Radiation Shielding Materials, Protection Technologies, and Transport Modeling

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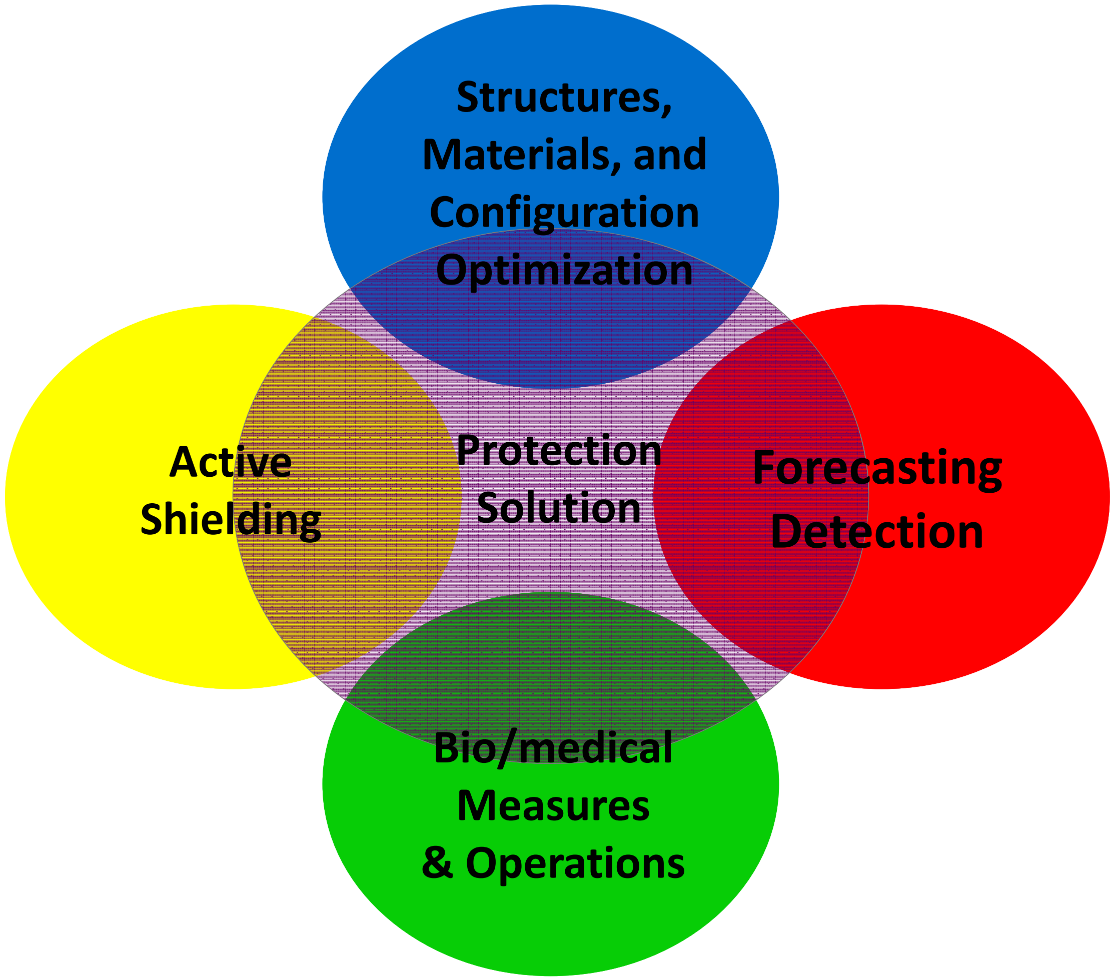
Integrated Approach to Radiation Shielding

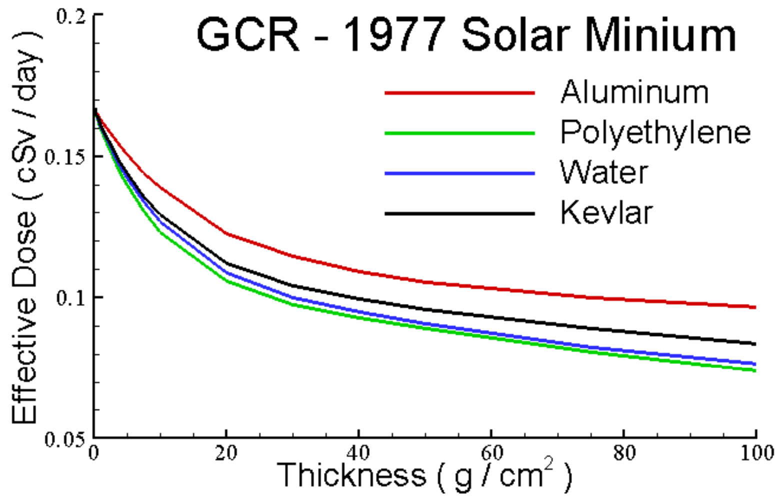
- More than one approach may be needed to meet protection requirements
- Materials can be engineered to provide more protection, but the physics still requires mass
- Structures and mass are at odds with lightweight radiation protection
- Modeling and analysis can be used to evaluate the combined effects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

