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ABSTRACT

The objectives of this report are twofold: 1) to describe the work that has been accomplished during the past two years in an ongoing effort to develop a human standards data base and data handling system for manned space flight programs; and 2) since this represents an extensive undertaking which is far from being completed, to describe an approach by which it is believed that standards can be more fully developed and utilized. This begins by describing limitations of currently available standards and indicates why it is important to develop a more comprehensive set of standards. Definitions of what is meant by human standards are then presented. With this as background, a hypothetical example is given to illustrate how the standards could be used, assuming they existed in the form described in this report. And finally, since there are still many problems to be resolved in the development and maintenance of such a data base and data handling system, recommendations are provided which indicate how the author believes these should be resolved.

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Preface

The objectives of issuing this report at this time are to stimulate the thinking of interested groups within NASA and its contractors so that whatever direction the development of human standards takes in the future, it may have the benefit of as much thought and discussion beforehand as possible. The contents of this report represent the thinking of Bellcomm personnel and does not necessarily reflect the views of NASA or the members of the Working Group. The author alone assumes full responsibility for the contents of this report.

Special acknowledgement should be given to Mr. Thomas A. Bottomley of Bellcomm for his critical review of, and helpful suggestions for, this report.

Many thanks are due Dr. Fred Benjamin, and Mr. Herbert Brownstein, of Space Medicine, and Col. Grady Wise of AFSC, for the many stimulating ideas and often spirited discussions, that have led to the crystallization of the author's thinking which is presented in this report. Also, Dr. Ross McFarland and Dr. Warren Tiechner, of Harvard University, have contributed many useful ideas about how human data should be reduced to a form that is directly useful as design standards. And, no less important are the ideas of Cmdr. George Hoover, Dr. Emmanuel Roth, and Dr. Al Schwichtenberg, of the Lovelace Foundation. Special thanks go to Cmdr. Hoover for his many stimulating ideas on how to analyze systems in a thoroughly systematic manner, for by using the "matrix" approach which he has done much to develop, he has provided many of the ideas for indexing and retrieval of standards contained in the approach described in this report. And, finally, thanks are due to Keith Carpenter of Bellcomm for looking over our shoulder and making sure that none of the concepts we have advanced here are incompatible with the world of computers.

Miss Alice Brumfield is responsible for the excellent job of transforming the illegible draft of the author into the finished product that is seen here.

January 1967

Summary and Recommendations

This report summarizes: 1) the work that has been accomplished during the past two years in an ongoing effort to develop a human standards data base and data handling system for use in manned space flight programs; and 2) to suggest an approach by which it is believed that the effort could be brought to successful fruition.

This effort was originally undertaken by Bellcomm in response to the need for human standards to be included or referenced in Apollo Program specifications. Since no suitable sources were available, the initial work consisted of systematically collecting and presenting under one cover the standards which are being used in the program but which exist in literally hundreds of Apollo specifications, research studies related to the program, and other less accessible sources. This document, entitled Human Standards for Apollo is in the second stage of iteration at the present time and still requires much additional data and refinement before a satisfactory reference document for human standards may be said to exist. Although the original intent in the preparation of this document was to provide a useful reference source for the remaining phases of the Apollo program, the advanced stages of the program make it unlikely that it will serve this purpose. Instead, it is being used as a test bed for organizing and evaluating the standards data which are available to the manned space flight program as a whole. Preliminary analysis of the data which has been collected suggests that there are many limitations in the available standards, and although much of this can be attributed to the lack of suitable research and flight experience with which to generate standards, much of it is also due to a lack of any systematic attempts to reduce the data which is available to a form useful for design and operational planning purposes.

Because of the problems in the availability and adequacy of existing standards data and the importance of having such a data base available for future manned space flight programs, a Human Standards Working Group has been organized by Space Medicine (MM) of the Office of Manned Space Flight, NASA. Members of this group include personnel from MM, MSC, Lovelace Foundation, Harvard University, and Bellcomm. The immediate objectives of this group are to develop the best standards possible in some of the more critical areas using all of the research and manned flight data available. These areas have to do primarily with the specification of acceptable physiological and performance tolerances to the various physical environmental hazards of space flight. Many other areas are important too, as the text of this report indicates, but the magnitude of this standards effort requires that available resources be used as expeditiously as possible.

The objectives of this report are to describe an approach which, if followed, should result in a workable human standards data base and data handling system. This approach is described by assuming that the standards data base is in existence and indicating how it would be used. Basically, this is as follows:

1. The human involvement in a particular manned space flight mission and system is determined in terms of: (a) the environmental conditions and their parameters to which man could conceivably be exposed, (b) the types of performances or duties and tasks the crew would be expected to perform, and (c) the hardware (such as controls and displays) or other crew equipment (such as spacesuits, etc.) with which the crew interacts or is dependent upon during the flight. (Detailed classifications of these three sets of items will be found in Appendices A, B, and C, respectively, of this report.)

2. The human involvement is then related, by means of a set of matrices, to the anthropometric, physiological, and performance categories and parameters (i.e., the human standards categories) to determine: (a) what should be considered about man during the design, and (b) to locate the relevant data within the standards data base. (Table 4 in the text illustrates these matrices.)

3. The relevant section(s) of the standards is then consulted to determine: a) what the standards are, and b) the assumptions and constraints pertinent to the interpretation and application of the data. Some brief examples are provided to indicate how the content of the human standards is organized and presented. (These examples are illustrated in Figures 3 through 9 and Table 7 in the text.)

4. Since the human data may not always be in a form that is directly usable by design personnel, an additional set of matrices is provided which indicates how the human data can be translated into design criteria; for example, the use of human visual acuity standards as criteria for the design of displays. (Table 6 indicates how one might go from the human standards data to the design, or more generally, the "applications standards" since crew operations, selection and training, and crew composition criteria are involved in addition to the hardware or design criteria. Detailed lists of the categories within the human standards and the applications standards are included in Appendices D and E respectively).

5. Finally, since the type of data base and data handling system which is described by means of this hypothetical example exists in only bits and pieces at the present time, a series of recommendations are provided which indicate how the author believes that this effort could be successfully completed using an incremental approach and fully utilizing the existing data and facilities within NASA and DOD as building blocks.

Because these recommendations are crucial to the success of any future work devoted to this subject, they are summarized here (page references are provided for each recommendation so that reader may locate detailed materials within the text pertinent to each of the recommendations):

1. Coverage of the Standards

   a. Attention should be given first to the development of human standards dealing directly with the use, protection, and support of flight crew personnel since this is an area in which the greatest need for standards exists at the present time (pp. 56-58, 8-18, Appendix D).

   b. Once these human standards have been developed, they should be translated into a form (i.e., the applications standards) that is directly related to the design and operation of systems and equipment on which the flight crew are dependent (e.g., environmental control systems, controls and displays, etc.) (pp. 57-58, 49-54, Appendix E).

   c. As the usefulness of the standards for design purposes is demonstrated they should be further expanded to include the design and operation of other man-machine systems and facilities within NASA (e.g., control centers, booster vehicles and their associated checkout and handling equipment, launch facilities, etc.). Other work related to these areas is noted in the text and recommendations are made (see Item 5 below) for integrating these efforts within an overall framework such as the one described in this report (pp. 57-58, 2-4).

2. Formatting and Indexing the Standards

Since the concepts described in this report represent only the beginnings of a workable data storage and retrieval system, the following recommendations are offered in this regard:

a. Terms (i.e., descriptors) for identifying and describing human involvement (e.g., environmental conditions, crew performances, and equipment and facilities with which the crew interfaces or interacts) in manned space flight systems and missions must be further developed and refined so that designers and operational personnel (i.e., the users of the standards) may systematically and thoroughly determine what must be considered about man for the design of a particular system performing a specific mission (pp. 58-59, 27-33, Appendices A-C).

b. In addition to the terms for classifying human involvement, means must be developed for identifying and manipulating the many interactions between human, equipment and environmental variables that are involved in the design and operation of these systems. The matrices provided in this report are only a beginning in this direction (p. 59, Paragraph 4, 27-33, Appendices A-C).

c. The standards must be presented in a form (quantitative, wherever possible and relevant) which is directly related to design and operational needs. For example, as already noted, the data about the visual capabilities of man are necessary to consider, but they are not very useful until they are translated into criteria for the design of displays, cabin windows, etc. Similarly, the oxygen requirements of man are also critical, but these must be translated into environmental control system design criteria before they are useful to the designer (p. 59, Paragraph 3, 49-52, Appendix E).

3. Processing of the Standards

a. Since standards data by themselves are useless unless means are provided for getting up-to-date data into the data base on the one hand, and getting them into the hands of the user on the other, equal attention should be given to the development of a data handling system and the data base. The text of the report describes the basic requirements for such a system (pp. 60-61).

b. Computerization of the standards represents one approach to the handling of the standards; however, there are many considerations involved in deciding to follow this approach. Several detailed recommendations are offered in the text with respect to deciding when and how much of the standards data base might be computerized, including both technical and managerial considerations (pp. 62-64).

4. Incremental Development of the Standards

a. Because of the magnitude of the effort involved to develop a truly comprehensive source of standards (and to keep it updated), it is recommended that an incremental approach be followed. Areas which are of greatest concern should be developed first, both to make them available for designers and to assess the feasibility of the approach that is used to develop and document them (pp. 60-62).

5. Coordination of the Human Standards with Other Data and Data Handling Requirements in NASA and DOD

a. Since the human standards data base and data handling system described in this report represents only a portion of the total data and data handling requirements involved in any complex design program, it is recommended that other facilities within NASA be examined for possibilities of combining developmental efforts and utilization (pp. 64, 2-3).

b. Also, as noted in the early part of the report, since there are other projects within NASA and DOD which are attempting to accomplish at least portions of the effort described here, careful consideration should be given to the utilization of these resources. Using all of the resources available in a cooperative fashion would be expected to more nearly accomplish the job than if piecemeal approaches are followed (pp. 64, 2-3).

6. Management of the Standards Development and Updating

a. It is recommended that the initial development of the standards data base described in this report be handled by Headquarters NASA, supported by the Centers and contractors as appropriate (pp. 64-65).

b. Once the standards data base and handling system have become operational, then major responsibilities for updating and refinement of various portions of it should be delegated to the Centers having the greatest interest in specific portions of the data base (pp. 64-65).

c. Headquarters NASA should continue to exercise a coordinating role and insure that communication is maintained between generators and users of the data. If the effectiveness and efficiency of such a system as the one described in this report is to be achieved and maintained, it should be developed on a sound foundation in the first place, and must be kept in good working order once it becomes operational (pp. 64-65).

AN APPROACH TO THE DEVELOPMENT OF HUMAN STANDARDS FOR MANNED SPACE FLIGHT

Background

Availability of Human Standards for the Manned Space Flight Programs

Since the first manned space flight in the United States five years ago, the programs have progressed to the point where the Mercury and Gemini flights have been successfully completed and the Apollo manned flights are imminent. Further, the Apollo Applications Systems are in advanced design phases and manned space flight to the nearby planets are now in the conceptual stages. Since we are about to begin flying our third generation of manned vehicles, and considerable man-related data has been collected from the Mercury and Gemini Programs, this is an appropriate time to begin the development of a human factors data base and data handling system for application to the future systems. Additional delay is not justified for the following reasons:

(a) future generations of manned spaceflight systems require this information now in order to have a significant impact on their design,

(b) there is no easily accessible, comprehensive source of human standards data available now,

(c) as systems evolve through succeeding generations, it becomes possible to standardize many things in the system, hence introducing economies into the design process,

(d) there is currently no systematic way of identifying gaps in our research knowledge at the present time; and

(e) the availability of a human standards data base, although as proposed here to be limited initially to spacecraft, crew systems, and flight crews, has considerable utility for the design of other man-machine systems related to space flight ground support activities.

The primary objective of the project, to be described in this report, therefore, is to organize the information which now exists or is being generated about the use, support, and protection of man to increase its availability to, and to ensure its use in the design of future manned space flight systems. Emphasis is placed on both the development of a data base and a data handling system.

There are a number of activities and documents within NASA and DOD which are concerned with the handling of data of this type. No one of these, in the estimation of the author, individually meet the total requirements for:

(a) comprehensive coverage of all the areas concerned with man,

(b) rapid updating of the data in those areas where standards are still being formulated, and

(c) direct application to the design and operational requirements for manned spaceflight programs.

However, each of these efforts do provide essential elements within the type of data base and data handling system to be described in this report, and therefore, a brief review of some of those that are directly related to this project is desirable.[1]

1) The Air Force's Handbook of Instructions for Aerospace Personnel Subsystem Designers (AFSCM 80-3, 196) is a loose-leaf volume with annual supplements which brings together a considerable amount of information about human capabilities and requirements for application to the design and operation of aerospace systems, and to the selection, training, and organization of personnel. Although much of this information is relevant to space flight crews, there are still important gaps in the content of the volume - some but not all of which can be attributed to lack of research data with which to formulate standards. More importantly, however, these standards are oriented to military operations, where differences in objectives may require unconservative tradeoffs which would not be acceptable in the NASA programs.

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[1]See the reference section of this report for a more complete listing of relevant documents and projects.

A companion set of documents: Human Engineering Design Criteria for Aerospace Systems and Equipment (MIL-STD-803A-1, 2, and 3, 1964) are basically abstractions of design criteria from the material contained in AFSCM-80-3 and are intended for application to ground systems, facilities, and aerospace vehicles. The last of these, for aerospace vehicles, is still in the preparation stage. A document for life support aspects of aerospace vehicle design and operation is also in the preparation stage (Proposed MIL-STD-853 (USAF), draft 15 March 1966).

2) Within NASA the preparation and subsequent updates of the Bioastronautics Data Book (NASA SP-3006, 1964) is a significant effort to collect under one cover data about the human being which is directly related to the use and support of man in space. Most of the data is basic to man and therefore, in most instances, it requires translation into design concepts before it is usable. In addition locating and retrieving relevant information is difficult. And finally, there are important areas which have not been included in the first edition.

3) The Marshall Space Flight Center has developed a standard entitled: Human Engineering Design Criteria Study; Final Report, MSFC-STD-267A, January 31, 1966, is intended to provide human engineering criteria for application to the design of the earth launch systems. Although this is concerned primarily with the ground based booster checkout equipment, and ground handling and fueling facilities, much of the data has applications to human requirements for the flight vehicles and ground command and communication facilities.

4) Also within NASA a computerized program is being developed to handle the medical data that is being collected from space flights and ground based simulator studies. This program will provide for the systematic collection, partial reduction, and storage of this data. This represents a potential source of important standards data for input to the data base described in this report.

5) There are a number of review reports and planned updates of existing human factors handbooks that are relevant to the role of man in space. Some of these, such as the reports on space cabin atmospheres, confinement, bioenergetics of space suits, etc., prepared by the Lovelace Foundation, are particularly relevant. Also, the revision of the Joint Services Guide or the Human Engineering Guide to Equipment Design, to be reissued in late 1967 or early 1968, will contain more data directly relevant to the use and support of man in space.

6) Currently an effort is underway within NASA to collect all of the human standards that are being used in the Apollo Program. (This will be discussed beginning on page 5.)

Advantages of an Integrated Human Standards Data Base and Data Handling System

The advantages to be gained from having available a comprehensive human standards data base and data handling system are similar to those for any other data requirements in system design and development: i.e., they help insure that the users will obtain the data they need, when they need it, and in a form most useful to them. More specifically, the advantages, and therefore the objectives of the project to be described in this report, are as follows:

1) Provide systematic checklists for rapid and complete identification and retrieval of data about the human being that are relevant to:

a. the design and operation of crew-related spacecraft systems,

b. the development of flight crew procedures for various flight regimes,

c. the selection and training of flight crews, and

d. the composition and organization of the flight crews.

These checklists also will aid in the determination of the appropriate phases in the system design and development process where the various human data are applicable.

2) Provide a common set of descriptors and formats so that new data can be reduced and inserted into the data base in a form useful to design, operations, training, and test personnel. This is particularly important in such areas as the effects of environmental stresses on human performance and requirements where flight and research data is being rapidly accumulated and must be processed into a form useful for design purposes.

3) Provide a means (i.e., the data handling system) for bridging the data accessibility and terminology gaps between the generators and users of human data. In addition, provide suitable feedback loops so that the users can request changes in the format or content of the human standards data or indicate research requirements.

4) And finally, as a by-product, provide a systematic method for the identification of research and data reduction problems.

Accomplishments in the Generation of Human Standards for the Apollo Program

The initial phase (Phase 1) for the development of human standards for the Apollo Program has already laid part of the foundation for the more extensive effort to be described conceptually in this report.[1] Therefore, a brief review of the objectives and accomplishments to date of this effort is appropriate. Figure 1 summarizes the work in process. Within this phase there are two parallel efforts; a) the collection and documentation of the human standards being used in the Apollo Program, and b) the preparation of human standards monographs in selected areas. Part "a" is intended to accomplish the following objectives:

1) Collect in one document the standards that are being used in the Apollo Program so that they may be referenced in other Apollo specifications or in revisions of these specifications.

2) Provide bases for the evaluation of the human standards that are available to manned space flight programs, and thereby indicate: a) areas in which data analysis and reduction is still required before acceptable standards can be said to exist, and b) areas in which further research is required.

3) Lay the groundwork for a more comprehensive program to develop and document human standards for future manned space flight programs. This objective is the subject of this report.

Part "b" of this project is devoted to the preparation of examples of human standards which are applicable to manned space flight programs as a whole. Based on the requirements of the Apollo Program several areas have been selected for initial development. These include radiation, atmosphere, acceleration, vibration, thermoregulation, acoustics, and vision. These areas represent, in the judgement of NASA personnel, those areas of first order significance with respect to the standards being used in the Apollo Program. Thus, these examples not only meet an immediate need in the Apollo Program, but (to the extent that they can be thoroughly developed) they will also serve as models for the generation

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[1] Chambers, A. N., and Bottomley, T. A., Jr., Human Standards for Apollo, Bellcomm Working Paper, August 1, 1966, Revised 1 March 1967.

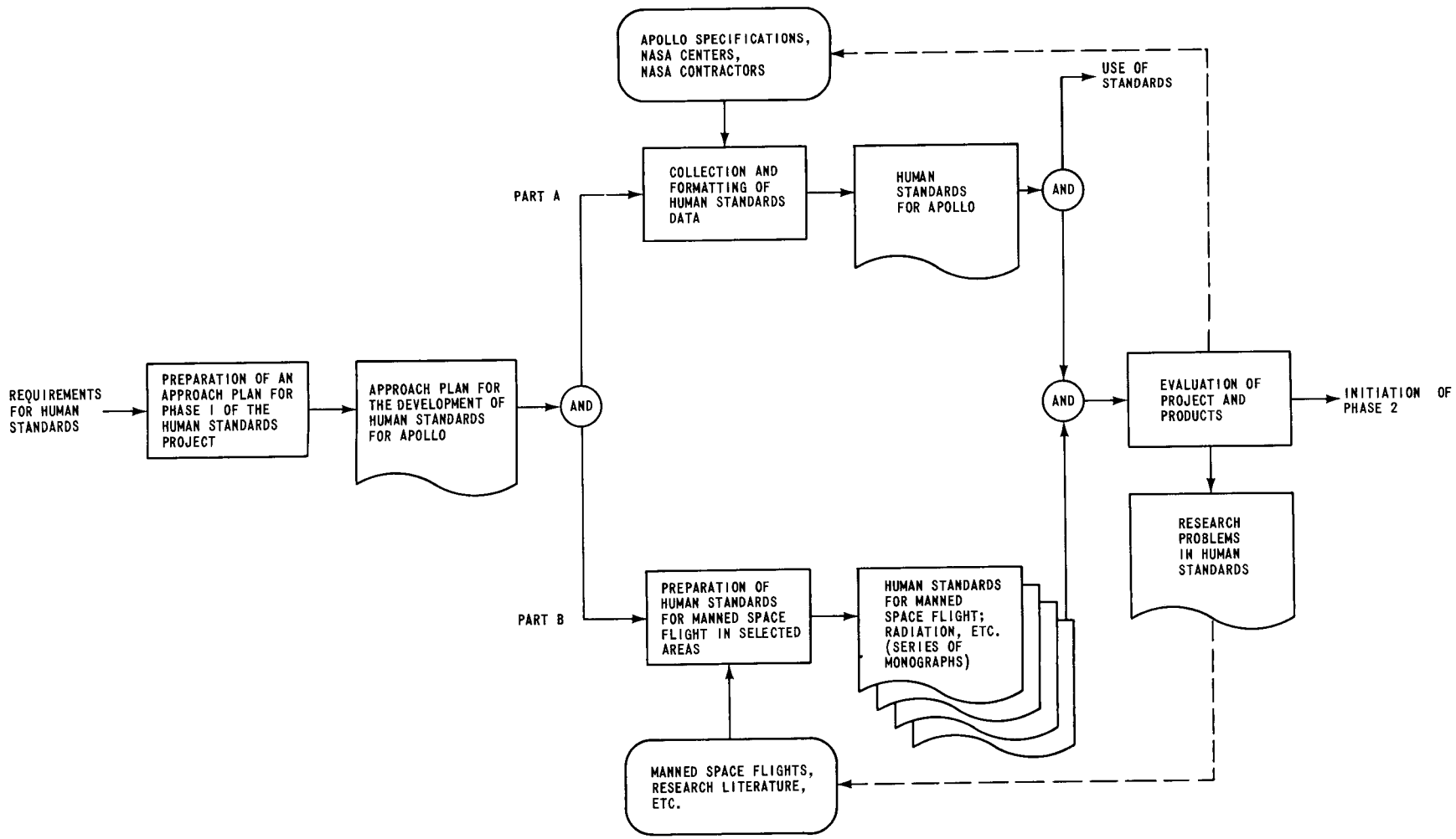

FIGURE 1: PHASE 1 OF THE HUMAN STANDARDS PROJECT

of standards in the many additional areas that are concerned with the use, support, and protection of man in manned space flight systems.

Definitions and Concepts

Before continuing with the approach to this project, it is desirable to define and describe some of the terms and concepts that are used in this report. Specifically, this includes:

a) what is meant by standards - human standards in particular,

b) what are the areas and content of human standards,

c) what are the uses of the standards, and

d) who are the users of the standards.

Each of these will be discussed in turn.

Definitions of Standards

The term standard, as generally used in the design of systems, has at least two meanings, a) the utilization of some process or object in a consistent or repetitious manner, or b) the utilization and/or maintenance of a function within specific boundaries or ranges. For the first case, standardization can mean, for example, the use of the same test procedures throughout the system design and development process, or it may also mean the use of the same components from equipment to equipment or from system to system.

Although both definitions of standards are relevant here, the second usage is of greater significance in considering man in the design of systems. For example, the physical dimensions of man establish the space requirements or boundaries for the design of suits or cabins. Similarly, the functional characteristics of man necessitate that he be maintained within certain prescribed limits or be able to perform in an acceptable manner. For example, man requires a certain amount of food and oxygen for bodily maintenance; or his environment must be maintained within certain temperature and humidity limits, etc.; or he can be expected to perform visual tasks within certain illumination ranges; or operate so many controls within a given period of time, etc.

Categories within Human Standards

The definition of human standards indicates that both the physical and functional characteristics of man are involved. It is convenient for data storage and retrieval to classify these into three major areas which are more or less derived from established scientific and technological fields. These are: a) anthropometry, b) physiology and medicine, and c) psychology or performance. A fourth category, physical environments, also will be used because it provides another essential approach to the retrieval of data for purposes of design. These four categories may be defined as follows:[1]

1) Anthropometric Standards includes the physical measurements of the human body which establish the space, form, movement, mass, volume, surface, and strength and endurance envelopes for the population of interest; initially, for the astronaut population.

These standards include both measurements for the individual for some parameters and averages and ranges for the unique flight crew candidate group for others. For example, the fitting of a space suit requires the measurements of each person. Or, the design of a seat or hatch may require the dimensions for the largest person. For others, the average may be sufficient, such as the surface area of the body for use in calculation of radiation exposures, or the calculation of heat losses. And finally, the placement of a control requires consideration of the arm reach measurement for the smallest person who is expected to use it.

2) Physiological and Biomedical Standards are concerned with the maintenance of bodily functions within certain prescribed limits, the protection of the body from various environmental stresses, and in some instances, the restoration of normal body functions if their limits have been exceeded.

Since these are primarily concerned with the functional requirements of the body, they generally take the form of normal ranges and limits for the population. The latter include points or levels at which discomfort or decrement in functioning might be expected to occur and extend to the

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[1]A detail outline of the sub-categories that have been developed to date will be found in Appendix D.

point or level where serious impairment of function or perhaps damage to bodily tissue can be expected. For some areas, the normal range can be specified in a relatively straightforward manner; for example, the caloric requirements per hour of a 160 lb. man at rest. For others, there is a much more complex interaction of variables, and the use of a mathematical model is necessary to establish adequate standards. For example, in the regulation of body temperature, many variables interact to determine the exchange of heat between the body and the environment. Deviations in one of these variables (such as wall temperature) can, within fairly narrow limits, be offset by a change in the value of another variable (such as ventilation rate) in order to maintain the body within a comfortable range. Therefore, to establish human physiological standards, it may be adequate to specify values for single parameters in some cases; in other areas it is necessary to specify multiple variables and a method (model) for calculating the effects of their interactions.

3) Psychological or Performance Standards are concerned with the use of the capabilities of the human being for the performance of useful work or tasks; and again, the maintenance of these performance capabilities within acceptable levels when subjected to various work and environmental stresses.

As with the physiological standards, both single and multiple variable standards must be specified. However, the quantification of human performance is generally a much greater problem than it is for the physiological functions. For example, it is possible to provide rather precise quantitative standards for some of the sensory capabilities of man (e.g., vision and hearing); but for problem solving, which is an extremely important human capability, it is not yet possible to provide precise quantitative measures--at least outside of the laboratory. However, qualitative statements in these areas are useful and should be included as guidelines.

4) Environmental Standards include the values for various physical environmental conditions which establish the limits for the physiological and psychological functioning of man when subjected to various environmental stresses.

The environmental standards begin with the environmental categories and parameters of space flight interest which are used to establish the limits of physiological

and psychological functioning when subjected to various amounts or combinations of these environmental stresses. Frequently, it is possible to establish a normal level or range of functioning where no impairment occurs in response to these environmental stresses; a performance limit, where excessive amounts of error or time become involved in the performance of tasks, and an emergency limit at which some physiological impairment or pathological condition can be expected to occur.

The relationships between the various classes of human standards may be summarized as follows:

Actual or observed physiological tolerances and performance capabilities	=	Basic human requirements and capabilities ± effects of personal variables ± effects of environment ± effects of equipment ± effects of procedures.

The hearing capability of man illustrates these relationships: For example, under quiet (no noise) conditions a person of the age and noise exposure experience of the astronaut population can be expected to hear speech over a certain frequency and intensity range in the face-to-face situation at a specified distance. However, if the ambient noise level is sufficiently high, some or all of the speech will be masked by the noise. Where this occurs, it may be possible to offset the effects of interference by the use of intercommunication equipment. Or if this is not feasible, visual means of communication may have to be utilized. Differences in the capabilities of different astronauts or within the same one at different times also must be considered. Inattention, hearing threshold differences, etc., may degrade or enhance performance. From the physiological standpoint, if the noise is of sufficient intensity and duration, temporary hearing loss or permanent damage to the ear may occur unless suitable protective devices are used, such as ear plugs, helmets, etc. The result of considering all of these factors in combination is to describe the performance and tolerances of man under the conditions to which he will be exposed. If the values for any of these variables exceed acceptable limits or boundaries, suitable means must be found to bring them within acceptable limits.

The physiological and psychological standards, in effect, define the "normal" types and levels of functioning of man as measured under some baseline condition and from there go on to define the limits for these functions when stressed by various environmental, operational, or other conditions. Most of the baseline measurements on human functions have been established under the conditions which obtain on the earth's surface, hence adjustments may be required in some of these as a result of the unique fixtures of the space environment.

Table 1: Categories within Human Standards

I. Anthropometric Standards (measurements of the physical characteristics of the human body for the unique astronaut population of interest).

A. Dimensions of the Head, Body, and Limbs

Includes both static dimensions such as height (usually from the floor), length, width, thickness, and circumference of the body and body parts; and dynamic dimensions of the body which include reach and body envelopes, such as arm reach or space required to crawl through a hatch, etc.

B. Movement of the Head, Body, and Limbs

Includes the range of movement in degrees about the various joints of the body; the capabilities for performing complex movements such as control manipulation; and capabilities for performing whole body movements, such as walking, climbing, etc.

C. Strength and Endurance of the Body and Limbs

Includes the strength and endurance of the body and limbs for performance of work in various planes and directions and for various periods of time.

D. Dimensions, Masses, and Volume of Organs and Body Parts

Includes the dimensions of organs, weight and specific gravity of bodily organs and parts, and the volume of the organs and body parts.

E. Centers of Gravity and Moments of Inertia for Body and Body Parts

Includes centers of gravity for the whole body in various positions, and for body parts such as limbs and organs, etc. The moments of inertia determine the amount of force required to rotate the body about its center of gravity.

F. Surfaces of the Body

Includes the skin area or projected area for the whole body in various positions, such as standing, crouching, etc., and for various portions of the body. Also, includes the thermal resistance of the skin.

G. Composition of the Body

Includes the chemical constituents, cells, and tissues, and organ characteristics of the body as related to the effects of acceleration, altitude, temperature, vibration, or radiation.

II. Physiological Standards (functional requirements of the human body for maintenance or restoration of normal health and for the protection of the body from various environmental factors).

A. Functional Requirements of the Respiratory System

Includes volume and rates of air movement, consumption of oxygen, production of carbon dioxide and water vapor, and exchange of gases in the lungs.

B. Functional Requirements for Digestive System and Nutritional Requirements

Includes the requirements for food and water. For food this involves the bulk, dietary composition, frequency of ingestion, etc. For water this involves the amount and frequency of ingestion.

C. Maintenance of Metabolic Balances[1]

This includes the functioning of several bodily systems in combination, but is primarily concerned with the requirements for maintaining a balance between caloric (food) and oxygen intake and work and heat output of the body. Also includes maintenance of fluid electrolyte balances in the tissues.

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[1]This type of category represents the combining of several basic physiological functions and therefore is somewhat redundant with some of the other categories. However, it represents a convenient method of grouping data for design purposes. As the data base is developed, undoubtedly better groupings of the data will become apparent.

D. Maintenance of Thermal Balances

Similar to above but is specifically concerned with the exchange of the body heat with the environment to maintain comfort and work efficiency.

