

Space Physics Data Facility (SPDF) Data Archives and Services in support of Heliophysics Digital Resources Library (HDRL)

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Abstract

In order to improve access to the data and models of the Heliophysics System Observatory (HSO) and NASA-funded research projects, the NASA Heliophysics archive and modeling groups are collaborating to create a Heliophysics Digital Resources Library (HDRL) for improved cross-mission and observation-model comparison, machine learning and other large-scale and collaborative analysis, increased discoverability and usability of data and model results, software and services, and more complete metadata and provenance and quality control. Observational data are archived and served by the Solar Data Analysis Center (SDAC) and the Space Physics Data Facility (SPDF). The Community Coordinated Modeling Center (CCMC) provides empirical and first-principles simulations and analysis and display tools. A number of largely cross-cutting registry, access, and analysis standards and tools are provided by the Heliophysics Data and Model Consortium (HDMC). As part of this effort, SPDF, as the active and final archive for non-solar NASA Heliophysics data, works with current operating missions and the Heliophysics community to ingest, preserve and serve a wide range of past and current public science-quality data from the mesosphere into the furthest reach of deep-space exploration. SPDF facilitates scientific analysis of multi-instrument and multi-mission datasets to enhance the science return of the many missions. SPDF develops and maintains the Common Data Format (CDF) and the associated ISTEP/SPDF metadata guidelines. SPDF services include CDAWeb, which supports both survey and burst mode data with graphics, listings and data superset/subset functions. SPDF is currently receiving and serving data from missions including Parker Solar Probe, Solar Orbiter, MMS, Van Allen Probes, THEMIS/ARTEMIS, GOLD, ICON, ACE, Cluster, IBEX, Voyager, Geotail, Wind and many others, and >120 Ground-Based investigations. SPDF also operates the multi-mission orbit displays and query services of SSCWeb and 4D Orbit Viewer, as well as the Heliophysics Data Portal (HDP) discipline-wide data inventory and access service, and OMNIWeb and COHOWeb for near-Earth and deep-space solar wind plasma, magnetic field, and energetic particle database, respectively.

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Space Physics Data Facility (SPDF) <<https://spdf.gsfc.nasa.gov>>

NASA Heliophysics Active Final Archive for Non-Solar Data

HELIOPHYSICS SYSTEM OBSERVATORY

- 20 Operating Missions with 27 Spacecraft
- 12 Missions in Formulation or Development
- 6 Under Study

