Solar Probe Plus

A NASA Mission to Touch the Sun

Integrated Science Investigation of the Sun Energetic Particles

Preliminary Design Review

05 – 06 NOV 2013

ISIS Science Ops Center

N. A. Schwadron
Instrument SOC Lead
U. New Hampshire

Science Operations Center Agenda

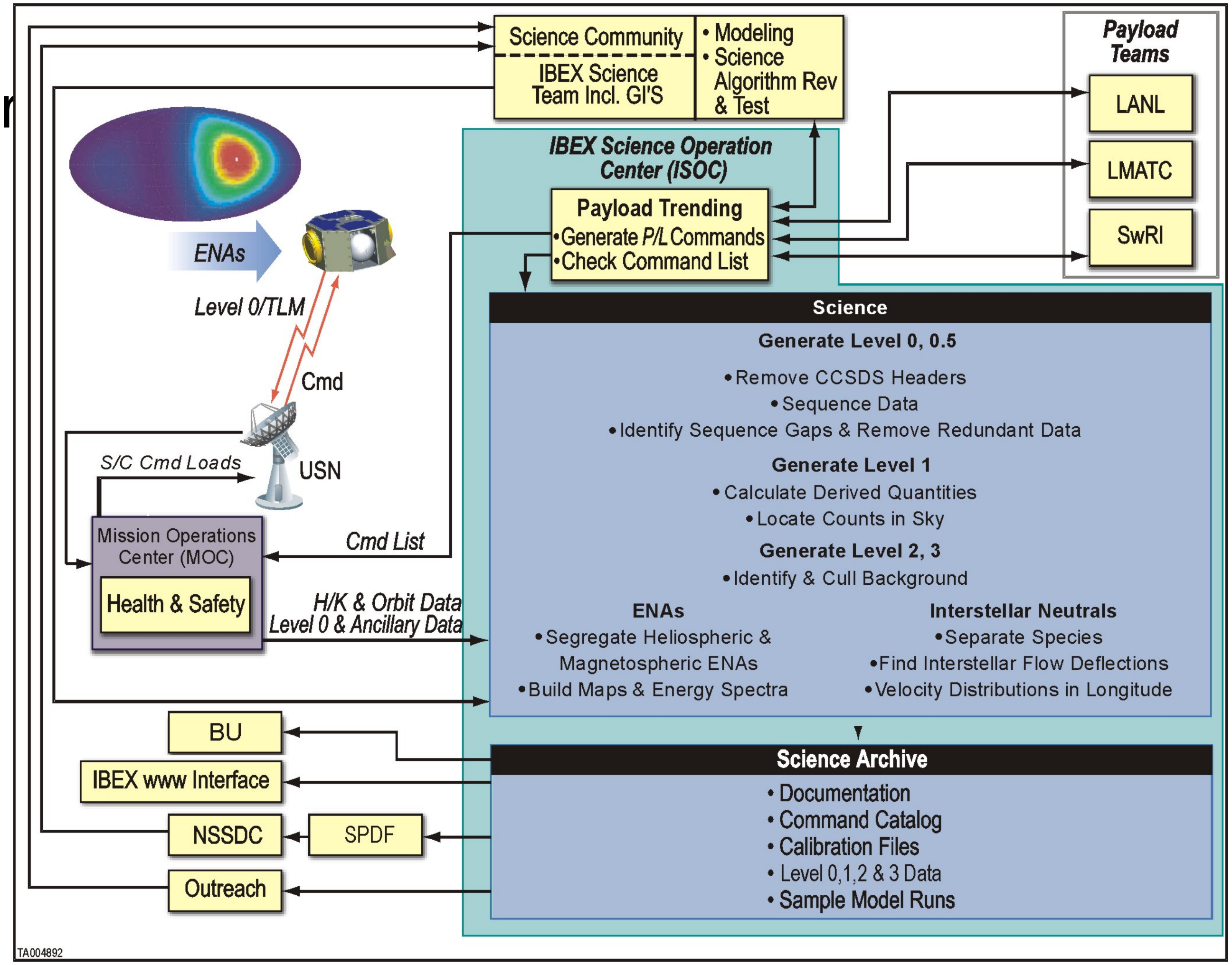
- List of Governing Documents
- Heritage
- SOC Organization
- Requirements Analysis
- SOC Description - Architecture
- SOC Description - Software Systems
- SOC Description - Operations Planning
- SOC Description - Commanding
- SOC Description - Instrument Health & Safety
- SOC Description - Telemetry
- SOC Description - Data Processing
- Data Products
- Development Plan and Schedule
- Test Plan
- Current Status

List of Governing Documents

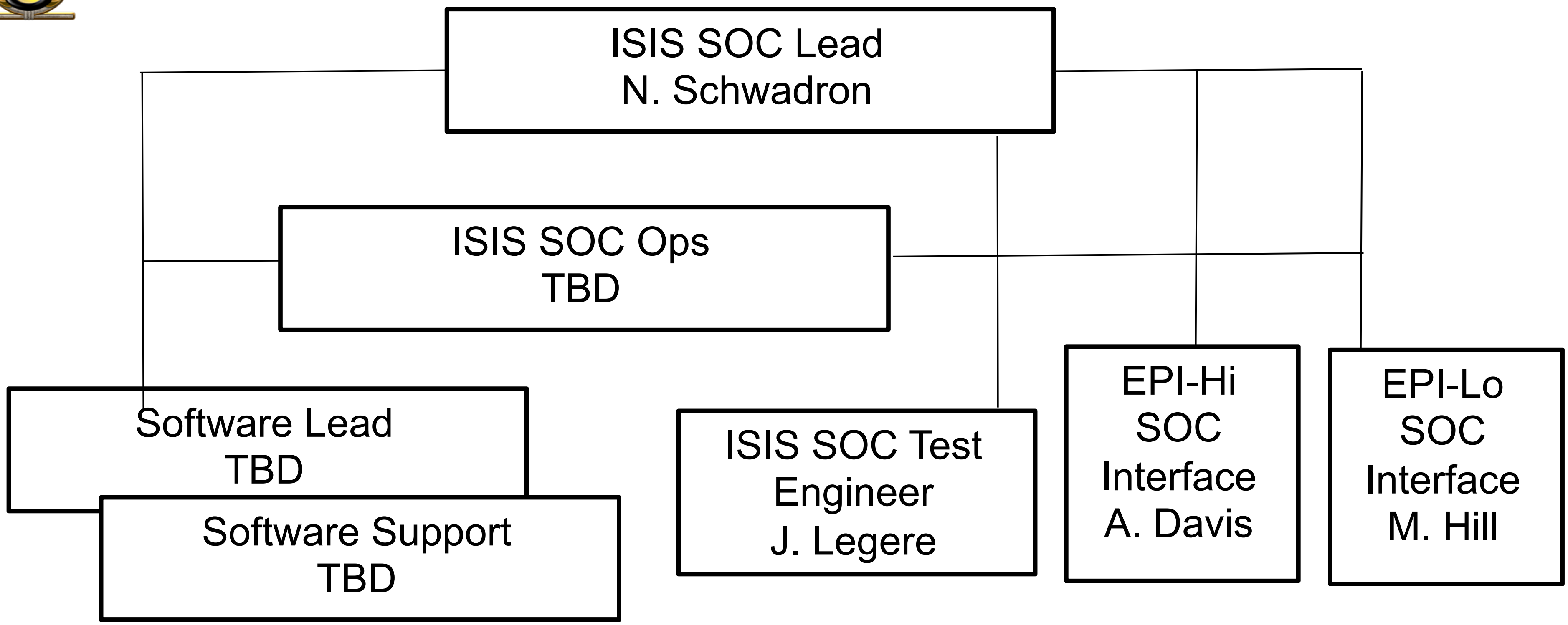
- 7434-9047 SPP Mission Requirements Document (MRD)
- 7434-9081 SPP Science Team Allocated Requirements Document (STARD)
- 7434-9101 SPP Science Data Management Plan (PDMP)
- 7434-9016 SPP Concept of Operations
- 7434-9078 SPP Mission Operations Center (MOC) to SPP Science Operations Center (SOC) and Interface Control Document (ICD)
- 7434-9139 SPP MOC Data Product Document

Heritage

- Interstellar Boundary EXplorer SOC (ISOC) at UNH
  - Two particle instruments
  - Software, Instrument Operations all managed by the ISOC
  - Interfaces with central MOC at Orbital



SOC Organization



- Science and Operations Functions managed by SOC
- Software development needed for Ops, Science and Health & Safety
- ISIS SOC Testing via GSEOS – "Test as you fly and fly as you test"

Solar Probe Plus

A NASA Mission to Touch the Sun

Integrated Science Investigation of the Sun Energetic Particles

Preliminary Design Review

05 – 06 NOV 2013

Requirements Analysis

Nigel Angold
Southwest Research Inst.

Requirements Analysis

1. Public quicklook data 60 days after downlink (6 months for first 3 orbits)
2. Public science data 6 months after downlink
3. Share science/engineering/ancillary data among teams
4. At SOC, archive all telemetry, data, software and docs for mission + 1 year
5. All SOC software + data to final, deep archive by 12 months after mission end
6. SOC must have APL (SPP project) approved security on computers
7. SOC able to receive "remote SOC notification" of instrument fault conditions as detected by the SC

Level 2 Requirements

- [MRD-29] System: Burst Mode
  - The Mission shall be capable of sharing a limited amount of instrument messaging information sufficient for the purposes of coordinating concentrated or focused measurement (burst mode) periods.
- [MRD-66] Data Delivery: Science Data Management Plan
  - The Mission shall create, update and adhere to a NASA Headquarters-approved Science Data Management Plan that specifies file contents, metadata, formats, standards, schedule and pathways for public data access, and the destination of the data upon mission termination.
- [MRD-58] Data Delivery: Quick-Look Data
  - The Mission shall ensure that each SOC provides for public dissemination a quick-look processed version of science data (e.g. thumbnails) within 60 days (TBR) of downlink.
- [MRD-59] Data Delivery: Sharing Among Instrument Teams
  - The Mission shall be capable of sharing data between instrument teams to support data analysis
- [MRD-60] Data Delivery: Engineering Data Sharing
  - The Mission shall be capable of sharing ancillary engineering information necessary to validate and calibrate science data sets to all investigation teams prior to depositing them in a NASA approved data repository.

Level 2 Requirements

- [MRD-61] Data Delivery: Public Release
  - The Mission shall ensure that each SPP science investigation provides processed science data obtained as part of the SPP mission to the public no later than 6 months (TBR) from downlink of all a given encounter's data.
- [MRD-63] CDH Data Delivery: Data Retention at SOC
  - The Mission shall ensure that all instrument telemetry received by the MOC, all associated ancillary data products generated by the ground system, and any processed science data products received by the MOC at any point in the mission life cycle are retained at the MOC throughout the duration of the operational phase of the mission plus one year (TBR).
- [MRD-64] Data Delivery: Data Retention at SOCs
  - The Mission shall ensure that each SOC maintains a data archive of its instrument science, documentation, software and science data products for the life of the mission plus one year (TBR).
- [MRD-65] Data Delivery: Data Delivery to NASA
  - The Mission shall ensure that each science investigation team delivers their respective data archive from the operational phase of the mission to a NASA-designated location for a deep data archive within 12 months of completion of the operational phase of the mission.

Level 2 Requirements

- [MRD-72] FP: Instrument Power-Down Time (*ISIS SOC Tracks this for Heath & Safety)*
  - The Mission shall provide instrument fault protection to include ground system monitoring of selected instrument health data, remote SOC notifications of critical fault conditions, and autonomous onboard instrument power-downs in response to instrument request and critical telemetry.

- [MRD-82] Safety: JHU/APL Network Security
  - The Mission shall ensure that all SPP equipment that connects to the JHU/APL internal or mission operations networks complies with JHU/APL security requirements.

Level 3 Requirements

- [PAY-133] CDH Data Delivery: Quick-Look Data
  - All Science Operations Centers shall provide for public dissemination a quick-look processed version of science data within 6 months (TBR) of downlink for the first three orbits after launch and 60 days (TBR) of downlink thereafter.
  - Traced back to MRD-58 : The Mission shall ensure that each SOC provides for public dissemination a quick-look processed version of science data (e.g. thumbnails) within 60 days (TBR) of downlink.
- [PAY-134] CDH Data: Data Sharing
  - All Science Operations Centers shall be capable of sharing data with other SPP instrument teams to support data analysis as specified in the Science Data Management Plan (7434-9101).
  - Traced back to MRD-59 : The Mission shall be capable of sharing data between instrument teams to support data analysis

Level 3 Requirements

- [PAY-135] CDH Data: Engineering Data Sharing
  - All Science Operations Centers shall be capable of sharing ancillary engineering information necessary to validate and calibrate science data sets with all investigation teams prior to depositing them in a NASA approved data repository
  - Traced back to MRD-60 : The Mission shall be capable of sharing ancillary engineering information necessary to validate and calibrate science data sets to all investigation teams prior to depositing them in a NASA approved data repository.
- [PAY-136] CDH Data: Public Dissemination
  - All Science Operations Centers shall provide processed science data obtained as part of the SPP mission to the public no later than 6 months from downlink of all a given encounter's data.
  - Traced back to MRD-61 : The Mission shall ensure that each SPP science investigation provides processed science data obtained as part of the SPP mission to the public no later than 6 months (TBR) from downlink of all a given encounter's data.

Level 3 Requirements

- [PAY-137] CDH Data Delivery: Data Retention at SOC
  - All Science Operations Centers shall maintain all instrument telemetry & all associated data products throughout the duration of the operational phase of the mission plus one year (TBR).
  - Traced back to MRD-63 : The Mission shall ensure that all instrument telemetry received by the MOC, all associated ancillary data products generated by the ground system, and any processed science data products received by the MOC at any point in the mission life cycle are retained at the MOC throughout the duration of the operational phase of the mission plus one year (TBR).
- [PAY 138] CDH Data Delivery: Data Retention at SOCs
  - All Science Operations Centers shall maintain a data archive of its instrument science, documentation, software and science data products for the life of the mission plus one year (TBR).
  - Traced back to MRD-64 : The Mission shall ensure that each SOC maintains a data archive of its instrument science, documentation, software and science data products for the life of the mission plus one year (TBR).

Level 3 Requirements

- [PAY-149] FP: Instrument Fault Protection (*ISIS SOC Tracks this for Heath & Safety)*
  - All instruments shall provide data to support instrument fault protection (including ground system monitoring of selected instrument health data, remote SOC notifications of critical fault conditions, and autonomous onboard instrument power-downs in response to instrument request, detection of stale instrument heartbeat, or overcurrent).
  - Traced back to MRD-72 : The Mission shall provide instrument fault protection to include ground system monitoring of selected instrument health data, remote SOC notifications of critical fault conditions, and autonomous onboard instrument power-downs in response to instrument request and critical telemetry.

Level 3 Requirements

- [PAY 139] CDH Data Delivery: Data Delivery to NASA
  - All Science Operations Centers shall deliver its data archive from the operational phase of the mission to a NASA-designated location for a deep data archive within 12 months (TBR) of completion of the operational phase of the mission.
  - Traced back to MRD-65 : The Mission shall ensure that each science investigation team delivers their respective data archive from the operational phase of the mission to a NASA-designated location for a deep data archive within 12 months (TBR) of completion of the operational phase of the mission.
- [PAY 151] FP: Instrument Power-Down Time (*ISIS SOC Tracks this for Heath & Safety)*
  - All instruments shall be capable of safely powering down within TBD s upon receipt of a status message with a bit indicating power-down command.
  - Traced back to MRD-72 : The Mission shall provide instrument fault protection to include ground system monitoring of selected instrument health data, remote SOC notifications of critical fault conditions, and autonomous onboard instrument power-downs in response to instrument request and critical telemetry.

Level 3 Requirements

- [PAY 221] FP: Instrument Reconfiguration (*ISIS SOC Tracks This For Health & Safety)*
  - All instruments shall be capable of autonomous reconfiguration to a pre-defined operational state following spacecraft-commanded power-down and subsequent power-on.
- [PAY 152] FP: Instrument Power-Down Preparedness (*ISIS SOC Tracks This for Health & Safety)*
  - All instruments shall be designed to accommodate immediate loss of power (without warning) without damage to the instrument.
  - Traced back to MRD-72 : The Mission shall provide instrument fault protection to include ground system monitoring of selected instrument health data, remote SOC notifications of critical fault conditions, and autonomous onboard instrument power-downs in response to instrument request and critical telemetry.
- [PAY 283] Compliance: MOC to SOC ICD
  - All SOCs shall comply with the requirements and constraints imposed by the MOC to SOC ICD 7434-9078.

Level 3 Requirements

- PAY 303 ISIS Calibration
  - ISIS shall shall be capable of operating to support calibration for at least 70% (TBR) of the time the spacecraft is not in a power or operationally-constrained mode outside of 0.25 AU.
  - Traced to MRD-97: Mission shall measure energetic protons and heavy ions …
- PAY-215 Payload: ISIS Burst Mode (*This is tracked by ISIS-SOC)*
  - ISIS shall be capable of sharing a limited amount of instrument messaging information sufficient for the purposes of coordinating concentrated or focused measurement (burst mode) periods, as defined in the SPP Instrument Shared Data Document 7434-XXXX (TBR).
  - This requirement meets Level 2 Requirements. ISIS will be participating in Burst Mode data sharing.

