

Guide

Terrestrial Environment Guidelines for Use in Aerospace Vehicle Development

AIAA standards are copyrighted by the American Institute of Aeronautics and Astronautics (AIAA), 1801 Alexander Bell Drive, Reston, VA 20191-4344 USA. All rights reserved.

AIAA grants you a license as follows: The right to download an electronic file of this AIAA standard for storage on one computer for purposes of viewing, and/or printing one copy of the AIAA standard for individual use. Neither the electronic file nor the hard copy print may be reproduced in any way. In addition, the electronic file may not be distributed elsewhere over computer networks or otherwise. The hard copy print may only be distributed to other employees for their internal use within your organization.

Guide

Terrestrial Environment Guidelines for Use in Aerospace Vehicle Development

Sponsored by

American Institute of Aeronautics and Astronautics

Approved February 2015

Abstract

This document is based on the NASA Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development and provides guidelines regarding current natural terrestrial environment criteria to be used for the design and development of aerospace vehicles traversing the terrestrial atmosphere. It provides, in one single reference, a comprehensive description of the state-of-the-art of these natural terrestrial environment inputs. This document reflects on aerospace vehicle development experiences and consolidates guidelines for natural terrestrial environments that have been utilized in a large number of space vehicle developments.

Published by
American Institute of Aeronautics and Astronautics
1801 Alexander Bell Drive, Reston, VA 20191

Copyright © 2015 American Institute of Aeronautics and
Astronautics
All rights reserved

No part of this publication may be reproduced in any form, in an electronic retrieval system
or otherwise, without prior written permission of the publisher.

Printed in the United States of America

ISBN 978-1-62410-302-5

Contents

Foreword	v
Trademarks	vi
1 Scope	1
2 Tailoring	1
3 Applicable Documents	1
3.1 General	1
3.2 Reference Documents	1
4 Vocabulary	2
4.1 Acronyms and Abbreviated Terms	2
4.2 Terms and Definitions	2
5 Introductory Discussion	2
5.1 Table of Contents for AIAA Guide (Taken only from NASA TM Section 1)*	2
5.2 Introduction	3
5.3 Title and Discussion	3
5.3.1 General	3
5.3.2 Engineering Importance	4
5.3.3 Terrestrial Environment Issues	6
5.3.4 Vehicle and Terrestrial Environment Areas of Concern	8
5.3.5 Environmental Test Procedures	9
5.3.6 Some Lessons Learned	10
5.4 Concluding Remarks	13
Annex A NASA /TM-2008-215633: "Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, 2008 Revision" Sectional Introductions and Tables of Contents	14
A.1 Introduction	14
A.2 NASA TM Table of Contents for Section 1	14
A.3 NASA TM Sections 2–16 Introductions With Their Tables of Contents	14
Annex B Errata	38
Figures	
Figure 1 — NASA's proposed launch vehicle: Space Launch System (SLS)	4
Figure 2 — Natural terrestrial environment definition and analysis for aerospace vehicle engineering application	6
Tables	
Table 1 — Key terrestrial environment parameters needed versus engineering systems (X) and mission phase (P). ..	9

Foreword

The NASA Marshall Space Flight Center Natural Environment Branch and its predecessor organizations have been responsible for each update of the NASA Terrestrial Environment (Climatic) Criteria Guidelines document, and subsequently hereafter be referred to as NASDA "TM" in text of this AIAA Guide. This NASA TM and its predecessors goes back more than 50 years to the early 1960s and has been updated many times since then. The last update was in December 2008 (NASA/TM-2008-215633) and replaces all previous editions of the document, with the latest state-of-the-art atmospheric type criteria being presented. It is not just a compilation of atmospheric or weather climatology but rather a statistically developed set of atmospheric criteria guidelines generated especially for use in the design and development of launch and space vehicles. There are other documents containing only weather or climate related values, but not specifically developed for a given launch vehicle with its particular set of requirements. There is one annex to this AIAA Guide document. Due to the great length of the parent NASA TM document, only the first Section of the NASA TM is presented here, along with a complete listing of the entire NASA TM table of contents as Annex A.

