Selecting suitable habitats for off-world living using 3D and super-resolution

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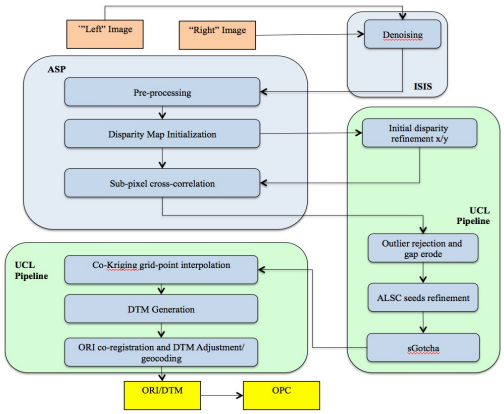
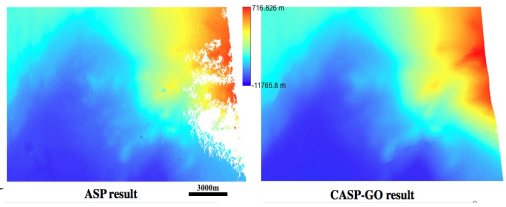
Surveying suitable locations

- Where should we live?
  - Building detailed 3D models using stereo photogrammetry fused with shape-from-shading
  - Building very high resolution (up to 5cm) using Super-Resolution Restoration
- How can we shelter?
  - Detecting suitable sheltered habitats (e.g. caves) using 3D and SRR
  - Detecting natural caves as pre-eminent shelters using machine learning
- Where do we find local resources
  - Using images to decide on the depth of the regolith
  - Using neutron spectroscopy & subsurface radar for subsurface water

Co-registered Ames Stereo Pipeline with Gotcha refinement and Optimization (CASP-GO)

CTX
HiRISE
HRSC
CaSSIS
LROC
SkySat
Carbonite-2





CASP-GO based on the open source NASA Ames Stereo Pipeline (ASP: Beyer et al., ESS, 2018). Open source tie-point based multi-resolution image co-registration (Tao & Muller, Icarus, 2016), and Gotcha (Shin & Muller, 2012) sub-pixel refinement method.

(a) Co-registered geo-spatial coordinates w.r.t HRSC (and thence MOLA) data;
(b) Improved DTM completeness for unmatched areas;
(c) Reduced DTM artefacts;
(d) Improved DTM accuracy;
(e) Fully documented uncertainty value for all interpolated area

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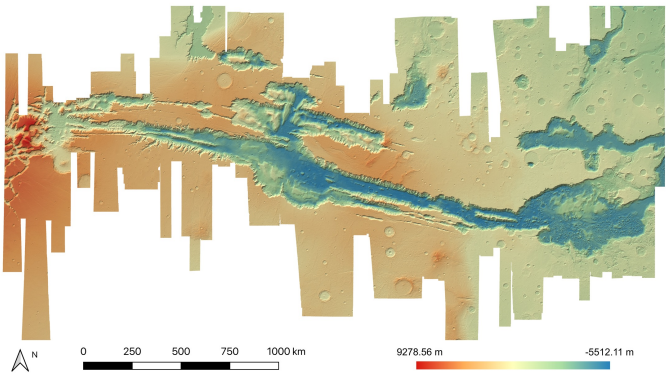
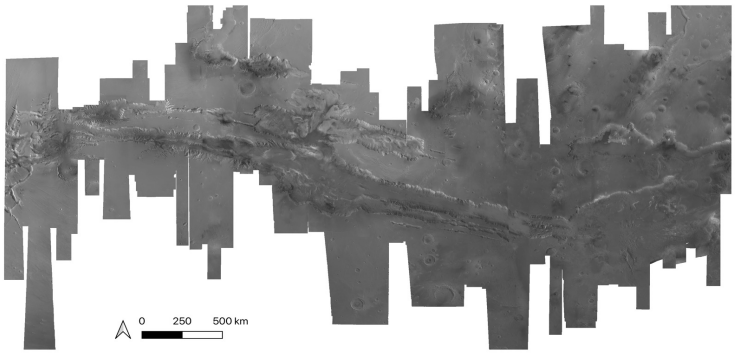
Version: 06.05.21