Solar Probe Plus

A NASA Mission to Touch the Sun

Integrated Science Investigation of the Sun Energetic Particles

Preliminary Design Review

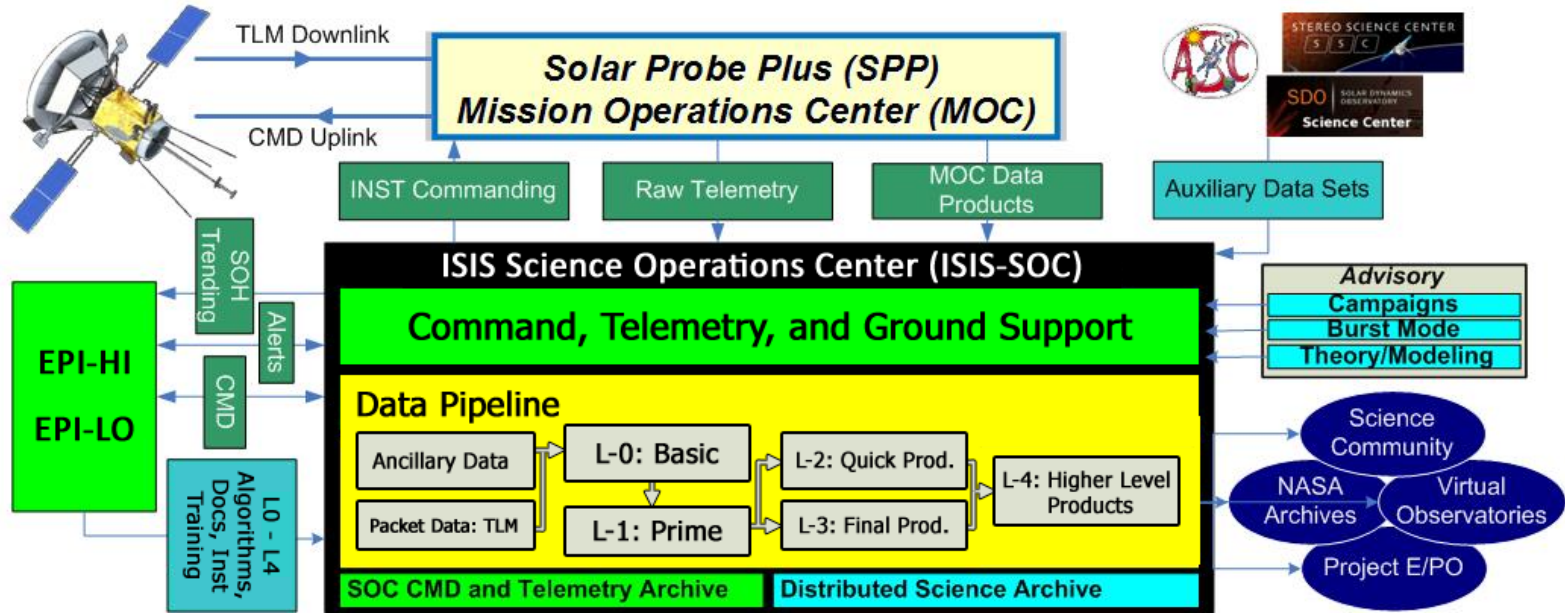
05 – 06 NOV 2013

ISIS
Solar Probe Plus
Energetic Particles
NASA • GSFC • SwRI • APL • Caltech • U-Az • U-Del • UNH

SOC Description

Nathan Schwadron
Instrument SOC Lead
U. New Hampshire

SOC Description - Architecture (1/2)



- Both instrument teams and SOC utilize GSEOS and have the capability to perform real-time commanding in the event of contingencies and during commissioning
- Instrument-to-MOC connections will be preserved and tested periodically to insure contingency preparedness
- Need dedicated EPI-Lo & EPI-Hi “Test SOCs” in Mission Ops Center
- SOC-MOC connections will be exercised as the standard mode of instrument commanding

SOC Description - Architecture (2/2)

- The ISIS Science Operations Center (ISSOC) manages the commanding of EPI-Lo and EPI-Hi in coordination with instrument teams.
- University of New Hampshire (UNH) hosts the ISSOC, which is staffed by a small team responsible for day-to-day operations.
- Operators are brought on-board early in the project and operate the instruments during I&T.
- Command and telemetry database developed during I&T is used during flight operations.
- ISSOC utilizes a similar architecture as the IBEX Science Operations that was developed by N. Schwadron and currently runs at UNH.

SOC Description - Facilities

Facilities:

- **Primary SOC at UNH**
  - **Heritage: IBEX SOC**
- **Backup SOC at SwRI or other institution (not UNH)**
  - **Heritage: IBEX SOC**
- **Dedicated GSEOS machines for EPI-Hi and EPI-Lo**

SOC Description - Command, Telemetry & Ground Support

Commanding Systems – GSEOS

State-Of-Health Products: SOH Software

Command Load Testing Software

Orbit Planning Products: Orbit Planning Software

SOC Description - Science and Data Pipeline Software Systems

Solar Probe Plus
A NASA Mission to Touch the Sun

Data Level Products:
Pipeline Software

Data Visualization Tools:
Pipeline Software

Ancillary Science Products:
Pipeline and Ancillary Software

Solar Probe Plus

A NASA Mission to Touch the Sun

Integrated Science Investigation of the Sun
Energetic Particles

Preliminary Design Review

05 – 06 NOV 2013

Operations

Eric Christian
GSFC

SOC Description - Operations Planning

- Commanding of EPI-Hi and EPI-Lo
  - "Flatsat" at UNH used to test command loads
    - SwRI engineer will be responsible for using the native design products during Phase C to create a "behavioral model" of EPI-Hi and EPI-Lo
    - Constraint Checking Modules
  - Standard Commanding performed via GSEOS at UNH SOC
  - Commissioning and Contingency response, commanding may optionally be done by EPI-Hi and EPI-Lo via GSEOS directly through MOC
- Planning for instrument operations
  - Planning software
    - Automated routines & Templates for initial planning
    - Interactions with ISIS SOC interfaces for finalization of planning
  - Develop rough plans three orbits ahead
    - Test command load
  - Develop definitive plans one orbit ahead
    - Final testing
    - Upload

SOC Description - Commanding

- GSEOS used during I&T and as much of testing as possible
  - Coordinated by ISIS SOC Test Lead
- Common GSE-OS platform for instrument GSEs/SOC
- "Fly as we test (*detailed further later)*"

Factors: ISIS Commanding Needs

- Particle events are sporadic so the goal is to approach 100% coverage
  - Whenever possible, we want ISIS instruments taking data
  - Do not preclude operations of instruments and data acquisition at any location or for any time interval during any orbit
- Need sufficient time to analyze data after solar encounter phase and prepare for any needed uploads prior to the next encounter
  - Considering ~daily snapshots for status/summary file
- Continual health and safety monitoring
  - Status/summary file sent down first in each DSN pass for health and safety monitoring
- Ability to download all data
  - Bulk of science data and burst mode in files subsequently sent down as downlink permits
- Three-step Hierarchy of planned commands for near-term and longer-term changes
  - Next Solar Pass
  - Next Solar Pass + 1
  - Next Solar Pass + 2

Commanding in First 2 Months

- Based on STEREO experience EPI-HI will require 10-20 opportunities (on separate days) to send commands in the first two months
  - Necessary to obtain/analyze at least a few hours of new data in between command opportunities to test whether the commands worked
  - Therefore, need to collect data between commanding opportunities
- ISIS EPI-Lo and EPI-Hi Statistics Gathering and Threshold Scans
  - After initial checkout it is important that ISIS instrument gather as much data as possible (especially raw event data)
  - Allows instruments to populate composition tracks so that TOF vs E flux boxes (EPI-Lo) and De vs Eprime boxes (EPI-Hi) can be adjusted before perihelion
  - Threshold scans to determine optimal threshold values
  - 6 weeks need for these activities
  - EPI-Lo does not need to be on continuously
- ISIS EPI-Lo and EPI-Hi Table Loads and/or Software Updates
  - Table updates expected (adjustment of flux box bins) 3 weeks into statistic gathering period
  - Software updates as needed

Normal Science Operations

EPI-Hi and EPI-Lo operate the same whenever powered-on except for the volume/content of the data sent to the S/C inside/outside 0.25 AU

- **Spacecraft- Sun Distance R<0.25 AU (Normal Science Mode)**
  - Full nominal power
  - High data collection rate and burst mode
- **Spacecraft- Sun Distance: 0.25 AU < R (Low-rate Science Mode)**
  - Full power when not downlinking and when possible
  - Reduced data collection rate
  - Commanding window should be scheduled late in the series of telemetry passes, although it may not be used every orbit
  - Minimize power cycling the HV supplies

Nominal Operations

EPI-Hi and EPI-Lo capable of switching between two routine modes autonomously (based on data received once-per-second from the spacecraft).

At least three special operational modes are currently envisioned:

- Software upload mode
  - During software upload mode, data acquisition functions and some non-essential functions will be halted.
- Calibration Science mode
- Safe mode

Solar Probe Plus

A NASA Mission to Touch the Sun

Integrated Science Investigation of the Sun Energetic Particles

Preliminary Design Review

05 – 06 NOV 2013

Testing, Processing, Data Products, Plan and Status

Nathan Schwadron
Instrument SOC Lead
U. New Hampshire

SOC Description - "Test as you Fly, Fly as you Test"

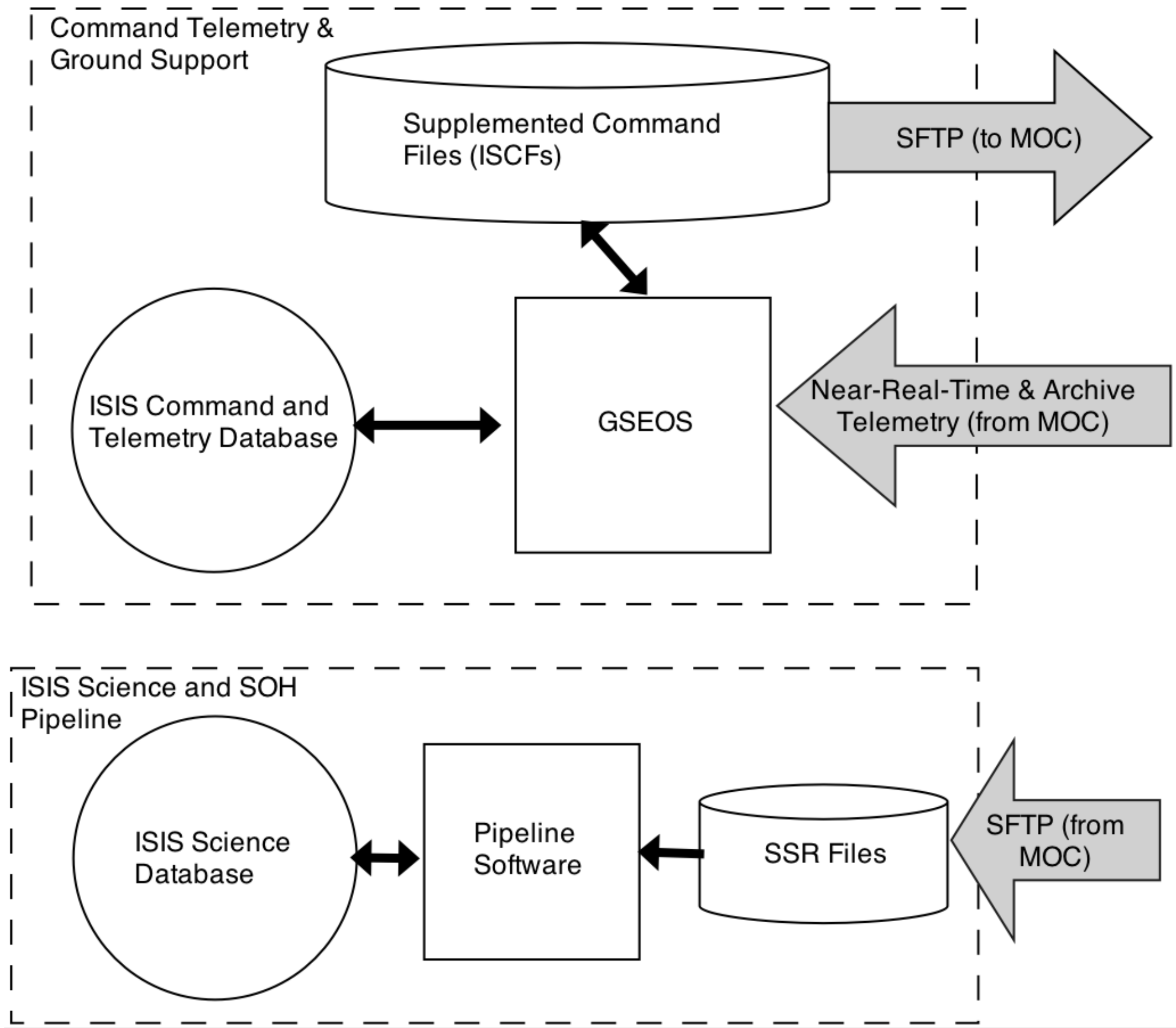
- Instrument GSEs may have two types of operation:
  - Specific: direct connection to instrument test ports
  - Flight Mode: spacecraft simulator → instrument
- GSE Flight-Mode operation incorporated into the SOC GSEO-OS system. Identical "look and feel" to the instrument/SOC teams during testing, I&T, commissioning and normal flight operations

SOC Description - Instrument Health & Safety

- Health and Safety limits checked throughout testing, I&T and monitored throughout commissioning and flight
- GSEOS used at ISIS SOC for health and safety monitoring during contacts
- ISIS SOC develops software, and team pages with State-of-Health checks and long-term trending

SOC Description - Telemetry

- Telemetry flows into ISIS SOC and Backup SOC



SOC Description - Data Processing

- Data processing systems
  - Pipeline code C, IDL, Perl, Java, etc ..
  - Tools (MIDL, IDL Savesets, etc..) available for visualization and analysis
  - Unix/Shell scripts launch executables in essentially any language to do their job with a clear i/o

- Data processing algorithms
  - Straightforward routines
    - Decommutation
    - Particle Identification
    - Application of calibration data

- Facilities
  - All formal pipeline processing processed at ISIS SOC

- Future planning products
  - Use of SPICE ephem, SOC calendars for planning
  - Automation where possible

Data Products (1/2)

- ISIS SOC builds Level 1 and higher level data products from the Level-0 (raw) data received from MOC
- Housekeeping and status data are processed as soon as possible after receipt (all products within 3 days, select quick products < 1 hour) and posted for viewing for the ISIS team through an ISIS SOC website.
  - Housekeeping and status data downloaded first after passes, provide critical information from which to build command loads in subsequent passes.
- Level 0 data are processed as they are made available after passes and are used to construct Level 1 and higher level data products

Data Products (2/2)

- Higher level data products include combined solar wind, magnetic field and energetic particle data, which are time-ordered with common timestamps at a cadences TBD.
- Level 1 and higher level data products are still in formulation as the instrumentation are in development.
- The ISOC archives all ISIS data and delivers data products to appropriate Heliophysics Virtual Observatories and Data Centers.