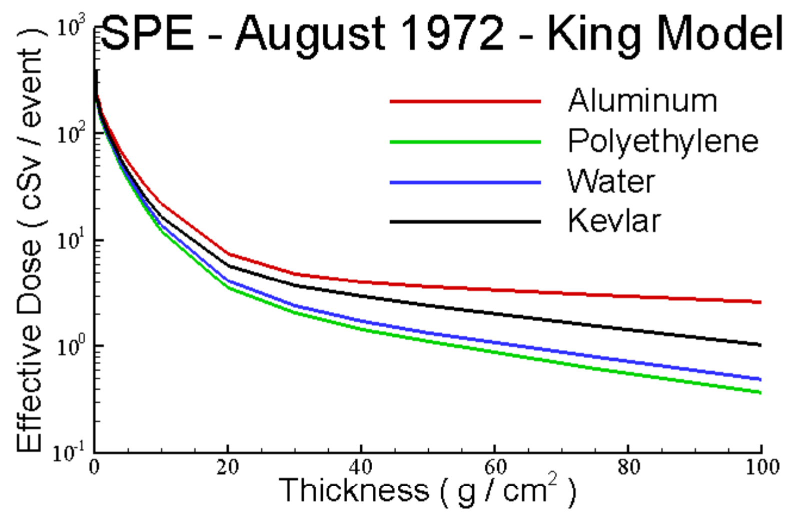


Improved shielding materials will not "solve" the radiation problem, but are one part of an integrated approach to radiation shielding.

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





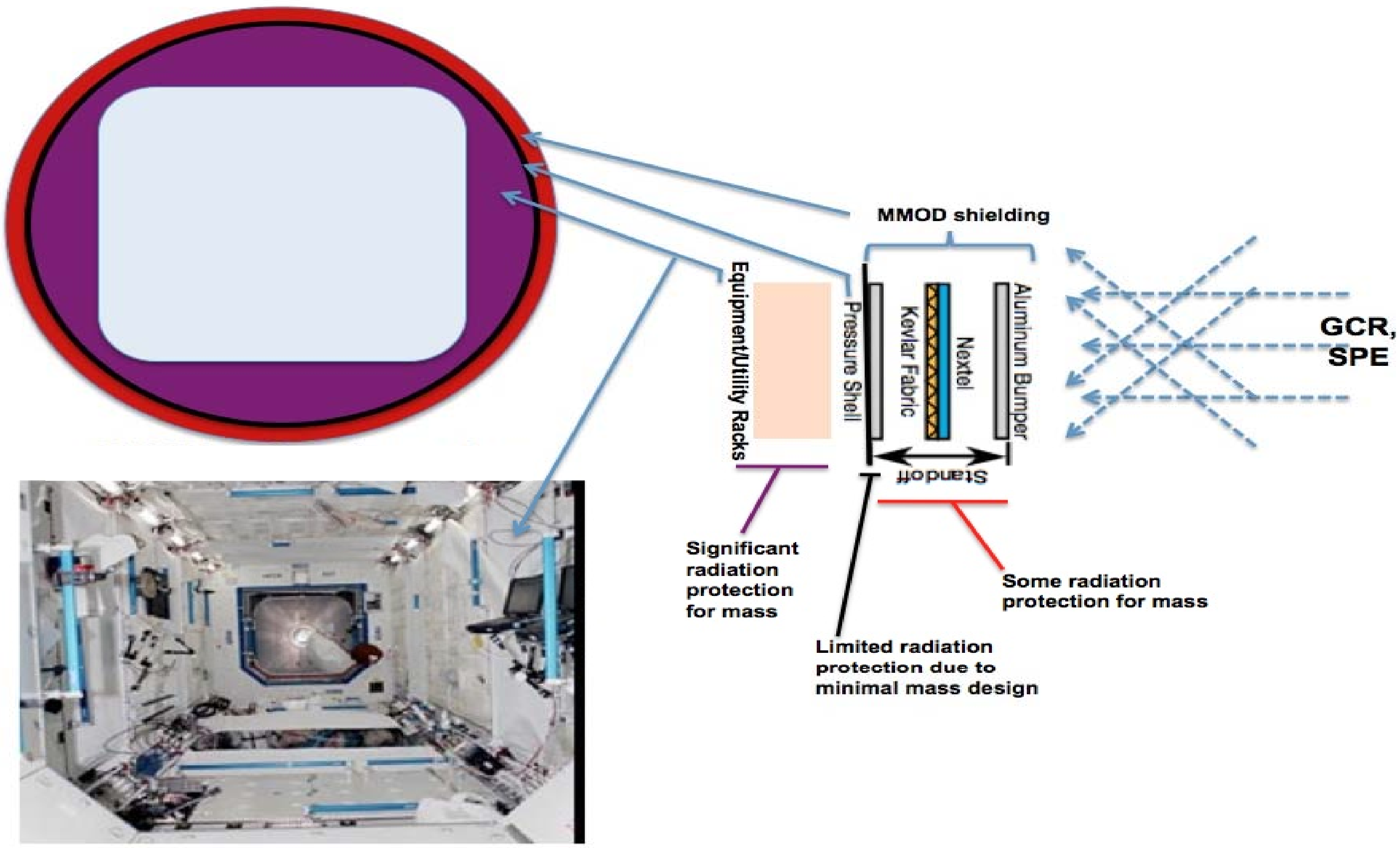
Shielding materials cannot eliminate astronaut exposure, but the use of hydrogen rich materials will reduce the effective dose.

