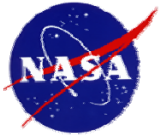


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# **Radiation Shielding Materials, Protection Technologies, and Transport Modeling**

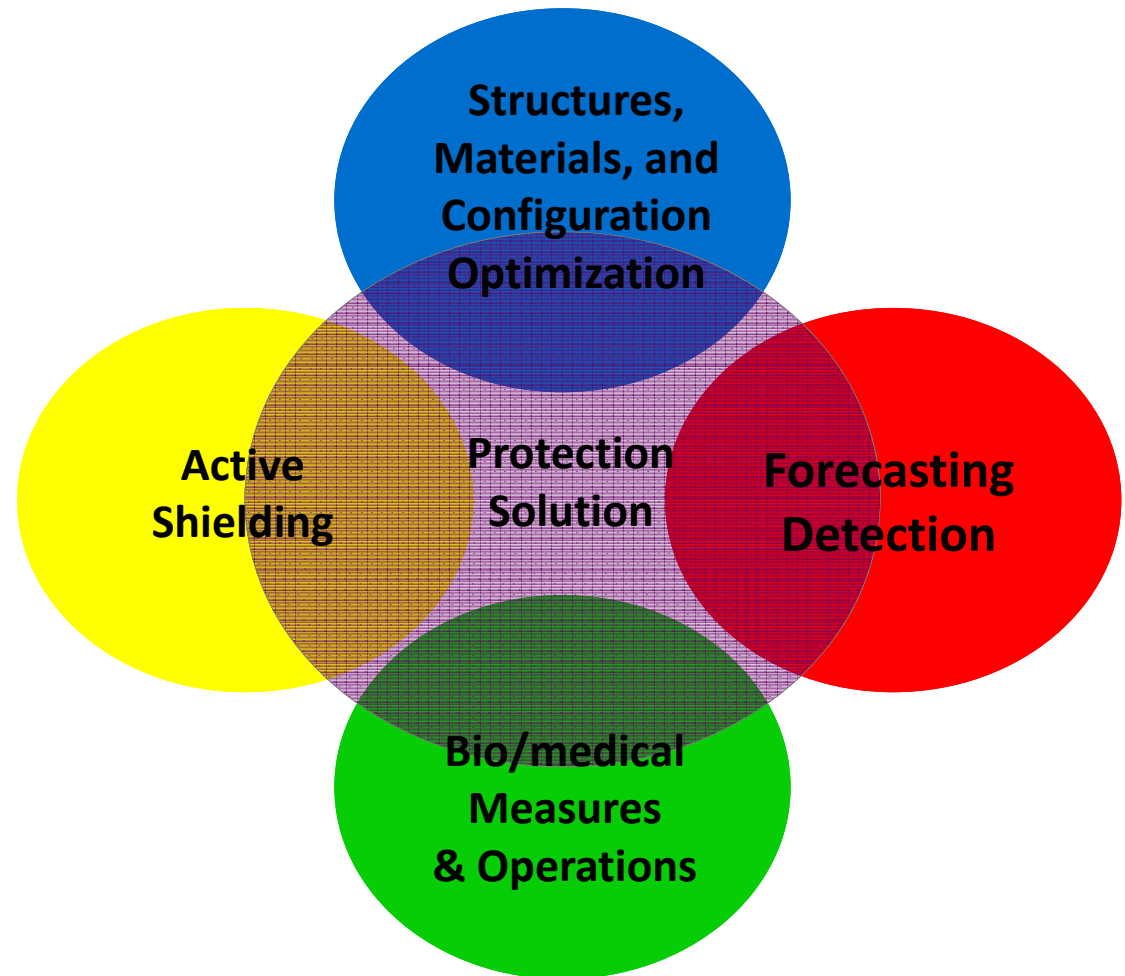
*presented for National Research Council*  
“Human Health and Surface Exploration Panel Workshop”  
Lunar and Planetary Institute, Houston, Texas  
April 26, 2011