Level 0 Status and Housekeeping

Data Level	Description	Latency	Users
L0 Status Data	Snapshots of EPI-Lo and EPI-Hi data through the orbit EPI-Hi accumulates 1-hr summary files from LET & HET include a subset of hourly average science, housekeeping data (health & safety monitoring). Summary files accumulated continuously over both the ≤0.25 AU and >0.25 AU orbit phases ~2 bps for LET and ~2 bps for HET	Downloaded first following each orbit	ISIS Instrument teams
L0 Housekeeping	EPI-Hi and EPI-Lo voltages, currents, temperatures, rate monitors **EPI-Hi:** These are engineering data needed to monitor the health and safety of the instrument. Included are (a) 1-min average count rates of the individual detectors and their segments; (b) 1-minute totals of instrument live time and number of analyzed events of various kinds; (c) temperature data; (d) 1-minute leakage currents from all detector segments; (e) settings of the onboard calibration DACs; and (f) threshold settings for the pulse-height analyzers. During the >0.25 AU portion of the orbit these will be 1-hr averages rather than 1-minute averages. **EPI-Lo:** HK in 2 groups (12 channels per group). Each group collected at 1 s cadence < 0.25 AU and 30 min cadence > 0.25 AU.	Downloaded first following each orbit	ISIS Instrument teams

Level 0 Command Response/Mem Dumps

Data Level	Description	Latency	Users
L0 Command Response Data	Data products that detail results of specific commands.	Data delivered asap after tests	ISOC and ISIS Instrument Teams
L0 Memory Dumps	EPI-Hi and EPI-Lo will perform slow (bit/s) memory dumps periodically. The frequency of these dumps is being discussed. One concept is to perform memory dumps once or multiple per orbit and have checksums sent down more often (e.g., once per contact).	Frequency under discussion	ISOC and ISIS Instrument Teams

Level 0 EPI-Hi Events (1/2)

Data Level	Description	Latency	Users
L0 EPI-Hi events (z & E)	The EPI-Hi instrument includes two Low Energy Telescopes (LETs) and a High Energy Telescope (HET) that measure energetic particles. Each telescope has a stack of silicon solid-state detectors that make multiple measurements of the energy loss and arrival direction of individual ions and electrons. Most of these detectors have multiple segments. These energy loss measurements are processed in real-time to determine the nuclear charge (Z) and kinetic energy E of individual particles at processing rates of >1000 particles/sec. A sample of these "events" is downloaded (selected by a priority scheme to include all species, energies, and directions). Included are the pulse-heights from all triggered detectors and the results of the onboard processing.	Data delivered after each pass	ISOC and ISIS Instrument Teams
L0 EPI-Hi Z vs E matrices	Each of the processed "events" is sorted into several Z vs E matrices that summarize the measured composition and energy spectra for 17 (TBR) different species ranging from H to Ni (1≤Z≤28), four element groups, and electrons (for a total of 22 (TBR) separate "species"). For each species there are ~20 energy intervals in each of LET and HET. The Z vs E matrices are accumulated on time scales that range from 1 s to 1 hour (the shortest time-scales include only abundant species like H, He, and electrons).	"	"

Level 0 EPI-Hi Events (2/2)

Data Level	Description	Latency	Users
L0 EPI-Hi Z vs. E vs. Dir Matrices	Some of the Z vs E matrices are accumulated over multiple look directions. There are a total of 75 look directions for the three ends of the LET telescopes and 50 look directions for HET. We will call these Z vs E vs Dir. Matrices to distinguish them from the Z vs E matrices that sum over all directions.	Data delivered after each pass	ISOC and ISIS Instrument Teams

EPI-Lo Level 0 Rates

Data Level	Description	Latency	Users
L0 EPI-Lo Electron Rates	These are composed of three types: • **Regular Electron Rates** (8 angle bins & 32 energy bins from 25-500 keV). 30 s integration rate <0.25 AU, 30 minute integration rate >0.25 AU • **Hi Angle Electron Rates** (80 Angular bins & 16 energy bins 25-500 keV). Same integration times as Regular Electron Rates • **Fast Electron Rates** (8 Angle Bins, 6 Energy Bins). 0.25 s integration time < 0.25 AU, 15 s integration time > 0.25 AU.	Data delivered after each pass	ISOC and ISIS Instrument Teams
L0 EPI-Lo Ion Rates	These are composed of five types: • **Total Ions (Fast)** (8 angle bins & 8 energy bins from 30 keV -7 MeV). 0.25 s integration rate <0.25 AU, 15 s integration rate >0.25 AU • **Proton Rates** (80 Angular bins & 29 energy bins 30 keV-7 MeV). Same integration times as Regular Electron Rates • **Helium Rates** (2 Species, 80 Angle Bins, 12 Energy Bins 20 – 1500 keV/nuc). Same integration times as Regular Electron Rates • **Heavy Ion (group 1) Rates** (80 Angle Bins, 14 Energy Bins 10 – 1500 keV/nuc). Same integration times as Regular Electron Rates • **Heavy Ion (group 2) Rates** (80 Angle Bins, 14 Energy Bins 10 – 1500 keV/nuc). Same integration times as Regular Electron Rates	“	“

Level 0 EPI-Lo Events

Data Level	Description	Latency	Users
L0 EPI-Lo PHA Events	Complete information on select events. Cadence of 0.1 s < 0.25 AU and 5 s > 0.25 AU	Data delivered after each pass	ISOC and ISIS Instrument Teams
L0 EPI-Lo TOF-Only Events	80 Angle Bins and 6 Energy Bins 4-30 keV/nuc. Time-Of-Flight information allowing detailed species separation. Same integration times as Regular Electron Rates	"	"

Level 1 Data (1/2)

Data Level	Description	Latency	Users
L1 EPI-Lo Events, Rates	Products similar to EPI-Lo L0 data products, however validated and time-sorted with redundancies removed. All rates are at least 16-bit since memory requirements are not a major issue at level 1	Data accumulated after each pass (N) and made available to public in pass (N+1)	SPP Science Community
L1 EPI-Lo Particle Intensities	Absolute intensities (in units of particles/(cm^2sr-s-MeV/nuc) for ion species and in electrons/(cm^2sr-s-MeV) for electrons). These are produced from the L0 data. The time bases will range from 1-s to 1-day.	"	"

Level Data (2/2)

Data Level	Description	Latency	Users
L1 EPI-Hi Events, Rates, Matrices	Products similar to EPI-Hi L0 data products, however validated and time-sorted with redundancies removed. All rates are at least 16-bit since memory requirements are not a major issue at level 1	Data accumulated after each pass (N) and made available to public in pass (N+1)	SPP Science Community
L1 EPI-Hi LET and HET Particle Intensities	Absolute intensities (in units of particles/(cm^2sr-s-MeV/nuc) for ion species and in electrons/(cm^2sr-s-MeV) for electrons). These are produced from the L0 data for (a) the Z vs. E matrices and (b) the Z vs. E vs. direction matrices. The time bases will range from 1-s to 1-day. The shortest time bases will be computed for only abundant species such as H, He, and electrons.	"	"
L1 EPI-Hi Expanded Event Data	These data are produced for a sample of the individual ions/electrons that trigger the instrument. A priority system will ensure that all species, energies, and directions are sampled. The events include a summary of everything measured for that particle, including the designations of detectors that were triggered and all of the measured pulse heights (proportional to energy loss). Also indicated is how the particles were sorted onboard (by Z, E, and direction). A typical event requires 50-100 bits.	"	"

Level 2 and Higher

L2 data sets	Higher level products that combine various data products. These are still being defined and refined. Examples include data products time-ordered with solar wind and magnetic field data, element abundance ratios, fits to particle anisotropy data, and particle intensities associated with particular solar events.	Data accumulated after each pass (N) and made available to public in pass (N+1)	SPP Science community

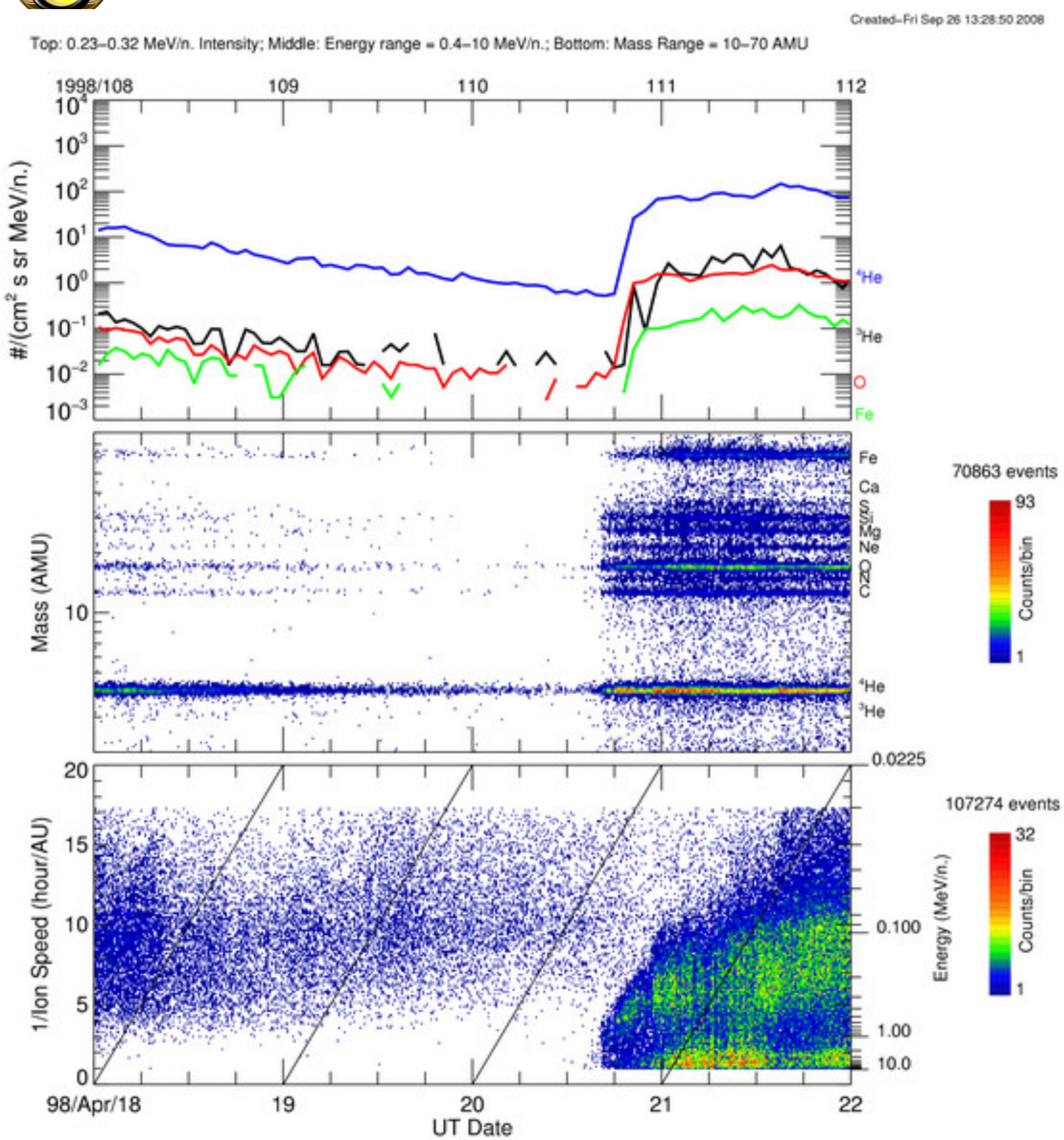
Data Products (Quicklook)

- All Science Operations Centers shall provide for public dissemination a quick-look processed version of science data within 6 months (TBR) of downlink for the first three orbits after launch and 60 days (TBR) of downlink thereafter.

- EPI-Lo:
  - Spectrograms of:
    - <1 MeV electron counts/data-interval (TBR) as a function of time, at a <= 1 hour (TBR) cadence, with 4 or more energy bins .
    - <1 MeV/nucleon total ion or single species (TBR) counts/data-interval (TBR) as a function of time, at a <= 1 hour (TBR) cadence, with 4 or more energy bins.

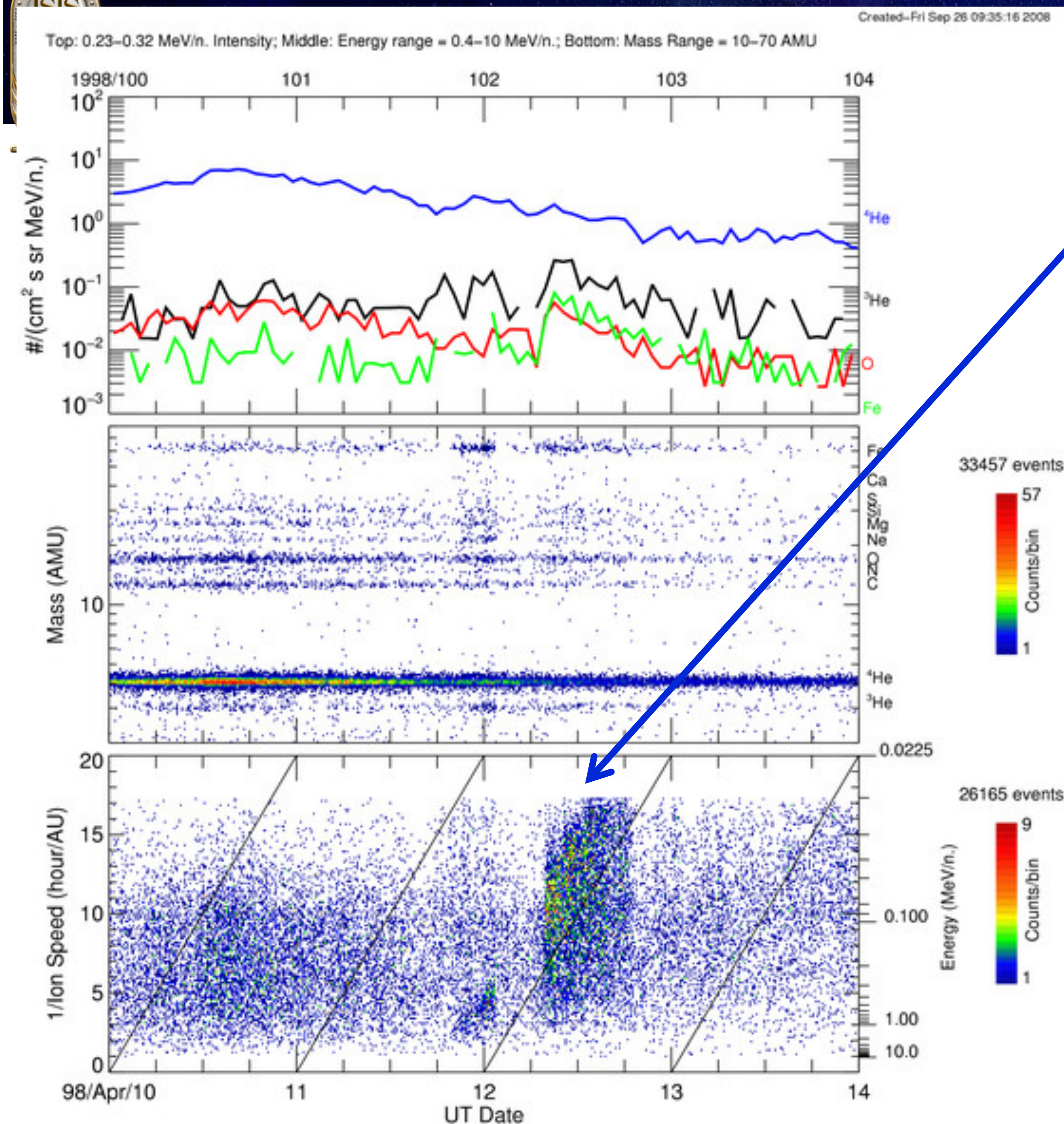
- EPI-Hi:
  - Plots of 1-hour averages of four rates:
    - 1-5 MeV electrons
    - 2-10 MeV protons
    - 10-50 MeV protons
    - 4-40 MeV/nuc HiZ ($6 \leq Z \leq 28$)

Possible data product

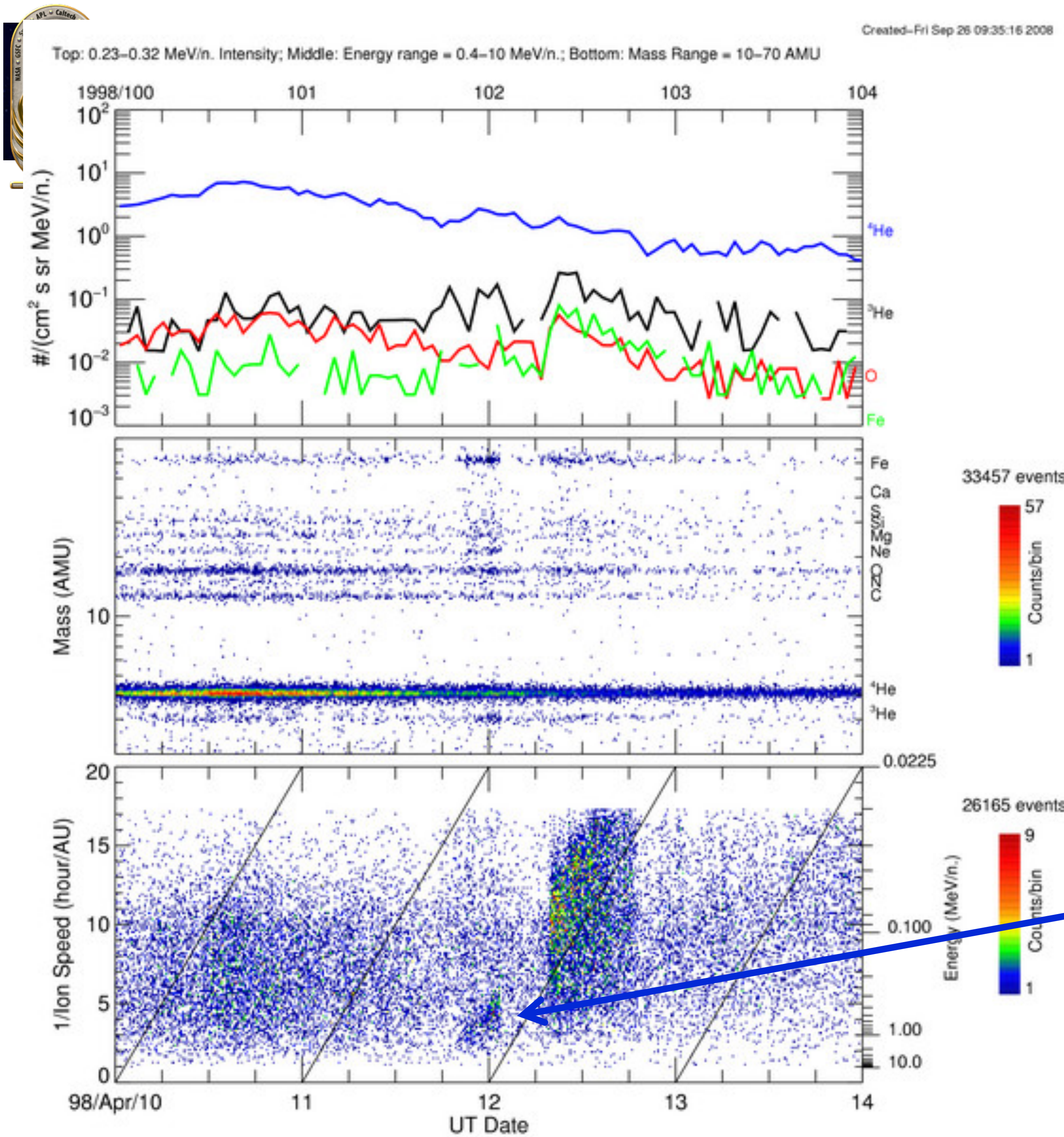


- One way of plotting SEP data
- Top plot is the usual time-intensity profile
- Each dot in the lower two panels is a particle detection
  - Middle plot shows particle mass
  - Bottom plot shows energy
- Advantages:
  - Easy identification of velocity dispersion in some events
  - individual events are separated more clearly
  - Composition easily identified