The full contents of the entire AIAA Guide comprising the NASA TM's 16 Sections are available at <http://arc.aiaa.org/userimages/ContentEditor/1405349521582/NASA%20Technical%20Report.pdf> (NASA-TM-2008-215633).

At the time of approval, the members of the AIAA Atmospheric and Space Environment Committee on Standards Terrestrial Working Group who prepared this document were:

Dale Johnson, Chair	NASA Retired
Sam Adhikari	Sysoft Corporation
Michael Bodeau	Northrup Grumman
Franz-Josef Kahlen	University of Cape Town (South Africa)
Jerry K. Owens	NASA Marshall Space Flight Center
Martin Ross	The Aerospace Corporation
William W. Vaughan	University of Alabama in Huntsville

The above consensus body approved this document in July 2014.

The AIAA Standards Executive Council (VP-Standards Laura McGill, Chairperson) accepted the document for publication in February 2015.

The AIAA Standards Procedures dictates that all approved Standards, Recommended Practices, and Guides are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. There is no agreement to adhere to any AIAA standards publication and no commitment to conform to or be guided by standards reports. In formulating, revising, and approving standards publications, the committees on standards will not consider patents that may apply to the subject matter. Prospective users of the publications are responsible for protecting themselves against liability for infringement of patents or copyright or both.

Trademarks

No commercial products that require trademark designation are mentioned in this document. This information is given for the convenience of users of this document and does not constitute an endorsement. Equivalent products may be used if they can be shown to lead to the same results. Product names may be listed in the various NASA TM Sections.

1 Scope

This AIAA Guide provides guidelines regarding the current natural terrestrial environment criteria for use in the design and development of aerospace vehicles traversing the terrestrial atmosphere (0–90 km altitude). This Guide specifies and provides, in one single reference, a comprehensive description of the state of the art of these natural terrestrial environment inputs. The contents to be used are based on aerospace vehicle development experiences and consolidated guidelines for natural terrestrial environments that have been utilized in a large number of space vehicle developments.

Aerospace vehicle design criteria guidelines are provided for the following environmental phenomena: winds; atmospheric models and thermodynamic properties; thermal radiation; U.S. and world surface extremes; humidity; precipitation, fog, and icing; cloud phenomena and cloud cover models; atmospheric electricity; atmospheric constituents; aerospace vehicle exhaust and toxic chemical release; tornadoes and hurricanes; geologic hazards; and sea state. Sections 15 and 16 of this AIAA Guide based on the referenced NASA TM include information on mission analysis, prelaunch monitoring, flight evaluation, physical constants, and metric/English unit conversion factors.

2 Tailoring

When viewed from the perspective of a specific vehicle program or project context, the information in this AIAA Guide may be tailored to match the actual requirements of the particular program or project with respect to expected operational launch site(s) for the vehicle. Tailoring of requirements shall be undertaken in consultation with the procuring authority where applicable.

This Guide may be cited in contract, program, and other documents as an applicable reference document. Mandatory requirements are indicated by the word *shall*. Tailoring of this standard for application to a specific program or project shall be approved by the technical authority for that program/project.

NOTE Tailoring is a process by which individual requirements or specifications, standards, and related documents are evaluated and made applicable to a specific program or project by selection and, in some exceptional cases, modification and addition of requirements in the standards.

3 Reference Documents

The following documents contain provisions that, through reference in this text, constitute provisions of this Guide. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Guide are encouraged to investigate the possibility of applying the most recent editions of the normative documents listed in Section 3.2. For undated references, the latest edition of the normative document referred to applies.

3.1 General

The documents listed in this section contain provisions that constitute requirements of this Guide as cited in the appendices. The latest issuances of cited documents shall be used unless otherwise approved by the assigned Technical Authority.

