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AEROSPACE METEOROLOGY: SOME LESSONS LEARNED

William W. Vaughan
University of Alabama in Huntsville

And

Dale C. Johnson
NASA-Marshal Space Flight Center (Retired)

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ABSTRACT

Aerospace Meteorology plays an important role in the design and operation of aerospace vehicles and in the associated integrity of aerospace systems and elements. This paper addresses some of the key Aerospace Meteorology issues and “lessons learned” that have been identified over a number of years and documented. Many of these issues and lessons occurred during the involvement of the authors with the development and interpretation of aerospace environment inputs, especially those of the terrestrial environment, for design and development requirements, and associated mission operations. Background for the actions needed to avoid the issue being repeated or the lesson having to be re-learned for both launch vehicle and spacecraft design and development are discussed. Some examples of the definition of the terrestrial environment for use in aerospace vehicle development are also presented.

INTRODUCTION

The natural environment is a significant input in the design and operation of aerospace vehicles and in the integrity of aerospace systems and elements. This paper is based on and reflects the contents of the recent revision by the authors and their colleagues of the report “Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development” published in December 2008 as NASA/TM-2008-215633. The terrestrial environment design criteria guidelines given in the report are based on statistics and models of atmospheric and climatic phenomena relative to various aerospace design, development, and operational issues. This revision contains new and updated material in all sections. Aerospace vehicle terrestrial environment design 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. Also included is information on mission analysis, prelaunch monitoring, flight evaluation, physical constants, and metric/English unit conversion factors. This unique 850 pp report may readily be accessed via URL:

http://trs.nis.nasa.gov/archive/00000802/.

The natural environment criteria guidelines presented in this report were formulated based on discussions with, and requests from, engineers involved in aerospace vehicle development and operations. Therefore, they represent responses regarding the terrestrial environment 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 associated with aerospace vehicle development have used this document extensively as a source document for guidelines relative to the development of terrestrial environment design requirements and criteria. The first version of the report was published in 1962 and has subsequently been updated periodically since that time by the NASA Marshall Space Flight Center.

Another important document related to the scope of this paper is the “Guide to Reference and Standard Atmosphere Models published as AIAA-G-003C-2009. The document contains the descriptions of over 75 Earth and planetary reference and standard atmosphere models developed by national and international organizations. It provides information on the scope, data bases, uncertainties, sources for codes, and applicable references. It was prepared based on the contributions of numerous authors. The objective of the Guide is to enable the reader to more readily ascertain the applicability of a model for their intended use. It may be accessed via http://www.aia.org

A companion paper to this one was prepared by the authors for presentation at the 48th AIAA Aerospace Sciences Meeting, January 2010, Orlando, FL.

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 provides a number of documents that address this subject. A companion paper to this one was prepared by the authors for presentation at the 48th AIAA Aerospace Sciences Meeting, January 2010, in Orlando, FL. Using the desired operational capabilities, launch locations, and flight profiles for the vehicle, specific definitions of the terrestrial environment can be provided which, if the aerospace vehicle is designed to accommodate, 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 and development of the vehicle and, accordingly, their interpretation relative to applications.

An aerospace vehicle’s response to terrestrial environment design 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 terrestrial environmental capability for launch and flight operations.

One must remember that the flight profile of all aerospace vehicles includes the terrestrial environment. 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 significant aerospace vehicle design and development inputs. This definition plays key roles; e.g., 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.

The close association between the design and test engineering groups and those responsible (central control point) for the terrestrial environment inputs is important 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 1 illustrates the necessary interactions relative to terrestrial environment definition and engineering application. Feedback is critical to the vehicle development process relative to terrestrial environment requirements and their interpretation, thus the ability to produce a viable vehicle design and operational capability.

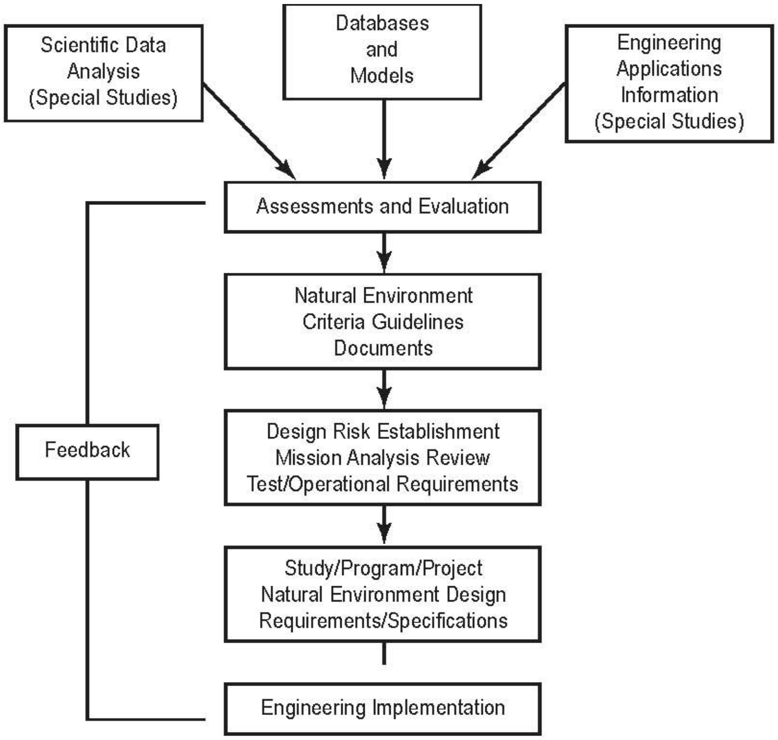

Figure 1-2. Natural terrestrial environment definition and analysis for aerospace vehicle engineering application.