**Dr. Martha Cloudsley**  
**NASA Langley Research Center**  
**Hampton, Virginia**  
**Martha.S.Cloudsley@nasa.gov**  
**(757) 864-1099**



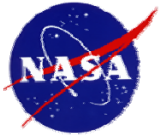
# Integrated Approach to Radiation Shielding

- More than one approach may be needed to meet protection requirements
- Materials can be engineered to provide more protection, but the physics still requires mass
- Structures and mass are at odds with lightweight radiation protection
- Modeling and analysis can be used to evaluate the combined effects of multiple technologies

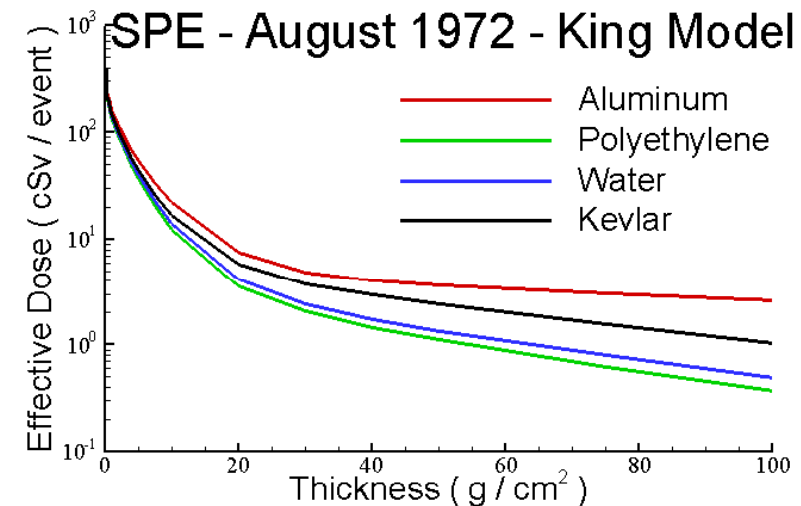
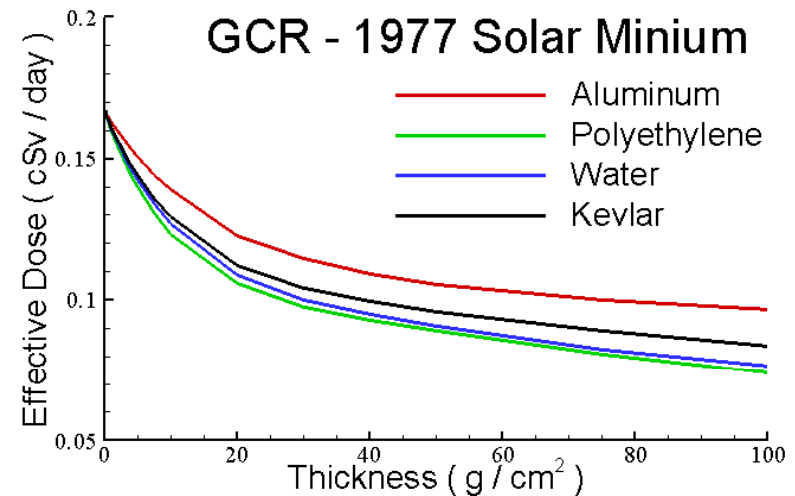


*Improved shielding materials will not “solve” the radiation problem, but are one part of an integrated approach to radiation shielding.*

# Shielding Materials for GCR and SPE Environments

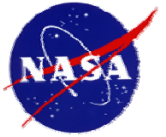


- Galactic Cosmic Rays (GCR)
  - Made up of heavy ions as well as alpha particles and protons
  - Modulated by the solar wind
    - always present
    - varies with the 11 year solar cycle
- Solar Particle Events (SPE)
  - Made up of a large number of particles, primarily protons
  - Correspond to large coronal mass ejections
  - Large SPE are rare and short lived
  - Large SPE could result in fatality



