INITIAL WORK BUILDING A NEXT-GENERATION MARS CRATER DATABASE: A CASE-STUDY OF MC-09 (THARSIS) CRATERS IN CONTEXT CAMERA IMAGES VERSUS THEMIS.

S.J. Robbins[*,1]. [*]stuart@boulder.swri.edu, [1]Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO 80302.

Introduction: Impact crater databases are important for understanding crater populations, model ages, resurfacing history, and for numerous other science investigations. The databases are useful not just to those that construct them, but to the broader scientific community who can use them for their own investigations, saving time by using work that someone else has already done.

Most databases are still constructed manually, either in whole or in part, because automated detection has not (yet) matured to a state of high enough accuracy that many would consider it useful for building reliable databases. Manual efforts themselves are not wholly repeatable, with variability of one researched over the course of time to variability between researchers [1]. We are slowly working towards a new study into this variability between researchers, but that is not the subject of this abstract.

In addition to some repeatability issues, impact crater databases – and feature databases, in general – are only as good as the input data. For example, the Robbins & Hynek global Mars impact crater database [2, "RH12"] was constructed over the course of several years (2007–2012) and several generations of the 232 meters per pixel (mpp) and 100 mpp global THEMIS Daytime IR basemap. In comparison with 6 mpp Context Camera (CTX) images, some of the database no longer holds up. The rest of this abstract describes known issues with RH12 database, new efforts using better basemaps, and where future work is headed.

Known Issues with the 2012 Database: At the PCC meeting four years ago [3], issues were discussed with the 2012 database. For context, they are reiterated here, in brief: (1) The image base used was THEMIS Daytime IR, and most of the database was identified and classified using incomplete THEMIS data (~10% gores) that was poorly georeferenced and rendered at 232 mpp. (2) The "confidence" column meant to provide a metric for what users might ignore based on the poorer quality data was extremely under-utilized. (3) There were some bugs in the circle- and ellipse-fit code, which have been fixed, but those were not well propagated to the various repositories that store the database. (4) Follow-up work [4] showed that MOLA depths for craters $D \lesssim 10$ km are unreliable and should not have been included. (5) The morphology conclusions (*e.g.*, ejecta type, preservation state) do not hold up well relative to modern data, and perhaps have poor repeatability between researchers (something that has not been studied).

While this paragraph might be read in part as self-flagellation, the purpose of explaining it is to show that some mistakes were made, and we have learned from them.

Fully Controlled Context Camera Basemaps: The primary reason that no large update on my part has yet been attempted is due to waiting for a significant improvement to the basemap, so a next-generation catalog can be built that corrects mistakes from the original. The next-generation basemap would be built with higher resolution data that is already fully controlled to a reference source so that feature locations will not change from one generation to the next (or, will not perceptibly change).

Unfortunately, a fully controlled CTX map – let alone a global CTX mosaic – was elusive. Hence, we began work to construct one. While we have been working on that, a CTX mosaic was released by CalTech, but as an uncontrolled product, it is not being used for this work because shifts will happen, and the data will not align with other controlled datasets. Therefore, this new crater work was on hold until the controlled product was available.

One of the first large, fully controlled regions of Mars that we made is Mars Chart #09 (MC09), "Tharsis," which spans 0° to 30° N latitude by 225° to 270° E longitude. It is completely within the Tharsis rise and includes the calederae of Olympus, Ascraeus, Pavonis, and Uranius Montes; Jovis, Tharsis, Biblis Uranius, and Ceranius Tholus; and Ulysses Patera. It is here that work began on a new Mars crater database.

Methods: The method of crater identification is the same as in my past work: Mosaics are examined in *ArcMap* software, craters visually located and identified, and the rims are traced using *ArcMap*'s "streaming" tool to create a vertex every few pixels. In my original work, I would create a vertex every ~2–3 pixels, which corresponded to ~500 m or, later, ~250 m. The controlled CTX mosaics are rendered at 6 mpp, and the goal for this new cataloging effort is a catalog complete for $D \geq 500$ m craters. Therefore, a vertex every ~2–3 pixels is much higher fidelity than needed, and it takes a needlessly long time given that the minimum crater would have >250 vertex points. Instead, vertex spacing is set to ≈100 m, allowing for ~15 points for the smallest craters.

Outside of *ArcMap*, following methods described in excruciating detail in [5], vertex points are projected into kilometers from the centroid of each trace using geodetic corrections. The rims are then fit with circles and ellipses, and the data stored.

Separately, craters are manually examined in the mosaics. Given community feedback, and the goals of this new work, only a limited set of relatively objective morphologies are noted, in addition to a subjective confidence in whether the feature identified is an actual impact crater. Specifically, the goals for this new work are in part to study secondary impact craters and possible binary crater impacts. For secondary craters, a variety of common criteria are flagged in various columns. For example, whether a crater is objectively in a narrow chain is noted, or whether the crater is in a tight cluster is noted. Later, a user of the database can decide what combination of criteria they want to use to designate a crater as secondary. For binary impacts, two columns record whether there is a straight septum between two craters that share part of a rim, and whether there is transverse ejecta emanating from the craters' rims.

