COLOUR AND STEREO SURFACE IMAGING SYSTEM ON THE EXOMARS TRACE GAS ORBITER: AN ASSESSMENT OF COLOUR AND SPATIAL CAPABILITIES THROUGH IMAGE SIMULATIONS. L. Tornabene[1], F. Seelos[2], A. Pommerol[3], N. Thomas[3], C. Caudill[1], J. Bridges[4], M. Cardinale[5], M. Chojnacki[6], S. Conway[7], G. Cremonese[8], C. Dundas[9], M. El-Maarry[3], J. Fernando[6], C. Hansen[10], T. Harrison[11], R. Henson[4], L. Marinangeli[5], A. McEwen[6], C. Okubo[9], M. Pajola[12], V. Roloff[3], S. Sutton[6], J. Wray[13], [1]CPSX, Dept. of Earth Sci., Western University (ltornabe@uwo.ca), [2]JHU/APL, Laurel MD, [3]Physikalisches Institut, Univ. Bern, Bern, Switzerland, [4]Space Research Centre, University of Leicester, UK, [5]DiSPUTER, Università degli Studi G.d'Annunzio, Chieti, Italia, [6]LPL, Univ. of Arizona, Tucson, AZ, [7]Laboratoire de Planétologie et Géodynamique, Université de Nantes, Nantes, France, [8]INAF, Osservatorio Astronomico di Padova, Padova, Italy, [9]USGS, Astrogeology Science Center, Flagstaff, AZ, [10]Planetary Science Institute, Tucson, AZ, [11]New Space Initiative, Arizona State Univ., Tempe, AZ, [12]NASA Ames Research Center, USA, [13]Earth and Atmos. Sci., GIT, Atlanta, GA.

Introduction: The Colour and Stereo Surface Imaging System (CaSSIS) is a full-colour visible to near-infrared (VNIR) bi-directional pushframe stereo camera onboard the ExoMars 2016 Trace Gas Orbiter (TGO). CaSSIS has fixed pointing 10° off nadir and a rotation mechanism used to acquire stereo images in a single orbital pass providing a 22.4° parallax angle [1]. CaSSIS will provide images up to ~9.4 km wide and ~47 km long, with four broadband colour channels (1BLU, 2PAN, 3RED, 4NIR) covering ~500 to 950 nm; at the highest un-binned resolution, these images will yield a 4.6 m/px spatial scale from TGO's anticipated 400-km mapping orbit inclined 74° from the equator [1]. CaSSIS will provide full-colour, stereo and repeat imaging spanning different times of day and covering all seasons. Such images will be used to address the following objectives: 1) characterizing possible [surface/subsurface] sources for methane and other trace gases; 2) investigating dynamic surface processes that may contribute to atmospheric gases; and 3) certifying and characterizing candidate landing site safety and hazards (*e.g.*, rocks, slopes, etc.).

Here we present a summary, and some highlights, based on the creation and analysis of simulated CaSSIS image cubes [see 2, 3]. These were specifically used to assess the colour and spatial capabilities of anticipated dataset collected over key sites of investigation on Mars. For more details on ExoMars TGO and its payload, please see [4], and for the CaSSIS instrument see [1]. For details on the first Mars Capture Orbit (MCO)-acquired CaSSIS stereo images and preliminary 3D reconstructions from them [5, this conf.].

CaSSIS Image Simulations: We generated simulated images that are spatially (4.6 m/px) and spectrally (4-bands) consistent with CaSSIS from existing Mars Reconnaissance Orbiter (MRO) datasets collected over 10 years. Simulated CaSSIS colours were generated from hyperspectral VNIR (S-detector) data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) after the methods of [6], which were then combined with spatially oversampled and resampled 32-bit calibrated I/F images from the Context Camera (CTX) and High Resolution Imaging Science Experiment (HiRISE) [2, 3]. The process was such that we could choose to assess colour capabilities separately (*i.e.*, without having to produce a fully-simulated CaSSIS cube), if so desired. For more of the details on the simulation process and the various products produced please see [2, 3].

