Spatial Products and Services for the Mars2020 Perseverance Rover. F. J. Calef III[1], T. J. Parker[1], J. Schroeder[1], N. Williams[1], and M.P. Golombek[1] [1]NASA/JPL-California Institute of Technology, Pasadena, CA, fcalef@jpl.nasa.gov.

Introduction: Mars exploration, from the earliest telescopic observations to modern orbiter and surface missions, have always relied on maps in one form or another to both record data, share hypotheses, as well as plan future observations. Once mobile surface missions were conceived to explore the planet in situ, not only were maps important for deciding where it was safe and scientifically viable to explore, they also became a critical component in mission operations. Maps provide a shared spatial context for features of interest locally and regionally, allowing the overlay of disparate datasets, like slope, geology, rock density, that provide significant information for rover operations on the science and engineering side.

Mapping on Past Mars Rover Missions: The first rover mission, Pathfinder, utilized Viking orbiter data, both visible and thermal, to mostly find a safe landing site by looking for smooth features and low rock abundance areas for surface mobility 'tech demo'[1]. That success lead to the two MER rovers, Spirit and Opportunity, who took advantage of the new Mars Global Surveyor instruments, MOLA and the Narrow Angle camera, to better understand the undulating surface[2]. However, the data resolution still lead to a large difference in orbital to surface resolution such that what the surface looked like was disconnected by several order of magnitude once they landed on the surface. However, the MER rover multiyear mission lengths combined with new Mars Reconnaissance Orbiter High Resolution Science Experiment (HiRISE) 25 cm/pixel allowed a direct connection between what was occurring at the surface and the orbital view. With 100+ meter drives and notable outcrops kilometers away, it became important to a) map where the rover was day-to-day and b) use geologic and related surface mapping to plan ahead to the next day all the way to next year (see [3]). Rover localization maps created by a 'Localization Scientist' which were used to add a HiRISE background for rover planning later in the mission [4,5], orbital chemistry [6], and in situ geologic maps [7] became standard fare in operations, albeit they were assembled using many different tools and mapping bases. The Mars Science Laboratory, aka the Curiosity rover, hired its first "Keeper of the Maps" to try to manage and contribute mapping as a formal mission function, albeit only a few months before landing. A separate 'Localization Scientist', much like on MER, reported the rover location based on a comparison between NAVCAM and a HiRISE orthorectified basemap using a combination of internal tools (MSLICE) and COTS software (Global Mapper). The unique change here is the same basemap, initially prepared for landing site analysis [8], was now used for localization, by the science team for geologic mapping [9], to record long term strategic goals, and by the rover planners for drive planning. Eventually, the Localization Scientist, Keeper of the Maps, and one additional mapper was added to the roster to provide map production for situational awareness, a spatial record of scientific observations, assistance in maps for publications, and answering spatial scientific inquiries (e.g. "How high has the rover driven since landing? How tall is that outcrop? What are the elevations for all our drills samples?"). As the mission progressed, our tools migrated from strictly COTS desktop packages, like ESRI ArcMap/ArcPro, to web-based open source mapping packages to allow the team more rapid access to the 25 GB visible basemap without having to download the file and learn complicated mapping software [10].

The Need for Operations Mapping: For the first time on a rover mission, mapping was integrated early and directly into the surface mission development cycle for surface science operations. This forethought lead to two action: assembling a formal mapping team, Mapping Specialists, who would provide new maps and mapping data daily based on the rover position, targeted science, and strategic mapping needs, as well as the necessity for a formal tool for strategic science mapping given the Perseverance mission's goal is to explore a multikilometer area for martian organics and create a sample cache for the potential return of those samples from Mars [11]. This new science operations mapping tool would be called the Campaign Analysis Mapping and Planning tool, CAMP. CAMP was built off of the Multi-Mission Geographic Information System [10] used previously on MSL and InSight, to bring a web-based mapping system to the whole operations team.

Daily Perseverance Maps: After each drive, the Mapping Specialist will create two maps: a localization map (Figure 1) showing the rover in context with the recent drive and in the mission area and a Target map which displays what science targets have been chosen by the science team in both an oblique/in situ and map ('top down') (Figure 2). Additional strategic maps may be created to help with science team decisions or to document accomplishments such as the location of sampling sites.

Spatial Datasets: Once the rover is localized by the Mapping Specialist against the missions basemap [12], several data products are created including the rover position, rover traverse, and target locations. Additional datasets from science team members, like geologic maps or orbital datasets from the team, are provided for all science team members to use as a reference for their mission planning.