Results— Size-Frequency Distribution: Figure 1 shows relative SFDs of craters in MC09 from [2] vs this new work. There is generally good agreement between the two databases when looking at overlaps between the ±95% confidence intervals. This is likely because Tharsis is a relatively easy area upon-which to identify craters, for there is generally little ambiguity except with pit craters (see next section).

RH12 [2] starts to climb to more craters for diameters ≲2 km, which in this case is likely due to the separation between primaries and secondaries, though it quickly decreases for smaller diameters due to that database's stated completeness of ≥1 km. The downturn near ~0.7 km for this new database's secondary craters, while potentially indicating poor completeness at identifying them, is likely here to be accurate: Secondaries in this region are dominated by craters from Poynting (≈8.5°N ≈247.3°E, $D \approx 70$ km) and a now-buried crater that deposited still-visible secondaries on the flanks of Tharsis Tholus. The secondaries produced in those two events are rather large and do not have a SFD that continues to ~10s m sizes, so this fall-off in Fig. 1 is likely real.

Results— Confidence: Despite some community feedback, I think that it is important to identify and include some features which might *not* be – but which still *could* be – an impact crater. Critically, doing so requires full use of a "Confidence" annotation in the database. In this region, fully 5% of craters were marked as having a decreased confidence, while [2] marked 100% of the craters as fully confident. In this region in particular, there is significant ambiguity about whether some features are impact craters or volcanic pit craters, so ambiguous features were occasionally included and marked with the lower confidence.

Future Work: The work so-far discussed in this abstract was done as a pilot effort for an MDAP proposal in the 2020 ROSES call. The grant was selected on a descope, funding the proposed database development and secondary crater studies, so new work will commence late this year.

Specifically, we proposed to construct a new crater database over most Hesperian and Amazonian -aged terrain on Mars approximately in the northern hemisphere (avoiding the poles and avoiding small areas in the southern hemisphere). We proposed 34.3% of Mars, with an additional 12.0% as a "reach" target if crater mapping goes faster than expected. Upon completion, this database will be made public, and we may propose to expand the revision into other areas through other funding, such as a PDART or follow-up MDAP.

Addendum: Preliminary Work— Rim Snapping: Another issue with manually tracing crater rims is that small, unconscious deviations can occur that might not even be apparent at the pixel scale displayed on-screen. These deviations can bias a circle fit and heavily bias an ellipse fit, as detailed in [5].

To mitigate this issue, I have worked on a "rim-snapping" tool which can take a rim trace, assume up to a few-pixels offset, and work to find the pixel-perfect rim in an image based on areas of maximum contrast (where the rim highlight transitions to rim shadow). While this work is still highly experimental and far from user-friendly, its results are promising and preliminary results from it – used on this MC09 region – will be shown at the meeting.

References: [1] Robbins, S.J. *et al.* (2014). doi: 10.1016/j.icarus.2014.02.022 [2] Robbins, S.J. and B.M. Hynek (2012). doi: 10.1029/2011JE003966 [3] Robbins, S.J. (2017) In *Planetary Crater Consortium*, **8**, Abstract #1703. [4] Robbins, S.J. and B.M. Hynek (2013). doi: 10.1016/j.pss.2013.06.019 [5] Robbins, S.J. (2019) doi: 10.1029/2018/JE005592

Funding: This work was funded internally by Southwest Research Institute.

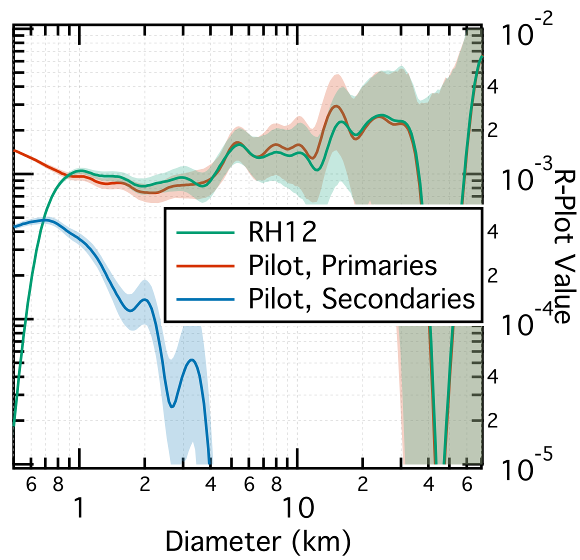

Figure 1: Relative SFDs of craters in MC09 from [2] compared with the primary craters and secondary craters from this initial work.