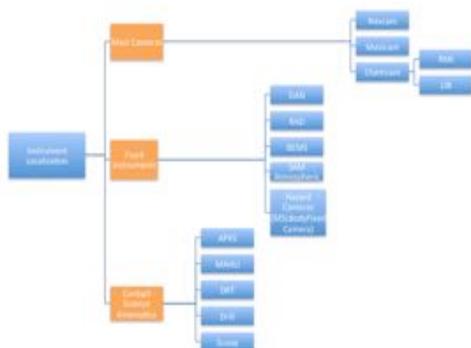


## MULTI-MISSION GEOGRAPHIC INFORMATION SYSTEM: AN OPEN SOURCE SOLUTION FOR PLANETARY SCIENCE OPERATIONS.

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**Introduction:** We've completed our three-year project developing the multi-mission geographic information system, MMGIS, as a new operations tool for the NASA Advanced Multi-Mission Operations System (AMMOS). MMGIS provides geospatial tools as part of a spatial data infrastructure for planetary science operations. This series of programs, workflows, and web-based interfaces unite mission base-maps with science products in their proper geospatial context with 'quicklook' instrument results. The software has now been deployed on two active missions, the Mars Science Laboratory rover and the InSight lander, and is in nearing completion of an adaptation for the Mars2020 rover as a strategic planning tool. In an effort to provide a low-cost, effective solution for planetary missions, this software is now released as an open source project.

**Science Data Product Localization:** MMGIS separates science data product localization into three categories: 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 linking spacecraft clock (SCLK) data labels to spacecraft localization, via translation from i,j image space to ground projection, inverse-kinematics, or using the planned target database as a proxy for instrument sample



fer. Let's take another observation to confirm this evaporite deposit hypothesis!"). The interface allows measuring distances, creating 3D profiles, and viewing targets on ground mosaics, all interlinked, providing rapid review and quick analysis (Figure 2). The main interface is a 2D map view in web Mercator projection. Linked to this map is a 3D "Globe" view developed in three.js and an "InSitu" viewer for displaying ground mosaics and other datasets linked to science targets, such as images and 3D object models. A custom 'Chemistry' tool displays a graph of "quick look" results, e.g. from the CHEMCAM or APXS instrument onboard the Curiosity rover. The modular structure of MMGIS allows adding on additional tools, building on the existing framework.

**Mission Operations:** MMGIS has been deployed on both the Curiosity rover mission and adapted to the InSight lander mission, both at Mars (Figure 3). For Curiosity, the MMGIS instance serves as a way for science team members to see rover traverse progress, view the most recent ground mosaics, and where science targets were acquired. In addition, its been used successfully for strategic rover planning to help develop a safe route up Mt. Sharp given science desirements for sampling specific geologic outcrops and evaluating mobility requirements (slope, terrain types). On InSight, we added an 'Instrument Placement' tool that was used to visually and qualitatively assess deployment of the seismometer (SEIS) and heat probe (HP3) instruments to the surface. We're currently adapting MMGIS for the Mars2020 rover mission called CAMP (Campaign Mapping and Planning) for strategic science operations that will be a fully Dockerized and cloud-deployed version using a RDS PostgreSQL/POSTGIS database to store science team member spatial annotations as well as strategic science targets and drive paths.

**Open Source Release:** Our first open source release has been posted on github under an Apache 2.0 license: <https://github.com/NASA-AMMOS/MMGIS>. Periodic updates will be made several times a year. We'll accept pull requests and merge branches into the master, after internal code review for consistency, security, and pertinence.

**Future Work:** Full migration to a node-based architecture is expected for most tools, moving away from the Apache webserver/PHP model. Our 'Drawing Tool' will be converted over to using PostgreSQL/POSTGIS as well as other updates for cloud support (e.g. better support for datasets in S3).

**References:** [1] Calef et al. (2017), LPSC, #2541 [2] Deen et al. (2015), 2<sup>nd</sup> Planetary Data Workshop, #7059 [3] Calef III, F.J. and Parker, T. (2016) PDS Annex USGS, <https://astrogeology.usgs.gov/search/>

map/Mars/MarsScienceLaboratory/Mosaics/MSL\_Gal\_e\_Orthophoto\_Mosaic\_10m\_v3 [2]

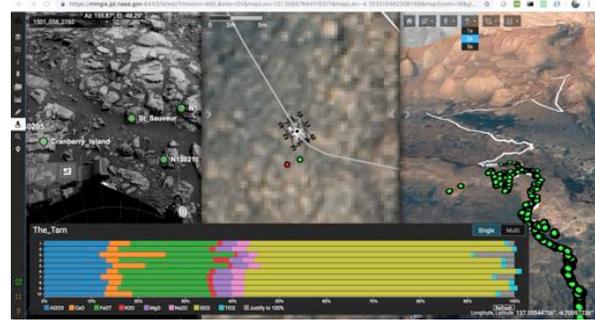


Figure 2: MMGIS web mapping interface with NAVCAM insitu view on left and orbital view on right. CHEMCAM 'quicklook' oxide data is displayed for target 'The Tam' as an interactive bar graph displaying percent of major oxides for each of ten LIBS shots.



Figure 3: MMGIS instance for the InSight mission. The 'Instrument Placement' tool was built to allow qualitative and quantitative assessment of the seismometer and heat probe in the lander's workspace. Instrument outlines were based off of instrument CAD models and also simulated tether placement based on attachment points and dimensions. A 3D view used 'as-built' CAD models and surface data to simulate deployment (right side of image).