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Cost Benefit Analysis

Cost Benefit Analysis for Human Effectiveness Research: Air Combat Capability Enhancement Suite

A Report for:
Air Force Research Laboratory
Human Effectiveness Directorate
Crew System Interface Division
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13. ABSTRACT ***(Maximum 200 Words)***

Human Systems IAC was asked to assess the costs and benefits associated with improving access to anthropometric information for Air Force decision-makers. To ensure that comments from individuals with a direct stake in this area of study were included, input was obtained from subject matter experts with both military and civilian backgrounds. A standard eight-step process was used to identify and evaluate the costs and benefits associated with the anthropometric information system in use and two alternative systems. This study evaluates the costs and benefits associated with these three anthropometric information alternatives. Each alternative was estimated for cost and evaluated for relative benefits. By assigning a numerical value to the benefits, Human Systems IAC was able to develop a cost/benefit ratio (CBR) for each of the three alternatives. The lower the CBR, the more desirable the alternative.
Human Systems IAC found that the most effective alternative with respect to the stated goals was alternative #3, Searchable Database with Expert Interface, (CBR = 212.5). The second most desirable solution was alternative #2, the Searchable Database (CBR = 260.5). Based on the evaluated cost and benefits the least cost effective solution for providing anthropometric information was alternative #1, the status quo (CBR = 712.1).

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NOTICE

This report is one of several cost benefit analysis efforts in the area of human effectiveness research sponsored by AFRL/HE. Other topics include Bioacoustic Protection, Distributed Mission Training (DMT), and a state-of-the-art report (SOAR) that outlines the general methodology to conduct effective cost benefit analyses on human centered technologies.

ACRONYMS

3-D	Three-dimensional
ACC	Air Combat Command
ACCES	Air Combat Capability Enhancement Suite
AFSC	Air Force Specialty Code
ASC	Aeronautical Systems Center
CBA	Cost Benefit Analysis
CBR	Cost Benefit Ratio
DoD	Department of Defense
DTIC	Defense Technical Information Center
HSIAC	Human Systems Information Analysis Center
IAC	Information Analysis Center
NTIS	National Technical Information Service
SME	Subject Matter Expert
SPO	System Program Office

EXECUTIVE SUMMARY

A. Overview

At the request of the Air Force Research Laboratory, Human Systems IAC assessed the costs and relative benefits of three select alternatives for improving accessibility of anthropometric data for military and civilian use. The three alternatives compared in our analysis were:

- Status Quo,
- Searchable Database, and
- Searchable Database with Expert Interface

The primary goal of the alternatives assessed was to develop an anthropometric size, shape, fit and accommodation information system for efficient and effective use by designers, manufacturers, buyers, and decision makers across a number of domains.

B. Study Methodology

1. Costs

Costs for the alternatives analyzed in this CBA were estimated using a variety of methodologies. Methodologies used include actual costs, expert opinions and estimating models. A summary of each alternative's groundrules and assumptions can be found in Section 2.4. Cost estimating methodology matrices and detailed worksheets for each are included in Appendix A. Table 1 summarizes the total cost, in both constant (FY02) dollars and then year (inflated) dollars, by program phase for each of the alternatives.

Table 1. Summary of Alternative Costs

Constant FY02 $000	**Alternative #1**	**Alternative #2**	**Alternative #3**
System Acquisition	$0	$2,136.4	$6,072.0
System Implementation	$66.23	$602.2	$354.0
Operation and Support	$4,918.50	$4,971.0	$7,024.7
Total	$4,984.73	$7,736.6	$13,450.7
Then Year $000	**Alternative #1**	**Alternative #2**	**Alternative #3**
System Acquisition	$0	$2,294.0	$6,334.4
System Implementation	$70.33	$629.8	$371.4
Operation and Support	$5,222.59	$5,268.5	$7,497.5
Total	$5,292.92	$8,147.3	$14,203.3

2. Benefits

Benefits were assessed in several ways as well. Many benefits were clear from information gathered in the literature search. Additional benefits were identified through an exhaustive coordination with subject matter experts and users who possess real world experience with the anthropometric information challenges being analyzed. Table 2 summarizes the agreed-upon benefits.

Table 2. Benefits Definitions

Benefit Name	Benefit Definition
Accessibility	System impact on ease of accessing anthropometric information; the number and type of individuals that can locate the info.
Accuracy	System impact on currency, correctness, and direct use of fit/accommodation information. Information provided is the correct solution for the task at hand.
Efficiency	System impact on speed of finding anthropometric fit/accommodation information. A more efficient system will require less time invested.
Scope	System impact on sufficiency of anthropometric fit/accommodation information provided to user. Information provided is in-depth enough to meet user's needs.
Usability	Ease of system use in accessing anthropometric fit/accommodation information. Level of effort required of designer to find information. A highly useable system requires little effort.

The assessment of these benefits was documented using a decision support software tool, Expert Choice. The tool was used to document the detailed assessment process and numerically rank the three alternatives. Expert Choice leads the decision-maker through a series of judgments between the alternatives and then between the benefits. The tool then combines all the priorities to arrive at an overall ranking of the alternatives. The resulting benefits analysis showed that, with respect to the prescribed goal, alternative #3, with a score of 63.3, best satisfies the requirements. Alternative #2 is the next best alternative, scoring 29.7. The least beneficial alternative, alternative #1, scored a 7.0.

3. Cost/Benefit Ratio

The cost/benefit ratio (CBR) was used as a method of combining the costs with the benefits to establish an overall conclusion regarding the investment alternatives. Combining costs and benefits determines the true value of each alternative. The CBR represents the cost per unit of benefit. Thus, a lower cost/benefit ratio is preferred.

Table 3. Alternative Cost Benefit Ratios and Rankings

Alternative	Cost (Constant FY02 $000)	Benefit Score	Cost/Benefit Ratio	Ranking
#1 Status Quo	$4,984.73	7.0	712.1	3
#2 Searchable D-Base	$7,736.6	29.7	260.5	2
#3 Searchable D-Base w/ Expert Int.	$13,450.7	63.3	212.5	1

Based on this data, alternative #3 was the most cost-effective. The analysis indicates it provided the greatest benefit for the money, with respect to the stated goal. Alternative #1 ranked the least cost-effective and alternative #2 fell in the middle.

4. Sensitivity Analysis

The sensitivity analysis focused on two areas. First was the dependence on expert opinion to estimate the software development effort common to both alternatives #2 and #3. Since this portion of the estimate was the same for both alternatives ($1.9M), variations in the input variables may change the total cost, but would not impact the comparative analysis between these two alternatives.

The second area of sensitivity was the method used to estimate the expert interface function unique to alternative #3.. The estimate for this portion of alternative #3 was based largely on information obtained from anthropometric experts envisioning how an expert system could deliver accurate anthropometric information. However, even if this particular cost element is overstated by as much as 50 percent, the total cost of alternative #3 would still exceed the cost of alternative #2.

5. Risk Analysis

From a cost perspective, two areas were addressed for their potential risk to the overall analysis. These are the application of expert interface technology in the area of anthropometry and the impact of expert opinion as a primary data source.

A significant portion of the total cost of alternatives #2 and #3 related to the cost element, Software Investment. Specifically, the introduction of an expert interface function into alternative #3 results in an increase of $3.8M over alternative #2 for this element alone. This makes the accuracy of the expert interface estimate crucial to the credibility of the overall rankings. As a result, this area may require additional research addressing the specific impact on the cost of the alternatives at that time.

The second area of cost risk relates to the use of expert opinion as the primary source of cost data for the three air combat capability enhancement suite (ACCES) alternatives. While some of the elements estimated using this source were based on known values (e.g., labor costs, hardware and software budgets, etc), others required the experts to envision a computerized capability that is, as of yet, unproven. As a result, this data, while the best available, is not based on documented information.

There were also two areas of risk identified with the benefits assessment. The first area was the absence of practical experience with the actual alternatives by the experts assessing one or more of the alternatives. The risk emerged in alternative #3, the searchable database with an expert interface. The potential variability was that the assessment of benefits related to this solution had to rely on the alternative as it was defined and its expected successful application in the anthropometric community. There was no actual entity to evaluate. As a result, there is risk that the technology may not work as expected when fully developed and used in this environment.

The second risk area related to the benefit assessment was that no novice users were included in the pool of experts who participated in the Expert Choice session. The group consisted of individuals that had extensive experience in the area of interest and was made up of both government and industry experts. However, if a new Expert Choice group was assembled, it is possible that the alternatives may be ranked in a different way, based on their own personal experiences and opinions.

6. Conclusions

This study evaluated the costs and benefits of three anthropometric information system alternatives. Using the cost estimate and benefit analysis developed for each alternative, Human Systems IAC calculated a cost/benefit ratio for each of the alternatives.

The most effective alternative with respect to the stated goals was alternative #3 the searchable database with expert interface, (CBR = 212.5). The second most desirable choice was alternative #2, the searchable database (CBR = 260.5). Based on the evaluated cost and benefits the least cost-effective solution for providing anthropometric information was alternative #1, the status quo (CBR = 712.1).

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1. INTRODUCTION

1.1 BACKGROUND

Designing for the user, be it accommodation in a crew station/cockpit or sizing of personal equipment and apparel, is often accomplished using outdated information or arbitrary, unrelated criteria. The result is poorly sized and inefficiently stocked equipment. Use of inaccurate data also results in errors in the selection process. It decreases the number of candidates available by eliminating individuals that are physically capable of working in a particular cockpit/crew station, while including some that are not. There must be a way for designers of crew stations and equipment to design for the user and provide for the selection of appropriate users, based on effective application of anthropometric data.

When developing and designing military equipment for use by human operators, it is important to design for the user. As the modern battlefield changes, so do the needs of designers. For instance, new roles for women in combat require body size data for a potential population of people, some of whom are not currently in the military. For example, the new U.S. Air Force T-6 II trainer was designed to accommodate pilots with statures ranging from 4'10" to 6'5" characterized by various body segment proportions in an effort to broaden the pool of potential pilots and meet international needs. This new trainer, along with the F-22 and Joint Strike Fighter (JSF), employed manikin sizes defined by the multivariate accommodation method rather than percentile method.

Unfortunately, anthropometric dimensions are not perfectly correlated with one another. For example, people with long legs do not necessarily have long torsos. This forces decision makers to consider the relationship between specific body dimensions in the design of systems based on combinations of dimensions, the intended use and user population. For instance, by designing for the 5^{th} to 95^{th} percentiles on more than one dimension, the design will exclude significantly more individuals than the implied 10 percent. In fact, Bittner (1974) showed in one study that applying 5^{th} and 95^{th} limits on each of 13 dimensions actually excluded 52 percent of the potential user population! Bottom line is that it is essential to consider the body dimensions important to the design, the population that will use the equipment, and resources required to provide the information needed.

When poor or incorrect anthropometric and accommodation information is used, the result can be a decrease in safety. For instance, in nine percent of aircraft accidents over the past 10 years body size was listed as a contributor (Zehner, 2001). Designing for varying body sizes should help decrease the number of accidents. Poor anthropometric accommodations also result in uncomfortable/poor fitting garments and cockpits that cannot accept all aircrew that it is intended to. The result from the use of incorrect information leads to the deployment of equipment and operators that simply cannot safely fit in all of the cockpits they are supposed to support.

Another result of incorrect information is that the equipment available does not fit and/or cannot be used by those that need it. Use of inaccurate data also result in errors in the selection process as they decrease the number of candidates available by eliminating individuals that are physically capable of working in a cockpit/crew station, while including some that are not. This is exemplified by Bittner (1974), as described above.

There must be a way for designers of crew stations and equipment to design for the user and provide for the selection of appropriate users, based on effective application of anthropometric data. The effort to develop the air combat capability enhancement suite (ACCES) will help decision makers make educated judgments about accommodation information system for use by decision-makers across a number of domains. The goal will be:

- A data base of current forces and the best equipment size, adjustments, etc. for usability, fit and safety;
- Information on areas of improvement for more cost-effective fit, assignment entry, fitness standards, and purchasing; and
- The best mix of stocked/special order/custom personal equipment sizes for rapid and cost-effective deployment.

1.2 PURPOSE OF CBA

In general, a cost benefit analysis (CBA) is a systematic method of assessing the economic desirability of selected investment alternatives based on their costs and benefits, respectively. The objective of this assessment is to identify one alternative that is preferable to all of the others.

The specific objective of this CBA project was to evaluate the economic desirability of three proposed anthropometric information systems for use by experts and novices, based on their respective cost and benefits. The alternative eventually implemented should provide appropriate and accurate anthropometric information to allow designers to provide for the selection of appropriate users. The alternative must also provide understandable, adaptable anthropometry and accommodation information to the user. Lastly, the alternative must incorporate previously gathered information and build upon research in 3-D shape that has already started.

