A "NEW" SCIENTIFIC CAMERA AROUND MARS, GETTING SCIENCE WITH VISUAL MONITORING CAMERA ONBOARD MARS EXPRESS

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Introduction:

The Mars Express (MEX) wide angle Visual Monitoring Camera (VMC) provides a unique global view of Mars but so far it has been devoted to engineering tasks (verification of the Beagle-2 lander separation), and public outreach and educational activities.

The strong science potential of the Visual Monitoring Camera has been recognized in the past years in the investigation of the cloud morphology and dynamics, the aerosols and dust, and the polar caps by providing wide-angle context images and encouraged systematic use of VMC observations for science purposes.

This contribution describes a new project funded by the ESA Mars Express mission to improve the science exploitation of the MEX VMC camera, comprising all the necessary scientific and technical support areas to make sure the final data is scientifically useful for the community, starting with the analysis and preparation of VMC observations, the adaptation of the existing data processing pipelines and the final archiving and distribution of the data files to the community, as well as some support for scientific calibration and analysis of the images.

Reactivation of VMC camera and use for Public Relations and Educations

Mars Express was launched in 2003 with a simple, low-resolution camera to provide visual confirmation that its Beagle 2 lander had separated. Once that was done, the camera was switched off for many years, and the mission started working at full speed with its main scientific mission using the scientific instrumentation.

After some years of successful science operations, in 2007 ESA decided to switch the VMC back on for testing to check whether it was still operational and it could still be used, with potential for education or science outreach, without interfering with routine operations or the mission's prime science investigations. The camera's uniquely wide field of view allowed to capture global images of the red planet, providing a wider context while the other scientific instruments were focusing on more specific targets.

The public outreach and education potential of the VMC camera has been well proven since the camera was reactivated, including posting of images on a dedicated web site (blogs.esa.int/vmc) and image browser immediately after their acquisition and performing dedicated communications and education campaigns. In recent years, the camera's Twitter (@esamarswebcam) channel has generated over 10 million views, while the photo archive in Flickr (www.flickr.com/esa_marswebcam) has generated 1.7 million views/downloads. A series of VMC student and youth outreach activities - including ESA's first-ever invitation to the public to submit imaging requests - have created a great deal of positive engagement. Overall, ESA's VMC outreach has been very positively received as a solid example of open science support, and future projects are now in development to include VMC as part of ESA's education program CESAR.

Scientific potential of VMC images:

Wide angle cameras on planetary missions have been extensively used for monitoring of atmospheres, cloud morphology, dynamical phenomena, and temporal changes on the surface, i.e. in those science tasks that can be fulfilled by an instrument with moderate spatial resolution but benefiting from regular semi-global observations of a planet. Good examples of the efficiency of such simple instruments with relatively low resource demands are presented by the Venus Monitoring Camera/Venus Express, Mars Orbiter Camera (MOC)/MGS, and Mars Color Imager (MARCI)/MRO. Such observations have been used to study Venus cloud morphology (Titov et al., 2012), catalog dust storms and their tracks on Mars (Cantor et al., 2001; Wang and Richardson, 2015; Guzevich et al., 2015), examine Mars water ice clouds (Wang and Ingersoll, 2002; Benson et al., 2006), track the expansion and contraction of the Mars polar ice caps (James et al., 2001; James and Cantor, 2001) and monitor the growth and decay of Mars global dust storms (Strausberg et al., 2005; Cantor, 2007).

The VMC images acquired in the past years for public outreach purposes have clearly shown the significant science potential of these observations. They address several important science objectives of Mars Express and complement investigations by the main payload. VMC imaging can be used to study *cloud morphology and dynamics (Fig. 1)*. The imag-

es taken in quasi-nadir geometry clearly show cloud systems, their morphology and dynamics. Tracking the cloud features in image sequences would enable the reconstruction of wind patterns. Limb observations reveal the vertical structure of the atmospheric dust distribution and detached aerosol layers. Observations of the terminator region can capture high altitude clouds. This context imaging would provide a valuable support to the OMEGA, HRSC and SPICAM observations, which are part of MEX's payload.

