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A Standard Ergonomics Reference Data System: The Concept and Its Assessment

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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*

Dr. Sidney Harman, *Under Secretary*

Jordan J. Baruch, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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EXECUTIVE SUMMARY

Today's consumer and worker expect to buy goods and work with products and equipment that function well within human capacities. To meet this expectation industry and government must be able to draw upon current, reliable ergonomics (human factors engineering)* data representative of the range of human characteristics to which technology must conform.

At present, limited amounts of ergonomics data are collected to meet specific, immediate needs. These data collection efforts are uncoordinated and unstandardized. Data that exist are of uneven quality, contain inconsistencies, inaccuracies and gaps, and are often unsuitable for general reuse. The net results are products, systems and equipment that may be unnecessarily unsafe, unreliable and unsatisfying to the user.

During the pilot study reported here, the Human Factors Section of NBS examined the needs of industry and government for ergonomics data, assessed the scientific and technical challenges to be met in meeting these needs and proposed a preliminary plan for development and operation of an ergonomics data system.

Major findings and conclusions derived from this pilot study are that:

1. A definitive survey of user needs and priorities is necessary in order to define the scope of the system.

2. Standards must be developed for the definition of units, measurements, measurement methods and reporting of data.

3. An assessment of alternative technologies for capturing, storing and processing ergonomics data must be made to identify a cost-effective approach.

4. Data derived from the published ergonomics literature and from a national ergonomics survey must be critically evaluated before they are systematically compiled and disseminated.

5. Provision must be made for the orderly management of system development.

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*For a more comprehensive definition of ergonomics, see footnotes on bottom of pages 2 and 5.

6. A period of three years would be required before data would be available to users.

7. An assessment must be made of the utility of the system and its capabilities in order to help ensure system responsiveness to the user community.

The data base proposed here owuld provide, for the first time, a single point of access to reliable and current anthropometric, behavioral and physiological data for application to technology design.

1. INTRODUCTION AND OVERVIEW

The ultimate expression of an effective technology is an information source from which may be drawn data and relationships which answer technical questions and against which hypotheses and issues of feasibility may be resolved. Such an information source would ideally contain, after a process of critical evaluation, all of the usable data required by technology and be amenable to quantitative operations of many kinds. Such a source would also serve to indicate the absence of information and, thereby, provide a picture of needed research.

The Data Source of the Physical Sciences

The important role played in the development of technology by a source of critically evaluated data from the physical sciences and engineering has long been recognized by government, commerce and industry. Today, collections of selected and evaluated numerical data on the properties of substances and materials are being developed in data analysis centers around the world. These centers extract, evaluate, organize and publish data from the scientific literature on topics ranging from the properties of neutrons and crystalline substances to the elastic characteristics of metals and alloys. Topics are selected for treatment to match the needs of a spectrum of users. When gaps in existing data or data of poor quality are discovered, research may be commissioned to fill the void. Evaluated data are made available to users from a single, central access point.

In the United States, a Congressionally mandated portion of this system is known as the National Standard Reference Data System (NSRDS) managed by the National Bureau of Standards (NBS). NSRDS generates outputs for its users in the form of monographs, critical reviews, printed tables of critical data and computer tapes. Users of these outputs come from all sectors of commerce, industry, government and the academic community.

Such a system has several benefits. The availability of information from a central point saves a user time in searching for needed data and, with the addition of the critical evaluation function, reduces the likelihood that erroneous or inaccurate information will be employed. The probability of repeating research that has already been conducted is decreased. In addition, the criteria used in the critical evaluation process along with the standards of quality exemplified by its outputs have a subtle but important impact on the quality of new research and research reporting.

NSRDS is linked with similar data systems in other countries. Together, these national data systems comprise an international data secretariat known as CODATA (Committee on Data for Science and Technology of the International Council of Scientific Unions). Along with national data systems, CODATA is a potent force in the diffusion of accurate, physical science and engineering knowledge into the stream of technological advance that has become vital to the world's economy.

The Data Source of the Human Sciences

While the information needs of commerce and industry were a stimulus to the development of a data system for the physical and engineering sciences, until recently the "human sciences" have not had a similar stimulus to develop a comparable system.[1] Instead, they have continued to pursue traditions of information exchange and publication well-suited to the needs of the scholarly academic community but ill-designed to make available the selected data about human characteristics needed to link and shape technology to its human users. Today, one is confronted with a large and growing literature that is not being fully exploited for reuse either to the advantage of the human sciences or to the benefit of technology. It is not our purpose to speculate why this is the case. Instead, it is instructive to consider the human sciences in historical perspective as they have been put to the service of technology and examine the inadequacies of the information mechanisms that have been used.

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[1]The term "human sciences" is used here to encompass the scientific disciplines concerned with the study of human behavior and functioning: anatomy, anthropology, experimental psychology and physiology. Recently, several applied disciples have developed from the human sciences. "Engineering anthropometry" is concerned with the measurement of the static and dynamic characteristics of the body as it occupies and moves in space and as the human body applies force to objects. Engineering anthropometry is derived from physical anthropology, anatomy and physiology. "Biomechanics" a related term, deals with the physics and engineering of human movement and the impact of physical forces upon the body. "Engineering psychology," "human engineering" and "biotechnology" focus on human information processing and action and with the conditions that affect the accuracy, reliability, precision and speed of response. "Human factors" and "ergonomics" are often used to encompass all of these applied fields.

Historical Perspective

The application of knowledge of the anthropometric and psychological characteristics of man to the design of tools, instruments, equipment and systems is so ancient that it is surprising that the notion has been rediscovered only recently.

Folk norms for the design of tools for digging, cutting and shaping developed very early in man's history (Drillis, 1963). These devices employed rules of thumb about the size of the hand, grasp of thumb and fingers, the length of the arm, and certain biomechanical properties to establish the lengths, configuration and moments of inertia of hand implements. Technology was being shaped by the characteristics of its users.

Perhaps because of the close relationship between early man and his tools, natural units of measurement first developed around the hand, fingers and foot. Only much later did physical units of measure replace them. These natural units are still used in many cultures: "le pied" and "le pouce" in French, "il peide" and "il pollice" in Italian, and "peda" and "pirksts" in Latvian have the same measurement implications as "foot" and "hand" in English (Drillis, 1963). Units such as these served well for centuries. The norms of people had become design criteria for the technology of the time. In the Middle Ages, for example, the "thumb-ell," a distance measured across the hand to the tip of the outstretched thumb of a chief (14 to 18 cm) was applied to the design of the handles of files, swords and jugs.

Although folk norms were used for centuries, there was no necessity to obtain precise measurements of the dimensions of individuals until the development of body armor created the need (Roebuck et al. 1975). It might be said that the science of "anthropometry," or body measurement, began at that time.

The behavioral and physiological characteristics of man also figured prominently in the history of tool and instrument design. The radius of action and speed of stroke for farm implements were enhanced by adjusting handle length to optimize the kinetic energy that could be used for striking activities. The latency of human response to a stimulus (reaction time) became an important factor in the design of precise astronomical measuring devices.

Although differences in the body dimensions, strength and performance capabilities of different races had been observed by Marco Polo over the period 1273-1295, an interest in taking accurate measurements of the characteristics of large groups of individuals did not occur until the 18th Century with the work of Linne and Buffon. This interest took a practical bent when statistics on the body dimensions of military recruits were used to size uniforms.

By the time of the Industrial Revolution, the use of folk norms had been replaced by the development of statistical tables and charts of selected human characteristics required to meet the needs of mass markets for furniture as well as clothing. One of the first systematic attempts to measure the performance characteristics and body dimensions of a large sample of the population of a nation was made by Sir Francis Galton. For a period of five years, in a laboratory at the London Health Exposition, detailed, quantitative measurements were made of the visual, auditory, psychomotor and anthropometric characteristics of over 9000 Exposition visitors. Among the measures taken were: the speed and force with which individuals could strike a blow; the highest audible frequency that could be heard; the reaction time to a stimulus; and the ability of individuals to discriminate objects of different weights (Galton, 1883).

Although Galton was one of the first in recent history to recognize the implications for technology of the measurement of human characteristics representative of a population, little was done of a practical nature to exploit the notion. However, the Gilbreths (Frank and Lillian of Cheaper by the Dozen) recognized the value of placing work within easy reach of the operator and initiated a study of work space dimensions (1917). In the same tradition, F.W. Taylor (1947) began to apply a number of behavioral principles to workplace design. LeGros and Weston (1926) were the first to do systematic studies of workplace seat design. Later, Lay and Fisher (1940) did detailed research on seat angles and comfort. Hooton (1945) conducted a large scale survey of the railroad-riding public, measuring over 3000 individuals in the Boston and Chicago railroad stations to develop criteria for seat design.

By World War II, military technology had become so complex that it had pushed many human functions to the limit. The problems were many. One has only to examine the cockpits of the aircraft of that time to appreciate the information processing, decision-making and environmental stress loads placed upon pilots by some designs. Instruments were frequently located in areas too remote to be easily reached or accurately read. A myriad of displays, designed with little regard for human use and limits, filled the cockpit workspace. Exotic environments--high altitudes and low temperatures, noxious fumes and exposed electrical and mechanical hazards--degraded performance, health and safety to the detriment of individuals and sensitive military missions.

In response to these problems, increasing numbers of psychologists, physiologists, anthropologists, physicians and industrial engineers were invited from the academic community to work as part of design teams. Soon a new interdisciplinary field, "ergonomics,"[2] began to emerge, and a large body of theory, research and data began to accumulate. An additional impetus was given to broadening the scope of ergonomics by the man-in-space program. Later, concern about highway traffic fatalities extended ergonomics into still another area.

By 1963, the amount of activity and the volume of literature in ergonomics had reached a level at which it became increasingly difficult to solve problems based upon existing data. Recognizing that the mechanisms for identifying, assessing and using published material were inadequate to the task, the Human Factors Society, a professional focus in the U.S. for the discipline, conducted a searching examination of the information system that then existed and attempted to pinpoint its inadequacies and suggest solutions. Among the proposals generated, several are worthy of note (Ronco 1963):

"(1) Greater commitments...to report information promptly and explicitly as circumstances permit...

(2) That documentation centers...undertake the individually impossible task of acquiring and organizing the existing literature...

(3) The support of...systems for the dissemination of relevant information by a variety of techniques (e.g., critical reviews, annotated bibliographies, and data sheets).

(4) ...periodic review of the accrued wisdom in the field not only to decide what is valuable and should be perpetuated, but also decide what is worthless and ought to be thrown out."

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[2] The term "ergonomics" is credited to W. Jarzebowski who first used the term in Nature and Industry in 1846. Its roots are Greek: "ergon" to work and "nomos" meaning natural laws.

Growth and Status of Ergonomics Information

Ronco (1963) and his colleagues have noted that the problem of improving the state-of-the-art in any applied scientific field has the following three aspects: (1) validating new knowledge, (2) combining that information into a data base, and (3) disseminating that knowledge to its users. Each of these merits further examination here in order to discover the strengths and weaknesses of the mechanisms associated with the field of ergonomics, conditions that still exist today 15 years later.

Validating New Knowledge

Quality control of published material in the human sciences has been accomplished by means of two mechanisms time-honored by the academic community: (1) peer review prior to initial publication and (2) the sifting and winnowing for the best research results that takes place as texts and monographs summarizing the published literature are prepared. Since there have been no explicit criteria for the specification of the conditions of research or the reporting of observations, research of uneven quality has been published, and the bad along with the good has been memorialized in the archives of the discipline.

As ergonomics began to emerge as a distinct human science discipline, much of its funding came from Federal agencies that required the publication of technical reports prior to any other form of publication. This introduced an additional, advantageous process of review and improved the quality of reported work. Furthermore, the lack of page limitations in technical reports facilitated more complete reporting.

In the late 50's, military standards and specifications for the application of ergonomic information and data to the design of equipment and systems were written and mandated for most government contractors. These standards tended to encourage the adoption of common research paradigms and methods and introduced greater uniformity in the conduct of research and reporting.

Despite the fact that these mechanisms have improved the quality of ergonomics data, they still fall short of providing the systematic, critical evaluation and validation of data needed for today's technology. Critical reviews of ergonomics research are still few in number and there are no formally established information analysis and evaluation centers as there are in some other sciences. However, some encouraging individual attempts have been made to critically evaluate and integrate research results. An example of one method of critically evaluating ergonomics data, prepared for this report by Warren H. Teichner, New Mexico State University, is presented in Chapter 4 to illustrate the process.

Combining Information into a Data Base

Several types of data bases exist in ergonomics as in other disciplines: (1) the published literature itself, (2) bibliographic aids containing citations, abstracts and indexes to the literature and (3) manuals, guides, handbooks and other compilations that summarize the basic data and methods of the field. Except for the lack of explicit criteria for reporting the results of research and describing experimental conditions, the existing journal and technical report literature in ergonomics serves well as a channel for the dissemination and archival storage of work in the field.

Existing ergonomics bibliographic aids and services are an effective means for locating needed references in the summary literature. Ergonomics Abstracts, started in the 60's when publication of the Tufts Annual Human Engineering Bibliography ceased publication, is a principal service. In addition, Psychological Abstracts, Biological Abstracts, Engineering Index, the Defense Documentation Center, the National Technical Information Service and the Smithsonian Scientific Information Exchange provide additional coverage of ergonomics and related literature. However, these reference works provide no indication of the quality of cited sources. Citation of the existence of a critical review of an article does not accompany the citation of the article itself as is done in some bibliographic services such as Mathematical Reviews. Nor do existing ergonomics bibliographic references employ data flags or tags to indicate the presence of data or measures of a given type in an article--a practice being adopted by some of the bibliographic services of the physical sciences and engineering.

Although a number of reference guides and manuals summarize the basic data and methods of important areas of ergonomics research, those existing guides and manuals--such as the Bioastronautics Data Book (Webb, 1964) and Human Engineering Guide to Equipment Design (Van Cott, 1972)--focus on the special problems of man in military and space systems and cannot usually be generalized to the many new, non-aerospace areas, such as consumer products, which ergonomics has entered in recent years.

Dissemination of Knowledge

The many dissemination mechanisms--journals, technical reports, bibliographic services and reference manuals--that exist today in ergonomics remind one of the problem of a child faced with an overabundance of food. His problem is not one of hunger, for there is far more than can be eaten, but of knowing what will best satisfy his needs from the abundance before him. Something is still missing.

In summary, there is an abundance of ergonomics literature of uneven quality. That literature is largely oriented around the ergonomics problems of the military and aerospace industries. There are gaps in data for many new non-military applications. The research that does exist has not been critically evaluated, organized around the needs of its users or integrated to reveal existing relationships. Numeric data are not always available or easily located for reuse, and lack of or incomplete descriptions of the conditions under which they were obtained makes the comparison of results difficult. As interest and concern for the health, safety, comfort and satisfaction of the consumer and the worker have increased, the need for ergonomics data of high quality and covering a variety of generic problem areas will undoubtedly increase. Having high quality ergonomics data implies that such data are expressed in functional form, based on ratio scales, and that such data are usable in various design engineering trade-off situations.

Specialized Ergonomics Data Bases

Within the U.S. a number of data bases are in various stages of development to meet specialized ergonomics data needs. At the Sandia Laboratories, A.D. Swain has established a human error rate data bank for use by military/aerospace system planners and designers and by reliability analysts and ergonomicists (Swain, 1970). At the Aerospace Medical Research Laboratory at Wright-Patterson Air Force Base, Ohio, Charles E. Clauser and his colleagues have been instrumental in establishing an Anthropometric Data Bank which incorporates at a single center current, U.S. military anthropometric data in comparable formats based upon many surveys (McConville, et al., 1977). These are two examples of ergonomics data bases focused on either specialized populations or around relatively restricted problem areas. Another development which came to the authors' attention as this report was being written is the Habitability Information Analysis Center being proposed by Dr. Roger Brauer and Robert Dinnat, Construction Engineering Laboratory, Champaign, Illinois.

Although specialized data bases of this type undoubtedly meet a need, their proliferation creates problems for the user who seeks a single point of access. They do not resolve the problem of providing a convenient single interface between the multiple users of ergonomics and a source of critically evaluated data.

The notion of developing an ergonomics data base to meet the needs of the technology of a nation is not unique to the United States. Efforts with similar aims are underway in other countries. In the Soviet Union, Vladimir Mounipov, Deputy Director of the Institute of Technical Aesthetics, VNITTE, Moscow, is collaborating with other Socialist East European countries on a common data base leading to an ergonomics data bank (Seminara, 1977). A Human Biometry Data Bank being developed under the direction of M.A. Coblentz of the Laboratory of Appled Anthropology, Rene Descartes University, Paris, France. This data bank, supported by the Directorate of Research and Test Facilities, is currently limited to selected anthropometric measurements. However, Coblentz envisions its expansion to cover other ergonomic data in the future (Coblentz, 1976). In Mexico plans for the orderly assembly of ergonomics data representative of the Mexican population are being developed.

It can be anticipated that similar developments will take place in other industrial countries as nations become increasingly concerned with the safety, comfort and satisfaction of their citizens. For example, the July-August 1977 issue of Information Hotline indicates that the South African Bureau of Standards has established an Ergonomics Information Service to make human factors data readily available to local industrial research organizations and educational institutions.

A single example illustrates the need experienced by U.S. industry for current, evaluated ergonomics data, particularly physical anthropometry. For years many segments of industry have relied upon the results of the 1939-40 Department of Agriculture anthropometric survey of the U.S. population (O'Brien and Shelton, 1941) for data on which to base the design and sizing of products, systems and clothing. However, as diet, exercise and other factors have altered the body dimensions of the population, these data have become obsolete and no longer represent the dimensions of today's child or adult. For example, between 1946 and 1977 significant changes have taken place in the average body dimensions of U.S. Army women (Human Factors Bulletin, 1977).

The problems caused by the lack of current, accurate anthropometric data have remained unsolved. Instead, industry has had to make do with trial and error and attempts to extrapolate from military anthropometric data to the general civilian population. The problem has been costly for both industry and consumers. One major clothing retailer, for example, estimates that its annual loss from garments returned because of poor fit exceeds $175 million.

In 1973 concern over this problem was intensified by the prospect of conversion to metric measurements. Attempts to make a direct conversion from U.S. to metric measures were singularly unproductive. As a result, 50 leading designers, engineers, quality control experts and officials from commerce, industry, government and professional organizations met in Washington, D.C. to discuss the matter and explore ways in which the problem might be resolved.

Following that meeting the participants wrote letters to various members of the NBS staff, including its Director, expressing an urgent need for a national anthropometric survey. Based upon these inputs NBS' Institute for Applied Technology requested its Technical Analysis Division to perform a preliminary study of user need, organization, potential scope, and cost of a national anthropometric survey. This culminated in a report addressing these issues and proposing that a national anthropometric survey be conducted by NBS to collect the needed data (Steinberg, 1974).

It was determined that while the Center for Health Statistics, Department of Health, Education and Welfare has the conduct of surveys as a part of its mission, such surveys are limited to the collection of measurements that are health related. Thus, many of the measurements needed for clothing, product and system design are not presently included. Furthermore, the Department of Agriculture, which had conducted the 1939-40 survey, is no longer staffed and equipped to collect the needed data.

In the Fall of 1976, the NBS Institute for Applied Technology funded the Human Factors Section of its Center for Consumer Product Technology (CCPT) to undertake a second pilot project. The proposal for the new project had been endorsed by the Center's external Evaluation Panel[3] and work started in January 1977. The aim of the new project was to explore the feasibility of an ergonomics data base that would include not only anthropometric but other ergonomic data as well.

Beginning in February 1977 and continuing throughout the duration of the study, project staff described the concept of a Standard Ergonomics Reference Data System to representatives of industry, government and the research community at a series of professional and scientific symposia and specialized meetings organized at NBS. The consensus of participants was that the proposed concept would serve the purpose of improving product and system design.

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[3]In its August 1977 report, the CCPT Evaluation Panel stated "There is a considerable lack of statistical data pertinent to the human animal that are necessary for optimum design of consumer products. This is true, and other organizations, in both the public and private sectors, are concerned about it . . . Representative Yatron from Pennsylvania contemplates legislation to develop important basic dimensions of the American Citizen. It would be appropriate for CCPT to direct such a study, if it is undertaken."

2. SYSTEM CONCEPT

The primary aim of a Standard Ergonomics Reference Data System (SERDS) is to provide a single source of critically evaluated, numerical data on selected human characteristics for use in the planning, design, test and setting of standards for the man-machine interface and environment of equipment, systems, consumer products and buildings. A second aim is to advance the level of ergonomics research by developing standards for ergonomics measurement and reporting.

A Model System

Is there a model for SERDS? In 1963, the Federal Council for Science and Technology requested NBS to assume primary responsibility in the Federal government for promoting and coordinating the critical evaluation of numerical data in the physical sciences. The program was conceived as a decentralized national effort with financial support deriving from a variety of government and private sources but with NBS responsible for overall planning and coordination. This allowed existing NBS data compilation activities to be strengthened, new projects to be initiated in neglected technical areas, and the entire effort to be molded into a coherent program (Rossmassler, 1975).

When NBS accepted responsibility for the National Standard Reference Data System (NSRDS), it established an Office of Standard Reference Data to manage the program. This office performs several functions:

- Allocation of that part of the NBS budget spent on critical evaluation within NBS and by contracts to outside groups.
- Monitoring of all projects that are supported by NSRDS.
- Management of a publications program and a limited information service.
- Assessment of domestic and international efforts to detect duplication and encourage coverage of important technical areas.
- Performance of research and development on computer handling of data and in the application of automated procedures to the activities of data analysis centers.

The compilation and critical evaluation of physical science data by NSRDS take place at data analysis centers on a continuing basis or through the "one-shot" compilation of critical reviews by individual scientists or small groups of collaborators. The one-shot efforts supplement the long-term bibliographic and analysis skills of the data analysis centers (Rossmassler, 1975).

A goal of the Office of Standard Reference Data has been to establish data centers in all technical areas which fall within the scope of NSRDS. These centers focus upon data areas for which there is a high intensity of demand or need.

The scope of each NSRDS data analysis center is not only need-oriented but is restricted to data that can be well-characterized and defined in terms of accepted physical theory. Such restrictions undoubtedly leave out data for which there are recognized needs but which are not amenable to clear-cut evaluations.

The products of NSRDS are derived from the regular search of the physical science literature, retrieval and indexing of papers of interest, and the extraction of numerical data for analysis and dissemination. Outputs of this process consist of tables of data, critical reviews of specific areas, magnetic tapes of selected data and responses to specific requests for data and information. Some NSRDS data analysis centers have large, computer based files from which bibliographic data and citations can be retrieved. The centers are able to respond to requests for specific information from interested users.

The budgets of NBS and several other Federal agencies, support from industries with interests in specific types of data, and fees from the dissemination of copyrighted NSRDS publications in the Journal of Physical and Chemical Data help maintain NSRDS.

Guidance to the NBS Office of Standard Reference Data is provided by a series of advisory committees formed under the auspices of the National Academies of Science and Engineering and the National Research Council. Since NSRDS has operated successfully for well over a decade, its organization and functions are useful for planning an ergonomics data system.

Functional and Organizational Requirements of SERDS

An examination of the NSRDS model reveals that several conditions must be met to achieve a collection of useful, critically evaluated ergonomics data. These include:

- User Needs - The needs for ergonomics data must be surveyed to identify the type of data required, the terms used in defining these data, and the measurement unit, precision and accuracy necessary for specific applications. These needs must be further examined to isolate those that are generic to a variety of areas in which the application of data is expected to generate a substantial economic or social benefit. The long-term development of the system must rely upon some scheme of setting priorities for the orderly and sequential development of data modules organized around those generic need areas.

- Data Input - Identified needs must be compared with existing data to determine which demands can be met from the existing supply and which will require new research.

- Critical Evaluation - Both existing and new data must be critically evaluated against explicit criteria (presently under development) to be eligibile for inclusion in the system.

- Data Processing and Output - Evaluated text and data from published sources must be processed and presented in output formats convenient for users. Processing may entail statistical computation, model development and use, data extrapolation and logical manipulation of data and text.

- Voluntary Standards - Standards for future ergonomics research must be developed for the definition of terms, units of measurement and measurement procedures to be used by the research community in generating new data.

- System - A system for meeting these conditions must be developed to manage and coordinate the acquisition, evaluation, processing and dissemination of ergonomics data.

Scope of SERDS

As is presently envisioned, the scope of SERDS would be initially restricted to well-defined anthropometric, behavioral, physical and physiological characteristics of normal-healthy men, women and children. Although this definition leaves out many borderline cases and rejects others, the intent is to concentrate on human characteristics which can be clearly defined in terms of existing theory and measurement practice. Characteristics that lack a solid foundation in theory, description and measurement would not be included. The focus of SERDS will be the application of ergonomics data to technological problems. With the above considerations in mind, several classes of data can tentatively be defined as being appropriate for SERDS:

Anthropometric Data - This class would initially include static measurements of the dimensions of the human body as a function of age, sex, occupation, ethnic origin and other demographic variables. Measures of the forces that can be exerted by muscle groups on physical objects would also be included for selected generic tasks. Measures of body proportions, contours, areas and volumes would be added when adequate measurement technologies have been developed and standardized. Data on the dynamic characteristics and movement of body members, such as inertial properties and static reach envelopes would be selectively included as data become available. Data would be collected not only on the adult male population but on females and children of both sexes. Women and children have been badly neglected in most past anthropometric studies.

Sensory Capability Data - This class would deal with the ability of human visual and auditory systems to detect, discriminate and recognize signals and signal patterns. Data on other sensory capabilities, such as those involving the cutaneous, kinesthetic, proprioceptive and vestibular senses, would be admitted if they are needed and can be readily characterized.

Performance and Performance Reliability - This class would be limited to simple, easily-measured and well-characterized aspects of human performance and performance reliability that occur frequently in operating man-built products and systems. Examples include: (1) simple and choice reaction times to signals and messages, (2) other components of human performance required of individuals in the use of switches, knobs, dials, keyboards and other manually manipulated objects/products and (3) information processing and decision-making as they occur in definable system contexts.

Physiological and Psychological Tolerance Data - This class of data would include measurements of the effects of such variables as toxic substances, noise and temperature that enhance or degrade performance, comfort, and physiological well-being.

The classes of data defined above are based on suggestions made by the various groups contacted in the course of this study and on the authors' judgments derived from past experience at NBS and elsewhere. Such judgments must be regarded as provisional in nature and subject to future modification.

SERDS Input

The principal inputs to SERDS would come from two sources:

- Data and information selected from the published literature of ergonomics and related sciences.

- A national ergonomics survey of selected anthropometric and behavioral characteristics utilizing a representative sample of the U.S. population.

The measurements taken in the survey would be limited to either those that are not covered in the present literature or are not representative of the U.S. population. Chapter 5 (National Ergonomics Survey) discusses the requirements for a national ergonomics survey and the technological and sampling challenges to be faced in survey planning and conduct.

Inputs from both sources must necessarily include bibliographic and descriptive information that permits each information source to be identified, describing the theoretical and procedural basis used to obtain the reported data. Numerical data alone are subject to gross misinterpretation and misuse unless these conditions have been met at the input stage.

Critical Evaluation

Critical evaluation of data required by SERDS will be accomplished by means of one or more critical evaluation and analysis centers. These evaluation centers would be located in Federal, academic or not-for-profit institutions that have been selected for expertise in bibliographic and data analysis in given subject matter fields.

