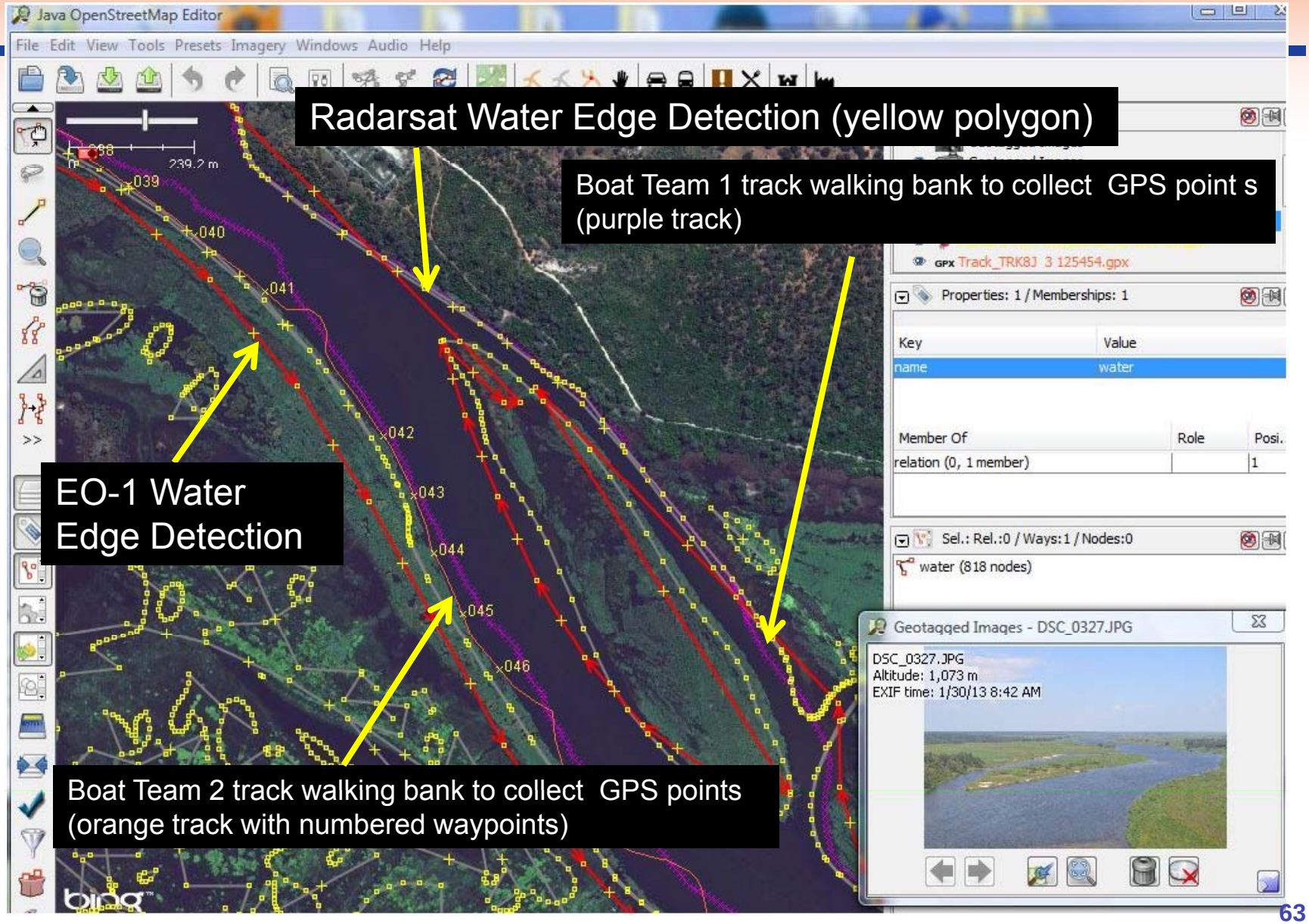
Flooding and Impacts on Local Livelihoods