SOME TERRESTRIAL ENVIRONMENT ISSUES

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 the development of design requirements 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; e.g., 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. The terrestrial environment guidelines report noted in this paper provides information relative to those severe weather characteristics that should be included in vehicle and associated facilities design requirements and specifications if required to meet the program’s mission operational requirements.

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 a vehicle 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 so necessary actions can be taken accordingly. 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.

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 the design requirements for 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.

Table 1. Key terrestrial environment parameters needed versus engineering systems (X) and mission phase (P).

X	Terrestrial Environment Parameter											P
Launch Vehicle Systems (sub-)	**Winds and Gusts**	**Atmospheric Thermodynamics**	**Atmospheric Constituents**	**Solar/ Thermal Radiation**	**Atmospheric Electricity**	**Clouds and Fog**	**Humidity**	**Precipitation or Hail**	**Sea State**	**Severe Weather**	**Geologic Hazards**	**Mission Phase**
System	X P	X P	X P	X P	X P	X P	X P	X P	X P	X P	X	Mission analysis
Propulsion/ engine sizing	X	X P	P		X		X P			X		Manufacturing
Structures/ airframe	X P	X P		X	X P		P	X P	X	X P	P	Testing
Performance/ trajectory/G&N	X P	X P	P	P	X P	P	P	P	P	P	P	Transport and ground hdl
Aerodynamics	X P	X P	P	P	P		P	P	P	P		Rollout/ On-pad
Thermal loads/ aerodynamics heat	X P	X P	P	X P	P	P	P	P	P	P		Prelaunch DOL count down
Control	X P	X P	P	P	X P	P	P	P		X P		Lift-off/ ascent
Loads	X P	X P			P	P		P	X P	X P		Stages recovery
Avionics	P	P	X	X	X P	P	X	P		X P		Flight
Materials	X	X P	X P	X P	X		X	X	X	X		Orbital
Electrical power	P	P	X		X P	X		X P		P		Desent
Optics	P	X P	P	X	P	X P	P	X P	P	P		Landing
Thermal control	P	X P	X P	X P	P		P	X P	P	P		Post-land
Telemetry, tracking, and communication	P	X P	X P	P	X P	X P	P	X P	P	X P	P	Ferry/ transport
	P				P		P	P		P	P	Facil/spt Equip
	P	P	P		P		P	P			P	Refurbishment
Mission operations	X P	X P	X P	X P	X P	X	X P	X P	X	X P	X P	Storage

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SOME EXAMPLES OF TERRESTRIAL ENVIRONMENT AREAS OF INTEREST RELATIVE TO AEROSPACE VEHICLE DESIGN AND DEVELOPMENT

Within this Section is presented selected natural terrestrial environment examples taken from the Terrestrial Environment (Climatic) Criteria Guidelines For Use In Aerospace Vehicle Development, 2008 Revision, NASA/TM-2008-215633 which is subsequently noted as **"TM"** in text of this Section. These examples are intended to illustrate how to make an engineering application for many of the natural environment parameters, models, etc.

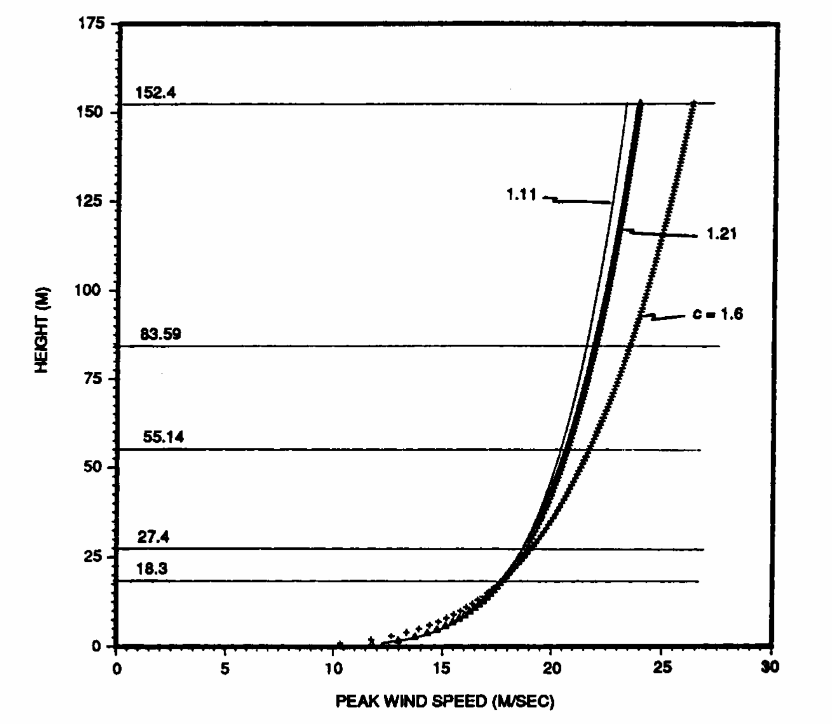
1. Wind Example: Design Peak Wind Profile Example - For Ground Winds

Using a Power Law relationship, as presented in **TM** Section 2.2.5.2, one can determine the Peak Wind Speed Profile at any level between 0 and 150 m altitude, by just knowing the Peak wind at the 18.3 m (60 ft) reference height (for KSC Florida):

$U(h) = U_{18.3} (h/18.3)^K$ (**TM** Equation 2.1)

Where: $K = C(U_{18.3})^{-0.75}$
(and U is in m/s, and h in m.)

