National Aeronautics and Space Administration

SCIENCE & TECHNOLOGY OFFICE


# Toward Radiation-Smart Structures and Designs

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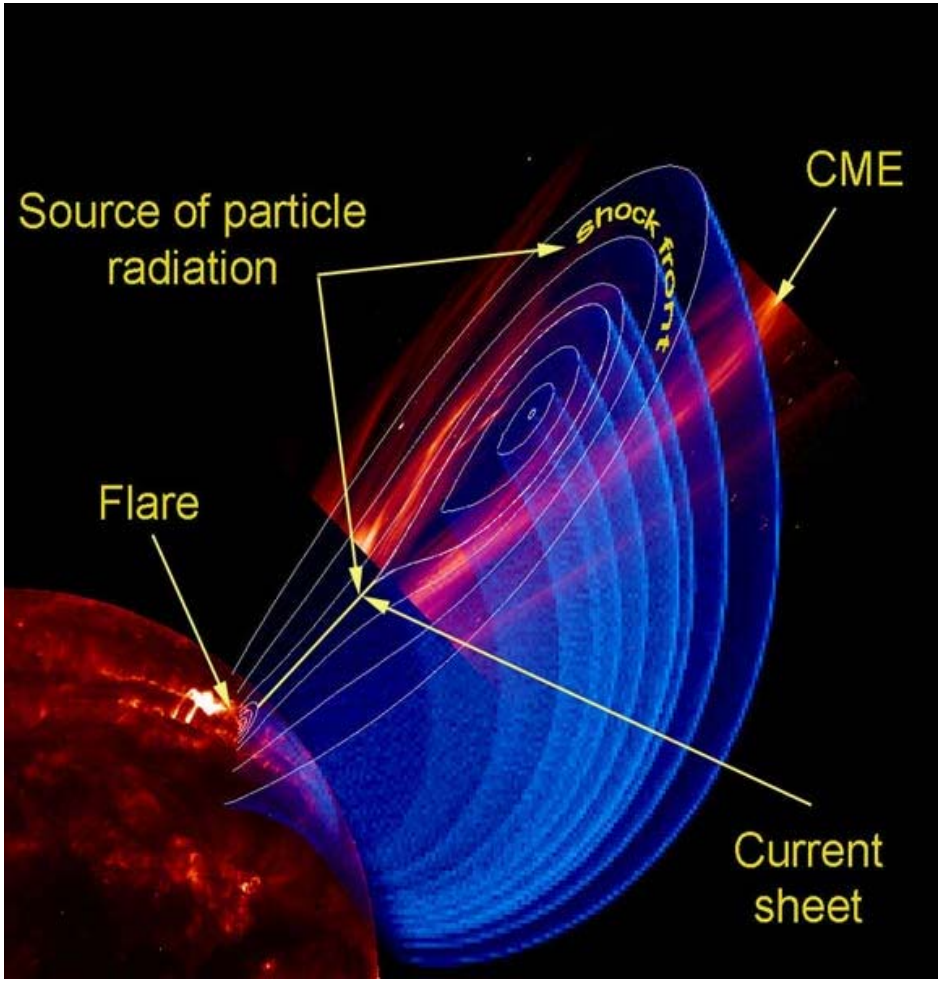
# GCR & Space Radiation

## Two main sources of ionizing radiation:




# Space Radiation: The Drive & The Challenges

## The Drive

A NASA strategic radiation protection guideline is the:

"*Demonstration of shielding concepts providing radiation protection focusing on light-weight multi-functional structure-capable materials that can provide GCR/SPE protection while providing other functionalities such as thermal insulation, structural integrity, and/or MMOD protection*."

## The Challenges

Effective shielding against the combined effects of GCRs and SEPs can be mass prohibitive

Shielding effectiveness of new, potential shielding materials (or combinations thereof) is not well characterized

Little data to guide dose and risk assessment models (large uncertainties and variabilities)

# Space Radiation: Monitoring & Detection

- Marshall scientists and engineers develop state-of-the-art charged particle and neutral particle detectors suitable for the harsh environments of space

***-Trapped and Solar Energetic Particle Spectrometer (TaSEPS)*:** *TaSEPS is a compact wide dynamic range charged particle spectrometer for measuring trapped and solar energetic protons by combing scintillation and Cherenkov techniques in a single CsI crystal that extends the dynamic range and reduces the mass and power requirements*