- FORMULATION
- IMPLEMENTATION
- PRIMARY OPS
- EXTENDED OPS

CubeSats

In Development

AEPEX	CuSP	LLITED
AERO / VISTA	DAILI	MinXSS-3
CIRBE	Dione	petitSat
CODEX	GTOSat	REAL
CURIE	LAICE	SPORT

On Orbit

ELFIN
SORTIE
CuPID

OPERATING & FUTURE



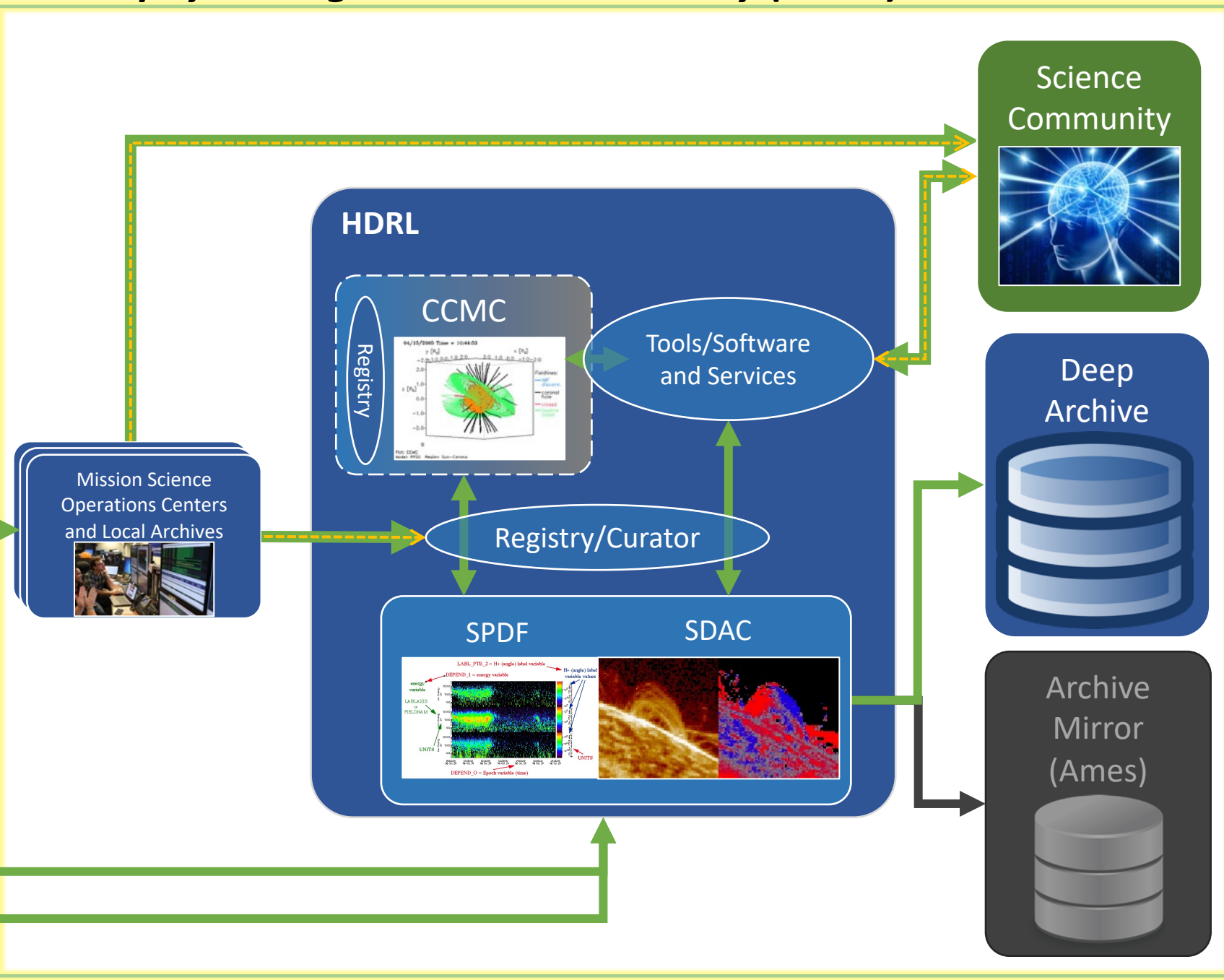
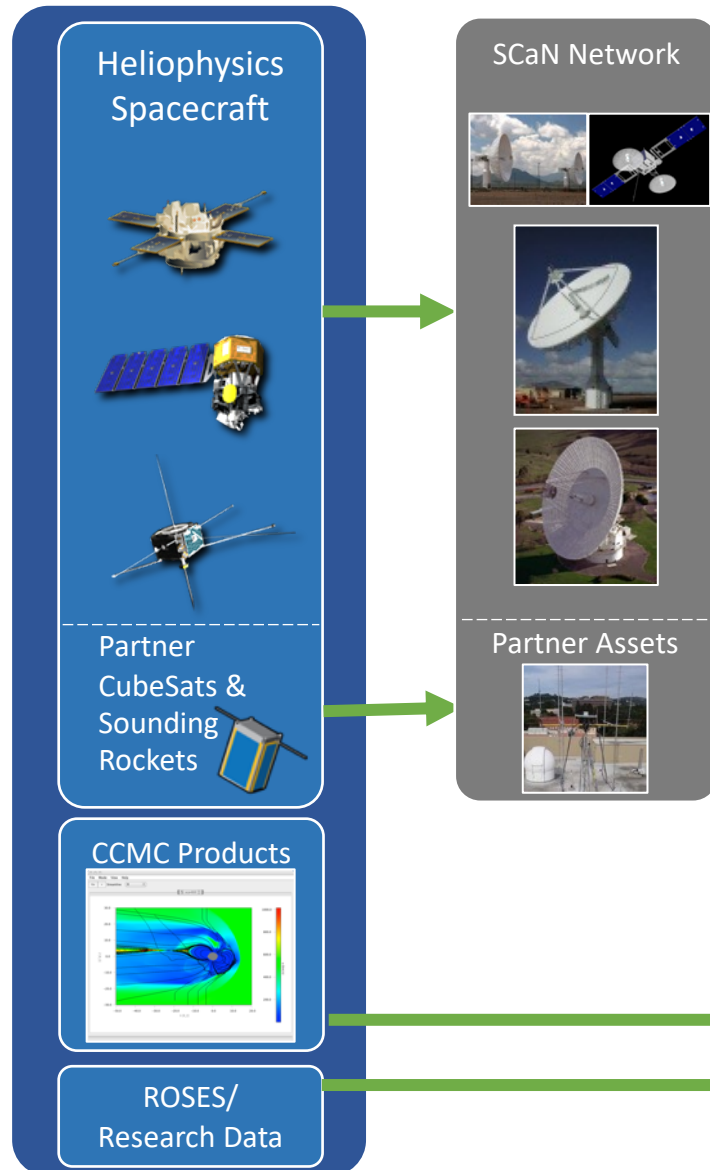
Introduction to Heliophysics Digital Resources Library (HDRL)

