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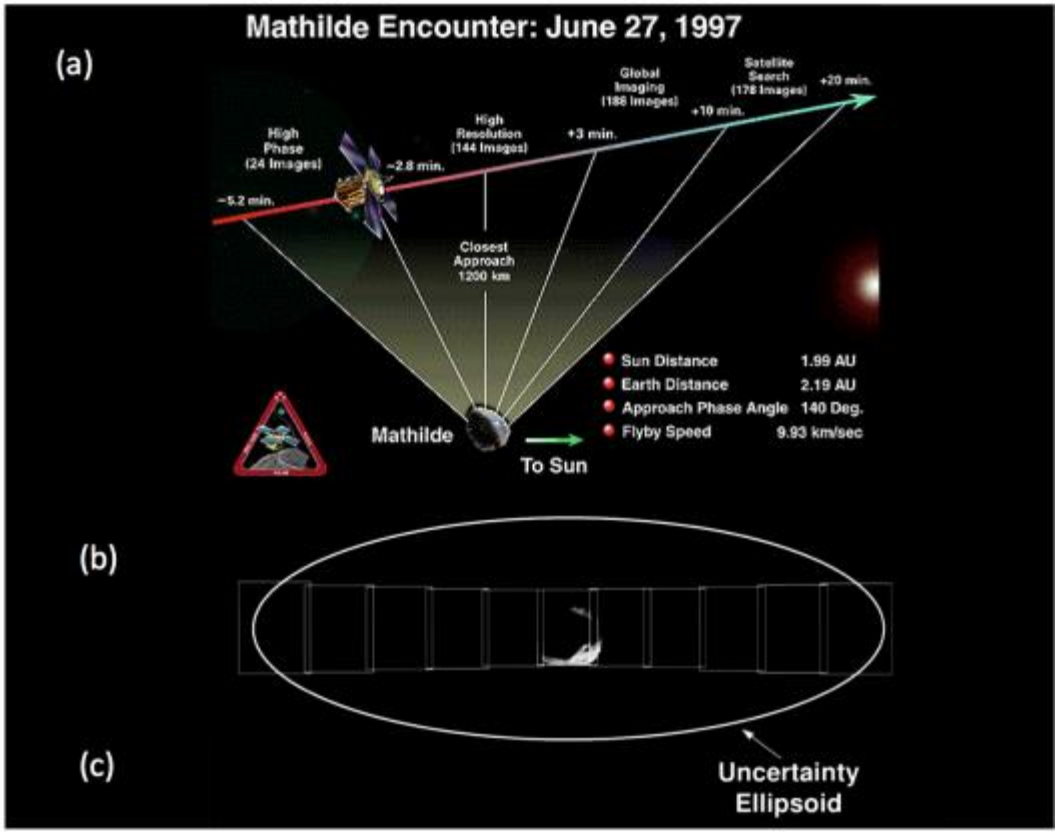
Application: Flyby Science

Jet Propulsion Laboratory
Keck Institute for Space Studies
Sponsored by the Jet Propulsion Laboratory and by the Keck Institute for Space Studies, California Institute of Technology
Caltech

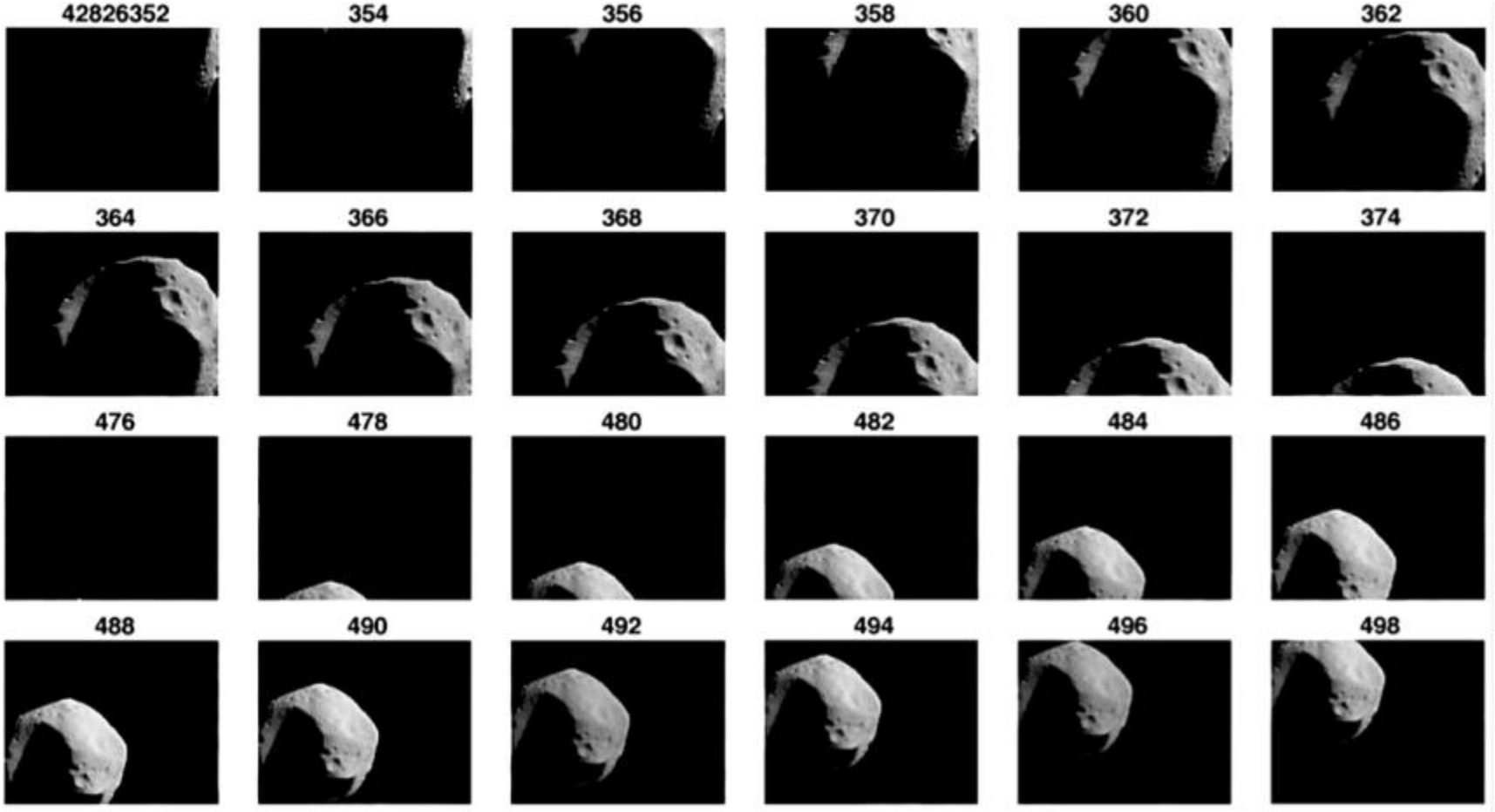
Flyby science is hard!

