NASA Space Radiation Program Overview

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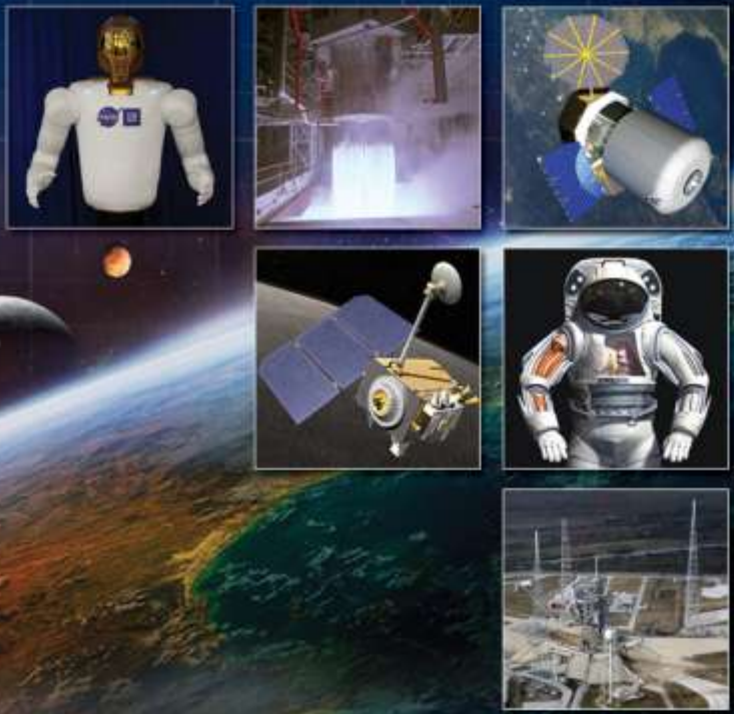
NASA Space Radiation Program

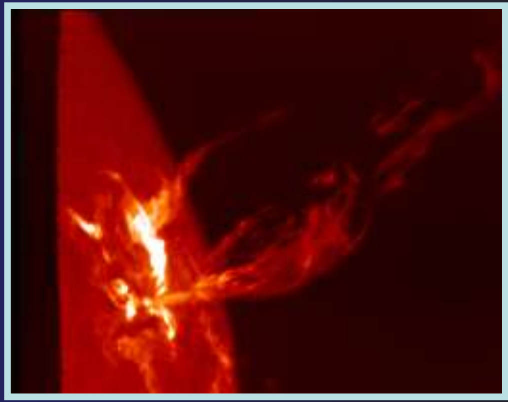


September 15, 2011
NIST-Dosimetry Standardization for Radiobiology


NASA Space Radiation Program Goal:
To live and work safely in space
with acceptable risks from radiation
Principles:
Risk Justification
Risk Limitation
ALARA

The Space Radiation Environment

- Trapped Radiation
  - Medium energy protons and electrons
  - Effectively mitigated by shielding
  - Mainly relevant to ISS
  - MAIN PROBLEM: develop accurate dynamic model

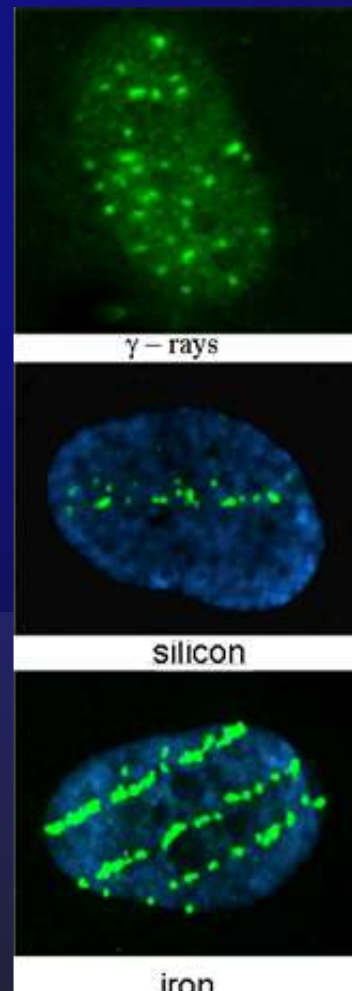


- Solar Particle Events
  - Medium to high energy protons associated with CME
  - Largest doses occur during maximum solar activity
  - MAIN PROBLEM: develop realistic forecasting and warning strategies

