An Overview of the Space Physics Data Facility (SPDF) in the Context of "Big Data"

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Topics

- As an active Final Archive, what is SPDF?
  - Scope, Responsibilities and Major Elements
- Current Data
- Future Plans and BDTF Questions

REFERENCE URL: http://spdf.gsfc.nasa.gov

SPDF in the Heliophysics Science Data Management Policy

- **One of two (active) Final Archives in Heliophysics**
  - Ensure the long-term preservation and ongoing (online) access to NASA heliophysics science data
    - Serve and preserve data with metadata / software
    - Understand past / present / future mission data status
    - NSSDC is continuing limited recovery of older but useful legacy data from media
  - Data served via FTP/HTTP, via user web i/f, via webservices
  - SPDF focus is non-solar missions and data
- **Heliophysics Data Environment (HpDE) critical infrastructure**
  - Heliophysics-wide dataset inventory (VSPO->HDP)
  - APIs (e.g. webservices) into SPDF system capabilities and data
- **Center of Excellence for science-enabling data standards and for science-enabling data services**

SPDF Services

- **Emphasis on multi-instrument, multi-mission science**
  (1) Specific mission/instrument data **in context** of other missions/data
  (2) Specific mission/instrument data **as enriching context** for other data
  (3) Ancillary services & software (orbits, data standards, special products)

- **Specific services include**
  - Heliophysics Data Portal (heliophysics-wide "find data" and services")
  - CDAWeb (multi-mission data browsing and correlative analysis)
    - Now: Wind, ACE, THEMIS, STEREO, VAP, MMS, many ground stations
    - Coming: ICON, GOLD, SPP (in-situ)
  - SSCWeb & 4D Orbit Viewer (satellite orbits and ground tracks)
  - OMNIweb Plus (solar wind parameters mapped to nose of bow shock)
  - CDF (Common Data Format) plus structure/metadata guidelines
    - Self-describing data format, scalar and multidimensional data, platform- and discipline-independent, common model with netCDF
    - Implementation guidelines for organization, naming, metadata
    - Use of "master" CDFs to update/add metadata and capabilities

CDAWeb Interface

- **Select one OR more Sources** (default = All unless no Instrument Types selected)
- **AND Select one OR more Instrument Types** (default = All unless no Sources selected)

Sources:
- ACE
- ARTEMIS
- BARREL
- CNOFS
- CRRES
- Cluster
- Cubesats
- DMSP
- Equator-S
- FAST
- GOES
- GPS
- Genesis
- Geotail
- Helios
- IMAGE
- IMP (All)
- ISS
- Interball
- LANL
- MESSENGER
- MMS
- NOAA
- OMNI (Combined 1AU IP Data; Magnetic and Solar Indices)
- POES/MetOp
- Pioneer
- Polar
- ROCSAT-1(FORMOSAT-1)/IPEI
- SAMPEX
- SNOE
- SOHO
- ST5
- STEREO
- THEMIS
- TIMED
- TWINS
- Ulysses
- Van Allen Probes (RBSP)
- Voyager
- Wind
- Ground-Based Investigations

Instrument Types:
- Activity Indices
- Electric Fields (space)
- Electron Precipitation Bremsstrahlung
- Engineering
- Ephemeris
- Ephemeris/Attitude/Ancillary
- Gamma and X-Rays
- Housekeeping
- Imaging and Remote Sensing (ITM/Earth)
- Imaging and Remote Sensing (Magnetosphere/Earth)
- Imaging and Remote Sensing (Sun)
- Magnetic Fields (Balloon)
- Magnetic Fields (space)
- Particles (space)
- Plasma and Solar Wind
- Radio and Plasma Waves (space)
- Spacecraft Potential Control
- Ground-Based HF-Radars
- Ground-Based Imagers
- Ground-Based Magnetometers, Riometers, Sounders
- Ground-Based VLF/ELF/ULF, Photometers

Missions and Instrument Types

CDAWeb Data Explorer

Select start and stop times from which to GET or PLOT data:

Use pre-defined start/stop times: September 2005 Events 2005/09/07 00:00:00 2005/09/20 00:00:00

Use custom start/stop times

Start: 2012/10/02 00:00:00 (YYYY/MM/DD HH:MM:SS.mmm)

Stop: 2012/10/03 00:00:00 (YYYY/MM/DD HH:MM:SS.mmm)

Select an activity:

Plot Data : *select one or more variables from list below and press submit.*
- Also create PS and PDF outputs (all plot types except images and plasmagrams).
- Many panels per dataset are allowed but <=4 panels optimal for standard Y-axis height and single page display. NEW

List Data (ASCII): *select one or more variables from list below and press submit. (Works best for <31 days)*

Download original CDFs : *press submit button to retrieve list of files. (Max. 200 days - use FTP site for larger requests)*

Create V3.4 CDFs for download or VIRBO Autoplot demonstration: *select one or more variables from the list below and press submit.*
- Create Version 2.7.2 compatible CDFs (Default is Version 3.4)

Note: CDF patch required for reading Version 3.4 CDFs in IDL or MATLAB.
Get CDFX - IDL GUI plotting/listing toolkit software. To be used with either the daily or "created" CDF files available above.

Plotting Options

- **Use coarse noise filtering** to remove values outside 3 deviations from mean of all values in the plotted time interval.
- **Double the Y-axis height** for time-series and spectrogram plots.
- **Combine all time-series and spectrogram plots**, for all requested datasets, into one plot file.

NEW **Pressing the "Submit" button will spawn a new window/tab in order to support the new "Previous" and "Next" functions.**

Submit Reset

Variable parameters (required for Listing, Creating and Plotting data only)

G10_L2_MAG

GOES-10 High Resolution Magnetometer data vectors (at 512 ms, ephem at 60 sec) - Howard J. Singer (NOAA Space Weather Prediction Center)

Available dates: 2007/01/01 00:00:00 - 2008/12/31 23:59:59
(Continuous coverage not guaranteed - check the inventory graph for coverage)

- Satellite geographic west longitude at noon UTC
- Magnetic local time at satellite position
- Satellite position (GEI)
- Satellite position (GSM)
- Satellite velocity (GEI)
- Satellite velocity (GSM)
- Unit vector in GEI perp to orbital plane (parallel to Earth's spin axis for 0 inclination orbit)
- Magnetic field in LH-ENP (P=northward Perp to orbital plane, E=Earthward perp to P and Earth center, N=eastward/LH Normal to P and E)
- Magnetic field in GEI
- Magnetic field in GSM
- Total magnetic field strength
- T1 magnetotorquer filtered counts
- T2 magnetotorquer filtered counts
- Data quality flag (7=good)

[GOES 8-12 draft magnetometer README file THEMIS web server]
[GOES magnetometer data THEMIS web server]
[GOES general information NOAA Space Weather Prediction Center]
[VMO product description for GOES10 512ms magnetometer data]

G11_L2_MAG

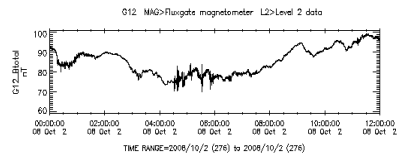
GOES-11 High Resolution Magnetometer data vectors (at 512 ms, ephem at 60 sec) - Howard J. Singer (NOAA Space Weather Prediction Center)

Available dates: 2007/01/01 00:00:00 - 2008/12/31 23:59:59
(Continuous coverage not guaranteed - check the inventory graph for coverage)

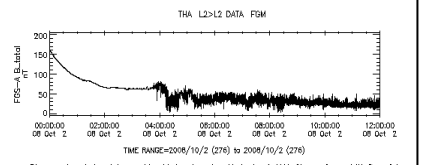
- Satellite geographic west longitude at noon UTC
- Magnetic local time at satellite position
- Satellite position (GEI)
- Satellite position (GSM)
- Satellite velocity (GEI)
- Satellite velocity (GSM)