- NASA Heliophysics archive and modeling groups collaborate to create a Heliophysics Digital Resources Library (HDRL) for:
 - Improving access to the data and models of the Heliophysics System Observatory (HSO) and NASA-funded research projects
 - Improving cross-mission and observation-model comparison, machine learning and other large-scale and collaborative analysis
 - Increasing discoverability and usability of data and model results, software and services, with more complete metadata and provenance and quality control.
- HDRL components
 - Solar Data Analysis Center (SDAC) archives observational solar data
 - Space Physics Data Facility (SPDF) archives observational non-solar data
 - Community Coordinated Modeling Center (CCMC) provides empirical and first-principles simulations and analysis and display tools
 - Heliophysics Data and Model Consortium (HDMC) provides largely cross-cutting registry, access, and analysis standards and tools

Heliophysics Digital Resources Library (HDRL) Architecture

→ Data
→ Metadata

Mission Operations



Introduction to SPDF

- SPDF is the active and final archive of **in-situ data** from NASA heliophysics missions, including collaborative missions with other US and foreign agencies, to facilitate scientific analysis of multi-instrument and multi-mission datasets and enhance the science return of the many missions
- We also archive other data **relevant to NASA heliophysics science objectives**
 - Related data from planetary missions (e.g., MESSENGER, MAVEN, New Horizons)
 - Heliophysics data from some NOAA and DoD satellites (e.g., GOES, DISCOVER)
 - Ground-based magnetometers, aurora cameras, radars, etc., which are funded by NSF or other agencies/programs
- The data covers the space from the Sun to the local interstellar medium, including magnetosphere, ionosphere, thermosphere, and mesosphere (M-ITM) of the Earth and other applicable planets
- SPDF provides three main science-enabling services besides archiving data
 - CDAWeb (Coordinated Data Analysis Web): browse, correlate, and display
 - SSCWeb (Satellite Situation Center): orbit/ground track displays and queries
 - OMNIWeb and COHOWeb for near-Earth and deep-space solar wind plasma, magnetic field, and energetic particle database, respectively
- SPDF enables multi-instrument, multi-mission heliophysics science
 - Specific mission/instrument data in context of other missions/data
 - Specific mission/instrument data as enriching context for other data
 - Ancillary services & software (orbits, data standards, special products)
- SPDF also builds critical infrastructures for the **heliophysics data environment**:
 - Common Data Format (CDF) self-describing science file format <<https://cdf.gsfc.nasa.gov>>
 - Heliophysics Data Portal <<https://heliophysicsdata.gsfc.nasa.gov>> discipline-wide data inventory and access service
 - ISTP Metadata Guidelines
- SPDF is currently receiving and serving data from missions including Parker Solar Probe, Solar Orbiter, MMS, Van Allen Probes, THEMIS/ARTEMIS, GOLD, ICON, ACE, Cluster, IBEX, Voyager, Geotail, Wind and many others, and >120 Ground-Based investigations.

