TABLE OF CONTENTS

TERRESTRIAL ENVIRONMENT (CLIMATIC) CRITERIA HANDBOOK FOR USE IN AEROSPACE VEHICLE DEVELOPMENT

SECTION 1

SUMMARY

Atmospheric phenomena play a significant role in the design and flight of aerospace vehicles and in the integrity of the associated aerospace systems and structures. Environmental design criteria guidelines in this report are based on statistics of atmospheric and climatic phenomena relative to various aerospace development, operational, and vehicle launch locations. This revision contains new and updated material in most sections.

Specifically, aerospace vehicle design guidelines are established for the following environmental phenomena and presented by sections: 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; Occurrences of Tornadoes and Hurricanes; Geologic Hazards; and Sea State. The last section in this document includes conversion constants.

Atmospheric data are presented for application to aerospace vehicle design studies and the development of design requirements/specifications. The atmospheric parameters are scaled to show the probability of reaching or exceeding certain limits to assist in establishing design and operating criteria. Additional information cited in the text on the different parameters may be found in the numerous references following each section.

1. INTRODUCTION

1.1 General. For climatic extremes, there is no known physical upper or lower bound except for certain conditions; for example, wind speed does have a strict physical lower bound of zero. Therefore, for any observed extreme condition, there is a finite probability of it being exceeded. Consequently, climatic extremes 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 estimates of extreme values are believed to be more representative than those indicated by empirical distributions from short periods of record. Therefore, theoretical values are given considerable weight in selecting extreme values for some parameters, i.e., the peak surface winds. Criteria guidelines are presented for various percentiles based on available data samples. Caution should be exercised in the interpretation of these percentiles in 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, and squalls. Atmospheric parameters associated with severe weather which may be hazardous to aerospace vehicles are strong ground and inflight winds, strong wind shears, turbulence, icing conditions, and electrical activity. The guidelines given usually provide information relative to severe weather characteristics, which may be included in design requirements/specifications if required.

Environmental data in this report are primarily limited to information below 90 km. Specific aerospace vehicle natural environmental design criteria are normally specified in the appropriate organizational aerospace vehicle design ground rules and design criteria data documentation. The information in this document is recommended for use in the development of aerospace vehicles and associated equipment design criteria (requirements/specifications) unless otherwise stated in contract work specifications.

The data in all sections are based on conditions which have actually occurred, or are statistically probable in nature over a longer reference period than the available data based on established theoretical models.

Assessment of the natural environment in the early stages of an aerospace vehicle development program will be advantageous in developing a vehicle with a minimum operational sensitivity to the environment. For those areas of the environment that need to be monitored prior to and during tests and operations, this early planning will permit development of the required measuring and communication systems for accurate and timely monitoring of the environment.

A knowledge of the Earth's atmospheric environment parameters is necessary for the establishment of design requirements for aerospace vehicles and associated equipment. Such data are required to define the fabrication, storage, transportation, test, preflight, and inflight design conditions and should be considered for both the whole system and the components which make up the system. One of the purposes of this document is to provide guideline data on natural environmental conditions, for the various major geographic locations which are applicable to the design of aerospace vehicle and associated equipment.

Good engineering judgment must be exercised in the application of the Earth's atmospheric data to aerospace vehicle design analysis. Consideration must be given to the overall vehicle mission and performance requirements. Knowledge is still lacking on the relationships between some of the atmospheric variates which are required as inputs to the design of aerospace vehicles. Also, interrelationships between aerospace vehicle parameters and atmospheric variables cannot always be clearly defined. Therefore, a close working relationship and team philosophy must exist between the design/operational engineer and the respective organization's aerospace environmentalists. Although, ideally, an aerospace vehicle design should accommodate all expected operational atmospheric conditions, it is neither economically nor technically feasible to design aerospace vehicles to withstand all atmospheric extremes. For this reason, consideration should be given to protection of aerospace vehicles from some extremes by use of support equipment and by using specialized forecast personnel to advise on the expected occurrence of critical environmental conditions. The services of specialized forecast personnel may be very economical in comparison with more expensive designing which would be necessary to cope with all environmental possibilities.

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 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 structural and control system design, the primary emphasis of this document. Induced environments (vehicle caused) may be more critical than natural environments 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 space vehicle criteria documents, which should be consulted for such data.

The natural environment criteria guidelines data presented in this document were formulated based on discussions with and requests from engineers involved in space vehicle development and operations; therefore, they represent responses to actual engineering problems and are not just a general compilation of environmental data. This report is used extensively by the Marshall Space Flight Center (MSFC), other NASA Centers, various other Government agencies, and their associated contractors in design and operational studies. Considerably more information is available on topics covered in this report than is presented here. Users of this document who have questions or require further information on the data provided may direct their requests to the Environments Group (ED44), NASA Marshall Space Flight Center, Alabama 35812.

1.2 Main Geographical Areas Covered in Document:

a. Kennedy Space Center, Florida
b. Vandenberg Air Force Base, California
c. Edwards Air Force Base, California
d. Johnson Space Center, Houston, Texas
e. White Sands Missile Range, New Mexico
f. Michoud Assembly Facility, New Orleans, Louisiana
g. Stennis Space Center, Mississippi.

Some other geographical areas are also presented.

This document does not include the subject of environmental test procedures. Reference should be made to MIL-STD-810E(3), *Environmental Test Methods and Engineering Guidelines,* July 14, 1989, available from Defense Automation and Production Service, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094. The standard may also be downloaded from the NASA Technical Standards Program Homepage: http://standards.nasa.gov. This MIL-STD covers procedures for: Low Pressure (Altitude), High and Low Temperature, 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. The *Glossary of Meteorology* published by the American Meteorological Society, 45 Beacon Street, Boston, MA 02108, may be consulted for the definition of terms not otherwise defined in this document.