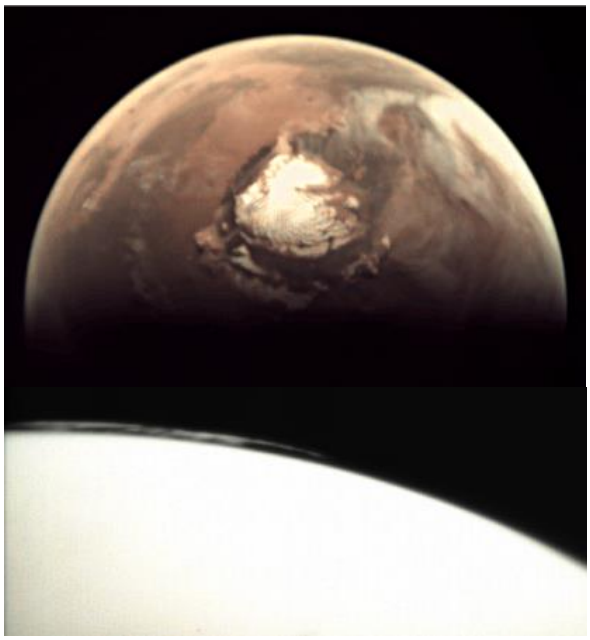

Figure 1. *VMC images of clouds in the Mars atmosphere: cloud system in the Northern polar region (upper right of the top image) and detached cloud layer at the Mars limb (bottom image).*

Imaging of specific surface features (e.g. Valles Marineris, Tharsis volcanoes, Hellas basin) can enable detection and monitoring evolution of aerosol systems associated with these topographic peculiarities, such as the formation of fog, cloud "tails", Lee waves, etc. (Fig. 2).

Figure 2. *Example of aerosols related to specific surface features: Valles Marineris filled with fog.*

The *physics and evolution of dust storms* on both local and global scales can be derived from regular imaging of Mars (Fig. 3). These observations would help to establish statistics and climatology of one of the most remarkable phenomenon in the martian atmosphere. Combined with simultaneous temperature sounding by the PFS and MaRS experiments on MEX, these observations would allow one to better understand the coupling between temperature structures and dust loading as well as improve the understanding of mechanisms of dust storm evolution.

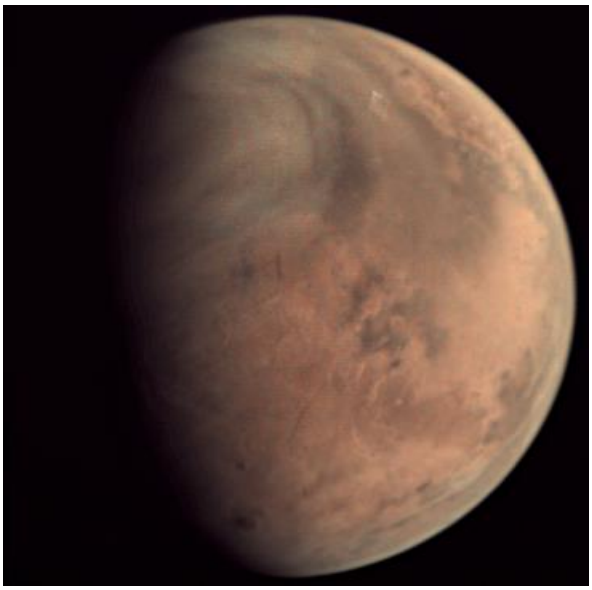

Figure 3. *VMC image of possible dust storm clouds in the Northern polar region.*

VMC is also capable of monitoring the *seasonal evolution of Mars' polar caps* by regular imaging of the polar regions to contribute to the understanding of the polar caps' behaviour (Fig. 4) thus complementing the mapping performed by the HRSC and OMEGA experiments on MEX.