Over 132 Missions Supported by SPDF

* Only orbit data available

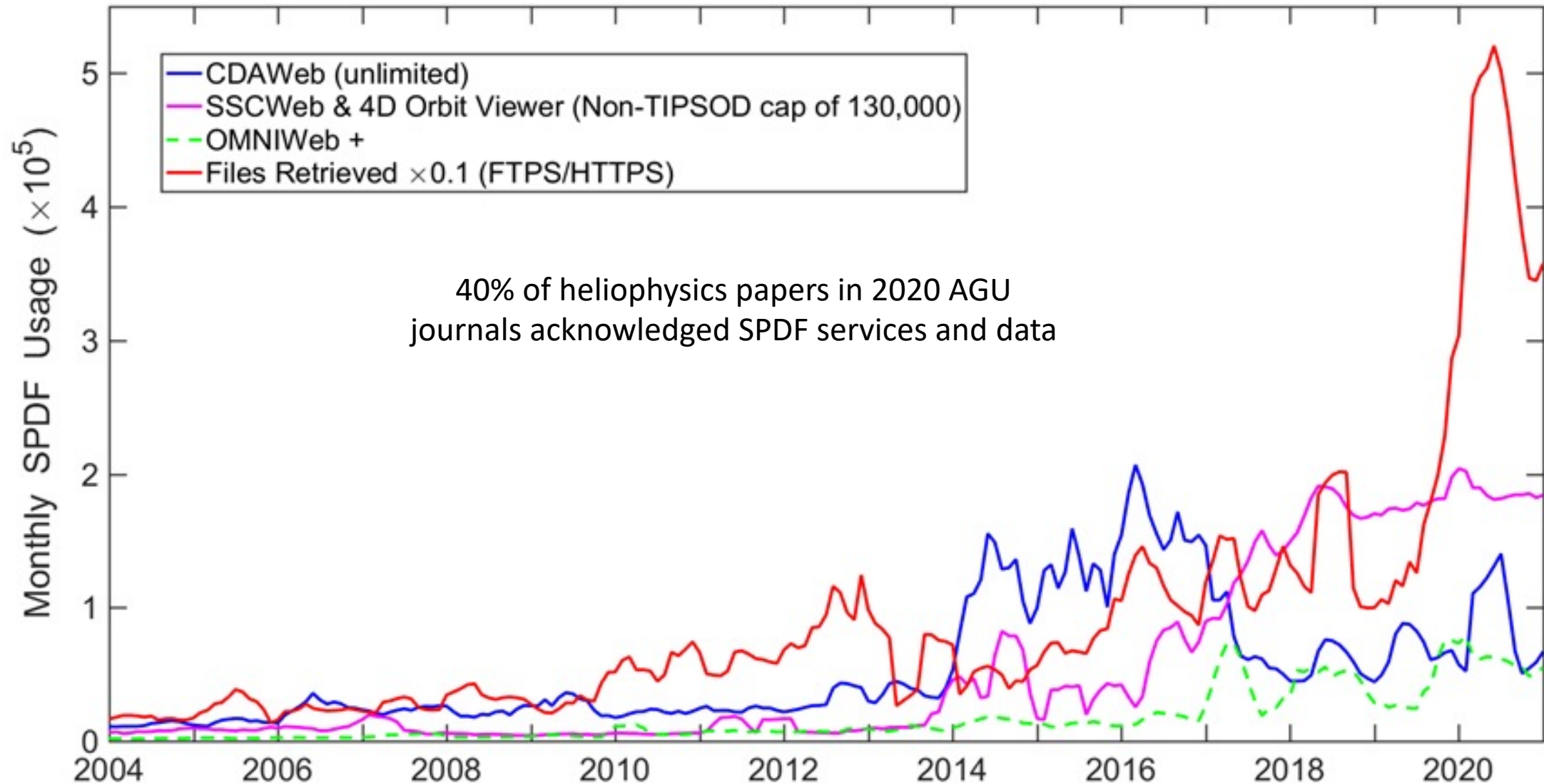
ACE		Cassiope		GOES		LUNA		Pioneer		STEREO	
Active*		Cluster		GOLD		Magsat		Pioneer 10		Suisei	
Aeros		Cosmos 900		GMS 3		MAP		Pioneer 11		Swarm	
AIM		C-NOFS		Granat		Mariner 10		Pioneer Venus		Tatiana	
Akebono*		CRRES		Hawkeye		Mars		Polar		THEMIS	
Alouette1		CSSWE		Helios		MAVEN		Prognoz		TIMED	
Alouette2		Dawn*		Hinode		MESSENGER		Reimei		TRACE	
AMPTE		DEMETER*		Hinotori		Microlab 1		Rosetta*		TWINS	
APEX-MAIN*		DMSP		IMAGE		Mir*		RHESSI		UARS*	
Apollo		Double Star*		IMP 7		MMS		ROC SAT-1		Ulysses	
Aqua		DSCOVR		IMP 8		MRO		SAMPEX		Van Allen Probes	
Ariel-4		DE		IMP_early		MSL		Sakigake*		Vega	
Arase (ERG)		Equator-S		Interball		MSX*		San Marco		Venera	
ARCAD		Explorer		ISEE		Munin		SCATHA*		Viking	
ARTEMIS		FAST		ISEE 3-ICE		New Horizons		SDO		Voyager	
ASTRID II*		FIREBIRD*		ISIS		NOAA*		SMILE		Voyager 1	
AE		Freja*		ISS		Oersted		SNOE		Voyager 2	
Aura		Galileo*		Jason 2		OGO		SOHO		Wind	
Aureol2		GCOM W1		Juno		Ohzora		SORCE		XMM-Newton	
BARREL		Genesis		Kepler		PARASOL		Spartan-A		Yohkoh*	
CALIPSO		Geotail		LANL		Parker Solar Probe		Spitzer		Zond	
Cassini*		Giotto*		LRO		Phobos		Sputnik 1			