UCL-FUB HRSC DTM and ORI mosaic products over Valles Marineris



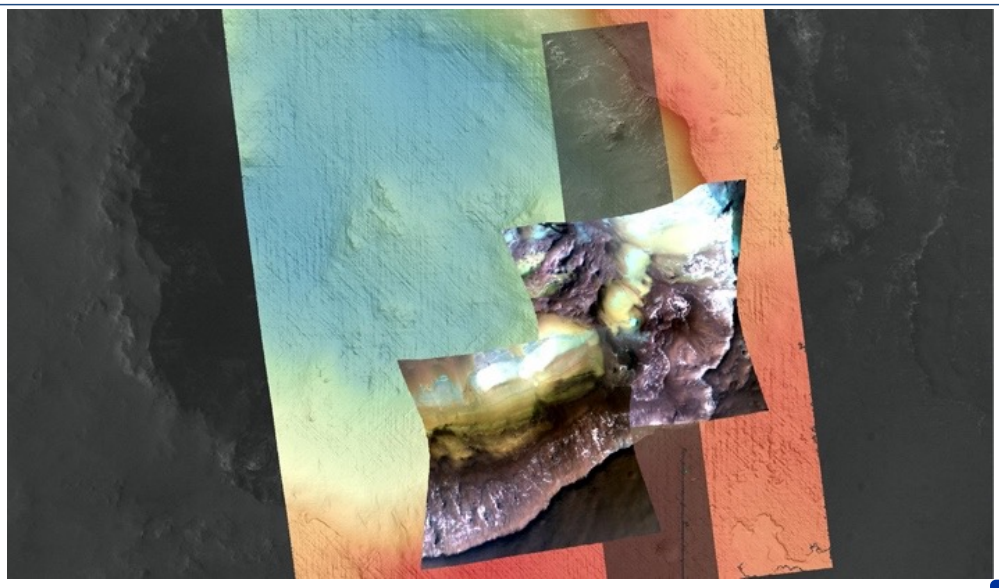


Mosaic of 82 of 50m HRSC Digital Terrain Models
Tao et al., Remote Sensing 2021

Mosaic of 12.5m HRSC Orthorectified and surface BRDF-corrected Images
Courtesy of G. Michael, FUB (ibid)

