TextureCam: A Smart Camera for Autonomous Astrobiology

David R. Thompson[1]
William Abbey[1]
Abigail Allwood[1]
Dmitriy Bekker[1]
Benjamin J. Bornstein[1]
Nathalie A. Cabrol[2]
Rebecca Castaño[1]
Tara Estlin[1]
Thomas Fuchs[3]
Kiri Wagstaff[1]

[1]Jet Propulsion Laboratory, California Institute of Technology
[2]SETI Institute / NASA Ames
[3]California Institute of Technology

Contact: david.r.thompson@jpl.nasa.gov

PDS ID 1N134591492EFF1000P1803L0M1

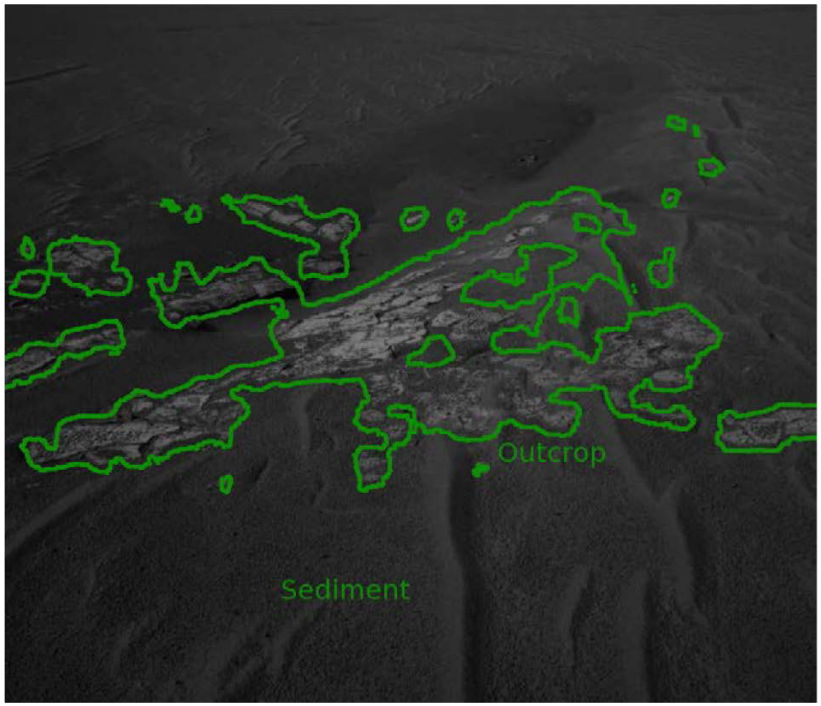
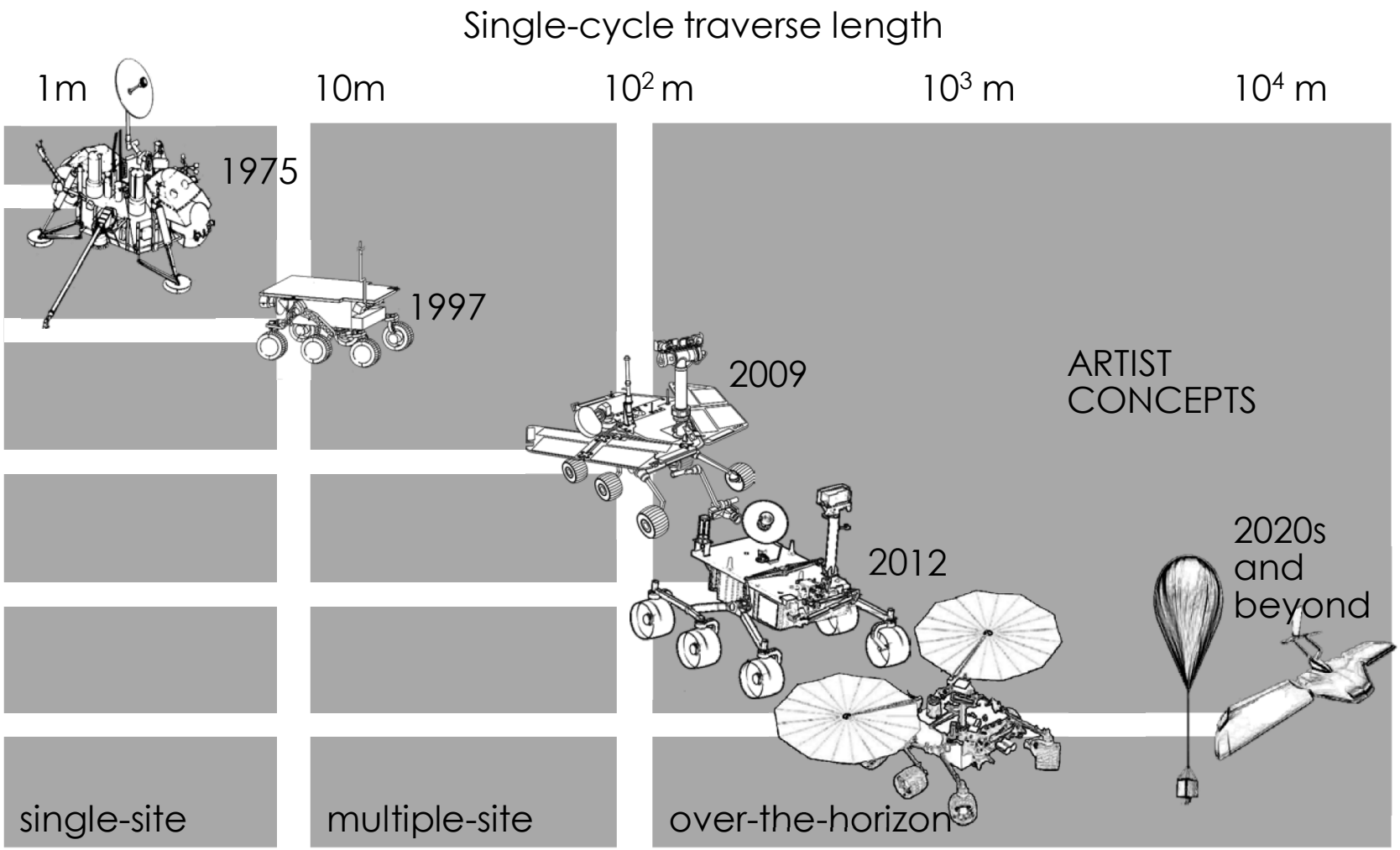


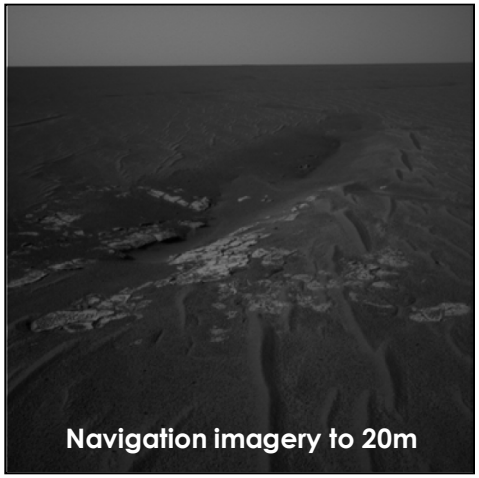
Image Credit: Caltech / NASA / JPL

TextureCam is funded by the NASA Astrobiology Science and Technology Instrument Development program (NNH10ZDA001N-ASTID). This presentation copyright 2012 California Institute of Technology. All Rights Reserved. US Government Support Acknowledged

