Planetary Data Archiving, Restoration and Tools 2016
Abstracts of selected proposals
(NNH16ZDA001N – PDART16)

Below are the abstracts of proposals selected for funding for the Planetary Data Archiving, Restoration and Tools Program. Principal Investigator (PI) name, institution, and proposal title are also included. 89 proposals were received in response to this opportunity. On November 7, 2016, 20 proposals were selected for funding.

James Bell/Arizona State University
Archiving the MSL Curiosity Rover Mastcam Multispectral Reflectance Data Set

The MSL Curiosity rover carries a multispectral imaging system called Mastcam that has been imaging the martian surface and atmosphere in 12 unique spectral bandpasses (including broad-band RGB) between 400-1100 nm since the rover landed in Gale crater in August 2012. The high spatial resolution color and multispectral imaging capabilities of Mastcam provide an im-portant operational resource used tactically to help choose specific drive paths and regions for more detailed in situ analyses and occasional drilling. Mastcam multispectral data also enable a limited analysis of the composition and mineralogy of the landing site and traverse for scientific assessment purposes. For example, 12-point “spectra” are sensitive to the amount of the dust cover on rock surfaces, the presence and crystallinity of certain Fe-bearing phases, and weak hy-dration features in mineral-filled veins.

Mastcam images are presently only being archived to the PDS as calibrated radiance factor or I/F (where I is the measured radiance, and pi*F is equal to the estimated solar irradiance at the top of the martian atmosphere at the time of the observation), without using any information from pre-flight or in-flight calibration or from the onboard Mastcam calibration target. In princi-ple, the archived I/F data can be used to compare 12-color Mastcam "spectra" to laboratory re-flectance spectra of rocks and minerals, for the purposes of detecting specific phases or attempting to model their relative abundances. However, in reality, the PDS archived Mastcam data do not correct for the significant and time-variable spectral influence of the dusty Martian atmosphere on the derived colors of the surface, nor are they calibrated to radiance factor using calibration target images or the latest analysis of pre-flight and in-flight calibration data sets (e.g., flatfields, radiance coefficients). The result is that users who attempt to create their own reflectance spectra from archived Mastcam radiance data sets end up with spectra that deviate substantially from previous telescopic, orbital, lander, and rover multispectral measurements of Mars. The Mastcam PI and team have no plans or funding to archive higher-fidelity Mastcam I/F data sets.

Here, we propose to create and archive in the PDS a more accurate and scientifically-useful set of Mastcam images calibrated to I/F for use in laboratory comparisons, radiative transfer studies, and spectral abundance/mixture modeling. A critical part of our approach will be to use the onboard Mastcam calibration target as a reference. Past

experience with MER and MPF im-ages calibrated using similar onboard calibration targets shows that relative calibration via the target corrects for most of the spectral influence of the Martian atmosphere and generates spectra that can be directly compared to lab and theoretical reflectance modeling results.

Our work is relevant to the objectives of the PDART program as a Data Product Generation effort that would create and archive higher-order, properly-validated data products that are more accurate and scientifically useful than those that currently exist within the PDS. Source data would be the existing raw Mastcam EDRs archived in the PDS Geosciences Node, and outputs would be robustly calibrated and validated RDRs that provide accurate estimates of radiance and radiance factor in each Mastcam filter.

Our team has substantial experience with the previous creation and archiving of I/F data sets from MPF and MER, and with the modeling work needed to properly calibrate the Mastcam data sets. We have also been actively involved in the acquisition of the Mastcam images and their tac-tical calibration, and so are intimately familiar with the starting data set for this project. We have discussed the project with the Geosciences Node and they have agreed to archive the data set.

Paul Byrne/North Carolina State University
Preparing the Geological Map of Mercury as a USGS Map Product

The first reconnaissance of Mercury was carried out by the Mariner 10 spacecraft in the 1970s. Three flybys of the innermost planet yielded images of just under half of the globe at a variety of viewing geometries and resolutions. These images were used as the basis for a series of Mercury quadrangle maps; however, the map authors did not follow a uniform set of mapping conventions or units, making it difficult to compare the geology of different parts of the imaged hemisphere or to interpret boundaries between the maps.

The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft orbited Mercury during 2011-15 and imaged the planet in its entirety with the Mercury Dual Imaging System (MDIS). MESSENGER image data products generated during the mission were used as the basis of the first global thematic map of Mercury, prepared by members of the MESSENGER science team at 1:15,000,000 scale within a geographical information system (GIS). Datasets from other published and ongoing local and regional mapping efforts were incorporated into the map wherever possible - albeit often subject to difference in resolution or map scales - including a global map of crater and basin rims, ghost craters, smooth plains, and tectonic structures. The locations of features not resolvable at this map scale, such as pyroclastic vents and hollows, were represented by point features to assist future analyses. Impact features >90 km in diameter were also classified with a revised version of the previously established five-age classification scheme for Mercury, and their ejecta deposits mapped; below this diameter, these deposits were generally too small to be resolved at the map scale.

Importantly, this thematic map and its component elements preceded the release in May 2016 of the final base maps generated from the MESSENGER mission. These new data include the first global DEM, global and regional multispectral mosaics with a new empirical calibration, and a global monochrome image mosaic base map at largely uniform viewing geometry and a resolution of ~166 m/pixel (together with two additional base maps taken under different lighting conditions). Accordingly, all previous map-based studies could not avail of the full orbital imaging campaigns, the most complete global control network for Mercury yet developed and the first global digital elevation model, or the final calibrations of the MESSENGER image data. Despite the immediate contextual utility of the current global thematic map, we anticipate that a global geological map of Mercury prepared to USGS standards with these new data as base maps would be of greater interest and benefit to the planetary community, and would substantially aid ongoing and future scientific analyses and exploration efforts of the planet.

We therefore propose a three-year project to refine the existing (but not yet standardized) thematic and topical science map of Mercury by subdividing plains materials, deriving crater size-frequency statistics for major map units for relative age assessments, and revising and (where necessary) mapping additional tectonic structures and point-feature landforms. The resulting map will conform to USGS standards by employing standard symbol, layout, and format guidelines and will be published as a USGS Scientific Investigation Map (SIM) series product at 1:15,000,000 scale. Standardization efforts will ensure that the final product is scientifically objective and cartographically consistent with other planetary geological maps and is, as a result, as broadly useful as possible to the scientific community and general public.

Ashley Davies/Jet Propulsion Laboratory
Incorporating Multi-Wavelength IRTF Io Thermal Emission Data into the PDS

The objective of this work is to digitize a unique multi-wavelength observation dataset obtained by the InfraRed Telescope Facility (IRTF) on Mauna Kea, HI, between 1983 and 1993 and incorporate the products into the Planetary Data System (PDS). This dataset consists of hundreds of observations of Io’s thermal emission at 4.8, 8.7, 10 and 20 Î¼m and currently exists only in printed (analog) form (Veeder et al., 1994) and a low-quality, non-searchable pdf file. The data will be incorporated into PDS4-compliant products and archived at the PDS Atmospheres Node, the current repository of other IRTF observations of the jovian system.

