Parker Solar Probe/FIELDS Data Products

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CrossMark

The FIELDS Instrument Suite for Solar Probe Plus

Measuring the Coronal Plasma and Magnetic Field, Plasma Waves and Turbulence, and Radio Signatures of Solar Transients

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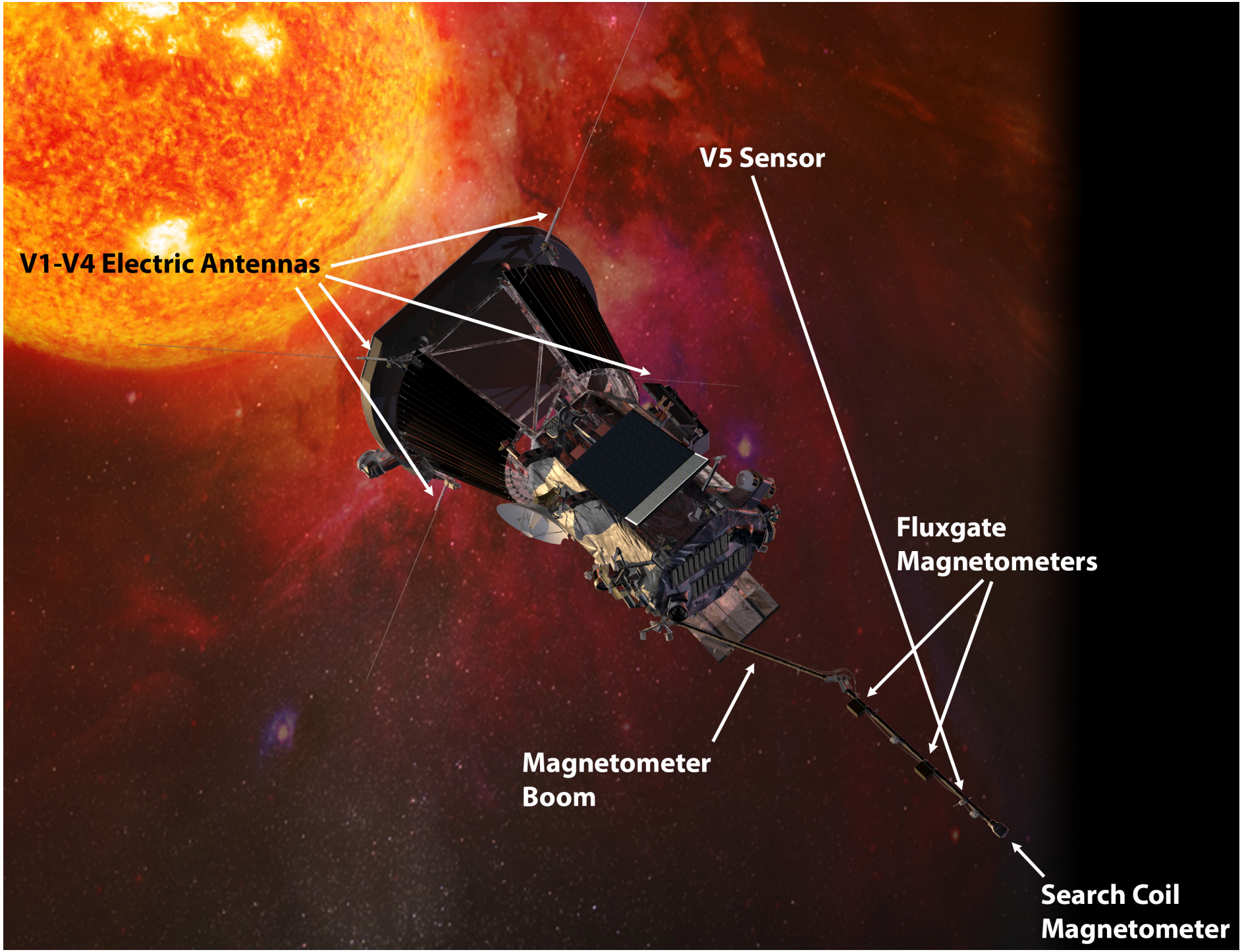
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Table 2 Expected typical values for plasma parameters and other derived quantities to be measured by FIELDS at different heliocentric distances. δB_A and δE_A are expectations for large Alfvénic fluctuations. δE_L is the expected level of wave electric field fluctuations given a scaling that assumes constant energy density

Parameters		10 R_s	55 R_s	1 AU
Magnetic Field	$\lvert B_0\rvert \sim \delta B_A$	2000 nT	70 nT	6 nT
Electric Field	$\lvert E_c\rvert \leqslant v_{sw}\delta B_A$	100 mV/m	30 mV/m	3 mV/m
Density	$n_e \sim \delta n$	7000 cm^{-3}	120 cm^{-3}	7 cm^{-3}
Electron Temperature	T_e	85 eV	25 eV	8 eV
Solar Wind Speed	v_{sw}	210 km/s	400 km/s	450 km/s
Alfvén Speed	v_A	500 km/s	125 km/s	45 km/s
Plasma Frequency	f_{pe}	750 kHz	100 kHz	24 kHz
Electron Gyrofrequency	f_{ce}	60 kHz	2 kHz	160 Hz
Proton Gyrofrequency	f_{cp}	32 Hz	1 Hz	0.1 Hz
Convected Debye Length	v_{sw}/λ_D	4 μs	8 μs	22 μs
Convected Electron Inertial Length	$v_{sw}/(c/\omega_{pe})$	0.3 ms	1.2 ms	5.5 ms
Convected Proton Inertial Length	$v_{sw}/(c/\omega_{pi})$	13 ms	50 ms	250 ms
Convected Proton Gyroscale	v_{sw}/ρ_p	3 ms	30 ms	200 ms
DC/LF Electric Fluctuations	$\delta E_A \sim v_A\delta B_A$	1 V/m	10 mV/m	1 mV/m
Kinetic Electric Fluctuations	δE_L	1 V/m	70 mV/m	10 mV/m

