Enhancing the 3-D capability of science and engineering cameras on the ExoMars Rover

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1. Context

The European Space Agency ExoMars Programme is sending a rover to Mars in 2022 equipped with a variety of instruments and a 2-meter drill which will be used to search for evidence of extant life below the surface.

The stereo camera systems on the ExoMars Rover are PanCam, a scientific instrument designed by MSSL/UCL, and the NavCams and LocCams, designed by Airbus for navigation. Both will provide 3-D imagery of the terrain around the rover for their respective communities. With more views of a scene it is possible to make better 3-D information, yet there are no plans to combine data from these two sets of cameras.

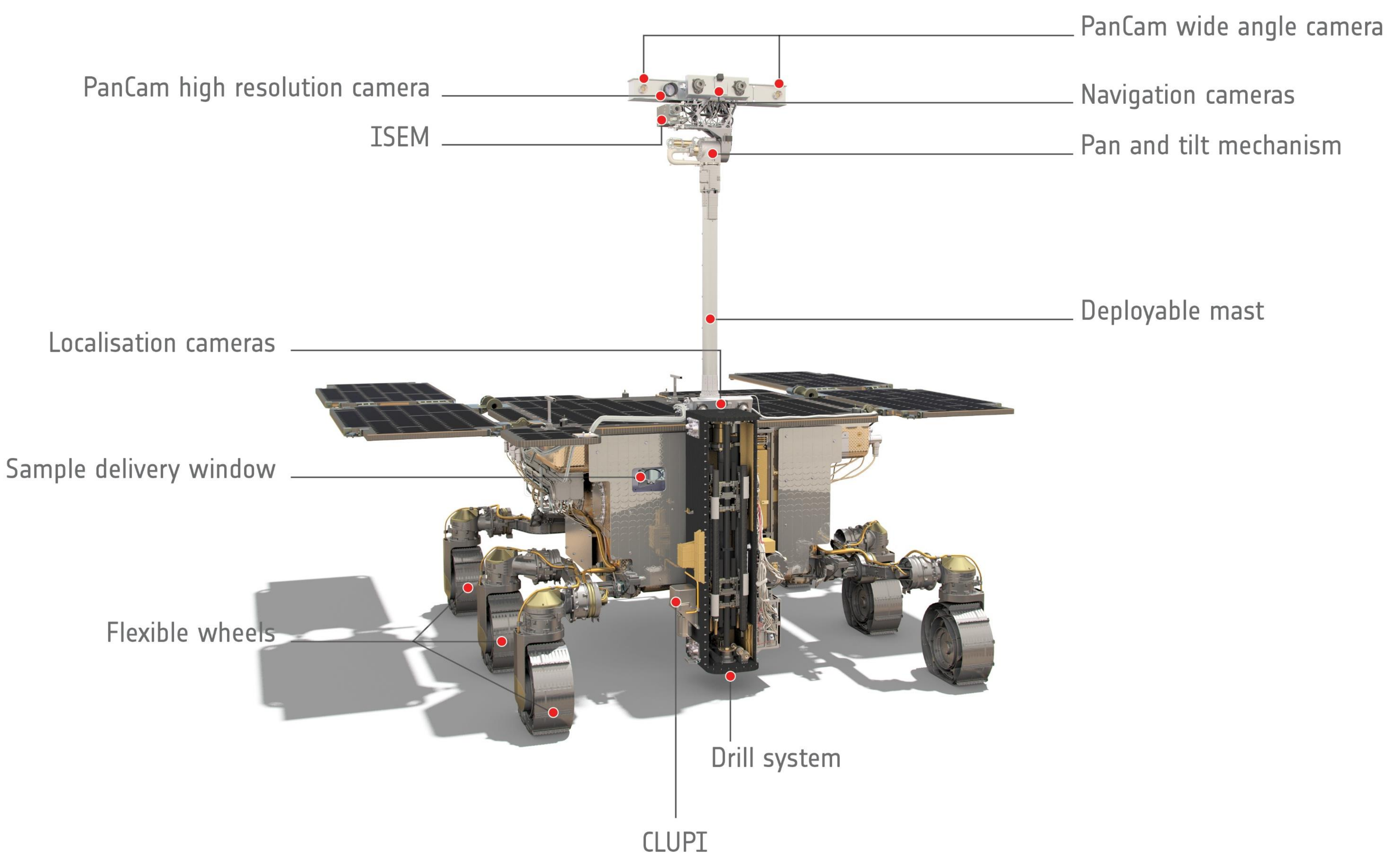

Figure 1. ExoMars “Rosalind Franklin” rover with major systems annotated. Credit ESAz

2. Objectives

- Investigate how 3-D capabilities can be improved by combining information from all rover stereo camera systems.
- Collect representative data of the landing in 2023 by building emulators of rover vision instruments.

