

Machine Learning for Planetary Science

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Big Data Task Force

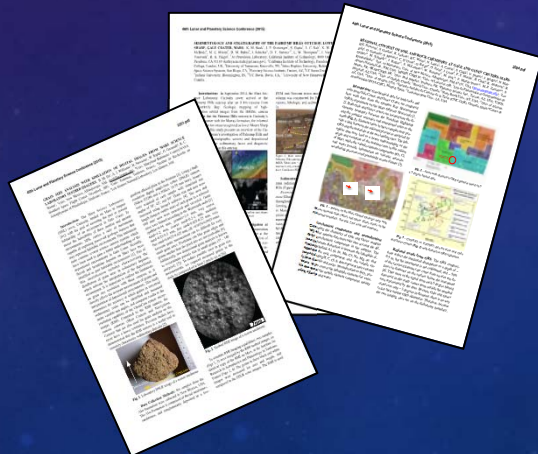
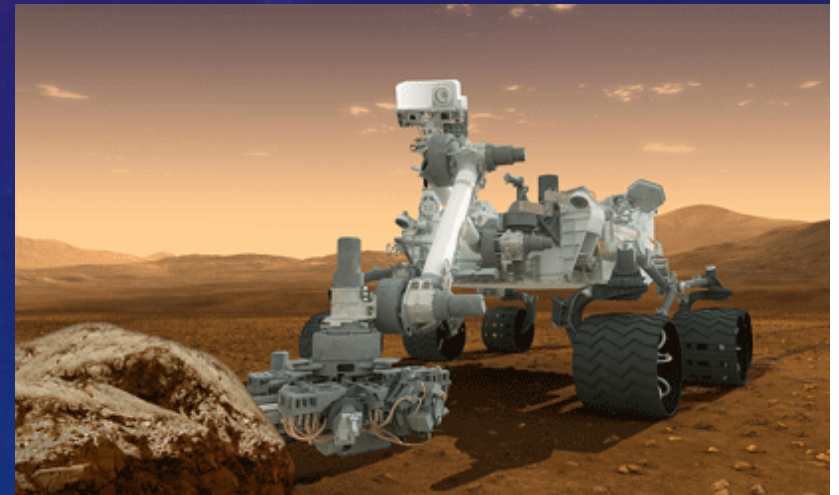
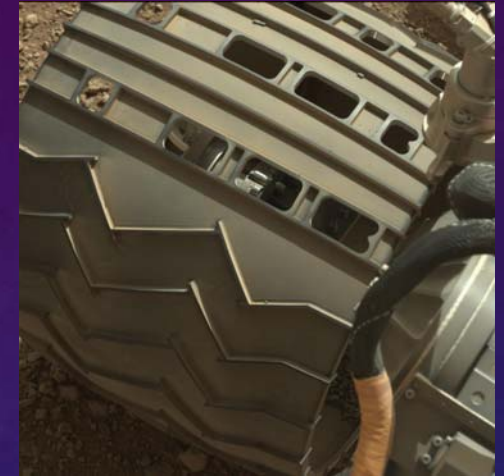
November 1, 2017

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ML for Planetary Science

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



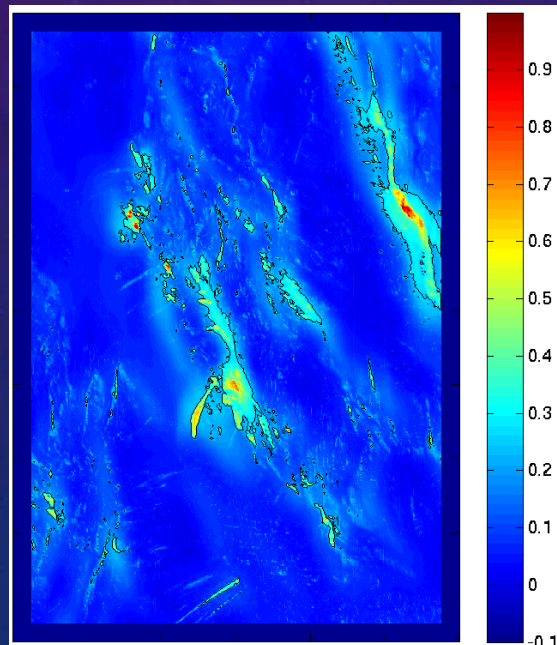
1. Content-based image classification

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

Find visually salient “landmarks”

