FULLY CONTROLLING MARS RECONNAISSANCE ORBITER CONTEXT CAMERA IMAGES AND PRODUCING COSMETICALLY STABLE MOSAICS: PRODUCTS.

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Introduction: The Context Camera (CTX) aboard NASA's *Mars Reconnaissance Orbiter* (*MRO*) [1] has been returning high-resolution (5–6 mpp) and -quality data of Mars' surface for over a decade. As of PDS release 55 (March 2021, including data through August 2020), the instrument has returned >115,000 images that cover ~99% of the planet in good quality. However, images often have ~100s meter offsets from each other and a controlled ground source, resulting in seam mismatches when mosaicking and poor matches to other, high-resolution datasets.

Over the last several years, we developed and improved upon an efficient, accurate workflow within *ISIS* (USGS's *Integrated Software for Imagers and Spectrometers*), driven by Python scripts, to automate much of the control process that can create a fully controlled CTX dataset. We demonstrated the viability of this workflow by producing a mosaic of Mare Australe ("MC-30"), covering south of –65°N, or 4.7% of Mars' surface [2] (Fig. 1). We have also done other regions of Mars, totaling >50% of its surface.

Over the past year, we have further improved the efficiency and speed, which have allowed us to create fully controlled networks for entire Mars Charts ("MC") in about one week (~3% of Mars, ~3000 images, ~2.0 TB of data). In this abstract, we discuss our progress on Mars, other bodies, and how we achieve cosmetic control. In a companion abstract to the 2021 (5th) Planetary Data Workshop, we discuss our current process of cartographic control [3].

Mars Mosaics via Context Camera Data: Our primary driver and application of this work has been to CTX data of Mars, given its significant utility to Mars surface investigations yet absence of cartographic control and mosaics from that control work. (We acknowledge [4]'s work on mosaics and producing a product warped to MOLA, but that is different from control of the images to each other and then to a stable ground source, solving for the SPICE data, and then producing a mosaic that factors in the revised instrument and spacecraft positions and pointings.)

Since late 2017, we have gone through numerous incarnations of our control process and controlled various different regions of Mars, including a ±7.5° latitude equatorial mosaic (~13% of Mars) [5], MC-30 (Mare Australe, including the South Pole; ~4.7% of Mars) [2], and numerous other small, scattered areas. A primary issue was that our code still had some problems scaling well to large, full MC regions of the planet all at once, meaning we worked in 1/16th MCs, or 1/480th chunks of Mars. Our latest work with that sized region was to control ~50% of Mars, working in three "rings:" ±7.5° latitude, MC-01 and MC-30, plus two rings of latitude at ±90° longitude, and the prime meridian through the anti-meridian. These form three interlocking rings at 90° angles to each other, cover 50% of Mars' surface, and 60% of CTX images.

We succeeded in that control work, except the north polar area (MC-01). MC-01 has proven challenging – more-so than MC-30, likely due to (a) much of the terrain's smoothness; (b) lower signal-to-noise during northern summer than southern summer; (c) and dune patterns that, under different seasons, confuse automated pattern matching. These issues mean multi-months'-long computer runs and large control networks, which led us to search for alternatives.

That is what drove our new code development [3]. The new code produces much more efficient, smaller networks, and it produces them more quickly. We have turned the code to MC-01, dividing the area into five regions: North of 83.75°, and 65°–83.75° in 90° longitude bands. Three of the five are almost done.

With the new code and a few spare computers (two laptops), we have started to re-work through Mars' equatorial MCs (MC-08 thru MC-23), and we are also testing it on the mid-latitude MCs (MC-02 thru -07 and MC-24 thru -29). As of April 19, 2021, *with only the new code*, we have controlled 7 of the 16 equatorial MCs and 1 of the 12 mid-latitude MCs.

Currently, our plans are to continue to work through the equator and publish that as one product, which will itself comprise 50% of Mars' surface area. Assuming our code is successful in working through MC-01, we plan to publish that as a separate product, much as we did MC-30. If we have resources available, we will then work through mid-latitudes with the goal of making a global product.

However, it should be noted that the work to-date has been funded by internal development at the authors' institution, and those funds are expiring. We will be submitting a PDART proposal to actually carry out the global work, which would include re-doing MC-30 with two full additional southern summers of imagery, and re-doing the other areas we have done with the latest imagery for a cohesive, single product.

Mid-Sized Saturnian Satellites via Imaging Science Subsystem: Our code is also able to work on this dataset, and we have succeeded in creating a controlled, color mosaic of Mimas (unpublished). We will be resubmitting our PDART to control all mid-sized Saturnian satellites and produce final mission mosaics. Existing mosaics do not factor in the last several years of mission data nor do they control all images that were available at the time, just enough to make the mosaics.

Mercury via Mercury Dual Imaging System: Our code also works well to control MDIS images of Mercury, something that is still needed to take advantage of the full MDIS dataset, since the most inclusive mosaics only controlled ~57% of greyscale and ~10% of color images. MDIS and ISS imaging present a different scenario from CTX: CTX has relatively few overlaps but consistent lighting and pixel scale, so control must focus on getting good points where those overlaps are; MDIS and ISS has an enormous amount of repeat imagery, but at a wide range of lighting geometry and pixel scales. However, in tests we have done, our code is still able to control MDIS regions well, though we have not yet worked to create a large-scale, single product.

