PRIFYSGOL ABERYSTWYTH UNIVERSITY

15/02/2008

ExoMars Rover Inspection Mirror (RIM)

Dr. Dave Barnes
Department of Computer Science
Aberystwyth University
SY23 3DB, UK
dpb@aber.ac.uk

Background

With the current baseline ESA ExoMars rover design (launch 2013) and the positioning of cameras – PanCam, NavCams, and HazCams, there are several regions of the rover that cannot be imaged. These regions include the front, sides, and underside of the rover. The inability to image these regions is also the case for the two NASA MER rovers. From both engineering and science standpoints, to be able to image these regions would be highly desirable. To address this imaging inability, Aberystwyth University is developing a Rover Inspection Mirror (RIM) for the ExoMars rover design. Such a mirror when used in combination with the ExoMars PanCam HRC (High Resolution [zoom] Camera) would negate the addition of an extra camera (and thus extra mass, volume and power) to provide the same imaging capability.

To demonstrate the application of the RIM, studies have been undertaken using rover 3D simulation and computer graphics software. The results of this work are shown here.

RIM Design and Placement

The convex mirror under study has a centre of curvature (C) = 40 mm, hence a focal point (FP) = 20 mm, and has a diameter (D) = 25 mm. The resultant field of view (FOV) = 106º. We propose that the mirror could be machined as an integral part of the ExoMars robotic ARM (or similar) structure. In the study, the lower wrist motor gearbox housing was chosen. Any protective coating would need properties so as to minimise any surface micro-structures, and hence minimise the aggregation of dust particles on its surface. All materials used would have to be fully compliant with Planetary Protection, not out-gas, UV tolerant etc.

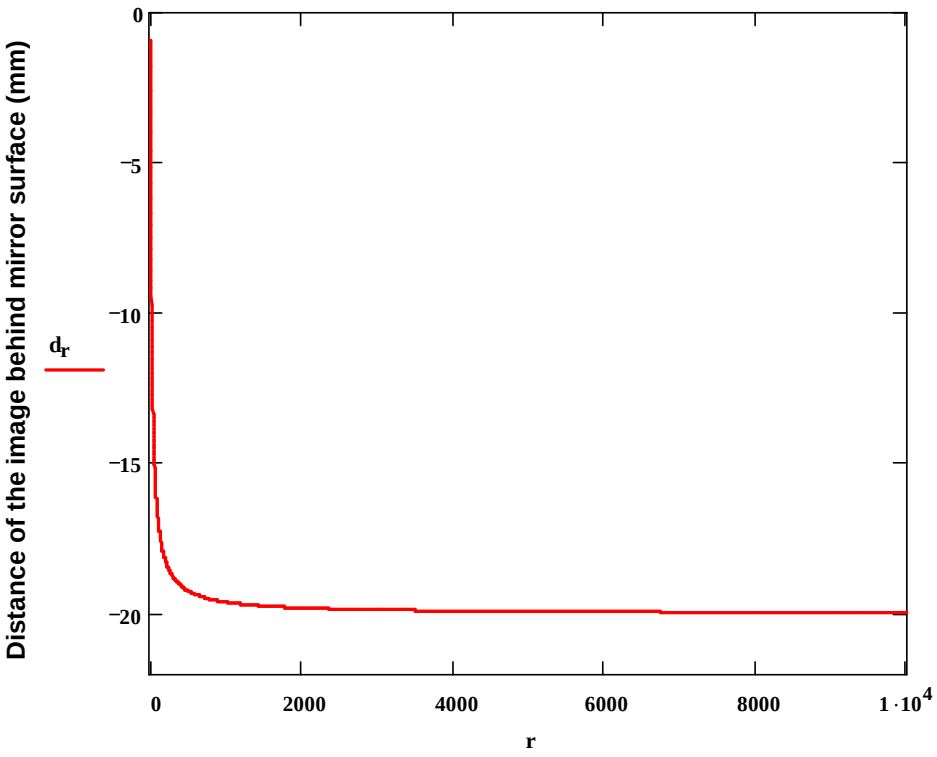
Placement of the RIM towards the end of the ExoMars robotic ARM means that it can be imaged by the PanCam HRC. The HRC provides a zoom-in capability (FOV > 5º), and with a focus drive mechanism providing object focus from 1 metre to infinity, it means that close-up images of the RIM can be obtained. When mounted on the Beagle 2 ARM lower wrist motor gearbox housing, for example, the distance from RIM to HRC is approximately 1600 mm when the ARM and the rover mast are in their nominal deployed operating configuration. HRC captured RIM images can be ‘unwrapped’ from a spherical to a planar projection, and ‘flipped’ horizontally as they are mirror-images.