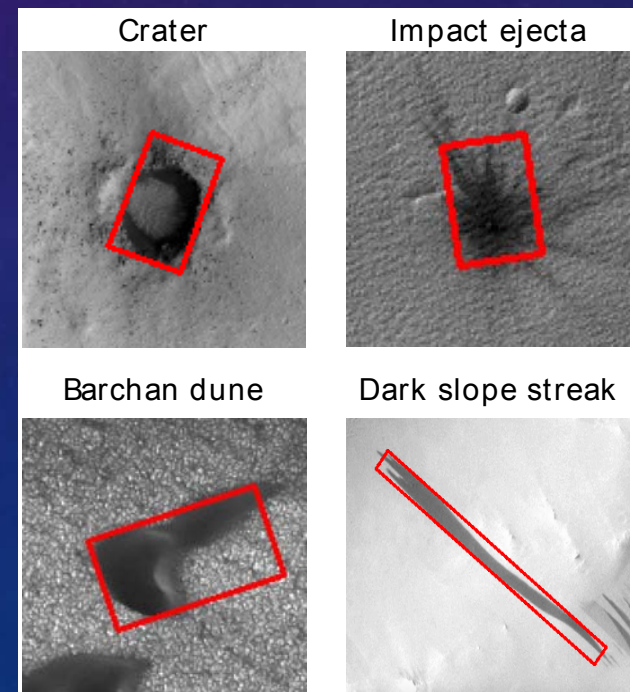


MOC, June 2000



Saliency Map

Train a classifier to label them



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

Planetary Image Atlas

NEW SEARCH

DATA PORTAL

ABOUT

HELP

FEEDBACK

HOME

Current Selection

remove all

(x) PRODUCT_ID:**RED**

(x) ATLAS_INSTRUMENT_NAME:hirise

(x) PRODUCT_TYPE:rdp

Search

(press ESC to close suggestions)

› Mission

› Instrument

› Target

› Product Type

› Lighting Geometry

› Filters

› Lat/Lon Bounding Box

› Time Constraints

› Orbital Mission Constraints

› Landed Mission Constraints

› PDS Archive Constraints

› Maps

› Report / Sort View Updates

› Bulk File Download

Results Per Page: 24

< 1 2 3 ... 1728 1729 > displaying 1 to 24 of 41496



Grid View

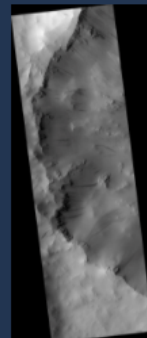


Sort View

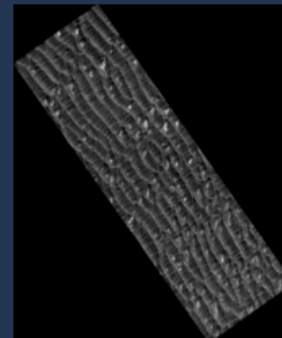
Sort By:

BRIGHT_DUNE_COUNTS

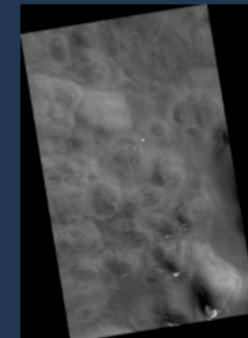
Clear



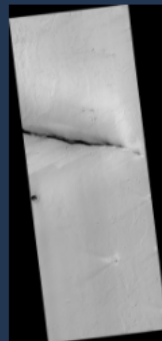
ESP_027488_2045_RED



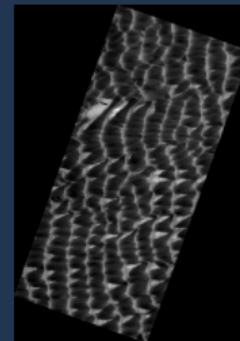
ESP_027488_2615_RED



ESP_027489_2535_RED



ESP_027490_1875_RED



ESP_027490_2620_RED

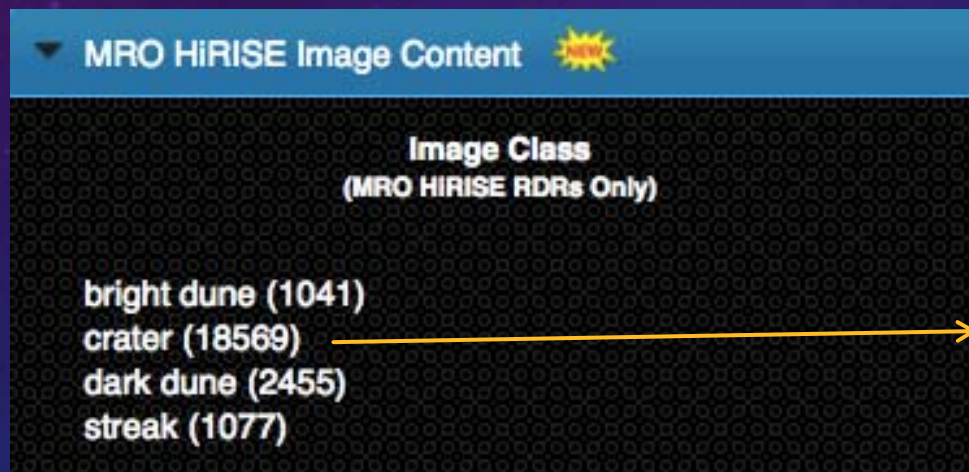


ESP_027491_2565_RED

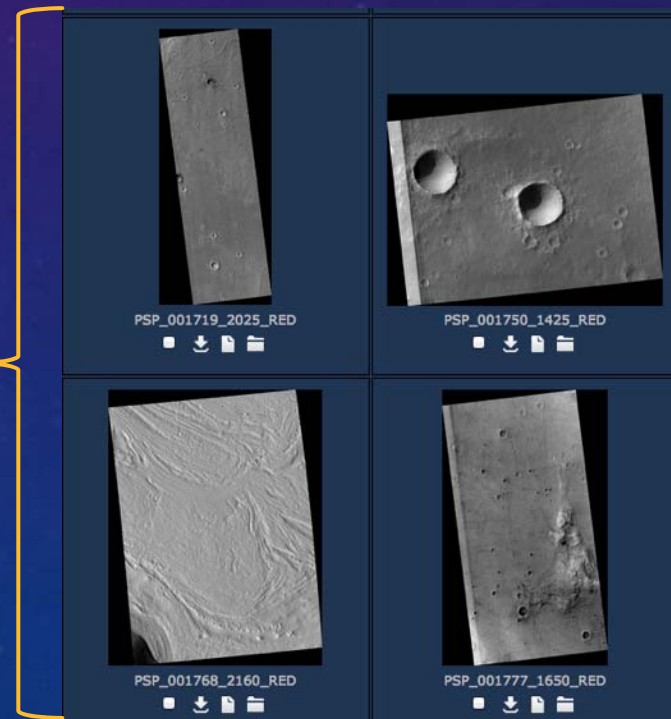
Content-based image search