Incorporation of Shielding Materials in Vehicle Architecture

ISS Wall Configuration

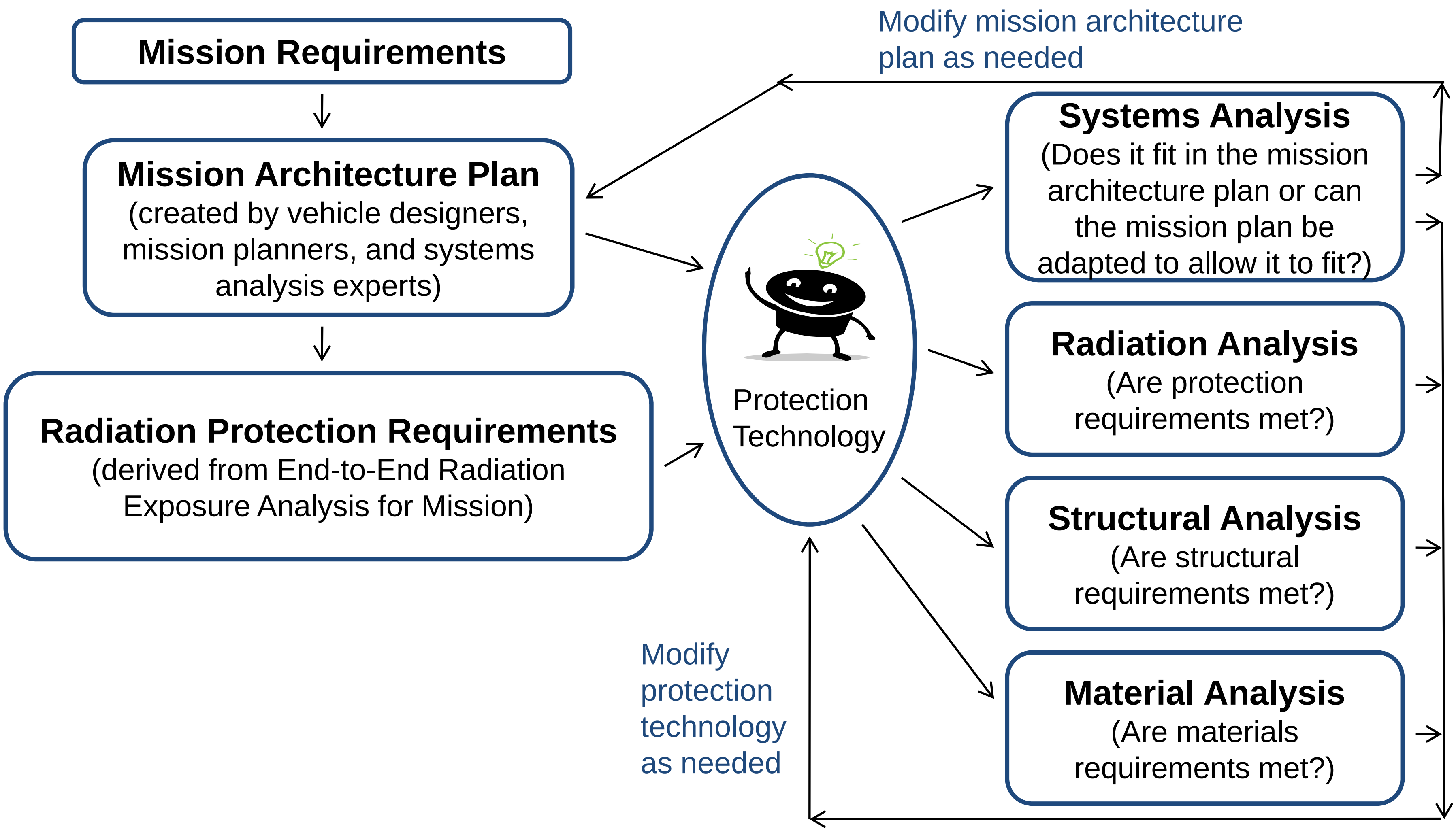
Conceptual Diagram

Photograph



Improved shielding materials should be incorporated into each vehicle system.

A Cross-Disciplinary Approach to Radiation Protection Technology

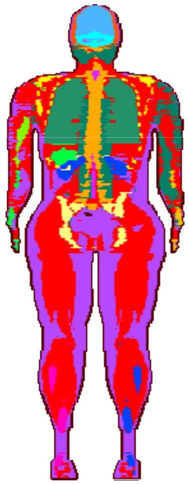


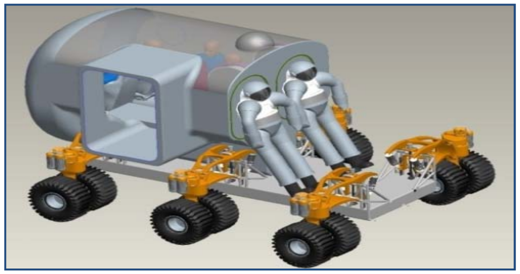
A multi-disciplinary approach is needed to reduce the risks associated with incorporating new concepts in mission architecture.