- Targets have diverse morphologies, compositions
- Target locations are not known in advance
- Closest approach may pass quickly (sub-hour timescales)
- Geometry and illumination constraints
- Features of interest are highly localized



J. Veverka and 16 co authors. Near's flyby of 253 mathilde: Images of a C asteroid. Science, 278:2109, 1997.

Flyby science (typical)



J. Veverka and 16 co authors. Near's flyby of 253 mathilde: Images of a C asteroid. Science, 278:2109, 1997.

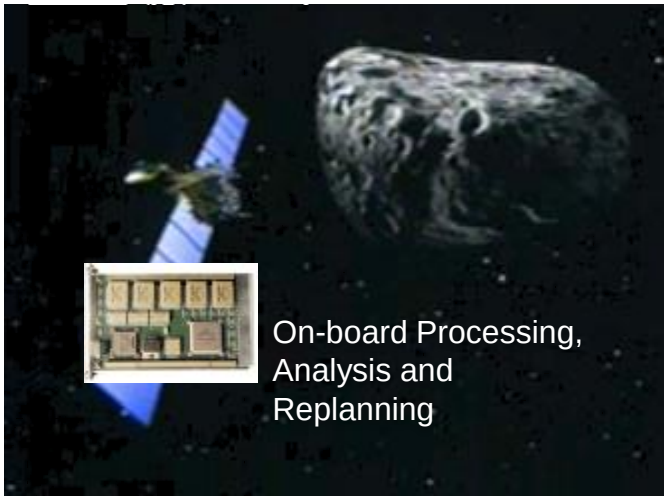
Status Quo: respond in days

Light time delay

Processing and analysis

Replanning and sequencing

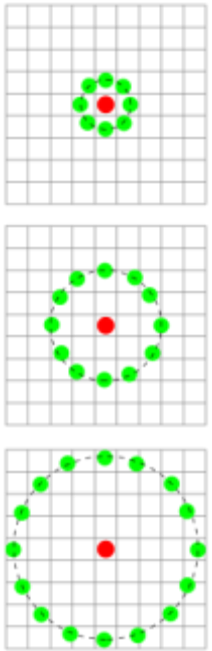
Onboard analysis: respond in minutes

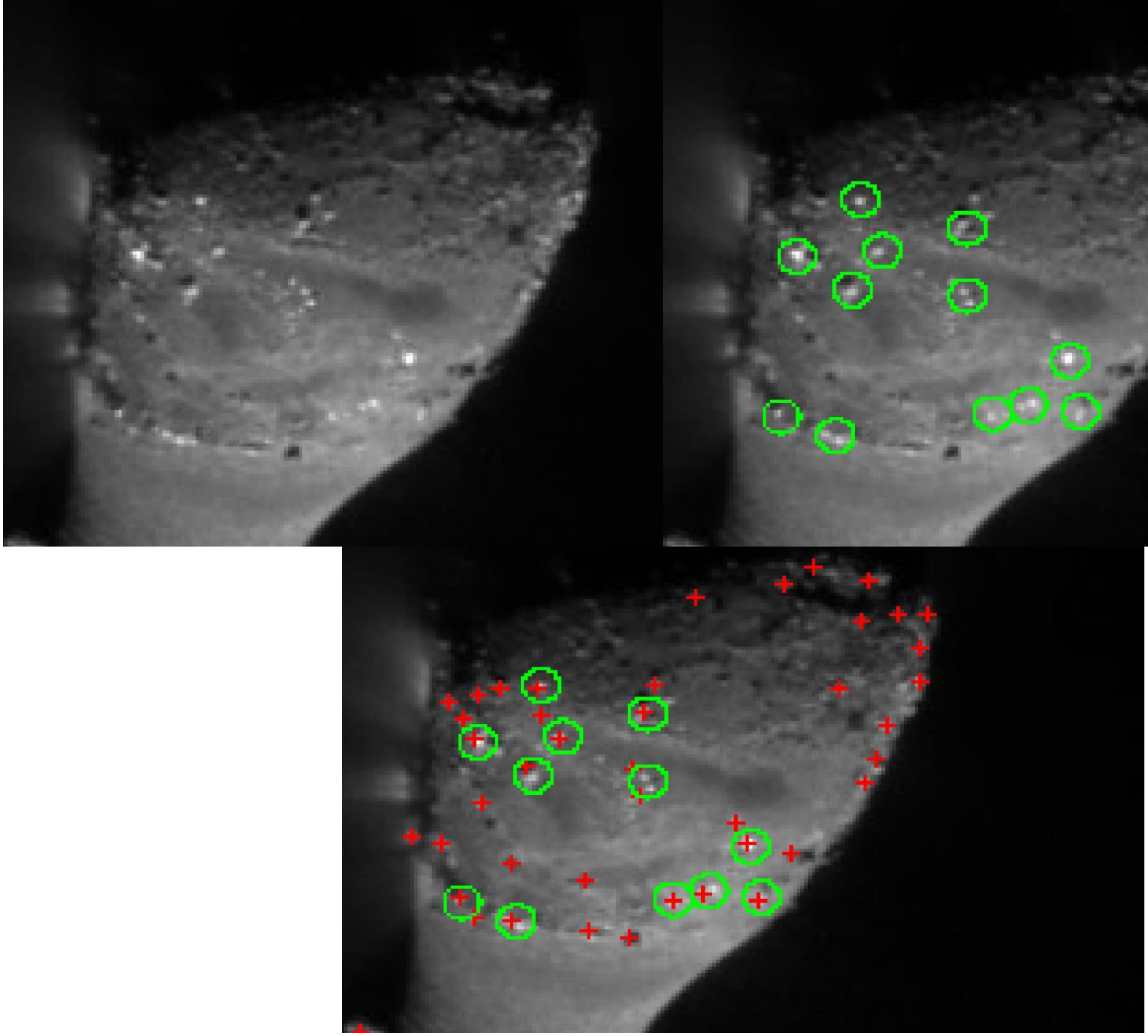


Rosetta graphic courtesy NASA / ESA / US. Rosetta
DSN image courtesy NASA / Caltech / JPL

Feature Extraction

- **Local Binary Pattern** (LBP) for texture description
- Image based binary and intensity weighted **Mean Shift** for mode detection
- Edge preserving constant time **Median Filter**
- **Integral Images** for Haar features, etc.
- 3D color histogram **features**, gradient histograms, census transform, etc.
- **Color** conversion: RGB, HSV, LAB, norm. col, etc.