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

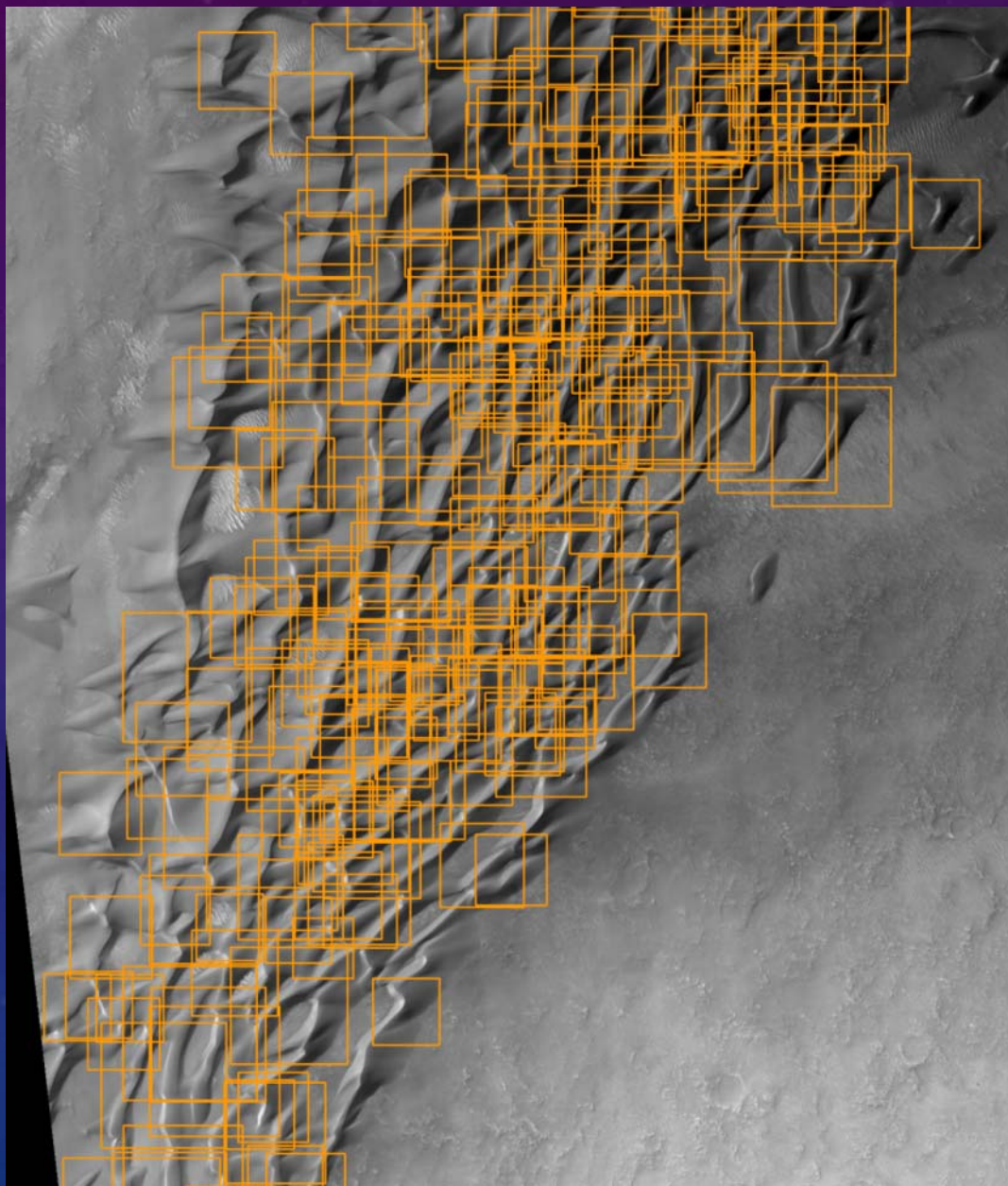
Planetary Image Atlas



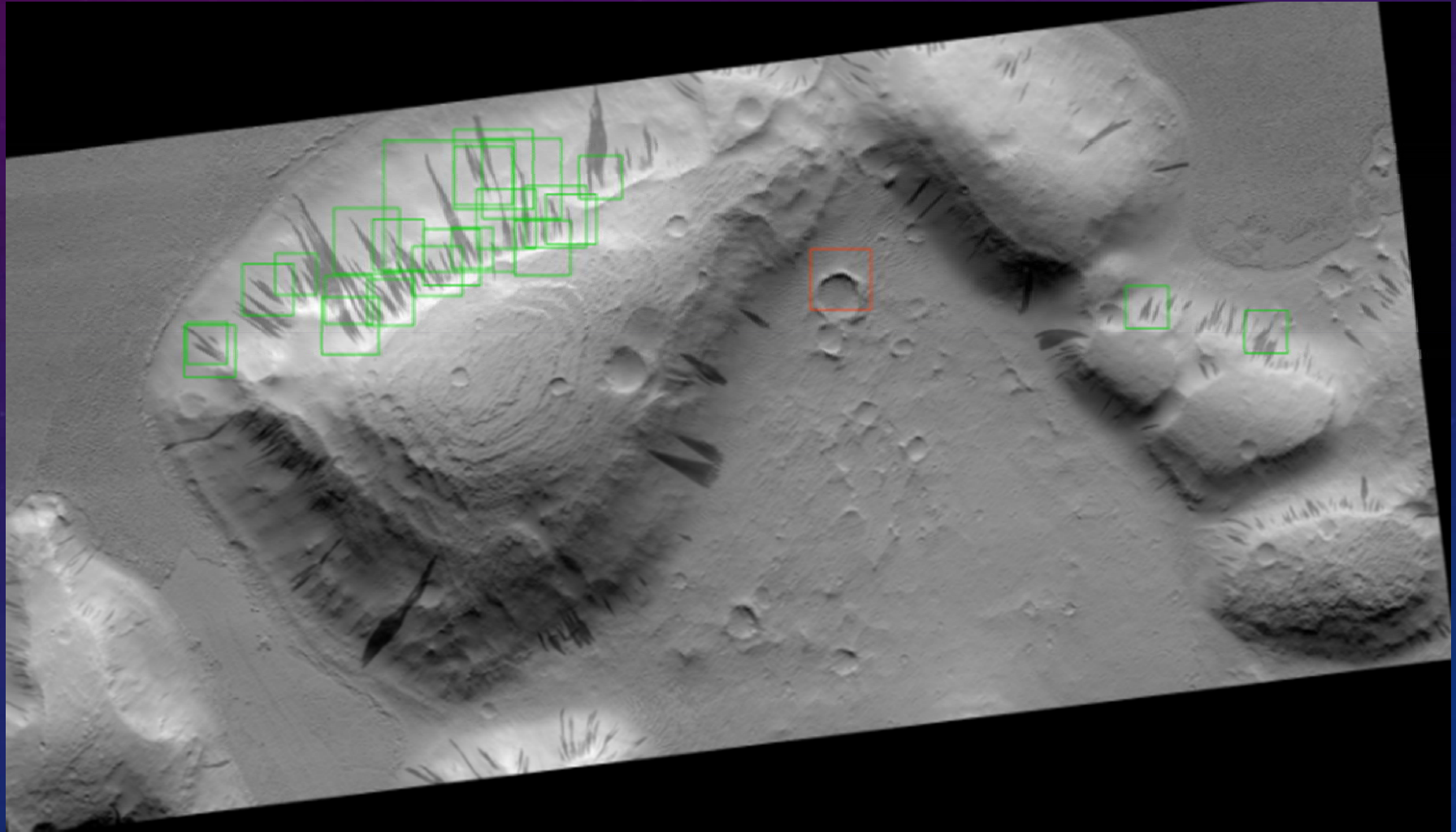
Example results from “crater” search



Dark dunes



Dark slope streaks



Benefits for mission operations

- ▶ PDS Archive Constraints
- ▶ Landmarks
- ▼ MSL Image Classification














































Image Class

wheel (12555)

