National Aeronautics and Space Administration

Responsive Onboard Science for the Europa Clipper Mission

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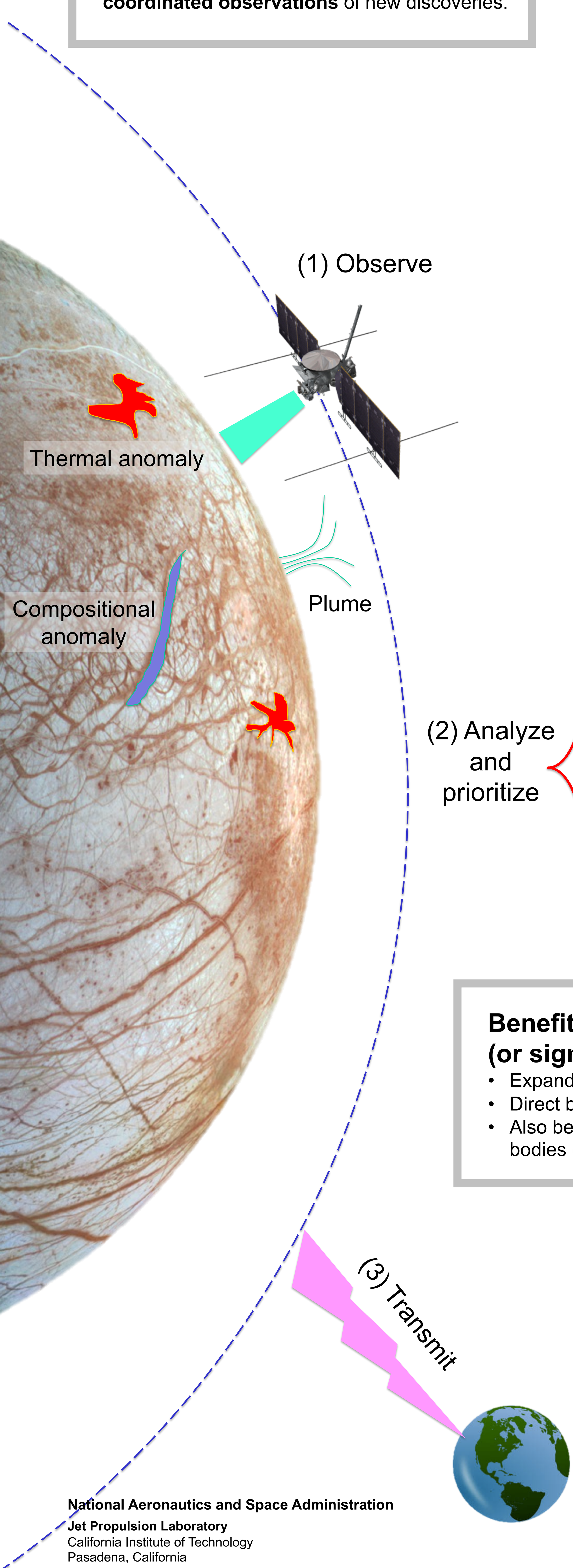
Program: Topic Area

Project Objective:

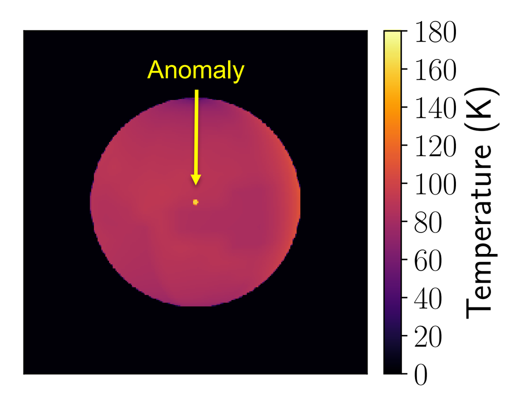
This task developed and validated onboard methods to **increase science return** for the Europa Clipper mission by **prioritizing data based on its content** and enabling **coordinated observations** of new discoveries.



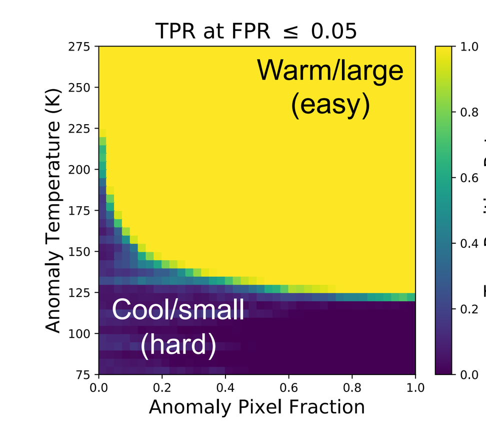
FY'19 Results:

1. Thermal anomaly detection in simulated E-THEMIS data

Data: 100,000 simulated E-THEMIS observations of Europa from different flyby altitudes, with synthetic anomalies injected (varying the size and temperature).