- SPP/FIELDS paper, recently published in a special issue of *Space Science Reviews*: “Developing the Solar Probe Plus Mission”
- http://link.springer.com/journal/11214/204/1/page/1

SPP/FIELDS Sensors



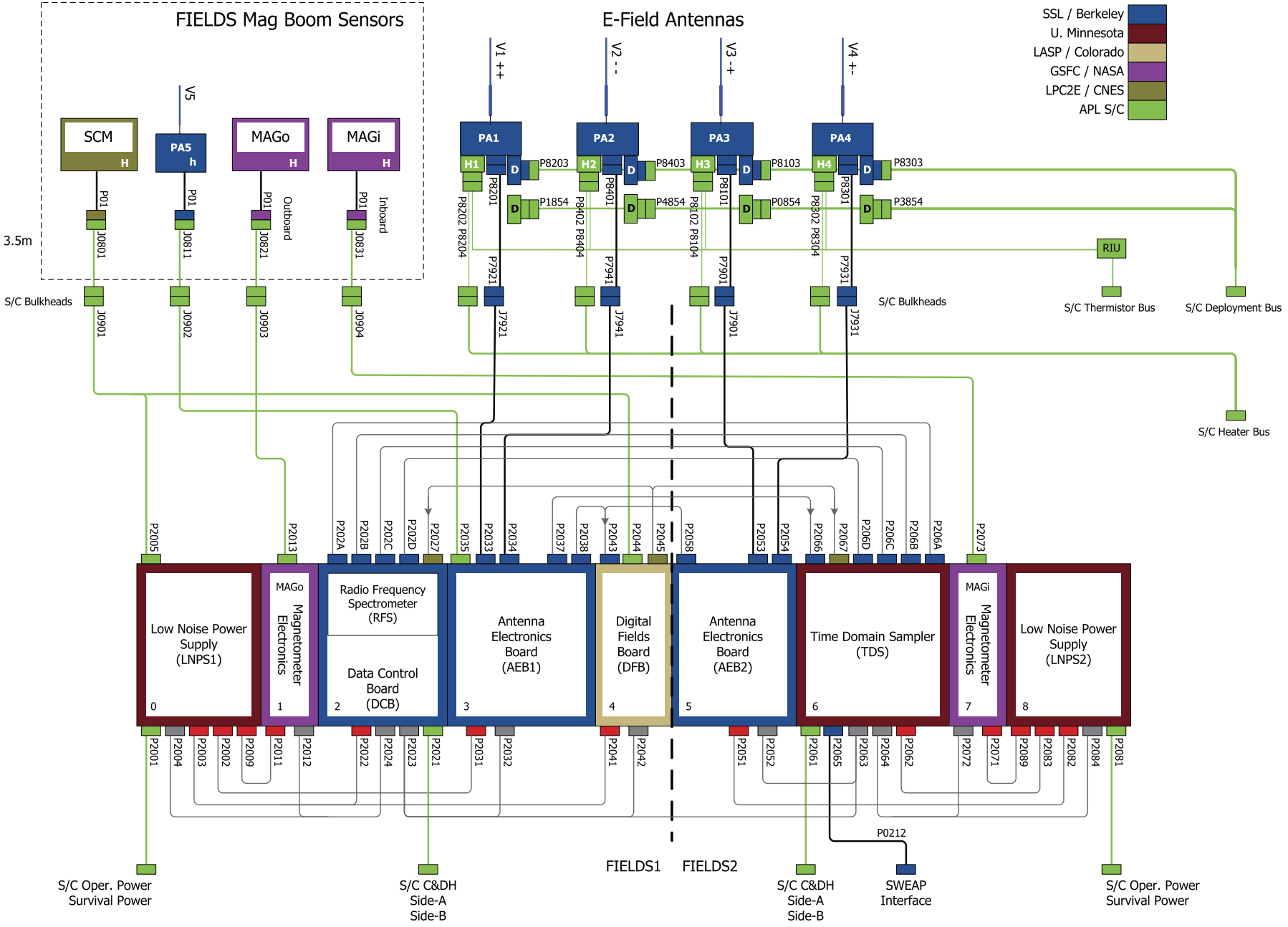
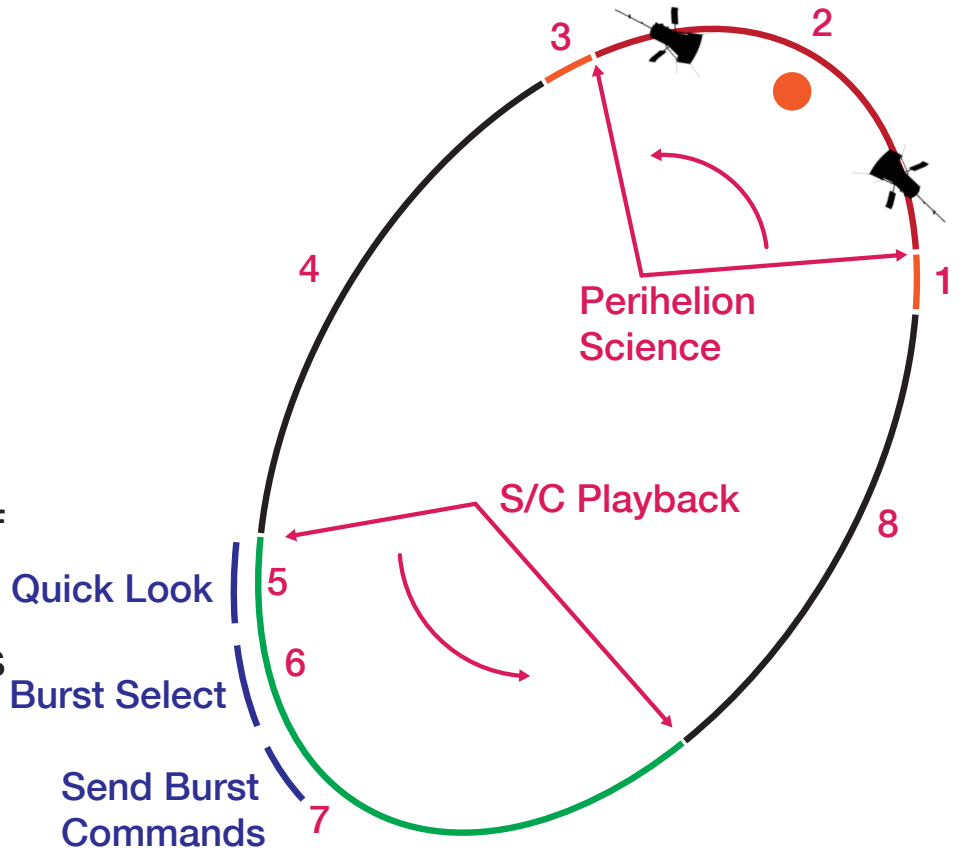