Simple Convex Mirror Equation

$f := -20$ Mirror focal length used in the study (mm)

$r := 1 .. 10000$ Range of distance of the object from the mirror's surface (mm)

$d_r := \frac{1}{\frac{1}{f} - \frac{1}{r}}$ Distance of the image behind the mirror's surface (mm)



The above graph shows that with a focus range from 0 mm (i.e. the HRC focused upon the nearest surface point on the convex mirror) to a point 20 mm behind the mirror (i.e. minus 20 mm relative to the convex mirror surface), then objects can be imaged with a range from 0 mm in front of the mirror (i.e. touching) to a distance at infinity. Hyperfocal distance settings for the HRC can ensure RIM image depth of field (DOF).

RIM CAD Images Mounted on Beagle 2 ARM Wrist Motor Housing

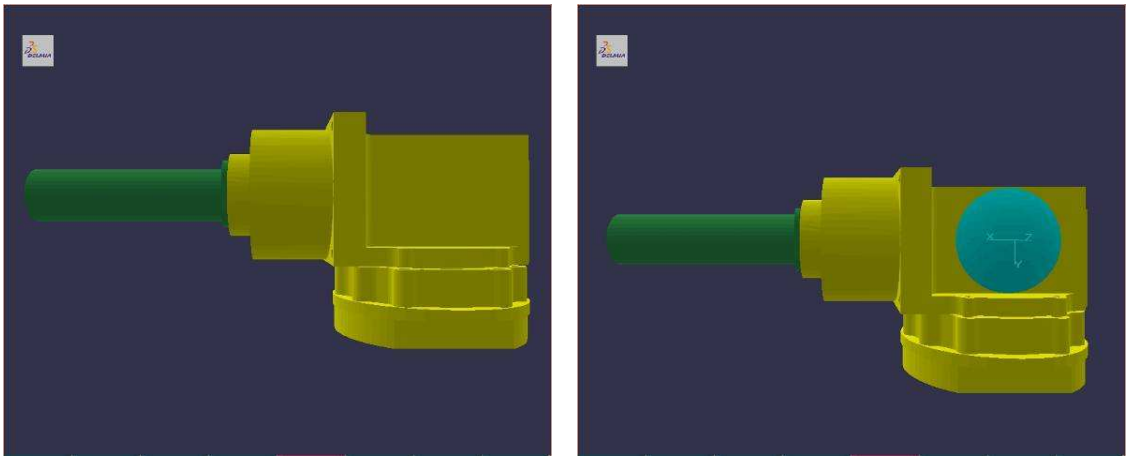


Figure 1 View of Beagle 2 wrist motor housing before and after RIM mounted.

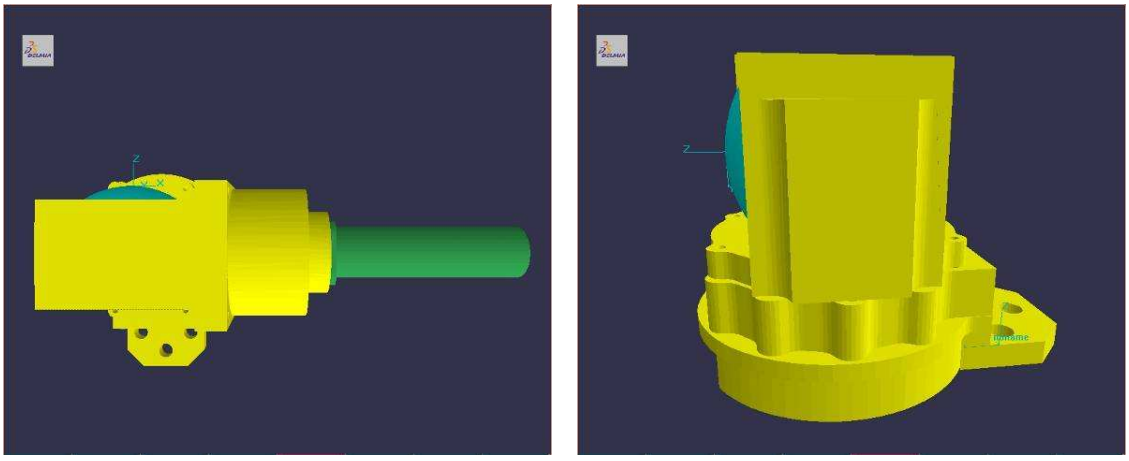


Figure 2 Top and side view of RIM mounted on Beagle 2 wrist motor housing.

