



# Space Exploration enabled by Onboard Computing and Decision-making

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[ai.jpl.nasa.gov](http://ai.jpl.nasa.gov)

slides & images: <http://ai.jpl.nasa.gov/public/home/chien/spring-agu-2006.html>

# 7 May 2004 ASE monitors Mt. Erebus

ASE images Erebus Night

13:40 GMT

} +10 min

ASE initiates band extraction

} +28 min

ASE runs thermal classifier

} +29 min

**THERMAL TRIGGERED**

Planner selects reaction observation  
(Stromboli observation replaced)

} +20 min

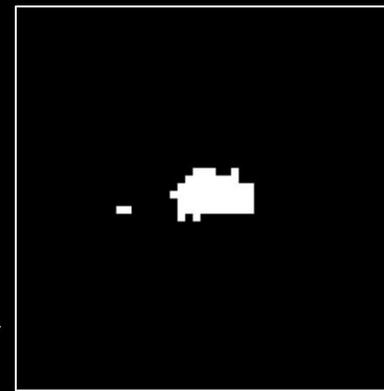
Thumbnail downlinked (S-band)

15:58 GMT

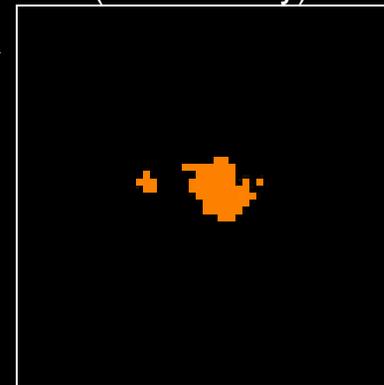
ASE images Erebus again

20:10 GMT  
+ 06:30

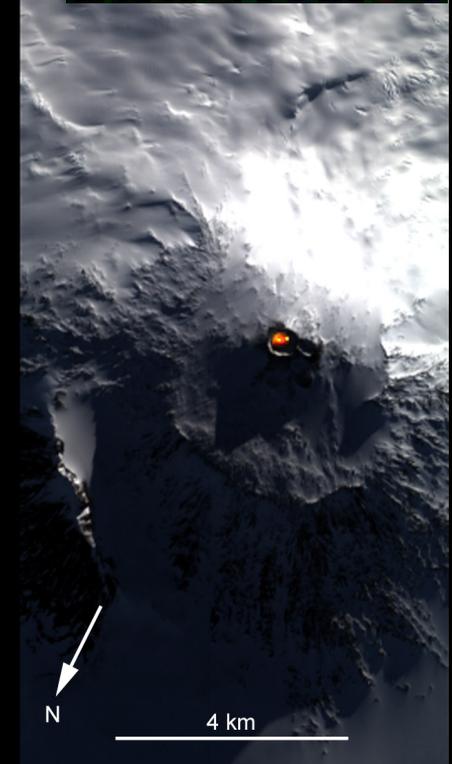
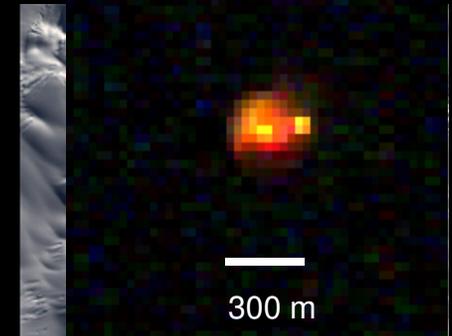
ASE Onboard  
Thermal Classifier  
Thumbnail  
(Erebus Night)