This is image taken from the ACE website: ULEIS 4-day browse plots

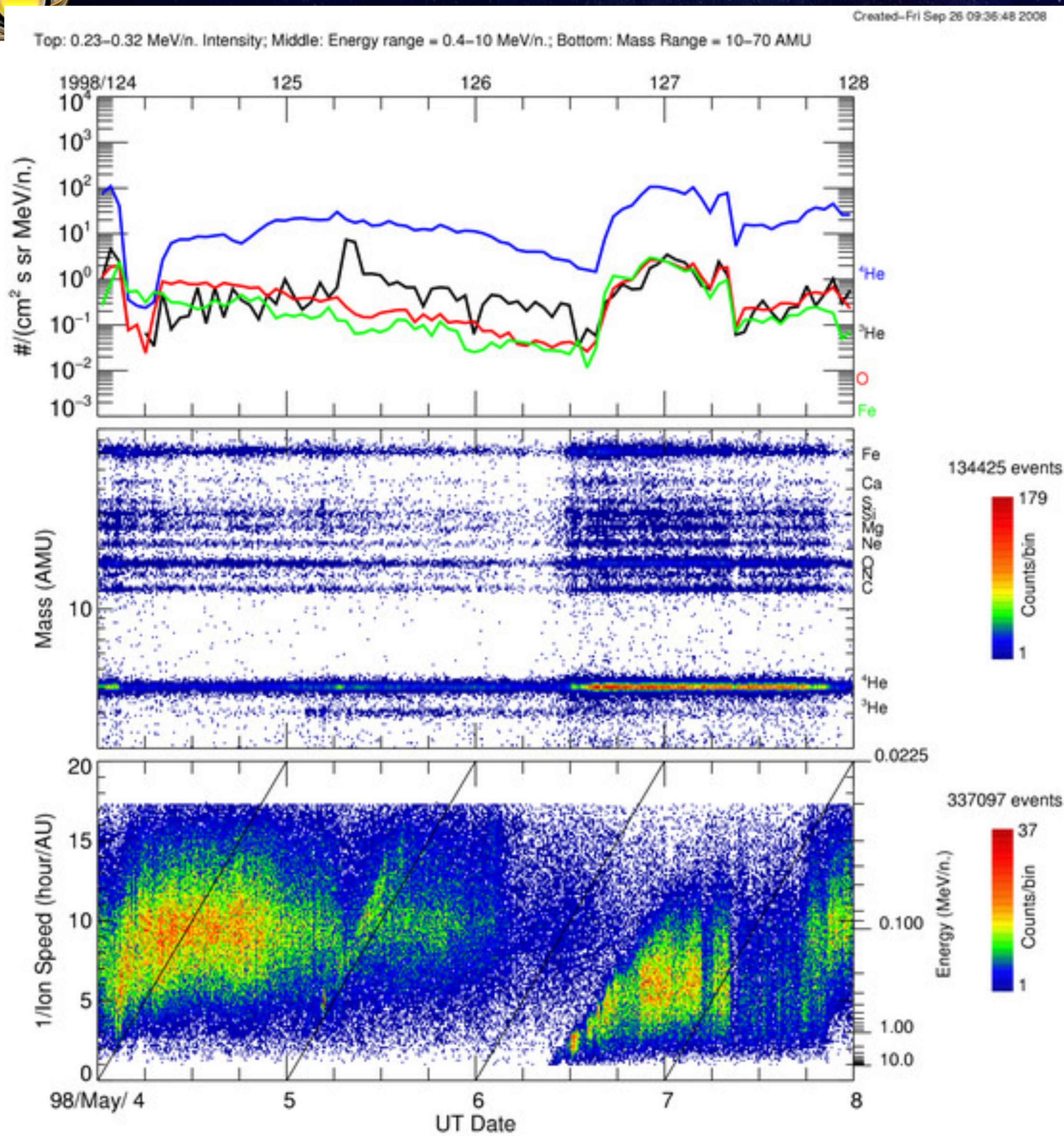


- This is an example of an event probably associated with an impulsive solar flare (rich is heavy ions and ^{3}He)



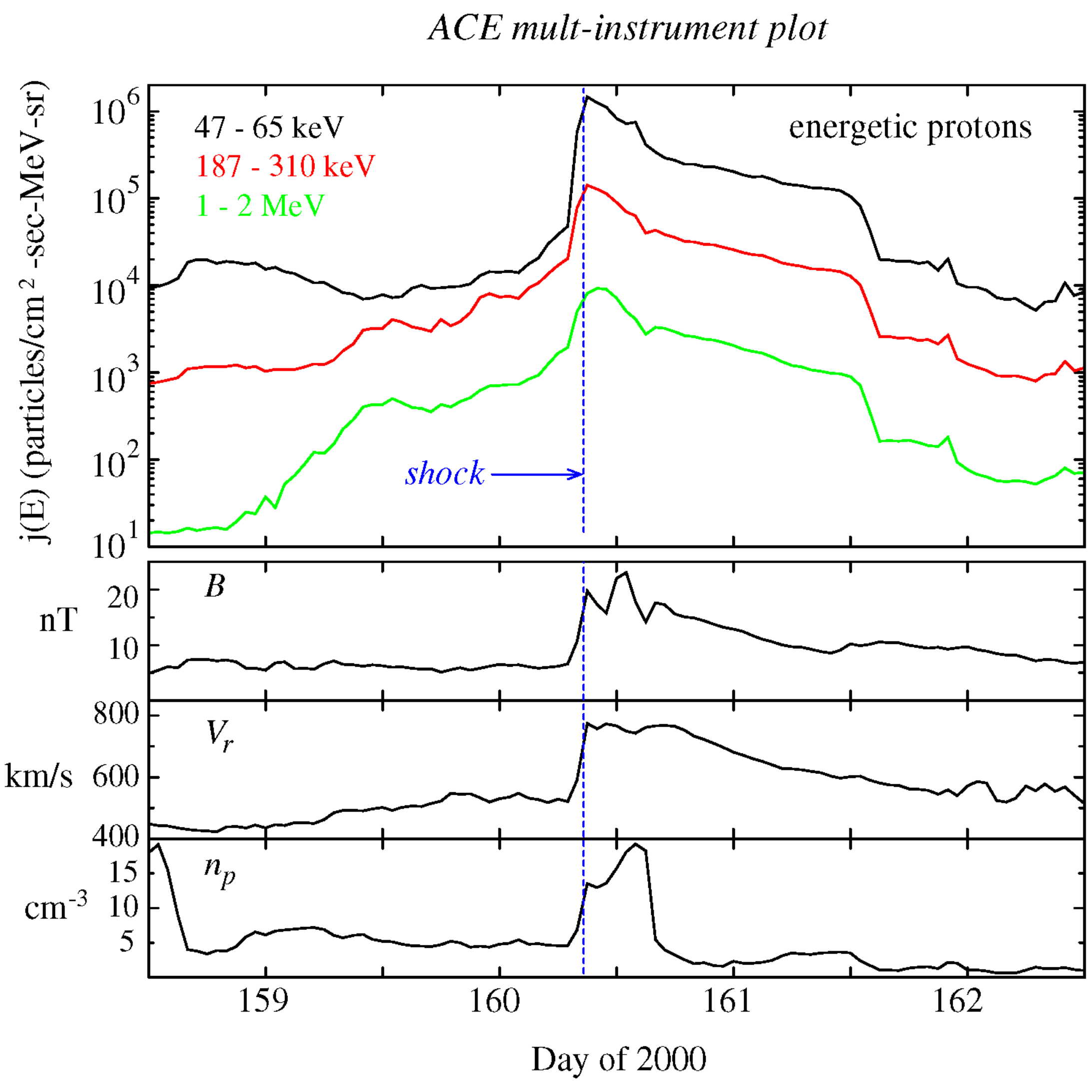
- This is an example of an event probably associated with an impulsive solar flare (rich in heavy ions and ^{3}He)
- The entire event shows a clear velocity dispersion, but there is also a dispersionless intensity "dropout" during the event

Possible data product



- Another good example (event starting before noon on May 6)

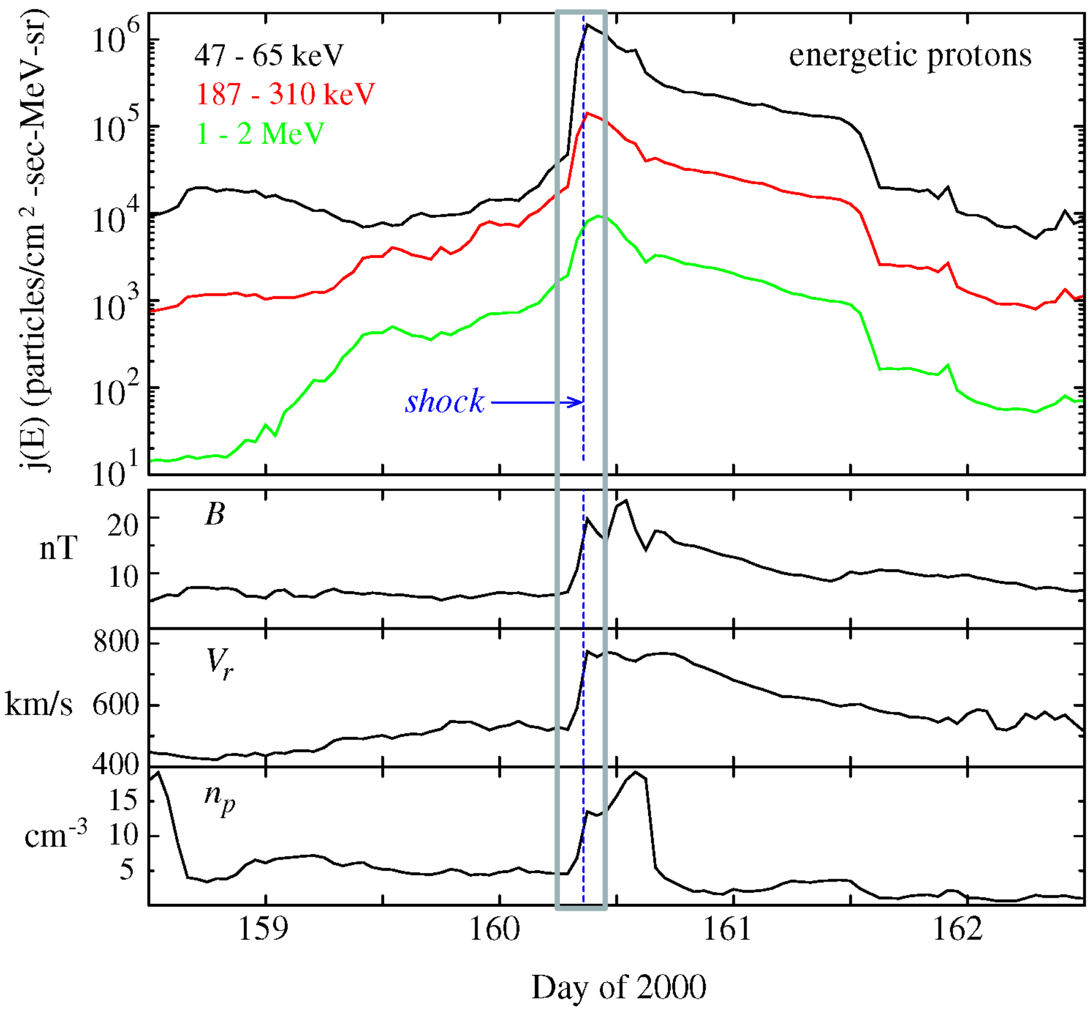
Possible data product: Multi-instrument plots



- Multi-panel plots showing energetic particle intensities along with field and plasma parameters

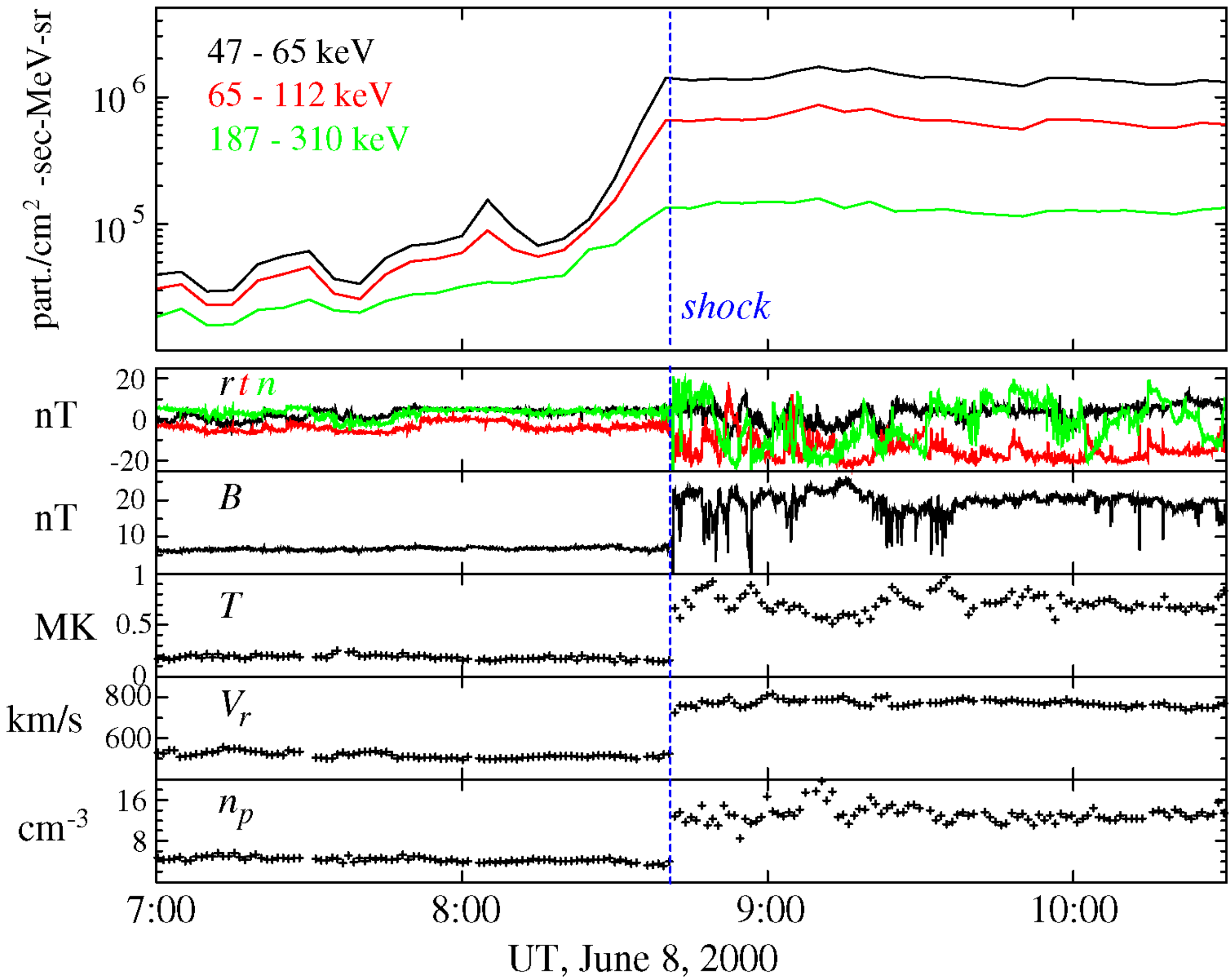
Possible data product: Multi-instrument plots

ACE mult-instrument plot



- It would be useful to be able to look at it in higher resolution as well

Same event at higher temporal resolution



Development Plan and Schedule (1/3)

- November , 2013 – I-PDR for ISIS/SOC - This review.
- (/2014) S/C emulator available, MOC-SOC ICD finalized - start of development of test SOC
  - [CSCI-1] Implementation of GSE-OS at UNH.
  - [CSCI-1] Begin writing/implementation of SOC/MOC communications layer [*note]
  - [CSCI-1] Start implementation of SOC – instrument teams communication layer
- (/2015) Pre-CDR ISIS SOC Peer Review (Paper-only review)
  - [CSCI-1] As instrument GSEs become operational/established, begin integration of instrument GSE-OS scripts, displays and codes into the SOC GSE-OS system – contingent on instrument GSE schedule
  - Purchase SOC HW components - Computers, servers, raids, UPSs, shipping crates, etc.
- (/2015) Test MOC available
  - [CSCI-1] Begin testing of SOC/MOC interface and communications.
  - [CSCI-1] As instrument GSE-OS codes are established at ISIS-SOC, test their functionality.
  - [CSCI-1] As instrument commanding protocols/codes are established, test SOC – instrument teams communication layer
  - [CSCI-1] As L0 test files become available test or implement HK, quicklook displays for SOC-CTG.
  - [CSCI-2] Start work with instrument teams to define L0 -> L1 processing codes