Although collected decades ago, these IRTF data are the state-of-the-art for thermal infrared measurements of Io’s global thermal emission. Recent mapping of Io’s volcanic activity, primarily from Galileo spacecraft data, but also utilizing data at wavelengths shorter than 5¼m from ground-based telescopes, has once again highlighted the uncertainty surrounding Io’s heat flow outside of volcanic hot spots. However, no other

dataset equivalent to Veeder et al. (1994) exists where observations have been obtained of Io for so long, and at so many thermal infrared wavelengths. This is therefore a valuable collection of data covering more than a decade. The IRTF Veeder et al. dataset enables the quantification of Io's evolving volcanic activity, surface temperature and area distribution, and secular variation on time scales from days to years to decades, but remains very difficult to analyze. We will make this unique dataset permanently accessible in machine readable form to the entire remote-sensing and planetary science communities through the PDS.

The proposed PDS products will support future investigation of Io's hot spot and background thermal emission, as well as planning for new and proposed missions to the jovian system. Additionally, Io is an extreme example of a tidally heated body, where heating has led to widespread volcanic activity. Some exoplanets may be similarly volcanically active. Io provides a template for understanding future thermal infrared observations of these bodies. The IRTF dataset is also of great historical significance since it contains the first multi-spectral detections of what are now known to be the most powerful class of ionian eruptions -"outbursts" - where fountains of lava gush forth at extremely high (>10^5 m3/s) discharge rates. Such events have also been observed by Galileo and at the Keck telescopes on Mauna Kea, HI. The data collected by Veeder et al. (1994) include large outbursts in 1986 and 1990 that can now be revisited using new, more sophisticated modelling techniques.

After consultation with the Planetary Data System, we have a formulated a credible and timely plan for the creation and release of these data in PDS4 format to be archived in the PDS Atmospheres Node, the repository of other IRTF observations of the jovian system.

Robert Deen/Jet Propulsion Laboratory
Mastcam Stereo Analysis and Mosaics

MSAM proposes to create higher-order datasets based on MSL Mastcam data. To date, none of these datasets have been systematically produced, released to the public, and archived.

Stereo Processing

The MSAM team will perform stereo analysis on all Mastcam stereo pairs in PDS (13,279 as of PDS Release 11, up to sol 1159) to recover quantitative terrain data.

Products to be produced:

* Decompanded images
* De-Bayered images
* Disparity maps
* XYZ point clouds

* Surface normals
* Range maps
* Slope maps
* Slope aspects
* Stereo anaglyphs
* Range Error

Terrain meshes

XYZ data from images acquired at the same location will be converted into terrain meshes. These consist of triangulated geometry, viewable in 3-D visualization programs.

Mastcam-Navcam Coregistered Mosaics

MSAM will produce cylindrical mosaics combining Mastcam images (including non-stereo) on a Navcam background, coregistered to reduce seams. The Navcam background provides geological context for the Mastcam observations, which is sometimes hard to determine from the Mastcam alone.

Although the Mastcam team has released many individual mosaics, the only known systematic production of them for the public is by Washington Univ. for their Analyst's Notebook. However, those products are not archived, do not contain Navcam context, and are not geometrically controlled.

Stereo Mosaics

Cylindrical-Perspective mosaics, intended for stereo viewing and including red/blue anaglyphs, will be created from stereo Mastcam data. Navcam will not be included due to disparity differences.

Orthorectified Mastcam Mosaics

Orthorectified mosaics will be made from suitable stereo Mastcam data. These provide a true overhead view, corrected using XYZ data to avoid layover and parallax effects.

Relationship between MSAM and MSL Operations Teams

All of the MSAM team members (except the collaborators) participate in MSL operations as part of the Operational Product Generation Subsystem (OPGS). One of the co-I's (Maki) is also a Deputy PI for the Mastcam. Stereo processing as proposed above is currently done systematically for operations by OPGS, and mosaics/meshes are produced on request. However, the agreement between the Project, Instrument PI, and PDS does not include archiving these products. Thus, production of these products for archive use is not redundant with the duties and responsibilities of the team as funded by the MSL mission.

The MSAM team will use the same software (VICAR/MATIS) that OPGS uses to make these products, but will maintain a strict separation between MSAM and OPGS/MSL. Separate computational resources will be used. Time spent on MSAM vs. OPGS will be strictly separated, and charged accordingly. All data used for MSAM will be obtained from PDS (both Mastcam and Navcam). Finally, MSAM products will not feed back into operations; the rover is already well beyond the Sol 1159 cutoff, making them not operationally relevant.

Software and Automation

The VICAR software is already capable of creating all products proposed here; examples will be shown in the Step-2 proposal. The only additional software needed is a PDS->VICAR conversion script (the team has verified that the necessary metadata is available in PDS). The only aspect not already automated is selection of which data is appropriate to mosaic/mesh; that will be mostly automated by the MSAM task via scripting.

PDS 4

Most of the MSAM team members are involved in preparing InSight data for PDS4 archive bundles, and InSight camera data is substantially similar to the MSAM format. MSAM archive production will leverage off this InSight development and expertise. The PDS4 archived images will be in PDS3-compatible format, making it possible to use the data with tools supporting PDS4, PDS3, or VICAR.

Lisa Gaddis/U.S. Geological Survey
PySAT: Multi- and Hyper-Spectral Data Analysis Tool for Planetary Science

The goal of this proposal is to develop a Python software library to enable spectral data visualization, thematic image derivation, and simple analysis in a cross-platform, open-source environment. This library, called PySAT (Python Spectral Analysis Tool), will be accessible via an Application Program Interface (API) and accompanying Graphical User Interface (GUI). PySAT will initially support hyperspectral data from NASA Moon Mineralogy Mapper (M3) on the ISRO Chandrayaan-1 mission and the NASA Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) from Mars Reconnaissance Orbiter. Hyperspectral data ingestion, spectral analysis and product generation will be supported through the implementation of common functions such as continuum correction, noise removal, band depth, position and shape analysis, and derivation of thematic products. The primary product of this proposal will be a set of tools for spectral data analysis that is open-source and freely available, so the tools can be readily modified and extended by the user to support many additional data sets and capabilities.

The proposed work has six major tasks:

1.) Implementation of a software library with accompanying API that supports data ingestion, spectral extraction and manipulation, simple spectral analysis functionality, and thematic product derivation.

2.) Development of automated unit and integration testing suites to ensure expected API functionality including the derivation of thematic products, manipulation of spectra, and analytical workflows.

3.) External validation of accuracy of derived products from relevant mission experts.

4.) Update and delivery of a Graphical User Interface (separate from the API) to support data visualization and exploratory data analysis, including the infrastructure to support future expansion via plug-in style contributions from the user community.

5.) Development of a desktop Geographic Information System (GIS) plug-in using the API within the open source QGIS application to demonstrate interoperability with existing open source software packages.

6.) Public release of the source code, precompiled binaries, and user documentation.
The proposed work addresses the PDART solicitation seeking to”generate higher-order data products” and to”develop or validate software tools” for planetary science, in accordance with program goals to”increase the amount and quality of digital information and data products available for planetary science research and exploration.” Among higher-order products supported by this project are derived mineral maps of the Moon and Mars using algorithms developed and validated by mission teams. The final deliverable will be a tested and validated software tool written in Python (a free package) to be used by planetary scientists to work with spectral imaging data. The software will be released as a highly accessible, open-source package via source code repositories (via the USGS Github site at https://github.com/USGS-Astrogeology), in binary form through the PDS Imaging Node”Tools and Tutorials” site (http://pds-imaging.jpl.nasa.gov/software/) and delivered to the NASA GitHub site as required by PDART for code archival. By releasing all of our tools publicly, we will support future use of hyperspectral data, make derivation of high-level products more straightforward and reproducible, and make other multi- and hyper-spectral data products currently in the Planetary Data System (PDS) more accessible to planetary scientists.