Mobility permits fast reconnaissance

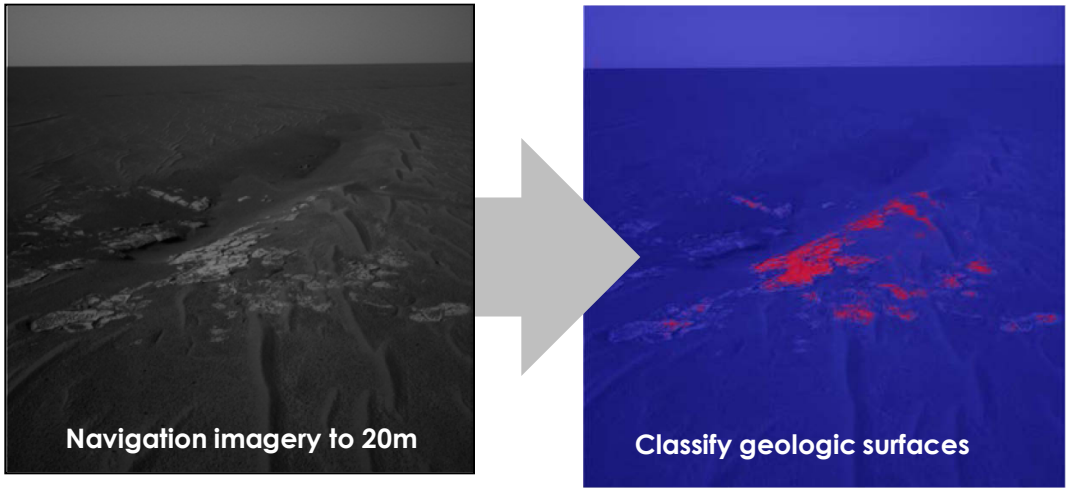


Multiple scales for a smart camera



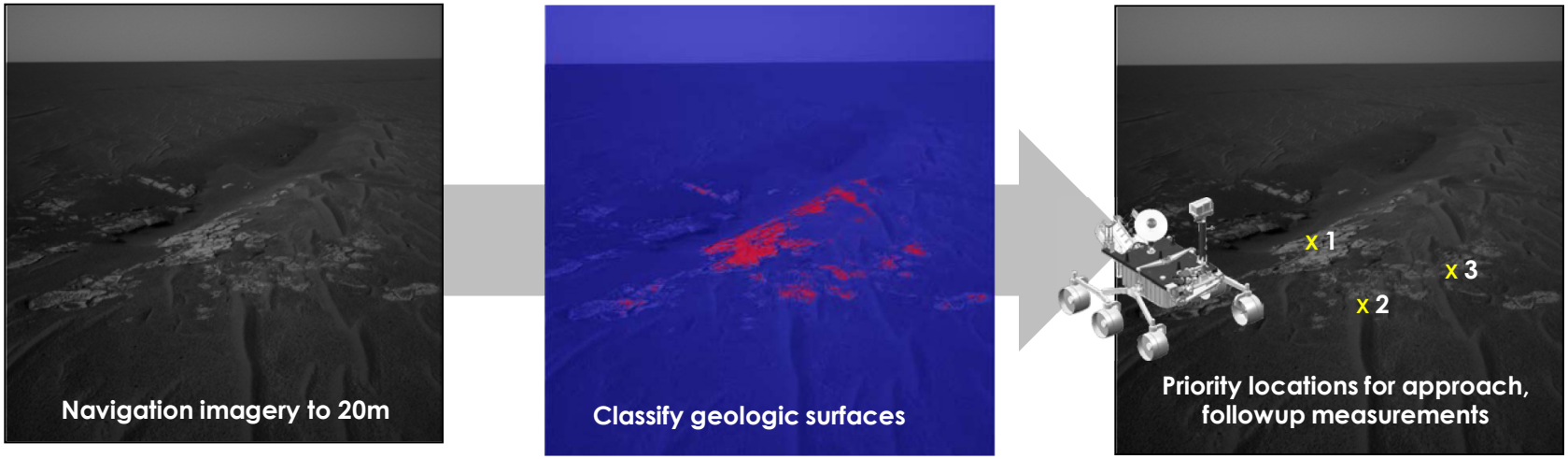
Images: Caltech / NASA / JPL / Alliance Space Systems

Multiple scales for a smart camera



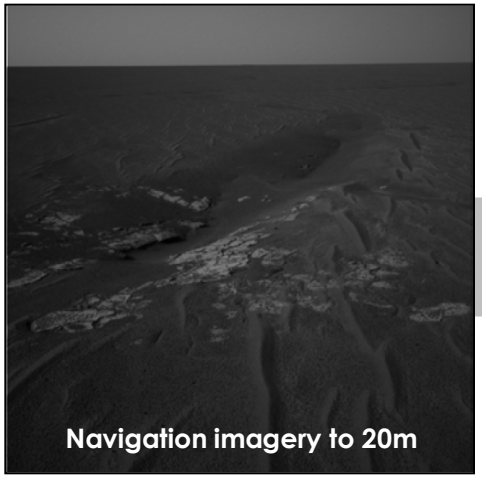
Images: Caltech / NASA / JPL / Alliance Space Systems

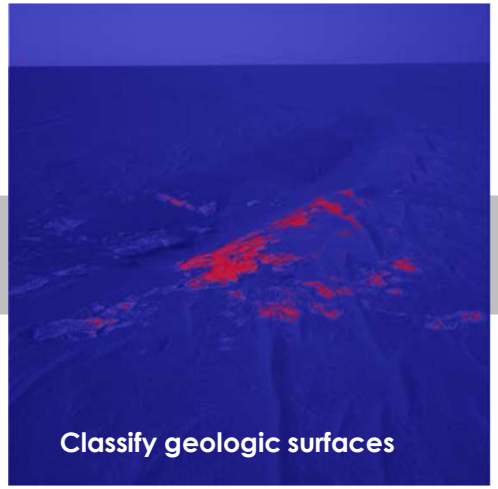
Multiple scales for a smart camera

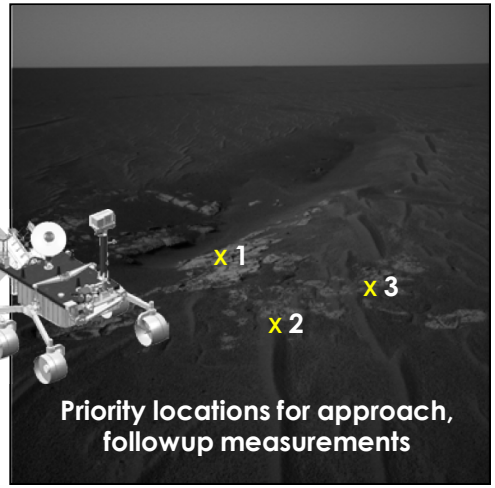


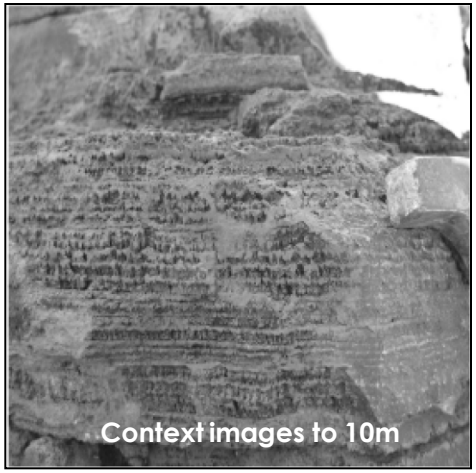
Images: Caltech / NASA / JPL / Alliance Space Systems

Multiple scales for a smart camera



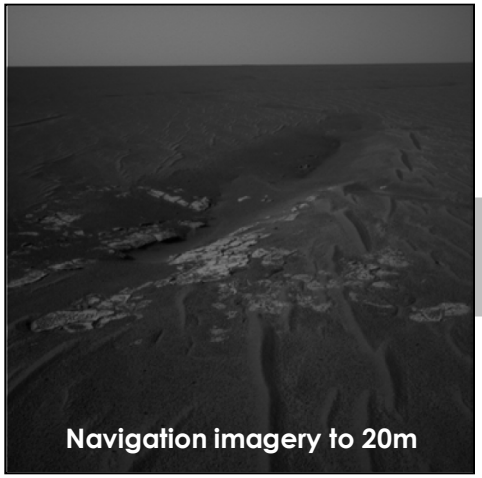


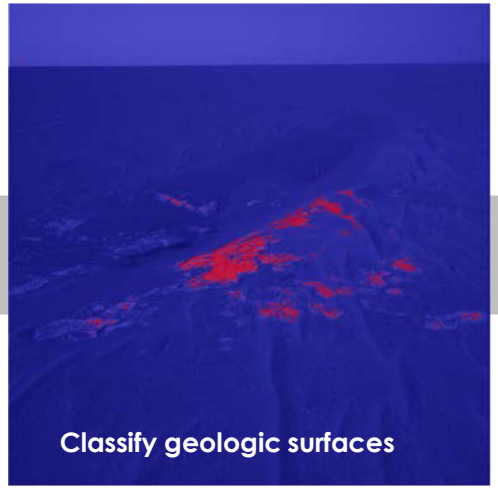


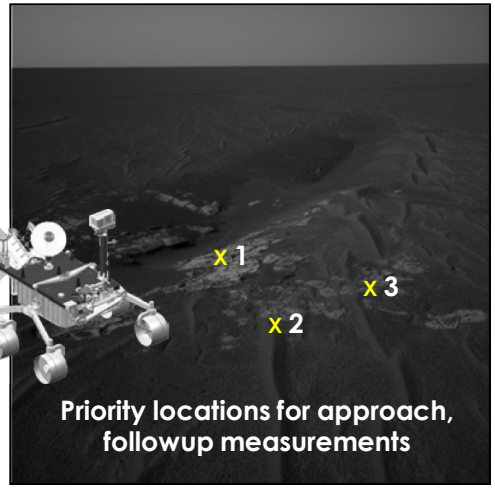


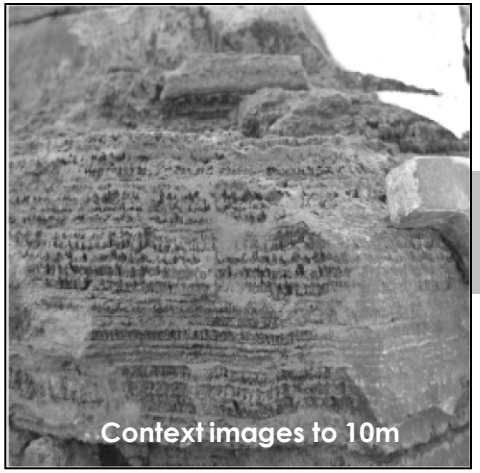
Images: Caltech / NASA / JPL / Alliance Space Systems

