TARGETS FROM THE SPIRIT MARS EXPLORATION ROVER IN THE MARS TARGET ENCYCLOPEDIA. K. L. Wagstaff[1], R. Francis[1], M. Golombek[1], S. Lu[1], E. Riloff[2], L. Tamppari[1], Y. Zhuang[2], and T. C. Stein[3], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, 91109, USA (kiri.wagstaff@jpl.nasa.gov), [2]University of Utah, Salt Lake City, UT, 84112, USA, [3]Washington University in St. Louis, St. Louis, MO, 63130, USA.

Introduction: The Mars Target Encyclopedia (MTE) provides information about surface targets (e.g., rocks, soils) identified by Mars surface missions[1]. The MTE links targets to publications that report information such as composition, appearance, interpretation, and other properties of each target. This resource benefits mission science team members, planetary science researchers, educators, students, and the general public.

The MTE is generated using automated text analysis tools applied to scientific publications followed by manual review [1]. The initial version of the MTE included targets observed by the ChemCam instrument on the Mars Science Laboratory (MSL) rover. The MSL Analyst's Notebook provides access to MSL target information derived from LPSC abstracts from 2014 to 2016 [2]. The MTE was subsequently extended to include targets observed by the Mars Pathfinder (MPF) and Mars Phoenix Lander (PHX) missions [3].

We have added a new collection to the MTE that encompasses targets observed by the Mars Exploration Rover Spirit. The incorporation of targets observed at different locations on Mars enables cross-mission analyses to identify common patterns as well as unusual exceptions. The use of automated text analysis tools provided significant time savings for generating the MTE content.

Spirit Targets in the MTE: The Spirit rover mission was active from 2004 to 2010. The much longer operational lifetime, compared to the Pathfinder and Phoenix missions, yielded an order of magnitude more documents to analyze to populate the MTE with Spirit targets. The source documents for the MTE are the proceedings of the Lunar and Planetary Science Conference (LPSC). We identified 1303 candidate documents that mentioned the Mars Exploration Rovers between 2004 and 2020.

We found that 315 documents (24%) mentioned at least one Spirit target, with 3352 total target name occurrences in 3174 distinct sentences ("mentions"). The target mentions comprise 320 distinct targets; many of them occur in multiple documents. Figure 1 shows the distribution of mentions of targets within LPSC abstracts from 1997 to 2020. As expected, the number of mentions is highest in the year that follows each mission's landing and decreases over time. Although the Spirit mission ended in 2010, findings about its targets continue to be mentioned and discussed to the current day. Often these targets are used for comparative, cross-mission analysis. The most commonly mentioned Spirit targets are *Home_Plate, Adirondack*, and *Comanche*[2]. There are 32 Spirit targets that occur at least 20 times in the collection.

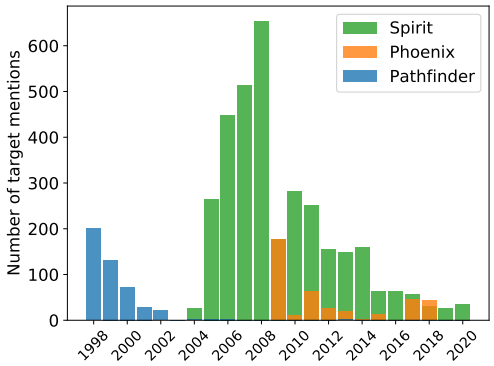

Figure 1: Number of target name occurrences (mentions) within LPSC abstracts for the Mars Pathfinder, Phoenix, and Spirit missions over time (mission bars overlap).

The MTE links targets to their mentions within documents, so a search across the collection brings all information about a given target into one place. For example, *Home_Plate* exhibits 16 elements, 29 minerals, and 115 properties across 105 documents. The MTE also provides the URL of each source document so users can immediately access the full text (PDF) of the publication.

Initial Analysis Results: The MTE includes target mentions as well as information about target composition and properties as reported in the source documents. For example, there are 39 Spirit targets described as containing olivine and eight targets that are described as pitted or having pits. Rare occurrences also stand out: *Wishstone* is the only target reported to have arsenic, and *Independence* is the only target described as containing gallium.

We are now able to compare findings across missions. The top five most common elements, minerals, and properties associated with each mission's targets are shown in Table 1 in descending frequency. These are not necessarily the most common aspects of the targets, but they are the ones that are most commonly written about in the literature. Minerals do not appear in descriptions of Mars Pathfinder (MPF) targets as that mission's instruments measured only individual elements (e.g., via APXS).