Chapter 4 (Critical Evaluation) of this report describes an approach to critical evaluation that has been successful in evaluating and validating knowledge in several ergonomics fields. Here, however, an important point should be made. For the scientist, knowledge derives from observations made under specified conditions. Description of these two aspects of knowledge, the observations and the specified conditions, represents two different, but important kinds of data of scientific interest that are essential elements in the process of critical evaluation. One has no meaning without the other. Observations or measurements may be summarized by means of a variety of units. Specified conditions include quantitative values of independent variables, control factors and experimental arrangements and procedures. Thus, a distinction can be made between those data that are the results of a scientific effort and those descriptive data which indicate the conditions under which the data were obtained.

Some scientists tend to believe that the reliability of the numerical results of anthropometric and behavioral studies is unacceptably low at almost any level of precision. It is our contention, however, that anthropometric and behavioral results at an appropriate level of precision and accurately described in terms of independent variables, are sufficiently reliable for effective use as an information source.

While it is also contended that the human sciences have not yet achieved the degree of rigor of the physical sciences, there have been many successful applications of human science data to applied problems. In short, if behavioral and anthropometric data can be used to resolve problems related to human safety, comfort and satisfaction then it is worthwhile to improve the process. Critical evaluation alone will not solve all of the problems of ergonomics, or any other science, but it can enhance the validity, reliability and utility of ergonomics data and save users from doing this most difficult task by themselves.

Data Processing and Output

Chapter 6 (Data Processing and Output) of this report reviews the requirements for SERDS data processing and output. However, several general summary comments should be made here on the types of data processing that will be required.

The variability (both within and among individuals in a given population) of anthropometric measurements and behavioral traits leads to the generation of large quantities of statistical data. These data can be reported as raw measures obtained for each participant and as summary statistics that describe the properties of distributions of measurements for all participants measured. If they are reported in complete form, raw data may be used to establish relationships and develop models not reported in the original research. Raw data may be used, for example, for extrapolation or be combined with new data to obtain a larger sample of measures for analysis. Although it is not the present practice of researchers to publish raw data, in our opinion this practice must be encouraged in order to fully exploit and reuse the research results that now exist. The large capacity and low cost of computer storage now make this possible.

Many human behavioral, anthropometric and biomechanical properties can be expressed by computerized, mathematical models. There are three general types of models. One is a "man-model" that serves as a reservoir of behavioral or anthropometric data. This model allows for greater versatility in storing, manipulating and retrieving information than is possible with printed data tables. A second model is the "reactive" model that responds to external events or forces such as visual stimuli or vibration. This model requires that selected, dynamic properties of an organ or human subsystem (e.g., the arm or other body segment) be characterized. The model becomes "reactive" through incorporation of external stimuli or stressors. A third type of model is the computerized analog of man in a work station or environment (office, home or vehicle). Computerization is achieved by defining properties of the environment to represent the location and characteristics of a number of alternative workplace configurations. For anthropometric applications, the dimensions of specially-formed components such as seats or controls can be included in the model. For behavioral applications, the information to be processed by an individual from a display can be included in the model (Roebuck et al., 1975). As it is now envisioned, data processing would include the capability to exercise existing models of each type using the SERDS numerical data base.

Another essential function of the SERDS data processing system is to perform logical operations on the data base. These operations may consist of relatively simple routines for the search and retrieval of bibliographic descriptors of interest to more complex routines for performing mathematical and statistical computations and combining data. The most common requirements for combining data will be to (1) develop statistical distributions and intercorrelation matrices, including derivation of a composite population distribution from the distributions of several known populations, (2) estimate an unknown measurement distribution by the addition, subtraction or application of some other combinatorial process to two or more known measurement distributions, and (3) calculate the group mean, standard deviation or other statistics.

SERDS Configuration

Although SERDS could be configured in a variety of ways, a promising approach at this point appears to be that of the National Standard Reference Data System described earlier in this chapter. Figure 1 represents a proposed configuration for the system.

Data obtained by means of continuing searches of the existing, published literature and data from a national ergonomics survey will be the inputs to the system. SERDS itself will be comprised of several data analysis centers operated under the general policy guidance of a SERDS Office. This office, the secretariat of the system, will receive policy guidance from an independent Advisory Panel and act upon proposals for system operation. A User Council representative of the system's users will also provide input to the office regarding system updating and improvement needs. Output of SERDS to government, industry and other research users will be provided by the SERDS Office. Feedback from users of the system will be employed in all phases of SERDS operation: the data to be selected, the criteria to be employed in data and system evaluation, and the formating of outputs for convenience of use.

It is anticipated that some SERDS users will encounter difficulties in converting SERDS data into a form suitable for a specific application. Raw anthropometric data, for example, require additional processing in order to arrive at acceptable sizing standards and tariffs for the manufacture of clothing. Clothing tariffs indicate the proportion of a given size in a population and determine the number and mix of persons to be measured. The SERDS data base will require additional manipulation by a specialist sufficiently familiar with such applications to be able to make the necessary translations. For this reason, a link between SERDS and its users--called Translation Support--must be included at the user interface. This support would be available when the requirement for a particular form of data translation exists.

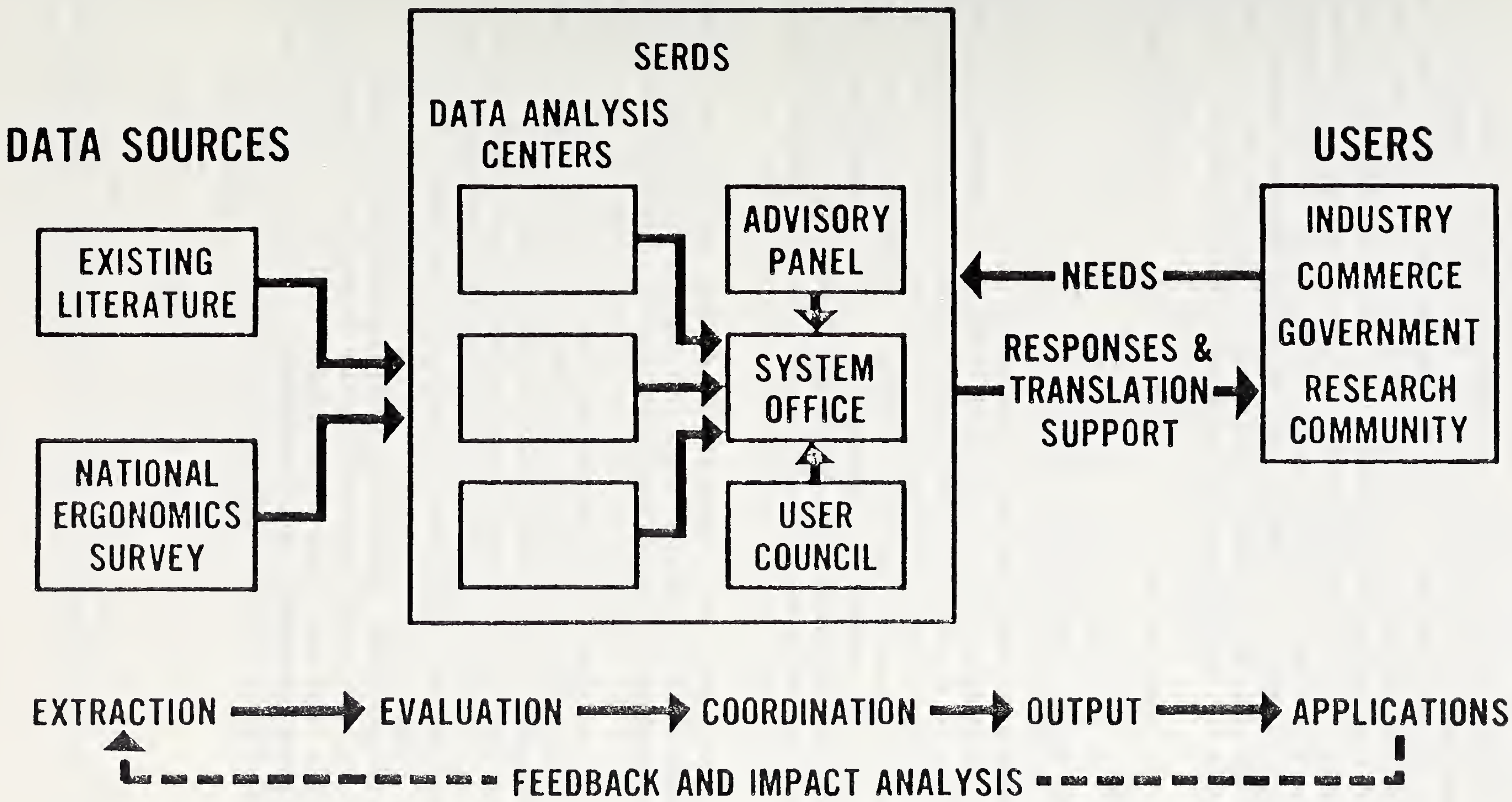

FIGURE 1. STANDARD ERGONOMICS REFERENCE DATA SYSTEM (SERDS) -- A POSSIBLE CONFIGURATION

Data Analysis Centers

Within the United States, a number of "centers of excellence" now exist in specialized ergonomics areas. Candidate SERDS data analysis centers will be selected from these centers of excellence. Some of these candidate centers focus upon the work of a particular investigator, several of whom now perform critical evaluation to advance their own research. Other centers have gone beyond critical evaluation into the development of specialized data bases. These are bibliographic centers that maintain comprehensive reference files of citations or literature in a given area or centers that maintain data bases of numerical information on a particular ergonomics topic. No major obstacles are foreseen in the selection of qualified organizations to serve as data analysis centers from among the pool that now exists.

Advisory Panel and User Council

In order to ensure that system policies are developed which reflect current and projected national needs for ergonomics data, an Advisory Panel will be established, comprising 10 to 15 outstanding leaders representative of the field of ergonomics and of ergonomics interests as they exist within commerce, industry, government and the research community. This panel would meet at least annually to review the SERDS program, to assess its effectiveness and to propose policy for its structure and function.

A sample of the user community will constitute a User Council. The council, consisting of delegates from each sustaining user group, will meet at least annually to advise the SERDS Office and its Advisory Panel on actions to be taken with respect to the scope, funding, operation and effectiveness of the system. The User Council will also be the principal focal point for the development of standards for the collection and reporting of ergonomics data. Unlike the ergonomics standards activities of standards setting organizations, such as the American National Standards Institute (ANSI) and the International Standards Organization (ISO), which center around ergonomic standards for particular products or systems, the standards activity of the User Council will focus upon criteria for the collection of ergonomics data rather than data application. This activity is seen as nonredundant and complementary to the activities of present standards setting organizations.

SERDS Office

Throughout the pilot project, various proposals for the location of the secretariat for SERDS were discussed with potential users in government and industry. Several alternatives were suggested: (1) an existing standards organization, (2) the National Science Foundation (NSF), (3) the National Center for Health Statistics of the Department of Health, Education and Welfare (NCHS/HEW), (4) a private organization, (5) a new organization established specifically for the purpose, and (6) the National Bureau of Standards (NBS). Each of these alternatives has advantages and disadvantages and each will be examined in detail to help ensure that a suitable locus is selected as the permanent "home" for SERDS.

Funding Sources

Until a detailed assessment has been made of user needs and data priorities, an accurate estimate of the funding required for the front-end development or subsequent operation of SERDS cannot be given. However, for the initial development of SERDS, which would entail several efforts of a planning nature, potential funding sources include:

- NBS Scientific and Technical Research Support (STRS);
- Support from other Federal agencies interested in participating in SERDS development.

Looking to the future, beyond FY 78, in addition to the above sources, other support for further development and operation of SERDS could come from the following:

- Support from trade associations or a consortium of industries interested in SERDS use. This support could take two forms: effort applied by industrial personnel on temporary assignment to SERDS (industrial fellowships) or direct monetary subsidies;
- Fees from users for receiving SERDS products and services;
- Fees from the sale of copyrighted material sold by SERDS. (NSRDS has established a precedent for this practice);
- Special congressional appropriation.

At this point, there is no clear-cut, definitive way in which the required timing, magnitude or mix of support from these potential sources can be projected.

3. USER NEEDS FOR ERGONOMICS DATA

Among the most important factors determining the success or failure of the ergonomics data system proposed in this report is the degree to which the system meets the data needs of its users. Clearly, the most sophisticated, up-to-date and comprehensive data base is of value only to the extent that it fulfills identifiable needs. Early in the pilot project effort it was recognized that a thorough assessment of these needs for a wide spectrum of potential users was essential, both to define the scope of the system and to assign priorities to the various types of data such a system might include.

The need for anthropometric and other ergonomic data was first addressed at a meeting in 1973 with representatives of the Federal government, industry, trade associations and researchers. Although that meeting, summarized in the report of a feasibility study of a national anthropometric survey prepared by NBS (Steinberg, 1974), pointed out the urgent need for up-to-date anthropometric data, further assessment of these needs was deemed necessary for the SERDS effort. A formal user needs study, proposed in Chapter 7 of this report, is planned for FY 78 to satisfy this requirement.

Although a comprehensive assessment of needs could not be performed in the course of the pilot project, a preliminary effort was undertaken, primarily by conducting a series of meetings with a variety of potential users from the industry, government and research communities. These meetings served both to inform the various groups about the SERDS pilot project and to solicit information about the data needs of potential users.

Summary of Meetings

Four major briefings were held with representatives of the following organizations:

March 16, 1977 - Sizing Committee of the Mail Order Association of America

March 25, 1977 - NBS Behavioral scientists from the Center for Building Technology, Center for Fire Research and the Auditory Acoustics Section

March 29, 1977 - Twelve Federal government agencies including: Army Natick Research & Development Command; Army Research Institute; Army Human Engineering Laboratory; Consumer Product Safety Commission; Defense Nuclear Agency; General Accounting Office; National Institute of Aging, NIH; National Science Foundation; Occupational Safety and Health Administration; Office of Consumer Affairs, HEW; Office of Naval Research and the U.S. Postal Service

June 7, 1977 - Management and technical staff of the Association of Home Appliance Manufacturers

In addition to meetings held specifically to solicit potential user interest and needs, several other technical and scientific organizations have been made aware of the SERDS concept through personal contact or presentations at conferences and technical sessions. Although these contacts were not established for the sole purpose of assessing the needs for ergonomic data, many expressions of need were brought to the attention of the project staff during and after the presentation sessions. Among the groups contacted were the Society of Automotive Engineers, American Apparel Manufacturers Association Technical Forum III, Engineering Foundation Safety Conference, and the Consumer Product Technical Interest Group of the Human Factors Society. Major SERDS symposia were held at the 1977 Annual Convention of the American Psychological Association in August, the 21st Annual Meeting of the Human Factors Society in October and the Canadian Human Factors Society Meeting in November. Minutes of two of the meetings described above can be found in
project are contained in Appendix B. Appendix C contains remarks made at the March 29 meeting by the external consultants to the project: Dr. Julien M. Christensen and Dr. Richard W.

As a result of these initial meetings and technical presentations, a substantial level of interest has been identified for the SERDS concept and for a variety of types of ergonomics data. The major needs identified from these sources have been summarized in Table 1. Those general areas of need which were expressed repeatedly are listed along with some examples of the specific data needs within these broad areas and potential applications of the data.

Given the obvious importance of continuously assuring that SERDS is responsive to the needs of its users, it is essential that the assessment of user needs does not end with the initial identification of data needs resulting from the proposed one-year needs study. Therefore,as SERDS becomes operational, a mechanism must be developed which will provide repeated, periodic reassessments of required data. Although such a mechanism has not been clearly defined at this point, two important sources for this information can be noted. First, the Users Council described in Chapter 2 will provide key guidance to SERDS management in this area. In addition, monitoring of the number and type of requests for data from SERDS will also provide information useful in the reassessment of data needs.

Table 1

DATA REQUIREMENTS OF POTENTIAL SERDS USERS

AREA of NEED	SPECIFIC DATA NEEDED	DATA APPLICATION
Static Anthropometry	Basic human body dimensions as function of age/sex etc.	Design of tools & other hard goods, development of clothing sizing & tariffs
Dynamic Anthropometry	Bending & stooping capabilities, reach dimensions	Control location & operation, workspace design
Strength Characteristics	Static & dynamic force measurements, lifting, pushing & pulling capabilities	Equipment & job design for industrial workers, product portability design
Physiological Characteristics	Aerobic & anaerobic capacity, maximal heart rate, expiratory volume	Environmental design, job specification; toxicity levels
Sensory/Perceptual Processes	Measures of visual & auditory acuity, color vision	Design of controls, digital displays, visual & auditory warning signals
Tolerance to Environmental Conditions	Exposure tolerance to physical & chemical agents, e.g. tolerance to high intensity light, noise, temperature, radiation	Protection of workers and environmental design
Reaction Time	Simple & complex reaction time to a variety of stimuli	Display-control relationships; blade stopping time
Information Processing/ Cognitive Functions	Interpretation of symbols, learning processes, memory	Design of displays, signals, instructional materials, training devices
Capabilities of Special Populations	Anthropometric, sensory, physiological measures of children, aged, handicapped	Product & environmental design

4. CRITICAL EVALUATION

Implementation of the SERDS concept advanced in this report requires a mechanism for the critical evaluation and selection of existing data for inclusion in the system. Readers of individual articles are often, though not always, provided with the appropriate caveats and qualifiers to the uses and origins of the reported data. Users of data handbooks are less likely to be exposed to such cautions or to remember them even if present, as published data compilations tend to achieve an aura of respectability whether deserved or not. Data retrieved from a computerized system often acquire even greater "respectability." Therefore, it is incumbent upon the builders of a data system to assure the validity of the data in the system (Kissman, 1975). Unless the methodology and conditions of each candidate publication are critically evaluated, proper qualifiers cannot be tagged onto the data.

Data evaluation becomes even more critical in light of one of the advantages of numeric data bases: the potential capability to recombine data for reuse in new application areas. Without critical evaluation of the data input to SERDS, it is conceivable that the system could provide a dangerous disservice to users by providing easy access to "bad" or misleading data. Granting the need for critical evaluation of data, the problem addressed in this chapter concerns the mechanisms for accomplishing such evaluation.

It has been suggested previously that Data Analysis Centers be established and charged with the responsibility for compilation and evaluation of specified, limited areas of data. One criterion for the selection of a particular organization as a Data Center would be demonstrated, resident expertise in the subject matter area(s) of interest. The importance of careful selection of these Data Centers cannot be overemphasized since, in any evaluation procedure, the role of subjective, expert judgment is crucial. Lide and Rossmassler (1973) recognized the importance of informed, subjective judgement in the evaluation of physical science data when they stated:

> "While any evaluation of data published by others should be as objective as possible, a certain amount of subjective judgment on the part of the evaluator is difficult to avoid. In every field of science there are individuals and laboratories known for their careful, consistent work, while others develop a reputation for undependable results and frequent mistakes. Likewise, some

authors describe their research clearly and precisely, while others omit details needed to make an independent value judgment. Such factors should be taken into consideration when assigning a weight to a given piece of published data, but it is difficult to do this in a quantitative, completely objective way." (p. 149)

Warren H. Teichner and his colleagues at New Mexico State University have employed a procedure for developing an information source for certain areas of human performance which may serve as a general prototype for the critical evaluation and compilation process. This procedure relies heavily on subjective, expert judgments within a framework designed to be as objective as possible.

Teichner and his colleagues' original interest in the information source concept arose from needs for their own research. After several years of developing a procedure aimed at meeting specialized needs, the feasibility of such a procedure for general use became apparent and had also been demonstrated.

Based upon certain previous speculations, Teichner and Olson (1971) hoped to use the quantitative results of the published literature in an absolute sense to establish functional relationships and models which would express the dependence of measures of human performance on the major variables to which they are related. Rather than search for those investigations which might provide the most comprehensive treatments and base relationships solely on the findings of one or two such studies, they attempted to base the relationships on trends that might be fitted across the results of all relevant, acceptable investigations.

Table 2 presents a listing of topic areas which were defined as those of interest, and within which an attempt was made to solve specific problems. To reduce the effort to a manageable scope, the problems were each defined narrowly. For example, all relationships of interest were to be restricted to those involving simple visual stimuli in "noiseless" situations. Once relationships were developed for these simple situations, these relationships were expanded to deal with more complex stimuli and situations.

Even with such a narrow scope the question was whether the large literature relevant to each of the situations of interest could be organized into a manageable form for

Table 2. Classes of Performance

Defining Measure	Class Name	Brief Description
Probability of Detection, $P(D_S)$	Sensory Searching	Signal detection in the absence of signal uncertainty
Probability of Detection, P(D)	Searching	Signal detection in the presence of signal uncertainty (spatial, temporal, frequency of occurrence, noise) and a limited search time.
Search Time, t_s	Unlimited Searching	Searching, but with an unlimited time available for target acquisition.
Percent or number correct, % C, N_C	Unidimensional Coding	Attachment of a name or other unique response to an attribute of a stimulus, e.g., color, pitch, direction, shape, position, letter, digit.
Percent or number correct, % C, N_C	Multidimensional Coding	Attachment of a name to a collection of stimulus attributes or of separate events or items, e.g., "John" for a person; flower, fleet, "attack" for a battle procedure, etc.
Percent or number correct, % C, N_C	Translation or Recoding	Use of a syntax, or set of rules, or other predefined relationship between two codes to relate or transform names or codes. S-S translations involve a transformation from one stimulus code to another; S-R translations involve a transformation of a stimulus code to a response code; R-R translations are between response codes.
Sensory Reaction Time or Latency, RT	Simple Reaction Time	Time from initiation of a signal in a sensory searching task to initiation of the detection reaction.
Reaction or Decision Time, CRT	Choice Reaction Time (CRT)	Time from initiation of a signal to initiation of response in a searching or coding task having signal uncertainty or more than one possible signal.
Percent Time-on target, RMS Error, etc.	Tracking	Alignment of response to a changing input.
More than one of the above; either % C, P(D), or time	Complex Task	Combinations of the above carried out successively or simultaneously.

In addition:

1. Measures of sensitivity include: Absolute threshold (ΔI), Relative threshold ($\Delta I/I$), d', psychological scale values.
2. Measures of accuracy include Information Transmitted.

quantitative analysis. To know that the conditions of different experiments were reasonably comparable required Teichner and his colleagues to establish some means for extracting detailed information from each paper, and to devise a coding scheme for subsequent collation. Furthermore, because of the enormity of the literature to be searched in a relatively short time, it was necessary that the information to be extracted be systematized so clearly that the process of extraction could be accomplished by supervised assistants. For this purpose a set of descriptive terms and definitions was established to provide a system for computer storage of the descriptive specifications of human performance studies. The terms underwent revision as variations were encountered in the literature. Table 3 presents the terms in their most recent form.

Since they are restricted to situations involving visual inputs, the terms employed represent only the foundation of a descriptive data base of human performance. Nevertheless, with that constraint, if one had that portion of the total literature of interest coded as shown in Table 3, studies could be collated and sorted in a large number of ways to find those which provide exactly the information desired. Otherwise, it would have to be concluded that the information is not available. If, in addition, the actual numerical data of those studies were available, i.e., the results base, various computations utilizing the data could be undertaken in an attempt to derive, or try to arrive at, quantitative answers to any problem. For example, one might simply want the average value of a dependent variable for all studies having a specified set of conditions, or desire a least squares fit of a particular function for all such studies represented, across values of a particular independent variable.

Whether or not one were successful in manipulating the descriptive and results bases would depend not only on how much between-experiment variability was present, but also on at least two other critical conditions: (1) whether the available studies provide sufficient descriptive information, and (2) whether the problem had, in fact, been made sufficiently specific for it to be answered in a reasonable way. In addition, success would depend upon having considerable expertise in the particular problem area when the information source was prepared in order to insure (1) that the appropriate information had been extracted and put into comparable terms, and (2) that low quality experimental reports had been rejected. The total process is illustrated in the following sections and some of the products resulting from use of the system are discussed.

TABLE 3

CATEGORIES OF INFORMATION EXTRACTED FROM THE LITERATURE

Number Code	Word Code	Explanation
01	Reference	Author, title, source date volume, pages
02	Experimental Method and Conditions	Psychophysical method used to present stimuli, e.g., method of constant stimuli; Pavlovian (classical) conditioning or operant conditioning; criterion for success, reinforcement schedule (i.e., FR, VR, FI, VI, etc.), reinforcement procedure (reward, punishment, avoidance, escape, etc.), choice reaction time, search, vigilance; site and method of implantation, self-stimulation; unusual instructions, route of exposure to chemicals and drugs; in vivo, in vitro, in situ.
03	Experimental Design	Within and between group comparisons and other factor designs; conditions for matching special conditions for selection (occupational background, living conditions, etc.); experimental controls.
04	Subjects	Number of human or animal subjects used per group or condition whose data were included in the analysis. Their age, sex, race, species, and occupation, if given. Any other subject characteristics if given; e.g., normal vision, handedness, prior experience, paid for participating, etc.
05	Group vs Individual Sessions	Were subjects run one-at-a-time or as a group?
06	Time per Session	For how long a time was the subject used in one session? Were there rest periods?
07	Number of Sessions	How many experimental sessions with what temporal distribution?
08	Number of Stimulus Events Displayed	How many different stimuli were presented at one time? A stimulus might or might not be a target, but it is always a unique event to which a response can be made. The total number of stimulus events displayed is the sum of signal and non-signal stimulus. Mention should be made here of repetitions of stimulus events in the display and to the dimensionality of stimuli. Also for sequentially presented stimuli, the number of stimulus events presented between successive response intervals is to be presented. See also #35.

Number	Word	Explanation
09	Method of Response	Oral, written, manual (key, button, lever), salivation, Galvanic skin response (GSR), foreleg withdrawal, bar press, maze running
10	Practice and Preliminary Preparatory Period	How much practice was provided before critical measures were taken. Preliminary period in conditioning studies: Habituation, orientation; How many conditioning and extinction trials?
11	Wavelength or Frequency	Wavelength property of signal light, color, pitch.
12	Monocular or Binocular Monaural or Binaural Dichotic or Dichoptic	Were one or two eyes or ears used by the subject? Binocularity is assumed unless other specific conditions are mentioned.
13	Sensory Adaptation	How much time was allowed in the dark for retinal dark adaptation before presentation of the stimulus? Pre-exposure duration to tones, etc.
14	Target, Signal or Stimulus Type	Light flash, digit, letter, geometric form, color, line orientation, gap, tone, pressure. Be specific concerning which letters, digits, forms, tones, etc.
15	Location of Stimulus	Location of stimulus field in space with subject as reference if no general or specific eye fixation is utilized (e.g., directly in front of S; on a curved survace extending from 30° left of S's median plane to 30° right of S's median plane) or with S's fixation point [fovea (1°)], central (5°) as reference (e.g., right of, left of, centered around fixation).
16	Target size	Physical size (diameter or area).
17	Viewing Distance	Distance of target from subject.
18	Retinal Size of Target Element	Retinal size in angular measure, (visual angle subtended). See also #24.
19	Intensive Properties of Target, Signal, or Stimulus	Intensity, luminance, sound pressure level of signals; includes masking condition, conditioned stimulus, unconditioned stimulus and intensity.
20	Intensive Properties of Field and/or Background	Field luminance, background luminance, ambient noise.