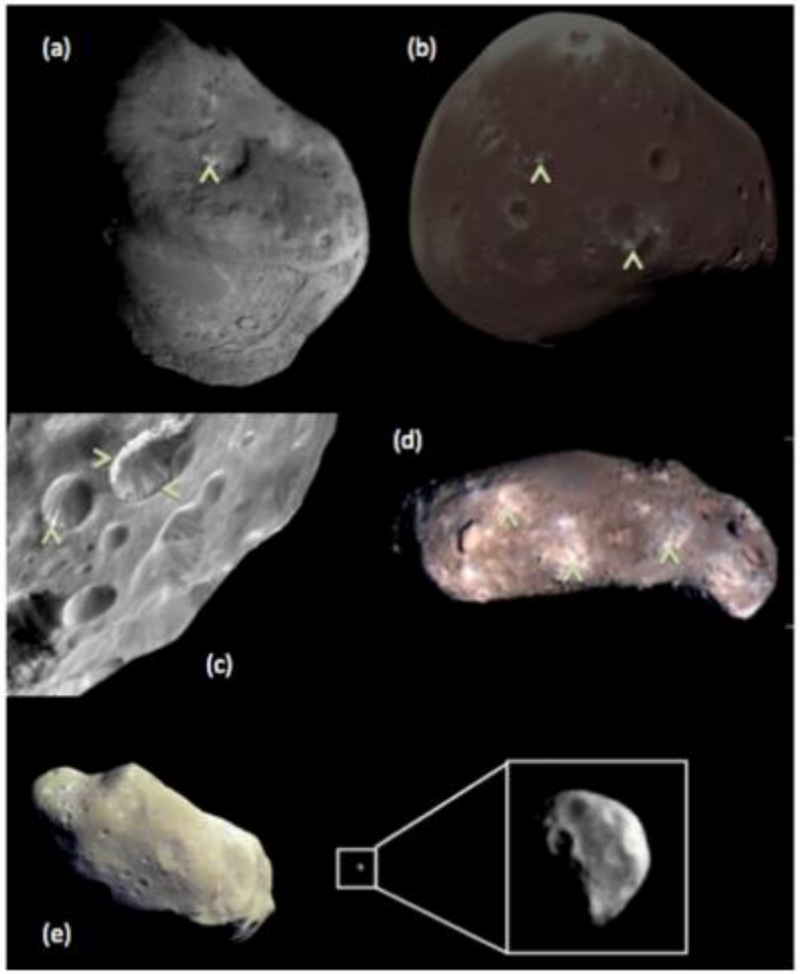


Our focus: Pattern recognition for surface features

Indicate fresh subsurface material uncovered by impacts or wasting events

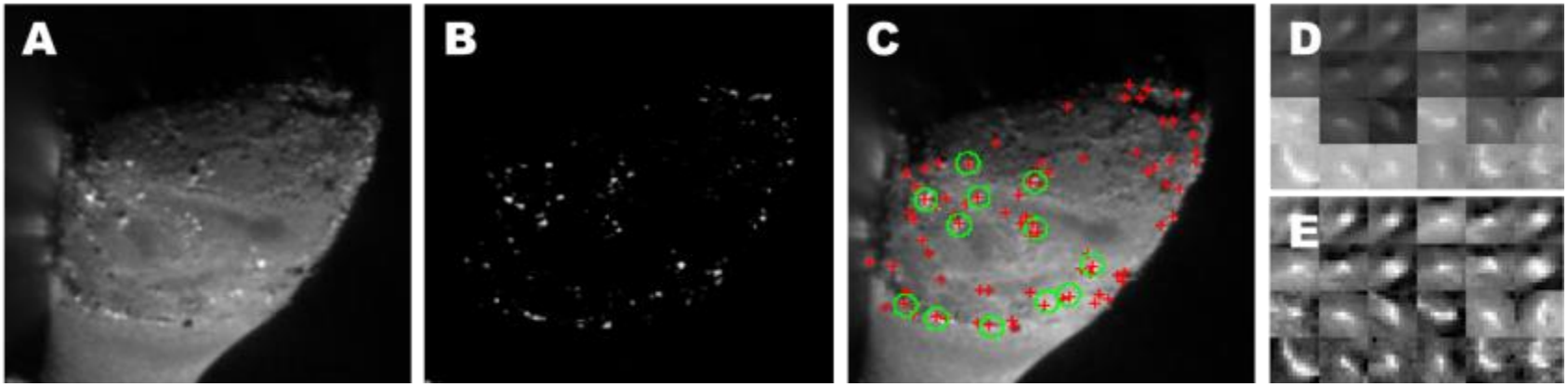
Reveals interior composition with stronger and more unique spectral signatures

A good candidate for followup measurements



Images: various sources (NASA, JAXA) available on request

Pattern recognition approach



Original (Hartley 2)