E. Functional Requirements of the Excretory Systems

Includes consideration of the amounts, composition, and frequency of excretion or elimination of all bodily wastes; therefore, it includes feces, urine, flatus, sweat, saliva, dried skin and sebum, tears, and ear wax. Also includes growth of hair and finger and toe nails.

F. Functional Requirements of the Cardiovascular System

Includes heart-rate and rhythm, distribution and flow of blood in the arterial, venous and the capillary systems, and the volume and composition of the blood.

G. Functional Requirements of the Nervous System

Includes the normal functioning of the central nervous system, peripheral nervous systems, and receptors and effectors in the senses, muscles, and glands.

H. Maintenance of Muscular Integrity

Includes strength, endurance, coordination of the muscles and the general tonus of the body.

I. Maintenance of Endocrine Balances

Includes what is known about the maintenance of endocrine balances - including the thyroid, pituitary, adrenal cortex, gonads, etc., when subjected to unusual environments, different work regimes, etc.

J. Maintenance of Immunological Responses

Includes consideration of what is required to maintain the body's defenses against infections.

III. Psychological Standards (functional capabilities and limitations of the human being for the performance of various duties and tasks.)

A. Functional Capabilities of the Visual Sense

Includes consideration of the field of vision, discrimination of light intensities and variations, discrimination of spatial relationships (visual acuity, depth discrimination, form discrimination, movement discrimination, and orientation) and discrimination of color.

B. Functional Capabilities of the Auditory Sense

Includes capabilities for reception of signals and speech as a function of intensity levels and differences and various noise conditions.

C. Functional Capabilities of the Kinesthetic and Vestibular Senses

Includes the capabilities for perception of position of the body and limbs, movement of the body and limbs, position of objects and vehicles (with the man in the vehicle), and the movement of vehicles (again with the man in the vehicle.

D. Functional Capabilities of the Somesthetic Senses

Includes the perception of temperature, touch, and pain both for whole body and body parts.

E. Functional Capabilities of the Olfactory and and Gustatory Senses

These ordinarily are not important capabilities of man in the design of systems. Includes perception of, and discrimination between odors and tastes.

F. Functional Capabilities for Perception

Includes the capabilities of man to interpret sensory inputs as meaningful objects and events.

G. Functional Capabilities for Problem-Solving and Decision Making

These are complex human capabilities and difficult to quantify but nevertheless are extremely important to consider. Includes such things as comparison, computation, reasoning, judgement, etc.

H. Functional Capabilities for Learning and Retention

Includes the learning of various types of skills and knowledges, their retention (or conversely forgetting), and the transfer of skills and knowledges from one situation to another.

I. Functional Capabilities of the Sensory-Motor Processes

Includes the capabilities of man for performing continuous control (tracking) tasks and complex sequential (keyboard operation) tasks.

J. Functional Capabilities of the Motor Processes

Includes the capabilities of man for performing simple movements such as operating a control, complex movements such as donning a pressure suit, and whole body movements such as climbing, walking, etc.

K. Functional Capabilities for Speech Generation

Includes consideration of man's capabilities for generation of speech and the use of meaningful vocabularies and syntax.

IV. Environmental Standards (effects of various environmental conditions on the functional requirements and capabilities of man.)

A. Effects of Atmosphere

This includes the effects of composition, pressure levels (both continuous underpressure and decompression, and continuous overpressure and blast), temperature, humidity, and ventilation (air movement).

B. Effects of Toxicants

Includes the effects of noxious and toxic vapors and particulate matter which may contact the skin or be breathed or taken orally. It includes the effects of various bacteria that may be generated from decomposing food, body excretions, etc.

C. Effects of Acceleration

Includes the effects of linear acceleration (both impact and sustained), angular acceleration, radial acceleration, and complex accelerations such as are involved in tumbling.

D. Effects of Gravitation

Includes the effects of sustained weightlessness, reduced gravitation, and eventually, increased gravitation.

E. Effects of Vibration

Includes primarily the effects of vibration on the body in the infrasonic range; some sonic and ultrasonic effects also are involved.

F. Effects of Noise

Includes effects of noise primarily on the human ear with respect to its masking effects on signals and speech, reduction of hearing sensitivity and damage to the structures of the ear.

G. Effects of Radiation

Includes non-ionizing radiation in the radio, radar, infrared, visible, and ultraviolet ranges; and ionizing radiation in the X-ray and shorter wavelength ranges.

H. Effects of Electricity

Includes effects of exposure to electric current.

I. Effects of Circadian Rhythms

Includes consideration of the effects of deviations from the normal earth cycles, such as day-night, on the functioning of the body.

J. Effects of Isolation and Confinement

Includes primarily physical confinement and isolation, although for extended manned space flights social confinement may become a problem.

K. Effects of Dietary Imbalances

Includes the effects of deviations from normal diet and water supply on the functioning of the body and performance.

L. Effects of Drugs, Illnesses, and Injuries

Includes projections of anticipated effects of illnesses and injuries and required prophylatic and ameloriative techniques and medical supplies. Also includes consideration of possible uses of drugs in space flight, where demonstrated to be effective.

M. Effects of Combined Stresses

Since environmental factors can have synergistic, or antagonistic, or even noninteractive effects, consideration must be given to these in design and operation as rapidly as they are identified and their importance is assessed.

Transformation of the Human Standards into Applications Standards

Human standards seldom can be directly used as criteria for the design and operation of systems. Most require an intermediate transformation into that which will be defined collectively as applications standards. For example, the distance a man can reach (an anthropometric standard) fairly directly establishes how far away a control panel should be placed. However, the visual capabilities of man by themselves may provide almost no guidance to the designer of a spacecraft. These capabilities become meaningful to him only when they are translated into criteria for the design of displays, or the placement and size of cabin windows, etc. Also, the oxygen requirements of man are relatively meaningless to the designer of a life support system until he knows the size of the crew, how many days the mission will last, the maximum oxygen consumption rates per day (or some other relevant unit), etc. In short, the human standards provide only a part of the information that is required about man, or provide it in a form not directly applicable to the design of the system. Therefore, it is necessary to bridge the gap between the life and behavioral sciences and the engineering and training technologies. Again, as with the human standards, these areas will be classified into several major categories.[1]

1) Life Support Engineering Standards are concerned with the design and operation of environmental control systems, support and restraint equipment, food and water management systems, and waste management systems, and with the provision of supplies (i.e., consumables, such as food, water, oxygen, etc.) which are required to protect and maintain the crew during space flight and recovery.

This area draws heavily from the human data classified under physiological standards and environmental standards.

2) Human Engineering Standards include the design and operation of the hardware with which the crew interacts (e.g., controls and displays) in the system. This area is also concerned with the dimensions and arrangements of the compartments, hardware, and clothing as it relates to the physical dimensions and mobility of man.

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[1]A detailed outline of the subcategories for the Applications Standards that have been developed to date will be found in Appendix E.

These standards are primarily dependent on the anthropometric data on man, and on the psychological and environmental standards for human performance data.

3) Procedures Development and Documentation Standards include criteria for the development of operational, maintenance, and other procedures (such as exploration of the lunar surface) that may be required of the crews. This includes their documentation in manuals. In the documentation the concern is with organization, contents, and formats of the manuals.

These depend heavily on the psychological standards for data; although the other standards areas also are involved. For example, the energy expenditures of the astronaut in a pressurized suit must be considered in the development of procedures.

4) Personnel Selection and Training Standards include the selection of personnel who are physically, emotionally, educationally, and experientially suitable for space flight crews and their training to insure that they are able to satisfactorily perform the tasks which are assigned to them.

These standards draw from all of the human standards categories.

5) Crew Composition Standards are concerned with the organization of crews to insure that they are composed of suitable numbers and types of specialists and are integrated to function as a team.

Most of these standards are dependent on the criteria provided in the psychological standards.

The major subcategories within each of these applications standards areas are described in Table 2.

Table 2: Categories within Applications Standards

I. Life Support Engineering Standards (includes the design and operation of equipment for bodily maintenance and protection).

A. Design of Protective Suits and Portable Equipment

Includes the support and protective aspects of clothing, anti-exposure suits, pressure suits, and portable life support equipment.

B. Design of Occupancy and Restraint Equipment

Includes the design and operation of equipment intended to protect man from the effects of weightlessness, acceleration, vibration, impact, etc. Also, comfort for long-term occupancy is considered here.

C. Design of Environmental Control Systems

Includes the design of systems provided in spacecraft and eventually lunar and planetary bases, for the control of atmospheric pressure, composition, temperature and humidity; control of toxicants and contaminants; and in some instances, radiation and noise protection.

D. Design of Food and Water Management Systems

Includes provisions for storage, preservation, preparation, consumption, and reconstitution of food; also includes provisions for storage, storage and purification of water for crew consumption and hygienic purposes.

E. Design of Waste Management Systems

Includes provisions for collection and disposal of human waste products; eventually will include design of reclamation systems.

F. Design of Monitoring Equipment

Includes provisions for selection of parameters to be monitored (mostly physiological parameters), design and mounting of sensors, design of recording and transmitting equipment and techniques for data analysis.

G. Provisions for Hygiene and Medical Supplies

Includes selection of medications, dressings, body cleansing supplies, and provisions for their storage, use, and disposal.

H. Design of Equipment for Maintaining Bodily Condition

Includes provisions for exercise, negative pressure suits, centrifugation, etc., depending on the results of further research.

I. Design of Escape, Survival, and Recovery Equipment and Supplies

Includes provisions for escape from the spacecraft; provisions for survival and recovery from land, water, and eventually, disabled space vehicles, lunar and planetary bases, etc.

II. Human Engineering Standards (includes those considerations which are related to the interaction or interface between the man and the equipment).

A. Design of Clothing, Suits, and Portable Equipment

Includes fit and mobility considerations, vision, and communication when helmeted, performance of simple, complex, and whole body movements - with a minimum of interference. It also includes coverage of donning, stowage, portability, and operation.

B. Design of Occupancy and Restraint Equipment

Limited to the fit, mobility, and support considerations of the equipment as opposed to its protective aspects.

C. Design of Cabins

Includes consideration of the general arrangement and location of windows, control and display panels, seats, and other equipment within the crews' operating station.[1] Also, considers effects of lighting, vibration, noise, acceleration, and other environmental variables as they affect performance.

D. Design of Display and Control Panels

Includes consideration of the location, grouping, labeling, etc., of displays and controls on panels.

E. Selection and Design of Displays

Includes consideration of the types of information to be displayed, the form (e.g., quantative or qualitative, etc.) in which it is displayed and design features such as dimensions, lighting, markings, coding, etc., of the displays. Verbal communication equipment (e.g., intercommunication systems) are considered here.

F. Selection and Design of Controls

Includes the types of controls to be used, their method of operation, and design features such as dimensions, torque, friction, markings, etc.

G. Design of Equipment for Maintenance

Includes provisions for fault identification and localization, replacement or repair, and tools and equipment for adjustments, replacement, or repair of equipment.

H. Design of Training Equipment

Includes many of the same design considerations noted

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[1]Eventually, design of larger facilities (such as manned orbital stations or lunar bases) and other types of vehicles (such as lunar surface exploratory vehicles) will have to be added to these categories since they also will involve human engineering considerations that are somewhat different from the categories listed here.

above but also includes provisions for training routines or programs, recording and evaluation equipment, and instructor's stations. Also includes initial decisions about the types of training aids and devices required.

III. Procedures Development and Documentation Standards

A. Development of Procedures

Includes consideration of the tasks required of the personnel, task loadings, communication requirements, and so forth. Includes development and evaluation of both normal and contingency procedures.

B. Documentation of Procedures

Includes the type of document, job aids, and the format and content of the documents.

IV. Personnel Selection and Training Standards

A. Selection of Personnel

Includes medical and physical selection techniques, educational criteria, and experience criteria.

B. Training of Personnel

Includes establishment of training requirements, training programs, training courses, and the selection or design of training materials, aids, and devices. Also includes proficiency (skills and knowledge), testing, and evaluation.

V. Crew Composition Standards (includes decisions about the number and types of personnel to be included for a given mission/system, the division of tasks between them, command structure, coordination of work and schedules between them, etc.).

A. Determination of Numbers and Types of Personnel

Includes the criteria for organizing crews.

B. Allocation of Tasks between Crew Members

Includes distribution of duties and tasks between crew members.

C. Establishment of Work Regimes

Includes establishment of work-rest cycles.

Users of the Standards

The definitions of human standards and applications standards indicate the variety of data that are concerned with the use, support and protection of man in the design of a system. They also suggest that a wide variety of scientific and technical people are required to interpret and apply the standards to the specific system design or crew related problems. The ultimate goal in many areas, as has already indicated, is to transform the human standards into applications standards; i.e., into a form that is directly usable by design engineers, mission planning and operations personnel, training specialists, and system test personnel. In other areas this is not required. And in still other areas it has already been largely accomplished (e.g., criteria for the selection and/or design of displays and controls). There are, however, many areas in which this transformation still remains to be done, and it is improbable that it can be completed in the foreseeable future. Therefore, a team of specialists will continue to be required to insure the appropriate application of data about man to the design and operation of these systems.

In the areas concerned with the use of human standards this requires specialists who are more knowledgeable about the human being and less so about the engineering and other applications aspects - but nevertheless aware of the technological and operational constraints imposed by the hardware and personnel. This includes persons who are trained in the more traditional areas of physiology, psychology, and anthropology and other research oriented areas. For the use of the applications standards this requires the more engineeringly oriented person, the medical practitioner, the human engineer and the other types of personnel more closely associated with the actual design and operation of a system and the selection and training of crews.

Utilization of the Standards Data Base: A Hypothetical Example

An effective means of describing for the reader the type of human standards data base and data handling system proposed here is to assume that it is in existence and demonstrate how it would be used in the storage and retrieval of data.[1] With this as background, it will then be possible to compare what is available now with the proposed plan and thereby provide the background for describing Phase 2 of the project. Figure 2 summarizes the data retrieval process described in the following paragraphs.

Step 1: Analysis of a Manned Space Flight Mission to Determine Human Involvement

Beginning with the conceptual phases of the system design and development process, a general description is prepared of the mission or missions to be performed by the system and the types of functions that must be performed by the system. As these concepts become more refined, it is possible to begin to identify the role of man in the system and the operating conditions to which he will be subjected. Specifically, to fully consider the use, support, and protection of man in the space flight environment, it is necessary to identify the following:[2]

a) The physical environmental conditions to which the crew will, or may be, subjected,

b) The tasks that the crew will be required to perform, including the conditions under which they will, or may be, performed, and

c) The systems and equipments that the crew will interface with, or interact with during the mission.

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[1]The data base described here is assumed to be limited to criteria required for the design and operation of spacecraft, crew systems, and the selection, training, and organization of flight crews. The general applicability of the concepts discussed in this report to other design areas will be treated later in this report.

[2]Outlines of the lists of descriptors for these categories that have been generated to date in this project are contained in Appendices A, B, and C.

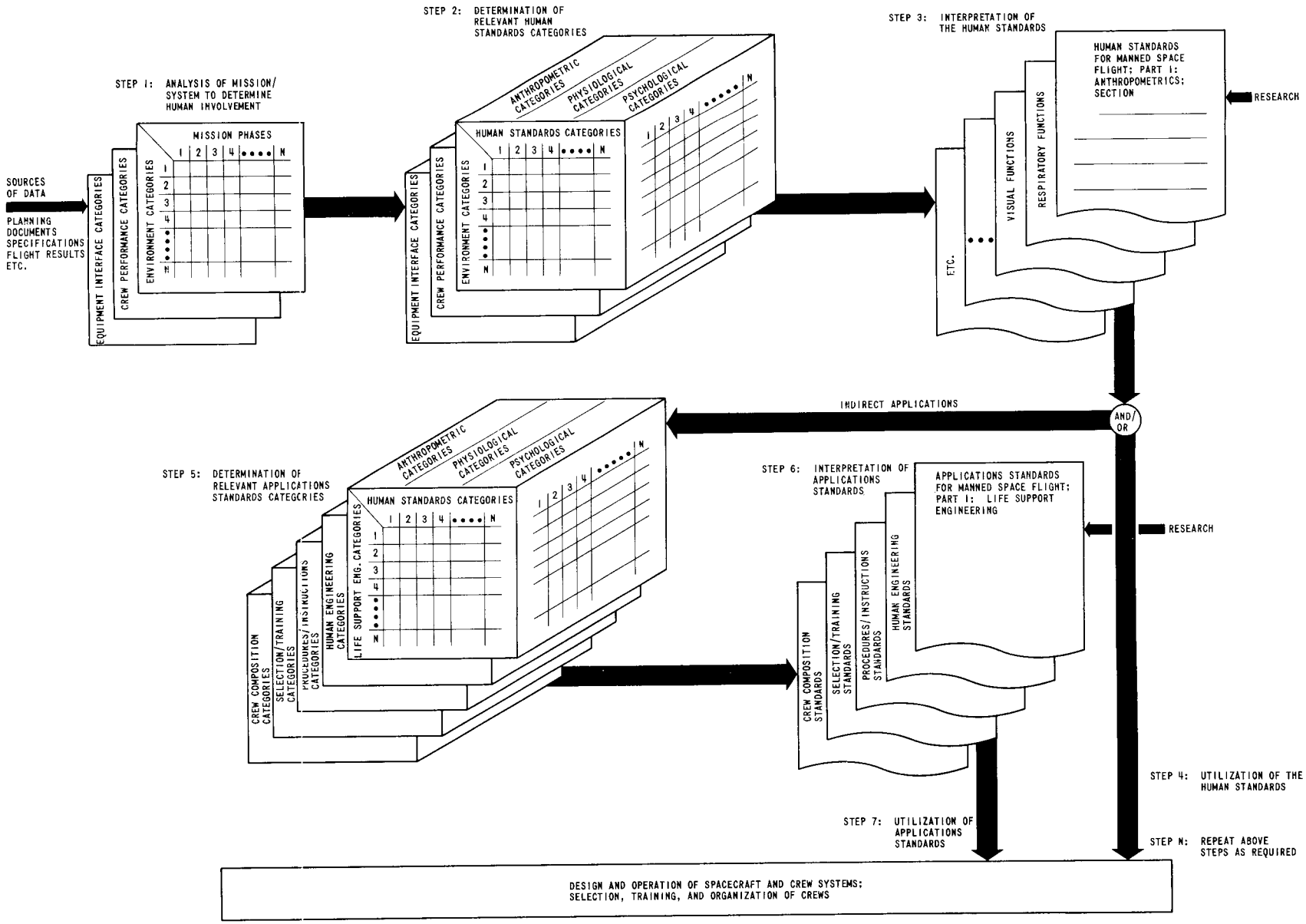

FIGURE 2: SUMMARY OF THE INDEXING AND RETRIEVAL SYSTEM FOR THE STANDARDS DATA BASE

Table 3 indicates how a given space flight mission (in this case the Apollo Lunar Landing Mission) might be analyzed to systematically identify this type of information. This table provides a checklist for establishing whether a given environmental, performance, or hardware category is involved in the mission.[1] A 1 indicates that it is; an 0 that it is not involved in the particular mission/system.

For each cell in this table which contains a 1 data should be obtained as early as possible in the design process which describes the factors involved within the category.

For example, if vibration is expected during the boost phase of the mission (as it is, in fact, in the example in Table 3), data should be obtained which describes the duration, frequency, amplitude, and spectral characteristics of the vibration expected. Also, the direction and point of application of the vibration to the body should be determined.

For the crew tasks the descriptions should be sufficiently detailed that they indicate the sensing, processing, and response elements involved as well as any quantitative information that can be identified (e.g., task duration, task loading, lighting conditions, etc.).

For the hardware with which the crew interfaces, this should include as precise a description as the design phase of the system permits.

The collection of these data is an iterative process and must be repeated as the design progresses until all of the design and operational parameters have been precisely defined. Some design and operational parameters must be accepted as given (e.g., weightlessness), and therefore means must be provided for insuring that there is a minimum of interference with the functioning of the crew. Other factors, such as the type of task or the design of displays can be manipulated within certain limits until the design for the system has been frozen. Many

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[1] All systems including manned space flight systems, essentially undergo this type of analysis and synthesis. However, in practice it is much more complicated than this conceptualization of the process indicates. Literally thousands of scientists and engineers may be involved. The objective of this approach is simply to demonstrate that such an analysis can be done on a systematic basis if the data requirements are made explicit.

TABLE 3a: ANALYSIS OF MANNED SPACE FLIGHT MISSIONS AND SYSTEMS TO DETERMINE SIGNIFICANT, ENVIRONMENTAL, CREW PERFORMANCE, AND EQUIPMENT CATEGORIES (BASED ON APOLLO LUNAR LANDING MISSION): PHYSICAL ENVIRONMENT CATEGORIES

			PHASE 1: PRELAUNCH										PHASE 2: LAUNCH						••••••	PHASE N
			SUBPHASE 1a: MISSION PREPARATIONS		SUBPHASE 1b: MISSION INITIATION		SUBPHASE 1c: PRE-COUNTDOWN		SUBPHASE 1d: COUNT-DOWN		SUBPHASE 1e: TERMINAL COUNTDOWN		SUBPHASE 2a: S-IC BURN		SUBPHASE 2b: S-II BURN		SUBPHASE 2c: S-IV BURN			
			NORMAL MODE	CONTINGENCY MODE	NORMAL MODE	CONTINGENCY MODE	NORMAL MODE	CONTINGENCY MODE												
PHYSICAL ENVIRONMENT CATEGORIES	ATMOSPHERE	COMPOSITION	0*	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1		
		PRESSURE	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1		
		TEMPERATURE/ HUMIDITY	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1		
	•••																			
	ACCELERATION	LINEAR IMPACT	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1		
		LINEAR SUSTAINED	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1		
		ANGULAR	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1		
		RADIAL	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1		
	•••																			
	VIBRATION	LONGITUDINAL	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1		
		TRANSVERSE	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1		
		FORE-AFT	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1		
	•••																			
	N																			

*KEY: 1 = RELEVANT

0 = NOT RELEVANT

TABLE 3b: ANALYSIS OF MANNED SPACE FLIGHT MISSIONS AND SYSTEMS TO DETERMINE SIGNIFICANT, ENVIRONMENTAL, CREW PERFORMANCE, AND EQUIPMENT CATEGORIES (BASED ON APOLLO LUNAR LANDING MISSION): CREW PERFORMANCE CATEGORIES

			PHASE 1: PRELAUNCH										PHASE 2: LAUNCH						••••••	PHASE N
			SUBPHASE 1a: MISSION PREPARATIONS		SUBPHASE 1b: MISSION INITIATION		SUBPHASE 1c: PRE-COUNTDOWN		SUBPHASE 1d: COUNT-DOWN		SUBPHASE 1e: TERMINAL COUNTDOWN		SUBPHASE 2a: S-IC BURN		SUBPHASE 2b: S-II BURN		SUBPHASE 2c: S-IV BURN			
			NORMAL MODE	CONTINGENCY MODE	NORMAL MODE	CONTINGENCY MODE	NORMAL MODE	CONTINGENCY MODE												
CREW PERFORMANCE CATEGORIES	SENSING	DETECTING	0*	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1		
		READING	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
		• • •																		
		N																		
	PROCESSING	CALCULATING	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
		COMPARING	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
		• • •																		
		N																		
	RESPONDING	VERBAL COMMUNICATING	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
		SIMPLE MOVEMENTS (OPERATE SWITCH)	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1		
		• • •																		
		N																		
	BODILY MAINTENANCE	EATING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		SLEEPING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		• • •																		
		N																		

*KEY: 1 = RELEVANT
0 = NOT RELEVANT

TABLE 3c: ANALYSIS OF MANNED SPACE FLIGHT MISSIONS AND SYSTEMS TO DETERMINE SIGNIFICANT, ENVIRONMENTAL, CREW PERFORMANCE, AND EQUIPMENT CATEGORIES (BASED ON APOLLO LUNAR LANDING MISSIONS): INTERFACE EQUIPMENT CATEGORIES

			PHASE 1: PRELAUNCH										PHASE 2: LAUNCH						••••••	PHASE N
			SUBPHASE 1a: MISSION PREPARATIONS		SUBPHASE 1b: MISSION INITIATION		SUBPHASE 1c. PRE-COUNTDOWN		SUBPHASE 1d: COUNT-DOWN		SUBPHASE 1e: TERMINAL COUNTDOWN		SUBPHASE 2a. S-IC BURN		SUBPHASE 2b: S-II BURN		SUBPHASE 2c: S-IV BURN			
			NORMAL MODE	CONTINGENCY MODE	NORMAL MODE	CONTINGENCY MODE	NORMAL MODE	CONTINGENCY MODE												
INTERFACE EQUIPMENT CATEGORIES	GARMENTS/ PORTABLE LIFE SUPPORT EQUIPMENT	THERMAL GARMENT	0*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		PRESSURE GARMENT	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1		
		RADIATION GARMENT	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1		
		•••																		
		PORTABLE LIFE SUPPORT EQUIPMENT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	SPACECRAFT	COUCH/ RESTRAINT EQUIPMENT	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1		
		PANELS	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1		
		DISPLAYS	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1		
		•••																		
		N																		
	•••••																			
	PORTABLE EQUIPMENT	TOOLS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		SCIENTIFIC INSTRUMENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
		•••																		
		N																		
	•••																			
	N																			

*KEY: 1 = RELEVANT

0 = NOT RELEVANT

of these factors are a primary concern of the human factors specialists who will participate in their manipulation (using the human standards as guidelines) until a satisfactory blend of system design and operation, and crew usage and support is achieved.

Step 2: Analysis of the Human Involvement to Determine Relevant Human Standards Categories

Once the environmental, crew performance, and equipment interface categories that are relevant to a particular mission-system combination have been identified, then the next step is to relate them by means of a second set of tables to the human standards categories. Table 4 indicates conceptually how this link can be made. The same environmental, performance, and equipment categories are listed as row headings. The column headings in this case contain the human standards categories and a section number that identifies where the actual standards data will be located. For each of the row headings that are relevant the user should examine each row-column intersection. He will find one of five ratings at each intersection.[1] These

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[1]It is important to point out that ratings of this type must be based on the judgment of scientific and technical personnel in a variety of fields in order to establish a high degree of validity and reliability. Hence a considerable number of representative judgments will be required before a high degree of confidence can be placed in them. In addition, the problem of developing a useful set of descriptors for human performance is a difficult one to solve. Nevertheless, by one means or another, it is necessary in systems design and operation to identify the types of human performance (e.g., visual detection and interpretation, or eye-hand coordination, etc.) involved in the tasks that are assigned to the crew. It is not possible to derive much performance information from typical task statements such as: "Perform navigational sighting using the sextant." It is necessary to determine the behavioral content of these tasks before it is possible to relate task information to human performance and then, in turn, to the human standards categories. However, it is possible to generate a relatively gross set of human performance descriptors that will serve as a retrieval tool until a better one can be developed. Appendix B lists the descriptors that have been developed to date for this project.

