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Development and Use of the Biodynamics Data Bank and Its Web Interface

Huaining Cheng
Stephen E. Mosher

ADVANCED INFORMATION ENGINEERING SERVICES
A General Dynamics Company
5200 Springfield Pike, Suite 200
Dayton OH 45431

John R. Buhrman

AIR FORCE RESEARCH LABORATORY

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Human Effectiveness Directorate
Biosciences and Protection Division
Biomechanics Branch
2800 Q Street, Building 824
Wright-Patterson AFB OH 45433-7947

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Instruction 40-402.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR

//Signed//

MARK M. HOFFMAN
Deputy Chief, Biosciences and Protection Division
Air Force Research Laboratory

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6. AUTHOR(S)
Huaning Cheng
Stephen E. Mosher
John R. Buhrman

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Advanced Information Engineering Services
A General Dynamics Company
5200 Springfield Pike, Suite 200
Dayton OH 45431

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14. ABSTRACT
The Air Force Research Laboratory's Biodynamics Data Bank (BDB) is the world's largest repository of human biodynamic response data. The contents include data from over 90 research efforts that include more than 10,000 impact acceleration tests conducted with both human and instrumented manikin subjects. The tests were conducted on man-rated impact test facilities that include a Vertical Deceleration Tower (VDT), Horizontal Impulse Accelerator (HIA), Vertical Impact Device (VID), Body Positioning and Restraint Device (BPRD), Helmet Drop Tower (HDT), and Horizontal Decelerator (HD). Slow motion videos and documentation photographs of the tests provide enhanced analysis capability. The BDB also contains general information for each research effort such as test matrix, test conditions, type of test equipment, objective, and results. Anthropometry measurements for the human and manikin test subjects are also contained in the BDB. A web browser, along with search and plotting routines, has been incorporated to enhance the usability of the BDB.

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PREFACE

This report serves as the documentation for the development of the Air Force Laboratory's Biodynamics Data Bank (BDB) and its web user interface. It also can be employed as a user's guide. The work described in this report was funded under Workunit 71840206 and was performed by the BDB team of the Biomechanics Branch, Human Effectiveness Directorate of the Air Force Research Laboratory at Wright-Patterson AFB, Ohio. Technical support for this effort was provided by General Dynamics AIES Corporation under contract F41624-97-D-6004 and by Dyncorp under contract F33601-96-DJ001.

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1. INTRODUCTION

1.1 Background

The Biodynamics Data Bank (BDB) was established in 1984 by a team of researchers at the Air Force Research Laboratory (AFRL) with the purpose of organizing and archiving thousands of impact acceleration tests conducted over the past several decades [1]. A main-frame command-driven database management system called BASIS was used for the initial development of the BDB. It has since evolved into a dynamic Windows-based system consisting of a Microsoft SQL Server™ database and web user interface with full search capabilities [2, 3]. The back-end SQL Server database stores and manages the data and the front-end web user interface searches, calculates, and displays the data.

As of year 2004, the BDB had data from over 10,000 impact acceleration tests conducted in-house at AFRL with both human subjects and instrumented manikins. The tests were conducted on man-rated impact test facilities capable of providing a wide range of acceleration pulses for simulation of both ejection and automotive impacts. The facilities include the Vertical Deceleration Tower (VDT) (Figure 1), Vertical Accelerator (VA), Vertical Impact Device (VID), Horizontal Impulse Accelerator (HIA), and Horizontal Decelerator (HD). These tests have been a primary source of biodynamic response data for engineers at AFRL as well as other research agencies and universities, and have led to improvements in the areas of ejection injury criteria, restraint system safety, and impact response modeling.

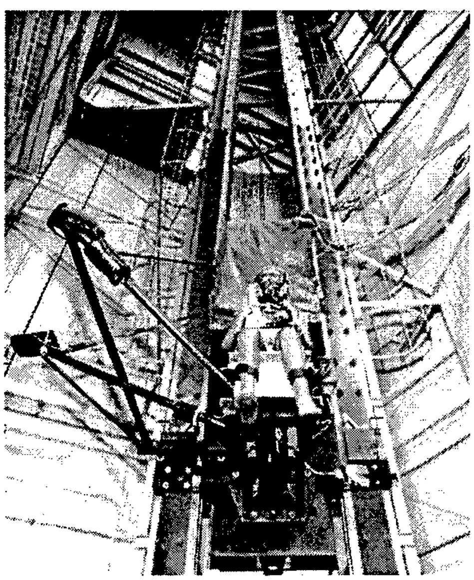


Figure 1. Manikin Test Subject on AFRL Vertical Deceleration Tower

Although AFRL maintains data from impact experiments conducted by Stapp and others as far back as the early 1950s, it was not until the 1970s that computer-controlled data acquisition systems and mass storage methods became available for use by researchers at

AFRL. This allowed for the relatively straightforward transfer of data into the BDB from tests dating back to 1978, which were already in digital format and stored on magnetic tapes. However, data from tests during the period from 1972 to 1977 were stored in analog format and therefore required digitization prior to entry into the data bank. This process has been completed and data from those tests are now in the BDB. In studies prior to 1988, motion data were recorded using high-speed 16mm cameras and analyzed using a film reader machine. Those data have recently been reformatted such that differences between the analyzed film data, the digital 3-D motion analysis system and the video motion analysis system are now transparent to database users. Test programs conducted prior to 1972 have not yet been fully incorporated into the BDB since these data are stored on chart recordings and other media that cannot be easily transferred into computer files. However, general study information and test parameters of many of those tests have been entered into the BDB.

The primary access to the BDB is through its web interface. Its user management system requires a basic user registration. The interface offers a comprehensive capability for data display, visualization, search, and analysis. Its search tools are designed to let users obtain information and data easily and quickly. Data cleared for public release are deployed to the Wright-Patterson AFB public server and are accessible through the Internet.

Data from the BDB have been used extensively by researchers in the areas of automotive crash protection and aircraft ejection seat safety. The data have been used in the evaluation of ejection seat and restraint system design, and in the establishment of safe parameters for human response to impact variables such as helmet weight, seat back angle, and multi-axial impact exposure. Human response data from the BDB have been employed in the development and validation of biodynamic models such as the Articulated Total Body (ATB) model [4]. The ATB is used to predict biodynamic responses of crewmembers and to evaluate injuries associated with diverse aircraft ejection events. Data from the BDB have also been used in the development and validation of the Head-Spine model (HSM), which is used to model the dynamic forces and moments acting on rigid skeletal segments and deformable elements such as muscles and joints [5].

1.2 Recent Additions to the BDB

The contents of the BDB have been significantly expanded over the past several years. At the end of 2003, the collection of in-house test data had increased to 9,620 tests grouped under 113 studies that were conducted between 1958 and 2003. More than 11,000 test videos and 22,000 photos were digitized and added to the BDB. In addition to the in-house tests, two new databases were added into the BDB. One of them, the ejection database, contains test data from nearly 1,000 rocket sled and ejection tests conducted at remote Air Force and Navy sites, including Holloman AFB in New Mexico (Figure 2). These tests were conducted with instrumented manikins at speeds and trajectories comparable to actual emergency aircraft ejections. Data from these tests have been used to establish the safety and reliability of ejection seats, restraint devices, and instrumentation systems. The other new database is the bibliographical database, containing over 12,000 references to publications and documents in the areas of impact and acceleration biodynamic research. While some areas of the ejection and bibliography databases are for internal use only, certain portions can be obtained by contacting the BDB administrator.

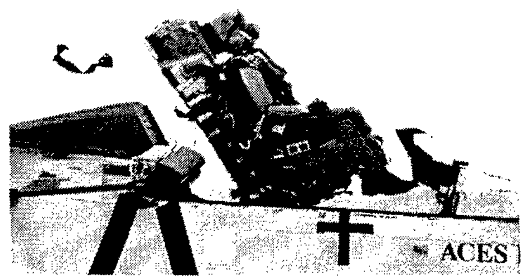


Figure 2. LOIS Manikin Being Ejected from Rocket Sled at Holloman AFB

The analytical program GEBOD (GEnerator of BODy Data) [7, 8] was integrated into the BDB. It adds a computational capability to the anthropometry section. The major function of GEBOD is to produce a segmented human body data set based on either basic measurements such as weight, height, and/or age, or a more complete measurement set of 32 body dimensions. The types of subjects computed by the GEBOD are child, adult human male and female. The data set produced has information on body measurements, segment data, and joint data. This program is often used in conjunction with the BDB to estimate mass properties of the human test subjects.

1.3 Future Objectives

The main objective of the BDB's future development is to transform it into the data management and data analysis center for the AFRL's biomechanics research. This objective requires:

- Consolidation and integration of existing and new research data sets into a centralized database to achieve efficient and secured resource management.
- Modification of the BDB's front-end web interface to accommodate different requirements from multiple research groups.
- Addition of more data analysis tools for mining in-depth information from test data.
- Upgrade of the user management system to accommodate more sophisticated registration and data restriction requirements.

New areas of biomechanics that are expected to be added to the BDB include anthropometric 3-D laser scan data, wind tunnel data, and vibration data. The development of the current and future web interface will involve adapting and applying the Microsoft .NET technology that is the next-generation software technology on all Microsoft products.

2. DATABASE STRUCTURE AND CONTENTS

2.1 Facilities and Equipment Used in BDB Tests and Data Collection

2.1.1 Major In-house Test Facilities and Their Profiles

- Horizontal Impulse Accelerator (HIA) (Figure 3)
  1. 80 m track, pneumatic piston
  2. Programmed G level (max 150 G) and duration

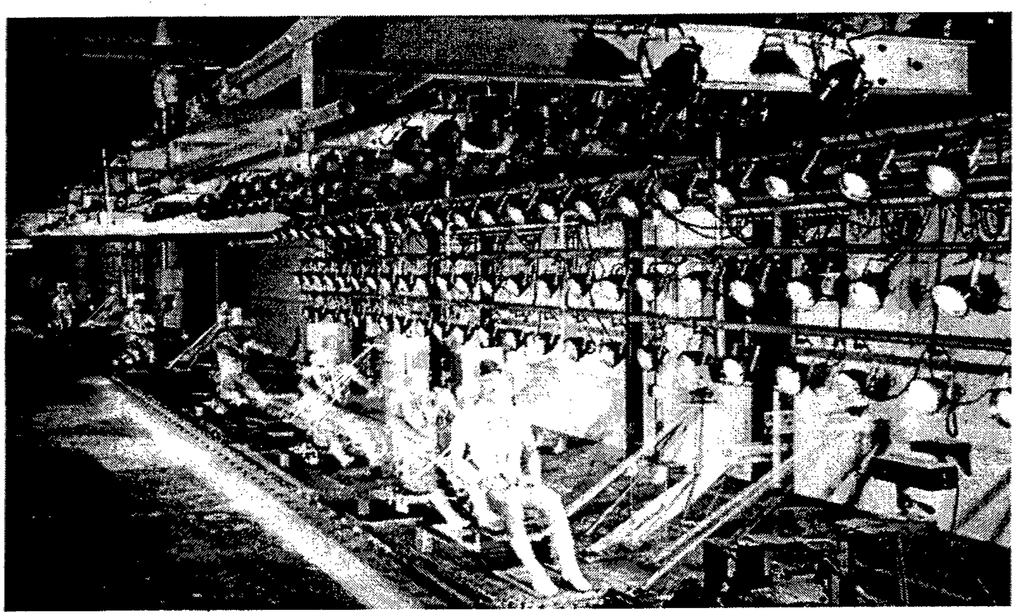


Figure 3. Horizontal Impulse Accelerator

- Horizontal Decelerator (HD)
  1. Uses energy of a 5400 kg flywheel to accelerate the sled
  2. Programmable hydraulic brake

- Vertical Deceleration Tower (VDT)
  1. Simulates upward ejection through vertical rails
  2. Deceleration pulse is generated through displacing a column of water

- Vertical Impact Device (VID)
  1. Free fall on vertical guide rail
  2. Simulates crash by producing high amplitude, short duration pulses through various elastomeric bumpers

- Body Positioning and Restraint Device (BPRD)
  1. Investigates the pre-ejection positioning and retraction in various seat configurations

2. Seven hydraulic cylinders retract the arms, legs, upper and lower torso either simultaneously or independently

- Static Airbag Deployment Test Stand (SAD)
- Subject Drop Device (SDD)
- Vertical Accelerator (VA)

2.1.2 In-house Test Data Collection

- DAS (Data Acquisition System) Data - Seat/subject accelerations, forces, and pressures, etc. are collected using an onboard data acquisition system (normally 1K samples/sec).
- Motion Analysis Data - The 3-D data are acquired using a digital 3-D motion analysis system and the video motion analysis system (normally 500 frames/sec).
- Video Data - Uses an onboard video system with a controllable recording rate (typically 500 frames/sec).

2.1.3 In-house Test Subjects

By the end of 2003, 273 male and 86 female human volunteers, as well as 17 different types of manikins had served as test subjects. There are about 60 anthropometry measurements in the database for each subject. The anthropometry measurements typically include dimensions for height, length, breadth, depth, and circumference, etc. Table 1 lists the ranges of some basic parameters for these test subjects.

Table 1. Ranges of Test Subjects

Type	Gender	Weight (lbs)	Standing Height (mm)	Age (yrs)
Human	M	101.0 ~ 283.0	1556.0 ~ 1905.0	18 ~ 45
Human	F	100.0 ~ 187.0	1464.0 ~1870.0	19 ~ 46
Manikin	M	104.0 ~ 245.0	1645.0 ~ 1923.0	N/A
Manikin	F	107.0 ~ 116.0	1476.0 ~ 1594.0	N/A

The ranges of female manikins are narrower than male manikins because there are only four currently in the database and all of them are 5th percentile types. Table 2 lists all manikin test subjects in the BDB.

Table 2. Manikin Test Subjects

Subject ID	Gender	Manikin
ADAM1-L	M	Large ADAM/NIOSH
ADAM-L	M	Large ADAM (Advanced Dynamic Anthropomorphic Manikin)
ADAM-S	M	Small ADAM (Advanced Dynamic Anthropomorphic Manikin)
AERO-5	F	Aerospace 5th Percentile
AERO-95	M	Aerospace 95th Percentile
CG-5	M	GARD CG 5th Percentile (Grumman-Alderson Research Dummy)
CG-95	M	GARD CG 95th Percentile (Grumman-Alderson Research Dummy)
HB2-50	M	Hybrid II 50th Percentile
HB3-5	M	Hybrid III 5th Percentile
HB3-50	M	Hybrid III 50th Percentile
HB3-5F	F	Hybrid III 5th Percentile
HB3-95 Auto	M	Hybrid III 95th Percentile Automotive
JPAT-L	M	Large JPATS (Joint Primary Aircraft Training System)
JPAT-S	F	Small JPATS (Joint Primary Aircraft Training System)
LOIS	F	LOIS (Lightest Occupant In Service)
LRE	M	Limb Restraint Evaluator Manikin
VIP-95	M	VIP 95 Percentile (Very Important People)

2.2 BDB Database Structure

The current BDB consists of four component databases. The main component is the impact test database, implemented as an SQL Server 2000 database and publicly accessible through the Internet. The bibliographic database is also an SQL Server 2000 database and some of the records are publicly accessible. The third one is the ejection database, implemented as a Microsoft Access database and currently only internally accessible through the Intranet. The fourth database is the BDB user manager database that is implemented as an SQL Sever database and allows restricted access by designated persons.

SQL Server 2000 is an enterprise level database management system. It runs on a Windows 2000 Server and has low maintenance and relatively inexpensive license cost. It offers some features that are important to the implementation, expansion, and future improvement of the BDB including:

- High scalability, speed, and performance.
- Improved analysis and development tools for increased productivity in database design work such as query and stored procedure developments.
- Automated routines that extract, transform, and load data from heterogeneous sources. They facilitate upsizing and integration of different databases such as the bibliographic database.
- Integration with Microsoft Visual Studio web development environment.
- Enhanced security mechanisms such as role-based security and file and network encryption.
- Simplified database administration with automatic tuning and maintenance.
- XML support that allows future enhancement of the BDB on cross-platform data access and transfer from remote test sites.

Because SQL Server 2000 is a relational database, the structure of the BDB consists of a set of data tables related to each other through primary/foreign keys relationships. Cascading referential integrity is enforced among tables to prevent erroneous input and keep consistency among the data. Some fields are also indexed to increase search performance. Figure 4 illustrates the basic structure of the impact test database.

The organization of the data is centered on test programs, referred to in the BDB as *studies*, which are experiments designed to answer particular questions in the areas of human dynamic response to impact and safety of ejection equipment. Most studies have a detailed technical report that can be accessed from within the database. Under each study, a series of *tests* are conducted and they are grouped into *cells*. All the tests in a cell have the same test conditions and parameters. For each test, there are up to one hundred data channels and their basic characteristic values are stored as *test extrema* and *3-D extrema* data. The motion analysis results from film and video cameras are stored in the 3-D extrema data table. Time histories of these data channels are exported into Microsoft Excel files and stored as data files that are linked to the database. Each test also produces a large amount of multimedia data in the form of test video and photo images. Many tests have multiple videos shot from different directions. These multimedia data are digitized into Windows Media files and graphical image files. They are also stored as individual data files separated from the database. Naming conventions and folder structures were developed for the technical report, time history, and multimedia data files to allow quick access to the files and their data.