Amanda Hendrix/Planetary Science Institute
The Archive for UV Data of Small Bodies

Science Goals and Objectives
A variety of important UV datasets on small solar system bodies exist, scattered in disparate locations in varying formats, on computers across the globe. Many of these datasets are simply inaccessible to potentially interested users. In fact, some potentially interested users may not even be aware of the existence of some of these data! We propose to remedy this problem by creating an archive of UV observations (derived products, namely reflectance spectra along with observational geometry) of small bodies - specifically asteroids and Mercury - in the PDS. These data need to be preserved for access and use - in one easy location - by the community, as interest grows in UV spectroscopy and primitive bodies. The UV Asteroid Archive will consist of asteroid data from sources including IUE, HST, Swift, Mariner 9 UVS, Galileo UVS and Rosetta Alice; we will also include groundbased data (UV-visible) from MMT. An additional dataset to be archived is Mercury observations from Mariner 10 UVS, which has never been archived in any format. We anticipate that these data will be useful to the community for compositional studies, to increase spectral coverage for comparison with longer wavelength datasets - as well as for the simple historical reason of documenting the data.

Our goal is to create an archive of UV data, a”one-stop shop”□ where even users who don’t normally use UV spectroscopy can relatively easily find asteroid data in usable formats for various applications. The archive will be part of the PDS SBN (except for Mercury data which will be located on the Geosciences Node; but we will include a link to the Mercury data for interested users on the SBN). Some of the datasets (namely, the IUE, Swift, Rosetta and HST observations) have been archived in different locations in their raw form; we propose to include those data as high-level science products (i.e. reflectance spectra along with associated geometry) in this archive.

Methodology.
To establish the UV Asteroid Archive, we propose to restore (as needed), reduce and archive the datasets discussed here. In the future, additional existing or new datasets may be added. We focus on archiving spectroscopic (rather than imaging) measurements. We note that all of the data included here are of good quality and will be usable by the community.

Relevance to PDART.
The proposed work is relevant to the Planetary Data Archiving, Restoration and Tools program because we will restore and archive datasets for use by the community. We will be producing new data products to be submitted to the PDS. A small amount of data analysis and interpretation may be performed to validate data products.

Henry Hsieh/Planetary Science Institute

Asteroids in the Archives - Compilation and Calibration of Serendipitous Archival Asteroid Photometry

Given the recent optical photometric calibration of field stars over the entire night sky from -30 degrees to +90 degrees in declination by the Pan-STARRS1 (PS1) survey, we propose to create a catalog of calibrated astrometry, photometry, and PSF measurements of serendipitously observed small solar system objects in public archival image data from various facilities (including PS1 itself, the Sloan Digital Sky Survey, or SDSS, and other large telescopes). We will extract and calibrate detections of known minor planets, measuring an estimated ~4x10^7 serendipitous observations of these objects, all obtained by large (2.5m-8m) telescopes, which we will make publicly available via NASA's Planetary Data System (PDS) and the Minor Planet Center (MPC).

We will utilize trail-fitting code originally developed for PS1 in order to obtain accurate astrometry and photometry for trailed objects in long-exposure images. PSF measurements will also be made to enable searches for previously unknown comet-like activity among our objects. These results will be made publicly available via PDS and also via an online search tool hosted by the Planetary Science Institute that will allow users to search for a particular object, list of objects, or objects or observations meeting certain criteria, and obtain a historical serendipitous observational record of that/those object(s) including astrometry, photometry, PSF measurements, associated metadata, JPEG preview imagery, and processed FITS files for each detection.

Our objective is to create an easily reconfigurable data reduction pipeline for this work. As such, though we will spend significant time developing pipeline code for the first data archives to be processed, this overhead should decline significantly for subsequent data archives, allowing us to eventually add additional archives with minimal additional effort. We also plan to periodically update our database as orbits of more asteroids become sufficiently well-determined for their positions to be accurately predicted, and as new data from our existing suite of processed data archives reach the end of their proprietary periods and become publicly available.

Besides improving the quality and usability of the 1.6x10^7 asteroid measurements in the PS1 database and expanding upon the current SDSS Moving Object Catalog (SDSSMOC; last updated in 2007), this project will exploit the vast quantity of publicly available archival optical imaging data from large telescopes that were originally obtained for non-solar system science and have therefore never been searched for solar system objects. We expect to extract data for ~2.5x10^7 new asteroid detections from non-PS1 sources. Many of these will be from telescopes with apertures ~8 m in size (i.e., the size of the planned Large Synoptic Survey Telescope, or LSST, or larger), with implications for a wide range of small solar system body science. As such, this project (and potential future updates) has the potential to have a significant impact on the field years ahead of the start of the LSST survey.

This program will generate higher-order data products from currently existing astronomical observations, most of which were not initially intended for use for solar system science research, and as such, is well-suited for the PDART program. It will increase the amount of data products available for planetary science research and produce tools that will enable and enhance future scientific investigations, as described in the PDART program solicitation. All data products from this program will be made publicly available via the Small Body Node of PDS, while all pipeline code, search tool source code, and documentation will be made publicly available via GitHub.

XINCHUAN HUANG/SETI Institute
Highly Accurate Ro-Vibrational Line Lists for HCN and HNC for use in Studies of Planetary and Exoplanetary Atmospheres

Hydrogen cyanide (HCN) is one of the most common molecules existing in many planetary atmospheres such as Jupiter, Neptune and Titan, as well as in both galactic and extragalactic sources including cometary atmospheres, T Tauri stars, extragalactic red giants and AGB stars, etc. In many interstellar clouds, the high-lying isomer hydrogen isocyanide (HNC), is often found to be as abundant as HCN. Models have shown that including HCN may alter the opacity of a planetary atmosphere by one or two orders of magnitude. Also HNC may play an important role in the opacity of HCN containing objects. Considering that HCN has been found in hot-Jupiter exoplanets, and the first super-earth exoplanet atmosphere detection of 55 Cancri e also hints at the presence of HCN, a highly accurate and complete HCN/HNC line list that performs up to 2000-3000K is needed. The line list will help astronomers to analyze and simulate the exoplanet spectroscopic data more accurately and reliably determine their atmosphere conditions, which will enable future planetary science studies.

The current HITRAN database has only ~3000 transitions up to 3400 cm-1 for HCN, and ~600 transitions for its 13C or 15N isotopologues. The ExoMol HCN/HNC line list (Barber R.J. MNRAS 2014, 437, 1828) was upgraded from an ab initio computational line list where ~168,000 levels were replaced by experimentally determined values and predictions. With band origins corrected, the original levels were still off by ~1 cm-1, otherwise it could be dozens of cm-1 for the high-lying states. The model based predictions probably diverge at high J's. The 3~4% uncertainty of the energy difference between the HCN / HNC minima may lead to ~10% opacity variation at high temperature. The ab initio intensity will be less reliable for the higher energy region, weak bands, and”hot”□ bands. All these will affect the accuracy of data analysis. In addition, the line lists of D, 13C, 15N related isotopologues are much further from completeness. In short, the latest ExoMol line list is not really suitable for high energy and especially high temperature studies of planetary and exoplanetary atmospheres.