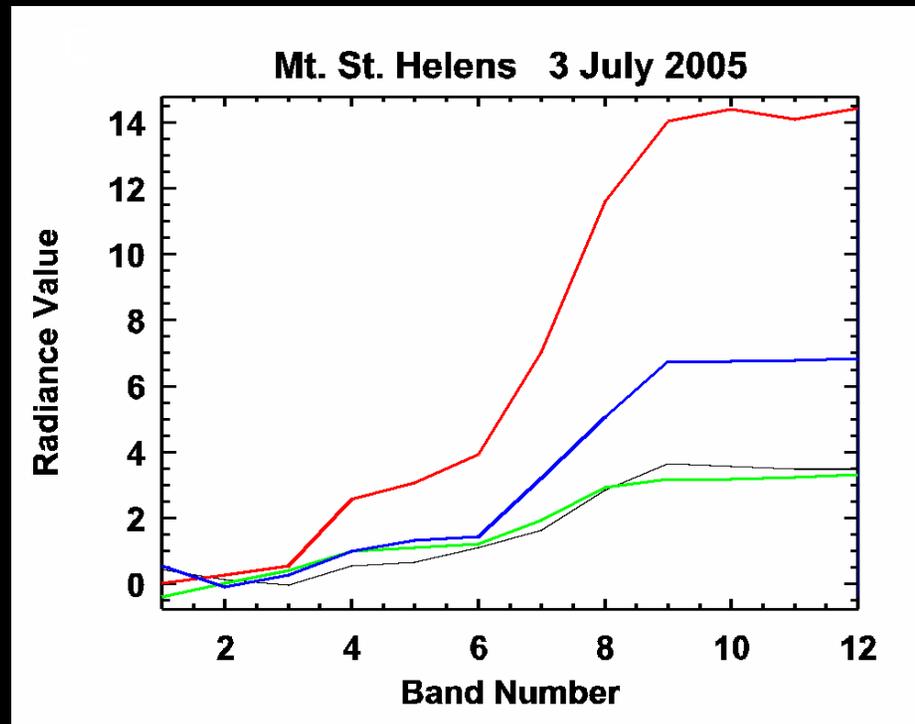
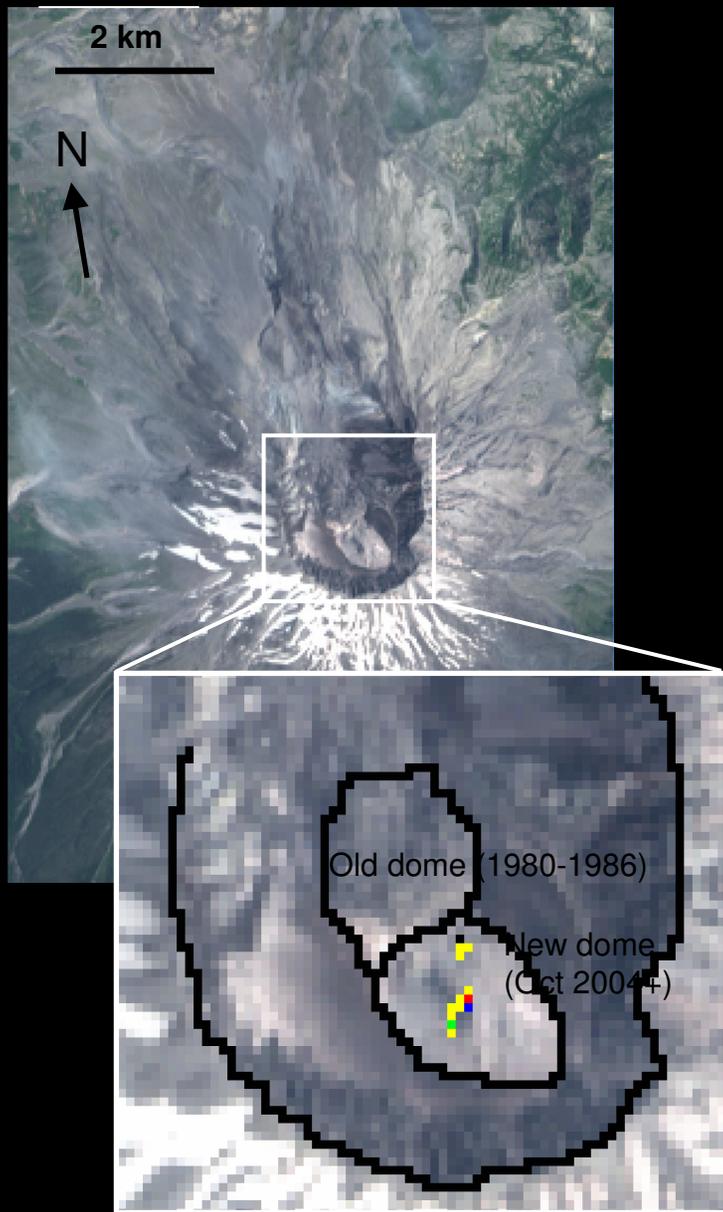
ASE Onboard  
Thermal Classifier  
(Erebus Day)



