National Aeronautics and
Space Administration

SLS-SPEC-044-07

BASELINE

EFFECTIVE DATE: DECEMBER 12, 2012

SPACE LAUNCH SYSTEM PROGRAM VEHICLE DESIGN ENVIRONMENTS

VOLUME 7: NATURAL ENVIRONMENTS

REVISION AND HISTORY PAGE

Status	Revision No.	Change No.	Description	Effective Date
Baseline	-	-	Baseline per JICBD SV2-02-0001, dated 12/12/12, (CR SLS-00039R1), PCN SV00091	12/12/12

NOTE: Updates to this document, as released by numbered changes (Change XXX), are identified by a black bar on the right margin.

TABLE OF CONTENTS

PARAGRAPH **PAGE**

APPENDIX

TABLE

1.0 INTRODUCTION

1.1 Purpose

The Space Launch System Program (SLSP) Vehicle Design Environments Volume 7: Natural Environments specifies applicable natural environments for the SLSP system and its elements. The applicable natural environments are obtained from SLS-SPEC-159, Cross-Program Design Specification for Natural Environments (DSNE). SLS-SPEC-159 specifies the range of natural environments that must be accounted for by the Exploration Systems Development (ESD) Enterprise. The purpose of SLSP Vehicle Design Environments Volume 7: Natural Environments is to allocate only those natural environments that are applicable to the SLSP integrated system and its elements. The applicable natural environments are levied upon the SLS Program by SLS-SPEC-032, SLSP System Specification [Requirement SLS.27]. Additional definitions, details, or interpretations of the natural environments given in SLS-SPEC-159 needed for SLSP design analyses will be provided in Section 3.3 of this document.

The SLSP system and its elements must assess each of the applicable natural environments listed in Section 3.2, Table 3-1. The preferred method to comply with this assessment is to design the flight system and support systems to withstand the natural environment. However, it is understood that in some cases it will be more effective to account for all or portions of the natural environments by institution of operational controls, or by accepting the risk of exposure to the natural environment. If design is not a viable option, use of operational controls or accepting risk of exposure must be approved by the SLSP Chief Engineer Control Board or a higher level SLSP board. Risk acceptance will be managed and documented in accordance with Appendix C of SLS-PLAN-001, SLS Program Plan and SLS-RQMT-015, SLSP Hazard Analysis Requirements. Accepted risk concerning natural environments will be documented in the hazard analysis process and will not become part of the SLS Program risk system. The listing of applicable natural environments provided in Table 3-1 will be updated to reflect how the combination of design capability, operational control, and accepted risk addresses the specific natural environment.

Compliance to the natural environment assessments, either by design, use of operational controls, or accepting the risk of exposure, will be summarized in SLS-HDBK-086, SLSP Natural Environments Data Book. Compliance assessments will be provided at each design review, or as requested. Information required to complete the compliance assessment will be coordinated with the discipline or element producing the information.

If design is a viable option, compliance can be met by referencing any SLSP system or element design analysis reports or documentation that provide evidence the full applicable natural environment was accounted for. In the case of operational controls or accepting risk of exposure, compliance can be demonstrated through CECB directives documenting Program approval. CECB directives will be referenced in this document for each affected natural environment. Operational controls will be documented in SLS-PROC-131, SLSP Launch Commit Criteria. Risk of exposure will be managed and documented in hazard analyses according to Appendix C of SLS-PLAN-001 and SLS-RQMT-015.

All design values and/or operational controls will be used to calculate launch probability due to natural environments, which will be monitored via a Technical Performance Measure (TPM) as described in SLS-PLAN-047, SLSP Technical Metrics Plan. Analyses and results to support launch probability will be documented in SLS-HDBK-086.

1.2 Scope

This document allocates the applicable natural environments to the integrated SLSP system, as well as its elements: Stages, Boosters, Engines, and Integrated Spacecraft and Payload Element (ISPE). The natural environments are also applicable to all configurations of the SLSP system. The individual Element Project offices have the responsibility of ensuring flow down of the applicable natural environments to its subsystems and/or components. A description of the SLSP system, elements, and configurations can be found in SLS-SPEC-032.

The natural environments are separated by mission phase, including prelaunch, launch and ascent, in space, entry and landing, and recovery and post-flight processing **<FWD-001>**. The applicable natural environments in this document are tied directly to the mission phases outlined in SLS-SPEC-159. Any changes to the mission phases will be updated in SLS-SPEC-159 and reflected in this document through a change request (CR).

