Autonomous Sciencecraft and Sensorweb: Over a Dozen Years of Autonomous Operations

The ASE and Sensorweb Teams
ase.jpl.nasa.gov sensorweb.jpl.nasa.gov

National Aeronautics and Space Administration

ASE Overview

The Autonomous Sciencecraft Software operated the Earth Observing One Mission:

- For over a dozen years from 2004 – 2017
- Acquiring over 67,000 images
- Issuing ~ 3M commands

ASE [1] enabled the spacecraft to automatically analyze imagery acquired and send down summaries and alerts as well as self retask to acquire further imagery.

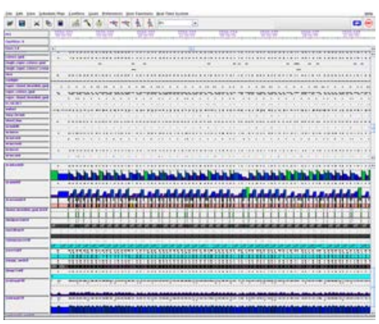
ASE was integrated with scores of other spacecraft aerial, marine, and ground assets to form a sensorweb to track volcanic activity, flooding, wildfires, cryosphere, marine, and other events, processing over 100,000 alerts and acquiring thousands of scenes directly with no human intervention.

Flight/Ground Automated Scheduling

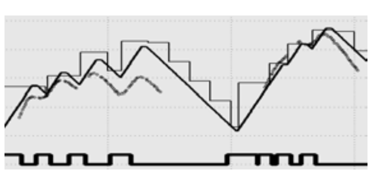
The Autonomous Sciencecraft flew the CASPER scheduler and SCL task executive onboard and also used the ASPEN planner on the ground to automatically plan (ground) and replan (flight) observations based on science image analysis.

This automated planning software enabled both rapid 24/7 response but also increased reliability, robustness to anomalies (such as ground station outages), and also cost avoidance.

The planning system controlled all EO-1 activities with the exception of maneuvers/orbit burns [2].



ASPEN One week timeline schedule for the Earth Observing One Mission

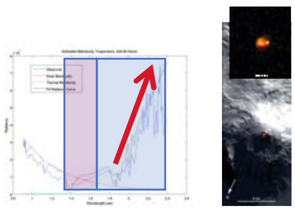


Improved thermal modelling in the ASPEN planner enabled a +33% increase in scene acquisition rate. Projected and actual thermal state of Hyperion instrument as predicted by ASPEN versus observed telemetry.

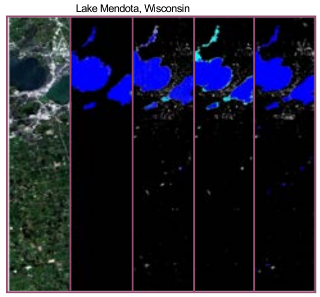
Onboard Data Analysis

ASE flew numerous onboard data analysis and machine learning algorithms for data interpretation. This onboard analysis enabled ASE/EO-1 to send alerts/summaries (potentially to other spacecraft), edit data, or self retask. Just a few of these are highlighted below.

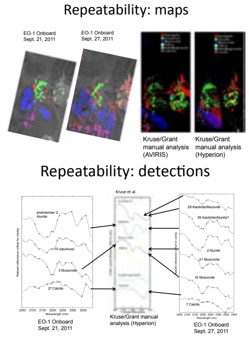
Onboard analysis of spectral magnitude and slope enabled thermal detection of volcanic activity and wildfires [3].



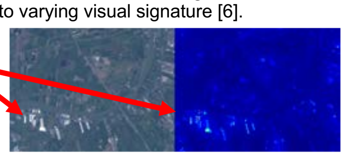
Support Vector Machine (SVM) machine learning was used onboard for ASE for over a dozen years. At right is shown the Snow Water Ice Land Cloud classification [4].



Superpixel segmentation and Hyperspectral unmixing were demonstrated onboard ASE/EO-1[5] unfortunately the lack of computing onboard restricted this to technology demonstration. Here we show comparisons of onboard analysis to ground analysis of Cuprite NV Kruse and Boardman.



Unsupervised outlier detection was also demonstrated. Here it detects buildings in rural Thailand due to varying visual signature [6].



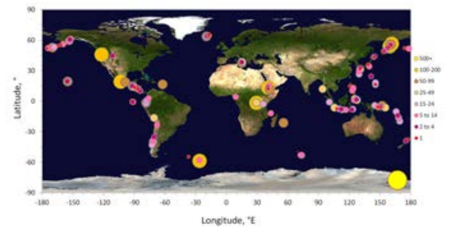
Volcano Sensorweb

Scores of space and ground assets were linked together to form a situational awareness of the activity of volcanic sites. Automated tasking ground→ space and space → space (both common) and space → ground (unusual) were demonstrated and used operationally [7].

Over 100,000 alerts/triggers were initiated in over a dozen years and thousands of scenes acquired with no human in the loop.

The active thermal signature (e.g. hit) rate of triggered scenes was over 35% as compared to a background MODIS "always on" monitoring rate of over 100x less.

Partners (incomplete list): MODVOLC, GOESVOLC, AFWA, VAAC, Iceland/MEVO, Etna VO (U. Firenze), MEVO (NM Tech), HVO (Kilauea), IEGPN (Ecuador), CVO (Mount St. Helens), Serganomin (Chile).



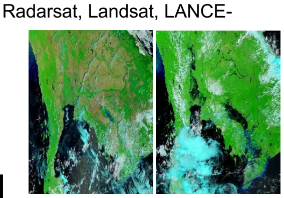
Heat map of Volcano Sensorweb acquired scenes

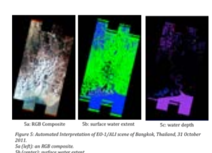
Flood Sensorweb

High coverage, low spatial resolution imagery (MODIS) was used to automatically direct low coverage high spatial resolution assets (e.g. EO-1, commercial) to increase temporal and spatial coverage of flooded areas achieving +100% temporal high resolution coverage [8].

Partners (incomplete list): HAII (Thailand), Digital Globe (Worldview), Geo-Eye, Radarsat, Landsat, LANCE-MODIS.

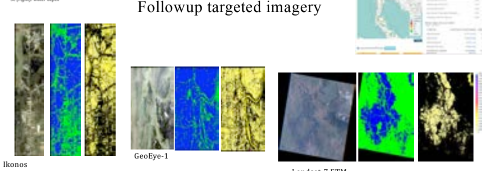
MODIS regional imagery for detection and location





In-situ data and Model

Followup targeted imagery



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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov