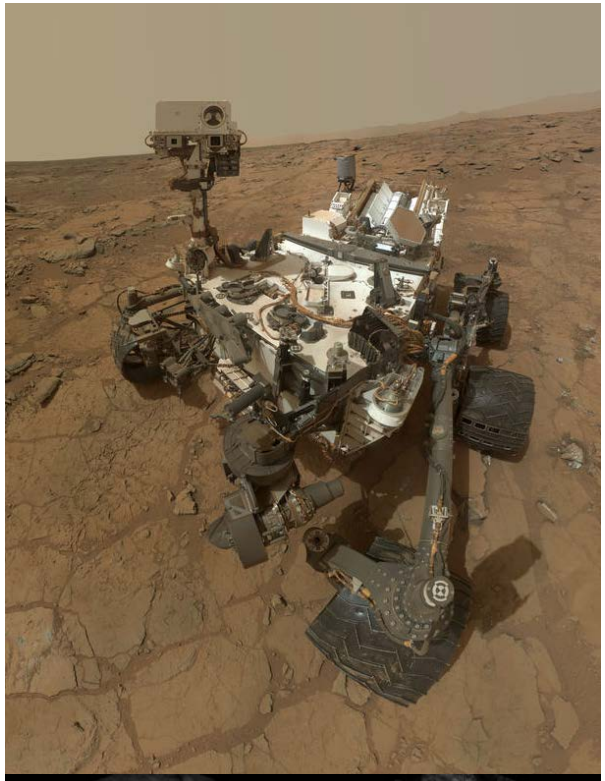

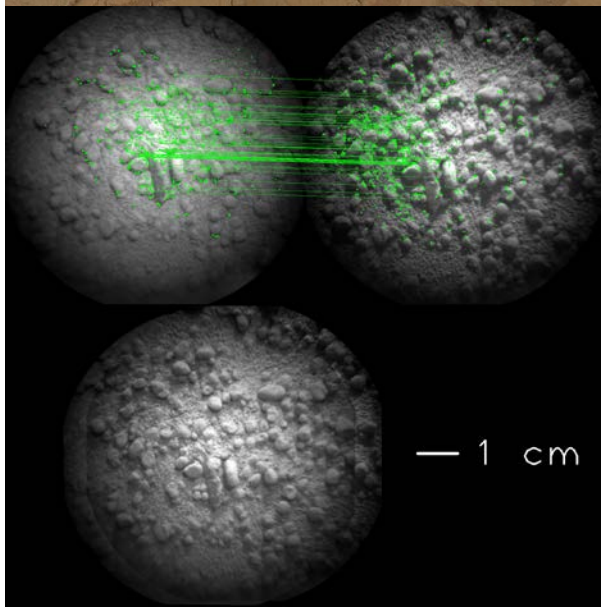

Precision Instrument Targeting via Image Registration for the Mars 2020 Rover

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IJCAI 2016
July 15, 2016

Jet Propulsion Laboratory
California Institute of Technology

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Overview

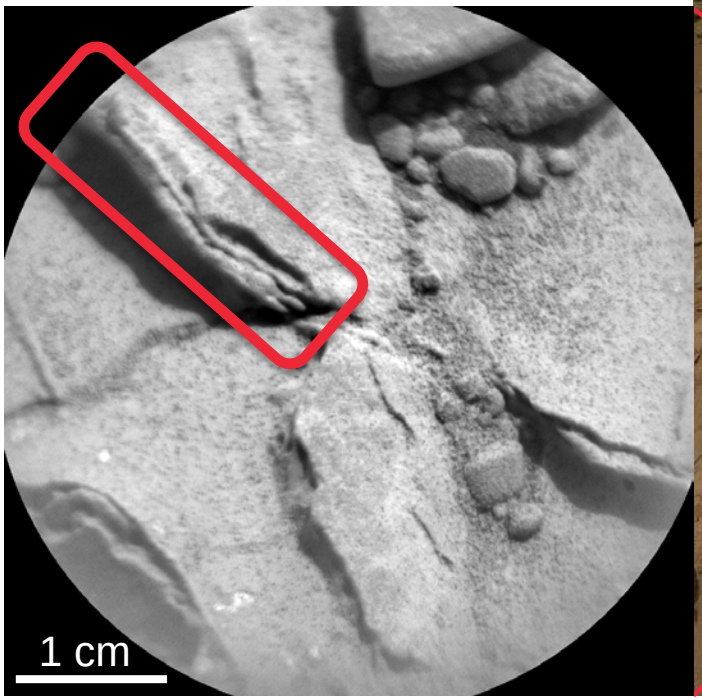
- **Challenge:** how to precisely point a narrow-field-of-view scientific instrument at a target on the surface of another planet?