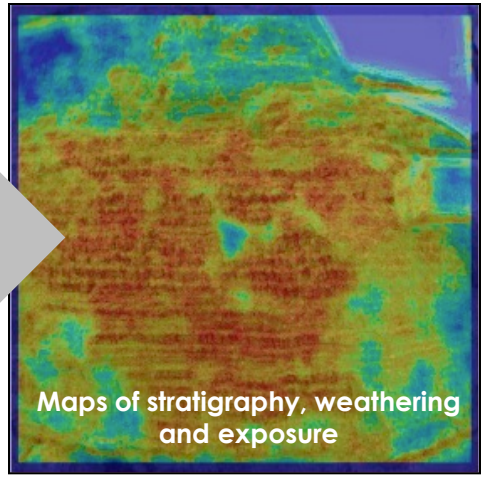
Multiple scales for a smart camera





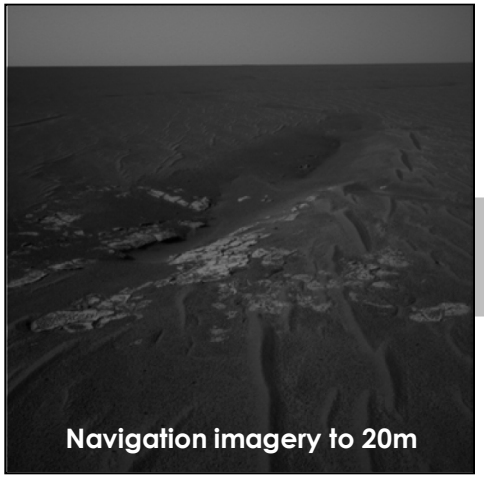


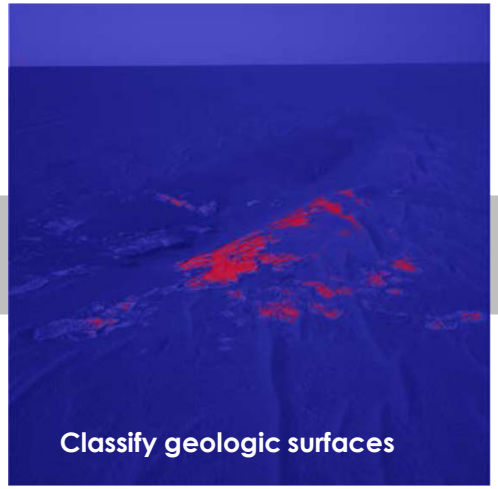


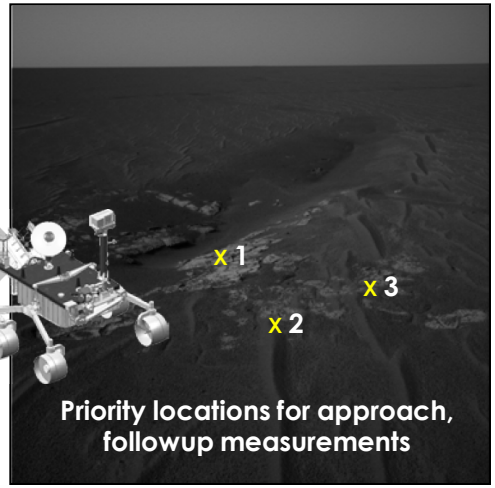


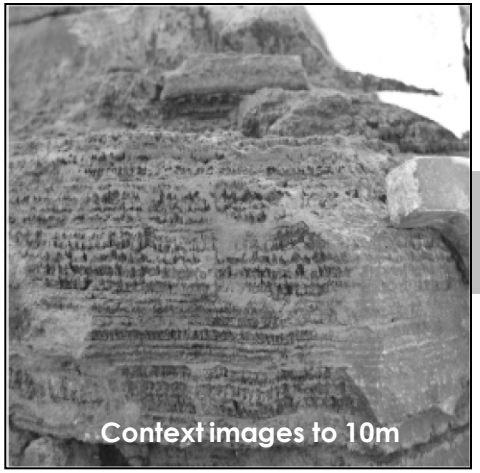
Images: Caltech / NASA / JPL / Alliance Space Systems

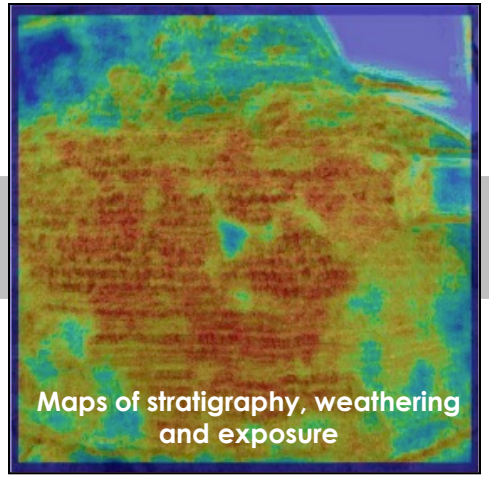
Multiple scales for a smart camera

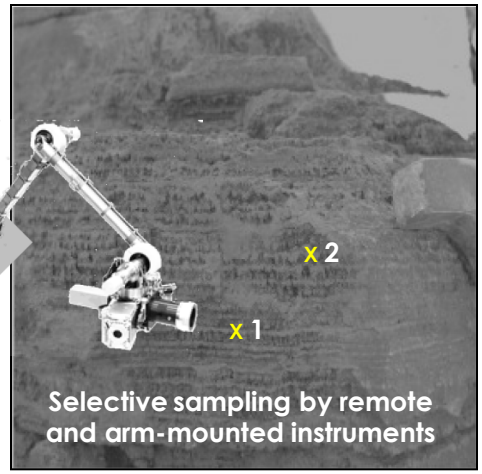








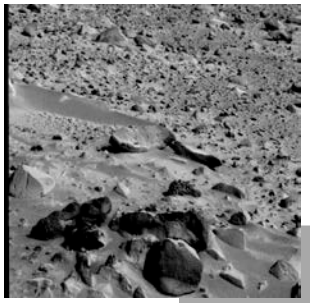




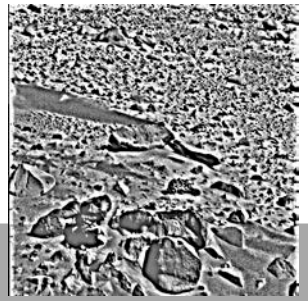
Images: Caltech / NASA / JPL / Alliance Space Systems