TABLE 4a: DETERMINATION OF THE RELATIONSHIPS BETWEEN THE ENVIRONMENTAL, PERFORMANCE, AND EQUIPMENT CATEGORIES AND THE HUMAN STANDARDS CATEGORIES: PHYSICAL ENVIRONMENT CATEGORIES

			PART 1: ANTHROPOMETRIC STANDARDS				PART 2: PHYSIOLOGICAL STANDARDS					PART 3: PSYCHOLOGICAL STANDARDS					PART 4: ENVIRONMENTAL STANDARDS				
			SECTION 1.1: DIMENSIONS OF THE HEAD, BODY & LIMBS	SECTION 1.2: MOVEMENT OF THE HEAD, BODY, & LIMBS	••••	SECTION 1.N	SECTION 2.1: FUNCTIONS OF THE RESPIRATORY SYSTEM	SECTION 2.2: FUNCTIONS OF THE DIGESTIVE SYSTEM	SECTION 2.3: MAINTENANCE OF METABOLIC BALANCE	••••	SECTION 2.N	SECTION 3.1: FUNCTIONS OF THE VISUAL SENSE	SECTION 3.2: FUNCTIONS OF THE AUDITORY SENSE	SECTION 3.3: FUNCTIONS OF KINESTHETIC & VESTIBULAR SENSES	••••	SECTION 3.N	SECTION 4.1: EFFECTS OF THE ATMOSPHERE	SECTION 4.2: EFFECTS OF CONTAMINANTS/TOXICANTS	SECTION 4.3: EFFECTS OF ACCELERATION	••••	SECTION 4.N
PHYSICAL ENVIRONMENT CATEGORIES	ATMOSPHERE	COMPOSITION	0*	0			3	1	3			1	3	1			3	2	0		
		PRESSURE	0	3			3	2	3			3	3	?			3	2	?		
		TEMPERATURE/ HUMIDITY	0	2			3	1	3			1	1	0			3	1	2		
	⋮																				
	ACCELERATION	LINEAR IMPACT	2	0			3	?	0			3	?	3			0	?	3		
		LINEAR SUSTAINED	0	3			3	?	?			3	?	3			?	?	3		
		ANGULAR	3	3			3	?	?			3	?	3			?	?	3		
		RADIAL	1	2			3	?	?			3	?	3			?	?	3		
	⋮																				
	VIBRATION	LONGITUDINAL	3	3			3	?	?			3	1	2			?	?	3		
		TRANSVERSE	3	3			3	?	?			3	1	2			?	?	3		
		FORE-AFT	3	3			3	?	?			3	1	2			?	?	3		
	⋮																				
	N																				

*KEY: ? = RELATIONSHIP NOT DETERMINED

3 = RELATIONSHIP IS CRITICAL TO CONSIDER IN DESIGN, OPERATION, ETC.; THEREFORE, CONSULT SECTION CITED IN COLUMN HEADING

2 = RELATIONSHIP IS IMPORTANT TO CONSIDER

1 = RELATIONSHIP IS DESIRABLE TO CONSIDER

0 = UNRELATED

TABLE 4b: DETERMINATION OF THE RELATIONSHIPS BETWEEN THE ENVIRONMENTAL, PERFORMANCE, AND EQUIPMENT CATEGORIES AND THE HUMAN STANDARDS CATEGORIES :CREW PERFORMANCE CATEGORIES

			PART 1: ANTHROPOMETRIC STANDARDS				PART 2: PHYSIOLOGICAL STANDARDS					PART 3: PSYCHOLOGICAL STANDARDS					PART 4: ENVIRONMENTAL STANDARDS				
			SECTION 1.1: DIMENSIONS OF THE HEAD, BODY & LIMBS	SECTION 1.2: MOVEMENT OF THE HEAD, BODY, & LIMBS	••••	SECTION 1.N	SECTION 2.1: FUNCTIONS OF THE RESPIRATORY SYSTEM	SECTION 2.2: FUNCTIONS OF THE DIGESTIVE SYSTEM	SECTION 2.3: MAINTENANCE OF METABOLIC BALANCE	••••	SECTION 2.N	SECTION 3.1: FUNCTIONS OF THE VISUAL SENSE	SECTION 3.2: FUNCTIONS OF THE AUDITORY SENSE	SECTION 3.3: FUNCTIONS OF KINESTHETIC & VESTIBULAR SENSES	••••	SECTION 3.N	SECTION 4.1: EFFECTS OF THE ATMOSPHERE	SECTION 4.2: EFFECTS OF CONTAMINANTS/TOXICANTS	SECTION 4.3: EFFECTS OF ACCELERATION	••••	SECTION 4.N
CREW PERFORMANCE CATEGORIES	SENSING	DETECTING	0*	2			3	1	1			3	3	3			3	3	3		
		READING	0	2			3	1	1			3	1	3			3	3	3		
		•••																			
		N																			
	PROCESSING	CALCULATING	0	1			2	1	2			2	1	2			3	2	3		
		COMPARING	0	1			2	1	2			3	3	2			3	2	3		
		•••																			
		N																			
	RESPONDING	VERBAL COMMUNICATING	0	1			3	1	1			1	3	1			3	2	3		
		SIMPLE MOVEMENTS (OPERATE SWITCH)	3	3			1	1	1			2	1	3			3	2	3		
		•••																			
		N																			
	BODILY MAINTENANCE	EATING	0	3			1	3	3			1	0	1			1	3	3		
		SLEEPING	3	3			3	1	3			0	0	2			1	2	3		
		•••																			
		N																			

*KEY: 3 = RELATIONSHIP IS CRITICAL TO CONSIDER IN DESIGN, OPERATION, ETC.; THEREFORE, CONSULT SECTION CITED IN COLUMN HEADING

2 = RELATIONSHIP IS IMPORTANT TO CONSIDER

1 = RELATIONSHIP IS DESIRABLE TO CONSIDER

0 = UNRELATED

TABLE 4c: DETERMINATION OF THE RELATIONSHIPS BETWEEN THE ENVIRONMENTAL, PERFORMANCE, AND EQUIPMENT CATEGORIES AND THE HUMAN STANDARDS CATEGORIES: INTERFACE EQUIPMENT CATEGORIES

			PART 1: ANTHROPOMETRIC STANDARDS				PART 2: PHYSIOLOGICAL STANDARDS					PART 3: PSYCHOLOGICAL STANDARDS					PART 4: ENVIRONMENTAL STANDARDS				
			SECTION 1.1: DIMENSIONS OF THE HEAD, BODY & LIMBS	SECTION 1.2: MOVEMENT OF THE HEAD, BODY, & LIMBS	••••	SECTION 1.N	SECTION 2.1: FUNCTIONS OF THE RESPIRATORY SYSTEM	SECTION 2.2: FUNCTIONS OF THE DIGESTIVE SYSTEM	SECTION 2.3: MAINTENANCE OF METABOLIC BALANCE	••••	SECTION 2.N	SECTION 3.1: FUNCTIONS OF THE VISUAL SENSE	SECTION 3.2: FUNCTIONS OF THE AUDITORY SENSE	SECTION 3.3: FUNCTIONS OF KINESTHETIC & VESTIBULAR SENSES	••••	SECTION 3.N	SECTION 4.1: EFFECTS OF THE ATMOSPHERE	SECTION 4.2: EFFECTS OF CONTAMINANTS/TOXICANTS	SECTION 4.3: EFFECTS OF ACCELERATION	••••	SECTION 4.N
INTERFACE EQUIPMENT CATEGORIES	GARMENTS/ PORTABLE LIFE SUPPORT EQUIPMENT	THERMAL GARMENT	3*	2			1	0	3			0	0	1			3	0	0		
		PRESSURE GARMENT	3	3			3	2	3			3	3	3			3	3	3		
		RADIATION GARMENT	3	3			1	0	3			0	0	1			3	0	0		
		•••																			
		PORTABLE LIFE SUPPORT EQUIPMENT	3	3			3	0	3			2	1	3			3	3	0		
	SPACECRAFT	COUCH/ RESTRAINT EQUIPMENT	3	3			3	1	2			2	1	3			1	0	3		
		PANELS	0	3			0	0	0			3	2	3			0	0	3		
		DISPLAYS	0	2			0	0	0			3	3	2			0	0	3		
		•••																			
		N																			
	•••••																				
	PORTABLE EQUIPMENT	TOOLS	3	3			0	0	2			3	3	3			3	0	3		
		SCIENTIFIC INSTRUMENTS	3	3			0	0	2			3	3	3			3	0	3		
		•••																			
		N																			
	•••																				
	N																				

*KEY: 3 = RELATIONSHIP IS CRITICAL TO CONSIDER IN DESIGN, OPERATION, ETC.; THEREFORE, CONSULT SECTION CITED IN COLUMN HEADING

2 = RELATIONSHIP IS IMPORTANT TO CONSIDER

1 = RELATIONSHIP IS DESIRABLE TO CONSIDER

0 = UNRELATED

are to be interpreted as follows:

- ? indicates that the relationship between the environment, performance, or equipment category and the human standards category has not been established; and therefore, further analysis and/or research is required.

- 3 indicates that the human standards category is considered critical in that failure to consider it in the design of operation of the spacecraft and crew systems, or in the selection and/or training of the crew could be expected to seriously degrade the performance of the crew, jeopardize their safety, or conceivably, could result in mission failure.

- 2 indicates that the human standards category is considered important in the sense that failure to consider it could degrade performance of the crew but not necessarily jeopardize their safety or prevent mission success.

- 1 indicates that the human standards category is desirable to consider if schedules, costs, state-of-the-art, etc., make it feasible. Most of these are comfort and convenience features.

- 0 indicates that the human standards category represented by the column heading is not relevant to the particular environment, performance, or equipment category; and therefore, that the human standards category need not be considered.

With these ratings the user is able to determine, on a priority basis, which of the standards sections should be consulted. The user then should examine each of the individual sections.

Step 3: Interpretation of the Human Standards

Within each section of the human standards data base the user will find the following organization:

a) Summary Standards

b) Definitions and Measures

c) Methods

d) Standards

e) References

The content of each of these sections typically will be as follows:

1) Summary Standards

The summary is confined to providing condensed qualitative or quantitative data in the form of figures, tables, and narrative which define the basic requirements or capabilities pertinent to the particular human standards category. Figures 3 and 4 provide examples of these summary standards.

To determine if these summary standards are sufficient for the particular application the following conditions must be met:

a) The standard can be applied directly to the design or operational situation without qualification. For example, the physical dimensions of man, which represent fixed values for a given individual or population, fall within this category.[1]

b) The boundaries specified by the standard are not approached or exceeded by the design or operation of the system. For example, if even under the most severe lighting (i.e., environmental) conditions expected the visual tasks required of the crew fall well within the visual acuity range of the crew, then the standard for visual acuity may be sufficient by itself.

c) The human standards category does not interact significantly with other physiological or performance categories or with environmental, operational, or hardware categories. For example, combinations of heat and acceleration produce greater decrements in performance than occur under each stress alone; therefore, the standards which treat these categories may need to be considered together.

2) Definitions and Measures

This subsection contains terms, units, and conversions that are essential to the interpretation and application

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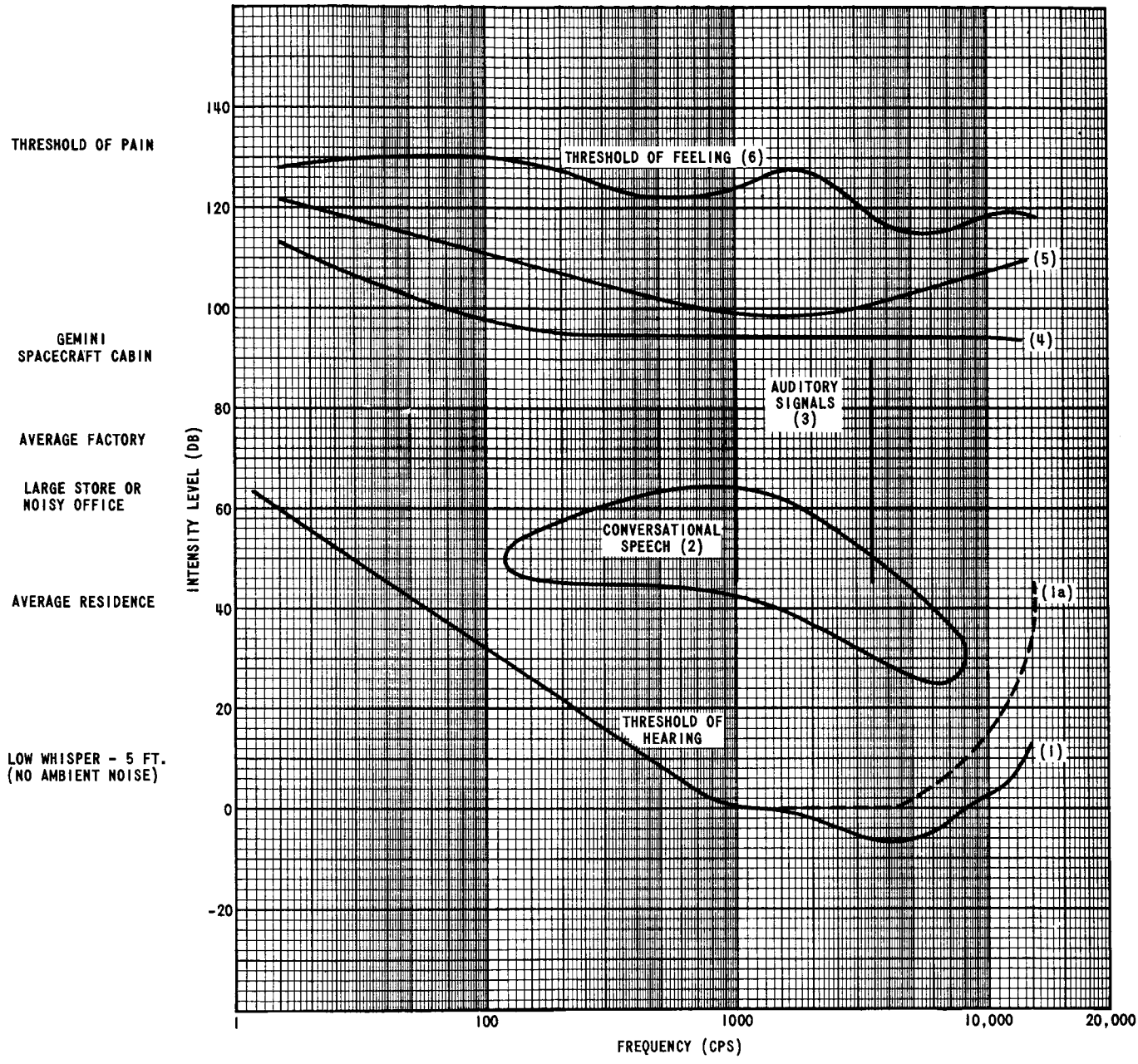
[1]Even here there is some room for interpretation. For example, clothing and space suits require addition of some increment to the nude measurements. If the design is concerned with the space suit itself, then these dimensions are sufficient. However, if the design is concerned with hatches, then the increments for the clothing and space suit must be added to the nude measurements. Again, this illustrates that human factors specialists are required to interpret the human standards for virtually all specific design or operational problems.



(1) BIANAURAL, AGE 20, 20 DB VARIATION IN THRESHOLD. (ROBINSON & DADE, 1956)
(1a) BIANAURAL, AGE 60. (ROBINSON & DADE, 1956)
(2) CONVERSATIONAL SPEECH AT 10-12 FEET, NO AMBIENT NOISE. (WOODSON, 1964)
(3) FREQUENCY RANGE FOR AUDITORY SIGNALS; INTENSITY LEVEL MUST BE ABOVE AMBIENT NOISE LEVEL BY 20 DB. (NAVWEAPS OD18413A, 1962)
(4) EAR PROTECTION MANDATORY, EXPOSURE FOR 8 HRS. +. (USAF AFSCM 80-3, 1964)
(5) MAXIMUM LEVEL FOR INTELLIGIBLE, UNCLIPPED SPEECH. (MORGAN, 1963)
(6) THRESHOLD FOR DISCOMFORT; SHORT EXPOSURE TIME. (WOODSON, 1964)

FIGURE 3: EXAMPLE OF SUMMARY STANDARDS FOR AUDITION. (GRAPH NOT TO BE USED - SCALE AND DATA NOT VERIFIED.)

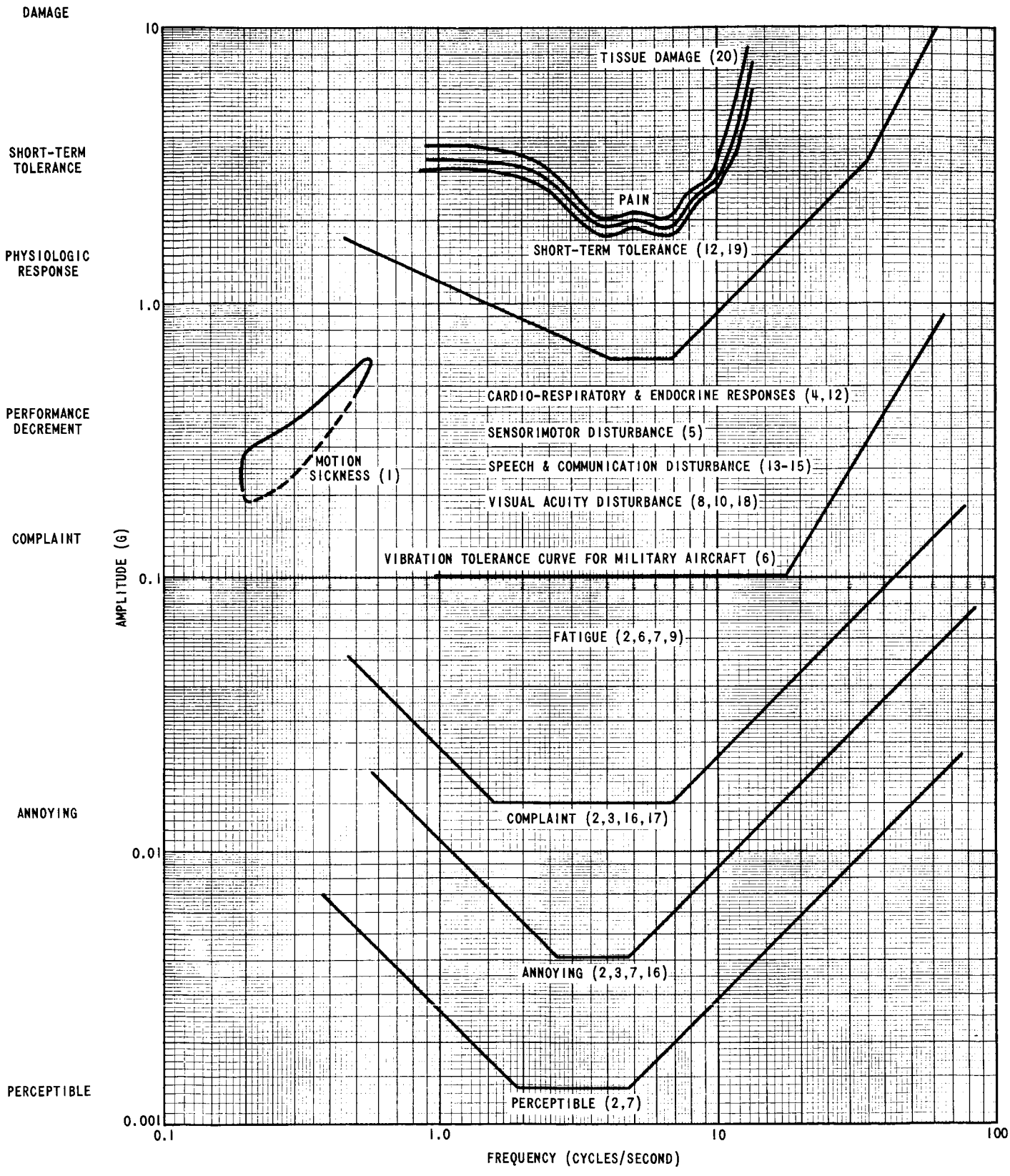


FIGURE 4 - SUMMARY OF TOLERANCE LIMITS TO SINUSOIDAL, WHOLE BODY VIBRATION (ENVIRONMENTAL BIOLOGY, 1966, PP 219-221)

(1) Seated subjects exposed for 20 min or less to vertical sinusoidal motion. (Alexander, S. J., et al. J. Psychol. 20:31, 1945.)
(2) Standing and recumbent subjects exposed for short durations (5 min or less) to vertical and horizontal sinusoidal motion (summary of Reiher-Meister data). (Boiten, G. G., Brit. Roy. Aircraft Estab. Library Transl. 695, 1957)
(3) Standing, seated, and recumbent subjects exposed for short durations (<20 min) to vertical sinusoidal vibration (summary of 10 original studies including Reiher-Meister, Lippert, Wendt, and others). (Burton, E. F., Ride and vibration data. Ed. 2. Riding Comfort Research Committee, Society of Automotive Engineers, New York. pp. 18-27, 1950.)
(4) Recumbent subjects exposed for short durations to vertical sinusoidal motion. (Clark, J. G., et al. Aerospace Med. 36:140, 1965.)
(5) Seated subjects exposed for 10-min periods to vertical sinusoidal motion. (Coermann, R. R., E. B. Magid, and K. O. Lange. Human Factors 4:315, 1962.)
(6) Subjects seated in military aircraft exposed for periods of approx 1 hr to flight-induced vibration, primarily in the vertical direction. (Getline, G. L., U. S. Dept. Defense Shock Vibration Bull. 22 (Suppl.), 1955.)
(7) Standing, seated, and recumbent subjects exposed for periods of 5-20 min to vertical or horizontal vibration (summary averaging of various data from Reiher-Meister and others). (Goldman, D. E., and H. E. von Gierke. Naval Med. Res. Inst. Lecture Rev. Ser. 60-3, 1960.)
(8) Seated subjects exposed for short durations to vertical vibration. (Harris, C. S., and R. W. Shoenberger. AMRL Mem. P-73, 1964.)
(9) Standing and seated subjects exposed for periods of 5 min or less to vertical sinusoidal vibration. (Janeway, R. N., Ride and vibration data. Ed. 2. Riding Comfort Research Committee, Society of Automotive Engineers, New York, pp. 18-27, 1950.)
(10) Seated subjects exposed for periods of approx 1 min to vertical sinusoidal vibration. (Lange, K. O., and R. R. Coermann. Human Factors 4:291, 1962.)
(11) Standing and seated subjects exposed for short durations to vertical or horizontal sinusoidal motion (summary combination of limits from Lippert, Goldman, WADC, and others.) (Linder, G. S., Aerospace Med. 33:939, 1962.)
(12) Seated subjects exposed for periods of 1 min to vertical sinusoidal vibration. (Magid, E. B., R. R. Coermann, and G. H. Ziegenruecker, Ibid. 31:915, 1960.)
(13) Seated subjects exposed for short durations to vertical vibration. (Nixon, C. W., J. Auditory Res. 2:78, 1962.)
(14) Seated subjects exposed for short durations to vertical vibration. (Nixon, C. W., and H. C. Sommer. AMRL-TDR-63-49, 1963.
(15) Recumbent subjects exposed for short durations to vertical and horizontal vibration. (Nixon, C. W., and H. C. Sommer. Aerospace Med. 34:1012, 1963.)
(16) Standing subjects exposed for short durations (<5 min) to vertical sinusoidal motion (summary of Reiher-Meister data). (Notess, C. B. Cornell Aeron. Lab. Mem. FDM-343, 1963.)
(17) Airline passengers exposed for continuous periods of 100 min principally to vertical vibration. (Notess, C. B., and P. C. Gregory. Soc. Automotive Engrs. Paper 679C, 1963.)
(18) Recumbent subjects exposed for periods of 1-2 min to vertical and horizontal vibration. (Taub, H. A. AMRL-TDR-64-70, 1964.)
(19) Recumbent subjects exposed for periods of 1-2 min to vertical and horizontal vibration at increasing amplitude up to the maximum voluntary tolerance. (Temple, W. E., et al. Aerospace Med. 35:923, 1964.)
(20) Vibration limits (general summary). (Von Gierke, H. E. Arch. Environ. Health 11:327, 1965.)

of the standards. Appendix F provides an example of these definitions from the standards on vibration.

3) Methods

This subsection contains descriptions - or references to where descriptions will be found - of the methods required for the interpretation and application of the standards. These are of three general types:

a) Methods which are essential for determination of the relevancy of a particular standard.

This includes the general indexing system described so far in this report, plus an additional submatrix for each section of the standards. This table or submatrix is intended to provide the user with a method for determining more concisely how or what aspects of the human standard is applicable to his particular design situation. For qualitative situations this consists of providing detailed principles or guidelines. For quantitative situations this indicates what parameters are relevant and within what ranges. Table 5 provides an example of one of these submatrices, in this case, the one applicable to the use of vibration standards. From this table it can be seen that the subcategories for vibration, plus other factors relevant to vibration, have been expanded in the row headings. For the column headings the human standards categories have been included which have been demonstrated through research to be affected by vibration. The cell intersections indicate the degree of relationship using the same rating system described in Step 2. The location of the data, in turn, is determined by means of the section numbers in the column and/or row headings.

b) Methods for establishing a human standard.

This includes, for example, the specification of experimental designs or test designs for establishment of an acceptable standard. For many areas primarily in the human performance areas, it is impossible to specify a meaningful standard in this type of data base. Instead, it is necessary to set up a test situation for determining an acceptable level or type of performance.

c) Methods for determining conformance with a standard.

This includes the determination of a "figure-of-merit" or "design index." For example, the computation of an

TABLE 5: EXAMPLE OF A SUBMATRIX FOR RETRIEVAL OF HUMAN STANDARDS (VIBRATION) DATA

				PERFORMANCE EFFECTS					PHYSICAL/PHYSIOLOGICAL EFFECTS		
				VISION	ATTENTION/ CONCENTRATION	REACTION TIME	• • • •	COMPLEX MOTOR PERFORMANCE	SUBJECTIVE RESPONSES	• • • •	RESPIRATION
PHYSICAL PARAMETERS	SINUSOIDAL VIBRATION	VERTICAL (Z BODY AXIS)	WHOLE BODY	3* (SECTION 5.5.3.1.1.1.1.2)	1 (SECTION 5.5.3.1.1.1.1.3)	2			3 (SECTION 5.5.3.1.1.1.2.1)		2 (SECTION 5.5.3.1.1.1.2.2)
			BODY PART	ETC.							
		FORE/AFT (X BODY AXIS)	WHOLE BODY								
			BODY PART								
		LATERAL (Y BODY AXIS)	WHOLE BODY								
			BODY PART								
		OFF-AXIS	WHOLE BODY								
			BODY PART								
	• • • • •										
	NON-PERIODIC VIBRATION (RANDOM)	VERTICAL (Z BODY AXIS)	WHOLE BODY								
			BODY PART								
		FORE/AFT (X BODY AXIS)	WHOLE BODY								
			BODY PART								
		LATERAL (Y BODY AXIS)	WHOLE BODY								
			BODY PART								
		OFF-AXIS	WHOLE BODY								
			BODY PART								

*KEY: ? = RELATIONSHIP NOT DETERMINED

3 = RELATIONSHIP IS CRITICAL TO CONSIDER IN DESIGN, OPERATION, ETC.; THEREFORE, CONSULT SECTION CITED IN COLUMN HEADING

2 = RELATIONSHIP IS IMPORTANT TO CONSIDER

1 = RELATIONSHIP IS DESIRABLE TO CONSIDER

0 = UNRELATED

"articulation index" or "speech interference level" to determine the intelligibility of speech is one figure of merit for assessing the adequacy of verbal communications under the operational conditions expected in a spacecraft.

4) Standards

This subsection contains the detailed data on which the summary standards are based and should be consulted by the user if the summary standards do not provide him with sufficient guidance. Figure 5, 6, 7, and 8 illustrate how these standards data are presented.

From these figures it can be seen that the organization of the standards data within each section follows the same basic pattern.[1]

a) Baseline data in the anthropometric, physiological or psychological category; e.g., the "normal" hearing capability of the astronaut population under standard or specified conditions of measurement.

b) Effects of personal variables or individual differences on the enhancement or reduction of the requirements or capabilities; e.g., effects of conditioning, fatigue, or training, etc.

c) Effects of environment on reducing or increasing requirements and capabilities from these baselines; e.g., reduction of speech intelligibility from masking by noise; or increases in oxygen consumption with increases in activity level, etc.

d) Effects of procedures on reducing or increasing the requirement or capability; e.g., changes in vocabularies to increase intelligibility, or reduction of workload or changes in pressure suit design to reduce oxygen requirements, etc.

e) Effects of equipment on enhancing or degrading the requirement or capability; e.g., reduction of ambient noise by use of ear plugs, or use of intercommunication equipment to increase intelligibility.

The results of combining these variables is to provide an indication of the actual (or observed) requirements and capabilities of the astronaut under operational conditions. By

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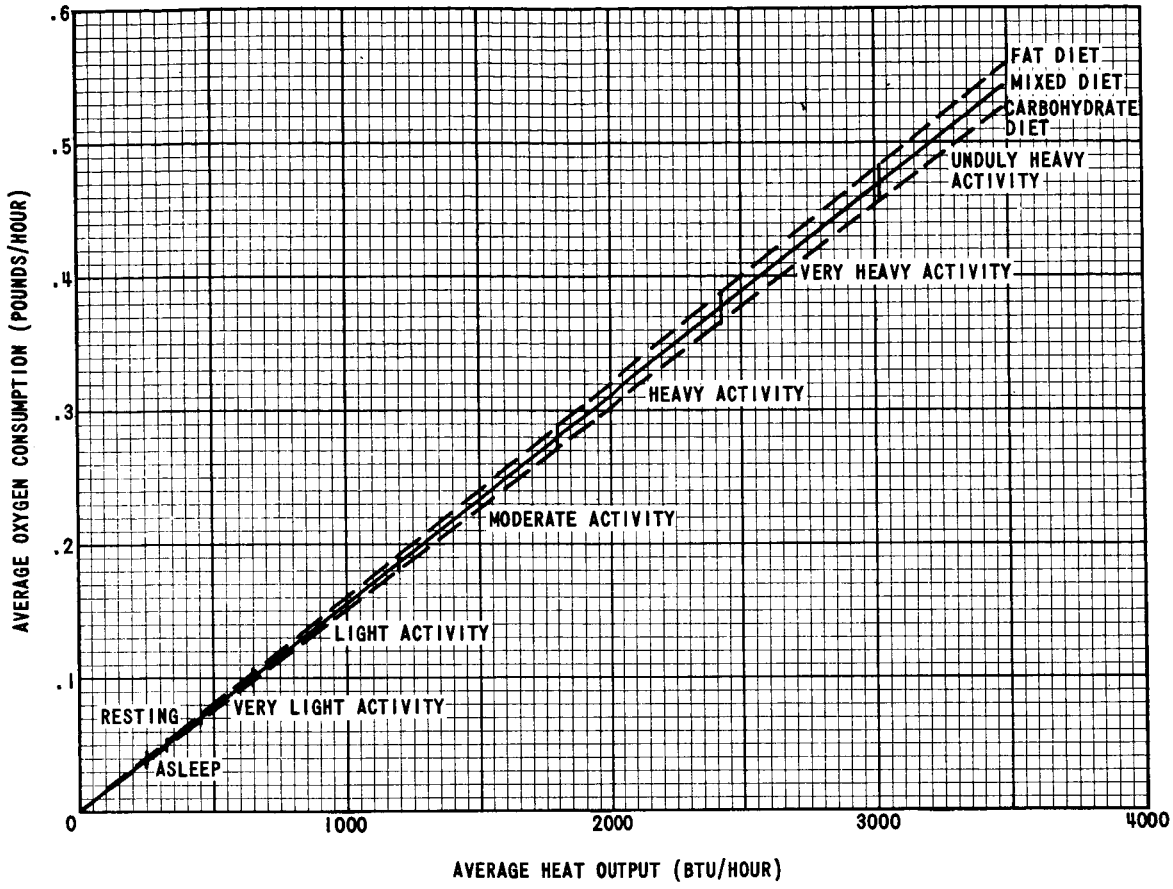
[1]Environmental standards follow a somewhat different pattern since they begin with physical rather than human parameters.