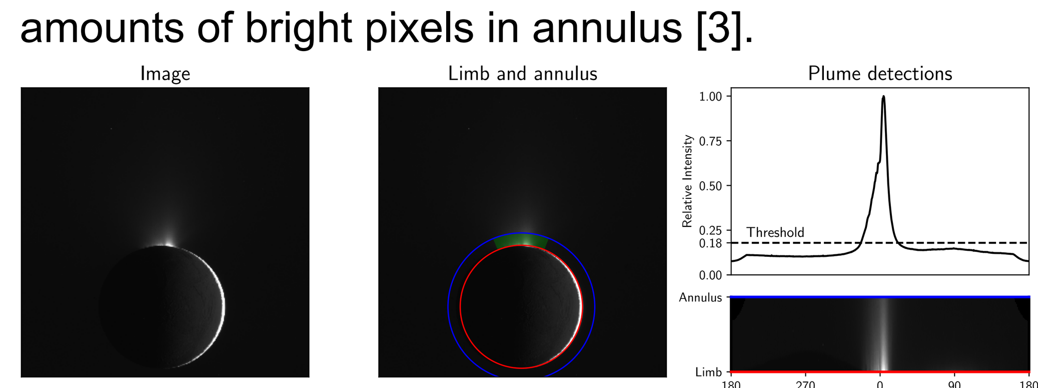


Results: Anomaly detection (true positive rate) given a limit of 5% false detections. Anomalies as cool as 150 K and as small as 20% of a pixel can be detected 95% probability [4].

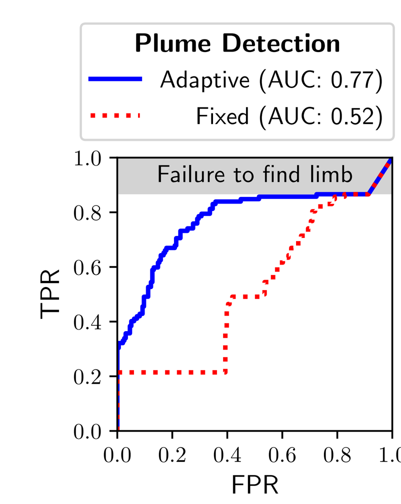


2. Plume detection for the Europa Imaging System (EIS) using analogue data

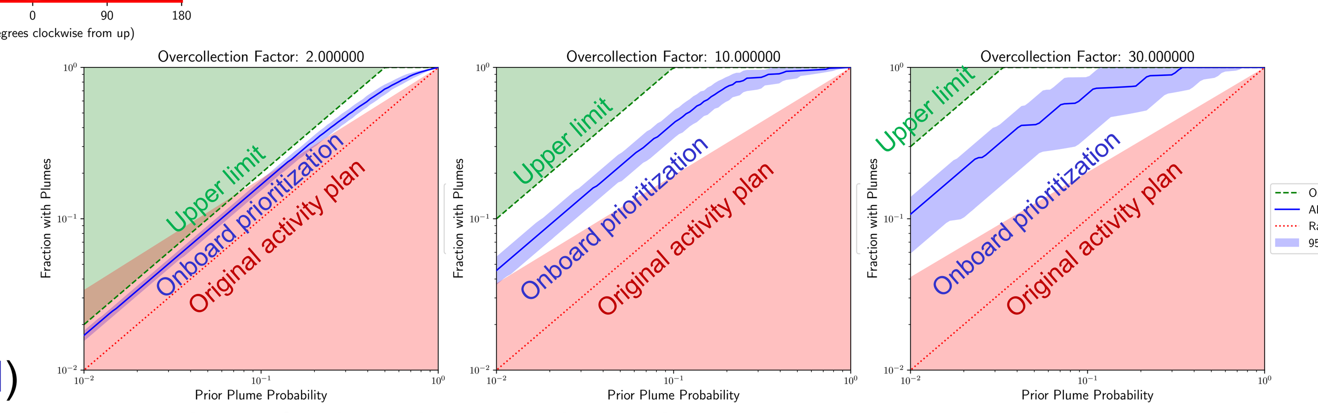
Data: 308 images of Mercury, Europa, Io, and Enceladus with and without plumes.
Method: Fit a circle to the limb, then detect unusual amounts of bright pixels in annulus [3].



Results: Adaptive threshold (based on inter-quartile range of intensity values) out-performs a fixed threshold, yielding 80% true positive rate (TPR) with only 36% false detections [4]. The limb could not be found in ~15% of images, which limits the upper bound on TPR to 85%.

