Planetary Data Archiving, Restoration and Tools 2019
Abstracts of Selected Proposals
(NNH18ZDA001N – PDART19)

Below are the abstracts of proposals selected for funding for the Planetary Data Archiving, Restoration and Tools 2019 (PDART19) program Principal Investigator (PI) name, institution, and proposal title are also included. One hundred-twelve (112) proposals were received in response to this opportunity. On November 6, 2019, 18 proposals were selected for funding.

Klaus-Michael Aye/University of Colorado Boulder
Cassini UVIS Data Product Enhancement

Objectives:
The limited content and inconvenient format of published Cassini Ultraviolet Imaging Spectrograph (UVIS) data products puts a high burden of remaining work tasks on the end user before a scientific investigation can begin. We propose to produce an upgraded data product in a modern format, add all required meta-data to remove the need of time-consuming geometry calculations, and perform a default calibration for the majority of data products. This will realize enormous gains and scientific efficiency in working with UVIS data. The proposed work will spare researchers beyond the UVIS team countless hours dealing with unnecessary technical issues and allow them to concentrate on scientific analysis. This work benefits all aspects of study related to UVIS observations: stellar and solar occultations of Saturn, emissions from the Titan atmosphere, satellite reflectance, ring spectroscopy, and more.
Methodology:
We propose to create enhanced UVIS data products, based on the datasets available in the PDS, by pre-calculating an expanded set of geometry parameters for each detector readout and applying a default calibration that varies with the observational scenario. This additional geometrical metadata required for full scientific investigations will be included with the original instrument data in a PDS4-compatible data product in the FITS format. Furthermore, we plan to merge the search, data management, analysis, and basic plotting into a common programmatic environment (Python and, to some extent, IDL). Procedures in Python and IDL will be provided to work with this product. We will provide basic data plotting routine and their source codes, based on the new data format.
Relevance:
As requested by the PDART solicitation document, section 1.2, we propose to generate higher-order data products for the UVIS instrument that will be delivered to the PDS, in the new and encouraged PDS4 framework. We also are relevant for section 1.7, as we will develop and deliver software tools and source code for basic visualizations of the new data product, and will store all produced source code at NASA s PDS Github site.

Ross Beyer/NASA Ames Research Center
Improving the NASA Ames Stereo Pipeline: Algorithms and Tools.

OBJECTIVES: To enhance the capabilities of the NASA Ames Stereo Pipeline by incorporating additional stereo matching algorithms from the computer vision and the Earth observing communities.

METHODOLOGY: For years the Ames Stereo Pipeline software has had one approach for stereo matching, namely block-matching, and has just recently added SGM as a second option. This work proposes to gather stereo algorithms from the computer vision and photogrammetry literature that have only been applied to terrestrial problems or in a simple research setting, and bring those algorithms into the production environment of the Ames Stereo Pipeline. There they can be robustly tested, tuned, and provided to users as additional choices for processing planetary and Earth data. We also plan to modify this software to make it easy to add new algorithms in the future as plug-ins with no modifications to the existing framework and to make it more scalable for multi-core and multi-process architectures. We have found in our work that there is no single best algorithm that performs well in all situations. Some algorithms work better on certain terrains and with certain types of images. Providing more algorithm options to Ames Stereo Pipeline users with tunable parameters and with guidelines for their use will allow those users to produce better data that will eventually lead to better science.

Beyond just stereo correlation algorithms, there are other techniques and tools that serve to improve the resultant terrain models. The externally-developed CASP-GO system consists of extra tools for co-registration and sub-pixel refinement that are wrapped around the core ASP functionality. As well as additional tools to evaluate height uncertainties. The CASP-GO system will be incorporated into ASP as additional options for all users of ASP.

A number of tests against existing terrain data will be performed during the development of this tool.

RELEVANCE: The result of funding this PDART proposal will be a software tool which has improved capability to derive terrain from planetary images. This improved capability will have a significant impact on science investigations and even engineering studies for landing site safety evaluations.

These proposed outcomes are directly relevant to the PDART call which seeks "to produce tools that would enable or enhance future scientific investigations." The resulting software tool will be archived according to the PDART requirements, and will continue to be released as open-source.

Christopher Edwards/Northern Arizona University
Improving THEMIS-based Compositional Analysis Accessibility: Generation of Emissivity Products and Processing Tools

Background and Objectives:
THEMIS (Thermal Emission Imaging System) on Mars Odyssey is a multispectral instrument consisting of a10-band infrared imager with ~100 m/pixel spatial resolution, allowing the community to study the properties of the surface materials over nearly all of Mars. However, THEMIS has been less widely used for surface spectral analysis due to the lack of a fully automated atmospheric correction tool or surface emissivity product. The objective of the proposed work is to develop a toolset to perform atmospheric correction for THEMIS daytime radiance images, and produce a suite of atmospherically corrected data products for approximately ~100 high priority sites (e.g. past landing sites that were under consideration; sites from the humans-to-Mars workshops, etc). The proposed work will boost the accessibility of THEMIS surface emissivity to the broader community.

Methodology:
Atmospheric correction of THEMIS images involves correcting for atmospheric emission and atmospheric transmission. Correction for atmospheric emission can be fully automated, whereas correction for transmission can be semi-automated. Thus, the proposed effort will consist of three tasks:
1. Generate a near-global data set of THEMIS images that have been corrected for atmospheric emission, using the best-available daytime THEMIS images. These images can then be corrected for atmospheric transmission by individuals using the tool developed in Task 2. The best-available THEMIS images include the warmest surface, highest signal-to-noise ratio, lowest dust coverage, limited water ice, and etc. We expect limited data coverage within higher latitudes (higher than 70°S and 70°N) and within the Tharsis volcanic plateau because of lower surface temperature and higher albedo, respectively. These will be made available as data layers within a standard JMARS software update.

