A Flight and Ground Operations Concept for the Intelligent Payload Module for the Proposed HyspIRI Mission

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Intelligent Payload Module Summary

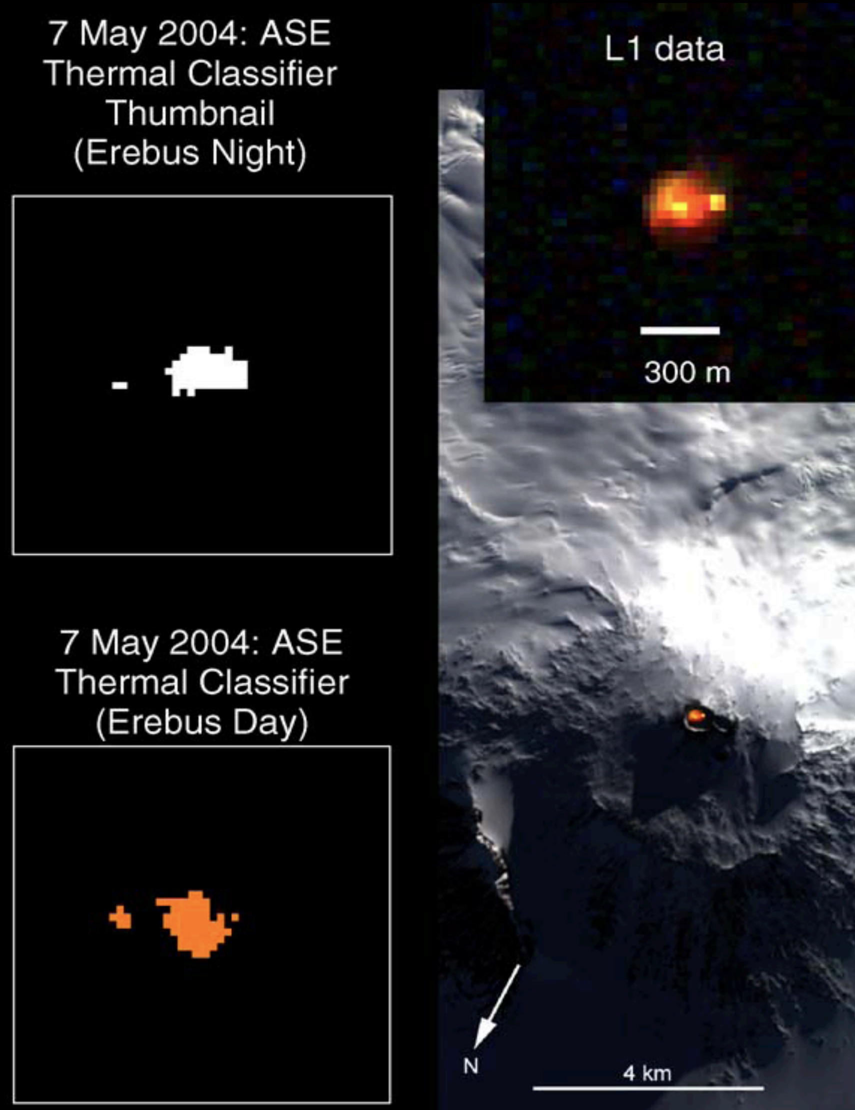
- The Intelligent Payload Module will enable near real-time downlink of selected subset (spatial, spectral, product) of VSWIR/TIR data using heritage Direct Broadcast/Direct Readout technology
- Direct Broadcast data rate:
  ~10 x 10^6 bits / sec out of
- Anticipated HyspIRI data rate:
  ~ 800 x 10^6 bits/sec = VSWIR + TIR
- ~40x oversubscription assuming standard (2x) compression algorithms

High Interest Heritage Products

Discipline	Products	Heritage (not exhaustive)	Interest
Cryosphere	Snow, Water, Ice Land	**Hyperion/EO-1 (onboard)**, MODIS, ASTER, AVHRR, Landsat (Ground)	High
Volcanology	Thermal emission	AVHRR, ASTER, MODIS (ground), **Hyperion (onboard)**	High
Hydrology	Surface Water Extent	MODIS, Landsat, WV2, Geo-Eye, Ikonos, ASTER (ground), **Hyperion (onboard)**	High
Wildfire	Thermal Mapping	MODIS, (Ground), **Hyperion (onboard)**	High
	Burn Scar	Landsat, AVHRR, Aviris, ALI, Hyperion, ASTER (ground)	High

