NASA-FDL: Artificial Intelligence in Planetary Science
Lunar Resource Mission

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Sara Jennings, James Parr

Gravity Recovery and Interior Laboratory (GRAIL) mission, NASA Goddard Space Flight Center: https://svs.gsfc.nasa.gov//vis/a000000/a004100/a004175/

Agenda

Great Opportunity
for young Scientists

- Frontier Development Lab (FDL) – an applied research accelerator
- Deep Dive in Artificial Intelligence (AI), Machine Learning, Deep Learning …. Big Data
- The Lunar Resource Missions of FDL 2017

Maybe nice but
not enough time
for a 'Deep Dive'

Quick fly trough

Nasa Frontier Development Lab NASA-FDL

‘FDL is an applied Artificial Intelligence research accelerator designed to enhance NASA’s capabilities by combining the expertise of NASA, Academia, and the private research community.’

Novel Private Public Partnership which brings together:

- Young Planetary and Data Scientists
- Domain experts from NASA and the private sector

FDL, 6 Missions addressed by one team

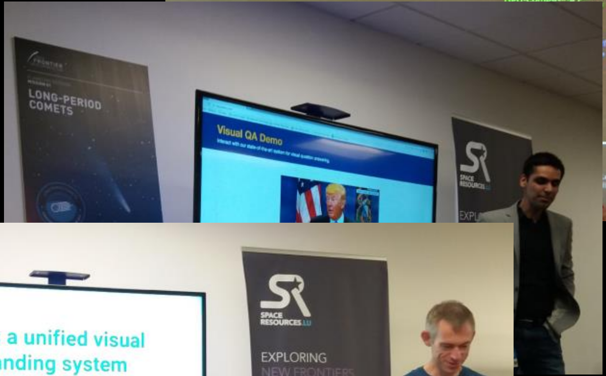
- Planetary defence
- Planetary resources
- Space weather prediction
- AI case study

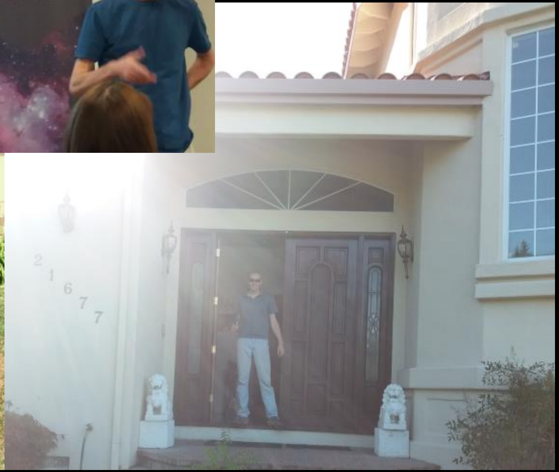
FDL Functions

- Research Accelerator
- Research Incubator

FDL Functions

- Summer School
- Team building and interpersonal skills





Automated Crater Detection

Using Deep Learning

NASA FDL Lunar Volatiles Team

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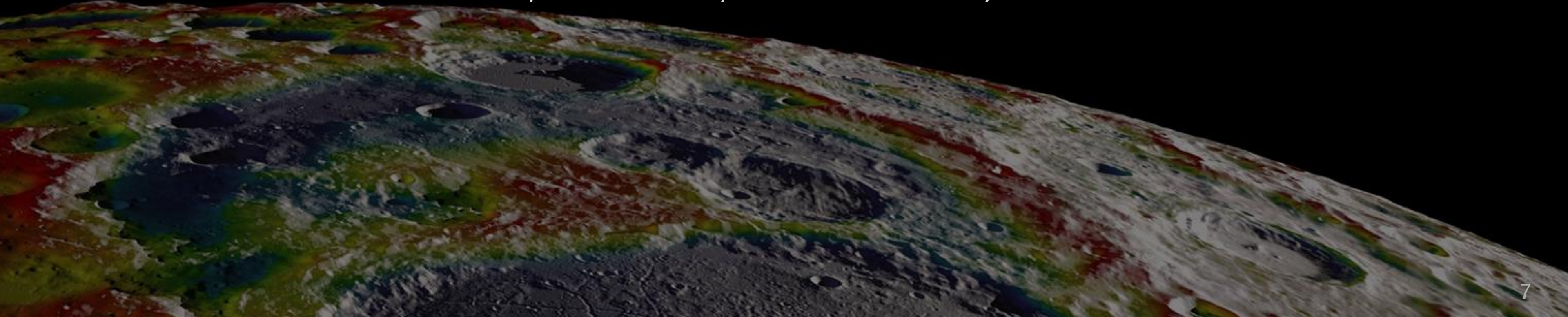

Gravity Recovery and Interior Laboratory (GRAIL) mission, NASA Goddard Space Flight Center: https://svs.gsfc.nasa.gov//vis/a000000/a004100/a004175/