Variables

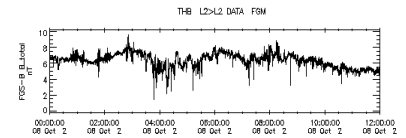
G12_L2_MAG



THA_L2_FGM



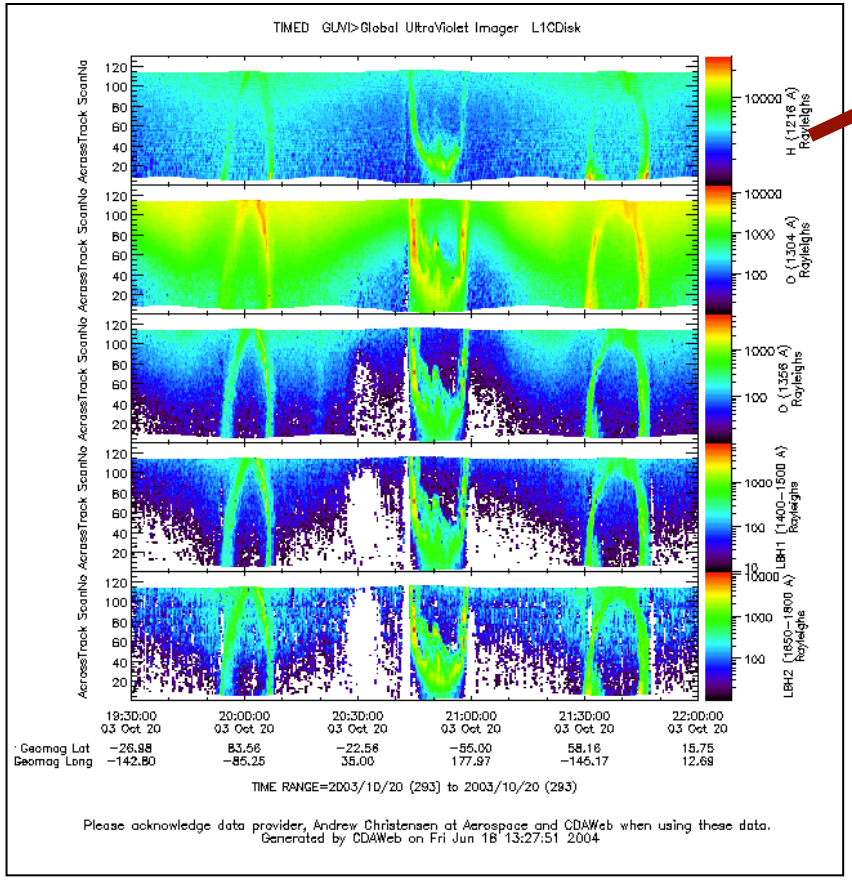
THB_L2_FGM



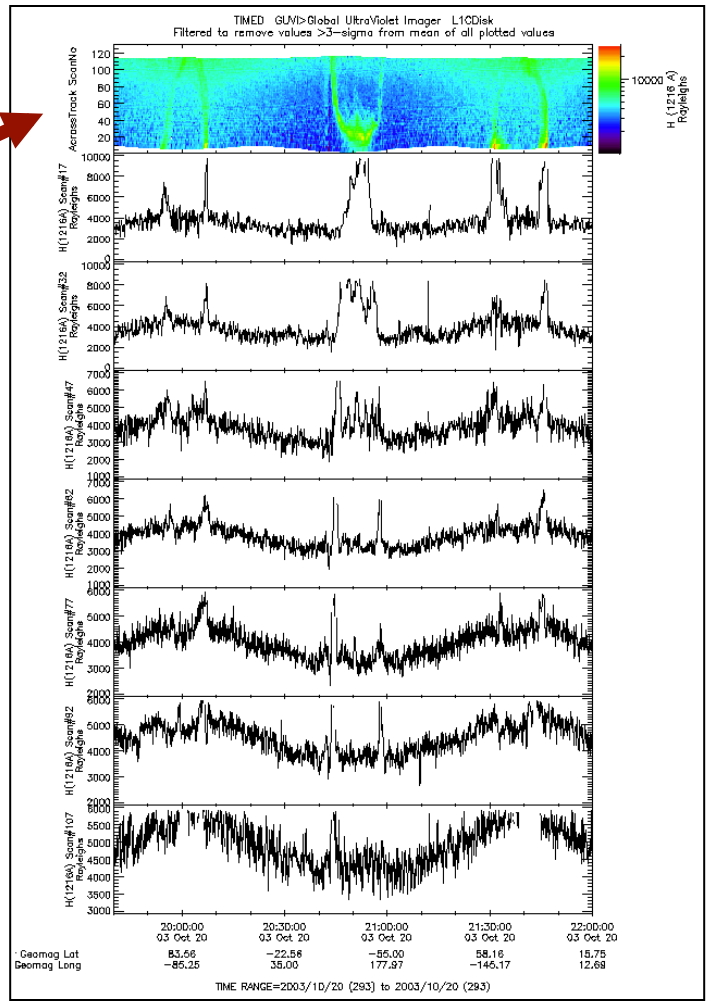
Sample Plots of GOES and THEMIS data

- Also ASCII and CDF downloads, with super/ subsets
- **All these services are also available through RESTful webservices API**