DEFINITIONS

ASLEEF (0.04 TO 0.05 LB O_2/HR)

RESTING (0.05 TO 0.07 LB O_2/HR) - RANGES FROM LYING FULLY RELAXED TO SITTING AT REST

VERY LIGHT ACTIVITY (BELOW 0.10 LB O_2/HR) - SEATED OR STANDING; E.G., WRITING, TAKING LECTURE NOTES

LIGHT ACTIVITY (0.10 TO 0.19 LB O_2/HR) - SEATED OR MOVING; E.G., PLAYING MUSICAL INSTRUMENTS, SLOW WALKING

MODERATE ACTIVITY (0.19 TO 0.28 LB O_2/HR) - LYING OR MOVING; E.G., CRAWLING, ARMY DRILL

HEAVY ACTIVITY (0.28 TO 0.38 LB O_2/HR) - LYING OR MOVING; E.G. SWIMMING, CLIMBING STAIRS (116 STEPS/MIN)

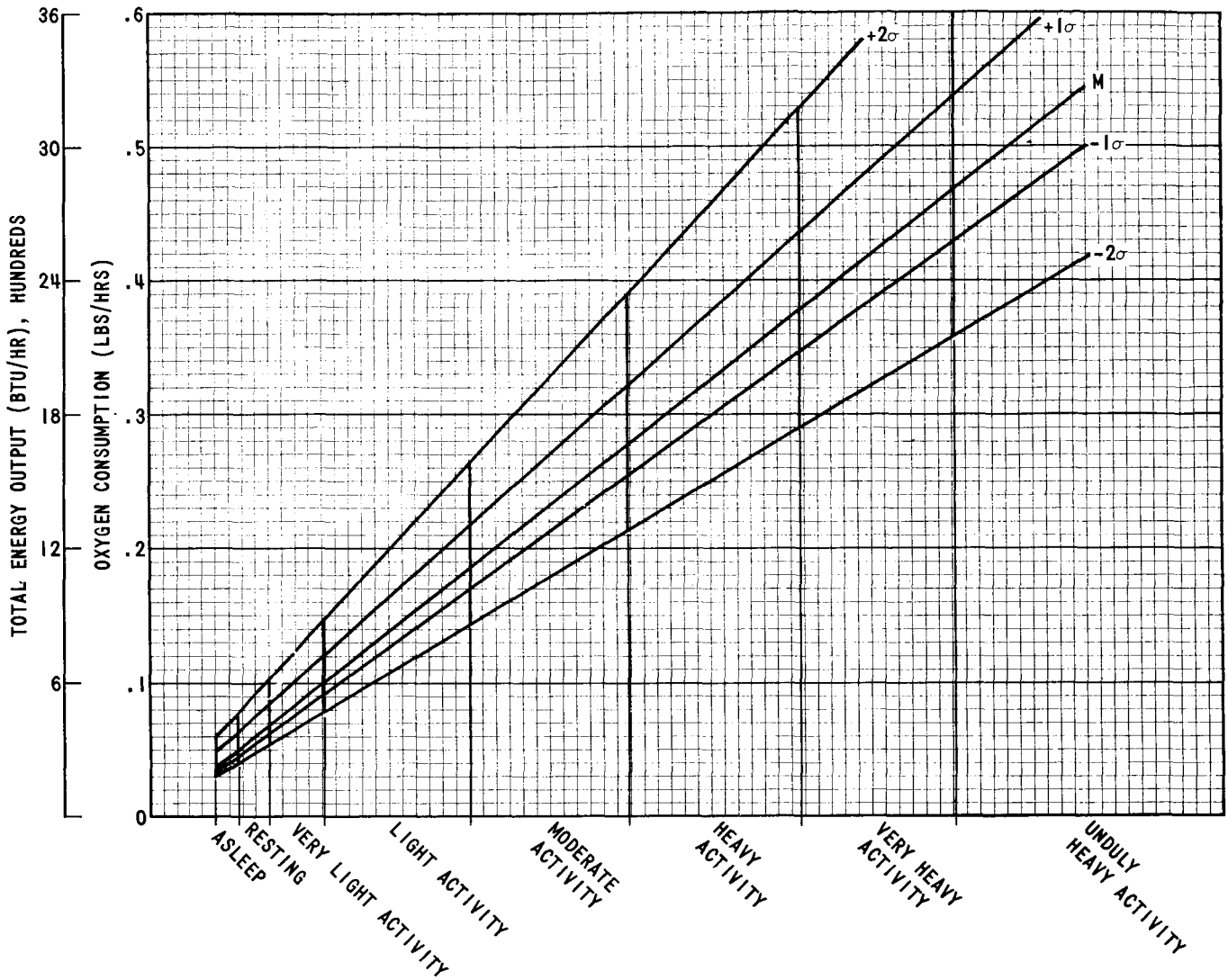
VERY HEAVY ACTIVITY (0.38 TO 0.47 LB O_2/HR) - SITTING OR MOVING; E.G., CYCLING (13.2 MPH), CLIMBING STAIRS (___ STEPS/MIN)

UNDULY HEAVY ACTIVITY (OVER 0.47 LB O_2/HR) - E.G., WRESTLING, HARVARD STEP TEST

CONSTRAINTS AND ASSUMPTIONS

1. THE VALUES ARE ADJUSTED FOR A MAN 69" TALL AND WEIGHING 167# (AVERAGE VALUES FOR MERCURY ASTRONAUTS)
2. FOR LARGE ASTRONAUTS VALUES SHOULD BE INCREASED BY 7.5% FOR SMALL ASTRONAUTS, DECREASED BY 6%.
3. VALUES ARE APPROXIMATE, SINCE THERE CAN BE AS MUCH AS 30% VARIATION BETWEEN MEN PERFORMING THE SAME TASK, WITH CORRECTION FOR BODYWEIGHT; ALSO THERE MAY BE AS MUCH AS 10 TO 15% VARIATION WHEN REPEATED MEASUREMENTS ARE TAKEN ON THE SAME PERSON.
4. HIGHER CONSUMPTION RATES CAN MAINTAINED FOR LIMITED PERIODS OF TIME (SEE FIGURE___)

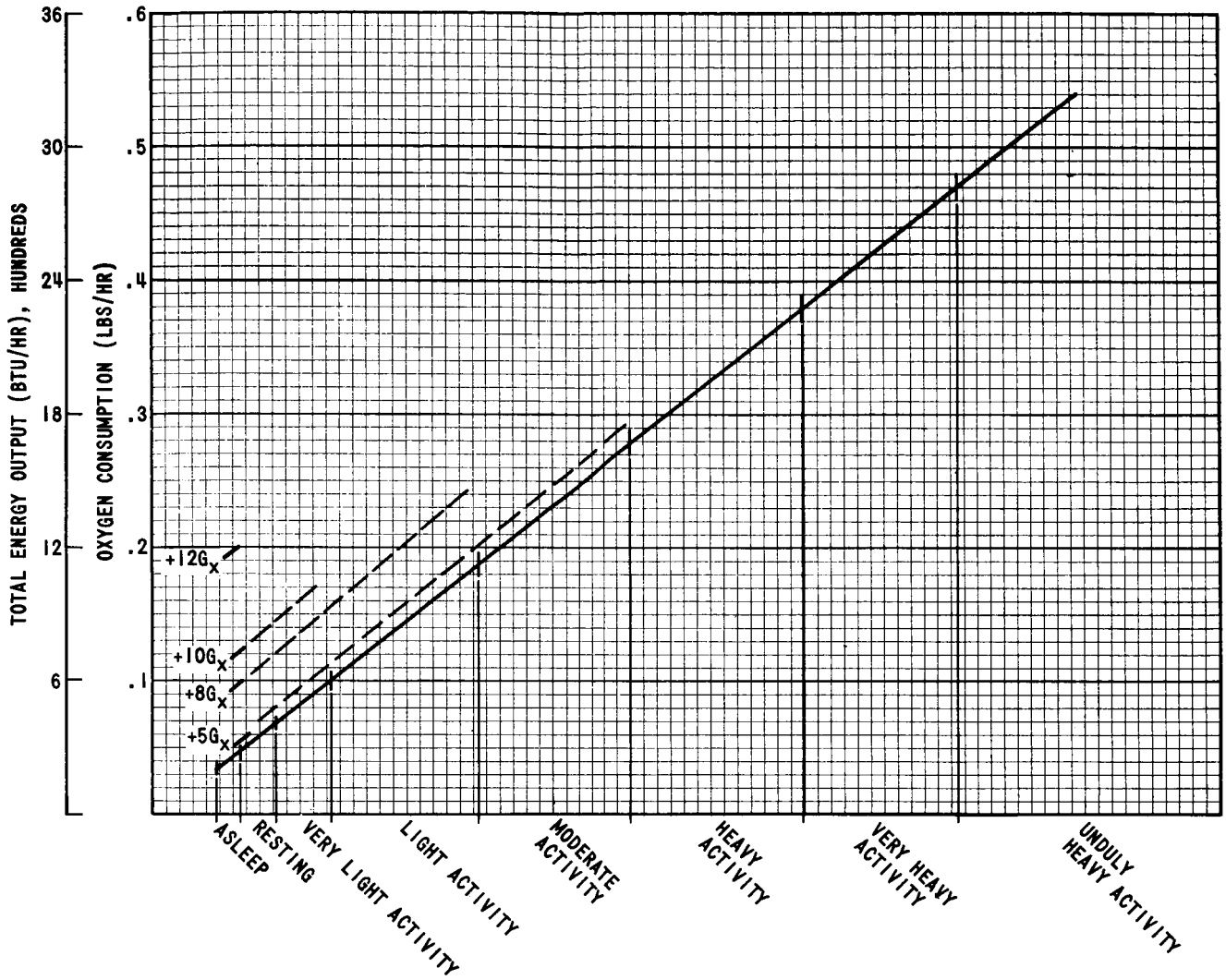
FIGURE 5: OXYGEN REQUIREMENTS AS A FUNCTION OF ACTIVITY LEVEL (BASED ON BIOASTRONAUTICS DATA BOOK, 1964, PP 173-175)



ASSUMPTIONS AND CONSTRAINTS

(WOULD BE SPELLED OUT IN COMPLETED STANDARDS)

FIGURE 6: OXYGEN CONSUMPTION AS A FUNCTION OF BODY WEIGHT (FIGURE NOT SCALED)



ASSUMPTIONS AND CONSTRAINTS

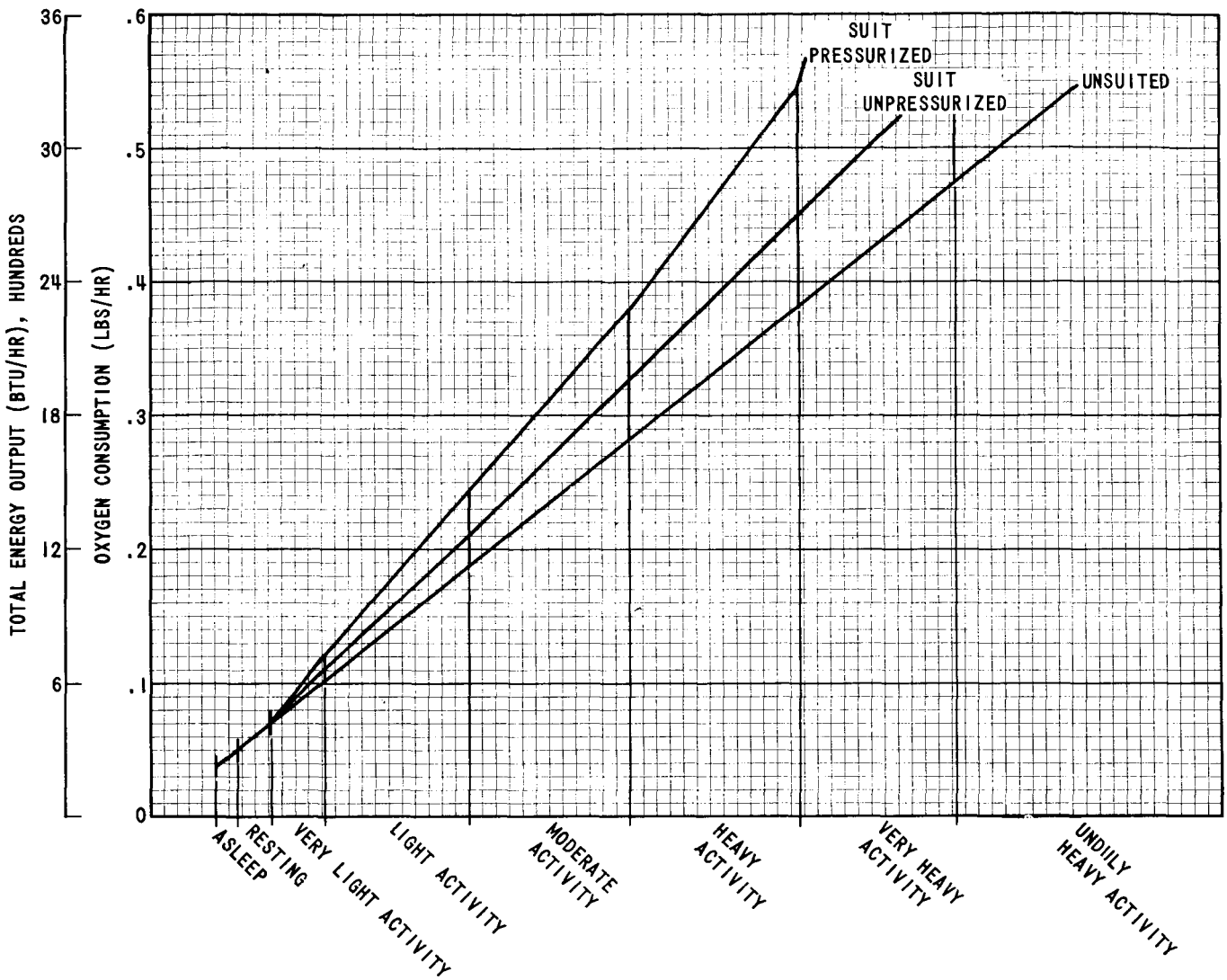
CONDITIONS

1. FORWARD ACCELERATION ($+G_x$), BUILT UP AT THE RATE OF 1 G/SEC.
2. THE G LEVEL WAS HELD FOR 1 - 2 MINUTES WHILE OXYGEN UPTAKE WAS DETERMINED.
3. THE CLEAR PORTION OF EACH BAR INDICATES CONTROL OXYGEN CONSUMPTION; THE SHADED AREAS SHOW THE ADDITIONAL OXYGEN CONSUMPTION FOR 1 MINUTE OF G.

NOTE:

O_2 CONSUMPTION FOR SEVERAL LEVELS OF ACTIVITY SHOULD BE DETERMINED IN ORDER TO COMPLETE CHARTS SUCH AS THIS. (BROKEN LINES INDICATE THAT HIGHER ACTIVITY LEVELS CANNOT BE REACHED UNDER HIGH G LOADS)

FIGURE 7: OXYGEN CONSUMPTION AS A FUNCTION OF ACCELERATION FORCES (FIGURE NOT SCALED)



ASSUMPTIONS AND CONSTRAINTS
(WOULD BE SPELLED OUT IN COMPLETED STANDARDS)

FIGURE 8: OXYGEN CONSUMPTION AS A FUNCTION OF PRESSURE SUITS (FIGURE NOT SCALED)

making explicit the major variables that are involved the designer is provided with more degrees of freedom in the design and operation of the spacecraft and crew systems.

5) References

This subsection contains references to sources of explanatory or supporting material for the standards.

Step 4: Utilization of the Human Standards

If the human standards provide the user with the information he requires, then the process becomes one of applying them until he is assured that the design or operation of the system is within acceptable boundaries for the use, support, and protection of man.

Step 5: Determination of Relevant Applications Standards

If, however, the user still does not have the information he requires, or in a form which is useful to him, he should consult Table 6 to locate the relevant applications standards data.[1] In this case the row headings consist of the applications standards categories. That is, life support engineering, human engineering, procedures development and documentation, personnel selection and training, and crew composition standards categories. As before, the five-point rating scale indicates the significance of the relationship. It should be noted that this table can be entered from either the rows or columns. If, for example, the user is interested in the design of an environmental control system, he can consult the table to determine what human standards categories are significant. If the user is a life scientist, he may wish to enter the column headings to determine the human standards categories that must be considered in the support of man in the space environment, and then, in turn, relate this to the design factors.

Step 6: Utilization of the Applications Standards

Although the content of the applications standards is somewhat different than the human standards, the overall format and content in each section is similar. Therefore, these will not be elaborated on in this report. Two examples of summary standards of this type are presented in Figure 9 and Table 7.

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[1]An outline of the applications standards categories developed in this project to date are contained in Appendix E.

TABLE 6a: DETERMINATION OF RELATIONSHIP BETWEEN HUMAN STANDARDS CATEGORIES AND APPLICATIONS STANDARDS CATEGORIES

			PART 1: ANTHROPOMETRIC STANDARDS				PART 2: PHYSIOLOGICAL STANDARDS					PART 3: PSYCHOLOGICAL STANDARDS					PART 4: ENVIRONMENTAL STANDARDS				
			SECTION 1.1: DIMENSIONS OF THE HEAD, BODY & LIMBS	SECTION 1.2: MOVEMENT OF THE HEAD, BODY, & LIMBS	••••	SECTION 1.N	SECTION 2.1: FUNCTIONS OF THE RESPIRATORY SYSTEM	SECTION 2.2: FUNCTIONS OF THE DIGESTIVE SYSTEM	SECTION 2.3: MAINTENANCE OF METABOLIC BALANCE	••••	SECTION 2.N	SECTION 3.1: FUNCTIONS OF THE VISUAL SENSE	SECTION 3.2: FUNCTIONS OF THE AUDITORY SENSE	SECTION 3.3: FUNCTIONS OF KINESTHETIC & VESTIBULAR SENSES	••••	SECTION 3.N	SECTION 4.1: EFFECTS OF THE ATMOSPHERE	SECTION 4.2: EFFECTS OF CONTAMINANTS/TOXICANTS	SECTION 4.3: EFFECTS OF ACCELERATION	••••	SECTION 4.N
PART 5: LIFE SUPPORT ENGINEERING STANDARDS	SECTION 5.1: SUITS/PORTABLE LIFE SUPPORT SYSTEMS	SECTION 5.1.1: CLOTHING	0*	0			1	1	3			1	1	2			3	1	1		
		SECTION 5.1.2: PRESSURE SUITS	0	0			3	3	3			3	3	2			3	2	3		
		SECTION 5.1.3: ANTI-EXPOSURE SUITS	0	0			3	1	3			1	1	2			3	3	3		
		• • • •																			
		SECTION 5.1.N:																			
	• • • •																				
	SECTION 5.3: ENVIRONMENTAL CONTROL SYSTEMS	SECTION 5.3.1: PRESSURE	0	0			0	0	3			0	0	0			3	1	1		
		SECTION 5.3.2: COMPOSITION	0	0			3	0	3			0	0	0			3	3	1		
		SECTION 5.3.3: TEMPERATURE/HUMIDITY	0	0			3	0	3			0	0	0			3	1	1		
		• • • •																			
		SECTION 5.3.N:																			
	• • • •																				
	SECTION 5.N																				

*KEY: ? = RELATIONSHIP IS NOT DETERMINED
3 = RELATIONSHIP IS CRITICAL TO CONSIDER
2 = RELATIONSHIP IS IMPORTANT TO CONSIDER
1 = RELATIONSHIP IS DESIRABLE TO CONSIDER
0 = UNRELATED

TABLE 6b: DETERMINATION OF RELATIONSHIP BETWEEN HUMAN STANDARDS CATEGORIES AND APPLICATIONS STANDARDS CATEGORIES

			PART 1: ANTHROPOMETRIC STANDARDS				PART 2: PHYSIOLOGICAL STANDARDS					PART 3: PSYCHOLOGICAL STANDARDS					PART 4: ENVIRONMENTAL STANDARDS				
			SECTION 1.1: DIMENSIONS OF THE HEAD, BODY & LIMBS	SECTION 1.2: MOVEMENT OF THE HEAD, BODY, & LIMBS	••••	SECTION 1.N	SECTION 2.1: FUNCTIONS OF THE RESPIRATORY SYSTEM	SECTION 2.2: FUNCTIONS OF THE DIGESTIVE SYSTEM	SECTION 2.3: MAINTENANCE OF METABOLIC BALANCE	••••	SECTION 2.N	SECTION 3.1: FUNCTIONS OF THE VISUAL SENSE	SECTION 3.2: FUNCTIONS OF THE AUDITORY SENSE	SECTION 3.3: FUNCTIONS OF KIN-ESTHETIC & VESTIBULAR SENSES	••••	SECTION 3.N	SECTION 4.1: EFFECTS OF THE ATMOSPHERE	SECTION 4.2: EFFECTS OF CONTAMINANTS/TOXICANTS	SECTION 4.3: EFFECTS OF ACCELERATION	••••	SECTION 4.N
PART 6: HUMAN ENGINEERING STANDARDS	SECTION 6.1: SUITS/PORTABLE EQUIPMENT	SECTION 6.1.1: CLOTHING	3*	3			0	0	0			2	2	1			0	0	0		
		SECTION 6.1.2: PRESSURE SUITS	3	3			1	1	0			3	3	2			0	0	0		
		SECTION 6.1.3: HELMETS/VISORS	3	3			0	0	0			3	3	1			0	0	0		
		•••																			
		SECTION 6.1.N:																			
	SECTION 6.2: OPERATIONAL EQUIPMENT	SECTION 6.2.1: SEATS	3	3			0	0				0	0	2			0	0	0		
		SECTION 6.2.2: DISPLAY/CONTROL PANELS	3	3			0	0				3	3	2			0	0	3		
		SECTION 6.2.3: DISPLAYS	1	1			0	0				3	3	1			0	0	3		
		•••																			
		SECTION 6.2.N:																			
	•••																				
	SECTION 6.N																				

*KEY: ? = RELATIONSHIP IS NOT DETERMINED
3 = RELATIONSHIP IS CRITICAL TO CONSIDER
2 = RELATIONSHIP IS IMPORTANT TO CONSIDER
1 = RELATIONSHIP IS DESIRABLE TO CONSIDER
0 = UNRELATED

TABLE 6c: DETERMINATION OF RELATIONSHIP BETWEEN HUMAN STANDARDS CATEGORIES AND APPLICATIONS STANDARDS CATEGORIES

			PART 1: ANTHROPOMETRIC STANDARDS				PART 2: PHYSIOLOGICAL STANDARDS					PART 3: PSYCHOLOGICAL STANDARDS					PART 4: ENVIRONMENTAL STANDARDS				
			SECTION 1.1: DIMENSIONS OF THE HEAD, BODY & LIMBS	SECTION 1.2: MOVEMENT OF THE HEAD, BODY, & LIMBS	••••	SECTION 1.N	SECTION 2.1: FUNCTIONS OF THE RESPIRATORY SYSTEM	SECTION 2.2: FUNCTIONS OF THE DIGESTIVE SYSTEM	SECTION 2.3: MAINTENANCE OF METABOLIC BALANCE	••••	SECTION 2.N	SECTION 3.1: FUNCTIONS OF THE VISUAL SENSE	SECTION 3.2: FUNCTIONS OF THE AUDITORY SENSE	SECTION 3.3: FUNCTIONS OF KINESTHETIC & VESTIBULAR SENSES	••••	SECTION 3.N	SECTION 4.1: EFFECTS OF THE ATMOSPHERE	SECTION 4.2: EFFECTS OF CONTAMINANTS/TOXICANTS	SECTION 4.3: EFFECTS OF ACCELERATION	••••	SECTION 4.N
PART 7: PROCEDURES DEVELOPMENT & DOCUMENTATION STANDARDS	SECTION 7.1: OPERATIONAL PROCEDURES & INSTRUCTIONS	SECTION 7.1.1: PROCEDURES	1*	1			1	1	3			2	1	1			1	3	3		
		SECTION 7.1.2: INSTRUCTIONS	1	1			1	1	3			3	1	1			1	3	3		
		⋮																			
		SECTION 7.1.N:																			
	⋮																				
	SECTION 7.N																				
PART 8: PERSONNEL SELECTION & TRAINING STANDARDS	SECTION 8.1: SELECTION	SECTION 8.1.1: PHYSICAL	3	3			3	3	3			3	3	2			3	2	3		
		SECTION 8.1.2: EDUCATIONAL	0	0			0	0	0			0	0	0			0	0	0		
		⋮																			
		SECTION 8.1.N:																			
	⋮																				
	SECTION 8.N																				
PART 9: CREW COMPOSITION STANDARDS	SECTION 9.1: NUMBERS & TYPES OF PERSONNEL	SECTION 9.1.1: NUMBERS	3	3			0	0	0			2	1	0			0	0	0		
		SECTION 9.1.2: TYPES	0	0			0	0	?			0	0	0			0	?	0		
		⋮																			
		SECTION 9.1.N:																			
	⋮																				
	SECTION 9.N																				

*KEY: ? = RELATIONSHIP IS NOT DETERMINED

3 = RELATIONSHIP IS CRITICAL TO CONSIDER

2 = RELATIONSHIP IS IMPORTANT TO CONSIDER

1 = RELATIONSHIP IS DESIRABLE TO CONSIDER

0 = UNRELATED

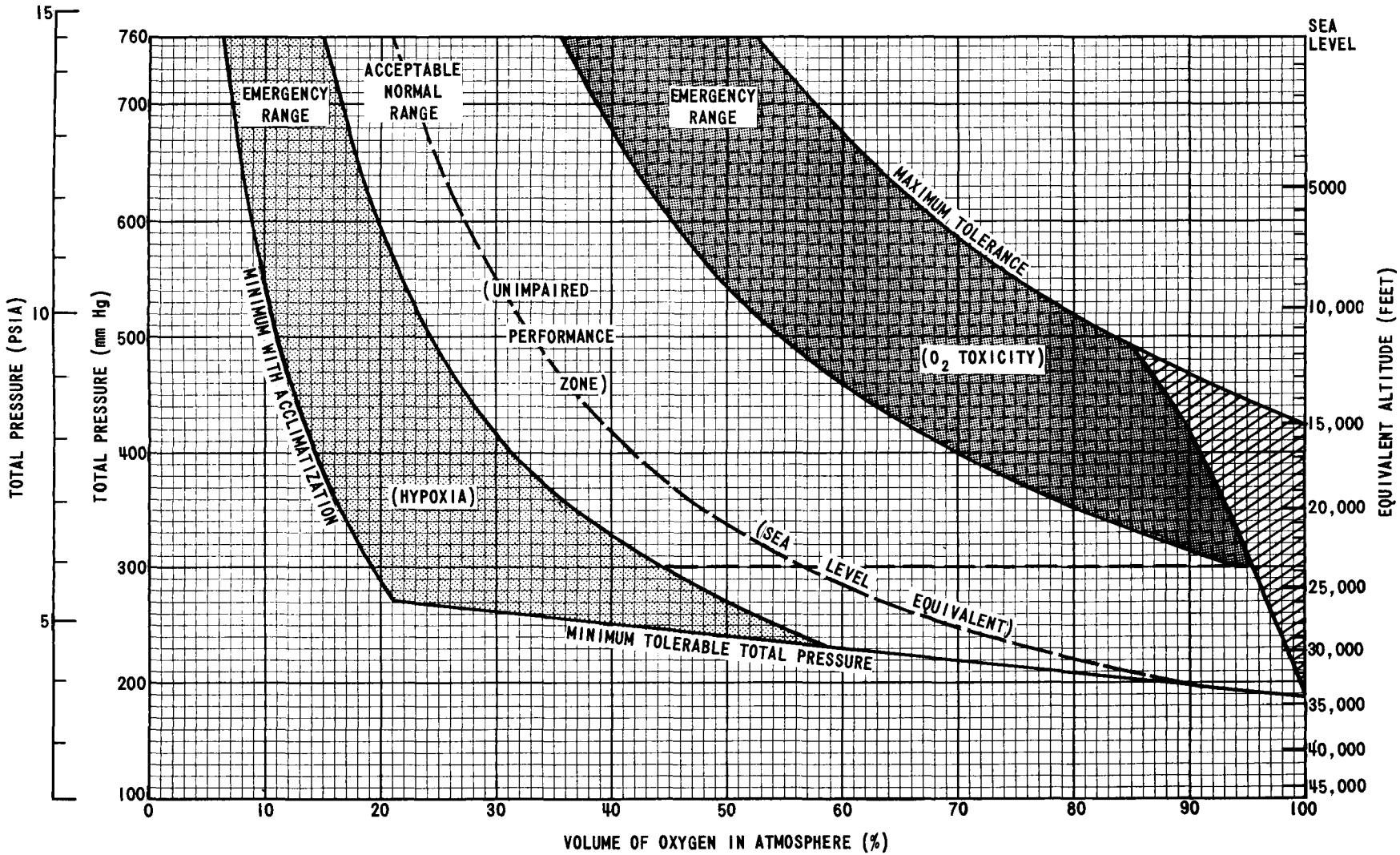

FIGURE 9: CRITERIA FOR THE DESIGN OF ENVIRONMENTAL CONTROL SYSTEMS (PARTIAL PRESSURE OF OXYGEN)
(BASED ON BIOASTRONAUTICS DATA BOOK, 1964, P 5)

TABLE 7 : CRITERIA FOR THE DESIGN OF SPACECRAFT CONTROLS[1]

	DIMENSIONS	DISPLACEMENT	RESISTANCE	●●●●●	OTHERS
1. PUSHBUTTON 1.1 ROUND	MINIMUM DIAMETER, FINGERTIP OPERATION: .5 INCHES[2] MINIMUM DIAMETER, EMERGENCY CONTROL: .75 INCHES MAXIMUM DIAMETER: NONE	MINIMUM: 1/8 INCH MAXIMUM FOR THUMB OR FINGERTIP OPERATION: 1-1/2 INCH	MINIMUM FOR FINGERTIP OPERATION: 10 OUNCES MAXIMUM FOR FINGERTIP OPERATION: 40 OUNCES		
1.2 RECTANGULAR (SWITCH LIGHT)	LEGEND AREA: 1.0 x 0.75 INCHES FINGERTIP CONTROL: 0.960 x 0.740 INCHES				
2. TOGGLE SWITCHES	MINIMUM CONTROL TIP DIAMETER 1/8 INCH MAXIMUM CONTROL TIP DIAMETER: 1 INCH MINIMUM LEVEL ARM LENGTH: 1/2 INCH MAXIMUM LEVER ARM LENGTH: 2 INCHES	MINIMUM (BETWEEN ADJACENT CONTROL POSITIONS): 30° MAXIMUM (TOTAL DISPLACEMENT): 120°	MINIMUM: 10 INCH OUNCES MAXIMUM: 40 INCH OUNCES		
3. KNOBS 3.1 ROUND	MAXIMUM DEPTH (GRASPING SURFACE): 7/8 INCH MINIMUM DEPTH (GRASPING SURFACE): 3/4 INCH MAXIMUM DIAMETER: 1-3/4 INCHES MINIMUM DIAMETER: 7/8 INCH		MAXIMUM FOR FINGERTIP OPERATION WITH SMALL KNOB. (.928" DIA.): 4.5 INCH/OUNCES MAXIMUM FOR FINGERTIP OPERATION WITH LARGE KNOBS. (1.772" DIA. KNOB): 6 INCH/OUNCES		
3.2 POINTER (TEAR DROP)	DEPTH (GRASPING SURFACE): 5/8 INCH DIAMETER (AT LARGEST POINT): 3/4 INCH		MINIMUM: 2 OUNCES MAXIMUM: 36 OUNCES		
3.3 POINTER (BAR-TYPE)	DEPTH (GRASPING SURFACE): 3/4 INCH LENGTH & WIDTH: 2-1/2 INCH x 3/4 INCH		MINIMUM: 37 OUNCES MAXIMUM: 48 OUNCES		
3.4 ROTARY DETENT SWITCHES	(SAME AS FOR ROUND KNOBS)	MAXIMUM DISPLACEMENT (BETWEEN ADJACENT DETENTS) FOR FACILITATION OF OPERATOR PERFORMANCE: 40° MAXIMUM DISPLACEMENT (BETWEEN ADJACENT DETENTS) WHEN SPECIAL ENGINEERING REQUIREMENTS DEMAND LARGE SEPARATION: 90° MINIMUM DISPLACEMENT (BETWEEN ADJACENT DETENTS FOR VISUAL POSITIONING: 15° (NON-VISUAL POSITIONING IS NOT RECOMMENDED.)			
4. HAND WHEELS (FOUR SPOKE/ NO RIM)	MINIMUM DIAMETER: 3 INCHES MAXIMUM DIAMETER: 1 INCH DIAMETER DEPENDENT UPON VALVE TORQUE THAT MUST BE OVERCOME				
5. CRANKS	MINIMUM RADIUS: 1/2 INCH MAXIMUM RADIUS (HEAVY LOAD): 20 INCHES MAXIMUM RADIUS (MINIMUM LOAD AND HIGH RATE UP TO 275 RPM): 4-1/2 INCHES	DISPLACEMENT SHOULD BE DETERMINED BY THE CONTROL-DISPLAY RATIO	RESISTANCE MEASURED AT THE GRIP WILL DEPEND ON THE SIZE OF THE CRANK AND SPEED OF OPERATION		
6. LEVERS	LENGTH SHOULD BE DETERMINED BY THE MECHANICAL ADVANTAGE WHICH IS NEEDED MINIMUM DIAMETER, FINGER GRASP: 1/2 INCH MINIMUM DIAMETER, HAND GRASP: 1-1/2 INCHES MAXIMUM DIAMETER: 3 INCHES	MINIMUM: NO MINIMUM ESTABLISHED: (PRESSURE CONTROLS WILL, OF COURSE, HAVE NO DISPLACEMENT, BUT USUALLY CANNOT BE USED FOR SETTING AND HOLDING.) MAXIMUM: FORE-AFT MOVEMENT: 14 INCHES MAXIMUM; LATERAL MOVEMENT: 38 INCHES	MINIMUM; LEVER HANDLE GRASPED BY HAND (RATHER THAN FINGER): 2 LBS. AIRCRAFT JOYSTICK: 5 LBS. MAXIMUM: (SEE TEXT, PAGE ___)		
7. PEDALS	MINIMUM: 1 BY 3 INCHES MAXIMUM: DETERMINED BY SPACE AVAILABLE & DANGER OF ACCIDENTAL ACTIVATION. SHOULD BE AT LEAST LARGE ENOUGH SO THAT THE ENTIRE WIDTH OF THE FOOT CAN REST ON IT & APPLY FORCE TO IT.	MINIMUM DISPLACEMENT, NORMAL: 1/2 INCH MINIMUM DISPLACEMENT, HEAVY BOOTS: 1 INCH MAXIMUM DISPLACEMENT, ANKLE FLEXION ONLY: 2-1/2 INCHES MAXIMUM DISPLACEMENT, LEG MOVEMENT: 7 INCHES	MINIMUM RESISTANCE, FOOT WILL NOT REST ON CONTROL: 4 LBS. MINIMUM RESISTANCE, FOOT MAY REST ON CONTROL: 10 LBS MAXIMUM RESISTANCE, ANKLE FLEXION ONLY: 20 LBS. MAXIMUM RESISTANCE, LEG MOVEMENT: 160 LBS.		