1.3 OVERVIEW OF APPROACH

As stated above, a CBA is a systematic method employed to make rational decisions on possible alternative systems by comparing selected alternatives based on their estimated costs and evaluated benefits. Conducting a CBA assists in the allocation of scarce resources by probing each investment alternative so that all questions relevant to an appropriate decision are answered. The overall objective and alternatives are clearly defined; costs and benefits are fully presented; and important assumptions, factors and judgments are highlighted. Outlined in the following sections, are the eight steps used by Human Systems IAC in conducting a CBA. They are:

1. Assess Current Environment
2. Perform Gap Analysis
3. Identify Investment Alternatives
4. Estimate Cost
5. Perform Sensitivity Analysis
6. Characterize and Evaluate Benefits
7. Determine Net Value of Each Alternative
8. Perform Risk Analysis

Once ground rules and assumptions are established, a cost estimate is prepared for each alternative and benefits are evaluated. Each estimate is then normalized to a constant year for cost comparison purposes. Analysis of the benefits is accomplished using decision support software (Expert Choice) that enables Human Systems IAC to leverage the expertise of key stakeholders and experts in the field.

2. COST BENEFIT ANALYSIS

2.1 CURRENT ENVIRONMENT

2.1.1 Process

In evaluating the current environment Human Systems IAC investigated the types of technologies currently being applied. The need for a material solution based on the objectives was also addressed. The current technology in anthropometric information was surveyed and thoroughly examined to establish a baseline for the analysis.

When assessing the current environment, Human Systems IAC analysts first "got smart" on the topic at hand. This began with an in-house literature search to ascertain the general nature of the topic. In this case, anthropometric databases were researched. Based on this search, a comprehensive list of keywords, catch phrases, subject matter experts (SME), and example articles was compiled. As is often the case, the customer was a subject matter expert in the field and knew a great deal about the specific topic of anthropometry. Therefore, this search strategy was developed in close coordination with customer review and feedback. Once coordination was received on the search strategy, an in-depth literature review of all appropriate databases was conducted. (See Appendix C for Search Strategy.) The ACCES search resulted in the identification of literally hundreds of citations. These citations were surveyed for the most relevant and insightful resources. The emerging sources became the backbone literature source of information used throughout the CBA.

Once the background work was completed, selected documents were acquired and SMEs were contacted. At this point, Human Systems IAC gathered all available documentation and information from the customer, asking numerous questions when necessary. The developed information was then combined to provide an accurate perspective of the current system.

2.1.2 Evaluation

Currently, the most effective way to obtain accurate anthropometric information is to contact an expert consultant, such as someone at AFRL/HE, to find the appropriate data and put it in a useful form for the particular project or problem. Once contacted, the experts search the most relevant resources available and provide a response. The consultant may or may not have the software and data resources readily available to accomplish this, therefore this information may have to be separately acquired. In addition not all anthropometric information is in a central location, nor can it's location be found from one central resource. In fact, the existence of the appropriate information and the existence of expertise to find or use it may not be known by the user. For example, a manufacturer of an oxygen mask may not know there is a 3-D face data resource available.

This approach is time consuming and often ineffective. The AFRL experts may be able to provide an effective solution given sufficient time, but their primary job is to develop new technologies and transition them, not to execute them once they are developed. Since it is not their normal job to serve as experts on acquisition programs, there is no routine mechanism to use AFRL experts in the acquisition process. As a result, they often are called upon to help very late in the process with little time left to help. Any consulting they do must fit into their normal duties. This further reduces their ability to help effectively and efficiently.

At the time of this report, the specific goals and requirements for this system were defined as described above, but remained somewhat vague. No mission needs statement (MNS) or operational requirements document (ORD) existed. Nonetheless, there are still possible solutions to the described shortfalls of the current system. Solutions to the problem of accessing data fall within two categories: material solutions or doctrine changes.

Material solutions would include improvements to computer systems associated with information storage and retrieval, better libraries, etc. Doctrine changes would include a completely new approach for handling the dissemination of useful, accurate information. This solution could include additional training or new information handbooks. An additional consideration to help solve the problem would be to remove the man from the system. For instance, the work being done by expert individuals could be conducted via an "expert system."

2.2 GAP ANALYSIS

2.2.1 Process

In addressing the gap, it was the task of Human Systems IAC to identify the techniques and technologies that work well and the underlying reason for the effectiveness. This step of the CBA was intended to illustrate the gap between what is and what is supposed to be. By understanding the desired system's requirements and the effectiveness of the current technology (baseline) in terms of meeting those requirements, it was determined where mission needs were not being met.

2.2.2 Evaluation

The most effective systems providing anthropometric information included those that provided complete and accurate information quickly. For instance, consulting a textbook may yield information quickly, but it may not be as complete or up to date and accurate as a less accessible website. Another consideration was the fact that current anthropometric information was distributed across several resources and databases, making it difficult to acquire, even for experts.

Technologies that worked well in providing anthropometric information vary from well-known handbooks to cutting-edge 3-D scanners. Each source has some positives and negatives associated with it. For instance, the information provided in the Army Anthropometric Survey (1988) is relatively easy to acquire and understand, but it is fast becoming obsolete. On the other hand, information from 3-dimensional scans is up to date and very complete, but the sheer amount of data makes it difficult to manage to reach an effective solution. Overall, critical features of an effective solution included an information system which provided accurate and complete information quickly and easily. Unfortunately, no system existed with all of these attributes.

When an effective solution was compared to the status quo, it was evident there was a significant gap between the information required and the information available.

2.3 INVESTMENT ALTERNATIVES

2.3.1 Process

Utilizing information from assessment of the current environment and the gap analysis, Human Systems IAC then added customer input and the opinions of technical experts to identify potential investment alternatives to investigate.

Alternatives can be identified in several ways. In general, the status quo (currently fielded system) is one of the alternatives examined as it establishes a baseline for comparison. Additional alternatives are often the next generation of technology identified in the literature search. Human Systems IAC analysts, SMEs, or the customer identify further choices.

2.3.2 Evaluation

The specific goal of the technologies under scrutiny was to develop an anthropometric size, shape, fit and accommodation information system for efficient and effective use by designers, manufacturers, buyers, and decision makers across a number of domains. The solution should also provide understandable, adaptable anthropometric and accommodation information to the user.

It was established during the assessment of the current environment that material and doctrine solutions were necessary. Key attributes of a material solution included technological improvements in the area of data storage and retrieval. Another important aspect of the material solution would be improved database capabilities and enhanced accessibility to information.

Key attributes of a doctrine change would include a fresh look at the use of anthropometric information by individuals. It would provide for the effective delivery of accurate information to the right people through training of those individuals or some other method. An expert interface that makes key decisions for the user could help alleviate the need for experts in the loop or additional training.

Human Systems IAC identified three alternatives to analyze with respect to these features. The first was the status quo information system. This alternative was included because it provided a baseline for comparison. The second investment alternative was a searchable database. This was the first step in improving information accessibility for the user. The third alternative addressed in this CBA was a searchable database with an expert interface. This final alternative incorporated all of the requirements and used the latest technology.

2.3.2.1 Alternative #1, Status Quo

Described fully in assessment of the current environment (Section 2.1.2), the status quo alternative included the additional resources described below:

- Printed texts with summary statistics from preset surveys such as mean, standard deviation and percentiles. Sample may not be representative of the desired population.
- Printed standards and handbooks such as MIL-STD-1472 and MIL-HDBK-743.
- Journal articles and human factors textbooks.
- One-dimensional (traditional tape measure, caliper type) data by survey in spreadsheets on CD, such as the USAF mini-survey.
- Collections of 3-D scans in original scan form on CD, such as the Dayton Survey and the USAF HGU-55/P survey.

2.3.2.2 Alternative #2, Searchable Database

This alternative consists of an on-line one- and three-dimensional database made up of all available Air Force anthropometric resources for fit and accommodation, with sample merging, weighting and segmenting capability. This searchable Oracle-based database will bring together previously unincorporated sources; information will either be located in the database or its location can be identified from the central information system. For example, when a query is made to the database, a list of resources is generated. From this, the user accesses the suggested resources, builds a data set and utilizes the statistics package to formulate an answer to his/her anthropometric question. Sometimes the answer will tell them what NEW data to collect and how to collect it. The data they need may not be in the database yet. Also, when they collect new data they will want to add it to the database for future use.

Because using the information still requires a knowledgeable expert to answer the questions in many cases, training is a key element of this alternative. In order to get the same

utility from this software as asking the experts, a user would have to be trained to ask the correct questions and make appropriate decisions based on the information presented. For example, if the user wanted to know which individuals could safely fit into a crew station, he/she would have had to know which measurements were important, which database had the most representative sample of those measurements, gather the information from the sources in the database, make any necessary calculations to normalize and average the date, and then make a decision based on the available information. The training course accompanying this alternative will guide the user through the information sources and process required to arrive at an accurate anthropometric solution.

In summary, this database would enable an expert to access the information and arrive at solutions quickly and easily, thereby increasing their effectiveness. It would also allow non-experts to easily gain an understanding of what information is available. The searchable database would include the following resources:

- Lessons learned and fit and accommodation maps,
- Human System Equipment size and shape information,
- Interfacing 3-D visualization and statistical analysis tools, including multivariate analysis software, and
- Electronic accommodation or fit prediction models.

2.3.2.3 Alternative #3, Searchable Database with Expert Interface

This alternative is basically the same as alternative two, a searchable on-line one- and three-dimensional database made up of all available Air Force anthropometry resources for fit and accommodation, with sample merging, weighting and segmenting capability. However, this alternative adds an expert user interface in the form of standard decision templates to allow non-experts to obtain and effectively use the information they need without additional training. For example, when a query is made to the database, a list of resources is generated. Some of these may be available from within the database, and some sources may simply list the location they can be retrieved from. The user is walked through a series of questions based on standard templates to simulate various anthropometric scenarios. Ideally, no complex calculations or expert decisions will be required. The user would simply have to ask a question such as "Which individuals can safely fit into a crew station with x-dimensions?" and the database would walk the user through the appropriate steps to provide that answer. The searchable database with expert interface would include the following resources:

- An interface that would allow a novice to locate the appropriate information in the format needed, by simply asking a question. The program would walk them through the answer to questions like:
  - Would this candidate be able to safely fly USAF fighter aircraft? Answer would include the aircraft that could be safely flown as well as any areas that might be on the borderline and by how much.
  - What percentage of the population would be able to fly this aircraft if this change were made? The interface would ask the novice specific questions to ascertain exactly what the population of interest might be. The answer would include the overall population, the male and the female populations and the minority population percentages.
  - What should the requirements be for a new oxygen mask? The interface would ask the novice questions to ascertain how the oxygen mask is intended to fit and function, and who the intended users would be using examples and pictures (3-D if available)

from the fit history files. The answer would include the statements to be written in the specification, and the data on the cases (3-D if necessary and available) to use to accommodate the population.

2.3.2.4 Global Ground Rules and Assumptions

The following ground rules and assumptions were used in estimating the costs and evaluating the benefits of each ACCES alternative:

- Three alternatives for retrieving anthropometric information were examined.
- Each alternative was estimated with the baseline goal of providing full capability anthropometric information for a 3-year period. Program schedules differ due to the varying assumptions for acquisition and implementation costs for each; Costs for each alternative begin in FY02.
- Costs for each alternative are assumed to be Air Force appropriation 3600, Research, Development Test and Evaluation (RDT&E) funds.
- All detailed costs were presented in both constant dollars and then year dollars using standard DoD inflation rates.
- Composite burdened labor rates were used for all civilian and military labor.
- Groundrules and assumptions specific to a particular alternative were summarized with the documentation for that alternative.
- The sources of information for all three alternatives are of three (3) types: 1. Hard copy (regulations, technical reports and handbooks) 2. Electronic databases and files and 3. Subject Matter Expert (SME) opinion.
- All databases referenced were assumed to contain valid anthropometric information; No cost of insuring data validity was included in the individual estimates.
- The domain of users was limited to inside the Air Force Civilian, Military and Contractor personnel.
- Databases used will be those the Air Force currently has in its possession, including some Army, Navy, and international sources, though these may not be the most recent.
- No schedule or budget limitations were known to exist.
- Costs associated with maintenance and updates to the referenced databases were assumed to be equal for each alternative and therefore were not included in the individual estimates.
- Technological solutions peripheral to the agreed upon alternatives were not addressed.

2.4 COST ESTIMATE

2.4.1 Process

For each alternative, technical, schedule and programmatic ground rules and assumptions were established. Based on this information an estimating methodology was selected and data was gathered. A cost estimate was prepared for each alternative and was then normalized to constant year dollars for cost comparison purposes.