TIMED GUVI Data on CDAWeb

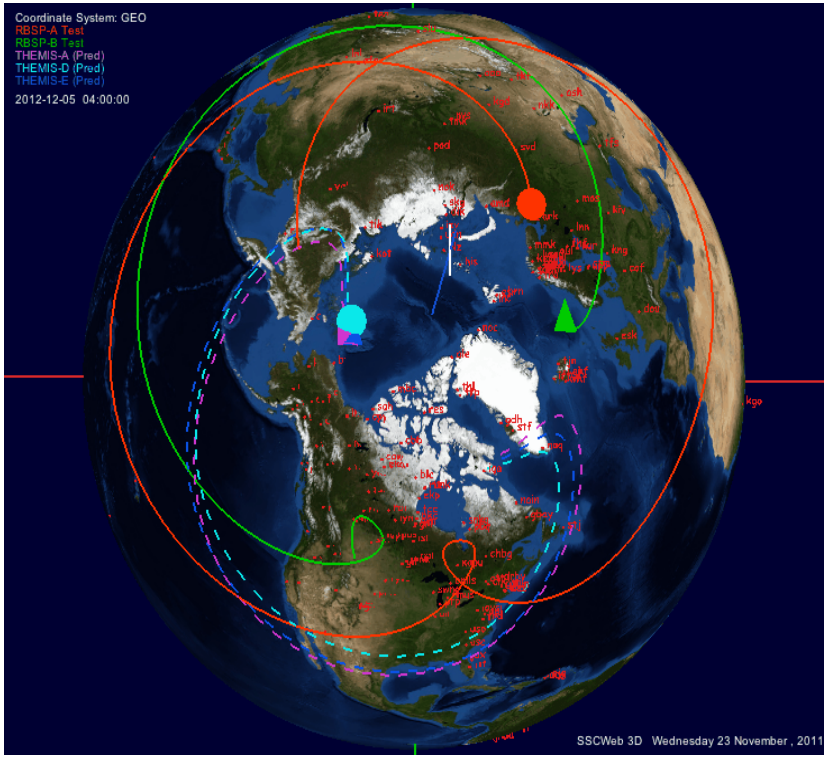


GUVI 1356 A intensities for Oct 20, 2003 19:30-22:00. Along track intensities for all five wavelength bands.

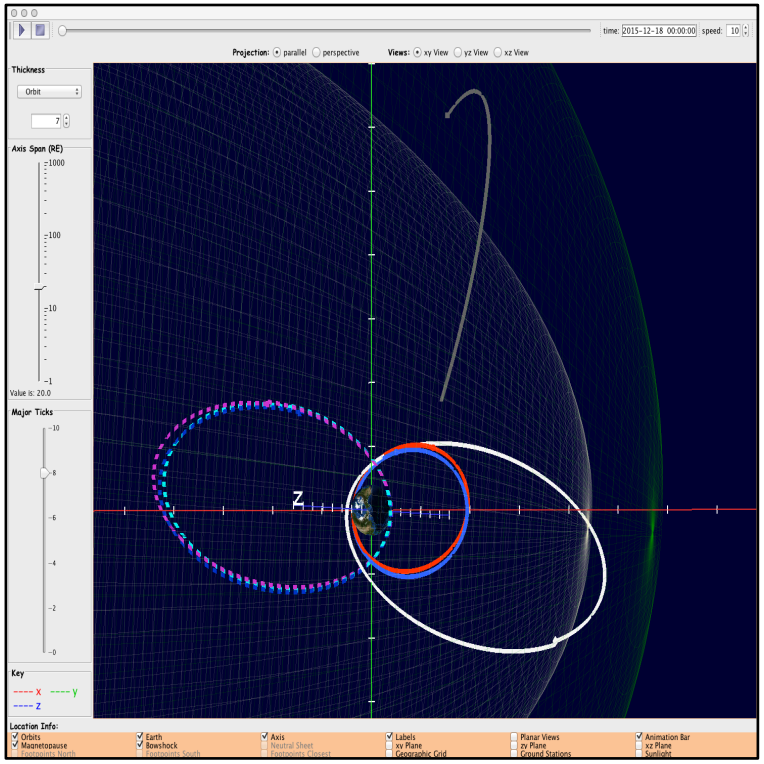


GUVI 1356 A intensities for Oct 20, 2003 19:30-22:00. Along track intensities at 7 across-track positions.

