

**Heliophysics Infrastructure and Data Environment Enhancements**  
**Abstracts of selected proposals**  
**(NNH14ZDA001N-HIDEE)**

Below are the abstracts of proposals selected for funding for the HIDEE program. Principal Investigator (PI) name, institution, and proposal title are also included. **17** proposals were received in response to this opportunity. On December 16, 2014, **10** proposals were selected for funding.

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**Peter Chi/University of California, Los Angeles**  
**Data Services Upgrade: Plasmaspheric Density Data Based on Field Line Resonance Observations**

This project provides a service upgrade of the existing plasmaspheric density data based on field line resonance (FLR) observations by the ground-based magnetometer networks in the North America. The main data product will consist of the equatorial plasma mass densities at low and middle L-values over several hours of local time at every 10 minutes. As one of the fundamental physical parameters, the plasma density provided by this project can enable a range of Heliophysics investigations, such as plasmaspheric dynamics, plasmasphere-ionosphere coupling, and the convection in the magnetosphere. The plasmopause location is known to correlate well with the inner edge of the outer radiation belt, thus useful for studies of radiation belt dynamics. Since the loss of telemetry signals from the IMAGE satellite in December 2005, there has been a void in global observations of the plasmasphere. This plasma density dataset can alleviate the problem by providing the equatorial plasmaspheric density and the plasmopause location in the portion of the plasmasphere monitored by ground stations in North America. The dataset can aid the interpretation of the observations by recent and ongoing NASA Heliophysics missions, addressing one of Heliophysics Decadal Survey: "Determine the dynamics and coupling of Earth's magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs."

It is well demonstrated that FLR frequencies can be used to estimate the plasma density for the associated magnetospheric field line. With a pair of suitably located ground-based magnetometers and the gradient technique, one can detect FLR frequencies with high confidence by using the gradient technique. Through recent research on this subject, we have developed the computer algorithms capable of automatically identifying the FLR frequencies in large amounts of ground magnetometer data. The plasma density data created have been used by recent studies of plasmaspheric dynamics. The time interval of the dataset starts from 2004 when some of the McMAC and THEMIS ground-based magnetometers have started operation.

This project enhances the utility and accessibility of the plasmaspheric density data based on FLR observations and make these data available for public use for the first time. SPASE descriptions of the data will be included, allowing the Virtual Magnetospheric

Observatories (VMO) and its users to access the dataset. All data will be stored in a form convenient for future archive at the NASA Space Physics Data Facility.

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**Guillaume Gronoff/NASA Langley Research center  
Data Service Upgrade. AtMoCIAD: the Atomic and  
Molecular Cross section for ionization and  
Airglow/Aurora database**

The objective of this proposal is to develop the web interface of AtMoCIAD (Atomic and Molecular Cross section for Ionization and Airglow/Aurora Database), a state-of-the-art database for cross sections, used to compute the ionization, excitation, dissociation of the atoms and molecules in planetary upper atmospheres.

The interface for AtMoCIAD will open up the possibility to have cross section data inputs from every interested group (either to share legacy cross sections or to propose new measurements), and the resulting debate concerning the selection of the recommended sets will bolster the communication between modelers, experimentalists, laboratory chemico-physicists, and the heliophysics community in general. These recommended set of cross sections for the computation of thermospheric parameters will enable reliable benchmark comparisons between planetary airglow models without ambiguities associated with different sources of cross section data.

Therefore, the development of the AtMoCIAD database addresses the recommendation of the decadal report [ The sun to the Earth and beyond. A decadal research strategy in Solar and Space Physics (2003) ] to increase the interactions between researchers in solar and space physics and those in allied fields such as atomic and molecular physics, laboratory fusion physics, atmospheric science, and astrophysics . The web-based release, specific to the HIDE program, will ensure the sustainability of this project.

