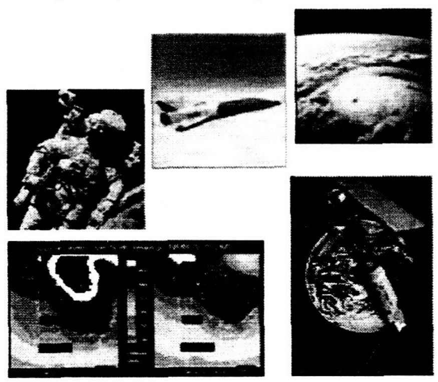
Model Requirements

Steering Committee
Presented by J. Barth

Working Group Meeting on New Standard Radiation Belt and Space Plasma Models

Increasing Reliance on Support Functions Provided by Space Systems

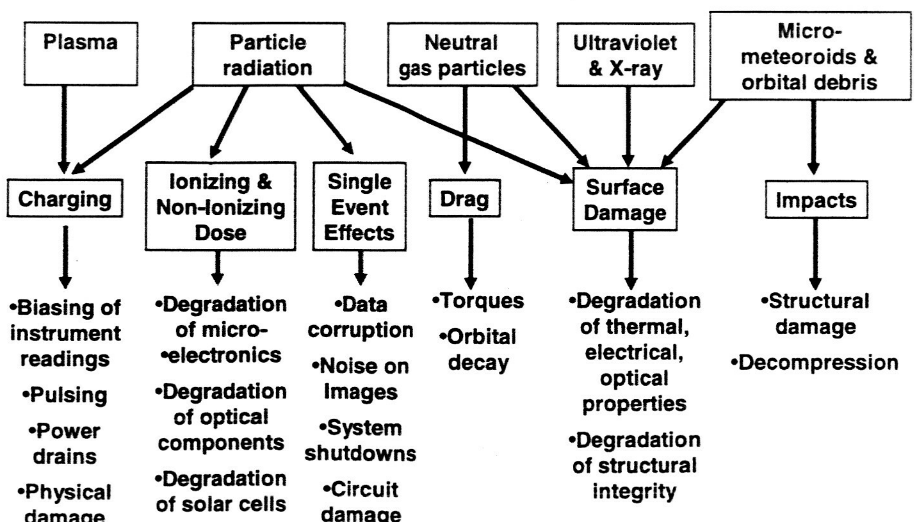
- Scientific Research
  - Space science
  - Earth science
  - Aeronautics and space transportation
  - Human exploration of space
- Navigation
- Telecommunications
- Defense
- Space Environment Monitoring
- Terrestrial Weather Monitoring



Why Are Radiation Models Needed?

- Primary purpose for new models
  - Spacecraft and instruments
    - Reduce risk
    - Reduce cost
    - Improve performance
    - Increase system lifetime
  - Reduce risk to astronauts
    - ISS
    - Traveling through radiation belts
- Contributors to increased risk and costs
  - Resource constraints
  - Increasing complexity of space systems
  - Lack of availability of space-validated components
  - Unknowns in space environment effects mechanisms
  - Inadequate space environment models
    - Large uncertainties in some regions
    - Environment definitions <u>do not exist</u> for some energy ranges

Effects of Space Environments on Systems
(Mechanism & Manifestation)



Barth/2003

Consequences of Space Environment Effects on Systems

- Loss of data
  - Single event upsets on flight data recorder
  - Interruption of data transmission
- Performance degradation
  - Reduced microelectronics functionality
  - Degraded imagers
- Interference on instruments
  - Noise on imagers
  - Biasing of instrument readings
- Service outages
  - System resets, safeholds
- Shortened mission lifetime
  - Solar array degradation, microelectronics degradation
- Loss of system or entire spacecraft
  - Catastrophic failure

Hazards for Humans

- Failure of life support systems
- Failure of space systems operational infrastructure
- The exposure received by humans from space radiation is an important occupational health risk.
  - Major concern is increased risk of cancer morbidity/mortality
  - Other possible health risks
    - Cataracts
    - Coronary disease
    - Damage to neurologic system (e.g., aging)
    - Genetic damage to offspring
  - The probability is *very small* of death during or immediately following a mission due to space radiation exposure

