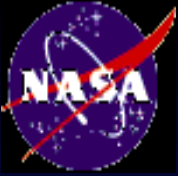


A Conceptual Framework for Utilization of Space Radiation Measurements

Walter Schimmerling and Francis A. Cucinotta

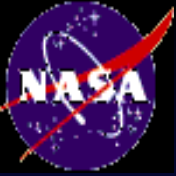


**Workshop on Radiation Monitoring for the
International Space Station
Oxford, UK
12-14 September 2001**



Space Radiation Measurements: SOME QUESTIONS TO ADDRESS

- What is the purpose of space radiation measurements?
- What is a “dosimeter”?
- How does one take conflicting results of similar measurements into account for radiation protection?
- How are data communicated, shared, evaluated, and archived?
- What data are properly used in maintaining radiation exposure records?
- How much radiation monitoring is “enough”?



Space Radiation Measurements:

1. Relevant Critical Questions

- **Space Radiation Environment**

- For a given mission, what are the fluxes of GCR in interplanetary space as a function of particle energy, LET, and solar cycle?
- What is the solar cycle dependence of space radiation?
- What is the trapped radiation flux as a function of time, magnetic field coordinates and geographical coordinates?
- What are the doses related to heavy ions in deep space?

- **Nuclear Interactions**

- What are the yields for nuclear interactions of HZE particles in tissue and space shielding materials?
- How are radiation fields transformed as a function of depth in different space materials?
- What are the optimal ways of shielding humans in space?

- **Atomic Interactions**

- What is the precise energy deposition of heavy ions?
- What are the yields and energy spectra of electrons?

- **Human Radiation Protection**

- What should be the radiation dose limits for manned deep space missions?
- What is the risk associated with each crew member at any time during a given mission?



Space Radiation Measurements:

2. Basis for Risk Assessment

What is risk?

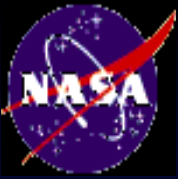
- a priori vs. a posteriori probabilities
- probability of defined effect (e.g., excess leukemia)
- architecture-dependent (trip duration, spacecraft, EVA's, etc.)

Prospective risk assessment:

- radiation monitoring
 - identify radiation in sufficient detail to understand results, i.e., spectral information may be required in addition to ionization chambers; area monitors to define radiation field
- risk assessment vs. risk estimate
- architecture issues

Archival risk assessment:

- legal
 - evidence of causation (or lack of causation) of an effect by exposure to space radiation
- medical history
 - acute effects: treatment, record
 - late effects: how?
- epidemiological
 - evaluate effects of cumulative population exposures



What is a “dosimeter”? Instrument Specifications

Anything that measures $\varphi(A,Z, LET, \dots)$, $D(LET)$, $QF(LET), \dots$

- **Particle identification:**

Positive charges vs. neutrons,
electrons, -rays

(1,1) (A,Z) (56,26) [p to Fe]
 $\Delta Z/Z$ 0.2]; $\Delta A/A$ 1

- **Energies:**

10 ϵ_{HZE} 1000 MeV/nucleon
10 keV ϵ_n 100 MeV
700 keV $\epsilon_{x, \gamma}$ 10 MeV

- **LET range:**

0.1 LET 2000 keV/ μ m

- **Acceptance**

- Solid angle (statistics) 2
- detection efficiency 10%
- $\Delta\theta/\theta$ (angular resolution) 3°

- **Rate Dependence**

R 10⁵ particles/sec; N 10⁴
particles/cm²
0.01 μ Gy/min D/ t 1 Gy/min

- **Localization**

- Portability
 - » Personnel dosimetry
 - » Area monitoring
- Shielding: traceable to mass distributions

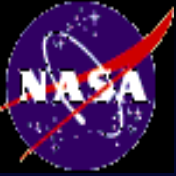
- **Data acquisition and recording**

- Telemetry and on-board readout
- Coincidence and correlation w/other instruments
- Autonomy > 90 days
- Availability and distribution < 30 days
- Stability: 50 yrs