Median filtering finds high-albedo spots

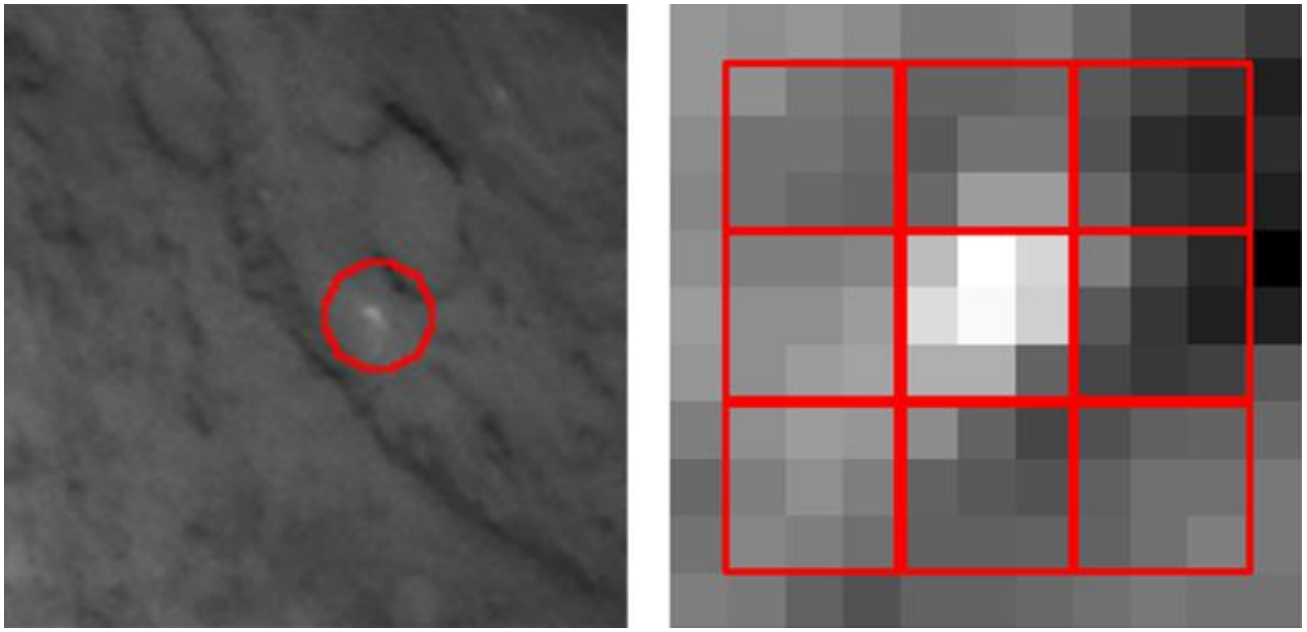
Random forest classification

Extracted image patches

- Median filtering finds candidate spots which are then filtered by a random forest classifier.
- Classification only runs on candidate pixels, making runtime amenable to a flight processor such as a Rad750-class device

Original image: EPOXI mission, Courtesy NASA

Surface feature attributes

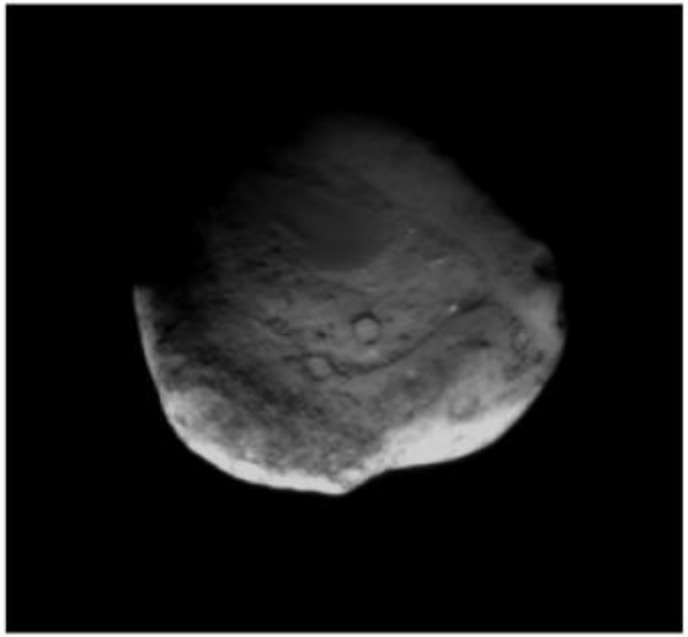


- Calculate attributes from 11 × 11 pixel image patches at the locations of each candidate.
- Include intensity values and general image statistics, gray value and gradient histograms, local binary patterns (LBP), etc.
- Normalize each patch by shifting and scaling the intensity values to a range of [0, 1].