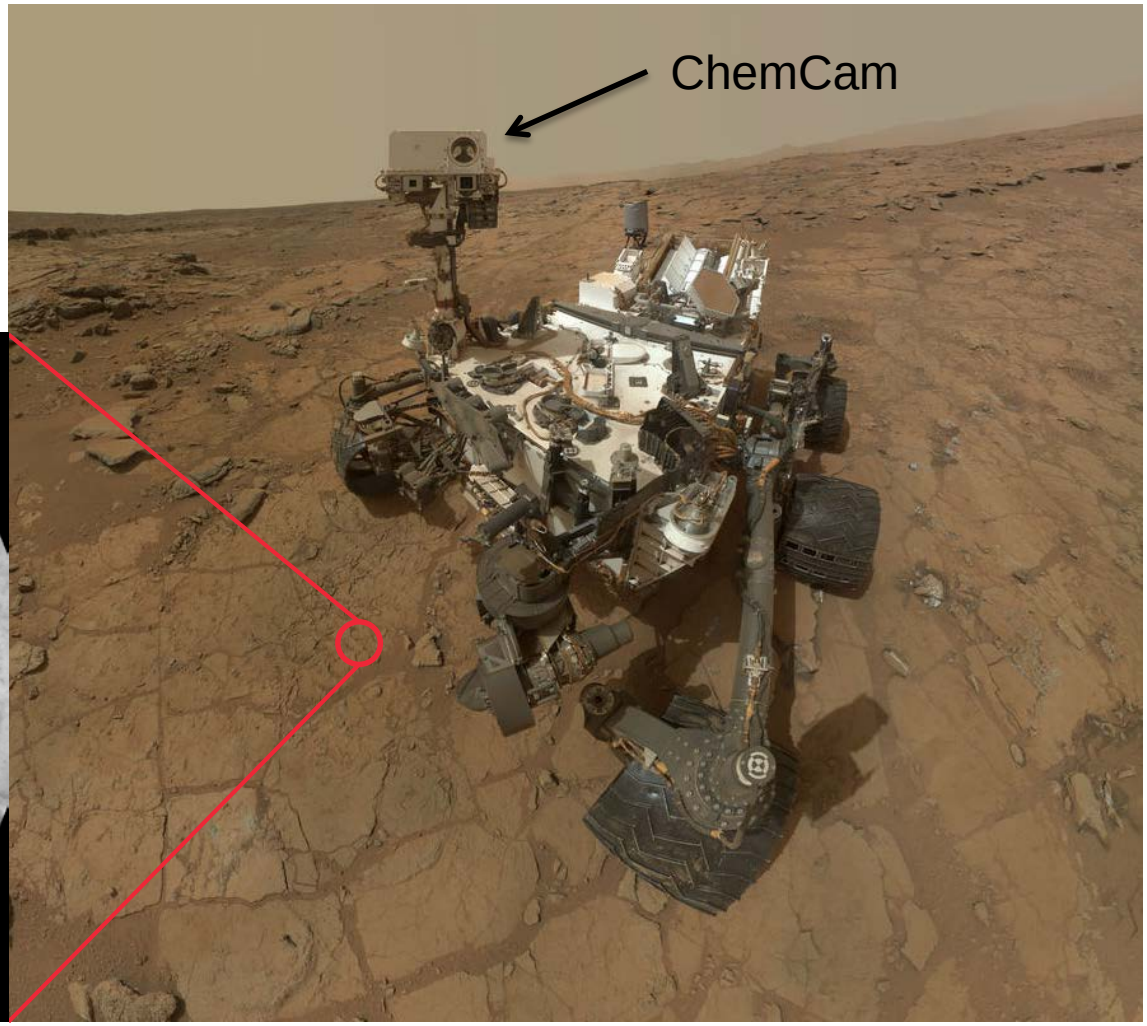
- **Approach:** define the target with respect to visual features rather than relying solely on estimated coordinates from stereo vision.

- **Results:** the system performs well under large initial offsets and lighting variability, and it accurately assesses its own performance.

Case Study: *McGrath*

Scientifically interesting erosion-resistant ridge targeted for observation with the ChemCam instrument on board MSL.





