GOTCHA! Machine Learning-assisted Mapping & Correlation of Co-InSight Impacts on Mars. V.T. Bickel[1], I.J. Daubar[2], G. Zenhäusern[3], S. Stähler[3], G. Doran[4], K. Wagstaff[5], A. Sokolowska[2], P. Grindrod[6], C. Charalambous[7], B. Fernando[8], J. Clinton[9], D. Giardini[3], [1]Center for Space and Habitability, University of Bern, CH (valentin.bickel@unibe.ch), [2]Brown University, USA, [3]ETH Zurich, CH, [4]Jet Propulsion Laboratory, California Institute of Technology, USA, [5]Independent Researcher, USA, [6]Natural History Museum, UK, [7]Imperial College, UK, [8]Johns Hopkins University, USA, [9]Swiss Seismological Service, ETH Zurich, CH.

Introduction: Fresh impacts are a major landscape-forming process on present-day Mars. Fresh impacts (when constrained by before-after orbital images) can provide information about the presence of shallow subsurface ice [1], the size frequency distribution of impactor populations [2], and the physical properties of the crust and mantle, if correlated to seismic data [3]. Previous surveys matched 8 fresh impacts with 8 InSight-recorded seismic events [4]. Those fresh impacts were manually identified in orbital images – globally, a total of 1203 fresh impacts were identified in orbital images from 2007 to 2021 [2]. However, given the current estimated impact rate [5] and the detectability of associated seismic signals, we suspect more impact signals remain unrecognized in the InSight data. Recently, [6] developed a machine learning-driven (ML) approach to accelerate the tedious search for fresh impacts in MRO CTX images, while addressing some of the observational and operator-related biases associated with human vetting. Here, we deploy the same ML approach [6] to create a new catalog of fresh impacts that occurred during the InSight mission (02/2019-12/2022), in a 50° (2900 km) radius around the lander, and attempt to correlate them to InSight-recorded seismic events in space, time, and magnitude/size.

Methods: Our processing pipeline retrieves all PDS-available CTX images over the study area, cuts them into 300x300 pixel tiles, and stacks them in a fixed spatial grid, as a function of time. We deploy an Inception v3 convolutional neural network fine-tuned using human-identified craters to classify all tiles as either 'non-impact' or 'impact'. The workflow flags all grid locations that contain tiles which change their classification from 'non-impact' to 'impact' over time. All flagged tiles are reviewed by a human operator and – if confirmed – a high-resolution MRO HiRISE image is requested to verify the existence of a new crater. We compile impact-specific information, i.e., location, date/time of the before/after images, and diameter. We consider a given fresh impact to be a potential match for the source of a seismic event if their timing and approximate location/distance match. In the future, we will additionally use crater size and estimated magnitude [7,8] to match events.

Preliminary Results: To date, we have compiled 55 co-InSight impacts in a 50° radius around the InSight lander (Fig. 1&2). Crater diameters range from 1.75 +/- 0.25 m to 21.5 +/- 0.5 m. Our current results suggest ~7 new potential matches with broadband events (BB, Fig. 2&3) as well as a number of potential re-assignments of matches made earlier [4]. We note that many of the newly discovered potential matches are located in Cerberus Fossae, including impacts as large as 21.5 +/- 0.5 m (ID 292, Fig. 1), i.e., larger than any other previously identified impact in the 50° perimeter around InSight. Potential matches between those impacts and seismic events would be significant, because they would represent – by far – the most distant (>1500 km) matches between impacts and 'small' Very-high Frequency (VF) events. They would provide a unique opportunity to re-calibrate earlier estimates of other VF event locations. This finding lends support to the hypothesis that the category of VF events may be associated with more unrecognized impacts [9]. We note that ID 292 was missed by all manual surveys despite being the largest impact in the vicinity of the InSight lander. Our results highlight the ability of ML tools to increase the scope and coverage of planetary science investigations. We will continue our systematic survey over the coming months.

References: [1] Byrne+ (2009) *Science*. [2] Daubar+ (2022) *JGR Planets*. [3] Fernando+ (2021) *Nature Astronomy*. [4] Daubar+ (2023) *PSJ* [5] Hartmann & Daubar (2017) *MPS*. [6] Wagstaff+ (2022) *Icarus*. [7] Wojcicka+ (2020) *JGR Planets.* [8] Ceylan+ (2022) *PEPI*. [9] Zenhäusern+ (in review). [10] MQS (2023) *Mars Seismic Catalogue v14*.

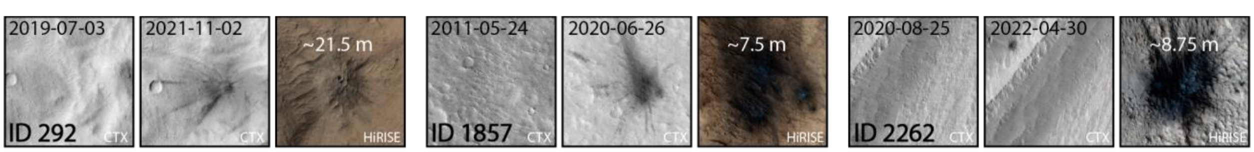

Fig. 1. Selection of fresh, co-InSight impacts in CTX before–after & HiRISE verification images; crater diameter indicated.