2. Develop a semi-automated toolset for correcting for atmospheric transmission based on TES (Thermal Emission Spectrometer) emissivity. The toolset will automatically query of TES data and compute their footprints overlaps on THEMIS images. It will look for temperature, emissivity and elevation variability under TES pixels to select the TES-based training emissivity and convert the training data to the same spectral resolution as THEMIS. Spectral contributions from atmospheric dust and water ice transmission will be determined by dividing the average emissivity from a spectrally uniform region by the TES-derived training surface emissivity from the same area.

3. Generate a small data set of fully atmospherically corrected THEMIS images for ~100 high-priority sites of interest. This list will include all sites previously considered for the MER, MSL or Mars2020 missions, as well as other sites of interest. We will archive the data set from Task 1 and the data product from this task via the Planetary Data System

(PDS). They will also be made available as data layers within a standard JMARS software update.

Relevance:
The proposed work is directly relevant to the PDART program (ROSES Appendix C.4) that it will 1) generate new high-order data products , and 2) not focus on hypothesis-based planetary science . The proposed data set is anticipated to enhance the science return from the THEMIS instrument through increasing the accessibility and utility of THEMIS-derived surface information to the scientific community. The surface emissivity data set derived from THEMIS instrument will provide characterization of surface mineralogy and complementary information to other spectral, morphological thermophysical and geologic data sets. Thus, the proposed data set will advance the current state of knowledge and provide more robust interpretations of Martian surface mineralogy.

Carolyn Ernst/Johns Hopkins University Applied Physics Laboratory
Enhancing the Features and Capabilities of the Small Body Mapping Tool

Spacecraft missions return valuable data, but those data can be hard to access, analyze, and interpret. The search for available data can be cumbersome, and matching and co-registration of the data can be difficult. Users often lack tools for easily finding the data needed to accomplish their science investigations. Once located, the data often must be converted into a more analysis-friendly format, which creates yet another barrier to access. These challenges significantly impact users new to a particular dataset, but they also hamper the efficiency of experienced scientists.

Spacecraft data for small bodies present additional complications. The irregular shapes of small bodies pose a considerable obstacle. Visualizing and mapping features on such bodies is a difficult task, and 2D map projections lead to severe distortions of spatial relationships and size. Downslope direction is often not apparent, yet is crucial for interpreting surface geology, material mobilization, and resurfacing. Analyzing spectral data is also complicated; to co-register and photometrically correct the data, a shape model with a resolution equal to or better than the spectral data is necessary to derive the proper location and incidence, phase, and emission angles.

The Small Body Mapping Tool (SBMT) addresses these challenges. The SBMT is a publicly available, interactive, 3D visualization tool developed at the Johns Hopkins University Applied Physics Laboratory to map and analyze features on irregularly shaped solar system bodies. The SBMT enables interactive searches for analysis-ready spacecraft data. Once selected, data can be projected onto the shape model and analyzed using the SBMT s built-in analysis tools, thereby integrating data discovery and data analysis. Essentially, it is a cross between a data search tool, data portal, and a three-dimensional Geographic Information System for irregularly shaped bodies.

In its current state, the SBMT is a powerful, easy-to-use tool for accessing and analyzing data from small bodies. However, the SBMT has been developed piece-by-piece on frugal budgets in response to the needs of the individual grants or missions, with a focus on generating new functionality to enable science analysis. This piecemeal development has meant that under the hood , the Tool is not as efficient as it could be when it comes to code base updates, adapting existing functionality to a new target bodies/mission data, interoperability across analysis tools, implementation of functionality across data types, and standardization of data formats and documentation. Many things can be done to improve interoperability, usability, and transparency for the planetary science community, and to enable growth and extension of the Tool for future applications. Our main objective is to make the Small Body Mapping Tool more user friendly, interoperable, and robust now and for next 10 yrs.

We propose to enhance the features and capabilities of the SBMT through seven proposed main tasks: (1) Update the Java and VTK code base to keep up with and take advantage of continually advancing capabilities and operating systems; (2) Increase the interoperability of the SBMT with other common, primarily 2D analysis tools; (3)

Reorganize and streamline several core functions of the Tool to enhance the user experience and simplify future code development and maintenance; (4) Compile and make available a library of tools that can be paired with SBMT to extend data analysis beyond the SBMT s built-in functionality; (5) Curate the available datasets, including adding headers to existing data products and producing detailed tracking of data files and assessments of data quality; (6) Archive existing shape models, image tracking and quality lists, smithed SPICE kernels, and geophysical maps with the PDS; (7) Increase visibility of the SBMT in the planetary science community via conference presentations and a publication.

Iouli Gordon/Smithsonian Astrophysical Observatory
Enhancing capabilities of the HITRAN and HITEMP molecular spectroscopic databases for planetary research