***Planned for a balloon flight***

# Near Earth Exposure

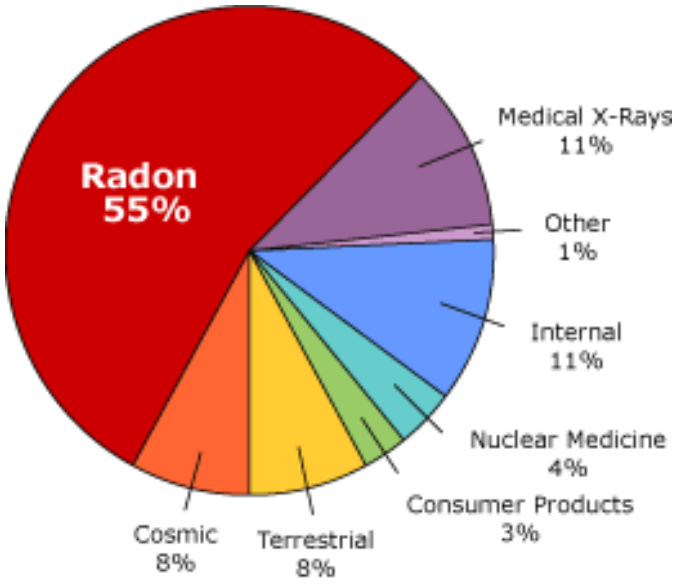
TABLE I: 1999 NCRP-recommended dose limits by organ and exposure duration.

| Limit (cSv) | Bone Morrow | Eye | Skin |
|---|---|---|---|
| 30-day Exposure | 25 | 100 | 150 |
| Annual | 50 | 200 | 300 |
| Career | 50-300 | 400 | 600 |

TABLE II: Expected doses on the lunar surface with and without shielding (no nuclear power source assumed).

| Duration (days) | GCR (cSv) | SEP (cSv) | Mission (cSv) |
|---|---|---|---|
| 10 | 0.3/0.8 | 7.5/20.5 | 7.8/21.3 |
| 30 | 1.0/2.5 | 7.5/20.5 | 8.5/23.0 |
| 180 | 6.0/15.0 | 7.5/20.5 | 13.5/35.5 |
| 360 | 12.0/30.0 | 7.5/20.5 | 19.5/50.5 |

