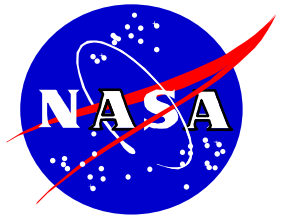

Natural Environment Definition for Exploration Missions

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13 April 2017
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Design Specification for Natural Environments (DSNE)

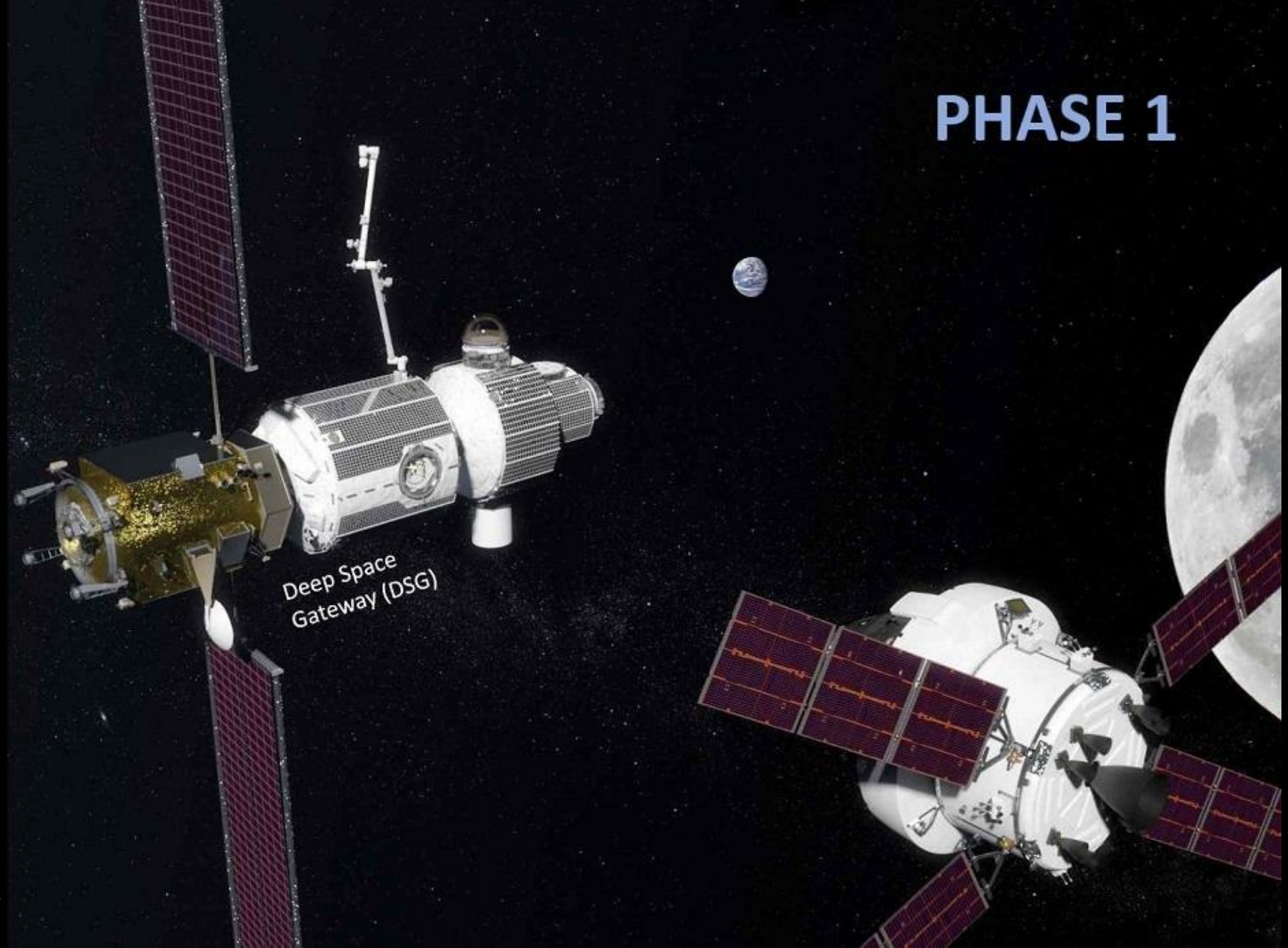
- SLS-SPEC-159 Rev D Cross-Program Design Specification for Natural Environments
  - Download from https://ntrs.nasa.gov/search.jsp?R=20160004378
  - Rev E is currently in the change process – corrects some typos and units errors
- Baselined for SLS and Orion – both programs have specs that copy or point to DSNE
  - Element applicability matrix in SLS-SPEC-044-07 SLS Program Vehicle Design Environments, Vol. 7 Natural Environments
- DSNE was developed to be as independent of vehicle configuration and mission as possible so it could be used by multiple programs
- In the documentation lists for Deep Space Gateway and Habitat Broad Agency Announcement
- Provided to other projects where applicable

