"SRAG in Wonderland"--Operational Space Weather Support for Manned Spaceflight

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Space Weather Support to Manned Spaceflight Operations

"This is an European/ESA meeting—why is NASA here?"

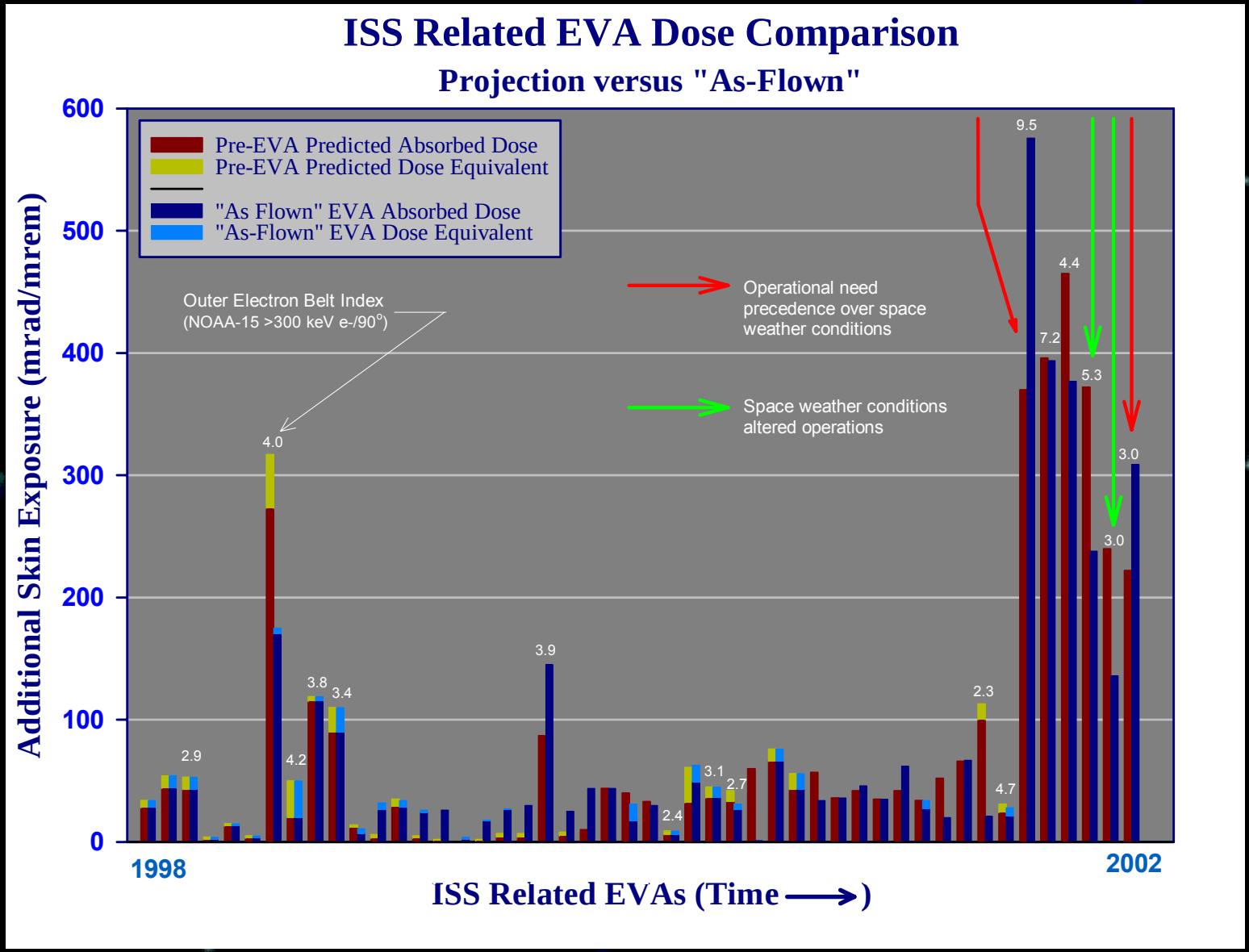
- Space weather and its impacts on human technologies spans geographic boundaries
- Space weather support services, in the not too distant future, will likely become so complex and costly that it will only be feasible only if it spans geographic boundaries
- International coordination/cooperation in manned spaceflight radiological support is increasing as the ISS program evolves
- Since inception of ISS missions (1995), 13 European astronauts have flown on Shuttle missions in ISS-type orbits

Space Weather Support to Manned Spaceflight Operations

"Do space weather data and forecasts ever impact a manned mission?"

YES!!