SSCWeb & 4-D Orbit Viewer



RBSP and THEMIS
Northern Hemisphere
Animated Ground Tracks
in December 2012

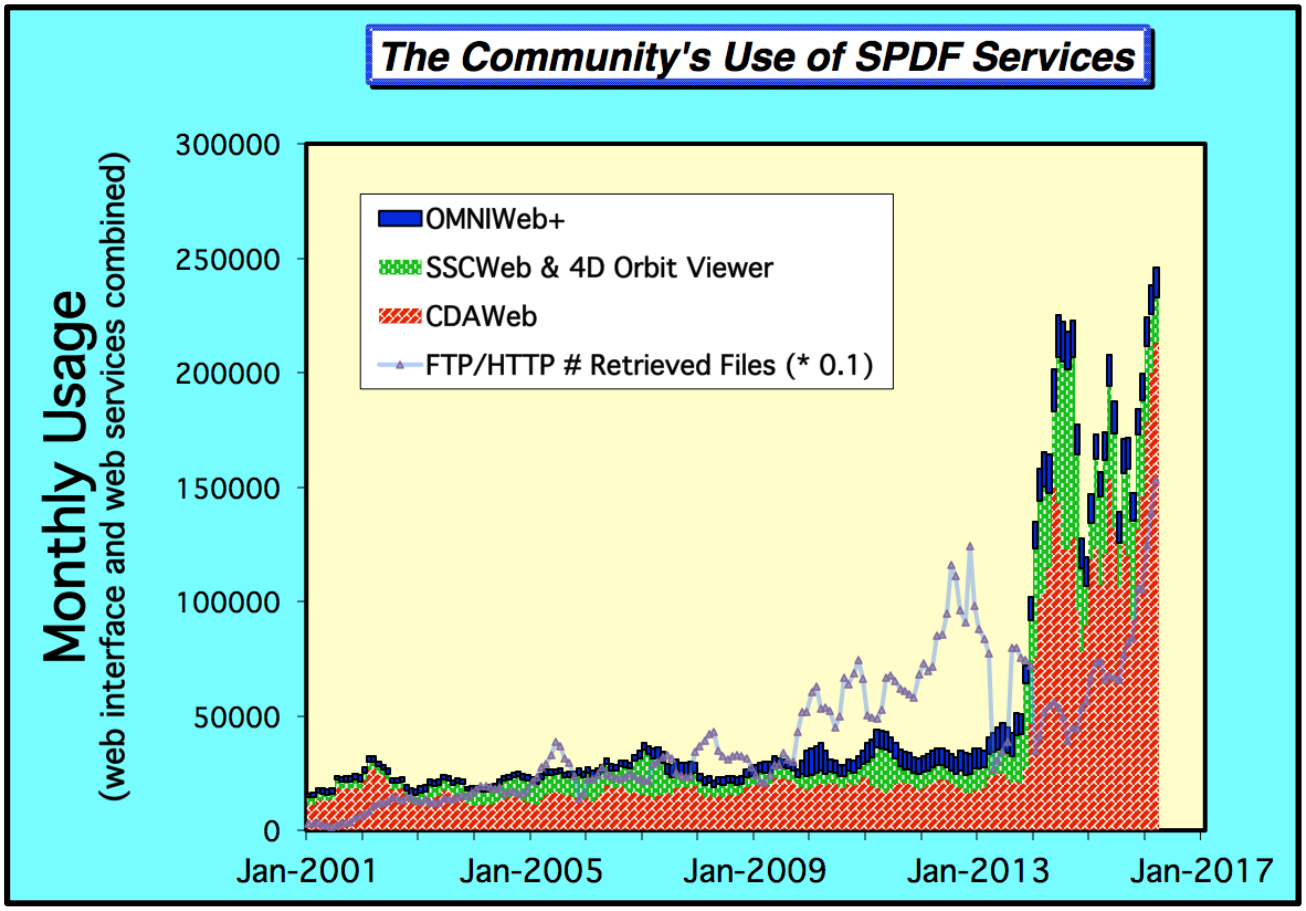


MMS, Van Allen Probes,
Cluster and Geotial orbits
December 12, 2015

FY16 Mission and Data Highlights

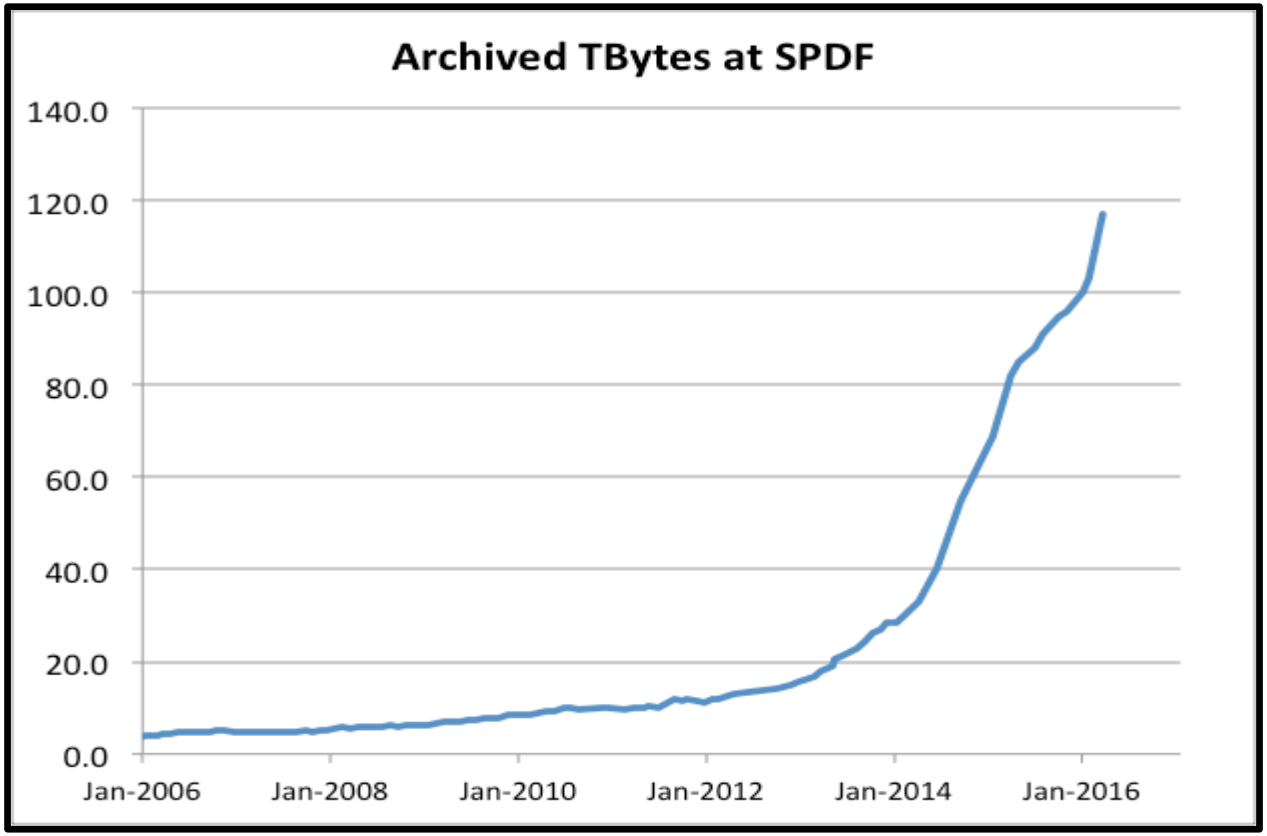
- **Ingest/serve data from operating heliophysics missions**
  - Now serving publicly released MMS L2 CDF data (50x4) and QL plots
  - Continuing to add Van Allen Probes L3 datasets (plus ongoing data flows)
  - Continuing archival data captures from AIM and TIMED (netCDFs)
  - New datasets from active missions, including e.g. Geotail CPI and EPIC
- **Other ongoing acquisition**
  - Past missions: E.g. Polar VIS, IMAGE, FAST, Tether
  - Other missions (NASA heliophysics relevant):
    - GOES/POES particles-magnetic field (w NOAA)
    - DMSP SSUSI (w APL), SSJ (w NOAA), SSM (w U. Colorado)
  - Orbit information for SSCWeb database
- **Ingesting and serving older data as available from NSSDC**
  - Unpacking and organizing, limited improved metadata
- **Regular interactions and planning with upcoming missions**
  - Presented at several GOLD team meetings; telecons with ICON
  - Regular participation in the SPP and SPP SOC meetings
- **Software and System to support ingests, new data, new capabilities**
  - Note CDF s/w and CDAWlib IDL library are open source

SPDF Data & Services are Used



~33% of 2015 papers in AGU's JGR Space Physics acknowledged SPDF services and/or data (acknowledgments were ~ 20-25% in 2009-2014)

