



Office of the Chief Health and Medical Officer OCHMO

Human Spaceflight Standards
Health and Medical Technical Authority (HMTA)

Dave Francisco
OCHMO
2021

https://www.nasa.gov/offices/ochmo/human_spaceflight/index.html

NASA Standards for Spaceflight

Knowledge Capture, Sets Agency Risk Posture, Generation of Program Requirements

Selection, Certification and Crew Health Standards

OCHMO-STD-100.1A
NASA Crewmembers Medical Standards
- Selection and Periodic Certification

NASA Space Flight Human-System Standard
NASA-STD-3001, VOLUME 1, Crew Health -
Rev. B Pending

Detailed Guidance

NASA Handbook
NASA/SP-2010-3407, Human Integration Design
Handbook, June 2014 - Update in Progress

Technical Briefs

Engineering Application Notes
https://www.nasa.gov/offices/ochmo/human_spaceflight/index.htm

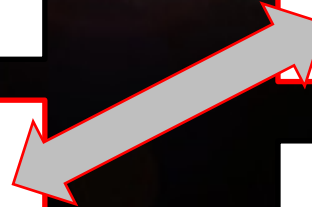
Vehicle Design for Humans

NASA Space Flight Human-System Standard
NASA-STD-3001, VOLUME 2, HUMAN FACTORS...
Rev. C - Pending

Spacecraft Water Exposure Guidelines for Selected
Waterborne Contaminants JSC 63414

Spacecraft Maximum Allowable Concentrations for Selected
Airborne Contaminants JSC 20584

Guidelines for Assessing the Toxic Hazard
of Spacecraft Chemicals and Test Materials JSC 26895



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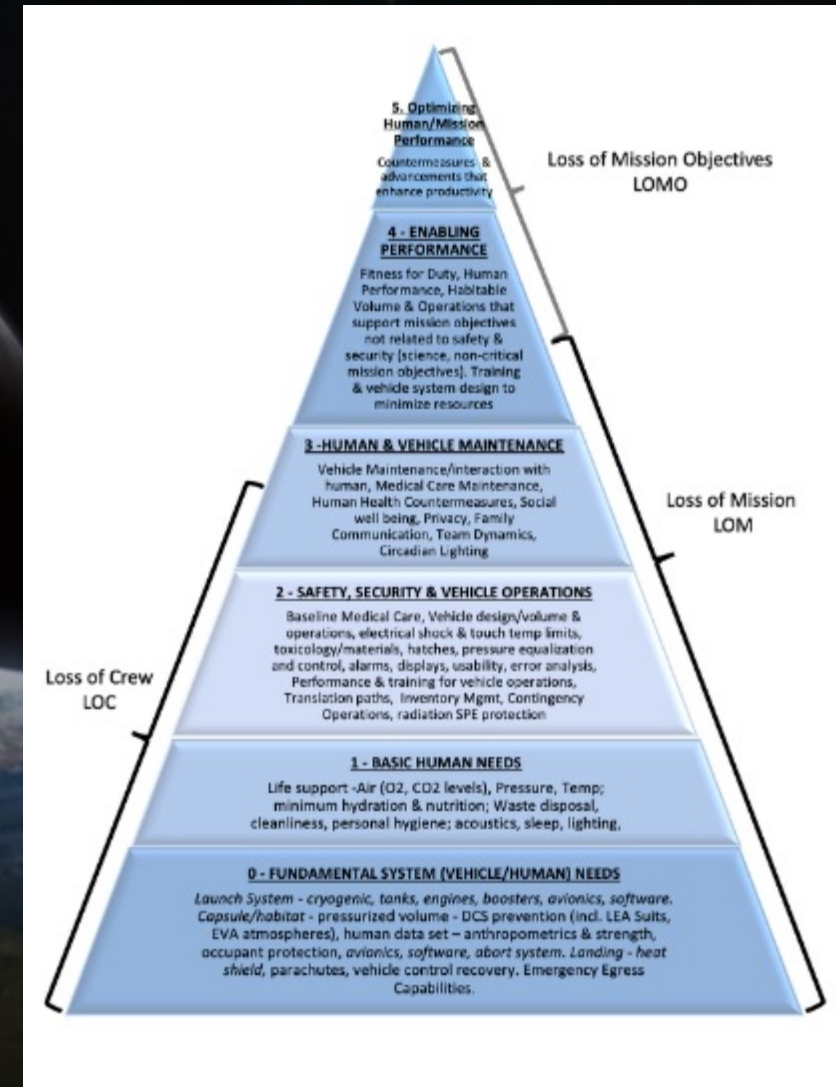
Human Spaceflight Standards NASA-STD-3001



