PanCam on the ExoMars 2018 Rover: A Stereo, Multispectral and High-Resolution Camera System to Investigate the Surface of Mars. A.J. Coates[2,3], R. Jaumann[1], N. Schmitz[1], C.E. Leff[2,3], J.-L. Josset[5], A.D. Griffiths[2,3], G. Paar[7], B.K. Hancock[2], , D.P. Barnes[4†], L. Tyler[4], M. Gunn[4], A. Bauer[7], C.R. Cousins[6], F. Trauthan[1], H. Michaelis[1], H. Mosebach[8], S. Gutruf[8], A. Koncz[1], B. Pforte[1], J. Kachlicki[1], R. Terzer[1] & the ExoMars PanCam team. 1 DLR-Institute for Planetary Research, Berlin, Germany, Nicole.Schmitz@dlr.de; 2 Mullard Space Science Laboratory, University College London, UK; 3 Centre for Planetary Science at UCL/Birkbeck, UK; 4 Computer Science Department, Aberystwyth University, UK; 5 Space Exploration Institute, Neuchatel, Switzerland; 6 School of Physics and Astronomy, University of Edinburgh, UK; 7 Joanneum Research, Austria; 8 Kayser-Threde GmbH, Germany.

Introduction: The ExoMars rover will carry a Panoramic Camera System ("PanCam"), which is designed to obtain high-resolution colour and wide-angle multi-spectral stereoscopic panoramic images from the top of the rover mast. The PanCam instrument utilizes two wide angle cameras (WACs), and a High-Resolution Channel (HRC) to map the terrain around the rover and acquire morphological information on the surroundings, while multiple narrow band filters allow the mineral composition of rocks and soils and the concentration of water vapour and the dust optical properties to be measured. Providing these information, PanCam will set the geological and morphological context for the Pasteur payload's investigations. The dedicated high-resolution channel allows for virtually zooming into wide angle panoramas by image mosaicking and furthermore enables high-resolution imaging of inaccessible locations on crater walls and in valleys and to observe retrieved subsurface samples before ingestion into the Sample Preparation and Distribution System (SPDS) of the Pasteur payload. Combined with a "Rover Inspection Mirror" (RIM), placed at the front end of the rover body, engineering images of the rover underside as well as views of the rover wheels for soil mechanics science or views of the underside of overhanging rock formations can be acquired with the HRC.

Figure 1: ExoMars rover, with PanCam on top

Overview of Scientific Goals: PanCam's Scientific goals include fulfilling the digital terrain mapping requirements of the mission as well as providing multi-spectral geological imaging, colour and stereo panoramic imaging, water vapour abundance and dust optical depth measurements [1]:

1. Locate the landing site and science sites and the rover position with respect to local references, by comparison and data fusion with orbital observations.
2. Provide 3D, geological and mineralogical context information for the rover and its environment, including digital elevation models and their proper visualisation.
3. Support rover track planning with geological context of remote objects.
4. Image the acquired surface and subsurface sample(s).
5. Study the properties of the atmosphere and variable phenomena, including water and dust content of the atmosphere.

PanCam Instrument Design: The ExoMars Panoramic Camera System is an imaging suite of three camera heads to be mounted on the ExoMars rover's mast, with the boresight 1.8m above the bottom of the wheels when the rover is on a flat surface. A rover-provided Pan-Tilt Unit (PTU) provides PanCam with a field-of-regard that extends across 360° of azimuth and from zenith to nadir, providing a complete view of the scene around the rover. The PanCam design for Mars (total mass 1.75 kg) includes the following major items:

a) A Wide Angle Camera (WAC) pair, for multi-spectral stereoscopic panoramic imaging, using a miniaturised filter wheel,
b) A High Resolution Camera (HRC) for high resolution uour images,
c) A Pancam Interface Unit (PIU) to provide a single electronic interface,
d) A PanCam Optical Bench (OB) to house PanCam and provide planetary and dust protection. The optical bench is located on a rover-supplied pan-tilt mechanism at the top of the rover mast, at a height of 1.8 m above the surface.
e) A rover deck mounted Colour Calibration Target, and Fiducial Markers for confirming the geometric calibration on Mars.
f) A wide angle Rover Inspection Mirror (RIM).
g) S/W for 3D vision, multispectral processing and visualization.