FDL Space Resources Team

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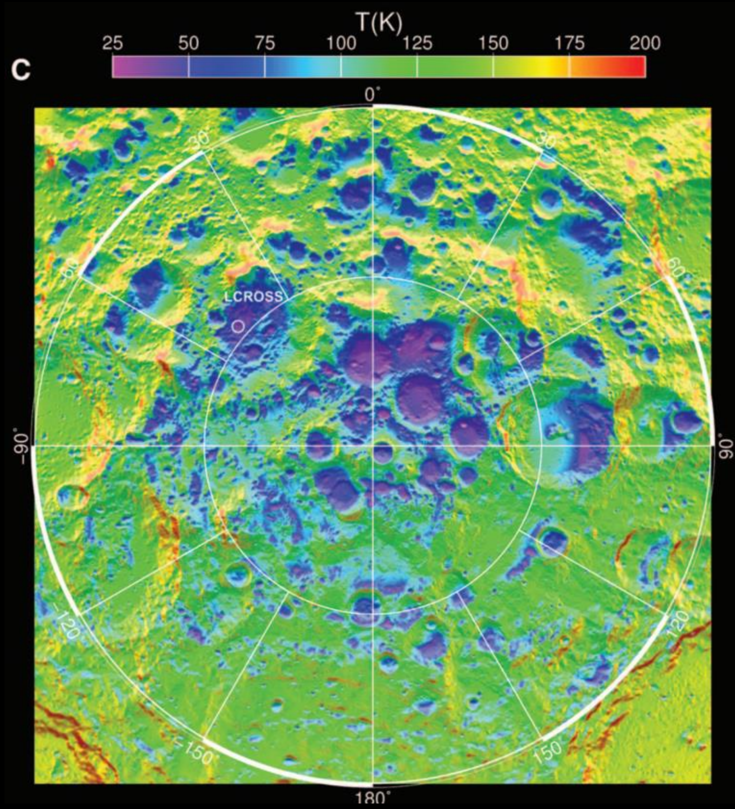
University of Oxford

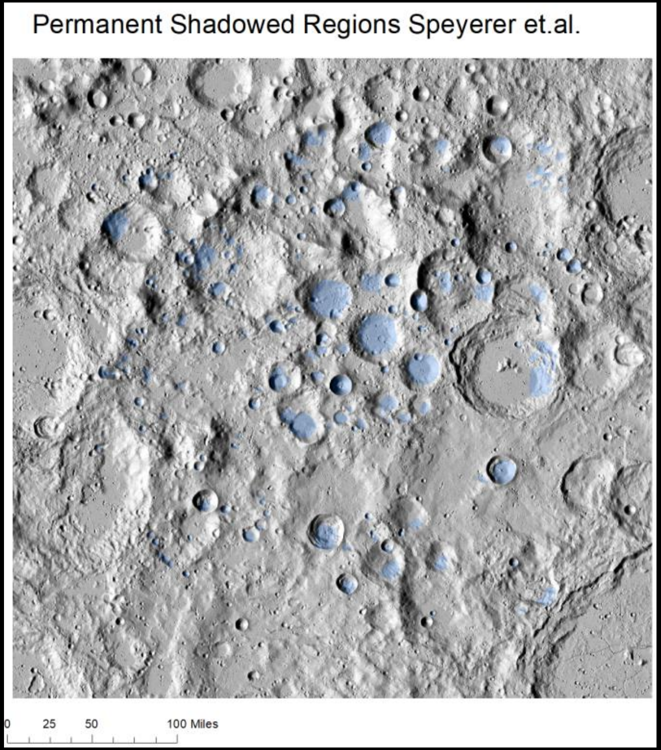
Where is water on the moon?

- Craters near the poles
- Some floors of these craters never see the sun
- Permanently Shadowed Regions (PSRs)



Simulated annual average near-surface temperatures
Paige et al., Science 330 (2010); www.sciencemag.org

Permanently Shadowed Regions

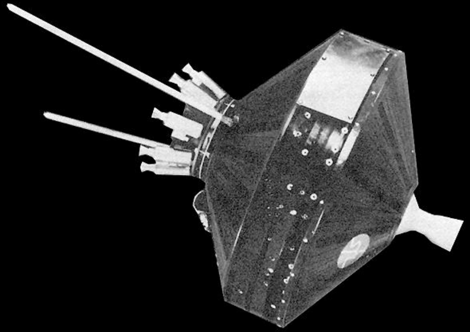


Speyerer E. J., S. J. Lawrence, J. D. Stopar, P. Gläser, M. S. Robinson, B. L. Jolliff (2016)
via http://lroc.sese.asu.edu

Missions are being planned for *In Situ* measurements

We learned that Mission Planners lack adequate maps.

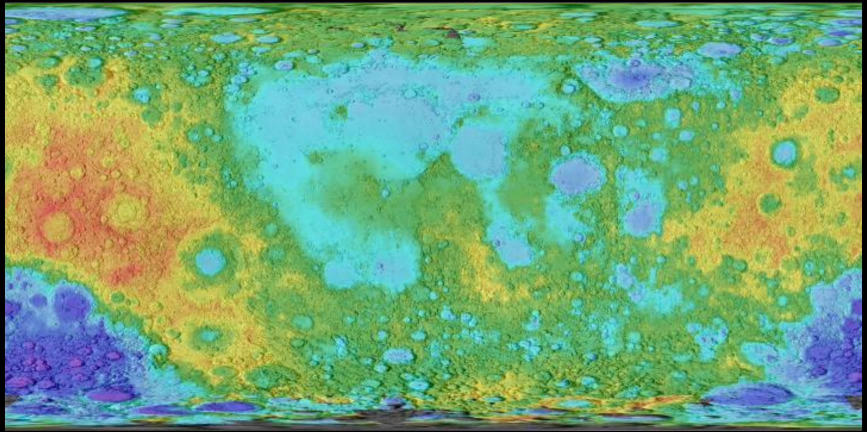
Mapping on the Moon:



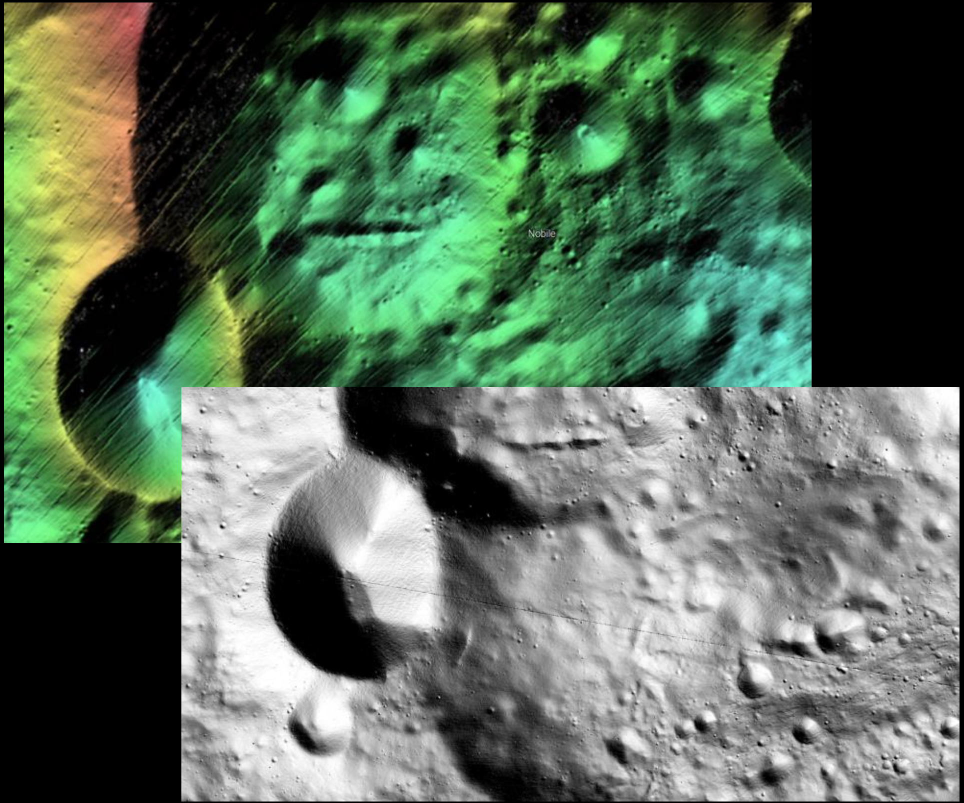
Reconnaissance Missions since late 1950’s - 1960’s

Plethora of Reconnaissance data

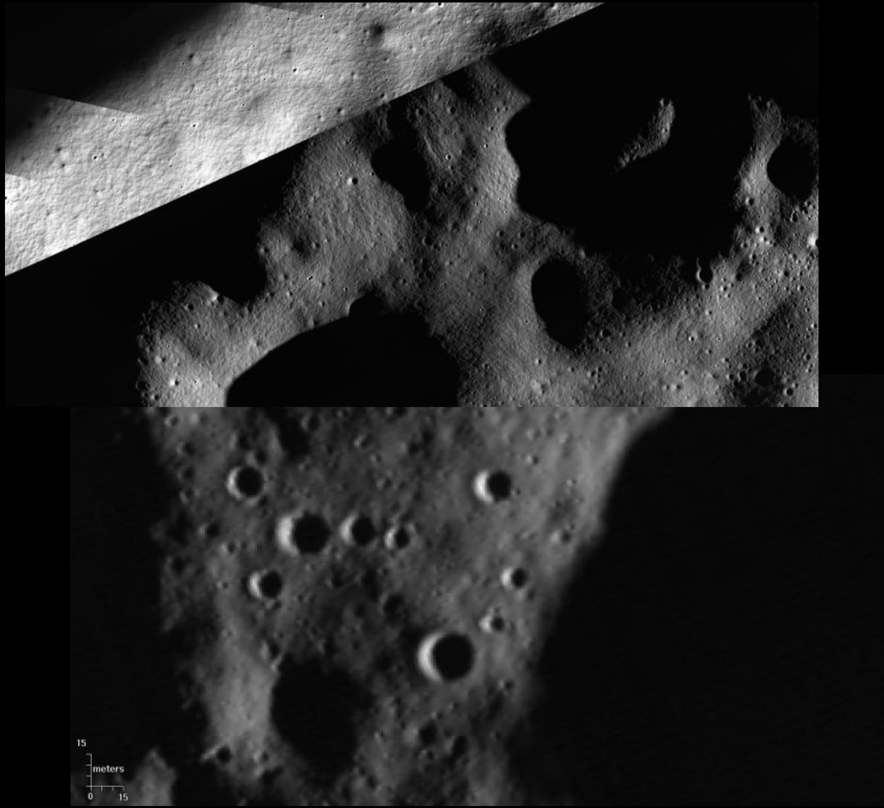
Lunar Reconnaissance Orbiter mission since 2009:



Mapping Quality

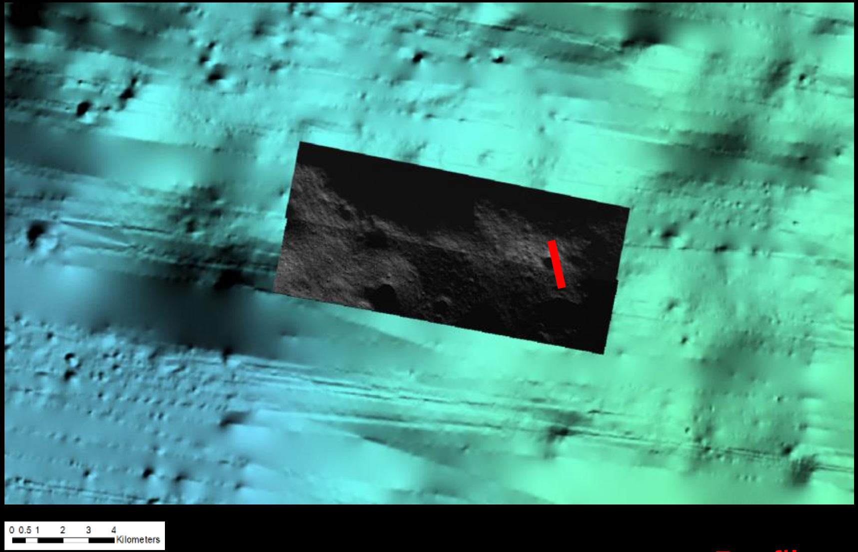


Lunar Orbiter Laser Altimeter
Digital Elevation Model (LOLA DEM), 20 m resolution