Accurate high-resolution spectroscopic reference parameters are crucial when interpreting planetary spectra recorded with ground-based and satellite-based spectrometers, including those on board numerous past, current and future space missions (Spitzer, Hubble, Cassini, Venus Express, JWST, and many others). Spectroscopy is a powerful tool for understanding the chemical abundance of constituents in planetary atmospheres, as well as determining their various physical conditions. In fact, even interpretation of low-resolution spectra from distant planets requires band models which are built from high-resolution line-by-line reference spectra.
All NASA planetary missions equipped with spectrometers of any resolution use band models or radiative-transfer codes that heavily rely on the HITRAN (and for higher temperatures HITEMP) molecular spectroscopic databases, which we have developed and maintained for half a century. Originally, funding of the HITRAN database was aimed at studies of the terrestrial atmosphere (i.e., limited to the species that are dominant light absorbers in the atmosphere of the Earth, at terrestrial temperatures, and assuming air as the main ambient gas). The situation changed when we succeeded in obtaining funding from the PDART program to extend the capabilities of the HITRAN and HITEMP databases towards planetary (and exoplanetary) studies. The line lists of many molecules of planetary interest were substantially updated by revising the existing parameters and by considerably increasing spectral and dynamic ranges, while new molecules were added. In addition, extensive updates to the collision-induced absorption (CIA) section of HITRAN and addition of new molecules to the HITEMP database were carried out. The infrastructure of the database was changed to allow the addition of new spectral parameters. Several molecules now have parameters associated with broadening and shifting of spectral lines by planetary gases (He, H2, CO2 and H2O) thanks to the semi-empirical models that we developed.
We propose to: 1) further develop the HITRAN and HITEMP databases by improving the quality of current parameters, and by adding i) new molecular species in both the line-by-line and experimental absorption cross-section parts of the database; ii) broadening parameters for additional molecules of planetary interest; iii) new molecular species and collision-complexes that are required for planetary research and 2) add new significant isotopologues for the existing molecular line lists. The tasks will include: a) Collection and evaluation of existing data in the literature (both experimental and theoretical). We emphasize that data validation is an integral part of the HITRAN philosophy. It includes cross comparisons of existing experimental and theoretical data, checking for basic selection rules, and validation against independent laboratory and field spectra. The HITRAN group also develops semi-empirical models for spectroscopic parameters that address existing deficiencies. b) All new data will be integrated into the freely distributed HITRAN and HITEMP databases and accommodated to work with the web interface (www.hitran.org) and HITRAN Application Programming Interface (HAPI) for the convenience of users. c) Providing support to the users. We have a long and successful tradition in this area and, apart from responding to frequent emails, plan to expand our

support for users by including more detailed manuals and additional instructive video tutorials.

The new data will provide an immediate boost in our ability to model spectra of planetary atmospheres (including exoplanets with extreme thermodynamic conditions), and will also be vital for calculations of opacity tables for planetary atmospheres over a wide range of temperatures with a variety of constituent gases.

Christina Hedges/NASA Ames
Leveraging the NASA Exoplanet Missions for Planetary Science

NASA s astrophysics division has launched two survey missions for searching for transiting exoplanets; Kepler and TESS. These missions have been extremely successful, owing to their large survey area and extreme photometric precision. Together they have provided thousands of light curves of transiting exoplanets to the astrophysics community. The Kepler and TESS datasets provide unrealized potential for the planetary science community. Hundreds of asteroids, comets and planets have been observed by Guest Observers using the Kepler telescope, and thousands of solar system objects will be observed in the TESS full frame images with a precision of 10% or greater. These observations can last up to two months with a virtually uninterrupted observing cadence of 30 minutes, providing extremely time dense and precise light curves, with which rotation periods, rotational modulation and eclipses on time scales from hours to weeks can be robustly measured. While this valuable planetary data resource is technically available, it is difficult to access, since the data products and tools funded by the mission are aimed towards supporting astrophysics investigations. We propose to develop a python toolkit to access, extract and process these light curves, based on our existing experience with the Kepler and TESS data for astrophysics research. We will develop tools to allow users to easily extract data for known objects in these data sets with simple queries, remove instrument systematics such as the K2 spacecraft motion and TESS jitter, and fit rotation periods and variability using Gaussian processes and eclipse models. We will provide interactive tools to identify star crossings, fit GP hyper parameters with a variety of kernels and Lomb-Scargle models of arbitrary order. We will build on our considerable experience in identifying exoplanet transits to add eclipse modeling tools with robust removal of long term trends from rotation. Alongside our tools we will provide in-depth documentation and tutorials so that users of all backgrounds and skill level can access our light curves. Finally, we will incorporate tools from existing and under-development packages (such as lightkurve and sbpy) to allow users to infer properties of asteroids based on these light curves. Alongside our toolkit, we will build light curves of the brightest objects observed by Kepler and TESS and deliver them to an approved archive.

Mark Looper/The Aerospace Corporation
Recovery of Voyager 2 CRS Data from Neptune Flyby

Objective:
Voyager 2 is the only spacecraft to have visited Neptune, with a 1989 flyby, and so the only in situ measurements of the planet s magnetosphere come from about twelve hours around Voyager 2 s closest approach to the planet. The Cosmic Ray Subsystem (CRS) aboard the spacecraft measured energetic protons and electrons during this time; however, only a small subset of this data has been archived in the Planetary Data System (PDS). When the Jet Propulsion Laboratory (JPL) assembled a model (NMOD) of energetic particles in the planet s magnetosphere in 2017, the only available CRS flux measurements were digitized from figures published in two journal articles and a PhD thesis.

The PI of the present proposal wrote that PhD thesis, and for thirty years he has had dozens of hardcopy plots of the CRS data that went into it stored in a box in his garage. When he was contacted by the author of NMOD seeking permission to use figures from the thesis in its documentation, we realized that digitizing these data would substantially increase the volume of CRS measurements of energetic particles at Neptune that are available to the scientific community. We propose to perform this digitization, and to submit the results to the PDS for ease of access by future researchers. We have also recently become aware that the raw Experiment Data Records (EDRs) do still exist in electronic form, and will be collecting some subsets of this data for preservation in the PDS. Finally, CRS took a very similar set of measurements during the Uranus flyby in 1986, and since those EDRs have also become available to us we will also convert the same subset of the Uranus EDR data into a form that can be archived in the PDS.

Method:
The data volume is not large compared to that of many missions, and so we will use one of the numerous readily available commercial or open-source plot digitization applications to scan the plots by hand. The main dataset includes the time series of fluxes in several proton energy channels that were reproduced in the thesis. It also extends this to higher energies, mostly with upper limits rather than nonzero measurements, that were not used in the thesis. We also have plots of the data in other forms, e.g., vs. radial distance rather than time or as energy spectra at a given time. All of these will be digitized as well and compared against each other and against the single-channel time series plots, to validate the dataset for internal consistency.