NASA Approach - *ALARA*

- **Legal, moral, and practical considerations require NASA limit astronaut radiation exposures to minimize long-term health risks**
- **Maintain astronauts' space radiation exposure *as low as reasonably achievable (ALARA)***
  - Radiation protection approach used by NASA and its International Partners
  - Assumes any radiation exposure, no matter how small, results in some finite increase in cancer risk
    - No threshold
  - Conservative approach is appropriate given the large uncertainties in the quantitative understanding of space radiation risk
    - NAS committee estimates uncertainty on the order of ± 400%

Focus of this Workshop?

New Standard Radiation Belt Models

- Identified by US Space Architect as a gap in the US Space Weather Program
- Identified by the US Space Technology Alliance's Space Environments and Effects Working Group as the #1 priority in space environments issues
- Identified in ESA R&D Roadmaps
- Why?
  - Required by engineers to build better spacecraft in <u>pre-operation</u> phases
  - Used to support operational planning and on-orbit anomaly investigations
  - Relativistic electron enhancements in belts #1 concern for astronauts on ISS (*Golightly, LWS User Requirements Workshop, 2000*)
  - Need improved models for safe passage of astronauts and their vehicles through the radiation belts

Phases of Spacecraft Development

- *Mission Concept*
  - Observation requirements & observation vantage points
  - Development and validation of primary technologies
- *Mission Planning*
  - Mission success criteria, e.g., data acquisition time line
  - Architecture trade studies, e.g., downlink budget, recorder size
  - Risk acceptance criteria – include assessment of Space Weather forecasting capabilities
- *Design*
  - Component screening, redundancy, shielding requirements, grounding, error detection and correction methods
- *Launch & Operations*
  - Asset protection
    - Shut down systems
    - Avoid risky operations, such as, maneuvers, system reconfiguration, data download, or re-entry
  - Anomaly Resolution
    - Lessons learned need to be applied to <u>all</u> phases

Space Environment Model Use in Spacecraft Life Cycle

Mission Concept
Mission Planning
Design
→ **Space Climate** Minimize Risk

Launch
Operations
→ **Space Weather** Manage Residual Risk

Anomaly Resolution → **Both** + *in situ* measurements

Space Environment Definitions

- *Space Weather*
  - *"conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health"*

  [US National Space Weather Program]

- *<Space> Climate*
  - *"The historical record and description of average daily and seasonal <space> weather events that help describe a region. Statistics are usually drawn over several decades."*

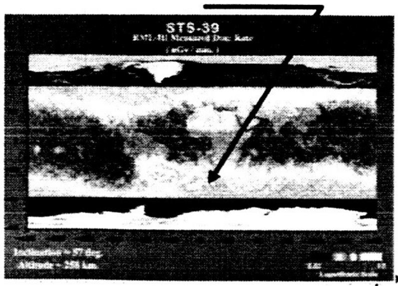
  [Dave Schwartz the Weatherman – Weather.com]

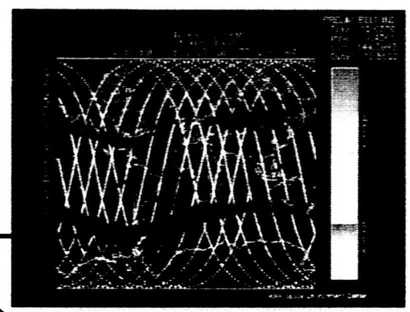
Hazards to Astronauts on ISS

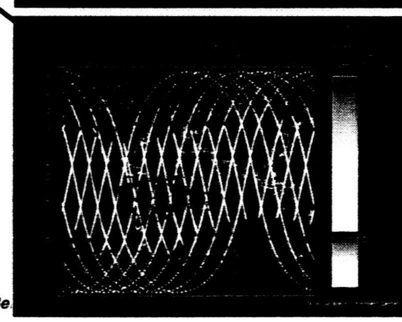
Golightly – AMS 2004

- Space weather can significantly enhance the ambient "space radiation" environment, increasing the exposure of humans in space

Outer Electron Belt Enhancement (EVA only)
SPE: protons, heavy ions (e.g., Fe)
Additional Radiation Belts: protons, high energy electrons?