L1 data

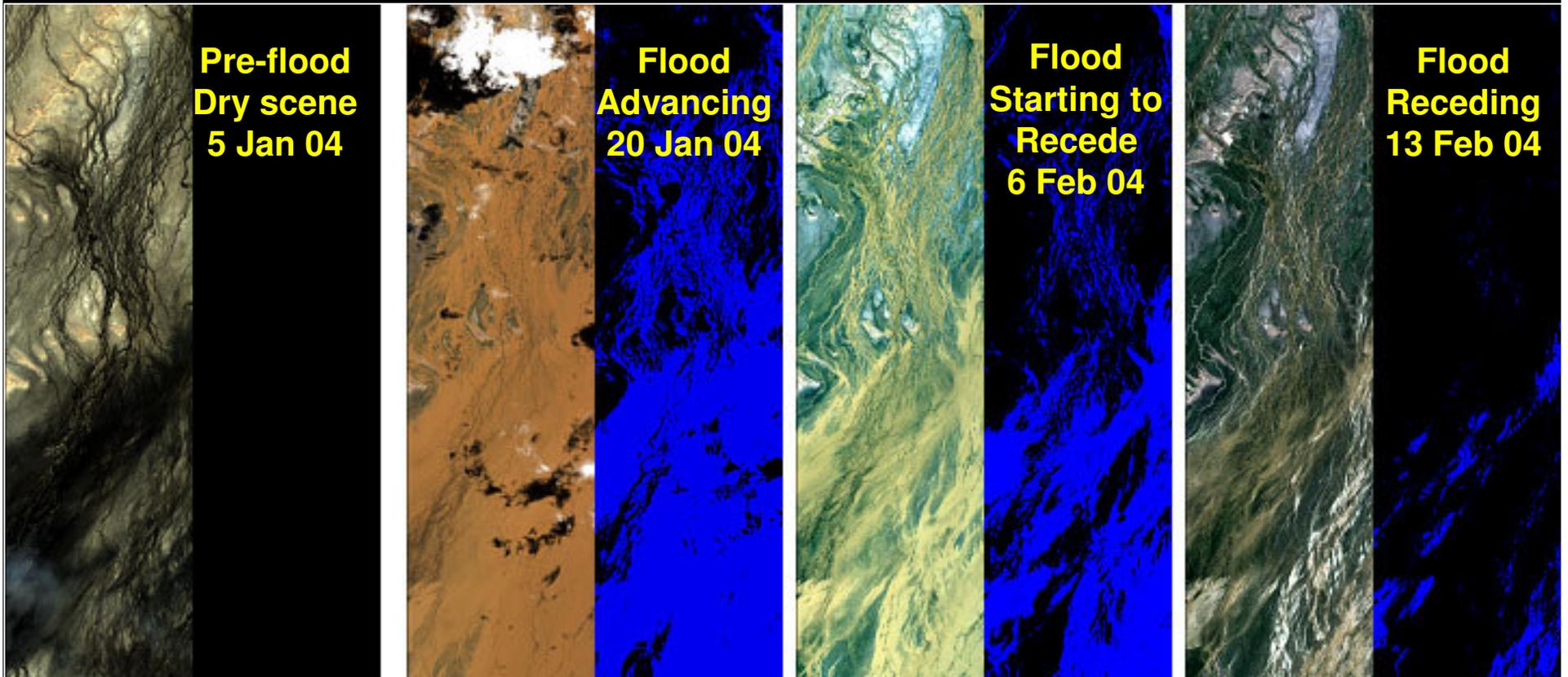


- ASE enabled rapid notification of volcanic event
- ASE enabled rapid re-imaging of this event
- **Autonomous response as normal operations!**
  - Highest leverage for deep space missions