We propose to compute a self-consistent, highly accurate & complete IR line list for the HCN/HNC system and its isotopolgoues. The”Best Theory + High-resolution Expt Data”□ strategy was adopted over the last decade for the best available IR line lists of

CO2 and SO2, where exact quantum rovibrational Hamiltonian calculations were carried out to refine an ab initio PES with selected experimental data. The superiority of this strategy is for Predictions! In addition to reproducing most existing measured transitions with 0.01 - 0.02 cm-1 and 2-10% intensity deviations, we can make predictions with similar accuracy. Predictions have been confirmed by many recent experiments: our SO2 line lists match line-by-line to the IR peaks observed in the lab; our CO2 lists based IR simulations are better than HITEMP when compared with 1550K and 1773K spectra. Compared to databases HITRAN, GEISA and CDSD,etc. our lists are far more complete, more self-consistent, and more reliable when extrapolated to higher temperatures and a higher energy range. We can also generate isotopologue line lists with similar accuracy, e.g. the Ames IR lists for 13 CO2 isotopologues are accurate up to 18,000 cm-1 and 1500K, which are the most complete and reliable CO2 IR lists for HOT-Jupiter like Exoplanets.

By adopting this proven strategy and using the latest experimental information, we expect the new HCN/HNC lists to have similar quality and range as we have achieved for CO2 and SO2, i.e. working up to 2000K or higher. The new line lists will be deposited onto the NASA PDS or HITRAN database.

This study responds to the call of Planetary Data Archiving , Restoration, and Tools, Sec.1.5 "Generation of New Reference Information”□ as the proposed HCN/HNC line lists is”intended for general use in planetary (atmosphere) science”□.

Sandee Jeffers/Southwest Research Institute
Making Venus Express ASPERA-4 ELS Background Data Publicly Available

Goals and/or Objectives

The Venus Express (VEx) Analyzer of Space Plasmas and Energetic Atoms (ASPERA-4) experiment package included an Electron Spectrometer (ELS) contributed by NASA and built by our group at Southwest Research Institute (SwRI). Data from this instrument are used to study the plasma environment around Venus. The ELS instrument data are publicly available on the European Space Agency (ESA) Planetary Science Archive (PSA) and can be retrieved via ftp from:

ftp://psa.esac.esa.int/pub/mirror/VENUS-EXPRESS/ASPERA4

However, these archived data are calibrated telemetry and are not corrected for noise from contamination sources. A sensor background data product that increases the science accuracy and improves the science quality of data exists within the science team, but it was not archived by ESA in the PSA. The objective of this proposal is to make that privately held background data publicly available through the NASA PDS public archive. The ELS background signals are a combination of randomly generated counts from the ELS microchannel plate sensor, electronically coupled anodes, charge sensitive

amplifiers, and from highly time-variable geophysical penetrating radiation such as from galactic cosmic rays and solar energetic particle (SEP) events from the Sun. Above 1 keV, background signals can dominate the electron spectrum, leading to nearly 100% error in the particle energy spectrum which would translate to large errors in the amount and location of particle energy deposited in the atmosphere, making an accurate subtraction of the ELS background crucial to analysis. This is particularly important during SEP events where ELS background levels are seen to increase by at least two orders of magnitude due to penetrating radiation within the instrument. Moreover, depending on the spacecraft orientation, the background is a function of ELS anode and time, all of which were characterized at SwRI during the Venus Express mission, but not archived.

Approach and Methodology

Throughout the nine-year VEx mission (launched in late 2005, arrived at Venus in 2006, and ended late 2014), all VEx ELS data were automatically processed and stored at SwRI in the Instrument Data File Set (IDFS) format. The VEx ELS data have been and are being used for collaborative studies, which necessitated the generation of the background data (also processed into the IDFS format). A software tool, IDFStoPDS, was developed to convert IDFS formatted data to PDS3 form since the IDFS format is not PDS-compliant. For this proposal, PDS4-compliant structures and labels are to be produced. Thus, this software tool will be updated and will be used to batch process all of the VEx ELS background data into PDS4-compliant form for submission to the PDS-PPI node for public dissemination. The associated documentation and file system structure will be developed and submitted with the ASPERA-4 ELS background data to PDS. Specifics, such as review of the data set, delivery frequency, and schedule will be finalized between the NASA PDS-PPI node and SwRI.

Scope Relative to the Program Element

This proposal archives background data from the ELS instrument from the VEx ASPERA-4 experiment. The proposed effort is within the scope of the PDART Program because instrument background is a higher-order data product that is not currently publicly available. It meets the criteria of section 1.2 of the appendix C.7 of the NASA ROSES call. Archiving privately held background data to make it publicly available will increase the science accuracy and improve the science quality for all researchers who use the VEx ASPERA-4 ELS data to investigate the interaction between Venus’ atmosphere, ionosphere, and the solar wind.

Paul Johnson/Jet Propulsion Laboratory
Radical Spectroscopy for Interpreting Observations of Triton, Pluto and other Kuiper Belt Objects

Science Goals and Objectives

Our objective is to measure the detailed spectroscopic properties of radical species such as methyl (CH3), ethyl (CH3CH2), cyano (CN), and methylene (CH2) in nitrogen ice from the vacuum ultraviolet (VUV) through the visible, near- and into the mid-infrared (IR; 120 nm - 5 Î¼m). The motivation behind this proposal is to provide the much needed spectral baseline for analysis and identification of species in observed spectra of Triton, Pluto and other Kuiper Belt objects (KBOs). Hodyss et al. [2011, Icarus 214(2), 748-753] have reported photochemical studies of cryogenic ice composed of N2, CH4 and CO in ratios analogous to those on the surfaces of Triton and Pluto. Radical species, such as C2, CN, and CNN, were observed in the visible and ultraviolet (UV) regions of the spectrum. These species imply a rich chemistry based on formation of radicals from methane and their subsequent reaction with the N2 matrix. This work strongly suggests that other radicals such as methyl (CH3), ethyl (CH3CH2), cyano (CN), and methylene (CH2) will also be present in the surface ices of these outer planetary bodies. However, their spectroscopy has never been studied under relevant conditions (i.e., isolated in N2 ice in the 25-45 K temperature range) making their identification difficult if not impossible.

Methodology

We will measure spectral properties for radical species that are expected to be present on the surfaces of Triton, Pluto and other KBOs and begin identifying them in observed spectra of these surfaces. Specifically, we will develop and refine procedures for producing radical species in sufficient quantities and purity for the proposed spectroscopic studies using a pyrolysis nozzle source. We will then deposit matrix-isolated radicals to measure their spectral properties from 120 nm to 5 Î¼m. Specifically, we will measure spectra of methyl (CH3), ethyl (CH3CH2), cyano (CN), and methylene (CH2) in nitrogen ice (25-45 K). All spectral data will be archived in NASA's Planetary Data System Small Bodies Node.