Simulated RIM Images

The simulations were performed on a dual AMD Athlon MP2800+ PC, 2.13 GHz, with 3.5 GB of RAM, and 3Dlabs Wildcat4 7210 graphics card. Total render time for a 640 × 480 pixel RIM image ≈ 10 – 15 minutes. The ExoMars rover simulation with robotic ARM is based upon the EADS Astrium led ExoMars Phase A Study results. As the ARM with RIM can be moved to different positions, and the mast pan and tilt mechanism altered so that the HRC can image the RIM, then many different views of the rover can be captured. In addition to the engineering images that can be obtained (for confirmation/investigation/planning), views of the rover wheels can be captured for soil mechanics science, and even for obtaining images of the underside of overhanging rock formations. Below is a selection of images.

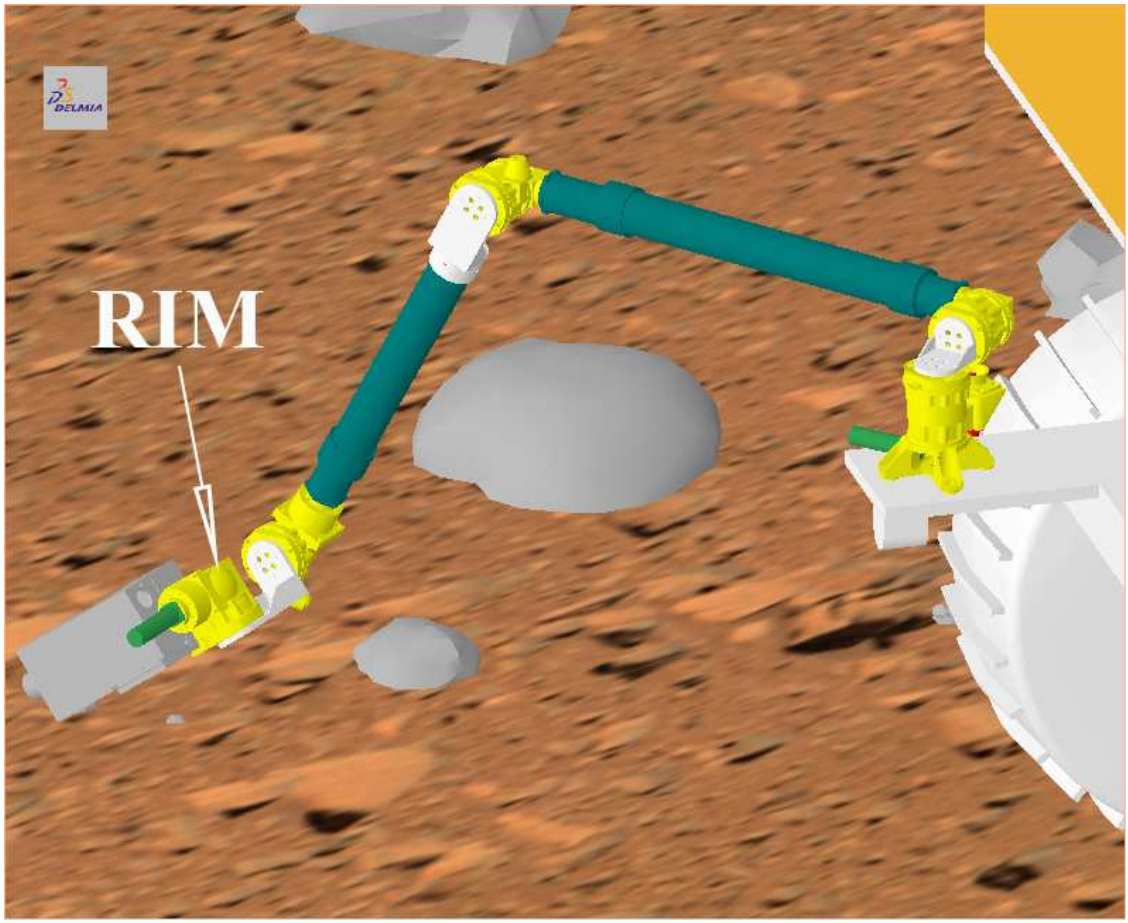


Figure 3 View of simulated RIM positioned on Beagle 2 ARM.