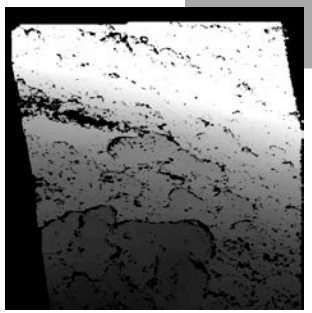
How it works

Pixel values

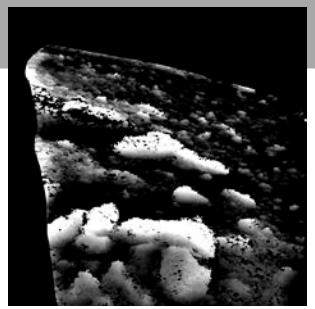


High pass



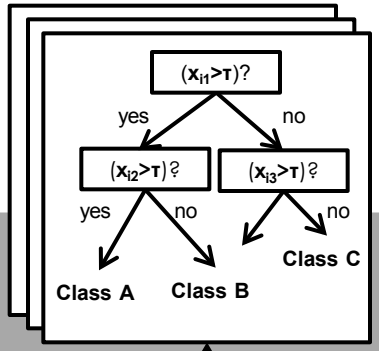


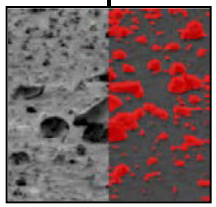
Range map



Height map

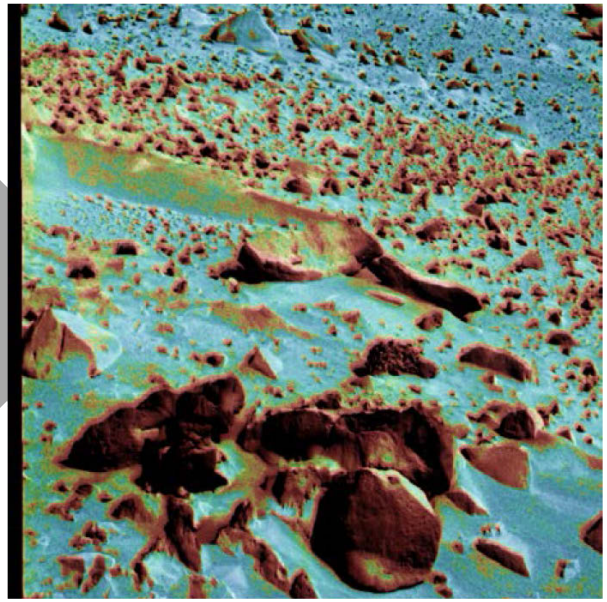
Decision forest





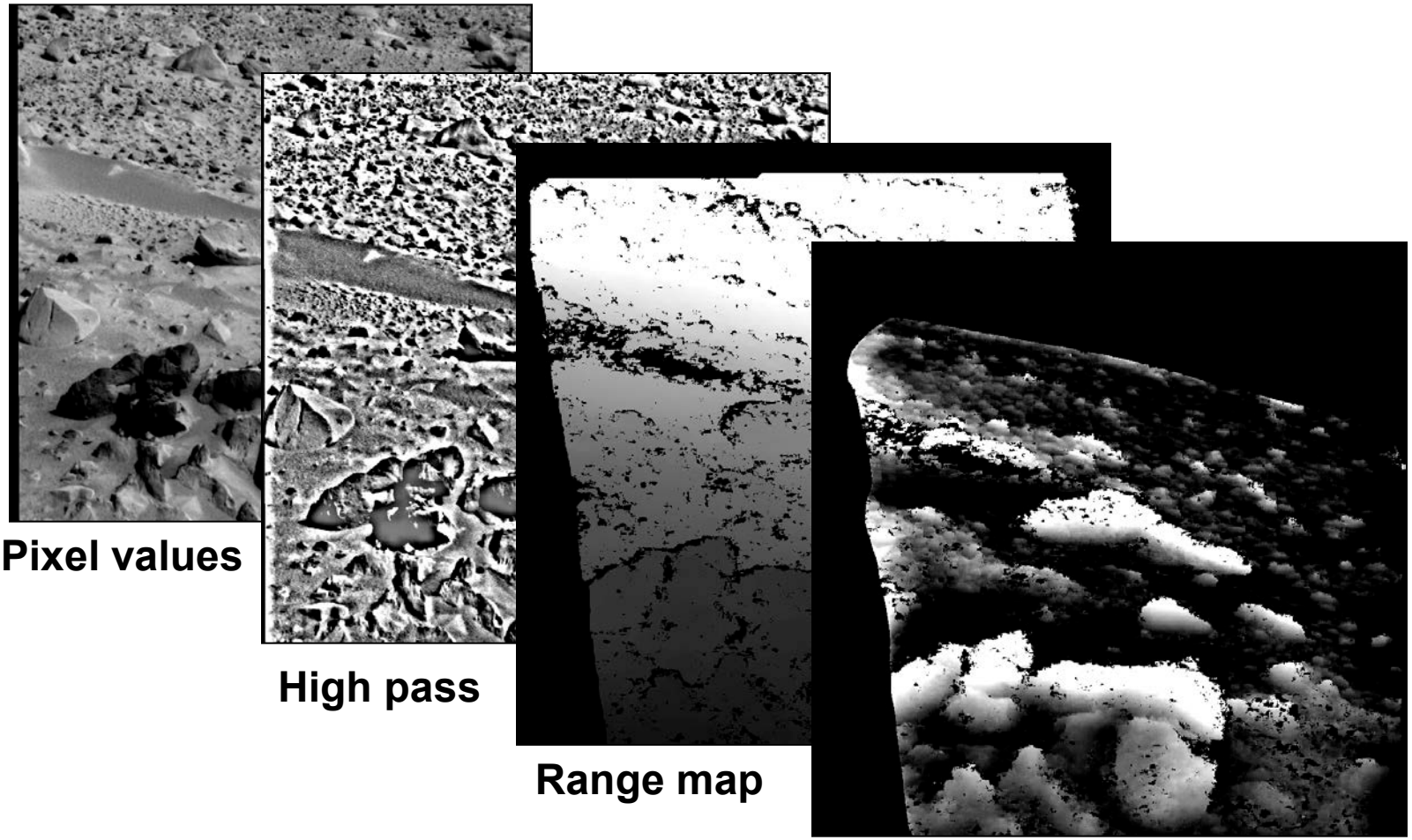
Training labels
(in advance)

Surface classification for new scene



Original image: NASA/JPL/Caltech/Cornell

Input channels



Pixel values

High pass

Range map

Height map

Original image: NASA/JPL/Caltech/Cornell

Random Forest Pixel Classifier

[Shotton et al., 2008]

Uses attributes based on pixels in a local window around the test point

- **values**
- **differences**
- **sums**
- **ratios**
- **absolute differences**

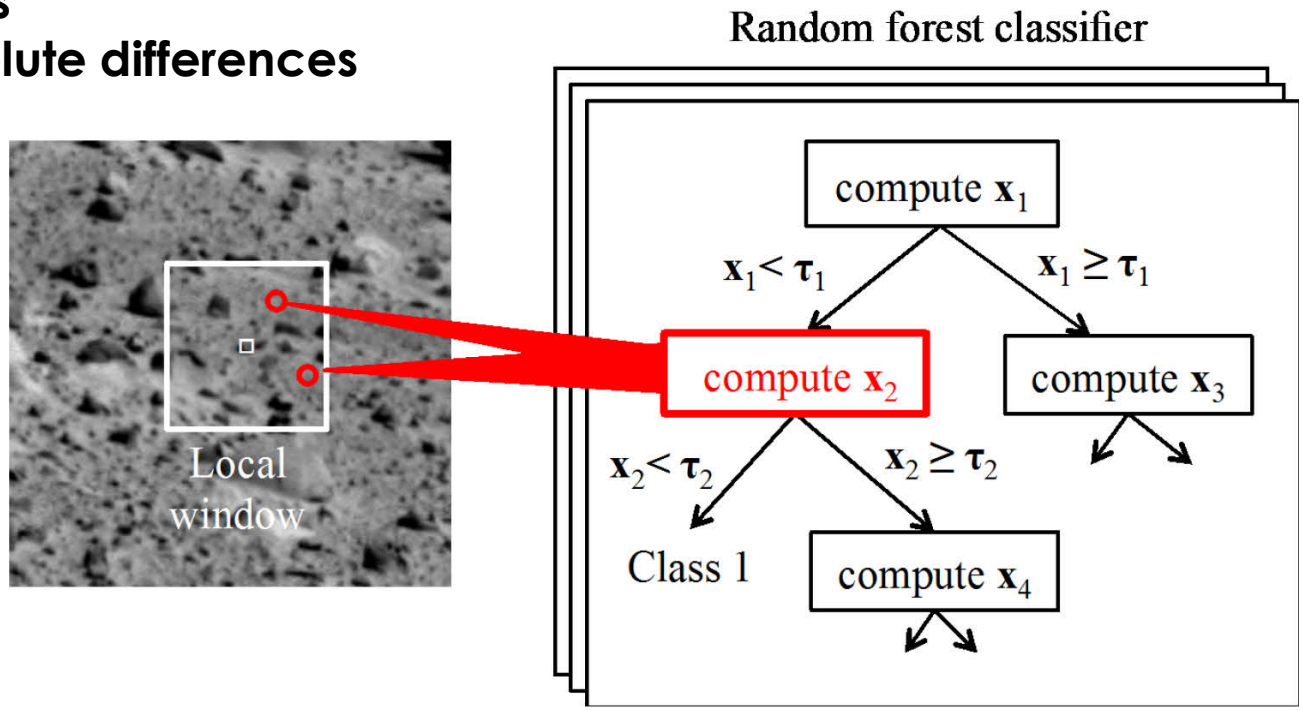


Image Credit: Caltech / NASA / JPL

Training procedure

- ID3 rule: choose the splitting criterion minimizing expected posterior entropy of texture classes

$$E[\Delta H] = -\frac{|I_l|}{|I_n|}H(I_l) - \frac{|I_r|}{|I_n|}H(I_r)$$

Entropy of left branch Entropy of right branch

- Search over all pixel comparisons and thresholds
- Grow the tree recursively from the root

Posterior class probabilities

- Average class distributions at the appropriate leaf nodes

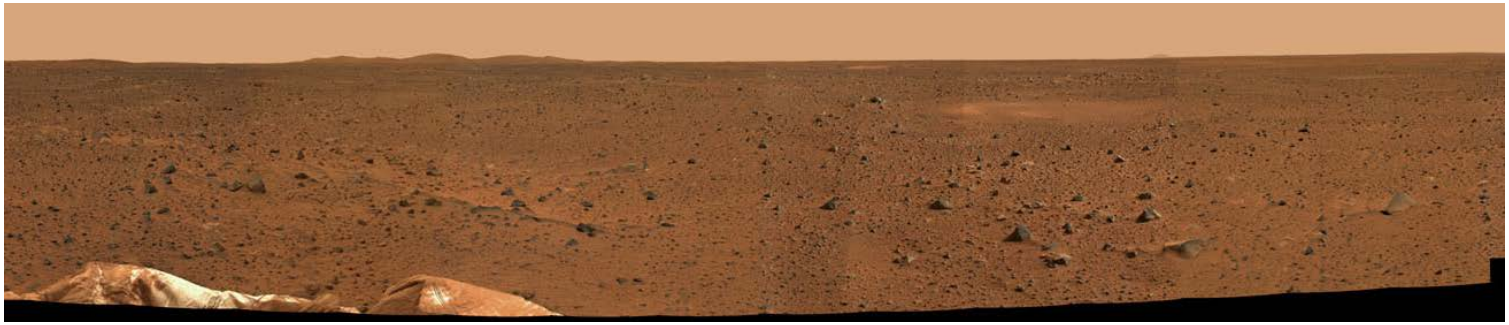
$$P(c|L) = \frac{1}{T}\sum_{t=1}^{T} P(c|l_t)$$

Evaluation: MER rock detection

- A clean test case because rocks are discrete objects
- Valuable for instrument target selection

Legacy panorama

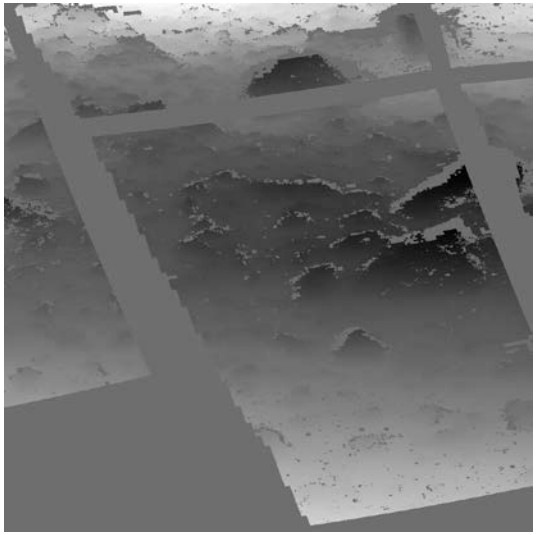
Mission success panorama



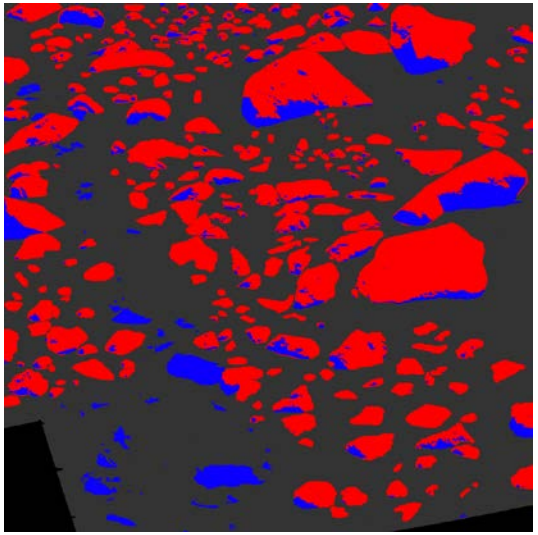
Evaluation: MER rock detection

- Used 1000s of labeled rocks in each panorama
- Trained on Mission Success panorama
- Tested on Legacy panorama