We will assemble and document a set of single-detector and coincidence rates from the Neptune EDRs, describing what particles each responds to since precise calibrations are not available. We will also collect measurements of the energy deposits of individual particles in two detectors that recorded these lower-energy particles, and will extract from the literature (and from other subsets of the sheaves of hardcopy plots in our possession) an algorithm to convert them from detector counts to particle fluxes. We will then apply this same processing to the Uranus EDRs.

Significance:
One of the purposes of PDART is to increase the amount and quality of ... data products available for planetary science research and exploration. By making available in the PDS the CRS data that has been unavailable to the community since the Uranus and Neptune flybys (except for the few published plots), the proposed work is directly responsive to this aim. In addition to the possible general interest of this data to scientists studying the magnetospheres of these ice giant planets, orbiter missions to one or both of the planets are being considered for inclusion in the next Planetary Science Decadal Survey. This was the impetus for the creation of the NMOD model and software at JPL, and the data we propose to recover could be used to enhance such models and to better design the spacecraft and sensors to measure and survive in the radiation environments around these planets.

Katherine Mesick/
Generating an Improved Mars Odyssey Neutron Spectrometer High-Level Time-Series Data Archive

We will generate an improved high-order data product for the Mars Odyssey Neutron Spectrometer (MONS) and deliver it to the PDS Geosciences node, including data from the beginning of MONS mapping operations in 2002 through quarter 2 of 2019. MONS, which is still operational, measures the leakage flux of neutrons and provides unique information about near-surface hydrogen inventories and the seasonal CO2 cycle. Processing of MONS raw data to a higher-order data product requires cleaning and numerous corrections to extract counting rates from raw spectral histograms. MONS contains two type of neutron counting rate products Category 1 events (thermal and epithermal neutrons) and Category 2 events (fast neutrons).

In previous work, we developed a new analysis code for processing MONS Category 1 data and produced an improved high-order data product through 2017 compared to what is currently available in the PDS. This project has 3 goals: 1) Extend the Category 1 data processing based on the already-developed code through quarter 2 of 2019 (raw data that will be available in the PDS at the start of this project), 2) Write Category 2 data processing code, following a similar methodology to previous work, to produce an improved Category 2 data product covering the same time frame, and 3) Generate and deliver to the PDS a PDS4 data archive package of the complete improved high-order MONS data product.

This work is directly responsive to the PDART proposal call: Proposals to generate new high-order data products or to improve or expand current high-order data products are encouraged. This work will generate an improved high-order MONS data product, increasing the quality of information available in the PDS for scientific research. MONS data is valuable for studying the near-surface water inventories on Mars, and the expanded time series of improved data that would be made available by this work of interest to studying inter-annual variability of Mars water and seasonal CO2 cycle, and area of growing interest due to the observational time scales now available to many instruments.

Mark Panning/Jet Propulsion Laboratory
Improving the Accessibility of the Apollo Passive Seismic Data: Archiving at IRIS and the PDS

Five passive seismometers were deployed on the Moon during the Apollo missions, and four remained operational until 1977. The data were archived on magnetic tapes. Since the data were recorded in proprietary formats, they are difficult for each individual researcher to use. Although they were also translated into a widely-used format (known as SEED), some timing issues were discovered in the traces. Consequently, the data are no longer available at IRIS (Incorporated Research Institutions for Seismology). We propose to make these data widely (and easily) available to seismologists via IRIS and the Planetary Data System (PDS).

Records of possible marsquakes or meteoroid impacts from the InSight mission have also made seismic data from the Moon a hot topic. More researchers are contacting us to learn how to use the original data. However, at the present time, this is a difficult and ad hoc process. In addition, we use these data to calculate the required instrument sensitivity for the proposed Lunar Geophysical Network and future Commercial Lunar Payload Services missions. We can also use the Apollo seismic records to assess the meteoroid flux on the Moon, which has relevance for astronaut safety at future Moon bases.

Ceri Nunn collaborated extensively with Yosio Nakamura (an original member of the Apollo seismic team) to extract the long-period data and deal with the timing issues. With some additional tests, the new imports can be shared. We propose to make these data widely available, and this can be achieved with the following steps. 1) Finalize and test these imports for the long-period instruments, and add new imports for the short-period instruments. 2) Upload these data to IRIS (so that they can be widely shared with seismologists). 3) Upload the data to the PDS. We will use the tools already developed by Renee Weber to archive the InSight data with the PDS. Uploading to the PDS will ensure that the data will be permanently and securely archived, and can be easily shared with planetary scientists.

The team members have extensive experience with extraterrestrial seismic data. Ceri Nunn is a lunar seismologist and has submitted a review paper on the Apollo seismic instrumentation. Renee Weber has reanalyzed data from the Apollo missions and is currently archiving data from the InSight mission with the PDS. Mark Panning is a Co-Investigator on the InSight mission to Mars.
This work will be of great benefit to the planetary science community since it will make it easier for new researchers to access these valuable data and apply new techniques to understand more about the structure of our nearest neighbor. Forward to the Moon!

Sharon Purdy/National Air and Space Museum

Preparing a Geologic Map in Margaritifer Terra: A Community Resource to Facilitate Future Scientific Investigations on Mars

Introduction: The southern Margaritifer Terra region on Mars preserves a long record of aqueous processes that include the highest density of valley networks on the planet, the Uzboi-Ladon-Morava meso-scale outflow system, and younger alluvial fans that partially fill numerous craters. Prior mapping of the region (published and in review), which focused on the drainage evolution and juxtaposition of various units in the eastern and western portions of Margaritifer Terra, demonstrates that activity began in the Noachian, likely peaked in the late Noachian-to-Hesperian, and persisted at least locally into the Late Hesperian or Amazonian. Nevertheless, likely source(s) of the water associated with the aqueous activity (e.g., relative contributions to runoff from groundwater versus precipitation), and the style and duration of the activity (e.g., short- or long-lived, pluses of activity over time), are not well constrained.