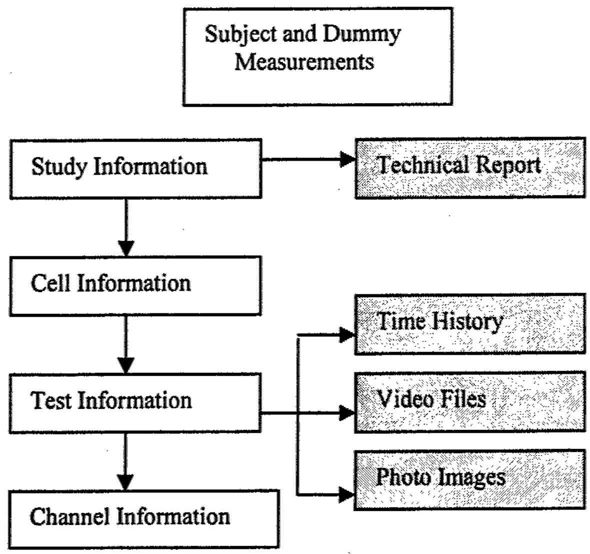


Figure 4. Basic Structure of Impact Test Database

Test subject information in the BDB consists of two tables of human and manikin anthropometric measurements, respectively. Complete lists of measurement fields for both human and manikin subjects can be found in the anthropometry search page of the web interface. Figure 5 shows the anthropometry search page for human subjects. Note that moving the computer pointer to the left star icon of a measurement field brings up its detailed definition. Other anthropometry related data in the BDB are mass properties measurements for some human and manikin subjects.

In summary, the relationships among major data tables are as follows:

- Study -> Cell: one-to-many
- Cell -> Test: one-to-many
- Test -> Channel Information: one-to-many
- Study -> Subject: one-to-many
- Test -> Subject: one-to-one

The design and implementation of the ejection database were done using similar methodology and structure except that there are many more test parameters in the ejection database than those in the impact database. The major additions include:

- Seat Properties --- seat type, version, weight, centers-of-gravity, moments-of-inertia, ballast weights, etc.

- Flight Equipment --- parameters on the helmet, HMD, oxygen mask, harness, flight jacket, gloves, boots, and anti-g vest, etc.
- Ejection Events --- times of catapult ignition, rocket ignition, catapult separation, drogue deployment, rocket burnout, manikin/ejection seat separation, recovery subsystem initiation, and manikin ground impact, etc.
- Extra Test Information --- mach, altitude, temperature, pressure, wind direction and speed, and canopy, etc.

The bibliographic and user databases were also designed as relational databases and the descriptions of their structures are omitted here.

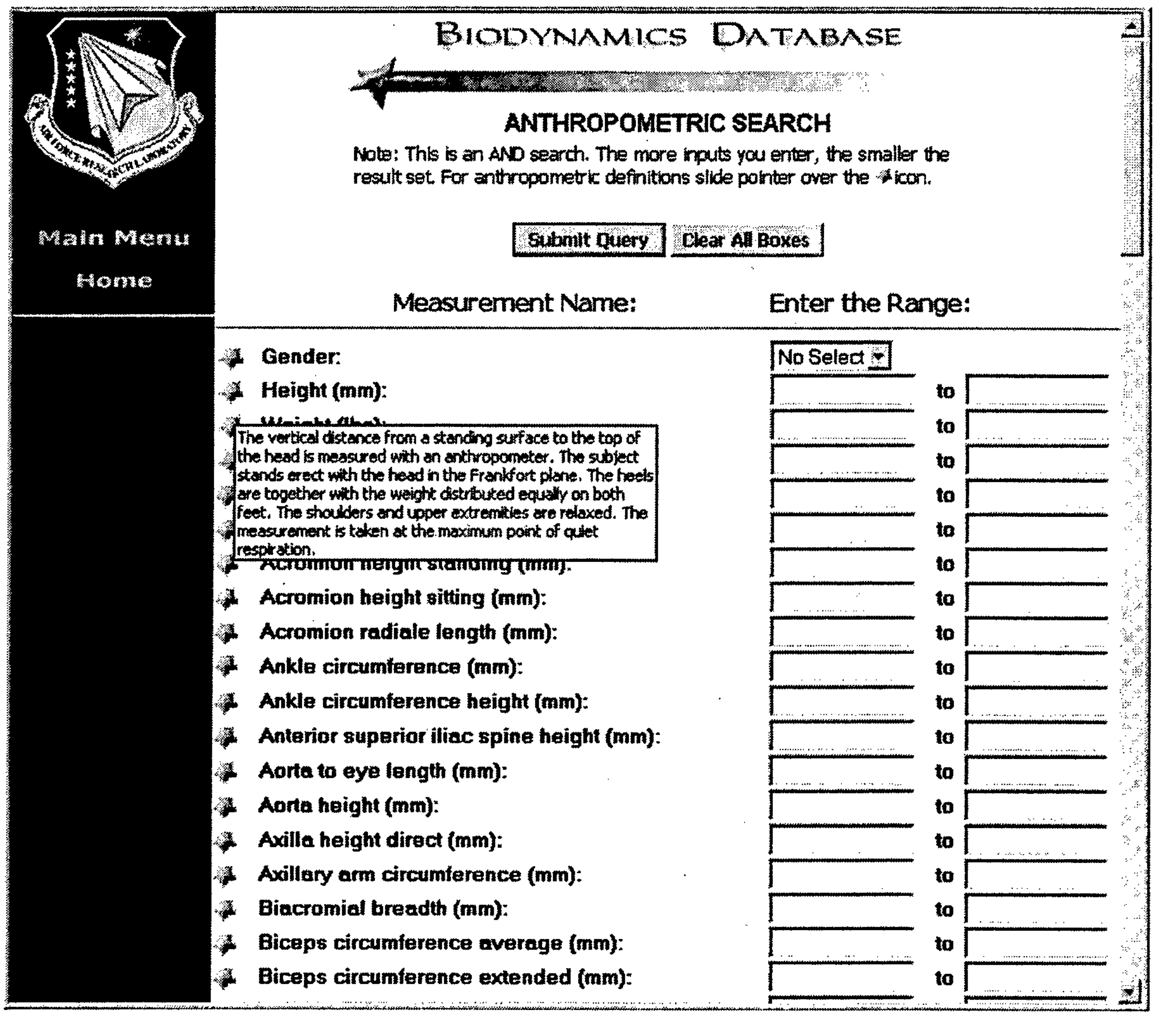


Figure 5. Web Page of Human Anthropometry Search in the BDB

2.3 BDB Database Contents

There are vast amounts of data stored in the BDB. Some large data tables contain hundreds of thousands of records. This section describes briefly the several major types of data.

General Study Information

- Summary information of each study program such as study title, date, facility, objective, instrumentation, results, comments, and investigators, etc.
- For most studies, a detailed technical report stored in Adobe PDF format.
- Contains more than 100 studies over the time period from 1958 to 2003.

Cell Information

- Each study contains several cells that group tests of identical test conditions together.
- There are 18 such test conditions. They are direction of impact, seat cushion, lap belt, headrest, flight helmet, and seat back angle, etc.

Test Information

- Summary information for each test such as duration of impact, rise time, maximum velocity, nominal G, peak G, subject type, weight, height, and sitting height, etc.
- Each study program may have several dozen or hundreds of tests.
- Over 9600 tests in the BDB at the end of 2003.

Extrema Information

- Summary information on each channel from sensors (acceleration, force, pressure etc. that were acquired using a data acquisition system) and motion analysis data (from film, 3-D, or video). The summary information includes peak values (maximum and minimum) of sampled data and times at the peak values, etc.
- Up to 64 channels of data per test including subject/seat forces, accelerations from the DAS, and displacements from the motion analysis system in multiple axes. Appendix A has a list of primary acceleration/force sensors and 3-D motion analysis target locations.

Multimedia Test Data

- Time history data of all channels are automatically exported into Excel files. They are typically sampled at 1,000 samples/sec.
- Excel files of motion analysis data.
- High-speed videos from the Kodak and Weinberger onboard video systems.

- Study documentation photos of test and subject configurations as well as test equipment.
- JPEG files of oscillograph traces from pre-1970s tests.

Because the other three databases are either completely or partially restricted from public access, detailed descriptions of their contents are omitted here.

2.4 BDB Data Input

2.4.1 Data Acquisition System (DAS) Data from Impact Tests

The data acquisition system (DAS) data were acquired using various digital data acquisition systems. The DAS units had a 12 to 16 bit digital resolution. Before 1979, the transducer data were stored on analog tape. The analog tapes were later digitized using a digital data acquisition system. The majority of the transducer data in the BDB were sampled at 1000 frames/second and filtered using a 120 Hz Butterworth filter. Various transducers were used during the testing, including linear and angular accelerometers, load cells, strain gages, tachometers and potentiometers. The measurements included acceleration, force, moments, velocity and displacement.