Image (pancam)

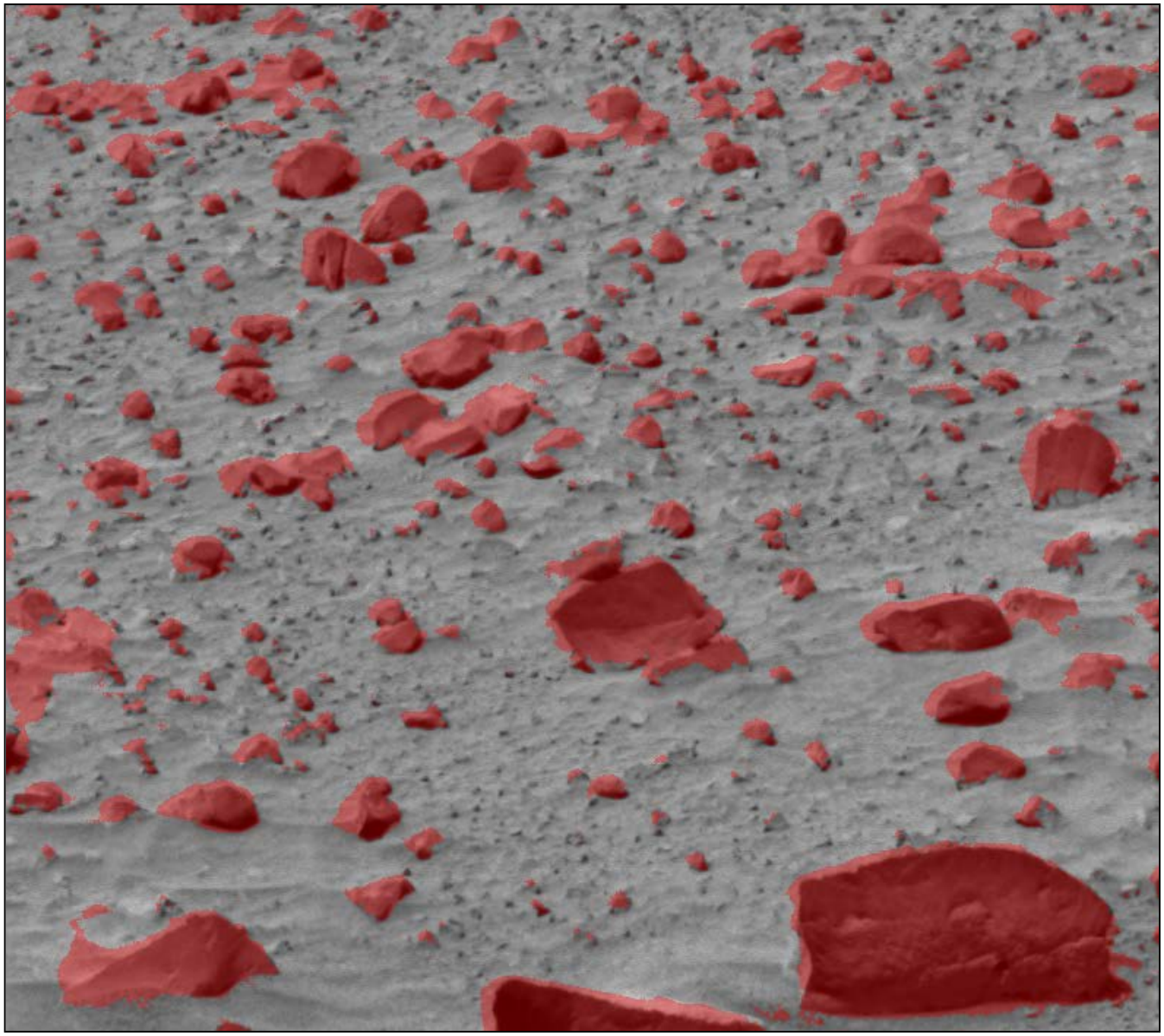


Heightmap



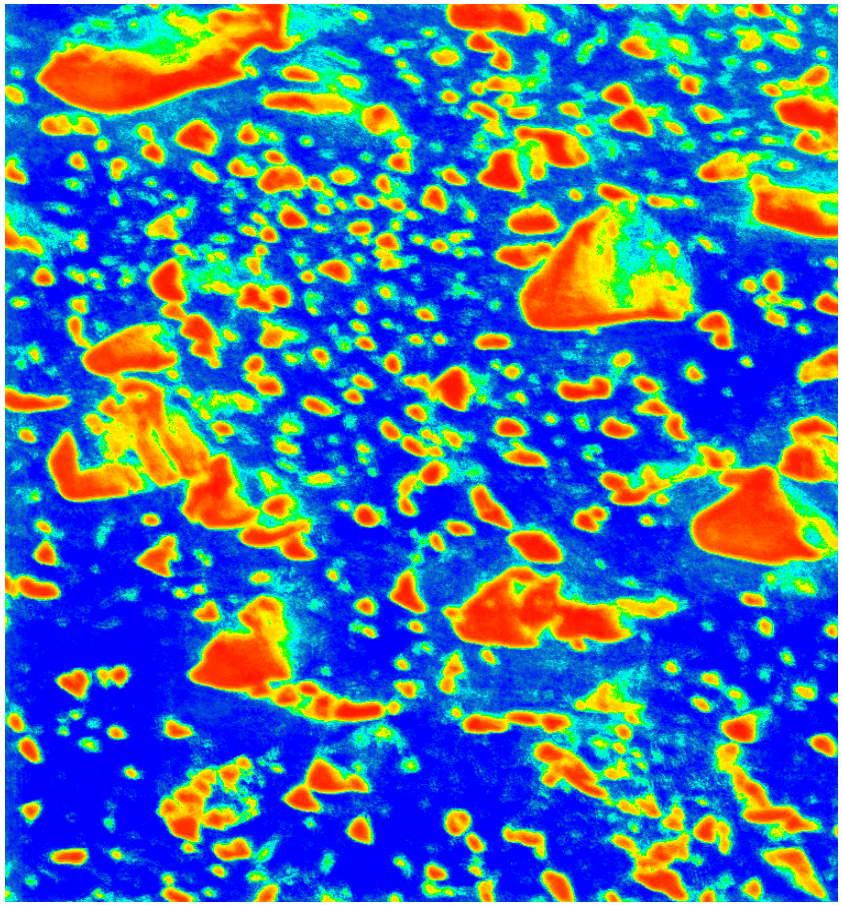
Pixel labels

Typical result

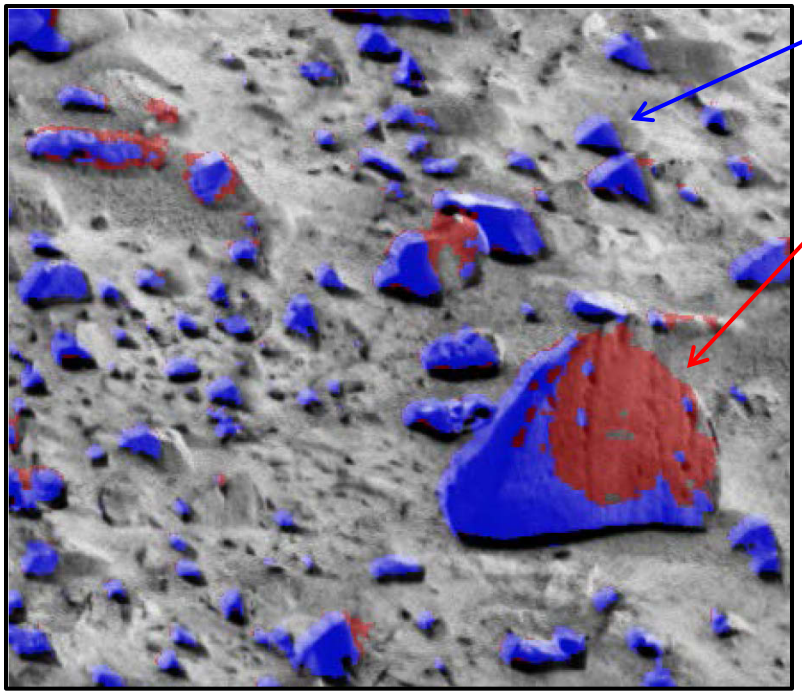


Original image: NASA/JPL/Caltech/Cornell

Probability maps



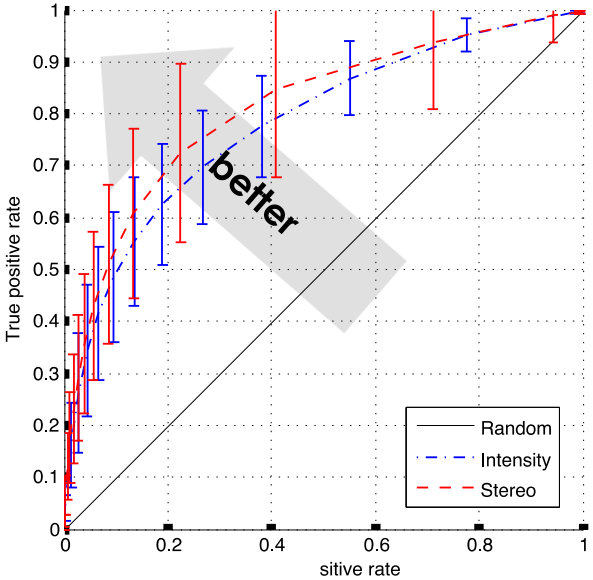
Performance: pixel classification



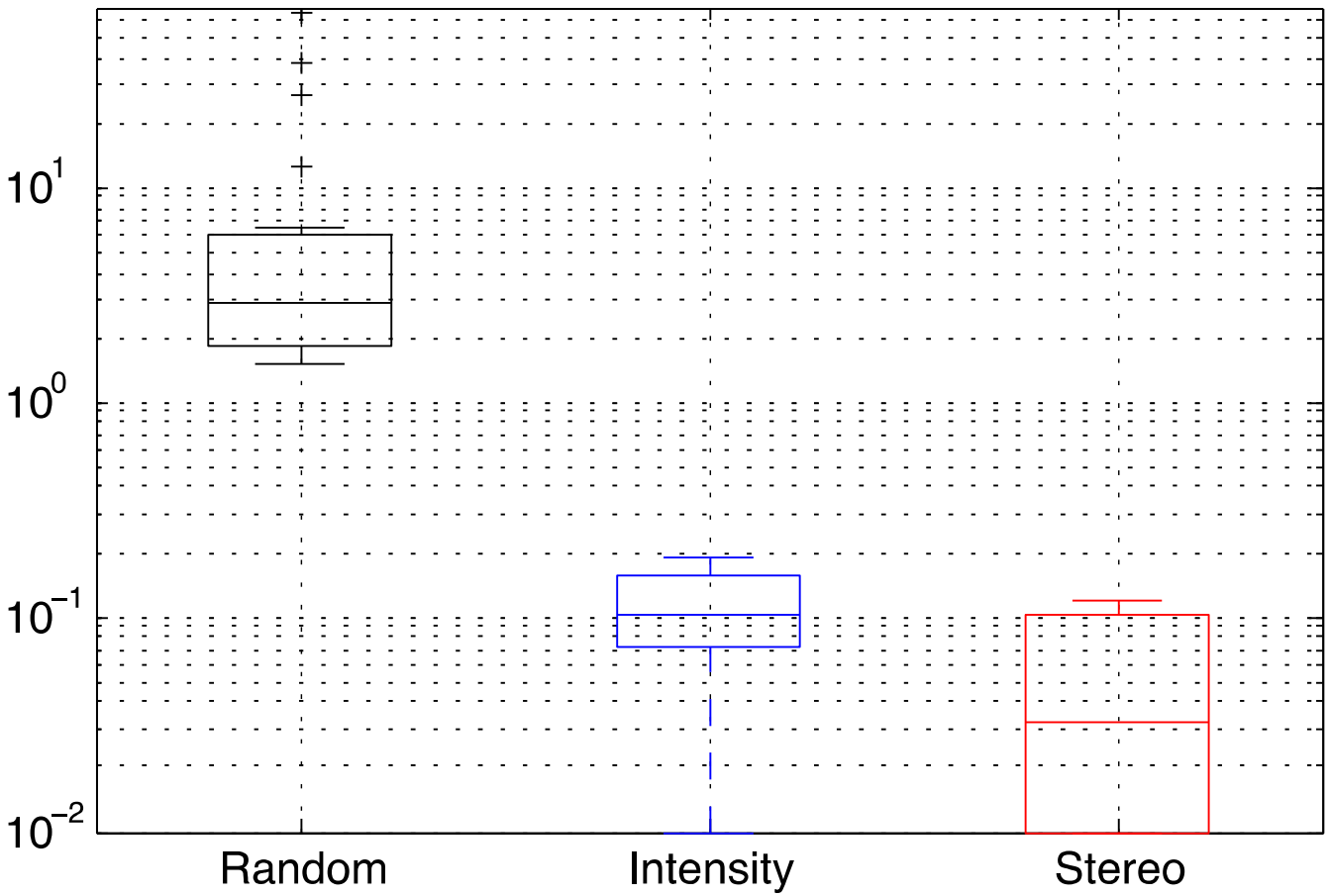
Classification based on pixel intensity data only

