Heliophysics Data Environment Enhancements
Abstracts of Selected Proposals
(NNH16ZDA001N-HDEE)

Below are the abstracts of proposals selected for funding for the Heliophysics Data Environment Enhancements program. Principal Investigator (PI) name, institution, and proposal title are also included. **24** proposals were received in response to this opportunity. On November 22, 2016, **7** proposals were selected for funding.

Seth Claudepierre/The Aerospace Corporation
Data Upgrade: Calibrating Van Allen Probe Measurements of 1-20 MeV Protons

There is a paucity of radiation belt proton measurements in the energy range of ~1-20 MeV, especially in the near-equatorial region. The proposed effort seeks to address this gap by calibrating 1-20 MeV proton measurements obtained by the ECT/MagEIS instrument on Van Allen Probes. The very fact that such data are sparse inherently limits our ability to understand the fundamental physical processes that govern the dynamics of these particles. Theories cannot be tested, nor can models be validated, without the observational ground truth. Thus, the potential for such measurements to have a wide-ranging application across NASA Heliophysics programs is high. For example, a more complete understanding of how solar variability influences the spatial distribution and temporal evolution of these protons, particularly at the outer edge of the inner proton belt, would contribute towards the goals of the Living with a Star Program. Specifically, we will obtain scientific knowledge relevant to mitigation or accommodation of undesirable effects of solar variability on humans and human technology on the ground and in space, since these particles can damage satellite solar cells or other lightly shielded components. Moreover, fundamental scientific investigations that would be enabled by these data include, for example, a better understanding of proton access to the inner magnetosphere during solar energetic particle events (e.g., geomagnetic cutoffs), and of the dynamics of the high-energy tail of the ring current. Thus, the proposed investigation would also support the goals of the Guest Investigator (GI) and Supporting Research programs. Indeed, the MagEIS team was contacted by two independent research groups about the prospect of using the 1-20 MeV proton measurements in their 2016 GI proposals. Unfortunately, we were not able to provide these data for their proposed investigations, because the data have not been calibrated and validated, as they are not supported under the Van Allen Probes mission contract. We emphasize that due to the paucity of such measurements, the role that 1-20 MeV protons play in the coupled solar/magnetosphere/ionosphere system, and their role in space environmental hazards, is largely unknown.

The proposed methodology has three components: (1) data calibration; (2) data validation; and (3) code development, data formatting, and data release. For the first task, the instrument will be modeled using Geant4 to characterize its basic response, obtaining the calibration factors necessary to convert the existing raw count rates into differential fluxes. In addition, we will characterize the instrument response to penetrating

backgrounds, such as relativistic inner belt protons and outer belt electrons. The second task will be focused on validating the calibrated data. This will be done through comparisons with the few available measurements in the same energy and spatial range, comparing with empirical models of the space environment (e.g., AP9), and using solar energetic particle events (SEPs; e.g., 2013 May 23) as a standard candle. SEPs are a particularly useful way to intercalibrate and validate such data, as these events bathe the entirety of geospace, including sensors in the solar wind and at lunar distances, with essentially the same particle population. This allows many different data sources to be compared against one another. The third and final task will be to develop code to process the data into ISTP-compliant CDF files and to coordinate the public data release. The code development, data processing, and data release will all benefit from several economies of scale due to the existing infrastructure of the Van Allen Probes mission. In particular, minimal code development will be required, as the basic code structure to read in and process these data already exists. The data processing and data release infrastructure that already exists via the ECT LANL SOC will be similarly leveraged.

James Eccles/Space Environment Corporation
Polar Cap s Topside Ionospheric Response to Storms: Data Upgrade to ISIS-II Topside Sounder Data

Data sets that examine the region of connection between the Earth s magnetosphere ionosphere (M-I) provide valuable insights into modeling of the Earth Space System response to solar drivers. Observations during large geomagnetic storms are at a premium for analyzing the geoeffectiveness of this M-I coupling. Such observations need to be made at high/polar latitudes. The topside sounder data beginning with Alouette-I and continuing through ISIS-II provide an extended and continuous examination of the topside ionosphere capturing many large geomagnetic storm periods. A small portion of the sounder data stored on 7-track magnetic tape has been retrieved and archived with hand-scaled ionograms at the Space Physics Data Facility (SPDF). However, a large part of the existing topside database is on 35mm film, which remains off-line, hence, difficult for researchers to access. The preservation of these unique films is only guaranteed for a few more years.