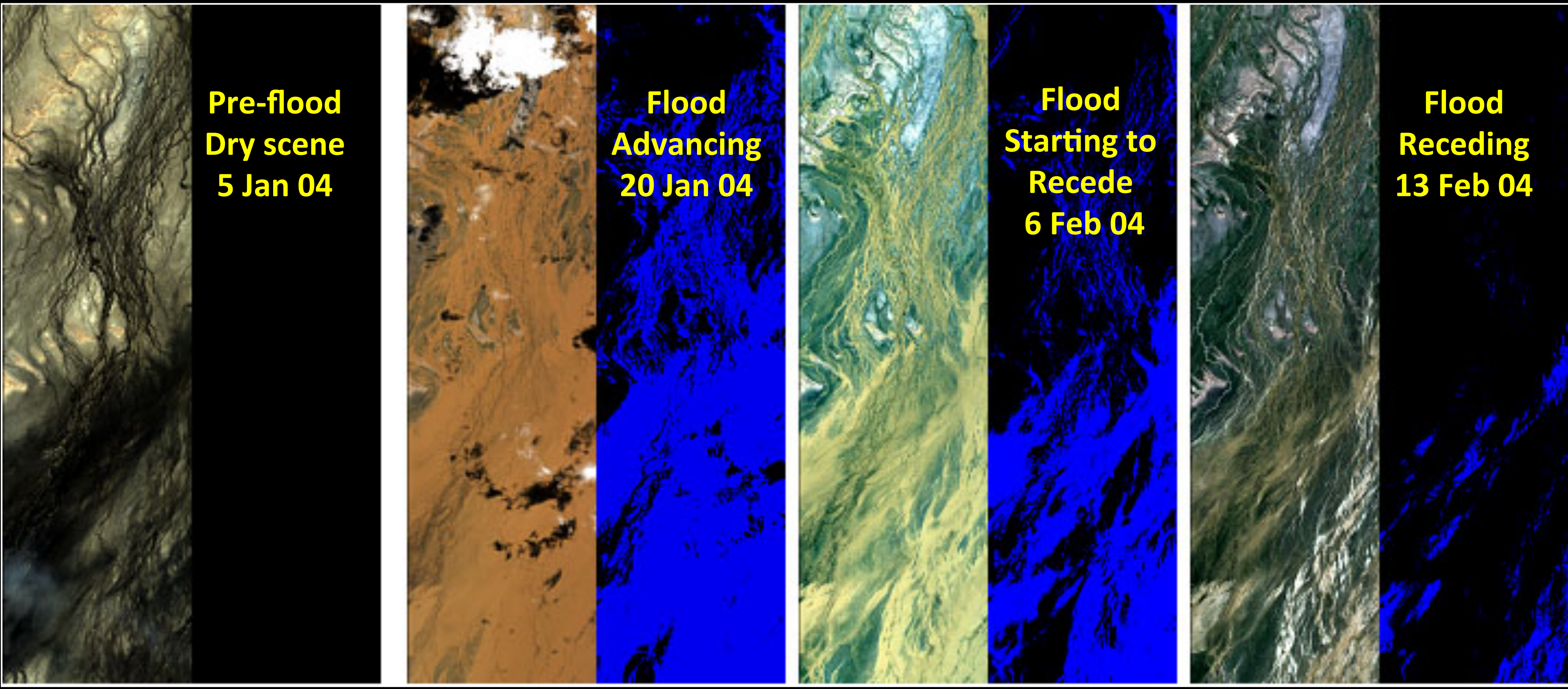
For further details see: S. Chien, D. Mclaren, D. Tran, A. G. Davies, J. Doubleday, D. Mandl, "Onboard Product Generation on Earth Observing One: A Pathfinder for the Proposed HyspIRI Mission Intelligent Payload Module, IEEE JSTARS Special Issue on the Earth Observing One (EO-1) Satellite Mission: Over a decade in space, 2013.

EO-1/ASE Onboard:
At left hot and extreme pixel classification maps developed onboard from Hyperion Data.
At right Level One full data downlinked and processed on ground. Both acquired of the Mount Erebus volcano 7th May 2004 on two overflights.
Courtesy NASA/GSFC/EO-1, A. Davies.



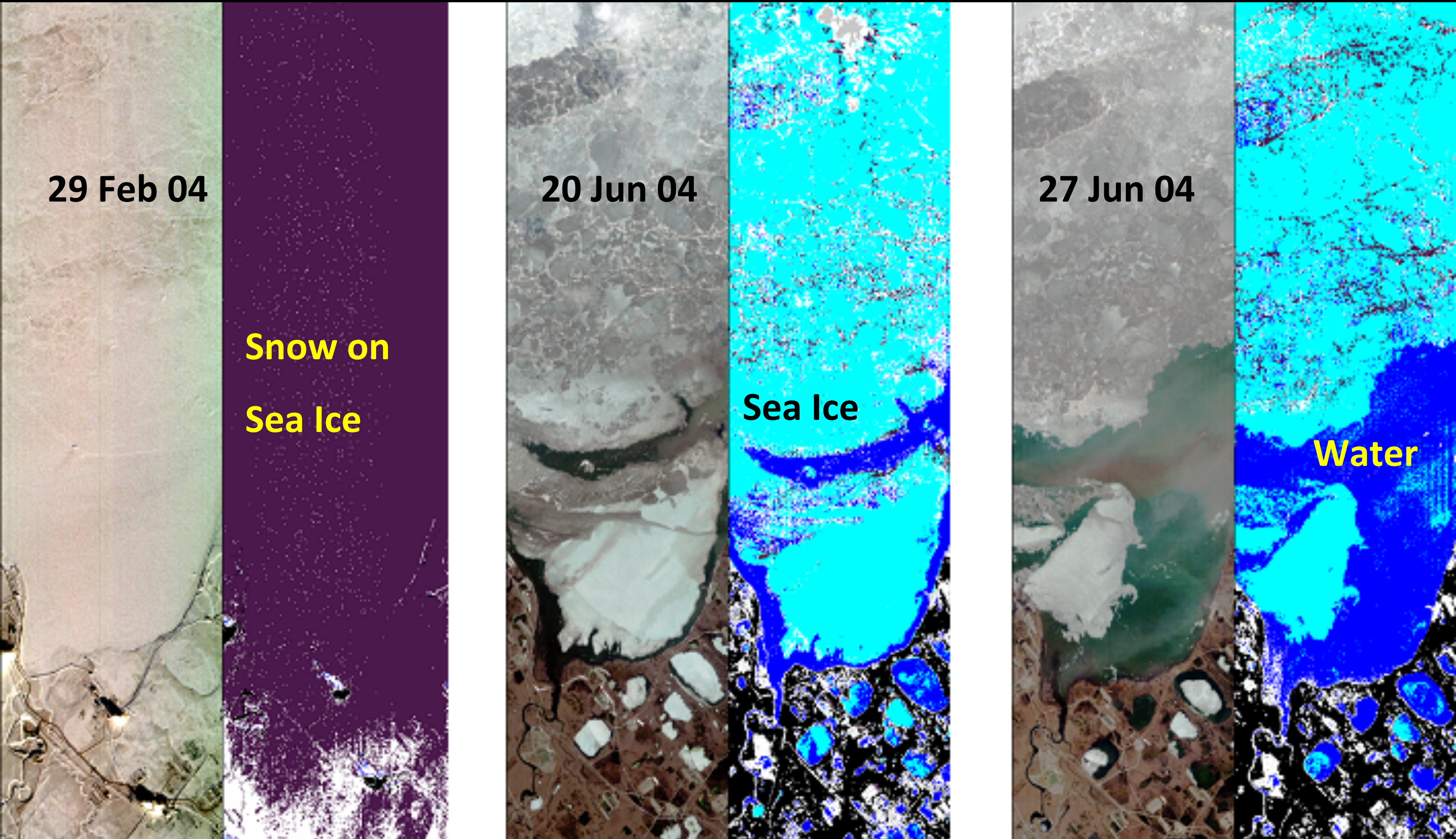
For further information see: Davies, A. G., S. Chien, V. Baker, T. Doggett, J. Dohm, R. Greeley, F. Ip, R. Castano, B. Cichy, R. Lee, G. Rabideau, D. Tran and R. Sherwood (2006) Monitoring Active Volcanism with the Autonomous Sciencecraft Experiment (ASE). *Remote Sensing of Environment*, Vol. 101, Issue 4, pp. 427-446.