Human Spaceflight Standards Hierarchy Pyramid

- “Standards pyramid of hierarchy” was developed to aid in the determination of individual standard's impact on missions.
- The purpose of this tool is to help look “across” all of the standards and assess their impact on a mission’s success related to loss of crew (LOC), loss of mission (LOM), and loss of individual mission objectives (LOMO).
- Categorizes standards that increase the probability of achieving mission objectives.
- Standards are in a CRADLE database that can be searched with keywords, sorted, exported and linked to program requirements

Goal is to maintain proper risk posture while determining the minimum applicability of standards for programs during the formulation stage of development



OCHMO Human Spaceflight Standards - 3001

Educate vendors on Human Spaceflight Requirements and Implementation

Technical Briefs (4-12 pages)

Educate vendors on Human Spaceflight

Integration of Requirements, Evidence/reference Data, Design and Application notes
Over 200 standards summarized and Integrated in Tech Briefs below:



- Acceleration
- Acoustics
- Apollo Lunar Lander
- Cabin Architecture
- Cognitive Workload
- Electrical Shock
- Lighting Design
- Hatch Design
- Radiation Protection
- Usability, Workload, Error
- Toxicology

Vehicle Design Notes on how to design hatches, implement acoustics, electrical shock, radiation protection

Waste Mgmt System Considerations, food, water

Decompression Sickness Application Notes – Resources vs. DCS Risk



- Behavioral Health
- Bone Loss
- DCS Technical Brief
- Carbon Dioxide (CO2)
- Food and Nutrition
- Lunar Dust
- Orthostatic Intolerance
- Waste Management
- Water Consumption

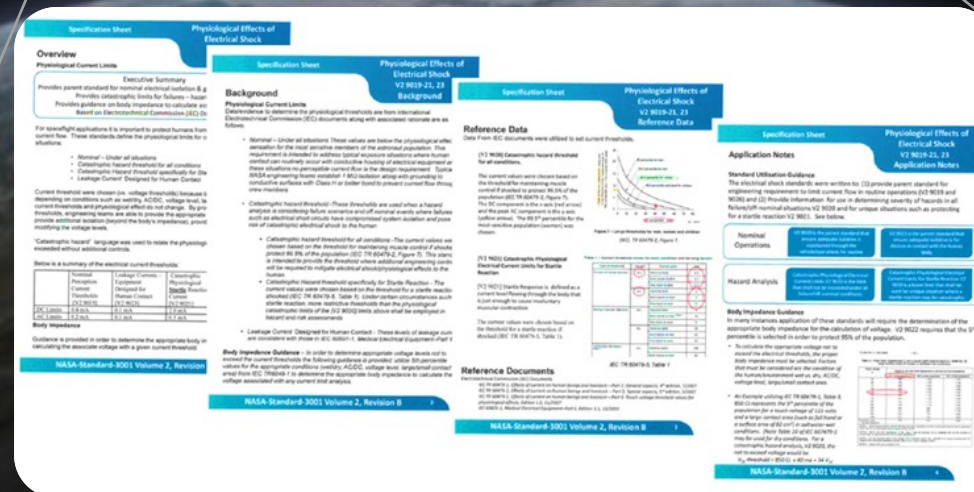


- Health Stabilization Program
- Longitudinal Health Surveillance
- Medical Care
- Pharmaceuticals