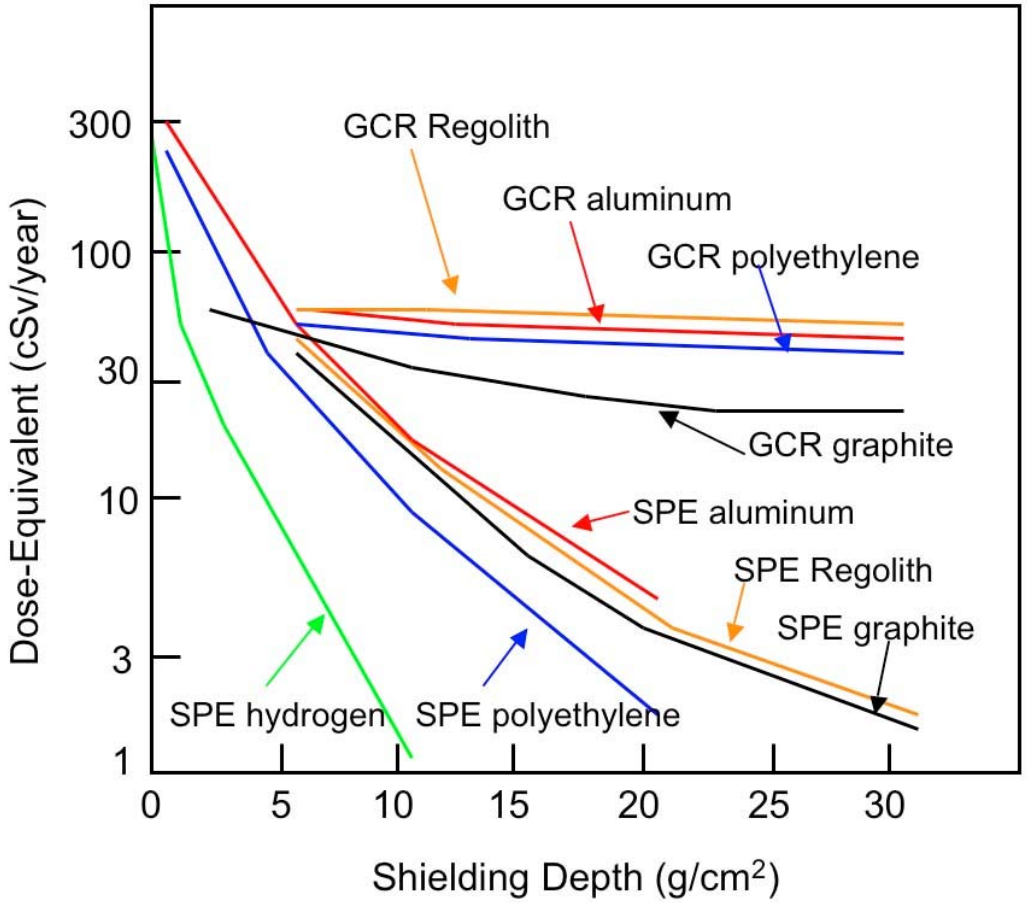
In-Space expected levels and limits




Distribution of terrestrial exposure of few cSv/yr

# Protection from GCRs and SEPs

-Materials vary in their ability to shield against GCR nuclei
-**Polymeric based materials tend to be most effective** but their structural properties remain poor
-**Aluminum**, like all metals, is **a poor GCR shield**