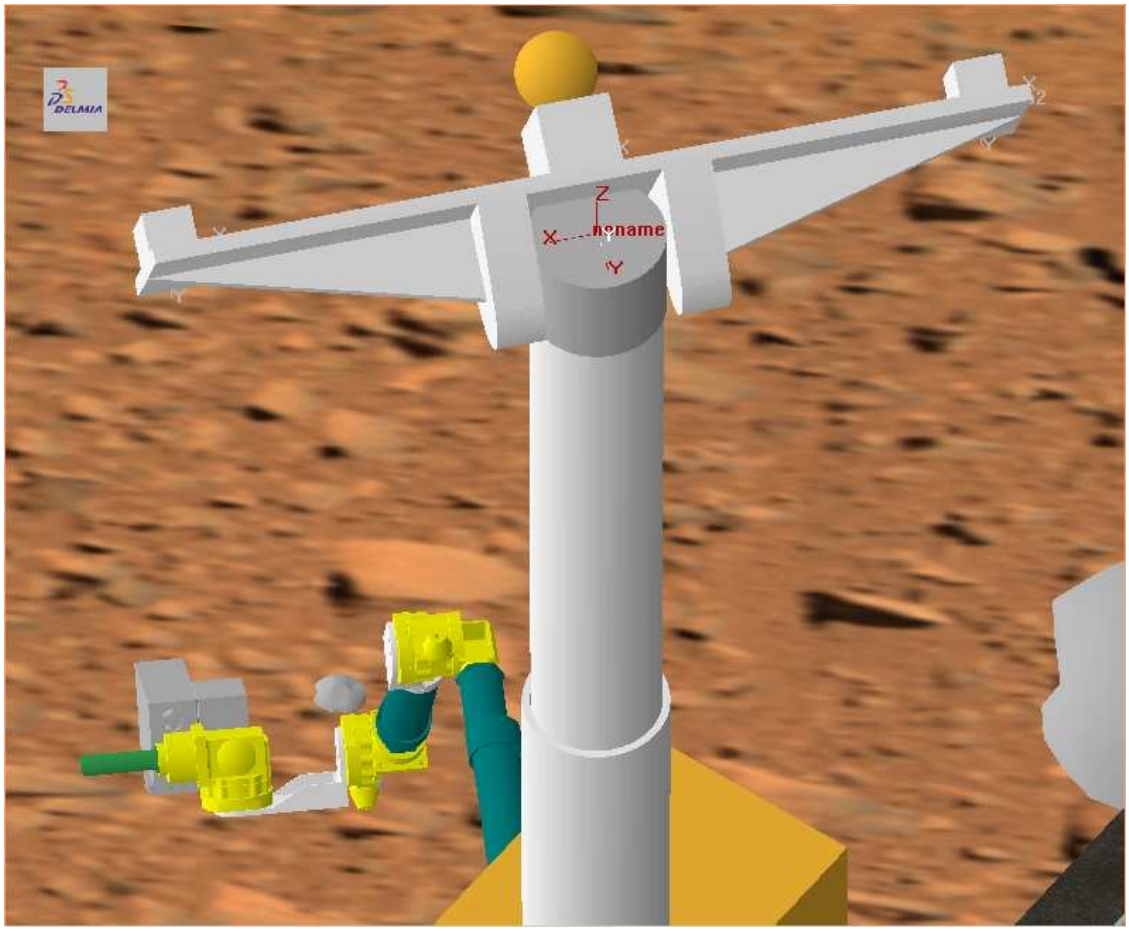


Figure 4 View of simulated PanCam HRC positioned to image the RIM.