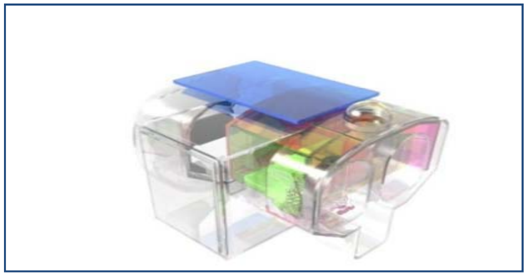
Analysis for Protection Technologies

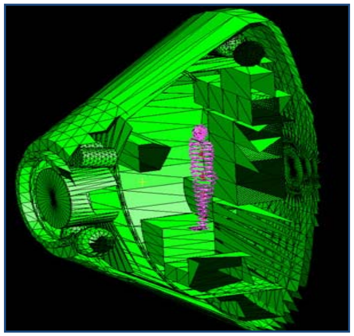
To evaluate the usefulness of protection technologies, a number of computation tools are needed:

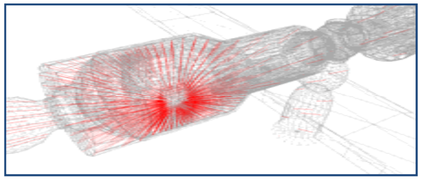
– space environment models, nuclear physics models, transport codes, response functions, human body models, vehicle/habitat shield models, tools for creating shield models, and user frameworks like OLTARIS (On-Line Tool for the Assessment or Radiation In Space)