EO-1: Onboard derived flood maps of Diamantina River, Australia, 2004.



Courtesy NASA/GSFC/EO-1/U. AZ/JPL

For further information: Ip, F., J. M. Dohm, V. R. Baker, T. Doggett, A. G. Davies, R. Castano, S. Chien, B. Cichy, R. Greeley, and R. Sherwood (2006) Development and Testing of the Autonomous Spacecraft Experiment (ASE) floodwater classifiers: Real-time Smart Reconnaissance of Transient Flooding. Remote Sensing of Environment, Vol. 101, Issue 4, pp. 463-481.



Snow
Water
Ice
Land
Unclassified

EO-1 Onboard: Cryosphere Classifier:

Deadhorse (Prudhoe Bay), Alaska

Courtesy NASA/EO-1/GSFC/ASU

For further information see: Doggett, T., R. Greeley, A. G. Davies, S. Chien, B. Cichy, R. Castano, K. Williams, V. Baker, J. Dohm and F. Ip (2006) Autonomous On-Board Detection of Cryospheric Change. *Remote Sensing of Environment*, Vol. 101, Issue 4, pp. 447-462.

More Advanced Products

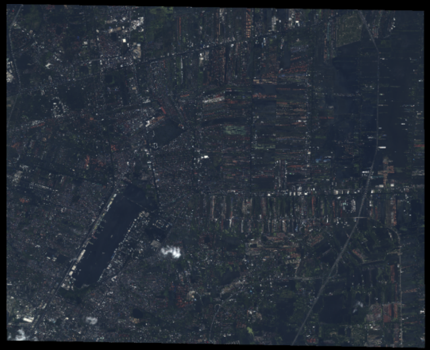
Moderate Interest Products

Discipline	Products	Heritage	Interest
Aerosols	Overwater Dust, Overland Dust	MODIS, ASTER, MISR, CERES, AVHRR, GMS-SEVIRI, CALIPSO (ground)	Moderate – technical challenge
Ecosystem	Vegetation Stress Indices	AVIRIS, Hyperion, AVHRR (ground)	Moderate – limited timeliness driver
Ecosystem	TIR Evapotranspiration	Landsat, MODIS, GOES (ground)	Moderate – limited coverage
Disease	Vegetation Disease Risk	AVHRR (ground)	Moderate – technical challenge – requires long historical baseline
Oceanography	Ocean Color	MODIS, AVHRR, MERIS, SeaWifs, ASTER, Landsat, VIIRS, Hyperion, CZCS, OCTS (ground)	Moderate – technical challenge, low strength signal
Oceanography	Sea Surface Temperature	MODIS	Moderate – technical challenge, small temperature differentials, callibration
Volcanology, Wildfire	Plume	ASTER, MODIS (ground)	Moderate - technical challenge, limited coverage

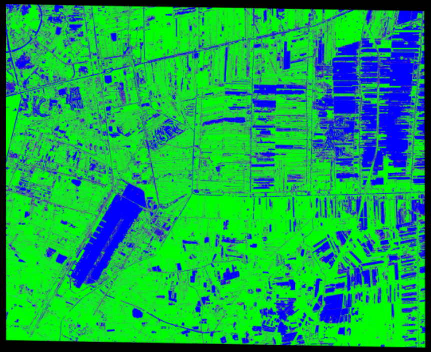
Also technology push concepts (following slides).

Flood Tracking

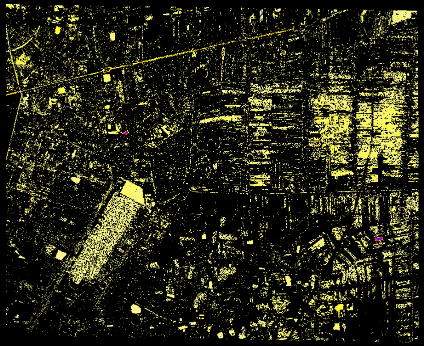
- Integrated WV-2 data (2m spatial resolution)
- Developed algorithms and workflows for water depth and volume estimation (incorporating DEM) – potential HyspIRI IPM algorithms



Reflectance of WV2 scene of Bangkok w/ flooded Don Muang Airport, acquired 11.3.2011



