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The High Resolution Stereo Camera (HRSC): 10 Years of Imaging Mars.

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The HRSC Experiment: Imagery is the major source for our current understanding of the geologic evolution of Mars in qualitative and quantitative terms. Imaging is required to enhance our knowledge of Mars with respect to geological processes occurring on local, regional and global scales and is an essential prerequisite for detailed surface exploration. The High Resolution Stereo Camera (HRSC) of ESA's Mars Express Mission (MEx) is designed to simultaneously map the morphology, topography, structure and geologic context of the surface of Mars as well as atmospheric phenomena [1].

The HRSC directly addresses two of the main scientific goals of the Mars Express mission: (1) High-resolution three-dimensional photogeologic surface exploration and (2) the investigation of surface-atmosphere interactions over time; and significantly supports: (3) the study of atmospheric phenomena by multi-angle coverage and limb sounding as well as (4) multispectral mapping by providing high-resolution three-dimensional color context information. In addition, the stereoscopic imagery will especially characterize landing sites and their geologic context [1]. The HRSC surface resolution and the digital terrain models bridge the gap in scales between highest ground resolution images (e.g., HiRISE) and global coverage observations (e.g., Viking). This is also the case with respect to DTMs (e.g., MOLA and local high-resolution DTMs). HRSC is also used as cartographic basis to correlate between panchromatic and multispectral stereo data. The unique multi-angle imaging technique of the HRSC supports its stereo capability by providing not only a stereo triplet but also a stereo quintuplet, making the photogrammetric processing very robust [1, 3]. The capabilities for three dimensional orbital reconnaissance of the Martian surface are ideally met by HRSC making this camera unique in the international Mars exploration effort.

Imaging Capabilities: The HRSC is a multi-sensor push broom instrument comprising 9 CCD line sensors mounted in parallel for simultaneous high resolution stereo, multicolour and multi-phase imaging by delivering 9 superimposed image swaths [1, 2]. Its design permits stereo imaging with triple to quintuple panchromatic along-track stereo including a nadir-directed, forward- and aft-looking (+/- 18.9°), and 2 inner (+/- 12.8°) stereo line sensors. Their spectral range covers 675 ± 90 nm. The along-track acquisition of stereo imagery reduces the influence of changes in atmospheric and illumination conditions, which so far have caused problems in the photogrammetric analysis of stereo images acquired at different observation times. The triple to quintuple stereo images permit robust stereo reconstruction, yielding Digital Terrain Models (DTMs) at a 3D accuracy better than the pixel resolution of the images.

The 5 panchromatic images are also used for multi-phase imaging allowing the determination of photometric surface characteristics. Multispectral imaging is realized by four line sensors in the blue, green, red and near infrared colour ranges (440 ± 45 nm, 530 ± 45 nm, 750 ± 20 nm, 970 ± 45 nm). All nine lines sensors have a cross track field of view of ± 6°. They are mounted behind a single optics. High-level image processing results in radiometrically corrected and orthorectified nadir and colour images as well as high precision DTMs (level 4), all of which are available via multiple platforms (see below). In addition, rectified images using the MOLA DTM as basis for orthorectification are produced (level 3).

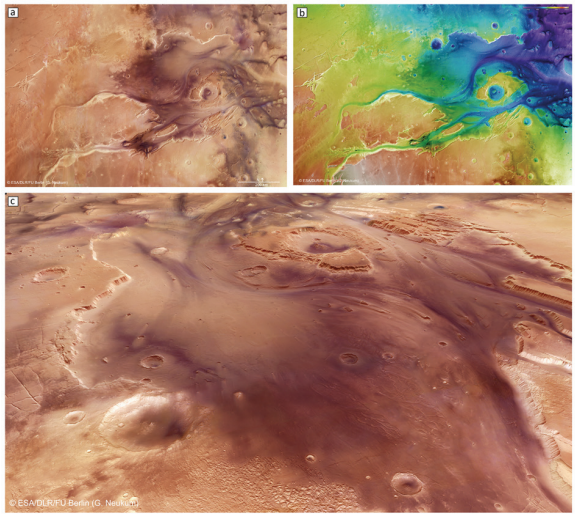

Fig. 1: HRSC view of the giant Kasei Vallis outflow channel on Mars. (a) Pansharped color mosaic. (b) Color-coded DTM. (c) 3D perspective view using image and DTM data. Image credit: ESA/DLR/FU Berlin.