Based on the recently developed capabilities to digitize and condition film-based topside ionograms from ISIS-II, this proposal addresses the task of inverting over 5500 ISIS-II digitized film ionograms into topside electron density profiles (EDP). These ionograms were recorded at Resolute Bay, Canada are from high/polar latitudes and span 8 large geomagnetic storms. Each storm period includes one or two quiet days prior or in the recovery phase of the storm. The topside EDP s will provide unique evidence on how M-I coupling, specifically the ionospheric polar wind, responds during major geomagnetic storms. A broad community of both magnetosphere and ionosphere researchers will have access to ground truth storm dynamics that is not currently available. During the prior development of the topside inversion technique anomalous profiles were detected that may provide the community with a promising storm-time research focus.

This 1-year proposed effort will leverage these newly developed film recovery procedures to significantly expand the topside sounder EDP data base archived at the SPDF. In addition, it will enable the analysis of observations taken during 8 large geomagnetic storms. The proposed study has the following objectives:

1) Deliver 5500 ISIS-II digitized ionogram files, in the standard CDF format, for archival in the SPDF.

2) Use the Space Environment Corporation s new inversion software to invert these topside ionograms into topside EDPs. Given that they correspond to 8 large geomagnetic storms they will provide a major SPDF M-I storm database.

3) Investigate the availability of additional topside ionogram 35-mm films for these storm periods recorded at other locations both in Northern and Southern hemispheres.

4) Alert the research community of the new topside storm database by submitting an EOS article and announcing the availability of the new data sets through GEM and CEDAR newsletters.

Syau-Yun Hsieh/Johns Hopkins University
Data Upgrade: IMAGE HENA Ring Current Ion Distribution Data

ENAs are produced when energetic ions charge exchange with neutral gas and is a recognized technique for remotely image ions trapped in a magnetosphere. The ENAs carry not only global spatial information of the energetic ions, but also the compositional information of the ion distributions. The ENA images of the inner magnetosphere, collected by the IMAGE HENA imager from the years 2000 to 2005, convey global information about the ring current morphology, dynamics and composition. The ENA observations have been invaluable for understanding for the first time the global dynamics of the hot plasma, its origin and how its currents change on global scale, . The HENA data has been widely used in many scientific studies and is the only way to validate global models of the ring current. The HENA dataset provides an enormous statistical database for ring current distributions so that a future mission can use it. However, the underlying ring-current parent ion distributions from ENA images have been limited to open access by the scientific community, largely due to the complex nature of retrieving the 3D ion distributions from the ENA images.

The HENA science team has made a significant effort in developing and validating a constrained linear inversion technique that retrieves the underlying ring current ion distributions from the HENA images. This HENA ENA derived ring current ion distributions can then be used to estimate a significant fraction of the global pressure distributions and thus, is a very essential dataset in the analysis of the coupling in the inner magnetosphere. Therefore, to make this dataset available and accessible to the Heliophysics community and further archived becomes important and necessary.

We propose to produce this dataset that contains the ENA derived ring current ion distributions for the majority of geomagnetic storms observed by the IMAGE spacecraft over the entire mission lifetime. In this proposed work, the ring current ion distributions will be derived using the HENA ENA measurements at the energy range from 27 to 39 keV for protons. We will validate this dataset using the in-situ measurements from the Cluster spacecraft. The proposed data product will be written in Community standard Common Data Format (CDF) with appropriate metadata information.

Our methodology can be summarized below:
(1) to produce this new HENA dataset in community standard Common Data Format (CDF) by thoroughly preparing, processing, validating, and verifying data to ensure the high data quality standard, (2) to develop sufficient and adequate documentation to ensure the independent use of data, (3) to make this essential dataset accessible and available to the Heliophysics community, (4) to improve the HENA website to include the access to this dataset and documentation which describes the data and the use of data; (5) to provide the expert assistance to the Heliophysics community in the use of this dataset, and (6) to prepare for the transition of this new HENA data product along with the documentation to Space Physics Data Facility (SPDF) for archiving.