Application of Space Weather Information to Flight Operations--*Example*

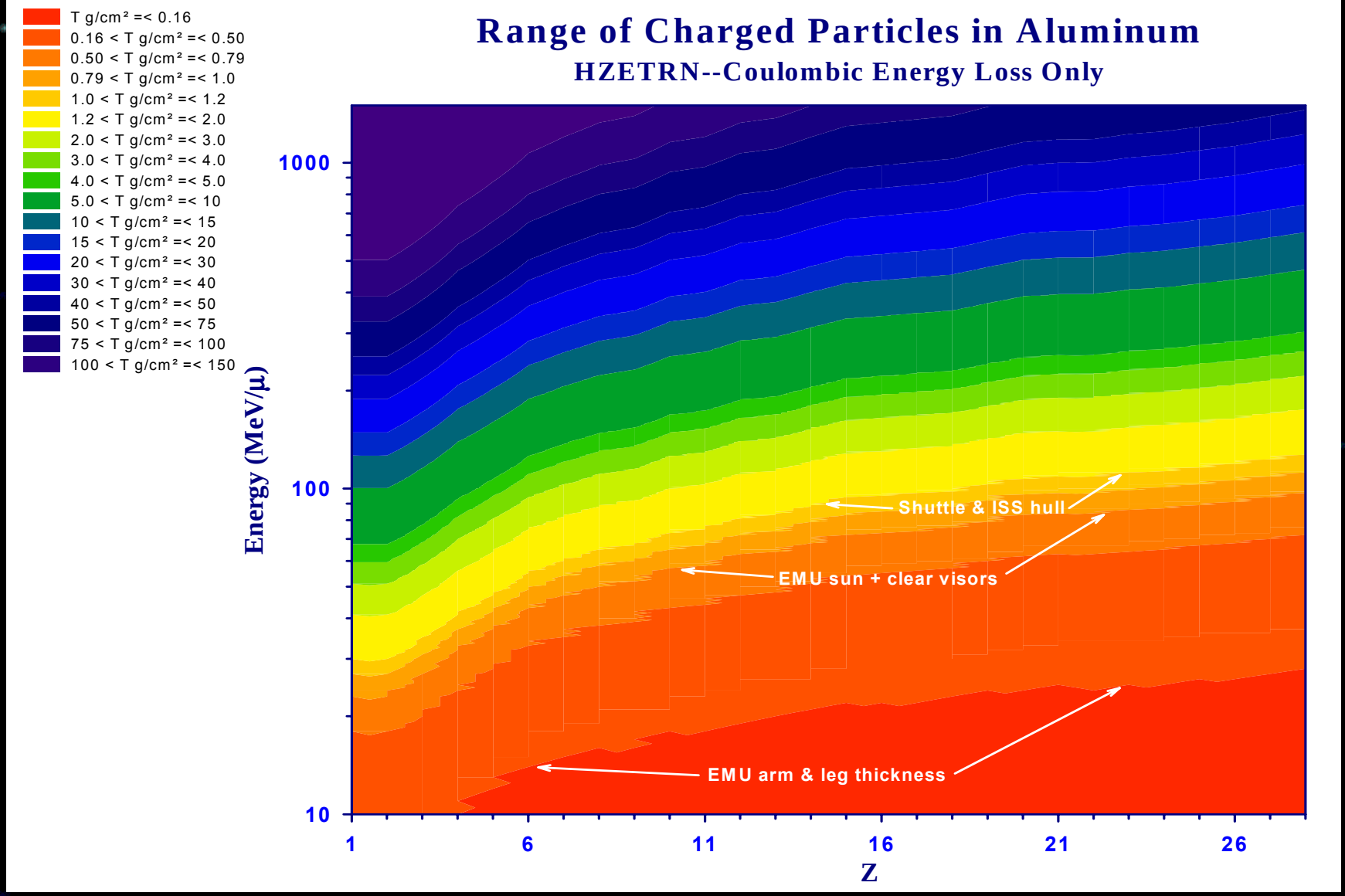


Space Weather Support to Manned Spaceflight Operations

"What do you want/need from a space weather service provider?"

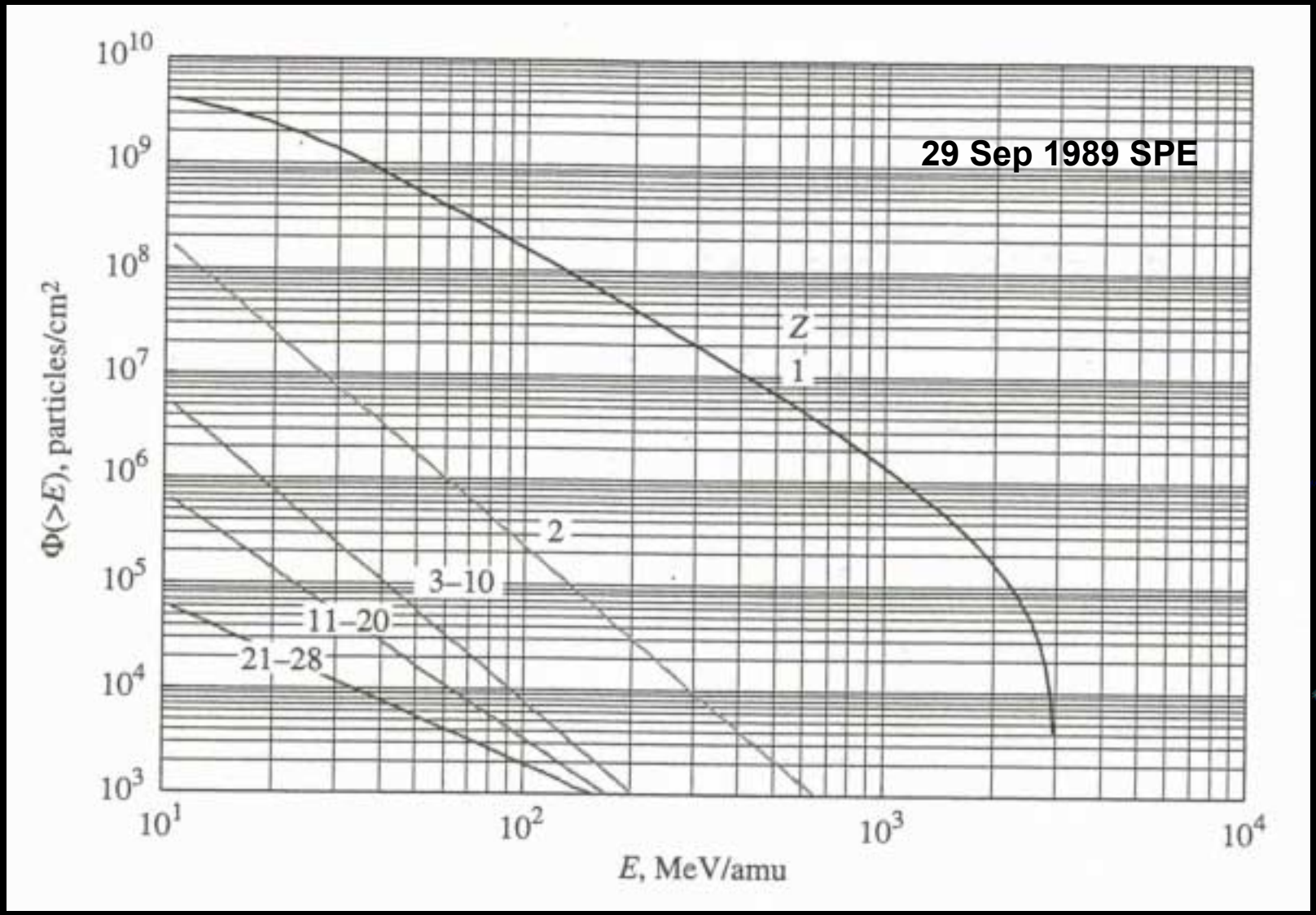
- Quantitative understanding of the state of energetic charged particle flux in low-Earth orbit (LEO)
- Forecasts of changes in the state of energetic charged particle flux in LEO due to space weather activity
  - Quantitative as well as qualitative
  - Temporal description as well as predicted maximum values
- Climatologic models of the energetic charged particle flux in LEO