Band	Wavelength, $\mu\text{m}$	Band	Wavelength, $\mu\text{m}$
1	0.630	7	2.022
2	1.245	8	2.103
3	1.266	9	2.254
4	1.599	10	2.264
5	1.659	11	2.274
6	1.780	12	2.285

# Detection of a Rare Major Flood on Australia's Diamantina River using the ASE "Muddy" Floodwater Classifier



Cause of flooding: Monsoonal rain

Wavelengths used: 0.86  $\mu\text{m}$  and 0.99  $\mu\text{m}$

V. Baker, F. Ip, & J. Dohm, University of Arizona

# Cryosphere Classifier

## Deadhorse (Prudhoe Bay), Alaska

29 Feb 04

Snow on  
Sea Ice

20 Jun 04

Sea Ice

27 Jun 04

Water

-  Snow
-  Water
-  Ice
-  Land
-  Unclassified

Wavelengths used in classifier:  
0.43, 0.56, 0.66, 0.86 and 1.65  $\mu\text{m}$



R. Greeley & T. Doggett  
Arizona State University  
Planetary Geology Group

# ASE Current Status

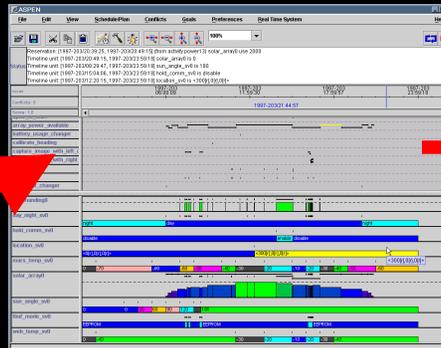
- Current count > 5000+ autonomous data collects
  - 1<sup>st</sup> flights in Fall 2003
- **ASE Software so successful it is now in use as baseline operations for the remainder of the mission (Nov 2004- )**
  - **Enabled > 100x increase in science return**
    - **Measured as: # events captured / MB downlink**
  - **Enabled a reduction in net operations costs**  
**\$3.6M/year → \$1.6M/yr ; over \$1M of reduction directly from ASE**
    - **Operations cost reduction critical in enabling extended mission**  
**Oct 2005 – Oct 2007**

# Sensorweb



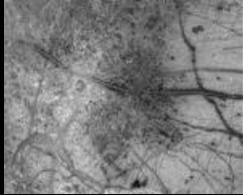
Re-tasking

Earth  
Observer  
One

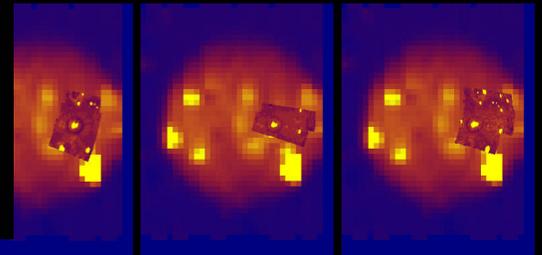


Triggers so far: Wildfires, Floods, Volcanoes (thermal, ash), Ice/Snow, in-situ sensors, modified by cloud cover