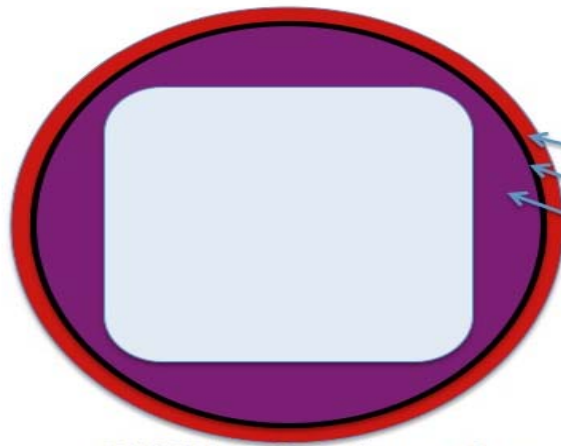
*Shielding materials cannot eliminate astronaut exposure, but the use of hydrogen rich materials will reduce the effective dose.*

# Incorporation of Shielding Materials in Vehicle Architecture

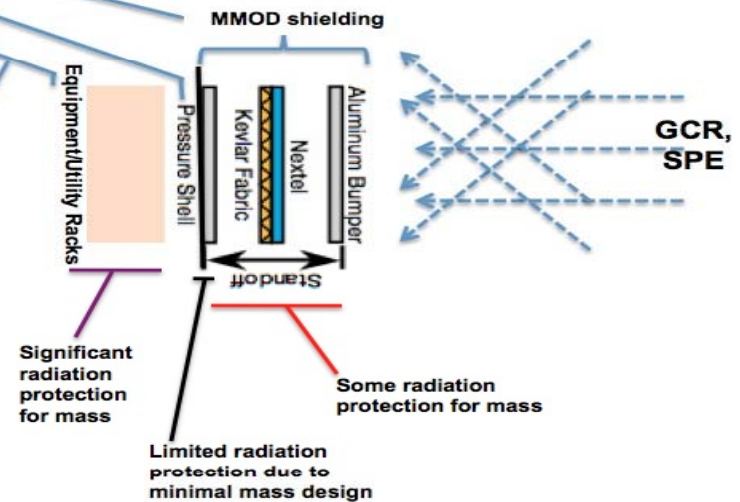


## ISS Wall Configuration

Conceptual Diagram

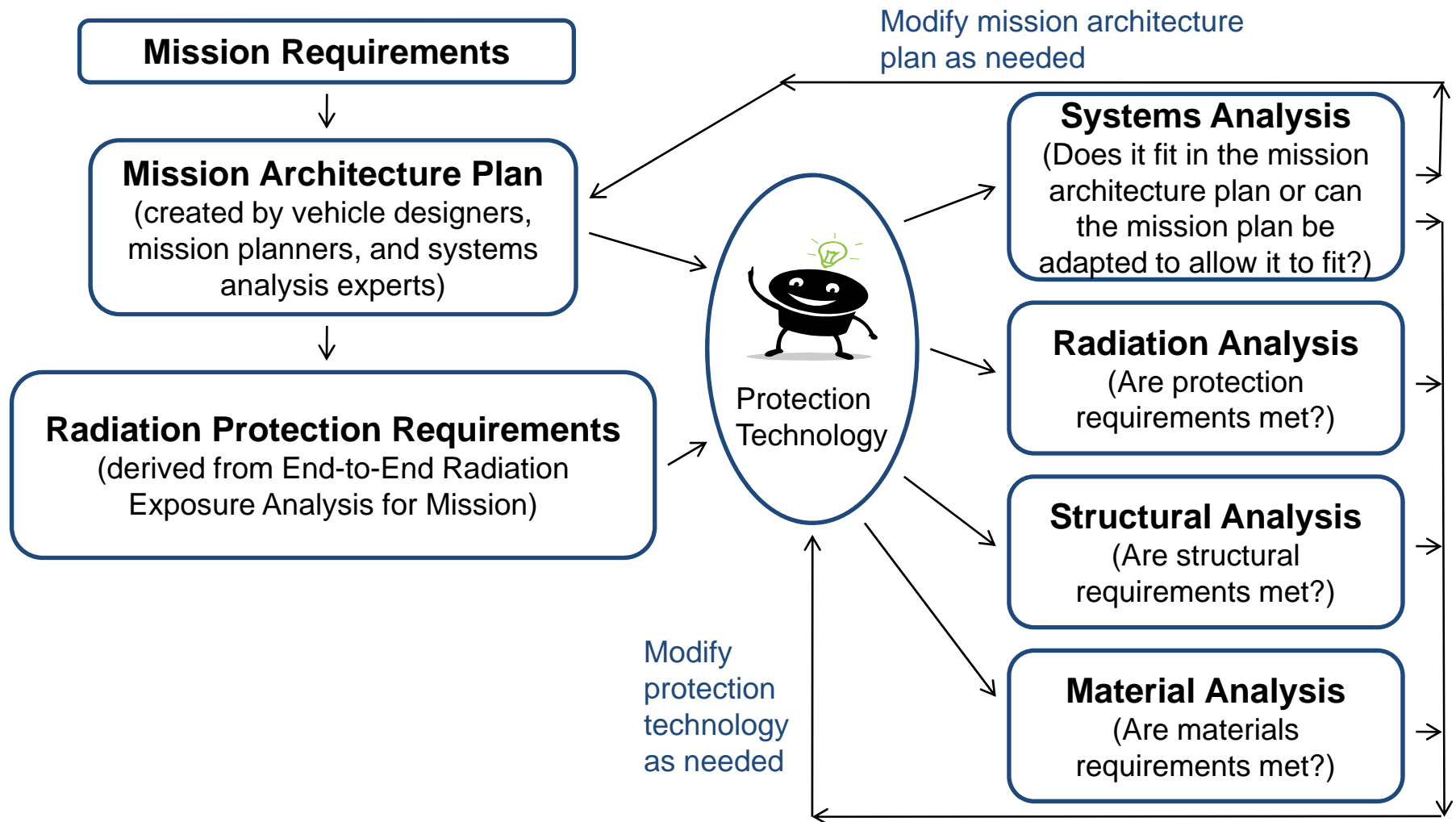
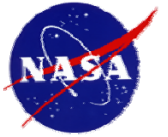