SPE Charged Particle Spectra—Importance of Protons versus Heavy Ions to Astronaut Exposure



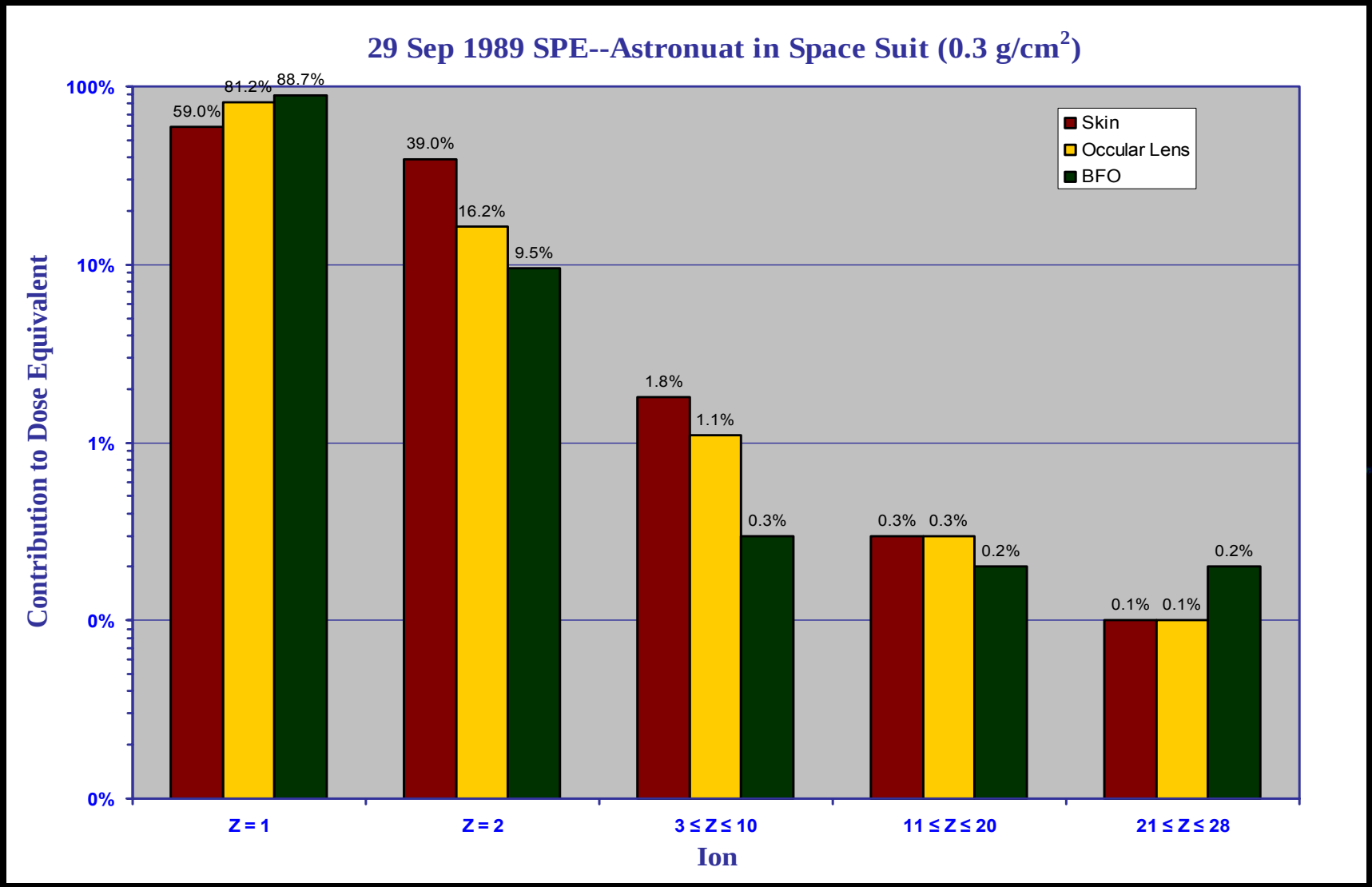
Ref: Zapp, N. Personal Communication (12 Dec 2002)

SPE Charged Particle Spectra—Importance of Protons versus Heavy Ions to Astronaut Exposure



Kim, M-H, J.W. Wilson, F.A. Cucinotta, *et. al.* "Contribution of High Charge and Energy (HZE) Ions During Solar-Particle Event of September 29, 1989." NASA/TP-1999-209320 (May 1999)

SPE Charged Particle Spectra—Importance of Protons versus Heavy Ions to Astronaut Exposure



Data from Kim, M-H, J.W. Wilson, F.A. Cucinotta, *et. al.* "Contribution of High Charge and Energy (HZE) Ions During Solar-Particle Event of September 29, 1989." NASA/TP-1999-209320 (May 1999)

Space Weather Support to Manned Spaceflight Operations

"For what types of particles and energies do you need nowcasts and forecasts?"