Classification incorporating stereo data (most important for large protruding rocks)

ROC Performance for Legacy panorama



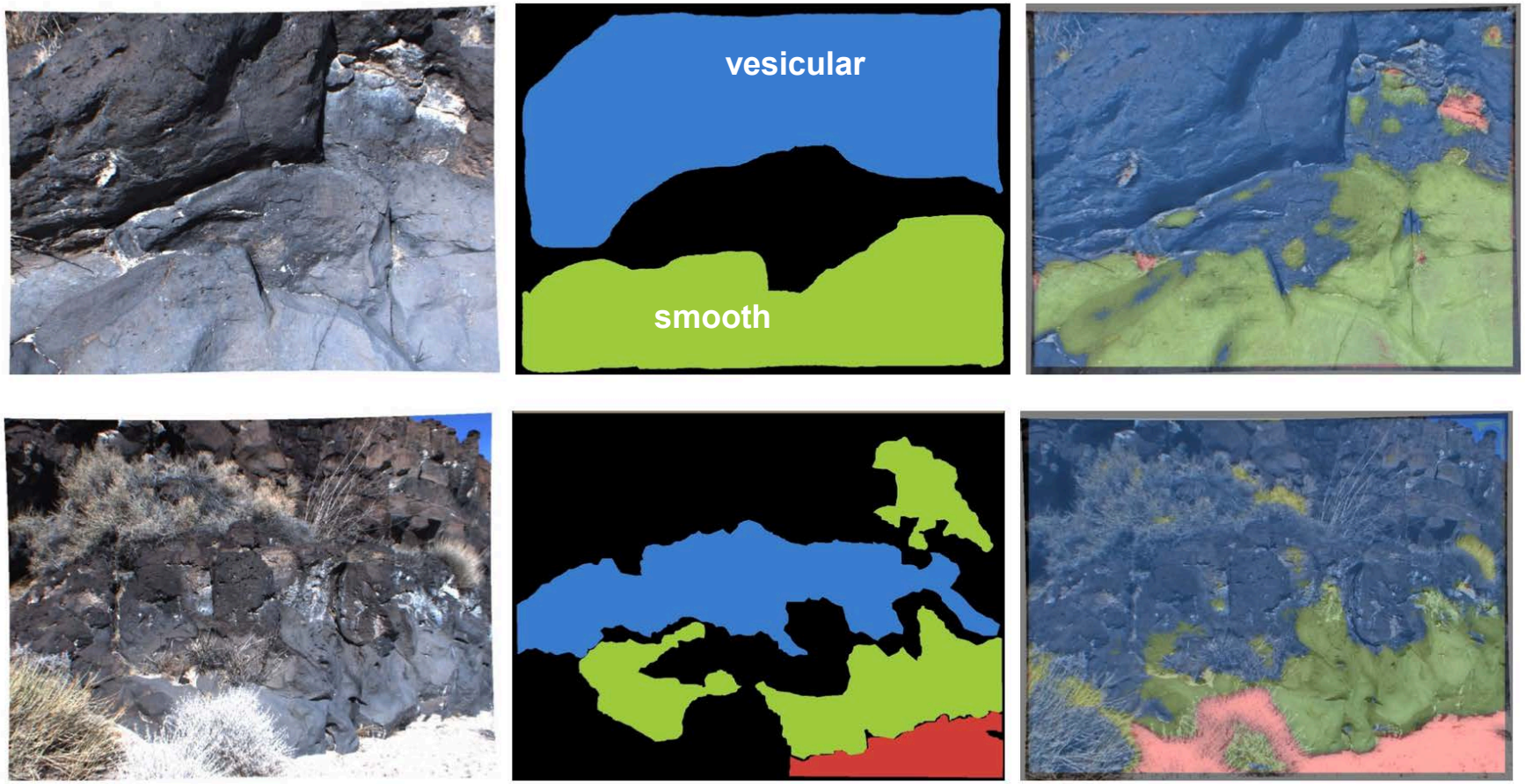
Performance: target selection



Mojave field test – range invariance

[Foil et al., in preparation]

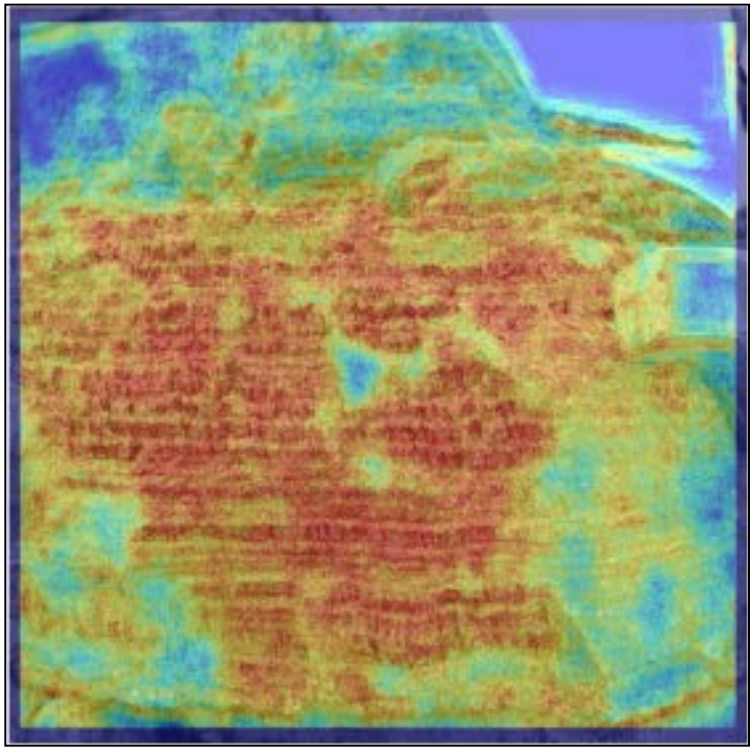
original | **ground truth** | **Automatic classification**