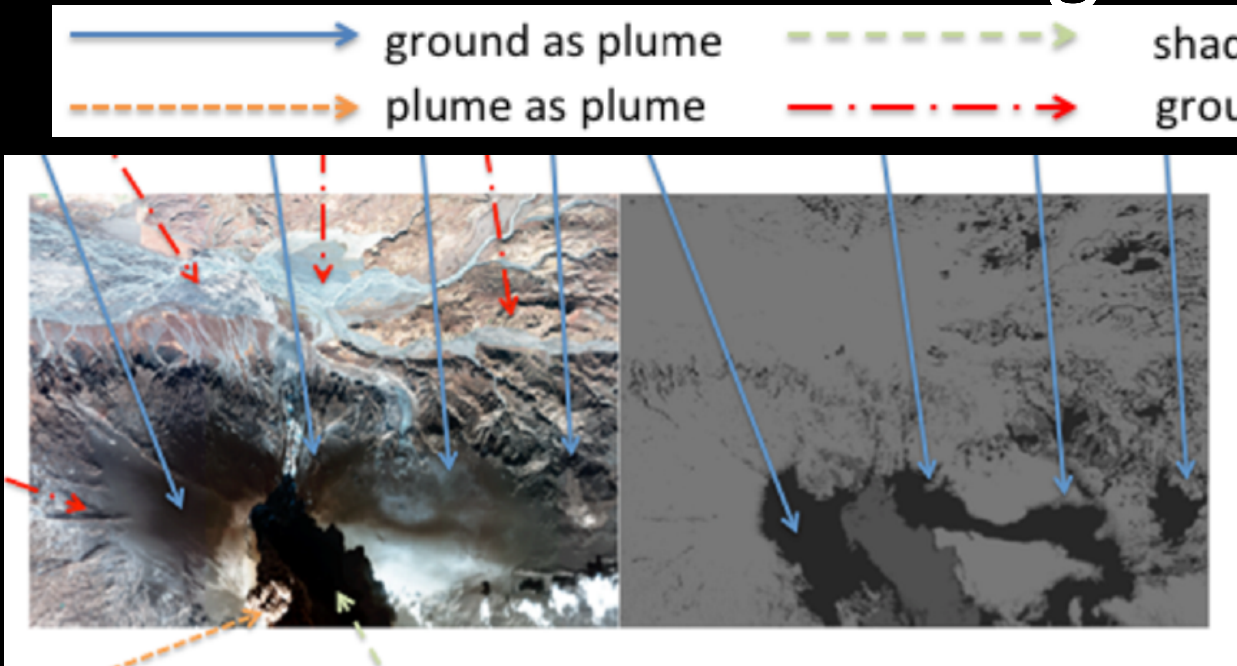
Surface water extent (blue) from SVM classifier using 5th degree polynomial kernel on 8 WV2 bands



Resulting water depth map calculated using SVM-classified surface water extent map and DEM. Total water volume calculated: ~27,872,000 m^3; average flooded pixel depth: 0.64 m.

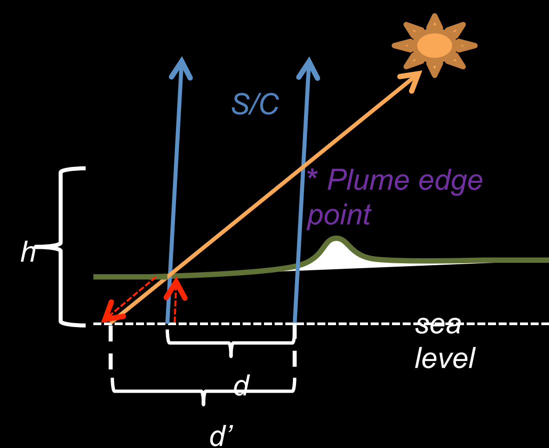
For further details see D. Mclaren, J. Doubleday, S. Chien, "Automated tracking of flooding using WorldView-2 imagery," Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XVIII, SPIE Defense, Security, and Sensing, Baltimore, MD, April 2012.

Volcanic Plume Height Estimation



Histogram-equalized WV2 image, acquired May 17, 2011

Classification map: black = plume, grey = shadow, light = land



d *: Initial shadow length*
d'*: Shadow length after projecting up to DEM & down along sun vector*
h *: Plume point height*

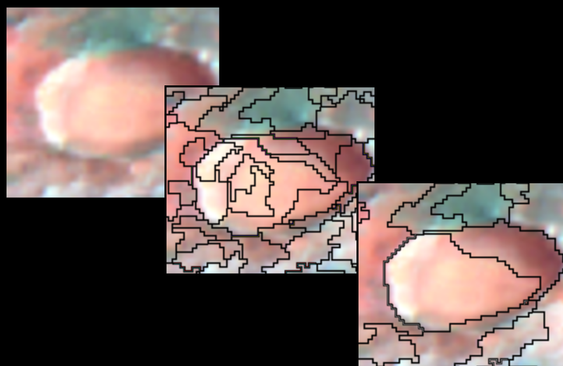
Plume & Shadow Classification using TextureCam Decision Forest Machine Learning [Thompson et al., LPSC, 2012]

Plume height calculation using classification, viewing and solar geometry, DEM.