Total: ~10,000 datasets, ~350 TB data

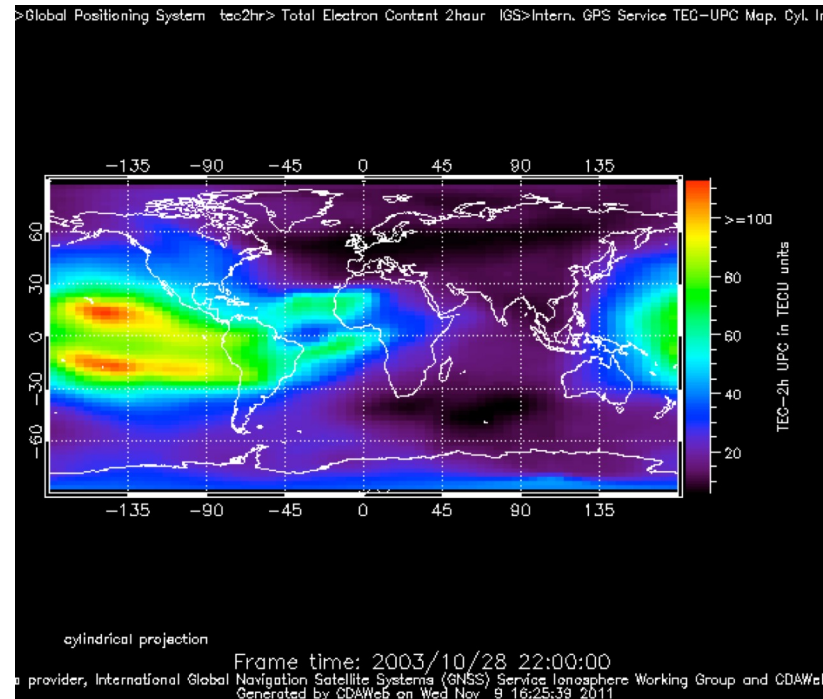
Recent average monthly data ingestion rate: ~0.6 million data files, ~13.7 TB data

SPDF Statistics

(see reports at <<https://cdaweb.gsfc.nasa.gov/publiclogs/>>)