2.4.2 Evaluation

2.4.2.1 Alternative #1, Status Quo

In addition to the global groundrules and assumptions, the following assumptions were made in preparing the cost estimate for this alternative:

- AFRL/HE receives an average of one question per week (50 per year).
- It takes an average of 240 hours to completely answer each inquiry (For example, pictures are reviewed, site visits are made, research is conducted, data is analyzed and answer is provided).
- The average of a GS-14 and GS-15 salary is assumed to be representative of the salary level of the variety of personnel who spend time answering the inquiries.
- The cost of contract management labor required to oversee the existing data collection contract is assumed to be equivalent to 15% of one GS-12 annually.
- The sources utilized for anthropometric information do not cost anything to access.
- There are no "non-organic" sources of information required.
- One half of the questions posed to AFRL/HEC require a site visit to properly answer them. For purposes of this estimate, a typical trip is 3 days in length and a typical location is San Antonio Texas.
- The cost of annual software maintenance and upgrades required to support this scenario is $50K annually.
- Technical support such as data management, backups, equipment and facility maintenance required is assumed to be equivalent to 10percent of the labor support.
- Annual hardware requirements are replacement/upgrade of 10 percent of the current systems each year. Specifically, two state-of-the-art PC's (one 50 gigabyte or larger), miscellaneous lab equipment and the FARO arm. Estimate includes $50K per year to cover these costs.
- There was assumed to be a cost of $1K annually for consumables associated with the delivery of technical reports (paper and CD's)

Table 1 summarizes the costs of alternative #1.

Table 1. Alternative #1 Costs (Constant FY02 $000)

Costs *	FY02	FY03	FY04	FY05	Total
System Acquisition	0	0	0	0	0
System Implementation	13.25	13.25	13.25	13.25	66.23
Operation and Support	983.70	983.7	983.7	983.7	4,918.5
Alternative #1 Total	**996.95**	**996.95**	**996.95**	**996.95**	**4,984.73**

* A cost estimating methodology matrix and detailed worksheet can be found in Appendix A. Numbers may not add due to rounding.

2.4.2.2 Alternative #2, Searchable Database

In addition to the global groundrules and assumptions, the following assumptions were made in preparing the cost estimates for this alternative:

- The database will be a web based Oracle system application.
- The searchable database will contain a statistics package capability (SAS).
- The data retrieved from electronic sources will be importable into the statistics package.

- The total population of potential users is 500; the maximum possible at any one time is 50.
- There are approximately 40 separate sources of information ranging from ASCII flat files to 3D databases. SMEs estimate it will require one person (GS-12 equivalent) working full time for one year to collate all sources, solve potential integration issues and sort out what should be included in the database as sources of information. Activities include figuring out the fields required, cross-referencing data from all the different sources and putting them in a consistent, standard format. Additional information on the primary data sources follows:
  - Cockpit Accommodation: Moderate file size in MS Access.
  - CAESAR: Unix-based cyberware format from silicon-graphics scans. File size=3.5MB compressed.
  - CG Whole Body: Unix-based cyberware format from silicon-graphics scans. File size=3.6MB compressed.
  - Pregnant Woman: Unix-based cyberware format from silicon-based graphics scans. File size=3.5MB compressed.
  - 3D Head: Unix-based cyberware format from silicon-based graphics scans. File size=434 kB compressed.
  - 30+ miscellaneous text-based ASCII formatted files minimal in size.
- There will be no requirement for classified/proprietary information.
- All hardware and network requirements to host this alternative are currently in place (PC server with multiple hard drives of 50 gigabytes or more each and a Linux based server linked to graphics workstations)
- The purchase of the Oracle object-oriented database management software is required.
- The current communication links have appropriate bandwidth to support operation of this application.
- The overall timeline is assumed to be representative of the project schedule outlined in Appendix A.
- Annual hardware requirements are replacement/upgrade of 10 percent of the current systems each year -- specifically, two state-of-the-art PCs (one 50 gigabyte or larger), miscellaneous lab equipment and the FARO arm. Estimate includes $50K per year to cover these costs.
- The cost of annual software maintenance and upgrades required to support this scenario is $50K annually.
- Project management is required during system implementation. 1 GS-14 equivalent one-half time during the first year.
- The effort required to develop a training curriculum requires two people (average grade GS-14) one half time for a three-year period. In addition, 1 person (GS-12) is required one-half time during the last year to finalize all course materials
- User training will be offered at Wright-Patterson Air Force Base (WPAFB), Ohio, three times per year to an average of 20 students per class. The length of the course will be equivalent to a 3-credit masters level course (45 hours of instruction) and will be taught by a GS-14.
- Course materials for the training are estimated to cost $25 per student (textbook and CD).
- Travel and per diem costs to attend the training will be covered by the student and are therefore not included in this estimate.
- There will continue to be a requirement for the status quo alternative while users become trained on this searchable database. SME's estimate the requirement for individual calls

to AFRL/HE will decrease as follows: 1st year: –25 percent, 2nd year: -50 percent, 3rd year: -75 percent.
- Annual support requirements (data systems manager, troubleshooter, maintainer of system security, provider of backups and updates to the system, etc) for this alternative are for one full time dedicated support technician (GS-12).

Table 2 summarizes the costs for alternative #2.

Table 2. Alternative #2 Costs (Constant FY02 $000)

Costs *	FY02	FY03	FY04	FY05	FY06	Total
System Acquisition	323.6	1,625.1	214.7	0	0	2,163.36
System Implementation	60.4	370.5	171.3	0	0	602.2
Operation & Support	983.7	983.7	1,228.3	1,040.9	734.3	4,971.0
Alternative #2 Total	**1,367.7**	**2,979.3**	**1,641.3**	**1,040.9**	**734.3**	**7,736.6**

* A cost estimating methodology matrix, detailed cost worksheet and project schedule can be found in Appendix A. Numbers may not add due to rounding.

2.4.2.3 Alternative #3, Searchable Database with Expert Interface

In addition to the global groundrules and assumptions, the following assumptions were made in preparing the cost estimate for this alternative:

- All assumptions from alternative #2 apply here except no training is required for the user.
- The overall timeline is assumed to be representative of the project schedule outlined in Appendix A.
- Five basic "templates" will be offered in the "expert" database function:
  - Generation of a requirements/specification document.
  - Development of a prototype.
  - Evaluation of an existing system.
  - Queries regarding who fits in what systems.
  - How to enter new data into the database.
- Each template will have the following basic steps:
  - Statement of the problem.
  - Identification of the environment and human constraints.
  - Selection of relevant dimensions.
  - Definition of a target population.
  - Determination of appropriate sample of the population.
  - Selection of cases from the sample to characterize the population.
  - Implementation of the cases into the output format.
- The average number of data sources required to obtain a solution for each template is five.

Table 3 summarizes the costs for alternative #3.

Table 3. Alternative #3 Costs (Constant FY02 $ in 000)

Costs *	FY02	FY03	FY04	FY05	FY06	Total
System Acquisition	721.1	4,123.8	1,227.1	0	0	6,072.0
System Implementation	45.7	134.5	173.8	0	0	354.0

Operation and Support	983.7	983.7	1,959.3	1,902.4	1,195.6	7,024.7
Alternative #3 Total	**1,750.5**	**5,242.0**	**3,360.3**	**1,902.4**	**1,195.6**	**13,450.7**

* A cost estimating methodology matrix, detailed cost worksheet and project schedule can be found in Appendix A. Numbers may not add due to rounding.

2.5 SENSITIVITY ANALYSIS

2.5.1 Process

The next step of a cost benefit analysis, the sensitivity analysis, illustrates how changes in key assumptions and variables within the cost estimate may have an impact on the total cost estimate. These changes are often referred to as "excursions." They answer the question, "What elements, if changed, would influence the overall cost of each alternative?" The result of such an excursion assesses the magnitude of change required within key cost elements sufficient to influence the outcome of the cost analysis. While many different excursions could be evaluated, the ones most likely to be of interest to the reviewers of the analysis are selected.

2.5.2 Evaluation

The sensitivity analysis focuses on two areas. First is the dependence on expert opinion to estimate the software development effort common to both alternatives #2 and #3 and second is the method used to estimate the expert interface function unique to alternative #3.

While alternatives #2 and #3 differ significantly in terms of total cost, both contain the same cost element, Software Investment. The software investment element is composed of software licenses and a software development effort. Specifically, the software development effort makes up a significant portion of the cost for both alternatives: 24 percent of alternative #2 and 44 percent of alternative #3.

The portion of the software investment element that is common to alternatives #2 and #3 is the development of an oracle database and the incorporation of a statistical analysis tool. Both alternatives #2 and #3 assume the use of an Oracle database with 1,000 to 2,000 function points (40,000 to 80,000 lines of code) and another 100 to 200 function points (3,200 to 6,400 lines of code) for the SAS integration. The SEER/SEM software cost estimating tool was used to estimate these components. The inputs for the model were gathered from anthropometric experts and considered the respective sizes of the existing files to be integrated into the ACCES system. Since this portion of the estimate is the same for both alternatives ($1.9M), variations in the input variables may change the total cost, but would not impact the comparative analysis between these two alternatives.

The key difference between alternatives #2 and #3 is the inclusion of an expert interface function for the third alternative (+$3.8M). The estimate for this portion of alternative #3 was based largely on information obtained from anthropometric experts envisioning how an expert system could deliver accurate anthropometric information. The total cost is sensitive to the inputs received from these experts who attempted to capture this function in terms of templates that will simulate possible anthropometric scenarios. However, even if this particular cost element was overstated by as much as 50 percent, the total cost of alternative #3 would still exceed the cost of alternative #2. The effect of this area of sensitivity will be further discussed in the risk analysis section (section 2.8) and combined with the impact of the benefits analysis to determine a potential influence on the overall ranking of alternatives.

The primary source of information for all three cost estimates was subject matter experts within the Air Force anthropometric community. To the extent possible, costs were estimated based on known variables (e.g., AFRL/HE labor costs, current network architecture, hardware

and software budgets, etc.). However, since alternative #1's cost estimate was based completely on these documented variables, it was not addressed in this sensitivity analysis.

2.6 BENEFITS CHARACTERIZATION AND VALIDATION

2.6.1 Process

Analysis of the benefits was accomplished using a decision support tool, Expert Choice, which enabled Human Systems IAC to leverage the expertise of key stakeholders and experts in the field. As stated in Section 2.3, the specific goal of the alternatives examined was to develop an anthropometric size, shape, fit and accommodation information system for efficient and effective use by designers, manufacturers, buyers, and decision makers across a number of domains. Key results of the alternatives under scrutiny were an appropriate and accurate anthropometric information system that allowed designers to provide for the selection of appropriate users. Additional results included understandable, adaptable anthropometric and accommodation information for the user.

Benefits were identified using a combination of bottom-up and top-down analyses. First, Human Systems IAC identified any and all terms or phrases that could be associated with an improvement or decrement in any of the three identified investment alternatives. In the case of ACCES, a list of over 40 possible benefits was initially developed. This bottom-up approach was intended to tease out any and all benefits of the three alternative systems. The resulting list was then segregated into categories of benefits. For instance, any benefit that influenced the ease of use of the system was included in the "usability" category.

The second step was to employ a top-down analysis on the benefits list. Using the overall goal (see definitions section) as a starting point, Human Systems IAC categorized the global areas of improvement or decrement that would realize a difference between the alternatives. For instance, the scope of information available was a major difference between alternatives and was identified as a possible benefit.

The final step in identifying alternatives was to compare the bottom-up with the top-down list. The top-down list described the global benefits and differences between investment alternatives. The bottom-up list described the specifics that should be represented by the global benefits. Any bottom-up benefits that were not represented in the global list were considered as a unique benefit. Any top-down benefit that was not well represented by specific instances from the bottom-up list was reevaluated as a benefit. In the end, five global benefits were identified using this combination approach. They were accessibility, accuracy, efficiency, scope, and usability.

The Expert Choice session began by reaching a general consensus on the definitions for the goal of the session, the three investment alternatives, and the five associated benefits to be evaluated during the session. Definitions played a critical role since evaluations made by the participants were based on their interpretations of those definitions. The Expert Choice process used in this approach is illustrated in Figure 1.

Expert Choice Process

Once the definitions were clearly defined and understood by all participants, the Expert Choice group ranked all five of the benefits in order of importance. For instance, accuracy is more important than accessibility, and accessibility is more important than efficiency. Based on the group's responses, the Expert Choice tool calculated the benefit scores and attached a value to the benefits and alternatives. The result was that the highest score determined the alternative with the most overall benefit value.

Then, the group ranked the three investment alternatives from highest to lowest importance for each benefit individually. As a result, the three alternatives were compared five times, once for each benefit. The alternative ranked with the highest importance meant that it realized the highest value for that benefit. For instance, if alternative #2 had the best usability features, according to the Expert Choice group, then it would have been rated highest on usability.

2.6.2 Evaluation

Stakeholders identified by Human Systems IAC and the customer participated in the evaluation. Among these stakeholders were government and civilian SMEs in anthropometry from AFRL, ASC, ACC, Human Systems SPO, and Boeing. Table 4 lists the participants and their affiliation.