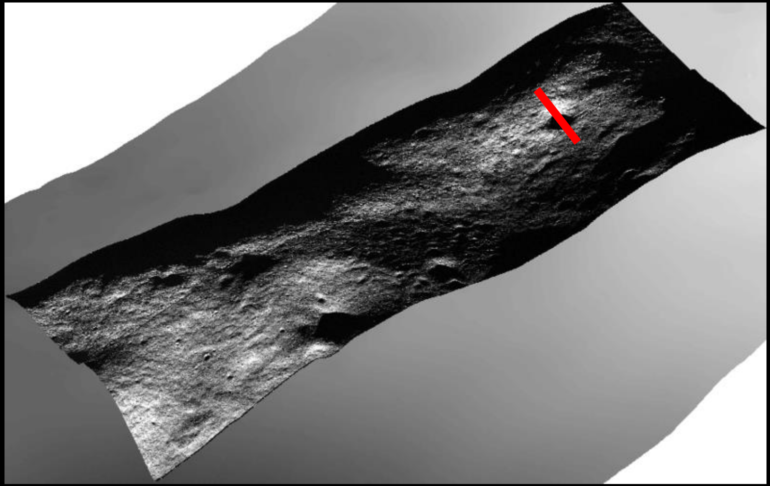


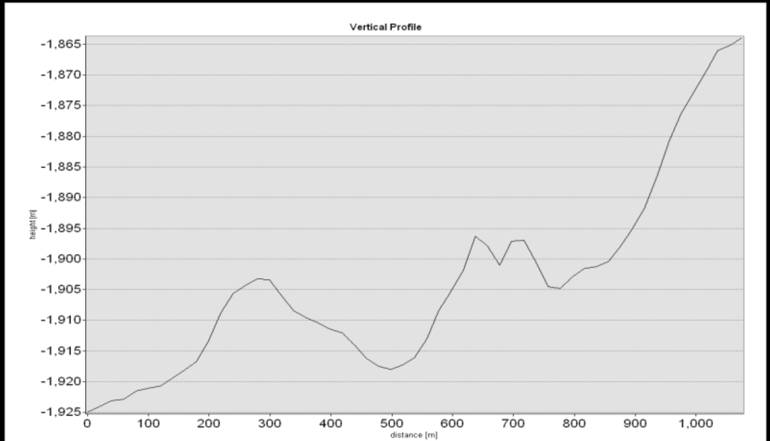
Narrow Angle Camera (NAC)
Optical images, 0.5 m resolution