Automated co-registration and orthorectification

- HRSC 50m DTM
- CRISM 20m HI
- CTX 18m DTM
- HRSC 12m ORI
- HiRISE 1m



Muller et al., 2021 ISPRS

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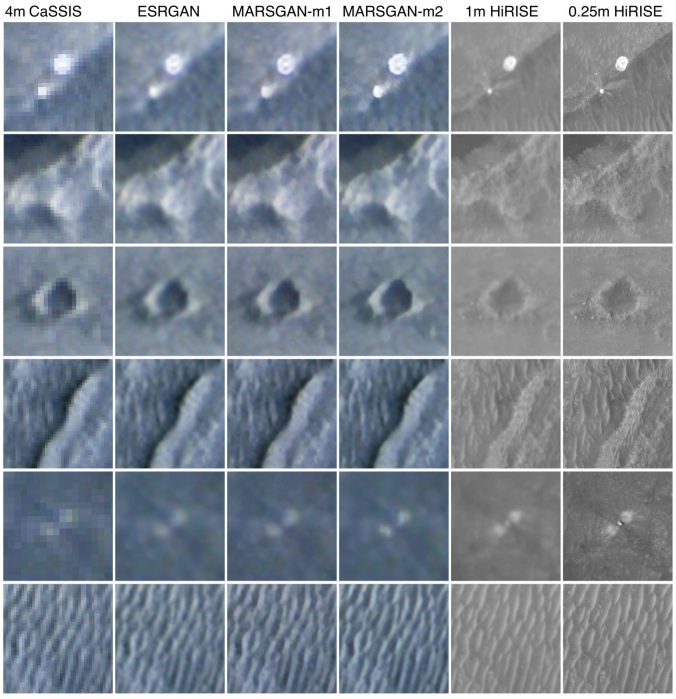
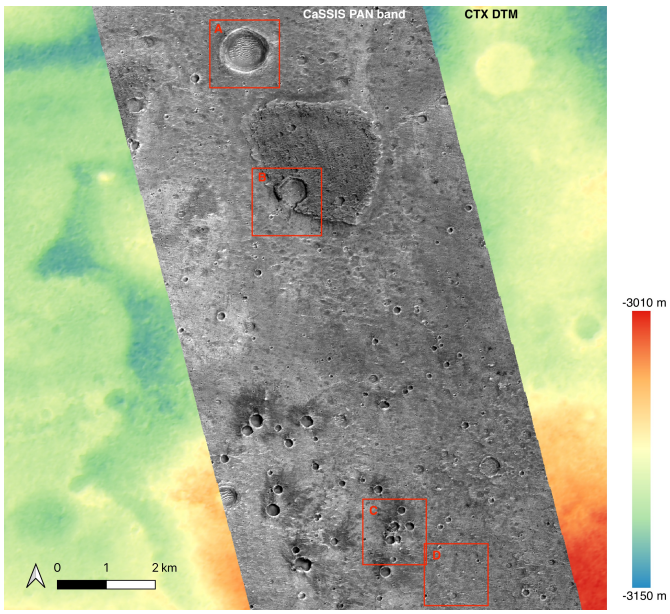
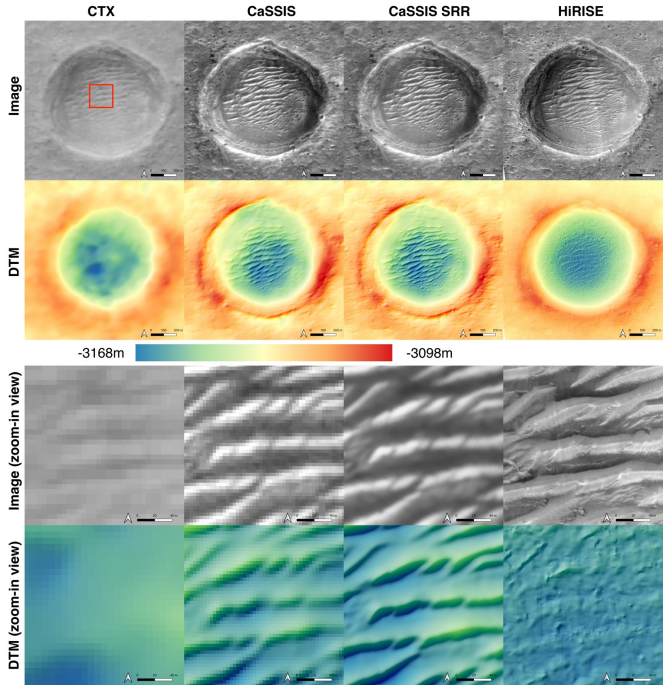
Super-resolution Restoration of single ESA CaSSIS from 4-6m to 1m

NASA Perseverance rover landing-site
Tao, Muller et al., Remote Sensing, 2021



Use of stereo CTX 18m and shape-from-shading +SRR->1m DEMs



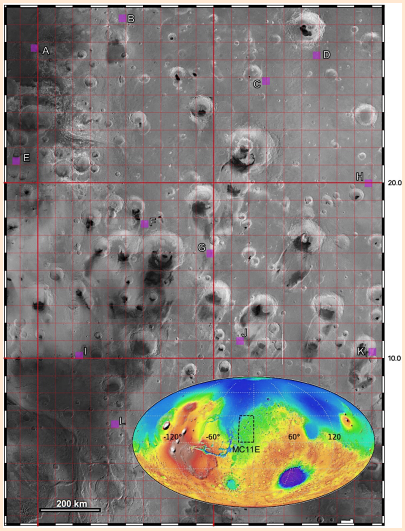


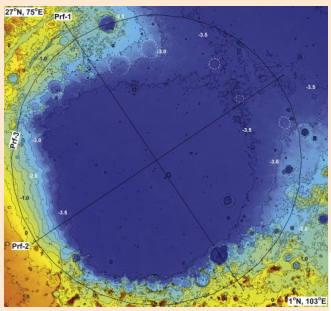
Tao, Muller et al., in preparation

Visualisation of SRR+SfS-DTM and subsequent 3D measurement (Pro3D® VRVis, Vienna, Austria)

Barnes, R., Muller, J.-P. et al. (2018) Geological Analysis of Martian Rover-Derived Digital Outcrop Models Using the 3-D Visualization Tool, Planetary Robotics 3-D Viewer-PRo3D. *Earth and Space Science* **2018**, *111*, E02S02.