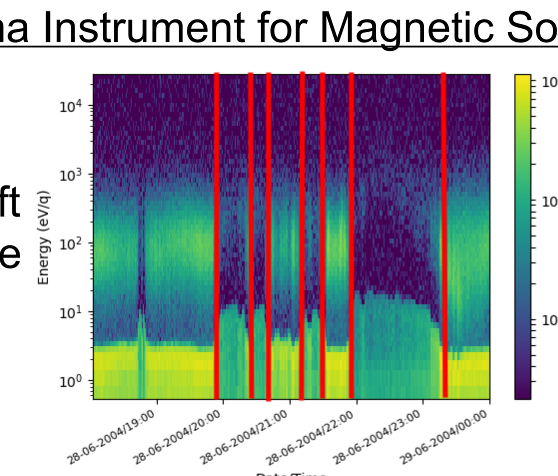


Potential increase in science return: The APGen simulator indicates that the EIS NAC could collect 2-30X additional observations with minimal resource impact. Given different assumed prior plume probability, we calculated the increase in science return (number of plumes observed) that could be achieved by collecting more images and analyzing them onboard.

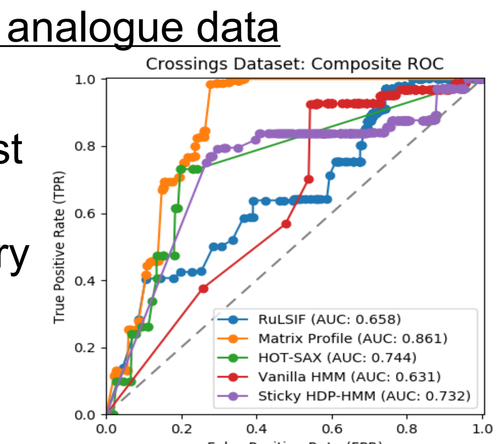


3. Plasma event detection for the Plasma Instrument for Magnetic Sounding (PIMS) using analogue data

Data: Cassini CAPS ELS (electron energy spectrum) data with 191 labeled events in which the spacecraft crossed from Saturn's magnetosphere to its magnetosheath (or back).
Method: Time series analysis to find "change points" (RuLSIF), anomalies (matrix profile), or state changes (HMM).



Results: Matrix profile yielded best performance at detecting boundary crossings.



4. Coordinated science scenarios: We identified eight scenarios for onboard coordinated science [5]. An example would be a hot spot detection by E-THEMIS triggering an image by EIS or a higher sampling rate for the REASON radar instrument.

Benefits to NASA and JPL (or significance of results):

- Expands science autonomy to outer planets
- Direct benefit to Europa Clipper
- Also benefits future missions to remote bodies (Enceladus, Titan)

Acknowledgments:
Our sincere thanks go out to the numerous Europa Clipper project personnel who consulted with us to inform and guide the development of operational scenarios for onboard science. We also thank Ameya Daigavane for evaluating time series anomaly detection methods during a summer internship at JPL in 2019, Marissa Cameron for developing coordinated science scenarios, Steve Wissler for his excellent work with APGen simulations, Jess Doherty for masterful video creation and editing, Jonathan Baspt for assistance with E-THEMIS data simulations, and Caitriona Jackman for the Saturn crossings data set.

Publications:

[1] Kiri L. Wagstaff, Diana L. Blaney, Srija Chakraborty, Steve A. Chien, Ashley G. Davies, Serina Diniega, and Gary Doran, "Spectral anomaly detection for the Mapping Imaging Spectrometer for Europa (MISE)," *50th Lunar and Planetary Science Conference*, Abstract #1604, March 2019.

[2] Kiri Wagstaff, Gary Doran, Ashley Davies, Saadat Anwar, Srija Chakraborty, Diana Blaney, Marissa Cameron, Jonathan Bapst, Steve Chien, Corey Cochrane, Ingrid Daubar, Serina Diniega, Cynthia Phillips, and Sylvain Piqueux, "Responsive onboard science for the Europa Clipper mission," *JPL Data Science Showcase*, Poster 29, April 2019.

[3] Gary Doran, Kiri L. Wagstaff, Marissa Cameron, Ingrid Daubar, and Cynthia Phillips, "Automatic plume detection for the Europa Imaging System," *Fourth Planetary Data Workshop*, Abstract #7026, June 2019.

[4] Kiri Wagstaff, Gary Doran, Ashley Davies, Saadat Anwar, Srija Chakraborty, Marissa Cameron, Ingrid Daubar, and Cynthia Phillips, "Enabling onboard detection of events of scientific interest for the Europa Clipper spacecraft," *Proceedings of the 25th International Conference on Knowledge Discovery and Data Mining (KDD)*, p. 2191-2201, August 2019.

[5] Marissa Cameron, Kiri Wagstaff, Gary B. Doran, and Ashley G. Davies, "Opportunities for increased data return through coordinated instrument observations on Europa Clipper," *Fall Meeting of the American Geophysical Union*, December 2019 (to appear).

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