Table 4. Expert Choice Participants

Participant	Affiliation
James M. Barnaba	ASC/ENFC
Eric Crawford	ASC/ENFC
Alfonso Gonzalez	Human Systems SPO, 311 HSW/YA
CMSgt Randolph C. Loving	ACC/DRSR
Teresa Perkins	ASC/ENFC
Kathleen M. Robinette	AFRL/HECP
Edward R Winkler	Boeing
Gregory F. Zehner	AFRL/HECP

As stated in previous sections, three alternatives were evaluated:

- Alternative #1 Status Quo,
- Alternative #2 Searchable Database, and
- Alternative #3 Searchable Database with Expert Interface

Each of the three identified investment alternatives was evaluated across five benefits using Expert Choice. Table 5 lists the alternatives along with the abbreviation used in the Expert Choice analysis.

Table 5. Alternative Abbreviations

Expert Choice Abbreviation	Alternative Name
STAT QUO	Status quo; inquiries to AFRL/HE
DAT'BASE	Searchable database
DBW/EXP	Searchable database with expert interface

The five global benefits were identified through a thorough review of the requirements, the literature, and SME input. Table 6 lists the benefits, their abbreviations used in the Expert Choice model, and a brief definition used in this analysis.

Table 6. Benefits Abbreviations and Definitions

Expert Choice Abbreviation	Benefit Name	Benefit Definition
ACCESS	Accessibility	System impact on ease of accessing anthropometric information; the number and type of individuals that can locate the info.
ACCURACY	Accuracy	System impact on currency, correctness, and direct use of fit/accommodation information. Information provided is the correct solution for the task at hand.
EFFICIEN	Efficiency	System impact on speed of finding anthropometric fit/accommodation information. A more efficient system will require less time invested.
SCOPE	Scope	System impact on sufficiency of anthropometric fit/accommodation information provided to user. Information provided is in-depth enough to meet user's needs.
USABL'TY	Usability	Ease of system use in accessing anthropometric fit/accommodation information. Level of effort required of designer to find information. A highly useable system requires little effort.

Benefits were evaluated using pairwise comparisons to "prioritize" the importance of each with respect to the goal. Table 7 shows the results of each comparison.

Table 7. Global Table of Pairwise Comparisons

ACCESS	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	⑦	8	9	ACCURACY
ACCESS	9	8	7	6	⑤	4	3	2	**1**	2	3	4	5	6	7	8	9	EFFICIEN
ACCESS	9	8	7	6	5	4	3	2	**1**	2	3	4	5	⑥	7	8	9	SCOPE
ACCESS	9	8	7	6	5	4	3	2	**1**	②	3	4	5	6	7	8	9	USABL'TY
ACCURACY	9	8	⑦	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	EFFICIEN
ACCURACY	9	8	7	6	⑤	4	3	2	**1**	2	3	4	5	6	7	8	9	SCOPE
ACCURACY	9	8	⑦	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	USABL'TY
EFFICIEN	9	8	7	6	5	4	3	2	**1**	2	3	4	5	⑥	7	8	9	SCOPE
EFFICIEN	9	8	7	6	5	4	3	2	**1**	②	3	4	5	6	7	8	9	USABL'TY
SCOPE	9	8	⑦	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	USABL'TY

Ratings: 1 = Equal; 3 = Moderate; 5 = Strong; 7 = Very Strong; 9 = Extreme
Example of interpretation: Accuracy (ACCURACY) is strongly more important than scope (SCOPE).

While Table 7 shows the global comparisons, Table 8 adds the rank order, individual score, and summarizes these comparisons into a single table. As can be seen in Table 8, the Expert Choice group determined that accuracy was the most important benefit, and scope was the second most important. Accessibility and usability followed as third and fourth and had about the same value. Efficiency was ranked the least important of the benefits.

Table 8. Rank Order of Benefits

Rank	Benefit	Benefit Rating (Score Out of 1.0)
1	Accuracy	0.552
2	Scope	0.268
3	Accessibility	0.073
4	Usability	0.071
5	Efficiency	0.037

2.6.2.1 Evaluation of Alternatives for Benefits

Supported by the information in Appendix B, the Expert Choice team discussed the positive and negative aspects of each alternative. Their inputs were distilled into a single ranking for each alternative across each benefit. These rankings were then used by Expert Choice to complete the benefits analysis.

Based on the results from the benefits analysis, shown in Table 9, the most effective solution was the searchable database with expert interface (63.3 out of 100), with the searchable database falling into the middle (29.7). The least effective alternative with respect to benefits was the Status Quo system, which scored only 7.0 out of 100.

Table 9. Alternative Benefit Scores

Alternative	Benefit Score
Status Quo System	7.0
Searchable Database	29.7
Searchable Database with Expert Interface	63.3

2.7 NET VALUE ANALYSIS

2.7.1 Process

The net value analysis is the combination of life cycle costs developed in the cost assessment with the alternative benefits established in the benefits assessment. Included in this portion of the report is the final cost benefit ratio that will act as the foundation of the recommendations provided. The cost benefit ratio is simply a combination of the costs (numerator) and the benefits (denominator) into a ratio. For example, the CBR for the first alternative would be:

$$\text{CBR Alternative 1} = \frac{\text{Cost of Alternative 1}}{\text{Benefit Score of Alternative 1}}$$

2.7.2 Evaluation

As stated in Section 2.6, the Benefits Evaluation, the overall benefit ratings by subject matter experts and stakeholders rated alternative #1, the status quo, with a score of 7.0. Alternative #2, the searchable database scored 29.7, and alternative #3, the searchable database with expert interface scored 63.3. When combined with the costs, we see that alternative #3, with a CBR of 210.5, has the greatest value when costs and benefits were combined. Alternative #2

has slightly less value, with a CBR of 256.3, and alternative #1 has the least value with a CBR of 712.1.

Table 10. Ranking of Alternatives Using Cost Benefit Ratios

Alternative	Cost (Constant $000)	Benefit Score	Cost/Benefit Ratio	Ranking
#1 Status Quo	$4,918.5	7.0	702.6	3
#2 Searchable D-Base	$7,736.6	29.7	260.5	2
#3 Searchable D-Base w/ Expert Int.	$13,450.7	63.3	212.5	1

Based on this data, alternative #3 is the most cost-effective. The analysis indicates it provides the greatest benefit for the money, with respect to the stated goal. Alternative #1 ranked the least cost-effective and alternative #2 fell in the middle.

2.8 RISK ANALYSIS

2.8.1 Process

In the final step of a cost benefit analysis, both costs and benefits are investigated from a risk perspective. The objective of this step is to isolate areas of the alternatives where uncertainties exist in the analyses. Program managers then have the added foresight to focus their attention on those risky areas when making programmatic decisions. In general, the more complex the alternative, the more likely it is that changes in schedule/cost, or benefit assumptions will result. For example, if certain cost assumptions or benefit assessments change dramatically, the overall findings will likely change as well. These possible areas of risk are highlighted in the evaluation below.

2.8.2 Evaluation

The areas of risk for costs and benefits will be addressed separately. From a cost perspective, there are two areas that are addressed for their potential risk to the overall analysis. These are the application of expert interface technology in the area of anthropometry and the impact of expert opinion as a primary data source.

As discussed in the sensitivity analysis, a significant portion of the total cost of alternatives #2 and #3 relate to the cost element, Software Investment. Specifically, the introduction of an expert interface function into alternative #3 results in an increase of $3.8M over alternative #2 for this element alone. While the incorporation of the expert interface function was estimated using inputs from extremely knowledgeable experts in the field of anthropometry, the actual application of an expert interface in this milieu is unproven. Should the input variables used to estimate this portion of alternative #3 vary significantly, the ranking of alternatives may change. To summarize the risk, even though the total cost of alternatives #2 and #3 vary significantly, alternative #3's cost would only have to increase by 22 percent in order for the cost benefit ratio to change enough to impact the overall ranking of alternatives. That is, if the cost of alternative #3 increased by 22 percent, it would change the cost benefit ratio enough o impact the ranking of alternatives. Thus, should the cost increase be realized, alternative #3 would no longer be the most desirable solution. This makes the accuracy of the expert interface estimate crucial to the credibility of the overall rankings. As a result, this area may require additional research addressing the specific impact on the cost of the alternatives at that time.

The primary source of cost data for the ACCES alternatives was expert opinion. Some of the elements estimated using this source were based on known values (e.g., labor costs, hardware and software budgets, etc.), while others required the experts to envision a computerized

capability that is, as of yet, unproven. In defense of this source's accuracy, the data gathering efforts used in developing the cost estimate combined the talents of experienced Information Technology experts and personnel with extensive knowledge of anthropometric data *and* the process required to utilize it appropriately. We are, however, confident that the effort resulted in estimates that are the most accurate reflection possible of the potential cost of implementing each of these solutions.

In addition to the two areas of cost risk, two areas of risk associated with the benefits assessment were identified. The first area of risk was the absence of practical experience by the experts assessing with one or more of the alternatives being assessed. The second area relates to the fact that no novice users were included in the pool of experts conducting the analysis of benefits.

Given that alternative #1 is the status quo, and the underlying technology supporting alternative #2 has been successfully applied in the real world, there was little risk associated with the evaluation of their benefits. The risk emerged in the third alternative, searchable database with an expert interface. The potential variability was due to the fact that assessment of benefits related to this solution had to rely on the defined alternative and its expected successful application in the anthropometric community. While searchable databases are used often, a true "expert interface" is a new and uncertain technology. As a result, there is risk that the technology may not work as expected when fully developed and used in this environment.

The group that participated in the benefits assessment had extensive experience in the areas of interest and was made up of both government and industry experts. However, as with the assessment of many benefits, the subjective opinions of participants formed the foundation of the benefits analysis. If a new Expert Choice group was assembled, it is possible that the alternatives may be ranked in a different way, based on their own personal experiences and opinions. Specifically, while an expert's focus may be on accuracy and scope of information, they may not take into consideration the needs of the common user. Due to this fact, the possibility exists that the rating of some benefits may be slightly skewed toward the expert user and not the novice. For instance, "usability" and "accessibility" may have held greater sway for a novice user who is simply trying to locate information. While worthy of mention, this possible change is unlikely to shift the overall ranking of the three alternatives due to the fact that alternative #3, the searchable database with expert interface, would be the most user-friendly of all the alternatives. This observation in no way negates the validity of the conducted assessment, but should be noted as a factor to consider when making programmatic decisions based on the conclusions contained in this report.

3. CONCLUSIONS AND RECOMMENDATIONS

This study evaluated the costs and benefits associated with three anthropometric information alternatives. Each alternative was estimated for cost and evaluated for relative benefits. By assigning a numeric value to the benefits, Human Systems IAC was able to develop a cost/benefit ratio (CBR) for each of the three alternatives and document the resulting rank order based on this CBR.

The most effective alternative with respect to the stated goals was alternative #3, the searchable database with expert interface (CBR = 212.5). The second most desirable choice was alternative #2, the searchable database (CBR = 260.5). Based on the evaluated cost and benefits the least cost-effective solution for providing anthropometric information was alternative #1, the status quo (CBR = 712.1).

In conclusion, the use of inaccurate or incomplete anthropometric information can lead to decreased safety, inefficient procurement of materiel, and ill-fitting, difficult to use man-mounted equipment. Therefore, there must be a way for designers of crew stations and equipment to design for the user and provide for the selection of appropriate users, based on effective application of anthropometric data. Based on the results of this cost benefit analysis, it is clear the effort to develop ACCES will help decision makers make educated judgments about accommodation information systems across a number of domains.