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**Timothy Guild/The Aerospace Corporation  
Data Services Upgrade: Process TWINS-ES/SCM and release to VxOs**

The stated intent of the Data Services Upgrade proposals is to improve the quality, utility, and accessibility of datasets relevant to Heliophysics research. We propose to improve the quality of existing Aerospace observations (Surface Charging Monitor, or SCM, plasma analyzers, 10 eV - 30 keV ions and electrons) made on both TWINS vehicles by normalizing the count rates in all SCM look-directions, correcting for background, and removing sunlight contamination from the dataset. We will improve the utility of the dataset by merging it with magnetic ephemeris generated from widely used magnetic field models. Most significantly, this proposed effort will make the dataset accessible to NASA virtual observatories (VxOs) with a sufficient amount of meta-data for science community use; presently it is not accessible to the broader Heliophysics community. As the NASA Van Allen Probes mission continues returning measurements of the inner magnetosphere, these TWINS-ES/SCM observations provide an important high-L constraint to the seed ion and electron population, just outside the L values accessible to the Van Allen Probes. The comprehensive understanding of energizing seed electrons

from their origin to radiation belt energies is a prime goal of NASA's Van Allen Probes mission, to which the concurrent TWINS-ES/SCM observations will contribute. Similarly, the highly-inclined orbits of the TWINS hosts put each into the mid-altitude dayside magnetosphere for several months per year, providing excellent observations of cusp plasma entry, magnetic reconnection exhaust, and other dayside magnetospheric phenomena. This support will be especially valuable for those analyzing dayside data from the upcoming MMS mission, which has a focus on these phenomena.

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**Donald Hampton/Geophysical Institute****Data Services Upgrade - GIMA data collection improvements.**

The key objectives of this project are to 1) Improve the reliability of the on-site data collection systems for the Geophysical Institute Magnetometer Array (GIMA) to support NASA sounding rocket projects launched out of Poker Flat Research Range (PFRR) and other basic Ionosphere-Magnetosphere research, 2) Reduce the infrastructure demands by the GIMA on-site data collection systems, specifically power and network rates and thereby 3) Enable the expansion of GIMA to more remote sites (should funding become available to do so).

Description: Magnetometer data from several remote stations across Alaska have been collected continuously since the mid 1990 s. These three-axis, 1Hz data are used to determine the currents associated with auroral activity in Alaska, and specifically to help determine the optimal time to launch sounding rockets from Poker Flat Research Range. The collection pipeline includes (a) the on-site data collection, storage and real-time transmission, and (b) the central data reception including storage and display. A recent HIDE project allowed us to completely redesign the central data system and modernized the software tools to open source software running on Linux systems. These changes have significantly reduced the time and effort needed by the staff at the GeoData center at the Geophysical Institute, which hosts the magnetometer data. The remaining portion of the GIMA system, the on-site data collection, was not addressed, and continues to operate on antiquated hardware using software that is no longer supported and is currently the major source of data loss.

Relevance to NASA: The aurora is a key coupling mechanism between the Earth's magnetosphere and ionosphere, and the magnetometers are used to remotely sense the ionospheric currents associated with aurora. Therefore this project is related to all of the Heliophysics Roadmap Research Focus Areas having to do with Magnetosphere-Ionosphere (M-I) coupling. The magnetometer data are used not only by NASA sounding rocket PIs, but also by many research groups and are currently part of UCLA's Virtual Magnetospheric Observatory (VMO), and the SuperMAG virtual observatory.

Proposed Upgrades: We propose upgrades to the GIMA on-site data collection software that will enable us to use low-cost, low-power Linux-based imbedded systems. The advantages are not only a high reliability operating system and closer integration with the central data storage system (Linux-to-Linux), but include lower power and network requirements at the remote sites, which will help maintain or reduce utility costs. All

changes in the remote software will be transparent to the user, and will not affect our deliveries to NASA sounding rocket PIs or to virtual observatories we now serve.

Deliverables and Data Products: The single deliverable is a set of modular scripts developed in open source languages (Python) to satisfy the four main requirements: 1) collect magnetometer values via RS-232 interface, 2) collect GPS timing to correlate with each magnetometer value, 3) transmit the collected data via UDP or TCP at 1 second intervals, and 4) store the collected data locally, and transmit to the central database on an hourly basis.