Results and Highlights of Capabilities: We created 156 simulated CaSSIS 5-band (4+1 synthetic band for blue) image cubes from which 28 fully-simulated cubes of 25 unique locations on Mars were created (*e.g.*, Fig. 1). Our simulation cubes have 5-bands instead of 4, as we denote an additional "synthetic blue" band (denoted as Band 0), which is calculated based on red and blue-green bands, and similarly to HiRISE [7], and is a required for producing an approximate "true colour" image. In addition to the 5-band cubes, one non-colour product was produced, an orthorectified CTX image pair with a temporal separation of 7.5 years. The pair was oversampled spatially to 4.6 m/px, and specifically used to assess the ability of CaSSIS to spatially detect changes within the Nili Patera dune field.

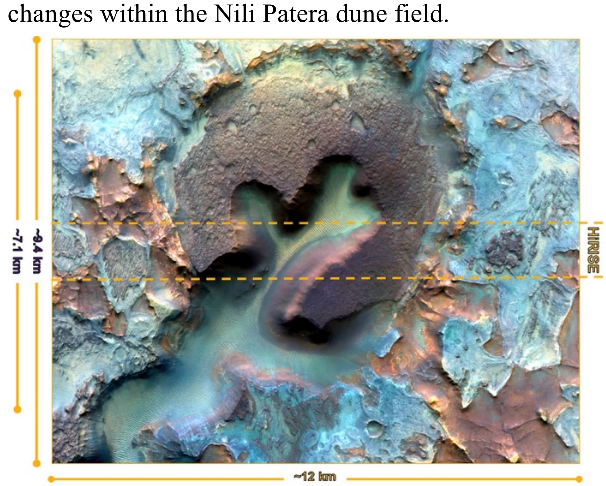

Fig. 1. A fully-simulated CaSSIS infrared-colour (Bands 4-2-1) image of a portion of the Nili Fossae region at 4.6 m/px and cropped to a length of 12 km and the anticipated 9.4-km swath width [see 4]. North is to the right.

Colour capabilities. Fig. 1 shows an example of a simulated cropped CaSSIS infrared-colour image with annotations to show the general swath coverage provided by CaSSIS (~9.4 km) compared to HiRISE colour coverage (dashed lines; ~1 to 1.2 km). The length of full-resolution HiRISE images is generally ~10 km, and no more than typically ~25 km. CaSSIS will be able to provide up to ~2x that length in full colour (or ~4x the length of the image in Fig.1). Our sims show that such colour coverage will be valuable towards facilitating and enhancing seasonal process and change detection studies. For example, a simulation image of Gasa crater (Fig. 2) demonstrates exactly how additional colour context would facilitate gully change detections that can be subtle and difficult to detect in single-band images, or when missed by the HiRISE colour swath.

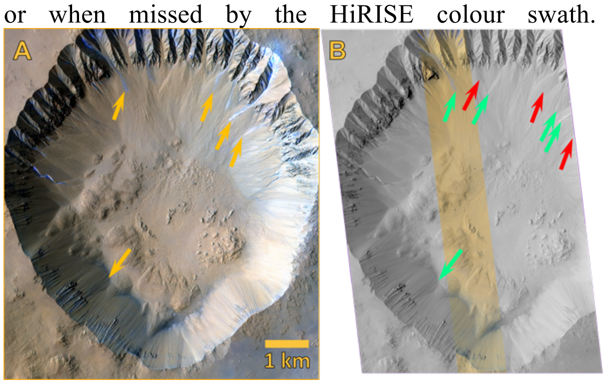

Fig. 2. Seasonally active gullies and mass wasting (arrows) in Gasa crater. A comparison of our fully-simulated CaSSIS infrared-colour (Bands **4**-**2**-**1**) image (A; yellow arrows = new detections) to its HiRISE MIRB temporal equivalent (B; green = readily detected; red = difficult to detect in greyscale).