SPDF Data Holdings by Volume



Dominant 2016 data ingests are MMS and Van Allen Probes

- GOLD data rate starting in 2018 will be comparable to MMS
- 1st Quarter 2016 data downloads ~20 Tbytes/~1.4M files per month

Missions Supported in SPDF

ACE
AE
Alouette 1/2
AMPTE
Apollo
Arcad
Ariel
ATS 1-6
BARREL Balloons
Cluster
CNOFS
CRRES
DE 1/2
DMSP
Explorer 4-35
FAST
Genesis
Geotail

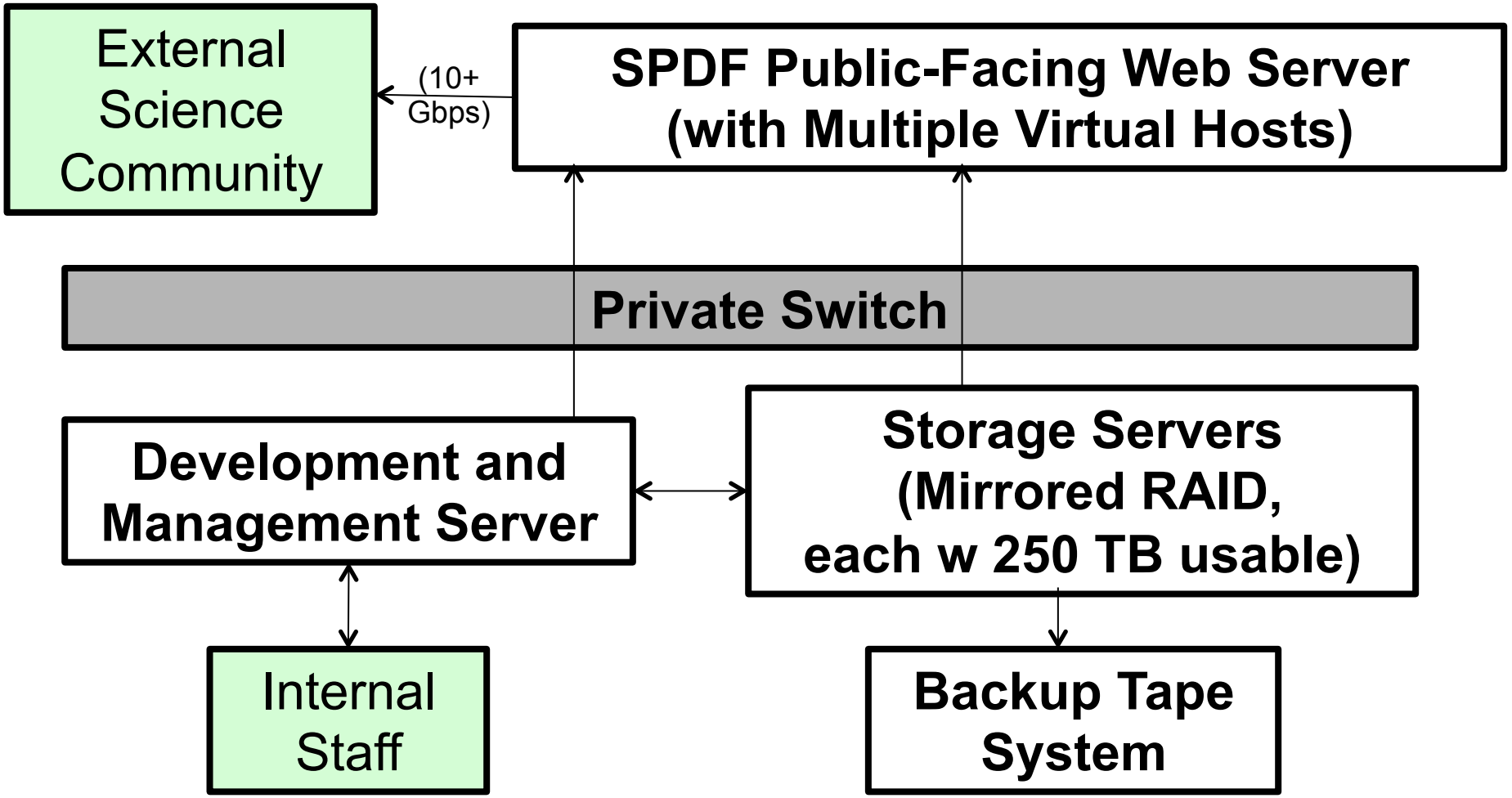
GOES 6-15
GPS
~120 Ground-Based Obs
Hawkeye
Helios 1/2
IBEX
IMAGE
IMP 1-8
INJUN
Interball
ISEE 1/2/3/ICE
ISIS1/2
LANL 1989-2002
MAGSAT
Mariner 4-9
Messenger
MMS
NOAA 5-19