Confidence Level

73 to 100

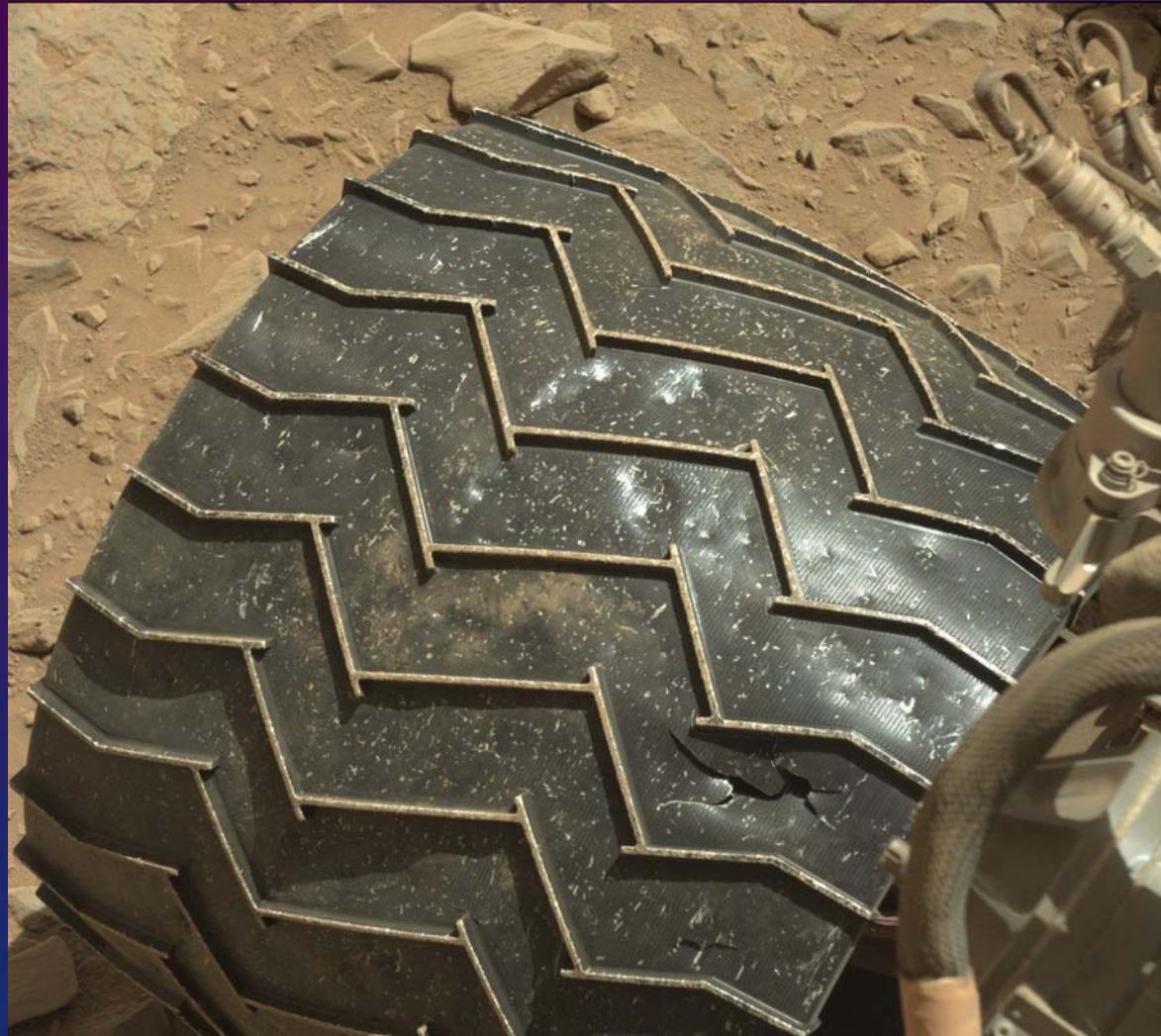
- ▶ Maps
- ▶ Report / Sort View Updates
- ▶ Bulk File Download

 <p>0468ML0018661180202121C00_XXXX</p>    	 <p>0468ML0018661180202121E01_XXXX</p>    	 <p>0468ML0018661180202121I01_XXXX</p>    
 <p>0474ML0018810010202170E01_XXXX</p>    	 <p>0486ML001915000202251E01_XXXX</p>    	 <p>0486ML001915000202251I01_XXXX</p>    
 <p>0486ML0019150010202252E01_XXXX</p>    	 <p>0486ML0019150010202252I01_XXXX</p>    	 <p>0486ML00191500202253E01_XXXX</p>    