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APPENDIX A. COST ELEMENT STRUCTURE, MATRICES & ESTIMATE DETAIL

Air Combat Capability Enhancement Suite (ACCES)
Cost Element Structure for all Alternatives

Element	Description
1.0 System Acquisition	**Roll-up element**
1.1 Acquisition Support	Roll-up element
1.1.1 Project Management	Technical and business management effort expended in the process of planning, analyzing, designing, and acquiring the system
1.1.2 RFP Preparation	Effort expended in the process of developing, refining, and releasing the request for proposals in a competitive bid
1.1.3 RFP Evaluation and Vendor Selection	Effort expended in the process of evaluating and comparing RFPs and selecting the winning vendor
1.2 Hardware Investment	Workstations, servers, network devices, peripherals, or other equipment procured to support implementation or operation of the system
1.3 Software Investment	Roll-up element
1.3.1 Software Development	Cost of developing, configuring and/or integrating software applications to provide ACCES functionality. Includes requirements analysis, design, coding, testing, and integration
1.3.2 Software Licenses	Initial, one-time license costs of other COTS/GOTS software procured to support implementation or operation of the system
1.4 Infrastructure Enhancements	Communications upgrades required to optimize system performance
2.0 System Implementation	**Roll-up element**
2.1 Project Management	Technical and business management effort expended in supporting, supervising, and directing implementation tasks and activities
2.2 Contract Management	Effort expended by contracting staff tracking financials, handling vendor relations, and other contract management responsibilities
2.3 Hardware Installation & Test	Installation and testing of hardware procured for system
2.4 Software Install & Test	Installation and testing of software procured for system
2.5 Data conversion	Collation and integration of data to be included in system. Includes actual data entry for populating database tables
2.6 User Acceptance	Effort expended in formal user testing of the production system
2.7 Training	Roll-up element
2.7.1 Training Development	Costs incurred in the development of appropriate training programs and material
2.7.2 Train-the-Trainer	Costs associated with in-depth, targeted instruction of primary training staff
2.7.3 End User Training	Costs associated with general instruction of system end users

3.0 Operations and Support	Roll-up element
3.1 System operations	Ongoing, dedicated staff support for operating new system hardware and software (over and above status quo operations costs)
3.2 Technical Support	Data management, backups, and facility maintenance
3.3 Software maintenance and upgrades	Recurring software licensing, upgrade, and maintenance costs
3.4 Hardware maintenance and upgrades	Recurring hardware upgrade, repair, and maintenance costs
3.5 Recurring training	Costs of periodic end user training, retraining, and refreshment
3.6 Other costs	Other miscellaneous costs of operations, such as office supplies and travel required to support the program

Air Combat Capability Enhancement Suite (ACCES)
Cost Estimating Methodology Matrix
Alternative 1: Status Quo

Element	Estimating Methodology
1.0 System Acquisition	**Assumed no acquisition efforts are required for the status quo.**
1.1 Acquisition Support	
1.2 Hardware Investment	
1.3 Software Investment	
1.4 Infrastructure Enhancements	
2.0 System Implementation	**Roll-up element**
2.1 Project Management	
2.2 Contract Management	15% of 1 GS-12 's labor is required.
2.3 Hardware Installation & Test	
2.4 Software Install & Test	
2.5 Data conversion	
2.6 User Acceptance	
2.7 Training	
3.0 Operation and Support	**Roll-up element**
3.1 System operations	Average salary of GS-14/15; 50 questions/yr; 240 hrs/question
3.2 Technical support	10% of System operations
3.3 Software maintenance and upgrades	$50,000/yr
3.4 Hardware maintenance and upgrades	$50,000/yr
3.5 Recurring training	Assumed no recurring training costs are required.
3.6 Other costs	25 trips per year @ $1,029/trip; $1,000/yr for consumables

Alternative #1, Status Quo (Constant FY02 $ 000)

Constant Year $ (000)	2002	2003	2004	2005	2006		Totals
1.0 System Acquisition	---	---	---	---	---		---
1.1 Acquisition Support	---	---	---	---	---		---
1.1.1 Project Management	---	---	---	---	---		---
1.1.2 RFP Preparation	---	---	---	---	---		---
1.1.3 RFP Evaluation and Vendor Selection	---	---	---	---	---		---
1.2 Hardware Investment	---	---	---	---	---		---
1.3 Software Investment	---	---	---	---	---		---
1.3.1 Software Development	---	---	---	---	---		---
1.3.2 SoftwareLicenses	---	---	---	---	---		---
1.4 Infrastructure Enhancements	---	---	---	---	---		---
2.0 System Implementation	**$ 13.25**	**$ 13.25**	**$ 13.25**	**$ 13.25**	**$ 13.25**		**$ 66.23**
2.1 Project Management	---	---	---	---	---		---
2.2 Contract Management	$ 13.25	$ 13.25	$ 13.25	$ 13.25	$ 13.25		$ 66.23
2.3 Hardware Installation and Test	---	---	---	---	---		---
2.4 Software Installation and Test	---	---	---	---	---		---
2.5 Data Conversion	---	---	---	---	---		---
2.6 User Acceptance	---	---	---	---	---		---
2.7 Training	---	---	---	---	---		---
2.7.1 Training Development	---	---	---	---	---		---
2.7.2 Train-the-Trainer	---	---	---	---	---		---
2.7.3 End User Training	---	---	---	---	---		---
3.0 Operations and Support	**$ 983.70**	**$ 983.70**	**$ 983.70**	**$ 983.70**	**$ 983.70**		**$ 4,918.50**
3.1 Systems Operations	$ 779.07	$ 779.07	$ 779.07	$ 779.07	$ 779.07		$ 3,895.34
3.2 Help Desk	$ 77.91	$ 77.91	$ 77.91	$ 77.91	$ 77.91		$ 389.53
3.3 Software Maintenance and Upgrades	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00		$ 250.00
3.4. Hardware Maintenance and Upgrades	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00		$ 250.00
3.5 Recurring Training	---	---	---	---	---		---
3.6. Other Costs	$ 26.73	$ 26.73	$ 26.73	$ 26.73	$ 26.73		$ 133.63
Totals	**$ 996.95**	**$ 996.95**	**$ 996.95**	**$ 996.95**	**$ 996.95**		**$ 4,984.73**

Alternative #1, Status Quo (Then Year $ 000)

Then Year $ (000)	2002	2003	2004	2005	2006		Totals
1.0 System Acquisition	---	---	---	---	---		
1.1 Acquisition Support	---	---	---	---	---		
1.1.1 Project Management	---	---	---	---	---		
1.1.2 RFP Preparation	---	---	---	---	---		
1.1.3 RFP Evaluation and Vendor Selection	---	---	---	---	---		
1.2 Hardware Investment	---	---	---	---	---		
1.3 Software Investment	---	---	---	---	---		
1.3.1 Software Development	---	---	---	---	---		
1.3.2 Software Licenses	---	---	---	---	---		
1.4 Infrastructure Enhancements	---	---	---	---	---		
2.0 System Implementation	**$ 13.25**	**$ 13.64**	**$ 14.05**	**$ 14.47**	**$ 14.91**		**$ 70.33**
2.1 Project Management	---	---	---	---	---		---
2.2 Contract Management	$ 13.25	$ 13.64	$ 14.05	$ 14.47	$ 14.91		$ 70.33
2.3 Hardware Installation and Test	---	---	---	---	---		
2.4 Software Installation and Test	---	---	---	---	---		
2.5 Data Conversion	---	---	---	---	---		
2.6 User Acceptance	---	---	---	---	---		
2.7 Training	---	---	---	---	---		
2.7.1 Training Development	---	---	---	---	---		
2.7.2 Train-the-Trainer	---	---	---	---	---		
2.7.3 End User Training	---	---	---	---	---		
3.0 Operations and Support	**$ 983.70**	**$ 1,013.21**	**$ 1,043.61**	**$ 1,074.92**	**$ 1,107.16**		**$ 5,222.59**
3.1 Systems Operations	$ 779.07	$ 802.44	$ 826.51	$ 851.31	$ 876.85		$ 4,136.18
3.2 Help Desk	$ 77.91	$ 80.24	$ 82.65	$ 85.13	$ 87.68		$ 413.62
3.3 Software Maintenance and Upgrades	$ 50.00	$ 51.50	$ 53.05	$ 54.64	$ 56.28		$ 265.46
3.4. Hardware Maintenance and Upgrades	$ 50.00	$ 51.50	$ 53.05	$ 54.64	$ 56.28		$ 265.46
3.5 Recurring Training	---	---	---	---	---		---
3.6. Other Costs	$ 26.73	$ 27.53	$ 28.35	$ 29.20	$ 30.08		$ 141.89
Totals	**$ 996.95**	**$ 1,026.85**	**$ 1,057.66**	**$ 1,089.39**	**$ 1,122.07**		**$ 5,292.92**

Cost Estimating Methodology Matrix
Alternative 2: Searchable Database

Element	Estimating Methodology
1.0 System Acquisition	**Roll-up element**
1.1 Acquisition Support	Roll-up element
1.1.1 Project Management	10% of 1 GS-15's labor for 8 months
1.1.2 RFP Preparation	25% of 2 GS-12s labor for 6 months
1.1.3 RFP Evaluation and Vendor Selection	100% of 2 GS-12s labor for 2 months
1.2 Hardware Investment	Assumed all hardware requirements are in place
1.3 Software Investment	Roll-up element
1.3.1 Software Development	Parametric estimate using SEER-SEM software cost estimating tool. Average loaded labor rate $14,300 per month. Assumed development of an Oracle database sized between 1,000 and 2,000 function points (40,000 to 80,000 source lines of code) Platform: Internet Development Application Type: Object Oriented Database Acquisition Method: New Development Development Method: Spiral Development Standard: Commercial Also assumed SAS integration of between 100 and 200 function points (3,200 to 6,400 source lines of code). Platform: Internet Development Application Type: Business Analysis Tool Acquisition Method: New Development Development Method: Off-the-Shelf Integration Development Standard: Commercial
1.3.2 Software Licenses	Oracle and SAS licenses for 500 users
1.4 Infrastructure Enhancements	Assumed all network requirements are in place
2.0 System Implementation	**Roll-up element**
2.1 Project Management	50% of 1 GS-14's labor for 18 months
2.2 Contract Management	15% of 1 GS-12's labor for 20 months (assuming that CM support will be required during the 2-month RFP evaluation period)
2.3 Hardware Installation & Test	Pursuant to element 1.2, assumed no effort is necessary
2.4 Software Install & Test	2 full-time vendor staff and 2 full-time GS-14s for 2 weeks, travel costs for the vendor staff
2.5 Data conversion and Entry	75% of 1 GS-12 for 17 months, 4 GS-7s for 5 months of data entry

2.6 User Acceptance	Assumed to be included in element 2.4
2.7 Training	Roll-up element
2.7.1 Training Development	2 GS-14s full-time for 1 year, 50% of 1 GS-12 for 6 months
2.7.2 Train-the-Trainer	Assumed the trainers are experts who need no additional training
2.7.3 End User Training	Assumed to be in element 3.5
3.0 Operation and Support	**Roll-up element**
3.1 System operations	Status quo costs with phase out plan
3.2 Technical support	Status quo costs with phase out plan, 1 GS-12 full-time after system implementation
3.3 Software maintenance and upgrades	$50,000/yr for normal upgrades ACCES application maintenance estimated using SEER-SEM. Assumed maintenance begins at the end of the development life cycle. 100% of system will be maintained, with an average annual change rate of 5%.
3.4 Hardware maintenance and upgrades	$50,000/yr
3.5 Recurring training	Three 45-hour training sessions per year – GS-14
3.6 Other costs	Status quo costs with phase out plan

Alternative #2, Searchable Database (Constant FY02 $ 000)

Constant Year $ (000)	2002	2003	2004	2005	2006		Totals
1.0 System Acquisition	**$ 323.57**	**$ 1,625.13**	**$ 214.66**	**---**	**---**		**$ 2,163.36**
1.1 Acquisition Support	$ 61.25	---	---	---	---		$ 61.25
1.1.1 Project Management	$ 9.73	---	---	---	---		$ 9.73
1.1.2 RFP Preparation	$ 22.08	---	---	---	---		$ 22.08
1.1.3 RFP Evaluation and Vendor Selection	$ 29.44	---	---	---	---		$ 29.44
1.2 Hardware Investment	---	---	---	---	---		---
1.3 Software Investment	$ 262.33	$ 1,625.13	$ 214.66	---	---		$ 2,102.12
1.3.1 Software Development	$ 136.33	$ 1,625.13	$ 214.66	---	---		$ 1,976.12
1.3.2 Software Licenses	$ 126.00	---	---	---	---		$ 126.00
1.4 Infrastructure Enhancements	---	---	---	---	---		---
2.0 System Implementation	**$ 60.42**	**$ 370.48**	**$ 171.32**	**---**	**---**		**$ 602.22**
2.1 Project Management	$ 20.68	$ 62.05	$ 10.34	---	---		$ 93.08
2.2 Contract Management	$ 6.62	$ 13.25	$ 2.21	---	---		$ 22.08
2.3 Hardware Installation and Test	---	---	---	---	---		---
2.4 Software Installation and Test	---	---	$ 39.98	---	---		$ 39.98
2.5 Data Conversion and Entry	$ 33.12	$ 77.31	$ 66.38	---	---		$ 176.80
2.6 User Acceptance	---	---	---	---	---		---
2.7 Training	---	$ 217.87	$ 52.41	---	---		$ 270.28
2.7.1 Training Development	---	$ 217.87	$ 52.41	---	---		$ 270.28
2.7.2 Train-the-Trainer	---	---	---	---	---		---
2.7.3 End User Training	---	---	---	---	---		---
3.0 Operations and Support	**$ 983.70**	**$ 983.70**	**$ 1,228.33**	**$ 1,040.95**	**$ 734.32**		**$ 4,971.00**
3.1 Systems Operations	$ 779.07	$ 779.07	$ 584.30	$ 389.53	$ 194.77		$ 2,726.74
3.2 Technical Support	$ 77.91	$ 77.91	$ 132.02	$ 127.26	$ 107.79		$ 522.88
3.3 Software Maintenance and Upgrades	$ 50.00	$ 50.00	$ 433.91	$ 452.74	$ 367.03		$ 1,353.68
3.4. Hardware Maintenance and Upgrades	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00		$ 250.00
3.5 Recurring Training	---	---	$ 8.05	$ 8.05	$ 8.05		$ 24.16
3.6. Other Costs	$ 26.73	$ 26.73	$ 20.04	$ 13.36	$ 6.68		$ 93.54
Totals	**$ 1,367.70**	**$ 2,979.31**	**$ 1,614.31**	**$ 1,040.95**	**$ 734.32**		**$ 7,736.58**