- Behavioral Health
- Decompression
- Entry Landing
- EVA Mishaps

Provides information to develop end to end medical care, Selection, Health Stabilization, In flight Medical, Pharmaceutical list, and Post flight care



https://www.nasa.gov/offices/ochmo/human_spaceflight/index.htm

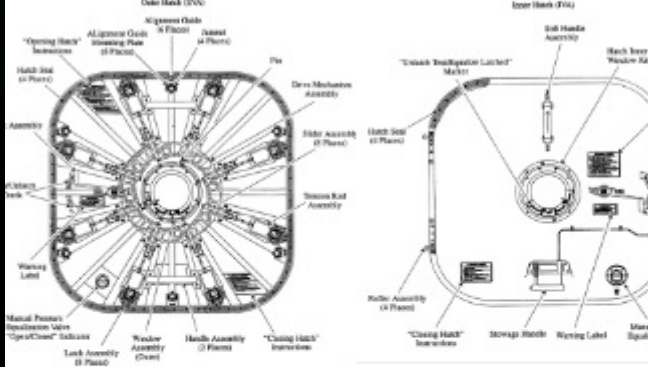
Technical Briefs - Examples

NASA-STD-3001 Technical Brief

Vehicle Hatches

V2: 4005; 4012; 6010; 6020;
8014; 8022-8032; 8040; 8041;
8043; 8045; 8053; 12006

Background



NASA-STD-3001 Technical Brief

Vehicle Hatches

V2: 4005; 4012; 6010; 6020;
8014; 8022-8032; 8040; 8041;
8043; 8045; 8053; 12006

Background

Pressure Equalization Valves

Positive Pressure Equalization Valve (PPEV)

- The PPEV is designed to regulate pressure during launch and limit the pressure differential across a module during transit to orbit.
- The PPEV drives the hatch closed while the Negative Pressure Relief Valve (NPRV) protects against overpressure that can push the hatch open.
- The PPEV is located inside the module and allows cabin air to exit in the event of over pressurization.
- When the pressure drops back to the acceptable level then the PPEV closes, maintaining the contents of the environment. The PPEV also allows sampling of the module atmosphere prior to change out.
- The PPEV will be mounted to the hatch until the module is mated, at which time a manual pressure equalization valve will replace it.
- Each side of each hatch shall have manual pressure equalization capability with its opposite side, achievable from that side of the pressure hatch by a suited or unsuited crewmember. **NASA Standard [V2 8028]**



- Manual Pressure Equalization Valve (MPEV)**
- Allows air from either side of the hatch to mix with air on the other side, thus equalizing the pressure on both sides. This ensures that the hatch can be safely opened.
 - Allows manual sampling of the air on the other side of the hatch to ensure that it is pure enough for human occupancy, especially after a contingency contamination scenario.
 - Assists with monitoring and proper depress of the vestibule area.

Operational Note - When the hatch is closed against a vacuum for a length of time, the space between the seal beads can bleed down to the vacuum. This can make it more difficult for the crew to open the hatch after opening the MPEV, as the MPEV on ISS does not vent the interstitial cavity between beads. The Orion hatch MPEV was modified to vent this volume when the MPEV is opened.

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This Technical Brief is derived from NASA-STD-3001 and is for reference only. It does not supersede or waive existing Agency, Program, or Contract requirements.

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NASA-STD-3001 Technical Brief

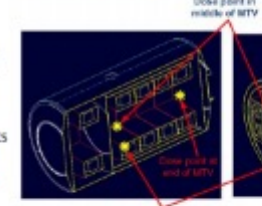
Design for Ionizing Radiation Protection

Reference Data

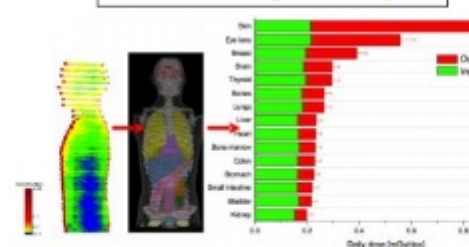
Ray Tracing tools and Effectiveness of Shielding

V1: 4.2.10.1
V2: 6095-6101

Tracing technology examines the effectiveness of shielding tools in blocking radiation. Evenly distributed rays are directed to start from dose point and end inside the vehicle. Each ray records distance and respective density of the parts it passes. Areal mass density is calculated using in transport code that evaluates dose flux at dose point.