3.2 Applicable Documents

The following documents are applicable to NASA TM Section 1 only. Each of the other sections has its own set of references.

NASA/TM-2008-215633; Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, 2008 Revision (Section 1).

Blair, J.C.; Ryan, R.S.; Schutzenhofer, L.A.; and Humphries, W.R.: "Launch Vehicle Design Process: Characterization, Technical Integration and Lessons Learned," *NASA/TP—2001–210992*, NASA Marshall Space Flight Center, AL, May 2001.

Johnson, D.L.; and Anderson, B.J.: "The Role of the Natural Environment in Launch Vehicle Development," Chapter 7, *Space Launch and Transportation Systems: Design and Operations*, Vol. 1, 2005, unpublished.

Johnson, D.L.; Hill, C.K.; Vaughan, W.W.; Brown, S.C.; and Batts, G.W.: "Natural Environment Requirements Definition and Significance for Aerospace Plane Development," *AIAA Paper No. 93–5074*, AIAA/DGLR Fifth International Aerospace Planes and Hypersonic Technologies Conference, November 30–December 3, 1993, Munich, Germany, American Institute of Aeronautics and Astronautics, Reston, VA.

Pearson, S.D.; Vaughan, W.W.; Batts, G.W.; and Jasper, G.L.: "Importance of the Natural Terrestrial Environment With Regard to Advanced Launch Vehicle Design and Development," *NASA TM 108511*, NASA Marshall Space Flight Center, AL, June 1996.

Ryan, R.; Blair, J.; Townsend, J.; and Verderaiame, V.: "Working on the Boundaries: Philosophies and Practices of the Design Process," *NASA TP-3642*, Marshall Space Flight Center, AL, July 1996.

Vaughan, W.W.; and Brown, S.C.: "Natural Environment Considerations for Space Shuttle System Development Support," *Journal of Spacecraft and Rockets*, Vol. 22, No. 3, pp. 355–360, 1985.

Vaughan, W.W.; Johnson, D.L.; Pearson, S.D.; and Batts G.W.: "The Role of Aerospace Meteorology in the Design, Development and Operation of New Advance Launch Vehicles," *Proceedings of the Seventh Conference on Aviation, Range and Aerospace Meteorology*, American Meteorological Society, Boston, MA, February 1997.

NOTE Further applicable documents are given at the end of each Section of the NASA TM, which is available at <http://arc.aiaa.org/userimages/ContentEditor/1405349521582/NASA%20Technical%20Report.pdf> (NASA-TM-2008-215633).

4 Vocabulary

4.1 Acronyms and Abbreviated Terms

The complete listing of Acronyms and Abbreviated Terms are given in each section of the NASA TM.

4.2 Terms and Definitions

For the purposes of this document, the definitions of terms are given in each section of the NASA TM.

5 Introductory Discussion

5.1 Table of Contents for AIAA Guide (Taken from NASA TM Section 1)

SECTION 5 TABLE OF CONTENTS

5.2	Introduction	3
5.3	Title and Discussion	3
5.3.1	General	3
5.3.2	Engineering Importance	4
5.3.3	Terrestrial Environment Issues	6
5.3.4	Vehicle and Terrestrial Environment Areas of Concern	8

5.3.5	Environmental Test Procedures.....	9
5.3.6	Some Lessons Learned.....	10
5.4	Concluding Remarks.....	13
NOTE	For contents of other sections for this AIAA Guide, consult Annex A.	

5.2 Introduction

The entire NASA TM 2008-215673 Section 1, which presents an introduction and discussion of the overall application of the terrestrial environment parameters with respect to launch and space vehicle design engineering analyses, is provided in Section 5.3.1 of this AIAA Guide. In addition, lessons learned from selected and learned applications between the two disciplines are presented.