Goals and Objectives: The existing United States Geological Survey (USGS) geologic maps in this region have been an important tool used to understand the distribution and general timing of aqueous activity, yet efforts related to defining the source(s) and nature of responsible runoff have been hampered by the lack of maps connecting the eastern and western portions of Margaritifer Terra. To fill this critical gap, we propose to produce a geologic map of Mars Transverse Mercator (MTM) quadrangles -20017, -25017, -20022, and -25022 at a scale of 1:1,000,000. The goal is to provide a standard USGS map that that can be used by Mars researchers to comprehensively evaluate the drainage evolution over a broad section of the planet.

The proposed map area includes the medial to distal portions of the Samara-Himera and Paraná-Loire valley network systems two of the most laterally extensive, well-integrated valley networks on the planet. The trunk segments of these valleys integrate much of the drainage coming from mapped areas to the east (with the exception of that draining into Noachis basin), as well as from the west including the eastern margin of Ladon basin to the west and further south. Because these drainages integrate discharge from such a broad region, their morphometry (e.g., valley density, occurrence of terraces, etc.) likely reflects runoff evolution over time that may be an indicator for changing water sources and environmental conditions.

Approach and Methodology: Standard planetary mapping principles will be used to define map units based on topography, morphology, stratigraphic relationships, and relative age. Mapping will employ methods and formats consistent with current established guidelines and USGS protocols, and will draw upon the results from prior mapping at similar and smaller scales to ensure consistent definition of units and seamless transitions between existing map coverage. Datasets (e.g., THEMIS, MOLA, CTX, HiRISE, CRISM) will be compiled and analyzed in ArcGIS 10.7 or ArcGIS Pro 2.3, and units and features will be identified using standard USGS symbols. Relative dating of surfaces will employ crater statistics and stratigraphic relationships, where crater statistics will be compiled in ArcGIS using a subset of a global CTX mosaic and

CraterTools, a plug-in software for ArcGIS. Interpreted absolute ages will be derived from segments of the plots for each unit that best match the expected production population based on multiple chronology functions in Craterstats2 software.

Relevance: The development of the proposed geologic map will complete a broader geologic mapping effort in the Margaritifer Terra region, and is relevant to the PDART program to &produce tools that would enable or enhance future scientific investigations (as described in ROSES Appendix C.4). This proposed work is not driven by hypothesis, yet the final map product will assist future scientific inquiries that will further our understanding of the unique region.

Nathaniel Putzig/Planetary Science Institute
Planetary Orbital Radar Processing and Simulation System (PORPASS)

We propose to develop a web-based Planetary Orbital Radar Processing and Simulation System (PORPASS), built around a new generalized radar sounder processor (GRaSP) and a new 3D orbital radar simulator (OaRS). PORPASS will access orbital radar data from the Planetary Data System or equivalent archive and use GRaSP to carry out customized processing for a chosen instrument and set of parameters. OaRS will generate simulated radar data using parameterized spacecraft orbital parameters, instrument configurations, space and planetary environments, surface topography, and subsurface attenuation and scattering effects.

Although orbital radars have added greatly to our understanding of planetary surfaces and subsurfaces, processing of raw radar data is often poorly documented and difficult to implement, leaving researchers to rely on results from standardized processing pipelines that may not be well-suited to specific scientific goals. The lack of readily available radar processors means that processing of radar data has been largely limited to instrument teams or radar scientists who are intimately familiar with orbital radar datasets, and customized processing has only ever been applied to small fractions of the available planetary radar datasets.

Geophysical data and their interpretations are intrinsically nonunique, and thus numerical models (simulators) are often used to bolster interpretations and help infer surface and subsurface properties. While various simulators are in use for planetary radar studies, they typically involve generic 1D or 2D codes that do not account for the full behavior of the spacecraft or instrument, nor do they take into account accurate 3D models of the planetary ionosphere, surface, and subsurface. Additionally, most published simulation results do not use openly available software, restricting the community s ability to verify radar imaging and published interpretations.

The heart of PORPASS will be the development of GRaSP. Most modern sounder systems rely on synthetic-aperture radar (SAR) processing to enhance along-track resolution and boost the effective signal-to-noise ratio. Despite the similarities across radar systems, instrument teams devote a substantial amount of time and effort to designing and enhancing new SAR processing systems specific to each new instrument. We will follow a modular design for GRaSP. For the initial development of GRaSP proposed here, we will focus on the incorporation and integration of data for three radar sounders: Shallow Radar (SHARAD) on Mars Reconnaissance Orbiter, Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) on Mars Express, and Lunar Radar Sounder (LRS) on Kaguya. For each instrument we will develop an independent module to preprocess the data before ingestion into GRaSP.

We will design OaRS to simulate various spacecraft and instrument configurations (e.g. SHARAD, MARSIS, LRS, and new mission concepts) as well as various space and subsurface environments. To ensure longevity and relevance, we will extend the modular design used in GRaSP to the development of OaRS, accounting for spacecraft movement

and instrument parameters as well as signal propagation through space and atmosphere, surface topography, and varying subsurface electromagnetic (EM) properties. To facilitate integration with GRaSP, the simulator output will be in the format specified by each instrument s engineering data records (i.e., raw data).

PORPASS directly addresses the PDART goal of producing tools that would enable or enhance future scientific investigations. In particular, our overarching goal is to enhance the scientific return from missions by allowing for parameterized processing and simulation of various planetary radar datasets during and beyond the life of any particular mission. PORPASS will enable closer collaboration within the planetary science community while also provide an avenue for citizen science and educational endeavors.