Automated Small Crater Detection



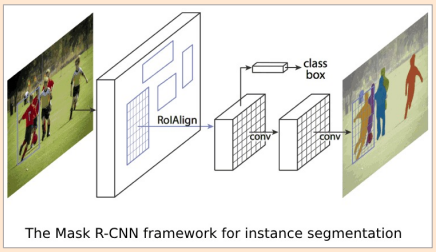


Isidis Planitia chosen as study site for analysis of small crater populations as area is one age. N.B. Mars2020 rover will land in this area.

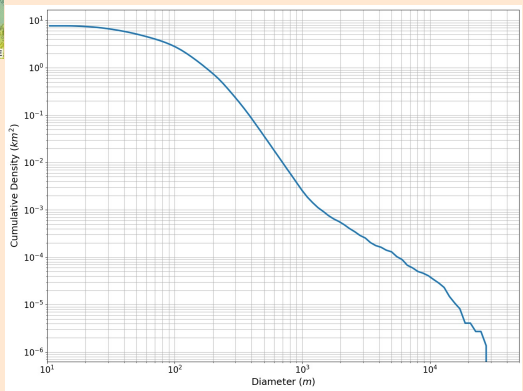
DATASET

Dataset of over 5,000 small craters from 12 random locations on MC-11 E, annotated by citizen scientists

Alistair Francis

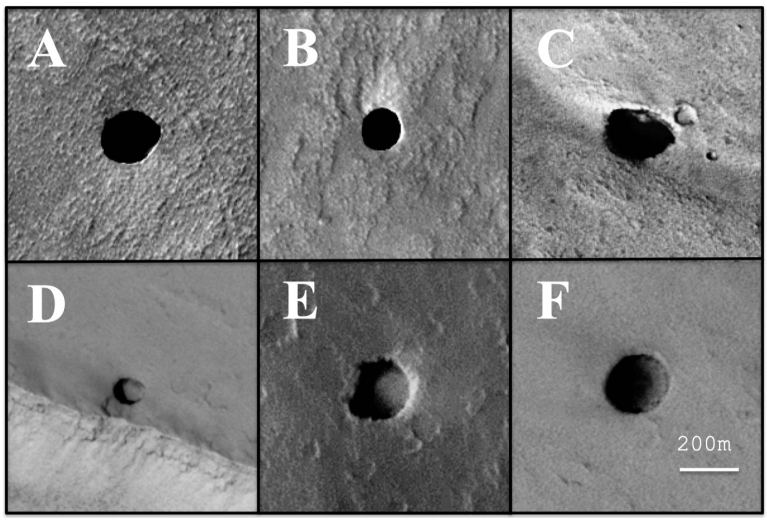


Implementation of Mask R-CNN for crater detection, trained on our dataset plus others.
Kaiming He et al. CVPR 2017

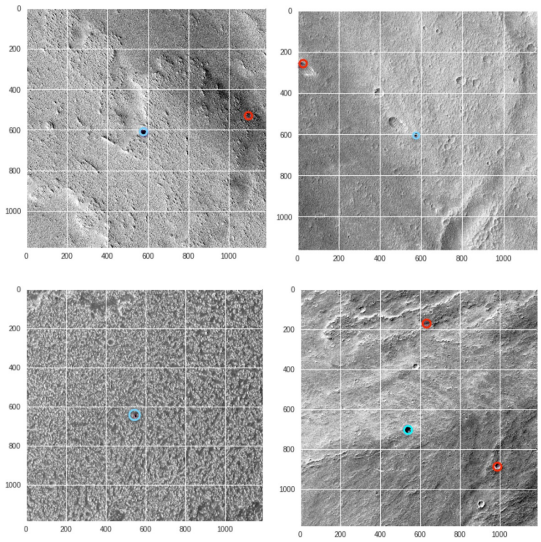


Over 8 million ≤1 km craters detected on Isidis Planitia. Study ongoing into cave and pit detections