1. BASED ON CRITERIA USED BY GRUMMAN TO DESIGN THE APOLLO LUNAR MODULE.

2. PARANTHETICAL COMMENTS WILL REFER TO TEXT WHICH INDICATES ANY QUALIFICATION (e.g. WITH OR WITHOUT GLOVES) TO THE CRITERIA GIVEN IN THIS TABLE. ALSO REFERENCES TO RESEARCH LITERATURE WILL BE INDICATED IN THE TEXT.

Development of Human Standards for Manned Space Flight; Problems to be Resolved

Development of the data base described in the preceding section is an extensive undertaking which will require considerable resources to implement. However, it is believed that there is sufficient justification for the undertaking, and that it can be successful if it is implemented on an incremental basis utilizing an efficient schedule and sufficient manpower. At least portions of it can become a significant tool for the design of manned space flight systems in the relatively near future. There are, however, many problems which should be resolved along the way. These include:

a) What areas should be covered by the standards, both from the standpoint of the topics to be included and the types of systems and facilities to which they should be applicable?

b) How should the standards be formatted and indexed?

c) What type of system is required for the collection, processing, and dissemination of the standards?

d) What types of incremental approaches are feasible for the development of the standards?

e) To what extent should the handling of the standards be computerized?

f) How should the human standards data and data handling be integrated with other efforts within NASA and DOD, both those directly related to human factors and those concerned with system design in general?

g) Who should be made responsible for the collection, processing, and dissemination of the standards?

Resolution of the more immediate of these would provide the basis for development of an approach plan to ensure orderly completion of the project which has its beginnings in the efforts described earlier in this report. Figure 10 illustrates a proposed approach to the continuation of this project, and will be used as the basis for discussing each of the problems.

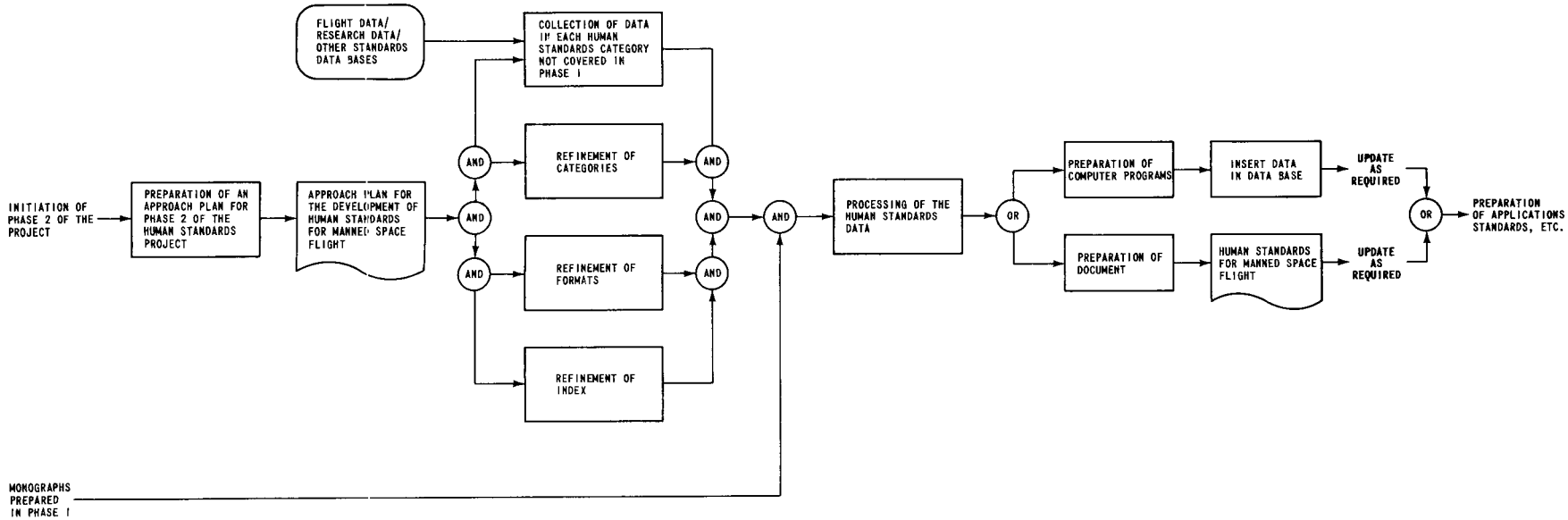

FIGURE 10: PROPOSED APPROACH TO PHASE 2 OF THE HUMAN STANDARDS PROJECT

Coverage of the Standards

The standards to be developed have already been implied in the preceding sections of this report; i.e., both human standards and applications standards, as they have been defined here, should be developed. Availability of standards in both of these is required to insure complete coverage of the considerations about the use, support, and protection of man in manned space flight systems.[1]

The problem with respect to coverage, however, is primarily one of determining the classes of systems and equipments to which these standards should be applicable. As has already been indicated, this project to date has confined itself to the development of standards which apply specifically to spacecraft flight crews. This undoubtedly would serve an important need and one in which there is considerable interest at the present time. However, it would be inefficient to restrict the standards to this population since much of the data is required for, and applicable to, other man-machine systems.

Historically, much of the standards data in use in the space program originated in response to the requirements for standards in military systems. Other standards, or data from which standards can be developed, have originated recently from manned space flight and are unique to that environment. The latter, however, does not constitute a large portion of the existing or required standards data.

Therefore, it is recommended that the future course of this project be directed along the following lines:

1) With respect to the content of the standards, attention should be given first to the development of human standards in all of the categories that are relevant to the use, support, and protection of flight crew personnel.

2) These human standards should be rapidly transformed into applications standards, as defined in this report, in the areas where this is meaningful and feasible.

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[1]See Tables 1 and 2 and Appendices D and E for a review of the categories within these two major groupings of the standards.

3) As the usefulness of the standards under discussion is demonstrated, consideration should be given to their generalization or broadening to apply to the design of other man-machine systems and facilities within NASA. These other systems and facilities include control centers, booster vehicles and their associated checkout and handling equipment, and launch facilities.[1]

This approach is proposed for two reasons: a) it represents an approach which could be expected to result in usable standards for some areas in a relatively short period of time and would require considerably less resources to implement than the entire proposed effort; and b) based on the premise that virtually all standards categories are involved in manned space flight programs, it would be relatively easy to extend the standards developed for these programs to include other systems and facilities.

Formatting and Indexing the Standards

The format and index for the standards has been implied in the preceding sections of the report in the example given for the utilization of the standards data base.[2] However, this is only a first approximation and will require refinement and testing before its usefulness is demonstrated.

Therefore, the following recommendations are offered:

1) The descriptors for crew performance require considerable

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[1]This should be coordinated with the efforts already undertaken by MSFC in the development of MSFC-STD-267A, Human Engineering Design Criteria, January 31, 1966. This document contains a large amount of the type of data being discussed in this report. This should be used as a basis for the further development and updating of the portion of the data base that is unique to booster vehicles and their associated equipment and facilities, and more importantly, for determining the extent to which the data is the same as that required for spacecraft design.

[2]See pages 27 to 54.

refinement to insure their usefulness. This includes:

a) Development of definitions for each descriptor.

b) Development of a dictionary of synonyms of equivalent descriptors. One set of descriptors is sufficient for the data base; however, there are many terms used to describe human performance, for example, and some means is required for determining equivalence and translating them into the terminology of the standards data base.

c) Reduction in the overlap between descriptors and at the same time, introduction of others to insure comprehensiveness. This is expected to be an evolutionary process and therefore, adjustments in the list will have to be made from time to time. This does not preclude the development of an initial set of descriptors that are usable; it does mean, however, considerable improvement in the initial set will still be required.

2) There is overlap between the standards categories and a continuing effort will be required to reduce this overlap but at the same time, not to reduce it to the point where the data retrieved is so fractionated that it is unusable.

3) There is a continuing need for increasing the precision of the standards to minimize their ambiguity. Much, but not all, of this problem centers about quantification of the standards. Some standards are simply statements of principles or guidelines, but for those where quantification is meaningful, attempts should be made to express these standards in a common set of units and scales which most easily permit their application to the design situation. Where this is not feasible, conversion factors should be provided, usually by means of tables, formulas, or nomographs.

4) There is a continuing need to develop techniques for handling the interactions between variables. The matrices provided in this report are largely confined to first order interactions, although some second order interactions can be inferred by comparing tables which have a common set of row or column entries. Additional schemes will have to be developed to show the more complex interactions. For example, the effects on body functioning and performance by combined environmental stresses, or the effects of environments on physiological functioning which in turn affect performance, etc., are not necessarily discernible in the scheme presented in this report. (More will be said about this in the discussion of computerization of standards.)

Processing of the Standards

The acquisition and utilization of data in all aspects of system design is a dynamic process. Both the data and the data handling techniques will require frequent updating--at least in some areas. Figure 11 illustrates the elements that are required within a system for the handling of this type of data. This figure simply indicates that data must get into the system, be processed appropriately, and be made available to the users, on a timely basis. It also provides provisions for control of the process (i.e., the steering committee, technical review/processing functions, etc.) and feedback loops for adjusting the content and format of the data base as required.

It is recommended that the NASA organization be reviewed to determine:

1) The most appropriate type of communications network that would permit the orderly and timely flow of human standards data from the generators, through the processors, to the users. This includes identification of the users or potential users of the standards as a group and providing them with a means for accessing the standards data base in a systematic manner. It also means identification of the generators or potential sources of standards and providing them with a means for insuring that their data find their way into the system.

2) The type of processing facility which should be set up to handle the formatting, indexing, storage, and retrieval of the standards. Ideally, this should utilize existing NASA facilities to the maximum extent possible.

Incremental Development of the Standards

Since extensive resources would be required to implement the entire standards project at one time, it is improbable that such a course will be feasible, or for that matter, desirable. It is important first to demonstrate the feasibility of the approach suggested in this report. To do this does not require undertaking all areas simultaneously.

Therefore, the following recommendations are offered for implementation of the project:

1) The development of the human standards, as they have

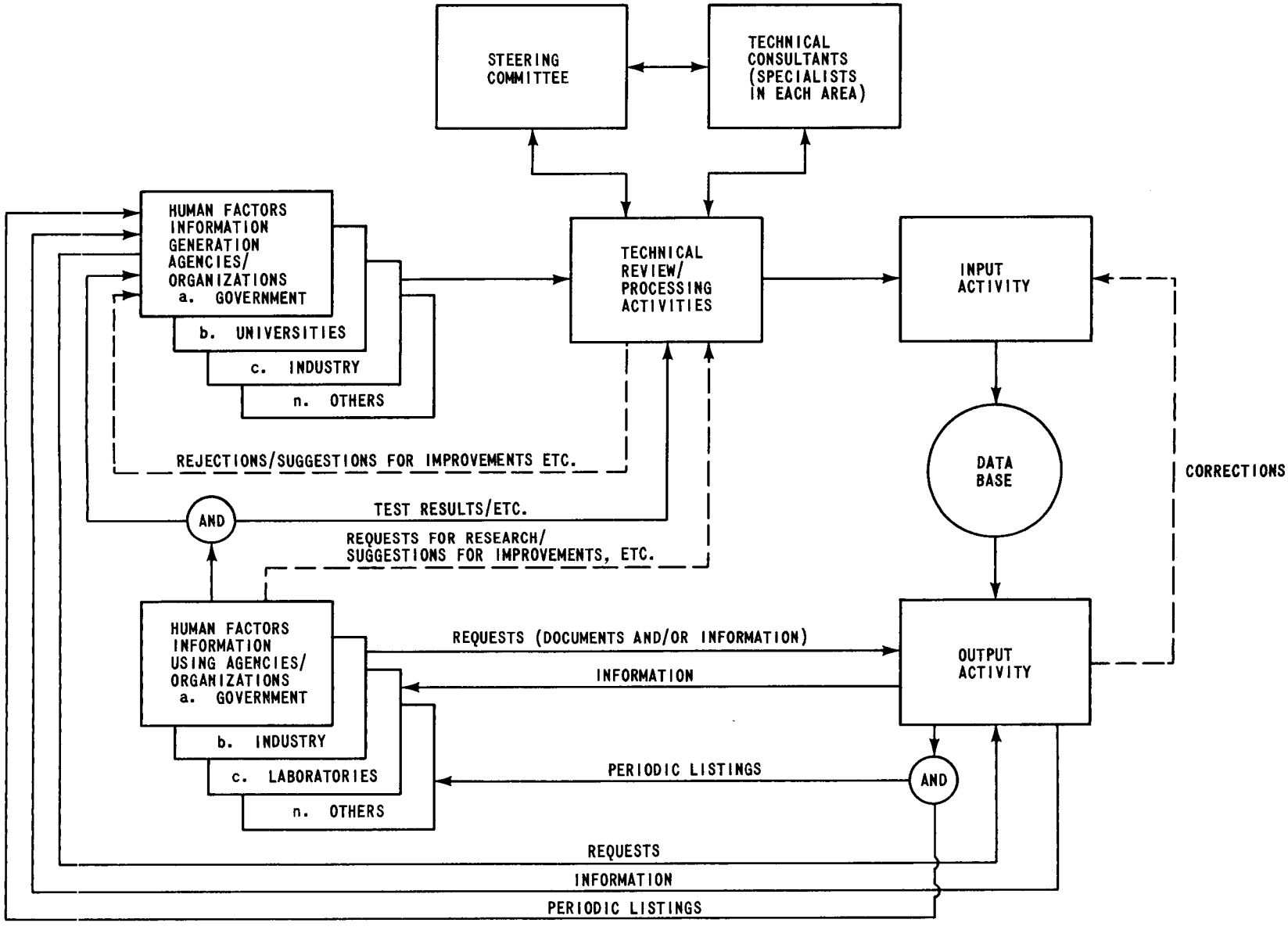

FIGURE 11 - SUGGESTIONS FOR A DATA PROCESSING SYSTEM FOR HUMAN STANDARDS (MANUAL OR AUTOMATIC)

been defined in this report, should be undertaken first. These are necessary antecedents for the preparation of the applications standards and can serve a very useful purpose, providing life and behavioral science specialists are available to interpret and apply them. (The process illustrated in Figure 10 is based on this approach.) Moreover, within the human standards categories certain of these can be selected out for initial development, as is in fact being done in Phase 1 of the project described in this report. The selection, of course, should be made on the basis of judgments that these represent more critical areas and that satisfactory standards do not now exist in these areas. Full use should be made of the data which already exists within NASA or DOD rather than duplicate any efforts that are already in process or completed.

2) Once the human standards data base or portions of it have been compiled, then decisions should be made about computerization and development of a communication network for dissemination of the standards. With the data collected in some form of preliminary document, it will be easier to determine its suitability for computerization.

3) Subsequent to completion of the first iteration of the human standards, the development of the applications standards should be undertaken and follow essentially the same course as the human standards. To have maximum utility, life and behavioral science specialists again will be required to aid in their interpretation and application. Further, coordination and collection of all of the relevant data within NASA and DOD should be undertaken in order to avoid duplication of effort.

4) Once the data base and data handling system are in operation, it will be necessary to modify portions of it from time to time to insure its continuing usefulness.

Computerization of the Standards

The use of automatic data processing equipment for the handling of the standards appears essential for efficient handling of the mass and variety of human standards data. Accordingly, much of the rationale developed in this report is directed towards computerization. In addition, the following guidelines are offered for deciding on the desirability and feasibility of computerizing the standards:

1) With respect to content, it is necessary to determine how frequently data must be updated. If existing data are adequate, non-variable and a function of a few parameters, it probably will be more efficient to document them in a book for use by the designer. However, for the data which change frequently, then the rapid updating capabilities of a computerized system are an advantage. The human standards and applications standards run the full range. To summarize, it appears that some data should be in documents, and other in computer storage, so that this criterion is not sufficient by itself to justify computerization.

2) With respect to application, it is necessary to assess the complexity of parametric relationships which must be known to use the standards data. If, for example, it is adequate to read one data point on a graph or to read a statement of a principle, then there are little advantages to computerization. However, if, as is usually the case, there are complex interactions between design parameters, then a computer indexing technique can be--if designed properly--the most efficient method of retrieving the relevant data. If additional computation is required, as it is with many of the standards, then the computer has distinct advantages over a document.

To the extent that the standards data base can be handled as an information retrieval system (as opposed to currently available library document title search and document retrieval systems), the computerized approach will be more efficient. The problem in information handling is not only one of determining what is relevant for the users purposes, but also in making sure that he is given only as much information as he needs. It is more efficient to retrieve a paragraph or a figure in a document, if this is all that is required, than be given the whole document.

3) The availability of existing and planned computer processing facilities within NASA or available to NASA and its contractors also needs to be determined in order to make maximum use of the capabilities.

Many options exist with respect to what the final appearance might be of the data base and data handling system. For example, the computerized portion might be nothing more than an indexing system (such as the matrices described in this report or a specification tree) which provides the user with a method of locating the data; which, in turn, might exist in a variety of places and forms. Or, the entire data base might be computerized and stored in some central location

and only exercised when new data is introduced into the system or when a request is received for the data. Since the appropriateness and completeness of the retrieval is more important than the time, there is little point to storing this mass of data in a computer, even assuming such storage facilities could be made available. Probably the best solution is some place in between. In any event, the system by which this data is tied together is much more critical to its successful usage than the extent to which it is a manual or computerized system.

Coordination of the Standards Project with other Data and Data Handling Requirements and Facilities in NASA and DOD

The coordination of the standards project described in this report with other efforts concerned with the use and support of the human being in systems has received considerable attention in this report. The problem of coordination is a significant one at other levels also since the human standards data base and data handling system represents only one of the many areas in systems design which require similar capabilities.

Accordingly, it is recommended that the data handling requirements for other aspects of manned spaceflight systems design be examined to determine:

1) What facilities already exist or are planned in NASA and in what way are they compatible with the data base and data handling system described here.

2) What are the possibilities for integrating the human standards data base with these other data bases and data handling systems?

Responsibilities for the Development and Maintenance of the Human Standards Data Base and Data Handling System

Since most of the discussion in this report has been confined to the technical aspects of the problem, some concluding comments relative to the management aspects of such an undertaking and the maintenance of the data base once it is operational are believed to be appropriate.

The following recommendations appear to provide an efficient method for proceeding:

1) The initial data base covering flight crews only should be developed by Headquarters NASA with MSC assistance.

2) Once the human standards data base for manned space flight systems has begun to function, it should be turned over to MSC for use and updating.

3) The expansion of the data base to include applications to other NASA systems should again be the responsibility of Headquarters NASA with assistance from the appropriate Centers.

4) As the expanded data base becomes available, access should be provided for all the interested centers and their contractors.

5) A permanent steering committee should be set up with responsibilities for ensuring that the data base is updated or the data handling procedures revised as required. The committee should consist of representatives from Headquarters NASA, the Centers, and DOD. Contractor resources should be made available for the actual processing of the data.

6) Finally, NASA contracts, standards, and specifications should reference the human standards as requirements and as sources of information for the system contractors.

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Appendix A: Descriptors for Environments

1. Atmosphere
1.1 Composition
1.1.1 Normal (earth environment)
1.1.2 Single Gas
1.1.3 Two Gas (partial pressures)
1.1.3.1 Oxygen - Nitrogen
1.1.3.2 Oxygen - Helium
1.1.3.N Others
1.2 Pressure
1.2.1 Overpressure
1.2.1.1 Continuous
1.2.1.2 Blast
1.2.2 Underpressure
1.2.2.1 Continuous
1.2.2.2 Decompression
1.3 Temperature and Humidity
1.4 Movement (circulation/wind/etc.)
2. Toxicants and Contaminants
2.1 Chemical Compounds
2.1.1 Carbon Dioxide
2.1.2 Carbon Monoxide
2.1.3 Freon 114
2.1.4 Ethylene Dicholoride
2.1.N Others
2.2 Microbial Agents
3. Acceleration
3.1 Linear
3.1.1 Impact
3.1.1.1 Transverse
3.1.1.2 Longitudinal
3.1.1.3 Vertical
3.1.1.4 Off-axis
3.1.2 Brief
3.1.3 Sustained
3.1.3.1 Forward
3.1.3.2 Rearward
3.1.3.3 Upward
3.1.3.4 Downward
3.1.3.5 Sideward
3.2 Angular
3.3 Radial
3.3.1 Roll (Right/Left)
3.3.2 Pitch (Up/Down)
3.3.3 Yaw (Right/Left)
4. Gravitation
4.1 Weightlessness
4.1.1 Momentary
4.1.2 Sustained
4.2 Reduced Gravitation
4.3 Increased Gravitation
5. Vibration
5.1 Infrasonic
5.1.1 Whole Body
5.1.1.1 Longitudinal
5.1.1.1.1 Sinusoidal
5.1.1.1.2 Random
5.1.1.2 Transverse
5.1.2 Body Part
5.2 Sonic Range
6. Noise
6.1 Infrasonic Range
6.2 Audio Range

6.2.1 Pure Tone Noise
6.2.2 Narrow Band Noise
6.2.3 Broad Band Noise
6.3 Ultrasonic Range
7. Radiation
7.1 Non-ionizing
7.1.1 Radio waves
7.1.2 Radar waves
7.1.3 Micro waves
7.1.4 Infrared
7.1.5 Visible
7.1.6 Ultraviolet
7.2 Ionizing
7.2.1 X-rays
7.2.2 Gamma Rays
7.2.3 Beta Rays
7.2.4 Neutrons
7.2.5 Protons
7.2.6 Alpha Particles
8. Magnetic Fields
9. Electric Currents
10. Isolation and Confinement
10.1 Isolation
10.1.1 Physical
10.1.2 Social
10.2 Confinement
10.2.1 Encapsulation
10.2.2 Mandatory (social)
11. Circadian Rhythms
12. Dietary Imbalances
12.1 Food
12.1.1 Deficiencies
12.1.2 Excesses
12.2 Water
12.2.1 Deficiencies
12.2.2 Excesses
13. Drugs
14. Illnesses and Injuries
14.1 Illnesses
14.1.1 Surgical
14.1.2 Medical
14.1.3 Dental
14.2 Injuries
14.2.1 Fractures/Dislocations
14.2.2 Surgical
15. Social Environment