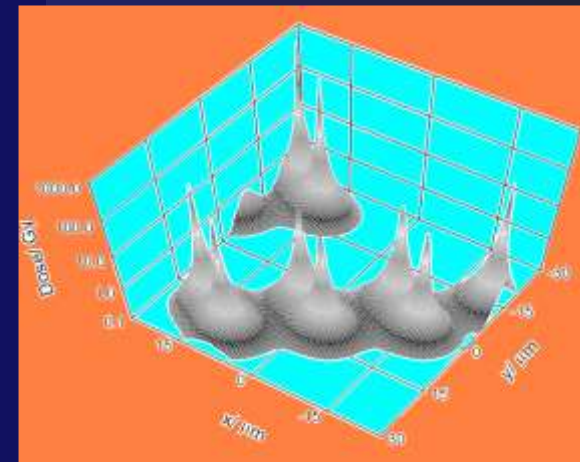
- Galactic Cosmic Radiation
  - High energy protons
  - Highly charged, energetic atomic nuclei (HZE particles)
  - Not effectively shielded
  - Abundances and energies quite well known
  - MAIN PROBLEM: biological effects poorly understood

The Space Radiation Problem: Heavy ions are Qualitatively Different from X-rays or gamma-rays

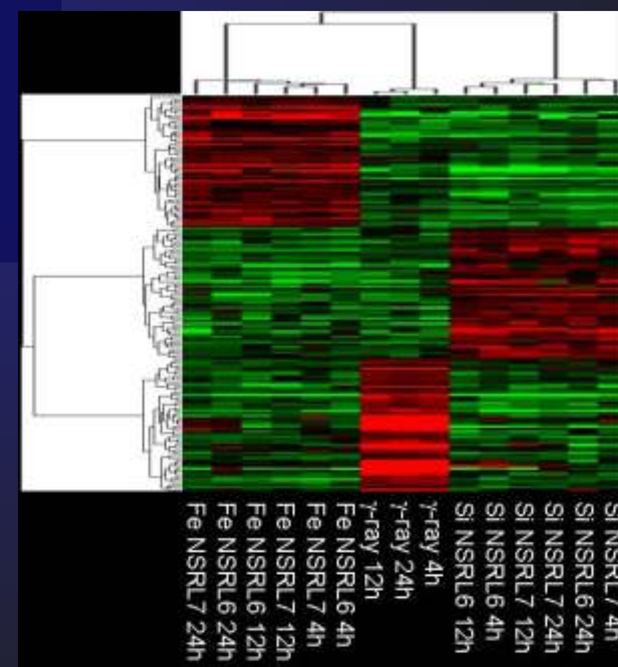
- Heavy ion exposure causes unique damage to biomolecules, cells, and tissues
- Shielding not effective
- No human data to estimate risk from heavy ion damage- large uncertainty
- New biological knowledge on risks is required



γ-H2AX foci



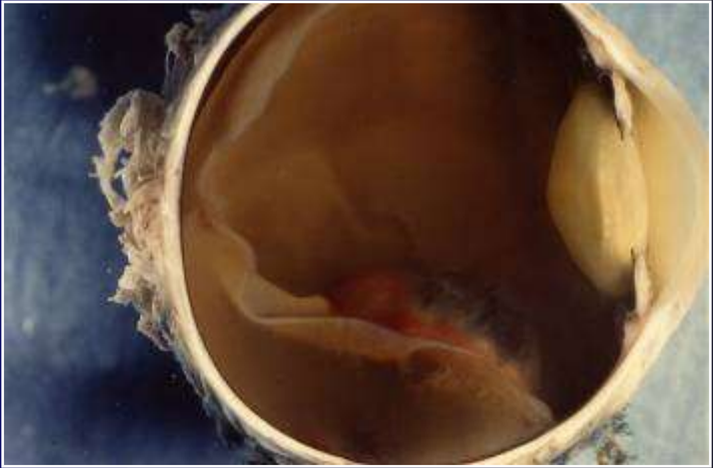
GCR iron nuclei energy deposition at D=0.1 Gy