Reasonable correlation with visual, radar based measurement from [Arason et al. 2011]

For further details see [Mclaren et al. 2012b, SPIE]

Onboard Hyperspectral Analysis



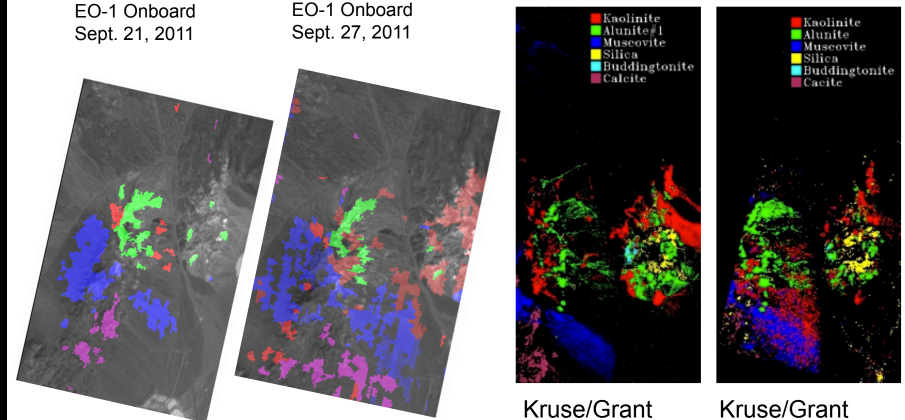
Superpixel segmentation
+
SMACC endmember extraction
=
onboard spectral search

Results from onboard EO-1 (9/2011)

For further details see
[Thompson et al 2009, TGARS]
[Thompson et al. 2012, TGARS]

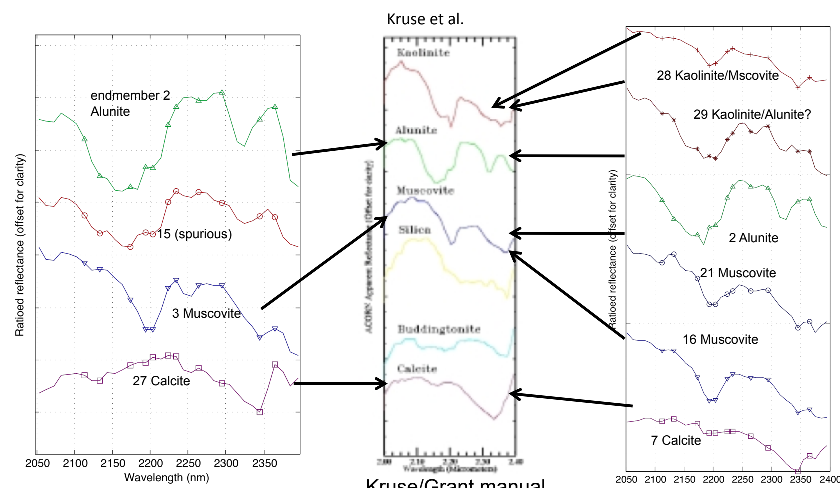
Repeatability: maps

EO-1 Onboard Sept. 21, 2011 | EO-1 Onboard Sept. 27, 2011



Kruse/Grant manual analysis (AVIRIS) | Kruse/Grant manual analysis (Hyperion)

Repeatability: detections



EO-1 Onboard Sept. 21, 2011 | Kruse/Grant manual analysis (Hyperion) | EO-1 Onboard Sept. 27, 2011

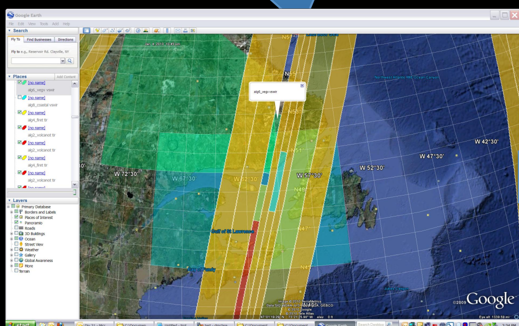
Intelligent Payload Module Operations

- How will Ground/Science/Applications team designate which data/products to downlink?

- A range of operations policies are possible.
- Requirements:
  - Flexible, dynamic
  - Open to a range of input sources (human, electronic)
  - Low operations cost
  - Mature, low risk

HyspIRI IPM Operations Concept

Users input product requests in Google Earth



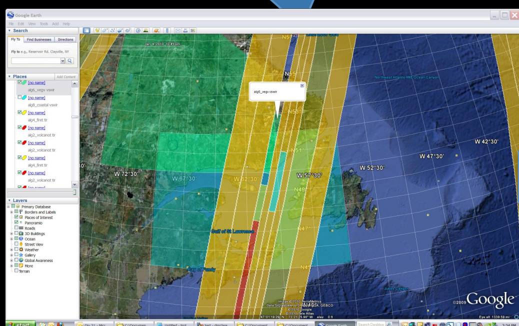
Electronic automatic tasking requests via Sensorwebs

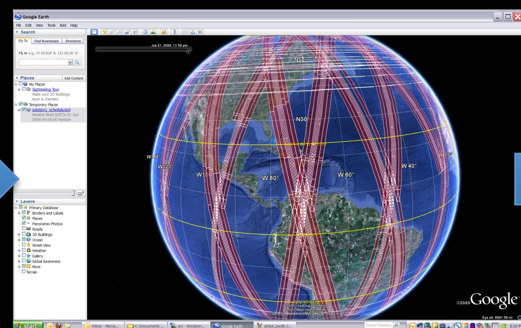
“lights out” payload operations

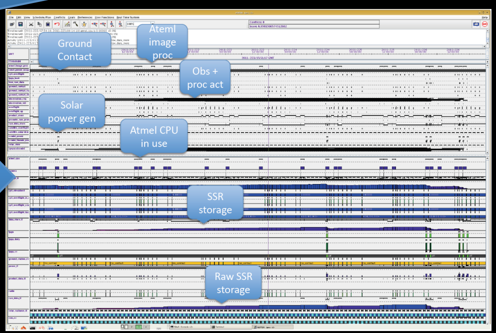
HyspIRI IPM Operations Concept

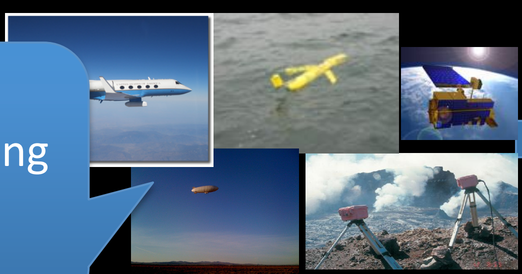
Users input product requests in Google Earth

