Machine Learning for Planetary Science

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Big Data Task Force

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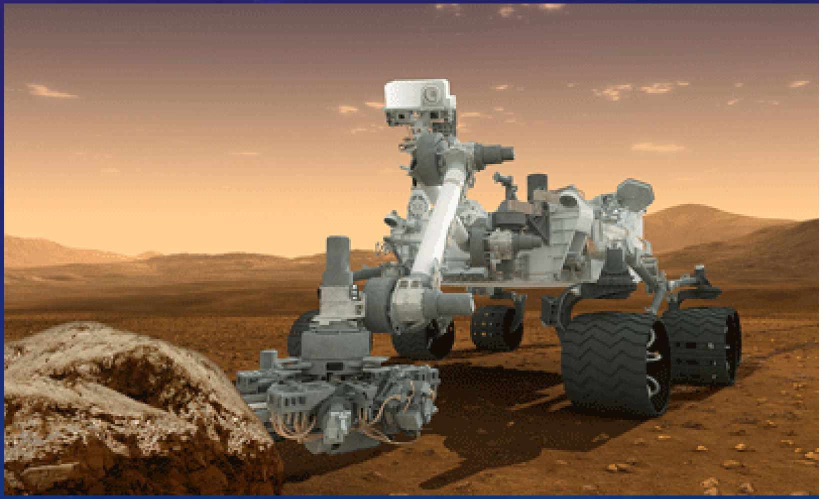
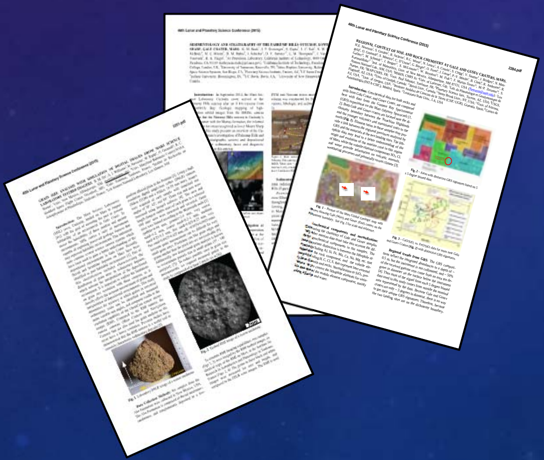
California Institute of Technology, under a contract with NASA.

ML for Planetary Science

1. Content-based image classification
2. Onboard data analysis and discoveries
3. Onboard data acquisition
4. Information extraction

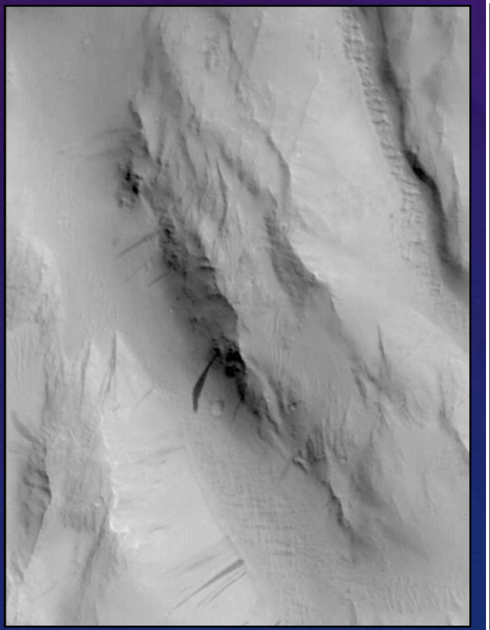




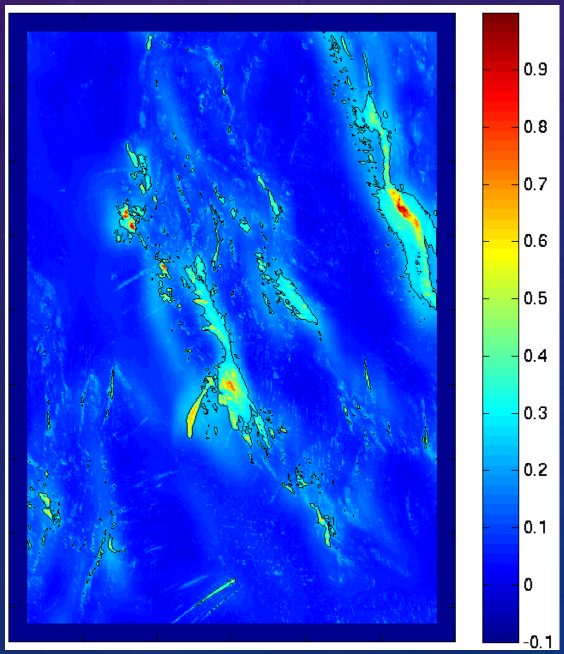
1. Content-based image classification

- NASA image archives: millions of images
  - Goal: enable search by content, not just pointing
  - Statistical analysis + deep learning classification

Find visually salient "landmarks"