Photograph



*Improved shielding materials should be incorporated into each vehicle system.*

# A Cross-Disciplinary Approach to Radiation Protection Technology

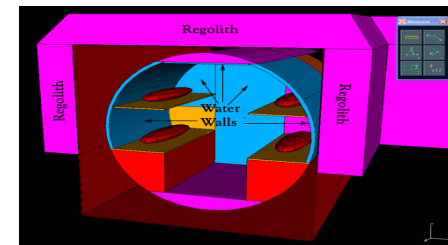
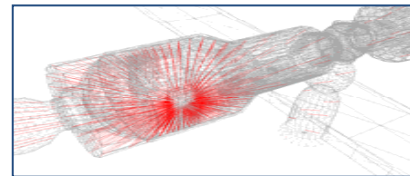
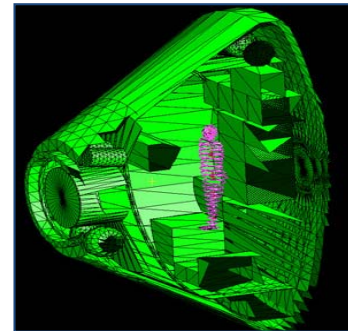
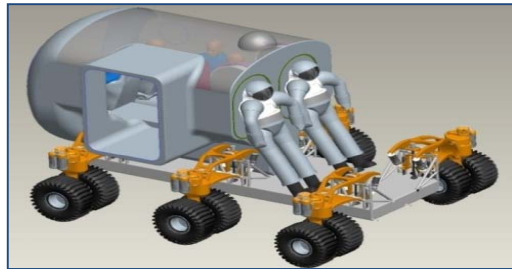
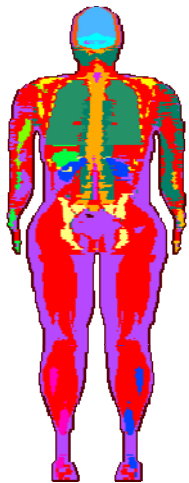