Planning system determines products based on overflights and resources (CPU, RAM downlink) CLASP+ ASPEN (ground), CASPER (onboard)









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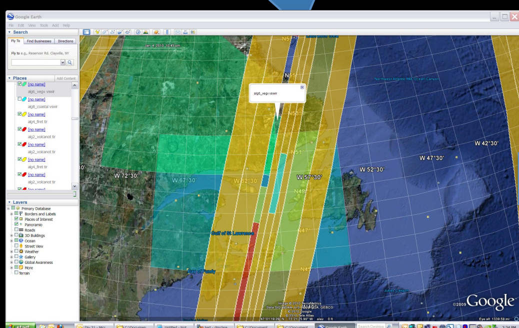
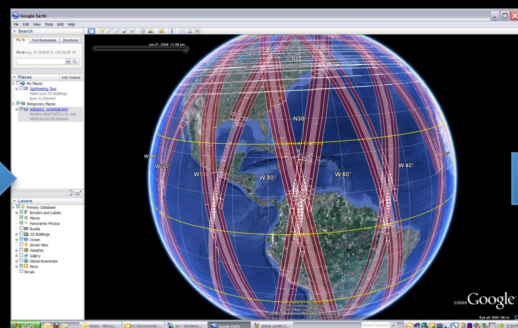
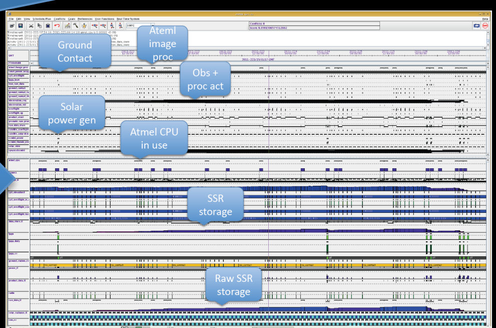
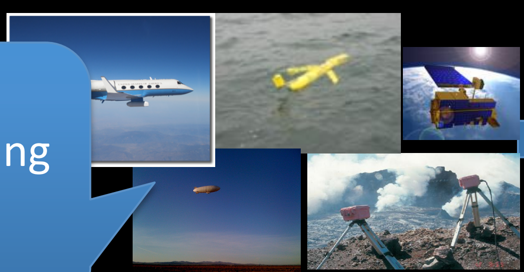


