

Defining the Natural Atmospheric Environment Requirements for the NASA Constellation Program

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The National Aeronautics and Space Administration began developing a new vehicle under the Constellation Program to replace the Space Shuttle. The Ares-I launch vehicle and the Orion capsule will be used to ferry crew and some payloads to the International Space Station and will also be used for new missions to the moon. As development of this new vehicle begins, the Natural Environments Branch at Marshall Space Flight Center has been tasked with defining the natural environments the vehicle will encounter and working with the program to develop natural environmental requirements for the vehicles' elements. An overview of the structure of the program is given, along with a description of the Constellation Design Specification for Natural Environments and the Constellation Natural Environments Definition for Design documents and how they apply to the Ares-I and Orion vehicles.

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8.4 DEFINING THE NATURAL ATMOSPHERIC ENVIRONMENT REQUIREMENTS FOR THE NASA CONSTELLATION PROGRAM

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1. INTRODUCTION

The National Aeronautics and Space Administration (NASA) began developing a new vehicle under the Constellation Program to replace the Space Shuttle. Within the Constellation program, the Ares-I launch vehicle and the Orion capsule will be used to ferry crew and some payloads to the International Space Station. They, along with the Ares V launch vehicle will also be used for new missions to the moon. As development of these new vehicles begins, the Natural Environments Branch at Marshall Space Flight Center (MSFC) has been tasked with defining the natural environments they will encounter and working with the program to develop natural environmental requirements for the vehicles' elements.

2. RESPONSIBILITIES OF MSFC'S NATURAL ENVIRONMENTS BRANCH

The Natural Environments Branch is located in the MSFC engineering directorate. The branch is composed of two teams, the terrestrial and planetary environments team and the space environments team. In general terms, the break between terrestrial and space environments is defined at 90 km above the earth's surface. The mission statement for the MSFC Natural Environments Branch is: To maintain expertise in terrestrial, space and planetary natural environments definition, characterization, and analysis and to disseminate this expertise to agency programs and projects in support of environment definition, requirements development, vehicle development, and sustaining engineering through the life cycle of the program. The Natural Environments Branch is responsible for natural environment definition for MSFC and most NASA programs. The Branch has the only full-service environments organization within NASA with responsibilities extending from the surface of the Earth to planetary atmospheres, spanning all mission phases, from requirements development to operations support. The Branch has the responsibility to develop environment models and databases, and uses state-of-the-art science data to develop these models and databases for engineering purposes (Edwards, et al., 2006).

3. NATURAL ENVIRONMENT DEFINITION FOR THE CONSTELLATION PROGRAM

In order to provide a uniform description of the natural environment for the Constellation Program, the "Constellation Program Natural Environment Definition for Design" (NEDD) was developed. The NEDD provides details of the environment data and models used to support analytical studies for Constellation systems.

The NEDD is divided into four main sections:

- a. Terrestrial Environments
- b. Near-Earth Space Environments
- c. Cis-Lunar & Lunar Environments
- d. Mars & Mars Transit Environments.

The natural environments described in the NEDD is intended to include all the environmental factors which are independent, i.e., outside the influence, of the systems in the Constellation Program. Orbital debris and some other man-made environments are included because they are beyond the Constellation Program's control. All induced environments, contamination and aeroheating, for example, are excluded because they are dependent on system design. Also, 'environmental impact', the effects of the Constellation systems on the environments, is not within the scope of the NEDD.

Since all of these factors are outside the control of the program, the program controls the "definition" of these factors, i.e. the models, data sets and descriptions in order to maintain a uniform, consistent and verifiable baseline for hardware development. This definition is contained in the NEDD.

The Terrestrial Environments, Near-Earth Space Environments and most of the Cis-Lunar & Lunar Environments sections of the NEDD are complete, with modifications being made as changes in the program occur. These sections apply to the Ares I-X and Orion vehicles that are currently being designed. They will also apply to the Ares V launch vehicle. There are currently only placeholders for the Mars & Mars Transient Environments section. The definition of these environments will be developed as the Mars reference mission becomes better defined.

