30TH INTERNATIONAL COSMIC RAY CONFERENCE

Virtual Cosmic Ray Observatory (ViCRO)

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Abstract: The Virtual Cosmic Ray Observatory (ViCRO) is proposed to extend planned capabilities of existing or developing heliophysics virtual observatories with a collection of important cosmic ray datasets with focus on interplanetary solar & heliospheric science applications and on planetary interactions. Core operational data sources include cosmic ray instrumentation on the Heliospheric Network (HN) spacecraft, ephemeris data services for these sources and solar system objects, and supporting data on high energy cosmic rays from ground-based neutron monitor and high-altitude balloon instruments. ViCRO would initially support data query, access, and other VxO functions through a common middleware interface already in development for the Virtual Heliospheric Observatory.

1. Introduction

Cosmic rays flow throughout the heliosphere from solar, interplanetary, and galactic sources. These suprathermal to highly energetic particles at keV to GeV energies and above can penetrate from heliospheric and local interstellar source environments deeply into planetary magnetospheres, atmospheres, and surfaces. This component of the space radiation environment has potential for literally high impact on all heliophysics disciplines as well on earth and planetary science, astrobiology, and manned & robotic exploration of the Moon, Mars, and beyond. One can note, for example, that the historical timeline of our human species from paleolithic to modern epochs is benchmarked by C-14 and other products of high-energy cosmic ray interactions in the Earth's atmosphere. Links to biological evolution through genetic interactions, to long distance radio communications through ionospheric interactions, and to global warming through aerosol-driven cloud formation are other important applications.

Cosmic ray irradiation is among the greatest threats to long-term health and safety for astronaut voyagers journeying beyond the protective cocoon of the geomagnetic field and the Earth's extended magnetosphere into local interplanetary space, eventually to Mars and other planets. Surface outposts of human explorers on the Moon would face full exposure to interplanetary cosmic ray fluxes during most of each lunar month. Long journeys to Mars may need to be timed for pro-

longed intervals of maximum solar modulation, but more frequent solar proton events in these intervals may offset the value of reduced galactic cosmic ray fluxes. The ICRC community requires full quantitative understanding of the flows of cosmic ray energy in space and time to support development of strategies and techniques to forecast and mitigate harmful effects for heliospheric and planetary exploration.

The Virtual Cosmic Ray Observatory (ViCRO) would serve the data and collaborative research needs of the U.S., and affiliated international, cosmic ray communities to support cross-disciplinary research on sources, acceleration, transport, and surface & atmospheric interaction effects of cosmic rays. ViCRO is proposed to provide a common view for U.S. and international users to the cosmic ray data environment across the many different spacecraft, suborbital, and ground-based data sources.

Necessary functions of ViCRO must include support for evolution of a common language that can be used to query the characteristics, location, and accessibility of relevant data sets from multiple sources that users may wish to utilize in addressing problems in cosmic ray physics and applications in various disciplines. Since data can only be used if commonly understood documentation is available, ViCRO needs to support standardized descriptions of data set contents including included data set parameters, processing methods, quality factors, provenance, and proper acknowledge of data providers. Usage of data from multiple instruments and platforms also motivates the development of common query language and technical approaches to intercalibration of data sets to produce flux and abundance distributions spanning multiple sources. Although ViCRO usage should not require prior knowledge of data set location, provenance and acknowledgement information are critical to cooperation of data providers needing to show usage of their data for continuance of funding support.

ViCRO is also proposed as an appropriate ICRC initiative for the International Heliophysical Year and the International Polar Year 2007-2009, both now in progress since March 2007. These international year activities involve intense international research campaigns that can be substantially enabled for cosmic ray science by the virtual observatory tools envisaged for ViCRO. Development of ViCRO would begin during this period and continue as a legacy for support of international cosmic ray research across all related space and earth science disciplines.

2. Cosmic Ray Data Environment

Within NASA's Heliophysics Global Observatory fleet of spacecraft, suborbital, and ground-based instrument platforms, the subset of Heliospheric Network (Figure 1) spacecraft all provide local point measurements in various scattered locations throughout the heliosphere. Repositories for much of the cosmic ray data from these NASA and International missions will be accessible by ViCRO from Heliophysics mission data active or permanent archive facilities and from the Planetary Data System.