Fig. 5 The FIELDS suite block diagram. Boom-mounted sensors are diagrammed in the *upper left dotted box*; these sensors are fixed to the boom and deploy with it. The four TPS-plane electric field/voltage sensors are deployed by actuation from the spacecraft. The Main Electronics Package (MEP) at the bottom is mounted within the spacecraft body and consists of two sides—FIELDS_1 and FIELDS_2—providing some redundancy in the case of power supply or computer failure. FIELDS also has a dedicated interface to the SWEAP instrument. Color-coding indicates institutional responsibility of each hardware component

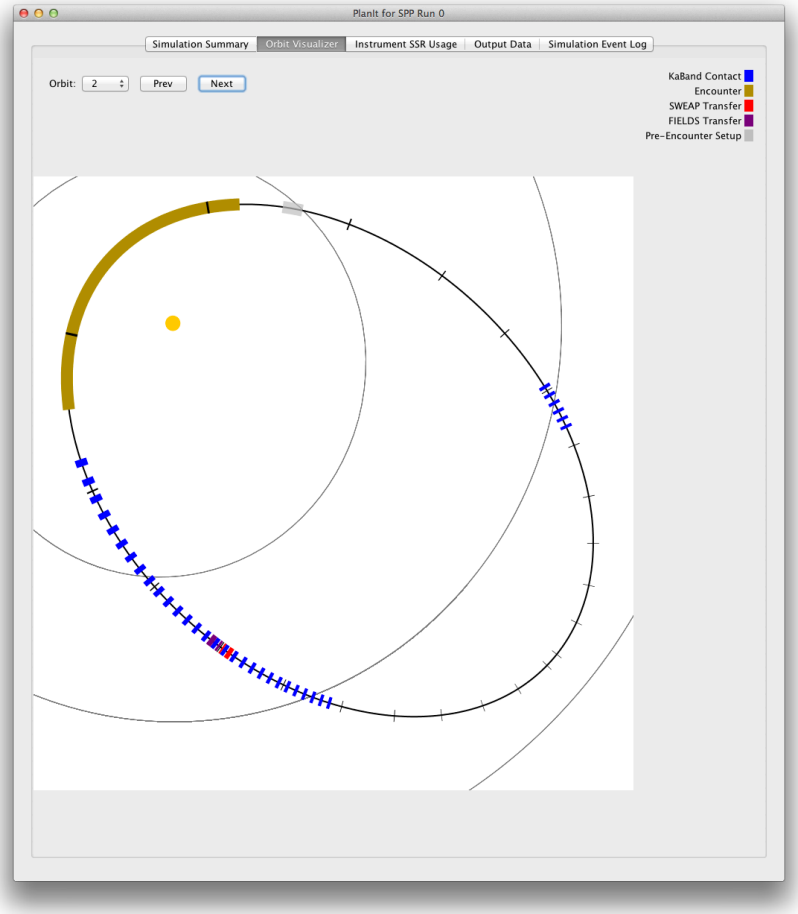
Science Planning: Orbital Operations Overview