Effect of ISS Shielding on crew daily dose



Effect of using water bags/stowage as a shelter during an SPE event beyond low earth orbit in a Capsule

Effective Dose (mSv) by crew location within capsule*	Crew #1	Crew #2	Crew #3
Effective Dose E	214	210	259
Effective Dose (Optimized Pre-Launch Stowage)	68	65	66
Effective Dose (Optimized Return Stowage)	83	75	73

*Note the different doses based on location within a vehicle

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NASA-STD-3001 Technical Brief

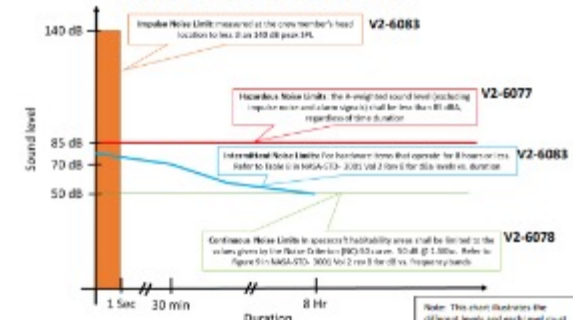
Acoustics

3001-V2-6073-6088,-6106

Background

- Acoustic levels are measured in the decibel - dB.
- Frequency and time weighting is applied in the processing stage of sound measurement to make statistical descriptions of sound (e.g., peak or average level) and/or to make the measurements better correspond to human perception.
 - Average Predicted risks of hearing damage are based on the noise source's level (typically reported in dBA) and duration of exposure.
 - "A-weighting" - dBA - compensates for the fact that the ear is comparatively less sensitive to lower and very high frequencies. Weighted between 1000 - 5000Hz.
 - Sound pressure level uses a logarithmic scale to represent the sound pressure of a sound relative to a reference pressure. The reference sound pressure is typically the threshold of human hearing: 2×10^{-5} Pa.

Noise Limits for On-Orbit Phase



- "Impulse" is defined as noises lasting shorter than one second.
- Intermittent limits are defined through durations up to 8 hours. For durations longer than 8 hours, the continuous limits take over.

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10/20/21

Standards related to actual designs

Operational Considerations

Design Tools

Explanation of Requirements

https://www.nasa.gov/offices/ochmo/human_spaceflight/index.html

OCHMO Radiation Standards

Astronaut's total career effective radiation dose (In 3001, Vol 1 Rev B)

600 mSv

Universal for all ages and sexes, 3% mean risk of cancer mortality, effective dose calculated using 35-year-old female

An individual astronaut's total career effective radiation dose due to space flight radiation exposure shall be less than **600 mSv**.

Galactic Cosmic Radiation (GCR) (under consideration) - achievable with $\sim 10\text{g/cm}^2$ Al

For missions beyond low Earth orbit, vehicles and habitat systems shall provide sufficient protection to reduce exposure from galactic cosmic radiation (GCR) **by 15%** compared with free space such that the effective dose from GCR remains below 1.3 mSv/day for systems in free space and below 0.8 mSv/day for systems on planetary surfaces.