DSNE (cont.)

- History of the document
  - Initially developed for the Constellation Program – CxP 70023 Aug. 2006
  - Has its origins in SSP 30425 Space Station Program Natural Environment Definition for Design and SSP 30512 Space Station Ionizing Radiation Design Environment
  - Modified for the Exploration Program for its specific Design Reference Missions
- Related document: Natural Environment Definition for Design – includes more detail and background information than DSNE including lunar surface environments
  - Was - CxP 70044 Rev A. Sept. 2008
  - Now – NASA-TM-2016-218229

Space Launch System

Orion


PHASE 1
Deep Space
Gateway (DSG)

DSNE Organization

3.1 Prelaunch

3.2 Launch Countdown and Earth Ascent

3.3 In-Space

3.4 Lunar Surface (Reserved)

3.5 Entry and Landing

3.6 Contingency and Off-Nominal Landing

3.7 Recovery and Post-Flight Processing Phases

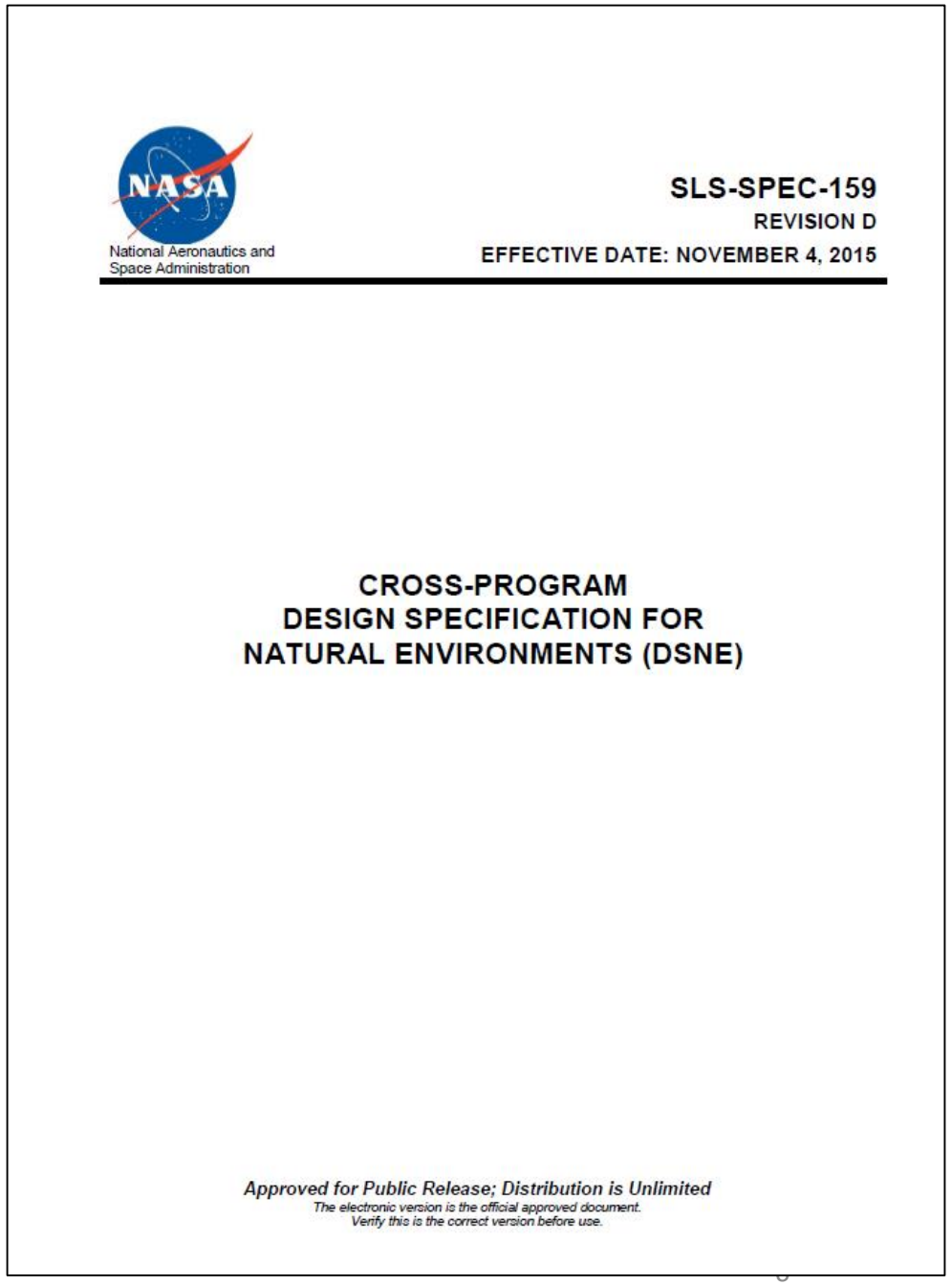
3.8 Interplanetary Space

3.9 Mars Orbit (Reserved)

3.10 Atmosphere and Surface Phase (Reserved)

3.11 Mars Moons (Reserved)

3.12 Near Earth Asteroid (Reserved)


National Aeronautics and Space Administration

SLS-SPEC-159
REVISION D
EFFECTIVE DATE: NOVEMBER 4, 2015

CROSS-PROGRAM
DESIGN SPECIFICATION FOR
NATURAL ENVIRONMENTS (DSNE)

Approved for Public Release; Distribution is Unlimited
The electronic version is the official approved document.
Verify this is the correct version before use.

DSNE Organization

3.3 In-Space

- 3.3.1 Total Dose