Mapping Quality



Profile

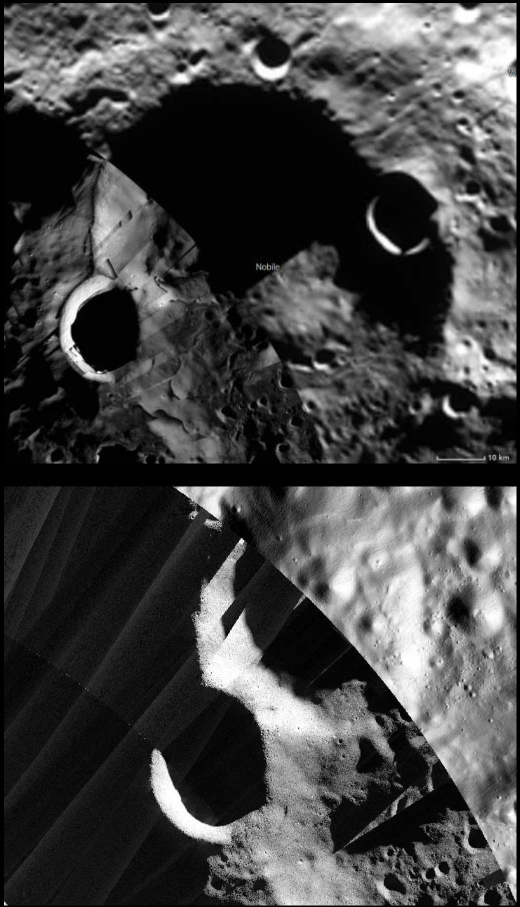




Elevation profile across a small crater

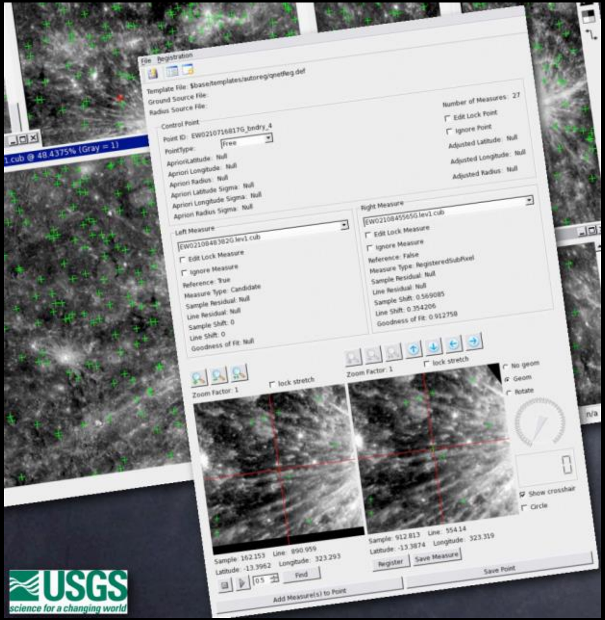
Problem Summary

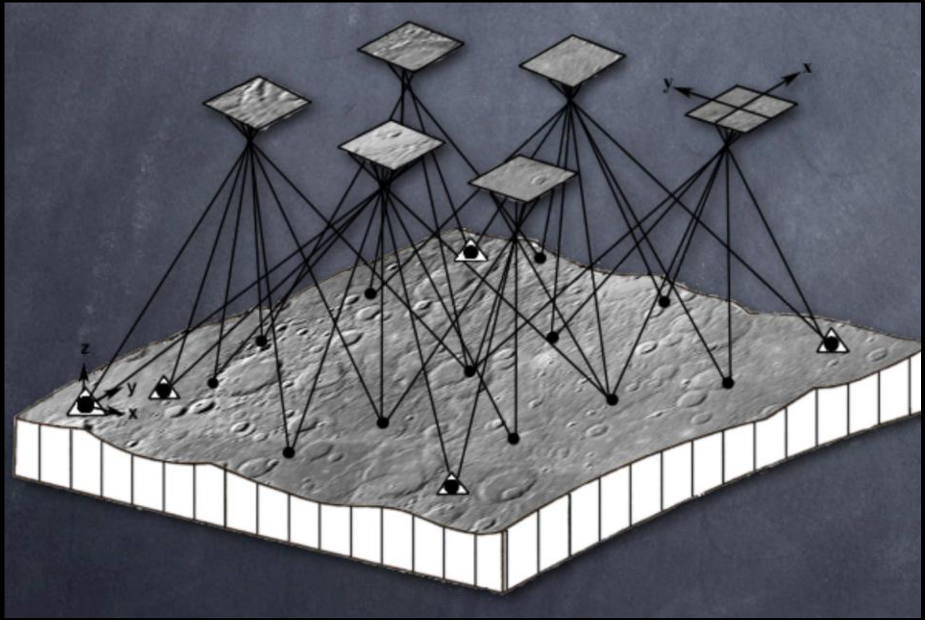
- Most of lunar water is in PSRs at the poles
- Mapping at the poles is problematic
  - Co-registration issues
  - Artifacts
  - Image illumination
- Labour intensive data preparation is required before meaningful mission planning can be conducted



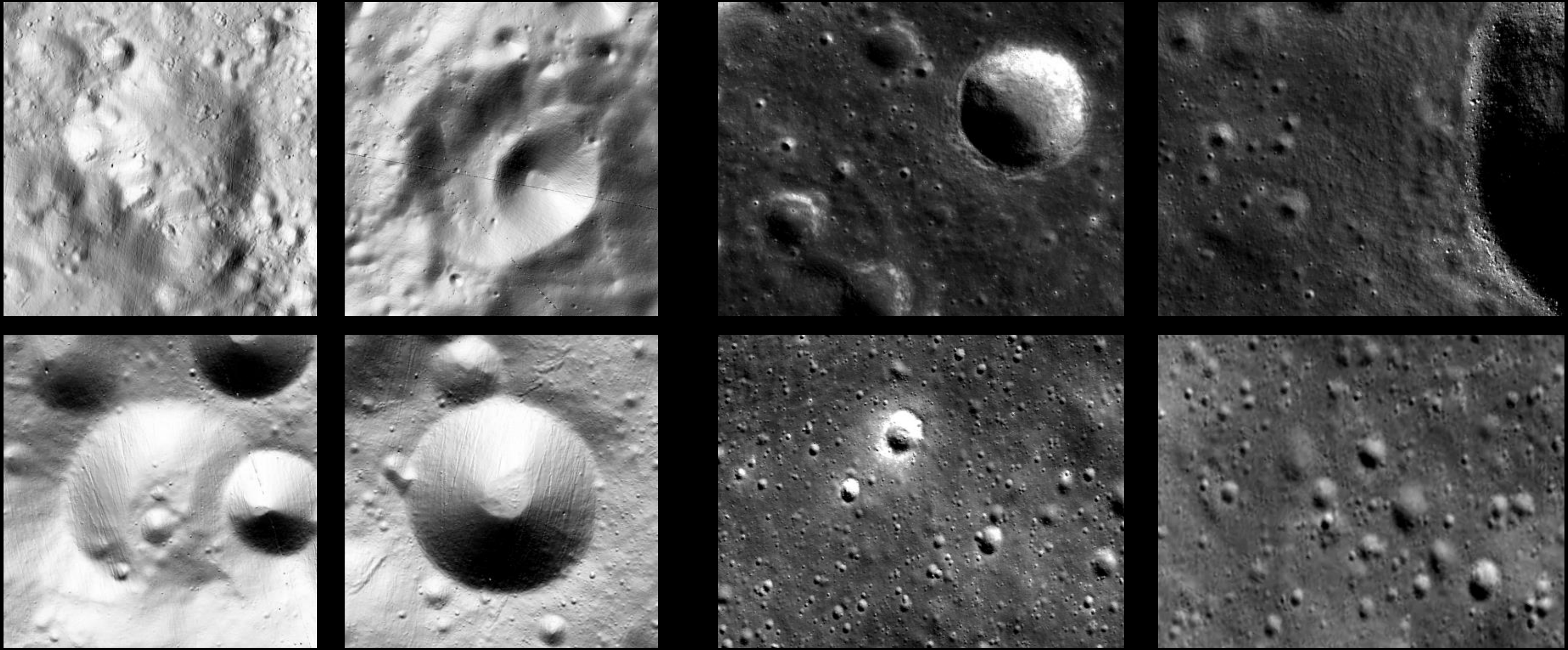
Nobile Crater: optical image mosaic overlaid over DEM

Improving Maps Conventionally,
how do we solve co-registration and artifacts?



