EYES IN THE SKY WITH THE EXOMARS TRACE GAS ORBITER MARS ATMOSPHERIC GLOBAL IMAGING EXPERIMENT (TGO-MAGIE).

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Introduction: In August 2010, the Mars Atmospheric Global Imaging Experiment (MAGIE) was one of five instruments selected to fly on the joint ESA/NASA ExoMars Trace Gas Orbiter (TGO) mission. The scientific objectives of the TGO mission are to detect a broad range of atmospheric trace gases, characterize their spatial and temporal variability, and localize potential source/sink regions [1]. The TGO spacecraft is presently planned to arrive at Mars in October 2016. Following the 6-9 months of aerobraking, the spacecraft will reach its planned orbit: ~74° inclination, ~400 km altitude, non sun-synchronous, 2-hour circular orbit. The primary scientific mission will begin shortly thereafter and last for 1 Mars year.

Instrument Description: MAGIE is a low-resolution, wide-angle "push-frame" imaging system (Figure. 1). The various elements of the system have a high degree of heritage from previous flight imaging systems, including the MER PANCAM mast, MRO MARCI, and MSL Mastcam, MAHLI, and MARDI. MAGIE consists of two visible filters (centered at 420 nm and 650 nm) and 2 ultraviolet filters (centered at 260 nm and 320 nm), with separate input optics for the visible and ultraviolet [2]. The intrinsic resolution at the nadir is ~480 m/pixel (unsummed) in the visible and ~7680 m/pixel (summed) in the ultraviolet. The ~140° FOV of the primary optics in the crosstrack direction provides limb-to-limb imaging on the dayside of each orbital pass. Over the course of a day (12-13 orbits), MAGIE will image the entire illuminated portion of the planet in all 4-filter bands, including the limbs for the two visible filters. The percentage of "global coverage" obtained daily will vary throughout the course of the mission because of the non sun-synchronous nature of the science orbit (i.e., it will depend on the time of day of the orbit). Fortunately, when the orbital passes occur within the mid-morning to mid-afternoon timeframe, the altitude of the TGO orbit allows for more complete overlapping coverage between consecutive orbits, producing fewer gaps in the global mapping than those seen in the MRO MARCI data-set.

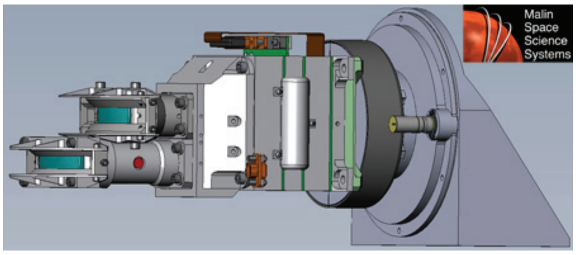

Figure 1. MAGIE camera including turntable and mounting bracket.

Objectives: In support of the overarching mission objectives, MAGIE's objectives are to:

1. Provide Meteorological Context for Trace Gas Observations: MAGIE will provide daily images that document the state of the Martian atmosphere (Figure. 2) at the same time that the TGO's trace gas detection instruments are observing. Nominally, MAGIE images will document weather conditions (condensate clouds, dust clouds, and active dust-raising events) on the entire illuminated portion of Mars on each orbit.

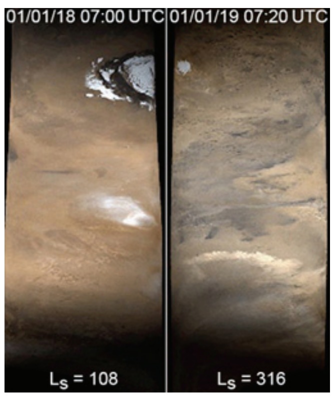

Figure 2. False color image swathes we expect to obtain at different times of day and seasons.

2. Map the Occurrence of Atmospheric Ozone: MAGIE provides daily UV images used to map the spatial and diurnal and seasonal distribution of ozone (O_3) (Figure. 3). Ozone is an important constituent of the Martian atmosphere due to its ability to be used as a tracer for photochemical models, as such, it is highly relevant to overall Mars atmosphere trace gas research. More specifically, ozone is a sensitive chemical tracer for hydrogen photochemistry in the Martian atmosphere [3], and thus knowledge of O_3 abundance can constrain GCM across the planet at all seasons and times of day. As is currently being done by the MRO MARCI team with MARCI's 2 UV-channel images [4-7], the ratio maps and ozone column density maps will be produced from MAGIE's UV images. These retrievals will characterize the temporal and spatial variations of Mars atmospheric O_3 and allow for correlations with hydrogen photochemistry and H_2O vapor abundances.