Number Code	Word Code	Explanation
21	Contrast	Let T be the target, B the background, and C the contrast. When $T > B$, $C = \frac{T-B}{B}$ and has a limit = ∞, when $B = 0$; when $T < B$, $C = \frac{B-T}{B}$ and has a limit = 1.00.
22	Duration of Target, Signal, or Stimulus	Target exposure time. Also masking duration. Conditioned stimulus and unconditioned stimulus duration, duration of irrelevant, novel, or dis-inhibiting stimuli.
23	Threshold Value	Definition of the threshold, e.g., 50% detection, or 50% corrected for guessing, or 60% detection, etc. LD_{50}, Threshold Limit Value (TLV), MAC.
24	Size of Visual Field	Area within which targets could and/or did appear. When appropriate, mention should be made of the size of the separations between target elements and/or groups of elements. Convert to visual angle when possible.
25	Spatial Distribution of Target Field	What constraints on target location within the total visual field? (e.g., targets arranged in row, column, circle, 10 x 10 matrix, etc.)
26	Distribution of Target Elements in the Target Field	What proportion of the numbers of targets presented fell in each part of the field? (e.g., target elements were equally distributed within row, targets were randomly distributed in row (or matrix) positions, etc.)
27	Number of Different Targets Possible	Number of alternate targets in the source as defined by the experimenter. (e.g., all 26 letters of the alphabet, 20 letters, 9 digits).
28	Information Content	Amount of stimulus information in bits.
29	Probability of Target Occurrence	Proportion of times a target occurs. 100% unless blank (catch) trials are utilized.
30	Warning Signal	A physical stimulus event presented prior to test stimulus: indicate the nature of the warning signal (not a conditioned stimulus).
31	Foreperiod, or Conditioned Stimulus - Unconditioned Stimulus Interval	Time between offset of warning signal and onset of test signal. In conditioning studies this is the time from onset of the conditioned stimulus to onset of the unconditioned stimulus.

Number Code	Word Code	Explanation
32	Presentation Rate or Interstimulus Interval (ISI)	Time between successive onsets of warning signals, if used, or of test signals if warning signals not used. For serial stimulus presentation, indicate the time interval required for total stimulus input and the intervals between the successive inputs. In conditioning studies this is the time from the onset of the conditioned stimulus to the next onset of the conditioned stimulus.
33	Intertrial Interval (ITI)	Time from end of response to onset of the next warning (or test) signal if set independent of S's response. Otherwise, self paced.
34	$P(D_s)$	Sensory probability of detection of the presented signal.
35	Number of Target Events Displayed	Number of targets presented simultaneously.
36	Constancy of Target Definition	Were the events designated as targets (i.e., the target population or source) the same throughout a session, constant, or was the subject told to respond to a different target(s) as correct before each trial, varied between trials, or each set (blocks) or trials, varied between blocks of trials?
37	Position Uncertainty (Constancy of Target Position)	Was the target field (stimulus display) in the same location, relative to S or S's fixation point, throughout a session, certain, or did it vary from trial to trial, or from trial block to trial block, varied between blocks?
38	Time Uncertainty (Constancy about when the next stimulus will occur)	If the ISI and the ITI are constant or if the foreperiod is constant, there is no time uncertainty about the occurrence of the test signal assuming a well-practiced subject. Otherwise uncertainty about when the signal occurs is assumed. No time uncertainty if the task is self-paced.
39	Number Uncertainty	When the number of targets presented simultaneously is variable from trial (or trial set) to trial and the subject does not know what the number on any coming trial will be, number (of targets) uncertainty is assumed.
40	Noise	May take the form of optical distortion, interspersed or overlaid line, shapes, dots, etc., or may be irrelevant or non-target sounds, letters, digits, colors, geometric forms, etc., i.e., irrelevant but codible stimulus events. Visual or auditory masking stimulus is noise; statistical noise. Specify all characteristics such as intensity and duration.

Number Code	Word Code	Explanation
41	Duration of Vigil	In watchkeeping or monitoring, the length of time of a session of continuous monitoring.
42	Acclimatization	History of pre-exposure of subjects to the environmental variable(s).
43	Environmental Variables	Environmental conditions, for example: carbon monoxide, mercury, temperature, humidity; how achieved, and how monitored, e.g., altitude chamber, compressed gas sources, chemical exposure chambers.
44	Environmental Exposure	Duration of exposure prior to and during environmental conditions. The time relation to the performance measure is indicated. Concentration and/or dosage (quantity), exposure rate, etc.
45	Recovery	Duration of the period between or following environmental exposure(s).
46	Exposure Frequency	Number of environmental exposures and recoveries during test session.
47	Medical and Psychological Syndromes	Emotional - Behavioral Disorders: anxiety, depression, neuroses, paranoia, schizophrenia, psychoses. Intellectual disorders: amnesia, mental retardation. Growth and Developmental disorders: weight, stunting, malformations, stillbirths, sterility, effects on pregnancy. Other Nervous System disorders: encepathology; myelopathy; nerve atrophy; loss of motor or physiological control, aphasia, palsy, spasticity, epilepsy, etc.
48	Physiological Measures	Major physiological measures and techniques for monitoring, how reported and when taken: heart rate, respiration, temperature, weight; also, electrophysiological measures taken such as EEG, EKG, rheoencephalogram, etc.
50	Number of Different Responses	How many responses are (can or should be) made on a given trial or within a given response interval?
51-56	Available for later use.	
57	Eye Movement Parameters	Eye movement parameters measured.
58	Apparatus	Type of apparatus and accuracy claimed.
59	Additional Variables	Independent variables whose variations are reported in the paper, but which are not cited in the base. Anything mentioned in the paper that is not included above.

Number Code	Word Code	Explanation
60	General Statement	Statement of the purpose and conclusions of the author and special comments of importance to use of the data. A brief abstract plus special notes.

The human performance information source that was developed should not be confused with the use of it. The intention was to arrive at functional relationships in certain subject-matter areas of human performance. Where data were available, they were used in the general manner indicated. When they were not available, hypothetical relationships were postulated in order to develop models of human performance. The degree to which one is willing to deviate from available information in a particular case depends on the purpose and in no way reflects on the adequacy of the information source for other cases, uses or users.

For each topic there is a descriptive base on IBM cards and a results base in the form of a book which provides the actual figures, graphs and tables contained in the source articles. Where only figures were available, the data were read from the figure to generate a table of numerical results. Studies in the results base are identified by the same study number used in the descriptive base. Thus, the results base in book form can actually be used by itself in a limited way. All of the human performance results bases have been produced in book form.

For computational work, data were selected by descriptive specification for a particular purpose(s). However, in their most recent effort, Teichner and his colleagues intermixed the results and descriptive data to obtain a single printout. This could be done easily because the data reported in the area were standardized in form and limited in scope. Keeping in mind the restricted scope of their effort, the following human performance information sources were developed:

1. Sensory Probability of Visual Detection: Contains those studies which report both the threshold and a measure of variability for detecting the visual stimulus as a function of brightness, contrast and size.

2. Simple Visual Reaction Time: Contains those studies of the reaction time to a flash of light in central vision.

3. Complex or Choice Reaction Time: Contains those studies using simple, familiar, visual signals and manual or verbal responses.

4. Probability of Signal Detection as a Function of Time: This contains the vigilance literature for simple targets.

5. <u>Visual Search for a Simple Target</u>: Contains those studies which have used simple targets in unknown positions under both "natural" and laboratory conditions.

6. <u>Coding</u>: Studies of errors in reporting the contents of briefly exposed displays.

7. <u>Complex Searching</u>: An expansion of #5 above which includes complex target situations.

8. <u>Eye Behavior and Measurement</u>: Contains studies concerned with the measurement of eye movements and other visual parameters.

Each of the above-listed analyses deals with important empirical and theoretical problems. In the following paragraphs, the major aspects of one of them is reviewed as a specific example of the application of the system.

Simple reaction time (RT) to a flash of light has been a matter of both practical and theoretical scientific concern for at least 150 years. It touches on every aspect of human endeavor including scientific observation itself. Mathematical models have been proposed which, unfortunately, have been based upon limited experimental findings. This problem was selected not only because of its long history and general importance, but because its theoretical background is easy to summarize.

It has been known for a long time that RT is inversely related to stimulus intensity and apparently varies with stimulus duration, warning signal - test signal time interval (foreperiod), whether vision is monocular or binocular and a number of other factors. It has been supposed, but never successfully demonstrated, that RT is a constant for a constant product of intensity and time (duration) and, thereby, follows Bloch's law for threshold vision.

Theoretically, it has been well-accepted for at least 100 years that RT consists of two components, one of which is a constant neural-muscular transmission lag and the other is a variable time which in turn depends on intensity and other factors. Thus, RT is generally understood to depend on the time needed for sensory processing of a signal. More complex information processing involving such activities as stimulus identification and problem solving is supposed to take place in a time period following the sensory processing. Thus, to determine the time required for more complex processing, it has been common to subtract the RT to the stimulus (measured separately) from the total time to process. Teichner's analysis of choice reaction time provided a strong basis for questioning these assumptions. At the same time the analysis provided useful empirical relationships.

The first step in dealing with the RT problem was to conduct a fairly quick review of the literature to assess the descriptive variability with which studies were reported and to determine if there would be any special information-extracting problems. With decisions made on this basis, the following specific assumptions were made and restrictions imposed as a basis for accepting any particular report:

1. Viewing was restricted to central vision.

2. Studies which did not specify either monocular or binocular viewing were assumed to have been binocular.

3. The spatial position of the signal had to be a constant and known by the subject.

4. The time of arrival of the signal had to be known by the subject within close tolerance. Studies using both random and nonrandom foreperiods were accepted if it could be assumed for the former that the subjects were well-practiced.

5. There could be only one possible signal and one possible response.

6. The report had to provide either the actual values of luminance, duration, visual angle and background luminance, or information from which those values could be calculated.

7. The procedures and experimental design had to provide unconfounded data.

In addition, with certain exceptions, the literature sources were restricted to papers in English.

Restriction #7 above, clearly, is one which draws upon a combination of expertise in the problem area and of knowledge of experimental design. Though this restriction was judgmental to a considerable degree, inadequate studies had to be isolated in advance of any attempt tc use their data or to include them in the information source. In attempting to organize data within a topic, one may find that the results of a particular study deviate markedly from other studies which used essentially similar control levels, and that a new reading of the paper may (or may not) reveal problems with the study that had not been noticed earlier. These issues are addressed in greater detail below on the general problem of avoiding error.

Acceptance of studies was not only specific to criteria of the sort listed above but also was restricted to studies which either provided results in a quantitative form or which were theoretical or review articles. For the latter, only the reference was provided along with a code indicating that the paper was of the theoretical or review kind. Experimental studies which did not provide actual results (figures or tables) were not referenced, although they could have been. For those that provided only figures, the values of the figures were read from the curves to create a table of numerical values. Some studies which provided results were rejected either because they failed to provide enough descriptive information with which to determine the critical values of control and experimental conditions, or for quality reasons. Rejected studies were included in the descriptive base by reference only and with a code indicating that the study had not been accepted. This was particularly true of studies which could be rejected by a quick skimming of the paper. The primary concern at that time was in assuring that already rejected papers were not re-read.

At the time, Teichner and his colleagues were concerned only with the data base as a tool for their own use. Later, as other researchers became aware of what was being done and with the encouragement to be more inclusive, all studies which had been analysed to some degree and then rejected were included. Occasionally, this even turned out to be useful to the system developers. For example, after completing a particular analysis using only studies which provided information about critical experimental conditions, Teichner discovered that some of those conditions were not really critical. This sometimes depended upon the precision of measurement in the field. Today RT, for example, is commonly measured in milliseconds. In any case, it was sometimes found that intensely studied variables had small, though statistically significant effects, which, compared to the effects of other variables, were negligible. Thus, Teichner could come back to a study rejected because it failed to report on that variable and find that it compared favorably with the overall trend of studies which did.

Teichner and his colleagues searched for and analysed papers, using an early version of Table 3. Every conceivable source was used including standard bibliographic services (e.g., Library of Medicine) and standard abstracting periodicals. The bibliographic services proved to be an almost total loss for this activity and every other search conducted. More pertinent information was obtained from Psychological Abstracts and Biological Abstracts than from the total listings for a topic from other bibliographic services. Generally, Teichner was lucky if a total listing provided two useful references. His experience might have been different if he tried to obtain references covering problems of wider scope than the particular problems selected, e.g., in terms of the whole categories of Table 2.

It was difficult for Teichner and his colleagues to estimate the time required to complete a search since all work on it was part-time. However, their coarse estimate for the topic of RT was two to three months. Analysis of the studies using Table 3 required an estimated average of 30-60 minutes, depending upon the clarity of the paper and the detail provided, with a range of perhaps five minutes to two hours. Sometimes an important methodological detail would be hidden in the discussion; sometimes calculations had to be made either because they had not been, or because the author's calculations were questioned.

Teichner and his associates learned to avoid reading anything but method sections until everything in those sections required by Table 3 was completed as far as possible. They learned to look first at the experimental design and, if the design confounded the variables of interest, the paper was summarily rejected. On the other hand, Teichner and his senior colleagues felt that they could not entrust that decision to assistants, even first-year graduate students. Consequently, the students were required to analyse the paper as far as possible otherwise. Decisions about experimental design as well as any other judgment of quality, e.g., adequacy of controls, were made by senior personnel.

Every paper that could be found was examined. Sometimes, a useful paper had a far-removed purpose. For example, RT has been used extensively to study personality, effects of hypoxia, noise and in many other ways. The author's reasons for using RT were considered totally irrelevant.

There is also the matter of statistical testing. As a policy, statistical findings were completely ignored. (Table 3 does not have this category.) The reasoning was that, depending on risk level, such tests apply to the expectation that a single experiment would provide the same data if replicated. Since the literature was being used to replicate, such tests tend to be meaningless.

Differences in procedures and methods of analysis were accepted as possible error. If one study reported median RT and another mean RT the differences were accepted as variations in a single statistic due to random error. Similarly, for other problems, the use of different psychophysical procedures was disregarded and variations in threshold were treated as though they were due to chance. If, however, the results had not been integrated across studies, those differences would have been looked at as a possible important source of noise. However, those differences never turned out to be important when considered against the variations among a large number of values.

For the simple reaction time problem, the literature from 1886 to 1971 was searched, applying the criteria noted above. It was difficult to estimate how many studies were actually reviewed, since a great many of them were rejected at the first reading. However, a total of 37 studies was accepted for inclusion in the descriptive base and 35 in the results base. Not all of those studies provided complete, descriptive information, but they did at least provide what appeared to be acceptable data and a majority of the required items of descriptive information. Of the descriptive base only 14 studies provided information which was considered to be sufficiently complete, and which also met the first five restrictions noted above.

The procedure of analyzing the data from the 14 studies was the same as that applied to all of the other analyses. In this case, most computational work was done by hand although it could have been done by computer. For some other analyses calculations were programmed in Fortran and computer plots obtained. However, only the toxicology study had all of its work done by computer. In all other cases, some degree of manual work was involved. Some additional explanation is needed since in all cases, the work could have been done by computer.

The explanation lies in the individual differences among researchers. Teichner has the conviction that he could not fully appreciate the possibilities of the data unless he plotted the data, tedious though that was. The task of organizing data as he and his associates have done is a creative process often requiring more time than all previous steps and, at least for them, the process is stimulated by hypotheses formed in the course of plotting an unfolding trend. Hypotheses can often be evaluated quickly by starting new plots. Use of the computer seems to reduce involvement with the data and discourage the testing of a succession of probe-like hypotheses. But this may be a matter of temperament rather than of necessity.

The first step in analysing the RT data, as with the other human performance data, was to assume that the measure of interest (here RT) depends entirely on one independent variable.

The data were then ordered with respect to that variable regardless of what studies they represented. Without exception, the resulting plot was chaotic, but did allow for inspection to detect patterns in the scatterplot representing the effects of other variables. If such patterns were found, or if the general findings of the literature suggested, a second variable was selected and a new plot of the first variable with the second as a parameter was made. The general plan was to do this systematically until some combination of variables organized the data into meaningful trends. There are powerful multivariate techniques which would permit this whole process to be accomplished quickly. Such methods, however, produce best fits of polynomials with no a priori rationalization. The purpose was to build rational models rather than to merely organize, as such models are needed to extend the data to other applications or regimes.

For the RT data, the first step was to plot RT relative to stimulus luminance. RT as a function of both intensity and time was the next plot. Size of stimulus and monocular versus binocular viewing were considered next. Finally, stimulus size was held constant, and RT was plotted separately for monocular and binocular modes, as a function of time (duration) with luminance as a parameter.

In doing this, faster RTs were found for monocular than for binocular data, a completely unreasonable result. After much data manipulation and rechecking studies, it was decided that the binocular data must be more reliable. Accordingly, mathematical functions were fitted to the binocular data for two different signal sizes: 0.5 degrees of arc and signals that were foveal, but whose area was larger than the fovea. In each case, a family of curves could be fitted with luminance as the parameter. The fits had some empirical value, but suffered because the best fitting functions were different and the fits were good only within narrow limits of the variables. Nevertheless, these analyses were completed because the results had the practical value of providing a knowledge of their limits.

The next step was to combine luminance and time into a single scale of stimulus energy. When this was done Teichner discovered that: (a) the binocular data were now faster, a reasonable result; (b) area, in the range available, had only a small effect; (c) Bloch's law does not hold for RTs; and (d) all of the data fell into two parallel trends, i.e., a monocular trend of stimulus energy and a binocular one.

The work to this point had not proved fruitful for the construction of models based on single variables, the general theoretical activity in the literature. The energy function which combines two variables was promising for practical use, but still not satisfying theoretically. However, a response criterion model for latencies in general was available which could become very powerful if it fit the data. The weakness of the model was the unavailability of a dependent measure to represent the response criterion. However, with a simple mathematical derivation it was possible to show that the criterion scale could be expressed as the amount of energy in the stimulus accumulated to the time of the response. All of the experimental results, regardless of any other specification, were then plotted with this measure calculated from the data, as a function of stimulus duration with luminance as a parameter. The result was that <u>all</u> of the data were rather neatly organized.

A final point is in order about the RT study as an example of an application of the information source. The literature surveyed covered a long period of time. Yet, only 35 studies (results base) with data of interest were found. Of these, only 14 were available in detail and in a form permitting data manipulation. Considering the many hundreds of RT studies done over the period studied, this would appear to be a remarkably small number. That would not have been the case, however, had the journals required some form of standard reporting, perhaps along the lines of the content of Table 3. Clearly, it would be easy for such information to be coded and packaged even in a journal article. Information considered especially important could be given further presentation in the paper. Some such approach would ensure that all of the relevant descriptive information needed to replicate the study was available. Incidentally, attempts were made on a few occasions to get information directly from authors. The effort was discouraging; those that responded generally did not have information about the details of a study published some time earlier.

Actually, the small number of studies available for use is less important than the fact that studies were found for which it was reasonably certain that the data were collected under the conditions of interest. It should be noted that the number of studies available for such use will vary with the topic. The choice reaction time literature provided 149 studies for the descriptive base and 84 for the results base. The Teichner analysis used 59 of those studies. On the other hand, the eye behavior information source contains 244 studies in the descriptive base and 55 in the results base. Of all of those studies only 14 contained both eye movement and performance data. Unlike the 14 RT studies, however, these 14 varied so widely in task and in ocular parameters reported that nothing could be done with them.

There are sets of data where the variations in methodology used are so large that the results of different studies are not comparable. There are also studies reporting dependent measures in ways that defy transformations to a common scale. Examples of the latter are difference scores and ratios of different kinds expressed without information about the reference used so that they cannot be recalculated to original data. In such cases, it may be possible to make the studies comparable by using relative measures. Examples of this may be found in Teichner and Whitehead (1971) which examined the effects of massed and distributed practice on human learning, the effects of noise on performance and the effects of feedback on tracking performance. These analyses, performed as demonstrations or exercises, represented a very early attempt at data base use. However, they also illustrate the use of relative measures (e.g., percent difference between experimental and control groups) as a means for answering scientific questions.

Teichner's work serves to make clear several important points about the evaluation and subsequent use of ergonomic data in a comprehensive data base. First, critical evaluation of data from the human sciences, while a difficult and perhaps tedious chore, can be productively accomplished. Second, critical evaluation and compilation of data in any subject matter area require intimate knowledge of the subject matter in order to appropriately define the criteria for selection of data to be accepted for inclusion in the data base. Finally, evaluation and compilation consist not of simple mechanical manipulation of abstract pieces of data, but require the full creative efforts of dedicated scientists. Lide and Rossmassler (1973, p. 135) perhaps best summarize the importance of these considerations when they note, with the help of Lord Rayleigh:

> "Critical data evaluation is a tedious and exacting job that lacks the glamour of research but requires many of the same intellectual attributes. The participation of experienced research scientists is essential to the success of any compilation effort, and our system of credits and rewards should reflect the value of such contributions to the progress of the profession. As Lord Rayleigh remarked about the work of one of his contemporaries:
>
> > 'Some may think that the same talents and industry would be better devoted to original work; but it must be allowed that to elucidate and render accessible the labours of others may be a service as valuable as the addition of new material to the common store'."

5. NATIONAL ERGONOMICS SURVEY

The SERDS concept encompasses two major categories of data: anthropometric (human body) and behavioral (human response) measurements. Both data categories are required by private industry, government and the research community. However, data available in the literature, are often out-of-date and, more importantly, not statistically representative of the civilian, American population. It is proposed that a National Ergonomics Survey be conducted to obtain such measurements on a representative sample of the U.S. population.

The National Ergonomics Survey will initially emphasize the collection of anthropometric measurements (SERDS Data Module I) for several reasons. First, such measurements appear to be more urgently needed by several industrial sectors than most behavioral measures. Second, once anthropometric data are obtained they are somewhat easier to organize, process and disseminate than behavioral data. Third, the technology used to obtain precise, accurate anthropometric measurements presents challenging, special problems including: definition of measurements, use and standardization of instrumentation and standardization of procedures for data collection. Planning for the development of several behavioral data modules is presently under way.

Objectives and Requirements

Given the anthropometric surveys that have been made of selected population samples for a variety of purposes by Federal agencies and private companies, one can question the need for a national survey considering the cost and other problems associated with its conduct. Unfortunately, anthropometric data generated in previous studies suffer from one or more of the following limitations (Steinberg, 1974):

1. The data were from select segments of the population and therefore have only limited generality;

2. The data do not include all or even most of the requisite measurements applicable to all potential users;

3. The data in many instances are obsolete and therefore not representative of the present-day U.S. population; and

4. The methods used to obtain data and the conditions under which they were obtained are often suspect or ill-defined.

These drawbacks may be attributable to two factors. First, no single agency or organization has been assigned or assumed the task of developing a comprehensive, anthropometric data base. Second, the collection and analysis of anthropometric data representative of the U.S. population is a costly, time-consuming and exacting task, requiring the establishment of a planned, structured and comprehensive program.

The only apparent alternative to making use of existing but obsolete data, rules of thumb and trial-and-error is to conduct a national survey of a sample representative of the U.S. population. The objective of such a survey would be in part to collect anthropometric data that will be useful to a large number of potential users. To meet this objective, a survey must satisfy the following basic requirements:

1. The survey sample must be statistically representative of the U.S. population with respect to age, sex, ethnic origin, socioeconomic, and other demographic factors;

2. Measurement methodology, instrumentation and procedures must be standardized;

3. Data capture, storage, retrieval and analysis must be computerized to permit the original, raw data to be manipulated in many ways;

4. Computerized data must conform to the data needs of potential users; and

5. The costs of instrumentation, data collection, processing and dissemination must be acceptable.

<u>State-of-the-Art of Anthropometric Measurement--Historical Perspective</u>

Following World War II, emphasis on fitting the machine to man became critical for the performance and economy of high performance jet aircraft and even more so for spacecraft. As human engineers and anthropometrists attempted to obtain more accurate and precise data, many different methods for capturing data were devised. These new methods were designed to have the characteristics of (1) rapid data capture, (2) the capture of data for unanticipated future use and (3) permanent data storage. As a result, the current state of anthropometric measurement is one of transition from a manual method, using well-trained teams and "classical" anthropometric instruments (i.e. anthropometers, calipers, and steel tapes), to semi-automated and automated methods which involve the use of computers and photographic equipment. Some of these methods are designed to yield additional information on body contours, surface areas and body volumes as well as single, linear body measurements. Proponents of some of the methods such as stereophotogrammetry (Herron, 1972) claim exceedingly accurate measurements; other investigators raise questions about the effects of such factors as time since last meal, respiration and subject motivation for even the most sophisticated instrumentation techniques. Since different investigators use different methodologies, questions also arise concerning the comparability of data derived from these different methodologies. This underscores the importance of defining and standardizing anthropometric measurement.

Recent Trends in Anthropometric Measurement

Starting with WWII two trends in anthropometric measurement have emerged. The first trend is associated with the need for sizing data and clothing tariffs for wearing apparel. The need for sizing data determines what measurements must be taken. The methodology used is manual because a number of measurements must be referenced to underlying bone processes that can be detected by only a manual approach. The most extensive compilations of such anthropometric data have been produced by the U.S.A.F. Aerospace Medical Research Laboratory at Wright-Patterson AFB, Ohio and the U.S. Army Quartermaster R & D Command at Natick, Massachusetts.

The second trend is related to the human engineering of the man-machine interface. Work in this area frequently involves dynamic anthropometry, biomechanics, physiology and psychology. The relationships among these disciplines are so closely interwoven that it is difficult to draw sharp demarcation lines among them. One of the distinctive aspects of this trend is the necessity to establish spatial relationships in three-dimensions, such as defining reach envelopes in the sitting position or the location of parts of the body in motion with respect to equipment or instruments. The addition of the third dimension requires sophisticated instrumentation.

Since 1960, the number of studies associated with both of these trends has greatly increased. These studies may be characterized as involving a relatively small number of subjects but a large number of complex measurements. The instrumentation used is state-of-the-art and expensive. However, some of the methodologies employed, such as stereophotogrammetry and ultrasonics, may ultimately replace the classical and manual form of data capture, especially when the data capture methodologies can be tied in with data computerization. This will eventually permit the determination and evaluation of relationships that could not previously be accomplished.

Today the U.S. defense establishment maintains and periodically updates the largest compilation of male and female anthropometric data. However, the applicability of this data is strictly limited by the unique age and physical characteristics distributions within the military services.

In contrast to the long history of military anthropometry, which dates back to the Roman legions, civilian anthropometry is virtually nonexistent. There are two reasons: (1) there has been no single, central agency responsible for delineating data needs and conducting data capture and (2) there has been no clearly-delineated and organized group of data users willing to sponsor and pay for data capture. As a consequence, different organizations have collected their own data according to their individual needs with only little regard to their potential for reuse.

Only one national survey of the U.S. civilian population has been conducted to collect data on a sufficient number of body dimensions of value to such data users as the wearing apparel and mail order industries. The results of this survey, published by the U.S. Department of Agriculture in 1941, covered women and children (white only) living (or visiting) in seven states and the District of Columbia (Obrien, Gershick et al., 1941; Obrien and Shelton, 1941). The objective of the study was to collect anthropometric data useful for garment and pattern construction. In point of fact, these data were used by NBS in developing sizing standards for women's and children's clothes. Although the data sample was not truly representative of the female/child population, they were the only available data based on a large sample size.