McGrath: Timeline of Events

Sol 174:
Target identified in NavCam

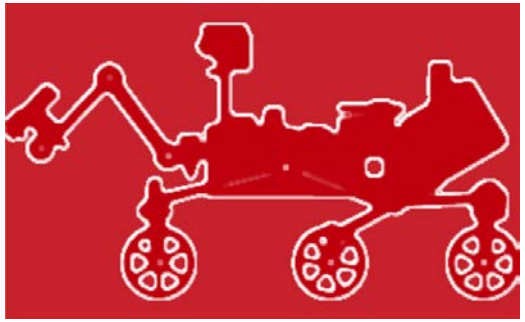
Sol 181:
Acquire image only to aid with pointing

Sol 185:
First measurement attempt misses

Sol 189:
Second attempt misses *again*

Sol 193:
Third attempt misses ***again***

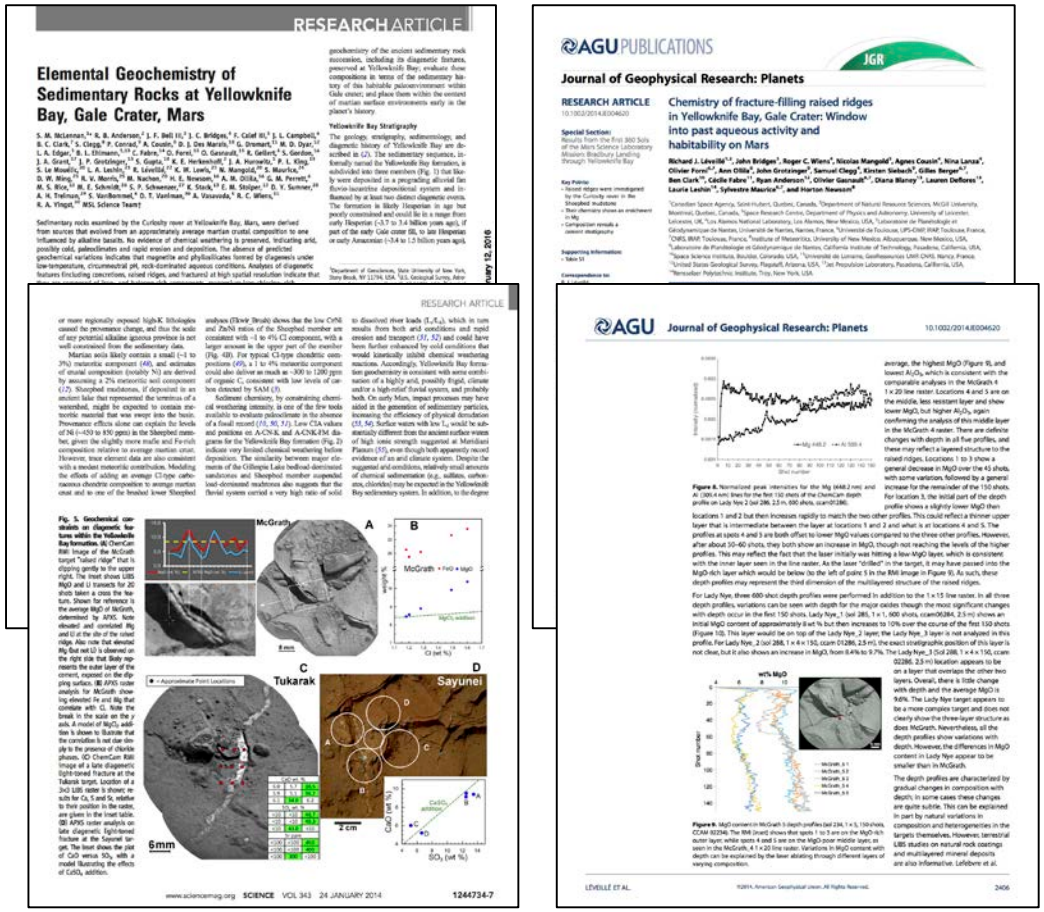
Sol 200:
MSL experiences a "potentially catastrophic" anomaly