- Electrons: 0.5 – 10 MeV
- Protons: 10 – > 500 MeV
- Helium: 10 – ~60 MeV/amu

Space Weather Support to Manned Spaceflight Operations—Information Used in Operations

Ground-based

- K_P, A_P
- K_B, A_B
- F10.7
- Sunspot Number
- H-α images
- NOAA SEC active region location, size, and magnetic configuration
- Solar radio burst and sweep data
- Thule and Climax neutron monitor data
- NOAA SEC daily forecast, alerts and warnings

Space-based

- GOES p^+ flux: >10 MeV, >30 MeV, >100 MeV
- NOAA/TIROS e^- flux: >300 keV/90º belt index
- GOES/SXI (Apr 2003)
- SOHO/EIT 195 Å (movies)
- SOHO/LASCO C2, C3 (movies)
- SOHO/MDI images
- ACE/SIS p^+ flux: >10 MeV, >30 MeV
- ACE/MAG: B_T, B_Z
- ACE/SWEPAM: V_{SW}, ρ_{SW}

Space Weather Support to Manned Spaceflight Operations

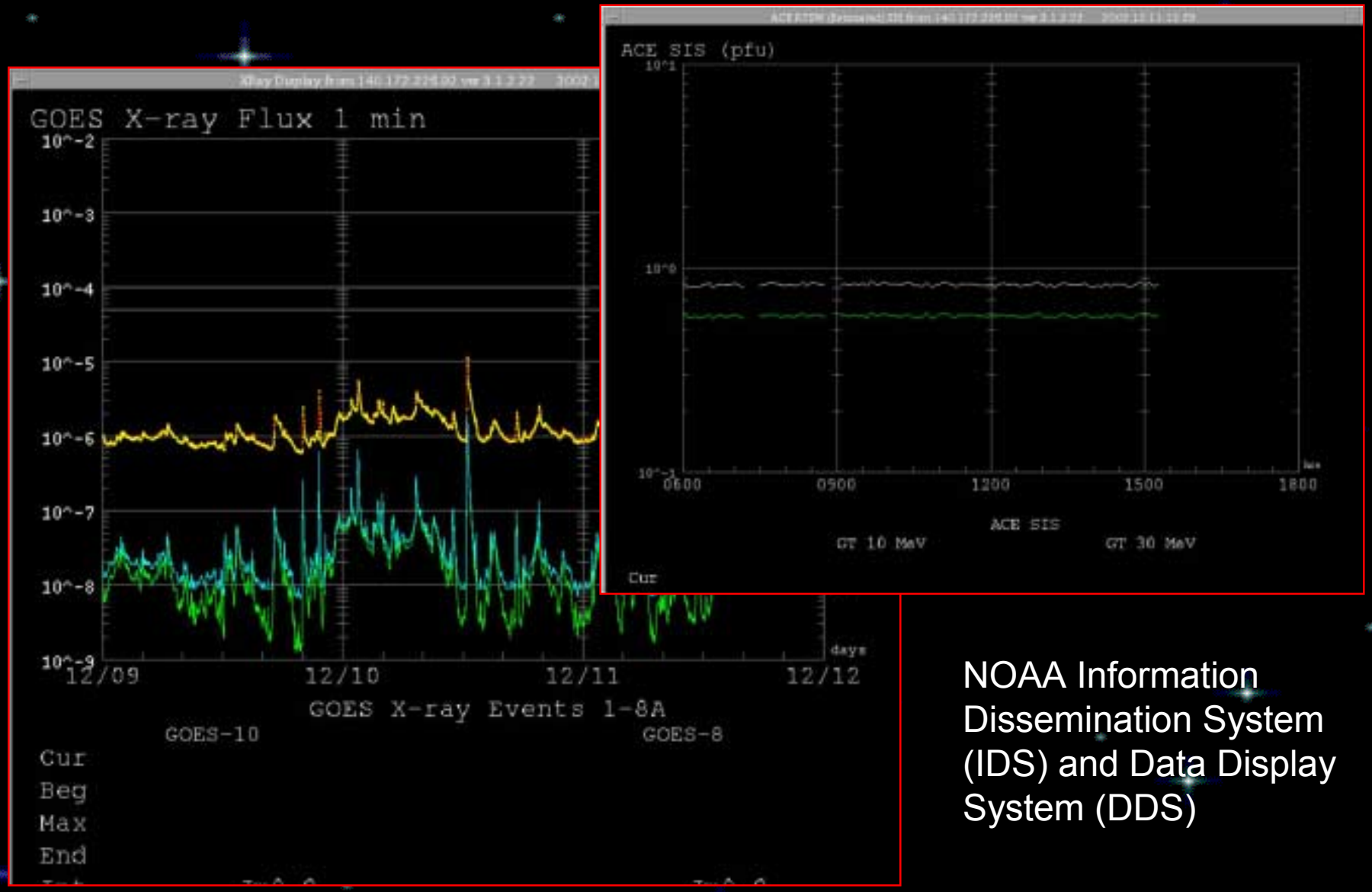
There are four types of interactions between a U.S. space weather customer and national U.S. space weather service provider

- User relies on generic products provided by service provider
- User requests service provider to provide a customized/ specialized product
- User pays service provider to provide a customized/ specialized product
- User builds own unique applications/products using service provider data
- User pays a third party vendor to build unique applications/ products using service provider data

Space Weather Support to Manned Spaceflight Operations—Service Provider Applications

