

FOREWORD

The quality of the interface which connects man with his machines frequently determines the ability and ultimate performance of the man/machine unit. The more dependent man is upon his creations the more critical is the connecting link and nowhere has he been more absolutely dependent upon the man/machine interface than in space flight. For every second of existence in space, for every moment of comfort, for every endeavor, man is completely dependent upon devices of his own making. The interfaces--whether they be space suits or rocket controls and displays--are crucial.

As might have been expected, putting man into space systems has been one of the most expensive and perplexing aspects of spacecraft design. The human body has evolved under, and in response to, the large and ever-present forces of gravity. It is not surprising, then, that when such a body is placed in a weightless environment it frequently finds itself at a distinct disadvantage. Man does, of course, adapt to weightlessness. Some aspects of this adaptation are apparently harmless while others could be incapacitating during and after return to one-g. Thus, in addition to helping the human body in zero-g maintain its mechanical one-g functions, space systems must accommodate changes in the body's size, shape and posture.

The beginning of any man/machine interface is objective knowledge of the full range of man's size, shape, composition and mechanical capacities. Hence, anthropometry is fundamental to successful designs for the future use and exploration of space. The only alternative is the costly process of trial and error.

At this writing we are in the process of designing a space vehicle which will carry large numbers of people, men and women of all nations and races and of a wide range of ages and sizes, into and out of weightlessness. It is inevitable that such a transportation system will be followed by space stations where people will function for long periods in an environment for which their bodies were not designed.

Fortunately, there is a great mass of anthropometric data available on sizeable samples of the world's populations. The first task, then, was collecting, standardizing and presenting sufficient data on the size, shape and mass of samples of the world's populations to give the designer primary information for accommodation of the subjects who will use the shuttle and other vehicles. Contained in this book also is a body of information on strength, reach, range of joint motion and mass distribution properties of the human body which are essential to the design of clothing, equipment and workspaces for use in space vehicles.

It is not enough, of course, to assemble information. Crucial to the effective use of anthropometric data is an understanding of their origin, limitations and proper application. To this end, chapters on variability of body size, statistical considerations and the application of anthropometry to sizing and design provide additional explanation and instruction to guide the reader in making meaningful use of the data contained in this book.

Central to the concerns of NASA design engineers is the problem of weightlessness. Unfortunately, in spite of 16 years of space flight, hard data on the changes which take place in man's size, shape and function in the zero-g environment are scanty. Interface problems are legion. A suit of clothing will hardly accommodate 10-centimeter changes in girth or 6-centimeter height changes, yet men undergoing such changes have had to operate in closely fitting space suits. A good look at the relaxed posture assumed by man in the weightless environment will suggest why the conventional seat is not only uncomfortable but also requires forceful strapping if a person is to even stay in it. If weightless anthropometric data are scanty and incomplete, they are nevertheless already sufficient to have redirected much of the space medical effort and to explain many of the phenomena described by crewmen which could seriously impede efficient operation unless dealt with. The opening chapter of this volume contains virtually all of what we now know about this subject. It is hoped that the very paucity of data will challenge future investigators to give this field proper attention.

Finally, those of us who are directly involved in space flight operations are grateful for the dedication of the man/machine engineers who make our lot better. We in turn shall make every effort to help them by bringing back the information they need to help us.

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PREFACE

The Anthropometric Source Book is designed to provide NASA, NASA contractors, the aerospace industry, Government agencies, and a wide variety of industrial users in the civilian sector with a comprehensive, up-to-date tabulation of anthropometric data. Specifically, it is tailored to meet the needs of engineers engaged in the design of equipment, habitability areas, workspace layouts, life-support hardware, and clothing for the NASA Space Shuttle/Spacelab program. The intent is to provide the designer not only with dimensional data but with underlying anthropometric concepts and their application to design.

All available anthropometric data collected in the weightless environment are documented in this three-volume book, which also includes an extensive tabulation of anthropometric data defining the physical size, mass distribution properties, and dynamic capabilities of U.S. and selected foreign populations. The material covers adult males and females of various age groups, socio-educational backgrounds, races, and ethnic backgrounds. Also included are size-range projections for a 1985 population eligible for manned space flight.

Volume I is a nine-chapter treatment covering all basic areas of anthropometry and its applications to the design of clothing, equipment, and workspaces.

Chapter 1, "Anthropometric Changes in Weightlessness," addresses the effects on the human body that occur as a result of weightlessness. Such topics as weight loss, height increases, neutral body posture, strength and body composition, changes in trunk and limb girth, and loss of muscle mass are discussed in detail. In addition to bringing together in a single source the most comprehensive collection of data on anthropometric change in weightlessness that exists in this country, this chapter calls attention to the potential impact of weightlessness on man/machine design and suggests areas of future study essential to the proper design of man's space environment.