20 mSv

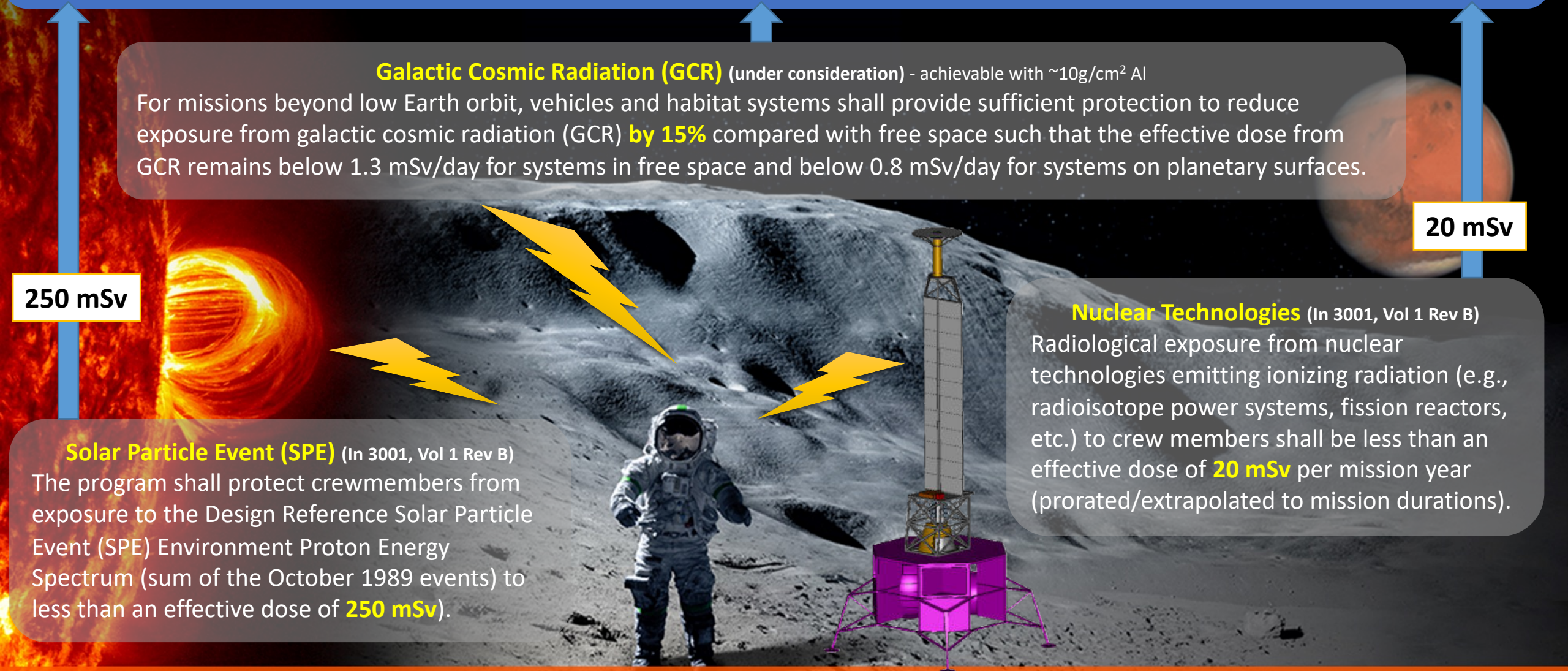
Nuclear Technologies (In 3001, Vol 1 Rev B)

Radiological exposure from nuclear technologies emitting ionizing radiation (e.g., radioisotope power systems, fission reactors, etc.) to crew members shall be less than an effective dose of **20 mSv** per mission year (prorated/extrapolated to mission durations).

250 mSv

Solar Particle Event (SPE) (In 3001, Vol 1 Rev B)

The program shall protect crewmembers from exposure to the Design Reference Solar Particle Event (SPE) Environment Proton Energy Spectrum (sum of the October 1989 events) to less than an effective dose of **250 mSv**.



Space Flight Human System Standards – NASA-STD-3001, Vol 1

Crew Career Permissible Exposure Limit for Space Flight Radiation

Sample Calculation – Male & Female Crew Members - 3 Missions						
Age	Location	Duration Days	Solar Cycle	Universal Effective Dose mSv	Female Mean REID %	Male Mean REID %
38	ISS	180	Min	86	0.37	0.27
44	ISS	180	Max	77	0.31	0.23
50	Lunar Surface	180	Min	222	0.82	0.61
50	Fission Power Source on Lunar Surface (Standard is < 20 mSv/year)	180	N/A	10	0.04	0.03
50	SPE Event in Orion Shielded (low probability occurrence)		N/A	125	0.50	0.37
Totals		540 Days		520 mSv	2 %	1.5 %