Sol 226:
The measurement is *finally* successful

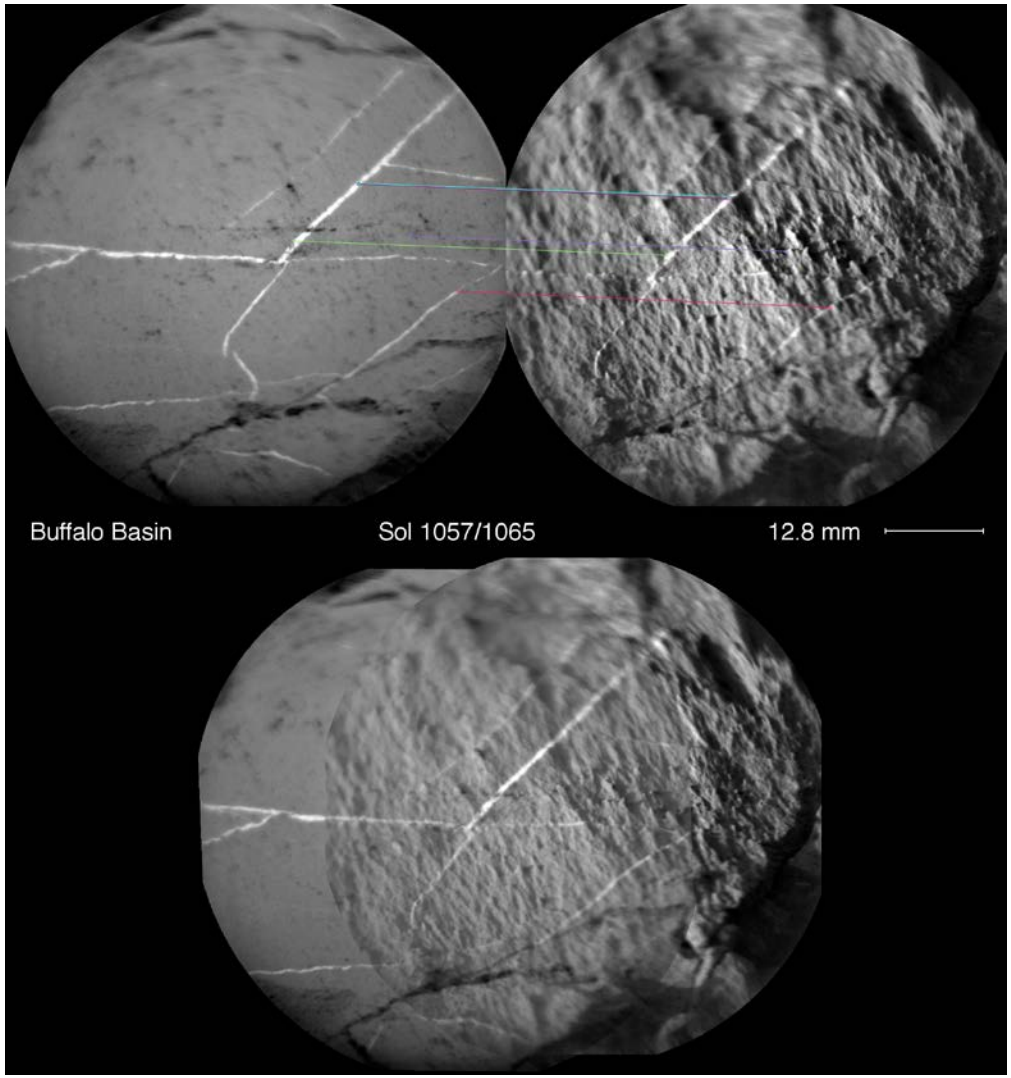
McGrath: Summary

- Successful measurement of McGrath required **4 attempts** over **45 sols**!
- The analysis of McGrath was important for understanding the geochemistry of the Yellowknife Bay Region.
- If there were not other ongoing activities, the mission might not have had a second (or third, or fourth) opportunity for a measurement.



What makes targeting challenging?

- Not for lack of trying; the ChemCam team had extensive discussions and carefully modeled each pointing for McGrath.
- Rover slip estimation, thermal fluctuations, and imperfect mechanisms all introduce errors.
- Since these errors can change over time, operators can be chasing a moving target.

