IMPACT (In-situ Measurements of Particles and CME Transients)

Instrument Overview

- **Boom Suite:**
  - Solar Wind Electron Analyzer (SWEA)
  - Suprathermal Electron Telescope (STE)
  - Magnetometer (MAG)

- **Solar Energetic Particles Package (SEP):**
  - Suprathermal Ion Telescope (SIT)
  - Solar Electron and Proton Telescope (SEPT)
  - Low Energy telescope (LET)
  - High Energy Telescope (HET)
IMPACT Team Member Institutions and Primary Roles

- University of California, Berkeley-Space Sciences Laboratory (IMPACT Management, SWEA, STE, IDPU)
- NASA Goddard Space Flight Center (MAG, SEP-LET, HET)
- California Institute of Technology (SEP-LET, HET)
- University of Maryland (SEP-SIT)
- University of Kiel (SEP-SEPT)
- Centre d'Etude Spatiale des Rayonnements CESR (SWEA)
- Los Alamos National Laboratory (Science Integration, SEP-SIT)
- Max Planck Institut fur Aeronomie (SEP-SIT)
- Jet Propulsion Laboratory (SEP-LET, HET)
- ESTEC-European Space Agency (SEP-SEPT)
- DESPA Observatoire de Paris-Meudon (SWAVES/IMPACT coordination)
- University of California, Los Angeles (MAG, IMPACT Data Web)
- SAIC-Science Applications International Corporation (IMPACT Modeling)
- NOAA Space Environment Center (IMPACT Modeling, Space Weather Applications)
- University of Michigan (IMPACT Modeling)
- KFKI-Hungarian Research Institute for Particle and Nuclear Physics (SEP Modeling)
IMPACT Electrons and Solar Energetic Particles (SEP)

(WIND data from Larson et al., 1996)

...aim for electrons is energy range, directionality, for SEP ions, also composition.

(adapted from the ACE science center news letters
figure by Mewaldt, Gloeckler and Mason)
## IMPACT Measurement Summary

### IMPACT Science Summary

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Instrument</th>
<th>Measurement</th>
<th>Energy or Mag. field range</th>
<th>Time Res.</th>
<th>Beacon Time Res. (*)</th>
<th>Instrument provider</th>
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</thead>
<tbody>
<tr>
<td>SW</td>
<td>STE</td>
<td>Electron flux and anisotropy</td>
<td>2-100 keV</td>
<td>16 s</td>
<td>2D x 3E, 60s</td>
<td>UCB (Lin)</td>
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<tr>
<td>SWEA</td>
<td></td>
<td>3D electron distrib., core &amp; halo distrib., temp. &amp; anisotropy</td>
<td>~0-3 keV</td>
<td>3D=1 min</td>
<td>Moments, 60s</td>
<td>CESR (Sauvaud) + UCB (Lin)</td>
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<tr>
<td>MAG</td>
<td>MAG</td>
<td>Vector field, ±500nT, ±65536 nT</td>
<td>1/4 s</td>
<td>60s</td>
<td></td>
<td>GSFC (Acuna)</td>
</tr>
<tr>
<td>SEP</td>
<td>SIT</td>
<td>He to Fe ions</td>
<td>0.03-2 MeV/nuc</td>
<td>30 s</td>
<td>3S x 2E, 60s</td>
<td>U. of Md. (Mason) + MPAE (Korth) + GSFC (von Rosenvinge)</td>
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<tr>
<td></td>
<td></td>
<td>He</td>
<td>0.15-0.25 MeV/nuc</td>
<td>30 s</td>
<td></td>
<td></td>
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<tr>
<td>SEPT</td>
<td></td>
<td>Diff. electron flux</td>
<td>20-400 keV</td>
<td>1 min</td>
<td>3E, 60s</td>
<td>U. of Kiel (Mueller-Mellin) + ESTEC (Sanderson)</td>
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<tr>
<td></td>
<td></td>
<td>Diff. proton flux</td>
<td>20-7000 keV</td>
<td>1 min</td>
<td>3E, 60s</td>
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<td></td>
<td></td>
<td>Anisotropies of e,p</td>
<td>As above</td>
<td>15 min</td>
<td></td>
<td></td>
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<tr>
<td>LET</td>
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<td>Ion mass 2-28 &amp; anisotropy</td>
<td>1.5-40 MeV/nuc</td>
<td>1-15 min.</td>
<td>2S x 2E, 60s</td>
<td>Caltech (Mewaldt) + GSFC (von Rosenvinge) + JPL (Wiedenbeck)</td>
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<tr>
<td></td>
<td></td>
<td>³He ions flux &amp; anisotropy</td>
<td>1.5-1.6 MeV/nuc</td>
<td>15 min</td>
<td>1E, 60s</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>H ions flux &amp; anisotropy</td>
<td>1.5-3.5 MeV</td>
<td>1-15 min.</td>
<td>1E, 60s</td>
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<td>HET</td>
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<td>Electrons flux</td>
<td>1-8 MeV</td>
<td>1-15 min.</td>
<td>1E, 60s</td>
<td>GSFC (von Rosenvinge) + Caltech (Mewaldt) + JPL (Wiedenbeck)</td>
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<tr>
<td></td>
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<td>H</td>
<td>13-100 MeV</td>
<td>1-15 min.</td>
<td>1E, 60s</td>
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<tr>
<td>SEP Common</td>
<td>IDPU (+Mag Analog)</td>
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</tbody>
</table>

(*) E=Energies, S=Species, D=directions
IMPACT SWEA and STE electron measurements, with MAG, probe solar connection magnetic topology.