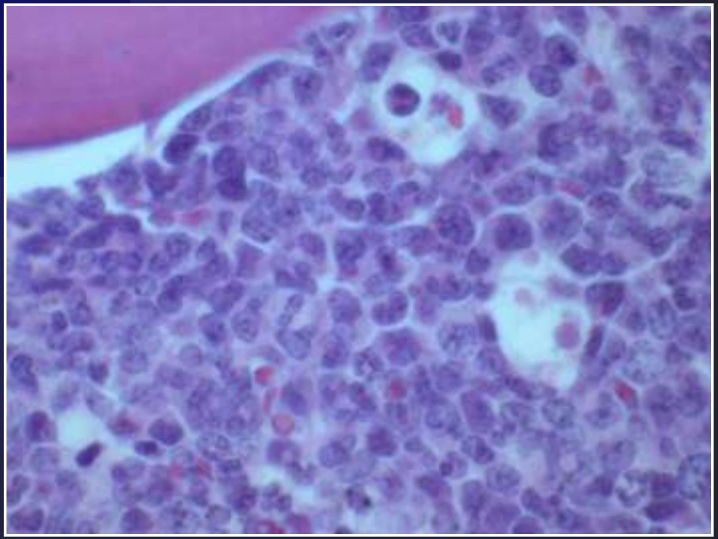
UTSW-NSCOR

Categories of Space Radiation Risk

- ***Cancer***
  - morbidity and mortality risk
- ***Acute and Late Central Nervous System (CNS) risks***
  - immediate or late functional changes
- ***Chronic & Degenerative Tissue Risks***
  - cataracts, heart-disease, etc.
- ***Acute Radiation Sickness***
  - Prodromal risks (nausea, vomiting, fatigue)



Lens changes in cataracts (E. Blakely)



First experiments for leukemia induction with GCR (R. Ullrich)

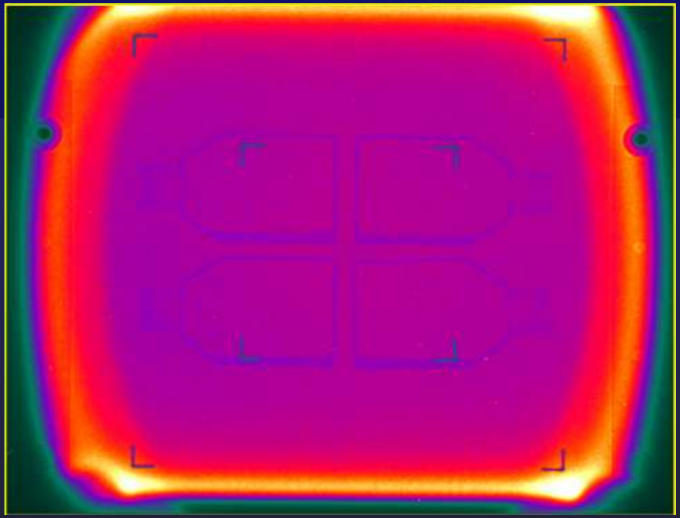
Foundations of NASA Space Radiation Program Research

- Ground based mechanistic studies to understand space radiation impacts in the 4 main risk areas (cancer, CNS, degenerative, acute)
- Broad program of solicited, peer-reviewed research at over 40 US Universities including collaborative research with DoE
- Five NASA Specialized Centers of Research (NSCOR's) studying the biology of space radiation risks (Lung, Colon, Breast, Leukemia, CNS)
- Simulate space radiation at the NASA Space Radiation Laboratory (NSRL)
  - located at DoE's Brookhaven National Lab
  - cell-based and small animal experimental models

NASA Space Radiation Laboratory

- NASA conducts 3 experimental campaigns each year at NSRL
- Beams of heavy ions are extracted from Brookhaven's booster accelerator with masses and energies similar to the cosmic rays encountered in space
- A 100-meter transport tunnel and beam line connects the accelerator to NSRL's 400-square foot shielded target room
- Includes a support building with laboratories for biological and materials experiments; and specimen, dosimetry, and control rooms

NSRL beam line and target room showing one of the four ion chambers used for beam imaging.