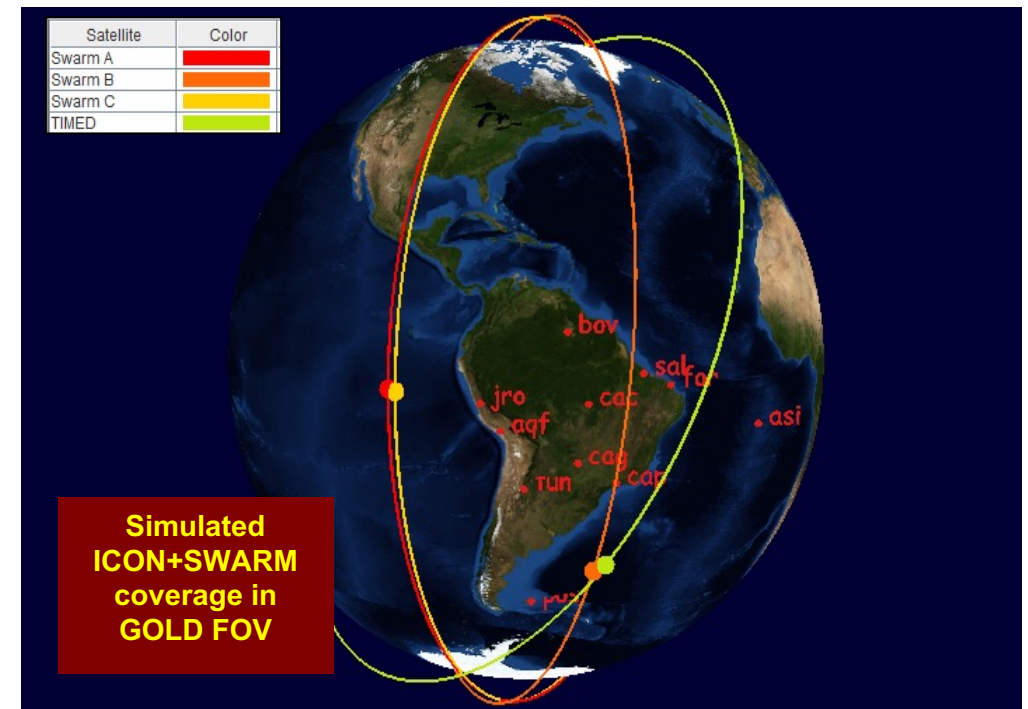
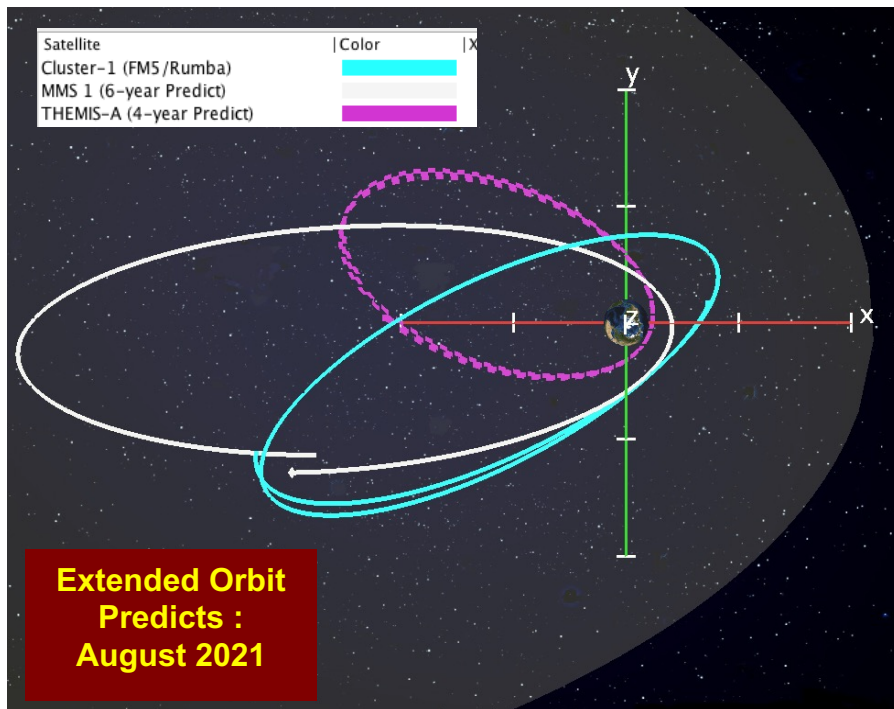


GPS International GNSS Service Total Electron Content

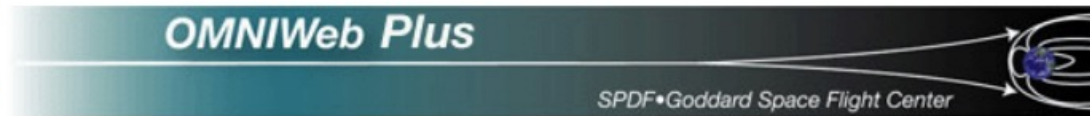


Satellite Situation Center (SSCWeb)