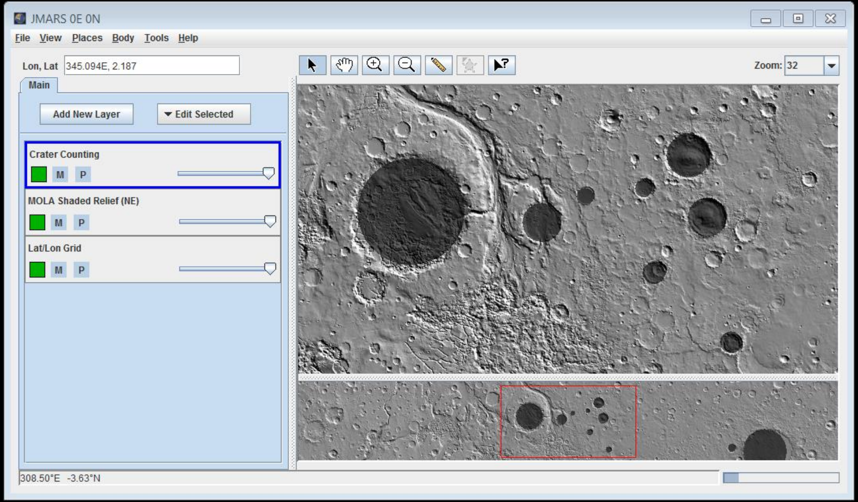


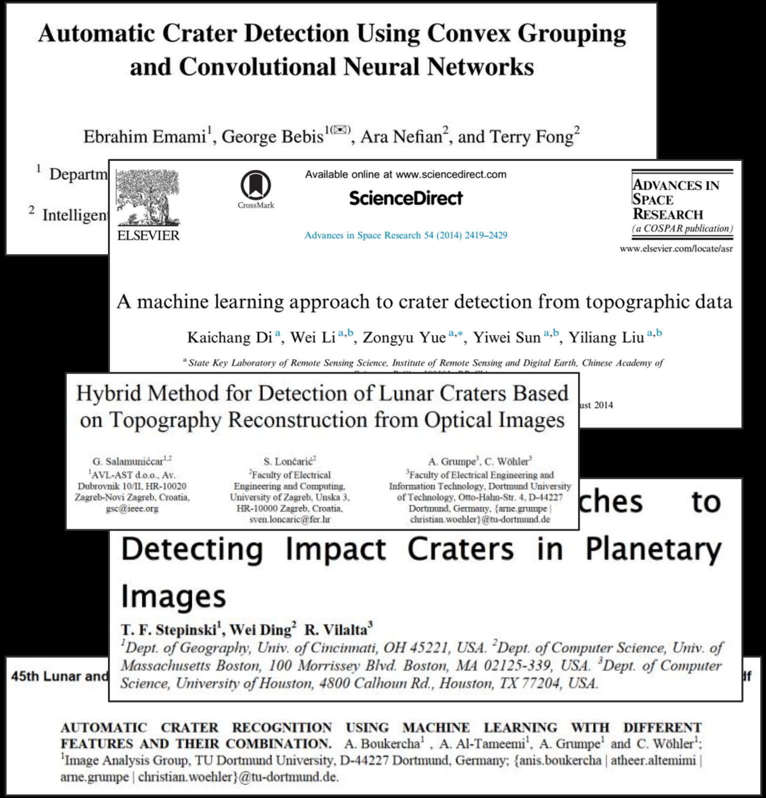
Common features are Craters



Crater Detection at Present

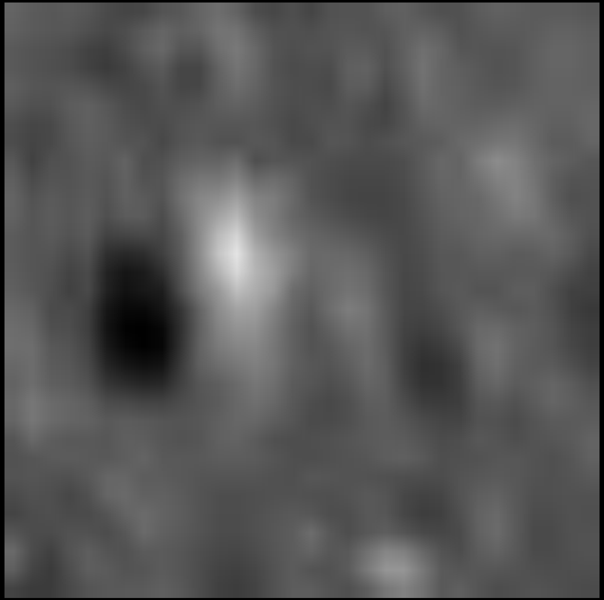
- ~77 crater detection algorithms published as of 2011 (Salamunićcar et al.)
- Rarely adopted by larger community
- Nearly all crater ID done by hand





Breakthrough Solution

Crater Extractor
for Polar and Equatorial Regions

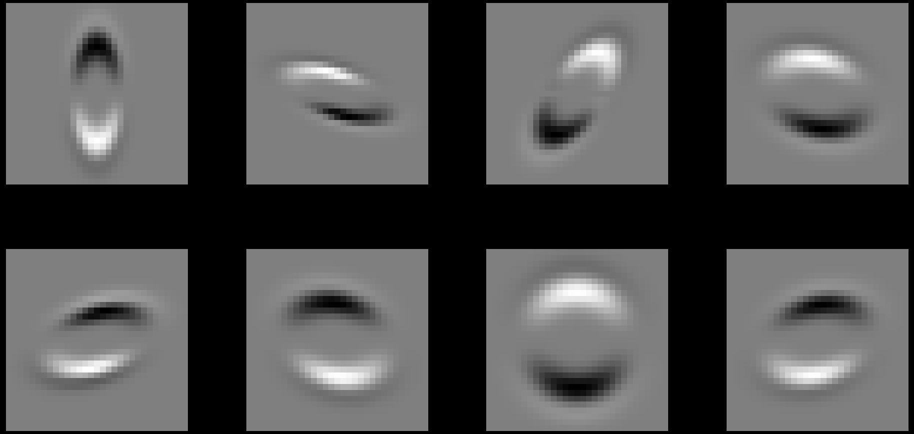


Vs.