The transducer data are presently added to the BDB by the post-test analysis software. The post-test analysis software was written using Microsoft Visual Basic and calls various external dynamic link libraries that were written using C, C++ or FORTRAN. In addition to performing the post-test analysis, the post-test analysis software creates the Excel time history files for the BDB and automatically stores the test parameters, preloads and extrema values in a separate SQL Server database that contains the test data from ongoing test programs. This allows the test data to be viewed immediately following the test from an internal "ongoing" web site. After the test program, when the test data and the test information have been verified to be correct, the test data are transferred to the primary SQL Server database where they can be viewed from the Bioweb web site.

2.4.2 Three-dimensional Motion Analysis Data from Impact Tests

The three-dimensional motion analysis data in the BDB come from three different sources: tracked targets on film from high-speed cameras, the Selspot Motion Analysis System, and tracked targets from the video cameras. High-speed film cameras were used until mid-1991. The Selspot Motion Analysis System was used from 1991 until the start of 2003. Since that time the 3-D motion analysis results have come from the Weinberger video cameras. Test data from the Selspot and the video cameras were normally sampled at 500 frames/second. The film cameras had a nominal speed of 500 frames/second. Although the speed of the film cameras varied somewhat, the data were always interpolated at 500 frames/sec.

The positions and displacement time histories for the 3-D motion data are normally filtered using a 30 Hz FIR filter. The velocity data are filtered and differentiated using a

20 Hz FIR filter. The accuracy of the velocity is limited due to the fact that the displacement must be differentiated in order to compute the velocity. A commercial program named Visual Fusion (Boeing-SVS, Inc.) is used to track the video targets. A VB.Net program is then used to filter the position time histories; compute the displacements, velocities, resultants and extrema; create Excel workbooks for the BDB containing the time histories; and add the 3-D motion analysis results to the SQL Server tables in the BDB.

2.4.3 Streaming Videos from Impact Tests

The video data in the BDB were acquired using high-speed film or video cameras. The films were first converted to analog video and then converted to digital AVI files. Before 2003, the video camera output was recorded on analog video tapes and later converted to digital AVI files. Since the start of 2003, the video camera output has been recorded directly as digital AVI files. The streaming video files are created using a Visual Basic program that searches for any new AVI files and automatically converts them to streaming video files. VB.Net programs are used to automatically create ASX files for the new streaming video files and to screen out streaming video files that are not associated with tests in the BDB.

2.4.4 Bibliographic Data

The bibliographic data were originally imported from preexisting Basis Plus and Access databases. Work is ongoing to eliminate duplicate records, fill in incomplete records, and add new references as they become available.

2.4.5 Photographic Data

Documentation photographs are stored in the BDB as JPEG digital image files. Prior to 2001, the photographs were taken using film and later converted to digital image files using a scanner. Starting in 2001, digital cameras have been used to document the test programs. The BDB contains a low-resolution and a high-resolution digital image for each picture. The high-resolution digital images normally have a resolution of 1500 or more pixels for the longest dimension.

2.4.6 Public Site

Test data from test programs that have been cleared for public release are transferred to the public site. The SQL Server database at the public site is updated using views that screen out data from restricted test programs. The time history files, streaming videos, photos and study reports at the public site are updated using VB.Net programs that automatically create new folders as needed, copy over new files, and screen out files from restricted test programs.

3. WEB INTERFACE DEVELOPMENT

3.1 Application Model and Programming Techniques

The original BDB had a simple interface constructed in Microsoft Access with a limited keyword-based topic search. Distribution to end-users required placing the entire contents on CDs. In addition, every set of time history files requested by the user had to be sent by CD. Therefore, the distribution of data was time-consuming and tedious. With the advancement of Internet technology, a complete new web interface to the BDB has been developed. Users can now access the BDB, conduct comprehensive searches/analyses, and download data easily and seamlessly through the Internet. This web interface offers up-to-date information and eliminates the need to distribute data on CDs.

The application model of the web interface is a three-tier service model as depicted in Figure 6. It is a thin-client/server application that places as little of the application as possible on the client, and keeps all the processing centralized on one or more servers. This reduces the burden and requirements for users' PCs and compatible browsers.

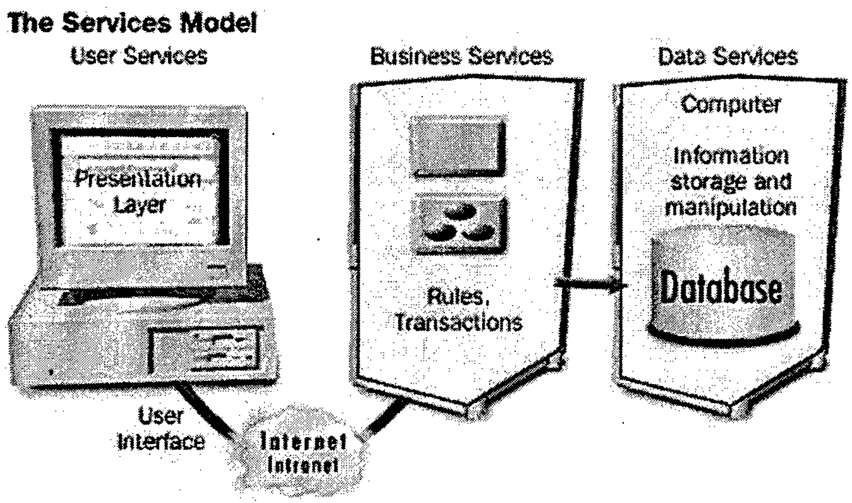


Figure 6. Web Interface Application Model[1]

The *User Services* tier provides the application with its user interface of web pages viewed by a web browser. The BDB's interface consists of two types of web pages - regular HTML pages and Active Server Pages (ASP). ASP pages contain server script that is different from regular web pages. The web server processes the script first and generates the HTML pages that are returned to the browser. Because most pages in the BDB's interface are used for displaying database search results, they are not regular static HTML pages and have to be generated "on the fly." ASP fulfills these needs and therefore most pages in the interface are ASP pages.

[1] Reference: Microsoft training course 1017A

Currently, Microsoft Internet Information Server (IIS) is used as the web server. It is running on a Windows 2000 server.

The *Business Services* tier enforces business rules and handles transactions. In the BDB's interface, business service is represented by a number of Component Object Model (COM) components that are used to process and analyze test data according to the users' inputs. For example, one of the COM components in the interface is to create time history plots on user-selected channels. It generates plots dynamically and embeds them into ASP pages as GIF format images. This gives users the capability of visualizing test data and viewing them directly from web browsers.

The *Data Services* tier provides storage and manipulation of data in a database. The BDB's web interface uses ActiveX Data Objects (ADO) for database access. ADO is a set of COM components that offers objects and methods to be called by ASP pages to accomplish database related operations. They include establishing connections to, passing queries to, and retrieving search results from the database. All of these operations are programmed either as server script in ASP pages or stored procedures in the SQL Server database. Both of them are processed on servers. What users actually see are the final search results displayed in HTML format.

Most parts of the web application are developed using Microsoft Visual InterDev [9] in Microsoft Visual Studio 6.0. Visual InterDev is a web programming toolkit that is designed for developers who are designing, building, testing, debugging, deploying, and managing component-based, data-intensive web applications. It integrates project management, database connection and access, HTML and ASP page creation, server script development, COM component development, and other server-side technologies under a single environment.

During the last two years, a complete new Windows application development technology, the Microsoft .NET technology, has dramatically changed Windows programming. Following this new trend, recent development work in the BDB, such as the integration of GEBOD, was done using Visual Studio.NET 2003, the .NET integrated development environment. Consequently, Visual Basic.NET [10], ASP.NET [11], and ADO.NET [12] (all Microsoft) are being introduced into the BDB development. Their concepts and programming methodologies are very different from the older ones.

The new .NET technology moves away from the COM model and into the new Common Language Runtime (CLR) defined by the .NET framework. It has some features that will open new development opportunities and offer performance enhancements for the BDB web interface, such as:

- Platform independent and language neutral --- different programming languages that are .NET-compliant use the same CLR. Code developed in one language can be directly mixed in and used by code developed in another language. This allows integration of GEBOD, which is a FORTRAN program, into the BDB.

- Completely object oriented --- code abstraction, encapsulation, inheritance, and polymorphism.
- Automatic garbage collection mechanism eliminates memory leaks.
- XCopy deployment --- deploys programs by simply copying files. This makes future deployment onto the public server less cumbersome.
- Structured exception handling prevents unhandled errors crashing entire programs.

3.2 BDB Home Page, User Management and Site Security

The web address of the public version of the BDB is http://www.biodyn.wpafb.af.mil. Figure 7 shows the home page.