3. Emulator Development

It’s not possible to run experiments on the real rover and it’s cameras, therefore we build emulators. Airbus has in-house emulators of the NavCams, LocCams and several for the entire rover. Within the scientific community, the University of Aberystwyth has developed the AUPE PanCam emulator for field testing. These are the first emulators of the collected stereo camera systems.

- Emulator 1 – three webcams on a music stand controlled using Matlab.
- Emulator 2 – four commercial off-the-shelf cameras representing the PanCam WACs and the NavCams mounted on a tripod. Shown in figure 2.
- Emulator 3 – six cots cameras representing the WACs, NavCams and LocCams in their respective geometries on a rover made from an electric wheelchair. The mast cameras are mounted on a pan tilt unit that allows for precise pointing using an onboard computer. Shown in figure 3.

Figure 2. (left) Photo of Emulator 2. The aluminium optical bench was mounted onto a tripod, making this practical for uneven terrain such as sand.

Figure 3. (right) Photo of Emulator 3 at Farnborough Airshow, author for scale. A wheelchair with the chair removed serves as a mobile base.

4. Simulated Rover Traverse

The rover trial was conducted at the Airbus Defence and Space ‘Mars Yard’ in Stevenage. This is a 30 × 10 m testing ground filled with sand, boulders and slopes to represent challenging Martian terrain.

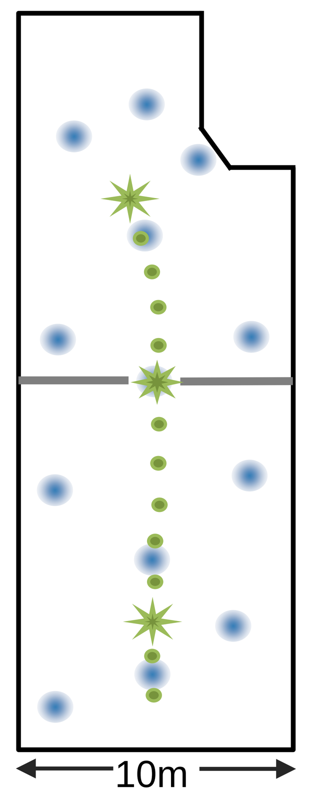

Figure 4. Plan view of Mars Yard. Lidar scans were taken at blue spots, the green dots are the each location of the emulator, the stars represent where a 360 degree panorama was taken.

