EUROPEAN GEOSPATIAL IMAGE UNDERSTANDING TOOLS FOR MARS EXPLORATION. J.-P. Muller[1], Y. Tao[1], P. Sidiropoulos[1], V. Yershov[1], J.G. Morley[2], J. Sprinks[2], G. Paar[3], B. Huber[3,] A. Bauer[3], K. Willner[4], C. Traxler[5], [1]Imaging Group, Mullard Space Science Laboratory, University College London, Dept. of Space & Climate Physics, Holmbury St Mary, Surrey, RH5 6NT, UK, j.muller@ucl.ac.uk; [2]Nottingham Geospatial Institute, University of Nottingham, University Park, Nottingham, NG7 2RD, UK, jeremy.morley@nottingham.ac.uk; [3]Joanneum Research F-GmbH, Steyrergasse 17, 8010 Graz, Austria, gerhard.paar@joanneum.at; [4]Dept. of Geodesy & Geoinformation Science, Technical University Berlin, 10623 Berlin, Germany, konrad.willner@tu-berlin.de; [5]VRVis Zentrum für VR und Visualisierung F-GmbH, Donau-City-Strasse, Vienna, Austria, traxler@vrvis.at

Introduction: Several European Union Seventh Framework funded projects (http://provisg.eu, http://proviscout.eu, http://provide-space.eu, http://i-Mars.eu) have and are developing tools for Mars exploration in preparation for the ESA-Roscosmos Exo-Mars Trace Gas Orbiter 2016 and rover mission in 2018. There are several common themes running throughout these developments including: a) the necessity to try to automate as much of the image processing as feasible so that future missions to Mars can be run with small teams of engineers and scientists; b) to provide VR tools to allow geoscientists to focus on the science and not get bogged down with the catalogues and arcane processing steps and; c) to try to ensure that we can exploit the superior geometric qualities of the only photogrammetric instrument (HRSC) to co-register all previous and future Mars oribital imagery including their data fusion with ground-level rover imagery. These developments are aiming to consolidate and spatially unify all of the exploration imagery to date to provide as seamless as possible a virtual exploration of the Martian surface. We describe here a number of these developments including the PRoViP toolkit for processing Mars rover imagery [1]; the PRoGIS web-GIS [2] for exploring what rover imagery has been acquired in a global context; a Java-based stereo workstation developed for platform independent visualisation of Mars rover imagery [3,4]; analysis of what imagery has been acquired since the 1970s for resolutions <120m [5] and recent advances in automated co-registration and its application to super-resolution restoration [6].

Orbital image co-registration: Existing orbital imagery have variable quality in SPICE kernels [6] resulting in existing products not being co-aligned. When applying terrain relief correction to generate orthorectified imagery (ORIs), there is also a need to have very accurate SPICE kernels to ensure that the correct elevation is employed. The HRSC 3D products [7] with georeferencing accuracy of ≤25m represent the best available geospatial reference dataset for co-registering all HiRISE, CTX, THEMIS, MOC-NA and Viking Orbiter imagery. An example of the misregistration errors is shown in Fig. 1 for HiRISE vs HRSC.

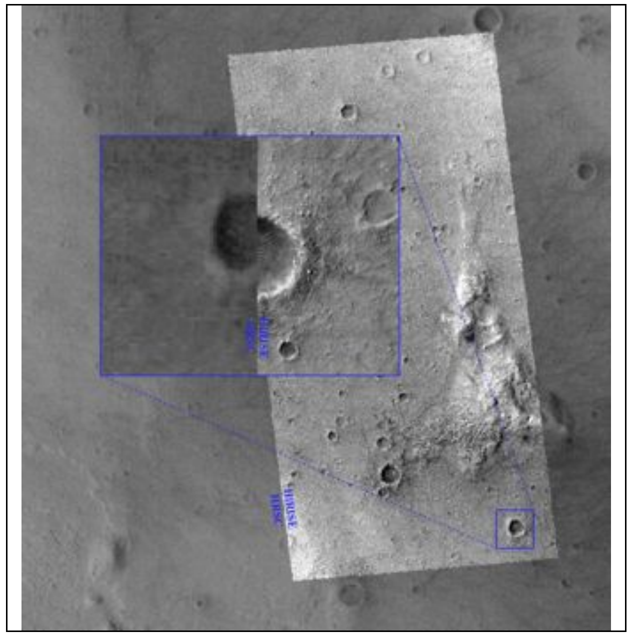

Figure 1. Example swipe view showing misregistration between HiRISE - HRSC ORI over MER-A

Such misregistration can now be minimised and an automated processing chain is being constructed and tested to allow the entire temporal record of orbital imagery to be co-registered to HRSC 3D products.

Rover transect delineation with orbital imagery: Two methods have been used to date for generating a rover transect: Interactive Bundle Adjustment and manual adjustment of rover NavCam ORIs using HiRISE ORIs. We have automated this process by matching common tiepoints between rover NavCam and HiRISE ORI using an extension of the automated co-registration of orbital imagery and now apply this regularly to updating the transect of current missions such as MSL Curiosity or MER-B Opportunity. The updated rover tracks are checked automatically using the rover tracks visible in the HiRISE imagery. An example is shown in Fig.2 for MER-B. The SPICE kernels are subsequently updated to allow the visual fulcra to be corrected using the high resolution DTM. Using these updated kernels and the processed rover imagery, it is possible to perform seamless visualisation through multiple resolutions [6].