Methods: We compiled an initial Spirit target list using the target names derived as part of the MER mission

[1]https://pds-geosciences.wustl.edu/missions/mte/mte.htm

[2]We use italics to visually highlight target names, as there is no formatting convention.

Table 1: Most common elements, minerals, and properties associated with MPF, PHX, and Spirit targets in the MTE.

Element	
MPF	sulfur, iron, titanium, magnesium, chromium
Spirit	iron, magnesium, phosphorus, chlorine, sulfur
PHX	magnesium, calcium, chlorine, sodium, potassium
Mineral	
MPF	N/A
Spirit	olivine, sulfate, hematite, silica, pyroxene
PHX	CO_2, carbonate, SO_4, olivine, nanohematite
Property	
MPF	pitted, rounded, dark, angular, banding, andesitic
Spirit	basaltic, layered, glass, clasts, alkaline
PHX	ice, trench, perchlorate, lag, subsurface

close-out process. The contact science targets [4] are available through the PDS[3] and the MER Analyst's Notebook [5]. We also included remote sensing targets that were mentioned in MER mission planning documents. The 1128 target names include some name variants, such as *Gertrude_Weiss* for *Gertrude_Weise*.

To find other naming variants in the LPSC documents, we trained a Named Entity Recognition (NER) model [6] to recognize Spirit targets. Mars target names often employ common nouns (*Cashew, Champagne, Plank*) or names of people and places on the Earth (*Arizona, Francisco Coronado, Nathaniel Pryor*), so simple keyword searches yield many false matches. The NER model employs local context (word and character patterns before and after a given term) to determine whether "Champagne" refers to the drink or to the Spirit target. We started with the NER model that was trained for Mars Science Laboratory targets [1] and augmented it with a "gazette" of known Spirit targets to allow it to specialize for this mission. This process automatically identified nine additional target names (e.g., *Rousseau, Zhong_Shan*).

To generate the compositional and property relations, we employed an automated relation extraction system called jSRE [8]. This approach examines a candidate pair that consists of a target T and a property P to determine whether a relationship exists between T and P (e.g., *Riquelme* and "clasts") based on the local context. If so, the relationship is automatically annotated for manual review (see Figure 2). We trained two separate jSRE models to detect properties (as above) and compositional relations. The jSRE models use a support vector machine to classify target-property or target-element/mineral pairs as being related. The model were trained on annotated documents from the MSL, MPF, and PHX missions to learn common language patterns.

[3] https://pds-geosciences.wustl.edu/missions/mer/mer_cs_targets.htm

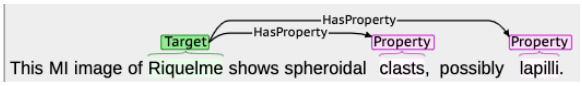

Figure 2: MTE properties of Spirit target *Riquelme* from [9].

The final step was to manually review the proposed MTE content. Based on a sample of 30 documents, the automated annotations reduced the review time from an average of 14.7 to 9.6 minutes per document, a time savings of 35%. We added 127 Spirit targets by hand; of these, 22 were abbreviations used within a specific document (e.g., *BB* for *Bread_Box* or *Adk* for *Adirondack*), 19 were typos (e.g., *Jibbsheet* for *Jibsheet* or *Methuslah* for *Methuselah*), and 12 were due to lack of space between words (e.g., *BigHole* for *Big_Hole*). Given a larger set of hand-annotated documents for training, the NER model may have found more of these targets automatically.

Conclusions and Next Steps: The Mars Target Encyclopedia (MTE) collects knowledge from a large collection of publications about Mars surface targets in a central, searchable database. The MTE now spans targets from the Mars Pathfinder, Mars Phoenix, and Mars Exploration Rover Spirit missions over more than two decades. It is possible to identify common target properties across missions (and their sites) as well as mission-specific differences. Targets without representation in the MTE could inspire new research investigations as well.

Our next steps are to add targets from the Opportunity mission and to expand the MTE to include content from peer-reviewed journal publications. MTE information for MER and Phoenix targets will soon be available through the Analyst's Notebook for easy access and search. We encourage the community to make use of the MTE to compare newly identified targets from the Mars 2020 and future missions to those characterized by historical missions for greater insights.

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