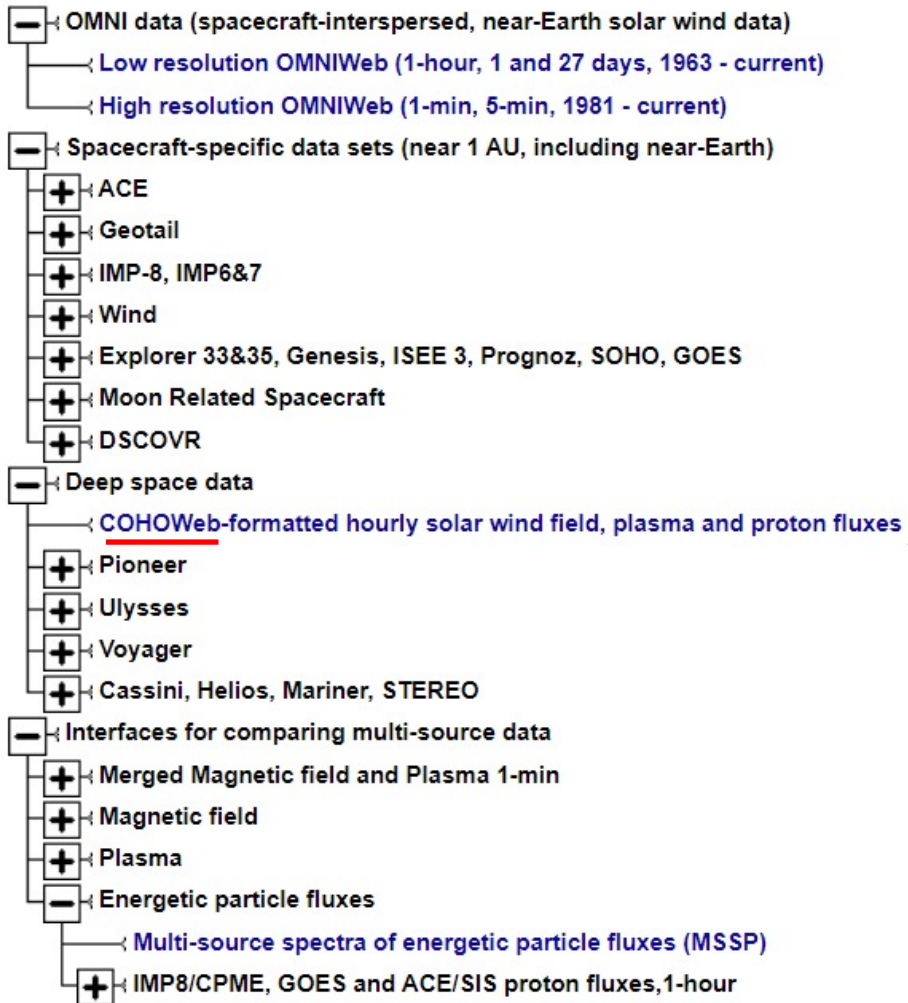
- Include most heliospheric satellites and many ground stations
- Plot and list orbits of multiple spacecraft in a variety of coordinate systems
- **4D Orbit Viewer:** Interactive 4D animation of orbits
- Query for satellite-satellite and satellite-ground station conjunction



- OMNIWeb Plus, Home
+ ABOUT THE DATA
+ABOUT THE INTERFACE
+Data from command line
+ SPDF/FTP
+ Citing OMNI data usage
DATA via FTPBrowser
Energetic Particle fluxes
ATMOWeb main page
CGM transformation



Paths to Magnetic field, Plasma, Energetic particle data relevant to heliospheric studies and resident at Goddard's Space Physics Data Facility.



[Heliocentric Trajectories for Selected Spacecraft, Planets, and Comets](#)

OMNIWeb Plus

- OMNI Data: Database of solar wind magnetic field and plasma parameters mapped to the nose of the Earth's bow shock
- Based on a large volume of quality-controlled satellite measurements (since Nov. 1963)
- **COHOWeb**: Solar wind field, plasma, and proton fluxes in other locations of heliosphere, especially useful for planetary studies and heliospheric model validation
- Interface for plotting, filtering, and downloading the data

Space Physics Data Facility (SPDF)