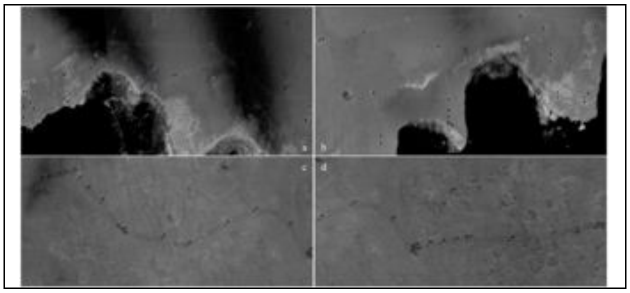

Figure 2. Two sections of the MER-B (a,b) and MSL (c,d) rover tracks showing rover traverses.

On-demand processing of rover imagery within a web-GIS (PRoGIS): PRoGIS is designed to give access to rover image archives in a geographical context, using projected image view cones (fulcra), obtained from updated meta-data as previously described, as a means to interact with and explore the archive. Moreover PRoGIS is more than a source data explorer. It is linked to PRoVIP (Planetary Robotics Vision Image Processing) system which includes photogrammetric processing tools to extract terrain models, compose panoramas, and explore and exploit multi-view stereo (where features on the surface have been imaged from different rover stops).We started with the MER-B rover as our test mission but the system is being applied to MER-A and shortly to MSL. For EU-PRoViDE until the end of 2015[8], we intend to handle lunar and other Martian rover & descent camera data. An example of PRoGIS displaying the fulcra is shown in Figure 3.

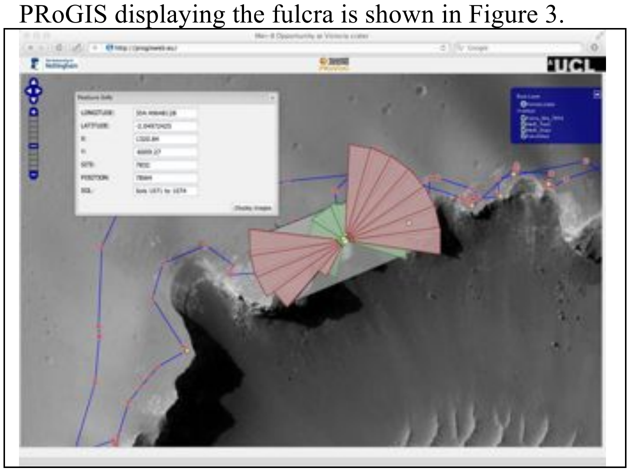

Figure 3. PRoGIS view showing HazCam, NavCam & PanCam in geographic context at Victoria crater

Data mining of changes since the 1970s: The iMars project [9] is developing a processing chain to generate a co-registered time series of all orbital Martian surface imagery over the last 45+ years. A preliminary investigation of all Martian surface imagery has recently been undertaken, assuming that SPICE kernels are accurate to ≤100m (which is doubtful for some older imagery). An example of one of the GIS products is shown in Figure 4 below which shows the existing HRSC DTMs, potential HRSC orbits which could be employed to generate DTMs and CTX stereo-pair which can also be employed in future..

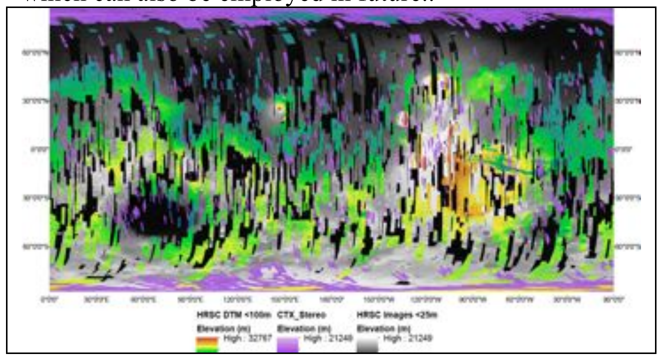

Figure 4. HRSC DTMs (coloured red to blue); CTX stereo-pairs (purple); HRSC image areas (grey); no stereo-pairs yet available of suitable quality (black)

Superresolution restoration of multiple HiRISE: For a very limited number of sites, HiRISE has been acquired multiple times. In the example shown in Figure 5, a 5cm image has been generated from a stack of 8x25cm HiRISE images. The rover track can be clearly seen. This will allow a more seamless rover-orbit view.

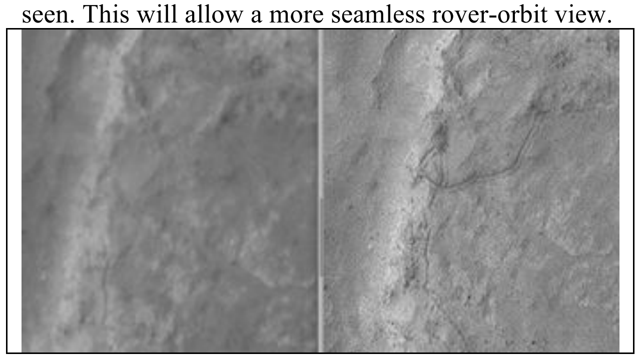

Figure 5. 25cm HiRISE (left) and super-resolution 5cm imagery generated from a stack of 8 inputs.

References: [1] Paar G. (2009) EGU2009-4473-6. [2] Morley J.G. et al (2012) *LPSC 43, 2896*.. [3] Shin D. and Muller J.-P. (2009) EPSC2009-390 [4] Shin D. and Muller J.-P. (2010) EGU2010-10851-1; [5] Sidiropoulos P. and Muller J.-P. (2014) ISPRS-Archives; [6] Tao Y. et al. (2014) ISPRS-Archives; Traxler C. et al (2014) EGU2014-12038; [7] Gwinner et al. (2010) Earth and Planetary Letters, 294:506-519; [8] Paar G. et al (2013) EPSC2013-289-2; [9] Muller J.-P. et al (2014) EGU2014-13744

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