5.3 Title and Discussion

INTRODUCTION to “TERRESTRIAL ENVIRONMENT (CLIMATIC) CRITERIA GUIDELINES FOR USE IN AEROSPACE VEHICLE DEVELOPMENT”

5.3.1 General

Atmospheric phenomena play a significant role in the design and operation of aerospace vehicles and in the integrity of aerospace systems and elements. The terrestrial environment design criteria guidelines given in this AIAA Guide are based on statistics and models of atmospheric and climatic phenomena relative to various aerospace design, development, and operational issues. The NASA TM revision on which this AIAA Guide is based contains new and updated material in most sections.

Aerospace vehicle design guidelines are provided (Annex A) for the following environmental phenomena: winds; atmospheric models and thermodynamic properties; thermal radiation; U.S. and world surface extremes; humidity; precipitation, fog, and icing; cloud phenomena and cloud cover models; atmospheric electricity; atmospheric constituents; aerospace vehicle exhaust and toxic chemical release; tornadoes and hurricanes; geologic hazards; and sea state. Sections 15 and 16 of the NASA TM includes information on mission analysis, prelaunch monitoring, flight evaluation, physical constants, and metric/English unit conversion factors.

In general, this document does not specify how the designer should use the data in regard to a specific aerospace vehicle design. Such specifications may be established only through the analysis and study of a particular design problem. Although of operational significance, descriptions of some atmospheric conditions have been omitted since they are not of direct concern for an aerospace vehicle system's design, the primary emphasis of this document. Induced environments (vehicle caused) may be more critical than the natural environment for certain vehicle operational situations. In some cases, the combination of natural and induced environments will be more severe than either environment alone. Induced environments are considered in other aerospace vehicle design criteria documents, which should be consulted for such information.

The natural terrestrial environment criteria guidelines presented in this document were formulated on the basis of discussions with, and requests from, engineers involved in aerospace vehicle development and operations. Therefore, they represent responses to actual engineering problems and not just a general compilation of environmental data. NASA Centers, various other government agencies, and their associated contractors responsible for the design, mission planning, and operational studies have used the NASA TM extensively. The *Glossary of Meteorology* and *Glossary of Weather and Climate*, published by the American Meteorological Society, 45 Beacon Street, Boston, MA 02108, should be consulted for the definitions of environment terms not otherwise defined in the contents of the NASA TM (Annex A).

This document also does not include information on the natural environment above 90 km. A recently issued document sponsored by the European Space Agency (ESA), ECSS-E-ST-10-04C, “Space

Engineering—Space Environment,” provides an excellent summary from the engineering application viewpoint on all aspects of the space environment. It may be downloaded from the European Cooperation for Space Standardization Web site, <http://www.esa.nl>. Also, the NASA Marshall Solar Activity monthly document that provides current and future estimates of 13-mo Zurich smoothed solar and geomagnetic activity may be downloaded from <http://sail.msfc.nasa.gov>.

5.3.2 Engineering Importance

It is important to recognize the need to define the terrestrial environment very early in the design and development cycle of any aerospace vehicle. The bibliography for Section 1 provides a number of documents that address this subject. This need is especially true for a new configuration, such as the new Space Launch System (see Figure 1) or any other future launch vehicle. Using the desired operational capabilities, launch locations, and flight profiles for the vehicle, specific definitions of the terrestrial environment can be provided that, if the aerospace vehicle is designed to accommodate them, will ensure the desired operational capability within the defined design risk level. It is very important that those responsible for the terrestrial environment definitions for the design of an aerospace vehicle have a close working relationship with program management and design engineers. This will ensure that the desired operational capabilities are reflected in the terrestrial environment requirements specified for design of the vehicle.