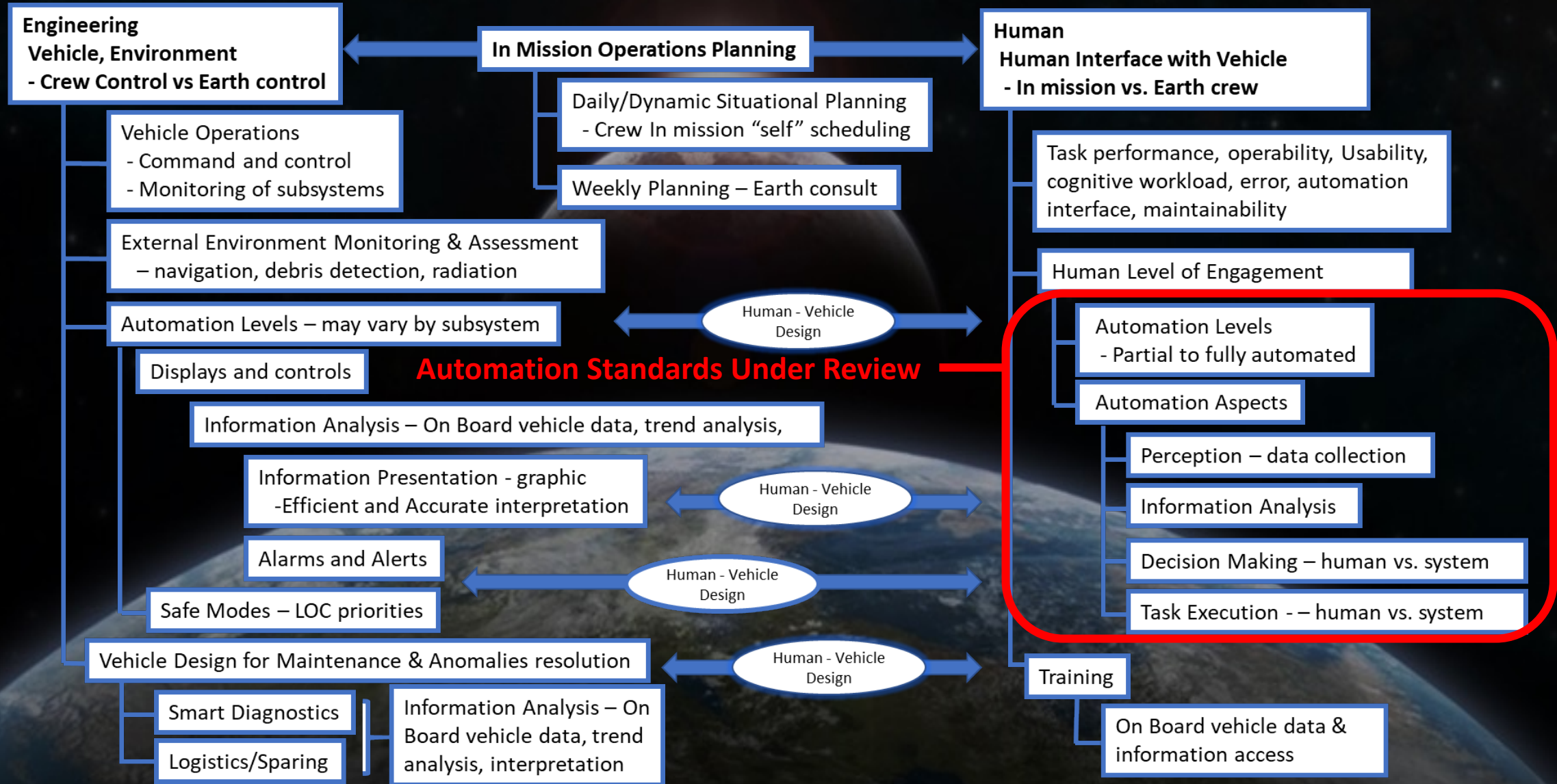
520 mSv of 600 mSv Career Dose Limit

Effective dose equivalent is based on known variations in human organ susceptibility to radiation (weighting factors) to radiation of the various organs of the body and is sex dependent. To determine career dose, female weighting factors (most conservative) are utilized for both male and female crew calculations.