Alternative #2, Searchable Database (Then Year $ 000)

Then Year $ (000)	2002	2003	2004	2005	2006		Totals
1.0 System Acquisition	**$ 323.57**	**$ 1,696.64**	**$ 228.83**	**---**	**---**		**$ 2,249.04**
1.1 Acquisition Support	$ 61.25	---	---	---	---		$ 61.25
1.1.1 Project Management	$ 9.73	---	---	---	---		$ 9.73
1.1.2 RFP Preparation	$ 22.08	---	---	---	---		$ 22.08
1.1.3 RFP Evaluation and Vendor Selection	$ 29.44	---	---	---	---		$ 29.44
1.2 Hardware Investment	---	---	---	---	---		---
1.3 Software Investment	$ 262.33	$ 1,696.64	$ 228.83	---	---		$ 2,187.79
1.3.1 Software Development	$ 136.33	$ 1,696.64	$ 228.83	---	---		$ 2,061.79
1.3.2 SoftwareLicenses	$ 126.00	---	---	---	---		$ 126.00
1.4 Infrastructure Enhancements	---	---	---	---	---		---
2.0 System Implementation	**$ 60.42**	**$ 386.78**	**$ 182.63**	**---**	**---**		**$ 629.83**
2.1 Project Management	$ 20.68	$ 64.78	$ 11.02	---	---		$ 96.49
2.2 Contract Management	$ 6.62	$ 13.83	$ 2.35	---	---		$ 22.81
2.3 Hardware Installation and Test	---	---	---	---	---		---
2.4 Software Installation and Test	---	---	$ 42.62	---	---		$ 42.62
2.5 Data Conversion	$ 33.12	$ 80.71	$ 70.76	---	---		$ 184.59
2.6 User Acceptance	---	---	---	---	---		---
2.7 Training	---	$ 227.46	$ 55.86	---	---		$ 283.33
2.7.1 Training Development	---	$ 227.46	$ 55.86	---	---		$ 283.33
2.7.2 Train-the-Trainer	---	---	---	---	---		---
2.7.3 End User Training	---	---	---	---	---		---
3.0 Operations and Support	**$ 983.70**	**$ 1,026.98**	**$ 1,309.40**	**$ 1,132.56**	**$ 815.83**		**$ 5,268.47**
3.1 Systems Operations	$ 779.07	$ 813.35	$ 622.86	$ 423.81	$ 216.39		$ 2,855.48
3.2 Technical Support	$ 77.91	$ 81.33	$ 140.73	$ 138.46	$ 119.75		$ 558.19
3.3 Software Maintenance and Upgrades	$ 50.00	$ 52.20	$ 462.55	$ 492.58	$ 407.77		$ 1,465.10
3.4. Hardware Maintenance and Upgrades	$ 50.00	$ 52.20	$ 53.30	$ 54.40	$ 55.55		$ 265.45
3.5 Recurring Training	---	---	$ 8.59	$ 8.76	$ 8.95		$ 26.30
3.6. Other Costs	$ 26.73	$ 27.90	$ 21.37	$ 14.54	$ 7.42		$ 97.95
Totals	**$ 1,367.70**	**$ 3,110.40**	**$ 1,720.85**	**$ 1,132.56**	**$ 815.83**		**$ 8,147.33**

Air Combat Capability Enhancement Suite (ACCES)
Cost Estimating Methodology Matrix
Alternative 3: Searchable Database with Expert Interface

Element	Estimating Methodology
1.0 System Acquisition	**Roll-up element**
1.1 Acquisition Support	Roll-up element
1.1.1 Project Management	10% of 1 GS-15's labor for 9 months
1.1.2 RFP Preparation	35% of 2 GS-12s labor for 6 months
1.1.3 RFP Evaluation and Vendor Selection	100% of 2 GS-12s labor for 3 months
1.2 Hardware Investment	Assumed all hardware requirements are in place
1.3 Software Investment	Roll-up element
1.3.1 Software Development	Parametric estimate using SEER-SEM software cost estimating tool. Average loaded labor rate $14,300 per month. Assumed development of an Oracle database sized between 1,000 and 2,000 function points (40,000 to 80,000 source lines of code) Platform: Internet Development Application Type: Object Oriented Database Acquisition Method: New Development Development Method: Spiral Development Standard: Commercial Also assumed SAS integration of between 100 and 200 function points (3,200 to 6,400 source lines of code). Platform: Internet Development Application Type: Business Analysis Tool Acquisition Method: New Development Development Method: Off-the-Shelf Integration Development Standard: Commercial Also assumed development of expert interface tool consisting of 5 templates, coded in a 4th generation programming language. Each template sized between 250 and 450 function points (5,000 to 9,000 source lines of code) Platform: Internet Development Application Type: Business Analysis Tool Acquisition Method: New Development Development Method: Spiral Development Standard: Commercial
1.3.2 Software Licenses	Oracle and SAS licenses for 500 users
1.4 Infrastructure Enhancements	Assumed all network requirements are in place

2.0 System Implementation	**Roll-up element**
2.1 Project Management	50% of 1 GS-14's labor for 20 months
2.2 Contract Management	15% of 1 GS-12's labor for 22 months (assuming that CM support will be required during the RFP evaluation period)
2.3 Hardware Installation & Test	Pursuant to element 1.2, assumed no effort is necessary
2.4 Software Install & Test	2 full-time vendor staff and 2 full-time GS-14s for 3 weeks, travel costs for the vendor staff
2.5 Data conversion and Entry	67% of 1 GS-12 for 19 months, 4 GS-7s for 5 months of data entry
2.6 User Acceptance	Assumed to be included in element 2.4
2.7 Training	Assumed no training required
3.0 Operations and Support	**Roll-up element**
3.1 System operations	Status quo costs with phase out plan
3.2 Technical support	Status quo costs with phase out plan, 1 GS-12 full-time after system implementation
3.3 Software maintenance and upgrades	$50,000/yr for normal upgrades ACCES application maintenance estimated using SEER-SEM. Assumed maintenance begins at the end of the development life cycle. 100% of system will be maintained, with an average annual change rate of 5%.
3.4 Hardware maintenance and upgrades	$50,000/yr
3.5 Recurring training	Three 45-hour training sessions per year – GS-14
3.6 Other costs	Status quo costs with phase out plan

Alternative #3, Searchable Database with Expert Interface (Constant Year FY02 $ 000)

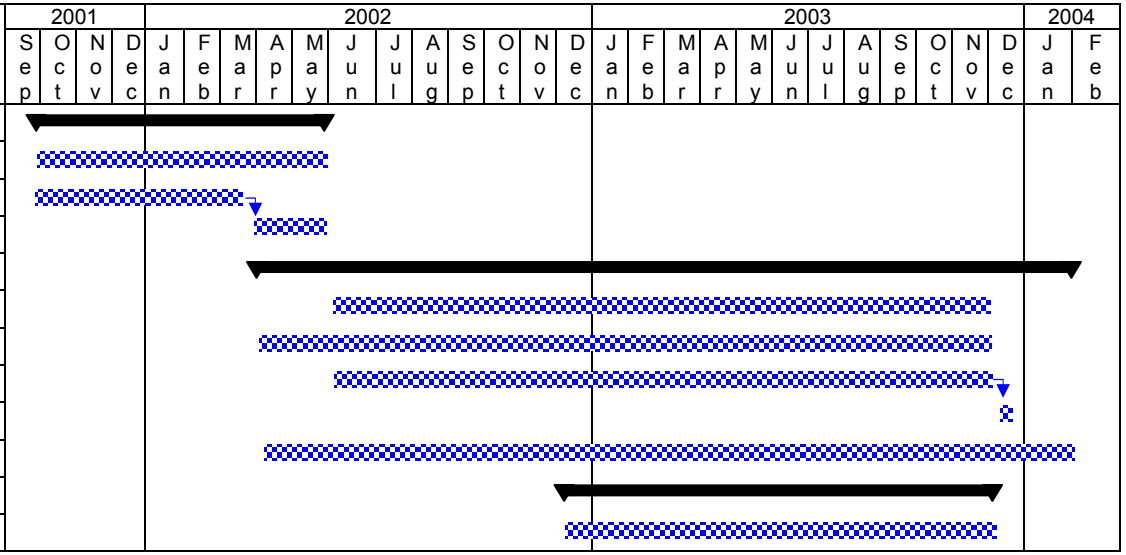
Constant Year $ (000)	2002	2003	2004	2005	2006		Totals
1.0 System Acquisition	**$ 721.10**	**$ 4,123.82**	**$ 1,227.06**	**---**	**---**		**$ 6,071.98**
1.1 Acquisition Support	$ 86.01	---	---	---	---		$ 86.01
1.1.1 Project Management	$ 10.95	---	---	---	---		$ 10.95
1.1.2 RFP Preparation	$ 30.91	---	---	---	---		$ 30.91
1.1.3 RFP Evaluation and Vendor Selection	$ 44.15	---	---	---	---		$ 44.15
1.2 Hardware Investment	---	---	---	---	---		---
1.3 Software Investment	$ 635.09	$ 4,123.82	$ 1,227.06	---	---		$ 5,985.97
1.3.1 Software Development	$ 509.09	$ 4,123.82	$ 1,227.06	---	---		$ 5,859.97
1.3.2 SoftwareLicenses	$ 126.00	---	---	---	---		$ 126.00
1.4 Infrastructure Enhancements	---	---	---	---	---		---
2.0 System Implementation	**$ 45.69**	**$ 134.46**	**$ 173.84**	**---**	**---**		**$ 353.99**
2.1 Project Management	$ 15.51	$ 62.05	$ 25.85	---	---		$ 103.42
2.2 Contract Management	$ 5.52	$ 13.25	$ 5.52	---	---		$ 24.29
2.3 Hardware Installation and Test	---	---	---	---	---		---
2.4 Software Installation and Test	---	---	$ 49.63	---	---		$ 49.63
2.5 Data Conversion	$ 24.65	$ 59.17	$ 92.84	---	---		$ 176.66
2.6 User Acceptance	---	---	---	---	---		---
2.7 Training	---	---	---	---	---		---
2.7.1 Training Development	---	---	---	---	---		---
2.7.2 Train-the-Trainer	---	---	---	---	---		---
2.7.3 End User Training	---	---	---	---	---		---
3.0 Operations and Support	**$ 983.70**	**$ 983.70**	**$ 1,959.34**	**$ 1,902.36**	**$ 1,195.64**		**$ 7,024.74**
3.1 Systems Operations	$ 779.07	$ 779.07	$ 584.30	$ 389.53	$ 194.77		$ 2,726.74
3.2 Technical Support	$ 77.91	$ 77.91	$ 109.94	$ 127.26	$ 107.79		$ 500.81
3.3 Software Maintenance and Upgrades	$ 50.00	$ 50.00	$ 1,195.05	$ 1,322.20	$ 836.41		$ 3,453.66
3.4. Hardware Maintenance and Upgrades	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00		$ 250.00
3.5 Recurring Training	---	---	---	---	---		---
3.6. Other Costs	$ 26.73	$ 26.73	$ 20.04	$ 13.36	$ 6.68		$ 93.54
Totals	**$ 1,750.49**	**$ 5,241.98**	**$ 3,360.25**	**$ 1,902.36**	**$ 1,195.64**		**$ 13,450.72**

Alternative #3, Searchable Database with Expert Interface (Then Year $ 000)