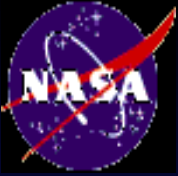
Relevant Radiation Measurements

	PASSIVE	ACTIVE
INDIVIDUAL	<ul style="list-style-type: none">• Emulsion• TLD• Nuclear track detectors• Internal Biodosimetry• Radioactivation of tissue• Other chemical or physical latency• Whole body/organ?	<ul style="list-style-type: none">• Pocket ionization chamber• Portable silicon detectors• High dose or dose rate warning monitors• Whole body/organ?
AREA	<ul style="list-style-type: none">• Emulsion• TLD• Nuclear track detectors• External Biodosimetry• Induced radioactivity• Other chemical or physical latency	<ul style="list-style-type: none">• TEPC and similar ionization detectors• Scintillation counters• Particle spectrometers• (Moderated) neutron counters



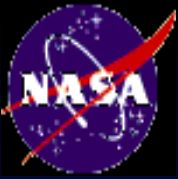
Instrument Requirements

- **Accuracy**
 - Calibration, pre-experiment testing, intercomparisons
 - Timing and location
- **Precision**
 - Geometry factors and acceptance
 - Resolution in A, Z, LET
- **Specificity**
 - No detection artifacts (e.g., response to unintended particles and/or energies, wall effects, kerma vs. dose)
 - Can the measurement be related to an individual exposure?
- **Sensitivity**
 - Signal-to-noise ratio
 - Dynamic range in particles, energies, LET
 - Doses, dose rates and flux
 - Sensitivity adequate for statistically significant results
- **Data quality**
 - Availability: space, ground, on-line, off-line, post-mission,
 - Stability of data, especially for integrating detectors
 - Can the data be interpreted in terms of individual risk?



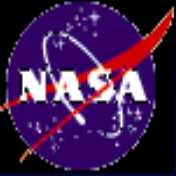
Sources of Dosimetric Data

- **Reference dosimeters**
 - Output used to determine individual radiation exposure for the record
 - Basis for implementation of ALARA
- **Solicited, peer-reviewed experiments**
 - Yield radiation measurements of interest for radiation protection
- **Unsolicited, non-peer-reviewed measurements**
 - May yield radiation measurements of interest for radiation protection
- **Supporting, relevant data from measurements on other spacecraft**



Space Radiation Measurements: Reference Dosimeters

- **Design and reference**
 - on file and accessible to qualified researchers
 - standard data output format
- **Calibration**
 - according to an international protocol
 - at “accredited” ground facilities
 - » measured instrument specifications
 - » confirmed with calculated response
- **Intercomparison**
 - at ground facilities
 - in space
- **Certification as a “Reference Dosimeter”**
 - by TBD (Mission Control? NIST? MMOP?)



Space Radiation Measurements: Data Certification

- **Defined data format**
 - original or converted from original format
- **Defined media on which data will be available**
 - e.g., web, server, disk, etc.
- **Procedures for data ownership**
 - copyright assignments, publication rights, etc.
 - adjudication of authorship of published data
- **Procedures for data storage**
 - how long? where?
- **Procedures for data access**
 - satisfy privacy concerns
 - provide appropriate public access



Space Radiation Measurements: Data Interpretation

- **Only certified data may be used for radiation protection**
- **Reference dosimeter data**
 - interpreted according to protocol(s) to be defined
 - are the only data that may be used for records
- **Data not obtained from reference dosimeters**
 - may be used to supplement reference dosimetry
 - may not be used independently of reference
- **The end-point of data interpretation is the assignment of a risk probability for a specified detrimental health effect and for a specified individual.**



Space Radiation Measurements: A Conceptual Framework for Utilization

- **Define reference dosimeter protocol(s)**
 - Accreditation of calibration facilities
 - Develop intercomparison protocols
 - Define access by proposed instruments
 - Define certification authority (-ies)
- **Define data certification process**
 - Incorporate into requirements for experiment approval?
 - Define certification authority (-ies)
 - Define formats, storage, access, etc.
- **Define data interpretation protocol**
 - Standardize calculations
 - Define sharing by appropriate international radiation protection officers

Objective:

**ONE COMMON, UNIVERSALLY ACCEPTED RISK ASSESSMENT
FOR EACH INDIVIDUAL CREW MEMBER AT ANY POINT IN TIME**