Roxanne Katus/Eastern Michigan University
Magnetospheric Ion Temperature Derived From TWINS ENA - Data Upgrade

Magnetospheric Ion Temperature Derived From TWINS ENA - Data Upgrade
In the proposed work we will complete the creation of a comprehensive database of magnetospheric ion temperature derived from NASA s Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS) Energetic Neutral Atom (ENA) instrument, provide critical metadata, and archive all of this at the NSSDC in a format compatible with the VxO architecture.
The terrestrial magnetosphere contains several distinct plasma populations: the plasmasphere, the ring current, the ionosphere, the radiation belts, and the plasma sheet. The plasma sheet is a layer of hot plasma that extends from the magnetotail into the inner magnetosphere. During a geomagnetic storm, reconnection in the tail forces energetic particles earthward through the plasma sheet into the ring current. This interconnection of the source and loss processes of the different plasma systems in the inner magnetosphere dramatizes the need to study these particle populations as one coupled system.
Production and availability of this dataset will allow future investigations of energy transfer across a broad range of solar wind driving conditions. This work will facilitate analysis of the ion temperature throughout geomagnetic events in terms of storm size and solar wind driver. These data will enable research on the transport of plasma throughout the coupled Sun-Earth system. These data will provide storm-specific ion temperature values with spatial and temporal resolution to establish accurate boundary conditions for inner magnetospheric models.
TWINS ENA measurements enable remote imaging, thus providing a global view of the magnetosphere. Using a novel method to calculate ion temperatures from ENA data [Scime et al., 2002; Keesee et al. 2011], two-dimensional ion temperature maps can be created throughout the evolution of geomagnetic storms. These maps have already been

created and validated with in situ measurements [e.g. Scime et al., 2002; Keesee et al., 2014; Katus et al., submitted]. Previous results were made available on CDAWeb as IDL savesets [Keesee and Scime, 2015]. This proposed work will improve upon these results by implementing a more robust and statistically verified ion temperature calculation algorithm established by Katus et al. [submitted] and will include all moderate (Dst d -60 nT) storms that occurred during the mission lifetime. In addition, we will make all of the data available in a more accessible format, i.e. CDF files, on CDAWeb with metadata describing the satellite parameters.

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Rudolf Komm/Association Of Universities For Research In Astronomy, Inc.

Subsurface Meridional Flow: a Dataset for Studying the Latitudinal Transport of Magnetic Flux

Science goals and objectives:

We propose to create a dataset of the (corrected) meridional flow in sub-photospheric layers (derived mainly from SDO/HMI) for scientific investigations by the Heliophysics community. The meridional flow plays an important role in a broad range of solar phenomena from the dynamo to the evolution of polar magnetic fields and the prediction of the solar cycle. The latitudinal profile of the meridional flow is a key ingredient in surface flux-transport models and greatly influences the polar field evolution. The meridional flow is thus a crucial component of the evolution of surface magnetic flux. The structure and the strength of the meridional flow sets the timing of the solar cycle in flux-transport dynamo models. The meridional flow and its temporal variation are thus a crucial part in predicting the solar cycle. With its comparably small amplitude (about two orders of magnitude smaller than the solar rotation rate), the meridional flow is susceptible to systematics and robust measurements are not easily available. We propose to create a data product that is corrected for systematics and is consistent during different phases of the solar cycle. The proposed data product can thus be used as input data in modeling efforts or as a benchmark to compare model predictions against. Making the corrected subsurface meridional flow available as a data resource to the Heliophysics community will greatly enhance the scientific return from SDO/HMI and will be crucial

for understanding the poleward transport of magnetic activity and predicting the solar cycle.

Methodology:
We will produce the following data product: the meridional flow at several depths in the subsurface layers as a function of latitude and time. The input measurements are the subsurface flows derived from SDO/HMI Dopplergrams analyzed with the ring-diagram technique from the surface to a depth of 16 Mm. From the daily full-disk flow maps (input data), we will calculate the average meridional flow (proposed data product) averaged over each complete Carrington rotation. We will remove systematic effects present in the subsurface flow measurements, such as systematic variations with disk position and annual variations due to the B0 and P angle, and average the corrected flows over each Carrington rotation. Then, we will use SOHO/MDI and GONG data to generate the corrected meridional flow for Solar Cycle 23 in addition to Cycle 24 covered by SDO/HMI data. We have already tested our method on existing (archived) subsurface flow data and plan to create these datasets first including their calibration and documentation. We will then create new data products as soon as a full Carrington rotations of subsurface flow measurements become available from SDO/HMI (via JSOC) and will add them to the data set. In this way, we will create a dataset that can be used for studies of the solar cycle as well as for modeling latitudinal flux transport of the current Sun.