SLS-SPEC-159, and therefore the applicable natural environment in this document, is not intended as a definition of operational models or operational controls, nor is it adequate, in and of itself, for ground facilities which may have additional requirements (for example, building codes and local environmental constraints). SLS-SPEC-044-07 does not allocate natural environments for ground support equipment.

1.3 Change Authority/Responsibility

The NASA Office of Primary Responsibility (OPR) identified for this document is the Marshall Space Flight Center (MSFC) Natural Environments Branch (EV44).

Proposed changes to this document will be submitted by an SLS Program CR to the CECB and the PCB for disposition. All such requests will adhere to the SLS-PLAN-008, SLS Program Configuration Management Plan.

2.0 DOCUMENTS

2.1 Applicable Documents

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein. Unless otherwise stipulated, the most recently approved version of a listed document shall be used. In those situations where the most recently approved version is not to be used, the pertinent version is specified in this list.

SLS-SPEC-159	Cross-Program Design Specification for Natural Environments (DSNE)
SLS-RQMT-040	Space Launch System Program Electromagnetic Environmental Effects (E3) Requirements

2.2 Reference Documents

The following documents contain supplemental information to guide the user in the application of this document.

SLS-HDBK-086	Space Launch System Program Natural Environments Data Book
SLS-PLAN-001	Space Launch System Program Plan
SLS-PLAN-008A	Space Launch System Program Configuration Management Plan
SLS-PROC-131	Space Launch System Program Launch Commit Criteria
SLS-PLAN-047	Space Launch System Program Technical Metrics Plan
SLS-RQMT-015	Space Launch System Program Hazard Analysis Requirements
SLS-SPEC-032	Space Launch System Program System Specification

3.0 NATURAL ENVIRONMENT SPECIFICATIONS

3.1 Design Description

Natural Environment Design Description

By application of design (preferred), operational controls, and/or accepting risk of exposure, the SLS Program will meet its functional and performance requirements during and after exposure to the applicable natural environments as defined in SLS-SPEC-159 and listed in Table 3-1 of this document.

Rationale: The SLSP system will be exposed to a variety of natural environments that could affect its ability to meet functional and performance requirements. This design description defines the applicable natural environments and provides three options on how to account for the effects of those environments. The first and preferred method is to mitigate the effects through design. When design is not feasible, the second preferred method is to limit exposure to the natural environments through operational controls, such as launch commit criteria or ground support equipment (covers, shrouds, etc.). It should be noted that the use of an operational control procedure will likely result in reduction in launch probability. Launch probability due to natural environments will be tracked via a technical performance measure as described in SLSP-PLAN-047. The third and least desirable method is accepting risk of exposure to applicable natural environments without any design or operational control. Although some natural environments have a low probability of occurrence, use of this method can result in serious adverse conditions, such as loss of mission or loss of crew. If design is not a viable option, use of operational controls or accepting risk of exposure must be approved by the SLSP CECB or a higher level SLSP board. Risk acceptance will be managed in accordance with Appendix C of SLS-PLAN-001 and documented in hazard analyses in accordance with SLS-RQMT-015.

3.2 Applicable Natural Environments

This document allocates the applicable natural environments to the integrated SLSP system, as well as its elements. The natural environments are separated by mission phase and map directly to the following SLS-SPEC-159 sections: 3.1 Prelaunch-Ground Processing Phases, 3.2 Launch Countdown and Earth Ascent Phases, 3.3 In-Space Phases, and 3.5 Entry and Landing Phases. Table 3-1 lists the applicable natural environments by system element and mission phase.

The listing of applicable natural environments provided in Table 3-1 will be updated to reflect how the combination of design capability, operational control, and accepted risk addresses the specific natural environment. Check mark entries indicate that the element will be designed to withstand the specified natural environment. For those natural environments that will employ operational controls or accepting risk of exposure has been approved, table entries will contain numbers which are associated with notes located at the bottom of Table 3-1. Each note will describe the compliance method, as well as referencing any supporting documentation, including CECB Directives, launch operations and controls documentation, and/or hazard analysis reports.