Villager shows flood damage and impact during team site assessment

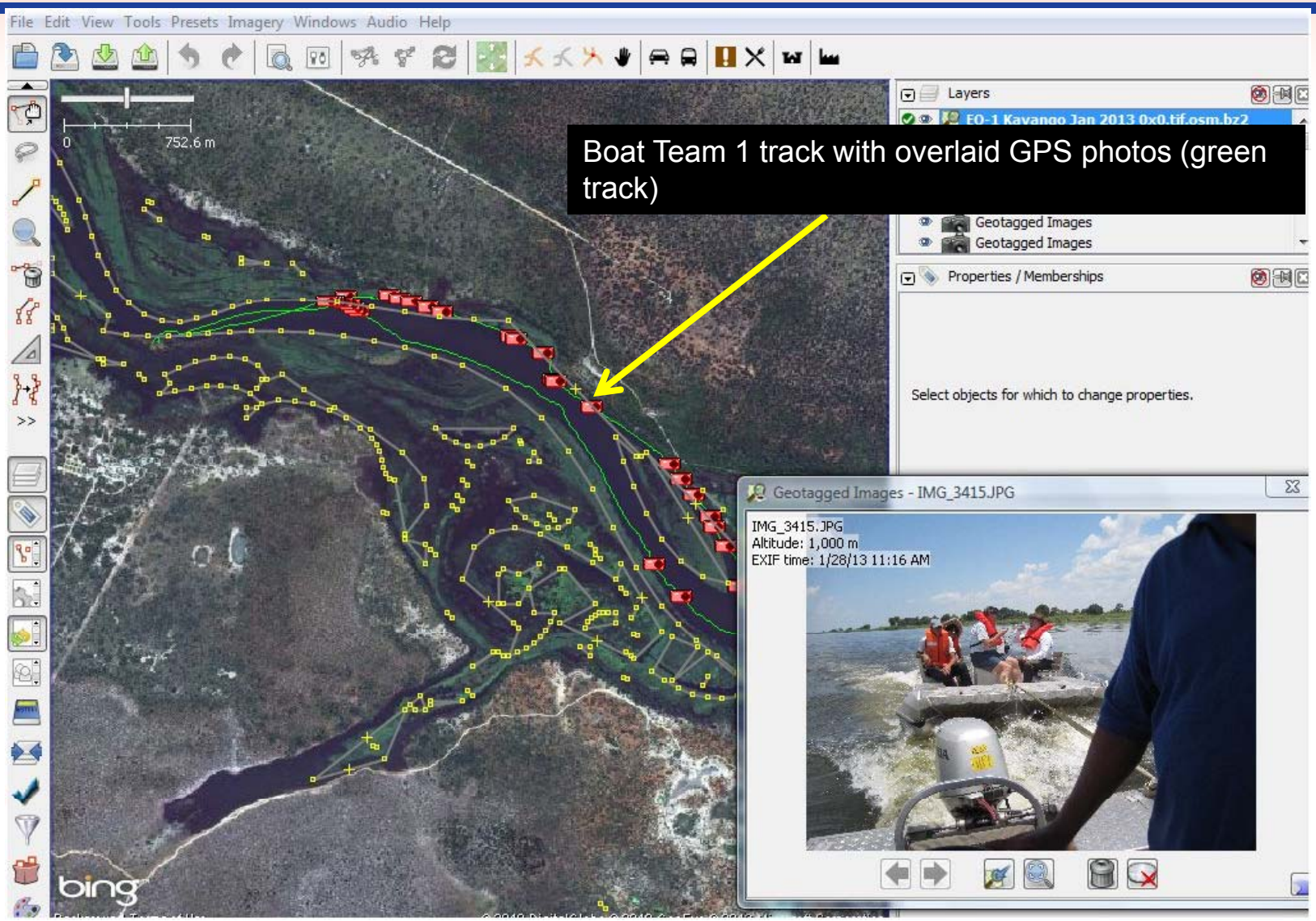
Conducted field exercises around Kavango river in 2012 and 2013 to train in country hydrologist and research methods to use in Namibia