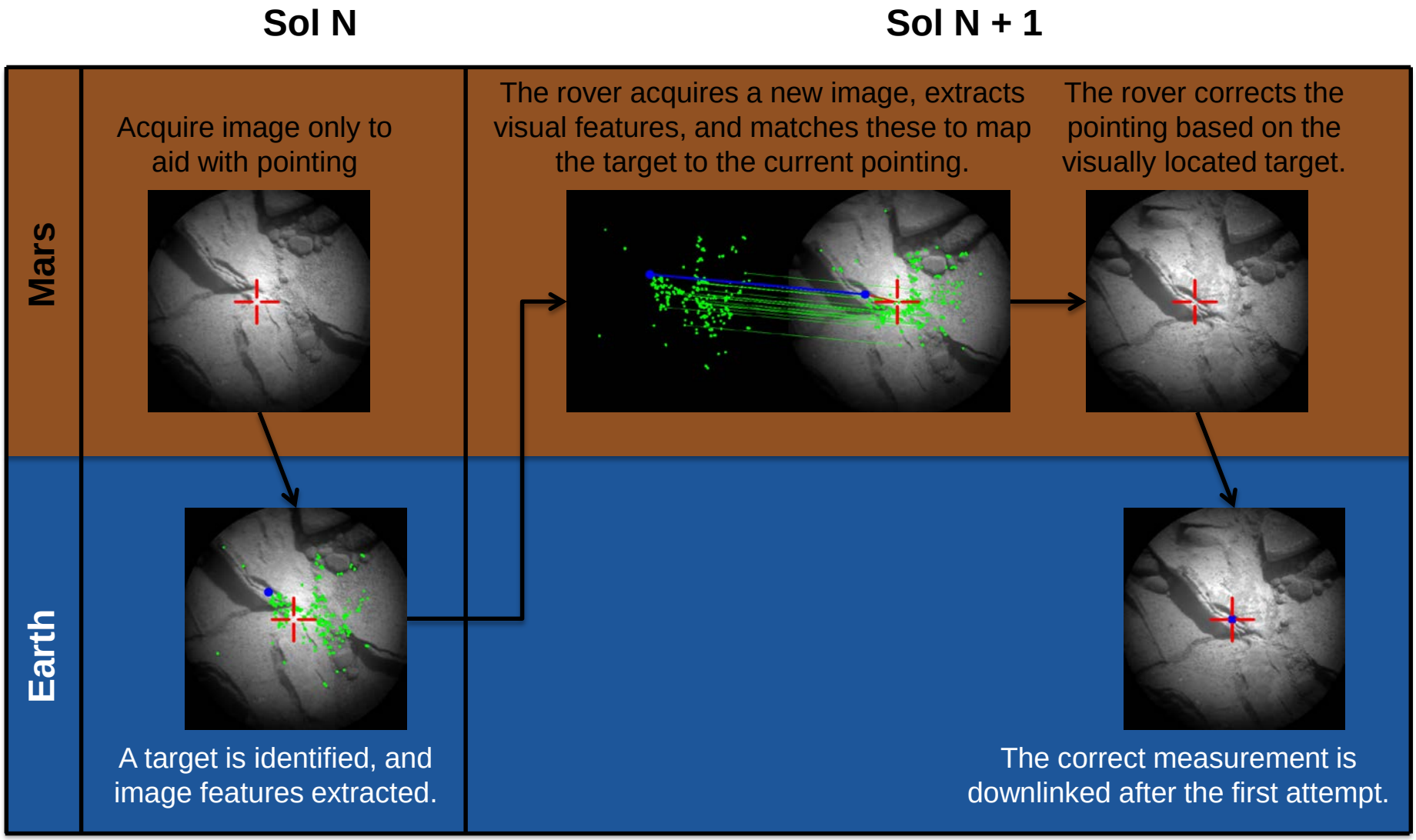


Visual Precision Targeting

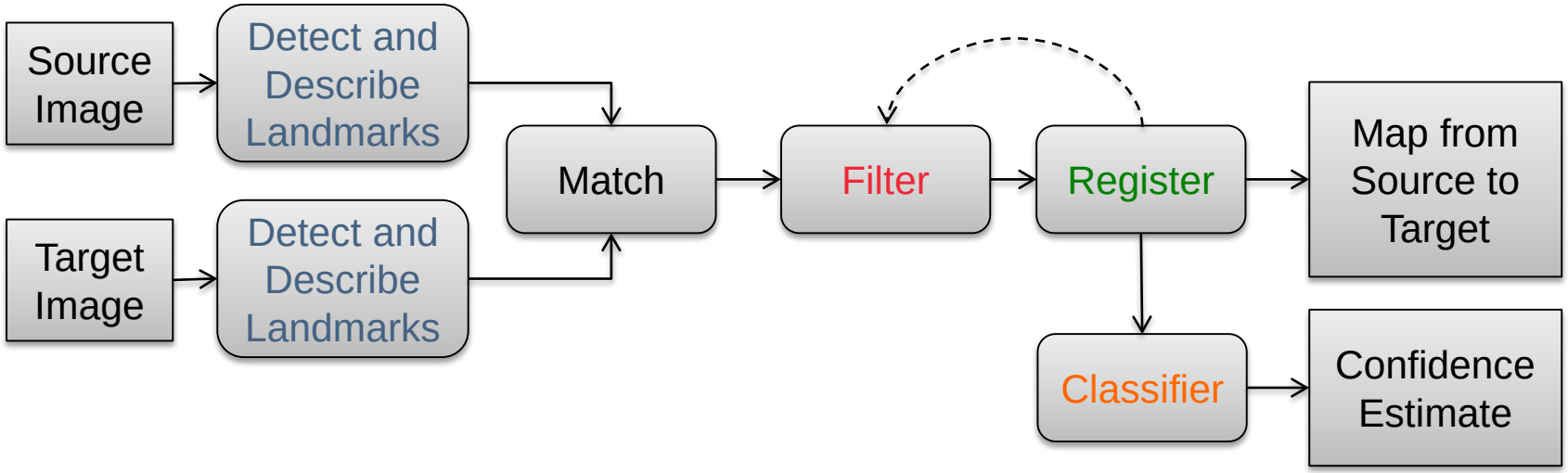
How to help rover operators take a measurement of the intended target (the first time)?