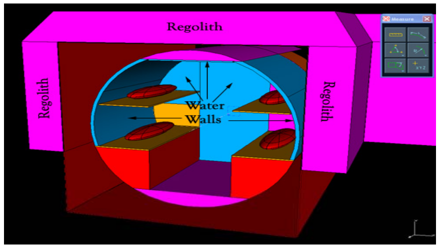








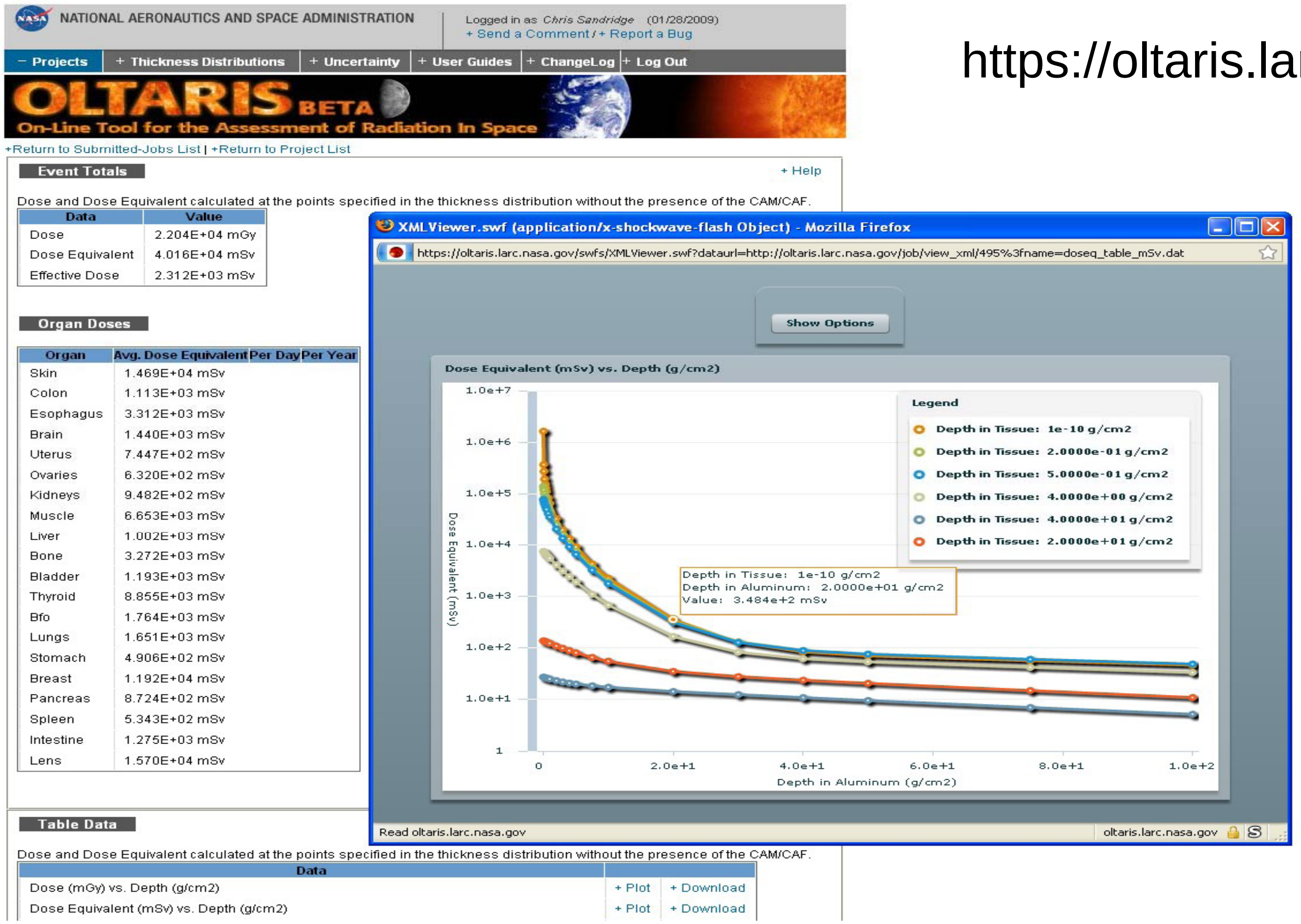




A variety of tools are needed to assess astronaut exposure in complex vehicles or habitats.