Another result based on our colour analysis includes, excellent separation of ferrous- and ferric-bearing surface materials provided by band ratio colour composite images utilizing the two NIR bands of CaSSIS (3RED, 4NIR). These images will be particularly useful for associating CaSSIS colour units with spectral units defined by orbiting spectrometers (*e.g.*, CRISM), and thereby extend spectral mapping to CaSSIS spatial scales. This will particularly be beneficial for landing sites where it is difficult to achieve continuous colour coverage with HiRISE.

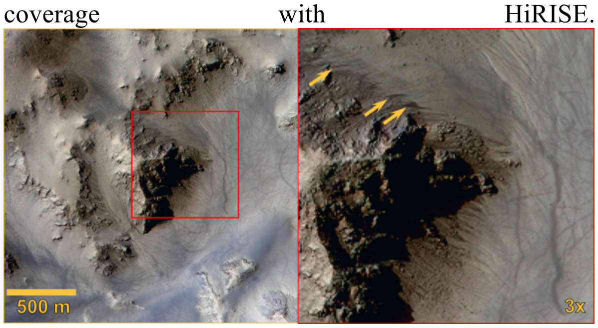

Fig. 3. Fully-simulated CaSSIS "true-colour" (Bands **2**-**1**-**0**) image of seasonally active RSL (arrows) in Horowitz crater. *Note*: Band 0 is a synthetic blue band [see 2,7].

Spatial capabilities. Our simulation and analysis shows that dune movement can be detected at the scale of CaSSIS, given a long enough baseline (Fig. 4). Larger individual Recurring Slope Lineae (RSL), and dense clusters of smaller sets, are also resolvable (Fig. 3). Other results based on our spatial analysis include (not necessarily excluding colour capability) resolving: 1) small impacts (including ice excavators) with some modest but useful detail when compared to HiRISE, and 2) surface changes associated with landers/rovers (NOTE: lander/rovers themselves, including tracks, are not resolvable.)

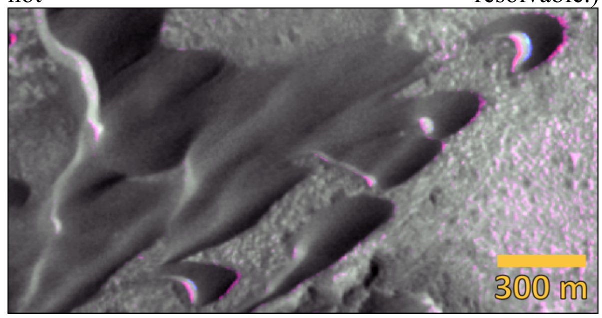

Fig. 4. Migrating dunes in Nili Patera [see 2]. Colour fringing in the image composite (magentas and blues) indicate the location of pixels where the largest changes have occurred over the last 7.5 years.

Conclusions & Future Work: CaSSIS is anticipated to provide high-resolution, full-colour stereo image pairs that will be useful as a stand-alone dataset, but also complement previous and future Mars spectral and time-series datasets. The ability of CaSSIS to acquire stereo pairs on a single pass will greatly enhance morphometric and change-detection analyses that rely on the derivation of elevation information and orthorectified images [see 5, this conf.].

We hope to report on comparisons of our sims with actual CaSSIS images taken in November 2016 and anticipated in March 2017. The successful colour and stereo images acquired during closest approach in November [see 5] showed that the camera is working better than anticipated. In the first week of March, two more orbits, which will be the first taken at the nominal mission phase orbital inclination of 74°, will be permitted for data collection and calibration just before aerobraking commences later that month.

References: [1] Thomas N. et al. (2016), *submitted to SSR*. [2] Tornabene L. et al. (2017), *submitted to SSR*. [3] Tornabene L. et al. (2016) *LPS 47*, Abstract #2695. [4] Vago J. et al. (2015) *SSR*, 49 518-528. [5] Cremonese G. et al. (2017) *LPS 48*, this conf. [6] Seelos F. et al. (2011) *AGU Fall*, vol. 23, Abstract #1714. [7] Delamere A. et al. (2010), *Icarus*, 205, 38-52.

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