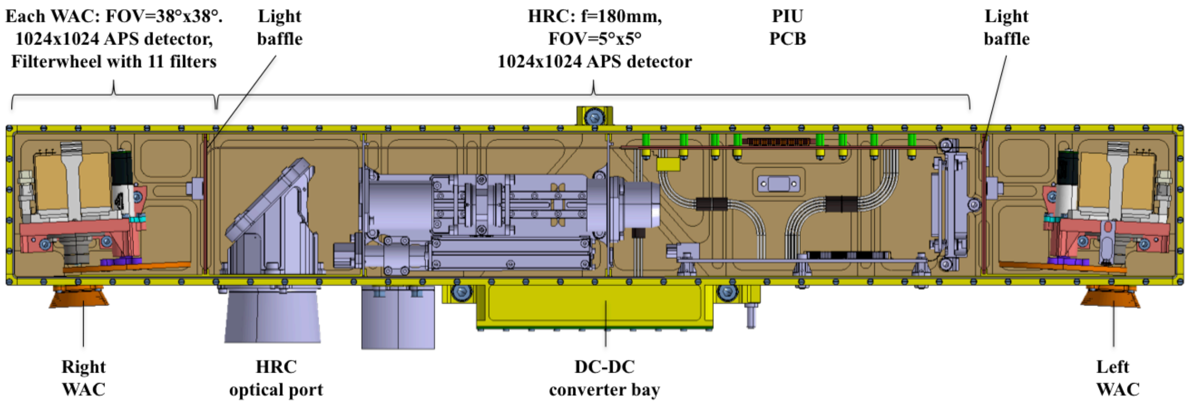

Figure 2: ExoMars PanCam, with left-hand (LH) and right-hand (RH) Wide-Angle Cameras (WAC), High Resolution Camera (HRC), PanCam Interface Unit (PIU), and DC-DC converter

All three PanCam cameras utilize the same 1024 x 1024 pixel CMOS imaging sensor. The two WAC arrays are combined with wide-angle optics and an 11-position filter wheel to form one "eye" of a multispectral stereoscopic imaging system. The stereo baseline of the pair is 500mm, and a toe-in provides adequate stereo parallax. The optics for both WACs are four-element lenses with 22mm focal length and a focal ration of f/10, yielding an IFOV of 652 µrad/pixel or a rectangular field of view of 38.28° x 38.28°. The optimal focus is set to 1.9 m and the focus range extends between 0.85 m (nearest view to the calibration target on the rover deck, tbc) and infinity. 11 filters per "eye" cover different visible and near-infrared wavelengths, as well as neutral density filters for viewing the sun. The filter wavelengths and bandpasses have been optimized for the ExoMars investigation (cf. **Figure 3**)

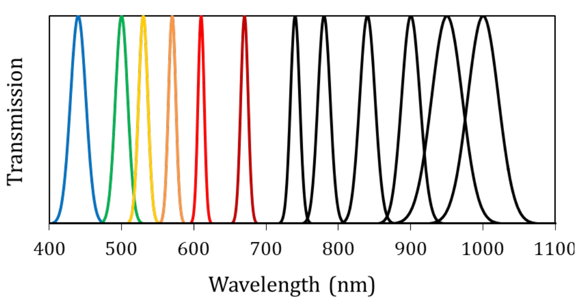

Figure 3: Modelled filter transmission curves for the PanCam „FERRIC" filter set [3].

The HRC imaging array is combined with a Cooke lens triplet with 180mm effective focal length and a focal ration of f/16, yielding a 4.88° x 4.88° square FOV or IFOV of 83µrad/pixel. The high resolution camera is required to focus between 0.98 m (nearest view to a subsurface sample on the rover's sample tray) and infinity. In order to be able to take images over such a wide distance range, the HRC narrow angle optics can be focused with a (auto-) focus mechanism in order to achieve optimum pixel resolution.

Aberystwyth University PanCam Emulator (AUPE) and field trials: A number of ExoMars-related field trials have been performed in the last few years, including participation in recent Arctic Mars Analogue Svalbard Expeditions (AMASE) 2008–2014, (see e.g. [4], [5]), ESA's 2014 „SAFER" rover test, as well as several geological identification tests performed in the field (e.g. [6]) and in the Aberystwyth University Mars analogue facility. For these tests, a representative PanCam simulator [7] was used, provided by Aberystwyth University. These campaigns have been used, in combination with teams from other ExoMars instruments, to develop working procedures representative of a mission to Mars, as well as to test instrument performance, develop calibration techniques and pursue scientific investigations of particular Mars-analogue areas. Selected results will be presented.

References: [1] Coates et al., Lunar PanCam: Adapting ExoMars PanCam for the ESA Lunar Lander. http://dx.doi.org/10.1016/j.pss.2012.07.017; [2] Jaumann et al., 2010, The PanCam instrument on the 2018 Exomars rover: Scientific objectives, EGU 2010; [3] Cousins et al., 2012, Selecting the geology filter wavelengths for the ExoMars Panoramic Camera instrument, PSS 71, 80-100; [4] Steele et al., Arctic Mars Analogue Svalbard Expedition (AMASE) 2009, LPI Contribution No. 1533, p.2398, 2010. [5] Schmitz et al., 2009, Field Test of the ExoMars Panoramic Camera in the High Arctic. EGU 2009, p.1062, 2009. [6] Cousins et al., 2013, Mars analogue glaciovolcanic hydrothermal environments in Iceland: detection and implications for astrobiology. JVGR, 256, 61 – 77 [7] Pugh et al., 2012, AUPE – A PanCam emulator for the ExoMars 2018 mission. Int. Symposium on Artificial Intelligence, Robotics and Automation in Space.