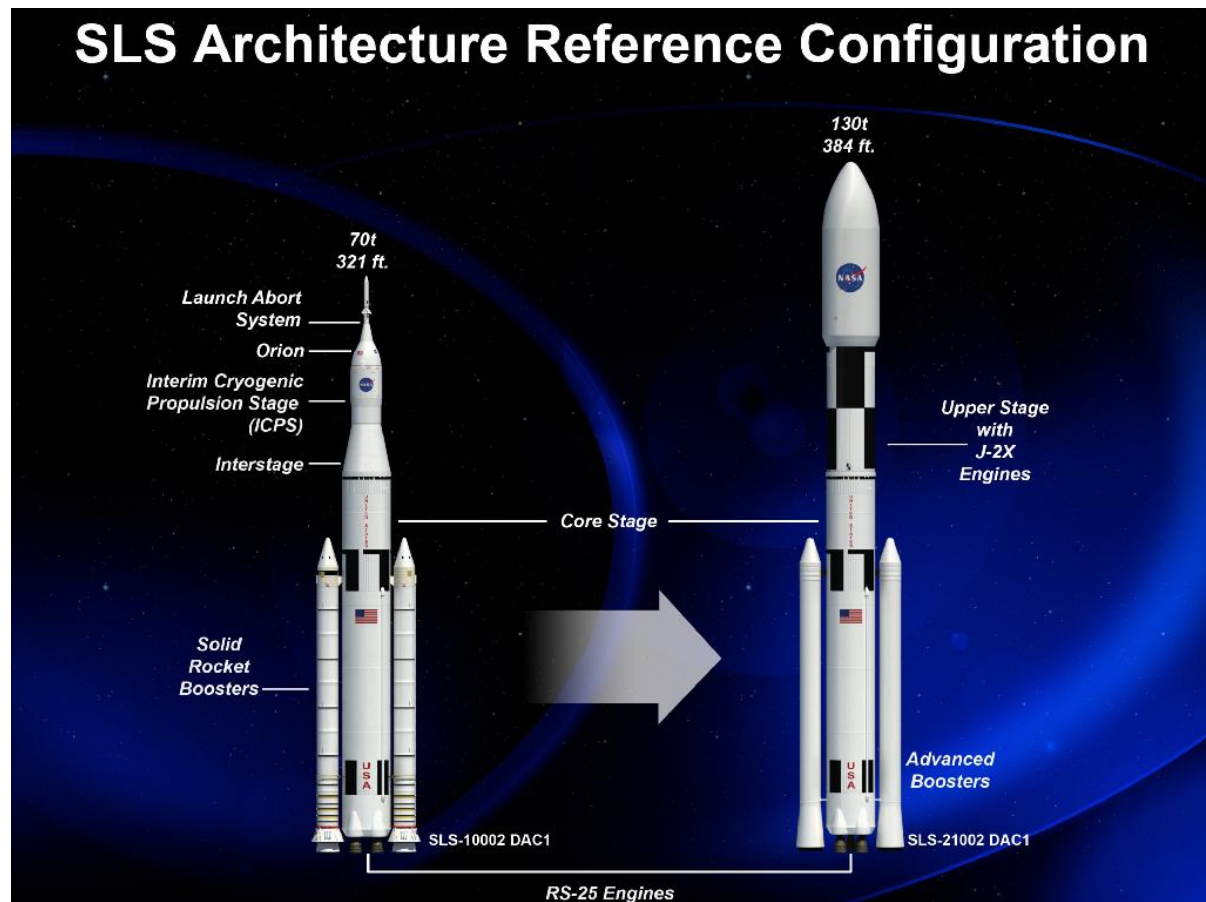


Figure 1 — NASA's proposed launch vehicle: Space Launch System (SLS)

An aerospace vehicle's response to terrestrial environment criteria must be carefully evaluated to ensure an acceptable design relative to desired operational requirements. The choice of criteria depends on the specific launch and landing location(s), vehicle configuration, and expected mission(s). Vehicle design,

operation, and flight procedures can be separated into particular categories for proper assessment of environmental influences and impact on the life history of each vehicle and all associated systems. These include categories such as (1) purpose and concept of the vehicle, (2) preliminary engineering design, (3) structural design, (4) control system design, (5) flight mechanics, orbital mechanics, and performance (trajectory shaping), (6) optimization of design limits regarding the various natural environmental factors, and (7) final assessment of the natural environmental capability for launch and flight operations.