Development Plan and Schedule (2/3)

- (/2017) Pre-Instrument Delivery ISIS SOC Peer Review (Full SOC/MOC interoperability)
  - [CSCI-2] Have full L0 -> L1 codes operational based on test / calibration data
- (/2017) MOC comes on-line
  - [CSCI-1] Full end-end testing of test SOC to support I&T
  - [CSCI-1] Transitioning of test SOC to APL for I&T
  - [CSCI-2] Start on work with instrument teams to implement L1->L2 processing codes
  - [CSCI-3] Extend PAPCO PRBEM cdf module to fully support ISIS data
  - [CSCI-4] Implement initial ISIS web sever with DAS-2 using ancillary data (UNH GEO, etc)
- (/2017) Pre-Launch ISIS SOC Peer Review (lessons learned from I&T)
  - [CSCI-1] Transition from test SOC to full flight SOC
  - [CSCI-2] Start work on L3 processing codes (needs sample data from other SOCs)
- (/2018) Mission Simulation #3 fill "in the life" test
  - [CSCI-1] Final SOC adjustments, modification
  - [CSCI-2] Complete on work with instrument teams to implement L1->L2 processing codes using best currently available calibration information
  - [CSCI-2] Complete and implement L3 processing codes

Development Plan and Schedule (3/3)

  - [CSCI-2,4] Implement and test SOC-SDC Quality control loop
  - [CSCI-3] Test full PAPCO operability with existing L1, L2 test data
  - [CSCI-4] Have working version of ECT web site with L1 to L3 data and ancillary data
- (/2018) Launch [L]
  - L to L+60days – Instrument Commissioning. Real Time SOC operations via Portable SOC at APL
  - >L+60days - Nominal Phase E Operations. SOC ops transitioned to fixed SOC at UNH.
  - L+90days – Return Portable SOC to UNH as redundant backup unit
- (Phase E) – normal ISIS-SOC operations at UNH
  - [CSCI-2] refinement of calibration procedures in L1-L2 codes based on on-orbit performance
  - [CSCI-2] Implementation of L3 -> L4 processing codes
  - [CSCI-3] Addition of Level 4 data products
  - [CSCI-4] Addition of Level 4 data products
  - [CSCI-3] (PAPCO) implementation of addition feature request from instrument teams
  - [CSCI-4] (DAS-2) implementation of addition feature request from instrument teams
- (TBD) Archive Activities

Test Plan

- GSEOS & Commanding
  - Create commanding scenarios
  - Test connectivity to MOC
  - Interfaces to EPI-Hi and EPI-Lo
  - Test command load on Flat-Sat at UNH

- Data flow between facilities
  - Creation of faux telemetry stream
    - State-of-Health packets
    - Science Data
  - Test flow from MOC to SOC
  - Test creation of science data through level 1 from telemetry stream through pipeline

Current Status

- Partial components of ISIS SOC exist in the IBEX SOC
- ISIS SOC GSEOS systems to be constructed
  - J. Legere to start working with instrument teams
- Facilities for the ISIS SOC including the SOC room and secure server room in existence and ready for ISIS SOC servers

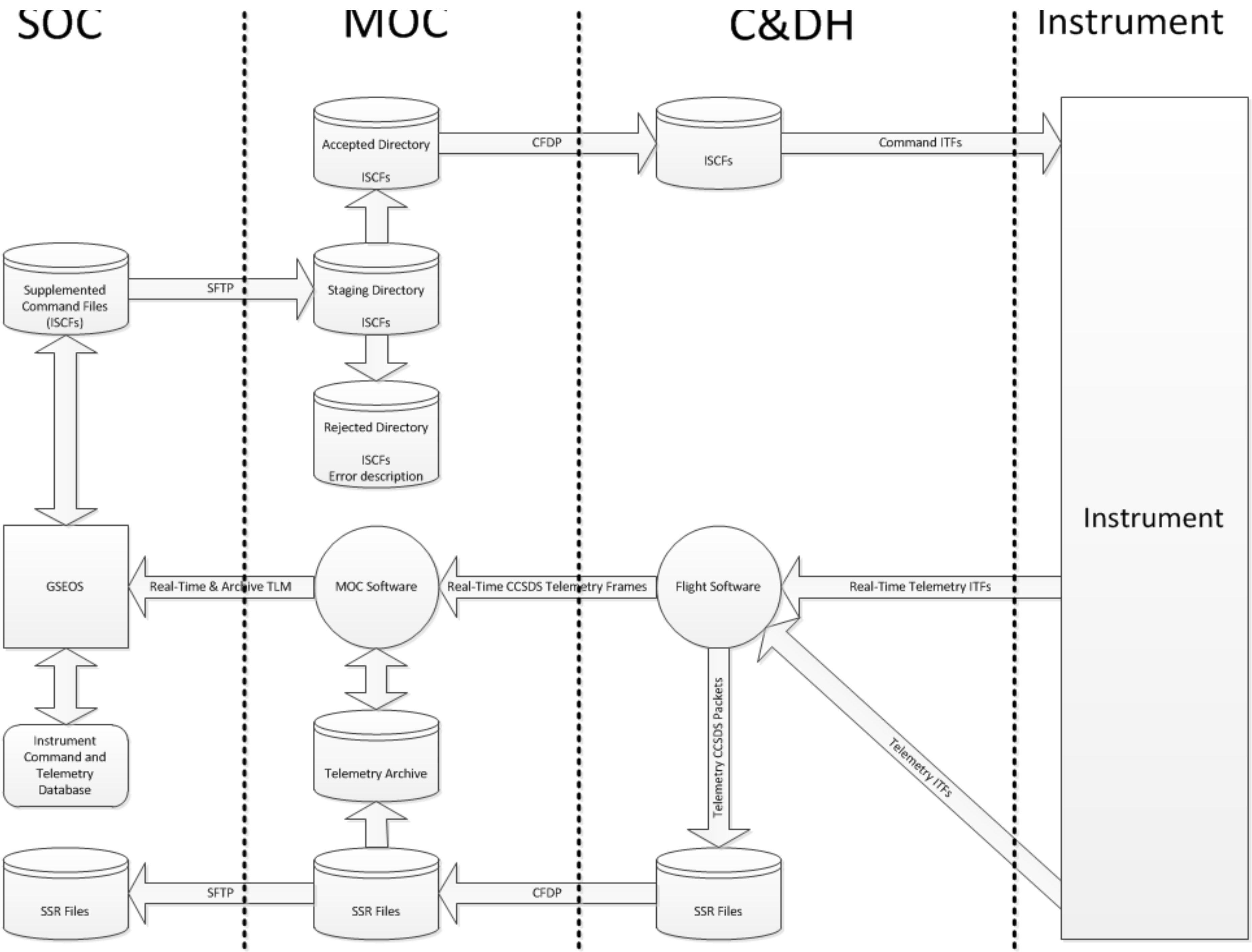
ISIS SOC is READY!

ISIS SOC team will support

→ Testing throughout Development

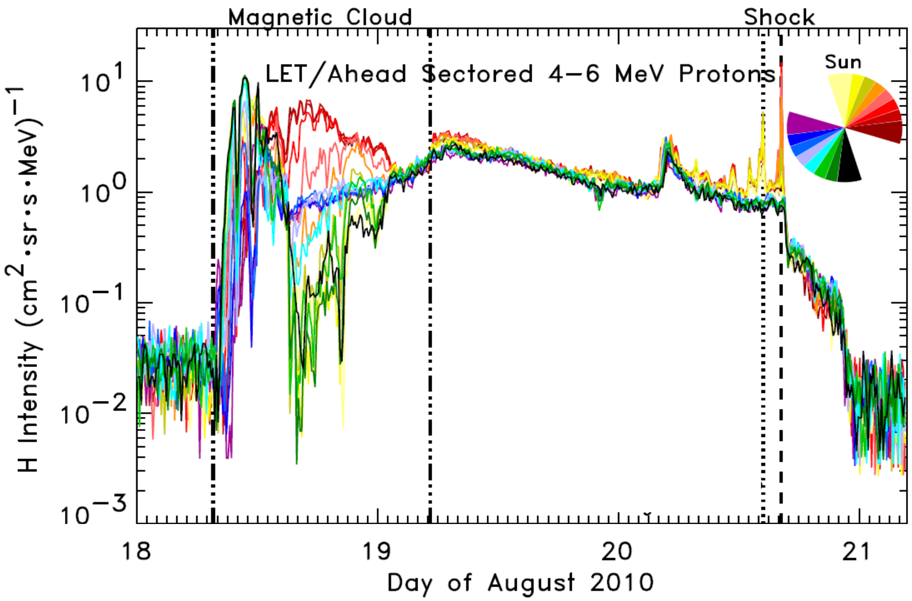
→ SPP Integration &Test

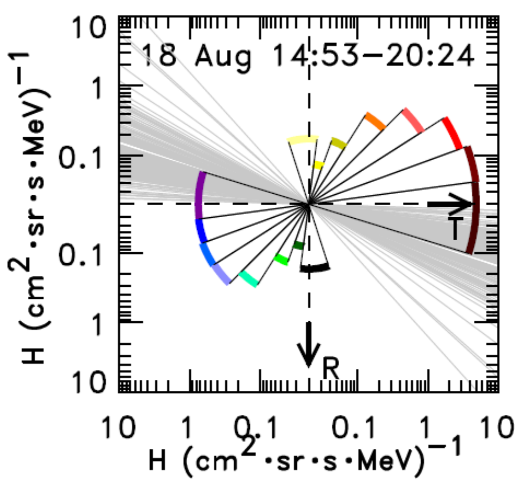
Additional Slides

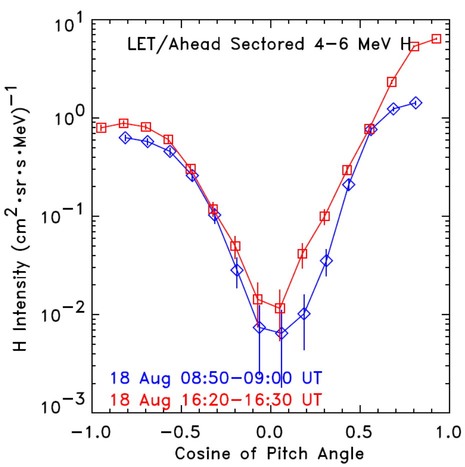

SOC
MOC
C&DH
Instrument
Accepted Directory
ISCFs
CFDP
ISCFs
Command ITFs
Supplemented Command Files (ISCFs)
SFTP
Staging Directory
ISCFs
Rejected Directory
ISCFs
Error description
Instrument
GSEOS
Real-Time & Archive TLM
MOC Software
Real-Time CCSDS Telemetry Frames
Flight Software
Real-Time Telemetry ITFs
Telemetry CCSDS Packets
Telemetry ITFs
Instrument Command and Telemetry Database
Telemetry Archive
SSR Files
SFTP
SSR Files
CFDP
SSR Files