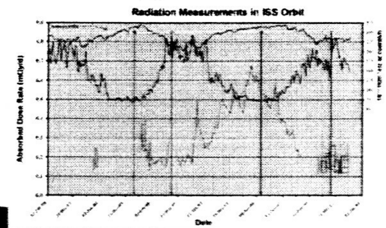
Space Weather vs. Climatology
What are the Impacts? *Golightly – AMS 2004*

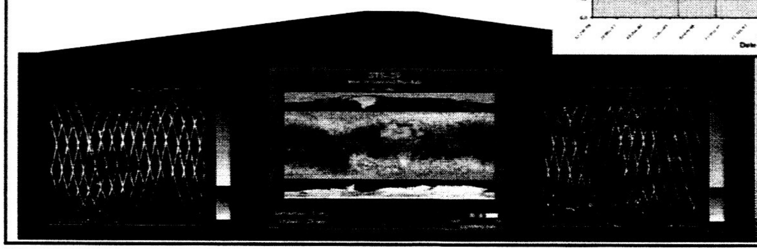
Space Weather

- 4 to 6 orders of magnitude increase in near-Earth proton flux
- Factor of 2 to ~100 increase in outer belt electron flux
- Decreased geomagnetic shielding (shielding against interplanetary charged particles)
- Additional trapped radiation belts

Space Climatology

- Factor of 2 to 3 modulation in GCR flux
- Factor of 2 modulation in trapped proton flux

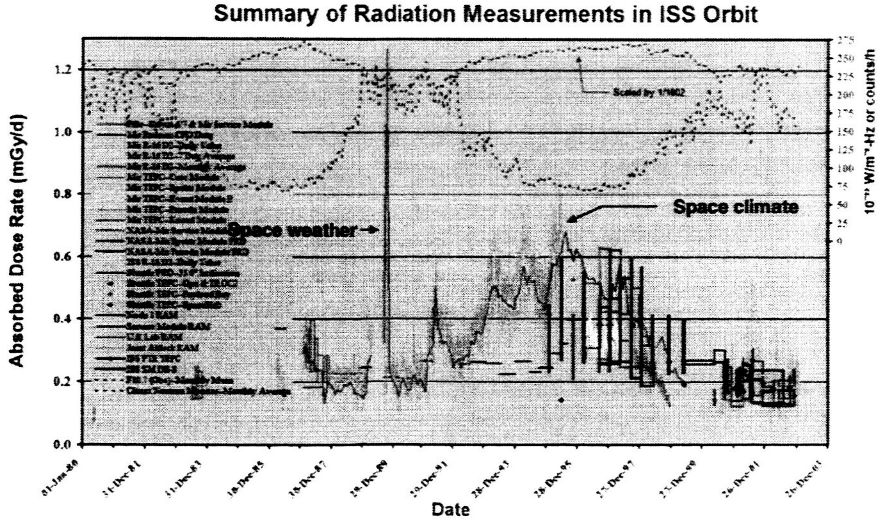




13

Space Weather vs. Climatology—*Which one is more important to astronaut exposures?*
Golightly – AMS 2004