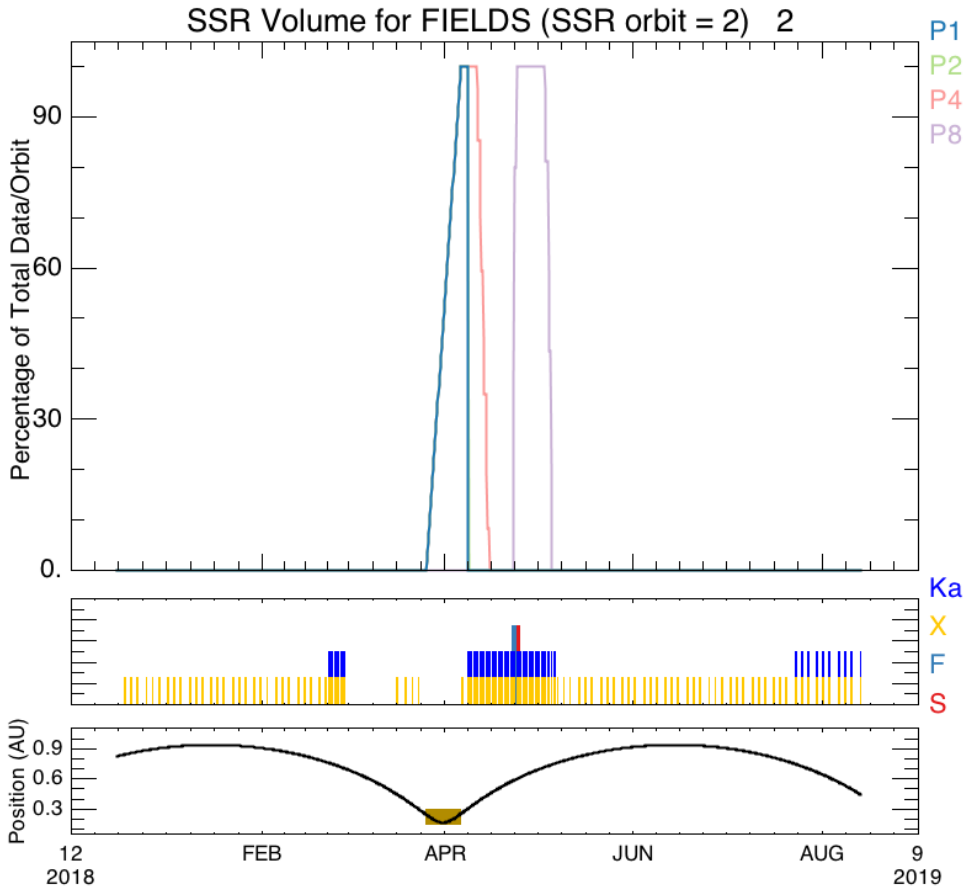
- Each encounter, the FIELDS SOC must coordinate several time sensitive activities:
  - Immediate processing of first data received/production of quick look plots
    - Requires smooth and rapid automated operation for producing useful data products
  - "Aphelion" science team meeting to select periods of interest for downlink of burst data
    - Requires appropriate facilities and tools for coordinated decision making
  - Uplink of burst playback commands and commands for next perihelion
    - Requires efficient command communication between Science and Ops teams



1. Calibration
2. High rate science
3. Calibration
4. Cruise
5. Data processing: Quick Look plots produced and distributed
6. FIELDS team convenes to select periods of interest for burst data
7. Command uplink / telemetry downlink
8. Cruise

Science Planning: Planning Tool





File Priorities

	FIELDS	SWEAP	EPI-LO	EPI-HI	WISPR	CB
Volume	20 Gb	20 Gb	13.7 Gb	4.3 Gb	25 Gb	Variable
Share CB	Yes	Yes	No	No	Yes	0-20 GB
P0	Only urgent S/C HK and urgent instrument HK					
P1	Only S/C HK					
P2	1%	1%	1%	1%	1%	
P3	1%	1%	1%	1%		
P4	50%	50%	8%	8%	6%	
P5						
P6			90%	90%	93%	
P7						
P8	48%	48%				
P9 (contingency SC HK)						

Data Types and Cadences

- FIELDS master frequency = 150 kHz * 2^8 = 38.4 MHz (set by EMC requirements)
- 38.4 MHz / 2^17 ≈ 293 samples/second = 256 samples / cycle
- Cycle sometimes called "New York Second" ≈ 0.874 sec
- Fluxgate magnetometers (MAG)
  - 3 axis measurements from inboard and outboard MAGs
  - Up to 256 samples / cycle
- Digital Fields Board (DFB): see next slide
- Time Domain Sampler (TDS):
  - 6 input signals at 1.92 MSa/s
  - Capture events organized and telemetered by quality
- Radio Frequency Spectrometer (RFS)
  - LFR (10 kHz–1.7 MHz, quasithermal noise)
  - HFR (1.3 MHz–19.2 MHz, radio bursts)
  - 2 channel auto and cross spectra with a cadence of ~1 / 8 cycles
- Housekeeping from various subsystems at ~1 sample / cycle

Data Types and Cadences (DFB)

- DFB offers a highly configurable set of time series and spectral measurements from DC to 60 kHz.
- See ***Malaspina*** et al. 2016 for details

Table 1. DFB Signals Available for Digital Signal Processing

Channel	Qualifiers	Input Range	Effective Sample Rate	Rate
V_1, V_2, V_3, V_4, V_5	DC	±115 (V)	18,750 S/s	Low rate
V_{Avg}	DC	±115 (V)	18,750 S/s	Low rate
V_1, V_2, V_3, V_4, V_5	AC	±10 (V)	150,000 S/s	High rate
V_{Avg}	AC	±10 (V)	150,000 S/s	High rate
E_{12}, E_{34}, E_z	DC, low gain	±15 (V/m)	18,750 S/s	Low rate
E_{12}, E_{34}, E_z	DC, high gain	±1.5 (V/m)	18,750 S/s	Low rate
E_{12}, E_{34}, E_z	AC	±5 (V/m)	150,000 S/s	High rate
B_x, B_y, B_z	LF, low gain	±3,000 (nT)	150,000 S/s	Low rate and high rate
B_x, B_y, B_z	LF, high gain	±200 (nT)	150,000 S/s	Low rate and high rate
B_x	MF	±6 (nT)	150,000 S/s	High rate

