IMPROVED DATA PROCESSING APPROACHES FOR FUTURE MARS EXPLORATION MISSIONS.
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The Challenge: The current approach to processing mission data with processes unique to each instrument leads to significant duplication of work, cost inefficiencies, and inconsistent products that result in severe challenges for intra-instrument data fusion. An assumption in the Challenge Areas listed for this workshop is that data from different missions can be used together to pick landing sites and to conduct surface operations. However, experience shows that without a plan to accomplish this, missions discover that working with multiple data sets is an expensive and difficult, yet essential, proposition.

Consistency Issues: An important aspect of all future Mars exploration missions will be reliable and standardized access to previously acquired data. Even when using data released to the Planetary Data System (PDS), incompatibilities between data sets create problems not just for science analysis, but also for mission operations. For example, operations teams learn to apply empirical "windage" when selecting targets using products created with inconsistent cartographic standards. In the case of high resolution imaging with HiRISE, when targeting on the THEMIS global mosaic, the error is often many thousands of HiRISE pixels and, in some areas, can lead to completely missing the intended target. This is especially important when monitoring a site for changes or attempting to combine high resolution imaging with spectral data. However, the underlying problem is systemic and affects landed operations (e.g., MER) in a similar fashion.

In a similar vein, there are multiple groups that can derive topography for Mars. The need to use a consistent set of standards in the derivation of topographic maps is essential, and the standards must be the same as for other data sets. Otherwise, important corrections to the image, radar, or spectral data will be inaccurate. Significant errors in scientific interpretation are likely in such cases. And yet, except for limited draft standards for lunar datasets [1] no such standards exist.

The inconsistency is rooted in the variety of data processing approaches developed over the last several years. While instrument team-generated reduced data are regularly made available through the PDS, most of these data are processed to different levels; use different file formats and keywords; are processed with inconsistent mapping parameters; or are projected onto different planetary shapes or topography.

A related issue is the lack of resources to reprocess legacy data sets to be compatible with the incrementally improving geodetic information.

Duplication of Effort: Decades ago essentially all U.S. planetary image data was processed at the JPL MIPL facility. However, with the advent of small, PI-led missions and the exponential reduction in cost for computational capability, ground data processing moved to many different institutions and key processing steps were deferred to the research and analysis programs in order to lower mission or instrument costs. The cost of setting up the hardware infrastructure for ground data processing is typically ~$1M, which is not large in the overall cost of even a small mission. However, this hides a much larger cost related to software development and training a cadre of proficient data processors. One of the major areas where a new instrument team often struggles is with establishing interfaces with the facilities that actually operate the spacecraft and the final archival repository of the acquired data (typically the PDS).

The largest duplicated cost is probably related to software development. While many instrument teams adapt an existing tool, there are now a plethora of software packages for both uplink and downlink operations. Clearly, the specifics of an individual instrument can necessitate custom software, especially for health and safety monitoring. However, an example of a specific area with less necessary duplication is web services to allow team access to the acquired data. Most instrument teams have scientists who are globally dispersed. Remote access to the most recent data products is often a basic requirement for the team to function. This shift to a cloud-based processing environment reduces costs and allows the teams to focus on the scientific analysis of mission products. However, this is an area where almost every team and the PDS have developed their own unique software systems.

A Different Approach: A return to a single center for processing ground data is probably impractical and not the most efficient, especially for smaller missions. However, a more consistent and coherent approach to processing data can be implemented without robbing instrument teams of the flexibility required to best meet their needs. Here we outline some specific recommendations for a different approach.

Cartographic Standards: A number of crises in the early operations of instruments can be avoided if a consistent set of cartographic standards is agreed to early in the development process. We note that the primary body for coordinating such activities at a high level is the International Astronomical Union (IAU), via their Working Group on Cartographic Coordinates (WGCCRE) [2]. There are also specific NASA Working Groups for Mars and the Moon [3, 4]. Following recommendations from these groups is also required by the PDS [5]. The issue is that these recommendations are rarely considered during the proposal preparation or selection process. The simple step of either having sufficient expertise as part of the proposed missions/instruments or educating the developers of any ground data system in these standards, especially during formal reviews, could alleviate a major portion of the problems in this area, with gaps in the existing standards being addressed well before an instrument begins to return data.

Software that uses Cartographic Standards: There are many different software packages that can do sophisticated image analysis. There are many other packages, especially geographical information systems, which can work in a cartographically rigorous fashion. However, many of these packages have (sometimes subtle) assumptions built in that the target body is the Earth. There are only two broadly available software packages that are primarily intended for cartographically correct image analysis of planetary data: JPL's VICAR and the USGS ISIS packages. A large number of camera teams rely on the ISIS package as part of their ground data system, especially for map projection. If the selection of planetary constants, digital terrain models, and map parameters followed a uniform standard, the data should be easy to combine. However, the PDS allows multiple standards and non-imaging instruments are not well supported by ISIS. The former may be addressed as the PDS moves from PDS3 to PDS4.

The expansion of ISIS to work with a broader range of instruments is currently being pursued using funding from the Planetary Geology and Geophysics Program. Over the next few years we anticipate that ISIS will provide more robust support for radars, spectrometers, altimeters, and sounders. An important aspect of this planned work will be to allow mapping of data collected from landers or rovers with orbital data sets. However, without substantial funding from some source, it is unlikely that improvements to ISIS – or any other software – will ever result in correctly reprocessing all Mars mission data.

Cartography and Geodesy Research: The continued improvements to ISIS are the fruits of more basic research into cartography and geodesy. Automatic registration of disparate data types is now an area of very active research, especially related to autonomous vehicles of many types. Another area of current research is in "data mining" which is extremely relevant when the volumes of Mars data returned by the MRO mission are considered. It is also important to use software that can take full advantage of the modern computing environment. Modest investments in these areas could greatly change the nature of mission operations with much more information readily available on a tactically useful timescale.

Summary: While often overlooked, data processing on the ground is an essential element of any future Mars mission. While computer hardware is cheap enough to allow such processing to be done at many different institutions, it is essential that the products conform to consistent standards, including standards still to be developed. The USGS Astrogeology Science Center has the historical and current expertise to provide advice and solutions for any future Mars missions.

References: [1] LGCWG (2009). ftp://ftpext.usgs.gov/pub/wr/az/flagstaff/barchinal/LGCWG/MosaickingRecommendations_090428-draft.pdf. [2] B. Archinal, et al. (2011), Cel. Mech. & Dyn. Ast., 109, 101-135[3] T. Duxbury, et al. (2002), ISPRS, 34, pt. 4. [4] B. A. Archinal and the LGCWG (2009), LPSC XL, #2095. [5] PDS (2009), Ch. 2 of PDS Standards Reference.