4. NATURAL ENVIRONMENT SPECIFICATIONS FOR THE CONSTELLATION PROGRAM

The range of natural environments that the elements of the Constellation Program are required to function in are defined in a document titled "The Constellation Program Design Specification for Natural Environments" (DSNE). The DSNE is based on the Constellation Design Reference Missions and Operations Concepts

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Document, and the models, data and environment descriptions in the NEDD. The document defines environmental parameter limits; i.e. maximum and minimum values, energy spectra, or precise model inputs, assumptions, model options, etc., to be used in the design and development of all Constellation Program elements. Its application is primarily for the design and development of flight hardware.

The DSNE completes natural environment-related requirements from architecture, system level, and lower tier program documents by specifying the ranges of environmental conditions that must be accounted for by the design of all Constellation Program elements. As such, it forms a part of those specifications. These natural environment specifications have been pulled out into a separate document to assure clarity and consistency, and to prevent the requirements documents from becoming cluttered with extensive amounts of technical material.

A listing of the table of contents for the DSNE is shown in Table 1. The specifications for the natural environments are located in Section 3 of the document. These specifications are listed according to the mission phase; i.e. pre-launch, launch and ascent, in-space, entry and landing, etc. Included in this section are terrestrial environments (winds, temperatures, pressures, surface characteristics, sea states, etc.), space environments (ionizing radiation, orbital debris, meteoroids, thermosphere density, plasma, solar, Earth and lunar emitted thermal radiation, etc.), lunar surface environments, and Mars atmospheric and surface environments.

The DSNE is a requirement document in the sense that its use is directed by the constellation Program, but it does not contain any "shall" language. For example, an element System Requirement Document, such as for the Ares I First Stage may state that the surface air temperature at launch shall not exceed the range specified in Section 3.2 of the DSNE.

Section 4 addresses the verification that the flight system will meet its functional and performance requirements during and after exposure to a range of natural environment factors. This requires a systematic, integrated approach that addresses not only effects to the integrated system, but to the individual elements. Also, in addition to the direct environmental impacts, interactions that are dependent on the configuration of the vehicle or operating conditions must be considered. For example, the thermodynamic properties of the Earth's atmosphere will have a different effect on the Orion capsule when it is integrated with the Ares-I launch vehicle during ascent compared to the entry phase when the capsule is a single element.

As with the NEDD, Sections 3.8, 3.9, and 3.10 are place holders and will be completed as the Mars reference mission becomes better defined.

5. UPDATES TO NATURAL ENVIRONMENT DEFINITIONS

As the Constellation Program continues through the design phase, the natural environment definition will

Table 1. DSNE Contents

Section	Title
1.0	INTRODUCTION
1.1	Purpose
1.2	Scope
2.0	APPLICABLE DOCUMENTS
2.1	Requirements Documents
2.2	Applicable Models/Datasets
3.0	NATURAL ENVIRONMENT SPECIFICATION
3.1	Pre-Launch – Ground Processing Phases
3.2	Launch Countdown & Earth Ascent Phases
3.3	In-Space Phases
3.4	Lunar Surface Phases
3.5	Entry & Landing Phases
3.6	Contingency & Off-Nominal Phases
3.7	Recovery & Post-Flight Processing Phases
3.8	Inter-Planetary Space Specification
3.9	Mars Orbit Specification
3.10	Mars Atmosphere & Surface Phase Specification
4.0	VERIFICATION FOR NATURAL ENVIRONMENTS
4.1	Integrated Verification Approach
4.2	Special Cases
5.0	REFERENCES

undoubtedly have to be revised. While it would be very desirable to have a vehicle that could launch in any type of weather conditions, i.e. an all-weather vehicle, cost constraints on the program will prohibit this. So, as trade studies are conducted by the design engineering community, the robustness of the vehicle system and elements with respect to natural environments may have to be reduced in order to control costs. This is done by modifying the definitions in the DSNE to remove environmental extremes the system or element is not designed to withstand. These environmental conditions then must be dealt with in terms of accepted risk or operational constraints.