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

https://oltaris.larc.nasa.gov



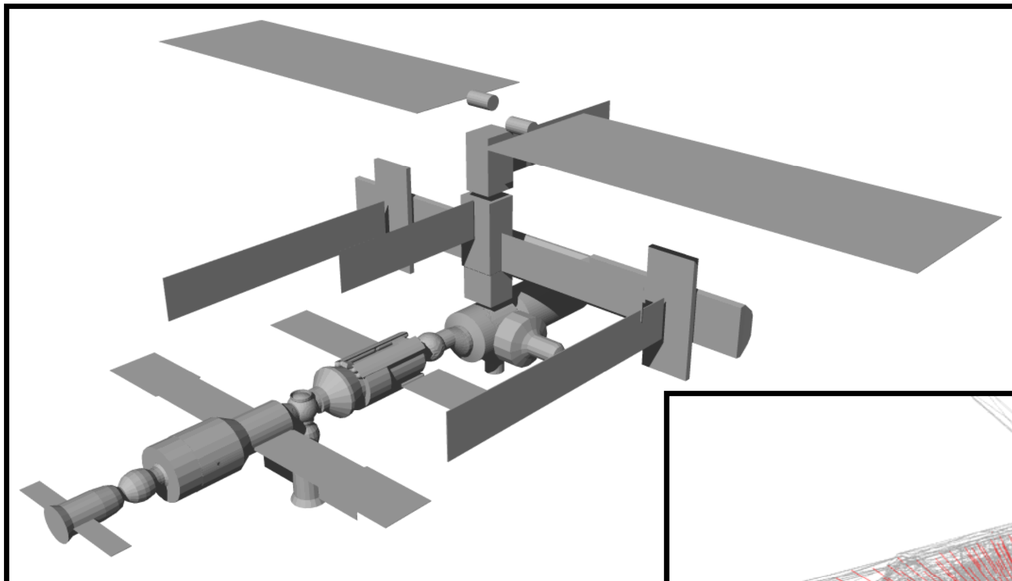
The OLTARIS website enables rapid exposure analyses for complex mission architecture.

Two Types of Transports Codes

- 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

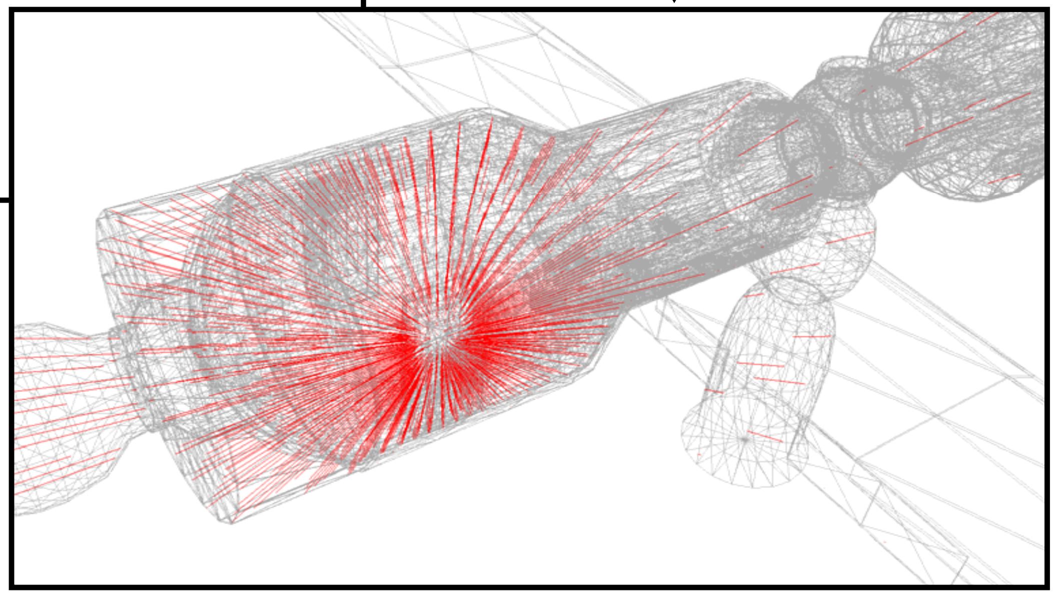
HZETRN enables calculations involving complex geometry, but Monte-Carlo codes more accurately model 3-dimensional transport.

