MMGIS: A MULTI-MISSION GEOGRAPHIC INFORMATION SYSTEM FOR INSITU MARS OPERATIONS.
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Introduction: The complexity, variety, and resolution of datasets for in situ Mars missions has grown with each new planetary mission. Missions have transitioned from single-point landed missions like Viking to observations covering rover traverses kilometers in length, sampling multiple geologic and geomorphic units. For example, the Mars Science Laboratory (MSL) has over ten instrument packages from fixed point weather instruments (REMS), remote imagers (NAVCAM, MASTCAM), and contact science instruments (e.g. microscopic imager (MAHLI), alpha particle x-ray spectrometer (APXS), drill) with resolutions from centimeters to microns. All of these ground observations are overlayed onto an unprecedented orbital mosaic composed of 25 cm/pixel visible imagery, hyperspectral chemical data, as well as a 1m/pixel digital elevation model (DEM) covering the landing ellipse and main science area in totality [1]. Over four Earth years, MSL has sampled thousands of individual science targets coupled to tens of thousands of unique science observations. Longer traverses like the Mars Exploration Rover (MER) Opportunity, have science observations spread over 40+ kilometers and greater than a decade in time! Precisely locating this scientific data down to millimeter accuracy onto the Martian surface combined with instrument science results is a time-consuming process requiring special knowledge in instrument coordinate frames, unique data formats, and advanced mapping capabilities. Valuable spatial relationships can remain hidden from scientists and engineers in the interim, resulting in loss of mission performance on tactical (i.e. daily) and strategic (weekly to monthly) timelines.

The MSL mission utilizes commercial-off-the-shelf (COTS) mapping software common across U.S. federal agencies, universities, and private companies. While being widely used, it has a steep learning curve. In addition, the combination of orbital and insitu datasets are tens of gigabytes in size presenting a difficulty in transferring to end-users, as well as properly accessing various raster and vector spatial data types.

User capability is varied with some users wanting the raw data and others relying on static maps for access, though everyone wants/needs instrument data in a spatial context to improve observations. We attempt to provide maps and localized data for science and engineering team members, but it can be time intensive for even simple queries (e.g. “What’s the elevation at each APXS?”) much less advanced ones (“What's the horizon mask for these locations?”). While we’ve automated some map generation, others require customization.

We have been working on a multi-mission geographic information system project, MMGIS, as a new tool for the NASA Advanced Multi-Mission Operations System (AMMOS). Now in our second year, we’ve developed a series of programs, workflows, and web-based interfaces to unite mission basemaps with science products in their proper geospatial context with ‘quicklook’ instrument results. We present our current development using Mars Science Laboratory rover mission data as a test-case prototype dataset for our tool development.

Objective: Our goal is to develop a multi-mission geographic information system (MMGIS) with geospatial data standards, tools, and interfaces for accessing science instrument data on a map in near-real-time [1]. This will be achieved by automating the localization/georeferencing of science data results and providing a unified mapping interface.

From such a system, we expect to:

- Reduce mission operations cost and risk, reduce processing time, and improve scientific cross-comparisons between instruments.
- Leverage technological advances and emerging standards, improving upon static maps by provide web-enabled map content for all instruments using free open-source software (FOSS) across multiple computer platforms (PC, mobile).
- Broaden support for future missions by standardizing geospatial position of landed and rover instrument science data.
- Increase science understanding within the mission for better science return and faster analysis.

Current status: MMGIS is beta-testing science data product localization for fixed-body, mast pointed, and arm attached (i.e. “Contact Science”) instruments (Figure 1). We’ve developed methodologies and workflows using Python and VICAR [2] for localizing/georeferencing science instrument data by tying spacecraft clock (SCLK) data labels to rover localization, via translation from i,j image space to ground projection, reverse-kinematics, or using the planned target database as a proxy for instrument sample location for all observations. This science product localiza-
tion information is translated from the instrument coordinate frame to a rover-centric coordinate frame, then into a Mars global coordinate system that matches the mission basemap [2]. Once collected, mapping coordinate values are then produced in a format conducive to a web-based mapping interface.

Science team members can access the localized science data via a web mapping interface to quickly assess and utilize recent results (Figure 2). Using open source tools such as Python (python.org), Leaflet (leaflet.org), and D3 (d3js.org), allowed the rapid development of a flexible and simple user interface with a short learning cycle with fast access to recent science data. The web-based mapping interface eliminates the need to download and install software and large multi-gigabyte datasets. Simple tools in the interface allow measuring distance, 3D profiles and views, and viewing targets on ground mosaics, all interlinked, providing rapid review and quick analysis (Figure 3).

Future Work: MMGIS tools, methodologies, and mapping interfaces are slated for delivery to the AMPMOS catalogue in the Fall 2017. A beta version is in use by the MSL Science Team and slated for future deployment to operations. Upcoming Mars missions like InSight and Mars2020 will use MMGIS as a starting point for future tool development.


Figure 1: Diagram of instruments to localization type.

Figure 2: MMGIS web mapping interface with NAVCAM insitu view on left and orbital view on right. CHEMCAM ‘quicklook’ oxide data is displayed for target ‘Piedmont’ as an interactive bar graph.

Figure 3: MMGIS web mapping interface with orbital view on left and 3D view on right (looking south). An elevation profile (red line) was created interactively showing the local relief. Red dots on each view represent the same science target on the surface.