



Prioritized Technology: System Autonomy – Reactive Science Autonomy

Technical Goal

Enable spacecraft to autonomously collect, process, and deliver science data about dynamic, ephemeral, transient phenomena (plumes, seeps, etc)

- Algorithms and on-board software to sense, learn, decide, and act
- Operate when cannot close the operational loop via ground control (due to time delay, limited bandwidth, comm availability)
- Operate when must react faster than is possible with ground control

Major challenges:

- Sensing dynamic phenomena requires integrating appropriate sensors, making measurements at the right time, performing on-board analysis
- Tracking dynamic phenomenon requires making decisions on-board

Technology advances are required in:

- Encoding science hypotheses (often partial) so that autonomous systems can evaluate observations and choose actions
- Autonomous perception algorithms to recognize dynamic phenomena of interest (automatically interpreting a range of instrument/sensor data)
- On-board reasoning to maximize information gain from actions

Technical Status

- Autonomous science data collection is only used under limited conditions
- Airborne Science & Airborne Astronomy (SOFIA) preview science data quality in situ with human-in-the-loop mission- and decision-support
- Conditional collection of Earth remote sensing data at pre-determined locations for known transient events (e.g., volcanic lava flows with EO-1)

Past Examples

- 2015 UAV "Payload-Directed Flight Control System" demonstrations
- 2014 "Planetary Lake Lander" adaptive science observations for dynamic phenomena (SMD ASTEP)
- 2013 Autonomous multi-km traverse with real-time VNIR spectral classification and hypothesis driven path planning,(SMD PSTAR)
- 2005-2015 EO-1 "Autonomous Science Volcano Monitoring"
- 2008 Automatic detection of dust devils and clouds on Mars with on-board science image analysis (Mars Exploration Rovers)
- 2006 Autonomous km-scale traverse with geologic classification and sample selection (SMD ASTEP)

Mission Applications

- Enable missions to Europa, Enceladeus, or Titan to measure dynamic phenomena from orbit or on surface
- On-board capability to fail-operational due to radiation events (required for Europa Multiple Fly-by)
- On-board trajectory planner for low altitude flyby course correction (required for impactor / observer missions)
- On-board real-time planner & task executive for time-critical events (required for dynamic reconfiguration)
- On-board real-time navigation for opportunistic targeting of dynamic phenomena (ejecta plumes, gaseous plumes, etc).
- On-board intelligent data gathering (required for managing high data volume instruments)

Development Cost and Schedule