(figures from D. Larson)
...and provide comparisons for modeling the ICME fields with magnetic flux ropes or other models

(flux rope fits by Tamitha Mulligan, from the paper by Yan Li et al., JGR 2001)
Coronal field models help relate the CME to the ICME magnetic signature

(figures from a paper by Yan Li et al., JGR 2001)
IMPACT SWEA and STE electron measurements combine with SWAVES radio burst data to diagnose ICME magnetic topology using flares
Contributions to the Oxygen Fluence
(10/97 to 6/00)

Particles/(cm² sr MeV/nucleon)

- Slow Solar Wind
- Fast Solar Wind
- Suprathermal Tail
- Gradual SEPs 11/97
- CIR 1/00
- Impulsive SEPs 11/97
- ACRs (10/97-6/00)
- GCRs

Composition:
- SIT
- LET
- HET

Arrival Directions:
- SEPT
- LET

Kinetic Energy (MeV/nucleon)
IMPACT SEP instruments will take “snapshots” of SEP spatial distributions.

SEP ion fluxes exhibit different time profiles at different locations along an interplanetary shock, related to acceleration and propagation processes.

(From Reames, 1999)
IMPACT SEP measurements...

Will identify connections to flares ... or ICME shocks
IMPACT Investigation Approaches:

- Multipoint interplanetary characterization of the imaged CMEs and their associated solar energetic particles (SEP) at increasing separations
- Quadrature measurements with imagers on STEREO and at Earth
- Space Weather detection, modeling and prediction
Doing STEREO Science

1. Flare
2. Interplanetary (Parker) Spiral Field Lines
3. Earth's Orbit
4. Impulsive W59, W59, W60, W62
5. 0.2-2 MeV e
6. 7-13 MeV p

Counter streaming electrons
CME Ejecta "cloud" or ICME
Interplanetary Shock
Plate SEPs
ICME SEPs

Ahead of S/C (1,2,3,4)

Behind S/C (5,6,7,8,9)

Vsw

Shock

Magnetic Cloud

Date 1982 August

Date 1995 Oct
At the beginning of the STEREO mission, IMPACT should observe major ICMEs at each spacecraft approximately once per month. How often will both spacecraft detect the same one?
Solar Cycle Influence on SEP

(CME cycle plot courtesy of Chris St. Cyr)

(figure from: Mt. Wilson Observatory website)

(figure from: Dick Mewaldt)
IMPACT Space Weather: lessons from ACE

Datasets: Dst Index Prediction
- We use ACE spacecraft solar wind data for input to a nonlinear magnetospheric dynamics model to predict the evolution of the Dst index.

Space Weather Specification and Forecast
- The data was collected Jun 08 2000 20:42 UT
- Current position of ACE in Earth's orbit: X = -2208 Y = 3112 Z = 0.0
- Submitted time: 2003 UT; next event time: 2003 UT
- Validation: 376 km/h and 12 minutes

IZMIRLAN/DMSP Electric Potentials and Global Ionospheric Convection

NOWCAST
- 2000-05-09 20:42 UT
- IMF Bn= -19.08 Bx= -4.29 By= -0.10

FORECAST
- 2000-05-09 21:00 UT
- IMF Bn= -0.03 Bx= -0.03 By= 0.00

Low-Energy Proton Fluxes from EPAM
- X>1 MeV Proton Flux from SM (Hourly averages)

Legend: Red contours - positive, blue contours - negative; potential plotted at the altitude 170 km.
Nearer northern and southern auroral regions are viewed from space. For lower values (CL) are shown. IFRD unavailable and then propagation time is estimated for YSO = 400 km/h. If IMF data unavailable, z are plotted.

(examples from ACE Real Time Space Weather data user websites)
Imagers can detect SEPs but...

... the information is limited. (images from SOHO, EIT and LASCO)
IMPACT SEPs give advance warning of an approaching ICME shock
SEP Hazard Predictions Depend on both: Polar Cap Size and SEP Fluxes

Space Station Orbit Is Exposed to High Energy Solar Particles

Exclusion Regions: 30.0, 45.0 For Geomagnetic Poles
15.0 For South Atlantic Anomaly


July 14, 2000 SEP event detected at SAMPEX (figure from R. Leske, Caltech)
...will be critical for interpreting the solar activity connection.

(figure courtesy of Dusan Odstrcil from work supported by NSF Space Weather Program)
Models can simulate both solar signatures:

(Results from the SAIC coronal model, figure courtesy of Jon Linker. Figure adapted from Linker and Mikik, SAIC, San Diego, CA)
...as well as in-situ (1 AU) signatures:

Radial-Meridional Distribution of the Meridional IMF at 360 h

Evolution at 1 AU

- $\theta = 70^\circ$
- $\theta = 80^\circ$
- $\theta = 90^\circ$
- $\theta = 100^\circ$
- $\theta = 110^\circ$

Bz ($-B_0$) Value (nT)

Dynamic Pressure (μPa)

Dst Index (nT)

(figures courtesy of Dusan Odstrcil from work supported by NSF Space Weather Program)