6. REFERENCES

Edwards, D., R. Suggs, B. Roberts, B. Cooke, 2006: *Capabilities of the Natural Environments Branch at*

NASA's *Marshall Space Flight Center*, Proceedings of the 10th International Symposium on Materials in a Space Environment and the 8th International Conference on Protection of Materials & Structures in a Space Environment, Collioure, France, 19-23 June 2006

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Natural Environments Branch

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Agenda

- Natural Environment Definition for Design (NEDD)
- Design Specifications for Natural Environments (DSNE)
- Call out of DSNE from other CxP documents

Natural Environment Definition for Design

- Purpose: To provide a uniform description of the natural environment to serve as a basic framework for both the crewed and robotic missions of the Exploration Systems Mission Directorate. It is intended to support engineering and analysis, requirements development, and verification involved in the development of exploration concepts and architectures, flight hardware, and new technologies. This document is a requirement in the sense that its use is directed by the Program, but it does not contain any requirement “shall” language. It provides a single description of each environment that requirements may be written against, thereby enabling clear definition of contract scope and control.
- Scope: Natural environment, as the term is used here, is intended to include all environmental factors which are independent, i.e., outside the influence, of the Program. Orbital debris and some other man-made environments are included because they are beyond Program control. All induced environments, contamination and aero-heating, for example, are excluded because they are dependent on system design.

Natural Environment Definition for Design

- CxP 70044, Natural Environment Definition for Design
- The NEDD is a handbook and source document for the environment models and data needed to support the Program throughout the development phase
- It is provided in four main sections which include all natural environments needed to support aerospace vehicle design and development activities
 - Terrestrial Environments
 - Earth's surface to 90 km; Includes surface and upper-level winds, lightning, etc., for several locations (KSC, EAFB, VAFB, etc.)
 - Near-Earth Space Environments
 - Earth orbital environment; Includes ionizing radiation, orbital debris and meteoroids, etc.
 - Lunar and Lunar Transit Environments
 - Lunar orbital and surface environments
 - Mars and Mars Transit Environments
 - Space environment for the Earth to Mars transit, Mars atmosphere, etc.