Another important matter that must be recognized is the necessity for having a coordinated and consistent set of terrestrial environment requirements for use in a new aerospace vehicle's design and development. This is particularly important when diverse groups are involved in the development, and is of utmost importance for any international endeavor. A "central control point" having responsibility for the definition and interpretation of the terrestrial environment inputs is critical to the successful design and operation of any new aerospace vehicle. Without this control, different terrestrial environment values or models can be used with costly results in terms of money, time, and vehicle performance. This central control point should also include responsibility for mission analysis, test support requirements, flight evaluation, and operational support relative to terrestrial environment requirements.

During the early stages of a new aerospace vehicle's design and development, tradeoff studies to establish the sensitivities of various terrestrial environment-forcing functions are important. Feedback from these studies is key to establishing the necessary terrestrial environment requirements for the vehicle's final design. A single source (central control point) responsible for the terrestrial environment inputs and their interpretation is important. This will preclude a multitude of problems in the final design and development process, and will enable terrestrial environment requirements to be established with a minimum amount of communications problems and misunderstanding of design issues.

The close association between the design and test engineering groups and those responsible (central control point) for the terrestrial environment inputs is key to the success of the vehicle's development process. This procedure has been followed in many NASA aerospace vehicle developments and is of particular importance for any new aerospace vehicle. Figure 2 illustrates necessary interactions relative to terrestrial environment definition and engineering application. Feedback is critical to the vehicle development process relative to terrestrial environment requirements and thus the ability to produce a viable vehicle design and operational capability.

Finally, although often not considered to be significant, it is very important that all new aerospace vehicle design review meetings include a representative from the terrestrial environment group (central control point) assigned to support the program. This will ensure good understanding of design requirements and timely opportunity to incorporate terrestrial environment inputs and interpretations, which are tailored to the desired operational objectives, into the design process. It is also necessary that any proposed deviations from the specified terrestrial environment requirements, including those used in preliminary design tradeoff studies, be approved by the responsible terrestrial environment central control point to ensure that all program elements are using the same baseline inputs. This will also help the program manager understand the operational impact of any change in terrestrial environment requirements before implementation into the design. Otherwise, gross errors and deficiencies in design can result from using different inputs selected from various diverse sources by those involved in design and other performance studies.

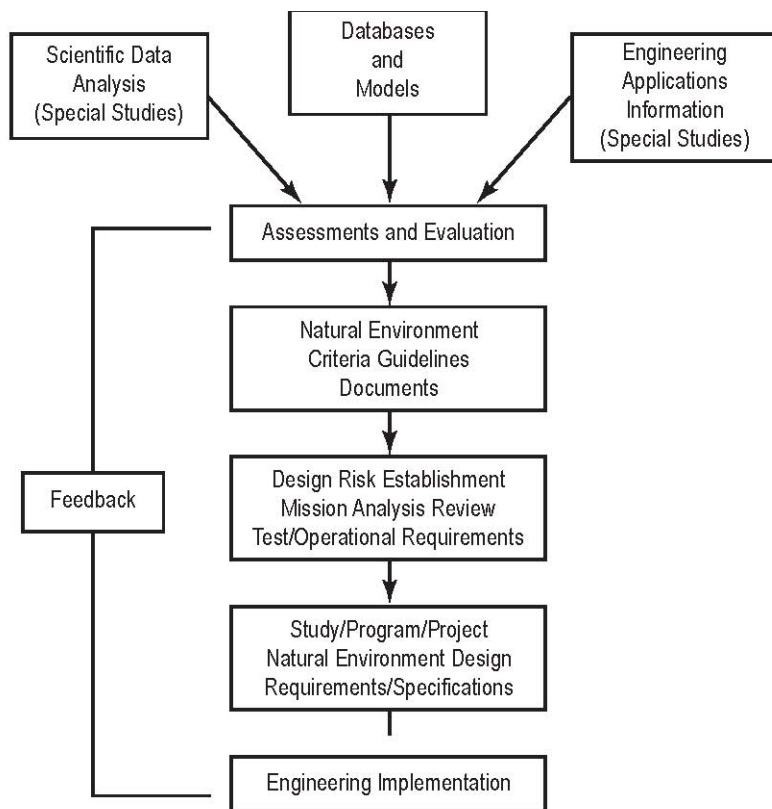


Figure 2 — Natural terrestrial environment definition and analysis for aerospace vehicle engineering application