Then Year $ (000)	2002	2003	2004	2005	2006		Totals
1.0 System Acquisition	**$ 721.10**	**$ 4,305.26**	**$ 1,308.05**	**---**	**---**		**$ 6,334.42**
1.1 Acquisition Support	$ 86.01	---	---	---	---		$ 86.01
1.1.1 Project Management	$ 10.95	---	---	---	---		$ 10.95
1.1.2 RFP Preparation	$ 30.91	---	---	---	---		$ 30.91
1.1.3 RFP Evaluation and Vendor Selection	$ 44.15	---	---	---	---		$ 44.15
1.2 Hardware Investment	---	---	---	---	---		---
1.3 Software Investment	$ 635.09	$ 4,305.26	$ 1,308.05	---	---		$ 6,248.41
1.3.1 Software Development	$ 509.09	$ 4,305.26	$ 1,308.05	---	---		$ 6,122.41
1.3.2 SoftwareLicenses	$ 126.00	---	---	---	---		$ 126.00
1.4 Infrastructure Enhancements	---	---	---	---	---		---
2.0 System Implementation	**$ 45.69**	**$ 140.38**	**$ 185.32**	**---**	**---**		**$ 371.38**
2.1 Project Management	$ 15.51	$ 64.78	$ 27.56	---	---		$ 107.85
2.2 Contract Management	$ 5.52	$ 13.83	$ 5.88	---	---		$ 25.23
2.3 Hardware Installation and Test	---	---	---	---	---		---
2.4 Software Installation and Test	---	---	$ 52.91	---	---		$ 52.91
2.5 Data Conversion	$ 24.65	$ 61.77	$ 98.96	---	---		$ 185.39
2.6 User Acceptance	---	---	---	---	---		---
2.7 Training	---	---	---	---	---		---
2.7.1 Training Development	---	---	---	---	---		---
2.7.2 Train-the-Trainer	---	---	---	---	---		---
2.7.3 End User Training	---	---	---	---	---		---
3.0 Operations and Support	**$ 983.70**	**$ 1,026.98**	**$ 2,088.66**	**$ 2,069.77**	**$ 1,328.36**		**$ 7,497.46**
3.1 Systems Operations	$ 779.07	$ 813.35	$ 622.86	$ 423.81	$ 216.39		$ 2,855.48
3.2 Technical Support	$ 77.91	$ 81.33	$ 117.20	$ 138.46	$ 119.75		$ 534.65
3.3 Software Maintenance and Upgrades	$ 50.00	$ 52.20	$ 1,273.93	$ 1,438.55	$ 929.25		$ 3,743.93
3.4. Hardware Maintenance and Upgrades	$ 50.00	$ 52.20	$ 53.30	$ 54.40	$ 55.55		$ 265.45
3.5 Recurring Training	---	---	---	---	---		---
3.6. Other Costs	$ 26.73	$ 27.90	$ 21.37	$ 14.54	$ 7.42		$ 97.95
Totals	**$ 1,750.49**	**$ 5,472.63**	**$ 3,582.03**	**$ 2,069.77**	**$ 1,328.36**		**$ 14,203.26**

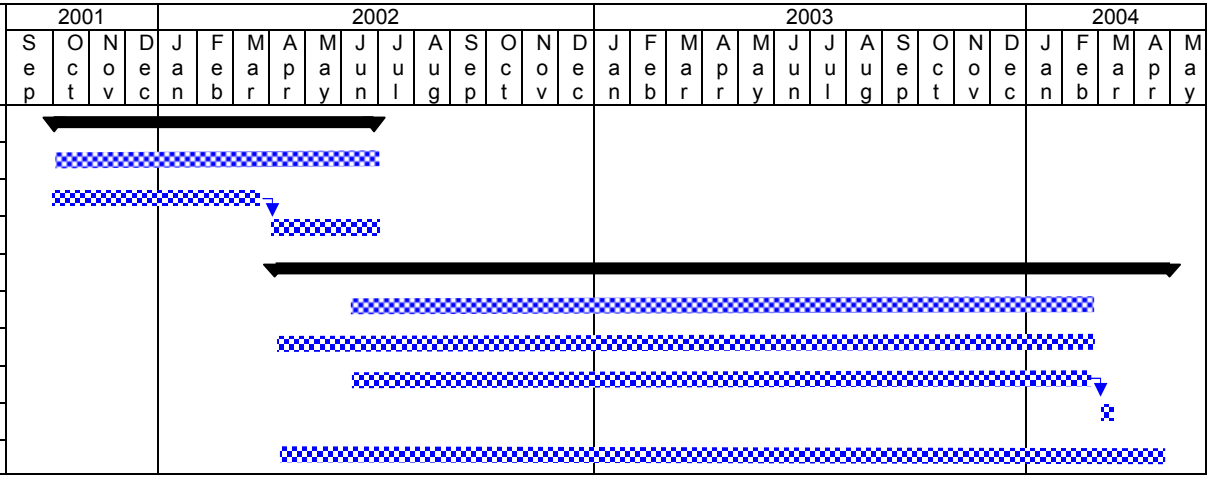
Project Schedule
Alternative #2, Searchable Database

ID	Task Name	Start	Finish
1	**Acquisition Support**	**Mon 10/1/01**	**Fri 5/31/01**
2	Project Management	Mon 10/1/01	Fri 5/31/01
3	RFP Preparation	Mon 10/1/01	Fri 3/29/02
4	RFP Evaluation and Vendor Selection	Mon 4/1/02	Fri 5/31/02
5	**System Implementation**	**Mon 4/1/02**	**Fri 1/30/04**
6	Program Management	Mon 6/3/02	Fri 11/28/03
7	Contract Management	Mon 4/1/02	Fri 11/28/03
8	Software Development	Mon 6/3/02	Fri 11/28/03
9	Software Installation and Testing	Mon 12/1/03	Fri 12/12/03
10	Data Conversion and Entry	Mon 4/1/02	Fri 1/30/04
11	**Training**	**Mon 12/2/02**	**Fri 11/28/03**
12	Training Development	Mon 12/2/02	Fri 11/28/03



Project Schedule
Alternative #3, Searchable Database with Expert Interface

ID	Task Name	Start	Finish
1	**Acquisition Support**	**Mon 10/1/01**	**Fri 6/28/01**
2	Project Management	Mon 10/1/01	Fri 6/28/01
3	RFP Preparation	Mon 10/1/01	Fri 3/29/02
4	RFP Evaluation and Vendor Selection	Mon 4/1/02	Fri 6/28/02
5	**System Implementation**	**Mon 4/1/02**	**Fri 4/30/04**
6	Program Management	Mon 7/1/02	Fri 2/27/04
7	Contract Management	Mon 4/1/02	Fri 2/27/04
8	Software Development	Mon 7/1/02	Fri 2/27/04
9	Software Installation and Testing	Mon 3/1/03	Fri 3/19/04
10	Data Conversion and Entry	Wed 5/1/02	Fri 1/30/04



APPENDIX B. PAIR-WISE COMPARISON OF ALTERNATIVES

Table B-1 shows the all the benefit pairwise comparisons.

Table B-1. Global Table of Pairwise Comparisons

ACCESS	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	⑦	8	9	ACCURACY
ACCESS	9	8	7	6	⑤	4	3	2	**1**	2	3	4	5	6	7	8	9	EFFICIEN
ACCESS	9	8	7	6	5	4	3	2	**1**	2	3	4	5	⑥	7	8	9	SCOPE
ACCESS	9	8	7	6	5	4	3	2	**1**	②	3	4	5	6	7	8	9	USABL'TY
ACCURACY	9	8	⑦	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	EFFICIEN
ACCURACY	9	8	7	6	⑤	4	3	2	**1**	2	3	4	5	6	7	8	9	SCOPE
ACCURACY	9	8	⑦	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	USABL'TY
EFFICIEN	9	8	7	6	5	4	3	2	**1**	2	3	4	5	⑥	7	8	9	SCOPE
EFFICIEN	9	8	7	6	5	4	3	2	**1**	②	3	4	5	6	7	8	9	USABL'TY
SCOPE	9	8	⑦	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	USABL'TY

Ratings: 1 = Equal; 3 = Moderate; 5 = Strong; 7 = Very Strong; 9 = Extreme
Example of interpretation: Accuracy (ACCURACY) is strongly more important than scope (SCOPE).

While Table B-1 shows the global summary of comparisons, the purpose of this evaluation was to assess potential benefits of fielding new anthropometric information systems compared to the status quo. It was also to "quantify" the subjective qualities of both the existing and presented system benefits. When combined with cost estimate, this data will contribute to the overall CBA results.

Please note that this appendix is intended to support information found in the benefits analysis, Section 2.6, it may repeat information found in the body of this document. The repetition is intended to allow this appendix to stand alone as a separate entity.

Recall that the customer defined goal for the three alternative anthropometric systems was to develop an international anthropometric size, shape, fit and accommodation information system for efficient and effective use by designers, manufacturers, buyers, and decision makers across a number of domains. It is with respect to this goal that all alternatives were assessed.

A table of global benefits can be found in Table B-2 below.

Table B-2. Benefits and Their Definitions

Benefit	Working Definition
Accessibility	System impact on ease of accessing anthropometric information; the number and type of individuals that can locate the info.
Accuracy	System impact on currency, correctness, and direct use of fit/accommodation information. Information provided is the correct solution for the task at hand.
Efficiency	System impact on speed of finding anthropometric fit/accommodation information. A more efficient system will require less time invested.
Scope	System impact on sufficiency of anthropometric fit/accommodation information provided to user. Information provided is in-depth enough to meet user's needs.
Usability	Ease of system use in accessing anthropometric fit/accommodation information. Level of effort required of designer to find information. A highly useable system requires little effort.

To reiterate, the investment alternatives were:

- Alternative #1 Status Quo - The first alternative assessed by the Expert Choice Team was the fielded system described in Section 2.1.2.
- Alternative #2 Searchable Database - The second alternative discussed by the Expert Choice Team was the searchable database described in Section 2.3.2.
- Alternative #3 Searchable Database with Expert Interface - The final alternative assessed by the Expert Choice Team was the searchable database combined with an expert interface capability, described in Section 2.3.2.

When ranking the three alternatives for each benefit, the Expert Choice team followed specific steps. These were:

- Review goal, benefits, and alternative definitions,
- Discuss examples of each benefit, then rank all benefits, and
- Identify variations between alternatives, then rank alternatives for each benefit

The following sections outline the pairwise comparisons made with respect to the investment alternatives and the benefits.

ACCESSIBILITY

Table B-3 shows the pairwise comparisons associated with the Accessibility benefit.

Table B-3. Accessibility Comparison

STAT QUO	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	⑦	8	9	DAT'BASE
STAT QUO	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	⑧	9	DBW/EXP
DAT'BASE	9	8	7	6	5	4	3	2	**1**	2	③	4	5	6	7	8	9	DBW/EXP

Definition

System impact on ease of accessing anthropometric information; the number and type of individuals that can locate the info.

Example

Some designers have access to up to date information or know where to look and some do not. Depending on the publicity of the source, some information is simply difficult to find and asking an expert is the only way designers would even know it existed.

Answers the question, "Who knows about and has access to the required information?"

Background on Investment Alternatives

"The lack of readily available and reliable data on (anthropometry)… is … a problem." (Ergotech, 2001). It is known that ANSUR 88 is reasonably available for use, but its current utility may be questionable. On the other hand, CAESAR data is more up-to-date and accurate, but few decision makers have access to it.

Alternative #1

With this alternative, novices would seek out information on their own through books, journals, and the like. Information could be gathered from printed standards and handbooks such as MIL-STD-1472, and MIL-HDBK-743, as well as journal articles, and human factors textbooks. The existence of the appropriate information and the expertise needed to find or use that information may not be known by the user. An expert consultant, such as someone at AFRL/HE, is sometimes used to find the appropriate data and put it in a useful form for the particular project or problem. For example, a manufacturer of an oxygen mask may not know there is a 3-D face data resource available.

Alternative #2

All of the above accessibility is included. Previously unincorporated sources will also be brought together, putting all pertinent information in the same place. As a result, information is located in or its location can be identified from one central information system location. This would include data from outside organizations worldwide.

Alternative #3

All of the above accessibility is included.

ACCURACY

Table B-4 shows the pairwise comparisons associated with the accuracy benefit.

Table B-4. Accuracy Comparison

STAT QUO	9	8	7	6	5	4	3	2	**1**	2	3	④	5	6	7	8	9	DAT'BASE
STAT QUO	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	⑧	9	DBW/EXP
DAT'BASE	9	8	7	6	5	4	3	2	**1**	2	3	④	5	6	7	8	9	DBW/EXP

Definition

System impact on currency, correctness, and direct use of fit/accommodation information. Information provided is the correct solution for the task at hand.

Example

Information provided is up to date and intended for design use. Information is appropriate for the context and intended use.

Answers question, "How correct is the information provided as it pertains to its intended use?"

Background on Investment Alternatives

Percentiles and averages are not always the best or most accurate source of design information. Similarly, current 3-D models are poor representations based on 1-D measurements (Robinette, 2001). "The lack of readily available and reliable data on (anthropometry)… and infrequent updating of populations is also a problem" (Ergotech, 2001). In fact, an estimated 9 percent of all aircraft accidents are anthropometry-related (Zehner, 2001). Furthermore, "Furniture, work tools, and personal protective equipment are areas where inadequate anthropometric data can result in ill-fitting and potentially unsafe designs…" (Phillips, 1995, p. 1)

Alternative #1

Novices must use printed texts with summary statistics from preset surveys such as mean, standard deviation, and percentiles. The sample used may not be representative of the desired population. Even the experts face the same problems, but know of more/better resources for accurate information.