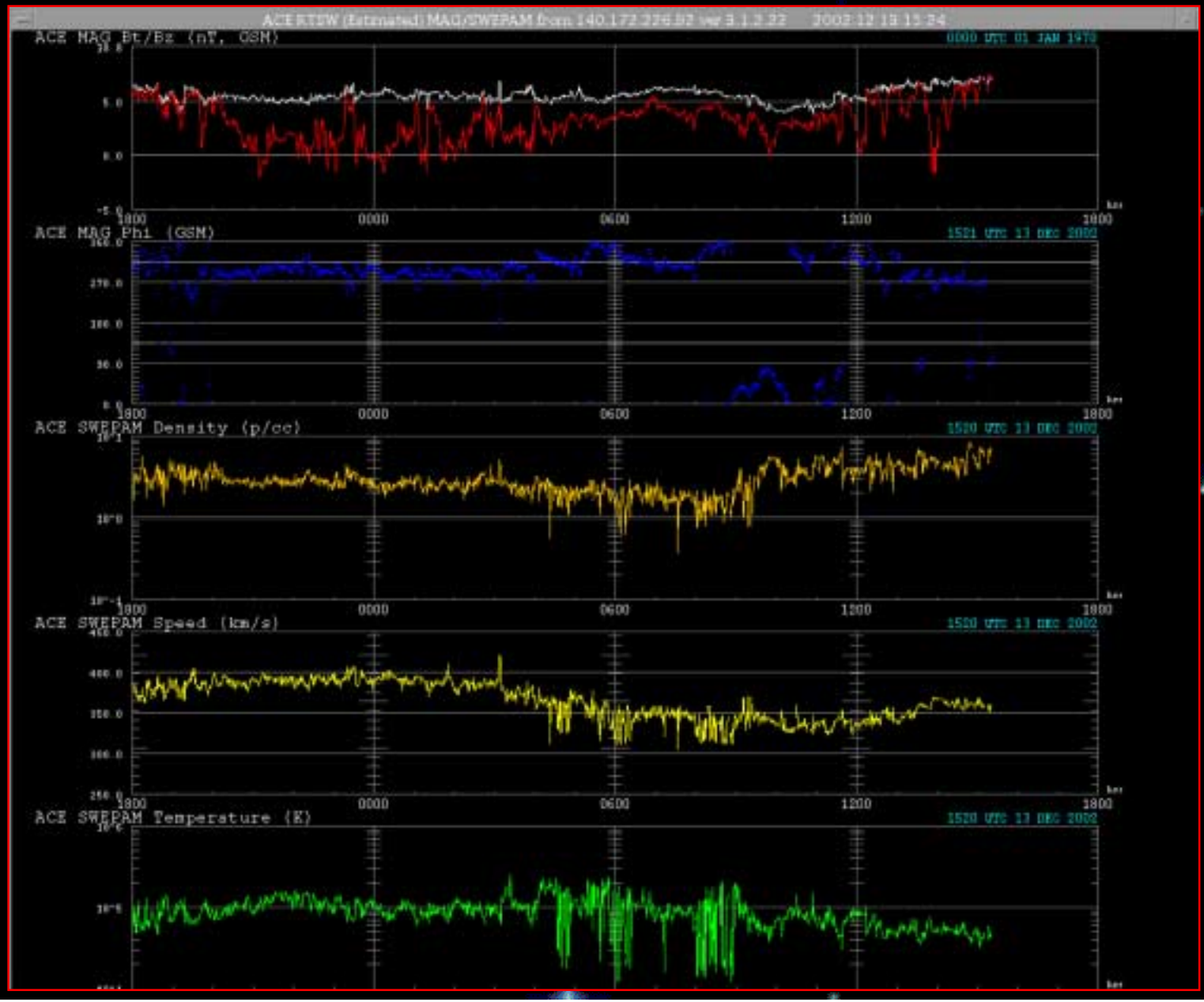
- Service provider requested to provide a customized/ specialized product
  - NOAA/TIROS Trapped Radiation Belt Index
- Service provider paid to provide a customized/specialized product
  - NOAA Information Dissemination System (IDS)
  - NOAA Data Display System (DDS)
  - NOAA Data Simulation System (DSS)

Space Weather Support to Manned Spaceflight Operations—Provider Funded to Develop Application



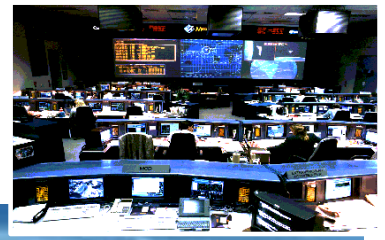
NOAA Information Dissemination System (IDS) and Data Display System (DDS)

Space Weather Support to Manned Spaceflight Operations—Provider Funded to Develop Application



Space Weather Support to Manned Spaceflight Operations—User Developed Application

NOAA Space Environment
Center (SEC)
Boulder, CO



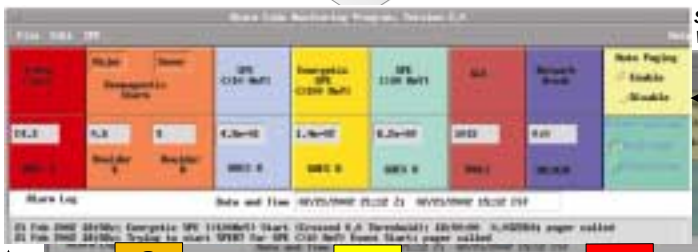
Mission Control Center–Houston
NASA Johnson Space Center
Houston, TX

NOAA Information Dissemination System (IDS)

GOES >10 MeV, > 100 MeV p+ flux
GOES 1-8 Å x-ray flux

A_B, K_B
Thule $^1n_0$ monitor

SRAG Space Weather Monitoring & Alarm System



SRAG Prime Workstation

Verify Network Connectivity

NOAA Information Dissemination System (IDS)

GOES >30 MeV p^+ flux
K_P

GOES >10 MeV p^+ flux
GOES > 100 MeV p^+ flux

Information Sharing Protocol (ISP)

ISS/STS state vectors

SRAG Internal Website

Verify Network Connectivity

GOES 1-8 Å x-ray flux >= M5.0

$K_B >= 6$
$A_B >= 50$

SRAG Backup Workstation

Strart SPE-RT

GOES p^+ (E> 10 MeV) >= 10 pfu
GOES p^+ (E> 100 MeV) >=1 pfu

SRAG Prime Workstation

From; system@bandera.jsc.nasa.gov
To:mgolight@ems.jsc.nasa.gov
Sent: Sat 09-Nov-2002 1331 CST (-6 GMT)
09 Nov 2002 19:30z SPE (>10MeV) Start (Crossed
1.000000e+01 Threshold) 19:30:00 11.307