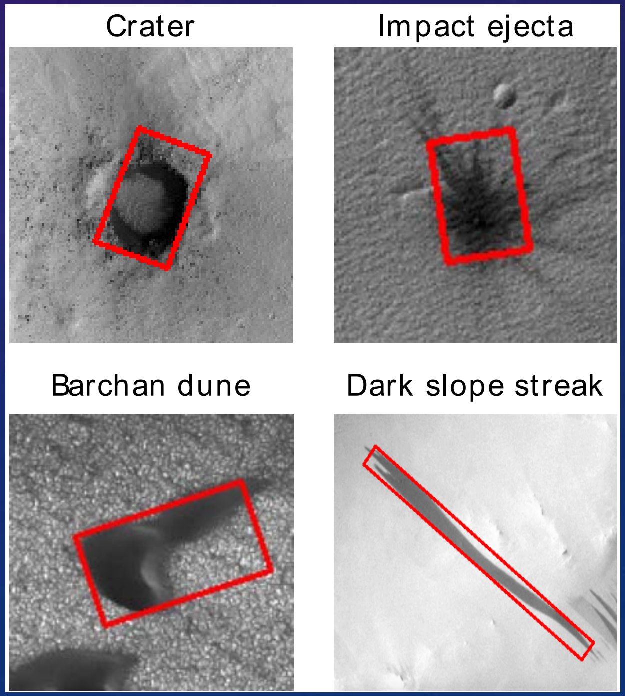


MOC, June 2000



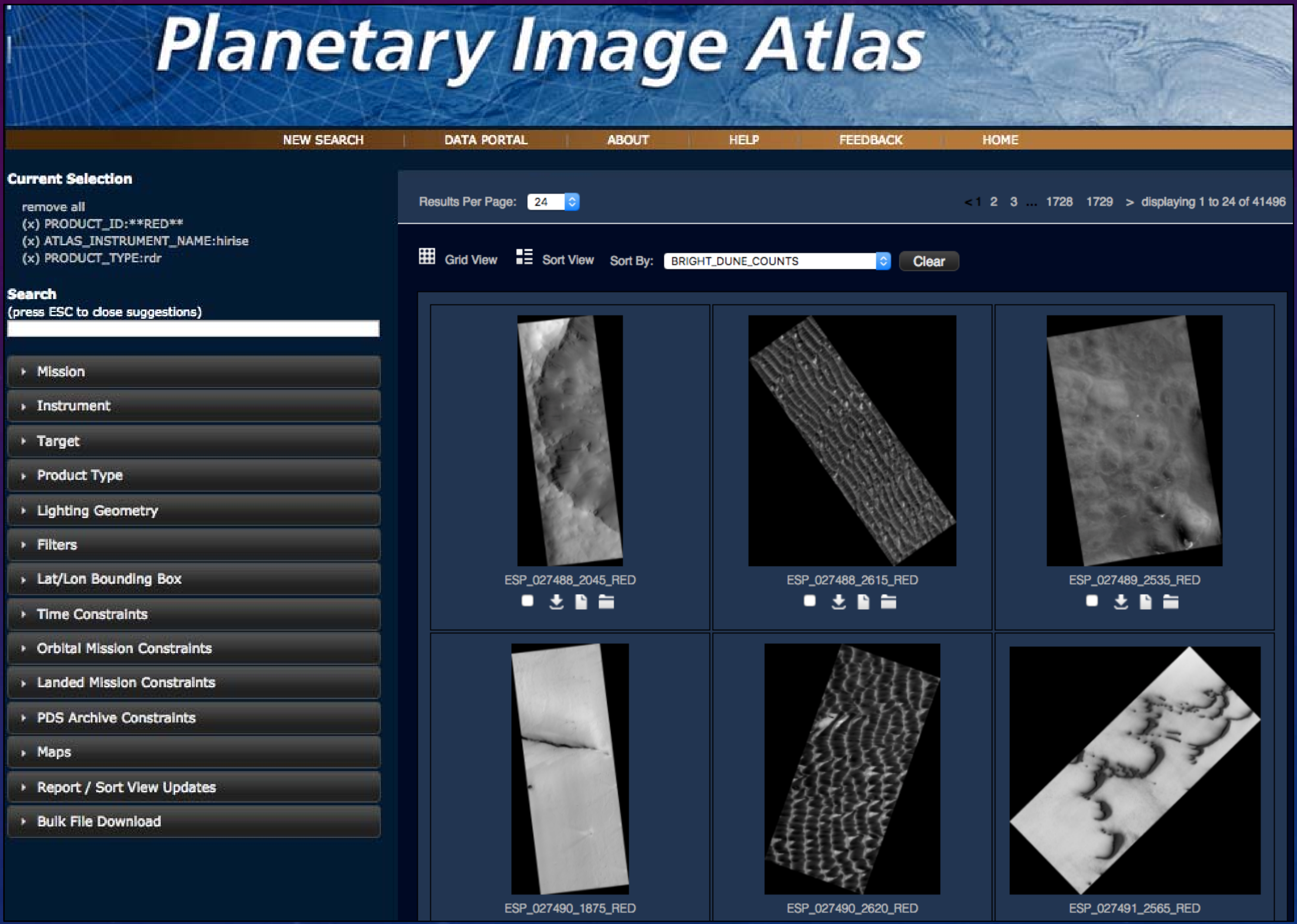
Salience Map

Train a classifier to label them



Kiri Wagstaff, You Lu, Alice Stanboli, Kevin Grimes, Gary B. Doran, Jr., Lukas Mandrake

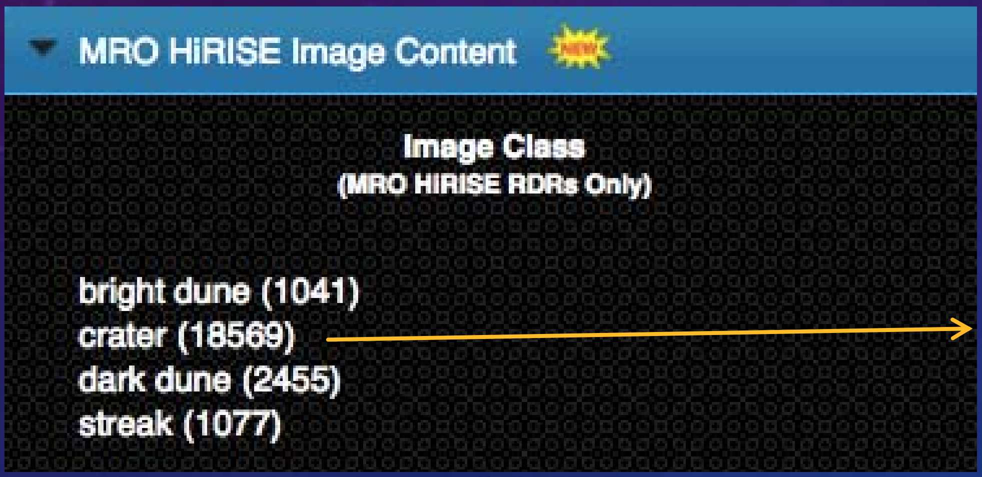
http://pds-imaging.jpl.nasa.gov/search/



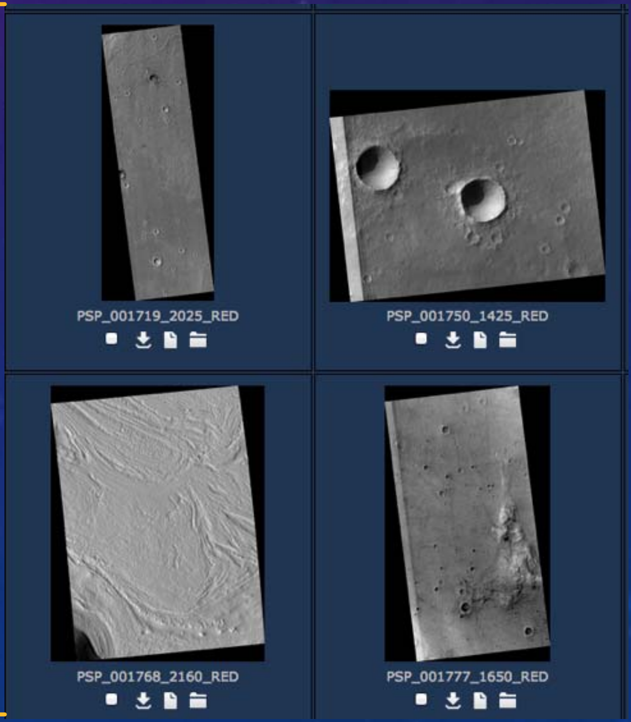
Content-based image search

- Detect landmarks -> image meta-data
- Enables search for images containing landmarks of interest