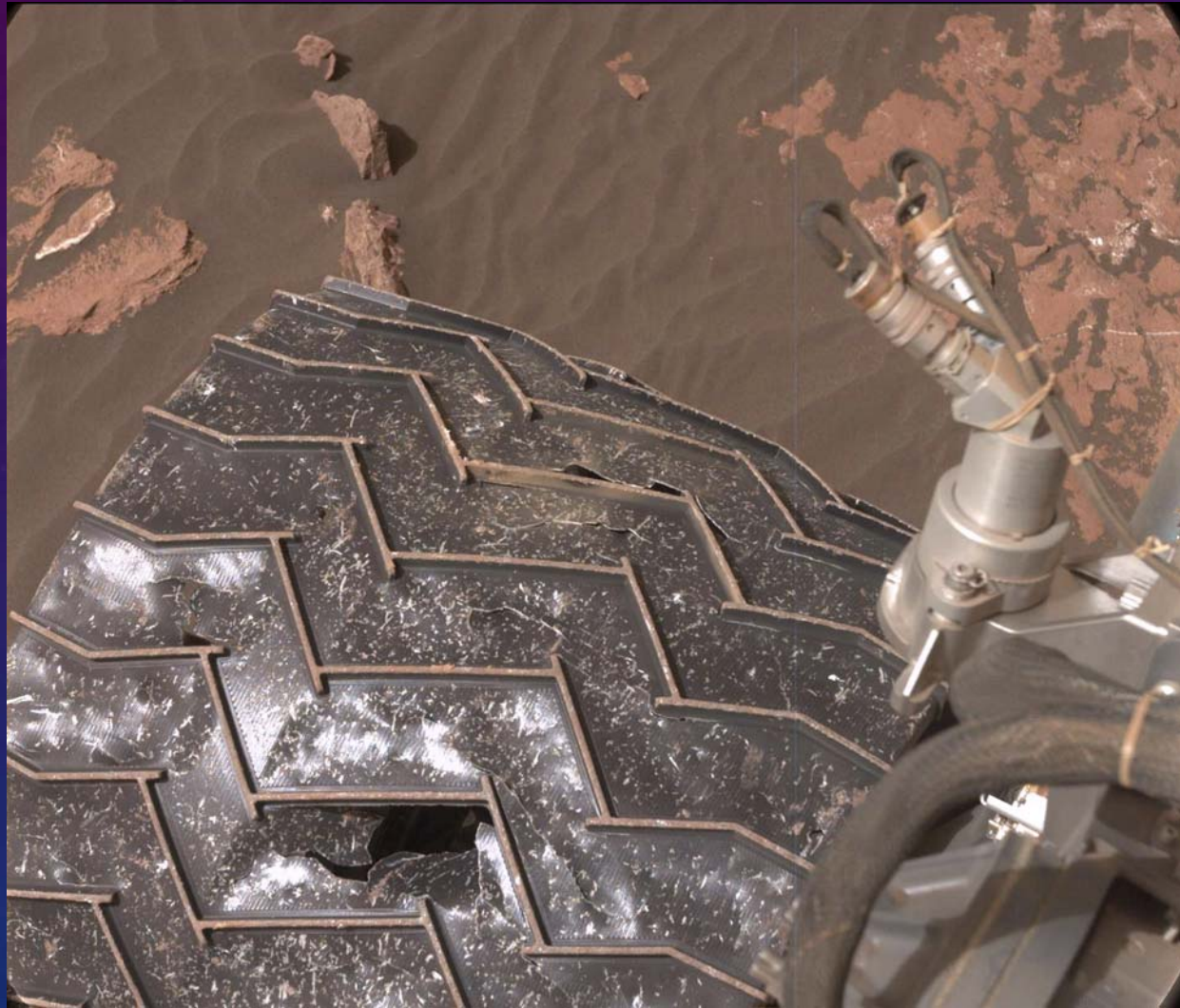
August 2012



December 2013

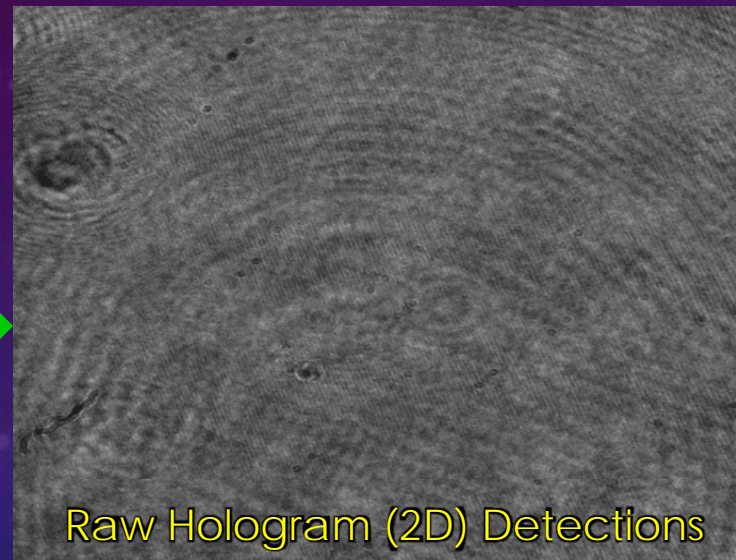


November 2016



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

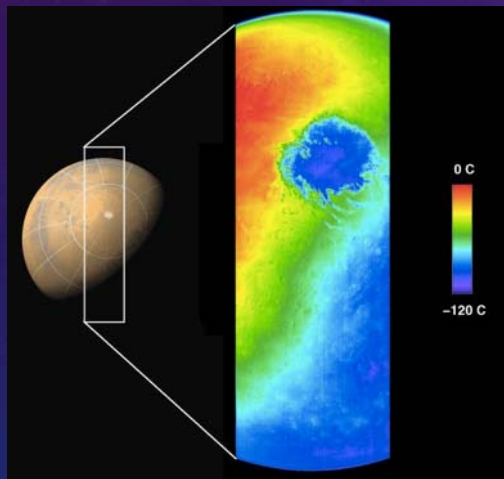
2. Onboard science: Dust devil (change) detection



- 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

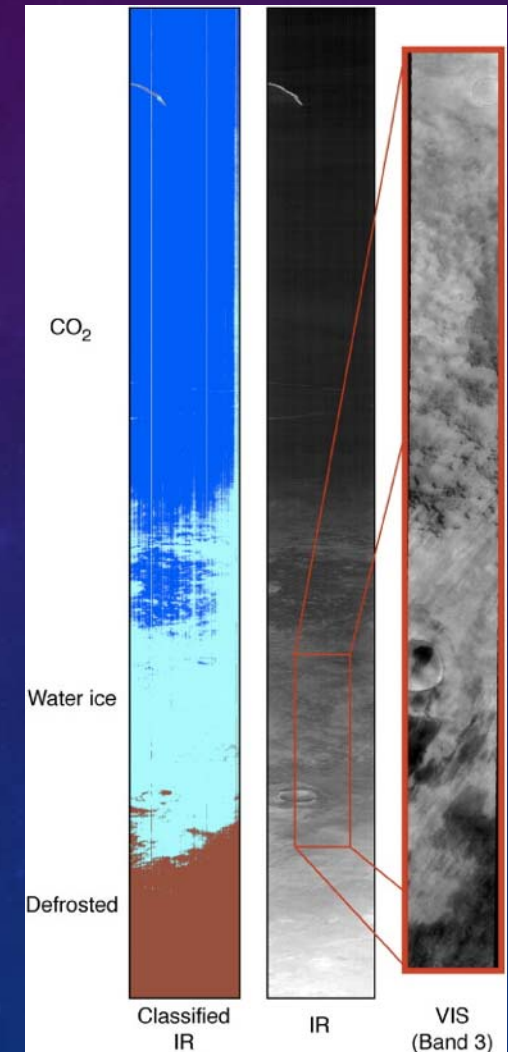
2. Onboard science for new discoveries

- Thermal anomaly detection
 - 14,856 THEMIS nighttime images
 - 143 images $> 240\text{K}$ ($12.57\ \mu\text{m}$)
 - 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