SLS-SPEC-159 Sections 3.1 (pre-launch) and 3.2 (launch and ascent) are allocated to the integrated SLS system and its elements. Section 3.3 (in-space) is allocated to the integrated SLS system, ISPE, and Upper Stage Engines. Section 3.5 (entry and landing) is used for Booster and Stages re-entry, break-up, and footprint analyses. Re-entry and break-up analyses for Stages is completed by the Stages Element Office. Footprint assessments for Stages are determined through system level analyses. Re-entry and footprint assessments for Booster are determined through system level analyses. Section 3.5 will also provide the necessary natural environments for abort analyses.

Table 3-1. Listing of SLSP DSNE Applicable Natural Environments for Use by the SLS Program

SLSP DSNE SECTION NUMBER	TITLE	Integrated System	ISPE	Boosters	Stages	Engines	
						Core Stage	Upper Stage
3.0 NATURAL ENVIRONMENT SPECIFICATION							
3.1 PRELAUNCH-GROUND PROCESSING PHASES							
3.1.1	Transportation Environment to the Launch Site KSC (Reserved)						
3.1.2	(Reserved)						
3.1.3	Ground Winds for Transport and Launch Pad Environment	✓	✓	✓	✓	✓	
3.1.4	Radiant (Thermal) Energy Environment for Ground Operations at KSC	✓	✓	✓	✓	✓	✓
3.1.5	Air Temperature Environment for Ground Operations at KSC	✓	✓	✓	✓	✓	✓
3.1.6	Air Pressure Environment for Ground Operations at KSC	✓	✓	✓	✓	✓	✓
3.1.7	Humidity Environment for Ground Operations at KSC	✓	✓	✓	✓	✓	✓
3.1.8	Aerosol Environment for Ground Operations at KSC	✓	✓	✓	✓	✓	✓
3.1.9	Precipitation Environment for Ground Operations at KSC	(1)	(1)	(1)	(1)	(1)	
3.1.10	Flora and Fauna Environment for Ground Operations at KSC	(2)	(2)	(2)	(2)	(2)	
3.1.11	Lightning Environment for Ground Operations at KSC	(3)	(3)	(3)	(3)	(3)	(3)

SLSP DSNE SECTION NUMBER	TITLE	Integrated System	ISPE	Boosters	Stages	Engines	
						Core Stage	Upper Stage
3.2 LAUNCH COUNTDOWN AND EARTH ASCENT PHASES							
3.2.1	Ground Winds Environment During Launch	✓	✓	✓	✓	✓	
3.2.2	Surface Air Temperature Environment During Launch	✓	✓	✓	✓	✓	
3.2.3	Surface Air Pressure Environments During Launch	✓	✓	✓	✓	✓	✓
3.2.4	Surface Humidity Environment During Launch	✓	✓	✓	✓	✓	
3.2.5	Aloft Wind Environment for Vehicle Ascent	✓	✓	✓	✓	✓	
3.2.6	Aloft Air Temperature Environment for Vehicle Ascent	✓	✓	✓	✓	✓	✓
3.2.7	Aloft Air Pressure Environment for Vehicle Ascent	✓	✓	✓	✓	✓	✓
3.2.8	Aloft Air Density Environment for Vehicle Ascent	✓	✓	✓	✓	✓	✓
3.2.9	Cloud and Fog Environment for Launch	(4)	(4)	(4)	(4)	(4)	
3.2.10	Rain and Precipitation Environment for Launch	(5)	(5)	(5)	(5)	(5)	
3.2.11	Flora and Fauna Environment During Launch and Ascent	(6)	(6)	(6)	(6)	(6)	
3.2.12	Natural and Triggered Lightning During Launch and Ascent	(7)	(7)	(7)	(7)	(7)	(7)
3.2.13	Ionizing Radiation Environment for Launch, Ascent and Re-entry	(8)	(8)	(8)	(8)	(8)	(8)
3.3 IN-SPACE PHASES							
3.3.1	Total Ionizing Dose	✓	✓				✓
3.3.2	Peak Flux for SEE Rate Determinations	✓	✓				✓
3.3.3	Cumulative Single Event Effects and Displacement Damage	✓	✓				✓
3.3.4	Ionizing Radiation Environment for Crew Exposure						
3.3.5	Plasma and Spacecraft Charging Environment	✓	✓				✓
3.3.6	Meteoroid and Orbital Debris Environment	(9)	(9)				(9)