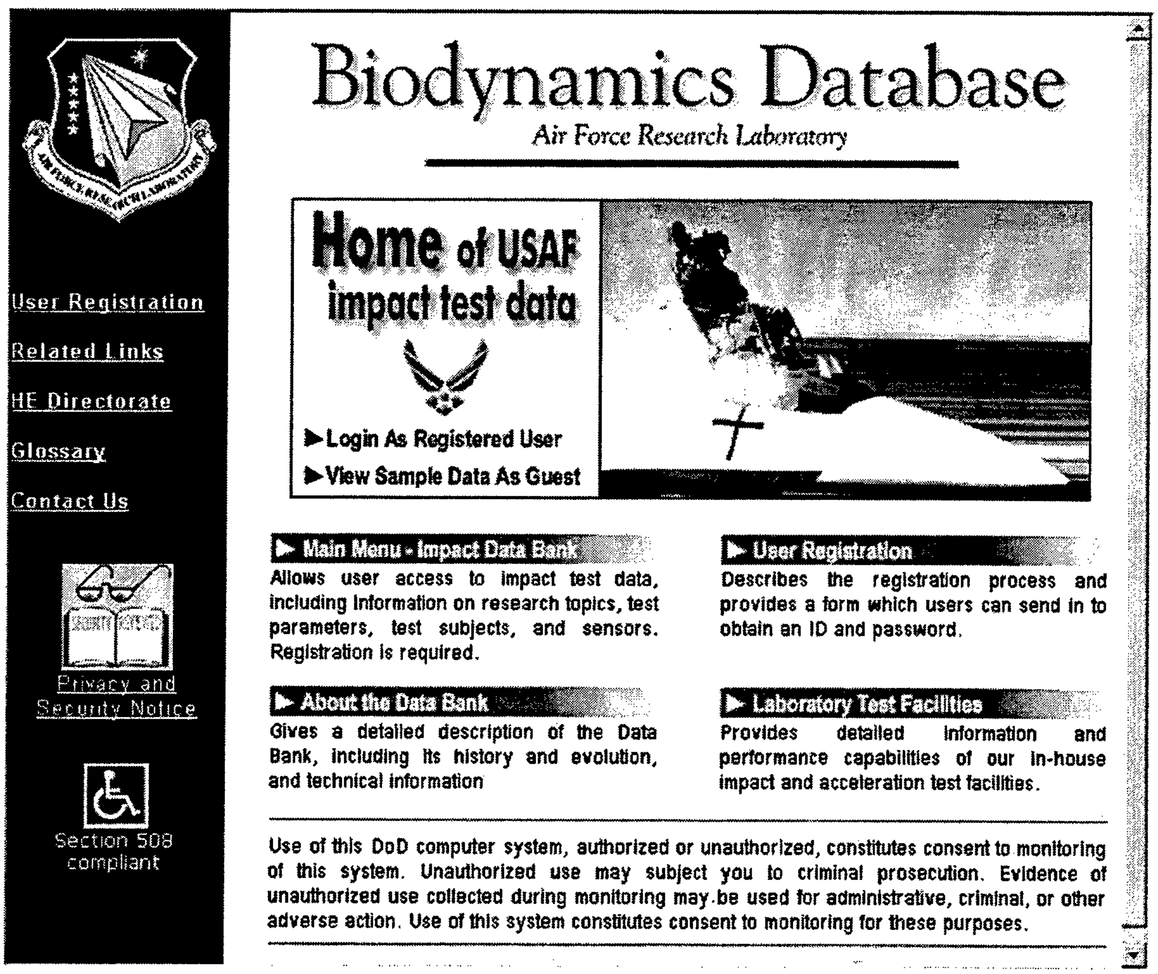


Figure 7. Home Page of the AFRL Biodynamics Data Bank

BDB access requires user registration, although there is an option of "View Sample Data as Guest" to allow unregistered users to view selected general areas. The user registration and user login are handled by the BDB User Manager, which is a separate database/web application. The BDB User Manager has the following functions:

- Collect user registration and login information and store them in the database.
- Notify the BDB administrator through email when a new user registration arrives.
- Allow BDB administrator to perform the following account management tasks:
  - Review new user registration and activate new user account (the account is in a holding status when a user makes a new registration).
  - Assign an access level to user account. Different access levels determine which areas of data can be accessed by users.
  - Assign file download quotas to user accounts. This controls the number of data files, such as technical reports, time history Excel files, and video files that can be downloaded by a user.
  - Renew expired user accounts or add download quotas.
  - Assign an account expiration date.
  - Deactivate or delete user accounts.
  - Review user feedbacks.
- Track downloads made by users.
- Automatically change account status to "expired" by checking regularly all accounts against their expiration data.
- Notify users through email whenever action is taken on the user account by BDB administrator.
- Collect user feedback.
- Password reminder if a user forgets his/her password.

The user registration, login, and account management are run through SSL (Secured Socket Layer) which encrypts communication between client and server.

Other cautions are also added into both internal and public sites, such as filtering out some characters from the URL string that may have malicious intentions.

3.3 Compliance with Section 508 of the Federal Disability Act

During the development of the BDB web interface, efforts were made to make all web pages compliant with Section 508 of the Federal Disability Act. For example, to help a blind user to understand what is playing in a test video, dynamically generated video description text tailored to each individual test is displayed side-by-side with the video. Database stored procedures were developed to retrieve test parameters and server script was written to plug these numbers into the description text. Some very detailed aspects of this compliance such as background colors were also taken into consideration.

All BDB web pages were tested and approved using the Air Force approved "Bobby" program which demonstrated no priority one accessibility errors. The Bobby program was developed by the Center for Applied Special Technology (CAST) (http://www.cast.org). In addition, further tests were done using the Microsoft JAWS screen reader program developed by Freedom Scientific (http://www.freedomscientific.com) to insure that web pages function correctly when users read and navigate through a screen reader.

3.4 BDB Web Contents Development

3.4.1 Objectives

The main objectives of the BDB web interface are:

- Offer biomechanics researchers and engineers an intuitive and readily available tool to access and view the BDB's data.
- Offer comprehensive search and analysis capabilities to facilitate mining and analysis of the BDB's data.
- Offer fast and simple means to distribute the BDB's data required by users.

To achieve these goals, web pages were designed with emphasis on clear and meaningful display of data contents rather than fancy graphics. The web plotting and streaming video were introduced to help visualization of data. Emphasis was also placed on the development of comprehensive search capabilities. These capabilities include a wide range of search options, from an overview type of topic search to a detailed type of parameter search. Sophisticated queries and script were created to accomplish the search and retrieval of data. Overall, these efforts have made the BDB a valuable and unique resource to many researchers working in the biomechanics and safety areas.

3.4.2 Main Menu and Major Types of Data Searches

As shown in Figure 8, the main menu includes different options for searches and access to various sections of data. By selecting an option, the user can go through a particular path to find relevant data based on his/her knowledge of the BDB.

"Research Topics" gives users the capability to perform searches on studies, using over 160 predefined keywords, as listed in Appendix B. The keywords can be *OR*ed together to generate a larger list of studies with multiple topics. The search acts like an index attached to the end of a book and is very handy for users who are not very familiar with the contents and test programs in the BDB. The result set displays a table of matched studies with their titles, test facilities, investigators, and subjects, as illustrated in Figure 9.

The user can then choose a particular study from the table by clicking at the study number. Based on the user's selection on the left-side "Choose a Page" radio buttons, the web interface will navigate the user to retrieve relevant information and data for that study.

Main Menu

Research Topics
- Match research topics to test programs
- Display test program summaries

Test Parameters
- Select impact parameters
- Select restraint configurations
- Display test information

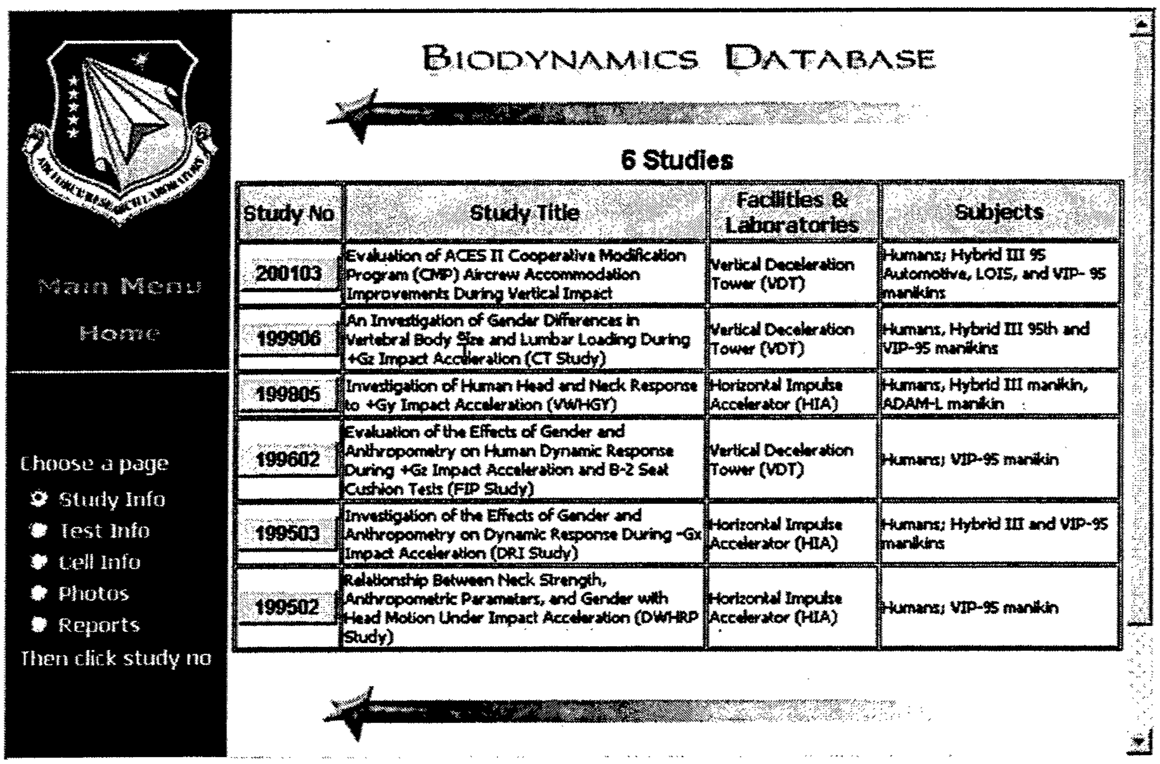
Anthropometry
- Display subject demographic information
- Display anthropometry measurements
- Perform anthropometry data searches
- Display manikin and human mass properties