Two datasets

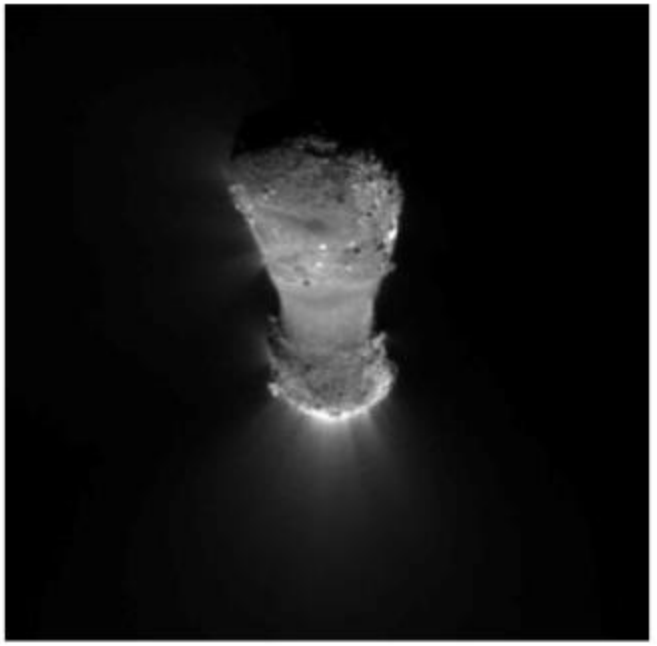
Tempel 1

72 Frames, subtle targets

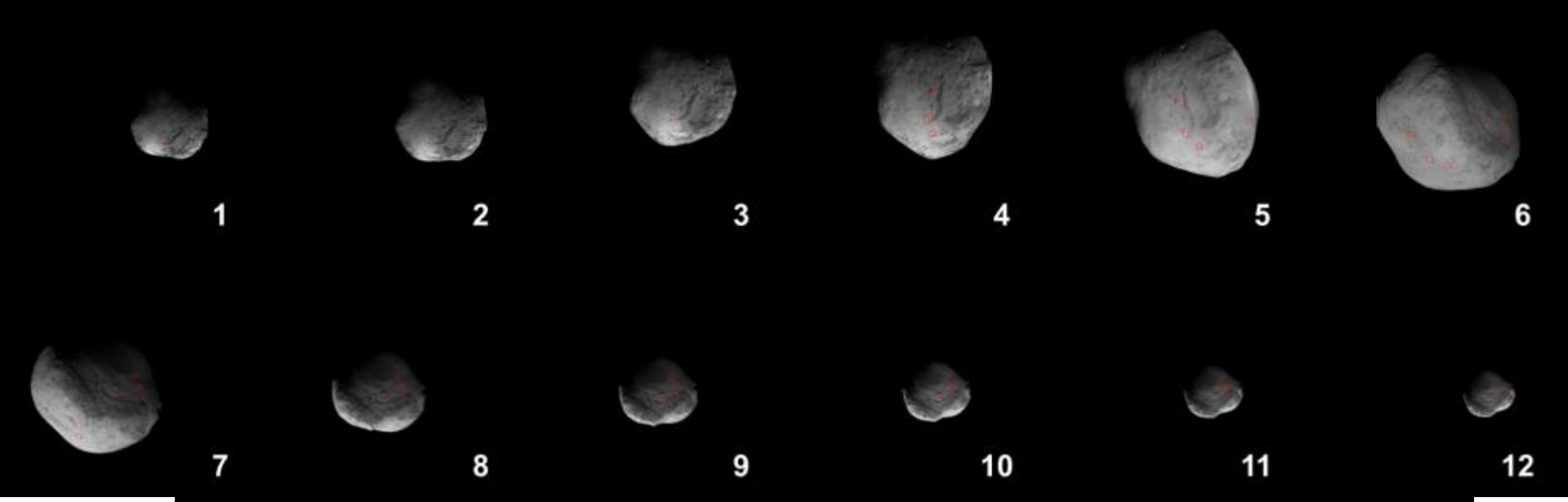


Hartley 2

47 Frames, obvious targets



Original images: Stardust and EPOXI missions, Courtesy NASA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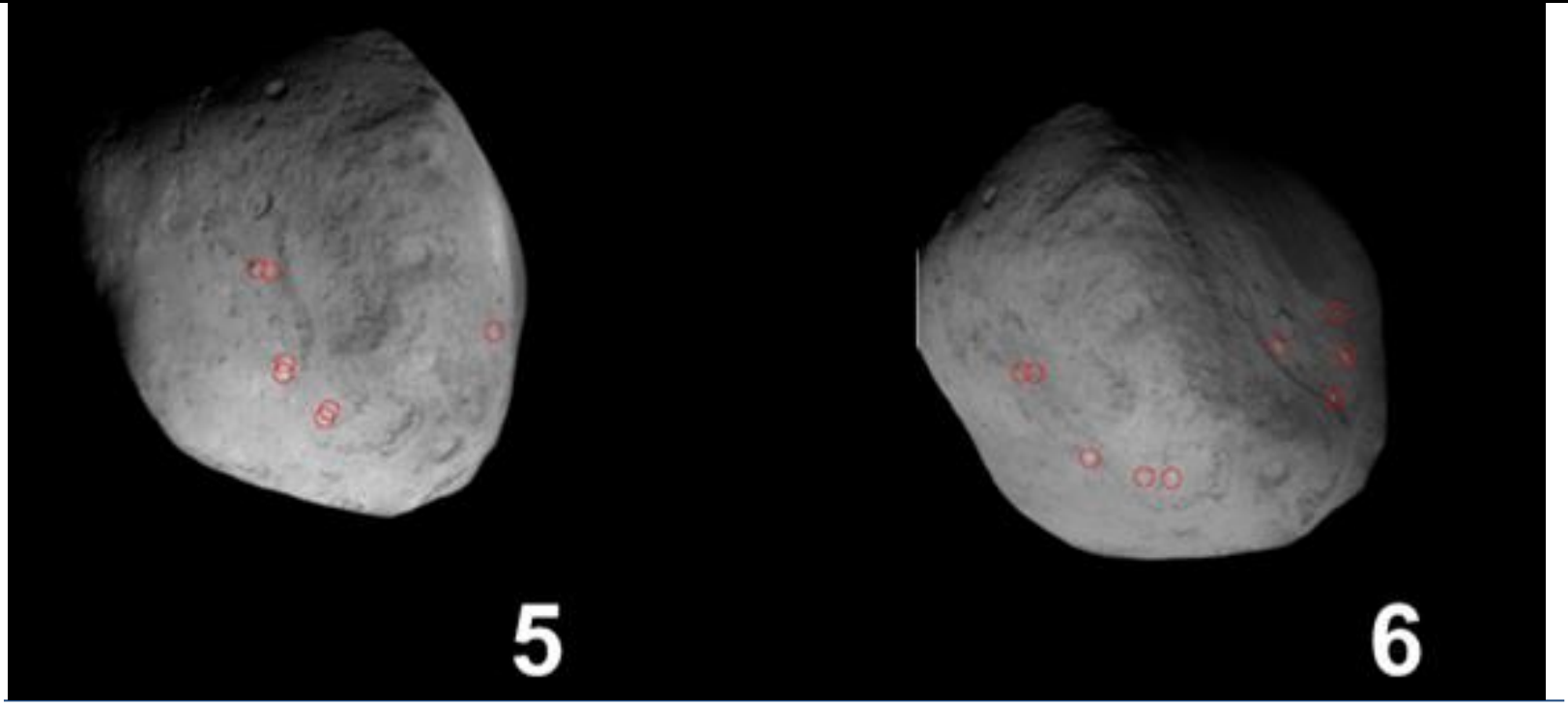