- 3.3.2 Single Event Effects
- 3.3.3 Plasma Charging
- 3.3.4 Ionizing Radiation for Crew Exposure – provided by JSC/SRAG
- 3.3.6 Meteoroids and Orbital Debris
- 3.3.7 Earth Gravitational Field
- 3.3.8 Lunar Gravitational Field
- 3.3.9 Thermal Environment for In-Space Hardware – similar to ISS spec for LEO, includes lunar albedo and infrared emission
- 3.3.10 Solar Illumination Environment for In-Space Hardware – solar spectrum, including lunar eclipses
- 3.3.11 In-Space Neutral Atmosphere (Thermosphere) density
- 3.3.12 Geomagnetic Fields (Reserved)

Table 3.3.1-1. Total Dose Applicability Matrix for the Design Reference Mission by Regions of Space

	LEO (3.3.1.1)	Staging and Transit Orbits (3.3.1.2)	GEO (3.3.1.3)	Interplanetary (3.3.1.4)	Lunar Orbit (3.3.1.5)	Lunar Surface (3.3.1.6)	NEA (3.3.1.7)	Mars Orb it (3.3.1.8)	Mars Surface (3.3.1.9)	Solar Particle Event (3.3.1.10)
Distant Retrograde Orbit	X	3.3.1.2.1 3.3.1.2.2		X						X
Crewed Lunar Orbit	X	3.3.1.2.1 3.3.1.2.2		X	X					X
Low Lunar Orbit	X	3.3.1.2.6 3.3.1.2.2		X	X					X
Initial Capability NEA	X	3.3.1.2.4 3.3.1.2.5 3.3.1.2.2		X						X
Advanced NEA	X	3.3.1.2.4 3.3.1.2.5 3.3.1.2.2		X						X
Full Capability NEA	X	3.3.1.2.6 3.3.1.2.7 3.3.1.2.8 3.3.1.2.5 3.3.1.2.2		X						X
Lunar Surface Sortie	X	3.3.1.2.6 3.3.1.2.2		X	X	X				X
ISS Crew Delivery Backup	X	None								X
GEO Vicinity	X	3.3.1.2.6 3.3.1.2.2	X							X
Martian Moon	X	Reserved		X				X		X
Martian Landing	X	Reserved		X				X	X	X