*A multi-disciplinary approach is needed to reduce the risks associated with incorporating new concepts in mission architecture.*

# Analysis for Protection Technologies

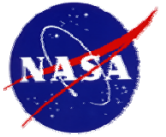
To evaluate the usefulness of protection technologies, a number of computation tools are needed:

- space environment models, nuclear physics models, transport codes, response functions, human body models, vehicle/habitat shield models, tools for creating shield models, and user frameworks like OLTARIS (On-Line Tool for the Assessment or Radiation In Space)



*A variety of tools are needed to assess astronaut exposure in complex vehicles or habitats.*

# The On-Line Tool for the Assessment of Radiation in Space (OLTARIS)



<https://oltaris.larc.nasa.gov>

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION | Logged in as Chris Sandridge (01/28/2009)  
 + Send a Comment / + Report a Bug

- Projects + Thickness Distributions + Uncertainty + User Guides + ChangeLog + Log Out

## OLTARIS BETA

On-Line Tool for the Assessment of Radiation in Space

+Return to Submitted-Jobs List | +Return to Project List

**Event Totals** + Help

Dose and Dose Equivalent calculated at the points specified in the thickness distribution without the presence of the CAM/CAF.

Data	Value
Dose	2.204E+04 mGy
Dose Equivalent	4.016E+04 mSv
Effective Dose	2.312E+03 mSv

**Organ Doses**

Organ	Avg. Dose Equivalent Per Day/Per Year
Skin	1.469E+04 mSv
Colon	1.113E+03 mSv
Esophagus	3.312E+03 mSv
Brain	1.440E+03 mSv
Uterus	7.447E+02 mSv
Ovaries	6.320E+02 mSv
Kidneys	9.482E+02 mSv
Muscle	6.653E+03 mSv
Liver	1.002E+03 mSv
Bone	3.272E+03 mSv
Bladder	1.193E+03 mSv
Thyroid	8.855E+03 mSv
Bfo	1.764E+03 mSv
Lungs	1.651E+03 mSv
Stomach	4.906E+02 mSv
Breast	1.192E+04 mSv
Pancreas	8.724E+02 mSv
Spleen	5.343E+02 mSv
Intestine	1.275E+03 mSv
Lens	1.570E+04 mSv

**Table Data**

Dose and Dose Equivalent calculated at the points specified in the thickness distribution without the presence of the CAM/CAF.

Data	
Dose (mGy) vs. Depth (g/cm2)	+ Plot + Download
Dose Equivalent (mSv) vs. Depth (g/cm2)	+ Plot + Download

**XML Viewer .swf (application/x-shockwave-flash Object) - Mozilla Firefox**

[https://oltaris.larc.nasa.gov/swfs/XMLViewer.swf?dataurl=http://oltaris.larc.nasa.gov/job/view\\_xml/495%3fname=doseq\\_table\\_mSv.dat](https://oltaris.larc.nasa.gov/swfs/XMLViewer.swf?dataurl=http://oltaris.larc.nasa.gov/job/view_xml/495%3fname=doseq_table_mSv.dat)