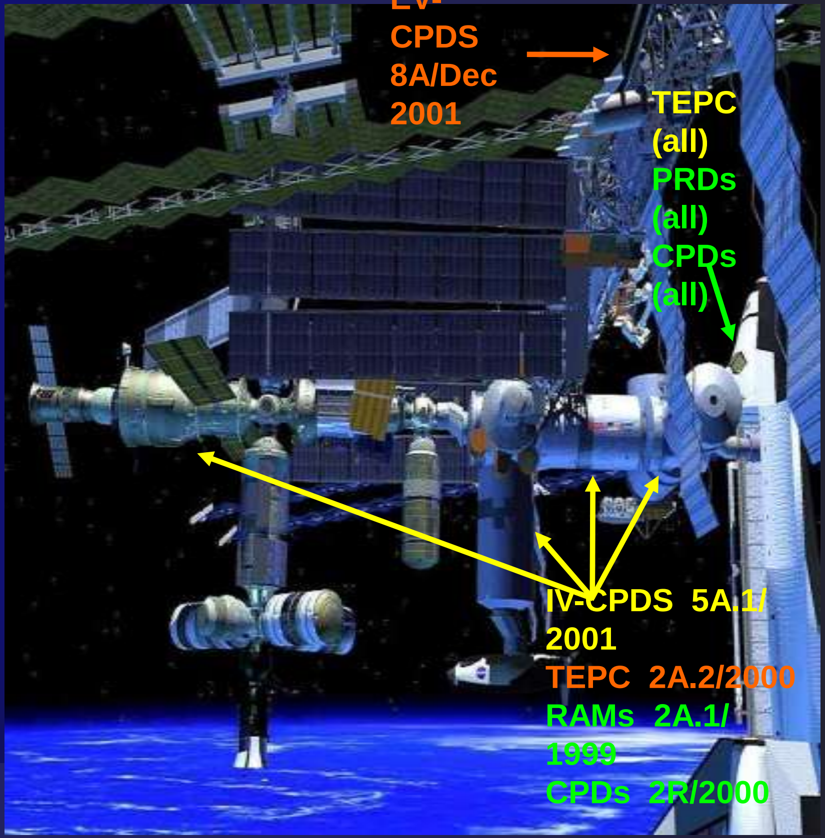
Beam Profile observed using the Digital Beam Imager. Pseudo coloring indicates that beam intensity is uniform across a 20 x 20 cm^2 exposure area. Typical beam uniformities of ±2% are achieved.

Details on Dosimetry at NSRL: http://www.bnl.gov/medical/NASA/CAD/Dosimetry_Calibration.asp

(Images Courtesy of Brookhaven National Laboratory)

Space Dosimetry

- The complex radiation environment in space presents unique dosimetry challenges for astronauts
- Current monitoring includes physical dosimeters inside and outside of spacecraft, as well as individual crew monitoring (NASA Space Radiation Analysis Group)
- Chromosome aberration formation in blood lymphocytes of astronauts post-flight is being assessed by the Space Radiation Program for use as a <u>biodosimeter</u> of exposure and biomarker of cancer risk



Active instrument real-time telemetry
Active instrument
no real-time telemetry
Passive instrument

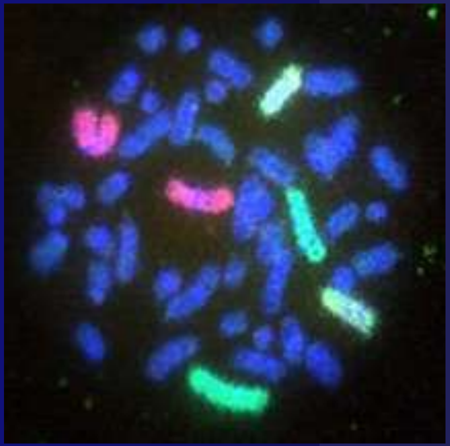
ISS Biodosimetry

Chromosomal aberrations are used as a biological dosimeter and potential risk biomarker

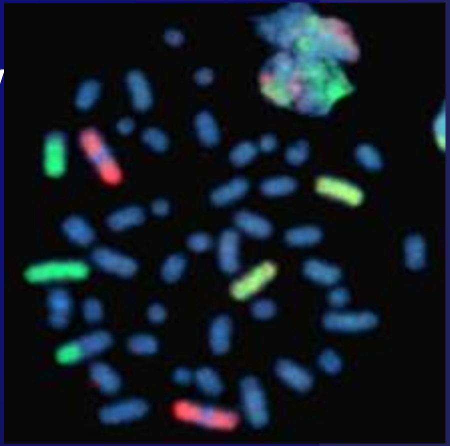
Methods: Use 3-color fluorescence *in situ* hybridization (FISH) to count frequency of specific aberrations (Chromosomes 1, 2, 4) in blood lymphocytes

Crew pre-flight blood draw is exposed to low doses of Cs^{137} gamma-rays to determine individual calibration curve