Ray-Tracing Technique for Transport Calculations Using HZETRN

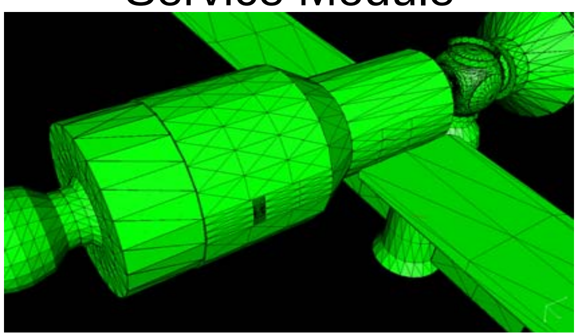


International Space Station (ISS)

Service Module Ray-Trace

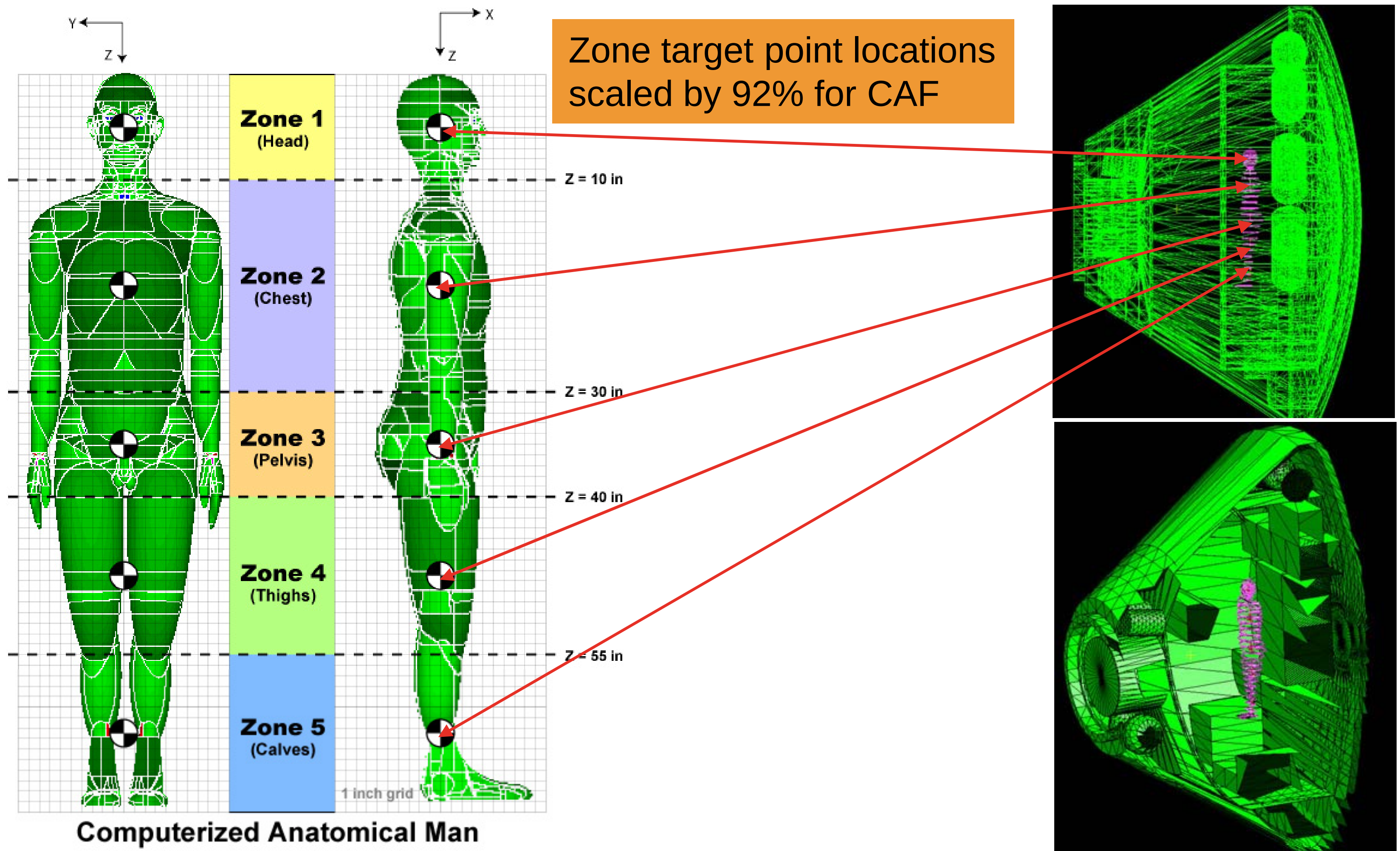


Service Module



The "straight ahead" approximation enables radiation analysis for complex geometries.

Incorporation of Body Models in Vehicle Geometry



Computerized Anatomical Man
Surfaces & Proposed Zone Definitions

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

Recommendations – Shielding Materials

- 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

- 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