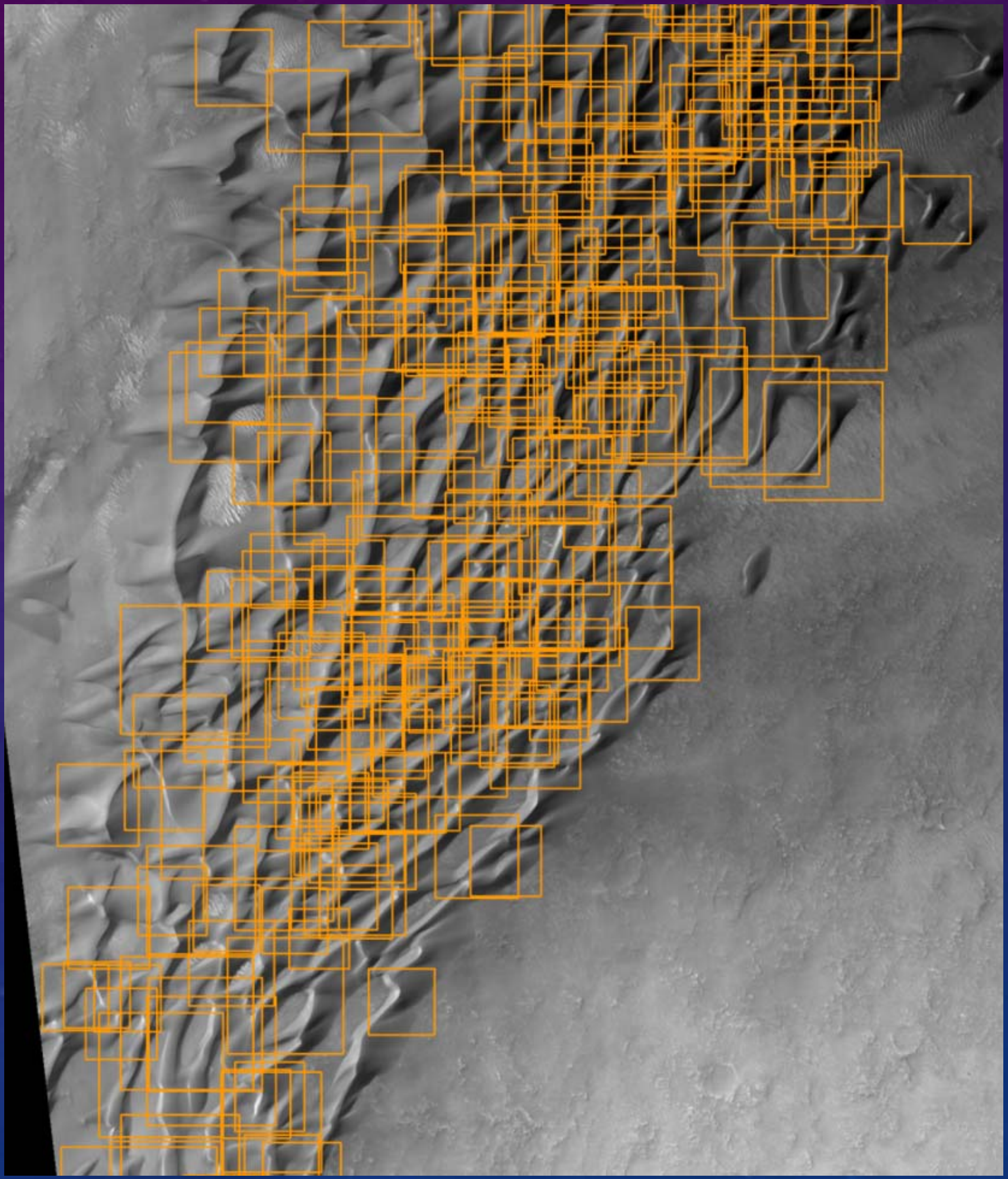
Planetary Image Atlas



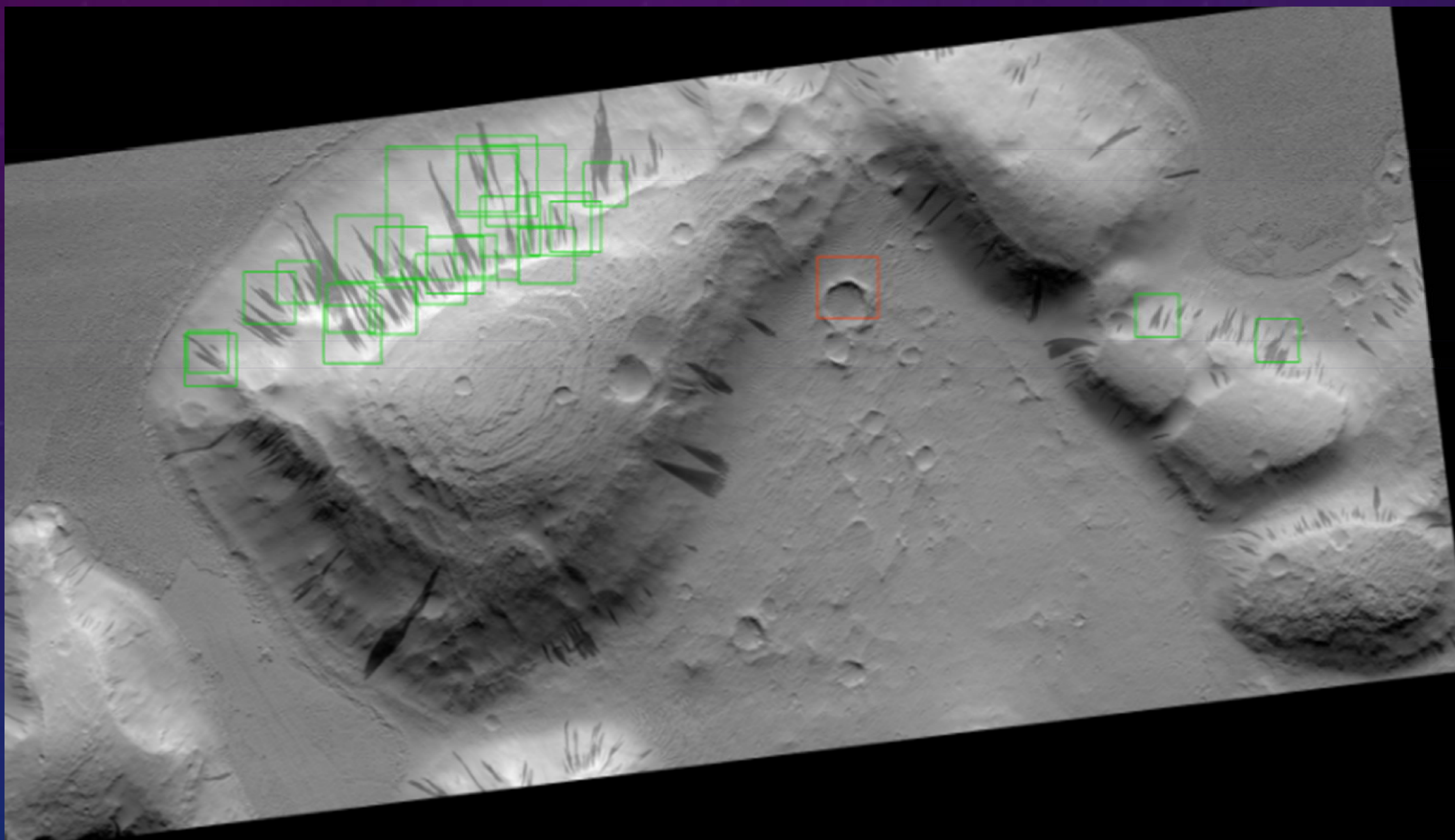
Example results from “crater” search



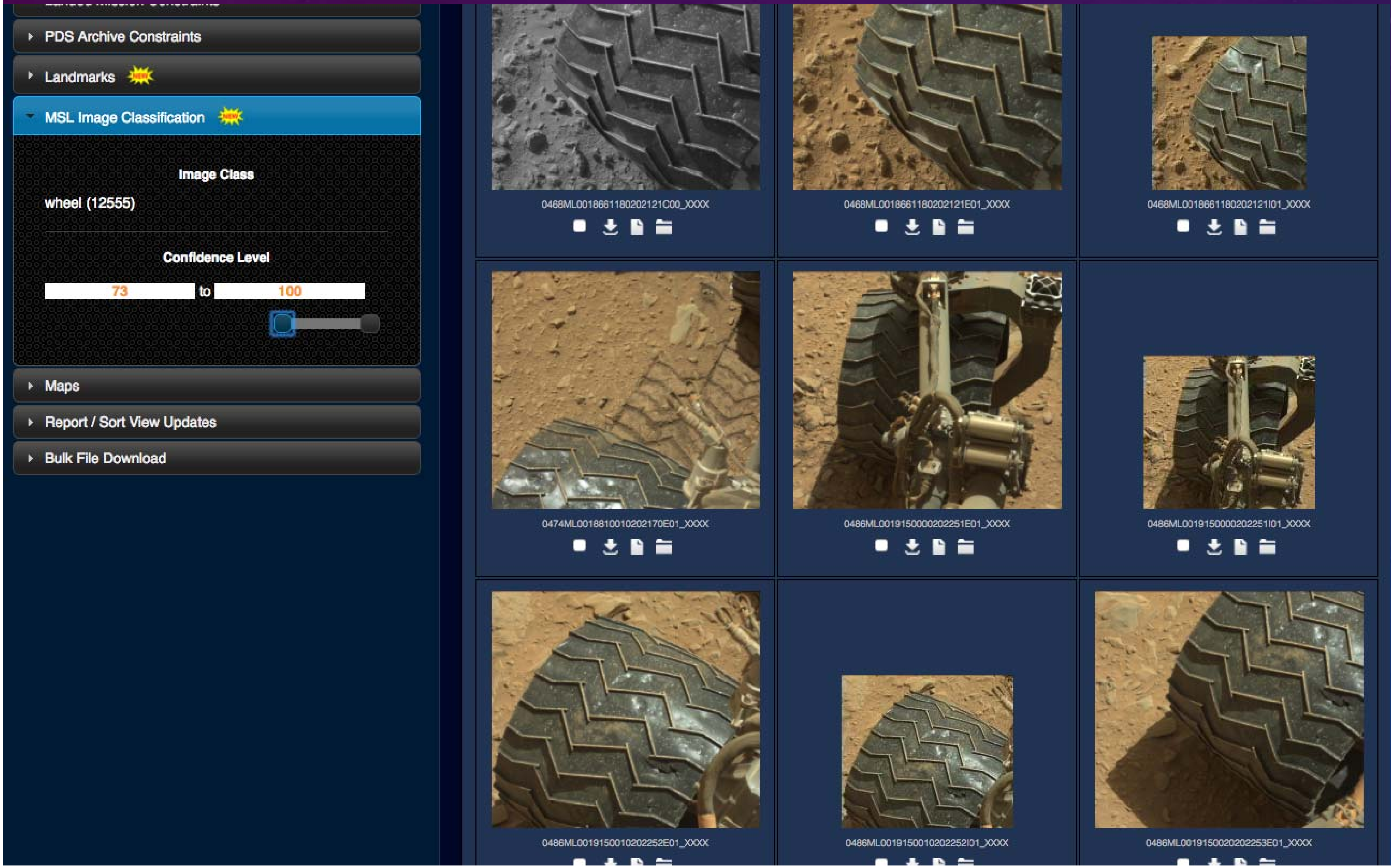
Dark dunes



Dark slope streaks

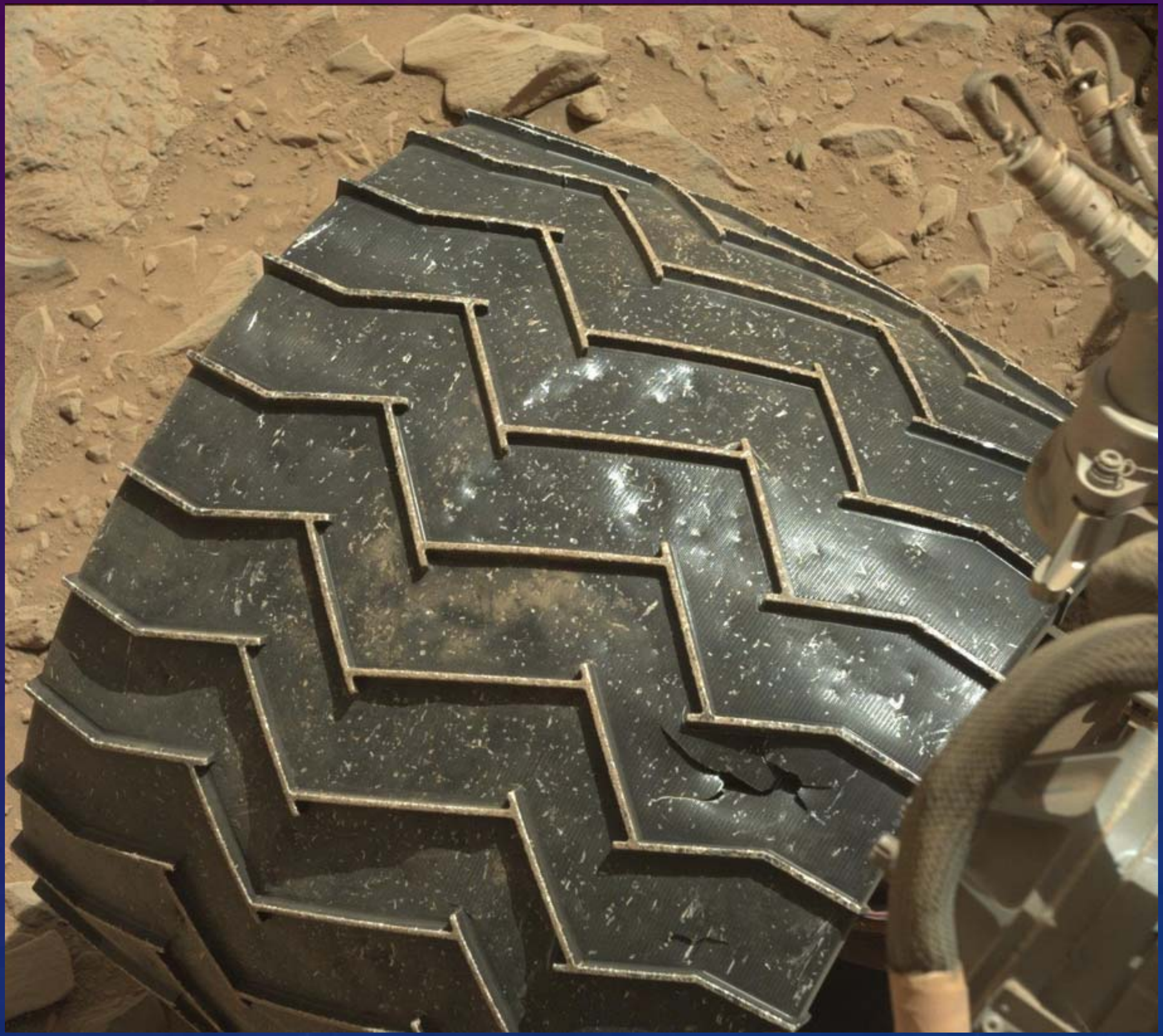


Benefits for mission operations

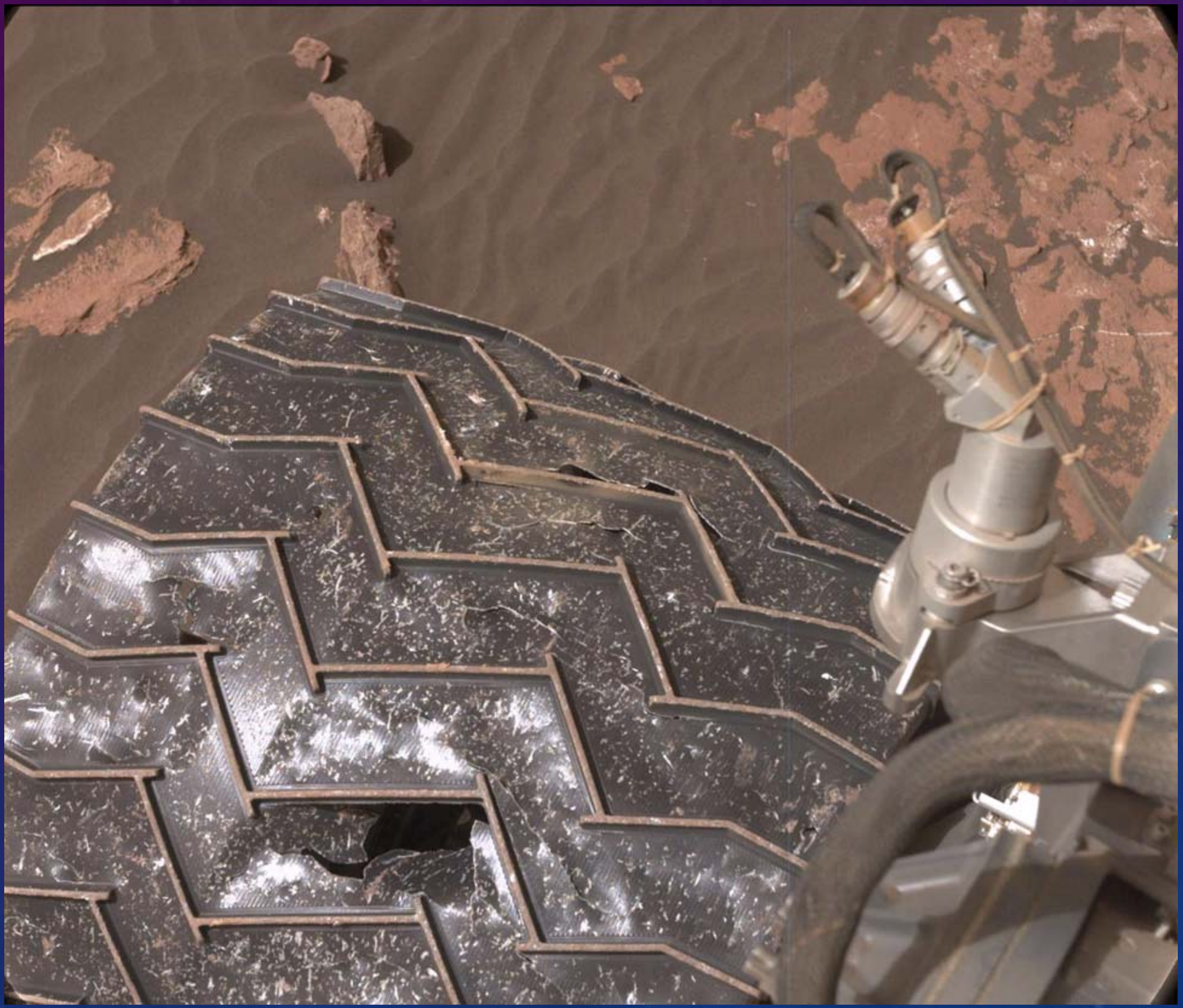


August 2012

December 2013