Chapter 2, "Variability in Human Body Size," describes and graphically documents the range of human-body variability found among homogeneous groups. Those trends that show significantly marked differences between sexes and among a number of racial/ethnic groups are also presented. This chapter alerts design engineers to the nature and extent of human-body variability and serves as a guide for modifying and designing man/machine systems.

Chapter 3, "Anthropometry," presents tabulated dimensional anthropometric data on 59 variables for 12 selected populations. The variables chosen were judged most relevant to current manned space programs. Appendix A to this chapter is a glossary of anatomical and anthropometric terms. Appendix B covers selected body dimensions of males and females from the potential astronaut population projected to the 1980-1990 time frame. Appendix C contains a 5th-, 50th-, and 95th-percentile drawing-board manikin based on the anticipated 1980-1990 body-size distribution of USAF fliers.

Chapter 4, "The Inertial Properties of the Body and Its Segments," is a user-oriented summary of the current state of knowledge on the mass distribution properties of the adult human body. The data presented lend themselves to mathematical modeling.

Chapter 5, "Arm-Leg Reach and Workspace Layout," is an informative chapter on functional reach measurements relevant to the design and layout of workspaces. Basic reach data are given, along with recommendations for applying corrective factors to adjust for differences in (1) workspace, task, and body position; (2) environmental conditions - primarily gravity forces; and (3) anthropometric characteristics of various populations.

Chapter 6, "Range of Joint Motion," discusses (1) selected reviews of the range-of-joint-motion literature; (2) techniques for measuring range of joint motion; (3) range-of-joint-motion terminology; (4) recommended range-of-joint-motion data for the design engineer; (5) differences in the range of joint motion due to the effects of age, sex, and protective clothing; and (6) the range of joint motion of selected two-joint muscles. Together, chapters 5 and 6 constitute a comprehensive data base and guide to workstation layout.

Chapter 7, "Human Muscular Strength," deals with (1) a general review of human muscular strength, (2) specificity of muscular strength, (3) relationships between static and dynamic muscular strength, (4) strength within the arm reach envelope of the seated subject, and (5) comparative muscular strength of men and women. This chapter should aid design engineers in relating strength data to workspace design.

Chapter 8, "Anthropometry in Sizing and Design," discusses the application of human body-size diversity and quantification to engineering design. Procedures are outlined for using anthropometric data in the development of effective sizing programs.

Chapter 9, "Statistical Considerations in Man/Machine Design," reviews statistical concepts that appear repeatedly in the NASA Anthropometric Source Book and touches on some statistical problems that will typically confront individuals using the data.

Volume I was compiled and edited by the following members of the Anthropology Research Project of Webb Associates, Yellow Springs, Ohio: Edmund Churchill, Lloyd L. Laubach, John T. McConville, and Ilse Tebbetts.

Volume II summarizes the results from anthropometric surveys of 61 military and civilian populations of both sexes from the United States, Europe, and Asia. Some 295 measured variables are defined and illustrated. The variable names are listed in alphabetical order. For each variable, there is a computer order number by which it is identified, a list of surveys in which it was measured, a group of summary statistics, and a series of values for the 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 99th percentile of the given population.

Preceding the presentation of the actual data are three indexes designed to assist the reader in the use of the material. The first of these indexes, entitled "Anthropometric Surveys: A Reference List," lists and describes the sources from which all the summary data in this volume were extracted. This enables the user to obtain additional information on any survey population if that is desired. The next index, entitled "Definition of Measurements," includes both written descriptions of all the variables cited and simplified line drawings, where feasible, to illustrate a particular measurement. The third index is provided to further guide the user in identifying and finding measurements relevant to his or her particular needs. It is entitled "Index of Dimensions." The variables are listed by name and are categorized by anatomical region and by anthropometric technique.

Volume II contains a minimum of text-type material and is primarily a handbook of tabulated dimensional anthropometric data. It is probably the most comprehensive source of summarized body-size data currently in existence.

Volume II was compiled and edited by the following members of the Anthropology Research Project of Webb Associates, Yellow Springs, Ohio: Edmund Churchill, Thomas Churchill, Kay Downing, Peggy Erskine, Lloyd L. Laubach, and John T. McConville.

Volume III lists 236 annotated references related to the field of anthropometry. Included are references to every anthropometric survey outlined in volume II, as well as a variety of other works on static and working anthropometry of U.S. and foreign populations, anthropometry of parts of the body related to the design of specific items such as gloves or helmets, joint range and arm reach, mass distribution properties of the body, strength data of various kinds, sizing systems, material on zero gravity, and some general reference works. The references listed were selected by the editors and contributors to volume I. Their objective was to reference those studies, reports, textbooks, and surveys that they deemed most related to their specific subject area and that would be most helpful to the user.

Volume III was compiled and edited by the following members of the Anthropology Research Project of Webb Associates, Yellow Springs, Ohio: Lloyd L. Laubach, John T. McConville, and Ilse Tebbetts.

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