Relevance and Expected Significance

This work is primarily motivated by the need for reliable spectroscopic data for the accurate interpretation and understanding of spectrally resolved observations of Triton, Pluto and other KBOs. By providing spectral data from the VUV to the mid-IR we maximize the utility of the data and their significance. Perhaps most notable is the enhancement of the data return from the New Horizons spacecraft. New Horizons has the capability of measuring spectral data in both the IR and the VUV. Further, UV and visible spectra will extend the application of this data to ground based telescopes, which could specifically target relevant spectral ranges where strong characteristic spectral features are identified by the proposed work.

Our experimentally measured spectra will allow comparison with data from New Horizons Ralph and Alice instruments as they become available. This will enable identifications of the targeted species and/or set limits on their concentration. The signal-

to-noise, spectral resolution, and spatial resolution of the New Horizons instruments will enable detection of species that are in significant abundance locally, but perhaps not globally, and in locations free of possible interfering spectral features of other surface constituents.

KBOs are likely to contain clues to the early history of our planetary system. These remote small objects are believed to have remained preserved, relatively unchanged throughout the history of the Solar System. By enabling a more thorough understanding of the composition (and chemistry) of the surfaces of Triton, Pluto, and other Kuiper Belt objects, this work will help to further improve our understanding of the evolution of the outer Solar System.

This proposal is particularly responsive to Section 1.5 of the solicitation,"Generation of New Reference Information."

Jason Laura/U.S. Geological Survey
Improved Data Access and Analytical Tools for the Kaguya SELENE Spectral Profiler Data Set

OBJECTIVES: The Japanese Aerospace Exploration Agency (JAXA) SELenological and ENgineering Explorer (SELENE) "KAGUYA" launched September 2007 with the Spectral Profiler spectrometer. The Spectral Profiler (SP) instrument is a spot spectrometer with broad spectral coverage, high spectral resolution, and large spatial coverage of the lunar surface. We propose to develop an efficient storage mechanism to support observation (as opposed to data file) level access to the hyperspectral data and accompanying metadata. The proposed work will result in an observation (spot) level, spatially enabled database that can support efficient spatial and/or spectral query, a web-map based interface consistent with current community standards, and an analytical toolbox to support spectral analysis of these data. This database would be a significant improvement over current data access that is either accessible via a size limited, form-based interface (JAXA) or a web-map (GEKKO) that offers no small scale data download capability.

METHODOLOGY: Currently, the SP data has been delivered to the U.S. Geological Survey (USGS) Astrogeology Science Center (ASC) from JAXA. The data set includes level 2B2 (700 Gigabytes) and level 2C (672 Gigabytes) of compressed data for a total data footprint of just under 1.4 Terabytes. Each compressed data files contains not only the spectral spot observation information but also the associated contextual Multiband Imager (MI) or Terrain Camera (TC) frame. We will decompress each data file, extract the spectral data, data correction information, and metadata. The extracted data will be stored in a database at the individual spot observation level to support access via a web-map based interface and through standards compliant web mapping protocols (e.g., Web Map Service or WMS). We will develop and optimize storage to support efficient observation level (Big Data) query with spatial, spectral, and/or metadata constraints.

Finally, we will develop and deploy both data access and analytical methods to support standard spectral analysis (e.g., continuum correction or computation of derived, absorption band-based parameters). The process of SP data extraction has been utilized for over two years at ASC, and the proposed work will focus on efficient storage, query tools, visualization, and the deployment of analytical methods.

RELEVANCE: Results include: (1) a database with a significantly lower bar for entry and access than any currently available tool, (2) the ability to apply more complex spatial and spectral queries to support scientific inquiry at the observation scale, and (3) support of high dimensionality, spatially enabled Big Data. These deliverables directly support scientific investigation, including compositional studies, and potential engineering studies for landing site selection.

The proposed work is directly relevant to the PDART call for "proposals to generate higher-order data products", "archive and restore data sets", and " develop or validate software tools".

Paul Lucey/University of Hawaii
High Resolution Mineral Maps of the Moon

The lunar science community benefits from a very large quantity of spectral data from several missions that provides information on the composition of the Moon at resolutions as high as 20-m. However, interpretation of spectral data is often the province of experts, which limits the accessibility of the compositional information. While there are many approaches to the analysis of spectral data, our research group has pursued publication and archiving of spectrally-derived mineral maps. Modal abundance of the major silicate minerals is a quantity used throughout geology and is the basis for the nomenclature of lunar rocks. Our team has recently archived maps at the USGS of the mineral system plagioclase-olivine-orthopyroxene-clinopyroxene derived from Kaguya multiband imager data at 60-m (512 ppd) resolution for latitudes between +/- 50 degrees. The proposed project has these objectives: 1) Produce and archive mineral maps at 20-m resolution from Kaguya UVVIS Multiband Imager data constrained by our prior maps, data from M3, Kaguya Spectral Profiler and from Diviner; 2) Validate these data with an existing data base of X-diffraction derived modal abundance of Apollo soils for over 100 sampling sites that can be individually resolved in Multiband Imager data. Our approach with the existing 60-m data set was to derive mineral abundance by comparing MI spectra to results of a radiative transfer model of lunar soil. In addition, will also use Chandrayaan-1 M3, Kaguya Spectral Profiler and LROC WAC to support mapping ilmenite, glass and spinel. We will apply these results as an additional constraint. The results will then be compared to, and finally reconciled with, the modal mineral abundances for 56 resolved Apollo sampling sites covered by 124 soils for which we have mineral abundances measured in the laboratory. The project generates and archives higher order data products (mineral maps) from existing mission data sets, and validates those data. The project will not include scientific analysis of the maps generated. The

mineral maps and modal data would be invaluable for studies performed under other programs, such as the Lunar Data Analysis program or other support for lunar science.

Michael Malaska/Jet Propulsion Laboratory
Registered and Modernized Europa NIMS Dataset

Hyperspectral data from the Galileo spacecraft's Near-Infrared Mapping Spectrometer (NIMS) represents an untapped resource of high value for assessing the surface properties and surface compositions of potential landing sites on Europa and for prioritizing future targeted observations obtained from orbit. There are approximately 30 NIMS high-resolution observations of Jupiter's moon Europa with spatial resolutions ranging from 0.7 km-8.7 km/pixel. However, the NIMS data available from the PDS are notoriously difficult to work with, and so only a handful of these observations have been subjected to a detailed analysis. One of the difficulties with the data set is that precise georeferencing of the NIMS near-infrared dataset with Galileo Solid-State Imager (SSI) visible imaging, which is desirable for compositional terrain analysis, is difficult to achieve, as the instruments were not boresighted, and rarely performed simultaneous observations. As a result, there are discrepancies between the coordinates supplied in the original (NIMS?) data products with respect to the modern USGS coordinate frame. In addition, not all NIMS observations were processed using the correct wavelength calibration. In the few cases where this precise co-registration and wavelength has been achieved, remarkable new insights into Europa's complex surface have been obtained (Shirley et al., 2010; Dalton et al., 2012; Cassidy et al., 2013).
The goal of our proposal is take the available highest-resolution NIMS Europa observations, and deliver to the PDS (in PDS4 bundle format) recalibrated NIMS observations that have been registered to the USGS Europa grid, as well as a separate bundle of recalibrated NIMS observations that have been registered, and despiked. In addition, we will also deliver intermediate products to the PDS as"miscellaneous" files that can be directly read into commonly-used GIS and spectral analysis programs such as ArcGIS, QGIS, and ENVI. Our efforts will enable researchers to more easily access these datasets for research and analysis of Europa's surface composition and geology.