Email

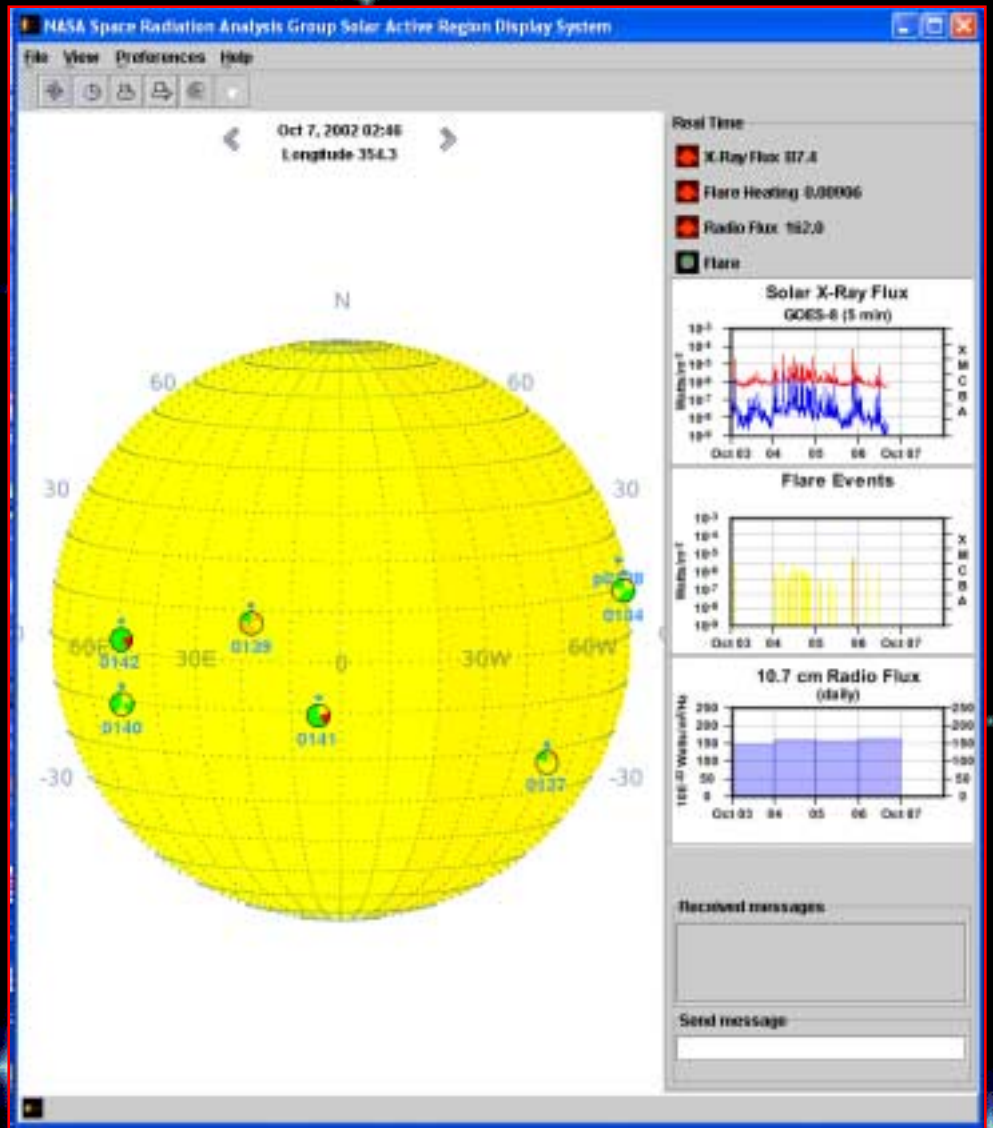
SRAG Backup Workstation

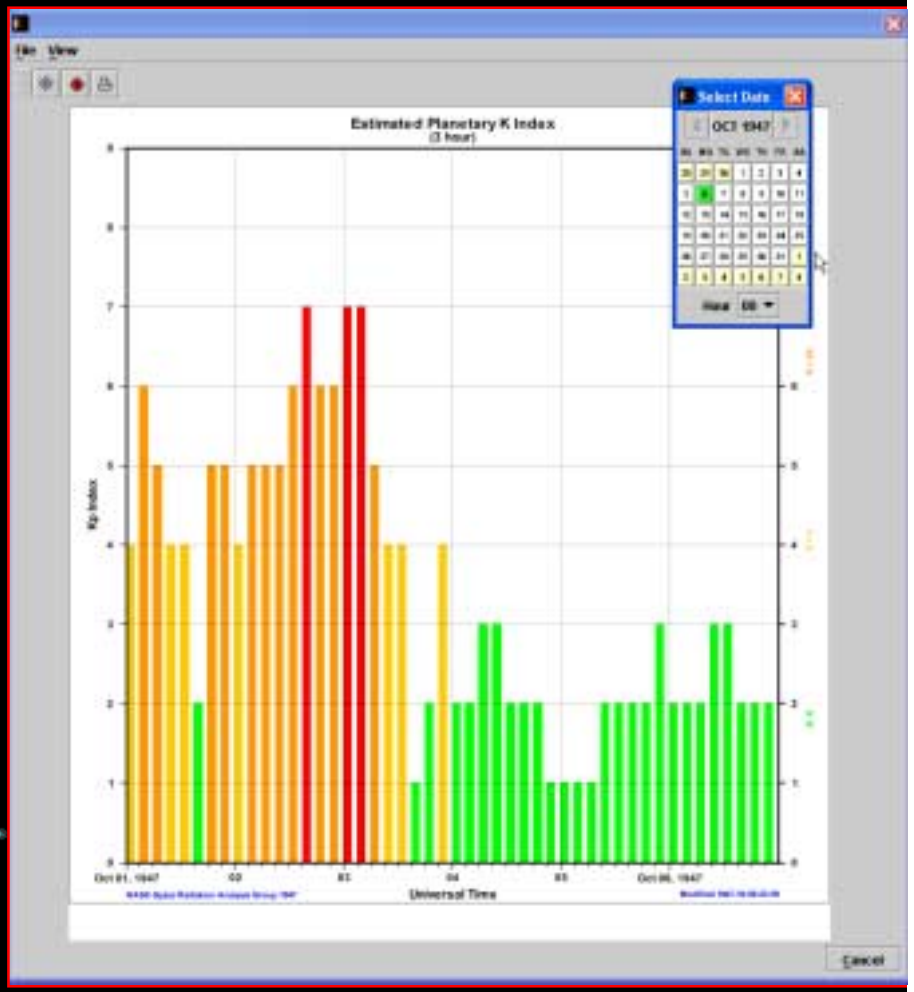
Dose rate/total dose
Vehicle location

Data for SRAG
Flight Controller

SRAG Web Server

Space Weather Support to Manned Spaceflight Operations—Third Party Developed Application