OGO 1-6
Pioneer 6-11
Polar
ROCSAT
S-Cubed
SAMPEX
San Marco
Skylab
SNOE
STEREO
THEMIS/ARTEMIS
TIMED
TWINS
Ulysses
Van Allen Probes (RBSP)
Voyager 1/2
Wind

The Complexity / Heterogeneity Dimension

- **Missions and data cover a wide scope of science problems and measurement techniques**
  - In-situ and remote sensing
  - Interplanetary to interstellar space,
  - Earth's magnetosphere
- **>1400 individual datasets and ~30M files**
  - With >25,000 individual parameters (just for the data now in CDF)
- **Mission/community acceptance of data standards is key**
  - Support standards with s/w and guidelines to enable serving data
  - Work with the missions in using these standards
  - Serving the data as an inherent value to the missions
  - Immediate capture of mission data best ensures long-term preservation and quality control by the community

SPDF Technical Architecture



A Status and Planning Summary

- **SPDF is a team effort**
  - Local SPDF scientists, software professionals and support staff
  - And … our mission data provider and research user communities
- **SPDF will be able to manage currently expected data volumes**
  - Direct work with missions and early capture of data are both very important
  - Safe copies of data are stored remotely from Goddard
  - SPDF has developed format converters e.g. CDF <-> netCDF
- **SPDF supports the wider Heliophysics Data Environment**
  - Standards + services + data available by webservices
  - Supporting infrastructure for analysis s/w such as Autoplot and SPEDAS
- **SPDF will consider cloud for next major storage increment**
  - e.g. single string our RAID storage and maintain second copy in a cloud

A Few Challenges and Other Notes

- **Technology continues to move rapidly**
  - H/W capabilities but also changing S/W development environment
    - What's the future of IDL? What's the future of Java?
    - Are there better stable options for long-term future development?
- **How should cloud technology support a long-term archive**
  - Need local copies for staging and to ensure preservation?
  - File organization (S3 vs. current disk directory organization)
  - Fedramp compliance can easily be a cost concern
- **Archiving**
  - Long-term approach to older data
    - All public SPDF data are kept online and accessible, even where difficult to use
  - SPDF current scope is observational data and not model outputs
  - Better to do "something"

BDTF Question #1

(1) What are the processes for planning for future (5-10 years) capabilities of your service? How and from whom do you gather input for this planning process and where does input typically come from? What new features have highest priority?

- Starting point is regular/ongoing assessment of upcoming (approved) missions for expected data volume and unique features or requirements to ingest/ preserve/serve that data
  - Very hard to go out beyond 5 years
- Regular telecons with various project, data and data services groups
- Staff attends/presents at science meetings regularly and brings back issues
- Ongoing process of technology assessment
- Periodic Senior Reviews or other program-level reviews

- Mission data and service requirements are highest priority
  - E.g. better support netCDF for the upcoming ICON & GOLD missions
  - E.g. expected GOLD data rate starting 2018 ~ same level as current MMS

BDTF Question #2

(2) What feature(s) of your service would you like to stop performing? How do you gather input for making such decisions and where does input typically come from? What is preventing you from stopping?

- All present services appear to be useful and are being used, based on usage statistics and individual user feedback
- Stopping any major capability would be discussed with HQs program management and advertised to the research community

BDTF Question #3

(3) What steps you are taking to make your data interoperable with allied data sets from other data sites in and out of NASA? How do you find allied data sets and what criteria make data sets candidates for enabling interoperability?

- Highest degree of interoperability is obtained by holding data to standards being used by other NASA heliophysics missions, i.e. holding/serving data in CDF and following the ISTP/SPDF metadata
- PDS is now accepting CDF (with a few specific extra constraints)

- First priority for ingest and preservation always goes to NASA Heliophysics mission and other NASA heliphysics data
- Other relevant data is usually brought to SPDF‘s attention by potential providers, because they like our services and want to be included
- Other NASA SMD and other non-NASA data is assessed for NASA science relevance/importance, special issues of urgency (e.g. important data at risk of loss or not easily available to public) and impact to SPDF resources, in consultation with our NASA HQs program manager