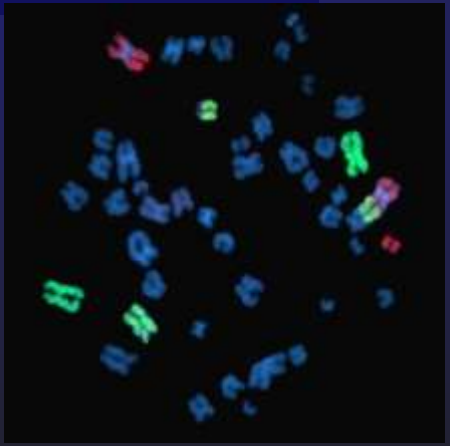
Crew post-flight blood draw is used as a comparison and for determination of equivalent biological dose



Normal



Simple exchange

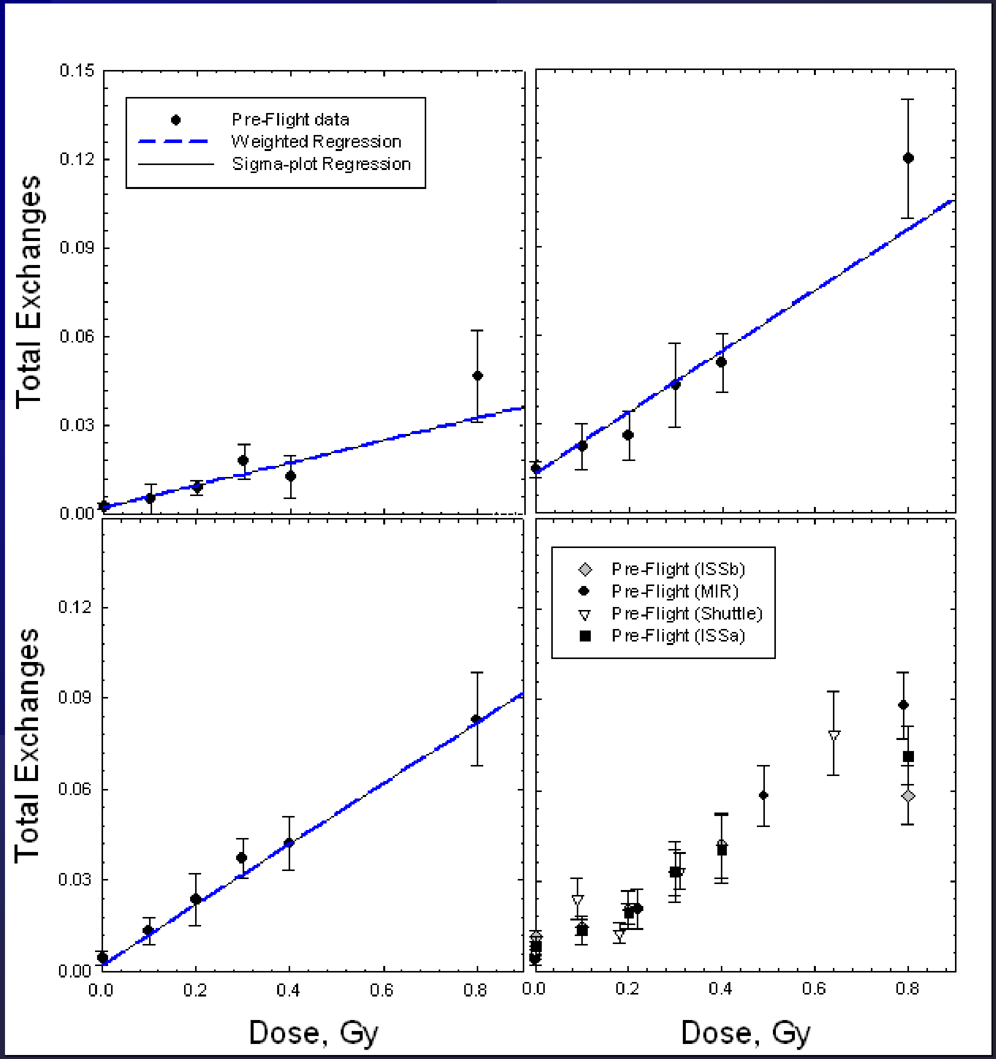


Complex exchange in ISS crew sample

Individual Preflight Calibration Curves

Measurements are Sensitive:

- Three different people – three different curves
- Same individual three different times – same curve
- Individual curves are reproducible