Appendix B: Descriptors for Crew Performances

1. Interacting with Objects (Materials, Equipment), other Personnel, or Environment

1.1 Sensing

1.1.1 Searching for and Receiving Information

1.1.1.1 Detecting (visual, auditory, etc.)

1.1.1.2 Inspecting

1.1.1.3 Observing

1.1.1.4 Reading (e.g., directions, instructions, etc.)

1.1.1.5 Receiving

1.1.1.6 Scanning

1.1.1.7 Surveying

1.1.2 Identifying Objects, Actions, Events

1.1.2.1 Discriminating

1.1.2.2 Identifying

1.1.2.3 Locating

1.2 Processing or Mediation

1.2.1 Information Processing

1.2.1.1 Categorizing

1.2.1.2 Calculating

1.2.1.3 Coding/Decoding

1.2.1.4 Computing

1.2.1.5 Interpolating

1.2.1.6 Itemizing

1.2.1.7 Tabulating

1.2.1.8 Translating

1.2.2 Problem Solving and Decision-Making

1.2.2.1 Analyzing

1.2.2.2 Calculating

1.2.2.3 Choosing

1.2.2.4 Comparing

1.2.2.5 Computing

1.2.2.6 Estimating

1.2.2.7 Planning

1.3 Communicating

1.3.1 Advising

1.3.2 Answering

1.3.3 Communicating

1.3.4 Directing

1.3.5 Indicating

1.3.6 Informing

1.3.7 Instructing

1.3.8 Requesting

1.3.9 Transmitting

1.4 Responding or Motor Processes

1.4.1 Simple/Discrete Responding

1.4.1.1 Activating

1.4.1.2 Closing

1.4.1.3 Connecting/Disconnecting

1.4.1.4 Joining

1.4.1.5 Moving

1.4.1.6 Pressing

1.4.1.7 Pushing/Pulling

1.4.1.8 Setting

1.4.2 Complex/Continuous Responding

1.4.2.1 Adjusting

1.4.2.2 Aligning

1.4.2.3 Regulating

1.4.2.4 Synchronizing

1.4.2.5 Tracking

2. Action on or with the Body

2.1 Ingesting (food, water)

2.2 Eliminating (micturation, defecation, etc.)

2.3 Sleeping

2.4 Grooming/Cleansing

2.5 Dressing/Undressing

2.6 Whole Body Movement (walking, climbing, etc.)

2.N Other physiological and performance functions

Appendix C: Descriptors for Equipment Interfaces

1. Clothing and Personal Equipment

1.1 Anti-exposure Suits

1.2 Pressure Suits

1.3 Helmets

1.4 Gloves

1.5 Boots

1.6 Portable Life Support Equipment

2. Portable Equipment

2.1 Tools

2.2 Scientific Equipment

3. Occupancy and Restraint Equipment

3.1 Seats

3.2 Couches

3.3 Bunks

3.4 Lap Belts

3.5 Shoulder Harnesses

4. Environmental Control Systems

4.1 Pressure Control

4.2 Oxygen Supply

4.3 Heating, Cooling, and Ventilation Control

5. Food and Water Management Systems

6. Waste Management Systems

7. Hygiene and Medical Supplies

8. Bioinstrumentation Equipment

9. Survival and Recovery Equipment and Supplies

10. Cabins

10.1 Hatches

10.2 Layout

10.3 Windows

11. Control and Display Panels (operational and maintenance)

12. Communication Equipment

12.1 Handsets

12.2 Intercommunication Equipment

13. Maintenance Equipment

13.1 Cabinets

13.2 Test Equipment

13.3 Connectors and Cables

13.4 Tools

14. Displays

14.1 Indicator Lights

14.2 Single Digital and Word Readouts

14.3 Meters, Dials, and Gages

14.4 Multiple Character Alphanumeric, Graphic and Pictorial Displays (CRT Displays)

14.5 Permanent Record Displays, Printers

14.6 Permanent Record Displays, Recorders and Plotters

14.7 Auditory Signaling, Caution, and Warning Displays

15. Controls

15.1 Pushbuttons and Keyboards

15.2 Toggle Switches

15.3 Control Knobs, Continuous Adjustment

15.4 Control Knobs, Discrete Adjustments

15.5 Levers

15.6 Hand Wheels

16. Training Equipment

16.1 Training Aids

16.2 Training Devices

Appendix D: Categories and Parameters for the Human Standards

1. Anthropometric Standards

1.1 Dimensions of the Head, Body and Limbs (in inches or centimeters)

1.1.1 Static Dimensions of the Head, Body and Limbs

1.1.1.1 Overall Dimensions of the Head, Body and Limbs

1.1.1.1.1 Height of Body, Erect

1.1.1.1.2 Height of Body, Normal

1.1.1.1.3 Height of Body, Sitting, Erect

1.1.1.1.4 Height of Body, Sitting, Normal

1.1.1.1.5 Height of Eyes, Standing

1.1.1.1.6 Height of Eyes, Seated

1.1.1.1.7 Height of Tragion, Standing

1.1.1.1.8 Height to Tragion, Seated

1.1.1.1.9 Height to Cervical Level, Standing

1.1.1.1.10 Height to Cervical Level, Seated

1.1.1.1.11 Height to Mid-Shoulder, Standing

1.1.1.1.12 Height to Mid-Shoulder, Seated

1.1.1.1.13 Height to Acromion, Standing

1.1.1.1.14 Height to Acromion, Seated

1.1.1.1.15 Height to Armpit, Standing

1.1.1.1.16 Height to Armpit, Seated

1.1.1.1.17 Height of Elbow, Standing

1.1.1.1.18 Height of Elbow, Seated

1.1.1.1.19 Height of Wrist, Standing

1.1.1.1.20 Height of Knuckles, Standing

1.1.1.1.21 Height to Substernal Level, Standing

1.1.1.1.22 Height to Supersternal Level, Standing

1.1.1.1.23 Height to Xiphoid Level

1.1.1.1.24 Height to 10th Rib

1.1.1.1.25 Height to Cristal Level

1.1.1.1.26 Height of Trunk, Standing

1.1.1.1.27 Height of Trunk, Seated

1.1.1.1.28 Length from Crown to Rump

1.1.1.1.29 Height from Acromion to Vertex

1.1.1.1.30 Height from Cervical Level to Vertex

1.1.1.1.31 Height to Trochanteric Level

1.1.1.1.32 Height to Crotch

1.1.1.1.33 Height to Gluteal Furrow

1.1.1.1.34 Height of Knee

1.1.1.1.35 Height to Superior Kneecap Level

1.1.1.1.36 Height to Popliteal Position

1.1.1.1.37 Height to Tibia

1.1.1.1.38 Breadth from Forearm to Forearm

1.1.1.1.39 Breadth from Elbow to Elbow

1.1.1.1.40 Breadth from Knee to Knee

1.1.1.1.41 Breadth of Body, Maximum

1.1.1.1.42 Depth of Body, Maximum

1.1.1.2 Dimensions of the Head

1.1.1.2.1 Length of Head

1.1.1.2.2 Breadth of Head

1.1.1.2.3 Circumference of Head

1.1.1.2.4 Height of Face, Total

1.1.1.2.5 Height from Pupil to Vertex

1.1.1.2.6 Height from Stomion to Vertex

1.1.1.2.7 Height from Tragion to Vertex

1.1.1.2.8 Length from Menton to Crinion

1.1.1.2.9 Length from Menton to Subnasal Position

1.1.1.2.10 Breadth from Ear to Ear

1.1.1.2.11 Distance between Pupils

1.1.1.2.12 Depth from Nasal Root to Wall

1.1.1.2.13 Depth from Pronasal Position to Wall

1.1.1.2.14 Depth from Pupil to Wall

1.1.1.2.15 Depth from External Canthus to Wall

1.1.1.2.16 Depth from Tragion to Wall

1.1.1.2.17 Breadth of Ear

1.1.1.2.18 Length of Ear

1.1.1.2.19 Length of Ear above Tragion

1.1.1.2.20 Breadth of Nose

1.1.1.2.21 Breadth of Nasal Root

1.1.1.2.22 Length of Nose

1.1.1.2.23 Diameter between Tragia

1.1.1.2.24 Length of Bitragion-Coronal Arc

1.1.1.2.25 Length of Bitragion-Crinion Arc

1.1.1.2.26 Length of Bitragion-Inion Arc

1.1.1.2.27 Length of Bitragion-Subnasal Arc

1.1.1.2.28 Length of Bitragion-Submandibular Arc

1.1.1.2.29 Length of Bitragion-Menton Arc

1.1.1.2.30 Breadth between Gonia

1.1.1.2.31 Diameter between Sygomatic Bones

1.1.1.2.32 Length of Lips

1.1.1.2.33 Breadth of Chin

1.1.1.2.34 Circumference of Neck

1.1.1.2.35 Depth of Neck

1.1.1.2.36 Breadth of Neck

1.1.1.2.37 Depth from Larynx to Wall

1.1.1.3 Dimensions of the Trunk

1.1.1.3.1 Breadth of Shoulders, Acromion

1.1.1.3.2 Breadth of Shoulders

1.1.1.3.3 Circumference of Shoulders

1.1.1.3.4 Breadth of Chest

1.1.1.3.5 Breadth of Chest, Bone

1.1.1.3.6 Circumference of Chest

1.1.1.3.7 Depth of Chest

1.1.1.3.8 Breadth of Waist

1.1.1.3.9 Width of Waist, Front

1.1.1.3.10 Width of Waist, Back

1.1.1.3.11 Depth of Waist

1.1.1.3.12 Circumference of Waist

1.1.1.3.13 Breadth of Hips, Standing

1.1.1.3.14 Breadth of Hips, Seated

1.1.1.3.15 Circumference of Buttocks

1.1.1.3.16 Breadth of Tochanters

1.1.1.3.17 Depth of Buttocks

1.1.1.3.18 Breadth of Iliac

1.1.1.3.19 Length of Seat

1.1.1.4 Dimensions of the Arms

1.1.1.4.1 Length from Acromion to Radial

1.1.1.4.2 Length from Shoulder to Elbow

1.1.1.4.3 Length from Radial to Stylion

1.1.1.4.4 Length from Forearm to Wrist

1.1.1.4.5 Length from Forearm to Grip

1.1.1.4.6 Length from Forearm to Hand

1.1.1.4.7 Circumference of Upper Arm, Auxillary Level

1.1.1.4.8 Circumference of Upper Arm, Relaxed

1.1.1.4.9 Circumference of Upper Arm, Flexed

1.1.1.4.10 Circumference of Scye (Sleeve hole)

1.1.1.4.11 Breadth of Elbow

1.1.1.4.12 Circumference of Elbow, Relaxed

1.1.1.4.13 Circumference of Elbow, Flexed

1.1.1.4.14 Circumference of Forearm, Relaxed

1.1.1.4.15 Circumference of Forearm, Flexed

1.1.1.4.16 Breadth of Wrist

1.1.1.4.17 Circumference of Wrist

1.1.1.5 Dimensions of the Hands

1.1.1.5.1 Length of Hand

1.1.1.5.2 Breadth of Hand at Metacarpal

1.1.1.5.3 Breadth of Hand at Thumb

1.1.1.5.4 Circumference of Hand at Metacarpal

1.1.1.5.5 Thickness of Hand

1.1.1.6 Dimensions of the Legs

1.1.1.6.1 Length from Buttock to Knee

1.1.1.6.2 Length from Buttock to Foot

1.1.1.6.3 Length from Buttock to Popliteal Position

1.1.1.6.4 Height of Thigh, Seated

1.1.1.6.5 Circumference of Upper Thigh, Standing

1.1.1.6.6 Circumference of Lower Thigh, Standing

1.1.1.6.7 Circumference of Knee

1.1.1.6.8 Circumference of Calf

1.1.1.6.9 Circumference of Ankle

1.1.1.7 Dimensions of the Feet

1.1.1.7.1 Length of Foot

1.1.1.7.2 Length of Foot, No Weight

1.1.1.7.3 Breadth of Foot

1.1.1.7.4 Breadth of Foot, No Weight

1.1.1.7.5 Breadth of Heel

1.1.1.7.6 Breadth of Heel, No Weight

1.1.1.8 Dimensions of Skinfolds

1.1.1.8.1 Subscapular

1.1.1.8.2 Juxti-nipple

1.1.1.8.3 Mid-Axillary Line-Xiphoid

1.1.1.8.4 Triceps

1.1.1.9 Weight of the Body

1.1.1.N Others

1.1.2 Dynamic Dimensions of the Head, Body and Limbs

1.1.2.1 Dimensions in Work Positions

1.1.2.1.1 Kneeling

1.1.2.1.2 Crawling

1.1.2.1.3 Prone and Supine

1.1.2.2 Reach with the Arm (Functional Arm Reach)

1.1.2.2.1 Forward Reach, Standing

1.1.2.2.1.1 Entire Arm

1.1.2.2.1.2 Forearm

1.1.2.2.2 Overhead Reach, Standing

1.1.2.2.3 Lateral Reach, Standing

1.1.2.2.4 Reach, Seated

1.1.2.2.4.1 0 Degrees from Midplane of Body

1.1.2.2.4.2 15 Degrees from Midplane of Body

1.1.2.2.4.3 30 Degrees from Midplane of Body

1.1.2.2.4.4 45 Degrees from Midplane of Body

1.1.2.2.4.5 60 Degrees from Midplane of Body

1.1.2.2.4.6 75 Degrees from Midplane of Body

1.1.2.2.4.7 90 Degrees from Midplane of Body

1.1.2.2.4.8 105 Degrees from Midplane of Body

1.1.2.2.4.9 120 Degrees from Midplane of Body

1.1.2.2.4.10 135 Degrees from Midplane of Body

1.1.2.3 Reach with the Leg

1.1.2.3.1 Forward Reach, Standing

1.1.2.3.2 Forward Reach, Seated

1.1.2.3.3 Sideward Reach, Seated

1.2 Movement of the Head, Body, and Limbs

1.2.1 Simple Movements (in degrees)

1.2.1.1 Movement of the Neck

1.2.1.1.1 Flexion of the Neck, Forward-Backward

1.2.1.1.2 Flexion of the Neck, Right-Left

1.2.1.1.3 Rotation of the Neck, Left-Right

1.2.1.2 Movement of the Shoulder

1.2.1.2.1 Abduction of the Shoulder

1.2.1.2.2 Adduction of the Shoulder

1.2.1.2.3 Movement of the Shoulder, Lateral-Medial

1.2.1.2.4 Flexion of the Shoulder

1.2.1.2.5 Extension of the Shoulder

1.2.1.3 Movement of the Elbow

1.2.1.3.1 Flexion of the Elbow

1.2.1.3.2 Extension of the Elbow

1.2.1.3.3 Rotation of the Elbow, Left-Right

1.2.1.4 Movement of the Forearm

1.2.1.4.1 Supination of the Forearm, Palms Up

1.2.1.4.2 Pronation of the Forearm, Palms Down

1.2.1.5 Movement of the Wrist

1.2.1.5.1 Adduction of the Wrist

1.2.1.5.2 Abduction of the Wrist

1.2.1.5.3 Palmar Flexion of the Wrist

1.2.1.5.4 Dorsiflexion of the Wrist

1.2.1.6 Movement of the Trunk and Torso

1.2.1.6.1 Rotation of Trunk

1.2.1.6.2 Flexion of Torso, Lateral-Medial

1.2.1.6.3 Flexion of the Torso, Forward

1.2.1.6.4 Flexion of the Torso, Backward

1.2.1.7 Movement of the Hip

1.2.1.7.1 Adduction of the Hip, Knee Bent

1.2.1.7.2 Abduction of the Hip, Leg Straight

1.2.1.7.4 Rotation of the Hip, Sitting Lateral

1.2.1.7.5 Rotation of the Hip, Sitting, Medial

1.2.1.7.6 Flexion of the Hip

1.2.1.7.7 Extension of the Hip

1.2.1.8 Movement of the Knee

1.2.1.8.1 Flexion of the Knee, Standing

1.2.1.8.2 Flexion of the Knee, Kneeling

1.2.1.8.3 Rotation of the Knee Lateral

1.2.1.8.4 Rotation of the Knee, Medial

1.2.1.9 Movement of the Ankle

1.2.1.9.1 Adduction of the Ankle

1.2.1.9.2 Abduction of the Ankle

1.2.1.9.3 Flexion of the Ankle

1.2.1.9.4 Extension of the Ankle

1.2.1.9.5 Rotation of the Ankle

1.2.2 Complex Movements

1.2.2.1 Movements of the Hand

1.2.2.1.1 Palmar

1.2.2.1.2 Finger Tip Prehension

1.2.2.1.3 Lateral Prehension

1.2.2.1.4 Grasp Pushing

1.2.2.1.5 Finger Operations (Pushbutton)

1.2.2.1.6 Finger Pulling Operations

1.2.2.1.7 Rotation of Hand

1.2.2.1.8 Movement of the Wrist

1.2.2.1.9 Movement of the Whole Hand

1.2.2.2 Movements of the Arm

1.2.2.N Others

1.2.3 Total Body Movements

1.2.3.1 Standing

1.2.3.2 Sitting

1.2.3.3 Walking

1.2.3.4 Running

1.2.3.5 Crawling

1.2.3.6 Climbing

1.2.3.N Others

1.3 Centers of Gravity and Moments of Inertia of Body

1.3.1 Center of Gravity and Position of Body

1.3.1.1 Standing, Arms at Side

1.3.1.2 Standing, Arms Overhead

1.3.1.3 Spread Eagle

1.3.1.4 Sitting

1.3.1.5 Sitting, Forearms, Down

1.3.1.6 Sitting, Thighs Elevated

1.3.1.7 Relaxed and Weightless

1.3.1.8 Couch Positions (e.g., in spacecraft

1.3.2 Masses of Segments of the Body

1.3.2.1 Head, Neck and Trunk

1.3.2.2 Upper Extremities, Total

1.3.2.3 Upper Arms, Both

1.3.2.4 Forearms and Hands, Both

1.3.2.5 Forearms, Both

1.3.2.6 Hands, Both

1.3.2.7 Lower Extremities, Total

1.3.2.8 Upper Legs, Both

1.3.2.9 Lower Legs Plus Feet, Both

1.3.2.10 Lower Legs, Both

1.3.2.11 Feet, Both

1.4 Strength and Endurance of the Muscles (in foot/pounds)

1.4.1 Strength and Endurance of the Hands

1.4.1.1 Hand Grip

1.4.1.2 Hand Prehension

1.4.1.3 Rotation of Wrist

1.4.2 Strength and Endurance of Arms

1.4.2.1 Push (includes right and left arms and force exerted for various positions and flexions of the arms, and ranges of movement)

1.4.2.2 Pull (same as above)

1.4.2.3 Right Movement (same as above)

1.4.2.4 Left Movement (same as above)

1.4.2.5 Combinations of Movements, Both Arms

1.4.3 Strength and Endurance of Back

1.4.4 Strength and Endurance of Legs

1.4.4.1 Extension of Leg

1.4.4.2 Extension of Ankle

1.4.4.N Others

1.5 Surfaces of the Body and Body Parts (in square inches or square meters)

1.5.1 Surface of the Body, Erect

1.5.2 Surface of Body, Semi-Erect

1.5.3 Surface of Body, Seated

1.5.4 Surface of Body, Crouched

1.5.5 Surface of Body, Projections

1.6 Dimensions, Mass and Volume of Organs and Body Parts (in inches or millimeters, and ounces or grams)

1.6.1 Body, Total

1.6.2 Muscle

1.6.3 Skin

1.6.4 Skin and Subcutaneous Tissue

1.6.5 Fat

1.6.6 Skeleton

1.6.6.1 Without Bone Marrow

1.6.6.2 Red Marrow

1.6.6.3 White Marrow

1.6.7 Blood

1.6.8 Gastrointentinal Tract (excluding contents)

1.6.9 Gastrointestinal Tract, Contents

1.6.9.1 Stomach

1.6.9.2 Upper Large Intestine

1.6.9.3 Lower Large Intesting

1.6.9.4 Small Intestine

1.6.10 Liver

1.6.11 Brain

1.6.12 Lungs, Both

1.6.13 Lymphoid Tissue

1.6.14 Kidneys, Both

1.6.15 Heart

1.6.16 Spleen

1.6.17 Bladder

1.6.18 Pancreas

1.6.19 Salivary Glands

1.6.20 Testes, Both

1.6.21 Spinal Cord

1.6.22 Eyes, Both

1.6.23 Thyroid

1.6.24 Teeth

1.6.25 Prostrate Gland

1.6.26 Adrenal Glands, Both

1.6.27 Thymus

1.6.28 Other (Blood Vessels, Nerves, etc.)

1.7 Composition of the Body

2. Physiological Standards

2.1 Functions of the Respiratory System

2.1.1 Movement of Air

2.1.1.1 Rate of Breathing (in breaths/minute)

(normal rates and variations)

(effects of activity)

(effects of equipment)

(effects of environment)

(atmospheric pressure)

(atmospheric composition)

(etc.)

(effects of body condition)

(others)

2.1.1.2 Volume of Air (in liters, or cubic feet)

2.1.1.2.1 Inspiratory Reserve Volume

(normal levels and variations)

(etc.)

2.1.1.2.2 Tidal Volume

2.1.1.2.3 Expiratory Reserve Volume

2.1.1.2.4 Residual Volume

2.1.1.2.5 Inspiratory Capacity

2.1.1.2.6 Functional Residual Capacity

2.1.1.2.7 Vital Capacity

2.1.1.3 Pressure in the Lungs

(normal level and variations)

(effects of overpressures: rupture)

(effects of underpressure: collapse)

2.1.2 Consumption of Oxygen (in liters/hour, or pounds/hour)

(normal amounts and rates)

(effects of activity; oxygen debt, etc.)

(effects of equipment; pressure suit, etc.)

(effects of environment)

(gravitation)

(atmospheric pressure)

(others)

2.1.3 Production of Carbon Dioxide (liters/hour, pounds/hour)

2.1.4 Production of Water Vapor (grams/hour, ounces/hour)

2.1.5 Exchange of Gases in the Lungs

2.1.5.1 Alveolar Ventilation (liters/minute, cubic feet/minute)

2.1.5.2 Alveolar and Arterial Gas Tensions (in mm/Hg)

2.1.5.2.1 Oxygen

2.1.5.2.2 Carbon Dioxide

2.1.5.3 Arterial Blood Gas Contents (% saturation)

2.1.5.3.1 Oxygen

2.1.5.3.2 Carbon Dioxide

2.1.6 Storage of Gases in Body (liters, cubic feet)

2.1.6.1 Nitrogen

2.1.6.2 Oxygen

2.1.6.3 Carbon Dioxide

2.1.7 Expenditure of Energy in Respiration (foot/pounds minute)

2.2 Functions of the Digestive System

2.2.1 Requirements for Food

2.2.1.1 Amount of Food (in pounds and kilocalories)

2.2.1.2 Frequency of Ingestion

2.2.1.3 Composition of Diet

2.2.1.3.1 Protein and Amino Acids (grams/day, ounces/day)

(normal diet for expected tasks/ environments)

(effects of dietary imbalances)

2.2.1.3.2 Fat and Fatty Acids (in grams or milligrams/day)

2.2.1.3.3 Carbohydrates (in kilocalories/day)

2.2.1.3.4 Vitamins (in International Units/day)

2.2.1.3.5 Minerals (in grams or milligrams/day)

2.2.1.4 Palatability and Acceptability of Food)

2.2.1.5 Digestion of Food

(normal process)

(effects of activity)

(effects of stress)

(others)

2.2.2 Requirements for Water

2.2.2.1 Amount of Water

2.2.2.1.1 Liquid (in liters/day, or pounds/day)

(normal amounts and variations)

(effects of activity)

2.2.2.1.2 Food

2.2.2.2 Frequency of Ingestion

2.3 Maintenance of Metabolic Balances

2.3.1 Consumption of Oxygen (in liters/hour, or pounds/hour)

(normal amounts and rates)

(effects of activity)

(effects of equipment; pressure suits, etc.)

(effects of environment)

(pressure)

(temperature)

(gravitation, etc.)

(effects of body condition)

2.3.2 Consumption of Food (in Kcal/day)

2.3.3 Production of Work

2.3.4 Production of Heat (in BTUs/hour)

2.3.5 Elimination of Heat (in BTUs/hour)

2.3.5.1 Loss of Heat, Insensible (lungs, skin)

2.3.5.2 Loss of Heat, Latent (sweat)

2.3.5.3 Loss of Heat, Sensible (gas steam, water)

2.3.6 Production of Carbon Dioxide

2.3.7 Production of Water

2.4 Maintenance of Thermal Balances

2.4.1 Production of Heat by Body (in BTUs/hour)

(normal amounts and rates; unstressed/stressed, probably include core/skin temperatures)

(effects of activity, etc.)

2.4.2 Absorption of Heat, from Environment (in BTUs/square foot/hour)

2.4.2.1 Absorption by Convection

2.4.2.2 Absorption by Radiation

2.4.2.3 Absorption by Conduction

2.4.3 Elimination of Heat (in BTUs/square foot/hour)

2.4.3.1 Elimination by Evaporation

2.4.3.2 Elimination by Convection

2.4.3.3 Elimination by Radiation

2.4.3.4 Elimination by Conduction

2.4.3.5 Elimination by Respiration

2.5 Functions of the Excretory Systems

2.5.1 Excretion of Urine

2.5.1.1 Generation of Urine (in liters/day, or ounces/day)

(normal rate and amounts)

(effects of diet)

(others)

2.5.1.2 Composition of Urine

2.5.2 Excretion of Feces

2.5.2.1 Generation of Feces (in grams/day, or pounds/day)

2.5.2.2 Composition of Feces

2.5.3 Excretion of Flatus

2.5.3.1 Generation of Flatus (in milliliters/day)

2.5.3.2 Composition of Flatus

2.5.4 Excretion of Sweat

2.5.4.1 Generation of Sweat (in milliliters/hour, or pounds/hour) (amounts and rates as function of temperatures, activity, etc.)

2.5.4.2 Composition of Sweat

2.5.5 Excretion of Saliva

2.5.5.1 Generation of Saliva (in milliliters/hour, or ounces/hour)

2.5.5.2 Composition of Saliva

2.5.6 Excretions of the Skin

2.5.6.1 Dried Surface Skin

2.5.6.1.1 Generation of Dried Surface Skin (in grams and milliliters/day)

2.5.6.1.2 Composition of Dried Surface Skin

2.5.6.2 Sebum

2.5.7 Excretion of Tears and Ear Wax

2.5.7.1 Generation of Tears and Ear Wax (in grams/hour, or ounces/hour)

2.5.7.2 Composition of Tears and Ear Wax

2.5.8 Generation of Hair

2.5.8.1 Generation of Hair (millimeters and milligrams/day)

2.5.8.2 Composition of Hair

2.5.9 Generation of Nails (in finger/toe)

2.5.9.1 Generation of Nails (millimeters and milligrams/day)

2.5.9.2 Composition of Nails

2.6 Functions of the Cardiovascular System

2.6.1 Performance of the Heart

2.6.1.1 Heart Rate (in cycles/minute)

(normal rates and variations)

(effects of activity)

(effects of environment)

(others)

2.6.1.2 Cardiac Output (volume)

2.6.1.3 Heart Rhythm

2.6.2 Distribution of Blood in the Arterial and Venous Systems

2.6.2.1 Blood Pressure (systolic/diastolic) (in mm Hg)

(normal levels and variations)

(effects of activity)

(effects of environment)

(others)

2.6.2.2 Blood Flow

(distributions in arteries and veins, capillary network, and organs)

2.6.3 Composition and Volume of Blood

2.6.3.1 Volume of Blood (total, plasma, cell (red, white))

(normal amounts and variations)

(effects of environment)

(others)

2.6.3.2 Distribution of Blood

2.6.3.3 Clotting Time

2.7 Maintenance of Fluid Electrolyte Balances

2.7.1 Distribution and Amount of Fluids

2.7.2 Distribution and Amount of Trace Elements

2.7.3 Regulation of Blood Pressure

2.7.4 Demineralization of Bones

2.7.5 Atrophy of Muscles

2.8 Functions of the Nervous System

2.8.1 Central Nervous System

2.8.2 Peripheral Nervous System

2.8.3 Senses, Muscles, and Glands

2.9 Maintenance of Skeletal Integrity

2.9.1 Demineralization of Bones

2.9.N Others

2.10 Maintenance of Muscular Integrity

2.10.1 Maintenance of Strength

2.10.2 Maintenance of Endurance

2.10.3 Maintenance of Coordination

2.11 Functions of the Tegmentum

2.12 Maintenance of Endocrine Balances

2.12.1 Thyroid

(normal functioning)

(effects of environment)

(weightlessness)

(vibration)

(radiation)

(temperature)

(circadian rhythms)

(confinement)

(others)

2.12.2 Pituitary

2.12.3 Adrenal Cortex

2.12.4 Gonads

2.12.N Others

2.13 Maintenance of Immunological Responses

2.N Others

3. Psychological Standards (i.e., performance capabilities of man)

3.1 Functions of the Visual Sense

3.1.1 Field of Vision (in degrees/or arcs)

3.1.1.1 Monocular Visual Field

3.1.1.1.1 Monocular Visual Field

3.1.1.1.1.1 Fixed

3.1.1.1.1.1.1 Central

3.1.1.1.1.1.2 Peripheral

3.1.1.1.2 Movement of Eyes

3.1.1.1.3 Movement of Eyes and Head

3.1.1.2 Binocular Visual Field

3.1.2 Discrimination of Light

3.1.2.1 Light and Dark Adaptation

3.1.2.2 Sensitivity Thresholds (Absolute Discrimination)

3.1.2.3 Brightness Thresholds (Difference Discrimination)

3.1.2.4 Brightness Tolerances

3.1.2.5 Flicker and Fusion Thresholds (in light-dark cycles per second)

3.1.3 Discrimination of Spatial Relationships

3.1.3.1 Acuity

3.1.3.1.1 Thresholds

3.1.3.1.1.1 Detection

(normal levels)

(effects of environment)

(levels of illumination)

(acceleration)

(others)

3.1.3.1.1.2 Recognition

3.1.3.2 Depth Discrimination

3.1.3.3 Form Discrimination

3.1.3.4 Movement Discrimination

3.1.3.4.1 Frontal (Tangential)

3.1.3.4.1.1 Central

3.1.3.4.1.2 Peripheral

3.1.3.4.2 Depth (Radial)

3.1.3.4.2.1 Central

3.1.3.4.2.2 Peripheral

3.1.3.5 Orientation

3.1.4 Discrimination of Color

3.1.4.1 Absolute Discriminations (number of colors correctly identifies in isolation)

3.1.4.1.1 Hue

3.1.4.1.2 Saturation

3.1.4.1.3 Brightness

3.1.4.2 Relative Discriminations (number correctly identified in pairs or larger groups)

3.2 Functions of the Auditory Sense (i.e., Bioacoustics)

3.2.1 Reception of Signals (in frequency/amplitude/time)

3.2.1.1 Absolute Thresholds

(normal levels)

(effects of environment)

(noise)

(pressure levels)

(others)

3.2.1.2 Difference Thresholds

3.2.2 Reception of Speech (measured in intelligibility indices)

3.2.2.1 Range of Speech

3.2.2.2 Masking of Speech

3.2.2.3 Identification of Voices

3.2.2.4 Intelligibility of Speech

3.3 Functions of the Kinesthetic and Vestibular Senses

3.3.1 Perception of Position of Body and Limbs

3.3.1.1 Perception of Vertical by Posture Cues

3.3.1.2 Perception of Vertical with Postural and Visual Cues in Conflict

3.3.1.3 Perception of Hand and Arm Position

3.3.2 Perception of Movement of Body and Limbs

3.3.2.1 Perception of Acceleration of Body

3.3.2.1.1 Linear Acceleration

3.3.2.1.2 Angular Acceleration

3.3.2.2 Perception of Rotation of Body

(Illusions)

(Vertigo)

(Motion Sickness)

3.3.3 Perception of Position of Objects and Vehicles (i.e., spatial orientation)

3.3.4 Perception of Movement of Vehicles (individual in vehicles)

3.4 Capabilities of the Somesthetic Senses (Skin Sensitivity)

3.4.1 Perception of Temperature

3.4.1.1 Thresholds

3.4.1.1.1 Absolute

3.4.1.1.2 Difference

3.4.1.2 Adaptation

3.4.2 Perception of Touch

3.4.3 Perception of Pain

3.5 Functions of the Olfactory and Gustatory Senses

3.5.1 Perception of Odors

3.5.2 Perception of Tastes

3.6 Functions of Perception

3.6.1 Identification of Objects and Events

3.6.2 Recognition of Patterns

3.6.N Others

3.7 Capabilities for Problem Solving and Decision-Making Behavior

3.7.1 Problem Solving

3.7.2 Decision Making

3.7.2.1 Unaided Decision Making

3.7.2.2 Decision Making Aided by Techniques and Technology (Heuristics)

3.8 Capabilities for Learning and Retention

3.8.1 Learning

3.8.2 Retention

3.8.2.1 Short-term

3.8.2.2 Long-term

3.9 Capabilities for Sensory-Motor Behavior

3.9.1 Pursuit Tracking

3.9.1.1 Internal Visual Field (displays)

3.9.1.2 External Visual Field (terrain, etc.)

3.9.2 Compensatory Tracking

3.10 Capabilities for Motor Responses

3.10.1 Movements

3.10.1.1 Simple Movements

3.10.1.2 Complex Movements

3.10.1.3 Whole Body Movements

3.10.N Others

3.11 Capabilities for Generation of Speech

3.11.1 Levels

3.11.2 Languages (vocabularies/ syntax)

3.N Others

4. Environmental Standards

4.1 Tolerances to Atmosphere

4.1.1 Tolerances to Composition

4.1.1.1 Single Gas

4.1.1.2 Two Gas

4.1.2 Tolerances to Pressure

4.1.2.1 Tolerances to Overpressure

4.1.2.1.1 Continuous Overpressure

4.1.2.1.2 Blast

4.1.2.2 Tolerances to Underpressure

4.1.2.2.1 Continuous Underpressure

4.1.2.2.2 Decompression

4.1.3 Tolerances to Temperature and Humidity

(Normal Range)

(Performance Limits)

(Emergency Limits)

4.2 Tolerances to Contaminants and Toxicants

4.2.1 Tolerances to Chemical Compounds

4.2.1.1 Carbon Dioxide

4.2.1.2 Carbon Monoxide

4.2.2 Tolerances to Microbial Agents

4.3 Tolerances to Acceleration

4.3.1 Tolerances to Linear Acceleration

4.3.1.1 Tolerances to Impact

4.3.1.1.1 Tolerances to Impact in Coronal Plane

4.3.1.1.2 Tolerances to Impact in the Sagittal Plane

4.3.1.1.3 Tolerances to Impact in the Transverse Plane

4.3.1.1.4 Tolerances to Impact in Off-Axis Planes

4.3.1.1.N Others

4.3.1.2 Tolerances to Brief Linear Acceleration

4.3.1.3 Tolerances to Sustained Linear Acceleration

4.3.1.3.1 Tolerances to Forward Sustained Linear Acceleration

(Performance Limits)

(Emergency Limits)

4.3.1.3.2 Tolerances to Rearward Sustained Linear Acceleration

(Performance Limits)

(Emergency Limits)