For a KSC Tower Clearance design analysis for a space vehicle launch problem example, for the windiest 1-hr exposure period, and assuming a 5% risk, Tabular values of C uses a C = 1.60. Therefore, given a known peak wind speed of 17.7 m/s at the 18.3 m level, the peak wind speed is calculated from the non-**TM** constructed Figure A to be 26.2 m/s at 152.4 m (500 ft).



Non-**TM** Figure A: Ground-level Peak Wind Speed versus Height based on a Power Law Relationship.

2. Tornado Probability Example: Tornado Probability Calculation

Based on the SAT 3.0 Tornado data base and program (see **TM** Section 12), one can estimate the probability of one or more tornadoes at KSC in N years in an area A_1 by applying Equation 12-6 of the **TM** on page 12-14). **TM** Equation 12-6 can be used rather than the general **TM** Equation 12-5, for $A_1 << A_2$ and $N < 100$.

$P(A_1;N) = ([xbar] [A_1] [N])/A_2)$ (**TM** Equation12-6)

Where; xbar is the mean number of tornadoes per year within the circular region (equivalent to a 1^o square). A_1 represents a representative area equivalent to most industrial complexes. Area A_2 represents the area equivalent to a 1^o square.

Therefore:
using A_1=7.3 km^2 (or 2.8 mi^2)
A_2=10,839 km^2 (or 4,185 mi^2)
N=100 years
xbar=2.38 tornadoes per year in circular region

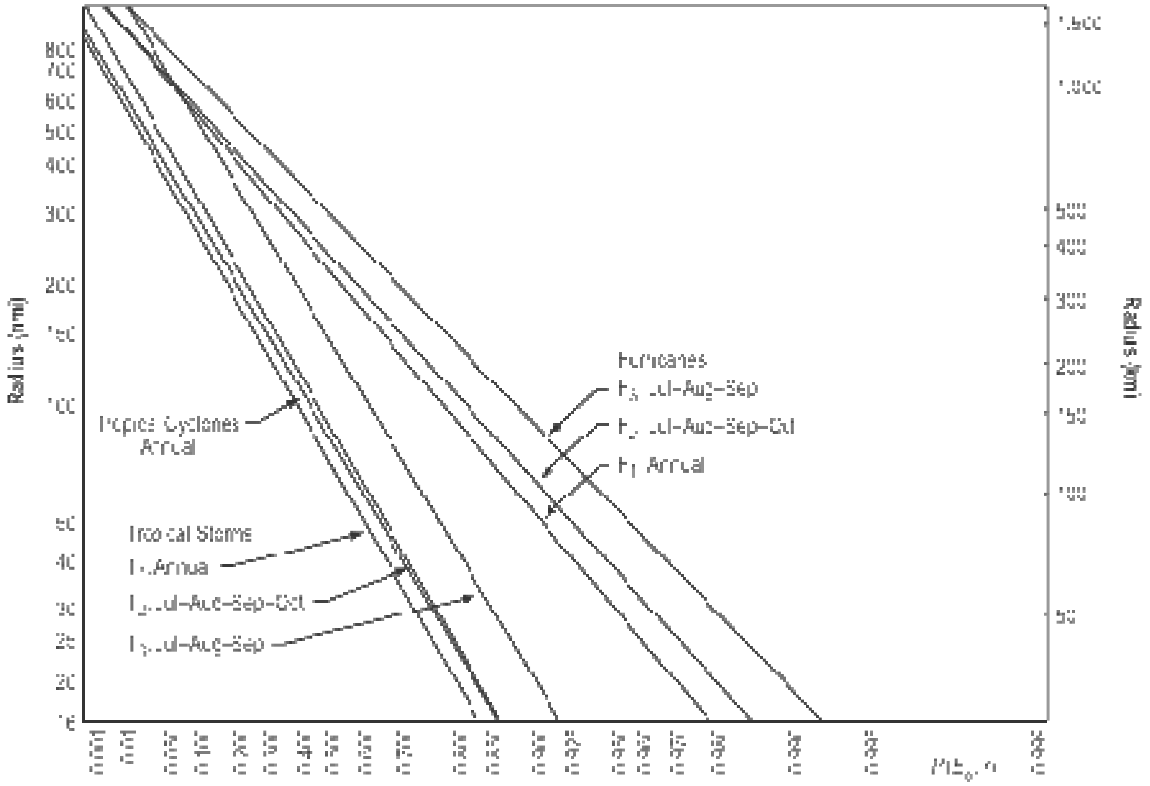
The resulting probability is ~16.0% for KSC.
With A_1=2.59 km^2 (or 1 mi^2), the resulting probability, for this smaller KSC area, is ~5.7%. These numbers don't quite match the **TM** Table 12-7 values for KSC (of 14.8% and 5.5%, respectively), as TM Table 12-7 values were computed from the more exact **TM** Equation 12-5. Also, the number of years (N) was not << 100, but in fact equal to 100.