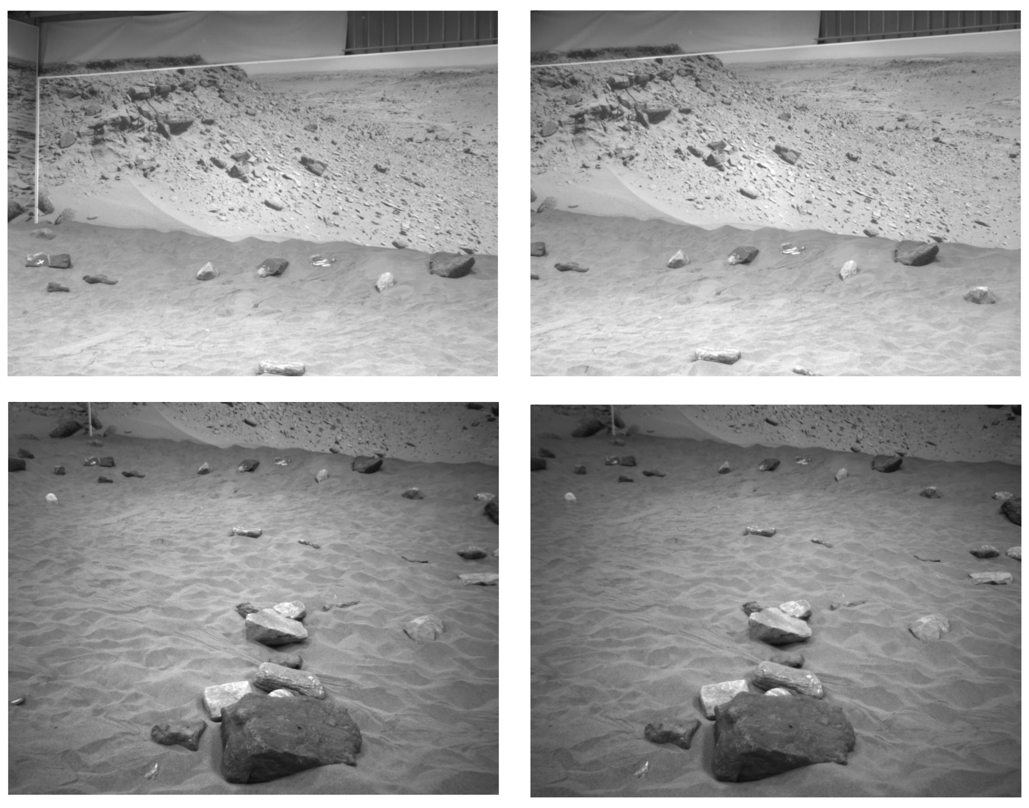

Figure 5. Simultaneous views from the PanCan WACs (top left and right) and Airbus NavCams (bottom left and right).

5. Methods for 3D model generation

3D from stereo - Image pairs were from the same instruments were processed into pointclouds using OpenCV’s python package.

Photogrammetry - Larger groups of images (triples to entire panoramas) were aligned and processed into point clouds and meshes using the Agisoft Metashape software.

Laser rangefinding - LIDAR scans recorded the area in 3D to a higher degree of accuracy than models made from images. This denser model was used as a “ground truth” to compare against 3D models from the emulator.

Figure 6. Dense point cloud made using views in figure 5 using photogrammetry.

6. Results

- Initial results confirm that incorporating more viewpoints gives a higher density of points, however they are not necessarily more accurate.
- The accuracy and errors of the points is dependent on many factors such as relative distances between cameras, focal length and distance from the object.
- Comparison with LIDAR scan highly dependent on manual alignment of both datasets.

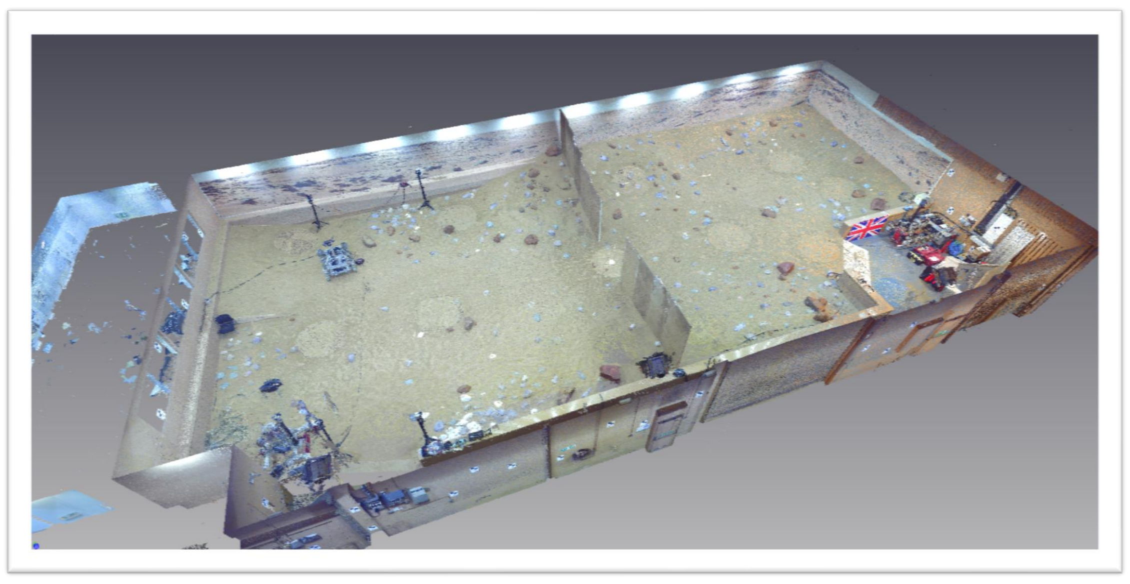

Figure 7. All aligned lidar scans of the Mars Yard.

7. Future work

- Simulate how extrinsic and intrinsic camera properties and geometries give rise to errors in point position.
- Find way to consistently align lidar with photogrammetric datasets, ideally automatically.

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