Deanne Rogers/Stony Brook University
Rock Thermal Inertia and Conductivity Measurements Under Martian Atmospheric Pressures

The objective of the proposed work is to generate a library of thermal inertia and conductivity values for a suite of well-characterized rocks under Martian atmospheric pressures. The proposed objective will be achieved through 3 tasks: 1) characterize, document and prepare rock samples for thermal measurement, 2) acquire thermal inertia and conductivity measurements under a range of Martian pressures (1-9 mb) and ambient pressure, and 3) document and archive all measurements on the PDS.

Thermal inertia measurements are commonly derived from orbital or lander-based temperature observations, and provide an important constraint on the physical properties of materials. Many laboratory studies have provided Mars-relevant conductivity measurements of particulate materials, as a function of grain size, density and composition, under Martian atmospheric conditions. These measurements permit the Mars science community to relate thermal inertia estimates to grain size. However, no laboratory thermal conductivity data exists for rocks under Martian pressures. Most rocks exhibit some porosity to varying degree. Because thermal conductivity is dependent on both the solid and gas conductivity (which is affected by atmospheric pressure), a porous solid, and thus most rocks, will exhibit differences in thermal conductivity with atmospheric pressure.

The proposed work will provide, for the first time, thermal inertia and conductivity measurements of a suite of 50 sedimentary and igneous rock samples of widely varying density, compaction and porosity, under Martian atmospheric pressures. The work will utilize a novel thermal inertia/conductivity analyzer that is already in place at Stony Brook University. Our sample suite includes rocks from various personal and published sources, including 7 rocks from the Mars2020 test suite. The specimens are currently undergoing bulk density and porosity measurements, and approximately 18 have been measured for uniaxial compressive strength.

Our library of thermal conductivity and thermal inertia measurements can be used to better interpret the physical properties of Martian rocks, and will be directly applicable to multiple existing datasets from THEMIS, Mini-TES, REMS, as well as future data from the Mars2020 Mars Environmental Data Analyzer (MEDA) instrument. The MEDA will measure, among other things, surface temperature and atmospheric pressure, permitting derivation of thermal inertia for a range of targets. Though not the primary objectives, our work will also establish empirical relationships between bulk density and thermal conductivity under a range of Martian pressures. In addition, for rocks of similar chemistry and grain density, we should be able to provide empirical relationships between thermal conductivity and porosity.

The proposed work is relative to Section 1.5 of the program solicitation, to make laboratory measurements, conduct experiments, or otherwise generate new reference information that is intended for general use in planetary science .

Paul Schenk/Lunar and Planetary Institute

Topographic Maps of the Galilean Satellites: Restoration and Archival of a Critical Data Set

Proposal Summary The Galileo mission's exploration of the 4 large Jovian moons (Io, Europa, Ganymede, and Callisto) represents our best current resource base for the investigation of these planetary scale worlds. Galileo's communication difficulties rendered each of the few high-resolution views obtained precious. These images were also the basis for the very limited topographic resources we have for these bodies, stereogrammetric and photoclinometric Digital Elevation Models (DEMS) of the surface covering roughy 20 to 75% of each body (at wildly variable resolutions). The PI has already constructed DEMs for all possible mapping sites using Galileo and Voyager data, and has built the only complete control networks for the entire high-resolution Galileo and Voyager data libraries. Together, these data are the only complete set of high resolution DEMs in existence for these bodies. However, these data were all constructed in an archaic and no longer supported ISIS2 (USGS) imaging format, and all associated control network information is embedded in the image labels in text format that is not readable in any currently operational software. We propose to recover these DEM data (and supporting image files) and archive as PDS4 compliant data, and restore the comprehensive camera kernel pointing information into NAIF-compatible format, making these (the only complete set of) high resolution DEMs available to the planetary community for the first time. In addition, 3 peer-reviewed articles and several conference presentations will be published describing these datasets, how they were constructed, and how they can be accessed.

Bradley Thomson/The University of Tennessee, Knoxville
Improved georectification of Mini-RF radar data of the Moon: A window beneath the regolith

Science goals and objectives:
This proposal is for a three-year period to reprocess the monostatic radar data of the Moon acquired by the Mini-RF instrument on the Lunar Reconnaissance Orbiter. These data were collected from 2008 2010 before the loss of the Mini-RF transmitter. As they were collected prior to the development of a high fidelity global lunar topographic data product, the original level 2 PDS data were processed using an assumed spherical Moon. This results in positional offsets of small and large features when attempting to co-align Mini-RF data with other data products. Here we propose to produce updated, spatially co-registered Mini-RF level 2 data using a revised processing pipeline.

Methodology: The USGS ISIS3 program has already been modified to include the ability to process or reprocess Mini-RF data; indeed, ISIS3 was used in the original processing pipeline. Here, we are modifying the pipeline to include updated spice and ephemeris data (i.e., spacecraft pointing and location information) and the latest global lunar topography, i.e., SLDEM2015, a joint SELENE TC/LOLA product [Barker et al., 2016]. We will also develop software routine to flag and correct aberrations noted in some swaths of Mini-RF data, including a cross-track gradient artifact evident in some swaths. Both revised individual swaths and mosaics of corrected data will be produced and delivered to the PDS.

Relevance to PDART Program:
This proposal is relevance to PDART in that it seeks to generate new high-order data products by producing georectified Mini-RF level 2 data swaths and level 3 mosaics. These data will be delivered to the PDS Geosciences Node and will supercede the existing data archive, thus greatly improving the interoperability of the Mini-RF data set. Because this proposal seeks to revise the processing pipeline of Mini-RF data but does not have a central motivating science question, it falls outside the scope of LDAP or other NASA programs.