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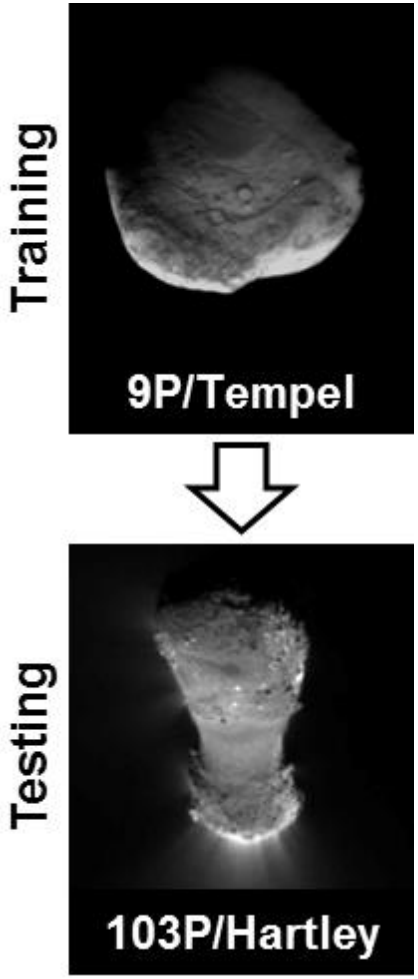
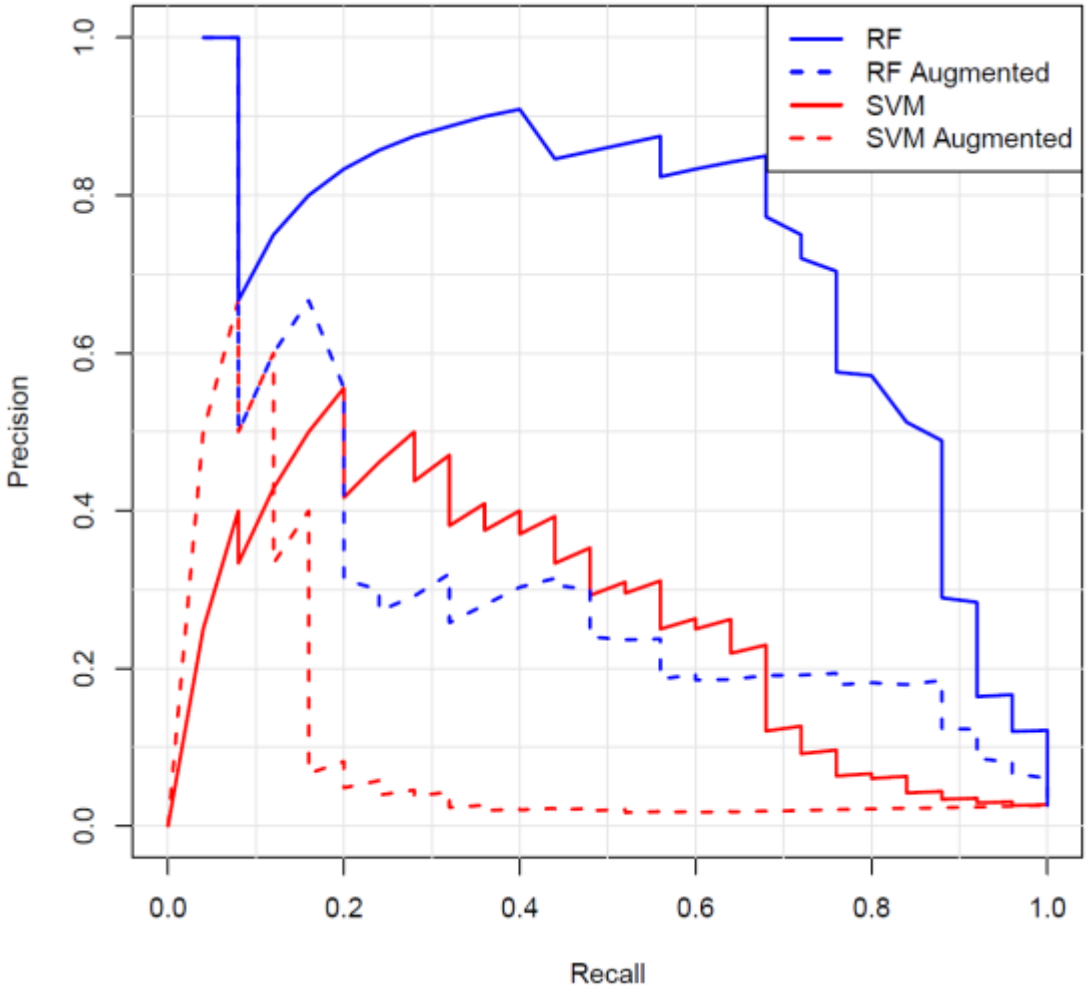
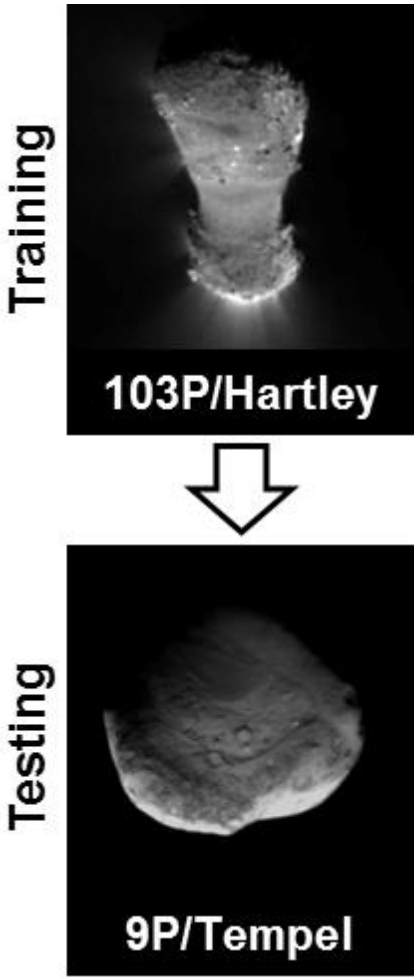
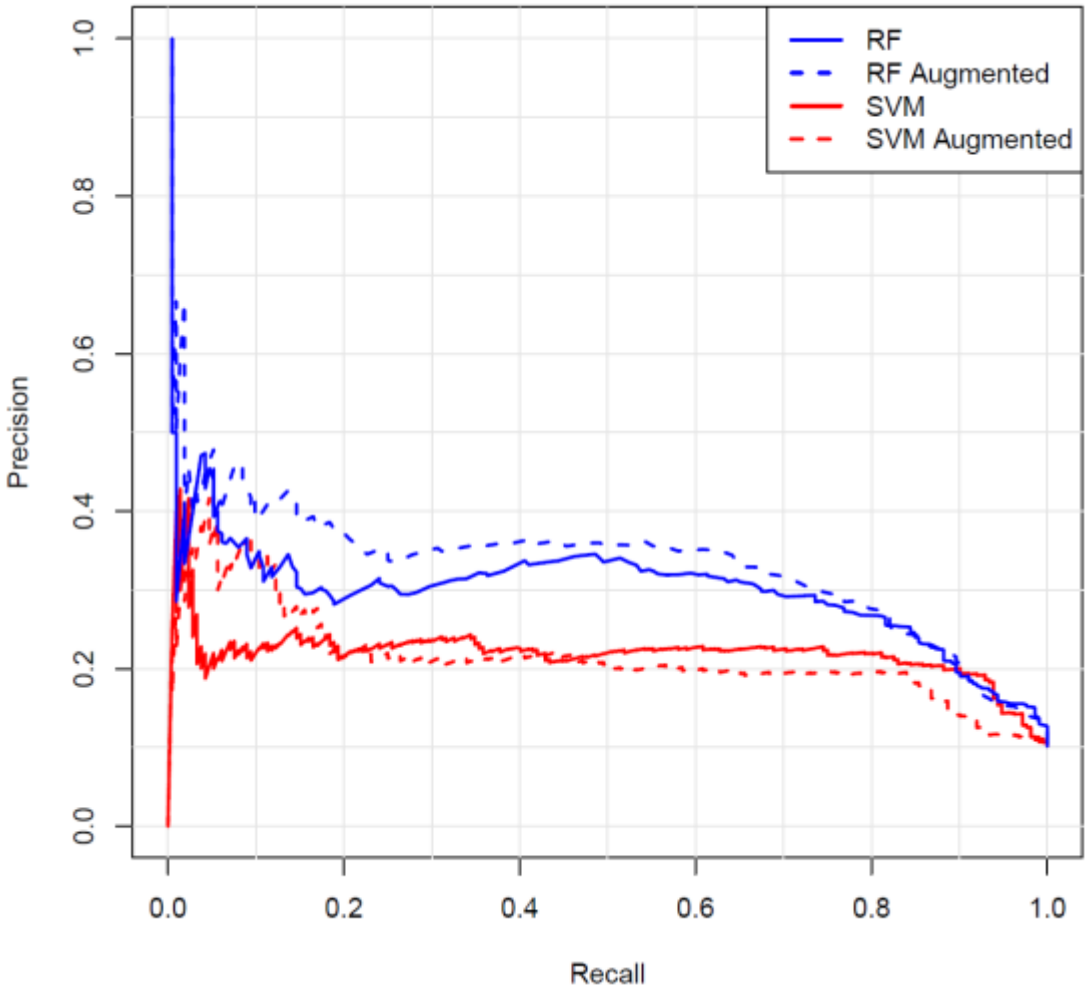
Performance generalization (hard target -> easy target)