STEREO Sees Enormous Proton Anisotropies in a Solar Energetic Particle Event

Solar Probe Plus
A NASA Mission to Touch the Sun





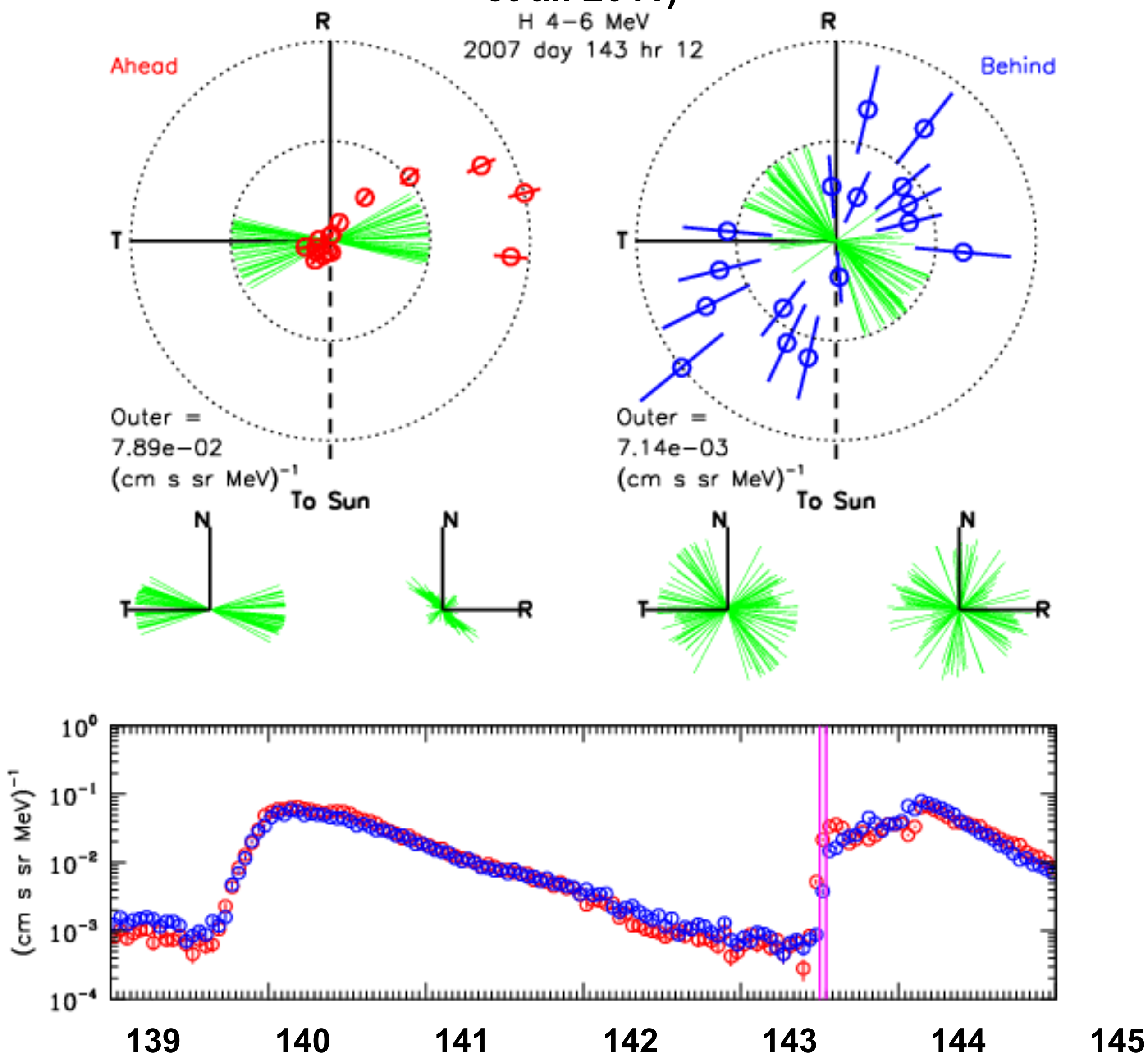


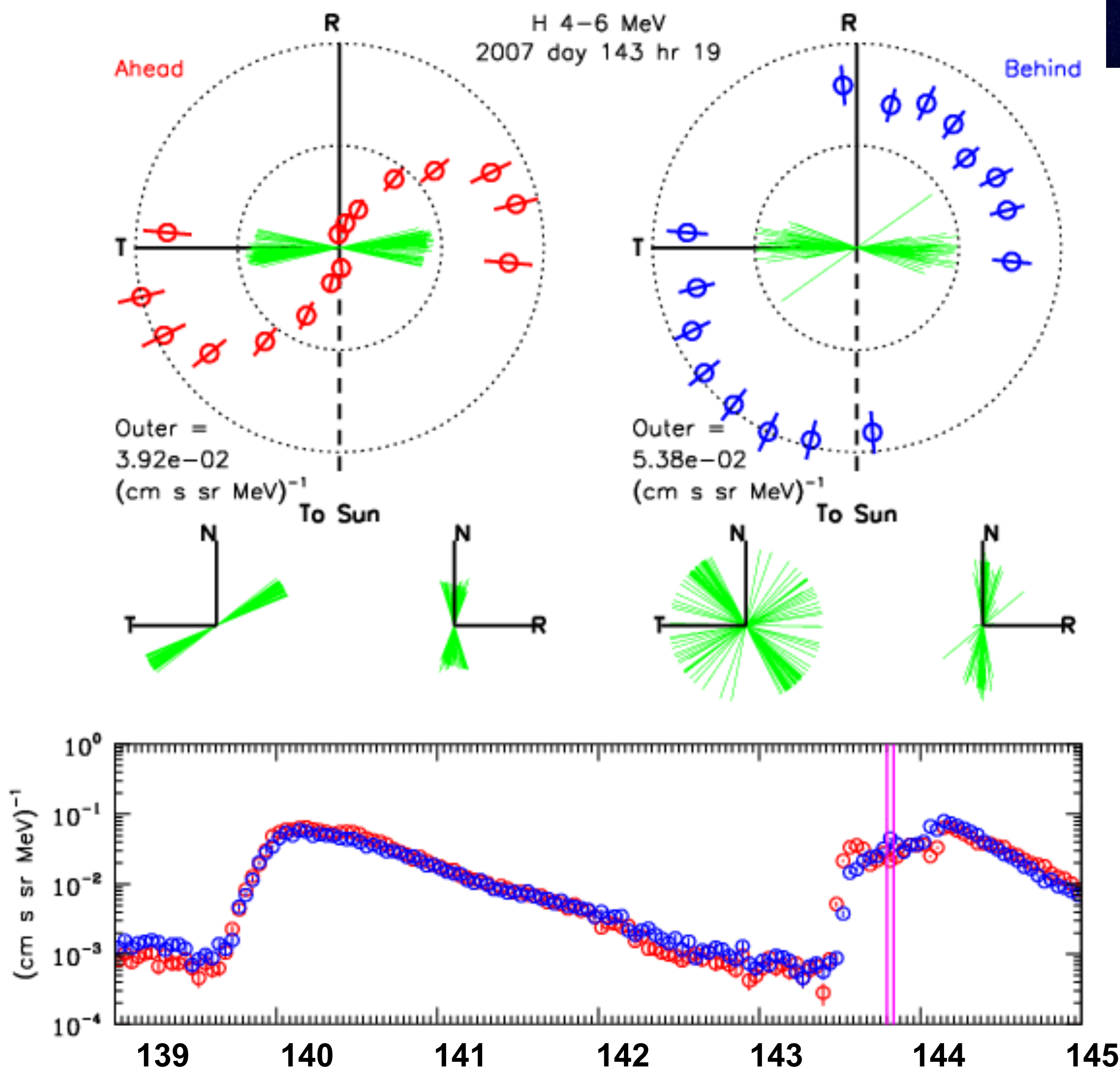
- Usually Solar Energetic Particles (SEPs) are mostly isotropic, with nearly equal intensities coming from all directions, although sometimes a "beam" of particles may appear for a few hours at the start of an event as particles stream outward from the Sun along magnetic field lines.
- The Low Energy Telescope (LET) onboard the twin Solar Terrestrial Relations Observatory (STEREO) spacecraft measures particle intensities in 16 viewing directions in the ecliptic (as illustrated by the color wheel in the top plot). During an SEP event on 18 August 2010, LET on STEREO-Ahead saw vastly different proton intensities in different directions, with intensities in some directions nearly 1000 times higher than those in others. These large anisotropies persisted for a long time, nearly 17 hours into the event.
- Particle intensities were highest along the magnetic field direction (shown by gray lines in the lower left plot) and lowest perpendicular to the field, and they traveled in both directions along the field (bottom two figures).

4 days earlier, the same solar active region produced a coronal mass ejection with a magnetic cloud, a structure of magnetic field lines twisted like a rope, with both footpoints anchored at the Sun. STEREO-Ahead was passing through this magnetic cloud when the 18 August event went off, sending particles down both legs of this conduit in a tight beam. The structure of the cloud caused the unusual distribution of particle intensities.

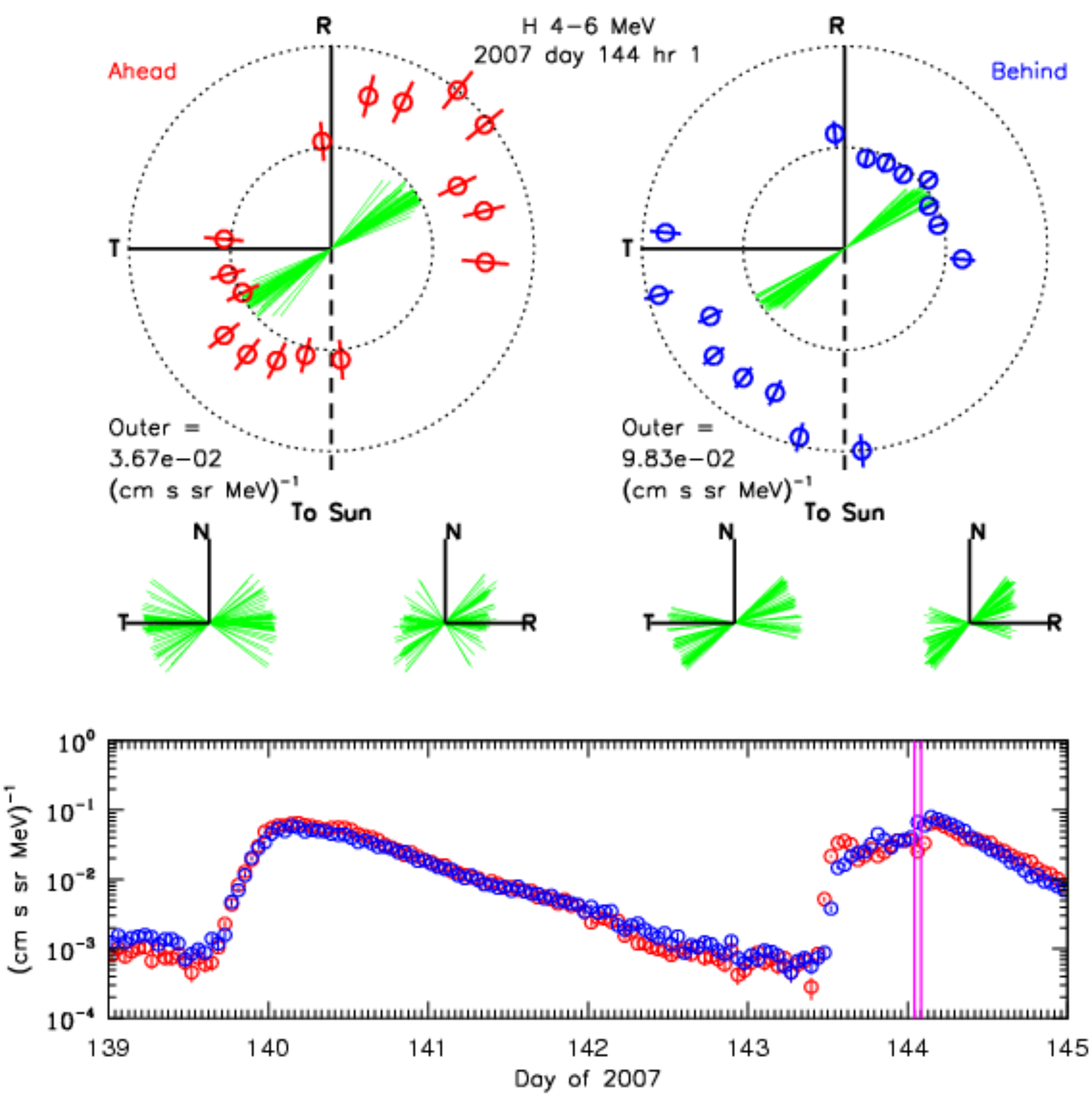
Figures from *Leske et al., Solar Physics*, 2012 (in press)

Pitch angle distributions from LET for the onset of the May 23 event (Alan Cummings makes movies of LET data using 1-hr averages. See 3 slides & Chollet et al. 2011)

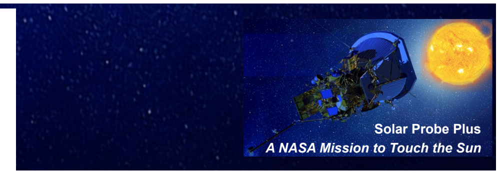




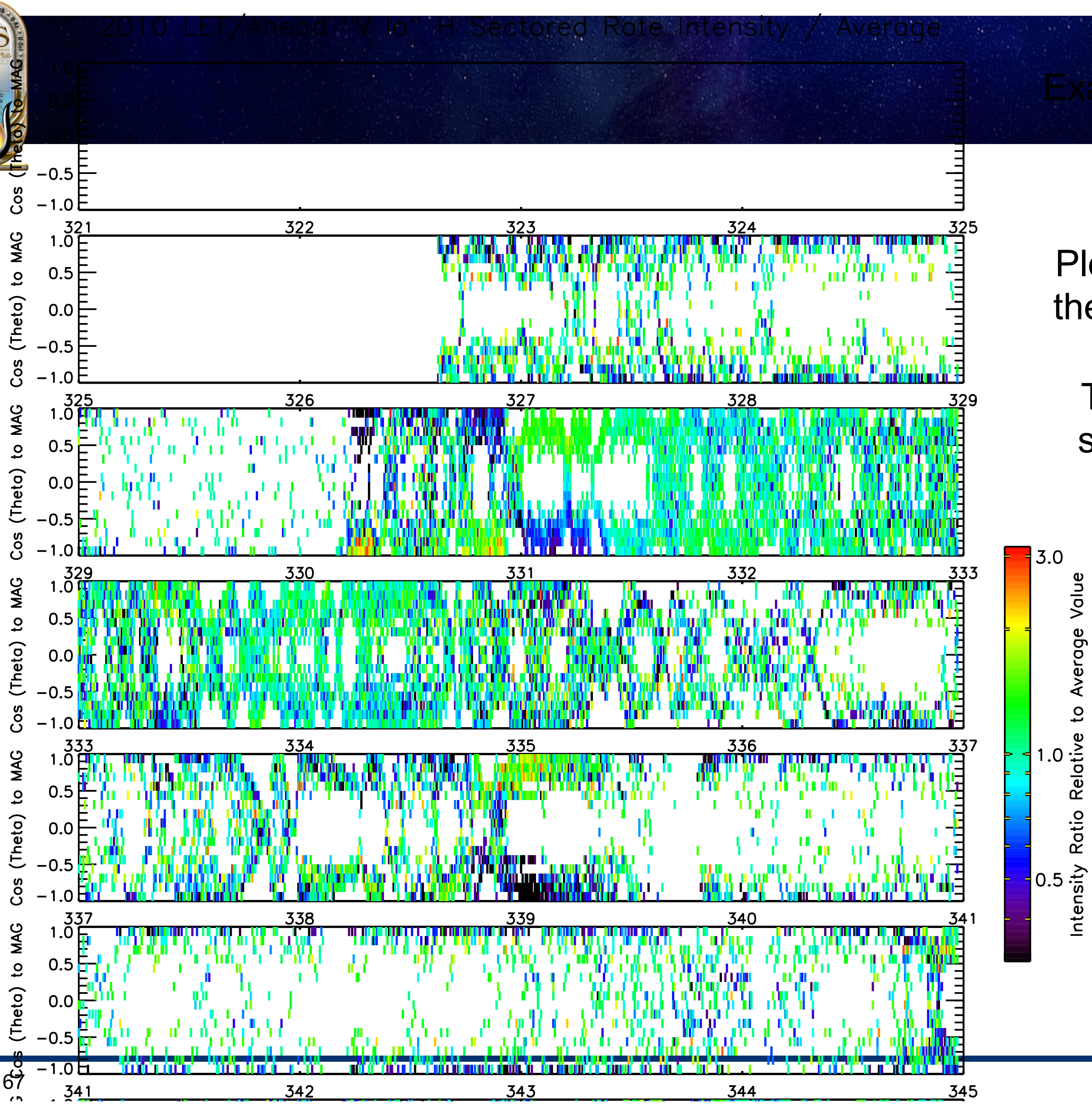
H 4–6 MeV
2007 day 143 hr 19
Ahead
Behind
R
T
To Sun
N
Outer =
3.92e–02
(cm s sr MeV)$^{-1}$
Outer =
5.38e–02
(cm s sr MeV)$^{-1}$
(cm s sr MeV)$^{-1}$
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
139
140
141
142
143
144
145



H 4–6 MeV
2007 day 144 hr 1
Ahead
Behind
R
T
Outer =
3.67e–02
(cm s sr MeV)$^{-1}$
9.83e–02
To Sun
N
R
T
(cm s sr MeV)$^{-1}$
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
139
140
141
142
143
144
145
Day of 2007



Solar Probe Plus
A NASA Mission to Touch the Sun



Example of display by Brandon Dotson

Plotted relative to the magnetic field

The horizontal scale is Day of 2010

LV and HV Checkout

- May be staggered, e.g., shift 1 EPI-Lo, shift 2 EPI-Hi, etc (IS THIS OK?)
- Both EPI-Lo and EPI-Hi require real-time commanding with simultaneous up/down linking and access to data during the initial turn-on
- EPI-Lo 3 days for LV and HV Checkout (approx. 1 track ~ 10 hours each)
  - Ideally consecutive/otherwise within a few days of one another
  - Day 1. LV checkout, including biasing SSDs.
  - Day 2. HV checkout 1. Initial ops and testing to low/intermediate voltage
  - Day 3. HV checkout 2. If no problems ramp to full voltage, gather engineering data
- EPI-Hi 2 days for LV and HV checkout (~4-6 hours each)
  - Day 1. Check engineering data, single-detector, and coincidence count rates and detector discriminator levels.   Most likely send commands to run diagnostic tests and possibly adjust thresholds if there are noisy detectors.
  - Day 2 can either be consecutive or a few days later.   Will also want real time data and ability to send commands to adjust discriminator levels based on data from Day 1. Could possibly upload revised tables.

Commanding in First 2 Months

- Based on STEREO experience EPI-HI will require 10-20 opportunities (on separate days) to send a few commands in the first two months
  - Necessary to obtain/analyze at least a few hours of new data in between command opportunities to test whether the commands worked
  - Therefore, we need to collect data between commanding opportunities

Nominal Operations

- R<0.25 AU
  - Full nominal power
  - High data collection rate and burst mode
- 0.25< R<0.76 AU
  - Full power when not downlinking
  - Full power or low-power mode when downlinking
  - Reduced data collection rate
  - A commanding window should be scheduled late in the series of telemetry passes, although it may not be used every orbit.
- R > 0.76 AU
  - Full or low-power mode
  - Reduced data collection rate

Prelim Data Downlink Requirements

	Perihelion (<0.25 AU)	Cruise (>0.25 AU)
I-EPI-Hi (rate)	3.2 kbps	60.5 bps
I-EPI-Hi (total)	3.2 Gbit/orbit	0.7 Gbit/orbit
I-EPI-Lo (rate)	12.6 kbps	225.4 bps
I-EPI-Lo (burst)	51.7 kbps	200 kbits/orbit
I-EPI-Lo (total)	12.7 Gbit/orbit	2.7 Gbit/orbit

Prior to Second Encounter

- Once telemetry from the first encounter starts, the high-priority Status-Summary file is sent down first to permit health and safety monitoring
- Bulk of EPI-Hi science data will be in lower-priority files that will be sent down as down-link permits.
- Inevitable need for commanding opportunities to adjust on-board analysis system, fine-tune thresholds, repeat diagnostic tests, late in series of telemetry passes.

Content Guidelines for the Definition of the ISIS Con Ops

1. Instrument deployment requirements, if any - Where in timeline?

   -Requirements on spacecraft during deployment

2. Instrument check-out requirements

   duration, power, data, command opportunities

3. Requirements prior to Solar Encounter
4. Solar Encounter ops scenario(s)
5. Data downlink requirements, downlink preview data/selected data
6. Special operations requirements (such as software loads, memory refreshes, etc.)