The National Center for Health Statistics (DHEW) initiated its Health Examination Survey (one of three programs of the National Health Survey) in 1959. The first cycle of this survey (1959-1962) was limited to civilian adults living outside of institutions. Its purpose was to determine the prevalence of certain chronic diseases; the status of auditory and visual acuity; the level of dental health; and 19 body size measurements thought to be the most widely used. The second cycle (1963-1965) involved selection and examination of a probability sample of noninstitutionalized children aged 6-11 years. Its purpose was to define the normal pattern of growth and development of children in the United States. The third cycle (1971-1973) involved children aged 12-17 years. The sample sizes were 6672, 7119 and 6768, respectively for the three cycles.

The DHEW surveys are conducted decennially and make use of a nationwide probability sample. This approach makes it possible to obtain the desired information in such a manner that the reliability of the results is determinable. This, together with the fact that the measurements are standardized and controlled, permits generalization of survey results to the entire U.S. population. Further, when conducted decennially, the health survey permits body changes to be detected over time due to changes in nutrition level, life style and other factors and allows trends to be discerned and used as a basis for meeting future requirements. Thus, the DHEW surveys meet approved standards of scientific rigor and provide the best statistical, anthropometric data on the U.S. civilian population that exists today. Unfortunately, because the survey's objective is to obtain health, growth and nutritional data, the number of body measurements taken is too restricted for use in other areas.

The number of individual growth studies that has been conducted, usually involving a limited number of body measurements, is very large (Krogman, 1941; Snyder, Spencer et al., 1973). These studies involve students from grade school through college. However, the utility of these data is low because of a lack of comparability from study to study.

The remaining civilian, anthropometric data of interest come from studies which are also based on specialized populations. Some of the major studies have covered industrial workers, bus and truck drivers, airline stewardesses, air traffic control trainees and law enforcement officers (Cathcort, Hughes et al., 1935; Martin, Sabeh et al., 1975; Stoudt, Crowley et al., 1970; Damon and McFarland, 1955; Snow and Snyder, 1965; Snow and Reynolds, 1975). Although these studies were often well-controlled, the populations surveyed are too specialized to permit generalization to the U.S. civilian population. In summary, there is no anthropometric data base representative of the U.S. Civilian population that contains enough body measurements to have utility for most potential data users. The following sections briefly describe alternative techniques and instrumentation that appear to be applicable to a nationwide anthropometric survey.

Classical or Manual Anthropometer

The classical anthropometer developed by physical anthropologists employs a set of manual measurement devices consisting of vertical and transverse linear scales, sliding inside and outside calipers, spreading calipers, steel measuring tapes, skinfold calipers and other specialized instruments. These instruments are graduated in millimeters, with the caliper verniers reading to 0.1 mm. In using these instruments, critical body reference points are "marked" on the body surface or on a body stocking. These markings, based on the underlying body structure, must be made by a skilled person to maintain comparability of measurement across subjects.

The chief advantage of the classical anthropometer is that it is a standard, off-the-shelf item. Such instruments are hand portable and can be used in practically any kind of environment to take almost all desired external linear body measurements. In the hands of a trained survey team, the data captured using the classical anthropometer would be comparable across different surveys.

One major disadvantage of the classical anthropometer is that, since manual procedures are required, use of the anthropometer is subject to human error and variability. Human error can occur in scale reading due to parallax problems, manual recording of data and transcribing data to permanent storage. Human variability may exist when measurement involves a subjective element, such as taking measurements with a given force required to compress body tissue. Human variability is also represented in the people being measured when, for example, one subject may have eaten a large breakfast while another has had none. The negative effect of such artifacts can be reduced, however, by (1) proper training of survey teams, (2) taking the mean of several independent readings, and (3) requiring that more than one person take the same reading. Also, since classical anthropometry involves manual procedures, it is relatively time consuming.

A second disadvantage of the manual anthropometer is that its use involves physical body contact. In a nationwide survey this would require the use of both male and female team members, thus making the survey effort labor-intensive. A third disadvantage is that unanticipated measurements can never be obtained after a subject has been measured unless the same subject is measured again. For example, if shoe manufacturers determine, after survey completion, that a new foot dimension is needed, a new survey would have to be conducted. Thus, present and future data needs must be fully anticipated before survey implementation.

Although the instrumentation costs of manual anthropometry are low compared to other techniques, the rate of data capture is also relatively low. This increases the time required to obtain needed data and raises labor costs. Since such instrumentation is highly portable and compact, survey members may move from site to site by car rather than in special vans required by other, more bulky equipment.

Automated Anthropometer

The automated anthropometer is basically the same as the classical anthropometer. However, data transducers, employing commercially available sensors and linear encoders, are added to permit data to be captured and read directly into computer storage. Precision of the linear encoders is greater than 0.1 mm. Using a portable minicomputer, data can be captured and stored on computer tape in real time. Various procedures can be implemented for permanent storage and data transport. At the end of each survey day, data can be transferred to a central computer via commercial data link.

In addition to automatic data sensing and readout, some instruments are equipped with pressure-sensing devices. These devices reduce survey team member variability (both within and between) in making measurements involving skin and hair compression and increase the comparability of data across subjects. Thus, the chief advantage of the automated anthropometer is a reduction in human error and variability. Automation also increases the speed with which readings of measurements can be taken, thus reducing labor cost and total survey time.

One potential disadvantage of automated anthropometers is that their bulk requires transport in a vehicle larger than the typical automobile, i.e., a large station wagon or van. However, a van does offer several advantages. It would be large enough to accommodate behavioral as well as anthropometric measurement equipment, a small portable computer for data storage, and facilities for survey team work and rest. The van itself may be used as the measurement environment as it is moved from site to site or be designed to permit equipment to be moved easily from the van to a nearby measurement site such as a school, fairground, park or place of business.

Single Camera Photography

The techniques described above produce independent body measurements. On the other hand, a photograph shows each body dimension precisely located with respect to every other dimension and also provides a record that can be retrieved for use in capturing unanticipated measurements.

Single cameras have been used in conjunction with a background grid, or a grid may be superimposed on the image for measuring major body parts (Dupertuis and Tanner 1950). However, this procedure introduces a parallax error, except when the distance between subject and camera is so large that the error becomes negligible. Correction for parallax can be made analytically, optically or physically.

One of the most sophisticated and expensive single camera techniques is the "Photo-Metric" system (Hunt and Giles, 1956). This system uses a combination of fixed mirrors, synchronized electronic flash units and a precision camera. A relatively long effective distance between camera and subject within a relatively small space is possible with this configuration. A precise arrangement of mirrors yields complete front, side, rear and overhead views of a standing subject. All views are exposed at once. Measurements, taken manually from the photographic images with graduated scales, have an error of approximately 0.1%. This method can be used with nude, marked subjects or with subjects clad in a body stocking.

Variants of the single camera system include the use of high-speed photography and videotape. The distance from camera to subject is constant, with the subject turning for front, side or rear views or, at short distances, portions thereof. Subject movements are not critical during high speed filming. Data capture is performed at a later date using a special ground glass projection screen, light or sonic pen and computer. This process is accomplished by projecting each film image on a screen, frame by frame. Behind the screen, the operator touches the pen to three points, namely: null, one end of dimension, and the other end. The computer, using a conversion algorithm, computes each distance. Since any number of frames may be used for one dimension, the computer sums and averages all measurements for a given dimension with the average being entered into permanent storage. This procedure averages out some, but not all, human error, thus permitting the use of relatively unskilled labor.

The main advantage of single camera photography is that it is a fast and efficient means of making a permanent record in the field. There are several other advantages of photography. No body contact is required. A body stocking does not distort measurements. Field personnel requirements are low. Finally, measurement does not fatigue the subject.

The Photo-Metric system is bulky, difficult to set up and expensive. However, it can be installed in a large van and checked out by skilled personnel prior to use, with only the care of the camera and the positioning of the subject left up to the survey team. Since front, side, rear and overhead views are taken simultaneously on one film, the procedure is relatively fast and efficient, and images are easily stored.

Single camera photography, and all other photographic methods for data capture, have two major disadvantages: they do not capture the third dimension and do not take into account the compressibility of soft body tissue. Volumetric body measurements cannot be obtained directly, unless circumferences and girths are measured manually. In addition, some measurements, such as finger length, are better made manually. Fine details of the face and extremities require close-up (or portrait type) photographs. The insensitivity of photographic recordings to the compressibility of the body is a problem, particularly for children whose waist circumferences and other measures are sensitive to the compression of body tissue. No existing camera recording technique appears to solve this problem effectively.

One minor disadvantage of photography is that data capture from photographic images is time consuming and laborious. More importantly, it is so fatiguing that human error poses a problem. A light/sonic pen/computer combination may help alleviate this problem. It should also be noted that (1) film processing must be done very carefully to assure that the paper is not stretched, (2) photographs must be stored in an environment where the temperature and humidity are fairly constant, and (3) if participants are photographed in the nude, the files must be secured to prevent unauthorized access.

Instrumentation costs for a good single camera system are a function of the degree of sophistication and accuracy required. For example, it is estimated that two partial mirrors could be set-up in vans for about $200K, including pilot study validation. Four photographs per subject would be taken representing the obverse and reverse of the x-y plane, the x-z plane and the y-z plane. Photographs of extremities and face would be made separately. This system could also be used in conjunction with the classical anthropometers, where the single camera system would provide back-up information and permit capturing unplanned measurements later on.

Photogrammetry

Historically, photogrammetry has been used to survey and measure the earth's surface from aerial cameras to develop various types of contour maps. In anthropometry, this technique consists of taking simultaneous photographs from two or three cameras located on mutually orthogonal axes at precisely-determined distances from a given, arbitrarily-defined origin.

In the Andrometric Camera System (Chaffee, 1961), the subject's body is marked for specific measurements and then placed at an arbitrary Cartesian coordinate origin. Working from negatives, measurements between marked parts are taken and converted to true scale values using a series of trigonometric equations. Direct measurements can also be made using a calibrated film reader or oscillographic reader.

Perhaps the best but most costly photogrammetric technique is an adaption of the stereophotogrammetric method used in aerial contour mapping (Hertzberg, Dupertuis, et al., 1957). A pair of aerial cameras (e.g., AF K-17s) is mounted approximately 5 feet apart and 12 feet from a subject to optimize the stereoscopic effect of simultaneous pairs of photographs. In one version, the photographic negatives are converted to a diapositive for use with a Kelsh plotter. The Kelsh plotter is used to plot equal dimension contours for each 90° rotation of the subject. Profiles, surface arcs and circumferences define the shape of the subject with an accuracy greater than the living body. That is, the error of measurement is less than the contour changes due to breathing and body movements. A less expensive plotting technique involves the use of twin projectors: one red-lighted and one blue-lighted. A white "flying spot" is used to identify equal height contours. An analog-to-digital (A/D) converter and minicomputer capture and convert the information to dimensional data. However, since the operator must wear red and blues lenses to achieve fusion of the stereopairs, only skilled and well-trained technicians can be used for data capture.

The Biostereogram technique, promulgated by R.E. Herron (Herron, 1972), employs a variation of the flying spot plotter. Algorithms, based on analytic geometry, are used to convert imagery information to body measurements, surface areas and contour characteristics, and body part volumes. Under precise conditions, stereophotos, holograms, X-rays, infrared rays, or other forms of imagery provide a means of measuring organic forms in three dimensions. Changes in form, as in movement or growth, can be determined using time as a fourth dimension. Thus the body can be characterized digitally, using Cartesian or other coordinate systems, or analytically using contour maps, cross-sections or physical replicas. Because of the accuracy and great wealth of data obtainable, stereophotogrammetry has been used in such fields as orthodontics, orthopedics, plastic surgery (facial restoration), prosthetic design, body and limb plethysmography and tumor detection and growth.

The chief advantages of stereophotogrammetry over single camera techniques are its smaller error of measurement and its greater information content, particularly with respect to the third and fourth dimensions. It is particularly useful when contour and volumetric data are desired. Space and set-up requirements are somewhat less than other methods and hence such equipment is relatively more portable. Like all photography, it is noncontact, does not tire subject or experimenter, and provides a permanent record for later data capture.

Although the field equipment is relatively inexpensive, central data capture equipment is expensive and labor intensive. Data capture also is laborious, time-consuming and requires a high skill level. Since this technique is based on man's natural, visual characteristics, the skilled technician must be able to fuse two slightly different images into a single image having three dimensions and have good depth perception to detect surfaces with the same dimension. Because the nude, human body is essentially monochromatic, Moiré fringe patterns may be added to increase contrasts between body points. Automating data capture may be difficult because both fusion and depth perception take place, not at the receptor level, but at a higher cognitive level, thereby necessitating a man in the system.

A minor disadvantage of this technique is the requirement of a dedicated computer and computer programs to reduce image information to a desired digital or analog form. These programs are based on the principles of trigonometry, analytical geometry or fast Fourier transforms.

A single study to capture clothing-type data by Biostereometry cost $150K for 30 subjects, or a per subject cost of $5K (R. White, U.S. Army Natick Lab, Massachusetts). This approach is obviously too costly to be used in a nationwide anthropometric survey. Other techniques such as x-rays, ultrasonics, laser and holographic interferometry appear to have potential use for a national anthropometric survey.

Advanced Technology

A number of advanced techniques have been explored on a preliminary basis as means of obtaining gross body dimensions automatically, i.e., without a human observer in the loop. The techniques included: optical/electro-optics, ultrasonics, infrared, X-rays, lasers, masers and holographic interferometry. With all these techniques, the x and y coordinates from an arbitrarily defined origin, whether Cartesian or other coordinate system, are determined by an electromechanical sensor. The types of sensors used range from linear optical encoders to a horizontal array of signal transducers which are swept sequentially. These sensors generally have high accuracy.

Basically, all these techniques determine the z coordinate in the same general way. Critical dimension points are marked on the subject and appropriate reflectors placed at these points. A collimated beam of energy is reflected off the subject and received by an appropriate transmit/receive device (TR). Distance between the subject and the TR device can be calculated from the time differential between the T and the R signals. The time differentials are then used to define the unique, three-dimensional characteristics of the human body.

Currently, a considerable amount of biomedical research on internal body organs (including tumors) is being performed using ultrasonics. Ultrasonics may have considerable potential as a fast, efficient and cost-effective technique for use in anthropometry. One version of the use of ultrasonics would employ a large diameter annulus of two to three meters on which signal transducers are located every 30°. Lateral resolution is determined from the transducer spacings. However, in the case of a single, traversing transducer, resolution could be obtained from the beam width of the acoustic pulse. Vertical resolution can be obtained from a radial optical encoder located on the annulus' tilt axis. Transverse resolution would be determined by acoustic travel time and have an accuracy equivalent to an acoustic wavelength. Because the travel time for ultrasonics is long, compared to electromagnetic energy, the determination of the time differential between the T and R signals requires less sophisticated equipment than would be required for other techniques.

The main advantage of these automated techniques is the speed of data capture. Digitizing the three-dimensional coordinates results in a data base that is versatile, parsimonious and compatible with the digital computer. Data capture and storage occurs in real time in the field. Later data retrieval, compilation or analysis can be performed relatively easily. Thus, the cost of human labor becomes minimal.

Like most state-of-the-art technologies, an R & D effort is required to go from the theoretically possible to the practically useful. Some of the problems that would be encountered are: synchronizing the z coordinate to its appropriate x and y coordinates, establishing the practical accuracy of the z coordinate, determining the measurements that can be made and their accuracy, determining the error introduced by the participant's positioning and movement and determining the error associated with the reflectors. Theoretically, these systems should be precise but practically they may not be as accurate as anticipated.

Depending on the number of people surveyed and the number of measurements taken, the cost per subject, including the R & D cost, may be the lowest for all the techniques available for a nationwide survey, particularly when the data base may have to be updated decennially.

Need for Technology Improvement

Historically, three international conferences have been held to achieve standardization in the field of anthropometric measurement. Today, with the increase in the number of measurements taken and the requirements of increased accuracy, a need remains to further up-date, improve and standardize the state-of-the-art in anthropometry.

The first area requiring up-dating and standardization is terminology, i.e., there is a need for more precise definitions. For static anthropometry, there is a need to incorporate such concepts as skin/hair compressibility, attitudinal states of the subject and time since last meal into the measurement definitions. The problem is to provide definitions which are independent of the technology or procedures used so that data obtained by contact measurement are comparable to the data obtained by noncontact measurement.

The second area of anthropometry which needs up-dating, improvement and standardization is measurement instrumentation and the procedures used. Research is needed to determine the comparability of results when the same measurements are taken with different techniques.

For a national survey, technology development and improvement is required in three areas: fast, efficient and cost-effective data capture and storage, the removal or reduction of the role of the human in the data chain and, finally, a reduction in space requirements to enhance the portability of the survey equipment. The latter may be achieved when the others are realized.

For the short term, technology development should begin with the automation of the classical anthropometer and its accessories. The University of Michigan, in a recent anthropometric survey of children for the Consumer Product Safety Commission, has developed the most extensive, systematic automation of the classical anthropometer to-date (Snyder, Spencer et al., 1975). Basically, the system involves modifying each instrument to incorporate a pressure sensing device and a length measuring device, such as a 10-turn potentiometer, coupled to the instrument blade by a pulley and cable system. Electrical readouts, activated by a push-button switch, are inputted to a minicomputer via a 12-bit, A/D converter. Two digital readout meters provide visual feedback for pressure control and measurement check. A keyboard/TV monitor provides input to the computer for other data, e.g., participant name, age and sex. A processor program completes the system; the system is easily portable in a small van.

For the long term, technology development should concentrate on the R & D of ultrasonics as a technique for large scale surveys involving major body dimensions. The major justification for an R & D program in ultrasonics is that it is currently being investigated as a potential tool in biomedical research. If, for example, ultrasonics can quickly and cheaply detect cancerous tumors, then it might be possible to combine a health survey with an anthropometric survey.

Proposed Survey Approach

Objectives

Data collected in any survey must be generalizable, with a reasonable degree of precision, to a clearly defined population. If the data include biases or threats to external validity, then the conclusions drawn will be ambiguous (Campbell, 1963). Biases that preclude desired generalization may originate from inaccurate measuring devices, the lack of standardized measurement procedures and biases that derive from the selection of participants. The latter are discussed in the following sections of this chapter.

In addition to the effects of biases that create a constant difference in sample values from the true population value, there are random departures in the sample values that are due to the fact that only a part of the total population is included in the survey. The precision of the sample data is a measure of how close these data are to the true population value. A primary measure of the adequacy of any survey is the precision of its findings. Precision, in turn, is a function of the variability of the population being studied and the number of participants in the survey. The number of participants is usually determined by the funds available for the survey and the manner in which such funds are allocated. Thus, the objective of a well-designed survey is to avoid, where possible, biases in participant selection and to obtain, for the amount of funding available, useful data as precise as their potential users require for a range of applications.

Criteria for Participant Selection

An unbiased selection of participants from a population can occur only if each member in the population has the potential of being selected with a calculable (and non-zero) probability. The most common version of this criterion in survey design is one that requires each member of the population to have an equal chance of being selected (Moser and Kalton, 1958).

The criterion that each member of the population must have an equal chance of being selected applies only in a design in which the total population is sampled without any further differentiation (stratification). Major revisions to this design occur when the population is stratified according to properties of its members such as age, sex, income and education attainment, or the members are grouped in clusters for sampling purposes according to geographical proximity. The advantages and losses that occur when these classifications are made are discussed below. The equal probability criterion should be maintained, however, for the subpopulations contained within each stratum.

Clustering generally prevents the equal probability criterion from being applied since only individuals in specific locales are surveyed. A measure of how restrictive clustering can be is provided by a measure of the similarity of the residents within the cluster. If the similarity is substantial, then cluster sizes will have to be reduced and the number of clusters visited increased.

Procedures for Selecting Individuals for the Anthropometric Survey

The method of choosing participants for a survey may be grouped into the following classes:

- "Judgement" or convenience sampling;
- Use of all or some fraction of the individuals who have voluntarily entered into some predetermined, geographically-defined area such as a shopping center, museum, fair and physician's office; and
- Random selection from a list of all members of the population.

The first procedure is employed in such applications as market surveys where the weights of the sample stratifications are adjusted to resemble the stratifications of the population. However, the selection of individuals in the lowest level of the design is not made at random but is rather based upon a fixed feature--such as individuals conveniently available to the survey team, or individuals who are aware of the existence of the survey and have contracted with the survey team to participate.

Since convenience sampling does not meet the criterion of equal probability sampling, convenience sampling can be justified only if it can be demonstrated that there is little or no variability in any particular sub-sample. This assumption is usually made but there are few instances in which it is empirically confirmed. Many texts have discouraged the use of convenience sampling (Moser and Kalton, 1958).

Sampling of participants who have voluntarily chosen to enter an area in which the survey team has placed data recording devices has increased in prominence with the current interest in unobstrusive measurements (Webb, et al. 1966). Measurements can be affected by a participant's "reaction" to the experimental or survey situation. One of the most serious of these is the knowledge that the participants are being compared with each other. Reactions or measurements under these circumstances may be sufficiently different from ordinary behavior to cast doubt on the validity of the data. This criticism can be avoided by not notifying participants of their involvement in the survey and taking measurements in unguarded moments. Obviously this approach is not feasible for an anthropometric study. In addition, voluntary entrance into a prescribed area such as a museum or shopping center may bias the sample. Museum attendees may include a disproportionate number of school children and their parents, whereas a sample of people at shopping centers may be weighted with housewives and younger children.

The most common practice in obtaining survey participants is to use a list of all individuals in the population and to extract names from this list with either a systematic or random procedure. A systematic procedure is generally discouraged--especially if it can be shown that there is any periodicity and/or grouping of names in the list on some relevant trait. If the listing is complete, without errors and redundancies, sampling can be performed without bias by the use of tables of random numbers. Participant lists which are free of imperfections are rare for any large population, but reasonable approximations do exist in such records as factory payrolls and school attendance rosters. For a national survey, the best approximation to a listing of the United States population is the list of "segments" maintained by the Bureau of Census. These segments are lists of households, rather than names. A single segment usually consists of six adjacent households. Usually, data are collected from all available members of a segment and generalizations can be made only to this population and not, strictly speaking, to all individuals in the United States.

However, if the Bureau of Census lists of segments were to be used in a national anthropometric survey, the population to which the results would apply would have to be revised to exclude two major groups--those people who reside together in a non-family relationship and residents of localities in which there have been sizable population changes since the last census, as indicated from other information sources.

<u>Use of More Complex Sampling Designs in Collecting Data for a National Anthropometric Survey</u>

The sampling plan described earlier for selecting participants at random from a list of candidates is essentially a simple probability sample. Simple probability sampling is used as a standard for other plans in which the basis of comparison is the precision of the different plans. Simple probability samples are also employed to collect data in pilot surveys.

Changing a sampling plan from a simple probability sample to a more complex plan is usually done to increase the sample's precision or for practical considerations in the collection of data. A plan may also be designed to answer specific questions, such as the difference between rural and urban communities on a trait being studied.

Clustering in Sample Design

In surveys, clustering involves the designation of a geographically restricted area such as a city block, town or group of homes. Some fixed percentage of available individuals is sampled within the cluster. The proximity of the participants in the cluster is its primary advantage. If vans are used to go to selected locales to collect anthropometric data, then these locales become the clusters in the sampling plan. Since the residents in the area would be within an acceptable traveling distance to and from the van, their appearance at the van for measurement is made especially easy.

However, the most serious limitation of clustering is the reduction in survey precision. The residents in a cluster may be more similar to each other, in many respects, than they are to individuals outside of the clusters. Individuals in a community may be similar to each other in income, age, race and occupation due to a tendency for individuals to group together on the basis of these characteristics. This increased similarity may reduce the "representativeness" of a cluster. To avoid the biasing effects of geographical proximity, the survey team(s) will have to collect a smaller amount of data from each cluster and include more clusters in the survey design.

The effect of clustering on the variability of the total sample is largely determined by the correlation between members in the cluster. The sampling variance following clustering [Var (C)] is measured utilizing the following formula:

Formula 1: $\mathrm{Var}\ (C) = \mathrm{Var}\ (R)\ [1 + (N - 1)\ \rho\ ]$;

Where Var (R) is the sampling variance for a simple probability sample of the same size as the clustered sample, N is the size of each sampled cluster, and ρ is the correlation between members in the cluster. This formula assumes that all N individuals in a cluster are measured.

Since (ρ) is multipled by (N - 1), the resultant effect of increasing the variability of the results and reducing the survey's precision is considerable. Cluster selection should be guided by a principle of choosing those clusters which have as much variability within them as possible.

Stratification in Sample Design

The primary method for improving the precision of a simple probability design is stratification. For example, to determine the effects of ethnic background on body dimensions, the population would be stratified using major ethnic categories--including categories of mixed and indeterminate background and then simple probability sampling would be performed within each stratum. The requirements are that the strata be mutually exclusive and that the categories encompass the total population in the proper proportion.

Properties or characteristics for which stratification may be desirable should form a continuum and thus a decision will have to be made as to where to divide the continuum to form categories. For example, if there is an interest in the effect of income on anthropometric measurements, it might be desirable to include representatives from low, middle and high incomes in the survey. The ranges of income within a stratum would have to be defined. Several techniques can be employed (Kesh, 1965); their utility is measured by the homogeneity of the individuals within each stratum as defined by the standard deviation. This classification principle follows from the rule that the subpopulation within a stratum, unlike the subpopulation within a cluster, should be as uniform as possible.

If there is no basis for stratification, there would be no reduction in the sampling error from that obtained with a simple probability sample. The difference between the variance of a proportionate stratified sample and the variance of a simple probability sample is approximately:

Formula 2: $$\mathrm{Var}\,(\bar{X}_{SPS}) - \mathrm{Var}\,(\bar{X}_{PROP}) \approx \frac{\Sigma n_i\,(\mu_i - \mu)^2}{n^2}$$

Where $\bar{X}_{SPS}$ is the mean of a simple probability sample, $\bar{X}_{PROP}$ is the mean of a proportionate stratified sample, μ_i is the population mean in the ith stratum, μ is the population mean, n_i is the sample size in the ith stratum, and n is the total sample size. The formula shows the importance of the difference between the μ_i's of the different strata on survey precision.

The proportion of the population within each stratum that is sampled may be either uniform or varied. The former, generally referred to as proportionate stratified sampling, will result if the size of the sample from a stratum is made proportionate to the size of the stratum with respect to the total population.

Optimum survey precision for the funds expended is attained if the sampling fraction in each stratum $\left(\frac{n_i}{N_i}\right)$ is directly proportional to the standard deviation of each stratum and inversely proportional to the square root of the cost per unit sampled. The sampling fraction then becomes:

<u>Formula 3</u>: $$\frac{n_i}{N_i} = k \frac{S_i}{\sqrt{c_i}} ;$$

Where n_i is the sample size in the ith stratum;

N_i is the population size in the ith stratum;

S_i is the standard deviation in the ith stratum;

c_i is the cost per unit sampled in the ith stratum; and

k is the proportionality constant.

If cost and standard deviation are the same in all strata, the optimum sample allocation is proportional to the size of each stratum.

If stratification is performed after the survey has been conducted, the mean for the entire survey would be calculated by weighting the mean of each stratum by its proportion of the total population so that the total survey sample mean ($\bar{X}$) becomes:

<u>Formula 4</u>: $$\bar{X} = \frac{\Sigma N_i \bar{X}_i}{N} ;$$

Where $\bar{X}_i$ is the obtained mean in the ith stratum and N is the total population size.