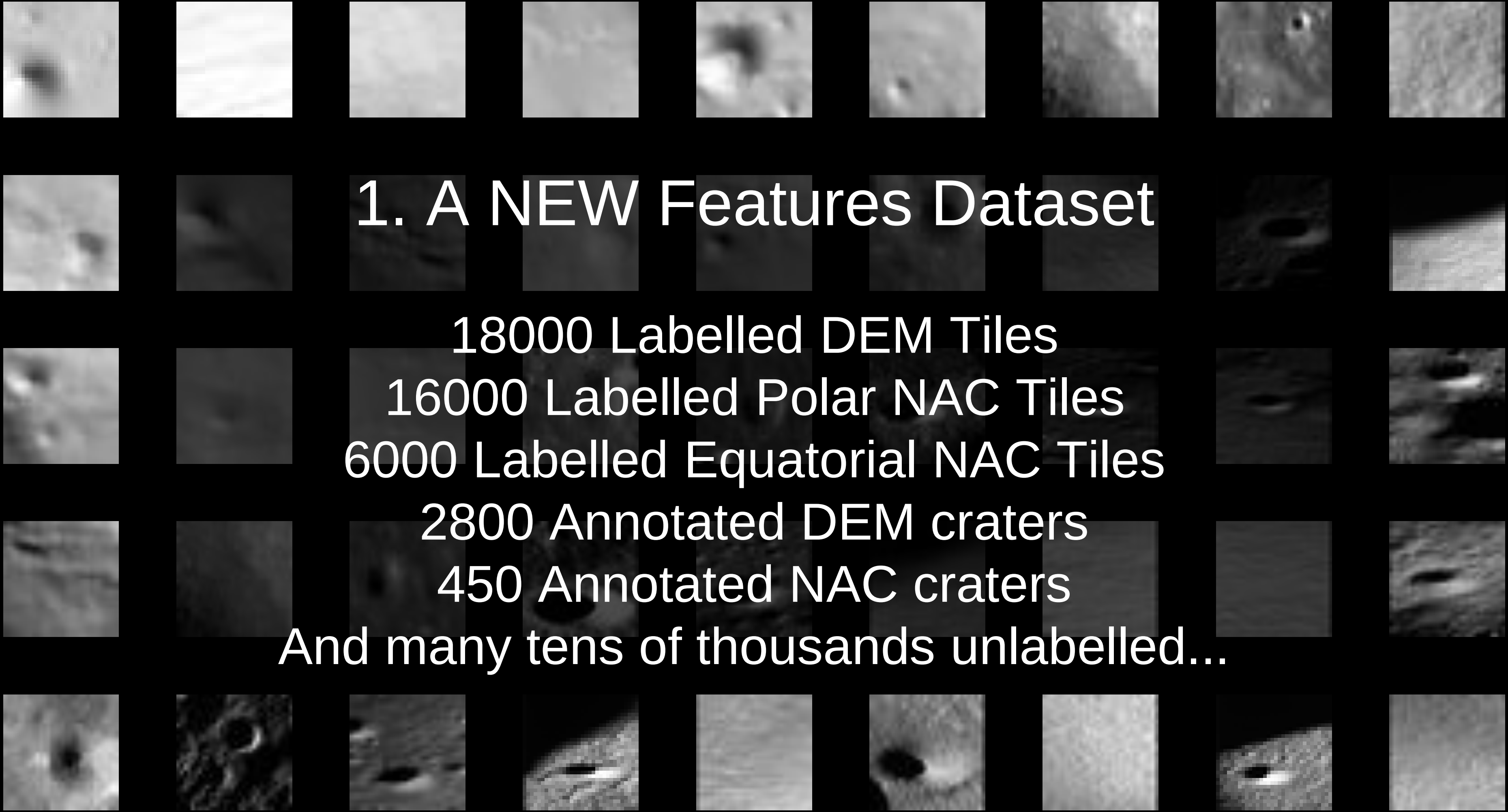
Crater?

No Crater?

Adaptive Convolution Filter



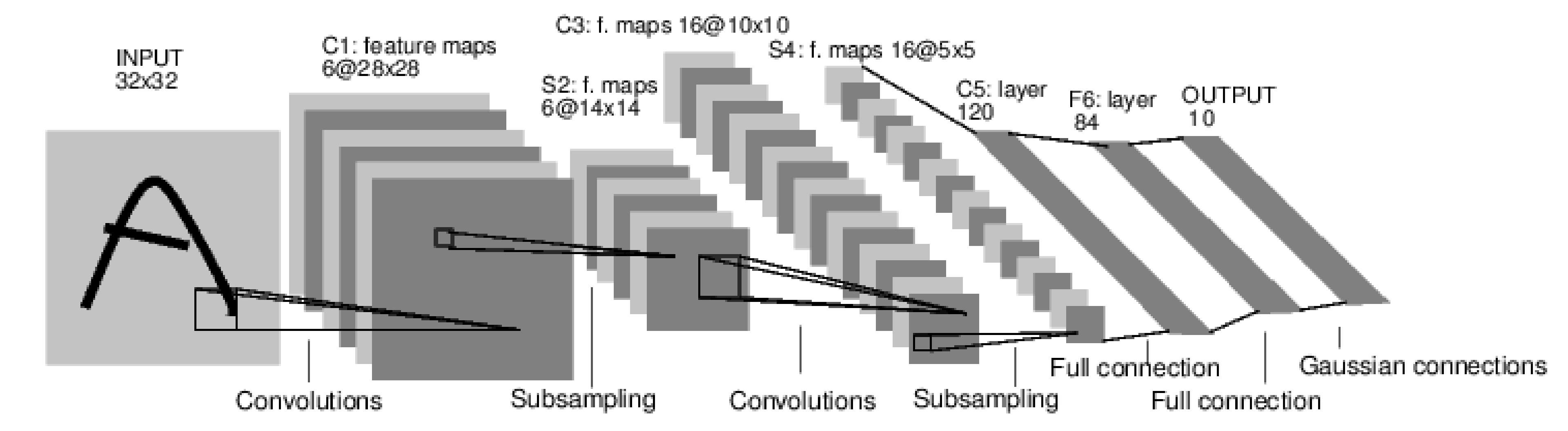
Represents a formulated baseline approach
to crater detection.