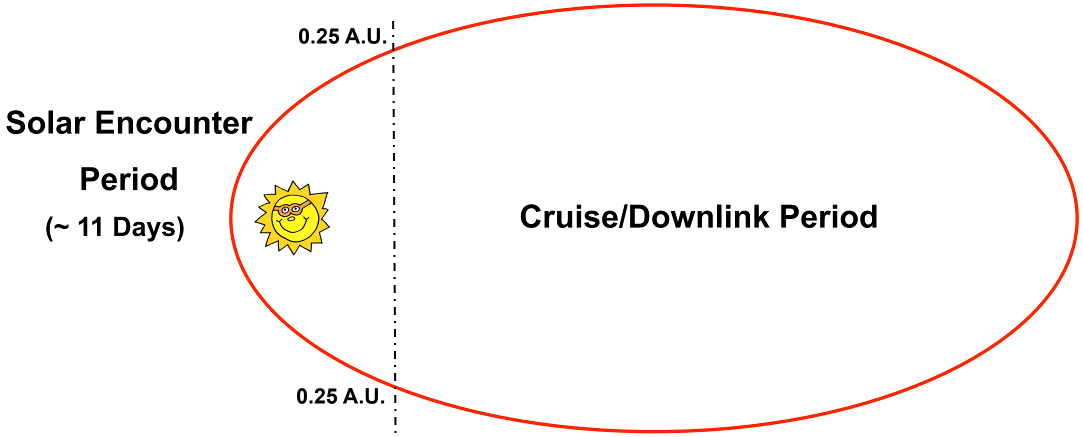
Operations Concept Drivers

- No requirement to change spacecraft attitude during solar encounter science operations
  - Enables decoupled spacecraft & payload operations

- Sufficient power for all instruments during solar encounter phase
  - No duty cycle requirements on instruments
  - Enables decoupled spacecraft & payload operations

- 7 Venus fly-bys and multiple TCMs
  - Requires mission design & navigation team interfaces
  - Requires detailed maneuver planning & execution process
  - No payload operations during Fly-Bys

Orbital Operations Planning Concept



24 Solar Encounter Orbits

Orbital Periods Vary (169 days to 88 days)

Solar Encounter Period

Encounter Phase

- Primary science data collection phase – All instruments can be powered on
- LGA periodically available for communications & Nav
- Real-time commanding supported but not nominally planned

Cruise/Downlink Period

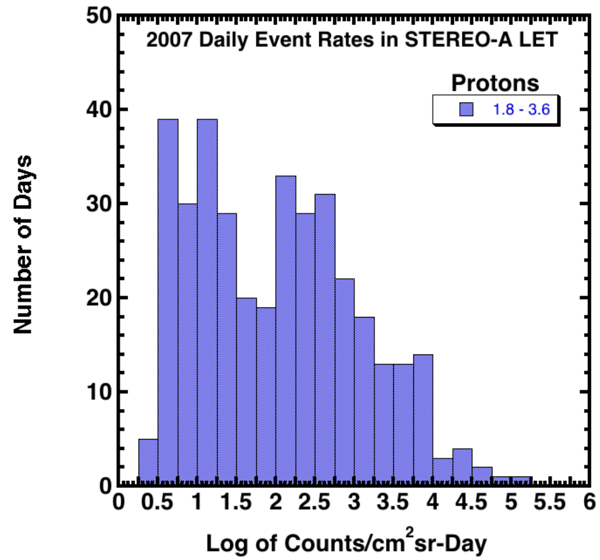
Cruise Phase

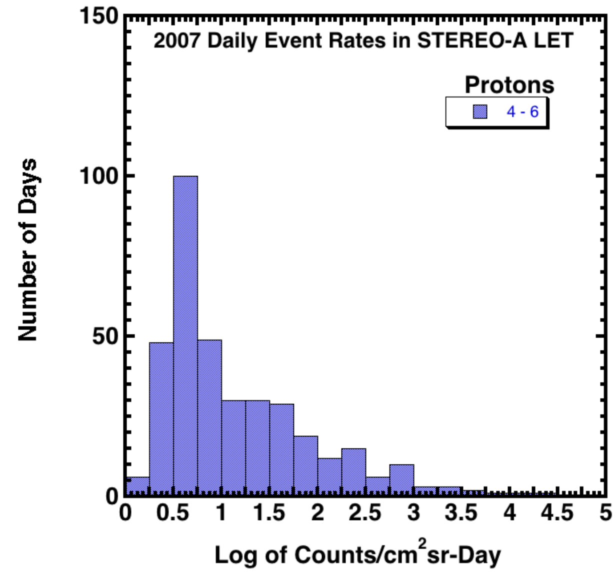
- All instruments nominally powered off
- LGA for communications – H/K data only
- Commanding as needed to support spacecraft maintenance
- Instrument commanding for next encounter

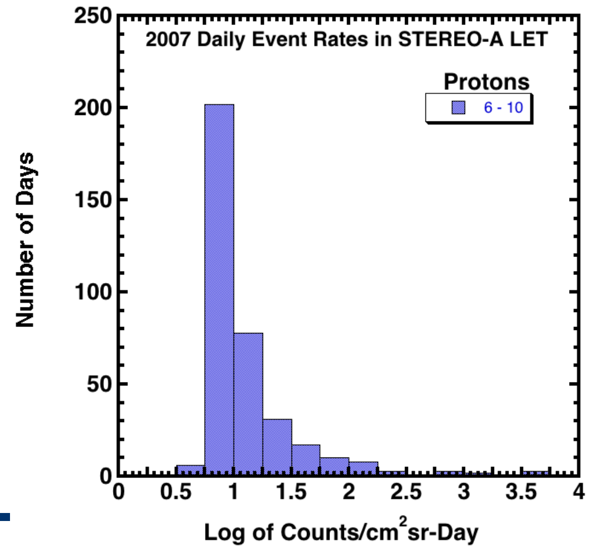
Science Downlink Phase

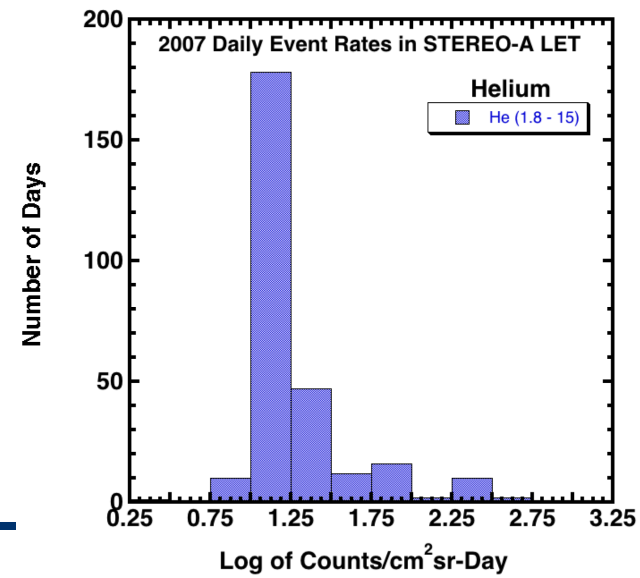
- All instruments nominally powered off
- HGA for communications – SSR playbacks
- Commanding as needed to support spacecraft maintenance

Examples of Daily event Rates based on 2007 STEREO Data (higher H and He rates mostly in CIR events and 2 small SEP events)

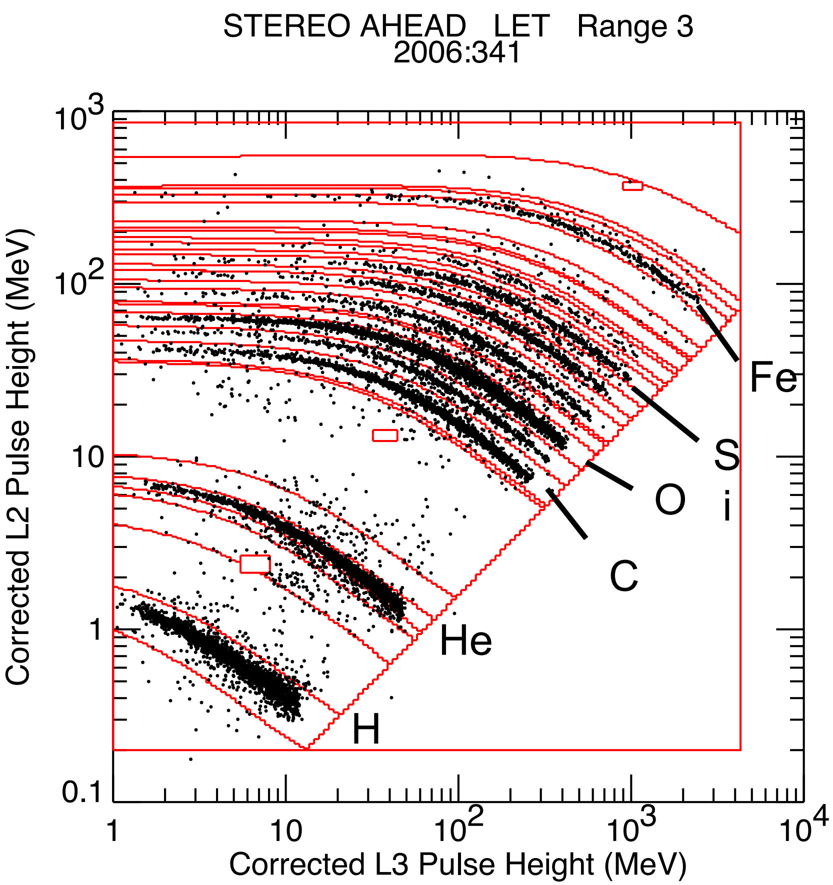








Calibration

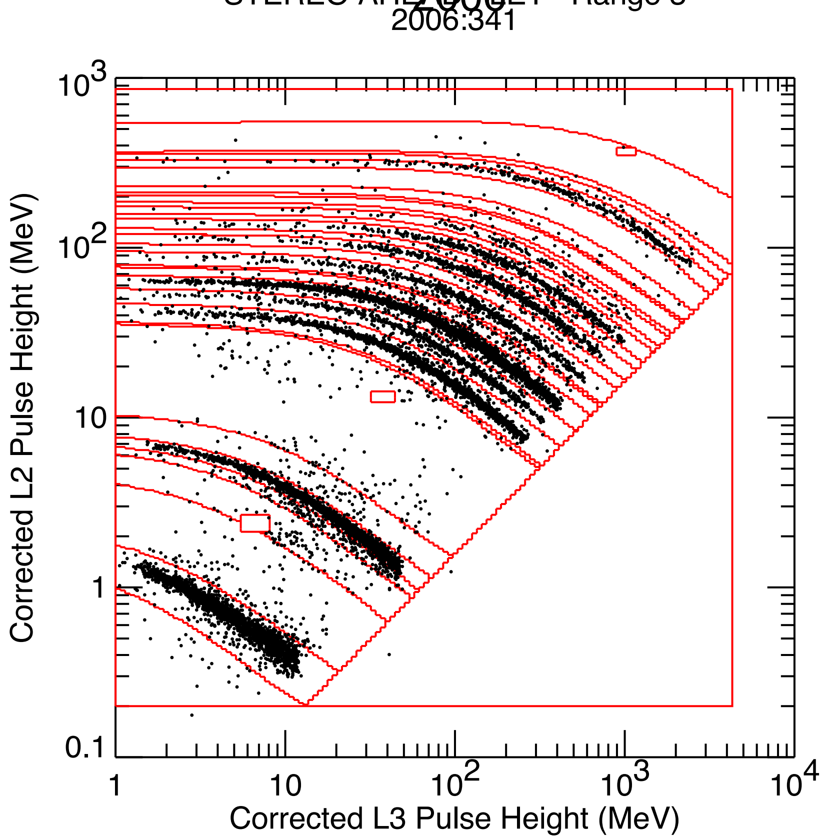


- the main data product from EPI-Hi consists of count rates as a function of species, energy, look direction, and time
- species are determined from plots such as the one shown in the figure
- each point on the plot derived from the measurement of a single energetic particle
- black tracks correspond to different chemical elements
- red lines defining boundaries between tracks are derived from a combination of calculations and corrections based on pre-flight accelerator test data
- the locations of the species boxes must by checked (and possibly adjusted) in flight
- without this adjustment the count rate data can be seriously compromised
- once the box locations have been correctly set they should be stable for years

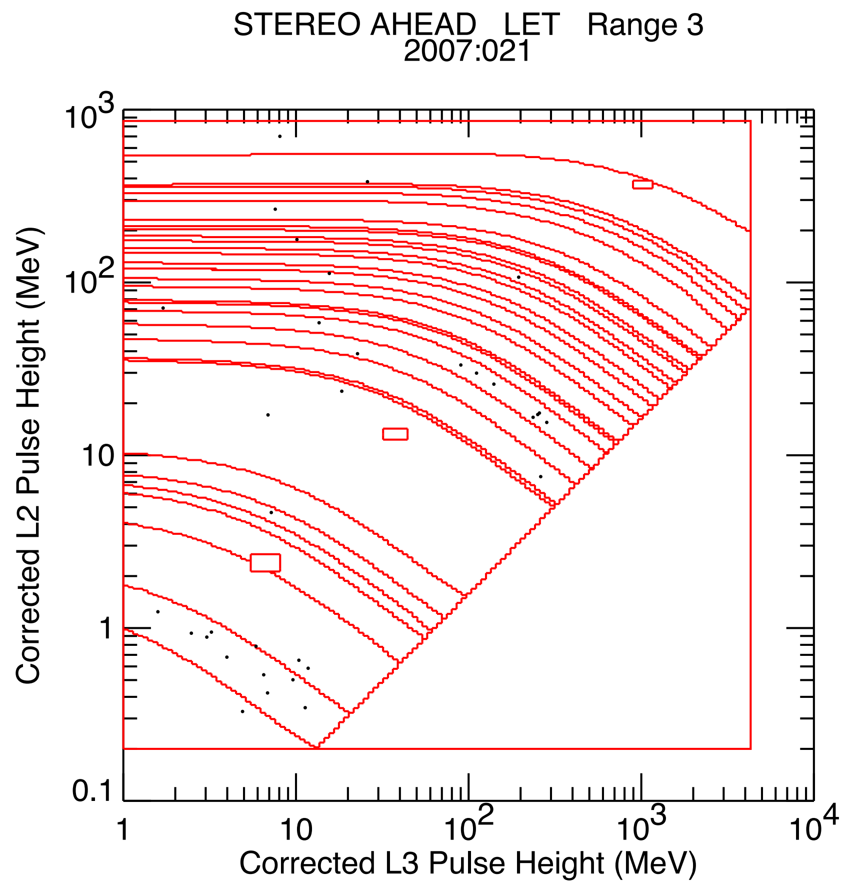
Calibration

Solar Probe Plus
A NASA Mission to Touch the Sun

One active day in December 2006



One quiet day in January 2007



- one active day of data can be sufficient for calibrating the locations of the tracks of all major elements
- data from a quiet day can give a good indication of the location of the proton track, but data are too sparse to calibrate tracks for most heavier elements

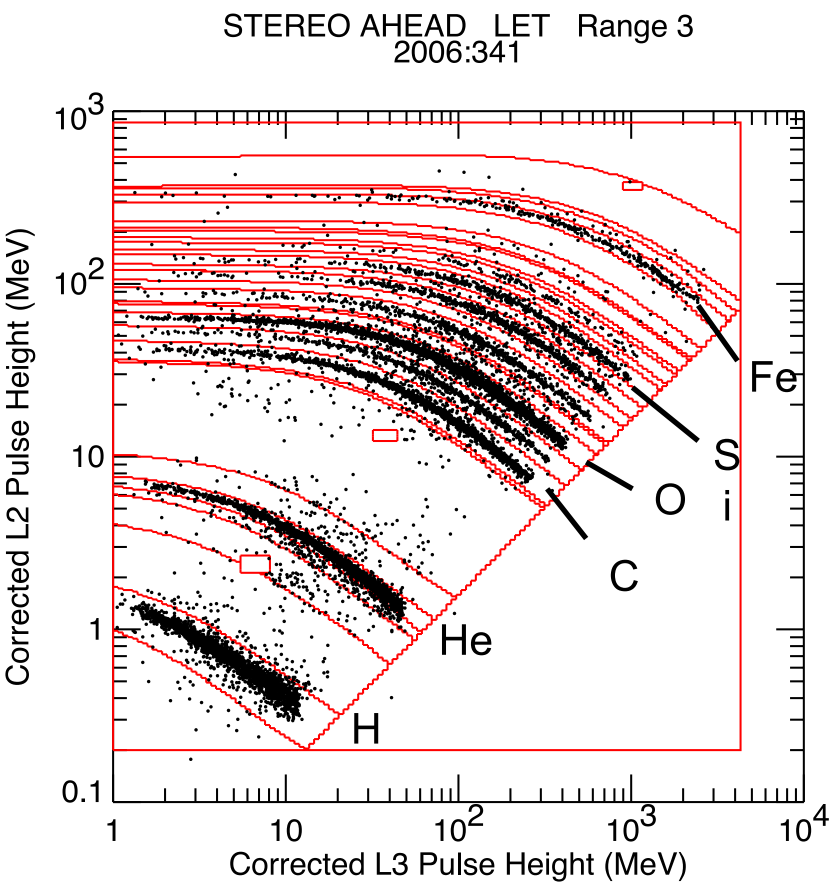
Proposed In-Flight Calibration Plan for EPI-Hi

Solar Probe Plus
A NASA Mission to Touch the Sun

in-flight calibration should be done after instrument commissioning has been completed; at that time detector thresholds will have been correctly set and basic functionality of the instrument will be have been checked

- in-flight calibration should take place as early as possible, preferably with enough time before first perihelion pass to allow evaluation of calibration data and adjustment of instrument parameters before the pass
- one day of data, even under quiet conditions, will be useful for allow checking the proton track location
- checking the location of heavy element tracks will require either a day of data taken during a significant solar energetic particle (SEP) event or an extended period of data collection under quieter conditions
  - large SEP events events could be rare in 2018 (near solar minimum) and their occurrence can not be reliably predicted
- need to have enough flexibility in scheduling so that a day of data accumulation can be scheduled with no more than 1 to 2 days notice when an active period does occur
- it is possible that no suitably-active period will occur before the first perihelion pass; in this case our best guess at species box locations will be used and calibration will be required during the first orbit that has significant activity

In-Flight Calibration Plan for EPI-Hi – Continued



in boxes we need to downlink a large sample of individual pha events containing the detailed information from which the black points on the plot are derived

- during normal operation (not calibration), only a small subset of the pha events are transmitted to the ground, thereby maintaining a modest a EPI-Hi telemetry allocation
- an average pha event consists of approximately 100 bits
- to calibrate species boxes for all of the EPI-Hi telescopes and energy ranges will require~10^6 pha events acquired during a relatively large SEP event (the plot at the left contains ~15,000 data points), thus ~100 Mb of downlinked pha data
- EPI-Hi will provide a mode for collecting pha events for transmission to the spacecraft at a higher than the normal bit rate in order to efficiently collect these data

Telemetry volumes

- Up to 125 Gbits collected each orbit
  - Assumes 11.6 days near perihelion
  - 138 .5 days in cruise phase