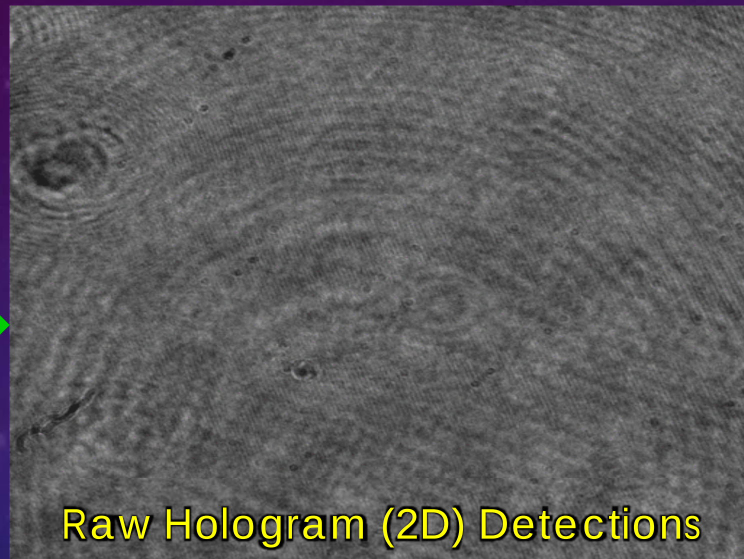


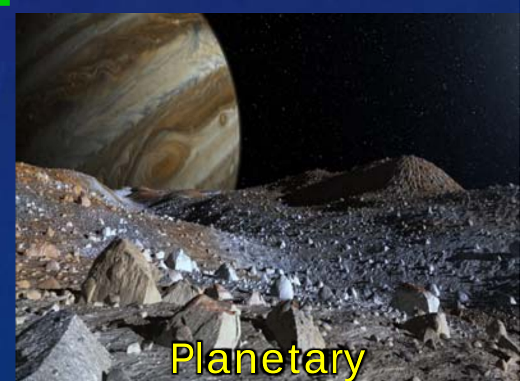
November 2016



2. Astrobiology: Holographic life detection

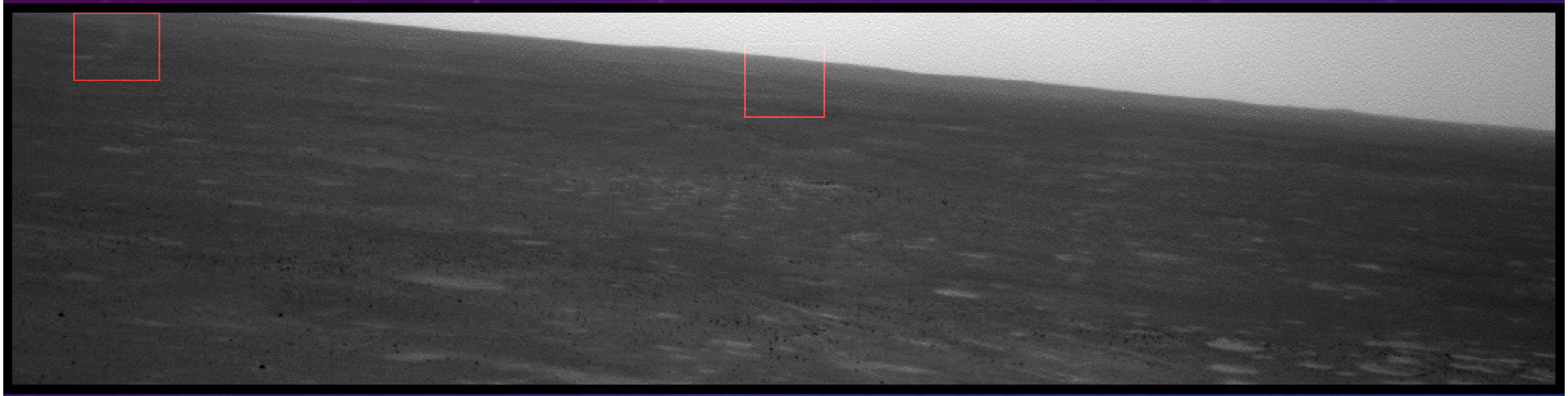
Lukas Mandrake, Gary Doran, Brian Bue





- Digital Holographic Microscopes
  - Big data (4D, ~GB/s), rare findings
- Motility ~ Life (composition agnostic!)
- HELM ML system detects, tracks, and classifies in messy, raw 2D holograms