Table 2. DFB Data Products for Notional Near-Sun Operation

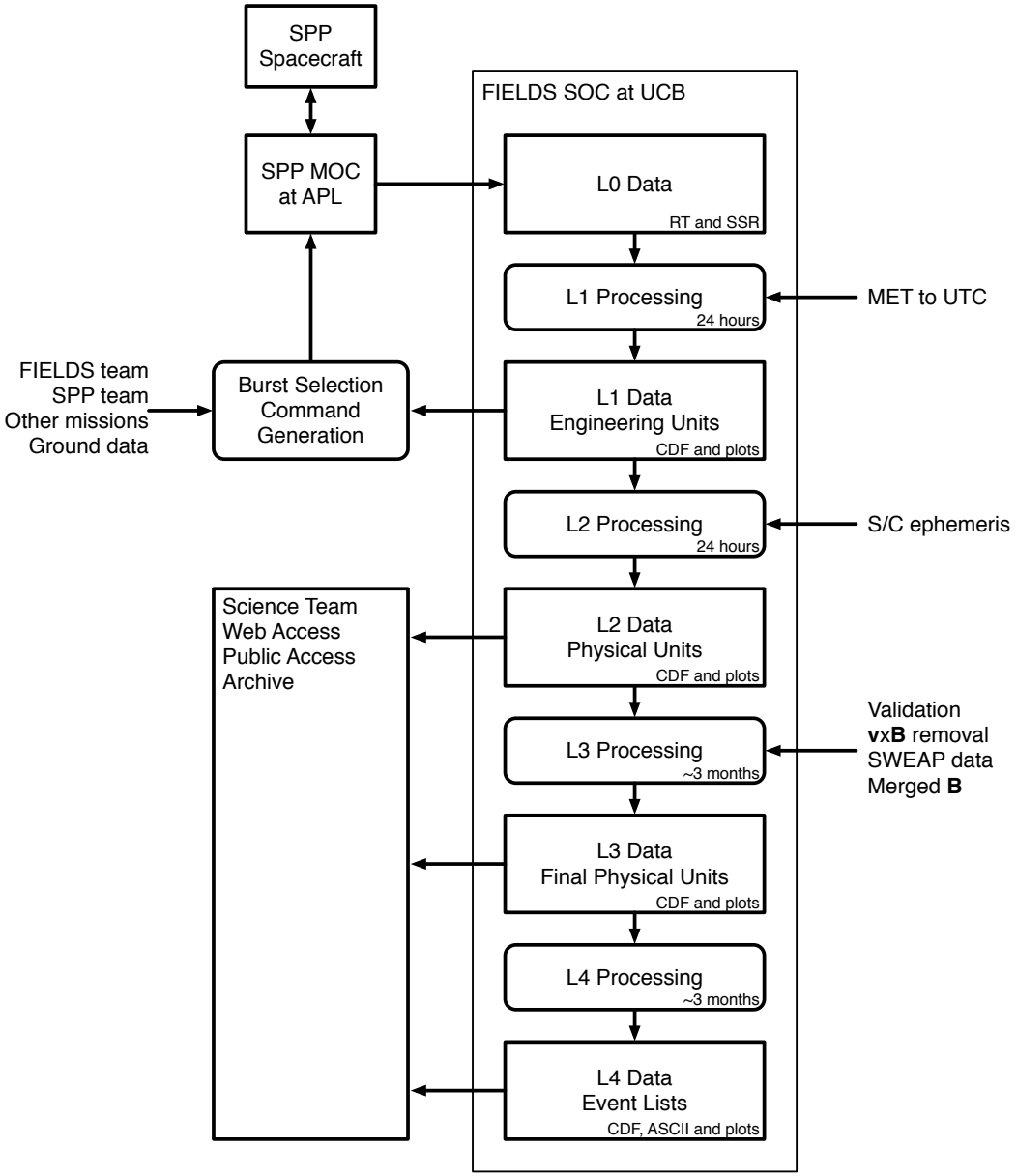
Data Product	# Channels	Cadence	Duty Cycle	Frequency Coverage (1/Cy)[a]
DC spectra	4	1 spectra / 64 Cy	100%	8–4,096
AC spectra	4	1 spectra / 1 Cy	12.5%	128–65,536
DC cross spectra	4	1 spectra / 4 Cy	100%	8–4,096
AC cross spectra	4	1 spectra / 1 Cy	12.5%	128–65,536
DC band pass	4 peak + 4 avg	1 spectra / 2 Cy	100%	0.5–8,192
AC band pass	4 peak + 4 avg	1 spectra / 2 Cy	100%	1,024–65,536
Continuous waveforms	8 (2V, 3E, 3δB)	256 S / Cy	100%	DC –128
Burst waveforms	6 (3E, 3δB)	131,072 S / Cy	0.01%	128 –65,536

[a]Ranges represent digital data product capability. DFB analog filter response significantly reduces AC signal amplitudes above 60,000 Hz ≈ 52,428 1/Cy and DC signal amplitudes above 7500 Hz ≈ 6553 1/Cy. See text for details.