Our proposed processing pipeline starts with NIMS and SSI data downloaded from the PDS that cover approximately the same area on Europa's surface. We will convert the SSI data into .cub format and import it into ArcGIS (ESRI) and register it to the lower-resolution SSI-based USGS Europa grid. We will take the NIMS data, recalibrate it, then import and register the data set to the higher-resolution SSI data set using the shorter wavelength NIMS data that overlaps with SSI wavelengths. We will also despike one set of NIMS data after recalibration and then register it to the SSI image using the same protocol. After registration of the datasets in ArcGIS, we will export the SSI and the two NIMS datasets as GeoTiff files and associated world files. These files will be converted into PDS4 usable files, but the user-friendly GeoTiffs also saved into the PDS. We will modify the headers for each to show our processing steps. We will generate three separate PDS4"bundles": SSI, NIMS"registered and recalibrated", and

NIMS”registered, recalibrated and despiked”□ and deposit them into the PDS. We have already contacted Lisa Gaddis at USGS who has agreed to be our PDS contact help us get our files ingested into the PDS archive.
Our proposal is relevant to Program Element Scope Section 1.2 Data Product Generation as we will take an existing dataset in the PDS (Galileo NIMS) and convert it to a higher-order product. The description of Section 1.3 Data Set Restoration and Archiving is also relevant, as one part of our proposed work is to recalibrate and restore the NIMS dataset. The data will be read from the PDS, manipulated using available software, and redeposited in the PDS in PDS4 format.

Emily Martin/Smithsonian Institution
Building a Geologic Map of Neptune's Moon Triton

In 1989, Voyager 2 encountered the Neptune system and returned images of its largest moon (~1350 km radius), Triton – and these images remain the primary data for our understanding of the satellite (Fig. 1). Triton was revealed to be a geologically active moon [Smith et al., 1989], and its activity has been linked to its dynamical history as a captured Kuiper Belt Object (KBO) [e.g. McKinnon et al., 1995]. Until the New Horizons mission flew by Pluto in 2015, Triton was the only KBO visited by spacecraft; however, Triton’s role as our only close-up example of a probable KBO was always dogged by the question of whether its geology was representative of other KBOs, or resulted from its unique history. That question has not yet been rigorously reassessed in the post Pluto-encounter era. Additionally, Triton bridges a gap between KBOs and icy satellites. As a likely KBO captured into Neptune’s orbit [e.g. McKinnon et al., 1995] it contributes to the diverse population of icy satellites, but its origin is unique relative to those of the icy satellites and likely contributes to its young surface and exotic terrains (Fig. 2) [Schenk & Jackson, 1993]. The capture of Triton by Neptune likely resulted in a massive heating event that resulted in resurfacing [McKinnon, 1984; 1992], possibly by cryovolcanism [Croft, 1990; Schenk, 1992]. Crater counts for both Triton [Schenk & Zahnle, 2007] and portions of Pluto [Stern et al., 2015] suggest that both surfaces are exceptionally young, which may indicate that neither Triton nor Pluto retain their original surfaces. The successful New Horizons flyby through the Pluto system opened the door to another part of the solar system revealing an extraordinary diversity of terrains, renewing interest in the origin, evolution, and diversity of KBOs [Stern et al., 2016], and by extension, Trition.

Voyager 2’s encounter with Triton and Neptune occurred on August 25, 1989 with closest approach to Triton of 39,800 km [Chapman & Cruikshank, 1995; Stone & Miner, 1989], but the inherent challenge with flyby missions, especially in the outer solar system, mean extremely limited data sets with long time lapses between missions. These obstacles are overcome by creative solutions for maximizing the data return, including detailed geologic mapping.

We propose to produce a complete framework of accessible data products and establish, through mapping, a geological foundation to facilitate and foster the resurging interest in Triton and KBOs. We propose to create a USGS global-scale geologic map of Triton to inform ongoing and future exploration of Triton and other KBOs. Additionally, we aim to restore and archive Voyager 2 data products that exist only on compact disks (CDs) at the USGS Astrogeology Science Center.

Molly McCanta/University of Tennessee at Knoxville
Advanced XAS Calibration Tools for In Situ Analysis of Redox States of FE, TI, MN, CR, V, and EU in Extraterrestrial Glasses

The emergence of oxygen and the evolution of planetary interiors are recorded in the redox states of multivalent elements (Fe, Ti, Mn, Cr, V, and Eu) that are locked in rocks, and the glasses and minerals that constitute them, on planetary surfaces. As recorders of formation conditions, glasses and amorphous materials comprise major constituents of planetary materials on bodies where magmatism and/or impact processes occur. Glass is common in stony meteorites (both achondrites and chondrites) and lunar samples and is likely to be present in samples returned from asteroids and planetary surfaces such as Bennu (target of OSIRIS-REx) and Mars. Robust laboratory analyses of multivalent element redox states in glasses from meteorites and returned extraterrestrial materials are thus essential to facilitate understanding of the role of oxygen in solar system processes.

However, interpretable measurements of redox states at sub-nm and pm scales still present formidable analytical challenges due to the lack of suitable calibration samples. Our group has already developed an internationally-used set of calibration samples/software for x-ray absorption spectroscopy (XAS) measurements of Fe redox states in garnets and amphiboles, as well as in a select range of terrestrially-relevant silicate glass compositions. This proposal seeks to broaden our glass calibration to include other transition metals (Ti, Mn, Cr, V, and Eu) and cover the reduced oxygen fugacities needed to represent the diversity of solar system materials. Such development of the capability to measure in situ redox states at atomic and near-atomic levels in glasses has the potential to make dramatic advances in the study of solar system materials in both returned samples and meteorites.

Therefore, this proposal seeks to create a broad suite of glasses of geological relevance for use as standards in XAS calibrations for the study of extraterrestrial glass samples. Using synthesized samples equilibrated over a range of oxygen fugacities representing those found in our solar system, we will generate XAS calibration data for redox calibrations of Fe, Ti, Mn, Cr, V, and Eu in glasses that are directly representative of observed meteoritic and planetary compositions. We will make these alibrations available to the planetary materials and broader science communities via distribution directly to all international synchrotron facilities, with spectral data posted on the PDS Geosciences Spectral Library. The tasks are as follows:

1) Synthesize glasses over a wide range of geologically-relevant chemical bulk compositions at several fO2's, using a range of naturally-occurring abundances for Fe and doping of other multivalent species including V, Ti, Eu, Mn, and Cr.

2) Characterize the redox content of each glass relative to composition and fO2 using MÃssbauer for Fe and ion microprobe for Eu and XAS techniques for Fe, V, Ti, Eu, Mn, and Cr.

3) Use those data to build a statistical model for measuring redox ratios for Eu and Fe (where we have independent measurements) and directly predicting oxygen fugacity for each of these cations across our broad compositional range, using sophisticated multivariate analysis techniques.