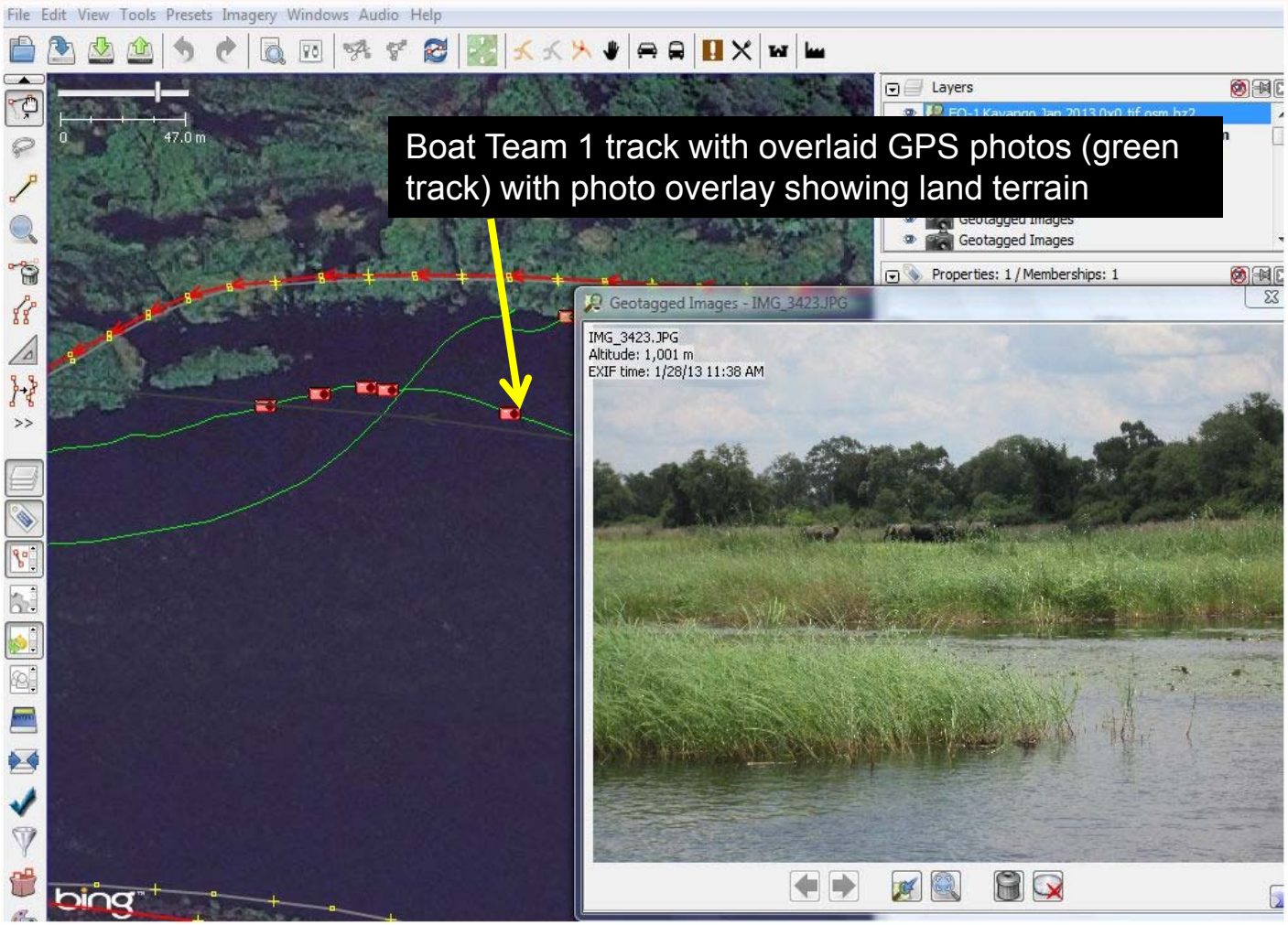
Integrated Water Edge Detection Display with Boat GPS Measurements, GPS located photos, Radarsat/EO-1 water edge detections