Sensors
- Display Selspot target locations & designations
- Display acceleration/force locations & designations

Test Data
- Display test information
- Display peak test data
- Plot data time histories

Bibliographic
- Display list of impact references
- View the abstract of each reference
- Search for references by author, title, or keywords
- Create and print subsets of references

Figure 8. Main Menu of the BDB Web Interface



6 Studies

Study No	Study Title	Facilities & Laboratories	Subjects
200103	Evaluation of ACES II Cooperative Modification Program (CMP) Aircrew Accommodation Improvements During Vertical Impact	Vertical Deceleration Tower (VDT)	Humans; Hybrid III 95 Automotive, LOIS, and VIP- 95 manikins
199906	An Investigation of Gender Differences in Vertebral Body Size and Lumbar Loading During +Gz Impact Acceleration (CT Study)	Vertical Deceleration Tower (VDT)	Humans, Hybrid III 95th and VIP-95 manikins
199805	Investigation of Human Head and Neck Response to +Gy Impact Acceleration (VWHGY)	Horizontal Impulse Accelerator (HIA)	Humans, Hybrid III manikin, ADAM-L manikin
199602	Evaluation of the Effects of Gender and Anthropometry on Human Dynamic Response During +Gz Impact Acceleration and B-2 Seat Cushion Tests (FIP Study)	Vertical Deceleration Tower (VDT)	Humans; VIP-95 manikin
199503	Investigation of the Effects of Gender and Anthropometry on Dynamic Response During -Gx Impact Acceleration (DRI Study)	Horizontal Impulse Accelerator (HIA)	Humans; Hybrid III and VIP-95 manikins
199502	Relationship Between Neck Strength, Anthropometric Parameters, and Gender with Head Motion Under Impact Acceleration (DWHRP Study)	Horizontal Impulse Accelerator (HIA)	Humans; VIP-95 manikin

Figure 9. Studies Retrieved From Keyword Search On "GENDER/SIZE EFFECTS"

"Sensors" provides a pictorial representation of the physical locations of the sensors on the test subjects, including accelerometers, load cells, and motion analysis targets (see Appendix A). A listing of all channel names and IDs is also provided, which investigators can use to generate a smaller list of channels for use in designing test programs.

"Test Parameters" permits an accurate and refined search of the BDB to retrieve tests satisfying a user-specified set of search parameters. It offers the capability of comparison searches. There are thirty-five search parameters grouped into three categories: impact environment, personal test equipment, and subject information, as illustrated in Figure 10. Ejection tests can also be queried by parameters such as sled speed, seat trajectory, and manikin type.

These thirty-five parameters are modeled using a set of HTML input elements:

- Input text box - entering of numerical values.
- Dropdown combo box - single selection from a list of predefined data values.
- List box - multiple selections from a list of predefined data values.

Server script was developed to collect and *AND* the selected input values to form the database search query string. However, for each parameter under the "Personal Test Equipment" category, multiple selections are allowed and those selected items are *OR*ed together for that particular parameter which in turn *AND*s with other parameters. Because there are many parameters, the search query may become fairly complex and take a few seconds to execute and retrieve the matched tests. Figure 11 shows the result of a detailed search based on a few test parameters as shown in the left menu bar area.

In this sample search result, the search criteria listed in the left menu bar are:

- Facility: HIA (Horizontal Impulse Accelerator)
- Peak G: 9 to 10.5
- Subject Type: MANIKIN-M (Male Manikin)
- Subject ID: ADAM-L (Large ADAM)

Compared with Figure 9, only those tests satisfying the specified criteria are listed for each study instead of all the tests done under the study. Therefore, "Test Parameters" gives a very detailed search capability. Clicking the "Num of Tests" link accesses the test information page (see section 3.4.4). In addition, the total number of matching tests is listed on the top of the result table in Figure 11.

"Test Data" allows the user to select groups of tests based on facility, test number, or study/test program. This option gives quick access to the desired tests if the user knows what he/she is looking for.

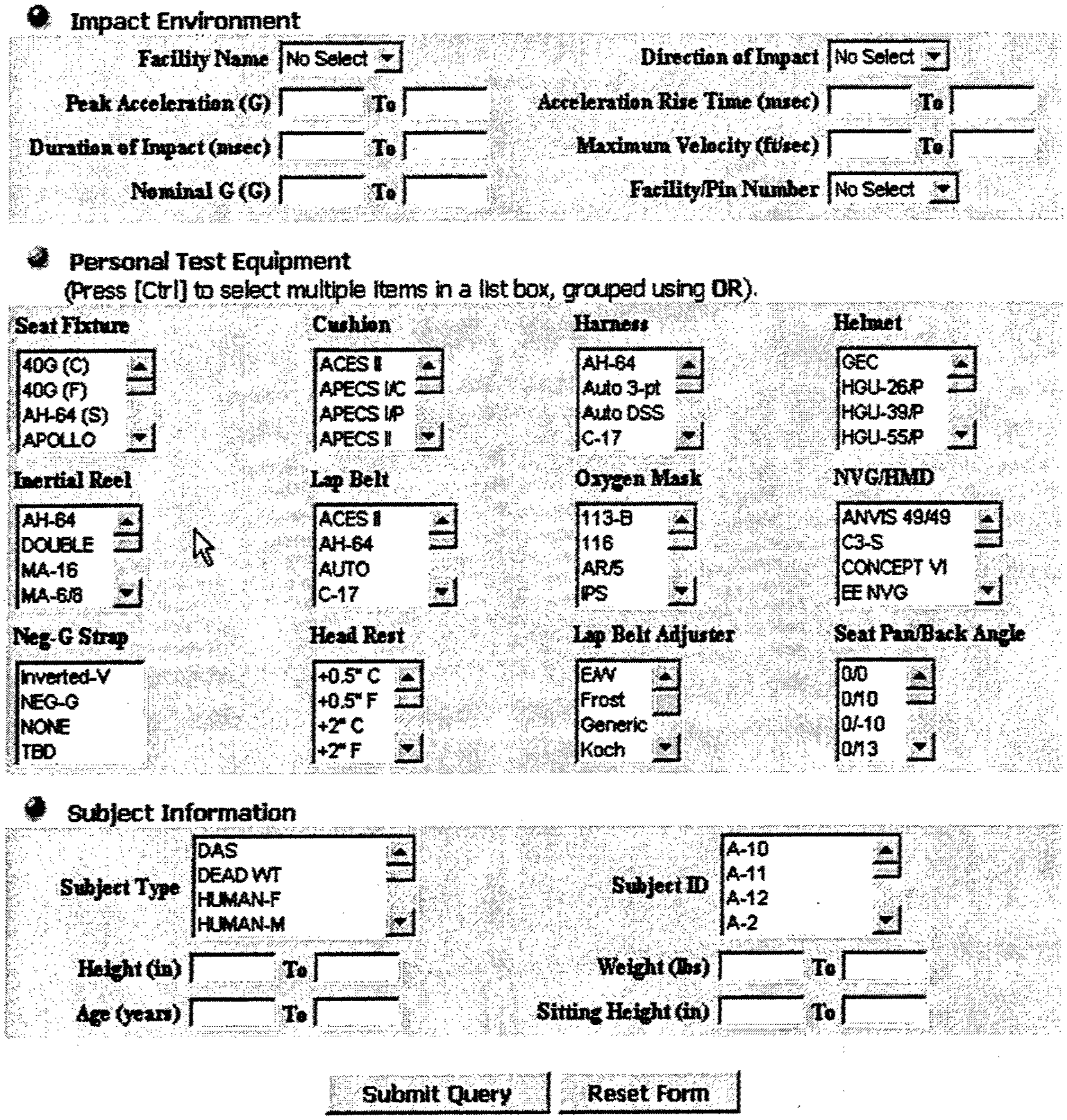
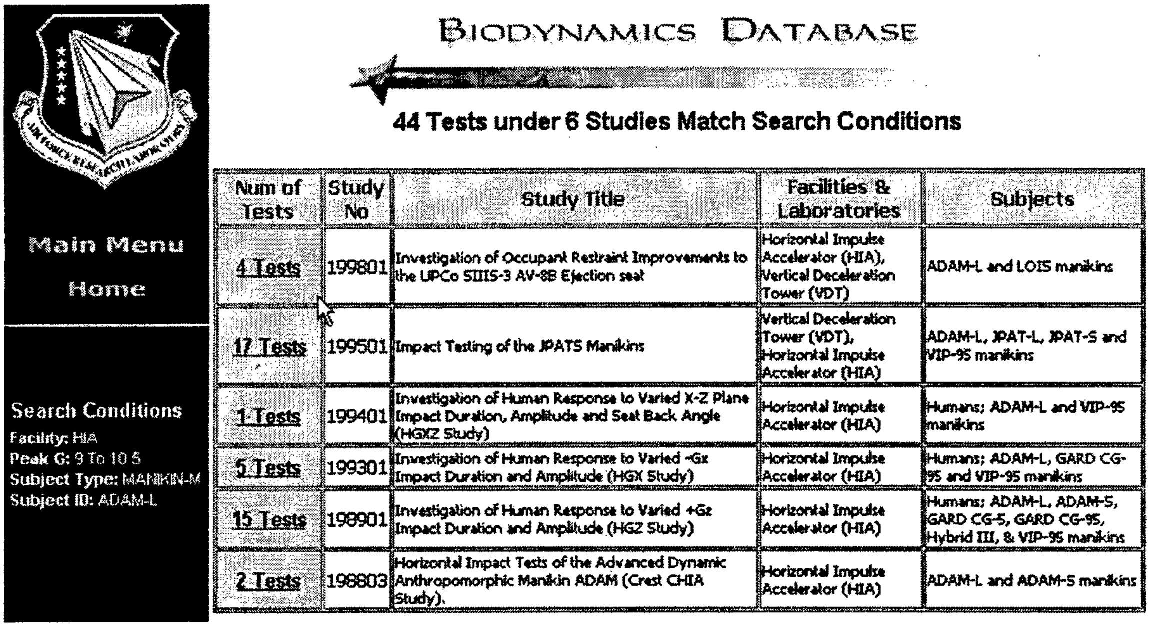