Show Options

**Dose Equivalent (mSv) vs. Depth (g/cm2)**

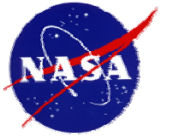
**Legend**

- Depth in Tissue: 1e-10 g/cm2
- Depth in Tissue: 2.0000e-01 g/cm2
- Depth in Tissue: 5.0000e-01 g/cm2
- Depth in Tissue: 4.0000e+00 g/cm2
- Depth in Tissue: 4.0000e+01 g/cm2
- Depth in Tissue: 2.0000e+01 g/cm2

Depth in Tissue: 1e-10 g/cm2  
 Depth in Aluminum: 2.0000e+01 g/cm2  
 Value: 3.484e+2 mSv

Read oltaris.larc.nasa.gov | oltaris.larc.nasa.gov

*The OLTARIS website enables rapid exposure analyses for complex mission architecture.*



## Two Types of Transports Codes

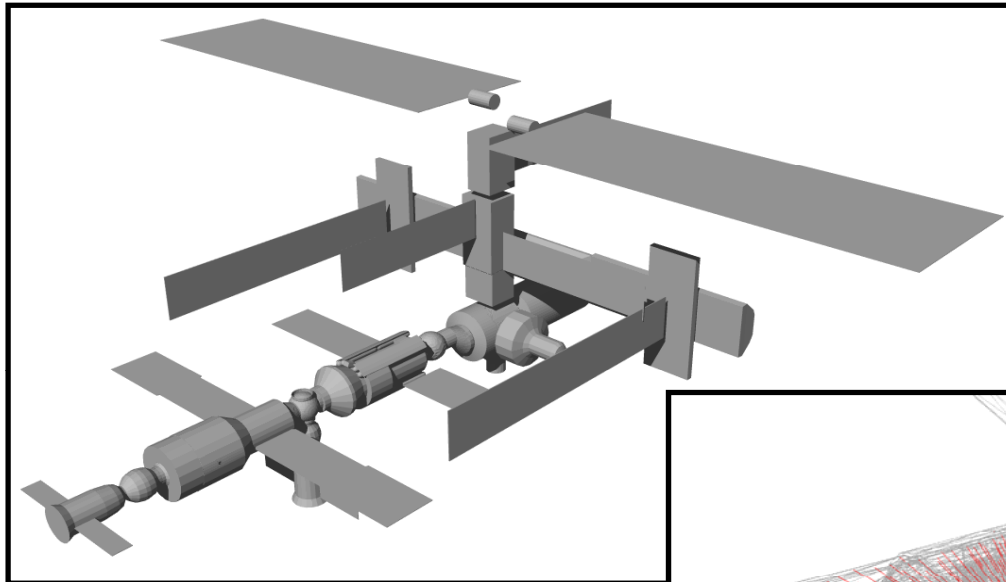
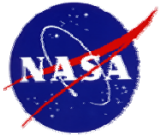
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- Monte Carlo Codes: FLUKA, PHITS, GEANT4, MCNPX, HETC-HEDS
  - Accurately model 3-dimensional radiation transport
  - Require large amounts of computer time
  - Very difficult to incorporate complex geometry
- Deterministic Codes: HZETRN, GRNTRN, CEPTRN
  - Accurately model the transport of neutrons, protons, light ions, and heavy ions
  - Provide rapid transport calculations
  - Can be used with complex vehicle geometry
  - Current versions of HZETRN utilize a “straight ahead” approximation
  - Current versions of HZETRN do not include pions, muons, or electromagnetic cascades

*HZETRN enables calculations involving complex geometry, but Monte-Carlo codes more accurately model 3-dimensional transport.*