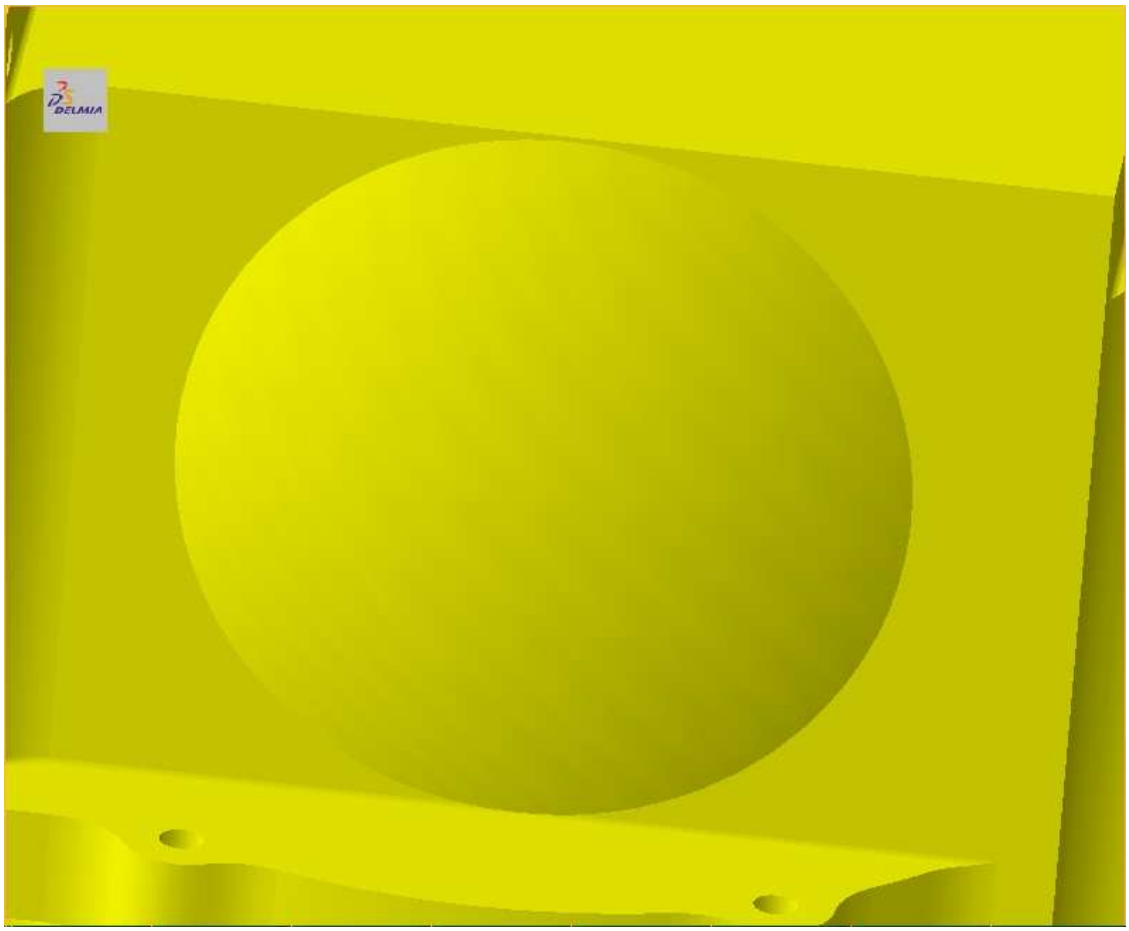


Figure 5 Close-up view of simulated RIM using HRC zoom capability. All rover and arm 3D geometry and camera view exported to computer graphics package and 'reflective' property assigned to RIM prior to image rendering.

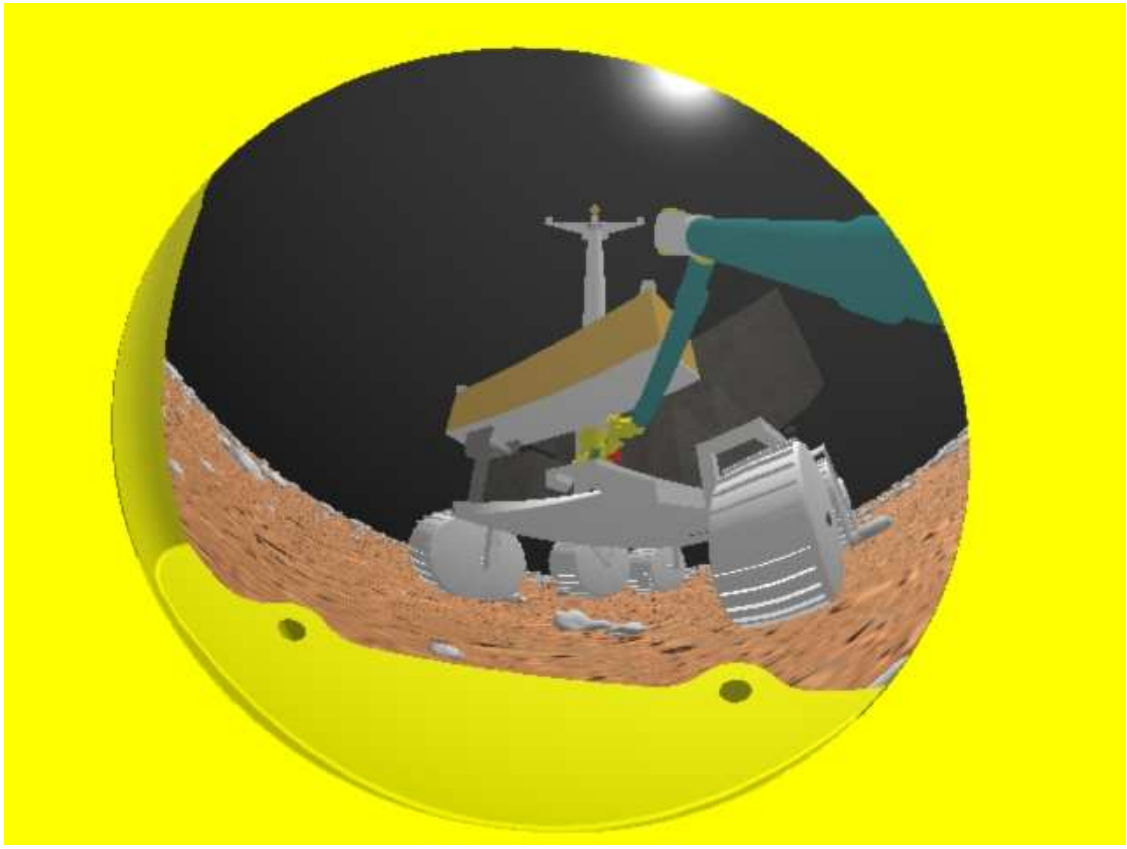


Figure 6 Post rendering - what the HRC would see when viewing the RIM. These images can be 'unwrapped' and 'flipped' horizontally as they are mirror-images.

