From engineering to science: Mars Express Visual Monitoring Camera's first science data release

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1. Introduction

The European Space Agency (ESA) mission ‘Mars Express’ (MEX) launched in 2003 equipped with seven instruments. The Visual Monitoring Camera (VMC) on board MEX was designed to monitor the release of the Beagle 2 lander, but was switched back on again in 2007. In the following years, in addition to helping engage the general public with the MEX mission [1] VMC images were used for atmospheric studies [2,3] and subsequently the camera was ‘upgraded’ to a scientific instrument in 2016. Hence, the mission ‘gained’ a scientific instrument in the form of the VMC. The scientific success [4] of this small camera is a part of the larger success story of Europe’s first Mars mission, serving as an example of how planetary missions can exceed and build upon their original expectations. This work details the journey of VMC from an engineering to a scientific instrument, including how VMC is operated, how the data is calibrated, and examples of the scientific work that has been undertaken with VMC data, images of which are exemplified in Figure 1.
2. Instrument Operations

The VMC is a 640x480 pixel camera with a large field of view (FOV) of ~40 x 31°. The wide FOV allows the camera to capture both the entire disk of Mars within the image and to perform observations over a wide portion of the limb. When taken in combination with the elliptical orbit of MEX, this enables observations at different local times and distances. VMC has a different data protocol and is offset from other instruments by 19°, and for these reasons cannot observe at the same time as other instruments on MEX. Since 2018, planning for the VMC has been integrated with planning for the other payload instruments, which takes place at the European Space Astronomy Centre (ESAC). This integration has increased both the quantity and the types of observations performed by VMC (Figures 2 and 3).

**Figure 1:** Examples of VMC images processed using the European Space Astronomy Centre (ESAC) VMC data pipeline in Madrid. From top left to bottom right: a cloud over Olympus Mons; the North Polar cap; a dust storm over the North Polar cap; Valles Marineris. Image credit: ESA/UPV-EHU.
Figure 2. The different types of VMC observations, these being apocentre, pericentre, and limb observations. Panel (1) is an example of an apocentre observation, panel (2) is an example of a pericentre observation, and panel (3) and (4) are examples of limb observations. Image credit: ESA/UPV-EHU.
3. Data Calibration

The VMC team has performed in situ calibration for VMC since no on-ground calibration exists for the instrument (discussed in [5]). Observations of dark sky were taken to create a master dark-current file for dark-current correction. Dark-corrected images of flat portions of Mars taken at pericentre that were well and uniformly illuminated, as free as possible from large structures and as flat as possible were used to create a file for flat-field correction. The boresight offset of VMC has also been calculated by comparing the location of stars in VMC images with the stars’ known positions given by the SPICE geometry information system.

4. Data Processing and Archiving

Since [5], the VMC pipeline has been updated in collaboration with the science team at UPV-EHU Bilbao. VMC data are dark-corrected, flat-fielded, and are now provided in raw, FITS and PNG formats. The VMC pipeline runs at ESAC and is utilised by the VMC science team, and the current dataset from 2007 to the present totals ~50,000 images distributed across ~3000 observations. VMC data for scientific usage have been prepared for ingestion into the Planetary Science Archives (PSA) over the summer of 2020. This will be the first science data release from the instrument, thereby augmenting the already extensive wealth of data obtained from Mars Express over the last 17 years. Data from the VMC instrument continue to be available for outreach purposes through Twitter and Flickr (@esamarswebcam, Flickr: https://www.flickr.com/photos/esa_marswebcam/).

5. Scientific Success

The regional and global scale atmospheric dynamics of Mars are fast-paced and so a high temporal resolution of observations at various local times is required to help us understand and constrain how such dynamics develop. As previously mentioned, the wide FOV of VMC coupled with the highly elliptical orbit of MEX allows VMC to take observations at diverse local times and therefore to capture these large-scale atmospheric phenomena (Figure 4). VMC images are taken approximately every ~48 seconds depending on exposure time, and so the science team has been able to stack images from the same observation and also produce mosaics and videos showing the movements of aerosols. VMC data has been used for the analysis of the Arsia Mons cloud [6]; a recurrent double

Figure 3: Number of VMC observations for each year. VMC observations have increased to over 400 a year since science planning was moved to the European Space Astronomy Centre (ESAC) in 2018.
cyclone in the north polar region [7]; the 2018 global dust storm [8] and local dust storms in 2019 [9]; and ‘twilight clouds’ in the Martian night [10].

**Figure 4.** Examples of VMC science applications. Image credit: ESA/UPV-EHU.

**References:**