The standard error of this mean is given by:

<u>Formula 5</u>: $$S.E. (\bar{X}_{strata}) = \sqrt{\frac{\Sigma N_i^2 \; s_i^2/n_i}{N^2}} ;$$

Where s_i is the standard error of the mean of the ith stratum.

If a decision is made to proceed with the survey without obtaining estimates of data variability or costs of collecting data, then the final sample could be picked by simply selecting a uniform number from each stratum and weighting this result by the proportion of the total population within a stratum. A more frequently used approach is to utilize a uniform selection fraction in each stratum so that the probability of picking a participant will increase with the size of the stratum relative to the total population. This is known as PPS sampling (Probability Proportional to Size) and is the sampling fraction used in many current surveys.

Selection of Strata

The previous section described advantages for stratification in survey design; however, there are important limiting factors in choosing strata. Strata will not be of any value if they do not provide any improvement in survey precision. In addition, they are of no value if they are based on factors for which there are no available data.

The stratification factors should have some reasonable and preferably known correlation with the variables being measured. In a national anthropometric survey the utility of race, age and sex categorizations could be justified due to their known associations with body dimensions. On the other hand, years of schooling, income level and occupation may have little or no relationship to body dimensions.

Stratification for a national survey requires that data on the entire population be available for each of the primary sampling units (PSU) in which the stratifications are made. Although data on each individual in a PSU are not likely to be available in any data base, the Bureau of the Census does provide statistical summaries of census tracts within Standard Metropolitan Statistical Areas (SMSA) and counties. If the PSU's are based on SMSA's and groups of adjacent counties, then these data could be used to form strata consisting of census tracts within the PSU's.

Some examples of properties for which stratification data are available are:

1. Percentage of the population in the tracts that is under 18 years of age;

2. Percentage of the population in the tracts that is over the age of 65;

3. Percentage of the population in the tracts that is black;

4. Percentage of the population in the tracts that is employed in blue collar occupations; and

5. Median family income in each tract (Bureau of Census, 1976).

Influence of Cost on Sample Design

As stated earlier, a primary consideration in survey design is to obtain data with the maximum precision possible within the resources available. An advantage of stratification is the fact that it allows the survey designer to apportion the total number of participants sampled in an optimal fashion, so that the number in a stratum increases with the variability of data in the stratum and declines as the cost of collecting data in the stratum increases.

In addition to the direct costs of collecting data, it is possible to distinguish two other sources which will reduce the amount of funds available for data collection. These are overhead or central costs, and moving expenses. The former includes the expenses involved in training, managing, analyzing data and operating a fixed site containing the central office. The latter includes the costs involved in locating, setting up and maintaining the mobile vans in which the anthropometric data may be collected. The travel costs will be affected by the number and location of clusters proposed for the survey. The number of clusters will be determined, in turn, by the similarity of the participants in each cluster.

If the total budget is stable, then the amount and geographical variety of data collected will be determined by the overhead costs. If overhead costs remain fixed as well, travel costs will be the limiting factor in the number of participants who can be measured.

An approximation to the number of sampling locations and participants can be made based upon the following cost relationship (National Center for Health Statistics, 1972):

Formula 6: $B = C_o + C_1M + C_2MN$;

Where:

B is the total survey budget;

C_o is the overhead cost;

C_1 is the cost associated with the establishment and maintenance of a sampling location;

C_2 is the cost associated with obtaining data from a participant at a sampling location;

M is the number of sampling locations*; and

N is the average number of persons measured at a sampling location.

The total number of participants sampled is given by:

Formula 7: $n = M\,N$;

Where n = total number of participants sampled.

A pilot study, may be conducted using simple probability sampling to estimate C_o, C_1 and C_2. B is usually determined by external factors.

The optimum value of N is:

Formula 8: $$N \text{ (optimum)} = \frac{S_w}{S_b} \sqrt{\frac{C_1}{C_2}} ;$$

Where S_w is the standard deviation of the population within a PSU, and

S_b is the standard deviation between PSU's.

Estimates of S_b and S_w can be obtained from a pilot survey using the following formulas:

Formula 9: $$S_b^2 = \sum_{i=1}^{M} \frac{(P_i' - P')^2}{M-1} ;$$

Formula 10: $$S_w^2 = \sum_{i=1}^{M} \frac{n_i}{n} (P_i' \; Q_i') ;$$

Where n_i is the number of persons measured in the ith sampling location;

P_i' is the proportion of persons sampled in the ith sampling location with the sample characteristic;

P' is the proportion of persons in the total sample with the characteristic; and

$Q_i' = 1 - P_i'$

* One sampling location is usually contained within each selected PSU.

Once N (optimum) is found, the number of sampling locations (M) can be derived from the following equation:

Formula 11: $$M\ (\text{optimum}) = \left(\frac{B - C_o}{C_1 + C_2} \right) \cdot N\ (\text{optimum})$$

Data on several characteristics of each person will be measured and collected in the anthropometric survey. A decision will have to be made on which characteristic(s) to use in the above formulas. A conservative approach would be to base the decision on the trait(s) which are the most variable. A more practical approach would be to use a trait (or a composite of traits) which is judged to be especially important for the purpose of the survey.

Effects of Nonavailability of Participants Selected for the Survey

The previous section discussed several issues related to obtaining the optimum number of sampling locations and participants for an anthropometric survey. The lists of participants would be derived from the lists of segments maintained by the Bureau of Census. A survey design comparable to the design used by the National Center for Health Statistics is described in the following section.

Although lists of prospective participants can be designated, the actual data collection will be for a smaller number than originally planned. This may be due to one or more of the following:

- Errors in the original list. Many of the errors are due to changes which make the original list obsolete. An example may be the listing of persons who are deceased or have moved out of the area being surveyed;

- Individuals may reside at the address shown in the list, but it may not be possible to reach them, if their work requires them to be away from their residence for long periods; and

- Refusals by persons who are designated and contacted to participate.

If these reductions in the survey size are small and are not biased--i.e., all individuals in the population have an equal chance of being omitted after being listed, then it will only be necessary to make an adjustment to the data similar to a correction for empty cells in an analysis of variance. One procedure is to employ a multiplier consisting of the number of participants selected for a sample in a particular subcategory divided by the number of participants from which data were actually obtained. This value is then used to weight the obtained data in each category (National Center for Health Statistics, 1970).

A more serious problem with the nonavailability of subjects is the bias that may be introduced. For example, individuals, such as salesmen, whose occupations require that they travel extensively, are less likely to be present during the period when the van is at a sampling location. Similarly, certain groups such as older women are more likely to refuse anthropometric measurement than other groups.

Biases occur, almost inevitably, in any survey and several procedures have been adopted to deal with them. As a rule they are only partly successful. These procedures include:

- Redefining the original population. If the lists from which potential participants are selected are taken from the last decennial census, then areas of substantial home clearance activity cannot be used. This might occur when offices and factories replace private residences as the character of a neighborhood changes. A common practice in major surveys is to exclude areas of large population change.

- The number of individuals who are difficult to reach may be reduced with repeated contacts at random times. The form of the contact should also be varied--telephone calls, letters and personal visits. If vans are used to collect data, they should be made available to the participants during weekend and evening hours.

- Payment of participants. This type of incentive seems to be more effective than any other inducement--such as a letter of appreciation. The optimum amount of payment for participation has not as yet been studied. The National Center for Health Statistics found that telling people that they would receive $10.00 at completion has a significant effect on reducing the proportion of persons who refuse to cooperate (National Center for Health Statistics, 1975).

Proposed Survey Design

The survey plan can be defined in detail only as information is made available related to those properties on which the sample should be stratified. Data may be obtained in a pilot effort on costs of establishing test facilities and collecting information as well as the variability of participants within clusters and stratum.

The design tentatively proposed is a multistage, stratified sampling plan whose ultimate samping unit is a cluster of adjacent households. These clusters are segments which are located and defined on the basis of segment maps provided by the Bureau of Census.

The survey would start with the use of TAB areas and Primary Sampling Units (PSUs). TAB areas divide the United States into subuniverses of major geographical areas, such as the Middle Atlantic States and all large, urban concentrations. Generally, TAB areas are used for administrative purposes in organizing a survey and analyzing data.

The survey would use the PSU as the basic element or unit for sampling. The United States has been divided into approximately 1900 PSU's, each of which consists of at least one or more contiguous counties. Each PSU contains a population of at least 7500 in the West and 10000 in the East. PSU maximum size is around 2000 square miles in the West and 1500 square miles in the East. In addition each Standard Metropolitian Area (SMA) is considered a PSU.

The Census Bureau attempts to make each PSU as physically compact and diverse in population as possible. Stratification of the United States (or of the TAB areas) should be made on the basis of the information available in Bureau of Census atlases. Some parameters which may be useful for stratification include: the proportion of the population that is non-white, population density (to insure a representation of small, rural areas) and percentage of labor force that is employed in blue collar occupations. After stratification has been completed, the selection of PSU's within each stratum should be made on a random basis with a fixed selection ratio from PSU's which have been adjusted so that their chance of selection increases with population size.

The PSU's that are picked would then be divided into Enumeration Districts of 500 - 1000 adjacent households. These would then be sampled randomly with another fixed selection ratio. Finally, the Ultimate Sampling Units (USU's) of individual segments would be obtained on a random basis within each Enumeration District with still another selection ratio. All individuals within a segment would then be asked to take part in the survey.

The sampling ratios at the different levels of the plan would be designed to produce a fixed number of PSU's and participants. These totals are determined from the formulas for optimal allocation of subjects and PSU's in a stratum after estimates are made of both cost and population variability.

The National Health Survey conducted by the National Center for Health Statistics uses an average selection ratio of 0.20 for each TAB area in selecting a PSU for stratification. The selection ratio for picking segments within a PSU is kept at 0.0036 so that the probability that any particular segment in a TAB area would be picked is 0.00072.

Problems Associated with a National Ergonomics Survey

Standardization of Terms and Measurement Techniques

Today, major problems in ergonomic measurement are standardizing terminology and defining a measurement technique for each dimension. In 1971, Garrett and others published "A Collation of Anthropometry" in two volumes. According to the authors, "This collation is a critical comparison of measuring techniques and anthropometric data from 48 American and Foreign sources. Approximately 2000 dimensions cover the anthropometry from 16 countries . . ." Several examples of a lack of standardization across different studies may be noted in examining this compilation of surveys.

For the term "Interscye," the following have been used: Interscye Breadth, Cross Back Width and Posterior Chest Width. These words may imply different operations to different investigators. Similarly, compare the two following operational definitions of "Interpupillary Distance":

(1) "Measure the distance between the subject's pupil centers. To do this, instruct him to look at whichever eye you hold open. Rest the sliding caliper lightly on his face, close your right eye, and center the fixed top before his right eye. Now open your right eye, close your left one, and center the sliding tip before his left eye. Do not allow his head, your head, or the caliper to move during the measuring," and

(2) "Subject sits. After instructing him to look at the point between the anthropometrist's eyebrows, and with the bar of the sliding caliper resting lightly on the subject's face, measure the distance between the centers of the subject's pupils."

Needless to say these two definitions generated different results for Interpupillary distance. Thus, the question of data comparability arises when studies are performed utilizing different definitions (instructions).

Definitional and procedural problems such as these cannot be handled without the development and adoption of voluntary standards by the ergonomics community. Accordingly, Chapter 2 (System Concept) addressed voluntary standards development as one of the principal functions of SERDS.

Comparability of Measurement Techniques

A second problem is data comparability when data capture involves different measurement techniques (instrumentation). To-date, no study has attempted to determine whether a number of measurements taken on a large number of participants by different measurement techniques yields equivalent data.

The types of measurements most likely to be affected by different techniques are those involving skin compression of soft-body tissue and those requiring a reference to prominent skeletal landmarks. Since children have undeveloped skeletons and proportionally more soft body tissue than adults, the problem of nonequivalence of data across measurement techniques should be greatest for children. Because of this problem, the use of contact measurement techniques (i.e., an automated anthropometer) appears to be the only way of insuring data reliability and accuracy.

Voluntary Participation

A third problem, unique to a nationwide survey of the civilian population, is that of voluntary participation. Although this was briefly touched on earlier, it deserves special emphasis here. Unlike military populations, the adult, civilian population is a "noncaptive audience." People may be motivated but cannot be forced to participate in a survey. This may have an effect on the degree to which the sample measured is actually representative of the U.S. population as a whole. For example, most adults will be at work during prime measurement time (8:00 am to 5:00 pm). Some may consider their time too valuable to volunteer. Certain groups may feel they are being used as guinea pigs for the benefit of other groups and not themselves. Others may have reservations about how and by whom data will be used.

Another problem associated with voluntary participation is the failure of population extremes to be represented in a statistical distribution of body measurements. Examination of data from two recent surveys of children conducted by the University of Michigan and the National Center for Health Statistics, DHEW, illustrates this artifact. The extremely endomorphic (or obese) and ectomorphic (very thin) children fail to show up in the results of these studies. Undoubtedly, one cause of the lack of participation by individuals that diverge from the population mean is personal sensitivity. On the other hand, the well-built, mesomorphic child, with positive feelings regarding his or her physique, is more likely to volunteer. As a result, the distribution of obtained measurements will be more peaked (leptokurtic) and have a smaller dispersion than the theoretically normal population distribution.

Other classes of individuals are also likely to be underrepresented in a general U.S. population survey. Included are the handicapped, elderly, institutionalized individuals and other persons unable or unwilling to volunteer for a measurement survey. With these factors in mind, it must be accepted that even the most carefully designed survey will produce only an approximation of the "true" U.S. population.

It may be claimed that the omission of population extremes will have only a negligible effect on the statistics of a sample distribution since they represent only a small proportion of the total population. However, unless the characteristics of the "true" population can be identified, the proportion of the sample distribution included by a process of self-selection is unknown. In other words, experience and logic suggest that population extremes do exist and must be taken into account when making population estimates from survey data.

Raw Data Storage and Personal Privacy

The ideal plan for a national ergonomics survey would predict all of the data required for all possible future applications. Only the grouped measurements and measurement statistics that satisfy these uses would be collected and retained. However, at present there is no technique for making an estimate of the data required for all foreseeable applications. Instead, it will be necessary to collect and store all measurements taken on each individual as raw data. Such storage would permit maximum freedom in the use of raw data for unanticipated data manipulations. For example, a manufacturer of shoes may require a correlational matrix to be developed for foot-length to foot-width ratios for white males, above 20 years of age, residing in an urban environment and earning an income of more than $20,000. A data base containing raw foot measurement data could be used to obtain the needed matrix; a data base using only grouped, rather than individual data, could not.

However, a data base of raw results poses a problem in terms of complying with the provisions of the Privacy Act. Therefore, the development of approved safeguards against noncompliance is essential to the acceptance and conduct of a national survey. One proposed approach is that recommended by the U.S. Department of Commerce (Fong, 1977). This approach utilizes a Data Base Management System consisting of two functions. The first function is associated with data base input and assigns a random number to represent each individual measured. The random number assignment eliminates the individual identification that is possible with a nonrandom sequence of number assignments. Individual residence information is identified only in relation to the Primary Sampling Units used.

The second Data Base Management System function prevents the output of data in any other than grouped, summary statistical form. This function is accomplished by system software. In addition, compliance is also achieved due to restrictions placed on the number of demographic stratifications that are employed. In other words, individual identifiers--age, sex, and birth date--will generate only relatively large groupings of data. In this manner, successive elimination through multiple regroupings could not be used as a basis to extract data on a single individual or small group.

Sexual and Ethnic Sensitivity and Personal Privacy

Many citizens are sensitive on matters of sex and ethnicity. These are natural concerns and must be respected. Sensititivity to sex and age can be reduced by the proper mix and training of individuals on the survey teams. For example, female team members are used when women are being measured and male members when males are measured. In certain regions of the country, survey teams would include a member of each, well-represented ethnic group. Individuals with prior teaching experience would be on the teams that measure children. Teams would receive pre-survey training on how to deal with these and other sensitivities such as choice of words used to represent minority groups and on how to treat participants who may be clad in body stockings for the measurement process.

In summary, social, psychological as well as technological issues must be carefully considered and satisfactorily resolved before any plan to conduct a national survey can be implemented. The acceptance encountered by survey researchers in recent years for handling issues such as these suggests not only that these matters can be satisfactorily resolved but that there is precedent for the manner in which this should be done.

6. DATA PROCESSING AND OUTPUT

The purpose of SERDS is to facilitate the use of critically-evaluated data extracted from the published ergonomics literature and from a national ergonomics survey of selected behavioral and anthropometric characteristics of a representative sample of the U.S. population.

All information and data considered for inclusion in SERDS will be assigned to appropriate data analysis centers for critical evaluation by subject matter specialists. General criteria for the evaluation process will be developed by the SERDS Office in conjunction with its Advisory Panel and User Council (as indicated in Chapter 2, System Concept). Specific criteria for critical evaluation are expected to vary from one subject matter area to another; therefore, each data analysis center will be guided by the general criteria but also will develop more specific criteria to guide its evaluation activities. Data and information that meet both sets of criteria would become part of the SERDS data base.

Three forms of information processing will be undertaken by SERDS:

- Scientific and editorial processing by data analysis centers or individual subject-matter specialists on a one-shot basis;
- Development of voluntary standards for ergonomics research and measurement; and
- Computer editing, processing and file updating of numerical data and narrative text.

It is anticipated that these forms of processing will meet a wide range of user needs and provide the housekeeping required to maintain and manage the SERDS data base.

Scientific and Editorial Processing

The scientific and editorial processing and repackaging of selected and evaluated source data and information may take one or more of the following forms:

- Preparation of critical reviews and surveys on topics of current interest;

- Production of tables of selected numerical data required routinely for ergonomics applications by the scientific and technical community; and

- Generation of selected, annotated bibliographies, notes on standards development activities and summaries of current ergonomics research.

The above are basically intellectual activities which may or may not require computer-assisted file searching, output formatting and text generation.

Repackaged data and information from this activity will be announced by means of scientific and technical journals, specially prepared mail circulars or a user-oriented newsletter. These products will be disseminated by the SERDS Office, data analysis centers, the National Technical Information Service and other means to help assure broad access and widespread use.

Two classes of users are anticipated: sustaining or continuing users who pay a fixed fee to subscribe for a period of service and nonmembers who pay on a service-by-service basis. Sustaining member users of SERDS would be entitled to products and services as part of an annual membership fee. Nonmember, individual or institutional requestors would be charged fees for these items at individual and group rates on a cost-recovery basis. The output from SERDS should complement and supplement, but not duplicate or compete with, other types of ergonomics information and data offered for sale by scientific and technical associations or the private sector.

Ergonomics Research Standards

As in other fields of science and technology that place a premium on originality of research, there is a lack of standardization in ergonomics research. Chapter 5 (National Ergonomics Survey) illustrated several of the problems that arise when a field has not yet achieved a satisfactory degree of agreement on the way in which it undertakes research. These include nonstandard terminology, measurement procedures, nonmenclature and instrumentation, calibration methods, and data recording, processing and reporting.

Although an excessive emphasis on standardization in these and other areas can hamper the advances that normally occur in science as new paradigms and practices are adopted, at no time has ergonomics or its related human sciences been afflicted by overstandardization. In fact, the single greatest obstacle to the present-day use of ergonomics data can be attributed to the lack of comparability of data caused by too little standardization. Thus, while standardization must be approached cautiously to avoid imposing undue restraints on the creative research process, standardization is essential to promote the growth and advancement of behavioral science.

Accordingly, it is envisioned that standards for ergonomics research will be a major aspect of the SERDS program and a principal activity of the SERDS Office. Standards preparation may take place based upon an initiating request from any interested individual or group or be commissioned by the SERDS Office to supplement its own activity.

Voluntary research standards will be disseminated widely to encourage their adoption in future research. Potential users of standards will include researchers, system planners and educational institutions that give research courses in ergonomics.

Other standards-related efforts of SERDS would include: coordination with national and international voluntary, standards-setting organizations in the development of product-specific standards; cooperation with scientific and technical associations in the development and promulgation of standards review projects; and developmental support to Federal agencies in their standards development programs.

Computer Processing and Output

Until more is known about the types and volume of literature and data to be processed by SERDS, it is not possible to do more than speculate on the hardware and software requirements of the data processing system. Most, if not all, of the functions that now appear to be called for--editing and file allocation, statistical computation, modeling, updating and display--are believed to fall well within the present state-of-the-art and can be implemented with existing software packages.

The data processing services to be performed by SERDS for its users will include but not be limited to:

- Combination of discrete sets of data;
- Computation of descriptive statistics;

- Development and use of behavioral and biomechanical models and algorithms;

- Routine listings of raw data;

- Production of magnetic tapes for SERDS users;

- Data base updating;

- Special search inquiry processing; and

- Remote terminal interfacing.

Again, products and services would be offered on a cost-recovery basis. Magnetic tape records would be leased to users at fees set to reflect the type, amount and frequency of updating of data requested.

7. PRELIMINARY SERDS PROGRAM PLAN

The Program Plan that follows has been structured to identify and meet the needs of commerce, industry, government and the research community for a single, reliable and valid source of ergonomics data. The goal of the plan is to provide access to a limited set of data by FY 81, to a more comprehensive data base beginning in FY 82, and to continuing development, services and products thereafter.

The program plan consists of three major subplans:

1. Plan for the Management and Operation of SERDS;

2. Plan for a National Ergonomics Survey; and

3. Plan for Critical Evaluation of Published Ergonomics Data

Plan 1 is essential to the accomplishment of the other two. Plans 2 and 3 are essentially independent and could be implemented individually or in sequence if budgetary or other factors do not permit simultaneous development. In this event, however, users would not have access to all of the data that would otherwise be available.

The three subplans are summarized in Tables 4, 5, and 6, respectively. Each plan starts with a statement of the objective, followed by a sequential listing of critical plan milestones. In order to show the interrelations among the plans, milestones from one plan which are in the critical path of another plan appear in lower-case letters, without sequence numbers. Horizontal lines designate the duration of each milestone activity from one fiscal year and quarter to another. Solid lines represent activities of a developmental, planning and management nature; and dashed lines denote continuing services or products to be provided by SERDS.

<u>Plan 1</u> - <u>Plan for Management and Operation of SERDS</u>

<u>Plan Objective</u>: To provide a focal point for the orderly planning, coordination, management and operation of a Standard Ergonomics Reference Data System.

TABLE 4. PLAN FOR MANAGEMENT AND OPERATION OF SERDS

Objective: To provide a focal point for the orderly planning, coordination, management, and operation of the Standard Ergonomics Reference Data System

MILESTONES/ACTIVITIES	FY	77				78				79				80				81				82				83			
	QTR	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Seq. No.																													
1.1 DEVELOP PRELIMINARY SERDS CONCEPT			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—												
1.2 CONDUCT USER NEEDS SURVEY						—	—	—	—																				
1.3 ESTABLISH DATA PRIORITIES								—	—	—	—	—																	
1.4 ESTABLISH PROVISIONAL SERDS PROGRAM OFFICE										—	—	—	—	—	—	—	—												
1.5 ESTABLISH PROVISIONAL ADVISORY PANEL												—	—	—	—	—	—												
1.6 ESTABLISH PROVISIONAL USER COUNCIL												—	—	—	—	—	—												
1.7 DEVELOP STAFFING PLAN FOR PERMANENT SERDS OFFICE														—	—	—	—												
1.8 STUDY ALTERNATIVES FOR LOCATION OF PERMANENT SERDS PROGRAM										—	—	—	—	—	—	—	—												
1.9 ESTABLISH PERMANENT SERDS OFFICE																		—	—	—	—	—	—	—	—	—	—	—	—

TABLE 4. PLAN FOR MANAGEMENT AND OPERATION OF SERDS (continued)

MILESTONES/ACTIVITIES	FY	77	78	79	80	81	82	83
	QTR	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Seq. No.								
1.10 ACQUIRE & PROGRAM DATA PROCESSING & ANALYSIS SYSTEM								
1.11 ESTABLISH & MAINTAIN PERMANENT ADVISORY PANEL								
1.12 ESTABLISH & MAINTAIN USER COUNCIL								
1.13 PROVIDE CONTINUING USER SERVICES, STANDARDS & ASSESS IMPACT OF SERDS ON USERS AND TECHNOLOGY								

1.1 Develop Preliminary SERDS Concept

The purpose of this effort, undertaken in FY 77, was to conduct a preliminary qualitative assessment of potential user needs for ergonomics reference data and develop a concept for meeting these needs. That assessment and concept development were reported earlier. It is envisioned that this preliminary report will be distributed on a limited basis to potential users early in FY 78 and will form the basis for a continuing dialog and revision of the concept in succeeding years.

1.2 Conduct User Needs Survey

Activities associated with this milestone are aimed at the development, pretest, administration and evaluation of a quantitative survey of user needs for ergonomics data. The purpose of the survey is to obtain detailed information on requirements for data, measurements, precision and accuracy of measurement, and examples of specific applications and their expected social and economic benefits. This information will be used to define the scope of SERDS and establish priorities for critical evaluation efforts and the characteristics to be sampled in the national ergonomics survey.

The specific activities planned include:

1.2.1 Preparation of a detailed list of potential data needs;

1.2.2 Development and pretest of a structured interview/questionnaire and schedule for assessing needs;

1.2.3 Completion of questionnaire by potential users followed by in-depth interviews of selected users; and

1.2.4 Reduction and analysis of questionnaire and interview data.

It is anticipated that this milestone will be accomplished by the end of FY 78.

1.3 Establish Data Priorities

The aim of this activity is to establish priorities for SERDS data. These priorities will be illustrated by means of a master table that summarizes and tabulates the frequency with which data needs, independent of their intended applications, occur across the spectrum of users surveyed. It is expected that this table will reveal a high level of demand for selected anthropometric and behavioral measurements not currently available in usable form from the published literature and thereby permit the isolation of the measurements required for the national ergonomics survey.

1.4 Establish Provisional SERDS Program Office

An interim mechanism for the management of SERDS will be required until a decision has been made regarding its ultimate, permanent organizational home. This activity will lead to a recommendation to management for providing a temporary organizational locus for SERDS within NBS. Alternatives to be studied for such a provisional arrangement include: augmentation of an existing section's/division's mission; formation of a new organizational entity; and creation of a special interim office.

1.5 Establish Provisional Advisory Panel

For SERDS to be properly managed there must be reliable feedback from the scientific and technical community. During the pilot project the services of consultants and advice from individuals attending the government and industry meetings served this purpose. However, a more formal, stable arrangement will be required if continuity and consensus of opinion are to be achieved during the initial phases of SERDS development. Therefore, it is planned that a Provisional, Ad Hoc Advisory Panel be created for this purpose from a list of nominees suggested by staff and approved by NBS management. This panel would operate throughout the last-half of FY 79 and in FY 80 and would convene at least twice during that period.

1.6 Establish Provisional User Council

Responsiveness of SERDS to its potential user community requires that it have a forum for the continuing identification of SERDS requirements and the uses to be made of the data base. During the pilot project this was accomplished by means of meetings and presentations to representatives of trade associations, other government agencies and contacts with specific industries. In the future a more formal and structured basis for obtaining user input will be required. Therefore, a Provisional User Council will be formed from among those trade associations and other organizations that have or will express an interest in SERDS. Selection of representatives will occur through self-nomination (followed by evaluation of credentials) and invitation. The User Council would be formed in the second-half of FY 79 and meet at least once during FY 80.