4.3.1.3.3 Tolerances to Upward Sustained Linear Accleration

4.3.1.3.3.1 Performance Limits

4.3.1.3.3.2 Emergency Limits

4.3.1.3.4 Tolerances to Downward Sustained Linear Acceleration

4.3.1.3.5 Tolerances to Sideward Sustained Linear Acceleration

4.3.2 Tolerances to Radial Acceleration

4.3.2.1 Tolerances to Roll (Right/Left)

4.3.2.2 Tolerances to Pitch (Up/Down)

4.3.2.3 Tolerances to Yaw (Right/Left)

4.3.3 Tolerances to Angular Acceleration

4.4 Tolerances to Gravitation

4.4.1 Tolerances to Reduced Gravitation

4.4.2 Tolerances to Weightlessness

4.4.3 Tolerances to Increased Gravitation

4.5 Tolerances to Vibration

4.5.1 Tolerances to Vertical Vibration

4.5.1.1 Tolerances to Whole Body Vibration

(Performance Limits)

(Emergency Limits)

4.5.1.2 Tolerances to Localized Vibration

4.5.2 Tolerances to Transverse Vibration

4.5.2.1 Tolerances to Whole Body Vibration

4.5.2.2 Tolerances to Localized Vibration

4.6 Tolerances to Noise

4.6.1 Tolerance to Infrasonic Noise

4.6.2 Tolerances to Audio Range Noise

4.6.3 Tolerances to Ultrasonic Range Noise

4.7 Tolerances to Radiation

4.7.1 Tolerances to Non-Ionizing Radiation

4.7.1.1 Tolerances to Radiowaves

4.7.1.2 Tolerances to Microwaves

4.7.1.3 Tolerances to Infrared

4.7.1.4 Tolerances to Visible Light

4.7.1.5 Tolerances to Ultraviolet

4.7.2 Tolerances to Ionizing Radiation

4.7.2.1 Tolerances to X-rays, gamma rays, beta rays, neutrons, protons, alpha particles, etc.

(Nominal Yearly Doses)

(Emergency Single Exposure Limits)

4.8 Tolerances to Food and Water (effects of deficiencies)

4.9 Tolerances to Drugs, Illnesses and Injuries

4.9.1 Effects of Illnesses

4.9.2 Effects of Injuries

4.9.3 Effects of Drugs

4.10 Tolerances to Deviations in Circadian Rhythms

4.11 Tolerances to Isolation and Confinement

4.11.1 Tolerances to Isolation

4.11.1.1 Physical

4.11.1.2 Social

4.11.2 Tolerances to Confinement

4.11.2.1 Encapsulation

4.11.2.2 Mandatory (social)

4.12 Tolerances to Combined Environmental Stresses

4.13 Tolerances to Social Environment

4.N Others

Appendix E: Categories and Parameters for Application Standards

5. Life Support Engineering Standards

5.1 Design of Suits and Portable Life Support Equipment (support/protection aspects)

5.1.1 Design of Clothing

5.1.2 Design of Anti-Exposure Suits

5.1.3 Design of Pressure Suits

5.1.4 Design of Portable Life Support Equipment

5.2 Selection and Design of Occupancy and Restraint Equipment

5.3 Design of Environmental Control Systems

5.3.1 Control of Atmosphere

5.3.1.1 Control of Pressure

5.3.1.2 Control of Composition

5.3.1.3 Control of Temperature and Humidity (Heating/Cooling/Ventilation)

5.3.1.4 Control of Contaminants and Toxicants

5.3.2 Control of Water

5.3.3 Control of Waste

5.3.4 Control of Radiation

5.3.4.1 Control of Non-ionizing Radiation (visible/infrared/ultra violet)

5.3.4.2 Control of Ionizing Radiation

5.3.5 Control of Noise

5.3.5.1 Control at Noise Source

5.3.5.2 Use of Ear Plugs

5.3.5.3 Use of Ear Muffs

5.3.5.4 Use of Helmets

5.3.6 Control of Vibration

5.4 Design of Food and Water Management Systems

5.4.1 Preservation of Food

5.4.2 Packaging and Storage of Food

5.4.3 Preparation of Food

5.4.4 Consumption of Food

5.4.5 Reconstitution of Food

5.4.6 Disposal of Residues

5.4.7 Determination of Water Requirements

5.4.8 Purification of Water

5.4.9 Consumption of Water

5.5 Design of Waste Management Systems

5.5.1 Determination of Waste Management Requirements

5.5.2 Design of Hygiene Stations

5.5.3 Disposal of Waste Products

5.6 Selection and Design of Monitoring Equipment

5.6.1 Selection of Physiological and Performance Parameters to be Monitored

5.6.2 Selection or Design of Sensors

5.6.3 Selection or Design of Processing Equipment

5.6.4 Selection or Design of Recording Equipment

5.6.5 Selection or Design of Transmission Systems (Telemetry)

5.6.6 Techniques for Analysis of Data

5.6.6.1 Display of Data

5.6.6.2 Reduction of Data

5.7 Provisions for Hygiene and Medical Supplies

5.7.1 Provisions for Medications

5.7.2 Provisions for Dressings

5.7.3 Design and Selection of Monitoring Equipment

5.7.4 Provisions for Hygiene Supplies and Equipment

5.8 Provisions for Maintaining Bodily Condition

5.9 Selection and Design of Escape, Survival, and Recovery Equipment

5.9.1 Determination of Operational and Environmental Conditions

5.9.2 Design of Ejection Equipment

5.9.2.1 Design of Seats

5.9.2.2 Design of Capsules

5.9.N Others

6. Human Engineering Standards

6.1 Utilization of Personnel

6.1.1 Allocation of Functions

6.1.1.1 Allocation of Functions between Personnel and Equipment

6.1.1.1.1 Establishment of the Level of Automaticity

6.1.1.1.2 Identification of the Human Functions

6.1.1.2 Allocation of Functions between Personnel

6.1.1.2.1 Determination of Duty Stations

6.1.1.2.2 Further Identification of Human Functions (Tasks)

6.1.1.2.2.1 Determination of Information Requirements

6.1.1.2.2.2 Determination of Problem Solving/Decision Making Requirements

6.1.1.2.2.3 Determination of Control Requirements

6.1.1.2.2.4 Determination of Sequences and Timing for Performance of the Tasks

6.1.1.2.3 Determination of Personnel Support and Protection Requirements (life support)

6.1.1.2.4 Initial Determination of the Types and Numbers of Personnel

6.2 Selection, Design, and Utilization of Displays

6.2.1 Selection and Utilization of Displays

6.2.1.1 Detailed Determination of Requirements for Information

6.2.1.1.1 Type of Information (qualitative/quantitative)

6.2.1.1.2 Complexity of Information

6.2.1.2 Detailed Determination of Conditions of Utilization

6.2.1.2.1 Compatability between Controls and Displays

6.2.1.2.2 Constraints Imposed by Work Environment

6.2.1.2.3 Frequency with which Information is Used

6.2.1.3 Determination of Availability of Required Signals

6.2.1.4 Determination of Availability of Required Displays Components

6.2.2 Design of Displays

6.2.2.1 Design of Visual Displays

6.2.2.1.1 General

6.2.2.1.1.1 Visibility (Dimensions of critical details, Contrast, Illumination, and Flicker)

6.2.2.1.1.2 Coding (Color, Numeral and Letter, Shape, Size, Brightness, Location, Flash, Line Length, Angular Orientation, Steroscopic Depth, Pattern/Configuration, and/or Auditory (supplementary))

6.2.2.1.1.3 Reliability

6.2.2.1.1.3.1 Equipment

6.2.2.1.1.3.2 Information

6.2.2.1.1.4 Maintainability

6.2.2.1.2 Indicator Lights

6.2.2.1.2.1 Dimensions

6.2.2.1.2.2 Illumination

6.2.2.1.2.3 Coding

6.2.2.1.2.4 Legends

6.2.2.1.2.5 Reliability

6.2.2.1.2.6 Maintainability

6.2.2.1.3 Single Character Digital and Word Readout Displays

6.2.2.1.3.1 Dimensions

6.2.2.1.3.1.1 Display Surface

6.2.2.1.3.1.2 Characters

6.2.2.1.3.2 Illumination

6.2.2.1.3.3 Coding

6.2.2.1.3.4 Legends

6.2.2.1.3.5 Reliability

6.2.2.1.3.6 Maintainability

6.2.2.1.4 Meters, Dials, and Gages

6.2.2.1.4.1 Scales

6.2.2.1.4.1.1 Scale Marker Dimensions

6.2.2.1.4.1.2 Scale Numbers and Numerical Progression

6.2.2.1.4.1.3 Interpolation and Graduation Interval

6.2.2.1.4.1.4 Multiple and Nonlinear Scales

6.2.2.1.4.2 Pointers

6.2.2.1.4.3 Illumination

6.2.2.1.4.4 Coding

6.2.2.1.4.5 Legends

6.2.2.1.4.6 Reliability

6.2.2.1.4.7 Maintainability

6.2.2.1.5 Multiple Character Alphanumeric, Graphic, and Pictorial Displays (Cathode Ray Tubes, Optical Projection Displays, etc.)

6.2.2.1.5.1 Capacity

6.2.2.1.5.2 Dimensions

6.2.2.1.5.3 Arrangement and Location

6.2.2.1.5.4 Formats

6.2.2.1.5.5 Illumination

6.2.2.1.5.6 Coding

6.2.2.1.5.7 Legends

6.2.2.1.5.8 Control

6.2.2.1.5.9 Reliability

6.2.2.1.5.10 Maintainability

6.2.2.1.6.1 Capacity

6.2.2.1.6.2 Dimensions

6.2.2.1.6.3 Arrangement and Location

6.2.2.1.6.4 Materials

6.2.2.1.6.4.1 Paper

6.2.2.1.6.4.2 Ink

6.2.2.1.6.5 Formats

6.2.2.1.6.6 Illumination

6.2.2.1.6.7 Coding

6.2.2.1.6.8 Legends

6.2.2.1.6.9 Control

6.2.2.1.6.10 Reliability

6.2.2.1.6.11 Maintainability

6.2.2.1.6.12 Noise

6.2.2.1.7 Permanent Record, Graphic Displays (Recorders, Plotters)

6.2.2.1.7.1 Capacity

6.2.2.1.7.2 Dimensions

6.2.2.1.7.3 Arrangement and Location

6.2.2.1.7.4 Materials

6.2.2.1.7.5 Formats

6.2.2.1.7.6 Illumination

6.2.2.1.7.7 Coding

6.2.2.1.7.8 Legends

6.2.2.1.7.9 Control

6.2.2.1.7.10 Reliability

6.3 Selection, Design, and Utilization of Controls

6.3.1 Selection and Utilization of Controls

6.3.1.1 General

6.3.1.1.1 Division of Work Between Body Limbs

6.3.1.1.2 Compatibility with Controller Object or Display

6.3.1.1.3 Conformity with Precision Requirements

6.3.1.1.4 Force and Range of Settings

6.3.1.1.5 Combinations of Controls

6.3.1.1.6 Environment

6.3.1.2 Discrete Controls

6.3.1.2.1 Requirements for Control

6.3.1.2.2 Conditions of Utilization

6.3.1.3 Continuous Controls

6.3.1.3.1 Requirements for Control

6.3.1.3.2 Conditions of Utilization

6.3.2 Design of Controls

6.3.2.1 General

6.3.2.1.1 Control/Display Ratio

6.3.2.1.1.1 Optimization of Ratio

6.3.2.1.1.2 Factors which Affect Ratio (Gear Ratio, Tolerance, Display Size, Viewing Distance, and Time Delays)

6.3.2.1.2 Resistance (Spring Loading (Elastic Resistance), Static (Stiction), Viscous Damping (Fluid Frictional Resistance), Inertia (Inertial Resistance), Coulomb Friction (Sliding or Kinetic Friction), and Operator Strength and Force Capacity)

6.3.2.1.3 Coding (Shape, Size, Color, Location, Labeling)

6.3.2.1.4 Compatibility between Controls and Displays

6.3.2.1.5 Accidential Activation of Controls (Recessing, Location, Orientation, Covering, Locking, Operation Sequencing, and Resistance)

6.3.2.2 Hand Controls

6.3.2.2.1 Push Buttons

6.3.2.2.1.1 Dimensions

6.3.2.2.1.2 Displacement

6.3.2.2.1.3 Resistance

6.3.2.2.1.4 Coding

6.3.2.2.1.5 Illumination

6.3.2.2.1.6 Accidental Activation

6.3.2.2.1.7 Other

6.3.2.2.2 Keyboards

6.3.2.2.2.1 Dimensions

6.3.2.2.2.2 Displacement

6.3.2.2.2.3 Resistance

6.3.2.2.2.4 Coding

6.3.2.2.2.5 Illumination

6.3.2.2.2.6 Accidental Activation

6.3.2.2.2.7 Other

6.3.2.2.3 Toggle Switches

6.3.2.2.3.1 Dimensions

6.3.2.2.3.2 Displacement

6.3.2.2.3.3 Resistance

6.3.2.2.3.4 Coding

6.3.2.2.3.5 Accidental Activation

6.3.2.2.3.6 Other

6.3.2.2.4 Rotary Selector Switches (Bar-Shaped Controls)

6.3.2.2.4.1 Dimensions

6.3.2.2.4.2 Displacement

6.3.2.2.4.3 Resistance

6.3.2.2.4.4 Coding

6.3.2.2.4.5 Accidental Activation

6.3.2.2.4.6 Other

6.3.2.2.5 Rotary Selector Switches (Thumbwheel Controls)

6.3.2.2.5.1 Dimensions

6.3.2.2.5.2 Displacement (Between Adjacent Detents)

6.3.2.2.5.3 Resistance

6.3.2.2.5.4 Coding

6.3.2.2.5.5 Accidental Activation

6.3.2.2.5.6 Other

6.3.2.2.6 Continuous Position Controls (Knobs)

6.3.2.2.6.1 Dimensions

6.3.2.2.6.2 Displacement

6.3.2.2.6.3 Resistance

6.3.2.2.6.4 Coding

6.3.2.2.6.5 Accidental Activation

6.3.2.2.6.6 Other

6.3.2.2.7 Handwheels

6.3.2.2.7.1 Dimensions

6.3.2.2.7.2 Displacement

6.3.2.2.7.3 Resistance

6.3.2.2.7.4 Coding

6.3.2.2.7.5 Accidental Activation

6.3.2.2.7.6 Other

6.3.2.2.8 Handcranks

6.3.2.2.8.1 Dimensions

6.3.2.2.8.2 Displacement

6.3.2.2.8.3 Resistance

6.3.2.2.8.4 Coding

6.3.2.2.8.5 Accidental Activation

6.3.2.2.8.6 Other

6.3.2.2.9 Levers

6.3.2.2.9.1 Dimensions

6.3.2.2.9.2 Displacement

6.3.2.2.9.3 Resistance

6.3.2.2.9.4 Coding

6.3.2.2.9.5 Accidental Activation

6.3.2.2.9.6 Other

6.3.2.3 Foot Controls

6.3.2.3.1 Foot Push Buttons

6.3.2.3.1.1 Dimensions

6.3.2.3.1.2 Displacement

6.3.2.3.1.3 Resistance

6.3.2.3.1.4 Coding

6.3.2.3.1.5 Accidental Activation

6.3.2.3.1.6 Other

6.3.2.3.2 Pedals

6.3.2.3.2.1 Dimensions

6.3.2.3.2.2 Displacement

6.3.2.3.2.3 Resistance

6.3.2.3.2.4 Coding

6.3.2.3.2.5 Accidental Activation

6.3.2.3.2.6 Other

6.4 Selection, Design, and Utilization of Control/Display Systems (Manual Tracking Systems)

6.4.1 Selection and Utilization of Control/Display Systems

6.4.2 Design of Control/Display Systems

6.5 Selection, Design, and Utilization of Communication Equipment

6.5.1 Selection and Utilization of Communication Equipment

6.5.1.1 General

6.5.1.1.1 Requirements for Speech Communication

6.5.1.1.1.1 Speech Interference Levels

6.5.1.1.1.2 Effects of Reverberation on Speech

6.5.1.1.1.3 Intelligibility of Speech

6.5.1.1.1.4 Effects of Earplugs on Speech

6.5.1.1.2 Arrangement of Interior Communication Equipment

6.5.1.1.3 Effects of Noise on Communication

6.5.1.2 Telephone

6.5.1.3 Announcing System and/or Intercommunication Systems

6.5.1.4 Recorded Signals and Directions

6.5.1.N Others

6.5.2 Design of Communication Equipment

6.5.2.1 General

6.5.2.2 Telephone

6.5.2.2.1 Receiver

6.5.2.2.2 Handset

6.5.N Etc.

6.6 Selection, Design, and Utilization of Control/Display Panels and Controls

6.6.1 Design of Control/Display Panels and Consoles

6.6.1.1 Position of Operator

6.6.1.1.1 Performance of Visual Operations

6.6.1.1.1.1 Seated Position

6.6.1.1.1.2 Standing Position

6.6.1.1.1.3 Orientation of Displays

6.6.1.1.2 Performance of Manual Operations

6.6.1.1.2.1 Seated Position

6.6.1.1.2.2 Standing Position

6.6.1.2 Configurations of Panels and Consoles

6.6.1.2.1 Contours and Slopes of Consoles

6.6.1.2.1.1 Display Surfaces

6.6.1.2.1.2 Control Surfaces

6.6.1.2.1.3 Work Surfaces

6.6.1.2.1.4 Under Console Area

6.6.1.2.2 Arrangement of Controls and Displays

6.6.1.2.2.1 Priorities for Location of Controls and Displays

6.6.1.2.2.2 Grouping of Controls and Displays

6.6.1.2.2.3 Association Between Controls and Displays

6.6.1.2.2.4 Spacing of Controls

6.6.1.2.3 Direction-of-Movement Relationships Between Controls and Displays

6.6.1.2.3.1 Rotary Controls and Operator Orientation

6.6.1.2.3.2 Linear Controls and Operator Orientation

6.6.1.2.3.3 Rotary Controls with Rotary Displays

6.6.1.2.3.4 Rotary Controls with Linear Displays

6.6.1.2.3.5 Linear Controls with Rotary Displays

6.6.1.2.3.6 Valves

6.6.1.2.3.7 Push-Pull (Plunger-Type) Controls

6.6.1.2.3.8 Spring-Loaded Unidirectional Controls

6.6.1.2.3.9 Direction-of-Movement Relationships in Tracking

6.6.1.3 Surface Finish and Markings

6.6.1.3.1 Finish Color and Gloss

6.6.1.3.2 Markings

6.6.1.3.2.1 Location

6.6.1.3.2.2 Content

6.6.1.3.2.3 Composition

6.6.2 Design of Support Equipment

6.6.2.1 Seats

6.6.2.2 Arm and Foot Rests

6.6.2.3 Back Rests

6.7 Design of Equipment for Maintenance

6.7.1 General

6.7.2 Design of Operational Equipment

6.7.2.1 Design of Units

6.7.2.1.1 Location of Components

6.7.2.1.2 Mounting and Assembly of Components and Units

6.7.2.1.3 Identification of Units and Components

6.7.2.2 Design of Covers and Cases

6.7.2.2.1 Characteristics of the Structure

6.7.2.2.2 Fasteners for Covers and Cases

6.7.2.2.3 Design of Handles

6.7.2.3 Design of Cables and Connectors

6.7.2.3.1 Design of Cables

6.7.2.3.2 Routing of Cables

6.7.2.3.3 Design of Connectors

6.7.2.4 Accesses to Equipment

6.7.2.4.1 Shape and Size of Accesses

6.7.2.4.2 Identification of Accesses

6.7.2.4.3 Provisions for Safety

6.7.2.5 Design of Test Points

6.7.2.5.1 Location of Test Points

6.7.2.5.2 Identification of Test Points

6.7.2.6 Displays for Maintenance (uses most of the criteria in Design of Equipment for Operation)

6.7.2.6.1 Selection of Displays

6.7.2.6.2 Placement of Displays

6.7.2.6.3 Identification of Displays

6.7.2.7 Controls for Maintenance (uses most of the criteria in the Design of Equipment for Operation)

6.7.2.7.1 Selection of Controls

6.7.2.7.2 Placement of Controls

6.7.2.7.3 Identification of Controls

6.7.2.8 Installation of Operational Equipment

6.7.2.8.1 Space for the Equipment

6.7.2.8.2 Access to the Equipment

6.7.3 Selection and Design of Test Equipment

6.7.4 Design of Bench Equipment

6.8 Design or Modification of Facilities

6.8.1 General

6.8.2 Design of Compartments and Rooms

6.8.2.1 Design of Traffic Spaces

6.8.2.1.1 Aisles and Corridors

6.8.2.1.1.1 Dimensions

6.8.2.1.1.2 Location/Number of Entrances/Exits

6.8.2.1.1.3 Location/Number of Doors Opening on Passageway

6.8.2.1.1.4 Levels of Illumination

6.8.2.1.1.5 Finish

6.8.2.1.1.6 Signs

6.8.2.1.2 Catwalks and Tunnels

6.8.2.1.3 Doorways and Hatches

6.8.2.1.4 Ladders, Stairs, and Ramps

6.8.2.1.5 Escalators and Elevators

6.8.2.1.6 Ceilings and Overheads

6.8.2.2 Design of Operating Spaces

6.8.2.2.1 Size and Movement of Body

6.8.2.2.2 Size of Group

6.8.2.2.3 Mobility of Group

6.8.2.2.4 Size, Number, Location, of Equipment

6.8.2.2.5 Communication between Members of Group (visual/auditory)

6.8.2.3 Design of Maintenance Spaces

6.8.2.4 Design of Information Centers

6.8.3 Design of Conference Rooms and Auditoriums

6.8.4 Design of Multiple Compartments and Rooms

6.9 Design of Handling and Transport Equipment

6.9.1 Design of Transporting Equipment (transporting, positioning, lifting equipment, etc.)

6.9.1.1 Configuration of Vehicles

6.9.1.1.1 Visability between Crew Members

6.9.1.1.2 Functional Design of Equipment

6.9.1.1.3 Color of Equipment

6.9.1.1.4 Name Plates and Labels

6.9.1.1.5 Access (for operation and maintenance)

6.9.1.1.6 Doors and Escape Hatches

6.9.1.1.7 Replacement of Units

6.9.1.2 Design of Transport Vehicles

6.9.1.2.1 Supply Trailers

6.9.1.2.1.1 Design of Operator Positions

6.9.1.2.1.1.1 Design of Seats

6.9.1.2.1.1.2 Design of Instrument Panels

6.9.1.2.1.1.3 Design of Controls

6.9.1.2.1.1.4 Design of Windshields and Windows

6.9.1.2.1.1.5 Control of Environment (i.e., illuminations, sound, vibration, temperature, humidity, toxicants)

6.9.1.2.1.2 Design of Auxiliary Equipment (i.e., tools, cables, towbars, ladders, etc.)

6.9.1.2.2 Trucks, Tractors, and Vans

6.9.1.2.3 Fueling Vehicles

6.9.1.3 Lifting Equipment

6.9.1.3.1 Hoists and Hoist Beams

6.9.1.3.2 Jacks, Elevators, and Lifts

6.9.1.3.3 Cranes and Slings

6.9.1.3.4 Cradles

6.9.2 Design of Remote Handling Equipment (to be developed)

6.10 Design of Clothing and Personal Equipment (human engineering aspects)

6.10.1 General

6.10.2 Selection and Design of Clothing

6.10.3 Selection and Design of Anti-Exposure Suits

6.10.3.1 Conformance to Bodily Dimensions and Contours

6.10.3.2 Mobility

6.10.3.3 Donning/Removal

6.10.3.4 Attachment/Access to Portable Equipment

6.10.4 Selection and Design of Partial-Pressure Suits

6.10.5 Selection and Design of Pressure Suits

6.10.6 Design of Personal (Hand/Back Carried) Equipment

6.10.6.1 Attachment

6.10.6.2 Portability

6.10.6.3 Operation

6.11 Design of Materials, Aids, and Devices for Training and Evaluation

6.11.1 General

6.11.2 Determination of Requirements for Training Materials and Equipment

6.11.3 Selection of Training Materials and Equipment

6.11.4 Design of Training Materials and Equipment

6.11.4.1 Design of Training and Evaluation Aids

6.11.4.2 Design of Training and Evaluation Devices

6.11.4.2.1 Design of Controls, Displays, and Trainee Stations

6.11.4.2.2 Development of Training and Evaluation Programs and Procedures

6.11.4.2.3 Design of Scoring and Recording Equipment

6.11.4.2.4 Design of Facilities for Instructors

6.11.4.2.5 Design of Facilities for Trainer

7. Procedures Development and Documentation Standards

7.1 Development of Procedures

7.1.1 General

7.1.2 Development of Operating Procedures

7.1.3 Development of Maintenance Procedures

7.1.4 Development of Management Procedures

7.1.N Others

7.2 Preparation of Instructions and Manuals

7.2.1 General

7.2.2 Preparation of Operating Instructions

7.2.2.1 Form of Presentation

7.2.2.2 Content of Document

7.2.3 Preparation of Maintenance Instructions

7.2.4 Preparation of Management Manuals

7.N Others

8. Personnel Selection and Training Standards

8.1 Selection of Personnel (to be developed)

8.1.1 Physical

8.1.2 Education

8.1.3 Experience

8.2 Training and Evaluation of Personnel (to be developed)

8.2.1 General

8.2.2 Determination of Training Requirements

8.2.3 Development of Training Content and Methods

8.2.4 Development of Training, Programs, Courses, and Materials

9. Crew Composition Standards (to be developed)

9.1 General

9.2 Determination of Requirements for Types/Numbers of Personnel

9.3 Organization of Personnel

9.4 Location of Personnel

9.5 Communication between Personnel

9.N Others

Appendix F: Example of Definitions for Human Standards (Vibration)[1]

a. Vibration is defined as the periodic motion of the particles of an elastic body or medium in alternately opposite directions from the position of equilibrium when that equilibrium has been disturbed. The vibration, therefore, may occur in air, liquid, or solid media; however, the primary concern here is with the oscillation of solid or semisolid bodies (e.g., structures of the spacecraft) in contact with the human body. Some non-auditory effects on the body are produced by transmission of vibration through the air; however, most of this occurs in the audio range and therefore is treated in Section 5.6: Noise.

b. The parameters of vibration (see Figure 5.5-1) which are significant for an understanding of the effects of vibration on the human body are as follows:

1.) Frequency, which is usually specified in cycles per second (cps) and may extend from greater than zero to the megacycle range (see Figure 5.5-2): however, the range of concern with respect to the effects on the human body is confined to less than 1000 cps. Most of the significant effects of vibration occur within the .5 to 50 cps range. Within this range the human body responds as a complex system of masses, elasticities, and dampers having lumped parameters (See Figure 5.5-3). Above 50 cps, it is more appropriate to regard the body as a continuous viscous-elastic medium for vibration applied to the surface of the body. Below 0.5 cps vibration is experienced as single jolts and as such, is similar to linear accelerations (See Section 5.3).

2.) Displacement, or amplitude, which is usually expressed in inches or centimeters, is defined as the maximum half-wave displacement (single amplitude) or full wave (double amplitude).

3.) Velocity, in inches/second, is the first derivative of amplitude and ordinarily is not used in describing the effects of vibration on the human body.

4.) Acceleration, in inches/second^2, is the second derivative of amplitude, and ordinarily is expressed in maximum or peak g, i.e.:

$$g = \frac{A(2\pi f)^2}{386}$$

[1] Chambers, A.N., Human Standards for Manned Space Flight; Section 5.5 Vibration, Bellcomm Working Papers, December 1966.

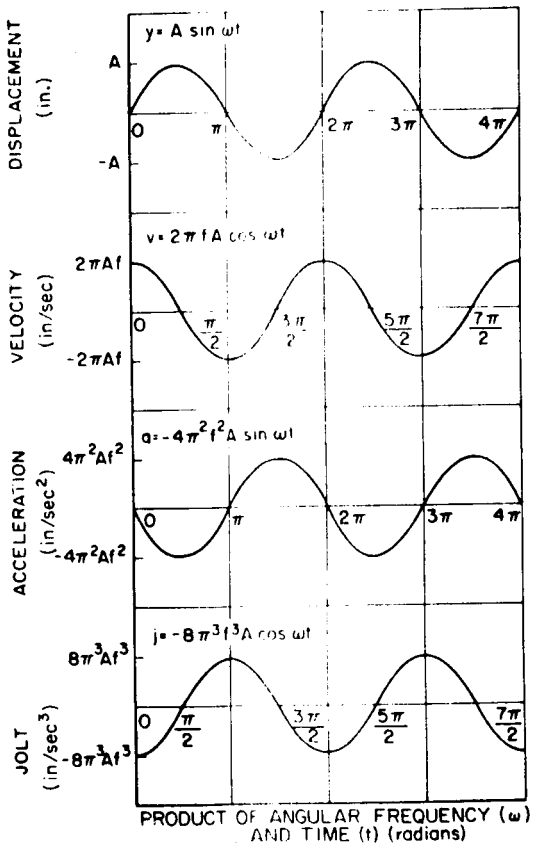

Figure 5.5-1a: Relationship of the Parameters of Vibration (Chapter 10, in Morgan, et al, Editors, Human Engineering Guide to Equipment Design, 1962).

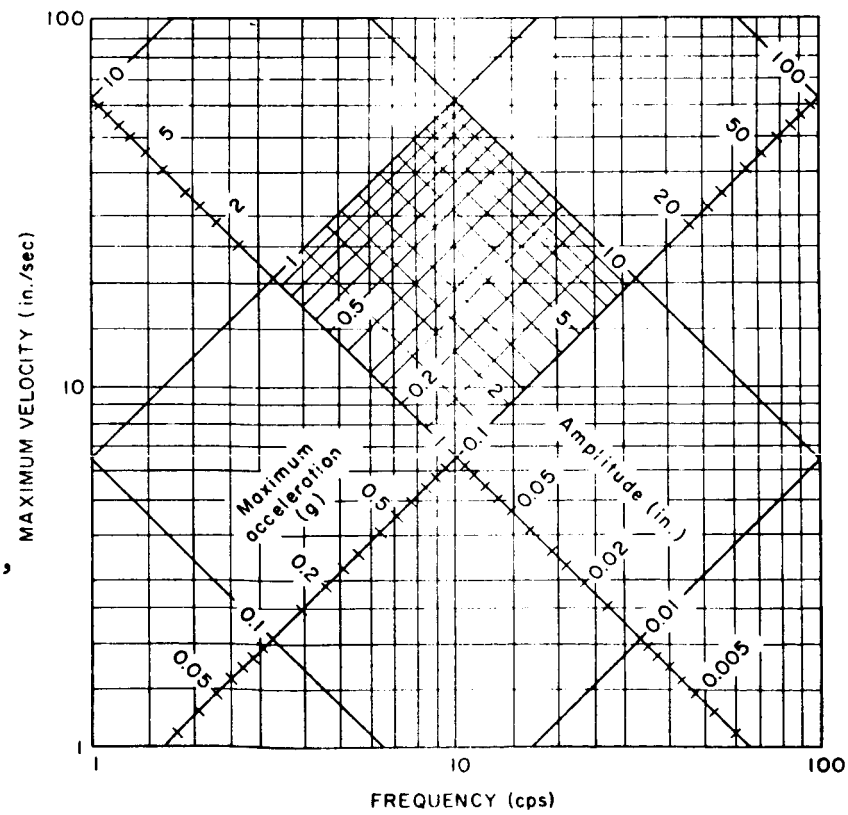

Figure 5.5-1b: Conversions between the Parameters of Vibration (Morgan, et al, Editors, Human Engineering Guide to Equipment Design, 1963).