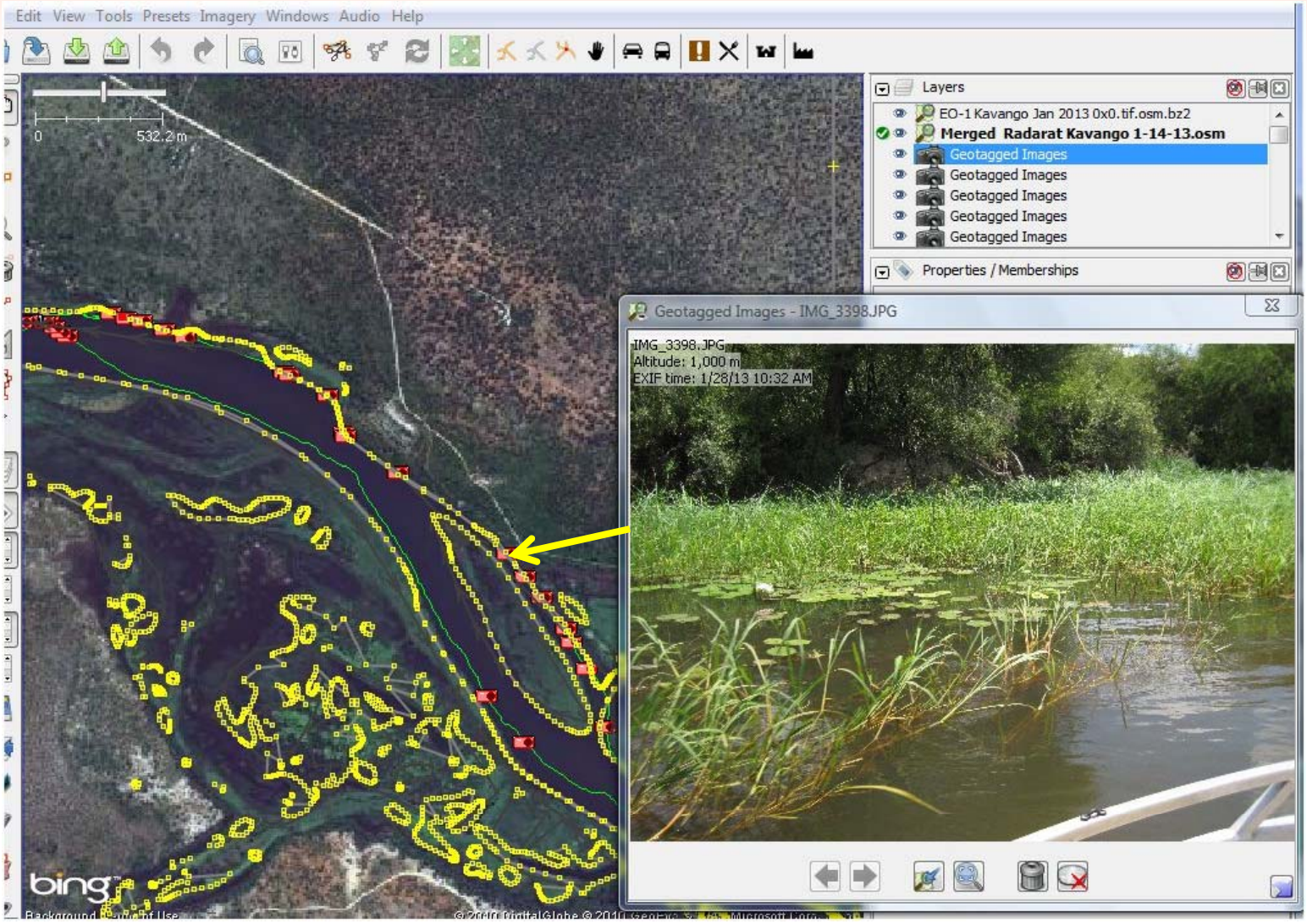
GPS photos Overlaid on Boat Track



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

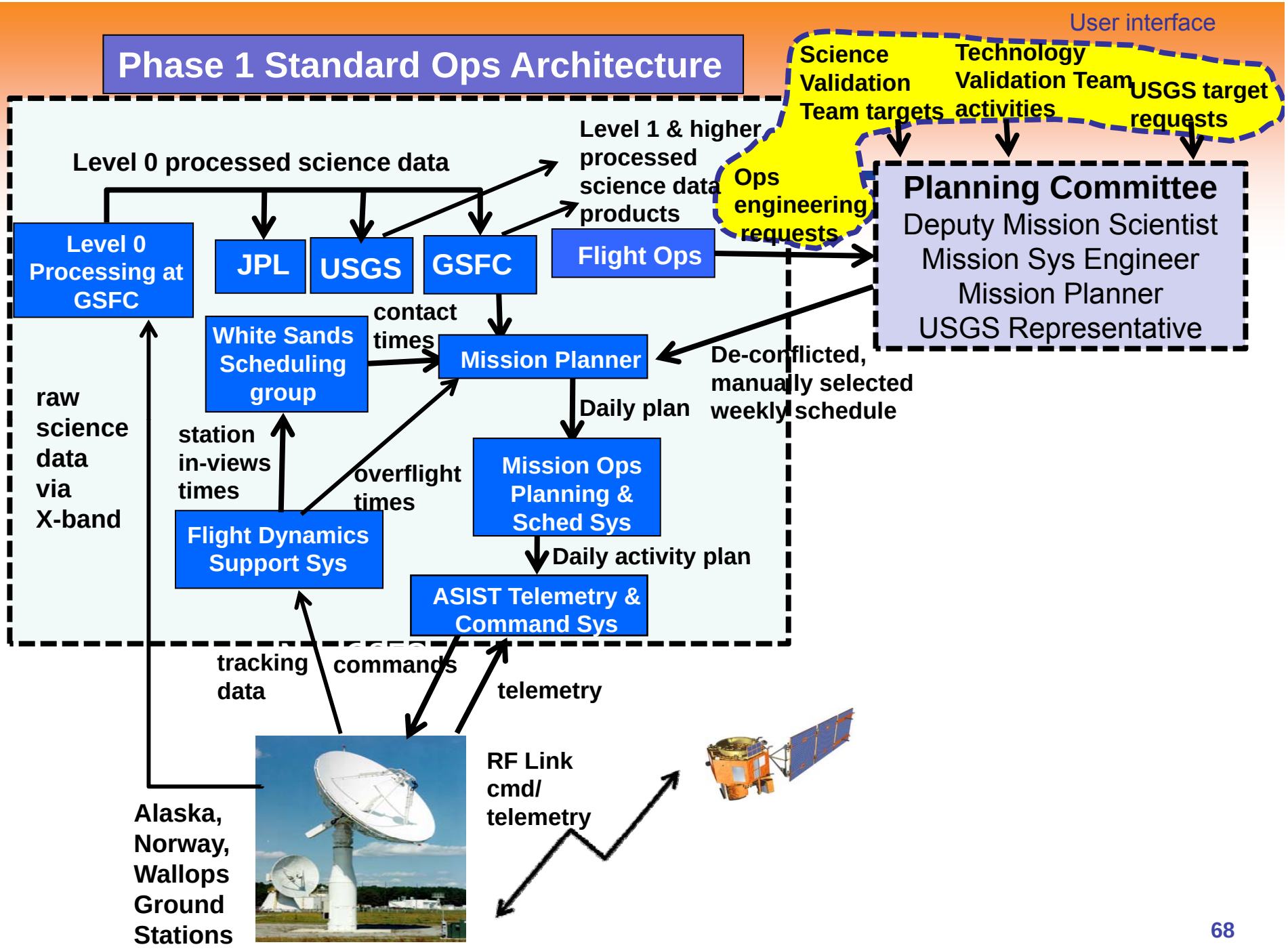


GPS Photo Shows Terrain Type Overlaid on Boat Track and Radarsat/EO-1 Water Detection



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

contact times

targets

White Sands Scheduling group

Mission Planner

De-conflicted, manually selected weekly schedule (backup approach & maneuvers)

raw science data via X-band

Daily plan

station in-views times

overflight times

Mission Ops Planning & Sched Sys

Flight Dynamics Support Sys

De-conflicted, manually generated replacement record file

Daily activity plan goals

ASIST Telemetry & Command Sys

ASPEN Ground Planner with Web Interface

tracking data

Commands, goals

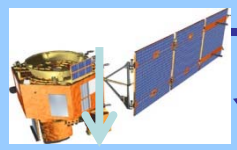
telemetry

RF Link cmd, goals/ telemetry

Alaska, Norway, Wallops Ground Stations

Onboard EO-1

goals



Science Processing

science data

cmds

CASPER Onboard Planner

activities

SCL-Meta-command controller

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

GSFC Sensor Observation Service(SOS) for ALI

GSFC Web Processing Service(WPS) for ALI

L1R, L1G

L2 Products

External and Internal User targets

Level 0 Processing at GSFC

White Sands Scheduling group

contact times

Mission Planner

FOT

JPL Sensor Planning Service (SPS)

raw science data via X-band

station in-views times

overflight times

Daily plan

backup

Mission Ops Planning & Sched Sys

JPL users targets

Mission Science Office

GSFC GeoBPMS (Secure Web Interface)