By specifying the target location in the visual context of an image, the pointing can be adjusted on board using the instrument field-of-view.

McGrath: With Visual Precision Targeting



Landmark-Based Registration



ORB: **O**riented FAST, Rotated **BR**IEF (Rublee et al. 2011)

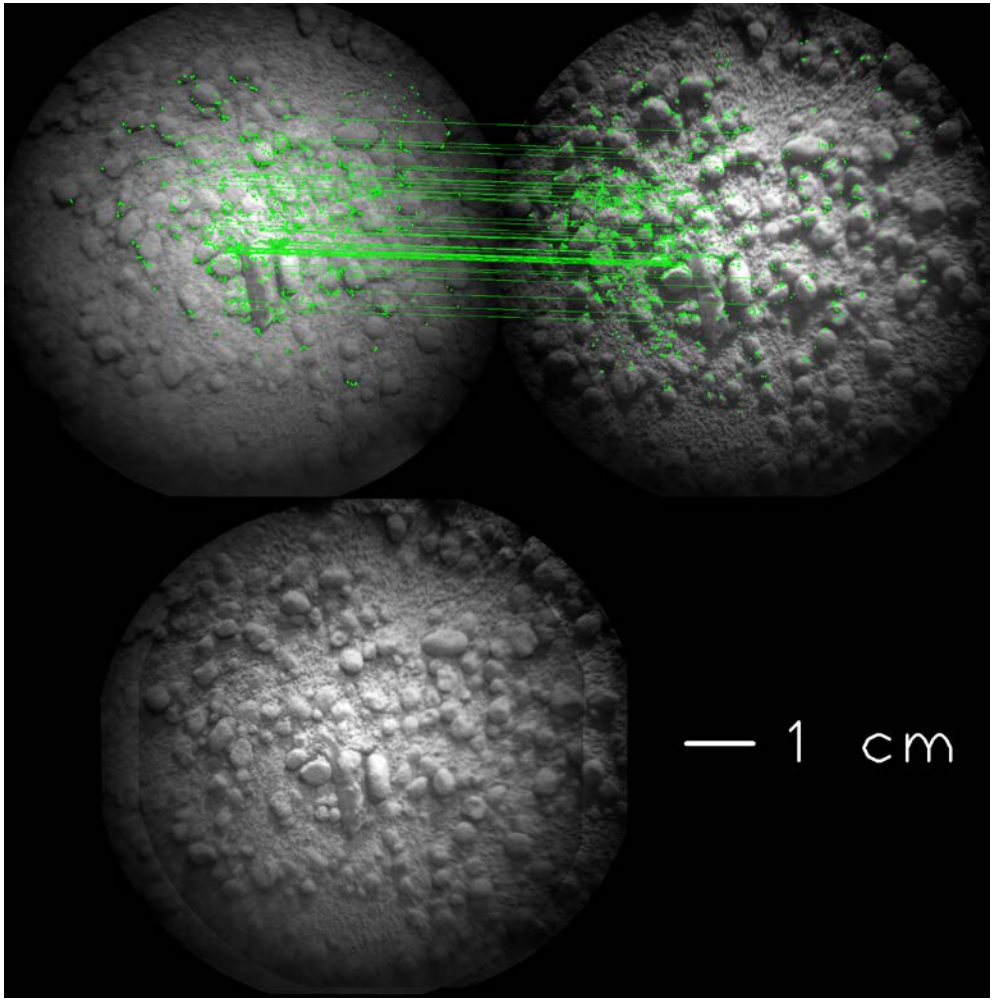
DBSCAN Clustering (novel filtering approach)