# Space Radiation at Marshall

- Monitoring & Detection

  protons- TaSEPS

  neutrons- ANS

- Forecasting

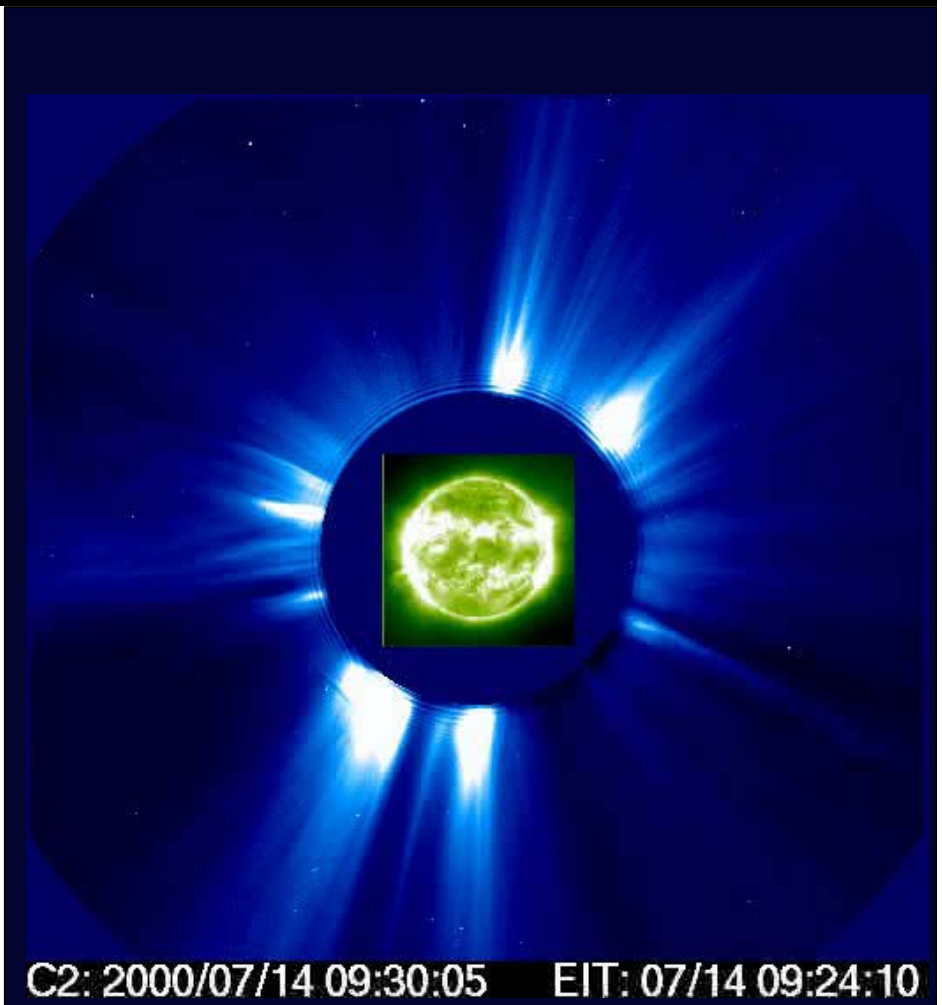
  Mag4

- Modeling & Simulation

  Geant4-based

- Radiation-Smart Structures

  Geant4-informed




***Bastille Day (2000 July 14) Flare, Coronal Mass Ejection and Solar Energetic Particle Event***

# Space Radiation: Monitoring & Detection

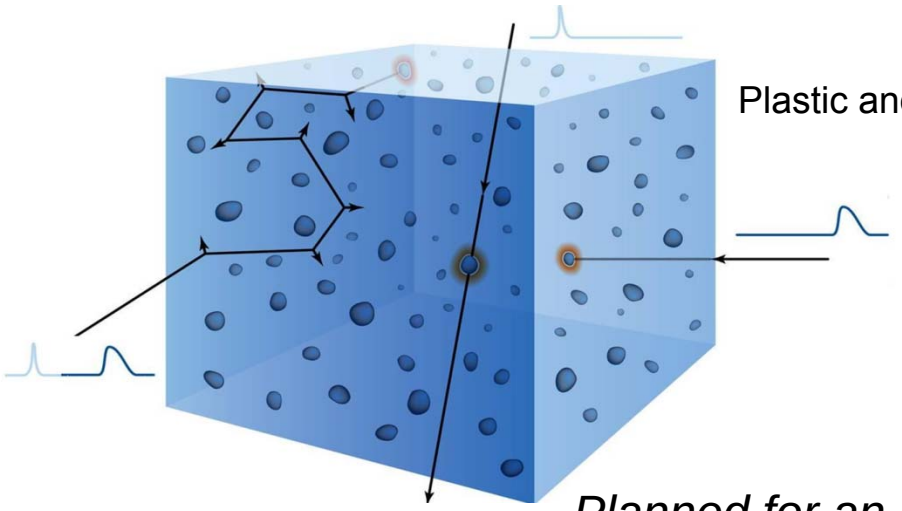
- Marshall scientists and engineers develop state-of-the-art charged particle and neutral particle detectors suitable for the harsh environments of space:

***-Advanced Neutron Spectrometer (ANS):*** *is a new instrument technique being developed to meet NASA's requirements to monitor the radiation exposure due to secondary neutrons for future crewed missions. New instrument designs are needed to achieve the measurement performance requirements that fit within the resource limits of exploration missions beyond Earth's protective magnetic field*

$n + {}^{6}Li \rightarrow {}^{3}H + {}^{4}He$
$Q = 4.78$

$n + Gd \rightarrow Gd^{*} + \gamma$
$Q = [0,2]$

$n + {}^{10}B \rightarrow {}^{7}Li + {}^{4}He$
$Q = 2.73\ (93\%)$
or $2.25\ (7\%)$