2. Onboard science: Dust devil (change) detection

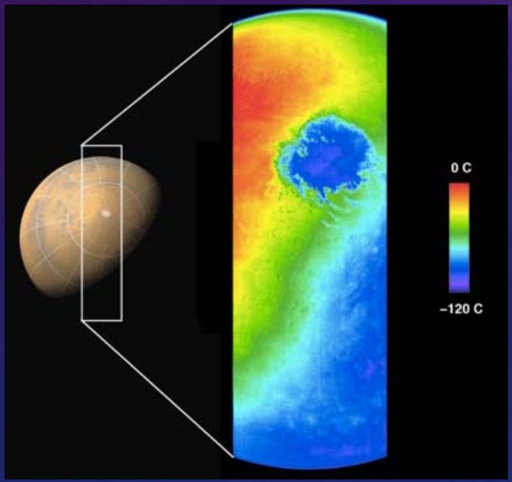


- Analyze sequence of images for motion detection
- Operationally qualified on Mars Exploration Rovers (2008)
- Consumes no data volume when no activity detected
- Achieved significant data reduction for MER

A. Castaño et al., 2007. *Machine Vision Applications*.

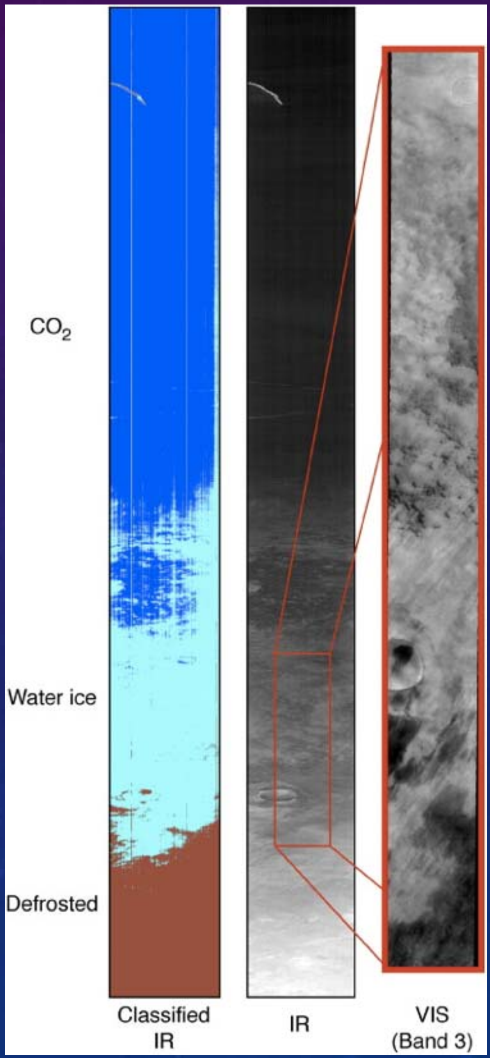
2. Onboard science for new discoveries

- Thermal anomaly detection
  - 14,856 THEMIS nighttime images
  - 143 images > 240K (12.57 um)
  - Synthetic positives: 100% detection



Mars south polar cap

- Polar cap tracking
  - Led to first discovery of north polar water ice annulus in THEMIS data [Wagstaff et al., 2008]
- Future: Europa Clipper