Jerry Manweiler/Fundamental Technologies, LLC
Data Upgrade of Voyager LECP Count Rate Data Products

The Voyager 1 and 2 spacecraft have explored regions of the heliosphere no other spacecraft has traversed. It will be many decades before any other spacecraft will provide in-situ measurements that traverse the outer heliosphere and into the local interstellar environment. Thus, it is critical to make sure that the body of data captured from both spacecraft is in a format that is usable to present Voyager team members and to the general scientific community for many decades. The Low Energy Charged Particle (LECP) instrument onboard both Voyager spacecraft provides detailed measurements of the energetic radiation environment both inside and outside the Heliosphere. The LECP instrument is capable of making species resolved measurements of electrons and ions from just below 1 MeV to upwards of 100 MeV.

The original Voyager data products were designed using the technologies of the 1970s and 1980s. As many critical individuals have been and are retiring from the Voyager program, it is necessary to re-evaluate the data products being offered to the scientific community overall. Those original data products had severe limitations in the filename length, data record length, and overall data formats that no longer exist for the modern technology. For instance, organization of the original data products was done by Print Groups (PGs) which comprised a somewhat logical relationship between the LECP energy channels and species measurements. Unfortunately, the record size during those days was strongly limited to either 80 or 144 characters which forced the data product designers to create an inordinate number of PGs (76 for the flux average products).

Scientists who are new to the Voyager data sets are easily confused by the cryptic filenames and group definitions, and become lost in the overall organization of the data products especially as the existing production system is not accurately captured by the Voyager LECP data product documentation.

Philip Scherrer/Stanford University

Data Upgrade: Re-Calibration of SOHO/MDI Doppler Data Prior to Final Archive Submission

The Michelson Doppler Imager on the Solar and Heliospheric Observatory (SOHO/MDI) observed the Sun from February 1996 through April 2011, providing a nearly uninterrupted 15 year series of Doppler data for helioseismic studies. Together with the continuing observations of the Helioseismic and Magnetic Imager on the Solar Dynamics Observatory (SDO/HMI) beginning in May 2010, this represents a helioseismic data series with which solar physicists may investigate the Sun's interior dynamics and structures as they evolve over nearly two solar cycles.

The SOHO instruments were designed to operate with the spacecraft axis aligned in one direction with that of the Sun's rotation axis, and for the first seven years of the mission it did so. Due to a malfunction of the SOHO antenna in June 2003, it became necessary to reorient the spacecraft once every three months, so that its axis alternately pointed in the direction of the solar north and south poles. Such realignments posed no problem for the magnetic imagery, and were not thought to seriously affect the Doppler calibration either. Local helioseismology dependent on the analysis of phase differences of the oscillation signals at different locations on the solar disc, however, is very sensitive to tiny errors in the calibration of the Doppler signal. It has been discovered that the flows and structures inferred from helioseismology are significantly different between the times when the spacecraft was in opposite orientations. Consequently, about half of the MDI data acquired during the period of 2003 to 2011 are not comparable with the rest of the mission data.

Analysis of data from SDO/HMI, which uses a very similar observing technique to MDI requiring similar calibration, during a recent period when the spacecraft was anti-aligned from its normal direction has led to new insights and improvements in the Doppler calibration for that instrument. Calibration data taken over the course of the MDI mission will allow us to apply these improvements to the MDI calibration procedure as well. We propose to implement these improvements in the MDI Doppler calibration procedure and to recalibrate the Doppler data during selected intervals when SOHO was regularly flipping orientation. Helioseismic analysis for those periods will establish the extent to which the recalibration corrects the deficiencies of the original calibration. If there is significant improvement as expected, then we will recalibrate the Doppler data for the entire mission, incorporating the new data in the MDI Resident Archive where they will be available for both revisited and new analysis by the community prior to final archive submission. Data of improved and more consistent quality over a long time span will help us to better understand the Sun and its activity cycles.