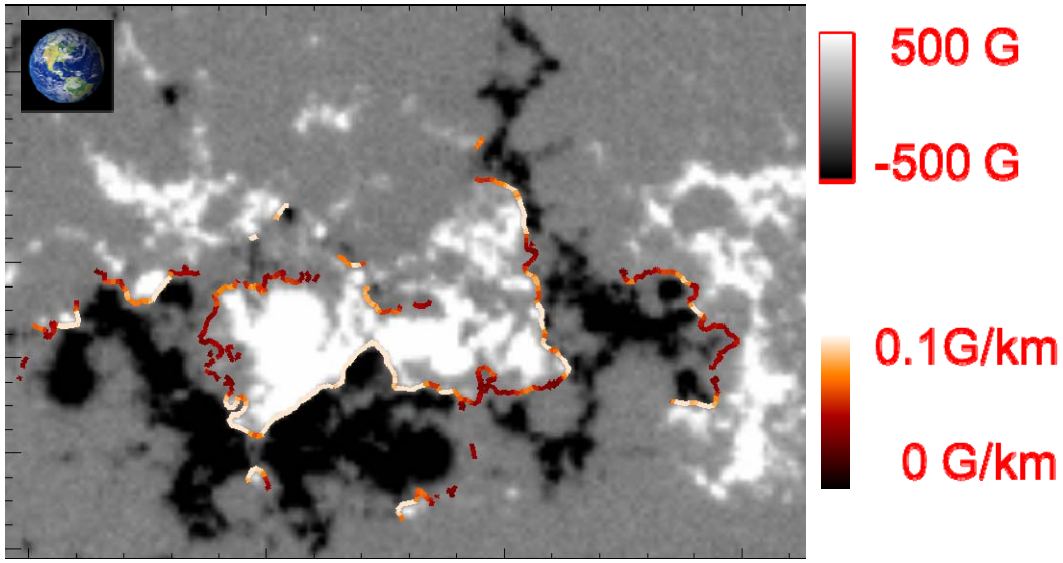



*Planned for an ISS flight demonstration*

# Space Radiation: Magnetic-based Forecasting (Mag4)

- Marshall scientists and engineers developed an automated prediction system that downloads and analyzes magnetograms from the HMI (Helioseismic and Magnetic Imager) instrument on NASA SDO (Solar Dynamics Observatory), and then automatically converts the rate (or probability) of major flares (M- and X-class), Coronal Mass Ejections (CMEs), and Solar Energetic Particle Events

  [Present cadence of new forecasts: **96 min**; Vector magnetogram actual cadence: **12 min**]




**A magnetogram of an active region on the Sun**

When the transverse gradient of the vertical (or line-of-sight) magnetic field is large, there is more free-energy stored in the magnetic field

For each Active Region: The integral of the gradient along the neutral line is the free-energy proxy