Data Products: Levels

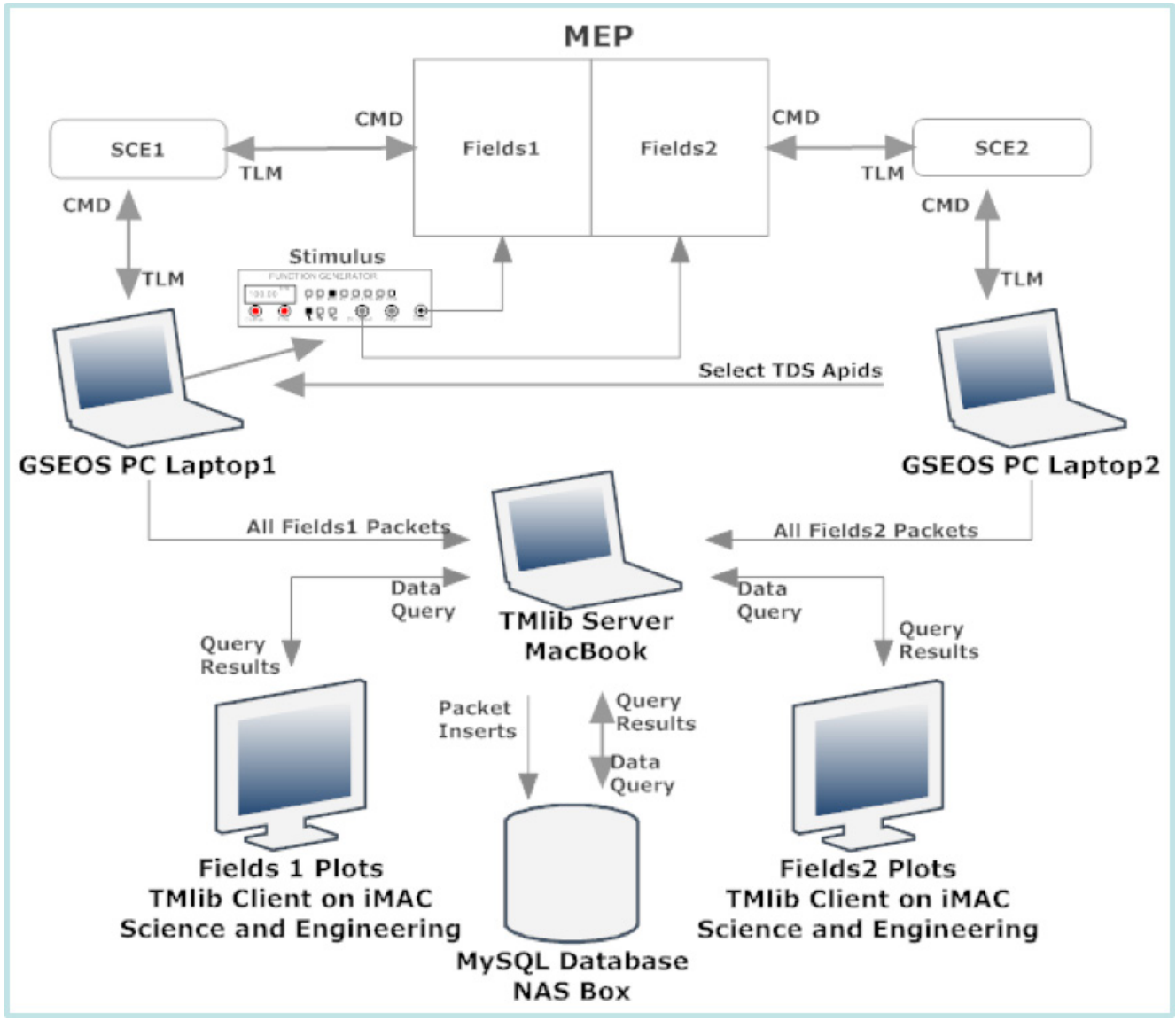
Level	Description	Time to Availability	Users
L0	Raw telemetry produced by SPP MOC. Possibly 24-hour, ApID-separated, sorted, cleaned. PTP and SSR binary files.	Files retrieved from MOC as soon as available. Processing time: < 6 hours after receipt time T_0	FIELDS SOC Archives
L1	Uncompressed and decommutated L0 + Time-tagged waveform and spectral data in telemetry and engineering units [V, dBs, nT] in spacecraft coordinate system. Data affinity groups. ISTP-compliant CDFs (one per subsystem per day).	Automated processing as soon as L0 files are available. Processing time scale: T_0 + ~1 day.	FIELDS SOC FIELDS team Archives
L2	L1 + Time-tagged waveform and spectral data in fully calibrated physical units [V, mV/m, nT, $(V/m)^2/Hz$, nT^2/Hz] in spacecraft and heliophysical coordinate systems. ISTP-compliant CDFs. Quick Look and daily/orbital summary plots.	Automated processing as soon as L1 files are available. Validated internally by FIELDS team and served via FIELDS SOC. Processing time scale T_0 + ~2 days	FIELDS SOC FIELDS team SPP science team Science community Public Archives Web access tools Other end users (archives, Virtual Observatories, etc.)
L3	L2 + VxB removal for DC E-field measurement, offsets and corrections with data quality flags. Plasma density. Spacecraft potential. Merged B. ISTP-compliant CDFs. Science data plots.	Requires V from SWEAP, full orbit's worth of survey data, and inspection by FIELDS team for quality determination. Processing time scale: T_0 + 1 orbit	
L4	Event lists (shocks, current sheets, radio bursts, stream interaction regions) with time tags and derived parameters.	Event lists will be maintained continuously and updated. Time scale: T_0 + 1 orbit	

Data Products: Pipeline



- L0 -> L1 -> L2 data processing and reprocessing occurrs automatically based on daily cron jobs, does not rely on input from other instruments
- L3 and above requires human in the loop for data validation, and input from other instruments (primarily SWEAP for solar wind parameters such as Vsw)
- Software to produce all levels version controlled using SVN, different versions of files produced identified with version numbers