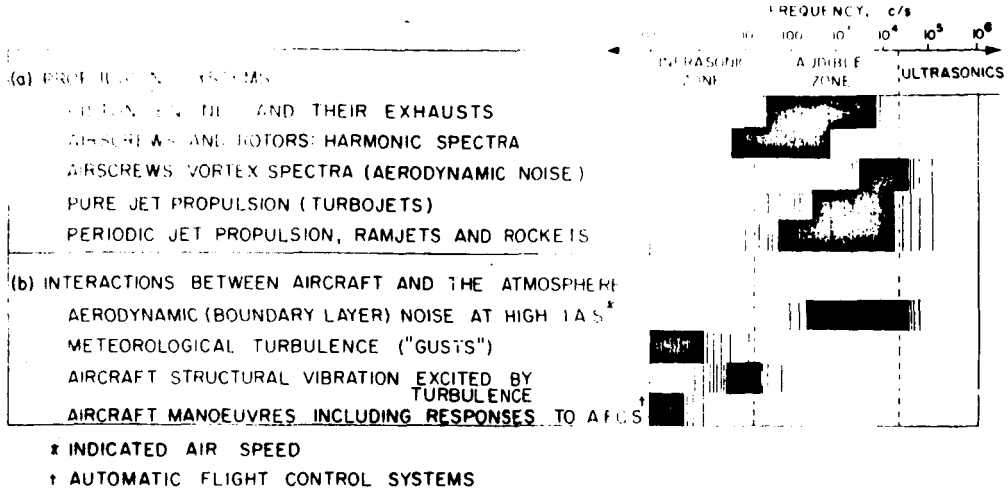

Figure 5.5-2: Principal sources of sound and vibration in aviation. The contributions made by aircraft propulsive systems, and by interactions between aircraft and the atmosphere. (To be revised to show spacecraft related sound and vibration.)

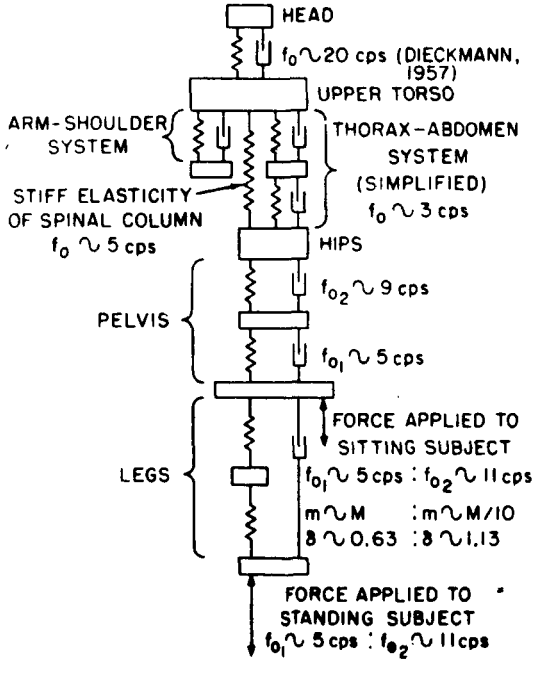

Figure 5.5-3: Model of the Dynamic Mechanical Properties of the Human Body (Coermann, R. R., et al, The Passive Dynamic Mechanical Properties of the Human Thorax-Abdomen System and the Whole Body System, Aerospace Medicine, June 1960, pp. 443 - 455).

The lack of rigidity of the human body makes measurement of particle acceleration preferable to displacement or velocity (Goldman, D. E., Effects of Vibration on Men, in Harris, C. M., Ed., Handbook of Noise Control, 1957). A nomograph is provided in Figure 5.5-4 for converting frequency and amplitude to acceleration.

5.) Jolt, in inches/second^3, is the third derivative of amplitude and, as noted previously, most of the effects can be treated as linear acclerations.

6.) Duration of vibration, in seconds, minutes, or longer time units, is important in establishing the effects of vibration. This includes short term exposures, long term exposures (over 1 hour) - for which there is very little research data - and repeated exposures.

7.) With respect to the spectral characteristics of vibration, it may be classified as:

(a.) Sinusiodal when composed of a single wave;

(b.) Complex when composed of two or more sinusiodal waves; and

(c.) Non-periodic which may approach randomness when composed of waves which do not repeat systematically. Random, or semirandom waves are usually characterized in terms of a power density curve (PSD) which is derived from the frequency bands that characterize the random vibrations.

c. The transmission of vibration (i.e., forced vibration) to and within the human body is dependent on the following:

1.) Direction of application of vibration to the human body which includes any, or any combination of the axes of the body (see Figure 5.5-5 for definitions). Most vibration research has been confined to the longitudinal axis (Z) of the body, since this has been the most common condition in most vehicles. However, in space vehicles much of the vibration can be expected to occur in the direction of the fore-aft (X) axis of the body.

2.) Point of application of vibration to the human body which includes whole body vibration transmitted through seats (when subject is seated), through the feet (when standing), through the length of the body (when reclining), or combinations of these. Also, vibration may be transmitted via a body part

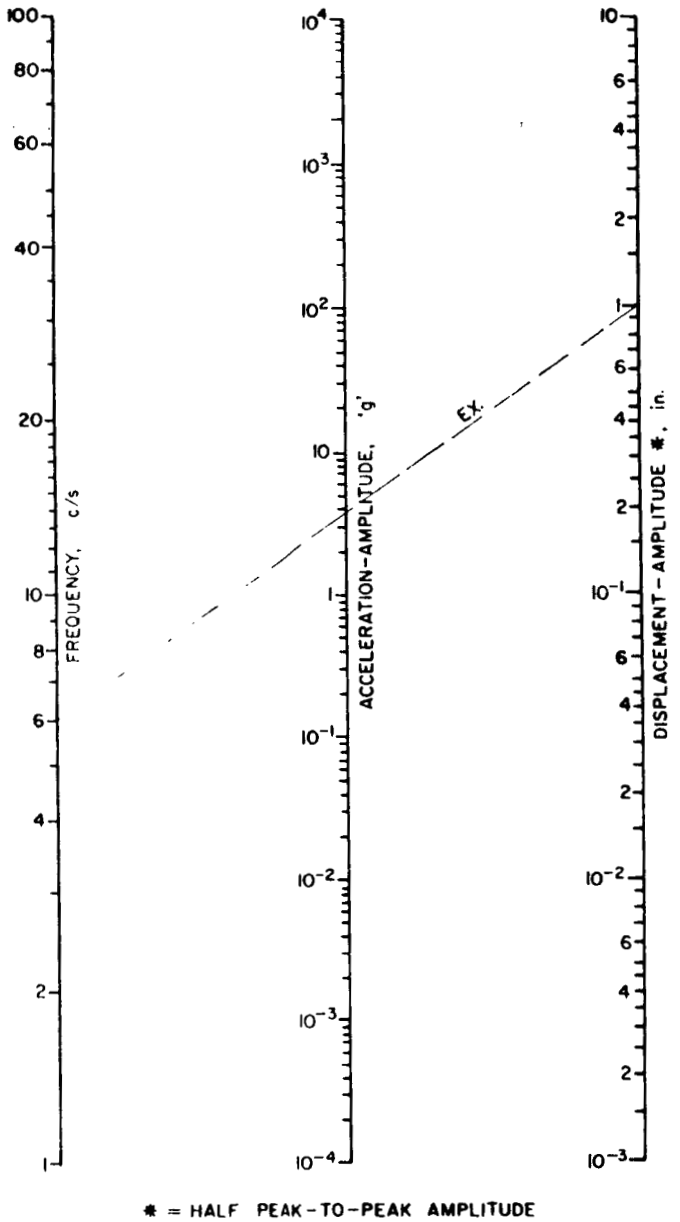

Figure 5.5-4: Nomogram of frequency, displacement-amplitude and acceleration-amplitude for sinusoidal vibration. Example of use: to determine the acceleration-amplitude of a vibration of 6 c/s at 1 in. (half-wave) amplitude (i.e., 2 in. peak-to-peak), lay a straight-edge across the chart joining 6 c/s with 1 in. amplitude. Answer: the acceleration-amplitude is 4 g (approximately).

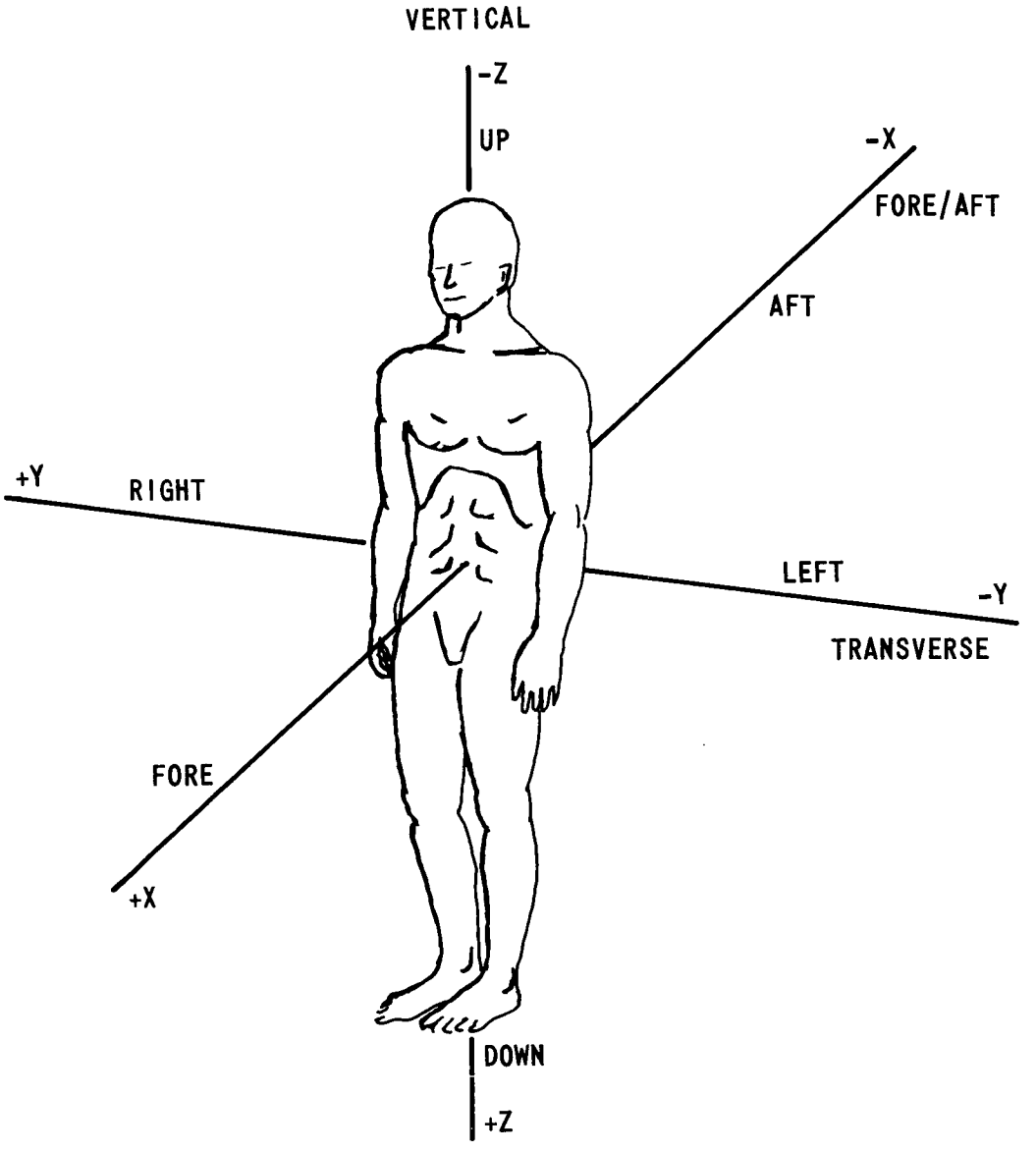

FIGURE 5.5.5: TERMINOLOGY AND COORDINATE SYSTEM FOR THE HUMAN BODY

such as the hand (when holding a vibrating control). Vibration of instruments may also be included in the later category since its effects are primarily confined to the eyes.

3.) Position of the body also determines the effects of vibration on the body and is related to the point of application. Effects are different depending on whether the person is seated, standing, reclining, prone, supine, or crouched.

4.) Materials interposed between the body and source of vibration effects transmission of vibration to the body. This includes the effects of padding on seats, spring mountings, etc.

5.) Restraint of the body may attenuate or increase the effects of vibration depending on the frequency and amplitude. This includes the restraint of the person by seat belts and harnesses against a vibrating seat, support for the arm in operating a control, wearing of girdles (which restrain the abdominal region), etc.

6.) Interaction with other environmental variables may also enhance or reduce vibration and vibration effects. The presence of acceleration forces (e.g., linear $+G_z$), reduced gravitation, and weightlessness can be expected to affect the transmission characteristics (See Section 5.5.1.2.3).

d. The transmission of vibration within the human body is dependent on the following:

1.) Body size, build, and weight with greater attenuation with larger masses and densities.

2.) Posture, whether erect or slumped; and

3.) Muscular tension, which is noticeably affected by fatigue resulting from prolonged vibration (Hornick, 1962).

e. The response of the human body, which establishes the criteria for the standards (Section 5.5.3) can be considered under the headings of physical, physiological, performance, and pathological. Of these, the physical responses (e.g., resonance which causes discomfort and pain) establish most of the physiological tolerance limits to vibration. Each of these response categories will be described in some detail.

1.) The physical responses of the body, as noted above, are primarily the result of the body acting as a complex system of masses, elasticities, and dampers in the low frequency range (i.e., up to 50 dps.). (See Figure 5.5-6.) The impedance of the body and its parts and organs damp vibration over certain frequency/amplitude ranges; for certain other frequency/amplitude ranges there are resonances which amplify the vibration within various portions or all of the body. The human body is considered to have a natural resonance between 4 and 6 cps. The impedance and resonance of the body and its parts influences the transmission characteristics of the vibration through the body and its parts.

Figure 5.5-7 illustrates some of these responses to vertical sinusiodal vibration. The subjective responses of the subjects range from the perception of feeling to pain and are the primary sensations correlated with the physical response of the body. Most tolerance criteria are based on these subjective responses. Testing to the point of serious physical or physiological damage to the body is, of course, unacceptable for human subjects. Presumably, the threshold for pain is below that for trauma.

For transverse vibration in the fore-aft direction of a seated subject, there is a shearing force applied to the buttocks. (Gillies, A Textbook of Aviation Physiology: 1965.) A low-frequency resonance occurs due to flexion of the lumbo-dorsal spine and, in fore-and-aft vibration, articulation at the hip joints. Von Bekesy (1939) recorded a lateral bending mode at 1.6 c/s. More recently, maxima in horizontal seat-to-head transmissibility have been reported in the range 1.5 to 2.5 c/s (Dieckmann, 1958b; Hornick et al., 1961). Resonance near 2 c/s is the dominant mode in horizontal vibration of the seated man. If the seated subject is vibrated in more than one plane simultaneously, his physical response and subjective appreciation of the motion depend upon the amplitude and phase relationships between the component vibrations. If a subject is exposed to simultaneous vertical and horizontal (fore-and-aft) vibrations of equal frequency and amplitude, such as are experienced in a helicopter, a circular motion of the seat may be produced by suitable phasing of the two vibrations (Grant, 1961). It has been demonstrated that, if the direction of circular motion of the seat is backward-running (i.e., anti-clockwise as viewed from the right), the subject's physical and subjective responses are essentially those characteristic of horizontal excitation; but, if the circular motion is forward-running, the response resembles that to vertical vibration.

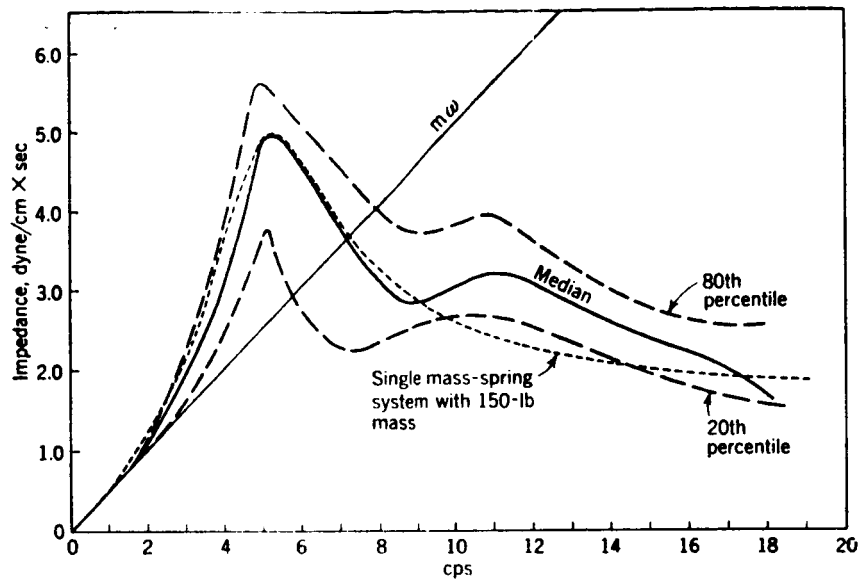

Figure 5.5-6a: Impedance of the Human Body. The median and the twentieth and eightieth percentiles of the impedance of five different subjects as compared with the impedance of a single mass-spring system and a pure mass system (mω). (After R. R. Coermann, et al., The Passive Dynamic Mechanical Properties of the Human Thorax-Abdomen System and of the Whole Body System, Aerospace Medicine, Vol. 31, June 1960, pp. 443-455.)

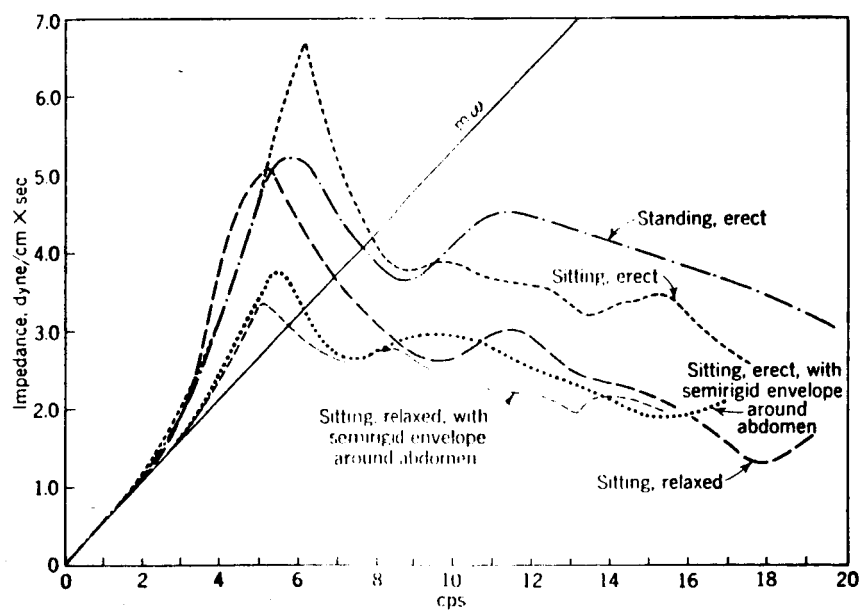

Figure 5.5-6b: Impedance of the Human Body. The mechanical impedance of one subject sitting and standing in varied postures and with varied supports. (After R. R. Coermann, et al., The Passive Dynamic Mechanical Properties of the Human Thorax-Abdomen System and of the Whole Body System, Aerospace Medicine, Vol. 31, June 1960, pp. 443-455.)

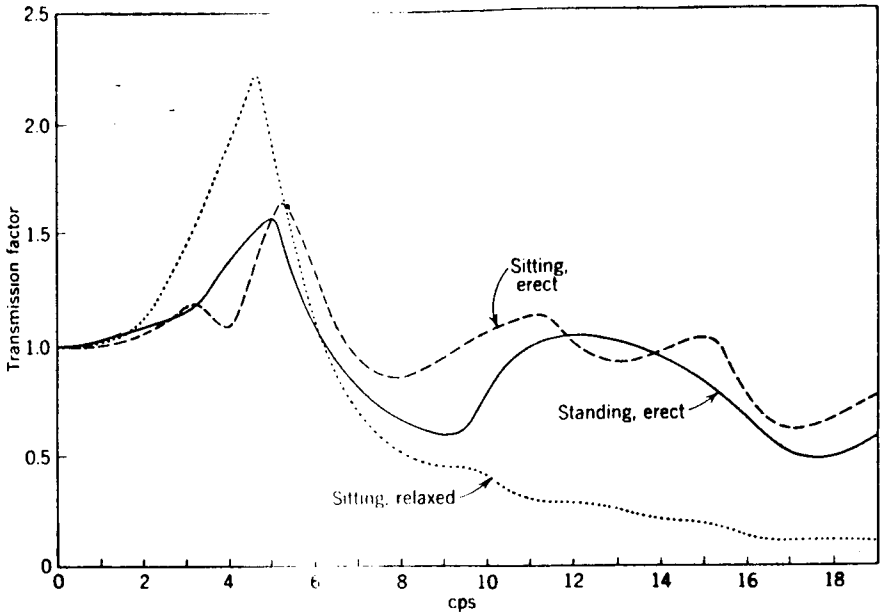

Figure 5.5-7a: Transmission of Vibration in the Human Body. The transmission of vibrations from the shake table to the head of one subject with varied postures. (After E. B. Magid and R. R. Coermann, The Reaction of the Human Body to Extreme Vibrations, Proc. Inst. Environmental Sci., 1960, p. 135.)

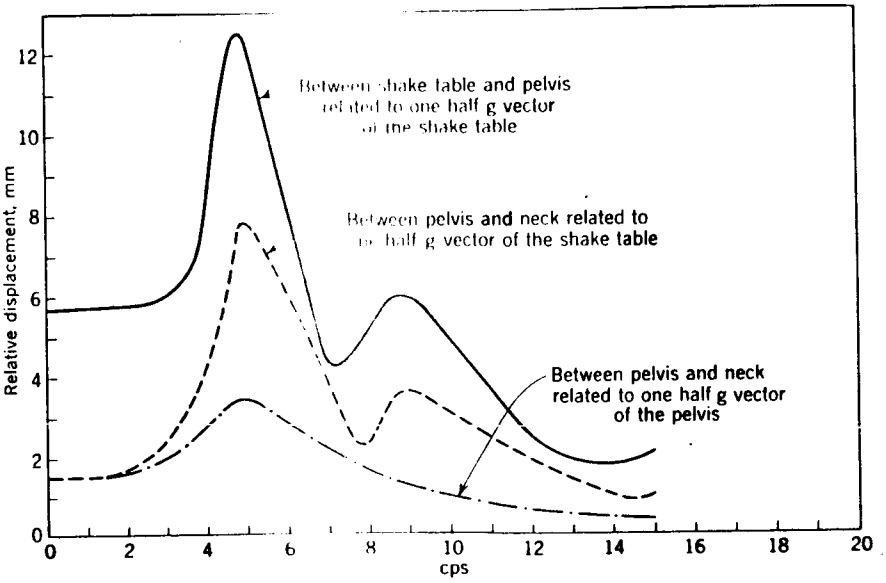

Figure 5.5-7b: Transmission of Vibration in the Human Body. Relative body displacements of one subject sitting erect during vertical vibration. (After E. B. Magid and R. R. Coermann, The Reaction of the Human Body to Extreme Vibrations, Proc. Inst. Environmental Sci., 1960, p. 135.)

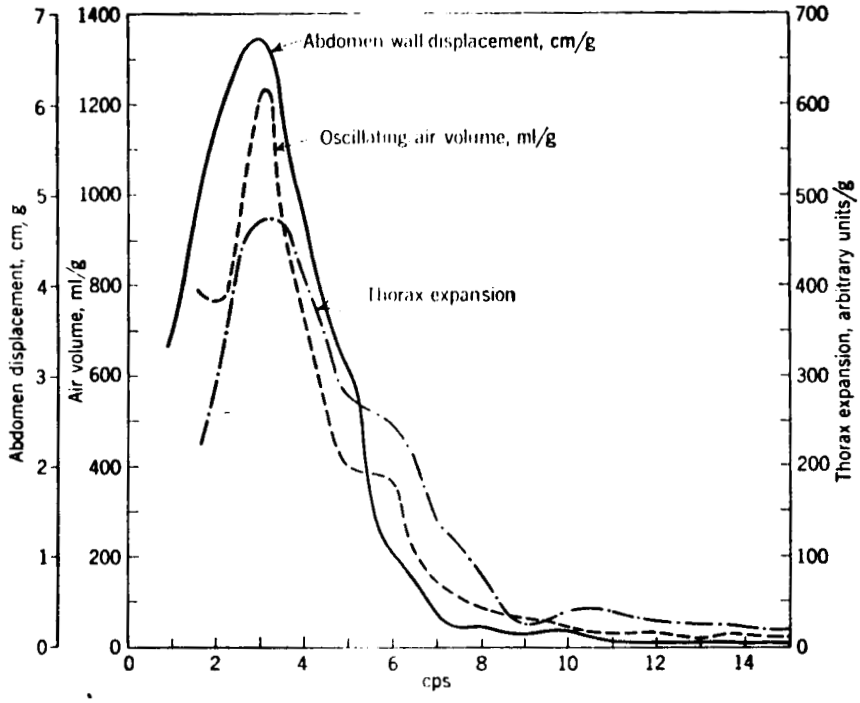

Figure 5.5-7c, Continued: Abdomen-wall displacement, thorax expansion, and oscillating air volume of a human subject (supine position, shaken horizontally). (After R. R. Coermann, et al., The Passive Dynamic Mechanical Properties of the Human Thorax-Abdomen System and of the Whole Body System, Aerospace Medicine, Vol. 31, June 1960, pp. 443-455.)

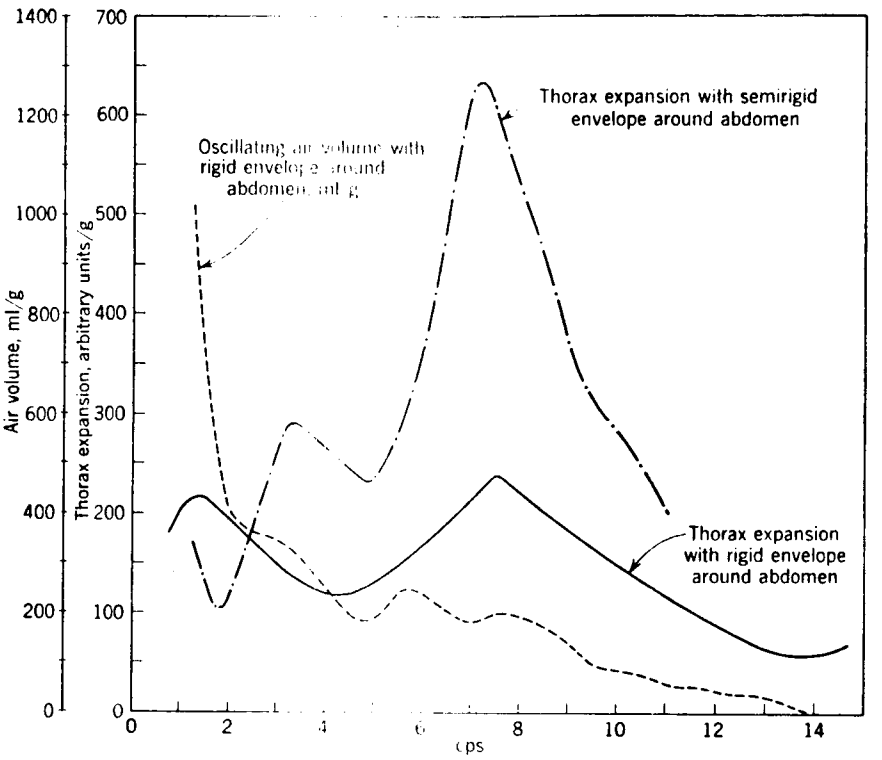

Figure 5.5-7d, Continued: Thorax expansion and oscillating air volume of a human subject with envelope around abdomen (supine position, shaken horizontally). (After R. R. Coermann, et al., The Passive Dynamic Mechanical Properties of the Human Thorax-Abdomen System and of the Whole Body System, Aerospace Medicine, Vol. 31, June 1960, pp. 443-455.)

2.) The effects on the physiological functioning of the body may be considered in two categories: a) those changes which are directly attributable to the differential vibratory movement or deformation of particular body structures and are primarily frequency dependent; and b) generalized responses to vibration as a non-specific stress and are more dependent on magnitude and duration.

The physiological functions which respond primarily to vibration include:

a.) Cardiovascular functions through changes in blood pressure, electrocardiographic outputs, and blood cell counts.

b.) Respiratory functions through changes in tidal volumes, rates, and valsalsa response.

c.) Metabolic balances through increased rates.

d.) Endocrine functioning, which appears to effect changes in functioning and shortening of life (based on animal studies).

e.) Neurological functioning, including the perception of vibration and regulation of posture.

3.) The effects on performance may be considered as a) direct mechanical interferences with performance, or b) indirect effects resulting from physiological alterations. Some of the types of performance which are significantly affected by vibration include:

a.) Visual tasks, including reduction in visual acuity and increased eye movements. Direct effects are primarily mechanical (resonance) for certain g-vector and frequency combinations; indirect include pain for other g-vector/frequency combinations.

b.) Vigilance, concentration, and reaction time, all of which are adversely affected.

c.) Body equilibrium, increases the difficulty of maintaining body posture and position.

d.) Simple motor tasks, such as operation of

switches, increases response time and number of errors.

e.) Complex motor tasks, such as tracking, reduces accuracy.

f.) Speech increases difficulty of articulation and makes speech less intelligible.

4.) The pathological responses include both traumatic and lethal effects from whole body vibration and disease produced by hand held tools.