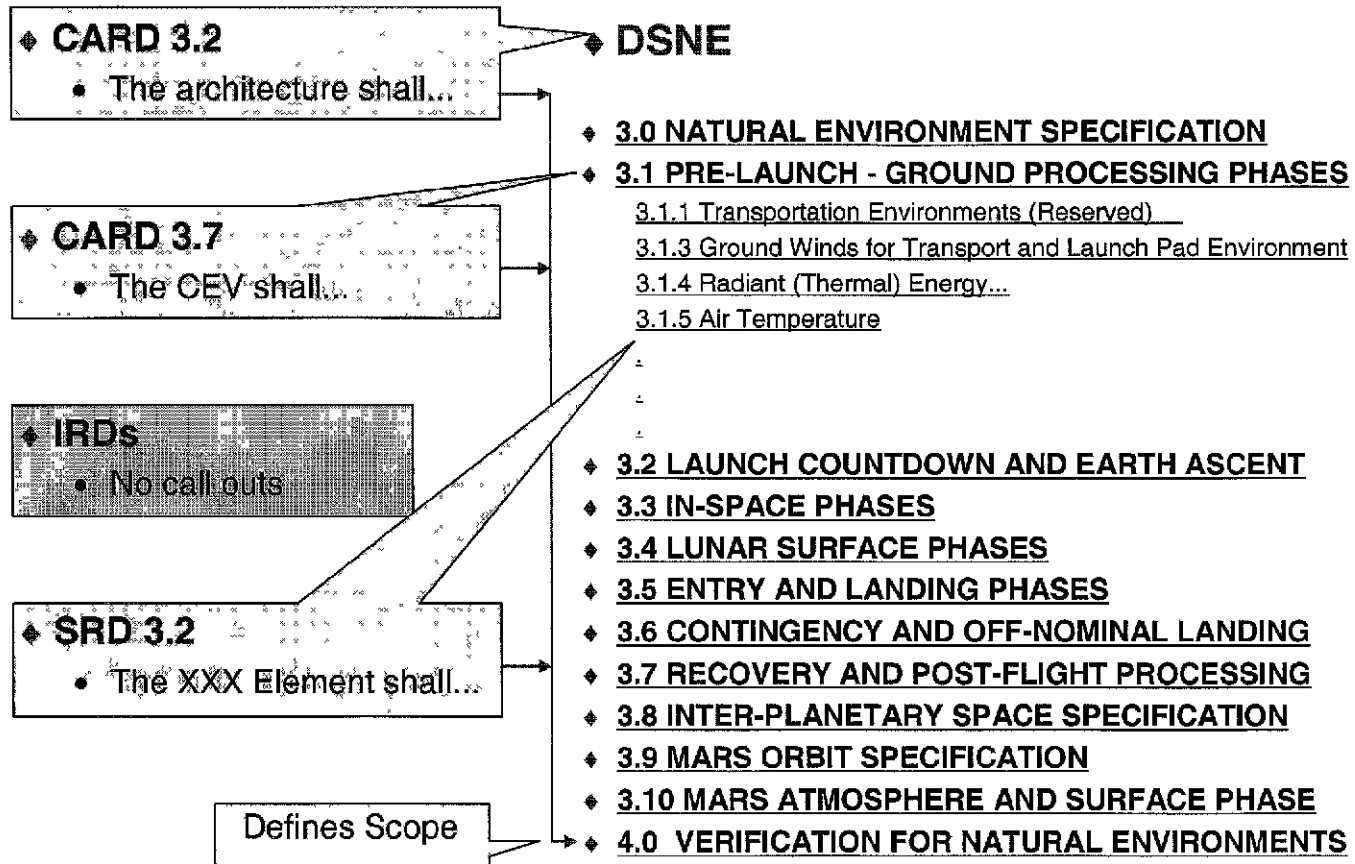
Design Specification for Natural Environments

- Purpose: The DSNE completes environment-related requirements from architecture, system level, and lower tier documents by specifying the ranges of environmental conditions that must be accounted for by the design of all Constellation Program elements
- Scope: This document defines the environmental parameter limits; i.e. maximum and minimum values, energy spectra, or precise model inputs, assumptions, model options, etc., to be used in the design and development of all Constellation Program elements. Its application is primarily for the design and development of flight hardware. It is not intended as a definition of operational models or operational constraints, nor is it adequate, in and of itself, for ground facilities which may have additional requirements (e.g. building codes and local environmental constraints).