SLSP DSNE SECTION NUMBER	TITLE	Integrated System	ISPE	Boosters	Stages	Engines	
						Core Stage	Upper Stage
3.3.7	Earth Gravitational Field	✓	(10)				(10)
3.3.8	Lunar Gravitational Field	✓	(10)				
3.3.9	Thermal Environment for In-Space Hardware	✓	✓				✓
3.3.10	Solar Illumination Environment for In-Space Hardware	✓	✓				✓
3.3.11	In-Space Neutral Atmosphere (Thermosphere) Density	✓	(10)				(10)
3.3.12	Geomagnetic Fields (Reserved)						
3.3.13	Geostationary Electron Environment (Reserved)						
3.5 ENTRY AND LANDING PHASES							
3.5.1	Re-entry Neutral Atmosphere	✓		(11)	(12)		
3.5.2	Reserved						
3.5.3	Lightning During Normal Landing Operations						
3.5.4	Aloft Winds for Normal Descent and Landing Operations	✓		(11)	(12)		
3.5.5	Aloft Air Temperature for Normal Descent and Landing Operations	✓		(11)	(12)		
3.5.6	Aloft Air Pressure for Normal Descent and Landing Operations	✓		(11)	(12)		
3.5.7	Aloft Air Density for Normal Descent and Landing Operations	✓		(11)	(12)		
3.5.8	Surface Winds at Landing Site	✓		(11)	(12)		
3.5.9	Surface Air Temperature for Normal Landing						
3.5.10	Surface Air Pressure for Normal Landing						
3.5.11	Surface Air Humidity for Normal Landing Operations						
3.5.12	Aerosols for Normal Descent and Land Landing Operations						
3.5.13	Precipitation for Normal Descent and Landing Operations						
3.5.14	Flora and Fauna for Normal Descent and Landing Operations						

SLSP DSNE SECTION NUMBER	TITLE	Integrated System	ISPE	Boosters	Stages	Engines	
						Core Stage	Upper Stage
3.5.15	Surface Characteristics and Topography for Normal Land Landing						
3.5.16	Cloud and Fog Environment for Normal Descent and Landing						
3.5.17	Radiant (Thermal) Energy Environment for Normal Landing						
3.5.18	Sea State for Normal Water Landing						
3.5.19	Reserved						
3.5.20	Sea Surface Temperature for Water Landings						
3.5.21	Aerosols for Water Landing Operations						

TABLE 3-1 NOTES:

(1) The prelaunch precipitation environment includes rain and hail. Hail during prelaunch is not allocated to the integrated system/elements as a design requirement. The risk of exposure to hail is assessed as part of the hazard analysis in accordance with SLS-RQMT-015. The rain environment during prelaunch is allocated to the integrated system/elements as a design requirement.

(2) The prelaunch flora and fauna environment includes fungus growth and common pests, to include birds, insects, rodents, wild boar, and alligators. Birds, rodents, wild boar, and alligators during prelaunch is not allocated to the integrated system/elements as a design requirement. The risk of exposure to these pests is assessed as part of the hazard analysis in accordance with SLS-RQMT-015. The fungus growth and insect environment during prelaunch is allocated to the integrated system/elements as a design requirement.

(3) Lightning direct effects (direct attachment to hardware) during prelaunch is not allocated to the integrated system/elements. Operational controls during rollout/rollback are used to limit exposure to lightning direct effects. A lightning protection system is used at the launch pad to deter direct attachments. Design for lightning indirect effects (i.e., currents induced by nearby lightning strikes) are levied upon the integrated system/elements via SLS-RQMT-040, SLSP E3 Requirements. The risk of exposure to lightning environments is assessed as part of the hazard analysis in accordance SLS-RQMT-015.

(4) The cloud and fog environment during launch and ascent includes liquid and frozen particles in fair weather cumulus and cirrus clouds. Convective clouds and thunderstorms are excluded. Fog is not allocated to the integrated system/elements as a design requirement and is addressed by operational controls. Clouds containing liquid and frozen particles are allocated to the integrated system/elements as a design requirement.

(5) The rain and precipitation environment during launch and ascent is not allocated to the integrated system/elements as a design requirement. Operational controls (launch constraints) are used to prevent launching through precipitation (rain, hail, snow, etc.).

(6) The flora and fauna environment during launch and ascent is not allocated to the integrated system/elements as a design requirement. The risk of exposure to this environment is assessed as part of the hazard analysis in accordance with SLS-RQMT-015.