4. Hurricane Probability Example: Distribution of Kennedy Space Center Hurricane and Tropical Storm Frequencies

In **TM** Section 12.6.9.5 the distribution of Kennedy Space Center hurricane and tropical storm frequencies is presented. Knowing the mean number of tropical storms or hurricanes (events) per year that come within a given radius of KSC, without knowing other information is of little use. Assuming the distribution of the number of tropical storms or hurricanes to be a Poisson-type distribution, the mean number of events per year (or any reference period) can be used to completely define the Poisson distribution function as demonstrated below.

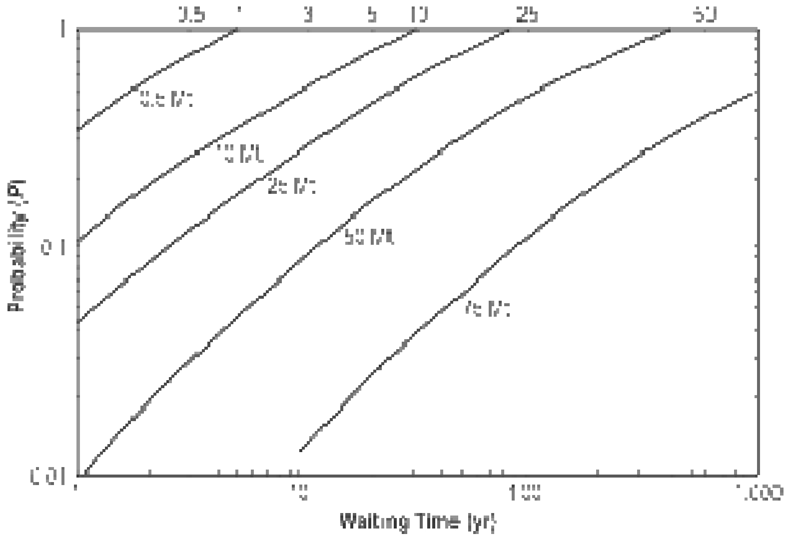
From **TM** Figure 12-38, the probability of no event, $P(E0,r)$, where r = radius, for the following example can be read:

(1) Tropical storms and hurricanes for annual reference periods, (2) tropical storms and hurricanes for July–August–September; and (3) tropical storms and hurricanes for July–August–September–October, versus radius (in kilometers) from KSC. To obtain the probability for one or more events, $P(E1,r)$ from **TM** Figure 12-38 the reader is required to subtract the $P(E0,r)$, read from the abscissa, from unity; i.e., $[1 - P(E0,r)] = P(E1,r)$. For example, the probability that no hurricane path (eye) will come within 556 km (300 n mi) of KSC in a year is 0.33 $[P(E0,r = 300) = 0.33]$, and the probability that there will be one or more hurricanes within 556 km (300 nmi) of KSC in a year is 0.67 (i.e., 1–0.33 = 0.67).



TM Figure 12-38. Probability of number of tropical storms or hurricanes for various reference periods versus various radii from KSC.

5. Volcanic Eruption Example: Probability an Eruption will inject Matter into the Stratosphere

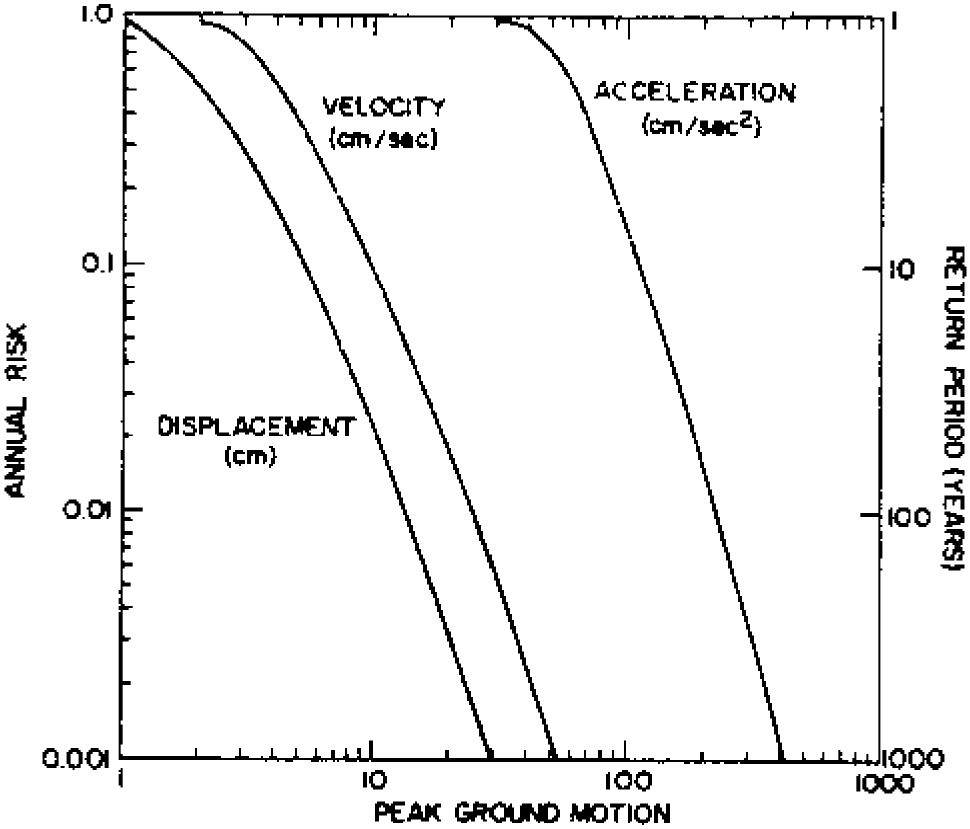


TM Figure 13-24. The probability (*P*) that a volcanic eruption will inject (add) a given quantity of matter (in metric tons (Mt) into the stratosphere (**TM** Ref. 13-70).