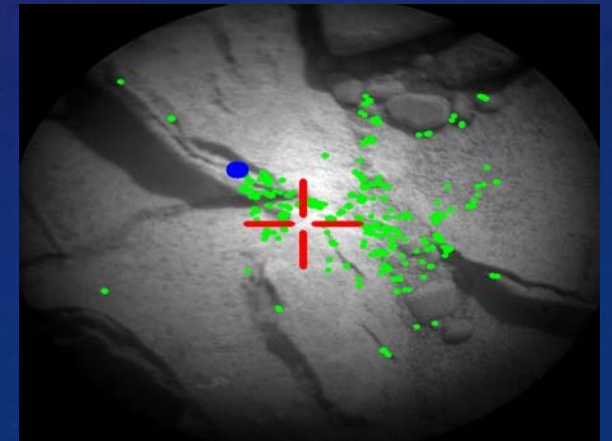
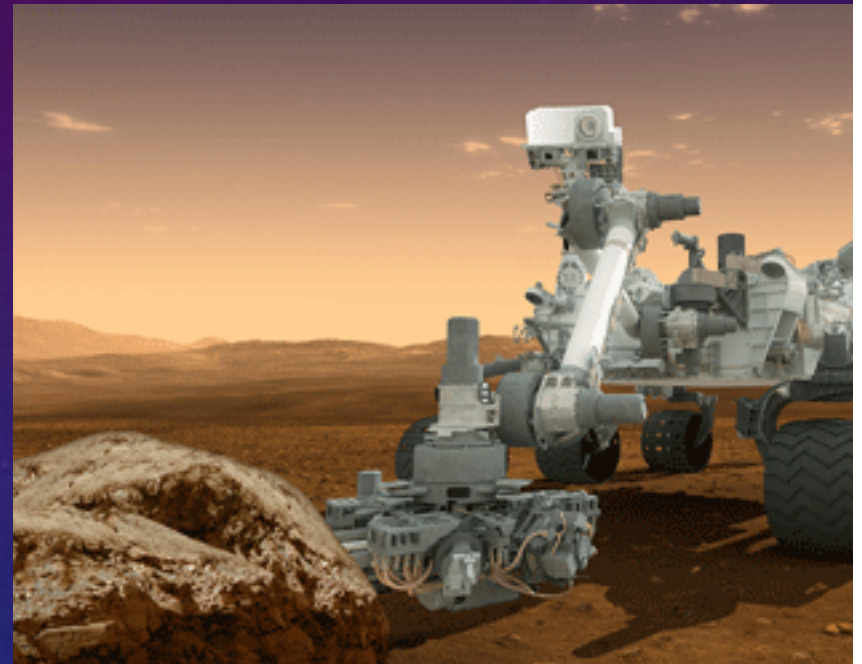
Mars north polar cap

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

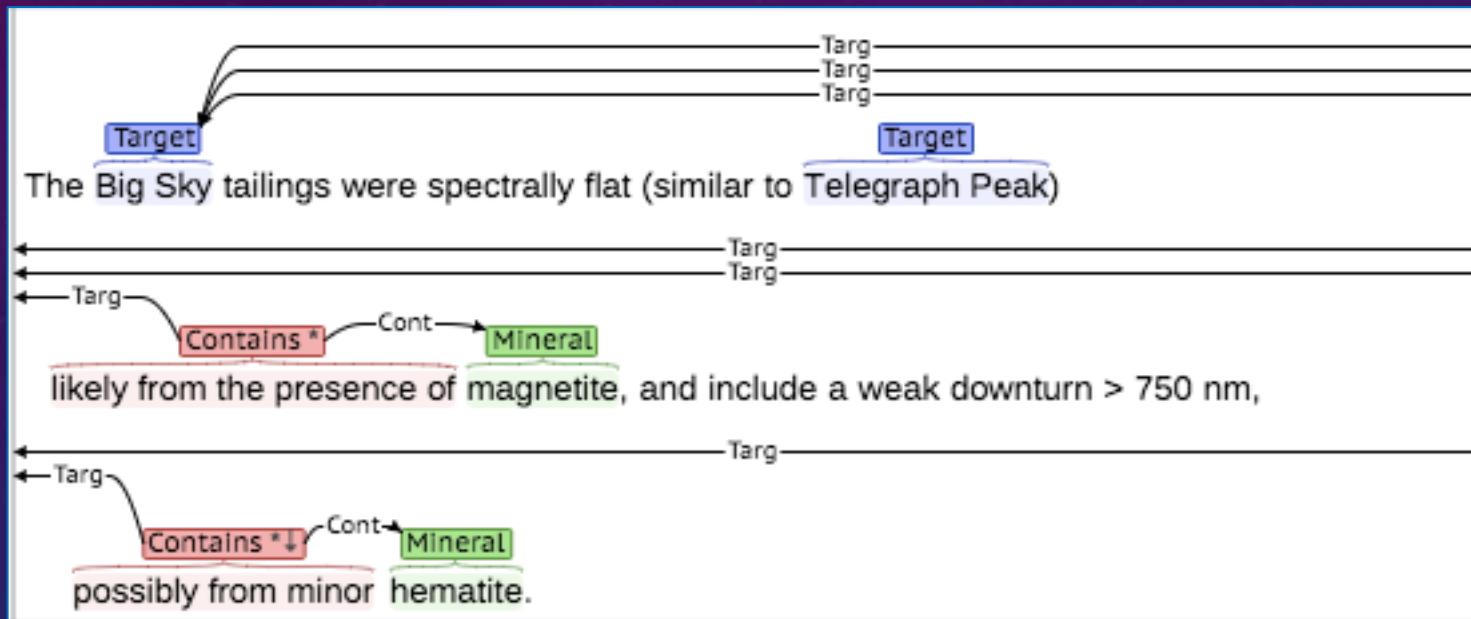
4. Information extraction for planetary science