One must remember that the flight profile of any aerospace vehicle includes the terrestrial environment. Terrestrial environment definitions are usually limited to information below ≈ 90 km ($\approx 295,000$ ft). Thus, an aerospace vehicle's operations will always be influenced to some degree by the terrestrial environment with which it interacts. As a result, the definition of the terrestrial environment and its interpretation is one of the key aerospace vehicle design and development inputs. This definition plays significant roles; for example, in the areas of structures, control systems, trajectory shaping (performance), aerodynamic heating, and takeoff/landing capabilities. The aerospace vehicle's capabilities which result from the design, in turn, determine the constraints and flight opportunities for tests and operations.

5.3.3 Terrestrial Environment Issues

Experience gained from developing terrestrial environment design criteria for previous aerospace vehicle programs has proven that, to be most effective, the terrestrial environment design criteria for a new vehicle should:

- (1) Be available at the inception of the program and developed to ensure the desired operational performance of the aerospace vehicle.
- (2) Be issued under the signature of the program manager and be part of the controlled program definition and requirements documentation.
- (3) Specify in the criteria document the terrestrial environment for all phases of activity, including prelaunch, launch, ascent, on-orbit, descent, and landing.

For extremes in the terrestrial environments, there generally is no known physical upper or lower bound. However, wind speed does have a strict physical lower bound of zero. Essentially all observed extreme conditions have a finite probability of being exceeded. Consequently, terrestrial environment extremes

used for design must be accepted with the knowledge that there is some risk of the values being exceeded. The measurement of many environmental parameters is not as accurate as desired. In some cases, theoretical model estimates are believed to be more useful for design use than those indicated by empirical distributions from short periods of record. Therefore, theoretical values have been given considerable weight in selecting the extreme values for some parameters, for example, peak surface winds. Criteria guidelines are presented for various percentiles based on the available data. Caution should be exercised in the interpretation of these percentiles in aerospace vehicle studies to ensure consistency with physical reality and the specific design and operational problems of concern.

Aerospace vehicles are not normally designed for launch and flight in severe weather conditions, such as hurricanes, thunderstorms, ice storms, and squalls. Environmental parameters associated with severe weather that may be hazardous to aerospace vehicles and associated ground support equipment include strong ground and in-flight winds, strong wind shears and gusts, turbulence, icing conditions, and electrical activity. Terrestrial environment guidelines provide information relative to those severe weather characteristics that should be included in design requirements and specifications if required to meet the program's mission operational requirements.

Knowledge of the terrestrial environment is also necessary to establish test requirements for aerospace vehicles and in design of associated support equipment. Such data are required to define the fabrication, storage, transportation, test, and preflight design condition and should be considered for both the whole vehicle system and the components which comprise the system.

The group having the central control point responsibility and authority for defining and interpreting terrestrial environment design requirements must also be in a position to pursue environment input-related applied research studies and engineering assessments and updates. This is necessary to ensure accurate and timely terrestrial environment inputs tailored to the program's needs. Design engineers and program managers who assume they can simply draw on the vast statistical databases and numerous models of the terrestrial environment currently available in the literature, without interpretation and tailoring to specific vehicle design needs, can prove to be a major deterrent to the successful development and operation of an aerospace vehicle.