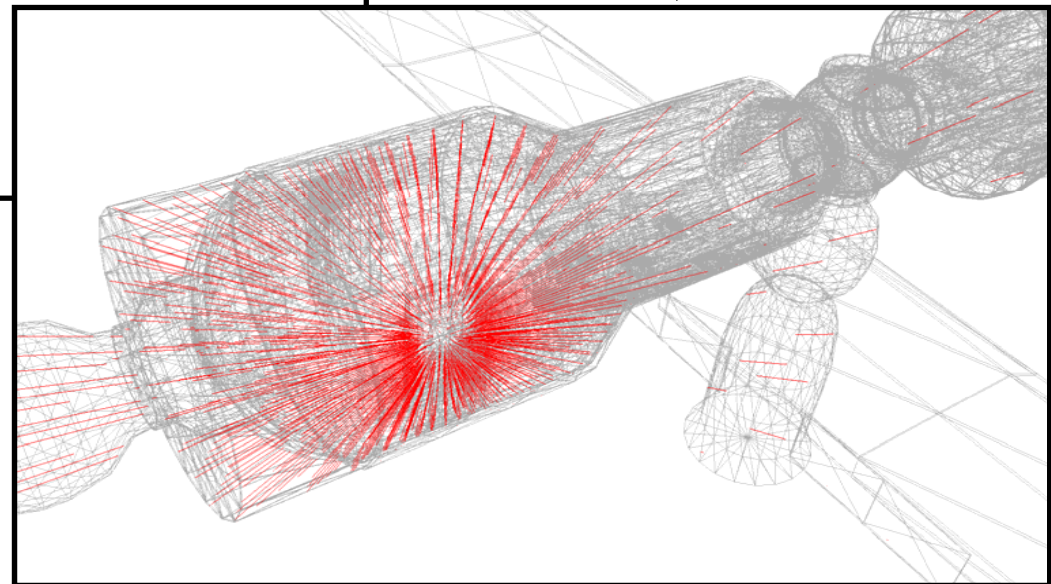


# Ray-Tracing Technique for Transport Calculations Using HZETRN

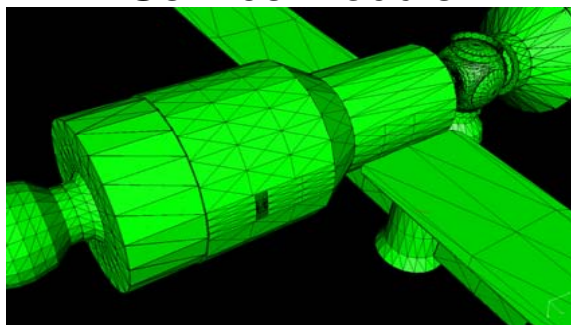


← International Space Station (ISS)