Reference:
Barker, M.K., E. Mazarico, G.A. Neumann, M.T. Zuberc, J. Haruyama, D.E. Smith, (2016), A new lunar digital elevation model from the Lunar Orbiter Laser Altimeter and SELENE Terrain Camera, Icarus, 273, 346 355, doi:10.1016/j.icarus.2015.07.039.

Kiri Wagstaff/Jet Propulsion Laboratory
Mars Target Encyclopedia Extensions for Historical Mars Missions

Objectives and Benefits
We will expand the contents of the Mars Target Encyclopedia (MTE) to include surface targets identified by four historical Mars missions, including the Mars Pathfinder lander (1997), Mars Phoenix lander (2008), and the two Mars Exploration Rovers (2004-2019). The MTE compiles target compositional knowledge from scientific publications (e.g., target Epworth is reported as containing fluorine in a paper by Forni et al., 2015). The MTE currently indexes targets identified by the Mars Science Laboratory (MSL) mission and connects them to scientific publications from 2014 to 2019. MTE users are able to search for targets by name or composition, as reported in the literature. This proposal is motivated by multiple requests from the planetary science community to expand the scope of the MTE to additional missions and to include content from peer-reviewed publications. Expanding the MTE in this way, which will encompass thousands of additional targets and publications, will increase the ease with which comparative analyses can be done and leverage the rich body of publications these missions have generated.

Methodology
We will employ the methodology that was used to construct the MTE for MSL observation targets. The MSL MTE source code is available through GitHub. The text analysis methods employ named entity recognition and relation extraction to identify relevant content in the document collection. Information is extracted automatically and then manually reviewed and filtered to ensure accuracy.

Information about Pathfinder, Phoenix, and MER observation targets occurs in the same set of publications currently indexed for MSL targets. This collection consists of ~12,000 publicly available two-page abstracts published by the Lunar and Planetary Science Conference (LPSC) from 2014 to 2019. We will first analyze the same LPSC publications to identify information relevant to Pathfinder, Phoenix, and MER targets. Next, we will add documents from LPSC proceedings from previous years (back to 2009 for Phoenix, 2004 for MER, and 1998 for Pathfinder), which are newly relevant given the historical scope of this expansion. In the second year of the project, we will also index content from papers published by journals such as the Journal of Geophysical Research, Geophysical Research Letters, Icarus, etc. At each stage, we will employ expert review to ensure the quality of the content. We will provide access to the new information via the PDS Analyst s Notebook for scientists, mission planners, and the general public. Any required updates to the MTE source code will be shared through the existing MTE GitHub repository.

Relevance to PDART
This project will greatly expand the existing Mars Target Encyclopedia database. The MTE is already serving the Mars community and has led to several requests for the inclusion of targets from additional missions. Expanding the MTE to include thousands of additional targets studied by Pathfinder, Phoenix, and MER will address PDART s

goal to increase the amount and quality of digital information and data products available for planetary science research and exploration. It is important to capture and make accessible the findings of these missions as they recede into history. In addition, linking observation targets to published literature can improve efforts to measure the scientific impact of historical Mars missions by going beyond keyword matching to precisely identify relevant content. Finally, there are benefits for the future: the MTE expansion can serve as a resource to assist mission planning for the upcoming Mars 2020 rover.

Huiqun Wang/smithsonian astrophysical observatory
Mars Daily Global Maps for Mars Reconnaissance Orbiter Mars Color Imager

Mars Daily Global Maps (MDGMs) provide a highly valuable user-friendly dataset for studies of time variable phenomena on Mars, such as dust storms, clouds and polar caps. The raw images taken by the Mars Reconnaissance Orbiter (MRO) Mars Color Imager (MARCI) are difficult to use directly due to their complex data organization and large radiometric / photometric brightness variation. A MDGM is composed from 13 consecutive sets of radiometrically and photometrically processed MARCI images taken during the course of about one day. These processed images are merged and projected onto regular (0.1 by 0.1degree and 0.05 by 0.05 degree) latitude/longitude grids using the geo-location information calculated from the Navigation and Ancillary Information Facility (NAIF) SPICE kernels. As a result, each map simultaneously displays the whole sun-lit part of the planet as seen at the spacecraft overpass time on a particular day, greatly simplifying the usage of MRO MARCI images.

A previous PDART grant supported the production and archive of MRO MARCI MDGMs for the first 4 Mars years. This proposal will continue the production and archive of a little over 2 additional Mars years of MRO MARCI MDGMs using the publically released raw MARCI images. Upon the completion of this proposal, the MRO MARCI MDGM will cover 6 Mars years, 2 of which are global dust storm years. In combination with the 4 Mars years of Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) MDGMs before the MRO mission, the long-term daily global record of MDGMs will provide the science community with a valuable data set to study the pattern and variability of Martian weather / climate and to empirically support spacecraft missions. The MDGM product generated in this proposal will be archived according to the PDS4 standard at the PDS Imaging Node by extending the existing MRO MARCI MDGM bundle.

This proposal will generate and archive a higher-order data product - the MRO MARCI MDGM. The product will increase the amount and quality of digital information for planetary science research and exploration. Thus, this proposal is within the scope of and aligns with the objective of the PDART program. The focus of this proposal is data production and archiving, not data analysis or modeling. Therefore, this proposal is relevant to NASA's PDART program instead of other programs. As this proposal is relevant to PDART, it is relevant to NASA's interests.