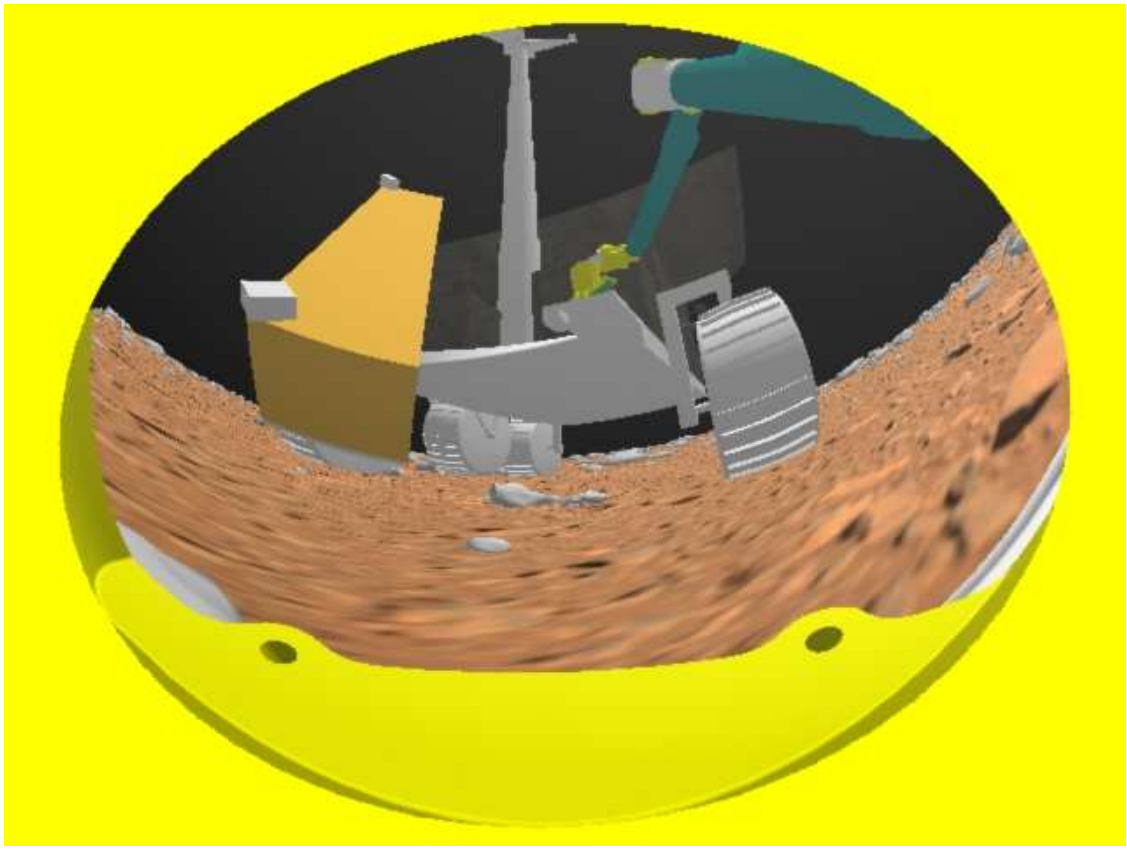


Figure 7 View of drill deployment using the HRC and RIM.