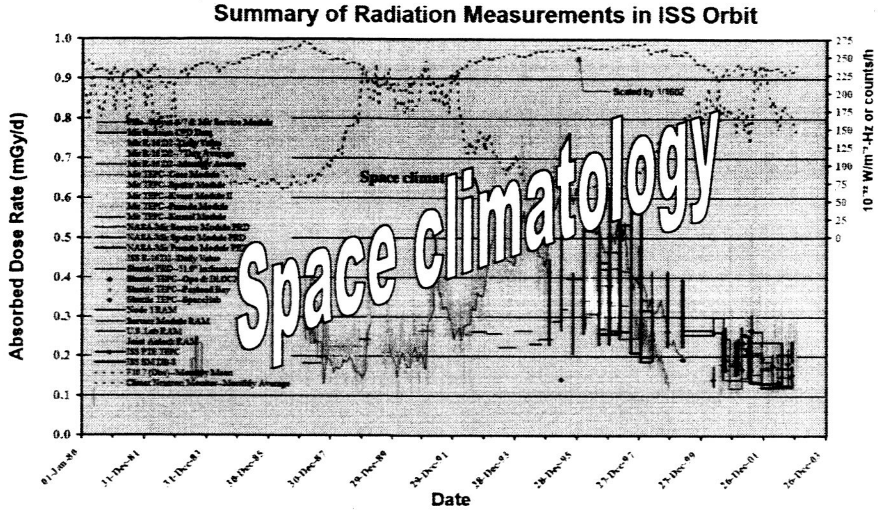
Summary of Radiation Measurements in ISS Orbit



Space Weather vs. Climatology—*Which one is more important to astronaut exposures?*

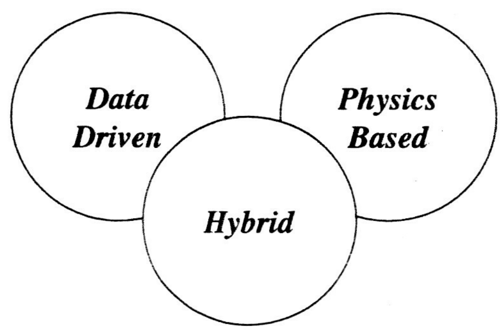
Golightly – AMS 2004

Summary of Radiation Measurements in ISS Orbit



Definition of future models?

Space Climate ⇔ Space Weather



“Plasma” Model Requirements

- **Required for surface charging and surface erosion predictions**
- **Charging**
  - Electrons models for 1 < E <100 keV
  - Better definition in MEO regions
- **Surface degradation**
  - Protons energies “as low as possible”
    - 50 eV to 100 keV
    - Information on ion species
  - Electron energies
    - 50 eV to 40 keV
  - Statistics on range of environment fluxes

Trapped Proton Model Requirements

- Required for total dose, displacement damage, and single events effects predictions
- Improved time resolution
  - AP8 has 4- and 6-year averages
  - Represent long-term variation over the solar cycle with at least 6-month resolution
- Broad energy range
  - 0.1 < E < 1.0 MeV – Surface effects
  - 1 < E < 10 MeV – Solar cell degradation
  - 10 < E < 100 MeV – Total dose, dose rate, single events effects
  - E > 100 MeV – Total dose, dose rate behind shielding, detector damage
- Statistical description of variations
  - Provide worst case estimates
  - Provide confidence levels
- Definition of transient belts
  - How often do they appear?
  - How intense are they?
  - How long do they last?
  - What are the highest energies observed?
  - What is the heavy ion content?

Trapped Electron Model Requirements

- Required for total dose and internal charging predictions
- Improved time resolution
  - AE8 has 4- and 6-year averages
  - Represent long-term variation over the solar cycle with at least 6-month resolution
- Broad energy range
  - $0.1 < E < 1.0$ MeV – Surface effects
  - $1 < E < 30$ MeV – Internal charging, Total dose
- Statistical description of variations
  - Provide worst case estimates
  - Provide confidence levels
- Definition of transient belts
  - How often do they appear?
  - How intense are they?
  - How long do they last?
  - What are the highest energies observed?

Dataset Management & Model Standardization

- Needs to be a cooperative effort
  - International
  - "Impartial" modeling center
- Needs long-term commitment
- Standardization options - AIAA, IEEE, and ISO
- Need to break through the funding "Catch-22"
  - Radiation Belt modeling is not considered a science activity, but ...
  - Experimental space scientists must be a significant part of the modeling effort