1.7 Develop Staffing Plan for Permanent SERDS Office

By the end of FY 79, it may be anticipated that SERDS planning will have reached a stage at which it will be possible to develop a staffing plan for a future, permanent SERDS office. This plan will identify the skills, levels and number of staff required to continue the management, coordination, planning and operation of SERDS as a permanent data service. The plan will also provide a basis for projecting the cost of the staff component of the SERDS budget.

Because of the expected use of contractor and consulting personnel on a temporary basis for various system development tasks, it is not presently anticipated that a large staff would be required for SERDS. However, a management and specialist core staff of from four to seven persons may be required beginning in FY 81.

1.8 Study Alternatives for Location of Permanent SERDS Office

In Chapter 2 (System Concept) several alternative sites for the location of a permanent SERDS Office were discussed. However, sufficient inforation was not available during the pilot project to present a thorough and detailed analysis of these alternatives. In FY 79 and 80 a study would be undertaken for this purpose.

1.9 Establish Permanent SERDS Office

SERDS products and services will be offered to the user community beginning in FY 81. At this time a permanent SERDS Office will be required in order to provide users with the assurance of system continuity and appropriate management. A decision regarding the formation of a permanent office should be made no later than the beginning of FY 81.

1.10 Acquire and Program Data Processing and Analysis System

The aim of this activity is to develop specifications for the procurement of computer time and programming for processing SERDS data. Tasks associated with this activity will focus on the design and application of a number of general-purpose, computer programs for data storage, retrieval and analysis; file manipulation; terminal access; and computer-assisted text preparation, editing and printing. It is anticipated that these efforts will benefit from close collaboration with the Data Systems Design Group of the NBS National Standard Reference Data System, the NBS Institute for Computer Sciences and Technology and the NBS Office of Technical Publications. The planned data processing and analysis will be capable of supporting the requirements of the national ergonomics survey and the critical analysis activities of SERDS Data Analysis Centers. Planning and development will be initiated in the third quarter of FY 79, with an operational processing system being targeted for the first quarter of FY 81. Thereafter, it is expected that data processing and analysis activities will continue in order to develop additional modules for the source automation of technical manuscripts, the statistical manipulation of data and the use of man-system models.

1.11 Establish and Maintain Permanent Advisory Panel

The goal of this activity, which is planned to coincide with the formal establishment of SERDS, is to replace the interim advisory panel with an enlarged and permanent advisory mechanism.

1.12 Establish and Maintain Permanent User Council

It can be expected that a number of Federal agencies and industries will choose to use SERDS on a continuing basis. Therefore, a mechanism for permitting these users to have a voice in SERDS planning and operations will be necessary to insure that the system is responsive to user requirements. One possibility is for users who wish to be represented on the Council to apply for renewable term membership on the Council at an institutional fee that will cover the cost of subscriptions to a selected number of SERDS products and a designated level of data processing service. The permanent council will replace the Provisional, User Council beginning in FY 81.

1.13 Provide Continuing User Services and Standards and Assess Impact of SERDS on Users and Technology

Sound system design requires that a system have a means for the periodic assessment of its effectiveness. In the case of SERDS, "effectiveness" can be measured in terms of system use by the scientific and technical community and the assessment of the value of its products and services provided to its users.

Accordingly, this effort will involve the collection and periodic reporting of usage and impact statistics. This evaluation activity will begin in the third quarter of FY 81, six months after the initiation of critical evaluation products and services (See Table , Milestone 3.5).

If an objective impact assessment indicates that the SERDS system is not being used or fails to meet the needs of its users, operation of the system should then be terminated after reasonable attempts to improve conditions have been exhausted. However, if impact assessments are positive, it then follows that SERDS should continue to provide products and services to the user community.

One of the major elements in this continuing program of service will be the development and support by SERDS of standards for ergonomics measurement. Examples of the forms which this service might take were described earlier in this report. Suffice it to say here that standards for ergonomic science, as for any other discipline, are essential to the creation of a valid and credible body of knowledge and timely, cost-effective application of that knowledge.

<u>Plan 2</u> - <u>Plan for a National Ergonomics Survey</u>

<u>Plan Objective</u>: To develop and provide a capability for user access to selected ergonomics data representative of the U.S. population.

2.1 Assess Alternative Measurement Technologies

Although many user needs for ergonomics data can be fulfilled by access to critically-evaluated data extracted from the published literature, existing published sources do not contain accurate, up-to-date information and data in many ergonomic areas for which there is a widespread technological need. Such areas include: the measurement distributions of the static and dynamic anthropometric characteristics of the human body and the sensory, information processing and response characteristics of man as such characteristics are represented in the U.S. population. Existing literature, for example, does not contain an adequate data base from which data can be obtained for use in sizing clothing, personal protective devices/equipment, the arrangement of workplaces or for the location and design of displays, controls and informative labels. At present a large number of devices exists for measuring and capturing such data. Chapter 5 (National Ergonomics Survey) discussed alternative anthropometric measurement techniques that are now in use. A similar situation

TABLE 5. PLAN FOR NATIONAL ERGONOMICS SURVEY

Objective: To develop and provide a capability for user access to selected ergonomics data representative of the U.S. population.

MILESTONES/ ACTIVITIES	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83
QTR	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Develop preliminary SERDS concept (see Table 4							
Conduct user needs survey (see Table 4)							
Establish data priorities (see Table 4)							
2.1 ASSESS ALTERNATIVE MEASUREMENT TECHNOLOGIES							
2.2 DEVELOP AND ADOPT STANDARDS FOR ERGONOMICS SURVEY MEASUREMENT							
2.3 PROCURE MEASUREMENT INSTRUMENTATION, DATA PROCESSING EQUIPMENT AND VANS							
2.4 DEVELOP SURVEY SAMPLING PLAN AND PROCEDURES							
Acquire and program data processing & analysis system (see Table 4)							

TABLE 5. PLAN FOR NATIONAL ERGONOMICS SURVEY (continued)

MILESTONES/ ACTIVITIES	FY / QTR	77 (1 2 3 4)	78 (1 2 3 4)	79 (1 2 3 4)	80 (1 2 3 4)	81 (1 2 3 4)	82 (1 2 3 4)	83 (1 2 3 4)
2.5 COLLECT SURVEY DATA								
2.6 LOAD SURVEY DATA								
2.7 USER ACCESS TO SURVEY DATA								
2.8 PROVIDE USER TRANSLATION SUPPORT								
Impact Assessment (see Table 4)								
2.9 REPETITION OF SURVEY								

NOTE: Solid lines denote developmental, planning and management activities.

Dashed lines denote continuing services and products exists with respect to the measurement and capture of other behavioral data such as the distribution of near- and far-point visual acuity, minimum hearing thresholds, and the speed and accuracy of response to signals of varying intensity, frequency, duration and repetition rate. Without a comprehensive examination of the many measurement devices or technologies that might be used in a National Ergonomics Survey, it would be impossible to select a cost-effective and technically adequate mix of instruments for use in the national survey. Accordingly, this effort is directed at evaluating alternative measurement technologies with respect to cost, feasibility, precision and accuracy. It is anticipated that this evaluation will begin in the third quarter of FY 78 and be completed by the end of FY 79. It would probably be performed under contract by a qualified organization with a demonstrated capability in ergonomics measurement and technology assessment.

2.2 Develop and Adopt Standards for Ergonomics Survey Measurement

Although attempts have been made to standardize the process of ergonomics measurement, a number of problems with respect to the use of common units, measurement techniques and reporting formats remain unresolved. Accordingly, it is proposed that an attempt be made to achieve a consensus among ergonomics specialists on the nomenclature, devices and practices to be used in the national ergonomics survey. This activity will represent the initiation of a continuing program aimed at promulgating voluntary ergonomics research standards. It is scheduled for completion at the end of the third quarter of FY 79. Activities 2.1 and 2.2 are critical to the accomplishment of all subsequent milestones in this plan.

2.3 Procure Measurement Instrumentation, Data Processing Equipment and Vans

Given the selection of a cost-effective mix of measurement technologies and equipment and agreement on voluntary standards for accomplishing measurement, the measurement equipment, field data processors, and mobile vans for equipment transportation can be specified and procured by either NBS or a contractor. This phase would be completed by the end of FY 80 and allows time for equipment development if suitable devices are not available off-the-shelf. It is anticipated that a minimum of four, fully instrumented vans will be required for the survey.

2.4 Develop Survey Sampling Plan and Procedures

Chapter 5 of this report has focused on the conceptual challenges to be met in developing and implementing a sampling plan and survey needed to acquire representative data. Development of a complete, approved survey plan should be accomplished by the end of FY 80. It is expected that this effort will rely heavily on the expertise of the Bureau of Census and the National Center for Health Statistics of HEW.

2.5 Collect Survey Data

By the beginning of FY 81 a position of readiness will have been achieved to permit field data collection of ergonomics data. Data collection is currently projected to last for a period of 15 months.

2.6 Load Survey Data

Although the data processing configuration can take any of several forms, it is anticipated that the data can be loaded into a central SERDS processor within three months after field data collection has started, beginning in the second quarter of FY 81 and continuing throughout the survey cycle through the third quarter of FY 82.

2.7 User Access to Survey Data

Data from the national ergonomics survey will be made available to system users upon the completion of data collection, loading, processing and analysis. Thereafter, continuing, on-line access will be available to users at prescribed times via data terminals and by means of periodically published data tables and other forms of output.

2.8 Provide User Translation Support

Data reported in a research paper or obtained from a survey and the data ultimately used for a given technology application are not always equivalent. For example, data on the distribution of the near-point visual acuity of the adult population does not readily translate into the many possible applications of acuity data to signal detectability or to the readability of text. Similarly, measures of human body size are of little use to the manufacturer of fire-resistant, cold weather or other clothing until they have been translated into pattern designs, sizing groupings and the tariff tables which define the number of items that must be manufactured to match the numbers of persons within the population subset that will use these items. Accordingly, it is proposed that a continuing service be made available to provide advice and assistance to industry or government in making translations from the SERDS data base to particular user applications. This translation support should be available when SERDS becomes operational during the last quarter of FY 82.

Although this activity is identified as part of the SERDS program, it is envisioned that translation support services would probably not be performed by the SERDS Office itself but rather by collaboration with a group which currently performs this function as part of its mission.

2.9 Repetition of Survey

No accurate estimate has yet been made of the rate at which behavioral and anthropometric changes take place in a population. However, population changes between 1941 and 1977 have been sufficiently great to render the earlier data obsolete. Looking ahead ten to 15 years after the 1981 national ergonomics survey data have been collected, it seems likely that these data will also become obsolete, thus requiring another survey cycle. An activity has been included in the plan to cover this contingency by repeating the survey at some, as yet unspecified, time in the future, possibly in conjunction with a census survey.

Plan 3 - Plan for Critical Evaluation of Published Ergonomics Data

Plan Objective: To develop and provide a capability for user access to critically-evaluated data from the published ergonomics literature.

3.1 Define Priorities for Critical Evaluation

Milestone 1.3 (See Table 4) is the establishment of ergonomics data priorities based on information received from a survey of potential SERDS users. Milestone 3.1 will define priorities for critical evaluation of the published literature by comparing the data required to meet these priorities with the existing published literature to identify those sufficiently comprehensive sources which justify analysis and critical evaluation by data analysis centers. This process would be initiated in the first quarter of FY 78 and would use bibliographic services to search for and identify candidate sources of data.

TABLE 6. PLAN FOR CRITICAL EVALUATION OF PUBLISHED ERGONOMICS DATA

Objective: To develop and provide a capability for user access to critically evaluated data from the published ergonomics literature

MILESTONES	FY	77	78	79	80	81	82	83
	QTR	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Develop preliminary SERDS concept (see Table 4)								
Conduct user needs survey (see Table 4)								
Establish data priorities (see Table 4)								
3.1 DEFINE PRIORITIES FOR CRITICAL EVALUATION								
3.2 EVALUATE EXISTING CENTERS OF EXPERTISE								
3.3 SELECT PILOT DATA ANALYSIS CENTER								
3.4 DEVELOP GENERAL CRITERIA FOR CRITICAL EVALUATION								

TABLE 6. PLAN FOR CRITICAL EVALUATION OF PUBLISHED ERGONOMICS DATA (continued)

MILESTONES	FY	77	78	79	80	81	82	83
	QTR	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Acquire and program data processing and analysis system (see Table 4)								
3.5 PROVIDE CRITICAL EVALUATION PRODUCTS AND SERVICES								
Impact assessment (see Table 4)								
3.6 ADD ADDITIONAL ANALYSIS CENTER(5)								

NOTE: Solid lines denote developmental, planning and management activities

Dashed lines denote continuing services and products

3.2 Evaluate Existing Centers of Expertise

In the past decade a number of universities, colleges, private consulting organizations and Federal agencies have become centers of excellence in specialized areas of ergonomics research. This planned activity will consist of identifying and evaluating the types and levels of expertise that currently exist in these centers with the objective of selecting organizations to become SERDS data analysis centers. Initially, up to six such centers may be considered in areas such as the following:

- Anthropometry
- Human information processing
- Human sensory processes
- Human performance
- Biomechanics and bioengineering
- Behavioral toxicity

Final decisions regarding these topical areas and their specific content will be made after the user need survey is completed. In addition to reviewing candidate centers of specialized expertise, individual specialists who might be employed to perform critical reviews on a one-shot basis also will be identified and evaluated.

It is anticipated that any funds allocated to centers or individual experts will augment and sustain but not be a substitute for other ongoing sources of financial support. Thus, the function of critical analysis will augment but not detract from continuing research programs in the field of ergonomics.

3.3 Select Pilot Data Analysis Center

Prudence dictates that a single data analysis center be established on a pilot basis for a trial period prior to the establishment of additional, permanent centers. The function of a pilot center would be to evaluate, organize and integrate data in a given area and to generate outputs for the user community on a continuing basis. These could be offered directly by the pilot center or be disseminated by the SERDS Office, whichever seems to offer the most effective service. The effectiveness of the procedure used by the pilot center and the quality and quantity of user responses to the service will be monitored carefully for a trial period. The pilot center will serve as a prototype for other additional centers.

3.4 Develop General Criteria for Critical Evaluation

This effort is aimed at establishing explicit criteria that would govern the screening, acceptance and critical evaluation of information by data analysis centers. It is anticipated that a publishable statement of these criteria will be available in FY 81 at the onset of critical evaluation activities.

3.5 Provide Critical Evaluation Products and Services

The services envisioned are summarized in Chapters 2 (System Concept) and 6 (Data Processing and Output).

3.6 Add Additional Data Analysis Centers

After the performance of the pilot center has been evaluated, other data analysis centers will be added. It is anticipated that such centers will be phased-in sequentially over a five year period beginning in FY 82.

Expanded Program

The plan presented above is oriented around the minimum effort judqed necessary to satisfy user requirements for ergonomics data. Looking beyond this focus, one can envision that a demand might be created to expand the scope of SERDS to provide data coverage for other problem areas. Such areas might include, but not necessarily be limited to: the application of human science data to problems of skill and knowledge acquisition and retention; physiological data and their medical applications; or behavioral and biological data and their application to forensic medicine and law.

Another form of program expansion might be required in response to industry requests for ergonomic data for non-U.S. populations that represent markets for products manufactured for export by U.S. industry. This demand could be met in part by unilateral agreements to share data with national ergonomics data centers in other countries or by a multilateral arrangement under the auspices of an international counterpart to the Committee on Scientific and Technical Data (CODATA) of the International Council of Scientific Unions. Focal points for such an international arrangement could be the International Ergonomics Society, the International Union of Psychological Science and the Abstracting Board of the International Council of Scientific Unions.

Whatever the future demands for expansion, it is important that the initial focus of SERDS be upon meeting current U.S. needs. An adequate "track record" of effective services must be achieved before any expansion can be contemplated and justified.

Resources Required

Preliminary estimates of required resources for accomplishing the major objectives of the SERDS program are summarized in Table 7. Funding sources are not indicated here, but include NBS, other Federal agency and industry support. Estimates of the degree of support from each of these sources cannot be made at this time. (Note: $K is dollars in thousands, SY stands for staff years.)

Presentation of this preliminary plan cannot conclude without a comment on the problems and challenges that can be expected to arise in the development of any scientific data system. It would be a grievious mistake to assume that this or any other plan could anticipate and forecast solutions for them all. Therefore, a large measure of flexibility will be required in implementing the plan to best meet SERDS' objectives.

In the opinion of the authors, the technologies for developing an ergonomics data system are within the present state-of-the art. The major problems to be faced center upon the intellectual challenge associated with the identification of data to be included and their extraction, integration and structuring into a data base of generic and useful information.

When one considers the social benefits that already have been derived from the proper application of accurate, up-to-date and representative ergonomics data, the challenge of developing a system to perform that task better than it is now being done merits acceptance. Perhaps the following forward-looking comments made by Dr. H. Wallace Sinaiko in the December 1963 issue of Human Factors are closer to becomming realty with this report:

> "not so near to realization, but a technique that will ultimately serve to keep human factors references up-to-date, is the use of automatic, i.e., computer-based systems. These systems will provide truly dynamic data bases . . . Users of such data systems will be able to query them from remote locations . . . Ultimately, however, this approach may eliminate completely the need for conventionally written and edited reference material."

PRELIMINARY ESTIMATE OF REQUIRED RESOURCES FOR SERDS (FY 78-83)

Objectives	Preliminary				First Four-Year Period								Total
	FY 78		FY 79		FY 80		FY 81		FY 82		FY 83		
	$K	SY	$K	SY	$K	SY	$K	SY	$K	SY	$K	SY	
1. Assess user data needs and priorities	155	2.6	60	1.0									215K; 3.6 SY
2. Assess alternative measurement technologies	100	1.7	250	4.2									350K; 5.9 SY
3. Define evaluation criteria and identify expertise	80	1.3	40	.7									120K; 2.0 SY
4. Develop system management capability	40	.7	100	1.7	40	.7							180K; 3.1 SY
5. Develop survey plan and acquire instrumentation			150	2.5	60	1.0							210K; 3.5 SY
6. Collect survey data					650	10.8	150	2.5					800K; 13.3 SY
7. Acquire and program data processing system			125	2.1	100	1.7	100	1.7	50	.8	50	.8	425K; 7.1 SY
8. Estab. init. pilot & other critical evaluation centers					100	1.6	300	5.0	500	8.4	600	10.0	1,500K; 25.0 SY
9. Provide access to evaluated literature & survey data					300	5.0	600	10.0	600	10.0	600	10.0	2,100K; 35.0 SY
Total	375	6.3	725	12.2	1250	20.8	1150	19.2	1150	19.2	1250	20.8	5,900K 98.5 SY

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APPENDIX A

Minutes of March 16, 1977, and
March 25, 1977 meetings.

MINUTES OF THE ERGONOMICS DATA COLLECTION MEETING WITH THE SIZING COMMITTEE, MAIL ORDER ASSOCIATION OF AMERICA*

March 16, 1977

National Bureau of Standards
Washington, D.C. 20234

Attendance:

Representing the Mail Order Association of America (MOAA), Sizing Committee

Fred Birdsong
Michael Feltser
Morton Goldner
Aubrey Jay, Chairman, Sizing Committee
W. M. Lowrey
Jim Niver
Charles Schmitt
Robert Ullman

Representing the National Bureau of Standards

C. W. Devereux
Joel Kramer
Melvin R. Meyerson
J. J. Persensky
Louis G. Porter
Harold P. Van Cott
Stanley I. Warshaw

Opening and Welcome

Dr. J. J. Persensky opened the meeting at 9:02 am. Participants introduced themselves and their respective organizations. Dr. Persensky then introduced Dr. Stanley Warshaw, Director of the NBS Center for Consumer Product Technology and Dr. Melvin Meyerson, Chief of the Center's Product Systems Analysis Division. Dr. Warshaw welcomed the Sizing Committee to the Bureau and briefly described the Center's mission and origins. He emphasized the importance that the Center places on the application of human factors data to soft- and hard-goods design and performance and the importance of a data base that would provide the human anthropometric

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and performance data needed in such areas as the sizing and performance of clothing and other consumer products: appliances, furniture, and energy-consuming products.

Earlier Efforts on an Anthropometric Survey

Mr. Joel Kramer, Human Factors Section, traced earlier interest in a National Anthropometric Survey by members of industry and cited the events leading to a brief feasibility study of a National Survey done by NBS in 1973. He explained that as a result of that meeting, industry representatives requested that NBS conduct a National Survey and that the Bureau had declined on the grounds that at that time it could not divert personnel and resources for such a survey but that the Bureau would be willing to provide technical advice if some other group, such as a trade association, could undertake such an effort. Mr. Kramer pointed out that there were several probable reasons why the Bureau did not act more positively in response to the industry request. These included the high cost estimated for the anthropometric survey in the feasibility study; the lack of qualified Bureau staff to actually conduct a national survey; and the brief period and limited funds of the feasibility study which did not give NBS the time to explore and develop a concept whereby a data base could be developed without total support in funds and manpower coming exclusively from the Bureau. He pointed out the need for careful and detailed planning jointly by NBS, other Federal agencies, and interested industry groups. A detailed user needs and priorities survey would provide the framework and much of the justification for proceeding with long-term developed of an ergonomics data base.

He estimated that if all went well and the recommendations of the Pilot Project were accepted by NBS management, further planning would continue in FY 1978 and collection of anthropometric data might take place as early as FY 1979.

Van Cott pointed out that the Bureau could not undertake the survey but might arrange to have it done. He also stressed the importance of obtaining funding and support from several other Federal sources, as well as from industry, in further planning and particularly in actual data collection. He concluded by commenting that of all of the areas in which data would be needed, body size data would be given a high priority and would be a good candidate for the area in which data collection would start.

The time table now projected by NBS for the development of a data base was discussed by Dr. Van Cott. He indicated that a year of further planning would be needed in FY 1978 to identify cost-effective methods for conducting a national anthropometric survey, to develop plans and schedules, to obtain NBS approval, and enlist aid from other Federal agencies and industry. Actual collection of data could not take place, in Van Cott's opinion, before FY 1979 and might be later if technical problems were encountered in using off-the-shelf equipment to collect body measurements. In the event that equipment must be developed, a contractor would require at least another year to conduct the necessary engineering development and feasibility tests of measuring devices. This might delay actual data collection until 1980 or later. Other problems, such as determining the sample characteristics and size needed to reflect such consumer variables as age, sex, occupation, might also arise. Despite these obstacles, Dr. Van Cott pointed out the need for careful, detailed planning and coordination if any data were ever to be collected.

Comments by Sizing Committee

Members of the Sizing Committee reiterated their impatience to get current body size data. They stressed the extent and scope in terms of the money and labor being expended by the clothing industry, the importance of proper fit to the consumer, and the enormous economic cost of garments that are returned each year due to poor fit. Further urgency is created by the impending need to convert to metric measurements which cannot be done with existing, obsolete and inaccurate data based on the 1939-1940 Department of Agriculture national anthropometric survey. This survey is no longer useful, forcing industry to rely, at great expense, on trial and error as the only basis for sizing clothing and establishing sizing tariffs. Dr. Van Cott invited industry representatives to document the problems and costs encountered in not having current sizing data.

Anthropometric Measuring Techniques; State of the Art Review

Dr. Louis Porter, Human Factors Section, reviewed existing techniques for taking body measurements and compared them in terms of speed, accuracy, and cost. These techniques range from classical anthropometry (tapes, calipers, etc.) to photography including biostereometric devices. In his opinion it is questionable as to whether biostereometrics, despite rumors to the contrary, could permit the collection of data on a nationwide basis for a reasonable cost. Dr. Porter then suggested that the automation of classical anthropometry, with all of its inherent limits, might still be the best solution; but that all alternative techniques must be carefully evaluated before data collection can begin.

Industry Comment

Members of the Sizing Committee expressed their concern that NBS might be striving for more accuracy than necessary in the collection of body size data. For garment sizes accuracies of from 1/4 to 1/2 an inch are probably adequate. NBS representatives pointed out, however, that accuracies greater than these may be needed for other applications, such as the design of anthropometric probes for evaluating product hazards; and that it would be necessary to determine the maximum accuracy needed if data for diverse applications were to be collected in any national survey.

Mr. Jay pointed out that raw anthropometric data were not what apparel manufacturers needed but rather data in the form of size groupings presented in the manner of existing NBS clothing size standards. Mr. Jay then made the following additional points: (1) volumetric data, as well as linear body measures, are needed in sizing shoes, bras, and other apparel items; (2) there is a need to consider updating sizing data by repeating a survey as often as every five years; and (3) size information must be presented as a function of age, demographic variables and in terms of the proportions of persons in each category having given dimensions. He repeated the urgency of the industry's need and pointed out that the major beneficiary of good sizing data is the consumer who has a right to proper fitting garments without trial and error in selection. Mr. Jay concluded by asking whether a "quick study" could be made to obtain the needed data, to be followed up by a more detailed, more precise survey later in time. He then presented a list of body dimensions (see Attachment 1) developed by the Sizing Committee which, in its opinion, covers the data needed not only for clothing but for many types of hard-goods as well. The list contains 142 dimensions. Of these, 30-40 dimensions as represented in existing NBS standards, are specially important. These do not, however, include volume data on such items as foundation garments, hats, and shoes. Nor do they completely cover data needed on the aged, disabled, or handicapped.

Further discussion by participants covered the need for an Advisory Board of industry representatives. Mr. Lowrey, of Sears, Roebuck, and Company, expressed Sears' interest in the long-term development of an ergonomics data base despite the fact that it may not be possible to meet metric conversion needs. He indicated that it was better to obtain good ergonomic data later rather than not at all considering the detailed planning needed for a program that was assured of success.

The meeting wad adjourned at 3:00 pm by Dr. Persensky.

ATTACHMENT 1

SIZING SUB COMMITTEE OF M.O.A.A.
Aubrey Jay, Chairman 11-5-73

Subject: Body Measurements to be taken in the Proposed Biostereometric Statistical Study of the Population of the U.S.A.

The undermentioned measurements were agreed to by the above committee in conjunction with representatives of the Fashion Pattern Industry (Simplicity and Butterick).

It is the thinking of those present at this meeting that these measurements will supply all of the information required to construct patterns, grade patterns, and give consumer sizing information for all types of apparel including intimate apparel, head and footwear, and gloves.

In addition this information will enable the accurate construction and sizing of the body forms used in the clothing industry, as well as shoe lasts.

1. Stature - total height.
2. Shoulder point height.
3. Suprasternale height.
4. Nipple height.
5. Waist height (This should be taken at narrowest part of adult body [male and female separately] and related to a vertebra number).
6. Wrist height.
7. Bottom of arm scye height.
8. Neck point height (where shoulder joins the neck at the highest point).
9. Gluteal furrow height.
10. Middle finger tip height.
11. Hip height (at widest point).
12. Hip bone height.