Figure 10. Search on Test Parameters

"Anthropometry" allows users to conduct several types of subject searches and anthropometry analyses. It has a submenu consisting of the following items:

- Human Anthropometry
  Displays basic demographic information on all test subjects. Registered users can also access a full list of anthropometry measurements for each subject.



Num of Tests	Study No	Study Title	Facilities & Laboratories	Subjects
4 Tests	199801	Investigation of Occupant Restraint Improvements to the UPCo SIIIS-3 AV-8B Ejection seat	Horizontal Impulse Accelerator (HIA), Vertical Deceleration Tower (VDT)	ADAM-L and LOIS manikins
17 Tests	199501	Impact Testing of the JPATS Manikins	Vertical Deceleration Tower (VDT), Horizontal Impulse Accelerator (HIA)	ADAM-L, JPAT-L, JPAT-S and VIP-95 manikins
1 Tests	199401	Investigation of Human Response to Varied X-Z Plane Impact Duration, Amplitude and Seat Back Angle (HGXZ Study)	Horizontal Impulse Accelerator (HIA)	Humans; ADAM-L and VIP-95 manikins
5 Tests	199301	Investigation of Human Response to Varied -Gx Impact Duration and Amplitude (HGX Study)	Horizontal Impulse Accelerator (HIA)	Humans; ADAM-L, GARD CG-95 and VIP-95 manikins
15 Tests	198901	Investigation of Human Response to Varied +Gz Impact Duration and Amplitude (HGZ Study)	Horizontal Impulse Accelerator (HIA)	Humans; ADAM-L, ADAM-S, GARD CG-5, GARD CG-95, Hybrid III, & VIP-95 manikins
2 Tests	198803	Horizontal Impact Tests of the Advanced Dynamic Anthropomorphic Manikin ADAM (Crest CHIA Study).	Horizontal Impulse Accelerator (HIA)	ADAM-L and ADAM-S manikins

Figure 11. Results of a Detailed Sample Search on Test Parameters

- Anthropometry Search
  Enables the user to conduct searches to locate subjects whose dimensions fall within specified ranges. Also displays definitions of all anthropometry measurements.

- Human Mass Properties
  Displays the mass properties of sixty-nine human subjects, obtained from a 1997 research study at AFRL.

- Manikin Anthropometry
  Displays basic demographic information on all manikins. Registered users can also access a full list of anthropometry measurements for each manikin.

- Manikin Mass Properties
  Displays mass properties and descriptive information of many of the manikins used by the U.S. Air Force and automotive industry.

- Manikin Drawings
  Displays detailed drawings and specifications of the ADAM manikins.

- GEBOD Program
  Starts the GEBOD program that generates human body data sets.

Using the submenu item "Human Anthropometry" as an example, a listing of all the human subjects in a table with columns of subject ID, height, sitting height, weight, gender, age, and date of measurements is displayed. By clicking on the Subject ID button, users have the options of viewing the subject's complete anthropometry measurements, locating studies/tests conducted with the subject, and viewing a list of study reports involving the subject. Figure 12 shows an example of the listing of all tests conducted using subject A-10, grouped by studies.

2 Studies and 12 Tests Using Subject A-10

Study No. 199902: FAST UPPER TORSO HAULBACK (FUTH)

Test No	Test Date	Cell	NOM G	Peak G	MAX VEL	Start Time	Rise Time	DUR OF IMP	SUB Type	SUB HT	SUB WT	SUBJ Sit HT	SUBJ Age
bpr1216	9/24/1999	A	TBD	21.67	8.53	-153	16	38	HUMAN-F	67	116	34.75	19
bpr1246	10/28/1999	B	TBD	22.57	8.35	-140	14	31	HUMAN-F	67	114	34.75	19
bpr1297	12/17/1999	C	TBD	24.3	8.44	-135	15	37	HUMAN-F	67	114	34.75	19
bpr1385	3/10/2000	G	TBD	28.4	9.5	-135	14	36	HUMAN-F	67	114	34.75	20
bpr1417	4/20/2000	I	TBD	24.4	9.55	-136	14	34	HUMAN-F	67	114	34.75	20
bpr1518	7/11/2000	J	TBD	29.23	10.32	-136	13	32	HUMAN-F	67	112	34.75	20

Study No. 199906: CT STUDY (CT)

Test No	Test Date	Cell	NOM G	Peak G	MAX VEL	Start Time	Rise Time	DUR OF IMP	SUB Type	SUB HT	SUB WT	SUBJ Sit HT	SUBJ Age
vdt3985	11/15/1999	A	6	5.97	19.84	-159	91.2	165.95	HUMAN-F	67	114	34.75	19
vdt4002	1/18/2000	A	6	5.9	20.65	-158	93.08	167.41	HUMAN-F	67	114	34.75	19
vdt4041	2/25/2000	B	8	8.14	21.1	-144	79.98	149.56	HUMAN-F	67	114	34.75	20
vdt4169	5/18/2000	C	10	10.04	27.83	-143	71.2	143.87	HUMAN-F	67	112	34.75	20
vdt4189	6/19/2000	C	10	10.03	27.61	-139	73.52	143.07	HUMAN-F	67	110	34.75	20
vdt4238	8/16/2000	C	10	10.17	27.78	-143	73.79	143.5	HUMAN-F	67	114	34.75	20

Figure 12. Tests Conducted with Human Subject A-10

"Bibliography" contains abstracts of references related to aircraft ejections, impact acceleration, sustained acceleration, and biodynamic modeling. The references can be searched by title, author, abstract, or citation, as shown in Figure 13.

The input values in the search field are used for a text search on the corresponding field in the bibliographical database to retrieve subsets of references. They are displayed with title, author, abstract, citation, and access restriction level. The user may then select references of interest and generate a list for printing.

3.4.3 Study and Cell Information Pages

Study information pages consist of two web pages displaying a comprehensive introduction and summary to the test programs. Figure 14 shows the first page of Study 200001 in the BDB. From these pages, users can learn the purpose of conducting this group of tests, areas of data collection, and findings and conclusions of the study, etc.

Based on this information, users can then decide whether this study and its tests are useful in his/her research and applications.