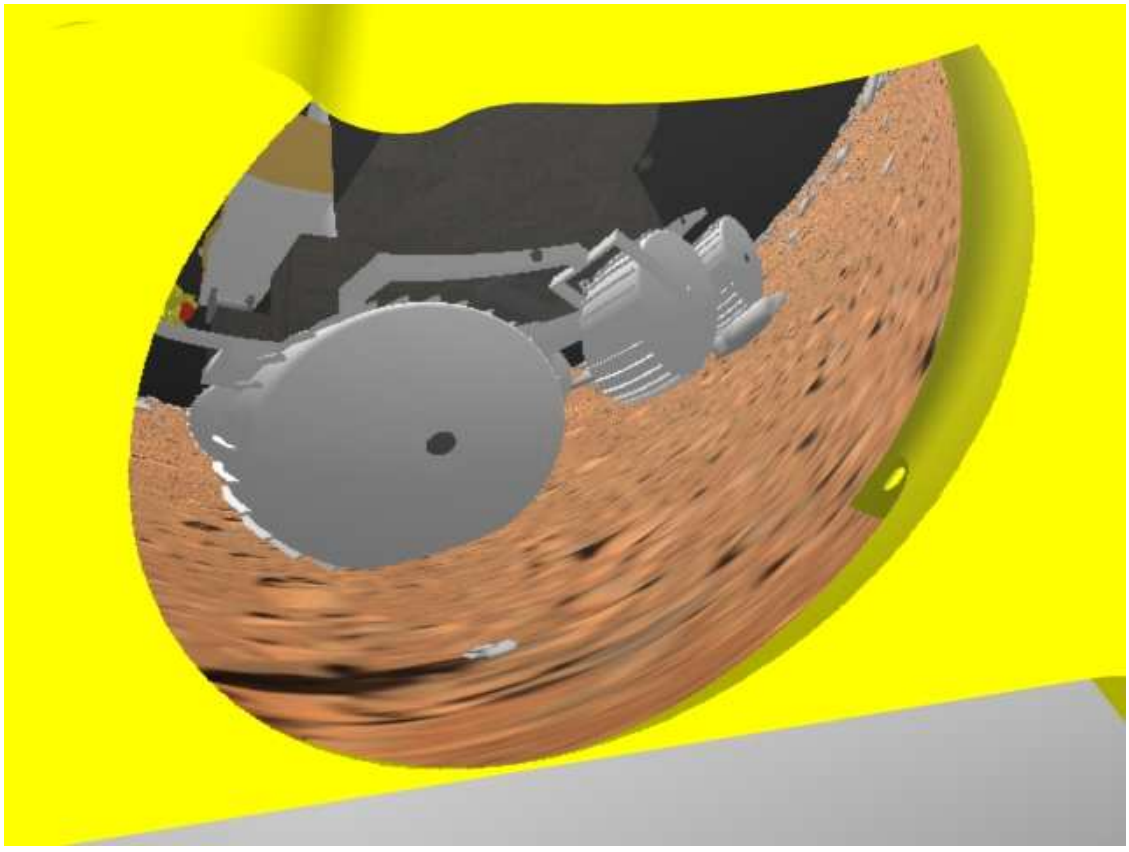


Figure 8 HRC/RIM view of rover wheels for soil mechanics science.