# Future Missions



Tracking crustal motion  
for Europa Orbiter

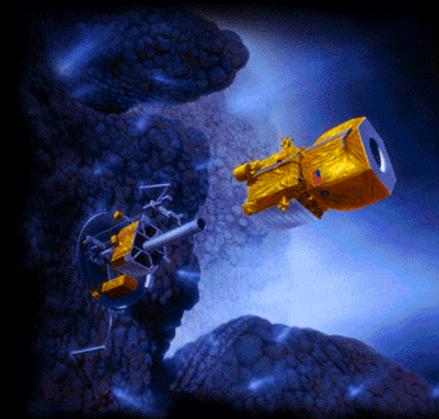


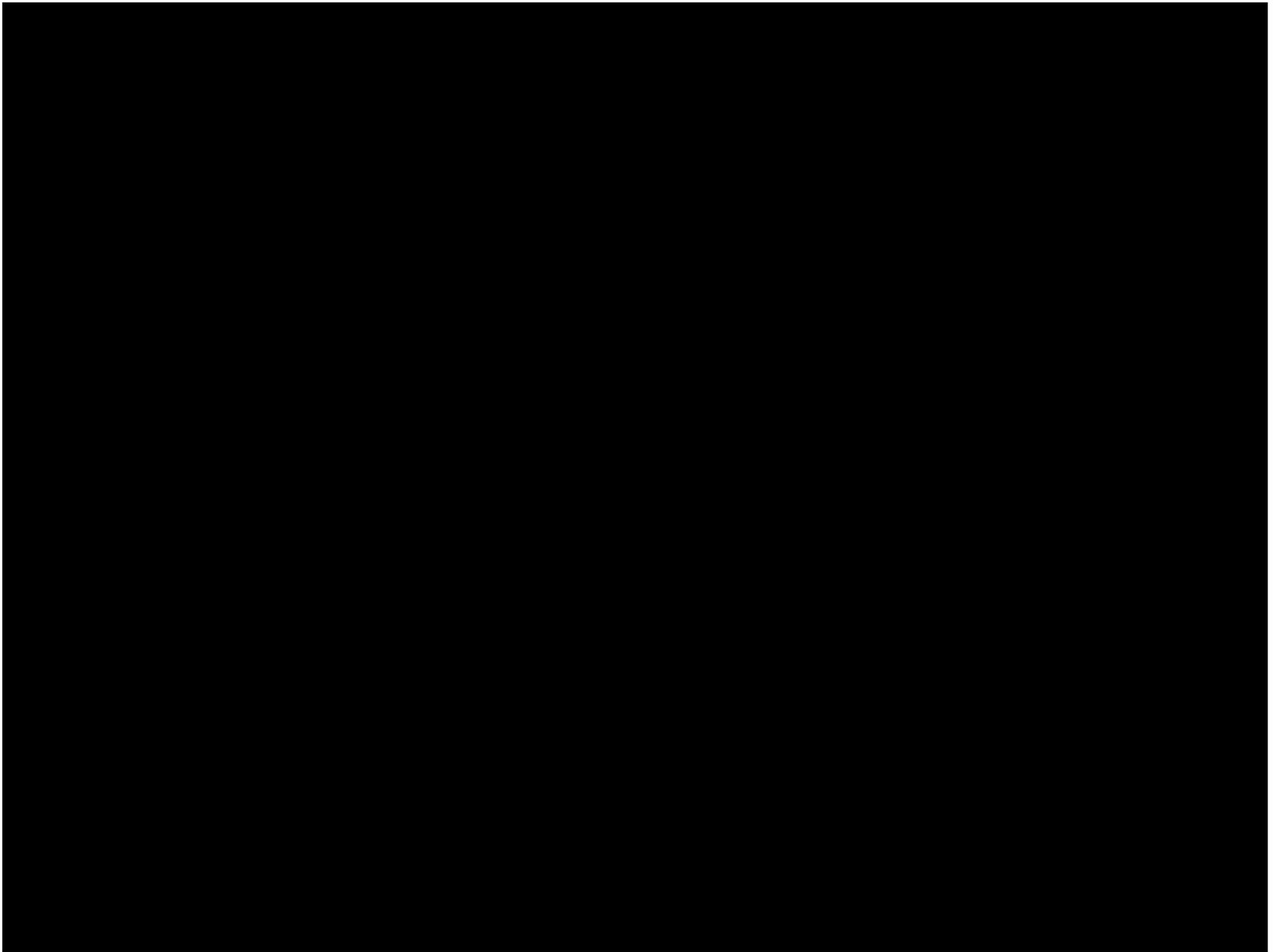
Io Volcanism



Europa Cryobot

Comets





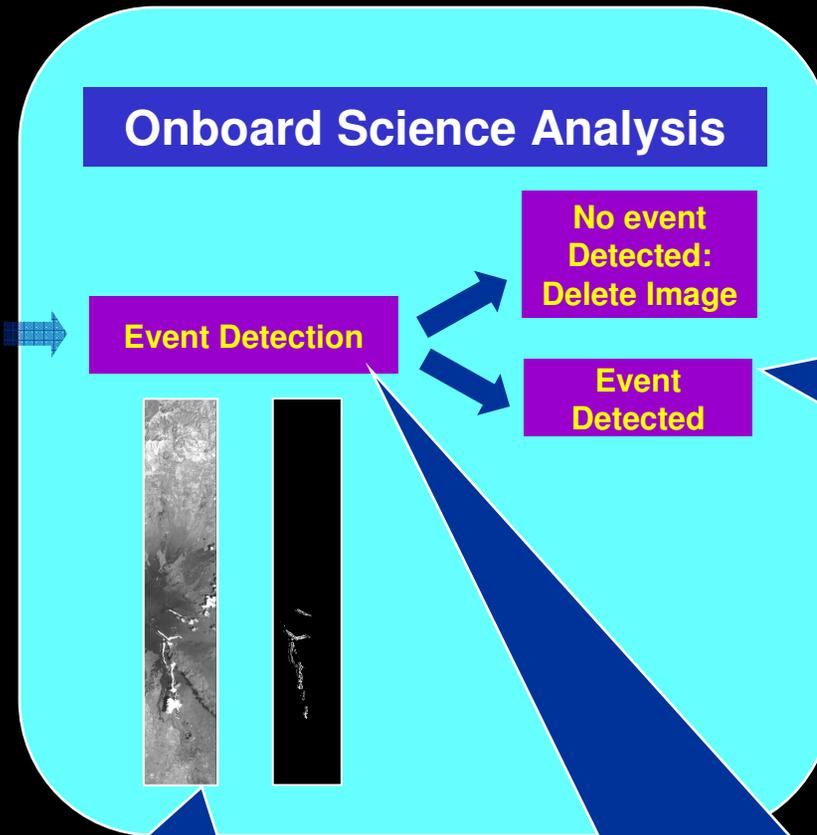
# Science Response

**Image taken by  
Spacecraft**



# Science Response

Image taken by  
Spacecraft



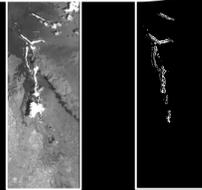
ASE uses state of the art Machine Learning to detect events in the presence of noise

Track a wide range of science events – floods, volcanoes, cryosphere, clouds,...

Key Insight: No need to replicate ground science analysis – just detect activity

# Science Response

*continuous planning*  
- enables seamless long-duration operations and rapid replanning despite limited onboard CPU



No feature Detected:  
Delete Image

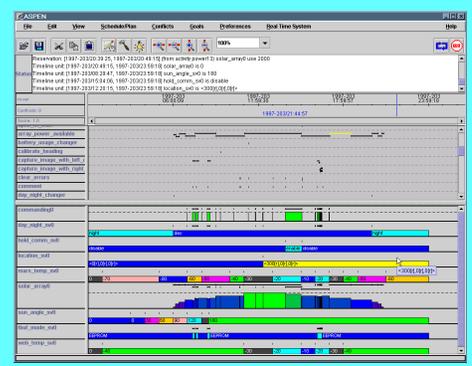
Goal

Feature Detected

Downlink Image and Possibly Re-image Same Area

Goal

## Autonomous Planning



Retarget for New Observation Goals

Onboard planning enables rapid response to detected event

# Science Response