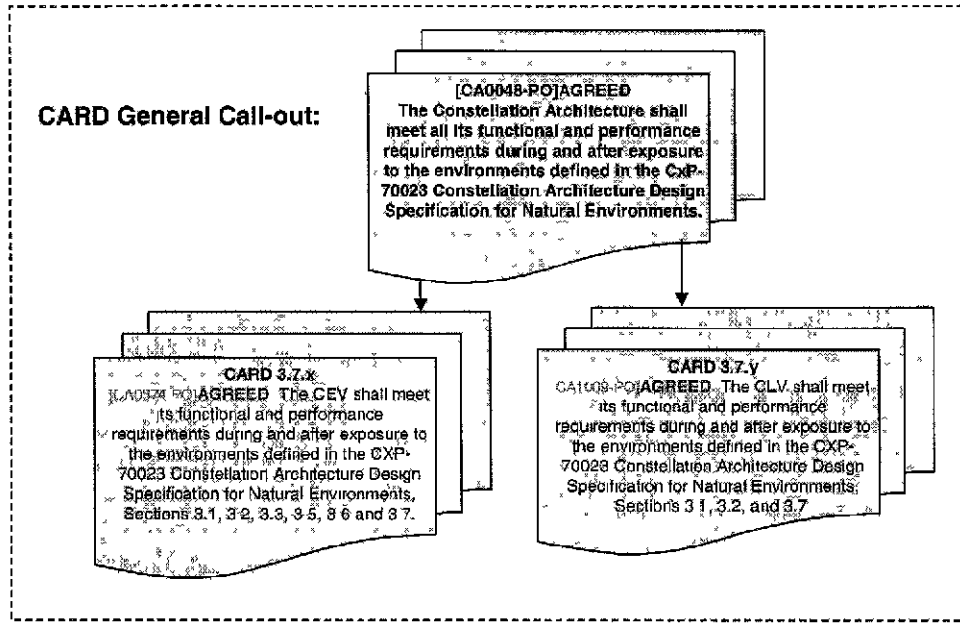
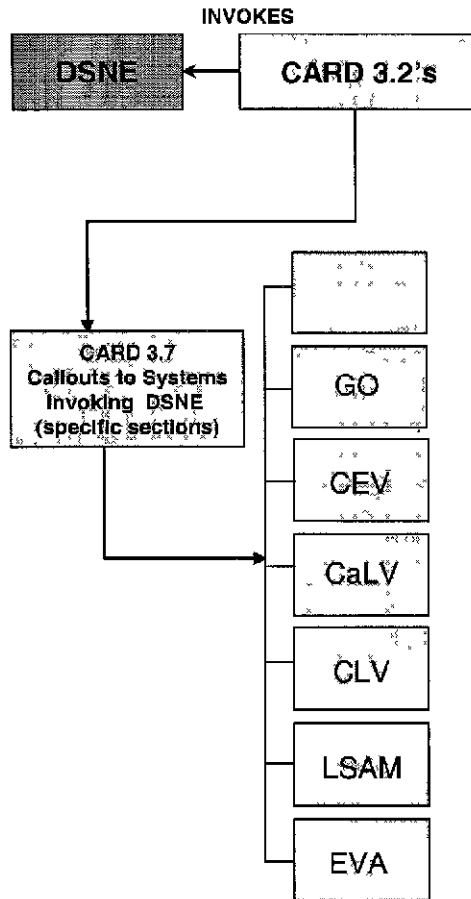
Design Specification for Natural Environments

- CxP 70023, Design Specification for Natural Environments
- Provides a unified specification of the design-to natural environment limits
 - All Systems designed to work in the same environments
 - All organizations know what the design capabilities are
- Developed to support the engineering team, not just levy specs
- Organized in a simple two-tier system:
 - Mission Phase
 - Specific environment (e.g. wind, temperature, sea state, ionizing radiation, orbital debris, meteoroids, etc...)
- Specifies environment models, data sets, upper and lower limits
- No “shall” language
- Each specification is “fleshed out” by a detailed technical handbook, CxP 70044, NEDD

DSNE Call Outs



DSNE Call Outs



The same call-out approach for:

CA0991-PO The Constellation Architecture shall meet its functional and performance requirements during and after exposure to the lightning direct and indirect environments specified in CxP 70023 Constellation Architecture Design Specification for Natural Environments, sections TBD and in accordance with CxP 70080, Constellation E3 Requirements Document, section TBD.

CA0406-PO The Constellation Architecture flight systems shall meet its requirements during and after exposure to the pre-launch environment as defined in CxP 70023 DSNE section 3.1 for at least 70 days (TBR-001-023).



DSNE Status

- The DSNE was baselined on 12/16/2006 and has no major outstanding issues
- Several areas have been identified by CEV where additional specifications are or may be needed
 - Transportation environments
 - Lunar dust and lunar thermal
 - Surface and soil properties at the landing sites
- Two areas are under study for further technical validation:
 - Worst-case sea state conditions for reliable crew rescue
 - Verification methodology for GN&C and other engineering parameters dependent on atmosphere profiles (winds, thermodynamic parameters).
- The following DSNE sections are empty and are not expected to be updated in FY07:
 - 3.4 LUNAR SURFACE PHASES (Except Lunar Dust section)
 - 3.8 INTER-PLANETARY SPACE SPECIFICATION
 - 3.9 MARS ORBIT SPECIFICATION
 - 3.10 MARS ATMOSPHERE AND SURFACE PHASE

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