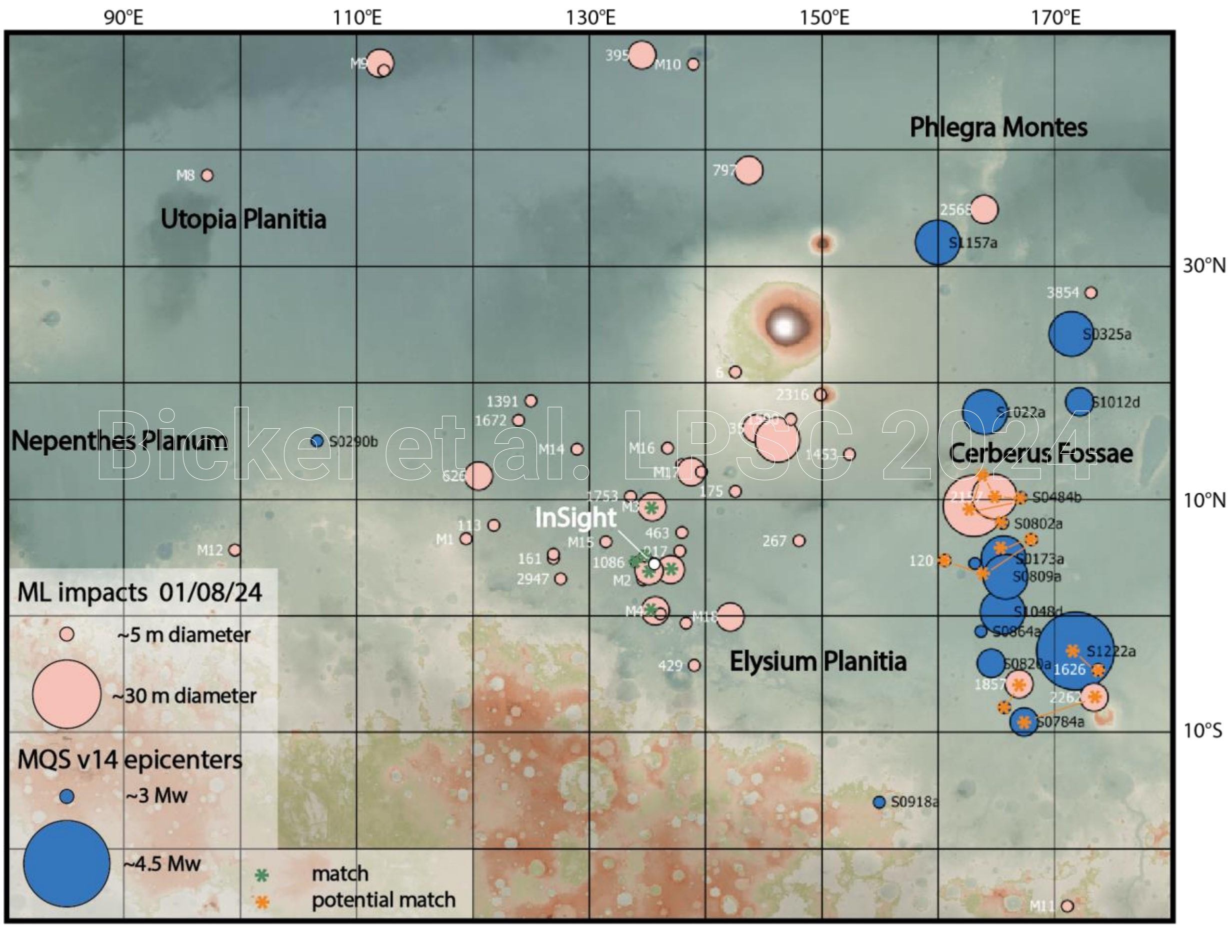

Fig. 2. Preliminary map of selected ML-identified fresh, co-InSight impacts (tan) and localized MQS v14 quake epicenters ([10], blue, BB). Circle size represents the diameter of the crater or magnitude (M_w) of the event; impact/seismic event IDs indicated; previous (green, e.g. [4]) and some of the potential new (orange, this work) event matches (location & timing) indicated. Blended MOLA topography and TES albedo products in the background.

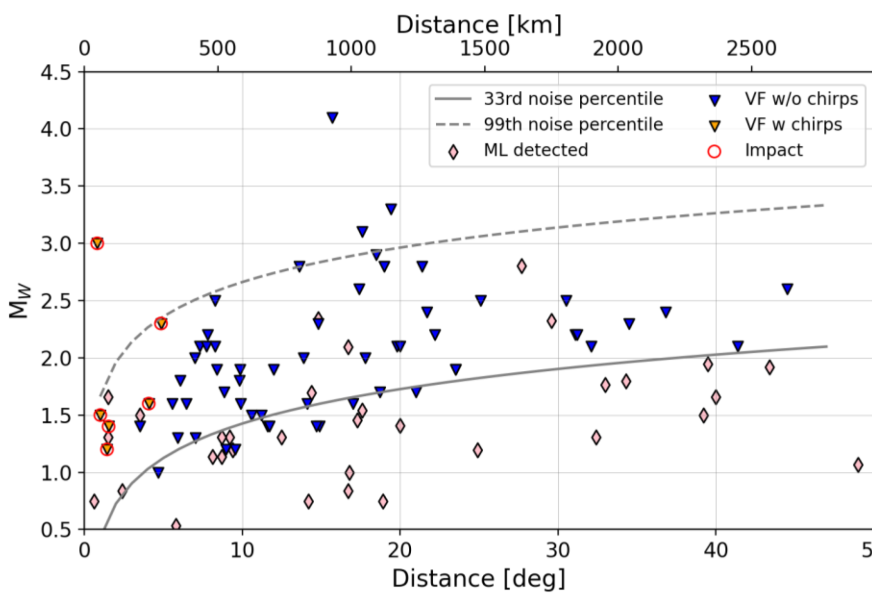

Fig. 3. M_w vs. distance plot for all MQS v14 VF events (blue triangles [10], 50° perimeter) and selected fresh, co-InSight impacts (tan diamonds, this work). InSight noise thresholds indicated by gray dotted lines; InSight events previously matched with impacts marked by orange triangles with red outline, e.g. [4].