Earth Independent Operations

Less Reliance on Ground Support

Hardware and Software Design to enable Automation



OCHMO Summary

There are many opportunities for collaboration
to reduce the human risks of exploration!

https://www.nasa.gov/offices/ochmo/human_spaceflight/index.html

OCHMO Human Spaceflight Standards Backup

4.8.2 Career Space Permissible Exposure Limit for Space Flight Radiation

[V1 4030] An individual astronaut's total career effective radiation dose due to space flight radiation exposure shall be less than 600 mSv.

[Rationale: This limit is universal for all ages and sexes. The total career dose limit is based on ensuring all astronauts (inclusive of all ages and sexes) remain below 3% mean risk of cancer mortality (risk of exposure-induced death [REID]) above the non-exposed baseline mean. Individual astronaut career dose includes all past space flight radiation exposures, NASA biomedical research exposures, plus the projected exposure for an upcoming mission. The effective dose is calculated using the NASA Q (based on the NASA cancer model of 2012) 35-year-old female model parameters (weighting factors, quality factors, etc.) for both males and females. This standard protects the career limits for all organs in Table 3, Dose Limits for Short-Term or Career Non-Cancer Effects (in mGy-Eq or mGy) (see [V1 4032]). Due to variability and subjectivity of the selection of model parameters, the model should not be updated unless a 25-30% change is seen in the effective dose associated with the 3% mean REID calculation.]

OCHMO Human Spaceflight Standards Team Backup

4.8.3 Short-Term Radiation Limits – Solar Particle Events

[V1 4031] The program shall protect crewmembers from exposure to the Design Reference Solar Particle Event (SPE) Environment Proton Energy Spectrum (sum of the October 1989 events) to less than an effective dose of 250 mSv).

[Rationale: The 250 mSv effective dose threshold was chosen to minimize acute effects and protects for the short-term limits for all organs listed in Table 3. See Table 3 for short-term dose limits. In the design process, ALARA ensures optimization of the design to afford the most protection possible within other constraints of the vehicle systems. The additional protection significantly contributes to the mitigation of long-term health effects such as cancer (refer to crew career radiation dose standard [V1 4031]).

The Design Reference SPE Environment Proton Energy Spectrum is referenced in Table 4, Design Reference SPE Environment Proton Energy Spectrum.

OCHMO Human Spaceflight Standards

4.8.4 Crew Radiation Limits for Nuclear technologies

[V1 4032] Radiological exposure from nuclear technologies emitting ionizing radiation (e.g., radioisotope power systems, fission reactors, etc.) to crew members shall be less than an effective dose of 20 mSv per mission year (prorated/extrapolated to mission durations) and ALARA.

[Rationale: This limit is based on not adding more than 10% radiation exposure beyond the space environment radiation of the mission. Based on an analysis for a surface-based mission (see Figure 2, Effective Dose (mSv per Mission Day) Variation with Solar Cycle), the radiation environment exposure is approximately 0.5 mSv per day; and 10% of this value sets the standard to 0.05 mSv per day and ~20 mSv/mission year. This standard is applied to both surface and free-space missions.

For a typical surface power application, the allowable astronaut dose can be converted to an effective reactor dose for shield sizing. The effective reactor dose would be calculated by estimating the time an astronaut spends in a shielded habitat versus the time spent during unshielded EVAs over a typical mission timeline. Exact mission assumptions should be considered when performing the calculation; parameters should include estimates of time in a habitat, habitat shielding, and EVA frequency. Example parameters to be considered: time fraction (67%) in the habitat, habitat shielding (20 g/cm²), terrain shielding, distance from source, line of sight to source, and time fraction (33%) of performing EVAs.

Space radiation and radioactive source tradeoff for a waiver of standard consideration: For missions that are leveraging nuclear sources for a propulsion system, the tradeoff of reduced mission duration due to faster transit which reduces the crew exposure to space flight radiation exposure should be considered compared to the increased exposure due to the nuclear source. For example, if the nuclear propulsion system saved 90 days of exposure during the transit to Mars which equates to 1.5 mSv/day × 90 days = 135 mSv “saved” space flight radiation exposure and the source generates 150 mSv, then the net exposure is +15 mSv. Other considerations for reduced mission time on engineering risks (systems reliability, logistics, etc.) and other human risks such as bone loss, renal stone development, and medical care should also be considered in the waiver process.]