Richard West/JPL-CalTech
Cassini Radar Observes the Brilliant Rings of Saturn

Goals and Objectives

The quest for a better understanding of the Saturn ring system its origins, composition, and evolution, has been a focus of scientific inquiry for many decades. The final year of the Cassini mission included a unique set of active radar scans of the ring system from close range. These provide the first ever high-resolution profiles of back-scatter at cm-scale microwave wavelengths from the rings. Radar pulses deeply penetrate the icy particles that make up the ring system, and measurements of their microwave back-scatter are sensitive to dielelctric structure and composition. In contrast with the active radar observations, short wavelength observations made by the ultraviolet, optical, and near infrared instruments are sensitive only to the surface layer of the ring particles while previous passive microwave observations are obtained at lower resolutions of hundreds of kilometers or more. The active radar measurements provide a new perspective on the rings combining deep penetration with potentially kilometer scale resolution using range compression processing. The objective of the proposed work is to make available high resolution radar back-scatter profiles of the rings in data products delivered to NASA's Planetary Data System (PDS). Future science investigations will be able to use these active radar measurements in combination with other passive measurements to constrain the composition and structure of the ring particles as a function of radial position. To achieve this goal the full high-resolution potential of the active radar rings data will need to be realized.

The proposed work will also address radar calibration work left incomplete when funding for Cassini mission activities was abruptly terminated half-way through FY-2019. A calibration processing summary of all the disparate measurements made by the Cassini radar will be produced and published. These calibration results will be important foundations for future scientific work based on Cassini radar measurements.

Approach and Methodology

The raw radar data from the four active radar ring scans will be processed for real aperture and high-resolution range compressed results. Most of the active rings data suffers from range ambiguities in the range compressed result due to limitations of the commanded timing parameters. Range ambiguities effectively mix together the echo power from different high-resolution radial bins. The relatively slow sweep rate of the scans allow an inversion technique based on singular value decomposition (SVD) to be applied to undo the mixing of powers from different radial bins. The ultimate resolution that can be achieved will depend on details of the timing and noise levels during the scans. We will implement an SVD-based algorithm and tune it for optimal performance across the available active radar rings data.

Calibration data collected throughout the mission will be analyzed for possible trends and summarized in a journal article for all the different measurement types. New data

products will be generated for the active ring observations including calibration data and then delivered to the PDS Cassini archive.

Relevance to this Program Element

The proposed work will create new higher order data products for the Cassini radar active rings observations based on raw data already available in the PDS. New calibration results relevant to all the Cassini radar data products will also be produced and published. The new data products will be accompanied by documentation describing the details of the calibration processing and high resolution processing of the active rings observations. These products directly address the scope of the PDART program element (section 1.2). The emphasis is on producing new higher order products rather than on science investigation, so the proposed work fits the PDART program better then the CDAP program.

David Williams/Arizona State University

Digitizing the Unique Photographic-Film Archives of the ASU Regional Planetary Information Facility, Part 2: The Ronald Greeley Slide Collection

The Ronald Greeley Center for Planetary Studies (RGCPS) is the NASA Regional Planetary Information Facility (RPIF) at Arizona State University (ASU). From 2014-2017 the PDART program funded us to begin digitization and online archiving of a portion of our unique collection of hardcopy data products related to planetary geology research projects led by the late ASU Professor Ronald Greeley (1939-2011). To date we have digitized and archived online the following products:

1) 266 field and aerial photographs (w/PDS4 labels) of the martian volcanic and aeolian analog site Amboy Crater, California. These digitized images were peer-reviewed and archived by the PDS Geosciences Node (https://rpif.asu.edu/fieldimgs_amboy_crater/). Another 3,459 digitized images of terrestrial analogs in Arizona, California, Bolivia, Italy, etc. are in preparation for PDS review;

2) 10 classic NASA Reports and Special Publications from the 1970s-1990s, led by Ron Greeley (e.g., Greeley, 1974; Greeley and Schultz, 1974; Greeley and King, 1977; Greeley et al., 1978; Carr and Greeley, 1980; Greeley et al., 1985; Greeley, 1990, 1994): https://rpif.asu.edu/nasa-pubs/;

3) 8 videos from the 1980s-2000, scanned from VHS videotape, of animations from the results of planetary missions, such as the Galileo Earth-Moon flybys (1990, 1992) and Magellan at Venus (1991): http://rpif.asu.edu/video-files/.

These planetary photographic and hard copy documents, which were produced and collected since the beginning of planetary geology research in the 1960s, have proven to be valuable resources for the planetary community for years, yet were not easily accessible except by visiting our facility, or obtaining one of the rare hardcopies of the reports. As we continue digitizing these products with funding support from NASA Headquarters to the RPIF Network, we want to digitize another collection for which NASA has NOT provide support: the Ronald Greeley Slide Collection. This collection of 14,435 35mm slides cover much of Ron Greeley s NASA-funded planetary geology research projects from the late 1960s through the early 2000s, of which most of the collection are aerial and field images of terrestrial volcanic and aeolian features that have been important analogs for understanding lunar, martian, venusian, and other planetary geologic features observed by NASA spacecraft. Thus, to make this slide collection more accessible to future generations of planetary researchers, we propose to digitize, archive, and distribute these slides via the Planetary Data System (PDS) to enable future research.

The objective of this proposal is to digitize the 14,435 slides of the Ronald Greeley Slide Collection, and then to archive and distribute these planetary images so that they can be better utilized by the whole planetary community for future research. We have already conducted a high-level inventory of the Greeley Slide Collection (Table 1). Through this proposal, we request funding to digitize these slides, create PDS labels, and archive them electronically, and distribute them through the PDS Geosciences Node (from which we have a letter of support). We emphasize that this work is outside the scope of the existing NASA funding to our RPIF, thus requiring submission of this one-

year PDART proposal. This project is directly relevant to NASA s goal of improving the availability of historical planetary data to the planetary community, and to PDART objectives of increasing the amount and quality of digital information and data products available for planetary science research and exploration, and Office of Science & Technology Policy (OSTP) that encourages preservation of historical materials in the Divisions of NASA s Science Mission Directorate.