# Mag4: A Comparison of Safe and Not Safe Days

June 26, 2013

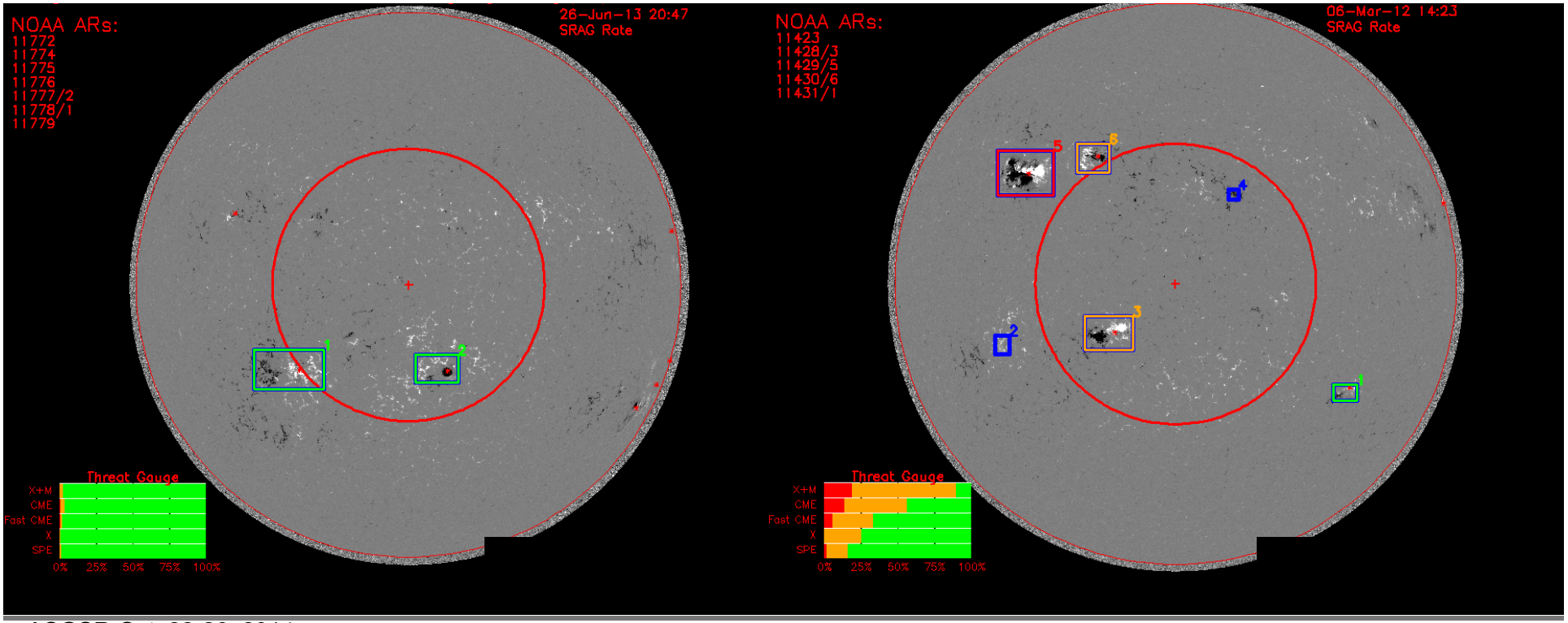
C1, C1.5 flares

March 7, 2012

X5.4, X1.3, C1.6

CME 2684, 1825 km/sec,

Solar Energetic Proton Event reaches 6530 ‘particle flux unit’ >10 MeV



# Space Radiation: Modeling & Simulation

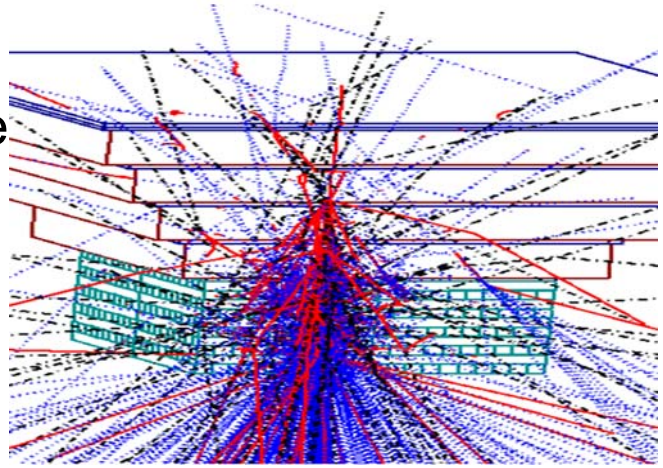
- Marshall scientists and engineers use Geant4 for the design, analysis, and development of

