EMIRATES MARS MISSION 2020: EMIRATES EXPLORATION IMAGER (EXI) STATUS UPDATE

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Introduction: The Emirates eXploration Imager (EXI) is a camera system onboard the Emirates Mars Mission (EMM), which went into orbit around Mars on February 9, 2021. The goal of EMM is to explore the dynamics of the Martian atmosphere across diurnal and seasonal timescales (e.g., Amiri et al., 2022). A particular focus of the mission is the circulation of the lower atmosphere and the connections to the upward transport of energy of the escaping atmospheric particles from the upper atmosphere. EXI is one of three complementary scientific instruments chosen to accomplish this goal (e.g., Almatroushi et al., 2021). The instruments and their specific goals have been described in detail elsewhere (Emirates Mars InfraRed Spectrometer (EMIRS) - Edwards et al, 2021; Emirates Mars Ultraviolet Spectrometer (EMUS) – Holsclaw et al, 2021; EXI - Jones et al., 2021). In this presentation, we will provide a very brief overview of several aspects of EXI. However, the focus of our presentation (but not necessarily in this abstract) will be a series of on-orbit status updates.

Brief Instrument Description: As mentioned above, EXI is described in detail by Jones et al. (2021). EXI is a multi-band, camera capable of taking 12- megapixel images. Given the science orbit of EMM, this translates to a spatial resolution of 2-4 km per un-binned pixel. It employs a filter-wheel mechanism consisting of 6 discrete bandpass filters that sample the optical spectral region. This are listed in Table 1.

Table 1: EXI Bandpass Description

Channel	λ_0 (nm)	FWHM (nm)
f220	250	107
f260	264	48.3
f320	321	24.1
f437	437	14.2
f546	546	15.0
f635	637	14.5

Radiometric fidelity is optimized while simplifying the optical design by separating the ultraviolet (UV) and visible (VIS) optical paths. The filters are naturally associated with a particular channel: UV(f220, f260, f320) and VIS (f437, f56, f635). An image cross section shown in Figure 1.

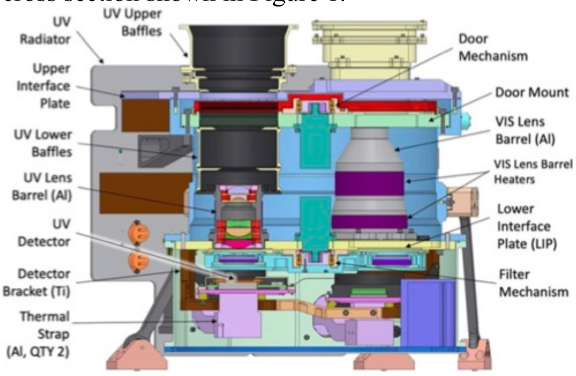

Figure 1 - Instrument cross section (after Figure 2 of Jones et al., 2021).

The instrument was developed jointly by the Mohammed Bin Rashid Space Centre (MBRSC), Dubai, UAE, and the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado, Boulder, USA. The instrument underwent an extensive ground-calibration effort, and included the following tests, Field of View Mapping (FOV), Focus/distortion mapping, Flat field/Broadband radiometry, Bandpass shape/Absolute radiance mapping. The calibration activities and their results were described by Jones et al. (2021).

In-flight Updates: During cruise and orbital operations, observations were obtained that allowed us to improve/update certain aspects of the instrument calibration with respect to the pre-flight values. These will be provided as part of our presentation, but we provide some current information in this abstract:

Radiometric Performance. EXI regularly observes two UV standard stars: α-Lyrae (Vega) and η-Ursae Majoris (η-UMa). These stars are part of a standard star program carried out by the Hubble Space Telescope; and have well characterized spectra (Bohln et al., 2001; 2019;

https://www.eso.org/sci/observing/tools/standards/spectra/hststandards.html). Using a combination of stellar photometry and the EXI instrument performance (i.e., bandpasses and spectral response), the conversions from Data Number to irradiance can be derived. Although still updated/finalized at the time of this abstract, the radiometric accuracy/precision of each band is summarized in Table 2. **Updates will be providing during our presentation.**

Table 2: Radiometric Accuracy of EXI

Channel	precision	Notes
F220	< 5%	Bandpass much wider than designed; see Table 1
F260	< 10-20%	This is due to out-of-band visible light; correction being developed
F320	< 5%	
F437	--	Awaiting additional more η-Uma observations, expected to be similar to f635
F546	--	See f437
F635	< 5%	

Camera Model and Pointing Offsets. The use of EXI data for remote sensing assumes the ability to map a pixel location to a physical coordinate system and associated directional cosines with a reference surface. However, a starting point is an undistorted detector frame. The camera model of EXI removes this distortion, introduced by the lens system. In addition, the orientation of the EXI optical axis with respect to the spacecraft reference frame(s) is necessary. Although it appears that this knowledge is accurate to a few pixels in each band, we are still actively attempting to quantify and improve on this result, our goal is to be provide registration to within a single pixel. **The status of this effort will be presented**.

eXi Observation Sets (XOS). There are two “workhorse” sets of observations for EXI, the so-called XOS-1 and XOS-2.