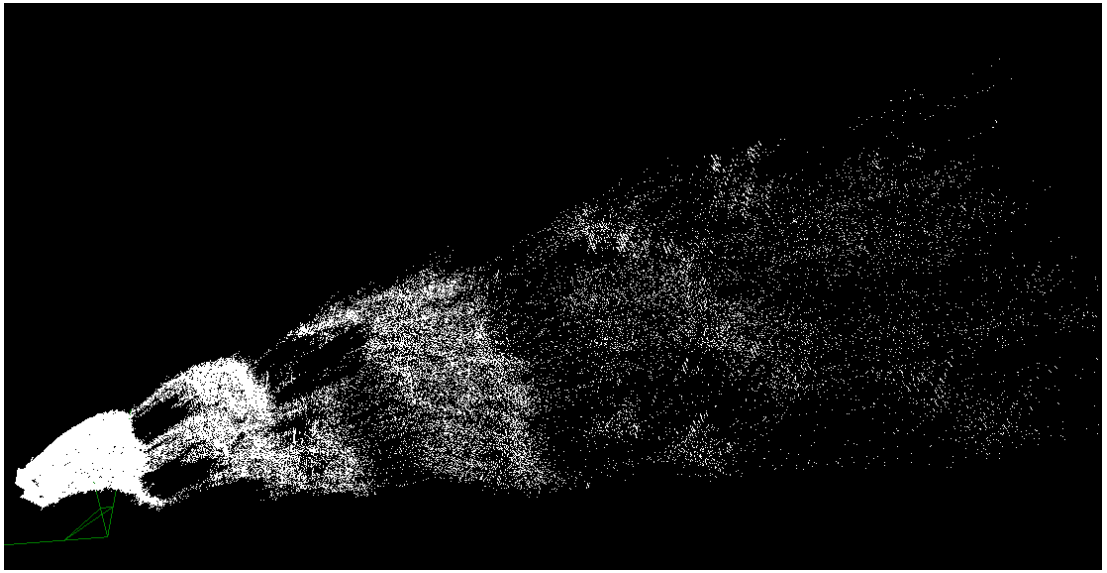


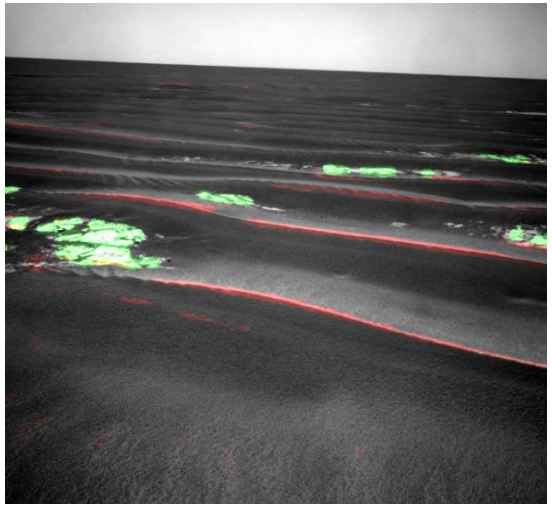
Performance generalization (easy target -> hard target)