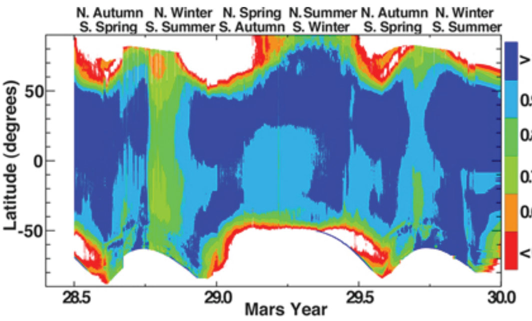

Figure 3. MARCI UV ratio map showing the latitudinal distribution of ozone as a function of Mars year.

3. Provide Geological/Surface Context for Trace Gas Observations: MAGIE daily global images (~ 4-7.7 km/pixel) and higher resolution nadir image sub-frames (480 m/pixel) provide an opportunity to connect inferences and interpretations regarding spatial and temporal variability of trace gas abundances (linked with the question of sources and sinks) to potential geological processes. Most features and processes that may be linked to trace gas emission or sequestration/destruction are either likely to be too small to observe with MAGIE (e.g., landform gradation due to sublimation of volatiles, mud volcanoes, new gully flows) or may be difficult to connect with images of any resolution and scale (adsorption in the regolith). However, there are some processes amenable to and relevant to MAGIE observations (e.g., volcanic or hydromagmatic eruptions, dust-lifting event, seasonal frost deposition or retreat, surface albedo changes, and new large impact crater releasing subsurface volatiles.

4. Extend the Daily Global Meteorological Record: MAGIE data are vital for long-term prediction and understanding of Martian meteorology and GCM validation. MAGIE will continue and extend the record of daily global images (Figure. 4) documenting the dynamic state of the atmosphere (dust storms, clouds) and surface (seasonal frost, albedo change) begun using the MGS MOC wide-angle cameras in March 1999 [8-14]. An effort that continues using MRO MARCI [9, 15-17] and now includes the same two UV bands as will be employed in MAGIE to monitor atmospheric O_3 and H_2O condensate opacity [18-19]. This record, now spanning more than 6 Mars years, has very few interruptions (e.g., communications outages due to solar conjunction periods and spacecraft upsets as well as small gores induced by spacecraft off-nadir slews). MAGIE will extend this record—if the MRO MARCI were to continue sending back data until MAGIE arrives, then the full record would span a little more than 10 Mars years by the end of the TGO Primary Mission. Unfortunately, TGO constraints on downlink data-rates will typically limit visible wavelength daily global monitoring to ~4 km/pixel resolution, which is between that of MOC and MARCI. Nevertheless, such data will not only provide a vital record—useful for prediction of future conditions—they provide the opportunity to further validate/constrain GCMs [20-22], which, in turn, are also used to predict future conditions and elucidate climate conditions in the more distant past.

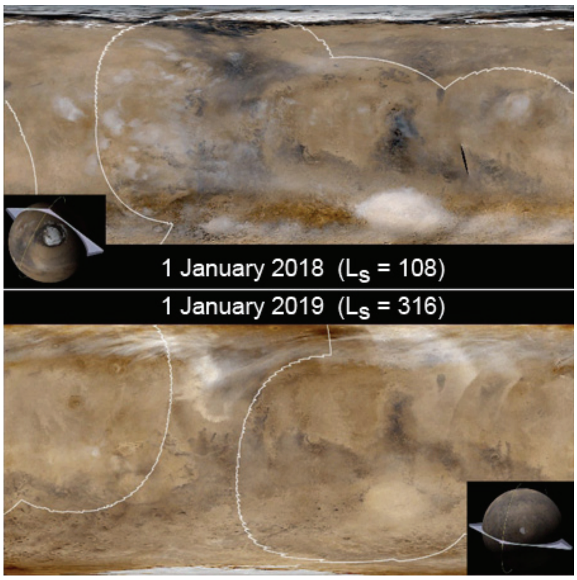

Figure 4. Daily global map coverage we can expect at different times of day and at different seasons. White line indicates the coverage of a single image swathe. Basemaps are from false-color global maps obtained by MOC, which were resampled based on TGO orbit and MAGIE FOV (small, global insets).