(7) The natural and triggered lightning environment during launch and ascent is not allocated to the integrated system/elements as a design requirement. Operational controls (launch constraints) are used to avoid launching when lightning is occurring and to reduce risk of triggering lightning during ascent. The risk of exposure to this environment is assessed as part of the hazard analysis in accordance with SLS-RQMT-015.

(8) The ionizing radiation environment is allocated to the integrated system/elements during launch and ascent as a design requirement. The ionizing radiation environment is not allocated to the integrated system/elements during re-entry as a design requirement.

(9) The meteoroid and orbital debris environment is not allocated to the integrated system/elements as a design requirement. The risk of exposure to this environment is assessed as part of the hazard analysis in accordance with SLS-RQMT-015.

(10) The Earth gravitational field and in-space neutral atmosphere environments are not allocated to the ISPE and Upper Stage Elements. The lunar gravitational field environment is not allocated to ISPE. These environments are assessed via integrated system analyses.

(11) The re-entry environments are used in the Booster Element break-up and footprint analyses. Re-entry environments for break-up and footprint analyses are not allocated to the Booster Element. These environments are assessed via integrated system analyses.

(12) The re-entry environments are used in the Stages Element break-up and footprint analyses. Re-entry environments are allocated to the Stages Element for break-up analyses. However, re-entry environments are not allocated to the Stages Element for footprint analyses. These environments are assessed via integrated system analyses.

3.3 Additional Natural Environment Information

This section will list additional natural environment definitions, interpretations, and/or details of the natural environments given in SLS-SPEC-159, which may be needed for design analyses.

RESERVED

APPENDIX A
ACRONYMS AND ABBREVIATIONS

A1.0 ACRONYMS AND ABBREVIATIONS

CECB	Chief Engineer Control Board
CR	Change Request
DRD	Data Requirement Description
DRL	Data Requirements List
DRM	Design Reference Mission
DSNE	Design Specification for Natural Environments
E3	Electromagnetic Environments Effects
ESD	Exploration Systems Development
HDBK	Handbook
ISPE	Integrated Spacecraft and Payload Element
KSC	Kennedy Space Center
MSFC	Marshall Space Flight Center
OPR	Office of Primary Responsibility
PCB	Program Control Board
RQMT	Requirement
SEE	Single Event Effects
SLS	Space Launch System
SLSP	Space Launch System Program
SPEC	Specification
TPM	Technical Performance Measure

A2.0 GLOSSARY OF TERMS

Term	Description
Integrated System	State of the SLS System when at least two elements are connected.

APPENDIX B
OPEN WORK

All resolved TBDs, TBRs, and forward work items should be listed on the Change Request (CR) the next time the document is updated and submitted for formal review and that will serve as the formal change record through the configuration management system.

B1.0 TO BE DETERMINED

Table B1-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBD item is sequentially numbered as applicable (i.e., **<TBD-001>** is the first undetermined item assigned in the document). As each TBD is resolved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be renumbered.

Table B1-1. To Be Determined Items

TBD	Section	Description
TBD-001		

B2.0 TO BE RESOLVED

Table B2-1 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBR issue is sequentially numbered as applicable (i.e., **<TBR-001>** is the first unresolved issue assigned in the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

Table B2-1. To Be Resolved Issues

TBR	Section	Description
TBR-001		

B3.0 FORWARD WORK

Table B3-1 lists the specific forward work items identified during this document's Change Request (CR) review and evaluation. Each item is given a sequential number using a similar format to that for the TBDs and TBRs. For each item, include the section number(s) of this document that the open work will impact, and in the Description include the specific number of the comment from the Change Evaluation (CE), i.e., CE-10, CE-27. Do not include a placeholder for forward work items in the body of the document; list them only in Table B3-1.

Note: If there are no forward work items, do not include this subsection in your document.

Table B3-1. Forward Work

FWD	Section	Description
FWD-001	1.2 3.2	Mission phases in SLS-SPEC-159, and therefore in SLS-SPEC-044-07, do not currently map to the mission phases as outlined in the Integrated Mission Analysis. Once mission phases are synchronized between ESD and SLS, SLS-SPEC-159, and therefore SLS-SPEC-044-07, will be updated to reflect agreed upon mission phases. [CE-26 and CE-28]