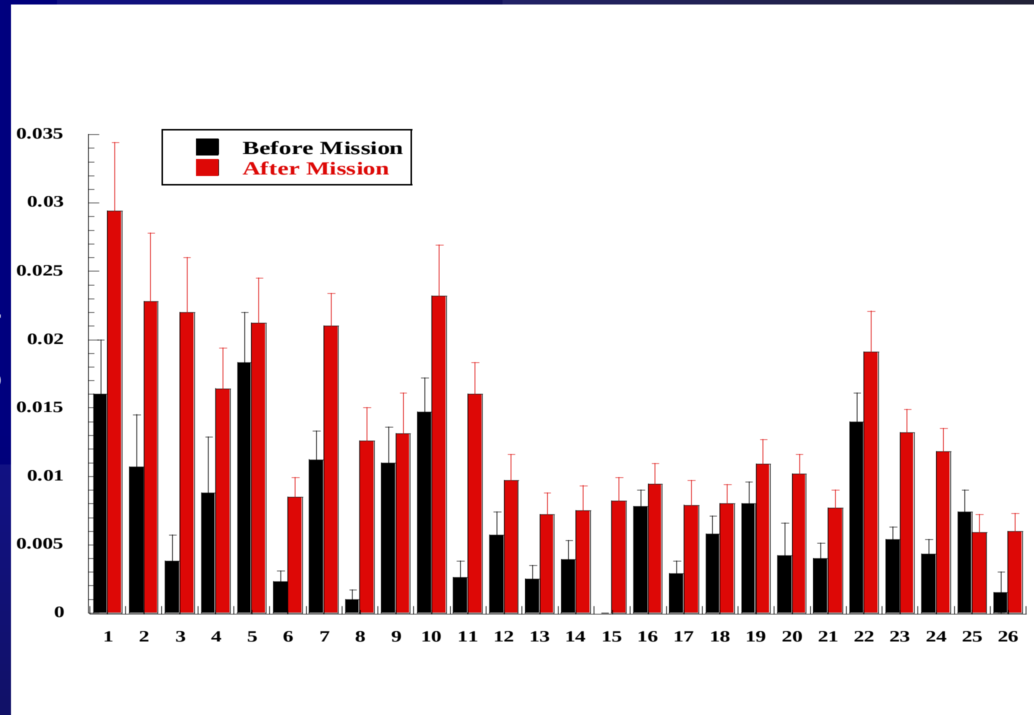


Cucinotta et al., Radiat Res. 2008 Jul;170(1):127-38.

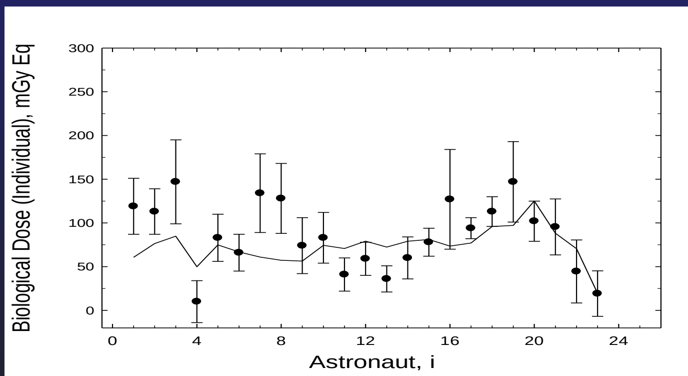
NASA Biodosimetry Results

- Over 30 assessments to date with several repeats
  - Mir 4 Crew
  - STS 2 Crew
  - ISS 24 Crew

- ***Total exchanges increased post-flight in all astronauts (except one short duration)***



Biological doses for 23 astronauts who participated in long duration missions



Solid line represents results of weighted linear regression model for estimating the dose using physical measurements

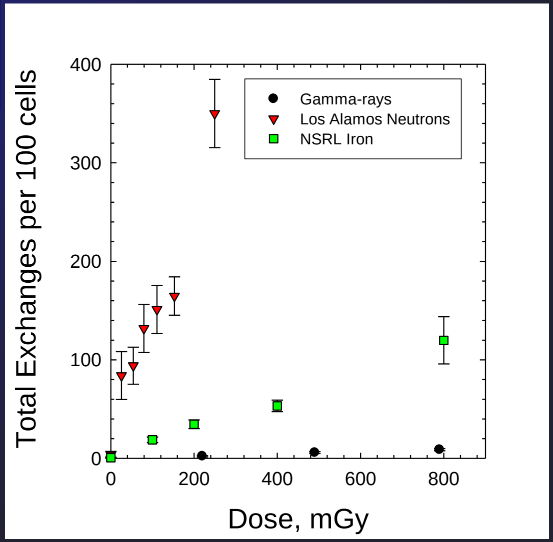
Close relationship between biological and physical dose

Cucinotta et al., Radiat Res. 2008 Jul;170(1):127-38.