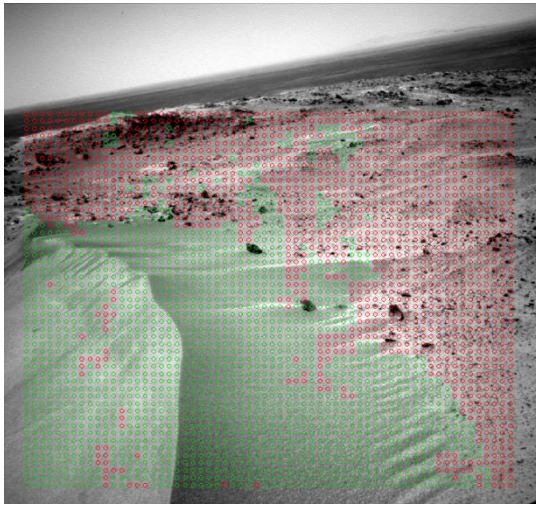


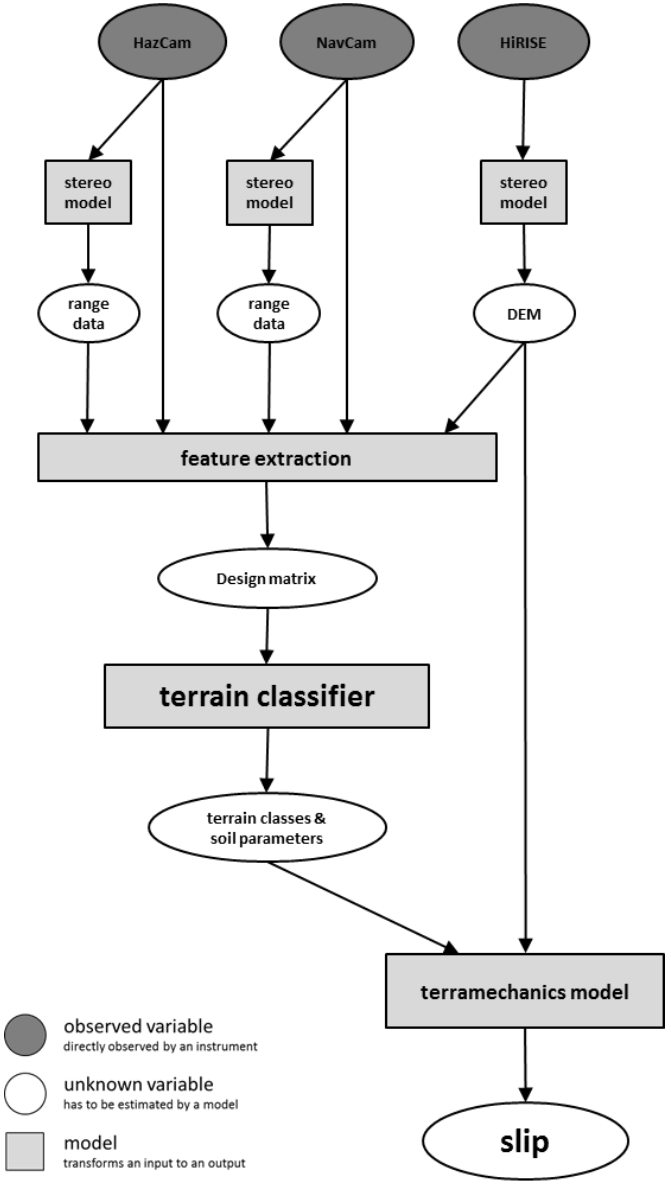


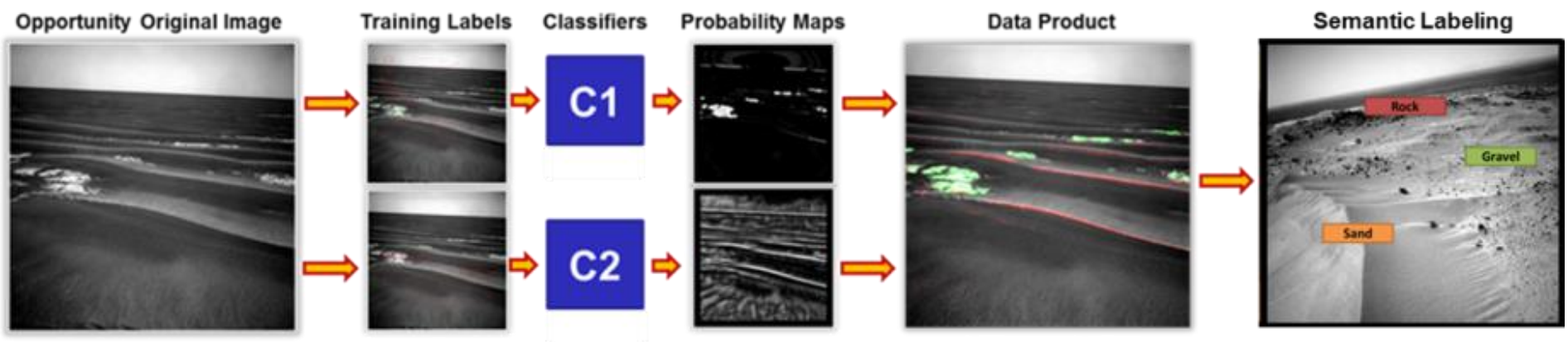
Martian Scene Understanding

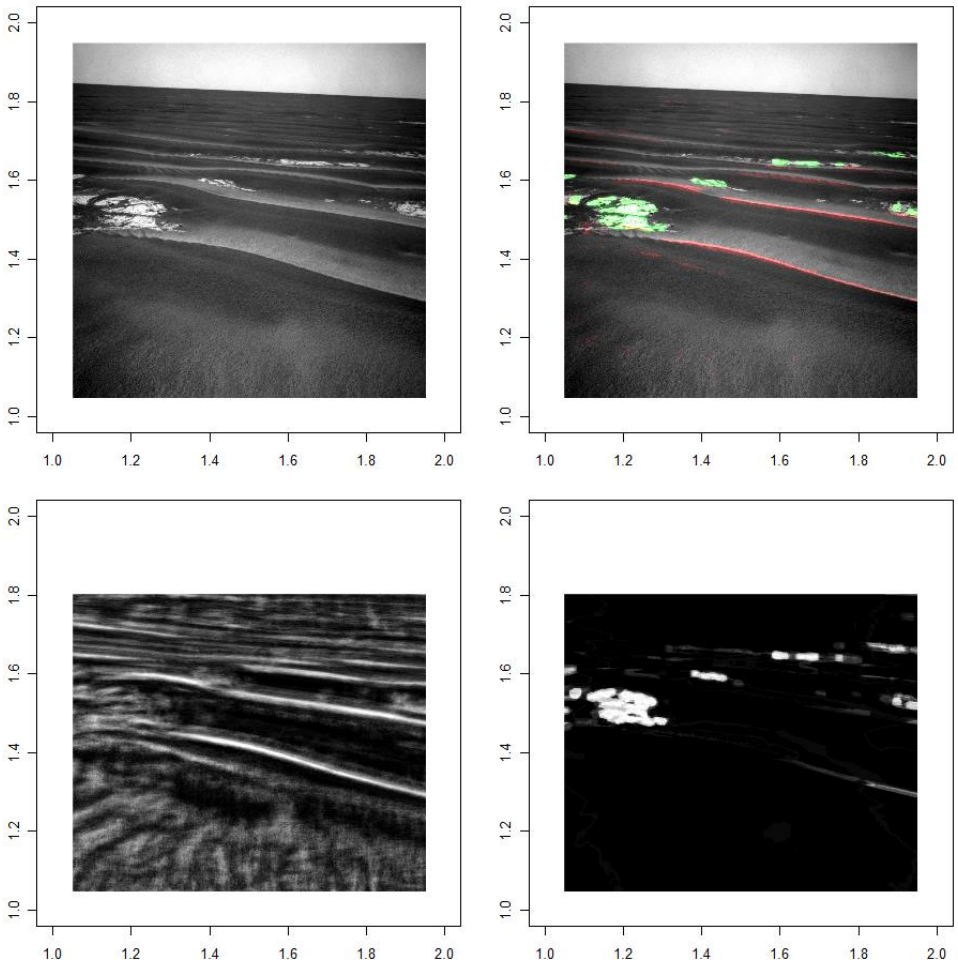









Opportunity Original Image
Training Labels
Classifiers
Probability Maps
Data Product
Semantic Labeling
C1
C2
Rock
Gravel
Sand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