The estimate of a volcanic eruption injecting an amount of matter (in metric tons [Mt]) into the stratosphere within a given number of years, for a probability of 0.1 (or 10%), can be obtained from interpolation of **TM** Figure 13-24, resulting in: 25 MT in ~2.3 years, 50 MT in ~11 years, and 75 MT in ~90 years, with a probability of 0.1 (or 10%).

6. VAFB Earthquake Example: Maximum Ground Motion Attenuation

VAFB is situated in one of the more seismically active regions of the United States and is characterized by a number of fault systems capable of generating major earthquakes. VAFB is located between two physiographic regions—the Transverse Ranges Province at the south and the Coastal Ranges in the north. Maximum ground motion attenuation—acceleration, velocity, and displacement—levels for VAFB can be calculated at the Point Arguello site (SLC6) at the 90 percent confidence level and are shown in **TM** Figure 13-30, as a function of 'annual risk' or 'return period'.



TM Figure 13-30. Annual seismic risk curves for peak ground motions at VAFB (SLC6)—given at the 90-percent confidence level and based on Battis' statistical method (TM Ref. 13-86).

For an annual risk of 0.1 (or a 10 year return period) the maximum ground motion attenuation for displacement, velocity and acceleration are: ~5.4cm, ~9.8cm/sec and ~115 cm/sec^2, respectively.

7. Sea State Example: KSC Sea State Duration Table Example

TM Table 14-11 presents KSC wind speed durations by mid-season months. Wind speed intervals for KSC are given in **TM** Table 14-12. Tables 14-13 and 14-14 of **TM** present the KSC wave height duration and interval statistics, respectively. When answering questions using the duration and interval tables, it is important to distinguish between questions that require the use of the number of episodes and those that require the number of hindcasts. Hindcasting involves analyzing past, measured site data in order to arrive at a data climatology for that site. Answers for questions regarding the percentage of time at or above, or below, certain thresholds require the use of the number of hindcasts. On the other hand, questions concerned with the percentage of episodes at or above, or below, certain thresholds demand the use of episode frequencies, where a 1-day episode or a 60-day episode will each count as one episode. The following example illustrates an application of the duration **TM** Table 14-11:

≥64																				2439
≥48	1															6-1	1	1		2439
≥41			2													18-2	2	3		2439
≥34	1		2													18-2	3	7		2439
≥28	6	2	1	3			1									42-1	13	32		2439
≥22	34	21	8	2		2	1	2	1				1			78-1	72	165		2439
≥17	62	30	23	23	11	8	6	3	3	1	1		1			1	96-1	173	529		2439
≥11	28	19	23	23	18	15	14	13	12	9	3	9	2			14	198-1	202	1293	1301	2463
≥7	22	21	14	18	20	5	13	8	13	10	5	3	7	8	3	34	306-1	204	1949	2005	2602
≥4	19	5	2	7	12	2	7	7	2	6	6	3	2	4	8	49	408-1	148	2272	2390	2666
	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96+	MAX	TE	T	Tx	TH

WS (kt) 42 221-1

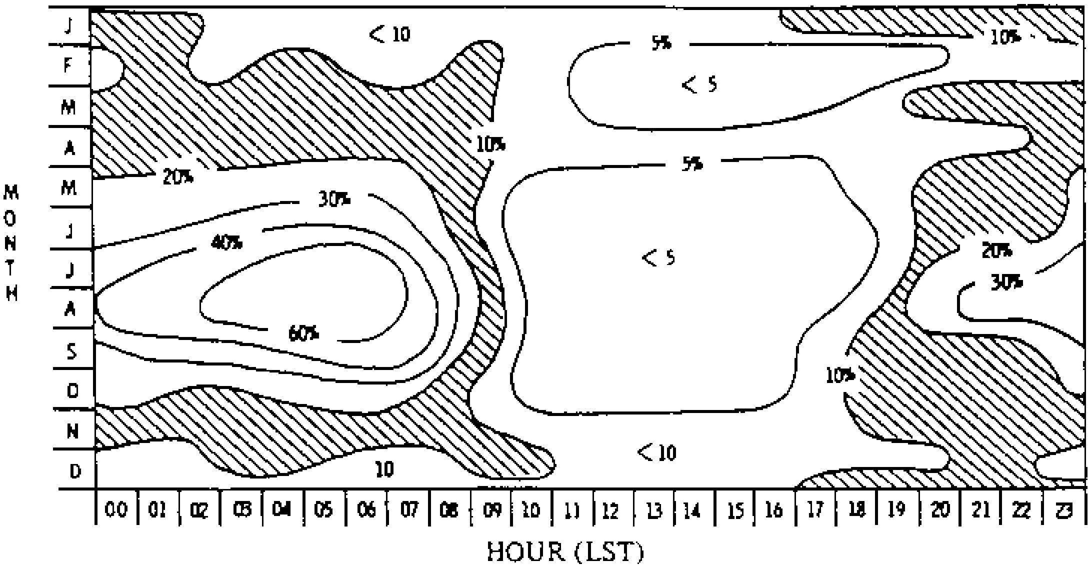
Duration of Events (hr)

TM Table 14-11. January KSC Wind Speed Durations, at Atlantic grid point 42: 30.4^{o}N., 77.9^{o}W.