13. Elbow height.

14. Cervical height.

15. Top of knee height.

16. Mid knee height.

17. Bottom of knee height.

18. Crotch height (from apex of body crotch round).

19. Chest depth.

20. Waist depth (measured at #5).

21. Buttock depth.

22. Chest breadth.

23. Back breadth.

24. Waist breadth (measured at #5).

25. Hip breadth.

26. Hip breadth sitting.

27. Under arm length (from bottom of arm scye to wrist bone protrusion).

28. Upper arm circumference flexed.

29. Elbow circumference flexed.

30. Half cross back (spine to back scye).

31. Arm length to elbow (spine to elbow with arm bent and held at right angle to body).

32. Arm length to wrist (taken as #31).

33. Waist (measured #5) to chair seat (subject sitting)

34. Posterior neck length.

35. Back waist length (measured at #5).

36. Total crotch length (measured #5) from back to front of body.

37. Anterior neck length.

38. Front waist length.

39. Neck base circumference.

40. Mid neck circumference.

41. Scye circumference.

42. High hip circumference (at hip bone).

43. Hip breadth (at hip bone).

44. Hip depth (at hip bone).

45. Hip/seat circumference.

46. Calf circumference (state where).

47. Calf height (state where).

48. Ankle circumference (apex of ankle bone).

49. Ankle height (bottom of ankle bone).

50. Vertical trunk circumference (at point where neck joins shoulder).

51. Upper arm circumference (extended).

52. Elbow circumference (extended).

53. Lower arm circumference (extended).

54. Wrist circumference.

55. Shoulder length (from where neck joins shoulder to end of shoulder bone).

56. Over shoulder circumference.

57. Chest circumference.

58. Waist circumference (measured at #5).

59. Upper thigh circumference (as close to where leg joins body as possible).

60. Mid thigh (mid way between upper thigh and top of knee height).

61. Lower thigh.

62. Knee circumference (at bottom of knee height).

63. Upper thigh circumference sitting (as per #59).

64. Mid thigh circumference sitting.

65. Hand length.

66. Palm length.

67. Hand circumference around thumb.

68. Hand breadth at thumb.

69. Hand thickness (at knuckle).

70. Hand breadth (at knuckle).

71. Finger diameter - 1st finger (at knuckle)

72. Finger diameter - 2nd finger (at knuckle)

73. Finger diameter - Middle (at knuckle)

74. Finger diameter - Index (at knuckle)

75. Thumb diameter (at knuckle)

76. Finger length - 1st finger

77. Finger length - 2nd finger

78. Finger length - Middle

79. Finger length - Index

80. Thumb length

81. Hand circumference around knuckles.

82. Foot length (heel to big toe).

83. Instep length (heel to ball joint).

84. Foot circumference (at ball joint).

85. Foot breadth (at ball joint).

86. Heel width.

87. Foot length (heel to little toe).

88. Foot circumference at instep.

89. Ear to ear breadth.

90. Distance between eyes (point to point nearest the nose).

91. Distance between eyes (point to point nearest the temple).

92. Head breadth.

93. Maximum forehead diameter.

94. Cheek to cheek diameter.

95. Top of nose breadth.

96. Nose width at widest part.

97. Upper lip length.

98. Lip length.

99. Cheek bone to cheek bone diameter.

100. Total ear length.

101. Ear length.

102. Head length (front to back).

103. Bitragion - Submandibular arc.

104. Bitragion - Menton arc.

105. Bottom of nose to upper lip length.

106. Length from center of eye to bottom of nose.

107. Bitragion - Coronal arc.

108. Sagittal arc.

109. Head circumference.

110. Bitragion - Minimal frontal arc

111. Bitragion - Subnasal arc.

112. Ear protrusion.

113. Bitragion posterior arc.

114. Maximum head diagonal from menton.

115. Head diagonal: nuchae to pronasal.

116. Top of eye to bottom of chin length.

117. Rib cage - Under bust (where breasts joins body) circumference.

118. Over chest circumference (at start of breasts).

119. Nipple to Nipple width.

120. Full strap (from nipple to nipple around back of neck).

121. Neck point to nipple length (where neck joins shoulder a highest point to nipple).

122. Neck point to center front waist (neck point see #121).

123. Cervical to center front waist length.

124. Scye depth (found by deducting #7 from #2).

125. Neck point to front waist (neck point see #121 over nipple and straight down to waist).

126. Across shoulder arc width.

127. Across shoulder width.

128. Apex of stomach to apex of seat depth.

129. Armhole depth (front to back).

130. Shoulder slope in degrees.

131. Age.

132. Weight.

133. Plumb line position.

134. Waist to crotch volume.

135. Crotch to knee volume.

136. Knee to ankle volume.

137. Top to bottom of knee volume.

138. Top to bottom of ankle volume.

139. Waist to ankle volume.

140. Left breast volume.

141. Right breast volume.

142. Rib cage volume (see #117).

MINUTES OF THE MEETING OF NBS BEHAVIORAL SCIENTISTS ON THE ERGONOMICS DATA BASE

March 25, 1977

Attendance:

John Archea	Architectural Research
C. W. Devereux	Standards Development Services
Jacquie Elder	Sensory Environment
C. Fried	Human Factors Section
Dane Harwood	Auditory Acoustics
J. J. Kramer	Human Factors Section
Steve Margulis	Architectural Research
M.R. Meyerson	Product Systems Analysis Division
John Molino	Auditory Acoustics
C.O. Muehlhause	Institute for Applied Technology
J. J. Persensky	Human Factors Section
Val Pezoldt	Human Factors Section
Brian Pierman	Office of Housing & Building Technology
Lou Porter	Human Factors Section
Hal Steinberg	Performance & Safety Analysis Section
H.P. Van Cott	Human Factors Section

Summary

The purpose of this meeting was to describe the concept for and receive comments on a data base of critically evaluated, numeric, ergonomics data that could be used by government, industry, and the academic community in the planning, design and evaluation of human-centered systems, products, built structures, and work and living environments.

Dr. J. J. Persensky, Human Factors Section, Center for Consumer Product Technology (CCPT), opened the meeting. Participants introduced themselves and opening remarks were given by Dr. Melvin R. Meyerson, Chief of the Product Systems Analysis Division, CCPT. Dr. Meyerson welcomed the invited guests and pointed out the importance of human factors in the Bureau's consumer related activities. He emphasized the importance of having accurate, up-to-date information on human characteristics that could be applied to the design of products, systems and environments to make them safer, less energy intensive and more effective in performing the tasks for which they were intended.

Dr. Harold P. Van Cott, Chief of the Human Factors Section, presented a paper that described a concept for a data base of critically evaluated ergonomics information on selected aspects of human anthropometry and performance that are needed in product design and evaluation. Past efforts at collecting quantitative ergonomics (human factors) data were described and found to be deficient in several respects. The nature and intensity of the need for current, accurate data in a form that could be readily applied by industry, Federal and state government and the research community were illustrated. Although there is a great deal of data available on human characteristics, the data of greatest interest and potential applicability consist of those relatively simple, easily modeled and characterized structural and performance characteristics (e.g., from human vision, hearing, and physical anthropometry). Though some quantitative information is available on other higher order human processes and performance, such data are of questionable generalizability and their basis for characterization, modeling or measurement is in doubt.

Dr. Van Cott indicated that a model for an Ergonomics Data Collection System could take a form like that of the NBS National Standard Reference Data System (NSRDS). He described NSRDS, its mission, orientation and manner of organization and used it to identify requirements for a system of critically evaluated, numeric, ergonomics data. He pointed out that although such a data system did not now exist, the capabilities to form such a system could be assembled by drawing upon proper representation from presently available organizations in the Federal, state and private sectors.

Dr. Van Cott concluded his remarks by describing the current IAT-funded pilot project to determine the feasibility of an ergonomics data system. He pointed out that the first step in such a system was to assess user needs for specific classes of data. These needs could then be used to develop plans, schedules and cost estimates for the future.

Mr. Joel Kramer, Human Factors Section, described the milestones that are presently envisioned for the FY 77 pilot project and for continued planning and development of the data base. He indicated that from the evidence currently available the module of data for which there appears to be the greatest need is for anthropometric data. This would require a national anthropometric survey of the type considered briefly by the Bureau in 1973-1974.

Following these formal presentations, there was a general discussion of the concepts that had been described. There was considerable discussion on the current lack of standardization of methodology used in data collection and, in some areas of human behavior, of the lack of precisely characterized models. This would require in some instances rather detailed descriptions for existing data to be usable and ultimately a major thrust in the area of standards development for data collection and reporting.

The suggestion was made that existing standards organizations such as ASTM might be appropriate alternative vehicles to NSRDS for the development of an ergonomics data base. However, it was pointed out that although ASTM, ANSI, and ISO did develop standards they were product specific, sometimes conflicting with one another, and not usually generic in their applicability.

The potential applicability of an ergonomics data base to problem areas other than consumer products, such as forensic considerations was mentioned by Mr. Steinberg. Information on blood types and other human properties were pointed out as instances of need. Mr. Steinberg also pointed out that court case data might be a source of information for identifying other needs.

There was a general feeling among the meeting participants that several areas of NBS activity, for example in hearing thresholds and work on environmental effects, could both contribute to the development of a data base and drawn upon one if it were in existence. Dr. Molino suggested that it would make sense to start the system with anthropometric data and then add later, as additional modules, audiometric data from Edith Corliss' program and other auditory data from his area of research. The importance of dynamic data collection was also stressed.

Dr. Muehlhause inquired about the state of critical evaluation in the behavioral sciences that would be required to develop a data base. It was pointed out that the efforts in this area, although limited, were significant. Dr. Warren Teichner at the University of New Mexico in Las Cruces, for example, has spent many years in developing functional relationships by the critical evaluation of data in the published literature.

Dr. Margulis indicated his endorsement of the concept and stressed the need to develop standardized and stable operational measurement methods.

Dr. Van Cott indicated that a cooperative effort by NBS behavioral scientists would be important in establishing an ergonomics data system and invited the participants to consider how and in what ways they might plan to become involved.

The general consensus of the meeting was that a collection of critically evaluated ergonomics data would be worthwhile and that the concept described appeared to be a reasonable one.

APPENDIX B

Supporting Letters

THE OHIO STATE UNIVERSITY

March 31, 1977

Charles L. Mauro, Co-Chairman
Committee on Civilian Anthropometry
American Society of Mechanical Engineers
United Engineering Center
345 47th Street
New York, New York 10017

Dear Mr. Mauro:

This past week, I learned about the plans for the Bureau of Standards Human Factors Section for a data base of anthropometric measurements. As I understand it, this data base would be available for filling many needs of business, industry and academics. I briefly saw Dr. John Fechter who is with the Human Factors Section and he invited me to come to one of their hearings or someone else could come during this week of March 28 to discuss needs for data. I was not able to reach you in time to see if anyone from our committee could go to the bureau for the meeting. However, it seems very important for our committee to be aware of the planned study at the bureau. You may be well aware of it, but I was thinking that we should be sure that all the committee is aware of it and see what data would be useful for filling the very needs for which our committee was formed.

Dr. Fechter would be receptive to any information about our committee which you might provide him and I would be very interested in any further information concerning their plans.

Sincerely,

Francille M. Firebaugh
Associate Dean and Director

cc: John Fechter
Human Factors Section
National Bureau of Standards
Room A353 Meteorology Building
Washington, D.C. 20234

Floyd L. Laubach
120 Miami Drive
Yellow Springs, Ohio 45387

LAND
SEA
AIR
SPACE

Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

(412) 776-4841
Cable Address: SOCAUTOENG, PA.

June 28, 1977

Dr. H. VanCott
Chief of Human Factors Section
National Bureau of Standards
Washington, D. C. 20234

Dear Dr. VanCott:

During the course of the National Bureau of Standards conference on June 16, 1977, concerning Voluntary Product Standards, the matter of NBS developing information and data in the field of Ergonomics was discussed.

The Society of Automotive Engineers, Inc. (SAE), as you may know, deals with standards related to all kinds of vehicles which use an internal combustion engine. This includes automobiles, buses, trucks, airplanes, aircraft propulsion systems, farm tractors, marine vehicles, motorcycles, snowmobiles and others.

The SAE, recognizing the needs to standardize the field of Ergonomics (Human Factors Engineering) in 1967, created the Human Factors Engineering Committee. In 1968, the International Standardization Organization Technical Committee 22 on Road Vehicles also saw the need for standards in Ergonomics and created ISO/TC 22/SC 13, Ergonomics Applicable to Road Vehicles. SAE was requested to act as the international secretariat of this group.

In addition, SAE's Construction and Industrial Machinery Technical Committee (CIMTC) has created a Human Factors Engineering subcommittee to work on Ergonomics applicable to off-highway equipment. The ISO Central Secretariat in Geneva saw the need for a coordinating group and created ISO/TC 159, Ergonomics. The American National Standards Institute (ANSI) asked SAE to serve as the United States Technical Advisory Group. ISO/TC 159 has created five subcommittees. SAE has become the U.S. secretariat for two of these subcommittees; namely, Subcommittee 3, Anthropometry and Biomechanics, and Subcommittee 4, Signals and Controls.

For your information, I am providing to you, with this letter, the accomplishments of the SAE Human Factors Engineering Committee and its current progress on existing projects. Also enclosed are the two most recent reports of the ISO/TC 22/SC 13, Ergonomics Applicable to Road Vehicles, as well as the recent minutes of ISO/TC 159 and Subcommittees 3 and 4. The SAE does see the need

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ROBERT A. TAFT LABORATORIES
4676 COLUMBIA PARKWAY, CINCINNATI, OHIO 45226

June 1, 1977

Mr. Harold Van Cott
Chief, Human Factors Section
Building 220, Room 8353
National Bureau of Standards
Washington, D.C. 20234

Dear Mr. Van Cott:

Thank you for meeting with us on May 4 to explain your Human Factors program and to find out about our research programs.

As you know, NIOSH is concerned with ameliorating or eliminating interactions between a worker's environment and the worker which are harmful to the worker's health. Two ways in which this interaction is minimized are by engineering controls and protective equipment. It is essential to understand and be able to specify quantitatively the characteristics of the worker which are involved with the harmful interactions as well as the characteristics which are related to the measures which are being used to protect the worker. Considered in this general way, the amount of data on worker characteristics which is necessary to a really satisfactory development of protective equipment test methods and criteria is potentially very great. Ideally, for a data base of the type NBS is suggesting, we would like to anticipate for acquisition all possible types of data which we are likely to find useful in the future as well as the types which satisfy present needs. Otherwise, repeat studies of similar populations will become necessary as our research progresses. For efficiency it would be good to do the survey once and get everything we could possibly want. However, there does not seem to be a way of specifying everything we could possibly want. We do not really know what is needed until we get to the point of having to use it. Also, even if all possible useful data types could be collected at one time, many worker characteristics have a time dependence which would necessitate periodic resampling of the population.

One of the strongest points in favor of the suggested NBS data base is the overlap in data interests of various research organizations. If one survey of the worker population can be utilized by more than one such organization through appropriate coordination, resources can be conserved. Also, centralized collection and storage would reduce data search time.

for a coordinating group within the United States to have available all of the Ergonomics work on-going in the various disciplines in the United States.

Sincerely yours,

M. LeRoy Stoner

M. LeRoy Stoner, Manager
Technical Division

del

Enclosures

cc: L. P. Ziegler

Mr. Van Cott

A researcher could be sure that all of the best public data available had been obtained if he got it from the proposed NBS data base.

The following is a list of worker population data which would be of current use to our research programs:

1) Facial dimensions
2) General body dimensions
3) Psychological attitudes toward respirator use
4) Worker's physiological response to respirator use
5) Worker tolerance of physical and chemical agents.

It should be pointed out that average values of worker characteristics are a necessary but insufficient part of the data needed. Distributions of characteristics are also required. It is important that the data be categorized as to occupation, industry, sex, locale, age, race and occasionally other variables.

We look forward to a mutually beneficial participation in the development of your national ergonomics data base. If you desire information that we have collected, or if you need more details on our data needs, we would be happy to cooperate.

Sincerely,

For John M Bryant

Walter M. Haag
Director, Division of Physical
Sciences and Engineering

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ROBERT A. TAFT LABORATORIES
4676 COLUMBIA PARKWAY, CINCINNATI, OHIO 45226

June 27, 1977

Harold P. Van Cott
Chief, Human Factors Section
United States Department of Commerce
National Bureau of Standards
Washington, D.C. 20234

Dear Mr. Van Cott:

I apologize for the long delay in answering your letter of May 11, 1977. However, I hope that it is not too late for you to take into consideration our needs in the development of your planned ergonomic data base.

The question which we are most often faced with here at NIOSH is whether the exposure of workers to certain physical and/or chemical agents is harmful. It is easy to answer this question if an agent occurs at a high enough level to cause an obvious disease within a relatively short period of time. However, to assess the effect of a low level of exposure over a long period of time, e.g. many years or a whole lifetime, it is very difficult to prove a cause-effect relationship, particularly if the target organ is not known or differs individually. In such instances, a deterioration of performance capacity would be a meaningful measure of the harmful effect. At the present, such assessment could be made only in a longitudinal study. However, if a data base of human performance capacity would be available, such deterioration would be assessable within a relatively short period of time.

The following measures are considered important in assessing human performance capacity:

<u>Anthropometric measures</u>:

Mobility of body parts at the joints

<u>Physiological measures</u>:

Aerobic capacity
Anaerobic capacity
Maximal heart rate
Static muscular strength
Static endurance
Dynamic endurance
Vital capacity
Forced expiratory volume
Maximal breathing capacity

Psychological measures:

- Reaction time (simple and complex)
- Eye-hand coordination
- Vigilance
- Learning
- Short-term memory
- Long-term memory
- Problem solving

I would add here that data on performance capacity would not only enable NIOSH to assess harmful effects of environmental agents but also would assist industry in fitting the task to the capacities of the worker population, thus preventing harmful affects due to excessive stress and fatigue. This is particularly true in materials handling since recent NIOSH studies showed that low back and other injuries occur more frequently if the load is beyond a certain percentage of the workers' maximal static strength.

Another area where the ergonomic data base may be helpful is in tool design. Most important from this point of view are the dimensions, the strength, and the mobility of the hand and arm.

In the past, we have accumulated data on some of the performance measures listed above, and we can make them available to you if so desired. We are also ready to provide you with such data to be collected by us in the future.

Please let us know if we can be of any further assistance in working out details of the ergonomic data base.

Sincerely yours,

Francis N. Dukes-Dobos, M.D.
Chief, Physiology & Ergonomics

National
Headquarters

SEARS, ROEBUCK AND CO.
SEARS TOWER
CHICAGO, ILLINOIS 60684

August 24, 1977

Dr. Van Cott
Chief Human Factors Section
National Bureau of Standards
Washington DC, WA 20234

Dear Dr. Van Cott:

Sears feels that it is necessary to do basic research in the area of body measurements for the following reasons:

a. Except for a few limited medical studies, most of the anthropometric data in this country is very old.

b. A new study of body measurements is necessary so that new clothing standards can be created as we move to a metric system of measurement.

c. The current lack of up-to-date standards causes consumer irritation and expense due to poor fitting clothing.

We hope that a new body measurement study will be possible.

Very truly yours

SEARS, ROEBUCK AND CO.

W. M. Lowrey
Manager, Patterns/Size Fit
Department 817

WML/byo

Tu/6507

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL

May 25, 1977

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH — ALOSH
944 CHESTNUT RIDGE ROAD
MORGANTOWN, WEST VIRGINIA 26505

Mr. Harold Van Cott
Chief, Human Factors Section
Institute of Applied Technology
A-353 Metrology
National Bureau of Standards
Washington, D.C. 20234

Dear Mr. Van Cott:

Dr. John Fechter, of your staff, visited with us on May 13, 1977, to discuss our potential interests with regard to the development of a human characteristics data base by the National Bureau of Standards. Our discussions with John were, in my view, very informative and mutually beneficial.

Our program here in Morgantown is the nucleus of the new Occupational Safety initiative instituted by NIOSH early in FY-77. The program will be responsible for developing, initiating, and conducting the Institute's occupational safety research program including the testing and certification of personal protective equipment. This is a multi-disciplinary program which seeks to examine the occupational safety issue from the perspective of the man-machine-environment envelope. As such, our interest in and need of a broad range of human characteristics data is keen and essential. Two particular areas of immediate interest are antropometric measurements and human performance capabilities.

An example of an area of immediate interest is our current program to develop quantative respirator fit criteria for respiratory protective devices. This requires the development and use of a "general worker" facial measurements data base. Should a "standard" data base already exist, such as in the program you are considering, our problem would be greatly diminished as would the resources we must now commit to such a program.

As is no doubt evident from the above, we would strongly support the establishment of a human characteristics data base by the Bureau. In addition, I feel that we could meaningfully participate in and contribute to the data base as it developed.

- Mr. Harold Van Cott

The CPSC data base maintained by the Bureau is also of interest to us as many products used in the general population are also used in the occupational setting. It is my understanding from John that this data base is also maintained by the Institute of Applied Technology.

I look forward to continued dialogue in this area as your planning progresses. If we may be of further assistance, please feel free to call upon us.

Sincerely yours,

James H. Cavender for

John B. Moran
Special Assistant for Safety and
Testing and Certification
Appalachian Laboratory for Occupational
Safety and Health

Simplicity Pattern Co. Inc.

200 MADISON AVENUE, NEW YORK N 10016

August 2, 1977

Dr. H. Van Cott, Chief Human Factors Section
National Bureau of Standards
Washington, D.C. 20234

Dear Dr. Van Cott:

It has come to our attention that your department is considering an anthropometric study to provide data on the sizes of people in this country.

As a leader in the home sewing industry that provides apparel for a large segment of the population, we wish to urge you to conduct this study with all haste. It has long been needed and the need becomes more acute each year.

The apparel industry, as well as commercial pattern companies, continues to size garments on "educated" estimates... with no firm statistics. In order to establish standards that will serve the U.S. consumer with proper fitting clothes, the study under consideration is of the utmost importance and will be of great benefit to the entire population.

The impending conversion to metrics makes the need for such a study most urgent. It would provide the data that would tell us how to convert.

I urge you to push for the study, and if there is any way in which this company can help in getting it going, I would appreciate your letting me know.

Sincerely yours,

Lilyan H. Affinito
President

LHA/es

OFFICES: ATLANTA • DALLAS • LOS ANGELES • NEW YORK • NILES • OMAHA • PITTSBURGH • SAN FRANCISCO •
LONDON • SYDNEY • AUCKLAND • JOHANNESBURG • KÖLN-RH

LEONARD J. D'AMICO, *President*
RAYMOND L. MURRAY, *Executive Vice President*
HY FEINER, *Executive Director*
PHILIP J. MARGOLIN, *Treasurer*

INTERNATIONAL ASSOCIATION OF CLOTHING DESIGNERS

7 EAST LANCASTER AVENUE • ARDMORE, PA. 19003 • 215/896 7010-11

August 4, 1977

Dr. H. Van Cott
Chief Human Factors Section
National Bureau of Standards
Washington, D. C. 20234

Dear Dr. Van Cott:

We understand that there is the possibility for an economic study concerning the Anthropometric measurements to cover sizing of apparel for men and boys. This study will also cover various socio-economic groups in the U.S.A.

At present there are no reliable studies or data concerning the sizing of men's apparel; therefore, the proposed study has great merit. In fact, present data is almost meaningless and cannot be converted to metrics.

The proposed study would certainly be of great importance to the consumer, the retailer, and the manufacturers; as well as apparel designers. We do require new standards for sizing mens and boys apparel.

Kindly advise.

Sincerely,

Hy Feiner
Executive Director

HF:NZ

cc: Aubrey Jay, J.C. Penney Co.

MONTGOMERY WARD

April 25, 1977

Mr. H. P. Van Cott
Human Factors Section
Center of Consumer Product Technology
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

Dear Mr. Van Cott

Relative to the meeting of March 16, 1977 and the need for a new anthropological study.

The attached are areas of concern to our hard lines design department.

Please keep me informed of any new developments.

Yours truly,

Michael Feltser
Quality Assurance Manager

Attachment.

cc: R. A. Noreen
R. L. Swanson

QUALITY ASSURANCE 393 FASHION AVENUE/NEW YORK NEW YORK 10001

APR 18 1977

April 15, 1977

Mr. Michael Felster
Quality Assurance Manager
New York Office

RE: National Bureau of Standards Human Factors Study

The Corporate Product Design Department of Montgomery Ward agrees that there is a need for certain updated and appropriate information which could be provided to designers and would benefit the consumer in better looking, quality constructed, easy to use and safe products.

The following are some of the data we feel would be necessary to make the study meaningful. Both inch and metric dimensions should be listed.

1. Age and Sex Distributions, as well as Averages and Percentiles in increments of 1, 2, 3, 4, 5, 10, 15, 20, 30, 40, 50, 60, 70+ years.

    - Weight
    - Standing Height.
    - Erect Sitting Height.
    - Normal Sitting Height.
    - Knee Height.
    - Popliteal Height.
    - Elbow Rest Height.
    - Thigh Clearance Height.
    - Buttock-Knee Length.
    - Buttock-Popliteal Length.
    - Elbow to Elbow Breadth.
    - Shoulder to Shoulder Breadth.
    - Seat Breadth.
    - Head.
    - Neck.
    - Chest.
    - Waist.
    - Arm and Leg Lengths.
    - Hand Width and Length.
    - Feet.

2. Data is needed on people in motion as well as stationary. We need motion studies and specific product/user interfaces. People by age and size do things differently - e. g., sitting in a chair, watching T.V., sleeping, etc.. We need action/reaction times both in normal use of product situation to dangerous panic times.

3. Being in mass merchandising, both in retail and catalog, data is needed on the physically and mentally handicapped, child care, senior citizens, obese individuals, giants and midgets, left-handed versus right-handed people, etc..

4. What are the occupational categories man falls into? What are his leisure activities (sports, travel, hobbies, etc.)?

5. How does man react and interpret colors? What colors are most and least visible? Most contrasts - indoor, outdoor, incandescent, fluorescent lighting. What about symbols rather than words?

6. What shapes and forms are easier to handle - e. i., shapes of soap, bottles, handles, knobs, etc.?

7. What are ideal locations and type preference for product controls by product - e. i., high, low, out-of-sight, pushbuttons, switches, graphic identification, remote, etc.?

8. We should get man's opinion on standardization of actual sizes for materials and products. A "2 x 4" piece of lumber is actually 1-5/8" x 3-5/8", a "2 x 2" is actually 1-5/8" x 1-5/8". Pipe sizes too, should be actual. What about shoe sizes, say 10-1/2 D? How wide actually is A, B, C, D....EEE?

9. What is man's reaction to the new sophisticated electronic controls....digital, LED, touch sensitive, etc.?

10. What are man's dislikes? What are his fears of certain products? T.V. and Microwave radiation? Air Cleaner and Dryer ozone scares? Flammability. Unsafe construction?

11. Data of health and hygiene could be useful.

    - Showers versus Baths.
    - Eating Habits.
    - Smoking and Drinking.
    - Types of Toiletries.
    - Vitamins.
    - Eyesight. How many people are 20-20, nearsighted, farsighted?
    - Hearing. How many people use hearing aids. Sound at a minimum, maximum and overage levels in both open and enclosed spaces. What about sound imitation? What products are annoyingly loud?

12. What products should man change? What new products does man foresee and need?

13. What productshave failed to satisfy him?

14. Incidence of product-related accidents and their causes.

15. We should measure stress and how it affects the human senses and reactions.

There is some overlap here with the Penney's and Sears' write-ups and some of their ideas we haven't mentioned. However, we feel all areas cited are pertinent and should be considered part of the final format.