Millions of observations...

What have we learned?



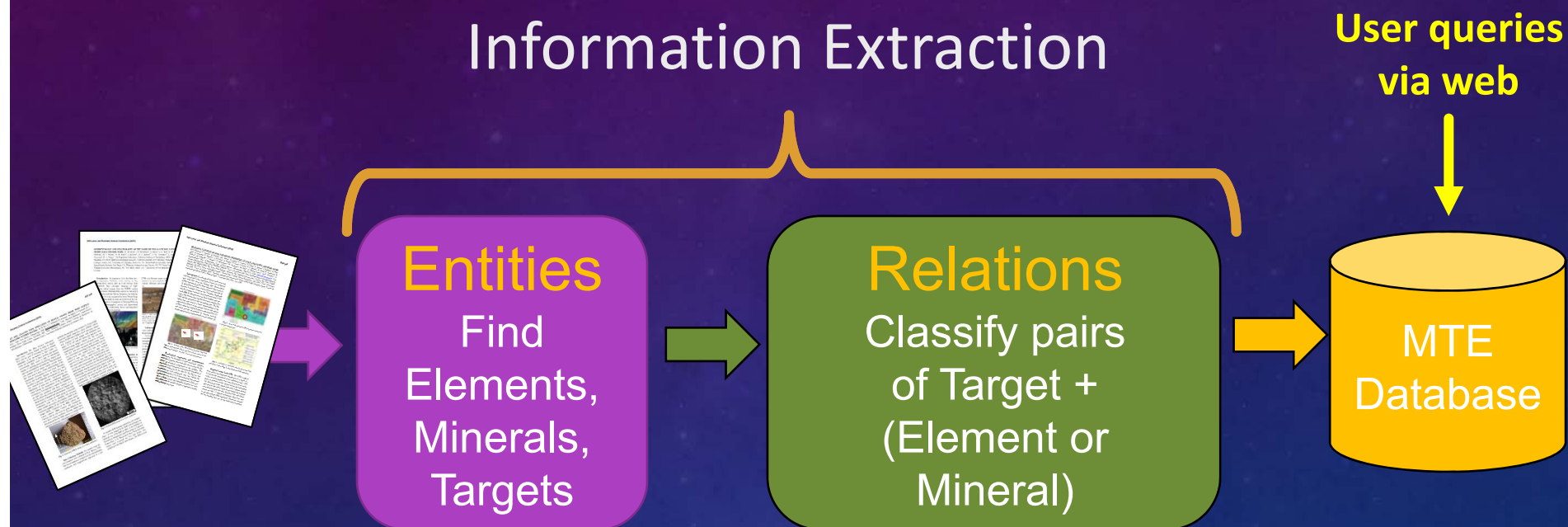
Mars Target Encyclopedia: Geochemical relationships



- Big Sky contains magnetite
- Big Sky contains hematite

Mars Target Encyclopedia: Geochemical relationships

Information Extraction



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

MTE Integration with the MSL Analyst's Notebook

The screenshot displays the MSL Curiosity Analyst's Notebook interface, divided into two main panels. The left panel, titled "MSL Curiosity Analyst's Notebook", features a navigation sidebar with icons for home, target, sun, search, north arrow, and user profile. The main content area shows site information for "Site 32 / 478 / 6".

Site 32 / 478 / 6
Items open . Change using "More" menu item above.

Sol	Drive toward Mt. Sharp and Remote Sensing	AP	CC	CM	DN	FH	MC	MD	MH	NC	RH	RD	RM	SM	SP
634	2014-05-19	2 Documents	0 Plans	0 Targets	19 Mosaics										
635	2014-05-20	2 Documents	1 Plan	3 Targets	6 Mosaics										

The right panel, titled "Traverse map", shows a grayscale image of the Martian surface with a red dotted line representing the rover's path. The path is annotated with green numerical labels: 1472, 1398, 985, 989, 656, 675, 743, 568, 608, 635, 424, 410, 375, 358, and 338. A north arrow and a scale bar are visible on the left side of the map. The coordinate "East: 8147599.04, 1" is displayed in the bottom right corner.

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)