- Question: Of all the events with wind speeds (*Ws*) ≥ 22 kt at grid point 42 in January (**TM** Table 14-11), what percentage had durations of longer than 1 day?
    - Answer: Consult **TM** Table 14-11. The number of events or episodes of *Ws* ≥ 22 kt (from TE column) is 72. The number of events of wind speeds ≥22 kt lasting more than 1 day is 2 + 1 + 2 + 1 + 1 = 7. The percentage of events of wind speed ≥22 kt lasting more than 1 day is then 7 ÷ 72 × 100 = 9.7 percent.

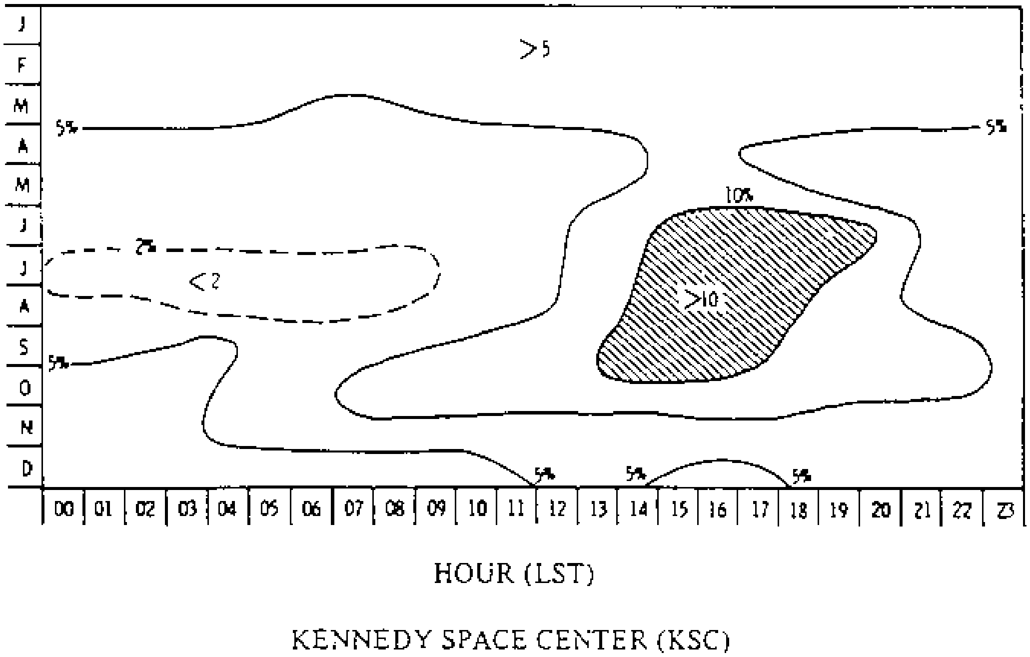
8. Precipitation/Fog Example

Precipitation or Fog occurrence at VAFB and KSC, from **TM** Section 7's Figures 7.24 and 7.25 (respectively), shows the percentage frequency of precipitation or fog with visibility □0.8 km (0.5 mi) at Vandenberg AFB and Kennedy Space Center. They were developed from historical records of hourly observations. Certain Vandenberg and Kennedy Space Center climatic characteristics that may be of significance to aerospace mission planning and operations are immediately apparent. That is, potentially unfavorable climatic conditions occur mainly during summer night and early morning hours at Vandenberg AFB but during summer afternoons at Kennedy Space Center. This, of course, is due to the high frequency of morning fog at Vandenberg AFB and summer afternoon showers in central Florida.



VANDENBERG AFB

TM Figure 7-24. Probability of Precipitation or Fog with visibility <0.8 km (<0.5 mi) at VAFB.



TM Figure 7-25. Probability of Precipitation or Fog with visibility <0.8 km (<0.5 mi) at KSC

8. Mission Analysis Example: Applying APRA at KSC

TM Section 15 presents the NASA Marshall Applied Parametric Risk Analysis Model (APRA) as a computer program which gives the simple statistical probability of -go or no-go based on counts greater than a threshold value for a selected atmospheric parameter. A long-term empirical data base is required as input to the APRA. The following list of 7 atmospheric and/or wind constraints are chosen as a mission analysis example, as input using the APRA model:

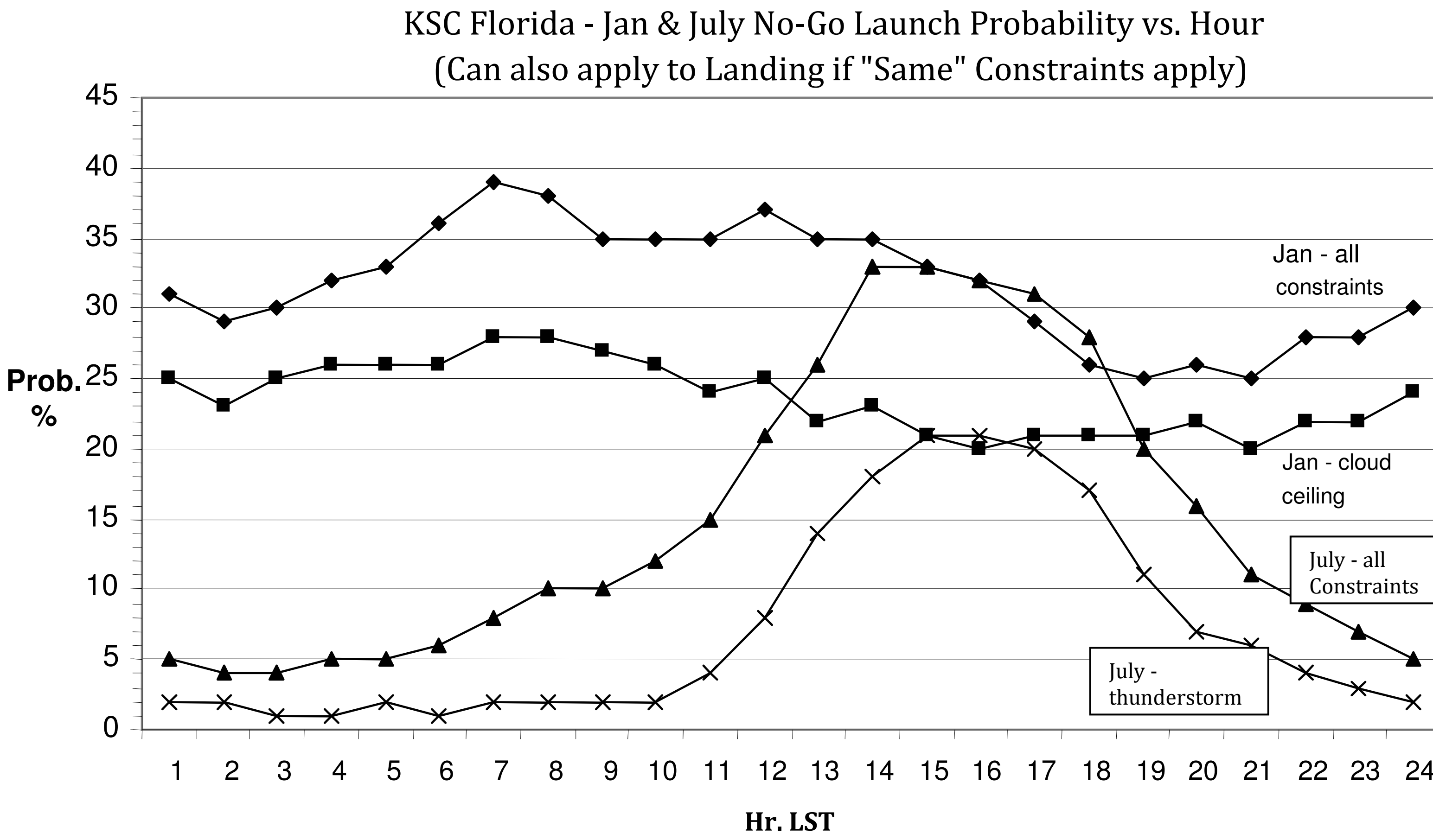
APRA Constraints Used:
1. Thunderstorms
2. Precipitation
3. Visibility, 5 nmi
4. Cloud Ceiling <8 K ft

Peak Winds:
5. Head >25 kt
   (SS=19 kt)
6. Tail >10 kt
   (SS=6 kt)
7. Cross >15 kt
   (SS=9 kt)

The resulting probabilities of no-go versus hour for January and July at KSC are given in **TM** Figure 15-1. The resulting KSC July probabilities peak out with ~33% (no-go) at ~14:00 hours LST. From **TM** Figure 15-1 one can see that summertime atmospheric thunderstorms are the major contributor to the probability (with a peak of ~21% at ~15:00 LST). Likewise, the KSC

January cloud ceiling constraint is the main contributor to the resulting all-constraints timeline. These types of mission analyses, utilizing the (APRS), can therefore be used in many mission planning scenarios in considering many atmospheric go or no-go studies for a selected site.

TM Figure 15-1. Mission Analysis: Applied Parametric Risk Analysis Model (APRA) – KSC Launch Example



Non-**TM** Figure Y. Mission Analysis: Applied Parametric Risk Analysis Model (APRA) – KSC (Examp

SOME TERRESTRIAL ENVIRONMENT RELATED LESSONS LEARNED

The NASA Marshall Space Flight Center’s Natural Environments Branch and its predecessor organizations have over 50 yr of experience in the development and interpretation of terrestrial environment requirements for use in the design and operation of aerospace vehicles. During this period, in addition to issues identified with the terrestrial environment inputs, a large number of “lessons learned” have formed the basis for the definition and interpretation of terrestrial environment design criteria. A few of these lessons learned are summarized in the following list:

(1) Title: Wind Vectors Versus Engineering Vector Conventions

- Background. Flight mechanics use of wind vectors versus conventional meteorological usage. In the case of flight mechanics, the vector is stated relative to direction that force is being applied. However, in meteorology, the wind vector is stated relative to direction from which wind force is coming.

- Lesson. The proper interpretation and application of wind vectors is important to avoid a 180º error in structural loads and control system response calculations.

(2) Title: Design Requirements, Not Climatology

- Background. While based on climatology and models, both physical and statistical, natural environment requirements are part of the overall vehicle design effort necessary to ensure that mission operational requirements are met. Thus, they must be selected and defined on this basis. Simply making reference to climatological on databases will not produce the desired vehicle performance.
- Lesson. Members of the natural environments group assigned as the control point for inputs to a program must also be part of the vehicle design team and participate in all reviews, etc. to ensure proper interpretation and application of natural environment definitions/requirements relative to overall vehicle design needs.