As we said at the start of this letter we agree the designers of America need information, but the time periods and the monetary outputs forecasted for the multi-phase study seem to us a little extreme. An effort should be made to gather, add to, edit and distribute the information that already exists.

The Armed Forces, certain universities, such as UCLA, USC or corporations like General Motors, and Industrial Design magazine should be contacted. These resources most likely have much of the human body statistics in a current usable form. An advertisement in the April 18, 1977 issue of Sports Illustrated magazine shows that Corporation Designers, Engineers, and Stylists worldwide use hnman factors in achieving their end results. The product is a BMW automobile manufactured in Germany. Some of the advertising copy reads as follows:

> "Part of the explanation of this phenomenon lies inside the car.... the interior of the BMW 630CS; while richly upholstered in supple leathers - is ergonomically engineered to the nth degree.
>
> All seats are orthopedically molded; all individual seats are infinitely adjustable. Controls are within easy reach and all instruments are instantly visible in an innovative three-zone control panel that curves out toward the driver in the manner of an airplane cockpit.
>
> So thorough is the integration of human and machine that the driver literally functions as one of the car's working parts - the human part that completes the mechanical circuit."

Once an appropriate questionnaire is established it could be incorporated with the Federal Income Tax Return for distribution and retrieval. When compiling the data be sure it is presented in human figure diagrams, bell curves, bar charts and other illustrative means for quick reference.

A suggestion for data gathering on product usages might be to select a group of average families, average singles, etc., and have them record their reactions and opinions to certain products they own, or are furnished, in their normal everyday life environment. Expose them to products and activities under their own conditions. Have them record times used, convenience, most used features, ease of operation, cleanability, etc..

We have one other thought to pass on for input. It has been said that the American is growing at 0.3 inch a decade. Products have various lifetimes before they wear out, breakdown or become obsolete. For most products to last 20 years is more than to be expected and the future users, if the products are handed down or sold, will grow only 0.6 inch in this period of time. Maybe we are over emphasizing the change in man as an ever growing body and should consider what is happening in America. There's the emphasis of compact living quarters, compact automobiles, compact appliances, food shortages, higher cost of living, microminiaturization, smaller families, energy, water and time conservation, and thus possibly smaller human beings.

If all this data gathering becomes a reality we will certainly reap the harvest with product improvements and future developments.

I hope the above thoughts will be supporting input for your presentation of the need for human factors in the B, C, and D Lines of Montgomery Ward merchandise.

Robert A. Noreen, Manager
Corporate Product Design Department, R & D 6-5

cc: Mr. R. L. Swanson, Mdse. Development

MONTGOMERY WARD

March 23, 1977

Human Factors Section
Center of Consumer Product Technology
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

Attention: Mr. Harold P. Van Cott

Dear Sir,

Relative to the need for new anthropological data, the following are some of the reasons why it is imperative to commence such a study as soon as possible:

- Current data is almost 40 years old. The relevance of this data to current body configuration is doubtful, particularly when changes in dietary habits and the infusion of various ethnic types into the population since the data was taken is considered.

- No data is available for adult males, protective headgear, shoes, hand covering or hosiery.

- New accurate data would provide hard and soft goods to be designed with optimum safety consideration for the consumer.

- Sizes or size ranges could be enlarged or lessened providing greater consumer satisfaction.

- The remaining size ranges would accurately reflect proper sizing, providing for less returns by the consumer, which can relate to lower prices. This in addition to less frustration or confusion at the point of purchase.

- Metrication - with the impending conversion to this system new data is a requirement. Conversion of the old data cannot be accomplished in a practical form useable by industry unless we are willing to settle for a standard invented by necessity which would gerrymander available data.

In synopsis the final beneficiary would be the consumer in the areas of reducing the plethora of size confusion, and those sizes remaining would be more accurately built to better service the consumer.

Yours truly,

Michael Feltser
Quality Assurance Manager

cc: A. Jay
L. J. Nolan
R. Swanson

QUALITY ASSURANCE 393 FASHION AVENUE/NEW YORK NEW YORK 10001

JCPenney

June 2, 1977

Mr. H. P. Van Cott
Chief, Human Factors Section
National Bureau of Standards
U. S. Department of Commerce
Washington, D. C. 20034

Dear Sir:

Please accept my apologies for the delay in writing to you regarding our March 16 meeting in Gaithersburg.

I cannot express strongly enough the dire need for a new ergonomic study of the population of the United States. The body size standards currently issued by your offices are an immeasurable value to the garment industry; however, their value is undermined by the fact that the data used, on which to base these various standards, is 30 years old and not totally intergrated and therefore does not provide a factual or logical procession from childhood through adolescent into adulthood.

Consumer awareness and consumer demand for correct fitting of clothing, as well I might add for every other item used by humans, is strongly felt by all segment of the manufacturing industry. Our responses to these demands are limited by lack of current factual ergonomic data on which to base our products.

The Sizing Subcommittee of the Mail Order Association of America of which I am chairman has for many years stressed the need for a new ergonomic study, and I know that I can speak for them in addition to myself, in urging your department to immediately take action to provide us with the standards we need to satisfy the consumers.

While endorsing the need and urging action for this ergonomic study, I would also urge that the method used in this study should be one where the information captured would be permanently on record and in such form as to be able to supplement the original information asked for. I stress this because with this study, I am sure, we will find applications for the use of the data not yet conceived in our minds. Therefore, it seems to me that stereographics-bio-stereometrics is the route to go.

J. C. Penney Company, Inc., 1301 Avenue of the Americas, New York, New York 10019

In closing, I would offer my own personal efforts and commitment in any way that you think would be meaningful and helpful to this proposed study.

I am, yours respectfully,

JCPENNEY COMPANY, INC.

Aubrey Jay

AJ/nc

cc: Mr. B. Hahn - M.O.A.A.

THE WORLD'S MO... FAM... ...

Jantzen

June 23, 1977

Mr. H. P. Van Cott
Chief of Human Section
National Bureau of Standards
U. S. Department of Commerce
Washington D. C. 20034

Dear Mr. Van Cott:

Jantzen recently as a company spent a considerable amount of time effort and money in attempting to determine what garment sizes should be used for nominal sizes in Misses and Junior sportswear.

Up until recently we have adhered to the National Bureau of Standards' body measurements as outlined in PS 42-70 to determine the critical measurements of women for various nominal sizes. We initiated a review of what other manufactures were doing and what the retailer expected from the manufacturer and found that there is a wide range of garment sizing with identical nominal size labels. I would suggest that to say that there is confusion in sizing in the market would be an understatement.

In a discussion with Mr. Aubrey Jay from J. C. Penney Co. he mentioned that there was a current proposal for additional study of body sizes. In my opinion, accurate, up-date information on body sizes which would result from such a study would be most valuable in terms of consumer satisfaction and elimination of confusion. If I can communicate this opinion more to any one who would be of help in advocating this study, please let me know.

Sincerely,

E, N, Waage
Director of Quality Control

pb

National Home Sewing Association
350 Fifth Avenue, New York, N.Y. 10001
Telephone: (212) 736-8820

September 12, 1977

Harold P. Van Cott
Product System Analysis Division
Building 220, Room A353
Washington, D. C. 20234

Dear Dr. Van Cott:

The Pattern Fashion Industry has brought to our attention your proposal for a national study to develop a new anthropometric data base. We would like to add our support and the support of our Members to your effort to accomplish this much-needed task.

From reading your paper, "Toward the Collection of Critically Evaluated Ergonomics Data", we know you are aware of the historical sizing difficulties of the apparel industry in general. Our move toward metrication offers a unique opportunity for the industry to reevaluate and standardize sizing -- and consequently reduce SKU's, inventory investment and inefficient stocking. But that standardization can only be effective if we have current and accurate body sizing data with which to work.

We in the home sewing industry have an additional reason for wanting anthropometric data developed. A recent study conducted for our Association shows that one of the greatest potential barriers to a successful sewing experience by a consumer is fitting the garment. We could be so much more effective in helping the consumer overcome that problem if we had accurate data on which to base product instructions and educational materials and services.

Please keep us posted on the progress of your project, and call on us if we can be of further service. We will check periodically with you and/or Joel Kramer to see what other support we can give, either documentation or communication urging federal funding.

Sincerely,

Leonard Ennis
Executive Vice President

LE:pk

cc: Joel Kramer
Alma Cunningham

November 7, 1977

REC'D NOV 10

Mr. C. W. Devereux
Standards Development Service Section
National Bureau of Standards
Washington, D. C. 20234

Dear Mr. Devereux:

The American Apparel Manufacturers Association is in full support of the proposal of the National Bureau of Standards, to develop a new anthropometric data base for standard body measurement in this country.

The AAMA Board of Directors, at its September 26, 1977 meeting, voted the following resolution:

"That in order for the apparel industry to design proper-fitting garments, and in order for the National Bureau of Standards to issue proper specifications, body measurements of our American population are needed.

"That because of the complexities of developing an anthropometric data base on which to develop appropriate standards for apparel, the project should be undertaken by the National Bureau of Standards.

"Development of a National Anthropometric Data Base by the National Bureau of Standards has the support of the major retailers.

"Be it therefore resolved that the American Apparel Manufacturers Association endorses the need for development of this data base and urges prompt action to achieve the necessary finding so the National Bureau of Standards can proceed with the project as proposed."

We will be anxious to receive news of the implementation of this program, and pledge the full support of this Association.

Cordially yours,

Ellis E. Meredith
President & Chief
Operating Officer

EEM:jsh
cc: Robert Ullman

1611 NO. KENT STREET • ARLINGTON, VIRGINIA 22209 • PHONE (703) 524-1864

National Home Sewing Association
350 Fifth Avenue, New York, N.Y. 10001
Telephone: (212) 736-8820

November 14, 1977

Harold P. Van Cott
Product System Analysis Div.
Building 220, Room A353
Washington, D.C. 20234

Dear Dr. Van Cott:

Mr. Ennis has asked me to reply to your letter of September 20. As mentioned in his first letter, our Association research shows that while many women sew for reasons associated with a better fitting garment, we also find that this is one of the most difficult aspects of the sewing experience for a consumer to complete successfully.

Good anthropometric data would, first and foremost for all clothing, provide the basis for more accurate standard garment sizes representative of the population at large. Of this you are already aware.

Secondly, specifically in relation to sewing, a consumer here has the option of making adjustment for deviations from standard body measurements. Sewing thus provides many with a better alternative than ready-to-wear for appropriately-fit clothing -- in fact for thousands of consumers perhaps the only way to achieve that end.

For us to be successful in fulfilling the need for such an alternative, not only norm data, but also frequent deviations-from-the-norm statistics would be helpful. If, for example, a standard female figure is 36-26-36, and we could predict that an additional 20% were 36-26-38, we could provide instructions for large hip adjustment on all patterns, thus satisfying the needs of a substantially larger number of consumers with the same standard product. Additionally, frequent deviations from the norm could provide the basis for much more simplified fitting textbooks and educational materials. At present, many such materials discuss every possible alternative. How much simpler and less foreboding they would be if they could treat the "20 most frequently needed fitting adjustments".

I hope the above is of some help in your program. If we can be of further service, please call.

Betty Ann Watts
Communications Director

BAW:pk

HILIP STEVENS
SSOCIATES LTD
EATELES N Y 13152 TEL (315) 685 5733

November 21, 1977

Dr. Harold P. Van Cott
Chief
Human Factors Section
United States Department of Commerce
National Bureau of Standards
Washington, D. C. 20234

Dear Dr. Van Cott:

It has been called to my attention in the October issue of APPLIANCE ENGINEER that you are interested in soliciting the comments of people who would be interested in having a Human Factors Data System within the National Bureau of Standards.

As a member of the Industrial Designers Society of America as well as chairman of the Government Affairs Committee and a past chairman of the Product Safety Committee, I think the idea is very commendable. There is a need for appliance designers as well as many product designers to call or write a Federal Clearinghouse which would be able to provide design human factors data within a very short amount of time. Normally it is impossible for us to spend a great deal of research time to find the critical human factors data because our budgets are limited and product development schedules are critical. We normally have to rely on material in our office.

Help from the Bureau of Standards in this particular area would be greatly appreciated. I am sure from my own experience as a consultant industrial designer I would support you in such an effort.

Yours truly,

Philip H. Stevens, F.I.D.S.A.

PHS/sa

APPENDIX C

Remarks made by Dr. Julien M. Christensen and Dr. Richard W. Pew at a meeting of government agencies convened at NBS on March 29, 1977, to discuss the concept of a National Ergonomics Data Base.
Drs. Christensen and Pew were retained as consultants to NBS Pilot Project Staff.

Reflections on the Development of an Ergonomics Data Base

Introduction

Just as innumerable tangible benefits have been realized from the establishment of data bases in the physical sciences, so will impressive benefits be derived from corresponding efforts in Ergonomics. In these remarks, I will examine the nature of the need for a data base in Ergonomics and some of the benefits that will be derived from this program. A few of the special problems attendant thereto will also be mentioned.

Before beginning this examination, however, we feel that a word of approbation to the National Bureau of Standards is in order for its explicit acknowledgement of the need in our technological society for an Ergonomics data base and for expression of its willingness to explore such a program with its resources and with its considerable prestige which is based on its past demonstrations of scientific thoroughness and excellence.

The Need

Statistics on accidents, mental health problems, environmental effects and societal effects dramatically support the contention that incompatibilities of significant dimension exist in our highly technical civilization. That incompatibilities exist should surprise no one since societies are a reflection of interactions among people and between people and things whose degree of complexity only recently has been appreciated and, even when appreciated, are acknowledged as being far from adequately understood.

The science of Ergonomics, or human factors, is evidence that a few people have recognized that our understanding of these interactions is rendered uncommonly difficult because of the lack of information from the biological and behavioral sciences that can be used appositively with information from the physical sciences in the development of the artifactual systems that characterize modern society. Most engineers, including those in the universities who are training their successors, have been painfully slow to acknowledge that since they, perhaps more than the members of any other profession, are responsible for the structure of technical societies, it follows inevitably that, to no small degree, they then are determiners of human behavior. We have often suggested that, while psychologists, sociologists and others study human behavior, in technical societies it is the engineers who, through their design of empirical systems, to a very significant extent, determine behavior. If one needs to be convinced of this, we suggest that he simply try to live even a single day without touching, seeing, or in any way interacting with products designed by man.

It is not paradoxical that one group of engineers, namely, those engaged in the development of military systems, accepted somewhat earlier than other groups of design engineers their responsibility to take into account man's capabilities and limitations when designing and developing the systems for which they had accepted responsibility. This was so because generally the designers of military systems have to extract the last bit of performance from each of the system components, whether those components be organic or inorganic, and, insofar as possible, to make provision for the manifestation of that performance under the most adverse of circumstances. Such a design milieu demands that every bit of available information on every component, human or material, be considered because the designer can be sure that potential adversaries are doing the same.

It is fair to conclude from all of this, at least as far as the United States of America is concerned, that there would be no science of Ergonomics as it is now known had military support for it not existed during the past 30 years. The fact that insufficient data existed, or exists even today, has only served to sensitize them to the need for their continued support and to increase their determination and that of other agencies such as NASA, to support the exploration for that which is lacking. NASA like the Department of Defense, is called upon frequently to place man, and to expect him to perform, in environments different in the extreme from that for which natural selection prepared him. This derivation will be carried only one step further by pointing out that the Department of Transportation has significant programs in Ergonomics, brought about, no doubt, by the realization that the operation of commercial and private vehicles of all types places demands on man that accident statistics strongly suggest have exceeded his capabilities.

Unfortunately, the lessons that should have been learned from experiences in these dramatic and even exotic circumstances have been transferred in significant measure to only a few of the remaining sectors of our society. Thus, the USA still suffers over 14,000 fatalities per year in its industries and, even more appalling, approximately twice that number, or 28,000 fatalities per year, in its homes. Nonfatal injuries are numbered in the millions; economic costs are counted in the billions of dollars.

What is the solution? As with any problem, the first step in the solution is to recognize that a problem exists. The second is for the members of our society to demand safer, better designed products. The third is for management to respond and demand that its engineering staffs assume responsibility for safe, effective design that is at least equal to the safe use or safe practices philosophy that, as the well-known product liability attorney, Harry Philo, observes, has dominated American thinking throughout our history. In fact, product liability suits are forcefully bringing to the attention of the designers and developers of empirical systems their special responsibility to those who must operate, maintain, live with or in, or otherwise interact with their products. In a sense, the courts are establishing Ergonomic standards.

The ultimate solution to the problems just described presumes the existence of principles and data of quantity and quality that do not currently exist. The establishment of the NBS Ergonomics Data Base will do much to consolidate what is currently known and, equally important, demonstrate what is not known.

This observation leads us, quite naturally, to an examination of some of the special problems associated with gathering the data needed for the Ergonomics Data Bank.

Special Problems

The data of the social sciences and the gathering of such data presents problems that are not found, at least to the same degree, in the physical sciences. One of the chief problems is varability--variability not only between people and within people at a point in time but variability over time. Provision must be made for keeping the NBS Ergonomics Data Base current since, unlike certain basic data in the physical sciences, basic data in Ergonomics varies over time.

Adequate sampling is another critical problem in Ergonomics. Much of the current USA data is based on experiments conducted on military or other special populations. Only limited information is available regarding the generality of these data with respect to the entire U.S. population and even less is known with regard to their generality to foreign populations.

Much of the current data is difficult for engineers to use directly in the solution of design problems. For example, functional relationships often are lacking. Data are often expressed in scalar values that are not of the ratio type (thus making trade-offs difficult) and often not scaled at all. Constants, as known in the physical sciences, are scarce. Criteria are frequently inadequate, particularly with respect to sensitivity to Ergonomic variables. It is hoped that the Ergonomics Data Base will focus attention on the needs that exist for additional research in areas such as these.

The theoretical understructure for Ergonomics is generally that of traditional experimental psychology, experimental physiology and others of the organic sciences. These theories, though often excellent in concept and formulation, do not usually reflect the possible impact of high technology on the definition of their variables or the interaction of their variables with changing technological conditions.

Ergonomics researchers have yet adequately to address questions of enormous importance such as sexual differences, motivational effects, cognitive functions, and many others.

While the material in this section may discourage some, it was not so intended. Rather it is hoped that it will be accepted as one of the great challenges of the scientific age. As Alexander Pope said, "The proper study of mankind is man." The time is now ripe for scientists and engineers to join forces, bringing to bear on these problems the common and unique combination of their scientific/engineering training and heritage. It could result in the development of what Bray many years ago called the need for a useful "technology of behavior."

Let us now examine some of the many benefits that will be derived from this technology with its attendant data base.

The Benefits

As has already been suggested, making available to designers in general what is already known in Ergonomics would be useful to the designers of many additional commercial and industrial products. This is so because the lag that exists between discovery and application exists in Ergonomics as surely as it exists in other scientifics areas. Present knowledge, if applied, would make possible the design of much safer, more effective commercial products, industrial tools, etc. even if another human factors experiment were never to be conducted. One reason that product liability suits are frequently so successful is that the designers did not even use the data that had been available for years at the time they formulated their specifications.

Before we place the entire blame for this state of affairs on the designers, however, we should consider the fact that those who educated them probably never insisted that they include any training in Ergonomics in their courses of study.

The Ergonomics Data Base will make established data more readily available to all potential users. Equally important, the consolidation and presentation of what is known will make glaringly evident that which is not known. The NBS Ergonomics Data Base should provide a rich source of experimental hypotheses for investigators in Ergonomics.

It is hoped also that a further recognition by engineering management of its responsibilities to society will cause them to demand educational experience in Ergonomics for their engineers. This should finally convince engineering educators that they must broaden their curricula to include training in Ergonomics. It is difficult to understand why the educators have not been the leaders instead of the followers in this regard.

The previously mentioned recognition of deficiencies in the Ergonomics data bank hopefully will foster a new and potentially, very fruitful relationship between investigators from the biological and behavioral sciences on the one hand and physical and engineering science investigators on the other hand. This interaction will add to the development of a more adequate data base, with improvement in systems and products--improvements especially in terms of such criteria as safety, economy and social suitability, perhaps reducing the terrible annual toll of over 100,000 lives and over 30 billion dollars of our resources in the U.S. from all accidents.

Another benefit may be (although this is by no means certain since there is evidence that is has not happened in the physical sciences) the reduction of the time lag between scientific discovery and engineering application. J.C.R. Licklider of MIT has commented frequently on the need to find ways to make scientific discovery flow quickly, naturally, and easily into technological application. Hopefully, the Ergonomics Data Base may help achieve this goal.

The previously mentioned interaction between Ergonomic scientists and engineers will result in better definition of experimental variables as well as criteria which will increase the utility of both underlying theory and specific experimental results. Functional relationships, with abscissae capable of engineering manipulation and, thus, useful in the ever-present trade-off situations of engineering design, will replace expressions of simple point differences. Investigators in the writer's primary field, experimental psychology, will find that optimal definition of variables from the point of view of theoretical development may not be coincident with that required for purposes of engineering design. In fact, the development over the past 20 years of the field of inquiry that has come to be known as "applied experimental psychology" is tacit recognition of this fact.

Finally, as mentioned previously, this enlarged awareness of the responsibilities of engineers and their supporting scientists in this technological era will add new dimensions to the measurement of systems effectiveness. Concepts such as product safety, job enrichment, and social utility will assume increased importance. Hopefully, the result will provide convincing rebuttal to those who see as the only solution a rejection of all technology and a return to a primitive existence. We need not less technology; we need better technology. The establishment of the Ergonomics Data Base represents a significant step toward the achievement of that worthwhile goal. It merits the full support of all who are interested in the development of a society that, for better or for worse, is irrevocably committed to the technological approach for solution of its problems and the enrichment of the lives of its members.

Julien M. Christensen, Ph.D
Professor and Chairman
Department of Industrial Engineering
and Operations Research
Wayne State University
Detroit, Michigan

Comments on the Development of a Critically-Evaluated Ergonomics Data Base

Introduction

The concept of a centralized repository for carefully screened ergonomics data is an appealing one and it makes emminent sense for NBS to be the focus of this kind of activity, both because of the role such a data collection could play in NBS' product safety and performance activities and because of the historical role of NBS as the national point of contact for scientific and technical standards. Given the state of the art in ergonomics, however, development of a repository of useful data will require careful planning and preparation, so that it does not become just another exercise in data collection that looks good on paper but is really applicable to few individual uses. In order to set this effort apart from a simple collection of technical reports and journal articles, it will be necessary to address three issues: 1) identification of data needs and availability; 2) collection and representation of the data in a form that is useful for designers and practitioners, rather than (or perhaps as well as) scientific investigators; and 3) imposition of quality control screening on the data that are to be admitted to the data base. Let us examine each of these issues in turn.

Identification of Data Needs and Availability

An important step in the planning phase of this undertaking is the identification of the target population of users for whom the data are to be responsive and, within each such population, to identify the kinds of data that would be useful. One purpose of this meeting was to sensitize various government agencies to this project so that they could begin to express their own needs. Further such meetings are being undertaken to identify potential users among particular product groups, such as clothing designers or appliance manufacturers. Here it also should be possible to contact trade associations and manufacturers associations to get in touch with the right populations of users.

With respect to product safety and performance, the NEISS data base may be a useful source of needs through retrospective analyses and it might also be helpful to examine a sample of product liability law cases in which the pivotal issue was one involving ergonomic considerations.

While no single legal case can establish a national need, we should be looking for collections of cases which have needs in common.

A second consideration in defining classes of data for inclusion should be the maturity of the methods used to collect the data. Data are only as good as the methods used to collect them, and for some purposes the statement of scientifically sound and acceptable methods are as important as the data themselves. While it seems likely that data on the workload demands of certain classes of tasks may be desirable, methodology in this field has not progressed to the point where one could place high confidence in data purporting to estimate such workload demand. On the other hand, methods of physical anthropometric measurement are well established and a great contribution could be made by systematizing and augmenting the data in this field in ways that are oriented toward direct application. Similarly, basic visual and auditory functions are well defined and should be relatively easy to incorporate into a data base in useable form.

The main point here is that converging operations focused on data needs on the one hand and reliable data availability on the other should be undertaken to define the candidate classes of data to be included. These efforts should be undertaken with modest goals at first, to meet a few well-defined needs, and then gradually expanded as experience accumulates over time.

Preparing Data in a Useable Form

A fact of life in the development of scientific data concerning human performance capacities and limitations is that most often the individuals collecting the data are concerned with basic science issues and do not have in mind potential applications at the time the data are collected. As a result the relevant data are fragmented and buried in journals and reports not readily accessible to the applied community. Often they are expressed in ways useful for testing hypotheses but not for describing functional relations between variables under the designers control and the resultant performance effects.

In some cases, comprehensive literature reviews exist which can form the basis for the reorganization and summarization of design oriented data. In other cases it will be necessary to commission specific parametric studies which sample a suitable population and explore the range of parameters of interest to the user population. Since so little of the performance literature has dealt seriously with individual differences, it will frequently be necessary to collect enough data so that it can be expressed in terms of percentile distributions as a function of the relevant parameters. It is my feeling that one of the most significant contributions that NBS could make would be the commissioning of studies of this kind which take what is known and prepare a parametric data set that expresses it in quantitative terms that would permit real design decisions to be based on it. This is an aspect of our science that has been almost totally neglected.

In the course of analyzing needs for data, it may also be possible to identify new ways in which the data need to be organized in order to make them applicable to the problem identified. A case in point is the development of the Eye Ellipse by the Society of Automotive Engineers. Automotive interior designers are not as interested in the physical location of the eye when an observer is seated in an automative seat as they are in what the observer can see from that position. The Eye Ellipse expresses in percentile terms the three-dimensional locus of lines of sight available to an observer. NBS' role in cases like this might not be one of directly funding such developments but rather stimulating the relevant industry association to undertake the project for later inclusion in the data base.

Quality Control

Regardless of the subject matter that ultimately is to be included in the data base, paramount concern should be given to ensuring that the data are reliable, repeatable and representative of the most advanced methods of data collection and analysis available in the field. To achieve this purpose, I would recommend the establishment of a panel of outside specialists; perhaps they could be formalized as a review board, representative of the ergonomics fields to be considered for inclusion. This board should have the opportunity to review plans for new data collection and be the final decision body to determine what data are to be made available to the community at large.

Summary

The idea of a critically-evaluated ergonomics data base is an important one. It has the potential to be useful so long as the project includes a component oriented to identifying real data needs, a component concerned with expressing the data in terms meaningful to the population of potential users of the data and, finally a component that will ensure that only data of highest quality and reflecting the state of the art in the field will be made available to the user communities.

Richard W. Pew
Bolt Beranek & Newman
Cambridge, Massachusetts

NBS-114A (REV. 7-73)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.*)

This report culminates a feasibility study effort aimed at assessing the needs of industry, government and the research community for standard ergonomics (human factors) data, proposing a system concept and preliminary plan for the development and operation of a standard ergonomics reference data system (SERDS) and assessing the scientific and technical challenges to be met in system implementation. The data base proposed here would provide, for the first time, a single point of access to reliable, current anthropometric, behavioral and physiological data for application to technology design. Critically evaluated numeric data, standardization and the conduct of a National Ergonomics Survey are the major focal points of the system concept.

17. KEY WORDS (*six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons*)

Anthropometry; consumer product technology; engineering psychology; ergonomics; human engineering; human factors; human performance; product safety; standard reference data

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