Structure of Each Section

- Design Limits
  - General discussion followed by figures and tables where appropriate
- Model Inputs
  - Orbits, size/energy thresholds, etc.
- Limitations
  - Caveats and uncertainties on the model outputs
- Technical Notes
  - Models used and their inputs when Design Limits are tabular

Orbits Specified for Ionizing Radiation Dose Section

3.3.1.1 LEO – ISS Orbit (500km, 51.6 deg) - conservative environment for SLS LEO phase

3.3.1.2 Staging and Transit Orbits

3.3.1.2.1 LEO 185 x 1806 km

3.3.1.2.2 Radiation Belt Transit

3.3.1.2.3 LEO 241 km Circular

3.3.1.2.4 HEO 407 x 233,860 km

3.3.1.2.5 HEO to NEA Transit

3.3.1.2.6 LEO 407 km Circular (see ISS Orbit)

3.3.1.2.7 Low Perigee – HEO 407x400,000 km

3.3.1.2.8 High Perigee – HEO Spiral to 60,000 x 400,000 km

3.3.1.3 GEO

3.3.1.4 – 3.3.1.7 Interplanetary, Lunar Orbit, Lunar Surface, NEA see 3.3.1.10.1

3.3.1.10.1 Geomagnetically Unshielded Solar Particle Events and Galactic Cosmic Rays

3.3.2.x.x similar structure for single event effects environments

LEO – low earth orbit
HEO – high earth orbit
GEO – geosynchronous orbit
NEA – near earth asteroid

Example plots and tables

Table 3.3.2.10.2-5. GCR Integral LET at Solar Minimum for Selected Al Shielding Thickness as a Function of LET

LET	Shield Thickness 0.0254 cm (0.0686 g/cm^2)	Shield Thickness 0.254 cm (0.6858 g/cm^2)	Shield Thickness 2.54 cm (6.858 g/cm^2)	Shield Thickness 5.08 cm (13.72 g/cm^2)	Shield Thickness 25.40 cm (68.58 g/cm^2)
MeV-cm^2/mg	Particles/cm^2-s	Particles/cm^2-s	Particles/cm^2-s	Particles/cm^2-s	Particles/cm^2-s
1.01	2.47E-03	2.32E-03	1.30E-03	7.76E-04	2.85E-05
1.27	1.32E-03	1.22E-03	6.01E-04	3.33E-04	1.03E-05
1.61	7.92E-04	7.22E-04	3.21E-04	1.70E-04	4.98E-06
2.10	4.59E-04	4.13E-04	1.69E-04	8.75E-05	2.55E-06
3.20	1.96E-04	1.74E-04	6.51E-05	3.29E-05	9.51E-07
4.05	1.19E-04	1.06E-04	3.84E-05	1.93E-05	5.43E-07
5.06	7.31E-05	6.59E-05	2.31E-05	1.15E-05	3.09E-07
6.46	4.16E-05	3.83E-05	1.31E-05	6.43E-06	1.61E-07
8.07	2.49E-05	2.35E-05	7.83E-06	3.81E-06	8.86E-08