RANSAC/Least Squares

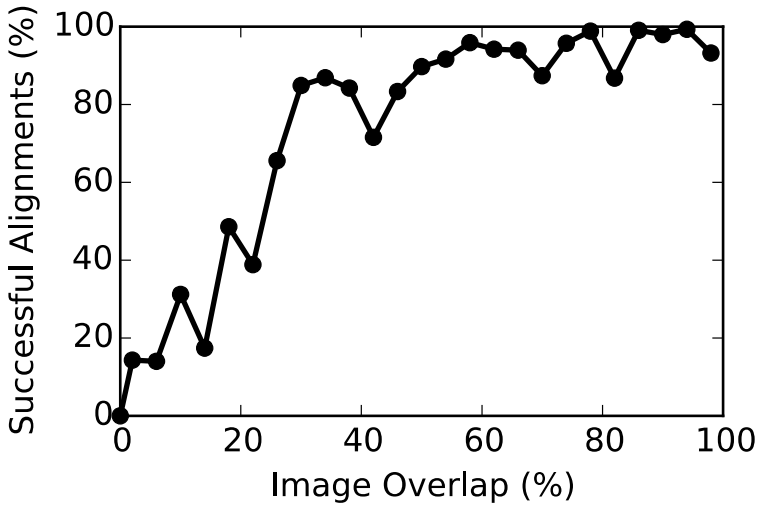
Random Forest Classifier (tuned to avoid false positives)

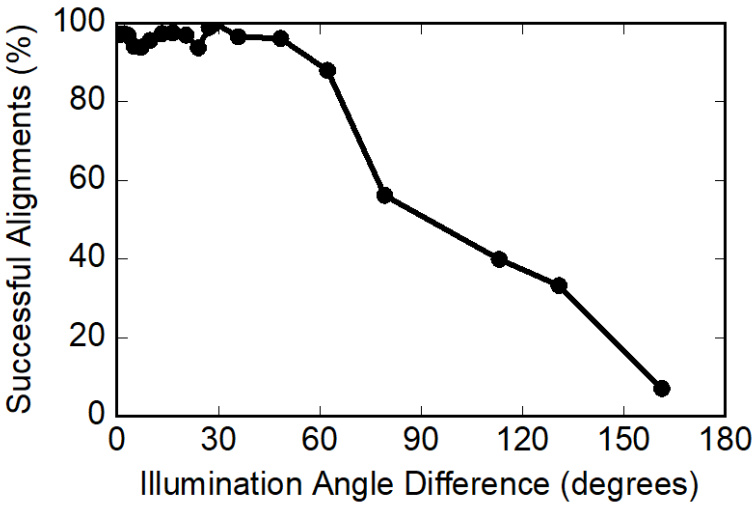
Evaluation: ChemCam Dataset

- Identify ~16,500 overlapping pairs of images from 3,800 images taken in the first 1,200 sols.
- Use natural variations in lighting, overlap, etc. to investigate performance.