  *particle detector systems*

  *exposures at accelerators and in-situ*

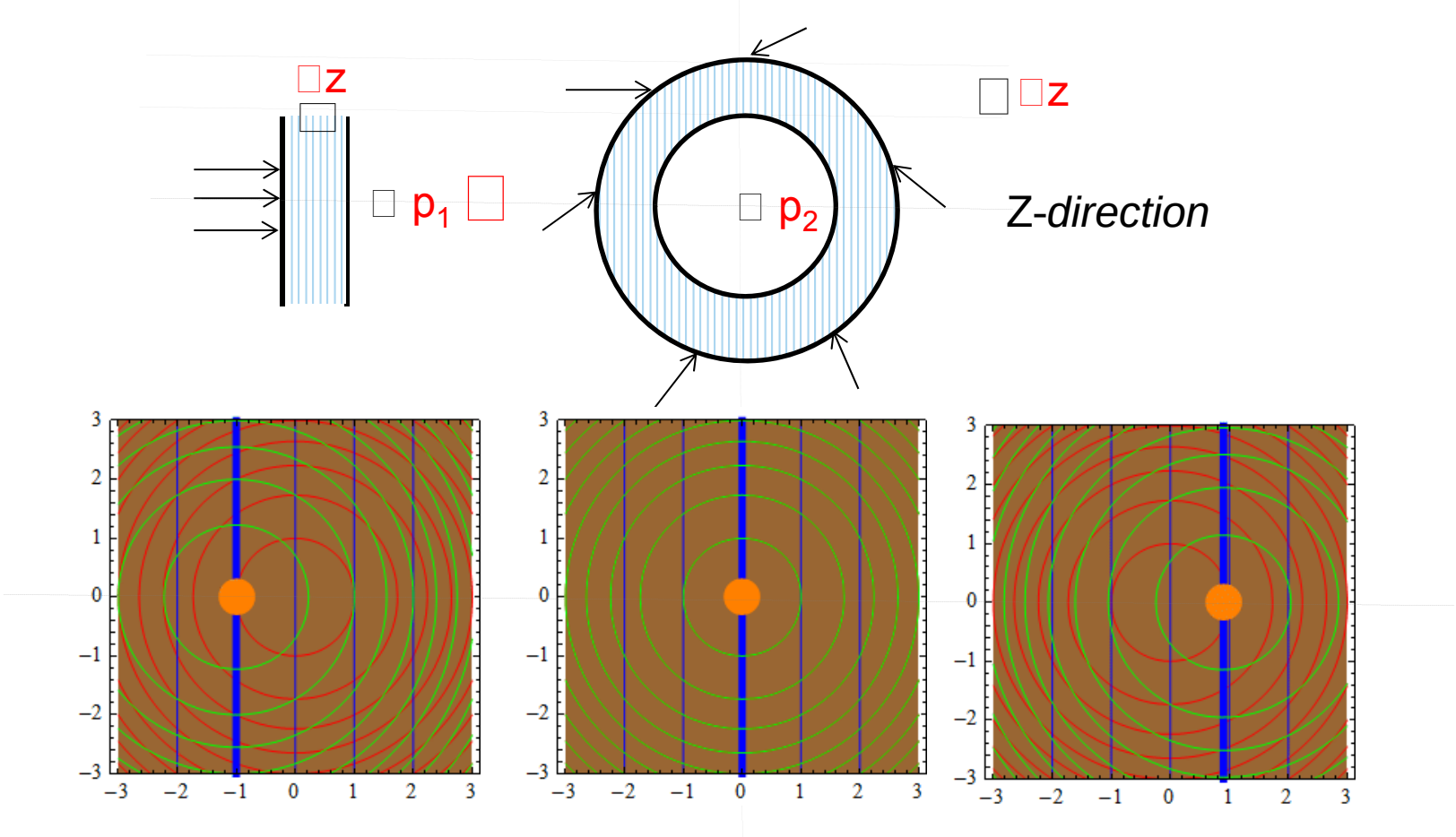
  *dose estimates*

  *shielding solutions*

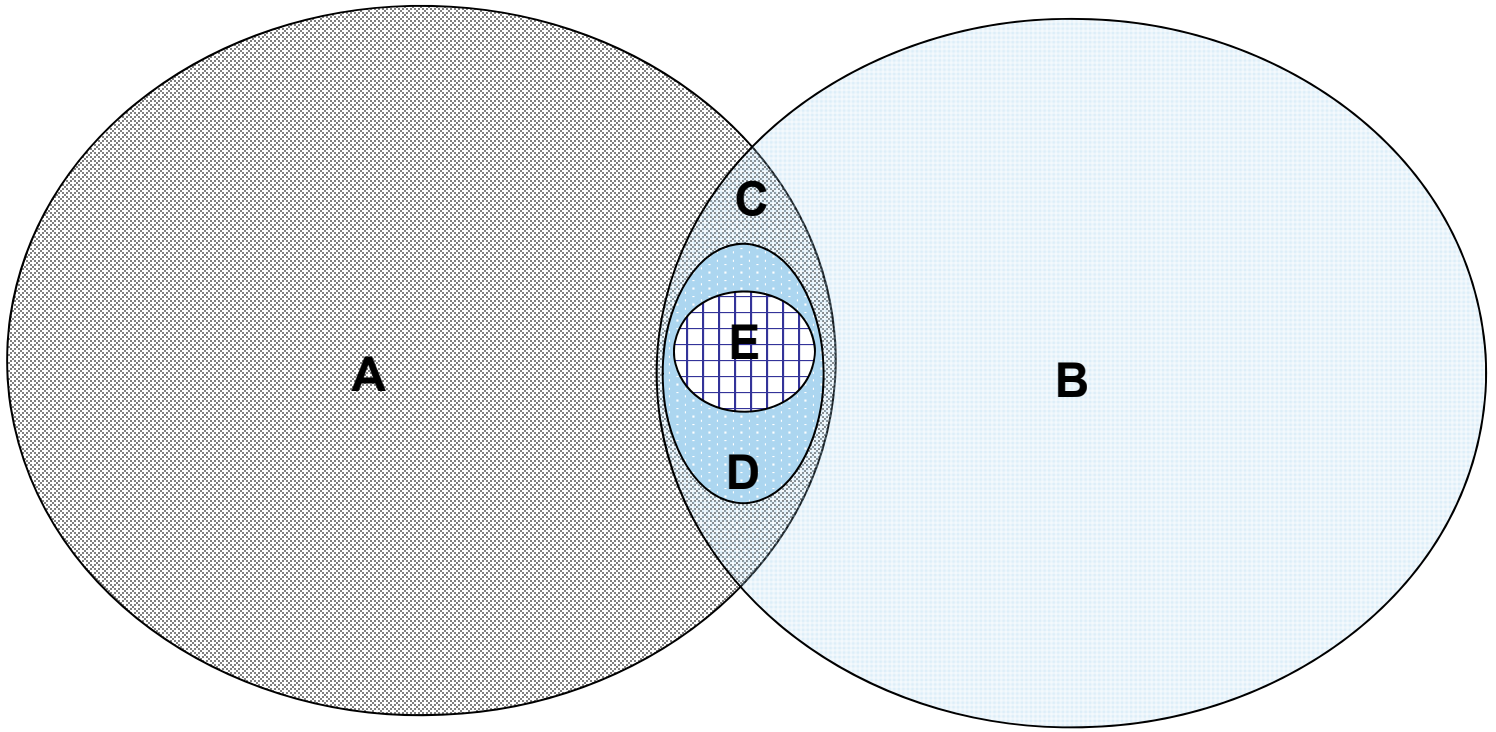


- Marshall scientists and engineers collaborate with experimental and theoretical and computational groups at Oak Ridge National Laboratory, Berkeley's Lawrence National Laboratory, Brookhaven National Laboratory, Indiana University's Cyclotron Facility, Japan's HIMAC facility, and others for basic and applied nuclear modeling, simulation, and exposure and shielding studies

# Space Radiation: Modeling & Simulation



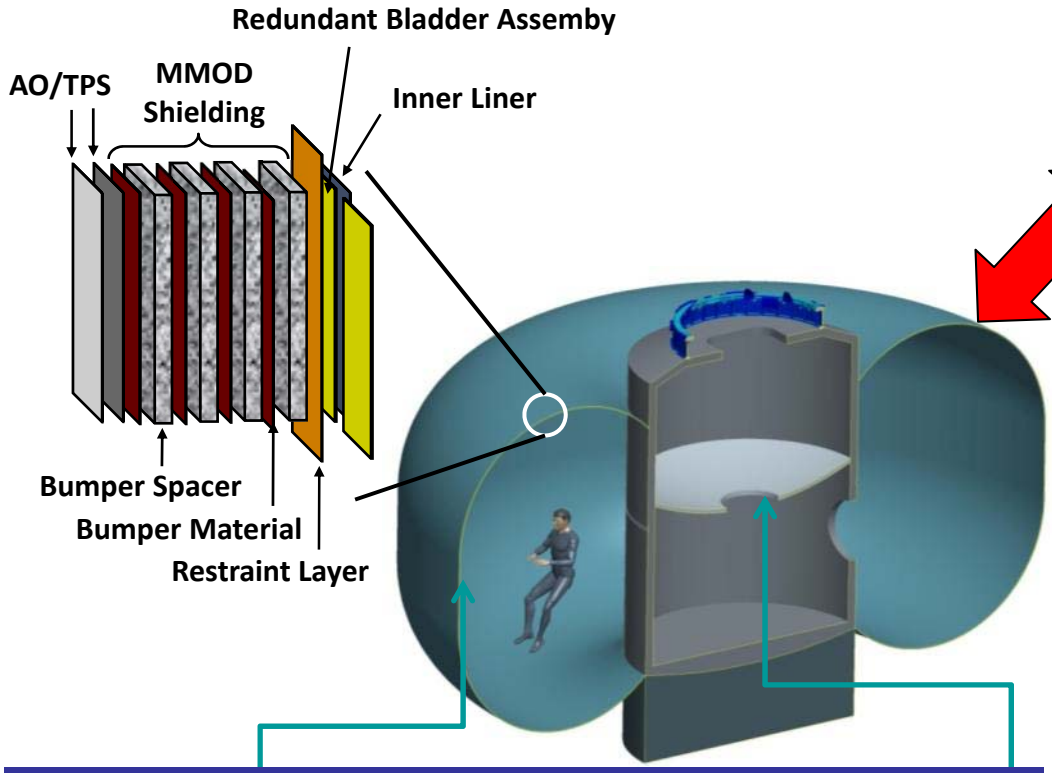
# Radiation-Smart Structures and Designs?




**A**: Adaptive Structures
**B**: Sensory Structures
**C**: Controlled Structures
**D**: Active Structures
**E**: Intelligent Structures

# Space Radiation: Radiation-Smart Structures and Designs

Smart Materials:
Multi-functional




Smart Designs:
Optimized

radiation shielding will most likely focus on MMOD shielding materials and core

# Space Radiation: Built-In Protection (A New Paradigm)

-NASA in collaboration with other federal agencies, FFRDC, academia, and the private sector is embarking on a new and radical way in looking at the challenges and solutions of space-radiation exposure; from the 'grounds' up

-Marshall is at the heart of this new paradigm making