Alternative #2

The information used by experts should be accurate and up to date. The database can be added by the user and updated using a standard database format. Novices using this system could get accurate information, but may not ask the right questions

Alternative #3

This system can be used by experts for advanced problems, research, or to override the generic output if desired. This might be necessary to use the most up-to-date methods as technology advances are made. The systems should also have about the same high level of accuracy for novices.

EFFICIENCY

Table B-5 shows the pairwise comparisons associated with the efficiency benefit.

Table B-5. Efficiency Comparison

STAT QUO	9	8	7	6	5	4	3	2	**1**	2	3	④	5	6	7	8	9	DAT'BASE
STAT QUO	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	⑦	8	9	DBW/EXP
DAT'BASE	9	8	7	6	5	4	3	2	**1**	2	3	④	5	6	7	8	9	DBW/EXP

Definition

System impact on speed of finding anthropometric fit/accommodation information. A more efficient system will require less time invested.

Example

A database can give immediate results, while contacting an expert could take one or more weeks to receive answer.

Answers question, "How long does it take to get answer?"

Background on Investment Alternatives

A 70 percent solution on time is more favorable than a 95 percent solution too late to be of use.

Alternative #1

Novices using books, journals, etc., must look up solutions on their own. For novices asking questions, it could take some time to get response. For experts answering questions, this method is not efficient as information may or may not be readily available. The consultant may or may not have the software and data resources readily available to accomplish this; therefore, these may have to be separately acquired. The information is not in a central location, nor can its location be found from one central resource.

Alternative #2

There was improved efficiency for experts using this system. Information will be located in the database or its location can be identified from one central information system, improving efficiency. This would include data from outside organizations worldwide. Database would be one- and three-dimensional searchable on-line, with sample merging, weighting and segmenting capability. This enables the creation of a more representative sample of the population of interest, such as the Joint Primary Aircrew Training System (JPATS) sample, or the National Health and Nutrition Examination Survey (NHANES) sample.

This solution does little to help novice, however.

Alternative #3

Expert interface should improve efficiency by significantly reducing time required to identify and locate necessary information. Should have about same, improved, efficiency for novice.

SCOPE

Table B-6 shows the pairwise comparisons associated with the scope benefit.

Table B-6. Scope Comparison

STAT QUO	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	⑦	8	9	DAT'BASE
STAT QUO	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	⑧	9	DBW/EXP
DAT'BASE	9	8	7	6	5	4	3	2	**1**	2	③	4	5	6	7	8	9	DBW/EXP

Definition

System impact on completeness and sufficiency of anthropometric fit/accommodation information provided to user. Information provided is in-depth enough to meet user's needs.

Example

A book could provide quick anthropometric information, but not enough of the right kind of information needed. A database could provide the right kind of information, but too much of it for the user to comprehend.

Answers the question, "What do I need to know to make an anthro/design decision?"

Background on Investment Alternatives

Matching crew with equipment is a two-part process (Robinette, 1999). In-depth information is needed for both steps:

1. Assigning crew to appropriate billets (over time), and
2. Sizing, issuing and stocking, appropriate apparel and personal equipment.

Alternative #1

A novice searching for information may not get all the information that he/she needs. Expert searching for information might be able to find everything he/she needs, for example: One-dimensional (traditional tape measure, caliper type) data by survey in spreadsheets on CD, such as the Army 1988 survey, the USAF mini-survey, etc.

Alternative #2

This system provides improved scope for experts and novices. Lessons learned and fit and accommodation maps are included. Also included are Human system equipment size and shape information and interfacing 3-D visualization and statistical analysis tools. As a result, novices may have difficulty identifying and using appropriate information (see Usability)

Alternative #3

This alternative has the same scope as above.

USABILITY

Table B-7 shows the pairwise comparisons associated with the usability benefit.

Table B-7. Usability Comparison

STAT QUO	9	8	7	6	5	4	3	2	**1**	2	3	4	⑤	6	7	8	9	DAT'BASE
STAT QUO	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	⑧	9	DBW/EXP
DAT'BASE	9	8	7	6	5	4	3	2	**1**	2	3	④	5	6	7	8	9	DBW/EXP

Definition

Ease of system use in accessing anthropometric fit/accommodation information. Level of effort required of designer to find information. A highly useable system requires little effort.

Example

A highly useable system provides information in a simple format with low demands on user. There is little training or extra work involved with a highly useable system.

Answers question, "How easy is it to access the required information?"

Background on Investment Alternatives

Current 3-D anthropometry information is not in a readily usable form and distilling is necessary (Robinette, 1999). "The future application of this (anthropometric) knowledge is in software packages and their ability to interact with one another." (Tucker & Brattin, 2000, p. 5)

Alternative #1

For novices asking questions, this system is reasonably usable. They simply have to ask questions of experts and wait for answer. They also can just look in books and find answers.

For experts answering questions, this system is much less usable. This is because information is not very accessible.

Alternative #2

This alternative is moderately usable by experts. Electronic accommodation or fit prediction models are included. On the other hand, this system is not very usable by novices. It requires a knowledgeable expert to locate the most appropriate information and answer the questions in many cases.

Alternative #3

This system has an interface that allows experts and novices to locate the appropriate information in the form needed, by simply asking a question. It will walk them through to the answer. Some sample questions include:

- Would this candidate be able to safely fly USAF fighter aircraft? Answer would include the aircraft that could be safely flown as well as any areas that might be on the borderline and by how much.
- What percentage of the population would be able to fly this aircraft if this change were made? The interface would ask the novice questions to ascertain exactly what the population of interest might be. The answer would include the overall population, the male and the female populations and the minority population percentages.
- What should the requirements be for a new oxygen mask? The interface would ask the novice questions to ascertain how the oxygen mask is intended to fit and function, and who the intended users would be using examples and pictures (3-D if available) from the fit history files. The answer would include the statements to be written in the specification, and the data on the cases (3-D if necessary and available) to use to accommodate the population.

APPENDIX C. LITERATURE SEARCH STRATEGY

Air Combat Capability Enhancement Suite (ACCES)
Cost Benefit Analysis

Literature Search Strategy

For: Air Force Research Laboratory
Wright-Patterson Air Force Base, OH

Background:

Human Systems IAC is conducting a cost benefit analysis on the Air Combat Capability Enhancement Suite (ACCES). This effort is tasked with developing and demonstrating an anthropometric fit and accommodation information system for use by decision-makers across a number of domains. It will provide three major resources: a) a data base of current forces and the best equipment size, adjustments, etc. for usability, fit, and safety, b) the best mix of stocked/special order/custom personal equipment sizes for rapid and cost-effective deployment, and c) information on areas of improvement for more cost-effective fit, assignment entry and fitness standards, and purchasing.

The specific goal of this literature search is to review recent literature on the three main topics: a) Human variability of advanced methods of characterizing human variability , b) anthropometric variability and the relationship between anthropometry and equipment systems, and c) anthropometry and accommodation data resources and issues, such as new information system methods, 3-D shape searching that allow a non-professional to get useable information.. The search results will help Human Systems IAC identify and understand the problems associated with the above issues. This review should also help identify the available alternatives and what the potential payoffs are for continuing R&D in the area of anthropometric databases and information presentation. This information will then be evaluated with the cost data to determine the alternative technology with the greatest return on investment.

The results of the literature search strategy will be used to derive cost and benefits as appropriate. The results are especially important in capturing the "value" of benefits in order to quantify them in our final analysis.

Search Terms:

See attached table of terms.

Key Authors:

Claire Gordon
Kenneth W. Kennedy
Kathleen M. Robinette
Gregory F. Zehner
Jennifer Crawford
Joseph Licina
Jeff Hudson
Brian Corner
Seven Daquette
Eric Paquet
Michael Vannier
Bruce Bradtmiller
Regis Mollard
Hein Daanen

Possible Databases: (Final list to be determined based on customer and expert searcher recommendations)
Aerospace Database
ISI Science Citation Index
NASA Recon
NTIS
PsychINFO
Naval Research Labs
U.S. Army Research Labs

Example Articles:

Topic 1: Human Variability is More Than a Small Female and a Large Male

Daniels, G.S.. 1952. *The Average Man?*. TN-WCRD 53-7. (AD 10 203) Wright Air Development Center, Wright-Patterson Air Force Base, OH.

Hendy, K.C.. (1990). Aircrew/Cockpit compatibility-a multivariate problem seeking a multivariate solution, in *AGARD, Recruiting, Selection, Training and Military Operations of Female Aircrew.* Defense and Civil Institute of Environmental Medician, Downsview Ontario.

Robinette, Kathleen M. and John T. McConville, 1982. "An Alternative to Percentile Models", SAE Technical Paper 810217, in *1981 SAE Transactions*, pp. 938-946, Society of Automotive Engineers, Warrendale, PA.

Zehner, G.F., Meindl, R.S., and Hudson, J.A. (1993). *A Multivariate Anthropometric Method for Crew Stations Design: Abridged*, AL-TR-1992-0164, Armstrong Laboratory, Air Force Systems Command, Wright Patterson Air Force Base, OH

Topic 2: Need to Know Both Anthropometric Variability AND The Relationship Between Anthropometry and Equipment Systems

Robinette, K.M. (2000) 3-D Fit Mapping. In *Proceedings of the International Ergonomics Association XIVth Triennial Congress and Human Factors and Ergonomics Society-44th Annual Meeting,* Human Factors and Ergonomics Society Inc., Santa Monica, CA .

Whitestone, J.J. and Robinette, K.M. (1997) Fitting to maximize performance of HMD systems, in *Head Mounted Displays, Designing for the User, editors Melzer, J. and Moffitt, K., chapter 7,pp. 175-202,* McGraw Hill Publishing, New York, New York.

Zehner, Gregory; Kennedy, Kenneth; Hudson, Jeffrey; Ivey, Larry; Andrews, Jenny Lt. (1997), *Anthropometric Accommodation in Training Aircraft*, Proceedings of the Thirty Fifth Annual Symposium SAFE Association, pp 373-379.

Topic 3: Anthropometry and Accommodation Data Resources and Issues

Churchill, E., T. Churchill, and P. Kikta. (1977). *The AMRL Anthropometric Data Bank Library: Volumes I-V,* AMRL-TR-77-1 (AD Ao47 314), Aerospace Medical Research Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, OH.

Coblentz, A., J.C. Pineau, and G. Ignazi.(1992). Ergodata an on line data base for ergonomics, *Proceedings of the 2nd Pan Pacific Conference on Occupational Ergonomics, "Ergonomics in Occupational Safety and Health"*, Safety and Environmental Protection Research Institute, MMI, Wuhan, China.

Robinette, K.M., Vannier, M.W., Rioux, M., and Jones, P.R.M. (1997*) 3-D Surface Anthropometry: Review of Technologies*, AGARD Advisory Report No. 329, Advisory Group for Aerospace Research and Development, 7 Rue Ancelle, 92200 Neuilly-Sur-Seine, France.

Robinson, J., Robinette, K.M. and Zehner, G.F. (1992). *User's Guide to the Anthropometric Data Base at the Computerized Anthropometric Research and Design (CARD) Laboratory*, AL-TR-1992-0036, Crew Systems Directorate, Human Engineering Division, Armstrong Laboratory, Wright-Patterson Air Force Base OH.

Rogers-Adams, Beth M., Andrew, J. Capt., Zehner, Gregory F. (1998). *Anthropometric Accommodation in USAF Training Aircraft: A Comparison of Operational Requirements*, Proceedings of the Thirty Sixth Annual Symposium SAFE Association pp 250-257.

ACCES CBA SEARCH STRATEGY								
	Main Ideas		Secondary Terms		Search Focus		Additional Items of Interest
1	Anthropometric accommodation Anthropometry	A N D	Human body size Human models Sizes	A N D	Multivariate Analysis Percentile	A N D	
	Goal: To acquire documents that define human variability.						
2	Anthropometric accommodation Cockpit accommodation Anthropometric survey Sizing Dimensions	A N D	Protective equipment Life support Cockpit Supplies	A N D	Helmets G-suit Survival vest Clothing Fit	A N D	Usability Safety
	Goal: To find documents that exhibit the relationship between anthropometric variability and equipment systems.						
3	Database 3-D Body data Anthropometry	A N D	Anthropometric accommodation Data management	A N D	Univariate Multivariate Integrate Ergodata NACSET (Navel Advanced Crew Station Evaluation Technique)	A N D	Analysis
	Goal: To find evaluations of anthropometry and accommodation data resources and issues.						
4	1 and 2 embedded on/in 3	A N D	Stocked equipment Supplies Equipment variability Sizes Cost effective	A N D	Anthropometric databases Equipment databases	A N D	
	Goal: To determine what type of, if any, anthropometric and equipment databases exist, and whether it is effective to combine anthropometric fit with accommodation systems.						