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

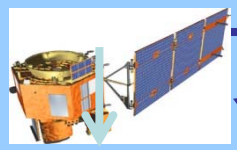
telemetry

RF Link cmd, goals/ telemetry

Alaska, Norway, Wallops Ground Stations

Onboard EO-1

goals



science data

Science Processing

cmds

SCL-Meta-command controller

CASPER Onboard Planner

activities

Detail of Phase 3 – User Services

Scheduling and Notification of EO-1 Image Acquisitions

Note: This follows the path of information only, not image data.

User Services

USGS EDC

GSFC Mission Science Office

JPL Users

New image request

Note: Each facility currently has its own user notification method.

new

Self serve users

New image request

You've got data

Your image has been scheduled *(not in place yet)*

GSFC GeoBPMS (Secure Web Interface)

Request for new or replacement image

Request for new or replacement image

Active list of images to be taken *(not in place yet)*

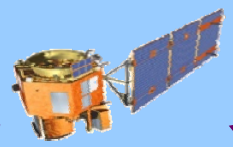
ASPEN Ground Planner with Web Interface at JPL (now)
New: Installed at GSFC in 2011

Collated list of images to take

Collated list of images to take

Onboard EO-1

goals



Science Processing

science data

cmds

SCL-Meta-command controller

CASPER Onboard Planner

activities

Notification of completed images

GSFC L1R, L1G Cloud Pipeline

GSFC Automated L0

Dash lines indicate future development of scheduling feedback so users know if their images have been scheduled.

Phase 4 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) to enable users to customize Level 2 products

Starlight 100 Gigabit Ethernet Exchange

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

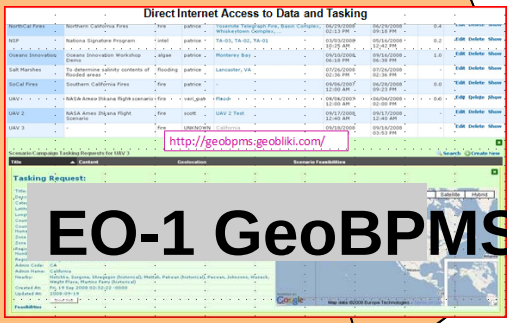
Atmospheric Correction for ALI & Hyperion