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**Jing Li/University of California, Los Angeles**

**Data Services Upgrade: A Database for Sunspot Magnetic Tilt Angles**

Sunspot magnetic tilt angles are fundamental physical parameters in solar physics. Two of the key century-old observations are the cyclic variations of the tilt angles known as Joy's and Hale's laws. There is no doubt that the sunspot tilt angles demonstrate the action of the cyclic global solar dynamo. However, we do not yet know how the change of the sunspot tilt angles plays a role in the magnetic energy release within a sunspot group. Sunspot tilt angles also reflect the process by which buoyant magnetic flux ropes rise from convection zone to the surface of the sun. Despite many applications to solar research, the sunspot magnetic tilt angles remain one of the few observable parameters poorly determined on the sun. The call of NASA ROSES-14 Data Environment Enhancements perfectly suits to support the task of setting up a database of sunspot magnetic tilt angles within the VSO environment. We have successfully produced the sunspot magnetic tilt angles from 1974 to 2012. We propose to setup a tilt angle data base with the measured tilt angles. We will also investigate the tilt angle uncertainty and improve the measurements by calculating the tilt angles of a sunspot group with multiple magnetograms a day. We believe that this effort will maximize the scientific return of the NASA missions and upgrade the existing VSO database.

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**Janet Machol/NOAA**

**Data Services Upgrade to the GOES Solar Extreme Ultraviolet Irradiance Measurements**

This proposal aims to provide a long-term calibrated and validated solar extreme ultraviolet (EUV) solar irradiance data set from the geostationary GOES satellites. The data will be better calibrated than previously by using instrument design details and cross-comparisons with measurements from other instruments. Once calibrated, the observations will provide a long term record of solar EUV that will be critical for ionosphere/thermosphere modeling. Understanding and predicting the states of the ionosphere and thermosphere are important because they have impacts on communications, GPS, and satellite orbits.

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**James Patterson/Fundamental Technologies, LLC**  
**Ulysses/HISCALE PHA Data Service Upgrade to Include Species-Resolved High-Resolution Energy Spectra**

The Heliospheric Instrument for Spectra and Composition At Low Energies (HISCALE) on the Ulysses spacecraft and the Electron Proton Alpha Monitor (EPAM) on the Advanced Composition Explorer (ACE) are nearly identical instruments as EPAM was the flight spare for HISCALE. This allows similar tools to be developed for the two instruments to generate nearly identical data products. Over the past year, we have constructed a method for extracting daily and hourly-averaged, high-resolution energy spectra for various  $Z>1$  ions using the Pulse Height Analyzer (PHA) system. We propose to modify this method for use with the HISCALE instrument and produce a similar data product.

The Ulysses spacecraft explored regions of the heliosphere no other spacecraft has, nor will in the near future. It's highly eccentric heliolar orbit allowed observations at nearly all latitudes and from radial distances as close as 1.3 AU and as far as 5.2 AU. The addition of these highly resolved spectra for the heavier ions will compliment the cosmic ray data from cosmic ray instruments on Ulysses, and will allow direct comparison to the 1-AU, in-ecliptic measurements taken by the ACE/EPAM instrument.

By plotting the energy deposited in the C and D detectors of EPAM's CA-60 telescope, the different ion species will trace unique tracks allowing for positive identification and total energy measurement of the incident ions. The counts are sorted along these various tracks into twelve bins resulting in a very high-resolution energy spectrum over a couple of decades of energy. As one might expect, the flux is low for these heavy ions, but using the two-parameter PHA measurements, the background noise is minimal permitting integration of these counts over long time intervals. This method has been very successful with the ACE/EPAM instrument, allowing for better comparison to spectra seen by other spacecraft such as the Van Allen Probes as we presented at the 2013 Fall AGU.

The method will be applied to data from the entire Ulysses mission beginning in late 1990 and continuing through mid-2009. The energy range for all species will be between about 0.3 and 10 MeV/nuc with eight to twelve data points within that range. Among the species to be identified by the process are helium, carbon, oxygen, neon, sodium, silicon, and iron. With the structure of the process already developed for the EPAM instrument, the process for adapting the method for use with the HISCALE instrument, generation of the data, and posting the results on our data server will only require about three months of time.

The data products, once produced, will be stored as easily accessible and portable comma-separated variable (CSV) flat ASCII files and as CDF files. The data will be publically available through the Fundamental Technologies website, [www.ftecs.com](http://www.ftecs.com). We will also generate yearly colorspectrograms based on these data as well as daily energy spectra for each species. We have already created these products for the EPAM instrument. The numeric data files can be found at [http://data.ftecs.com/VHO/VEPO/ace\\_epam/pha/spectra/](http://data.ftecs.com/VHO/VEPO/ace_epam/pha/spectra/), and the colorspectrograms can be found at [http://data.ftecs.com/archive/ace\\_epam/plots/PHA/colorspectra/](http://data.ftecs.com/archive/ace_epam/plots/PHA/colorspectra/).