The individual images can be mosaicked to regional expanding image or DTM datasets (Fig. 1a, b) and turned into 3D-perspective views (Fig 1c) or anaglyphs.

Coverage: After 10 years of orbiting the planet, HRSC has covered more than 90 % of the surface with image resolutions up to 10 m/pixel (Fig. 2a, 3). By the time of writing, the HRSC has taken more than 4166 image sequences acquired during 3894 orbits of image acquisition (MEx flew a total of 13047 orbits by now). High precision digital elevation models of up to 50 m grid spacing, generated from all suitable datasets of stereo coverage, currently cover about 40 % of the surface (Fig. 2b).

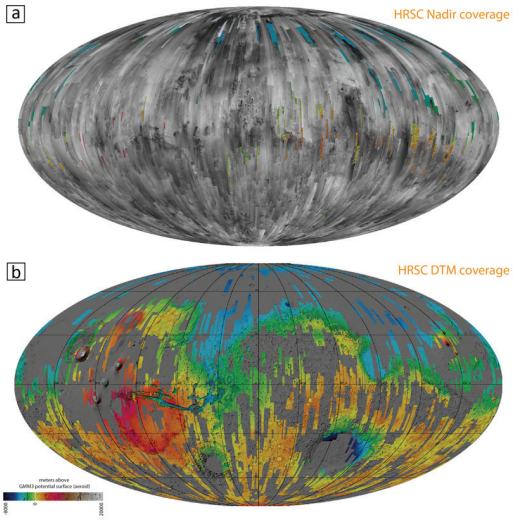

Fig. 2: HRSC coverage maps. (a) Global HRSC nadir mosaic (grey) draped onto color-coded MOLA topography. Highest orbit number is h13021. (b) Global color-coded HRSC DTM mosaic draped onto MOLA shaded relief map in grey. Highest orbit number is h6509.

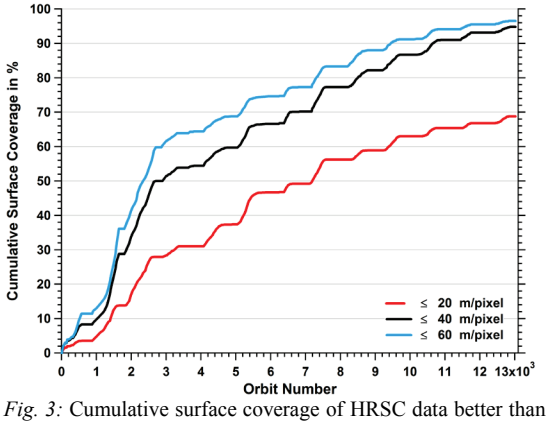

Fig. 3: Cumulative surface coverage of HRSC data better than 20, 40 and 60 m/pixel gained during the last 10 years of image acquisition. Last counted image number is h13021.

Scientific Achievements: HRSC continues yielding numerous scientific results in a variety of geological topics [e.g., 5, 6, 7, 8]. Parts of the accomplishments of the last years are collected in the Earth and Planetary Science Letters special issue *"Mars Express after 6 Years in Orbit"* of 2010 [e.g., 9, 10]. Recent results on the Martian Moons based on HRSC data are summarized in the 2014 PSS special issue on Phobos and Deimos [e.g., 11, 12, 13]. Another Mars Express special issue in PSS on occasion of the 10th mission anniversary is currently under preparation and will include an HRSC experiment status paper [14] and a synthesis of scientific findings of the last ten years [15].

Data download platforms:

http://www.rssd.esa.int/index.php?project=PSA (PSA)
http://ode.rsl.wustl.edu/mars/ (PDS)
http://europlanet.dlr.de/mex/ (Europlanet)
http://maps.planet.fu-berlin.de (FU Berlin)
https://jmars.mars.asu.edu/ (JMARS)
http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10333/ (Mars Express @ DLR)

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