…

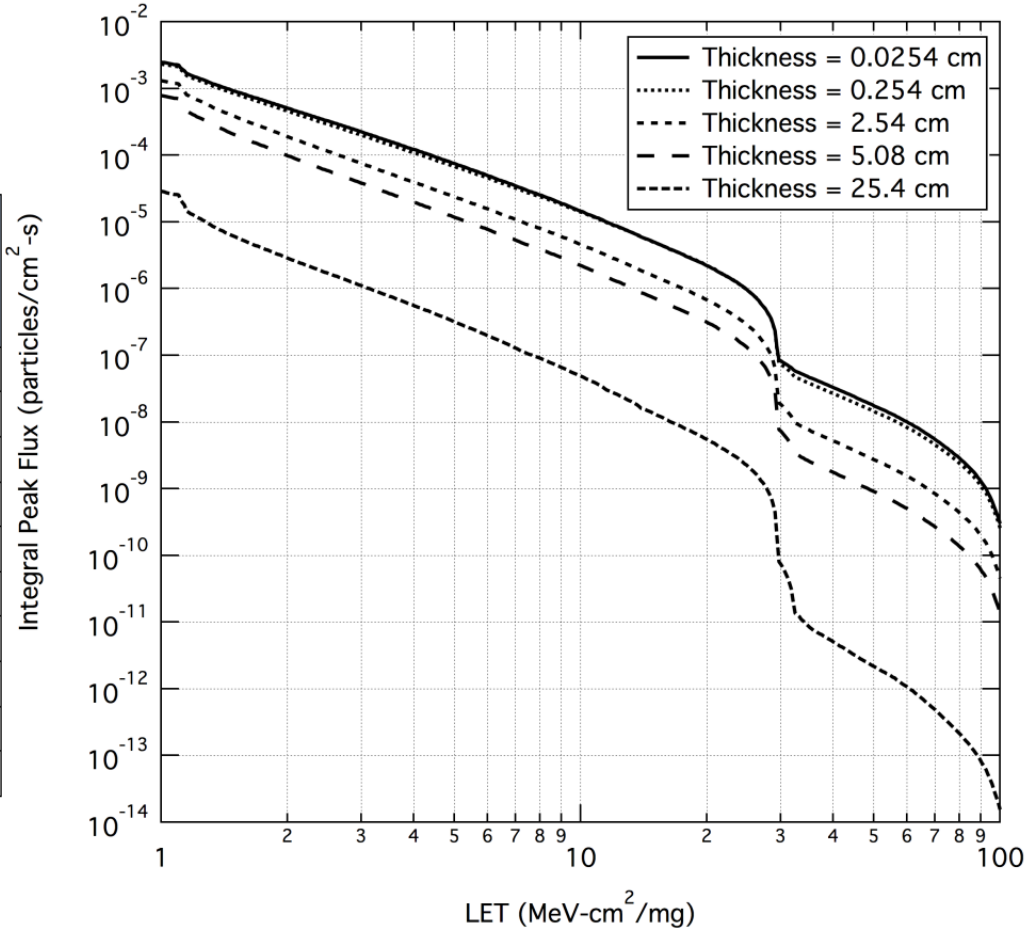


Figure 3.3.2.10.2-5. GCR Integral LET at Solar Minimum for Selected Al Shielding Thickness as a Function of LET

Plasma/Spacecraft Charging Environments

- Ambient Plasma for less than 1000 km
- Geosynchronous orbit – based on SCATHA data
- Interplanetary (magnetosheath/magnetotail and solar wind)
- Radiation Belt Transit – Fennell et al. 2000
- Lunar Wake – Haleakas et al. 2005, Minow, et al., 2008
- Polar Orbit – Nascap 2K defaults

Space Environment Models Specified or Used

- GGM02C Earth Gravity
- GRAIL Lunar Gravity
- Meteoroid Engineering Model (MEM) R2 Meteoroids
- ORDEM 3.0 Orbital Debris
- Earth-GRAM 2010 includes thermosphere models
  - NRL-MSIS
  - Marshall Engineering Thermosphere
- Ionizing radiation
  - AE8/AP8 Trapped Particles
  - ESP/Psychic Solar Energetic Particles
  - CREME-96 Galactic Cosmic Rays
  - Shieldose2 total integrated dose

Conclusions

- The DSNE provides environment definitions for all phases of manned exploration missions from launch to landing
  - It is baselined for the SLS and Orion
  - It is in use as a reference environments for other space missions