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**Alexei Pevtsov/National Solar Observatory**  
**Data set of sunspot field strengths**

This proposal targets the Data Environment Enhancements (H-DEE, Data Services Upgrade) element of NASA's Heliophysics Infrastructure and Data Environment Enhancements (H-IDEE) program.

Some recent studies suggested possible changes in sunspot field strengths, indicating the incoming Grand minimum in solar activity. Other studies, however, challenge that claim and suggest that these recent changes could be part of long-term trends observed in the past. The modern magnetographic observations of sunspot magnetic fields do not go far enough in time to resolve that issue. Likely, there are manual daily measurements of sunspot field strengths from the Mount Wilson Observatory (MWO), which started in 1917 and continue till the present. The data consist of daily drawings of sunspots with the corresponding field strength and polarity measurements handwritten on these drawings. All the drawings are scanned to digital images (JPEG or GIF formats). However, the lack of tabulated data severely limits the use of this unique data set. The main objective of this project is to convert the digitized information contained in the MWO sunspot drawings into a digital tabulated format. The digitized data will be provided to the research community and used in studies of long-term variations of sunspot field strengths over the period of ten solar cycles. The data set can be used to answer a number of important scientific questions that are crucial for understanding the physics of stellar activity cycles and the dynamo theory, for example: (1) the long-term variation of statistical properties of sunspot field strengths and their relation to the characteristics of solar cycles (including comparison with current cycle 24), (2) the study of area, tilt, and compactness of active regions and their relation with the corresponding sunspot field strengths, (3) how this historic measurements of sunspot field strength compare with sunspot field strengths derived via modern inversion techniques (e.g., used by SDO/HMI, SOLIS/VSM and other modern vector magnetographs).

Science goals this proposal will enable: This digitization project will allow exploring a long-term archive of nearly 100 years of sunspot field strength measurements, covering about 10 solar cycles. This unique data set will enable studies of long-term changes in properties of solar activity cycles and allow putting the current solar cycle into the perspective of previous solar cycles.

The small amount of funding sought by this proposal will make a complete MWO data archive available to the community, which will facilitate a significant scientific return from a unique long-term data set. The study of sunspot field strengths in past solar cycles may also aid forecasting of long-term and short-term solar variability. This is a key element in space weather prediction. In addition, the data will be used for studies targeted at important questions in solar/stellar astrophysics: the activity cycles and dynamo theory.

Brief description of the methodology: We will start from the software package that was previously developed by us to convert scanned images to tabulated data sets, and further improve the software to include more automation in identifying the key features in scanned images. The tabulated data will be verified and put into a public domain via NSO

**Aki Takeda/Montana State University**

**Data Services Upgrade: Creation of Seamless GOES/XRS Flux Data Archive based on Yohkoh GOES Database**

The Yohkoh project is one of the most successful solar missions, providing X-ray images and spectra of the sun from September 1991 through December 2001. It was the only space mission for the solar research community in the early 1990s until SOHO became operational in 1996. The Yohkoh data analysis system (the Yohkoh software and database) developed during this period forms the base of the current data analysis system (SolarSoft) predominantly serving the worldwide heliophysics research community.

The solar X-ray flux from the GOES satellites, i.e., data from short(0.5-4A) and long(1-8A) wavelength bands of the X-Ray Sensor(XRS), are one of the most frequently used data sources, not only for monitoring the current solar activity, but also for studying long-term variation of the Sun. Due to the above historical reason, the GOES data catalogs were initially developed as a part of Yohkoh database (\$SSWDB/ydb). Although a separate GOES data archive was later developed in SolarSoft (\$SSWDB/goes) by SDAC, those in Yohkoh database are still generated daily and maintained by the Yohkoh Legacy data Archive. In 2011, ydb GOES files were carefully examined to replenish their missing records with the original dataset obtained at NOAA/NGDC, and thus have the better time coverage for the period 1991 through 2010 than the SDAC GOES archive.

Using the ydb GOES database, we propose to create a single seamless series of FITS and text (ASCII) files of solar X-ray flux from GOES/XRS short and long bands by appropriately selecting the primary satellite when multiple satellites were available. A series of daily flux files, with 3 seconds resolution and their 1 minute averaged data, will be created for the period from 1991(Yohkoh launch) through 2010 (start of GOES15). The new files will have the following advantages compared with the corresponding files found in the current SolarSoft database (\$SSWDB/goes), and will enhance the data analysis environment of heliophysics research.