This work is highly relevant to NASA's PDART program as it will generate valuable new reference information (laboratory samples and XAS measurements) and develop high-order software for predicting valence state. The latter tools will enable use of the XAS technique to produce redox state measurements of Fe, Ti, Mn, Cr, V, and Eu with known accuracy for a wide range of extraterrestrially-relevant glass compositions. Our deliverables will ensure that microanalysis of redox states can be used broadly by the planetary community to maximize science return from precious extraterrestrial samples.

Jeffrey Morgenthaler/Planetary Science Institute
Archiving Two Decades of Wide-Field Space-Based UV-Visible Observations of Comets

Recent in situ observations of comets have highlighted the importance of volatiles other than water in driving comet activity even at small heliocentric distances. CO2 and CO have been shown to be particularly important. Rosetta observations are suggesting new ideas about the primary drivers of comet activity at large heliocentric distances. These developments are driving a paradigm shift in comet studies which calls for the reanalysis of all comet observations. By archiving with the PDS a significant and unique collection of wide-field space-based comet observations, our effort provides data critical to answering this call.

The Midcourse Space eXperiment (MSX), the Galaxy Evolution Explorer (GALEX) and the Swift Ultraviolet/Optical Telescope (Swift/UVOT) are non-Planetary Science Division space telescopes which have observed more than two dozen comet apparitions since 1996. Three were contemporaneous with spacecraft flybys and four were observed on two apparitions each. Comets of all dynamical classes have been observed, most over a range of heliocentric distances, the largest of which being 0.8 -- 5 AU.

Unique features of the MSX, GALEX, and Swift/UVOT observations include their wide fields of view (17 arcmin -- 10 degrees) and their sensitivity to UV emissions. In fact, for emission longward of H-Lyman alpha, these spacecraft have collected almost all of the

available wide-field UV data! The wide-field far-UV capabilities MSX and GALEX make possible the study of atomic end-members H, O, C, and S, which have very long lifetimes. Scientific fruit has already begun in this direction with a sensitive measurement of the ionization lifetime of carbon by Morgenthaler et al. (2011). Swift is an active astrophysics mission and is still adding to its list of 19 comets observed, 9 of which will be archived with the support of our proposed project. Swift's imaging and spectro-imaging capabilities in the UV and visible enable it to study the suite of molecular emission diagnostic of fragments of volatile species: CS, OH, CN, C3, and C2. Science results from Swift/UVOT observations have already begun to flow (e.g., Bodewits et al. 2011, 2014, 2015).

Our proposed efforts will support archiving of MSX, GALEX, and Swift/UVOT data in the Planetary Data System (PDS) in a format that is accessible to comet scientists. The MSX data covering 1000A -- 9000A with a variety of imaging and long-slit detectors and imagers, has never been publicly archived. The GALEX and Swift data are publicly archived, but the data were processed with the assumption that the comets were fixed targets. PI Morgenthaler and Co-I Bodewits have developed the necessary algorithms to accommodate moving targets and, with the support of our proposed effort, will apply them and archive the resulting products in the PDS.

We will also archive a unique set of ground-based observations of C/1996 B2 (Hyakutake) and C/1995 O1 (Hale-Bopp) which complement space-based observations. The data include a rich set of synoptic observations of H2O+ in Hale-Bopp which have never been published and velocity resolved H-alpha observations of Hale-Bopp which enable the testing of the hydrogen coma model used to interpret the SOHO/SWAN, which has observed 56 comets since 1996.

Archiving these data will "increase the amount and quality of digital information and data products available for planetary science research and exploration...." and is therefore highly relevant to the PDART.

Glenn Orton/Jet Propulsion Laboratory
Reduction and Archiving of Mission-Supporting Ground-Based Thermal Observations of Jupiter: Mapping Atmospheric Properties

Extensive ground-based mid-infrared observations of thermal emission from Jupiter have been made to support missions that encountered Jupiter, such as Galileo and New Horizons, as well as special events on the planet, such as the Shoemaker-Levy 9 and subsequent impact events. We propose to verify and, as necessary, refine the radiometric and geometric reduction of these images and to archive them with the Planetary Data System (PDS) for use by the greater community. The archived data will consist of the primary image and a cylindrical-map projection, accompanied by ancillary data on the emission-angle at each position on the map. We will use the same data-reduction as in our Planetary Astronomy / Solar System Observations programs, the Data Reduction

Manager (DRM). This IDL-widget-based graphic-user interface will allow us to examine the radiance calibration and geometric calibration of a series of infrared images of Jupiter.

After archiving the data, we propose to create maps of temperatures, minor-constituent abundances and clouds from these observations and submit these results to the PDS for archiving in parallel. These results will be useful to the general community working on outer-planetary atmospheres, particularly to those working on or supporting the active phase of the Juno mission at Jupiter by providing a historical context of atmospheric behavior that exists nowhere else. Information in these maps will be useful for detecting and characterizing thermal waves, seasonal and non-seasonal variability in the time domain such as auroral-related polar and near-polar emissions, and the events surrounding planetary-scale changes observed in the morphology of the visible cloud system.

Stuart Robbins/Southwest Research Institute
Morphology and Morphometry Data Acquisition for a Global Lunar Crater Database of Craters ≥1 km in Diameter

Science and Database Background:

Impact craters are arguably the main exogenic process that makes a significant contribution to the post-formation evolution of solid bodies in the solar system. Craters span the entire observable history of the Moon, and understanding their populations is a major tool for unraveling the history of its surface, the impactor population that affected it, and understanding how craters form. There is no broad, publicly available lunar crater database that exists down to kilometer-scale features. This is a critical diameter range that would inform many poorly understood lunar processes, and existing databases at large diameters omit morphometry and morphology data that would be useful for numerous science investigations.

The PI has been in the process of producing such a crater database for the past few years, and the basic information (crater latitude, crater longitude, and crater diameter) has been completed for all craters with diameters D â‰¥ 1 km by the PDART Step-2 submission deadline. While this basic information is useful, including additional information about each impact crater would vastly increase the utility of this database.

Scientific Description of Proposal:

This 3-year proposal is to do this additional work to make this database significantly more useful to the community. Robbins and Hoover would be responsible for adding the morphology and morphometry data. They would use publicly available data primarily from the Lunar Reconnaissance Orbiter's Camera's (LROC) Wide-Angle Camera (WAC)

and Laser Altimeter (LOLA) in conjunction with Kaguya's Terrain Camera (TC) mosaics and DTMs.

Morphology: Morphology classification is a two-step process. First, the global mosaics would be systematically searched and fields of obvious secondary impact craters would be identified. Second, each impact crater would be examined individually and the secondary crater classification validated, and then interior morphology (simple, complex features), ejecta presence and relative albedo, preservation class, and confidence the feature is an impact crater would be recorded.

Morphometry: The WAC, LOLA, and Kaguya DTMs would be used to analyze each D â‰¥ 1 km crater that is resolvable in these datasets to derive rim height, approximate surrounding surface elevation, and floor depth. The method uses computer-assisted code that has already been written and validated on 10s of thousands of Martian impact craters (Robbins & Hynek 2012, 2013).

Data Archiving and Data Validation:

This final dataset would be submitted to PDS and other repositories for archiving. While the PDS submission process does a basic validation of the data (e.g., flag a crater at +1200Â° N), it does not check each crater for validity of the parameters. Because we want to produce a reference database that the community can confidently use, Co-Is Chapman, Kirchoff, Singer would spend 2 weeks each year to check 1000s of craters and provide validation of the measurements. We anticipate they would be able to check 3-4% of the database, which via random sampling would provide a good estimate for the overall reliability of the database.