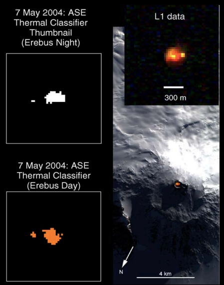




Electronic automatic tasking requests via Sensorwebs

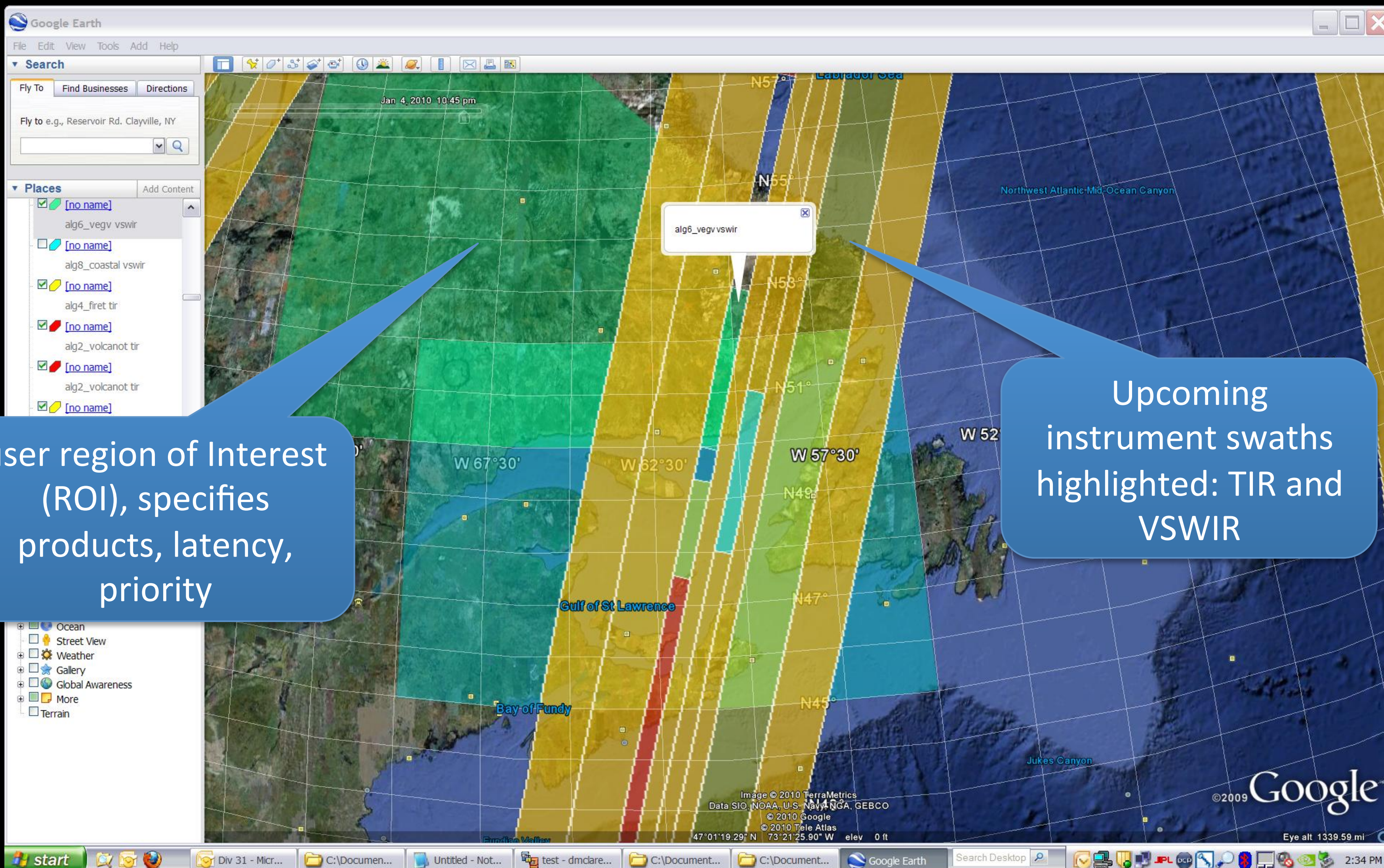


Spacecraft acquires imagery, generates product onboard (including onboard event detection), downlinks product