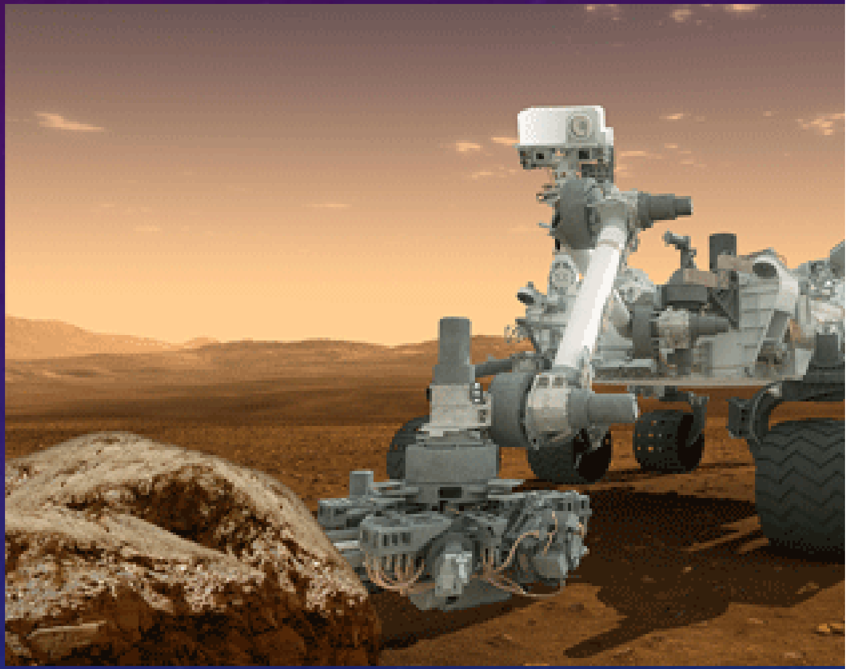


Mars north polar cap

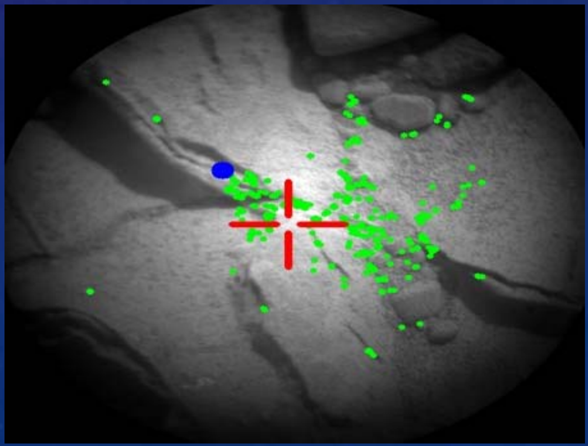
Image credit: Mars Odyssey team, ASU, JPL, NASA

R. Castaño et al., 2007. *Knowledge Discovery and Data Mining*.
K. Wagstaff et al., 2008. *Planetary and Space Science.*

3. Onboard science: Data acquisition



- AEGIS: Autonomous Exploration for Gathering Increased Science
  - Find and prioritize rocks
  - Fire ChemCam laser and collect spectra
  - Operational on MSL since 2016
  - Baselined for Mars 2020
- Automatic pointing refinement
  - Developed for Mars 2020 (PIXL)



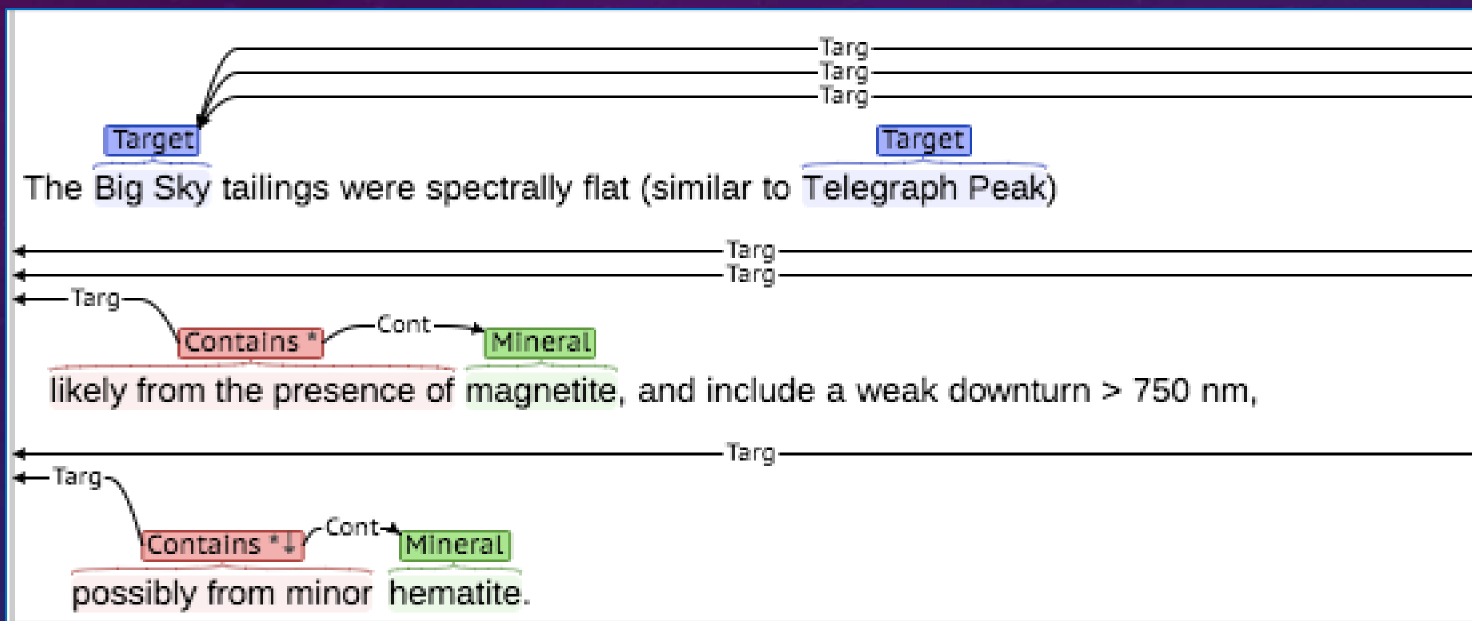
Tara Estlin, Benjamin J. Bornstein, Daniel M. Gaines, Robert C. Anderson, David R. Thompson, Michael Burl, Rebecca Castaño, and Michele Judd