Namibia Flood Dashboard

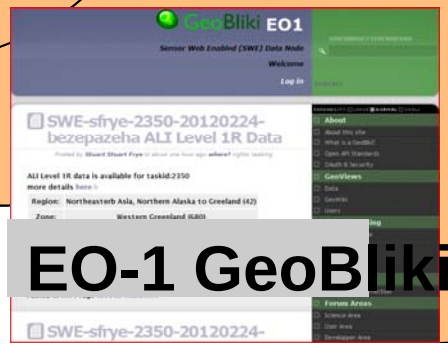
Multi year data product archive

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

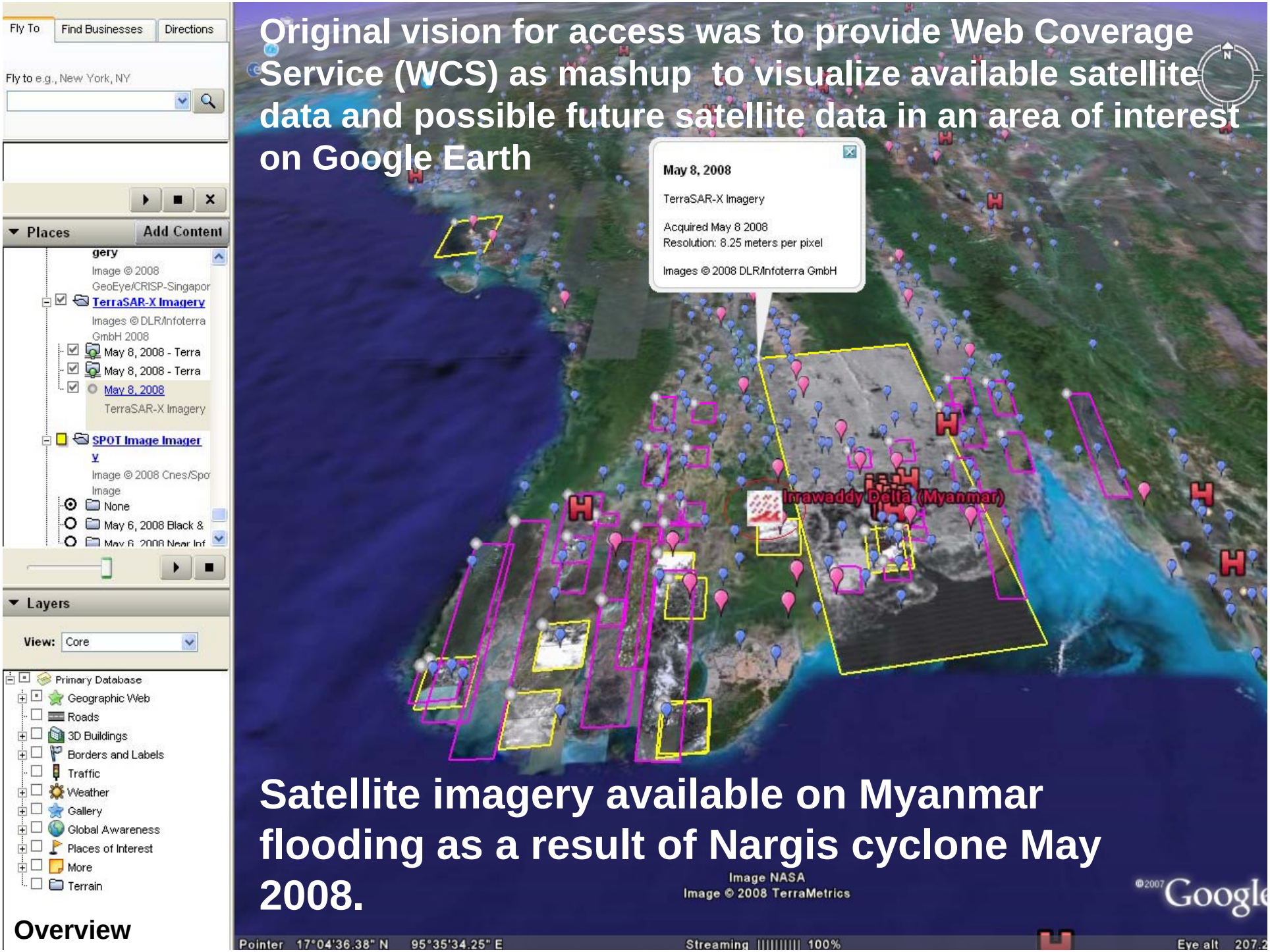


EO-1 GeoBPMS

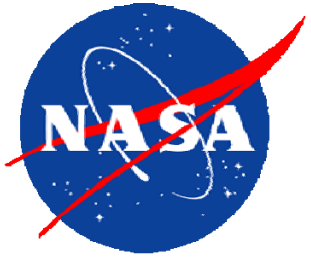


EO-1 GeoBliki

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


Fly To
Find Businesses
Directions
Fly to e.g., New York, NY
Places
Add Content
gery
Image © 2008 GeoEye/CRISP-Singapor
TerraSAR-X Imagery
Images © DLR/Infoterra GmbH 2008
May 8, 2008 - Terra
May 8, 2008 - Terra
May 8, 2008
TerraSAR-X Imagery
SPOT Image Imagery
Image © 2008 Cnes/Spot Image
None
May 6, 2008 Black &
Layers
View: Core
Primary Database
Geographic Web
Roads
3D Buildings
Borders and Labels
Traffic
Weather
Gallery
Global Awareness
Places of Interest
More
Terrain
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
May 8, 2008
TerraSAR-X Imagery
Acquired May 8 2008
Resolution: 8.25 meters per pixel
Images © 2008 DLR/Infoterra GmbH
Irrawaddy Delta (Myanmar)
Satellite imagery available on Myanmar flooding as a result of Nargis cyclone May 2008.
Image NASA
Image © 2008 TerraMetrics
©2007 Google
Pointer 17°04'36.38" N 95°35'34.25" E
Streaming 100%
Eye alt 207.2

Overview


NASA