	Perihelion (<0.25 AU)	Cruise (>0.25 AU)
I-EPI-Hi (rate)	3.2 kbps	60.5 bps
I-EPI-Hi (total)	3.2 Gbit/orbit	0.7 Gbit/orbit
I-EPI-Lo (rate)	12.6 kbps	225.4 bps
I-EPI-Lo (burst)	51.7 kbps	
I-EPI-Lo (total)	12.7 Gbit/orbit	2.7 Gbit/orbit

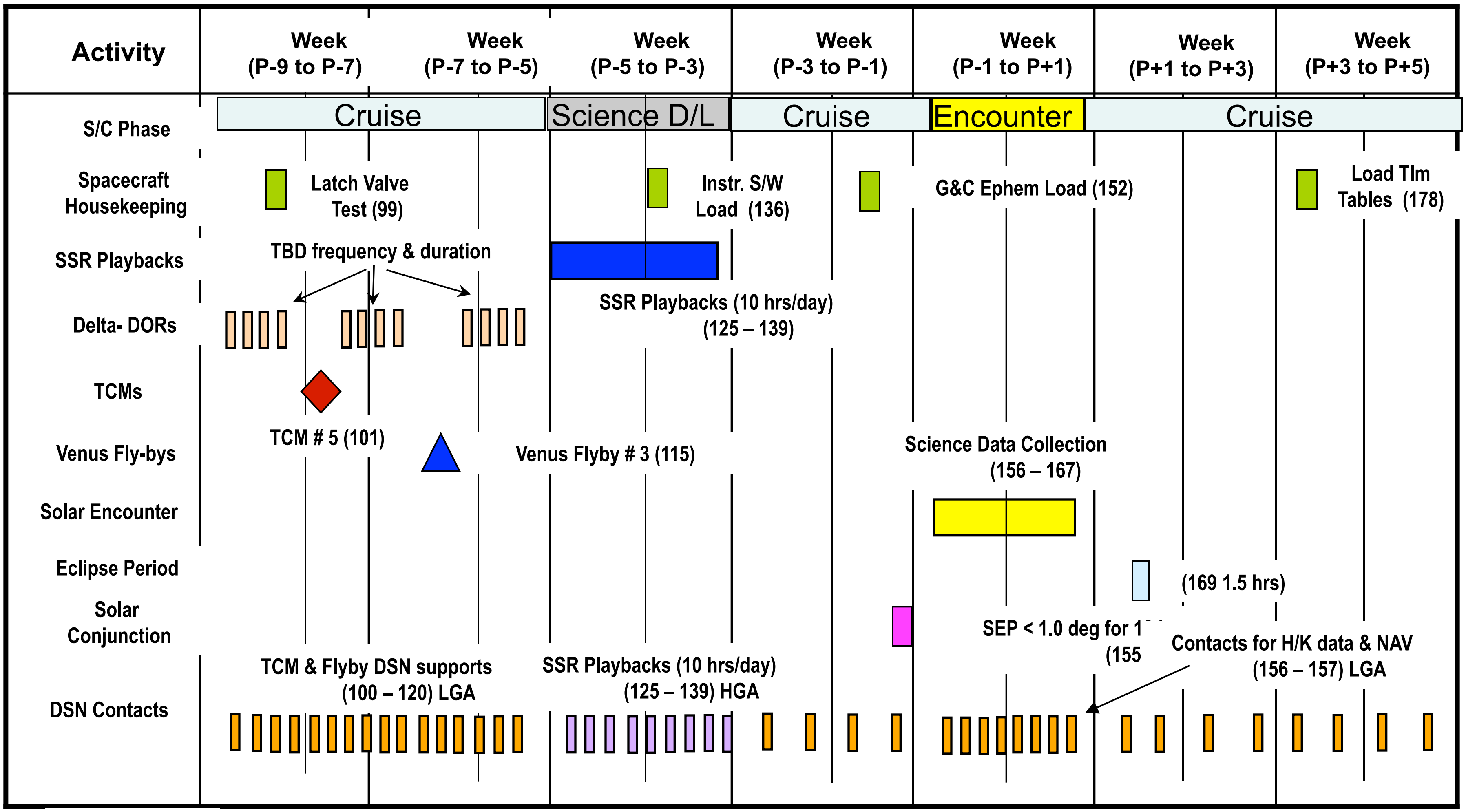
Orbit Planning Activities

- Detailed operations planning performed for each orbit
  - 24 total orbits (Orbital period varies between 169 - 88 days)

- Key operations planning required for each orbit include:
  - Venus Fly-By Events
  - TCMs
  - Spacecraft Slews
  - HGA downlink opportunities
    - High priority downlink periods each orbit
    - Dictates SSR management scheme
    - Slews will be required for some downlinks
  - Spacecraft housekeeping & maintenance activities
    - Flight software loads   Command Sequence Uplinks
    - Autonomy loads   Parameter maintenance
    - Special sub-system and/or payload tests
  - Eclipse & solar conjunction periods
  - Doppler range & Delta-DOR tracking requirements
  - Solar encounter operations (POCs)

- Orbital operations template created to capture and schedule these activities

Orbital Operations Template



P = Perihelion

Note – Numbers in parentheses denote DOY for illustrative purposes only

Decoupled Payload Operations

- Heritage on TIMED, STEREO and planned for RBSP
- Instruments operate independently of S/C bus operations and each other
- Nominally all instruments are powered ON for this approach
  - Enough power to operate all instruments simultaneously during entire solar encounter
  - Outside of solar encounter may not have enough power to operate all instruments simultaneously
- No requirement to change spacecraft attitude during normal instrument operations
  - Except for periodic calibrations?
- Instrument POCs operate their instrument (plan, cmd, assess)
  - Instrument POCs forward commands to MOC independent of station contact times; commands are stored in a POC Queue; Queue is opened during station contact and commands are transmitted to S/C.

Decoupled Payload Operations

- S/C bus controls power switching to the instrument's main power
- Instruments cannot command the S/C bus (i.e. cannot control S/C Attitude or Power switching)
- Mission Operations Team (MOT) operates the S/C bus and controls power status of Instruments – normally always ON
- Mission Operations Center (MOC) monitors detailed Health and Status of the Spacecraft Bus through "alarms"
- Each Instrument POC is responsible for monitoring their own instrument's health and safety
  - MOC monitors high-level instrument Health and Status
    - Current draw from bus
    - Temp sensors from S/C bus

Questions from the MOC

- What is needed during commissioning?
- Before 0.25 AU do we *require* data?
- What do we need before 0.25 AU?
- How do we want to split out the three available files?
  - Status/Summary
  - Nominal mode data
  - Burst Data
- Note that we will have up to 3 files, and may have different APIDs within each file

Additional Questions

- Will not have much time before solar passes (<0.25 AU)
  - Two levels of changes
    - Changes to upload prior to next solar pass
    - Changes to upload prior to (next solar pass + 1)
- ~Daily snapshots (or on some cadence)
  - This would allow us to get down and analyze data covering the solar pass quickly to assess what changes will be needed in the next solar pass

Data Products (2/3)

Data Level	Product Title	Contents	Volume	Format	Latency	Frequency
L1	Science Rates	Uncalibrated instrument science rates at highest resolution	~170 Mbytes/ day	ASCII, CDF	60 days (TBR)	TBR
L1	Engineering Data	Uncalibrated instrument engineering rates at highest resolution, HK data, Cmd-responses.	~15 Mbytes/ day	ASCII, CDF	60 days (TBR)	TBR
L1	Event Data	Raw event data, unpacked into data structures, but otherwise unprocessed.	~100 Mbytes/ day	TBR	60 days (TBR)	TBR
L2	Hi-res Particle Intensities	Calibrated electron, proton, and heavy-ion particle intensities at highest time, energy, and look-direction resolution, in physical units. See L4 Instrument Requirements Doc for details.	~170 Mbytes/ day	ASCII, CDF	60 days (TBR)	TBR

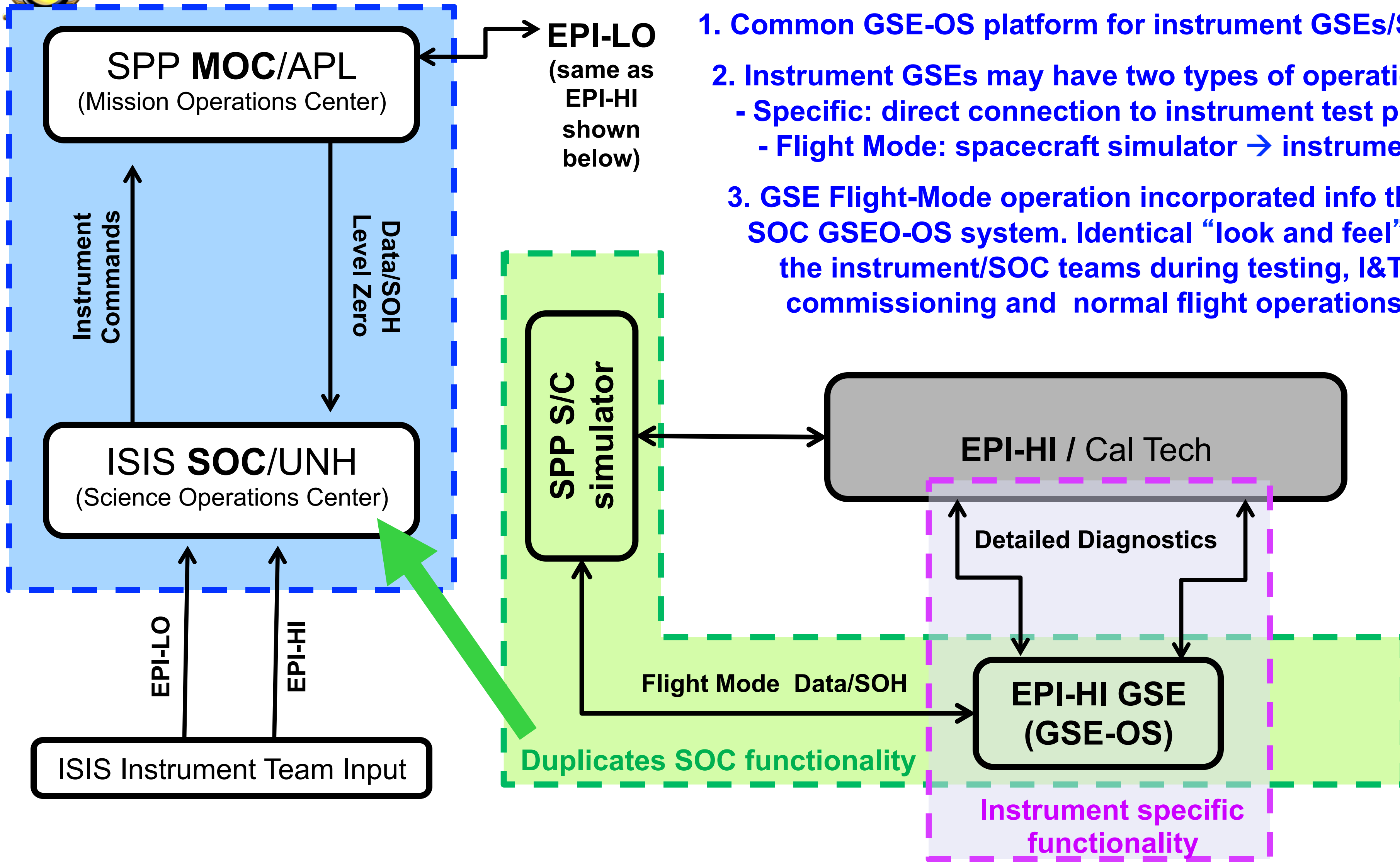
Data Products (3/3)

Data Level	Product Title	Contents	Volume	Format	Latency	Frequency
L3	Averaged Particle Intensities	Calibrated electron, proton, and heavy-ion particle intensities averaged into (TBD) appropriate sets of larger time, energy and look-direction bins, in physical units. These products are derived from the Hi-res Particle Intensities.	~120 Mbytes/ day	ASCII, CDF	60 days (TBR)	TBR
L4	Derived Data Products	Particle spectra and fluences for specific events and/or periods. Particle anisotropy parameters/plots. Others TBR	TBR	TBR	TBR	TBR

BACKUP

ISIS Science Operations Center Description: “Test as you Fly, Fly as you Test”

1. Common GSE-OS platform for instrument GSEs/SOC
2. Instrument GSEs may have two types of operation:
   - Specific: direct connection to instrument test ports
   - Flight Mode: spacecraft simulator → instrument
3. GSE Flight-Mode operation incorporated info the SOC GSEO-OS system. Identical “look and feel” to the instrument/SOC teams during testing, I&T, commissioning and normal flight operations



Command-Load Sizes

- EPI-Lo
  - Command lengths vary.
    - For example to set a HV level would require five bytes.
    - Table loads would need much more space, typically 256 bytes
- EPI-Hi
  - Instrument commands are variable in size.
    - Routine instrument commands are generally 10 - 100 bytes.
    - Flt software patches can be hundreds of bytes.
    - Flt software binary upload would be thousands of bytes.
  - For the longer commands and table uploads, we generally break the upload into a sequence of separate commands designed to fit into the size of the CCSDS telecommand packet defined in the MOC-SOC ICD.
  - During the definition of the MOC-SOC ICD, we work with the MOC and SOC to ensure that the sequencing of these multi-packet uploads can be properly orchestrated, with appropriate hand-shaking, etc.

Number of commands in an orbit

- EPI-Lo
  - Plan to be in one mode throughout encounter (< 0.25 AU), so there should be few to none.
  - Still the possibility that we might want to use a super-high rate "burst mode" during intervals within 0.25 AU, but ideally that would require only a macro to be fired to set the new mode and another macro to return to the old mode. Maybe a few bytes for each operation.
  - More commands during cruise as we power on/off and into various modes.
  - Many commands during commissioning.
- EPI-Hi
  - We do not yet know

ISIS Macros

- EPI-Lo
  - Macro capability and plans to use it
- EPI-Hi
  - Macro capability
  - Mix of macros and “raw commands”

Commissioning

- At least once during the instrument commissioning period, and perhaps occasionally afterwards, ISIS will need to collect a large quantity of raw event data (e.g., Pulse Height Analysis measurements) during a sizable SEP event outside 0.25 AU. Obtaining high quality ion composition is one of the prime reasons for this need.
- **EPI-Hi Commissioning several days**
- **EPI-Lo Commissions 7 days**

EPI-Lo Commissioning

- **EPI-Lo Commissioning**
- **EPI-Lo Post-Launch Operations**
- From launch to mission day ≥14.
- - EPI-Lo remains off except for decontamination heaters (or elevated temperatures using S/W controlled S/C heaters)
- **EPI-Lo Power On and Checkout**
- From mission day ≥14 to EPI-Lo checkout day 7
- - Day 1: LV checkout, turn HV on to low levels (e.g. MCP=400V)
- - Day 3: Bring HV to intermediate (e.g. MCP=1600V)
- - Day 5: Bring HV to barely operational (e.g. MCP=1800V)
- - Day 7: Bring HV to operational (e.g. MCP=2000V)
- Notes
- 1. Other checkout activities may be run in parallel with EPI-Lo HV ramp up.
- 2. All HV ramp up should be done with real time visibility, although HV can remain up between passes (off track).
- 3. Before continuing HV ramp up each day, the data from the previous "night" should be downloaded and reviewed for signs of trouble.
- 4. It might be possible to conduct these four days of checkout on consecutive days, but this is not preferred.
- 5. We must delay HV ramp up until after primary deployments are completed, as these can generate contamination

Calibration Science Mode

- Calibration Science mode is a mode during which statistically significant samples of Pulse Height Analysis (PHA) event data will be accumulated and returned to validate onboard assignments of species, energy, and incidence angle, and for assessing instrument backgrounds. ISIS requests that this mode be activated outside 0.25 AU by command one or more times early in the mission when and if sufficiently high intensities of solar energetic particles are present for calibration purposes. This mode, which will be used for a few days after activation of the mode, will require the return of a data volume significantly greater than that provided by the Low-rate Science Mode but will be maintained within the ISIS data-per-orbit allocation. The details of implementing this mode are TBD.
- Safe mode is a mode where the instrument sits in a ``quiet'' state, awaiting commands from the ground, performing no data acquisition functions. This mode is reserved for instrument I&T, commissioning, and instances where the flight software encounters some irrecoverable fault (TBD).
- The modes provided here are quite high level and many additional modes will be defined in the future. Many of these modes will be specific to EPI-Hi and to EPI-Lo. Detailed operation and specification of the mission, spacecraft, and ground systems will influence the modes of the instruments. It is possible that some “modes” rather than strictly being distinct instrument configured modes could be modes of operation.
- EPI-Lo has limited storage capacity, while EPI-Hi has none (apart from buffering in RAM). Except for a small amount of EPI-Lo burst data, all engineering and science data are almost immediately sent over to s/c.

OLD – no to use ..

"Do you store the commands inside your instrument and operate on them using the command timing or do you expect the

- EPI-Lo
  - Expect the S/C to send commands at the proper times
  - Have the capability to load a macro that can then wait for a specific MET to execute a command.
  - If command-space is at a premium during particular phases we could utilize this capability by loading a macro during another phase, alleviating the need for the s/c to command us at the busy time.
- EPI-Hi
  - Expect the spacecraft to send the commands to our instrument at the proper time.
  - If we have to implement our own command-storage and timing, it would be an extra instrument Flt software development task, perhaps several days to ~1week of work.