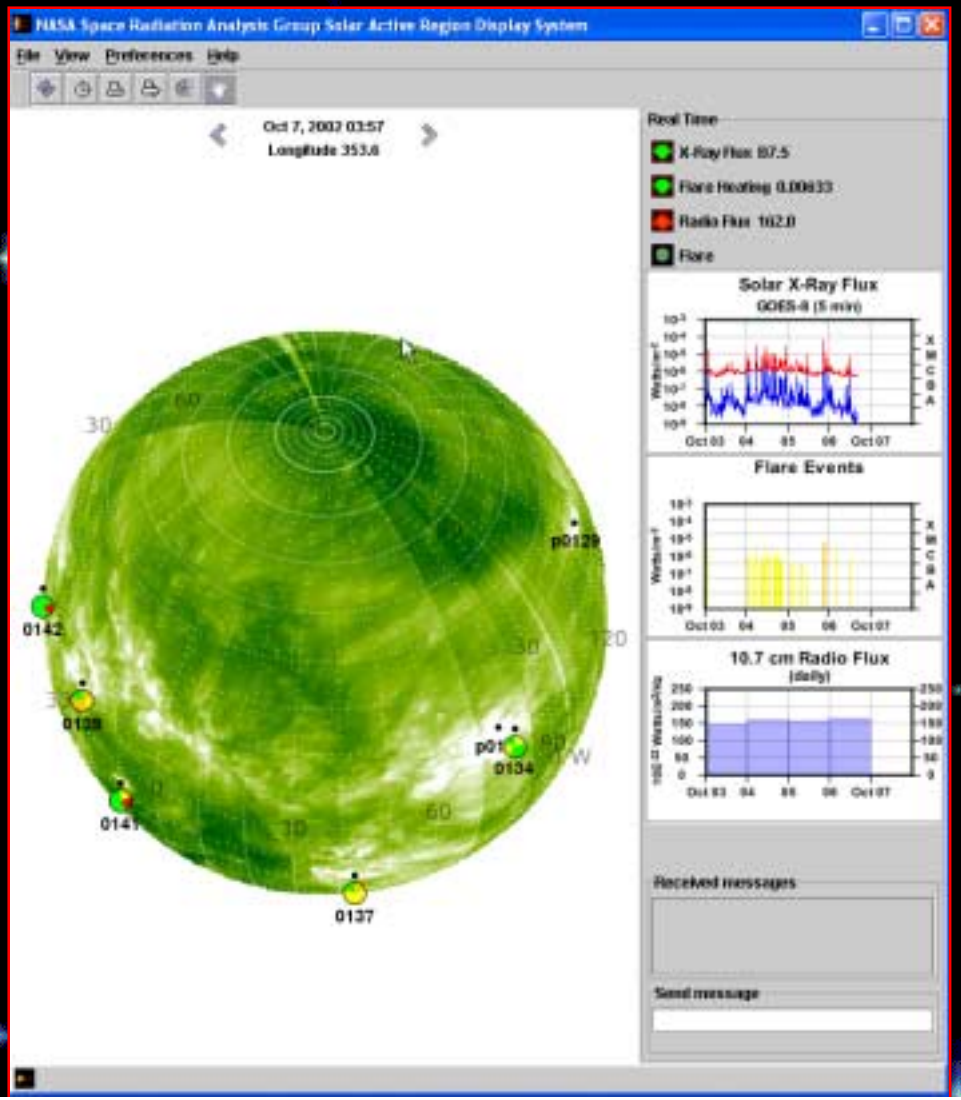


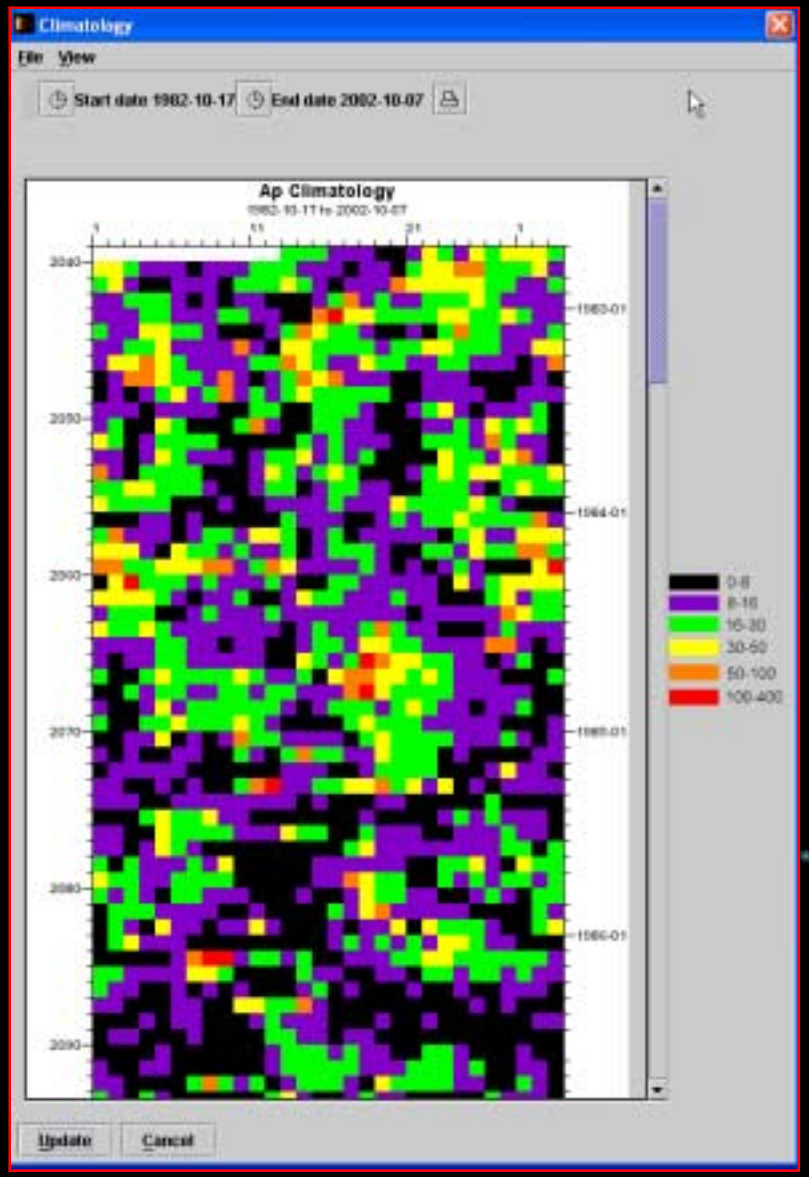


Solar Active Region Display System (SARDS) by *Raben Systems, Inc.*

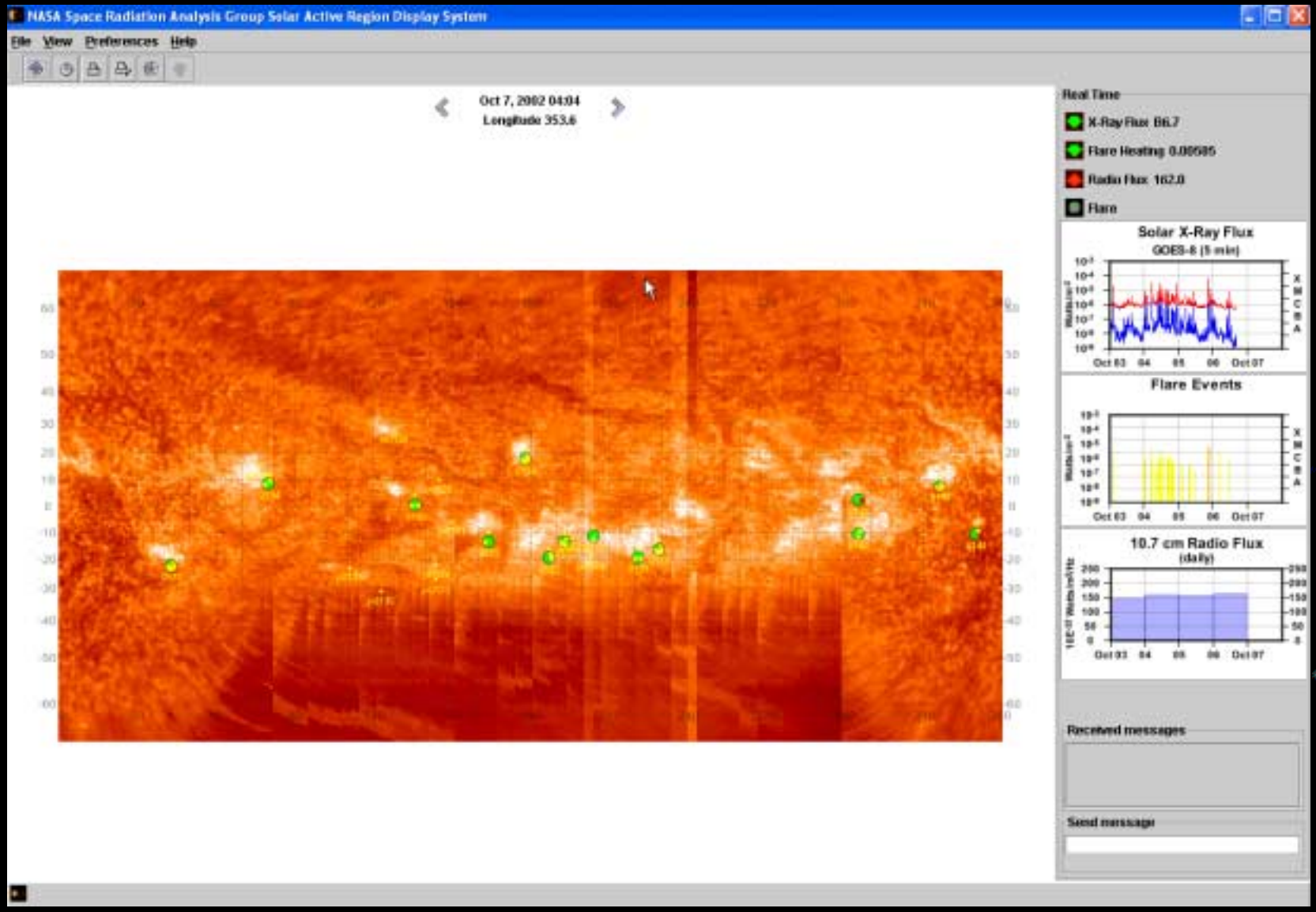
Space Weather Support to Manned Spaceflight Operations—Third Party Developed Application

Solar Active Region Display System (SARDS) by *Raben Systems, Inc.*





Space Weather Support to Manned Spaceflight Operations—Third Party Developed Application



Solar Active Region Display System (SARDS) by *Raben Systems, Inc.*

SRAG in Space Weather Support "Wonderland"

"Wonderland" Data Providers

- Data available in (near) real-time
- Data reliably available on a fixed schedule
- Preferably redundant data access methods
- Data quality control
  - Bad and/or missing data flagged
- Data accessible autonomously by computer systems
- Data access method supports firewalls

SRAG in Space Weather Support "Wonderland"

"Wonderland" Space Weather Model Providers

- Models are relatively evolutionarily stable
  - Do not want to frequently update/revise software or system integration
- Models can be successfully run with available operational space weather data
  - e.g., (near) real-time data available from NOAA Space Environment Center
- Model architecture must be robust
  - Handle missing/corrupted data
  - Validate input parameters
  - Return intelligible error codes/messages
- Model output includes uncertainty & confidence interval
- Model can't require a supercomputer to run, yet!

SRAG in Space Weather Support "Wonderland"

"Wonderland" Space Weather Model Providers (*cont.*)

- Model runs fast enough on typical "high-end" PC or workstation to keep pace with operational needs
  - "Operational need" time scales range from once per minute to once every few months
- Modularized software architecture/design for easy updating
  - Include version control at the module level
- Software available as source code and/or libraries with well-defined interface
  - Need to be able to integrate into existing operational support systems
  - Need to be able to add a GUI (if one not provided with system)
- Software is preferably platform independent

SRAG in Space Weather Support "Wonderland"

"Wonderland" Space Weather Model Providers (*cont.*)

- Did we mention comment statements and documentation?
  and
- Shouldn't have to be the world's expert to run