Relevance:

The objective of the PDART Program is "to generate higher-order data products," including "generate new reference information" and "Reference Database Creation." This proposal is to create a reference database (Â§1.4 of the PDART call) - a higher-order data product from lunar imagery and topography data. Specifically, PDART solicits "proposals to create “¦ reference databases useful for planetary science research." There will also be no hypothesis-based science in this proposed work.

Ted Roush/Ames Research Center
Visible to Mid-Infrared (VMIR, ~0.3-6 Micrometer) Complex Refractive Indices of Carbonates

Scientific Motivation and Objective:
Ca-, Mg-, and Fe-carbonates have been identified on Mars. Calcite and dolomite, among other carbonates, are identified in meteorites. The complex, real and imaginary, indices of refraction are the fundamental quantities that describe how these materials interact with electromagnetic radiation and are critical input parameters used in radiative transfer

models to estimate abundances from observations. Yet in the key wavelength region used to identify carbonates on Mars, the visible to mid-infrared (VMIR, ~0.3-6 micrometer) there is a dearth of complex refractive indices for many of these materials. This is the motivation for the proposed research. The objective is to determine the VMIR complex refractive indices of carbonates that will enable more quantitative estimates of the abundances of carbonates from existing observations.

Methodology:
Hapke's model of the interaction of light with particulate surfaces is used to determine the imaginary index by iteratively calculating the reflectance and comparing the result to the measured reflectance using a chi^2- criterion. Reflectance measurements of multiple grain sizes of the same sample are used. These are readily available via multiple on-line spectral libraries; NO NEW LABORATORY MEASUREMENTS ARE REQUIRED. The wavelength dependence of the real index is determined via a subtractive Kramers-Konig [SKK] analysis that requires knowledge of the imaginary index of refraction over a broad wavelength range. Infrared (IR, >6 micrometers) complex refractive indices are available for calcite, magnesite, and dolomite; NO NEW LABORATORY MEASUREMENTS ARE REQUIRED. Using the initial assumption of a wavelength independent variation of the real index of refraction in the VMIR, the analysis proceeds as follows:

A) Use Hapke model to independently determine the wavelength dependent imaginary refractive index for each grain size from the reflectance spectra.

B) Combine the results of (A) with IR imaginary refractive index.

C) Use the results from (B) in a SKK analysis to determine the wavelength dependent variation of the real refractive index.

D) Use the results from (C) and repeat (A)-(C) until the real and imaginary refractive indices from subsequent analyses no longer change.

All programs necessary to undertake the proposed research exist and have been used extensively. NO NEW PROGRAM DEVELOPMENT IS REQUIRED.
Results will be compared to the sparse data available at VMIR wavelengths. Resulting refractive indices of refraction will be published in an open source journal, and submitted for archival in NASA's PDS.

Relevance and Perceived Impact:
The proposed effort will generate new reference information, and as such is relevant to the stated scope of PDART (section 1.5)."Proposals to "¦ generate new reference information that is intended for general use in planetary science will be considered. Examples may include,"¦ optical constants"¦of materials." It is perceived that the results of the proposed effort will enable improved mapping of carbonates in/on the martian atmosphere/surface and asteroids (parent bodies of meteorites).

Glenn Stark/Wellesley College

Laboratory Measurements of Photoabsorption Cross Sections in the Ultraviolet for the Martian Atmosphere

Our research focuses on the measurement and modeling of vacuum ultraviolet and UV molecular photoabsorption cross sections with the highest practical resolution and accuracy. It supports efforts to interpret, model, and understand observations of planetary atmospheres, and it responds to the specific data needs of ongoing NASA missions. We request funding to support laboratory work on the isotopologues of CO2, O2, and CO and on N2, with current Martian atmosphere applications being the primary drivers.

CO2, O2, and CO: Isotope ratios of atmospheric species reveal much about the evolution of a planet's atmosphere and volatile reservoirs. We focus here on the O and C isotopologues of CO2, O2, and CO in the Martian atmosphere. Present-day isotopic ratios in the Martian atmosphere are signatures of the long-term evolution of the atmosphere and climate. Isotopic fractionation in the photodissociation of CO2 and O2 is expected to strongly influence the 16O/17O/18O composition of the atmosphere, while photodissociation of CO is the primary photochemical source of the escape of atomic carbon from Mars. The quantitative interpretation of ongoing observations of the Martian upper-atmosphere isotopic composition by the MAVEN NGIMS instrument requires detailed knowledge of isotope-selective processes during photodissociation. These in turn require accurate isotopic cross sections. We propose to:

a) measure the cross sections of the relevant CO2 isotopologues (13C16O2, 12C16O17O, and 12C16O18O) from the ionization limit, 90 nm, to 190 nm;

b) measure the cross sections of O2 isotopologues at Lyman-alpha (121.6 nm) to verify predictions of strong fractionation effects associated with this strong solar feature;

c) measure cross sections of 12C16O and 13C16O from 91.2 nm to approximately 80 nm to support evaluations of strong 12C/13C fractionation in the photochemical origin of atomic carbon escape from Mars following photodissociation of CO.

The proposed measurements will be carried out on the DESIRS beamline of the SOLEIL synchrotron, the premier facility in the world for gas-phase high-resolution photoabsorption measurements.

CO Cameron Bands and N2 LBH Bands: The Cameron bands of CO are prominent middle-ultraviolet airglow emission features of Mars, and the Lyman-Birge-Hopfield (LBH) bands of N2 were recently observed in emission in the Martian upper atmosphere by the IUVS on MAVEN. LBH bands also dominate the VUV airglow emissions from Titan's upper atmosphere; the analysis of their prominence has long been a central component of upper-atmospheric models of the N2-rich atmospheres of Earth, Titan, Triton and Pluto. The distribution of radiant energy within the CO and N2 bands provides insight into temperatures, pressures, and densities as well as the distributions of electron

and ion energies as functions of altitude. The interpretation of the emission intensities relies on a suite of electron-impact excitation and emission cross section measurements for relevant gases. The extractions of these cross sections from the laboratory data are susceptible to subtle, but important, effects associated with the dipole-forbidden nature of the CO Cameron and LBH transitions. We are initiating a collaborative effort with Dr. Charles Malone (JPL), a key author on the most recent relevant laboratory studies of electron-impact on CO and N2 excitation and emission, to measure the photoabsorption cross sections of the Cameron and LBH bands at to apply our measurements to improve the accuracy of he Cameron and LBH emission cross sections.

The proposed research contributes to the PDART program via the generation of new reference information (Scope of Program element 1.5). The spectroscopic data are directly relevant to ongoing Martian atmospheric research and are also intended for general use in planetary science. We will archive our data via the Atmospheres node of the NASA PDS.

Paul Withers/Boston University
Archiving Ionospheric and Neutral Atmospheric Profiles from Pioneer Venus Orbiter

- Description of science goals and objectives

The objective of this proposal is to recover ionospheric and atmospheric profiles acquired by the Pioneer Venus Orbiter (PVO) Radio Occultation Investigation from NSSDC dataset PSPA-00345 and published arti

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