(3) Title: Early Input of Natural Environment Requirements Based on Interpretation of Mission Purpose and Operational Expectations

- Background. One needs to develop the natural environment definitions and requirements for a program as soon as possible after one has the level one requirements for the program's mission. Thus, all concerned with the development will have a common base with associated control on changes made to natural environment definitions/requirements and associated vehicle operational impacts.
- Lesson. The definition of the natural environment requirements for a vehicle that are necessary to meet the mission requirements is important for all concerned with the program. This provides visibility to all, especially the program manager and systems engineers, relative to the impact on the operation of the vehicle and to natural environment design requirements on the program's mission.

(4) Title: Natural Environment Elements That Cannot be Monitored Prior to Operational Decision Must be Minimum Risk Level Possible Consistent With Mission Capability Requirements

- Background. For an aerospace vehicle launch, most natural environment elements can be monitored and thus taken into account before making a launch decision. The same is true for some on-orbit and deep-space spacecraft operational requirements. In such cases, lower probability occurrence environments may be considered, consistent with mission requirements, along with subsequent savings on design. Vehicle ascent winds through max Q versus reentry winds is an example of lower probability (higher risk of occurrence) versus higher probability (lower risk of occurrence) natural environment design requirements for a vehicle. However, for minimum risk of occurrence, natural environment requirements must be used for design to ensure operational capability when natural environments cannot be measured or monitored.

- Lesson. It is necessary to carefully analyze the mission requirements relative to vehicle operations and provide the natural environment definitions and requirements accordingly in collaboration with the vehicle program manager to ensure understanding of the implications of environments provided for design.

(5) Title: Maintain Natural Environment Requirements for Design as a Separate Document but Integral to Overall Mission Requirements for Vehicle

- Background. The natural environment definitions and requirements for the Space Shuttle and Space Station were provided so they could be controlled and available in separate program documents as part of the overall design requirements documentation. This not only provided direct access for all concerned with use of natural environment inputs into design and mission planning but also provided an easy control of inputs. Changes, where required, were readily possible with the change of one document that had application for all natural environment inputs to the program.
- Lesson. Each vehicle development program should have only one natural environment definition and requirements document. It should be an integral part of the overall mission requirements for the vehicle design, development, and operations, and be controlled accordingly.

(6) Title: Atmospheric and Space Parameter Analysis Model

- Background. The ability for a program manager to easily access information on the operational impact of a vehicle design change relative to the natural environment is an important tool for decision making. In addition, such a tool provides additional insight into mission planning activities, including launch and landing delay probabilities.
- Lesson. Knowledge by mission managers, chief engineers, mission planners, etc. on the availability of an Atmospheric and Space Parameter Analysis Model is a valuable decision-making tool and should be utilized in making the tradeoff decision when the desired operational natural environment is a factor.

(7) Title: Reference Period for Design Statements of Natural Environment Definitions and Requirements Relative to Launch and On-Orbit Operations

- Background. For launch statements on natural environment definitions and requirements, the worst reference month should be used. This provides an operational capability relative to the natural environment that ensures that for any given month, the desired operational capability will be met. Thus, for the worst month reference period, the minimum risk of launch delay due to the natural environment will occur with all other month shaving less probabilities of launch delay. The same situation exists for natural environments associated with on-orbit operational capability, and deep-space operations. In other words, for these cases, the anticipated lifetime in these operational conditions must be taken into account along with the acceptable risk for comprising the mission relative to natural environment conditions exceeding the design requirements.

- Lesson. All launch terrestrial environment definitions and requirements for the design of a vehicle must be made with respect to a worst month reference period. For natural environments associated with on-orbit and deep-space operations, the anticipated lifetime in these operational conditions must be taken into account along with acceptable risks for operations.

SUMMARY REMARK

Aerospace Meteorology plays an important role in the design and operation of aerospace vehicles and in the associated integrity of aerospace systems and elements.

A historical note regarding the origin and development of the term “aerospace meteorology”. Based on a preliminary search of some past Bulletins of the American Meteorological Society, in March 1964 the Bulletin made reference to a proposed statement on meteorology and aerospace vehicles prepared by the AMS Committee on Atmospheric Problems of Aerospace Vehicles and the AIAA Atmospheric Environment Technical Committee. The statement was published in the June 1964 BAMS issue. In March 2-6, 1964 the AMS’s “Fifth Conference on Applied Meteorology: Atmospheric Problems of Aerospace Vehicles” was held in Atlantic City, NJ. Prior to this time Conferences on Applied Meteorology included wordage associated with upper atmosphere and satellite exploration, meteorological rocketry, support of aerospace testing and operations, and atmospheric problems of aerospace vehicles. It seems the first conference to use the words aerospace meteorology was entitled “Sixth National Conference on Applied Meteorology (Aerospace Meteorology) Co-sponsored with the AIAA Atmospheric Environment Technical Committee and held March 28-31, 1966 in Los Angles, CA. The Bulletin also contains an announcement about the “Seventh Conference on Aviation, Range, and Aerospace Meteorology” held February 2-7, 1997 in Long Beach, CA. It evidently took the conference number from the numbering of the Aviation Weather System conferences. The Aviation, Range, and Aerospace Meteorology (ARAM) Technical Committee, often in collaboration with the AIAA Atmospheric Environment Technical Committee, subsequently co-sponsored many of the AMS’s Aviation, Range, and Aerospace Meteorology Conferences.

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