Although a vehicle design ideally should accommodate all expected operational environment conditions, it is neither economically nor technically feasible to design an aerospace vehicle to withstand all terrestrial environment extremes. For this reason, consideration should be given to protecting vehicles from some extremes. This can be achieved by using support equipment and specialized forecast personnel to advise on the expected occurrence of critical terrestrial environment conditions. The services of specialized forecast personnel may be very economical compared to the more expensive vehicle designs that would be required to cope with all terrestrial environment possibilities.

The terrestrial environment is a major environmental driver for an aerospace vehicle's design and is the focus of this document. However, the natural environment above 90 km must also be considered for aerospace vehicles. The orbital operating phase of an aerospace vehicle includes exposure to the space environment, including atomic oxygen, atmospheric density, ionizing radiation, plasma, magnetic fields, meteoroids, etc., plus a few manmade environments, such as orbital debris. Specific aerospace vehicle terrestrial and space environments design requirements are normally specified in the appropriate vehicle design criteria documentation.

Good engineering judgment must be exercised in applying terrestrial environment requirements to an aerospace vehicle's design analysis. Consideration must be given to the overall vehicle mission and system performance requirements. Knowledge is still lacking on relationships between some of the terrestrial environment parameters that are required as inputs to the design of aerospace vehicles. Also, interrelationships between vehicle parameters and terrestrial environment variables cannot always be clearly defined. Therefore, a close working relationship and team philosophy must exist between the design and operational engineer and the respective organization's terrestrial environment central control point specialists.

5.3.4 Vehicle and Terrestrial Environment Areas of Concern

As noted, it is important that the need for defining the ground, ascent, on-orbit, and descent aerospace vehicle operational terrestrial environments be recognized early in the design and development phase of the vehicle program. Engineering technology is constantly changing. In some cases, the current trends in engineering design have increased a vehicle's susceptibility to terrestrial environment factors. Based on past experience, the earlier the terrestrial environment central control point specialists become involved in the design process, the less the potential for negative environmental impacts on the program downstream through redesign, operational work-around, etc.

In many cases, it is impossible to clearly define the limiting extreme values for a particular terrestrial environment parameter that may occur during the desired operational lifetime of the vehicle. It may not be technically nor economically feasible to design a vehicle to withstand an extreme environment value. However, a lower value may be defined such that the probability is small that the lower value will occur during the desired operational lifetime of the vehicle. Additional launch delay risks may also be acceptable versus the expense of additional design considerations. Because of these and other considerations, a value less than the extreme may be a more appropriate design requirement. The terrestrial environment specialist has the responsibility to provide the program manager and chief engineer with pertinent information so they can determine the highest risk value that is feasible for the program in that particular environment area. Therefore, it is very important that the aerospace vehicle program manager and the chief engineer have a good understanding of the operational risks due to the selected design terrestrial environment.

Table 1 provides a reference guide for the terrestrial environment specialist, program managers, design engineers, and others on the development team for a new aerospace vehicle program. This information summarizes potential terrestrial environment areas of engineering concern when first surveying a vehicle project. As the table indicates, terrestrial environment phenomena may significantly affect multiple areas of an aerospace vehicle's design, and thus operational capabilities, including areas involving structure, control, trajectory shaping (performance), heating, takeoff and landing capabilities, materials, etc.

5.3.5 Environmental Test Procedures

This document does not address the subject of environmental test procedures. Reference should be made to MIL-STD-810F, "Department of Defense Test Method Standard for Environmental Engineering Consideration and Laboratory Tests," January 1, 2000, available from the Defense Automation and Production Service, 700 Robbins Avenue, Philadelphia, PA 19111-5094. This standard may also be downloaded from the DoD via <http://www.everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL STD 810F 949/>. MIL-STD-810F covers procedures for low pressure (high altitudes), high and low temperatures, temperature shock, temperature altitude and temperature-humidity altitude, solar radiation, rain, humidity, fungus, salt fog, dust (fine sand), and space simulations (unmanned test). An excellent comparison of the various international environmental testing standards may be found in the *Journal of Environmental Sciences*, Vol. XXIV, No. 2, March/April 1981.