1. A NEW Features Dataset

18000 Labelled DEM Tiles
16000 Labelled Polar NAC Tiles
6000 Labelled Equatorial NAC Tiles
2800 Annotated DEM craters
450 Annotated NAC craters
And many tens of thousands unlabelled...

2. Deep Learning Classifier



Automated Crater Detection

Accuracy Compared with Previous Work

Group	Vijayan et al.	Di et al.	Emani et al.	**FDL**
Year	2013	2014	2015	**2017**
Method	Pattern recognition	Pattern recognition	CNN	**CNN**
Precision (%) (Accuracy)	91	87	86	**98**
Error Rate (%)	9	13	14	**2**

The Importance of Being Polar

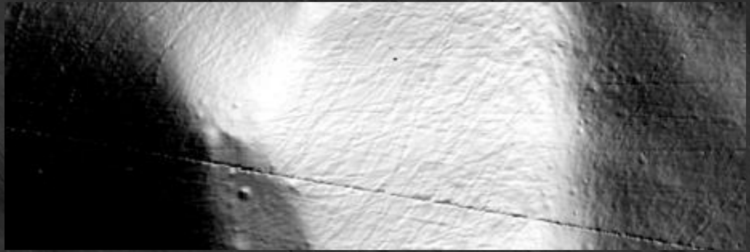
Dataset	Test Region	Error Rate (%)
Equatorial	Equatorial	5.05
Equatorial	Polar	9.68
Polar	Polar	2.02
Both	Polar	**1.61**

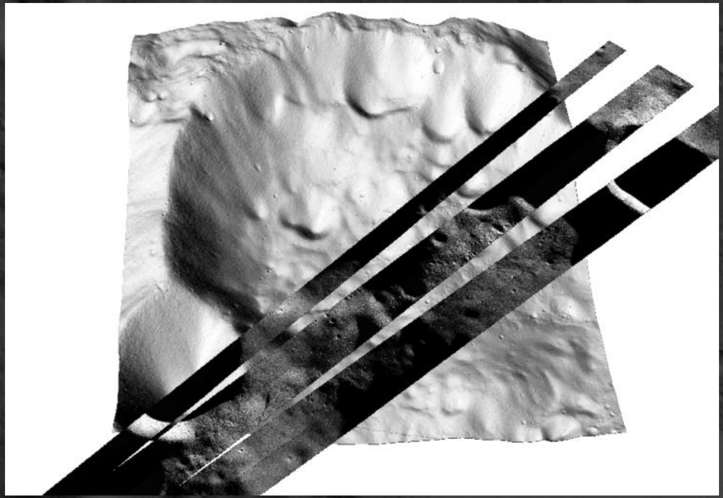
Timing Comparison of Our Techniques

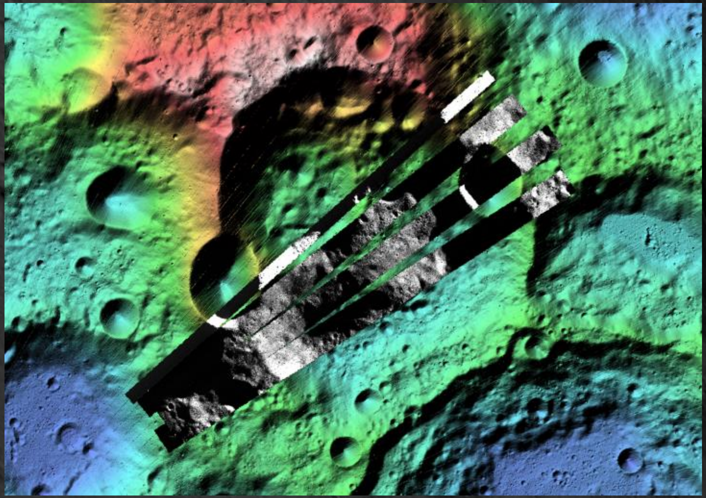
Group	Human	Single-Layer	**CNN**
Accuracy	-	Poor	**98.4%**
Time (1000 Images)	1-3 hours	10 hours	**1 minute**
Person-hours	1-3 hours	-	**-**

We need more training data: http://www.frontierdevelopmentlab.org/ai-lunar-mapping/moonshot.html#

Future Opportunities







Acknowledgements

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intel

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SPACE RESOURCES.LU

Take away:

FDL:

- Great opportunity for young Scientists
- Call for FDL 2018 is open: http://frontierdevelopmentlab.org/#/apply

Lunar Resource Missions & Artificial Intelligence:

- FDL2017 defined a project and set up early prototypes
- The mission will continue in 2018: intel.ly/fdl

AI will have a considerable impact to EO and RS

Thank You