FIELDS SOC I&T Setup



Data Production and Sharing

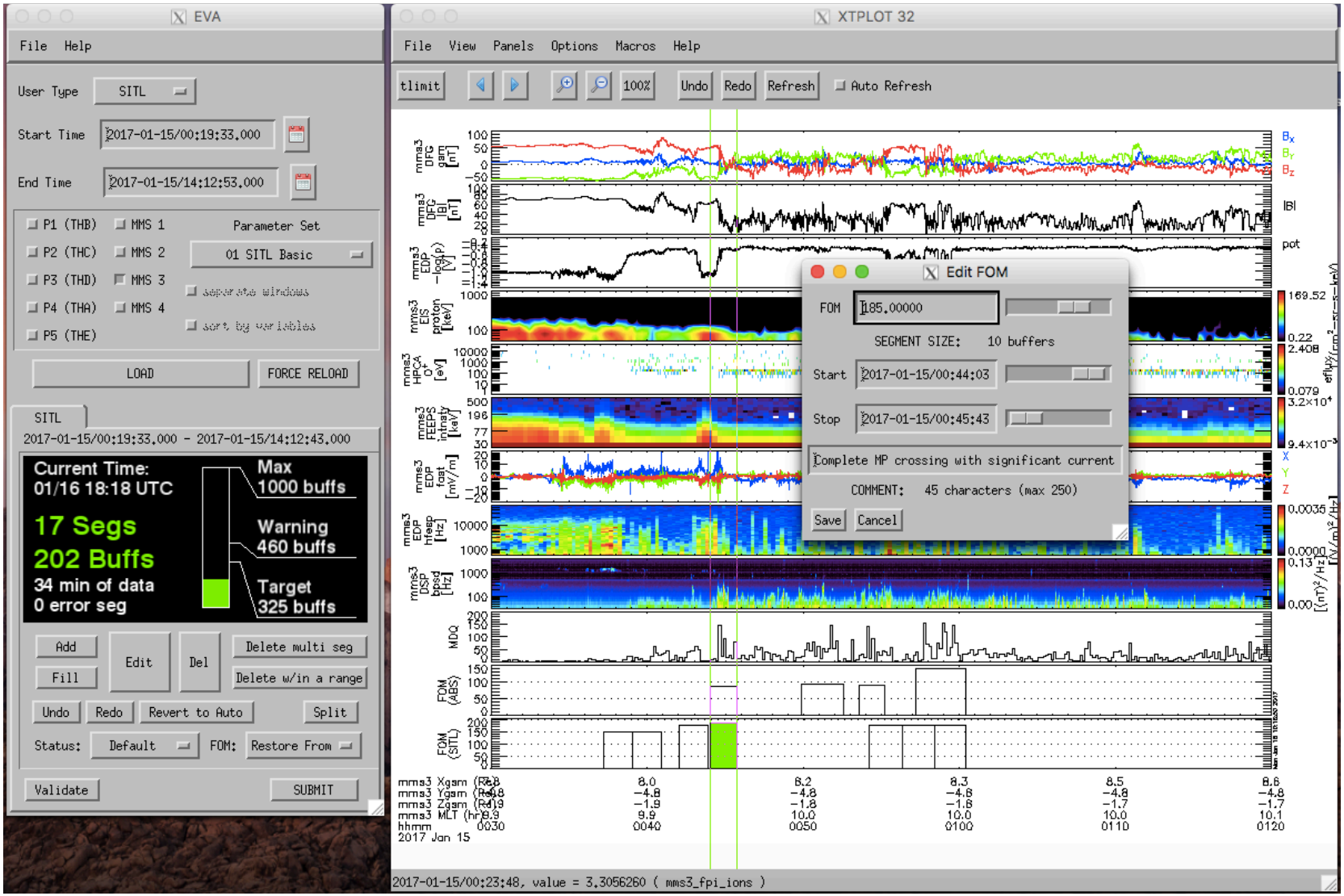
- SPP IDL code is being developed as a part of the SPEDAS package. Loading routines will be provided for IDL users, other users can simply load CDF files
- In the repository, FIELDS IDL code goes in subdirectory:
  - projects/SPP/fields
- To download the nightly build, use
  - http://themis.ssl.berkeley.edu/socware/bleeding_edge/spdsw_latest.zip
- FIELDS data products will go on the SSL server:
  - http://sprg.ssl.berkeley.edu/data/spp/data/sci/fields/
  - Daily CDF files in directories `<data_type>/<level>/<YYYY>/<MM>/`
  - `(Example: rfs_hfr/l1/2018/08/)`
- L1 CDF file format will be close to the packet definition
  - for example: MAG data comes 512 vectors/packet–this will have a single timestamp in the L1 file
  - L2 and above may differ

FIELDS Burst Selection

- FIELDS burst data is approximately half the volume of the FIELDS dataset (~10 Gb)
  - Duty cycle (~0.01%)
  - High time resolution bursts from DFB and TDS, selected saved to FIELDS onboard memory
  - Quality score assigned based on analyses of the waveforms and on parameters measured in the FIELDS survey data or by SWEAP
  - After encounter, FIELDS science team can select time intervals for which some of the saved burst data is telemetered
  - Difficulty (data volume and schedule) depends mainly on orbital geometry
- Looking for phenomena such as (e.g.):
  - IP shock
  - Reconnection exhaust region crossings
  - Quiet intervals for turbulence studies