4. Information extraction for planetary science

Millions of observations…

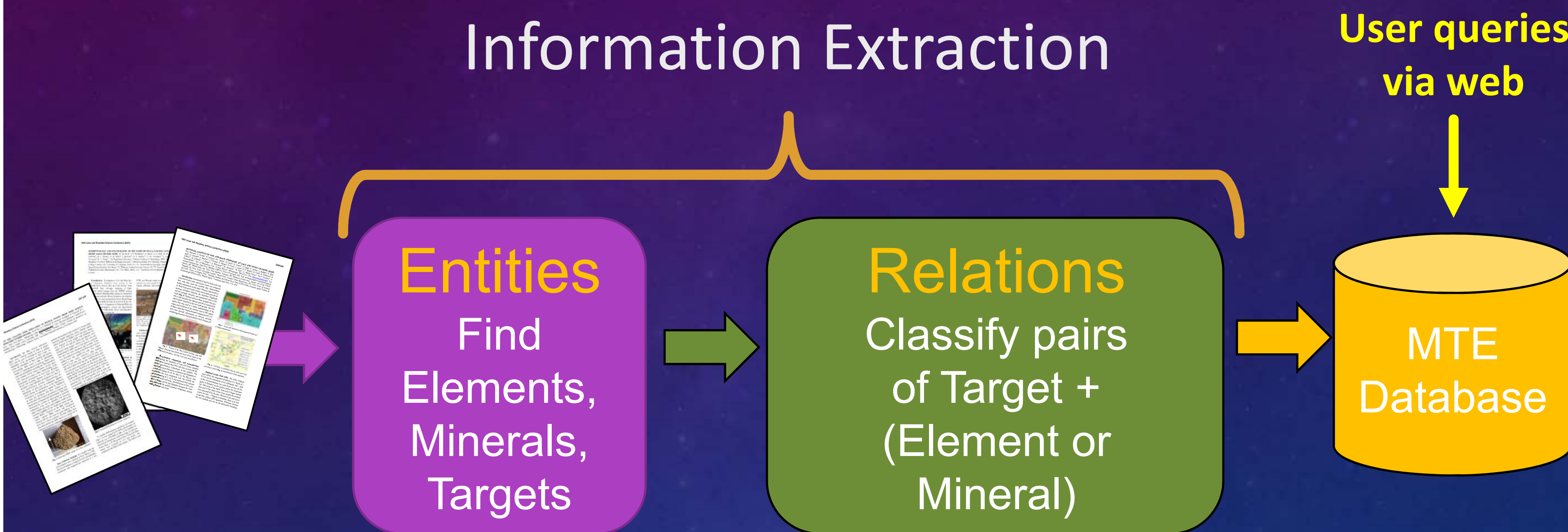
What have we learned?

Mars Target Encyclopedia: Geochemical relationships



- Big Sky contains magnetite
- Big Sky contains hematite

Mars Target Encyclopedia: Geochemical relationships



- Train: 118 manually annotated documents
- Deploy: 5,920 automatically analyzed
- Speed: 30 minutes/doc => 5 seconds/doc

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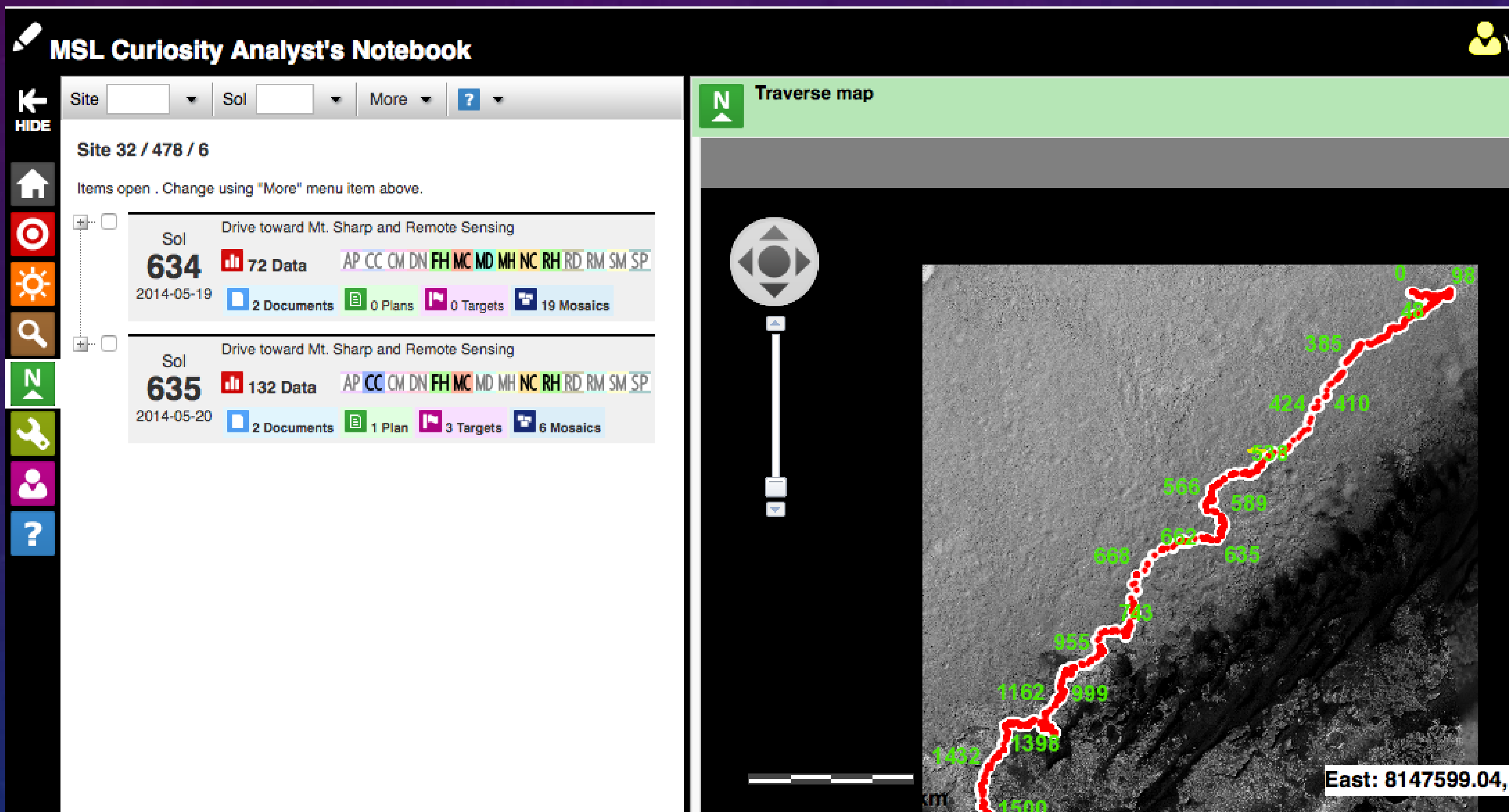
MTE Integration with the MSL Analyst's Notebook



How to ↑ support for ML + planetary science

- For research advances
  - ROSES call for ML+planetary science collaborations
- For spacecraft infusion
  - Funds for maturing algorithms for onboard use
  - Funds for infusing algorithms into flight software
- For community impact
  - Funds for connecting algorithms to data systems (e.g., PDS)