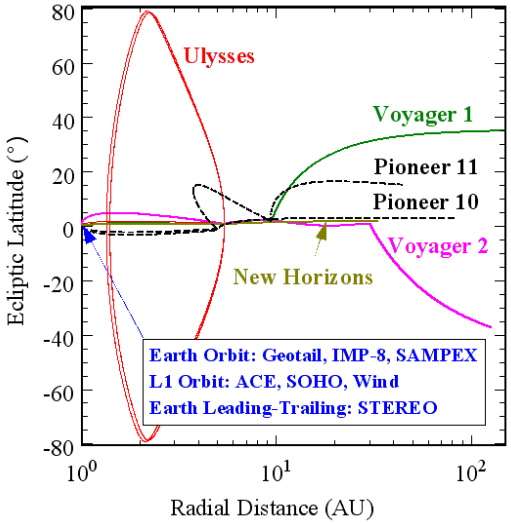

Figure 1. Operational (solid) and legacy (dashed) interplanetary spacecraft, plus 1-AU spacecraft (box), of the Heliospheric Network will provide data to be accessed by the cosmic ray community via ViCRO. Interplanetary cruise data for cosmic rays are also available from planetary missions including New Horizons, now approaching Jupiter enroute to Pluto and the Kuiper Belt, and Cassini, previously enroute to Saturn during 1997 – 2004 and now in orbit there.

3. Functional Description

Within the heliophysical data environment of NASA, ViCRO must be defined for consistency with the following definition: "A Virtual Observatory (VO) is a suite of software applications on a set of computers that allows users to uniformly find, access, and use resources (data, software, document, and image products and services using these) from a collection of distributed product repositories and service providers. A VO is a service that unites services and/or multiple repositories." An example of the functional architecture for an existing and evolving VO is that of the Virtual Heliospheric Observatory (VHO) now under development at NASA Goddard Space Flight Center. Initial development of ViCRO will be leveraged from the VHO core system architecture shown below in Figure 1, and later evolution of ViCRO will be timed to take advantage of planned enhancements in the VHO middleware.

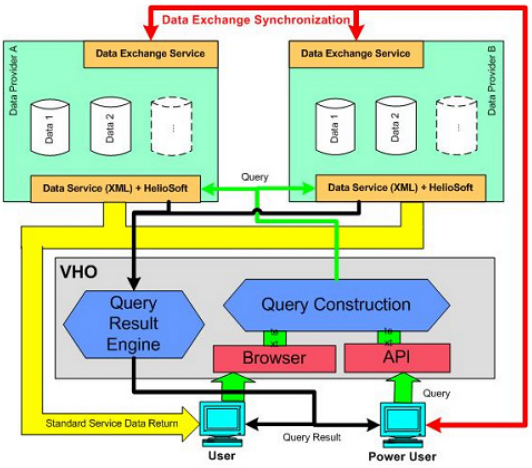

Figure 2. VHO core functional architecture to be adapted for initial implementation of ViCRO. Essential components include middleware in the diagram center that allows users to send queries to participating data providers via either a browser or API interface. The main data transfer to regular users (left) occurs independently of the middleware. Power users, e.g. members of the ViCRO partnership, would both receive and send data, including value-added (e.g., intercalibrated, event-subsetted, merged, averaged) data products, along the data exchange backbone shown in red.

The evolving VHO functions to be utilized for ViCRO include lightweight middleware with search capability, common metadata description of products and services based on the SPASE (Space Physics Archive Search and Extract) dictionary with enhancements for heliospheric resources, data exchange and synchronization mechanisms, minimum possible requirements on data providers, and low cost extensibility to the final VHO architecture. VHO connects to users, data repositories, and service providers through web browser functions and the VHO Application Programming Interface (API). A core function of the middleware is exchange of automated queries with data sources based on industry standard protocols and with other VxOs.

