Space Exploration enabled by Onboard Computing and Decision-making

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7 May 2004 ASE monitors Mt. Erebus

- ASE images Erebus Night
- ASE initiates band extraction
- ASE runs thermal classifier

THERMAL TRIGGERED

Planner selects reaction observation (Stromboli observation replaced)

Thumbnail downlinked (S-band)

ASE images Erebus again

- 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

13:40 GMT
  $\{+10 \text{ min}\}$
  $\{+28 \text{ min}\}$
  $\{+29 \text{ min}\}$

15:58 GMT
  $\{+20 \text{ min}\}$

20:10 GMT + 06:30
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<th>Band</th>
<th>Wavelength, µm</th>
<th>Band</th>
<th>Wavelength, µm</th>
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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 µm and 0.99 µm

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

Wavelengths used in classifier: 0.43, 0.56, 0.66, 0.86 and 1.65 µm

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

- Current count > 5000+ autonomous data collects
  - 1st 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
Sensorweb

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

Onboard Science Analysis

Event Detection

No event Detected: Delete Image

Event Detected

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

Onboard planning enables rapid response to detected event
Science Response

Image taken by Spacecraft

Land Feature Detection

Onboard Science Analysis

No feature Detected: Delete Image

Feature Detected

Downlink Image and Possibly Re-image Same Area

Retarget for New Observation Goals

New Science Images

Autonomous Execution

Event-driven execution of response image