XOS-1 consists of 5 filters (f220 is not a part of this XOS because of the wide bandpass, i.e., it is not useful for the intended purpose of the dust column retrieval). In order to maximize the number of observations with respect to available data volume, on-chip binning is used: three bands employ 2×2 binning model (f260, f320, f635) and the other two use 4×4 (f437, f536).

XOS-2 includes all six filters but is heavily summed: 16×16. Because of the small data volume, it was decided to keep the f220 image to allow for its potential use in monitoring in the degradation in the UV throughput. The XOS-2 is used after an EMIRS observation to capture any pixels that were observed by EMIRS but not present in the XOS-1. This order of observations can be seen in the schematic in Figure 2.

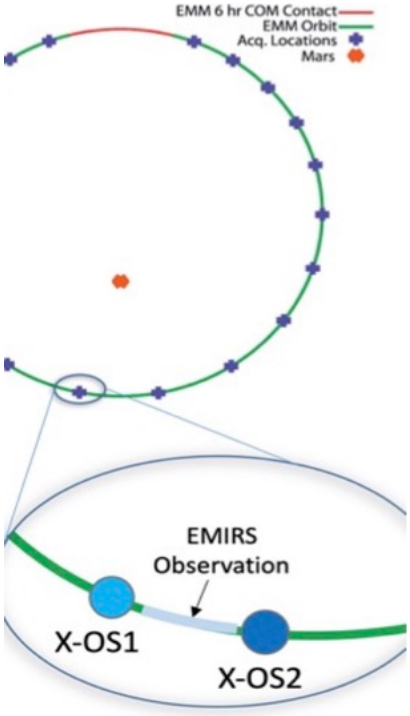

Figure 2: Schematic representation of the use of XOS-1 and XOS-2 with respect to a standard EMIRS observation.

Additional XOS have been defined since launch as well as some no longer being used. **A list of XOS potentially relevant to the community will be summarized in our presentation.**

Figure 3 - Color image created through an automated processing of a the RGB channels of a Level 2B file for an observation in early December 2021.

Data Levels. There have been some changes to the design of the various levels of data products since launch Jones et al. (2021) versus those provided by the Science Data Center (see URL in references). In addition, a particular product is still being developed that is map-project data cube (the so-called Level 2B), which allows for easy generation of registered, multi-band color (e.g., RGB color) such as seen in Figure 3. This removes the effect of spacecraft motion, planetary rotation, and offsets between the UV and VIS detector FOVs. Any of the channels can be wrapped around a globe again to provide an image without the camera distortion discussed above. See Figure 4.

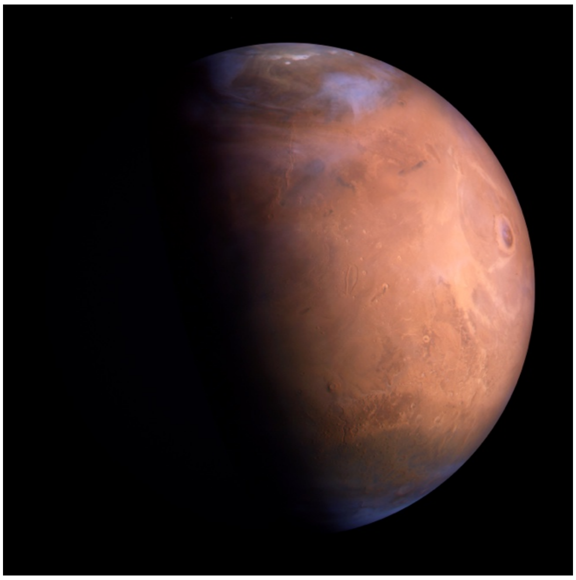

Figure 4: The Level 2B-based product shown in Figure 3 wrapped around a globe to provide the original observational perspective, but without the effects of camera distortion.

Also being finalized is the so-called Level 3 water ice cloud optical product (which is the focus of the analyses presented by Wolff et al. elsewhere at this conference). **These two formats, as well as those discussed in the current EXI Data Guide (2022), will be summarized in our presentation.**

EXI in the Science Data Center (SDC): The EXI team is developing the concept of calibration memos and instrument science reports which will be distributed through the Science Data Center Archive (see URL in references). These are meant to address topics that are beyond the scope of the EXI Data Product Guide. Examples include the analyses and details behind such things as the Top-Of-the-Atmosphere Solar flux values and the radiometric conversion coefficients found in the data product headers. **These efforts will be summarized in our presentation**.

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