5. Provide Meteorological Support for 2018 and 2020s Mars Missions: Since July 2007, orbiter wide-angle cameras for meteorological monitoring (MGS MOC and MRO MARCI), have been used to support every U.S. Mars mission since the Mars

Pathfinder (MPF) [23]. The periods of interest have been those of elevated atmospheric dust opacity (i.e., regional- to planetary-scale dust storm activity) that may impact efforts in orbiter aerobraking (MOC supported MGS, Odyssey, and MRO aerobraking) and lander EDL. Owing to the repeatability of weather events, the MOC and MARCI daily global meteorological record have been employed to predict—several years ahead of time—weather conditions for EDL at specific sites on the planet for the MER, Beagle 2, Phoenix, and the Mars Science Laboratory (MSL) [23]. In addition, MOC and MARCI data were used in the month leading up to each EDL event and during the course of the landed missions to observe weather conditions and alert Project officials of any concerns that might, for example, impact solar array power generation. Indeed, in one case in November 2008, a sudden and unexpected dust storm alert from the MARCI team saved the Spirit rover operators from allowing their battery usage to dip to a dangerously low level [24]. MAGIE will be in a position to continue these support efforts for future planned missions, such as the joint NASA and ESA 2-rover mission to launch in 2018 [25-27] and a possible Mars Sample Return missions to follow in the early 2020's [28].

Data Products: Beyond the regularly released lowest level data products (single filter images), a number of higher order data products will be produced on a regular basis to meet the instrument's science objectives. These include:

1. Single-band global map mosaics in each of the 4-filter bandpasses.
2. False color global maps.
3. Condensate cloud (water-ice) and dust opacity maps.
4. Ozone column density maps.
5. Targeted, localized/regional visible wavelength images.

These higher order products will be made available to the scientific community in a timely manner.

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References: [1] ESA/NASA Joint Engineering Working Group, ExoMars Orbiter Experiment Proposal information Package, EXM-OM-IPA-ESA-00001, 2010. [2] Malin, M. C. et al., Icarus, 194, 501-512, 2008. [3] Lefèvre, F. et al., JGR (Planets), 109, E07004, 2004. [4] Clancy, R. T. et al., LPIC, #3082, 2007. [5] Malin, M. C., Icarus, 194, 50-512, 2008. [6] Haberle, R. M. et al., LPIC, #9109, 2008. [7] Wolff, M. J. et al., Eos, Trans. Amer. Geophys. Union, 90(52), # P53A-09, 2009. [8] Cantor, B. A. et al., JGR, 106, 23,653-23,688, 2001. [9] Cantor, B. A., 7th LPIC, #1353, 2007. [10] Wang H., and A. P. Ingersoll, JGR (Planets), 107, 5078, 2002. [11] Benson, J. L. et al., 165, 34-52, 2003. [12] James, P. B. et al., 106, 23,635-23,652, 2001. [13] Benson, J. L., and P. B. James, Icarus, 174,513-523, 2005. [14] Cantor, B. A., Icarus, 186, 60-96, 2007. [15] Malin et al., Icarus, 194, 501-512, 2008. [16] Clancy, R. T., JGR (Planets), 114, E11002, 2009. [17] Cantor et al., Icarus, 208, 61-81, 2010. [18] Wolff, M. J. et al., this meeting. [19] Clancy, R. T. et al., this meeting. [20] Kahre, M. A. et al., JGR (Planets), 111, E06008, 2006. [21] Wilson, R. J. et al., LPIC, #1447, 2008. [22] Noble, J. et al., Fall AGU, #P11A-1254, 2008. [23] Malin, M. C. et al., Mars, 5, 1-60, 2010. [24] http://marsrovers.jpl.nasa.gov/spotlight/20081120_Spirit.html, 2008. [25] Vago, J. L., and ExoMars Project Team, Astro. Sci. Conf., #5518, 2010. [26] Des Marais, D. J. et al., Astro. Sci. Conf., #5532, 2010. [27] Feldman, S. A. et al., 41st LPSC, #2384, 2010. [28] Borg et al., http://mepag.jpl.nasa.gov/reports/NDSAGreport_FINALb1.pdf, 2008.