Comparison: Physical and Biological Dosimetry

Astronaut Dosimetry	Physical	Biological
Area Sampled	~1 cm^2	>1000 cm^2
Tissue Shielding	Skin only	Yes- at deep tissues
Directionality	Torso Front	Omni-directional
Radiation Quality Sensitivity	TLD poor for High LET	Excellent for all radiation types
Individual Sensitivity	No	Yes

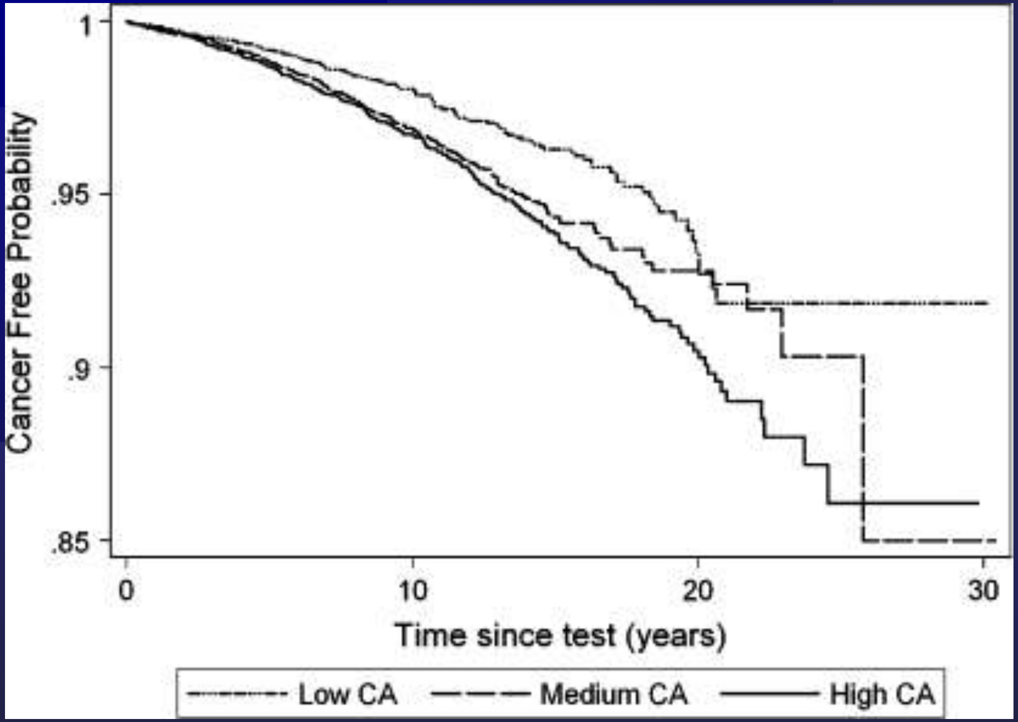
Biodosimetry has several advantages over physical dosimetry including exquisite sensitivity to neutrons and the ability to assess individual sensitivity



Chromosome Damage as Biomarker of Cancer Risk

Bonassi et al. (Carcinogenesis. 2008 Jun;29(6):1178-83) study of cohort of 22,000 shows significant association between chromosomal aberrations and cancer incidence many years later (10-25 years post scoring)

The relative risk (RR) of cancer was increased for subjects in M and H tertiles compared to L group



- RR for medium tertile = 1.31 [1.07-1.6]
- RR for high terile = 1.41 [1.17-1.72]

