

THE PDS ANALYST'S NOTEBOOK: PROVIDING CONTEXT FOR LANDED OPERATIONS AND ADDING VALUE TO MISSION ARCHIVES. T. C. Stein¹ and R. E. Arvidson¹, ¹McDonnell Center for the Space Sciences, Department of Earth and Planetary Sciences, Washington University in St. Louis, 1 Brookings Drive, CB 1169, St. Louis, MO 63130, tstein@wustl.edu, arvidson@wustl.edu

Introduction: Planetary data archives of surface missions contain data from numerous hosted instruments. Because of the nondeterministic nature of surface missions, it is not possible to assess the data without understanding the context in which they were collected. The Planetary Data System (PDS) Analyst's Notebook (<https://an.rsl.wustl.edu>) [1] supports data discoverability and access for landed missions by integrating sequence information, engineering and science data, observation planning and targeting, and documentation into a web-based application. Notebooks are available for the Mars Science Laboratory [2], Mars Exploration Rover (MER) [3], LCROSS [4], Mars Phoenix Lander [5], and Lunar Apollo [6] surface missions. In addition, Notebooks are being developed for the InSight [7] and Mars 2020 [8] missions, and a Notebook is planned for the Dragonfly [9] mission to Titan.

Origin: The genesis for the Analyst's Notebook (AN) was founded in developing a tool for supporting active mission surface operations. The April 1999 Field Integrated Design and Operations (FIDO) [10] rover test was held in the Mojave Desert, California, in preparation for the MER mission. By the third day, the 20-person team in the field test realized the need to capture test plans and actions, raw scientific and engineering data, and processed data and special products in a unified resource that would be available for reference during the mission. In addition, such a resource would serve the science community long-term after the mission. AN concept versions [11] were developed for each of the FIDO tests from 1999 to 2002.

Supporting the MSL mission: The MSL AN for the Curiosity rover was developed by the PDS Geosciences Node in collaboration with the MSL science team. By agreement, a special version of the AN is available to the team during landed operations as a non-mission critical tool. Content such as data, plans, traverse data, and support documents are ingested daily. Observation planning and targeting information are extracted from mission science plans. Source commands are linked with resulting data products where possible, albeit with limits due to the absence of round-trip data tracking.

This approach assists with data validation and builds on strong collaboration between data producers and PDS archivists that began soon after mission selection with creation of the project data management and archive plans.

The public version of the MSL AN was released in February 2013 coincident with the first PDS release of

MSL data and is updated with each subsequent data release. It contains all peer-reviewed, released data. Importantly, it also contains information that is not archived in PDS, including daily activity plans, drive traverse data, higher-order data products, and ~4000 Science Operations Working Group documentarian and mission manager reports. All content has been ITAR cleared.

Navigating the Notebook: The AN is designed as a virtual notebook for the planetary scientist, with different sections that provide unique views into the mission archives. The AN feature set varies by mission, depending on the availability of information. Those developed for more recent missions (e.g., MSL) generally have more features. The PDS Geosciences Node regularly assesses the potential and value for updating AN feature sets as resources allow.

Mission Summaries. A searchable, sortable, and downloadable summary table provides an overview of surface operations by sol (Mars day), with links that enable quick access to details for a given sol. Another table lists science planning targets with links to images and data products when known.

Sol Summaries. The Sol Summaries are the primary interface to integrated data and documents contained within the AN. Data, documents, planned observations, targets and mosaics are grouped for easy scanning. Detailed information is displayed as items are selected by the user.

Data products are displayed in order of acquisition, and are grouped into logical sequences, such as a series of image data. Sequences and the individual products that comprise them may be viewed in detail and downloaded, either directly or as part of a cart order.

Detail data product views vary by instrument. PDS labels, data set documents, and activity details are available for all products. In some cases, derived data also are available. Image data are presented in both browse and full-resolution versions.

Maps. In the MSL and MER AN, the rover traverse is plotted on a HiRISE basemap using corrected drive telemetry provided by the project. The Apollo AN also includes landing site maps. Users may zoom and pan the map. Clicking on a traverse location brings up links to corresponding data.

Searching. The AN supports searches on data products, sol documents, and targets. For example, MSL and MER data products may be searched by time, location, instrument, command sequence, product type, image

eye and filter, product type, and product ID. Sol documents may be searched by type, time, and filename. In addition, free text searches are supported. In the MSL AN, targets may be searched by name, time, and location, as well as for links to literature references. Searches can be bookmarked for later recall.

Resources. Data set documents and references to published mission papers are contained in the Resources, along with links to related web resources.

Online Help. Guidance is provided through a series of searchable help pages. Topics include release notes, landing site, coordinate frame, instruments, data processing, and data product file naming and structure.

Adding value to the PDS archives: Planetary data archives are enhanced by incorporating higher order products and external resources into the AN. Included data visualization and analysis tools support data discoverability.

Mars Target Encyclopedia (MTE). The MTE is a reference database containing compositional information about MSL ChemCam targets extracted from publications [12]. MTE results have been integrated into the MSL AN, allowing users to find what has been published about targets, elements, or minerals of interest. Each reference includes the document lead author, year, title, and publication. Links to the source documents (PDFs) are included as well.

APXS and ChemCam Data. Chemical concentration results derived from archived data by the MSL APXS [13] team and ChemCam Remote Micro-Imager (RMI) [14] data have been added to the MSL AN. Annotations on RMI mosaic images denote locations of ChemCam LIBS data elemental abundance acquisition. The RMI image taken after LIBS acquisition is on top to show the laser pits. For both instruments, data are associated with specific targets and can be found using the AN Target search function.

Image Measurement and Drawing Tools. The AN assists users with image analysis via the included Image Viewer. Measurement tools provide location and distance measurements for images with stereo coverage from the MSL and MER Hazcam, Navcam, and Pancam instruments. In addition, elevation profiles may be created. Drawing tools allow the user to add shapes and text to any single-frame image, regardless of stereo coverage.

Planning Target Images. The MSL AN includes planning targets defined by the operations team, each associated with a locator image. Additional images are automatically identified using a target's ground coordinates, image metadata, and the MSL CAHVOR image model [15]. The newly developed MER target archive is scheduled for release and inclusion in the MER AN in February 2020.

Context Mosaics. The PDS data archive for MSL includes mosaics generated by the science team from Navcam data. However, sometimes sequences of single frame images are acquired for the purpose of creating a mosaic without a formal data product being archived. For these cases, we have created context mosaics, which are not calibrated science products, from Navcam, Mastcam, and MAHLI images [16] and included them in the MSL AN.

Additional Features: Features continue to be added to the AN to improve usability. The additions are based on feedback from the user community.

Data Ordering Via Cart. MSL and MER data and documents may be ordered using a shopping cart paradigm. Selected items may be added to the user's cart in the Sol Summaries and Search portions of the AN. Users may elect to receive a zip file of data or display a web page of links to requested items.

Data Transformation. In addition to PDS versions of data, images may be saved in JPEG format and in stretched or unstretched, lossless PNG format. This option is available on image product detail pages and may also be applied to all images ordered using the cart.

Future Development: Several AN functions are based on previous user suggestions, and feedback continues to be sought. (User feedback should be submitted to an@wunder.wustl.edu or by using the online form.) Work continues to incorporate additional features, especially in the areas of related observations, visualization, data transformation, and improved search.

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