ViCRO will also be leveraged by the data system facilities and data technology expertise of the Space Physics Data Facility. Several popular data services within SPDF include OMNIWeb for solar wind plasma, magnetic field, and selected proton flux channel data, CDAWeb for the broadest access to data sets across instrument and spacecraft platforms within the heliophysics data environment, SSCWeb for spacecraft ephemeris data in Earth-centered coordinates, and HelioWeb for heliospheric coordinates of selected Heliospheric Network spacecraft. These services can be currently be accessed separately through the main SPDF web page at http://spdf.gsfc.nasa.gov/ and will be more directly accessed by ViCRO through system-level calls adapted from VHO APIs.

4. Implementation Tasks

Bringing ViCRO into active usage within the heliophysics data environment requires completion of a series of tasks, i.e. construction of the "seven pillars of wisdom" **(***Wisdom hath builded her house, she hath hewn out her seven pillars,* Proverbs 9:1**).** The tasks as proposed to NASA for funding of ViCRO development are as follows:

4.1 Coordinated Discovery and Access

Implement ViCRO front-end web site tailored to needs and resources of Cosmic Ray Data Environment and support user query, search, and access functions for Discovery and Access of data

and other resources in this environment through utilization of VHO middleware for query and search functions and ViCRO – VHO systems for data access. The NASA heliophysics virtual observatories program has been supporting development of the needed middleware and initial products of this effort for VHO are becoming available for integration into ViCRO.

4.2 Understanding of Data Needs

Assess needs of the U.S. and collaborating international cosmic ray community for resources of the Cosmic Ray Data Environment, recruit new data providers through conferences, team meetings, and individual collaborative research, and provide data and documentation requirements for provision of access to ViCRO. The international cosmic ray research community involved in the present ICRC meeting is the group best able to support the needed assessment.

4.3 Standards and Metadata

Participate in SPASE (Space Physics Archive Search and Extract) development, leading on definition of more appropriate terminology for the Cosmic Ray data Environment, and provide standards documents on ViCRO query and data set metadata for usage by the ViCRO Partnership and other providers. This task involves the needed development of common language terms for specification of desired data products, documentation, and services by ViCRO users.

4.4 APIs and Web Services

Adopt the web services Application Programming Interface (API) of VHO to create a single point of service and program access to ViCRO data and service resources. Automated responses to user queries require underlying system communications between ViCRO middleware and corresponding software of other virtual observatories and data provider systems.

4.5 Value Added Services

Build on existing data service models from OMNIWeb, COHOWeb, and CDAWeb to develop a prototype service to enable user access to uniformly formatted data accessed through ViCRO to support intercomparison and intercalibration of cosmic ray data in different formats from different data sets, Heliospheric Network sources, and ViCRO data providers. Research experience within our co-author group and the proposed ViCRO partnership suggests that ViCRO value-added support for user community production of integrated multi-sensor flux data sets, modeled in part on those already produced from ACE and Voyager data, should receive high priority.

4.6 Ancillary Data Access

Augment ViCRO-accessible data with ancillary ephemeris, solar activity, neutron monitor, solar wind, and event data from SPDF data systems and other resources. SPDF already provides independent on-line access to the SSCWeb, HelioWeb, and OMNIWeb data services for some of the needed ancillary data, and neutron monitor data can be accessed from other available web sites of the data providers.

4.7 Usage Assessment and Provenance Protection

Define and implement ViCRO metrics for community utilization and provenance protection protocols for assurance of accurate data usage acknowledgement to data providers. These metrics and protocols are essential to documentation of ViCRO usefulness to the data user community and to provision of appropriate acknowledgements to data providers for community usage of their data through ViCRO.

5. Summary

ViCRO is the requisite component of the emerging virtual observatory program at NASA to serve the cross-disciplinary science needs of the U.S. and international cosmic ray research community as represented at the current ICRC meeting. Principal data sources for ViCRO are the various spacecraft of the Heliospheric Network, cosmic ray balloon experiments, and ground-based neutron monitors. The proposed rapid pathway to ViCRO implementation utilizes existing and evolving middleware of VHO to support the primary data discovery and access function. The common ViCRO view of the cosmic ray data environment requires a common language based on SPASE but with an expanded lexicon. SPDF will provide support on data technology, ancillary data access, and value-added data services.