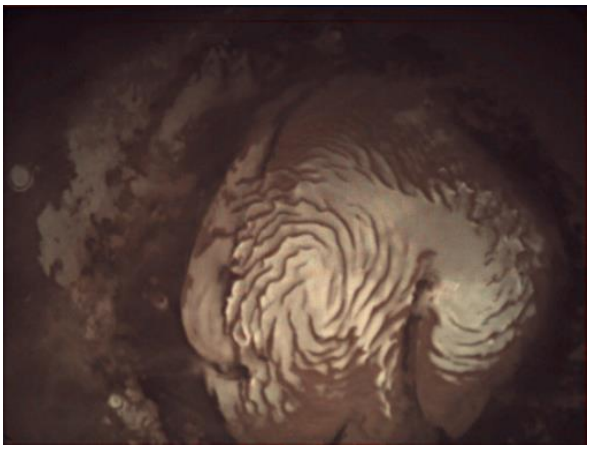

Figure 4. *VMC image of the Northern polar cap at close approach during a full orbit test "movie".*

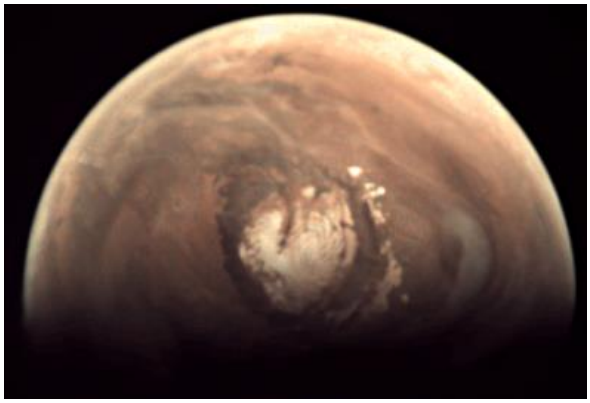

Figure 4. *VMC images of the polar caps: North polar cap at close approach and further distance.*

The VMC observations are strongly complementary to similar imaging by wide angle cameras onboard the NASA spacecraft: MOC/ MGS and MARCI/ MRO. Both of them are in low Sun-synchronous orbits. Therefore, imaging by MOC and MARCI is limited to relatively narrow swaths around fixed local solar times. The non-Sun-synchronous elliptical orbit of Mars Express enables imaging of the planet with spatial coverage from regional to global scales at all local solar times. Also the VMC imaging that started in 2007 would complement and extend the time record provided by MOC/MGS (Sept 1997-Nov 2006) and MARCI/ MRO (2006-now).

Boosting science with VMC: Scientific and Technical Support for science data exploitation

In 2016 ESA reached an agreement to support the technical and scientific activities of the VMC camera in order to improve and facilitate the scientific exploitation of the data by the community. This new project is funded by the Mars Express mission in an international collaboration between ESA's three main sites *ESTEC*, *ESAC* and *ESOC*, with the *University of Pais Vasco* and the company *Dias Almeida Data Processing Systems*, to provide all the necessary support for the adaptation of the existing VMC data pipeline to cover all aspects of a science instrument, including scientific analysis and technical development in various areas with the final goal of facilitating the scientific exploitation of VMC images. This will include both adjusting the current VMC pipeline developed at ESOC with some of the algorithms provided by external contributors, and support the development of new tools for the preparation of science observations, processing of the data at various levels for science analysis, and final archiving.

Acknowledgements
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Wang, H., Ingersoll, A.P., 2002. Martian clouds observed by Mars Global Surveyor Mars Orbiter Camera. J. Geophys. Res. 107 (E10), 5078. http://dx.doi.org/10.1029/2001JE001815

Public Outreach Web References

VMC blog:
http://blogs.esa.int/vmc/

VMC twitter:
https://twitter.com/esamarswebcam

VMC image archive:
http://www.flickr.com/esa_marswebcam

VMC picture of Beagle 2 lander separation:
http://www.esa.int/Our_Activities/Space_Science/Mars_Express/Mars_Express_releases_Beagle_2

CESAR ESA Education Project:
http://www.cosmos.esa.int/web/cesar