Extension of machine learning techniques to automated cave detection on Mars



Training dataset CTX images@6m



Auto-Cave detection using Machine learning

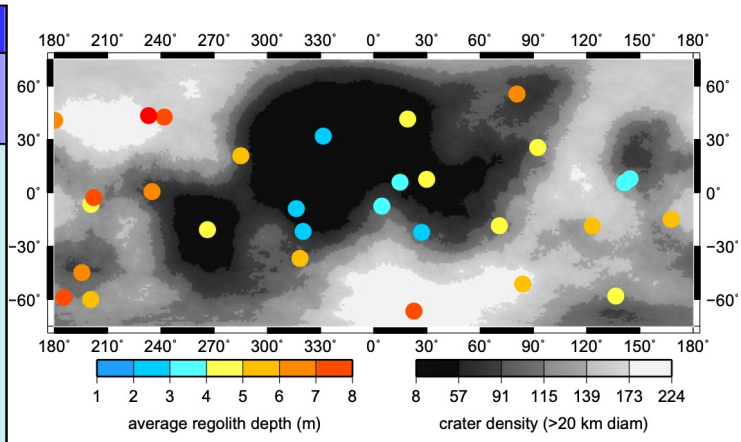
Eleni Ravenis (MSc Planetary Science) and Alistair Francis (PhD candidate)

How do we make concrete on the Moon & Mars – regolith and water

	TYPE OF CONCRETE	
	Lunar soil but water and alumina cement from Earth	All materials from Earth
Compressive strength	10,970 psi	7960 psi
Static modulus of elasticity	1.1 million psi	1.8 million psi
Dynamic modulus of elasticity	3.12 million psi	2.81 million psi
Poisson's ratio at peak load	0.39	0.27
Modulus of rapture	1210 psi	1240 psi
Coefficient of thermal expansion	0.0000029 in./in./F	0.0000035 in./in./F

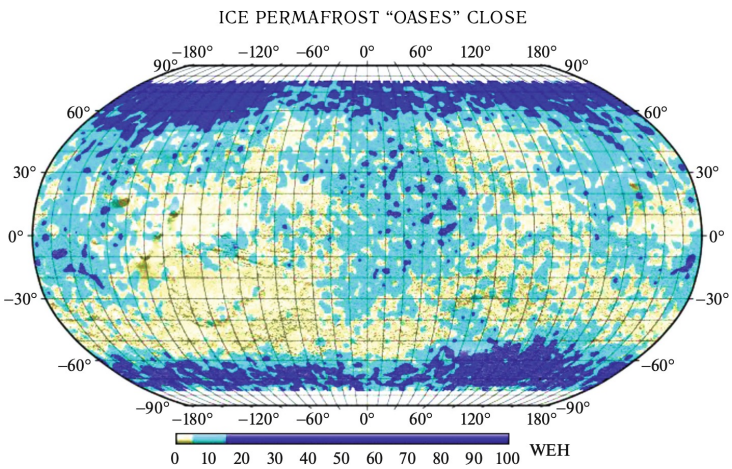
Figure 1. *Small cubes and beams made with lunar soil brought from the moon by Apollo 16 were tested and compared with similar specimens made entirely from earth materials. The results show that lunar soil would make an excellent aggregate for concrete.*

Concrete Construction, T.D. Lin, 1987



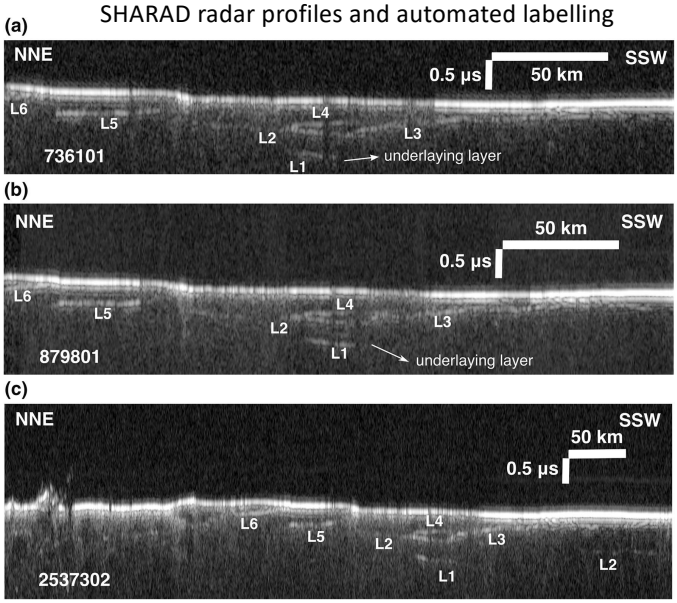
Bart et al., Icarus, 2011
Based on visual interpretation of crater erosion

Where do we find water?



Neutron spectroscopy – HEND on TGO2016
Malakhov et al., Astron. Lett., 2020

SHARAD radar profiles and automated labelling



Xiong..Muller, Earth & Sp. Sci. 2020