(1) Except for text files of the most recent few years (after GOES14), GOES X-ray flux files in both SDAC and YDB archives are created separately for each available satellites, which sometime cause difficulty in obtaining data for time ranges surrounding switch-over of the primary satellite. The creation of a single series of files will reduce the effort of users or of software to find available data while minimizing or eliminating data gaps.

(2) Use of the ydb GOES database guarantees the best time coverage of the new GOES database for the proposed period of data production (1991 -- 2010).

(3) NOAA/NGDC recently (March, 2014) announced the correction to the published GOES flux data from GOES 8 --15. While neither of the current GOES archives has yet

applied this correction to their data files, we are ready to apply them in our proposed database.

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**Yongliang Zhang/Johns Hopkins University / APL**  
**Net nitric oxide radiance from TIMED/GUVI data**

(1) Key objectives and their scientific importance

The key objectives of the proposed work are to extract the net radiances of nitric oxide (NO) emissions in FUV (around 180 nm) from the TIMED/GUVI spectrographic data, store the net NO radiance data in NetCDF format permanently on the TIMED/GUVI website and add them to the access list of the Virtual Ionosphere Thermosphere and Mesosphere Observatory (VITMO) for the community to use. NO in the low thermosphere is mainly produced by energetic particle precipitation in the high latitude auroral regions and solar X-rays in the mid and low latitudes. During space weather events (such as geomagnetic storms), the NO density is significantly enhanced and transported to mid and low latitudes. Because of its strong infrared radiation, NO is one of the major cooling agents in the low thermosphere. Specifying the NO density is important for understanding the thermospheric conditions and dynamics. The dayside NO radiances around ~180 nm are due to solar resonant fluorescent scattering and depend on the NO density and the solar FUV flux. Because of little change (less than 2%) in the solar FUV flux over a solar cycle, the net NO radiances are directly proportional to the NO density or column density. The net NO FUV radiance data open a door to estimation of the NO density. Furthermore, simultaneous observations of the net NO radiances and O/N<sub>2</sub> column density ratio (another key TIMED/GUVI product) will also help to provide a better and more complete picture of the thermospheric condition and dynamics.

(2) Methodology

There are three steps to extract the net NO radiance in FUV around 180 nm (between 178 and 182 nm) by using the spectrographic data between wavelengths 140 and 185 nm. In this wavelength range, the major emission sources are N<sub>2</sub> LBH, NO  $\mu$  band (170-260 nm, peaked around 180 nm), N<sub>2</sub> VK band, and some Rayleigh scattering. The VK band is usually much weaker than the LBH band and can be ignored. The first step is to determine the reference spectra and their dependence on solar zenith angle (SZA) where the NO contribution can be ignored. The reference spectra will be constructed by averaging the geomagnetic quiet (e.g. Kp < 1) and low solar X-ray (solar minimum years 2008 and 2009 and during a low phase of solar rotation) at different SZA between 0 and 90. The second step is to scale the reference spectra to fit given GUVI spectra by minimizing their differences between 140 and 160 nm (excluding wavelengths around the NI 149.3 nm line) where the emissions are dominated by the N<sub>2</sub> LBH band but without the NO contribution. The scaled reference spectra are then subtracted from the GUVI spectra to get the net NO spectra. The net NO spectra are summed up between 178 and 182 nm to give the net NO radiance. Finally, the net NO radiance and associated date, UT, geo-location and SZA will be collected and saved in NetCDF and IDL save set files for each GUVI orbit (2008 present and beyond). A document on the above procedure and definition of final NO radiance will be made available to public through the TIMED/GUVI website at <http://guvi.jhuapl.edu> and VITMO.



### (3) Significance and Relevance to NASA Objectives

The proposed work will provide net nitric oxide radiance data in FUV to the community. The NO radiances can be directly used to estimate the thermosphere NO density or column density that is important for the energy balance in the low thermosphere due to its strong cooling mechanism and significant enhancement during geomagnetic storms. This proposed work directly supports the NASA H-IDEE program to enable breakthrough research in Heliophysics by providing a state of the art data environment and necessary supporting infrastructure to maximize the scientific return of the NASA missions. The proposal also supports the Heliophysics research programs that address understanding of the Sun and planetary space environments.