Mars Images: Caltech / NASA / JPL

Other applications: layer detection

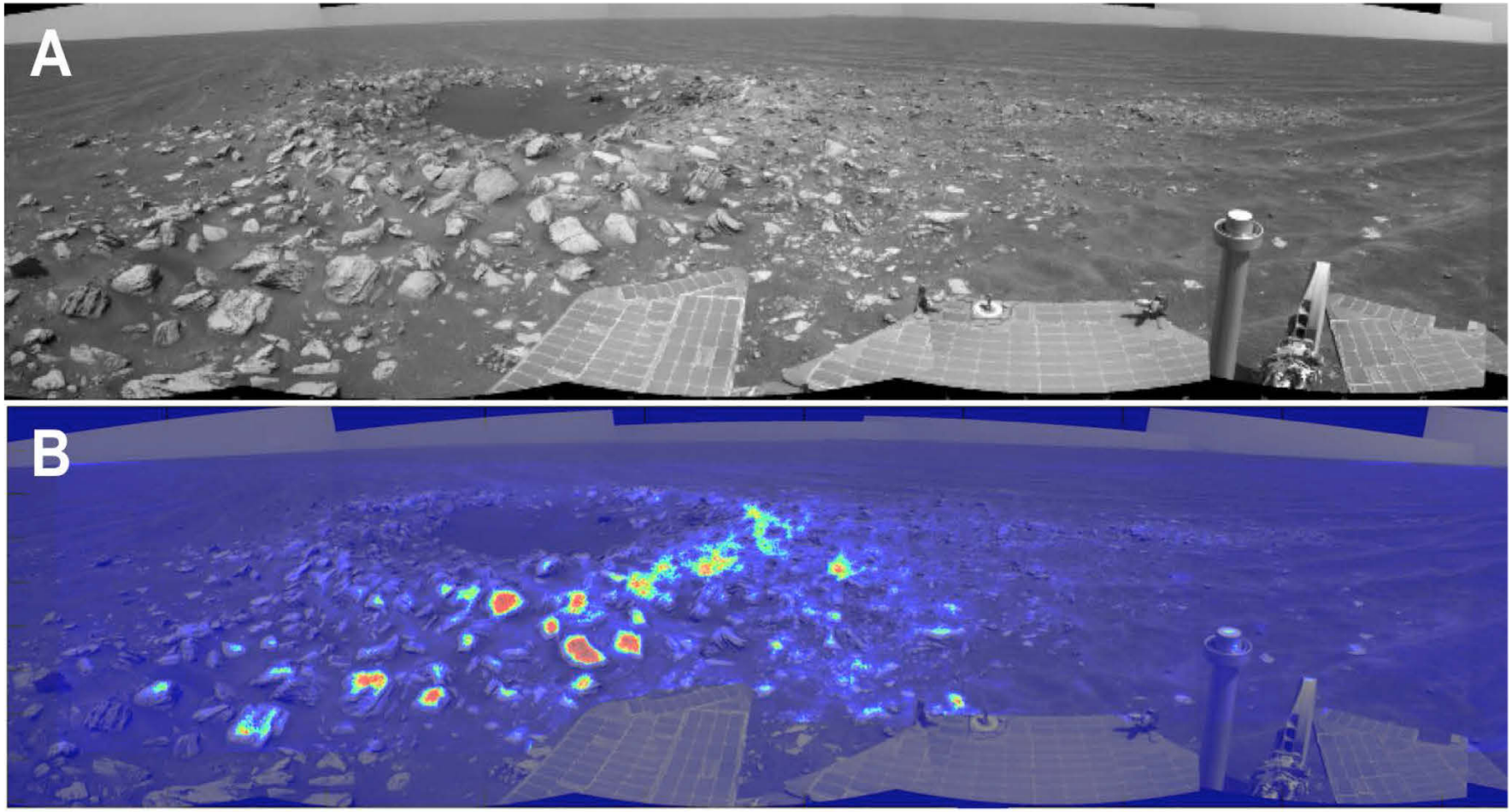
Stromatolite
Western Australia



Stratigraphy probability
[Thompson et al., LPSC 2012]

Mars Images: Caltech / NASA / JPL

Other applications: exposure index



[Thompson et al., AbSciCon 2012]