Cosmetic Corrections [6]: Normal equalization methods that adjust brightness and contrast are insufficient for images that are internally variable relative to others, such as containing an along-track gradient. A method that has been somewhat informally used in the literature but described in detail by [7] is to use a low-resolution, photometrically stable source image or mosaic, and tie the brightness of the higher resolution images to it. Mars Orbiter Camera Wide-Angle images, taken limb-to-limb, have this property when hundreds of images are combined. We created mission-averaged mosaics at cardinal L_s times (±5°) to generate this photometrically stable, low-resolution (9 ppd) basemap [8]. To that, we tie CTX images in order to create a brightness-stabilized, high-resolution product (Figs. 1–2).

References: [1] Malin et al. (2007). "Context Camera Investigation on board the Mars Reconnaissance Orbiter." doi:10.1029/2006JE002808. [2] Robbins et al. (2020). "Fully Controlled 6 meters per pixel Mosaic of Mars' South Polar Region." doi:10.1029/2019EA001053. [3] Robbins et al. (2021). "Fully Controlling Mars Reconnaissance Orbiter Context Camera Images and Producing Cosmetically Stable Mosaics: Methods." Planetary Data Workshop, 5, Abstract 7086. [4] Dickson et al. (2018). LPSC #2480 doi:10.1029/2010JE003755. [5] Robbins et al. (2019). "Fully controlled 6 meters/pixel mosaic of Mars' south pole and equator from Mars Reconnaissance Orbiter Context Camera, I." Lunar & Planet. Sci. Conf., 50, Abstract #2132. [6] Robbins et al. (2020) "Empirical Photometric Control of Mars Context Camera Images." doi:10.1029/2019JE006231. [7] Michael et al. (2016) doi:10.1016/j.pss.2015.12.002. [8] Robbins (2020) "Mars' Red … Reflectivity Averaged Over Mars Year 24–28 from Mars Orbiter Camera." doi: 10.1029/2019JE006231.

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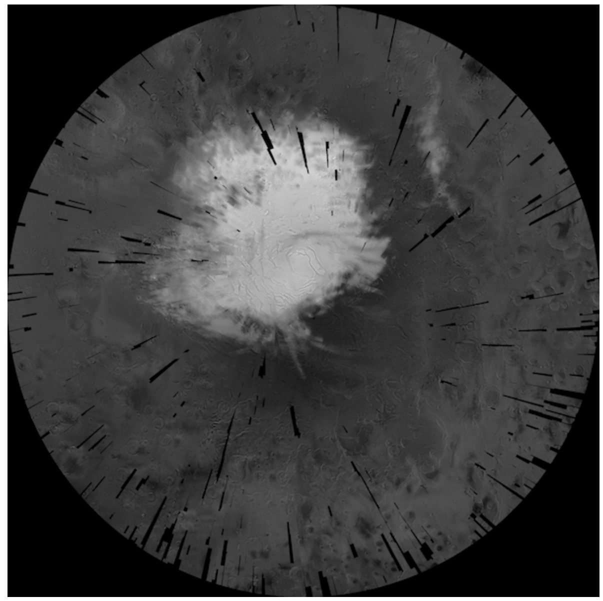

Figure 1: Very low-resolution version of the MC-30 mosaic, with non-linear brightness scaling applied to reproduce well here.

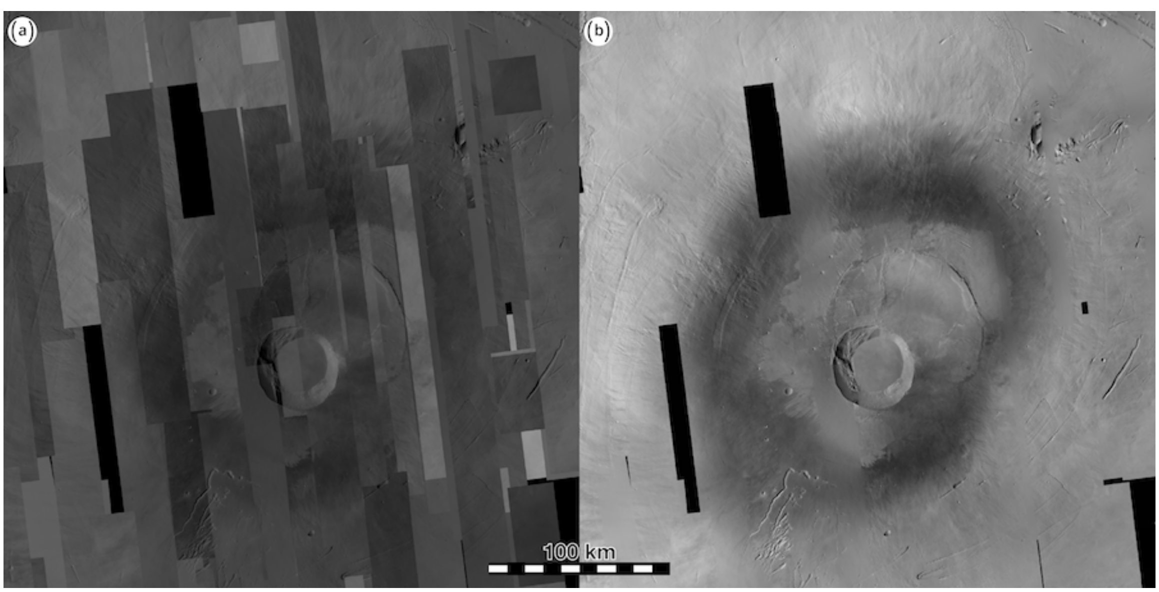

Figure 2: 214-image mosaic centered on Pavonis Mons [6], (A) cartographically and (B) cosmetically controlled.