Service Module Ray-Trace

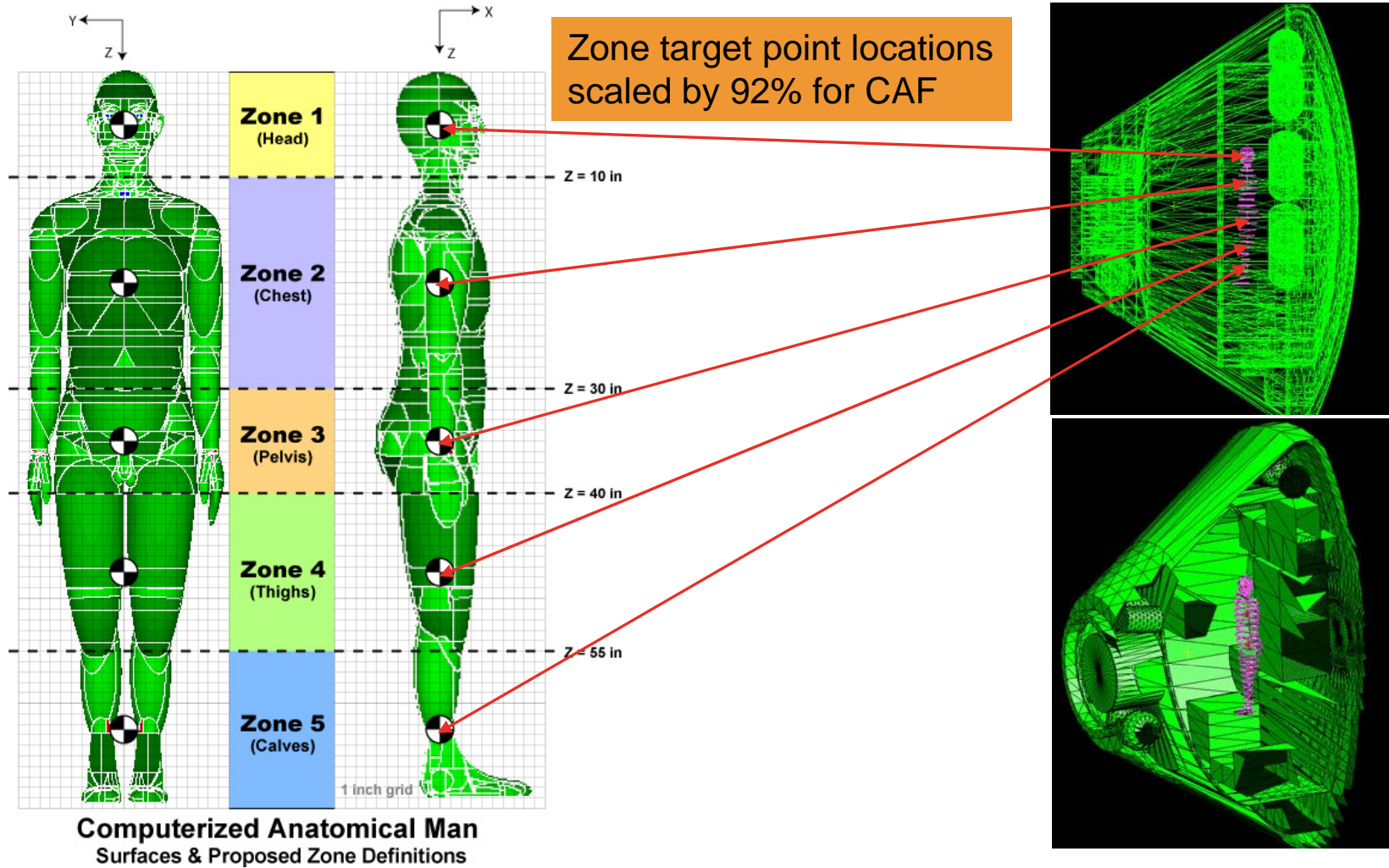
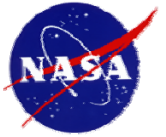


Service Module

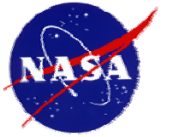


*The “straight ahead” approximation enables radiation analysis for complex geometries.*

# Incorporation of Body Models in Vehicle Geometry



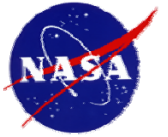
*OLTARIS utilizes detailed human body models. The user chooses the astronaut position and orientation.*



# Recommendations – Shielding Materials

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- Basic materials research is needed for the development of improved shielding materials
  - Boron nitride nanotubes
  - High hydrogen, high strength, high temperature polymers
  - Multi-layered material systems
  - .... The next great idea
- A broad effort to raise the technical readiness levels (TRLs) of existing shielding materials and material systems is also needed
  - Testing and analysis to fully characterize shielding materials
    - Structural, thermal, environmental
  - Development of vehicle/habitat components and sub-components utilizing these materials and material systems
  - Inclusion of these components in habitat demonstrations and analogs



# Recommendations – Exposure Analysis Tools

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- Space radiation transport calculation can be improved by:
  - Extending one dimensional transport to include pions, muons, and electromagnetic cascades
  - Improving nuclear physics models, particularly light ion production
    - Cross section measurements are required
  - Evaluating the impact of three dimensional effects on vehicle analysis and exposure estimates
- Vehicle/habitat analysis can be improved by:
  - Improving methods for infusing CAD architecture into Monte-Carlo transport codes
  - Incorporating improved space weather models into analysis tools to enable probabilistic design
  - Incorporating human response functions into analysis tools