Interactive Mapping: While these described geospatial datasets are available to all team members, most of the science team lacks the mapping tools or knowledge to interact with them. Some of these datasets are tens of GB in size, making their distribution problematic, not to mention the bit depth for elevation data (32-it float) is often unreadable in common COTS software making them unreadable. The Mars2020 mission incorporated and modified a open source, web-based GIS application called Multi-Mission Geographic Information System (MMGIS) [13] into the Campaign Analysis Mapping and Planning (CAMP) program. For example, the mission built a Viewshed tool that can display the viewable area from any location on the basemap and even simulate a camera view frustrum (Figure 3). There are also enhanced drawing collaboration tools for sharing vector datasets between team members. All the new features, save a few mission specific ones, have been folded back into MMGIS for other missions to take advantage of.

Situational awareness in and outside the Mission: CAMP is used by the science team for tactical and strategic operations as well as by rover planners and helicopter operations for strategic traverse/flight planning. Externally, spatial data from the mission is shared with the Mars Sample Return (MSR) mission to help locate potential future depot locations like ThreeForks. Our same basemap and spacecraft positions are uploaded to an outreach site that uses the same software (Figure 4).

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References: [1] Golombek et al., JGR, 1997. [2] Golombek et al., doi:10.1029/2003JE002074. [3] Golombek et al., JGR, doi:10.1002/2014JE004658. [4] Li et al., doi.org/10.1029/2010JE003773. [5] Deen et al., PDW2015, #7064. [6] Arvidson et al, DOI:10.2138/am-2016-5599, 2016. [7] Crumpler, Geology, DOI:10.1130/G46903.1, 2019. [8] Golombek et al., DOI: 10.1007/s11214-012-9916-y, 2012. [9] Calef, III F. J. et al. LPSC XLIV, #2511, 2013. [10] Calef et al., PDWPSIDA, 2021, #7061. [11] Boeder and Soares, SPIE, DOI:10.1117/12.2569650, 2020. [12] USGS, DOI:10.5066/P9QJDP48. [13] NASA AMMOS MMGIS, https://github.com/NASA-AMMOS/MMGIS.

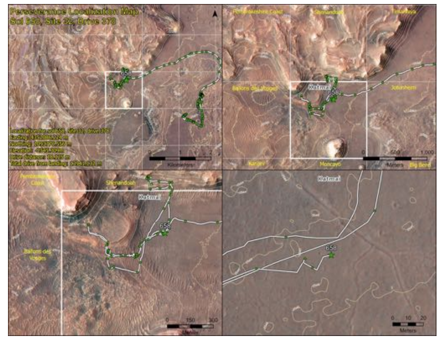

Figure 1: Mars2020 localization map.

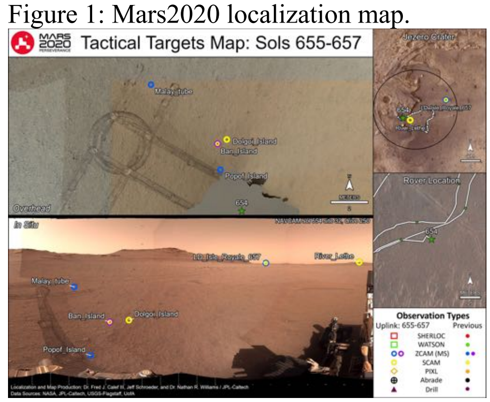

Figure 2: Science target map for sol 655-657.

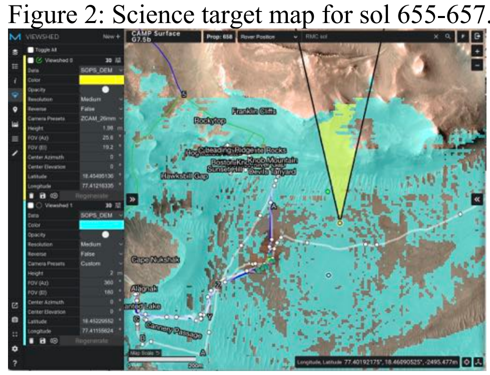

Figure 3: Viewshed inside CAMP (MMGIS).

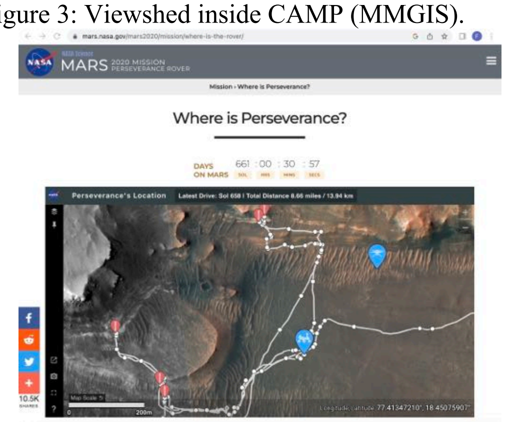

Figure 4: Outreach version of CAMP/MMGIS. Sample location with red icons and rover and heli current positions with blue icons (https://mars.nasa.gov/mars2020/mission/where-is-the-rover/).