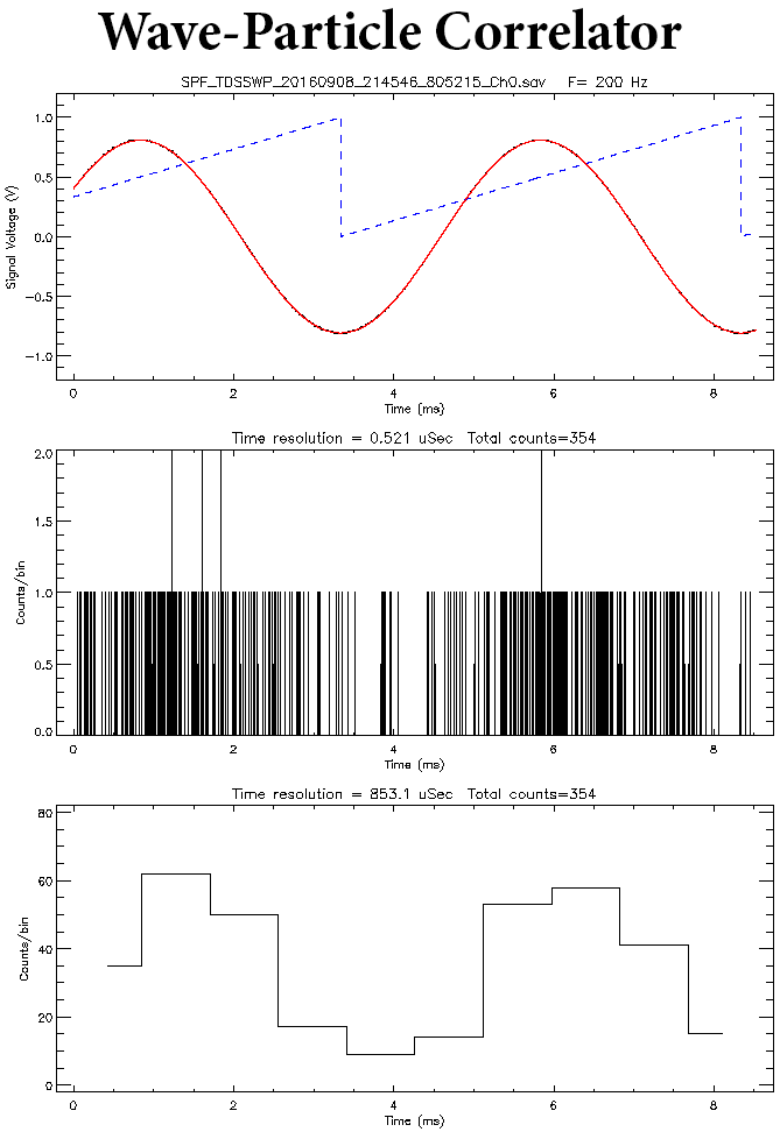
FIELDS Burst Selection Tool

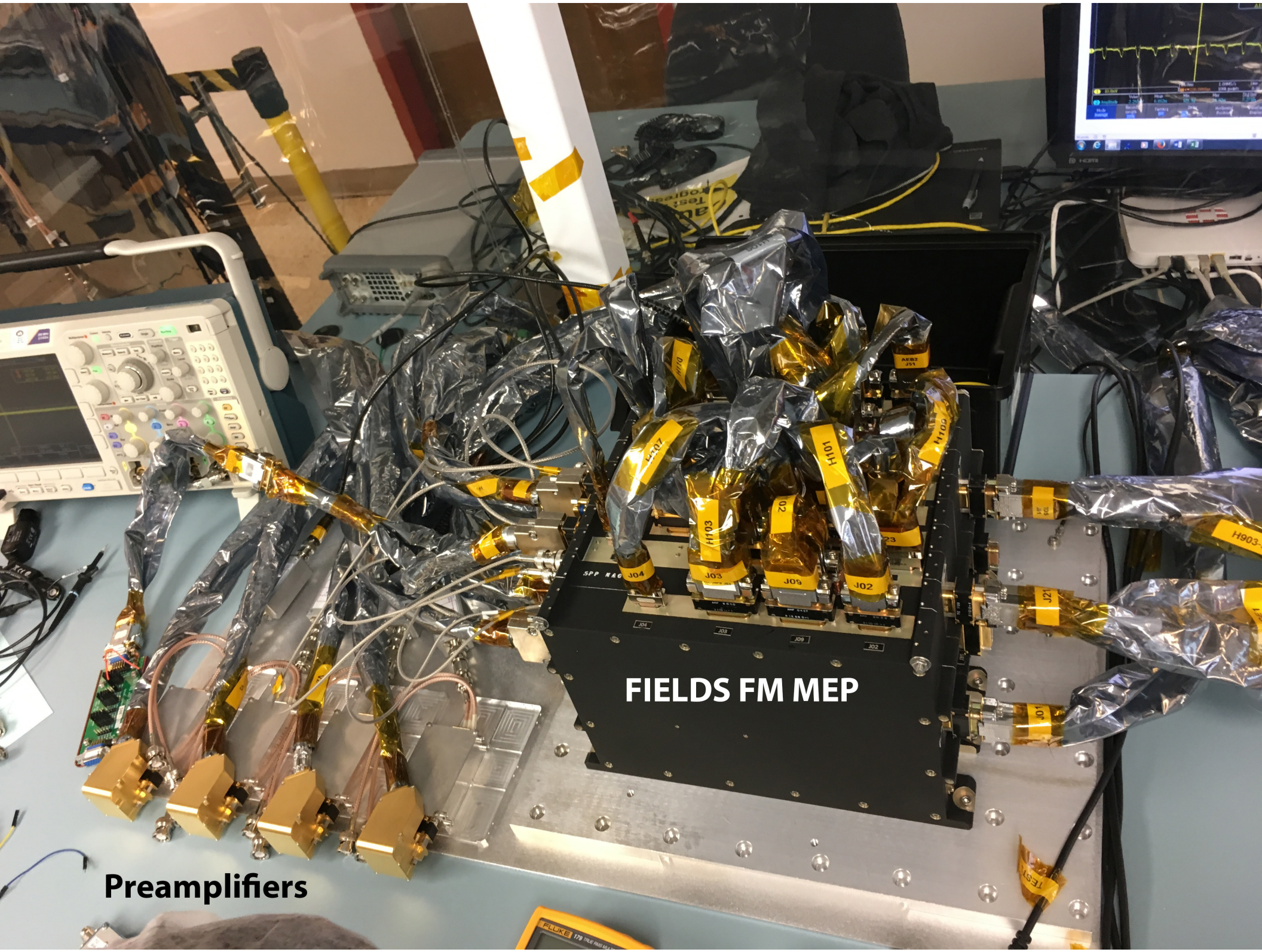
- Based on MMS SITL tool (EVA) developed at SSL by Mitsuo Oka



FIELDS/SWEAP Wave-particle correlator

- Wave-particle correlator: dedicated low latency interface between FIELDS and SWEAP
- Particle input: SWEAP SPAN ion and electron detectors (selected anodes)
- Input to TDS receiver, sampled at the same time as the E and B fields
- Events come down in FIELDS telemetry




FIELDS FM MEP
Preamplifiers