<https://spdf.gsfc.nasa.gov>

<https://spdf.gsfc.nasa.gov/pub/documents/SPDF/presentations/>

SPDF provides multiple services and access methods

- Direct file downloads via FTPS and HTTPS <<https://spdf.gsfc.nasa.gov/pub/data/>>
- Orbit and ground track displays/queries via SSCWeb and 4D Orbit Viewer
- CDAWeb services:
 - Data files, plots and listings with supersets or subsets by time & selected variables, time-binning
 - Web service interfaces (REST, SOAP, IDL, Matlab, Java, Python) <<https://cdaweb.gsfc.nasa.gov/WebServices/>>
 - New HAPI (Heliophysics API) <<https://cdaweb.gsfc.nasa.gov/hapi/>>
 - Autoplot autoplot.org/help#CDAWeb
 - Other methods such as IDL <https://cdaweb.gsfc.nasa.gov/alternative_access_methods.html>
- SPDF complements the services of the mission and instrument teams
- SPDF auto-ingest scripts check all supported mission data sites daily to retrieve new data files, and CDF files are validated and ingested
- Master CDFs add or improve metadata for use in CDAWeb
- The **SPASE** (Space Physics Archive Search and Extract <<http://www.spase-group.org/>>) team use the master CDFs to generate SPASE IDs and descriptions for all datasets, to add entries to the **Heliophysics Data Portal** <<https://heliophysicsdata.gsfc.nasa.gov>> and mint DOIs for each dataset

SPDF activities in past year

- Added many new datasets from ICON, GOLD, Parker Solar Probe (87), IBEX (40), Solar Orbiter (81), MMS (16), BARREL (219), FAST, Voyager PWS waveform, and many other spacecraft, rocket, balloon, and ground instruments
- Final data from Van Allen Probes (RBSP), with most datasets entirely reprocessed
- Automated ingest pipeline for > 75 missions out of over 200 missions for a total of ~4,000 datasets using ~400 TB (ingest and usage logs: <https://cdaweb.gsfc.nasa.gov/publiclogs/>)
- Creating CDFs from SOHO in-situ data and finishing making CDFs for IBEX data and Wind STICS
- Continue population of OMNI, COHO, SSC databases
- CDAWeb plot and display improvements, waveforms, inventory plots, time slices, audification
- Adding SPASE Resource IDs and DOIs to CDAWeb metadata and displays
- Working towards a grand vision as part of NASA's Heliophysics Digital Resource Library, including 6 new curation scientists (part-time)

CDF Plans

- High-level functions to read variables or whole CDF into a map structure for IDL, Java, Perl and C#
- CDF-JSON converter
- Improve Windows installer, autoconf/make build/install, Mave/Ant/Gradle installs
- Improve documentation, beginner's guides, add to Wikipedia CDF entry
- Standardize ISTP/IACG Metadata Guidelines with version control, etc.
- New SKTeditor in Javascript or Python, perhaps also SPASE metadata creation
- Look into supporting CDFs in cloud object storage, perhaps Zarr like netCDF is exploring
- Define CDF MIME type and international standard
- Apache 2 license in place of current custom license
- Update CDFML and its corresponding JSON representation with cdf.xsd use more specific datatype (e.g., xs:dateTime, xs:integer, xs:float, etc.) instead of just xs:string

Abstract

In order to improve access to the data and models of the Heliophysics System Observatory (HSO) and NASA-funded research projects, the NASA Heliophysics archive and modeling groups are collaborating to create a Heliophysics Digital Resources Library (HDRL) for improved cross-mission and observation-model comparison, machine learning and other large-scale and collaborative analysis, increased discoverability and usability of data and model results, software and services, and more complete metadata and provenance and quality control. Observational data are archived and served by the Solar Data Analysis Center (SDAC) and the Space Physics Data Facility (SPDF). The Community Coordinated Modeling Center (CCMC) provides empirical and first-principles simulations and analysis and display tools. A number of largely cross-cutting registry, access, and analysis standards and tools are provided by the Heliophysics Data and Model Consortium (HDMC).

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Plain-Language Summary:

Working in cooperation with current operating missions and the Heliophysics community, Space Physics Data Facility (SPDF <https://spdf.gsfc.nasa.gov>), as one of the NASA Heliophysics active final archives, preserves and distributes in-situ data. SPDF ingests, preserves and serves a wide range of past and current public science-quality data from the mesosphere into the furthest reach of deep-space exploration from a wide variety of Heliophysics missions. SPDF is collaborating with the other NASA Heliophysics archive and modeling groups to create a Heliophysics Digital Resources Library (HDRL) for improved cross-mission and model comparison, machine learning and other large-scale and collaborative analysis, increased discoverability and usability of observation data and model results, software and services, and more complete metadata and provenance and quality control.