Results: ChemCam Dataset

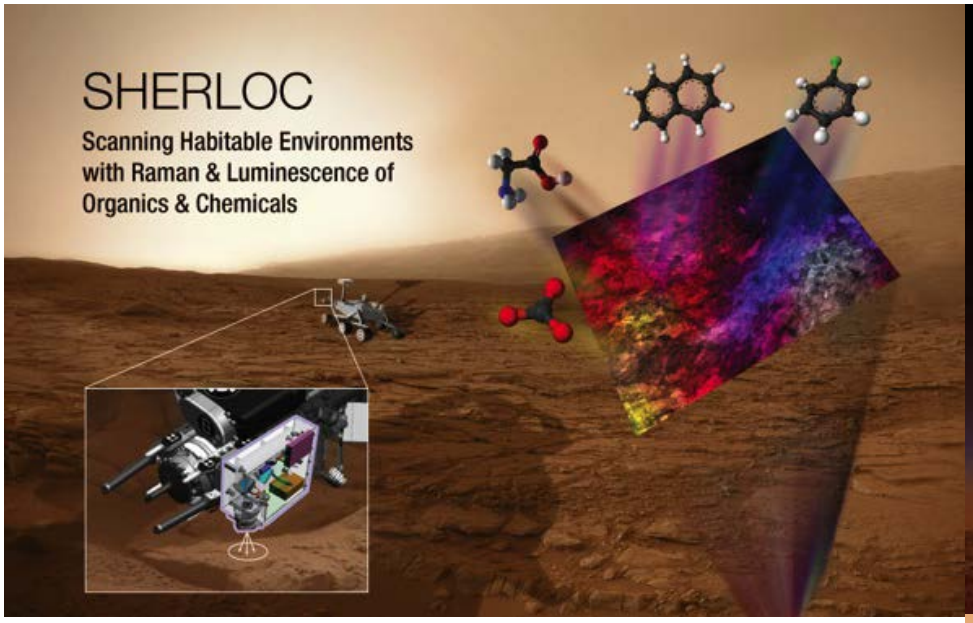


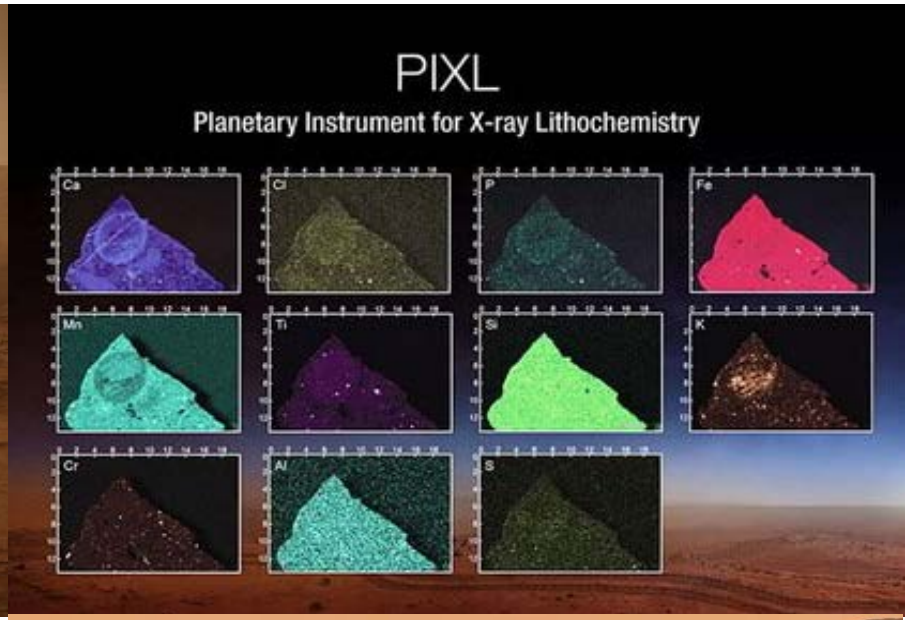


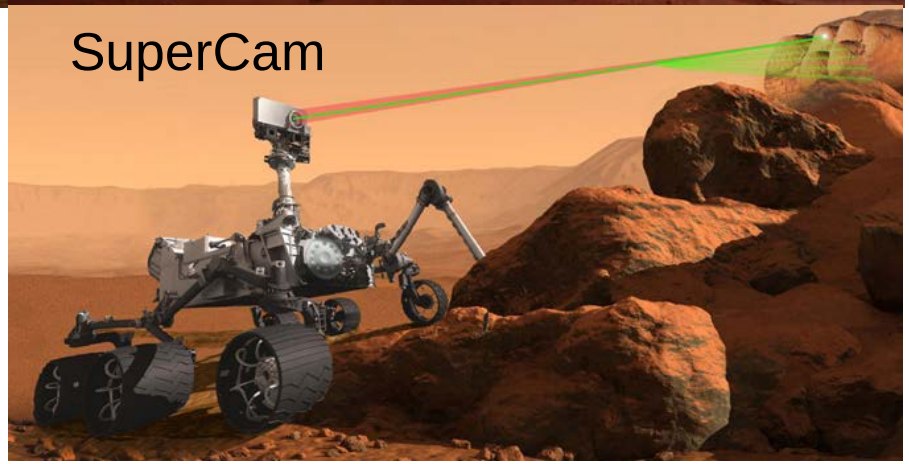
Memory requirement:
3x image size (<5 MB)

Running time:
(< 1 min on 150 MHz LEON4)

Applicable 2020 Rover Instruments







Instruments with small (centimeter-scale) fields-of-view.

Conclusions

- It is challenging to precisely target millimeter-sized features with Mars rover instruments.
- Fine-scale measurements are required by the 2020 rover mission, which will focus on identifying potential bio-signatures in samples that will be cached for potential later return to Earth.
- Using a visual targeting approach is more robust to noise in arm/mast mechanisms, environmental variations, and rover position/attitude.
- Our results demonstrate the feasibility of this technology to efficiently, reliably, and safely perform this precision targeting on board the rover.

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