Mars Images: Cornell / Caltech / NASA / JPL

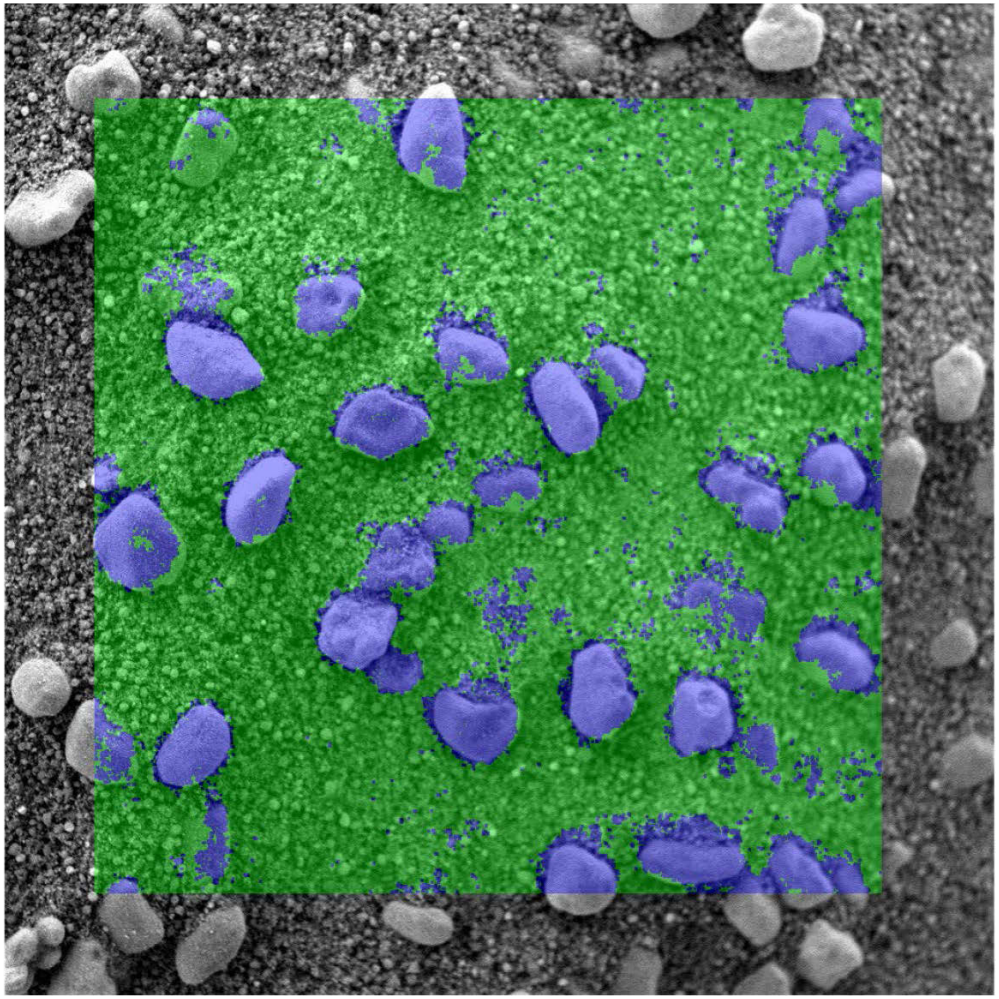
Other applications: plume detection

- **Volcanic Plume detection [McLaren et al., SPIE 2012]**

Plume detection for height analysis, Eyjafjallajökull volcano

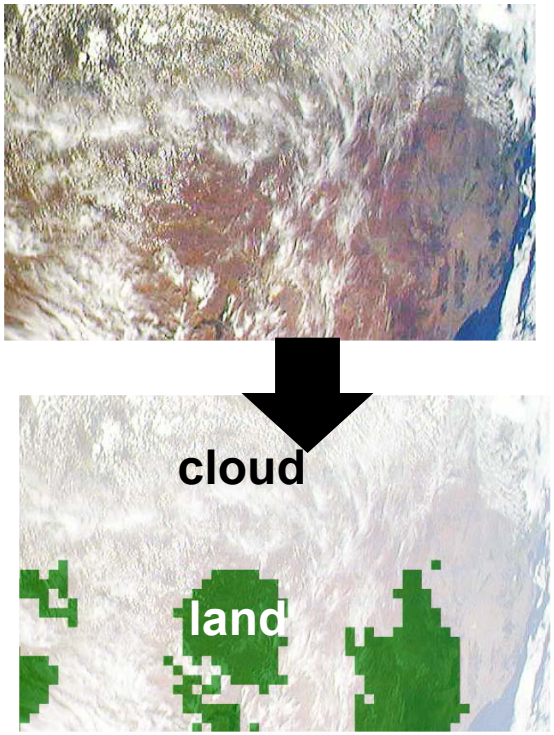
Image Credit: Worldview

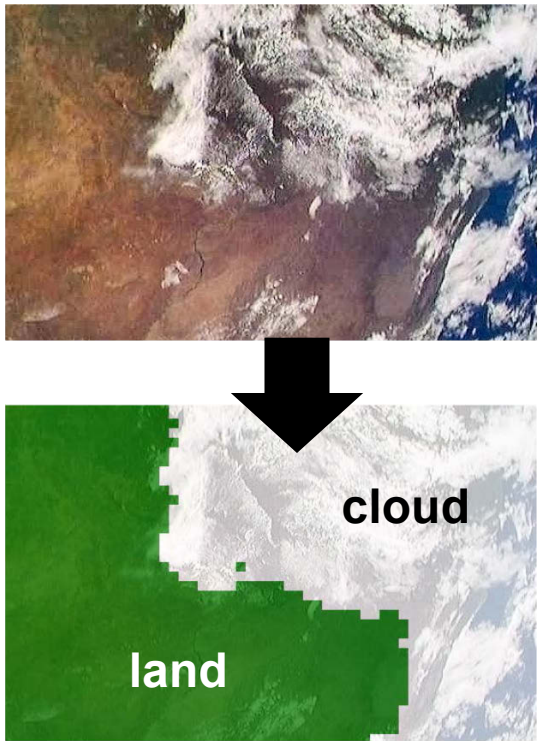
Other applications: sedimentology

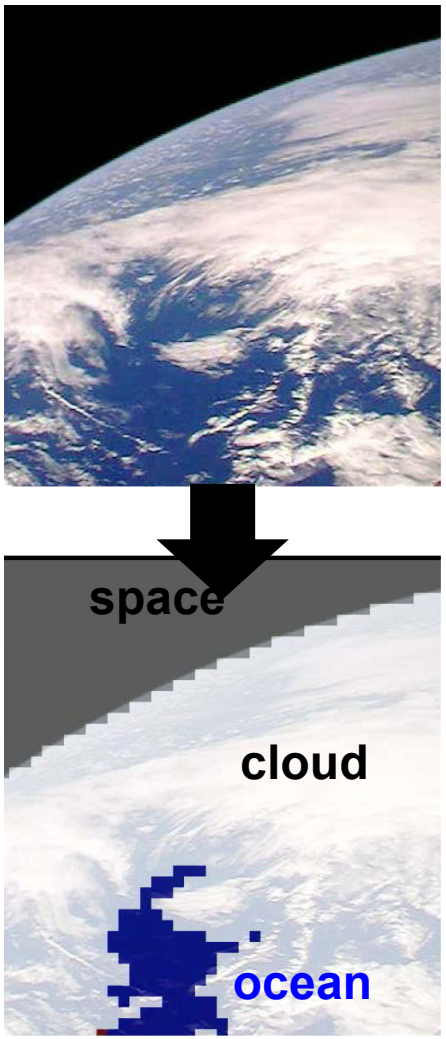


Mars Images: Cornell / Caltech / NASA / JPL

Other applications: selective downlink for cubesats

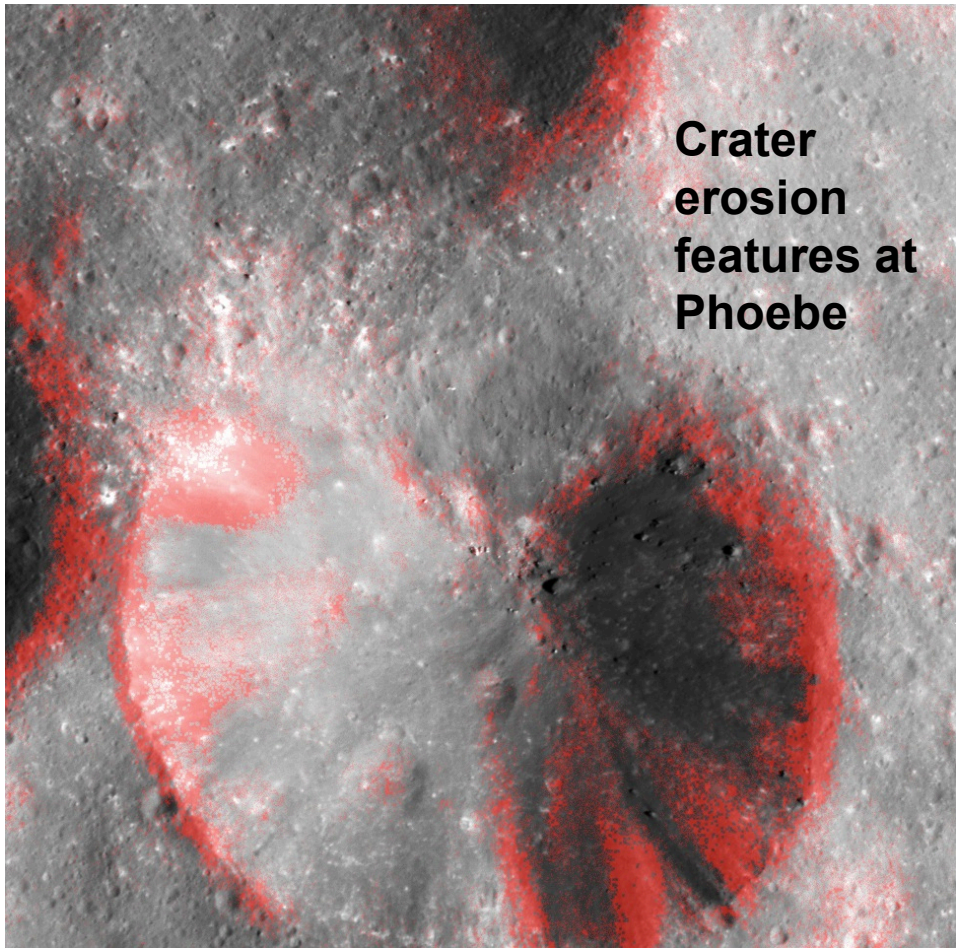






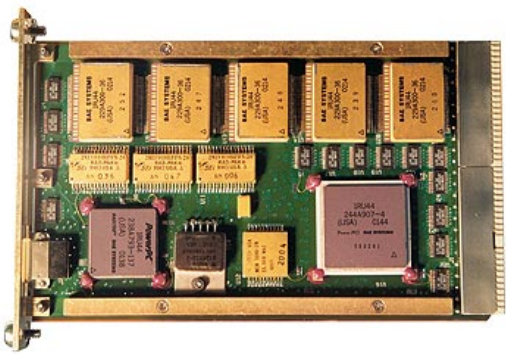
Images courtesy MASAT-1 mission

Other applications: primitive bodies exploration



Images: Caltech / NASA / JPL

Flight hardware options



Flight computer

Analyze specific images

- **Single-command instrument placement** by identifying contiguous exposure, stratigraphy
- **Selective targeting at specified sites** by classifying exposed outcrop and float rocks

Dedicated FPGA

Analyze all images

- **Continuous mapping** during long traverse (e.g. find meteorites)
- **Trivial CPU cost** to operate alongside computer-intensive actions
- **Trivial time cost**

Next steps

Virtex-5 FPGA development in progress

Goal: 1 Hz or better at full resolution

Retrainable for different mission requirements

Mars Images: Cornell / Caltech / NASA / JPL

Questions?

David R. Thompson
William Abbey
Abigail Allwood
Dmitriy Bekker
Benjamin Bornstein
Nathalie A. Cabrol
Rebecca Castaño
Tara Estlin
Thomas Fuchs
Kiri L. Wagstaff

Contact
david.r.thompson@jpl.nasa.gov

PDS ID 1N134591492EFF1000P1803L0M1

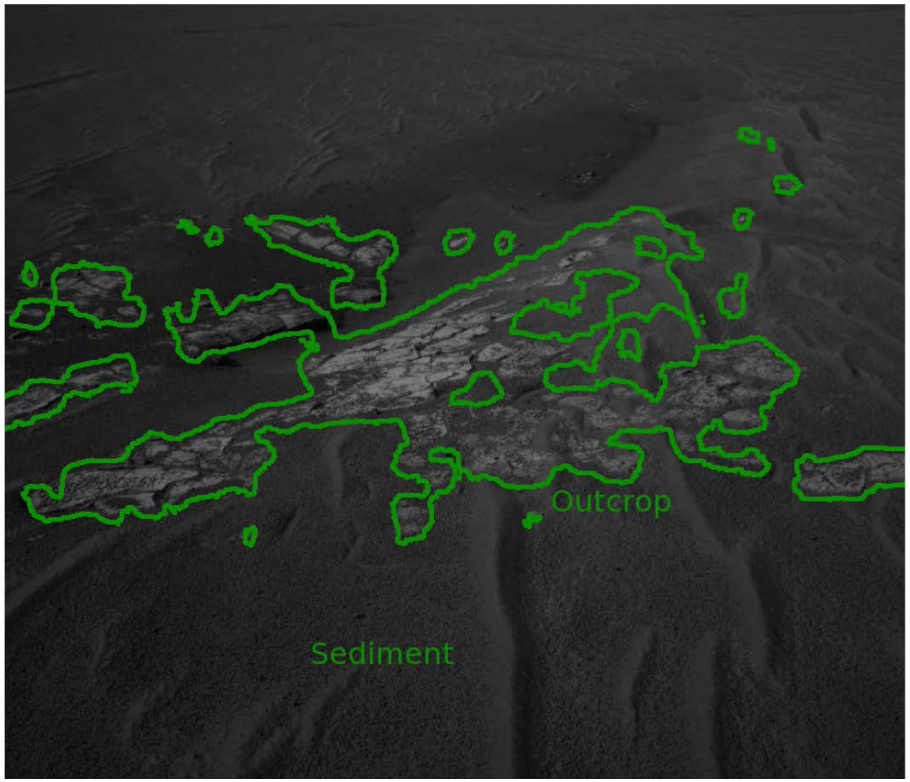


Image Credit: Caltech / NASA / JPL

Copyright 2012 California Institute of Technology. All Rights Reserved. Not for general distribution .