“lights out” payload operations

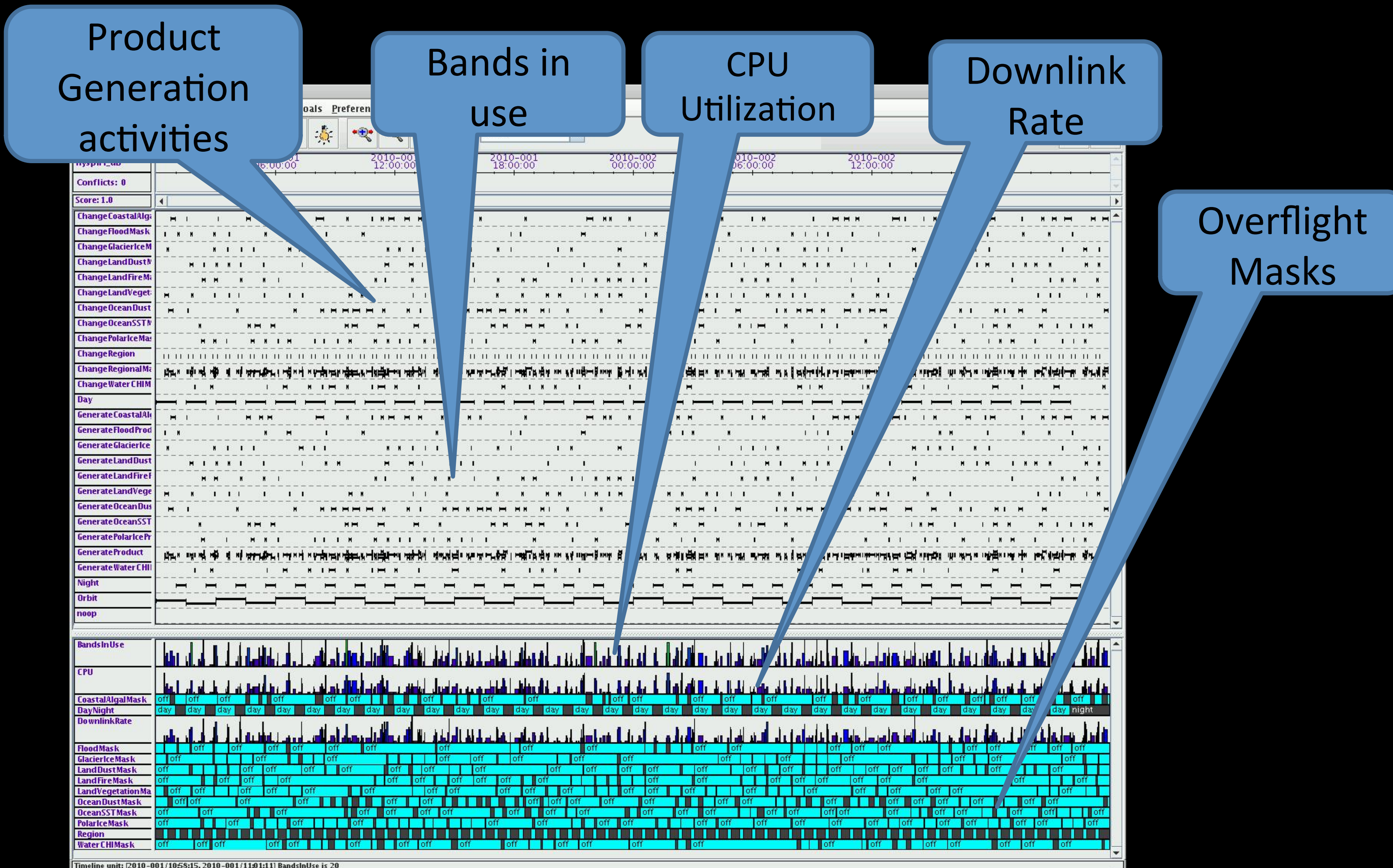
Input via Google Earth KML



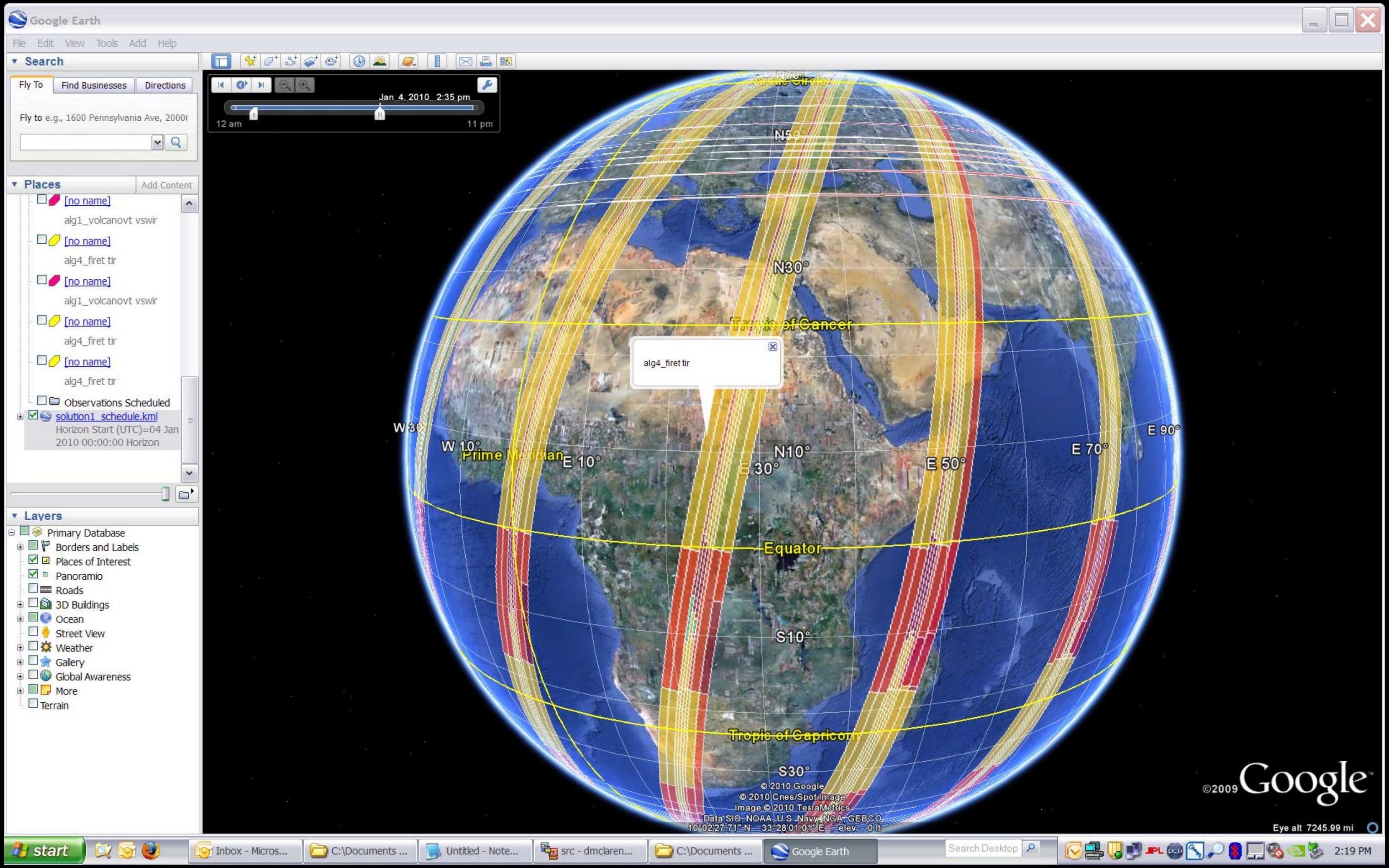
Automated Planning Technology is Mature

- Many of the operations concepts have been in successful use on EO-1 2004- present
- Operations technologies (automated mission planning) in operations use on many missions (see [Chien et al. 2012 SpaceOps] for a survey).
- Range of operations policies are possible
  - If onboard processing and downlink is restricted to real-time (e.g. steady state equilibrium) optimal scheduling is tractable (local greedy algorithm is optimal).
  - If some level of buffering and lag behind incoming data is allowed, problem is exponential in the size of the lag (greedy with corresponding scheduling window is optimal)
  - Luckily (computation) or unluckily (flexibility) the anticipated instrument data rate is very large so feasible buffering of raw data is minimal.

ASPEN Generated Processing + D/L Plan



Users can view upcoming acquisition and processing plans

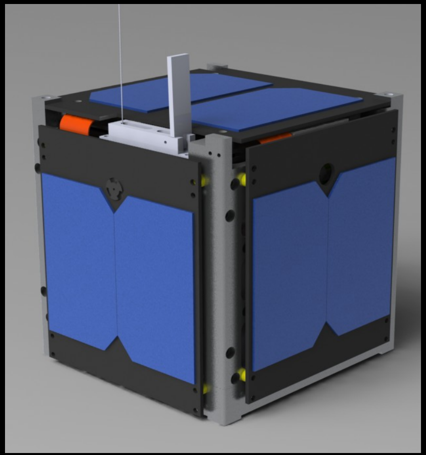


Operations Concept Maturity

- The software for this automated operations concept is *already implemented*.
- Software was first demonstrated in 2010, and has undergone minor enhancements since.
  - Enhancement: specification of latency so that products can be designated for later downlink over desired target ground stations.
  - Enhancement: enables dynamic across track swaths based on overlap with regions of interest

Intelligent Payload Experiment (IPEX)

- IPEX Cubesat will validate elements of HyspIRI IPM concept (launch scheduled 05 Dec 2013)
  - IPEX will generate products onboard
    - Some based on onboard image analysis
  - IPEX will use the proposed HyspIRI IPM web-based, automated operations concept



IPEX Model

Image from July 2012 balloon test flight

IPEX Acquisition Plan

Conclusions

- HyspIRI Intelligent Payload Module will enable delivery of low-latency products and data subsets (spectral, spatial)
  - Mature, heritage products (minimal onboard computing required) and
  - More advanced products (enhanced onboard computing needed)
- Operations concept uses a *simple, web-based interface* to specify products, regions, priorities
- Operations concept is *fully automated* and *does not require dedicated operations staff*