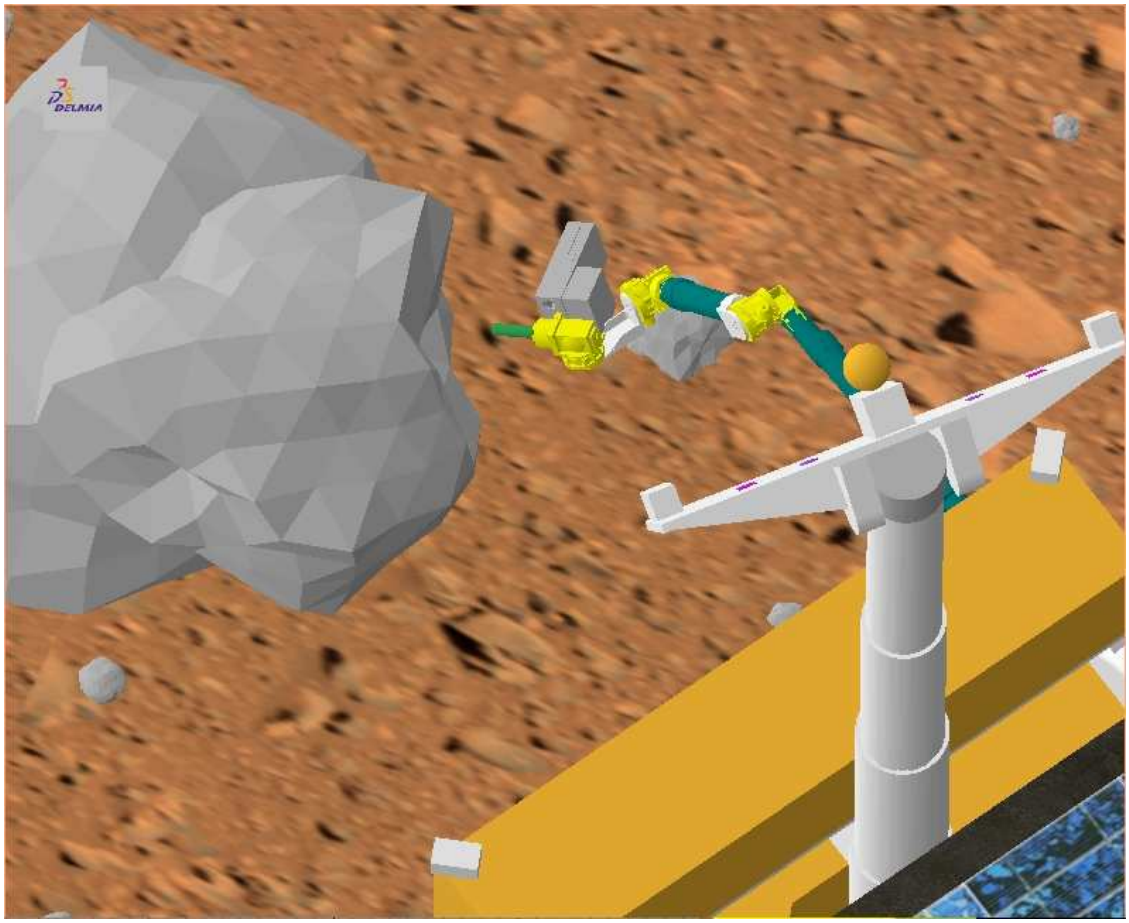


Figure 9 Overhanging rock formation - underside cannot be imaged by PanCam (or HazCams) alone. RIM positioned prior to being imaged by HRC.

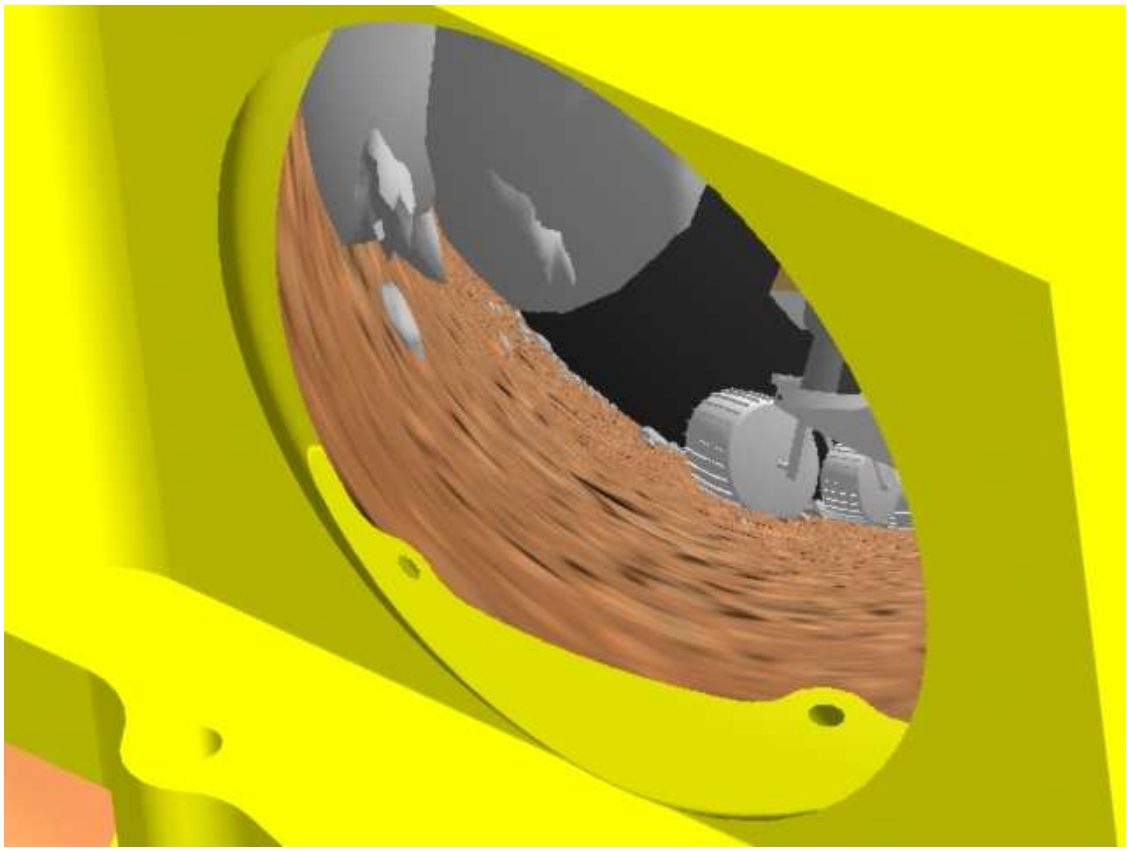


Figure 10 HRC/RIM image of underside of overhanging rock formation.