ISS Biodosimetry Summary

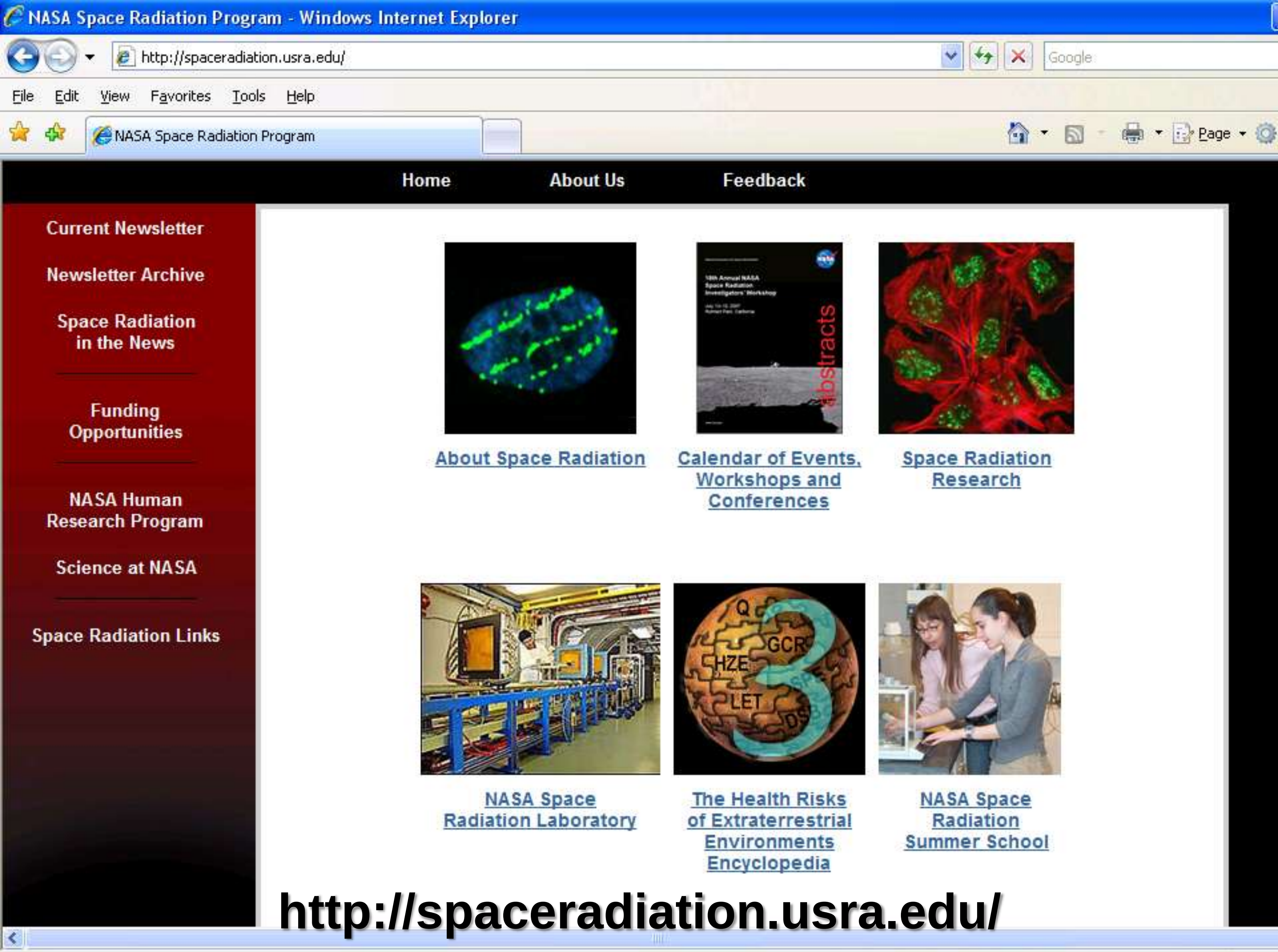
- Biodosimetry estimates assessed 1 or 2 weeks after single space flights are within the range expected from physical dosimetry and biophysical models.

- The lowest dose that can be assessed is around 10 cGy. This generally restricts the use of biodosimetry to missions lasting at least 3 months

- Biodosimetry has several advantages over physical dosimetry including exquisite sensitivity to neutrons

- Biodosimetry assesses inter-individual response to radiation, not just dose

- Chromosome damage is a biomarker of cancer risk, astronauts who remain in the higher tertile may a higher cancer risk



http://spaceradiation.usra.edu/

Thank You!

M17: A Hubble Close-Up : Sculpted by stellar winds and radiation, these fantastic, undulating shapes lie within the stellar nursery known as M17, the Omega Nebula, some 5,500 light-years away in the nebula-rich constellation Sagittarius.

(Credit: NASA, ESA, J. Hester (ASU); Astronomy Picture of the Day, http://apod.nasa.gov/apod/ap040828.html)