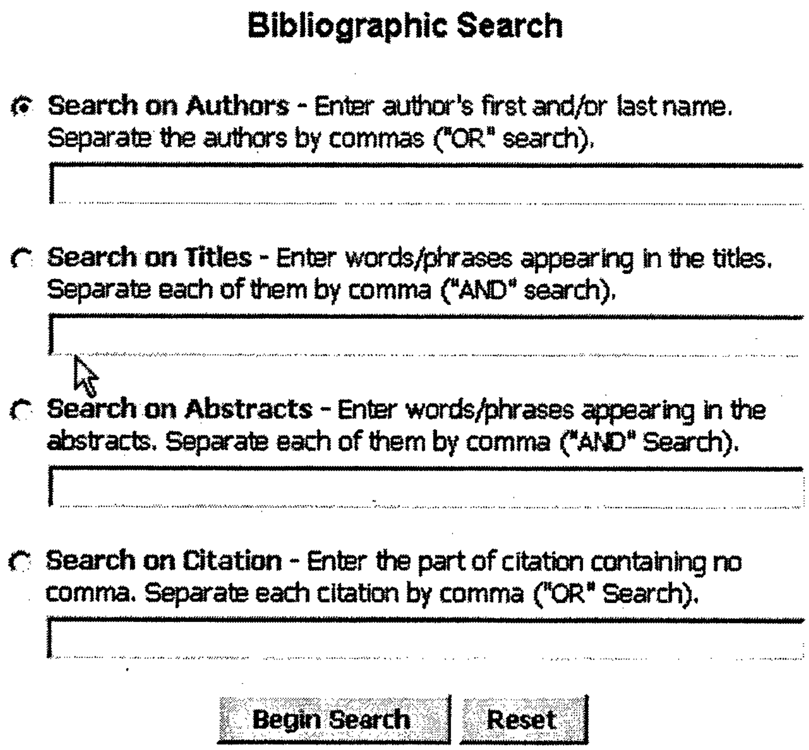


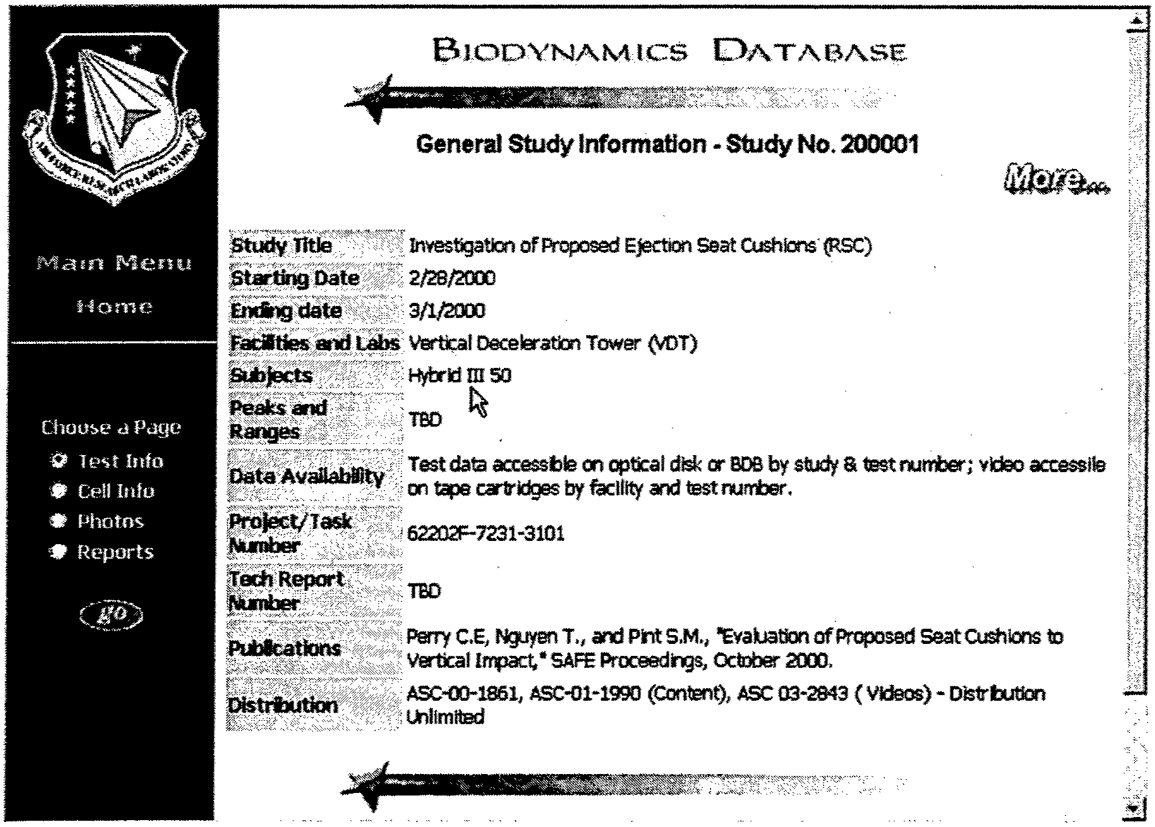
Figure 13. Bibliographic Search

More details of the study are contained in the second page. Clicking on the "More..." image button accesses the second page. It includes information such as investigators, objectives of the study, test matrix cells, measured variables, instrumentation, incidental equipment, results and/or conclusions, and interpretation/remarks. Appendix C depicts the contents of both pages of Study 200001. The Ejection Data Bank program summaries include additional information on flight equipment and seat properties.

From the left menu bar of the Study Information page, users can choose to see cell information, test information (see section 3.4.4), study photos (see section 3.4.5), and study reports.

Figure 15 shows the first of the two Cell Information pages for Study 200001. As stated before, each cell has 18 test parameters. Tests grouped under the same cell have identical values for each of the test parameters:

- Axis: axis of seat acceleration.
- NEG-G: negative-G or crotch strap.
- Cushion: type of seat cushion.
- FACIL: facility where the tests were conducted.
- Harness: type of restraint harness.



BIODYNAMICS DATABASE

General Study Information - Study No. 200001

More...

Main Menu

Home

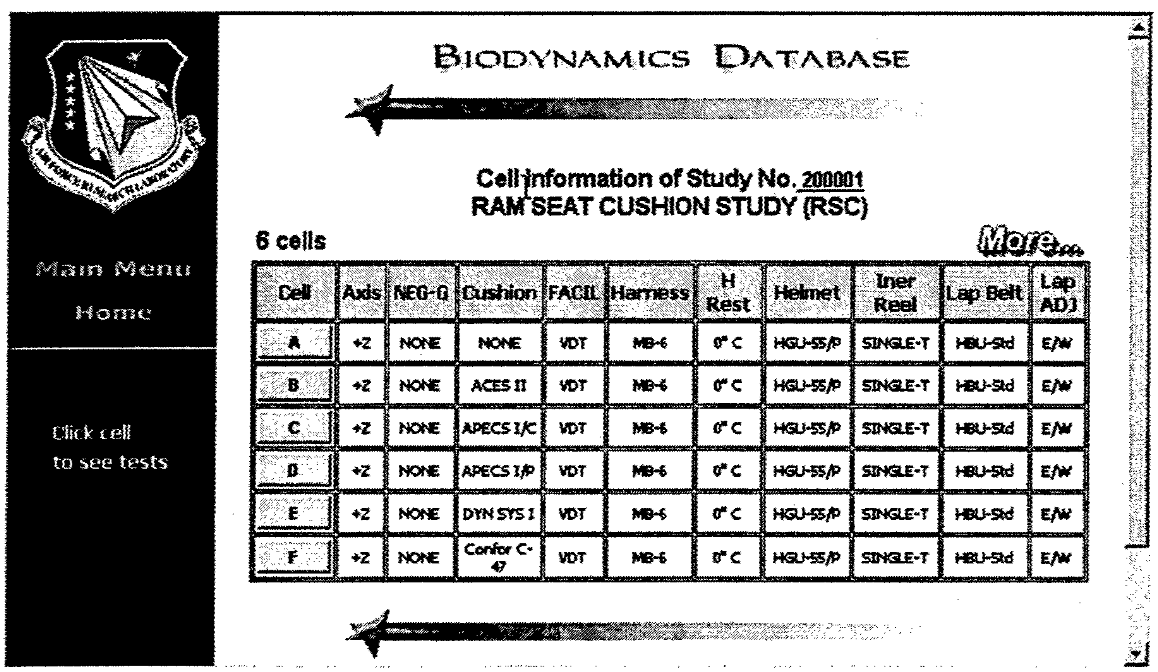
Choose a Page

- Test Info
- Cell Info
- Photos
- Reports

go

Study Title	Investigation of Proposed Ejection Seat Cushions (RSC)
Starting Date	2/28/2000
Ending date	3/1/2000
Facilities and Labs	Vertical Deceleration Tower (VDT)
Subjects	Hybrid III 50
Peaks and Ranges	TBD
Data Availability	Test data accessible on optical disk or BDB by study & test number; video accessile on tape cartridges by facility and test number.
Project/Task Number	62202F-7231-3101
Tech Report Number	TBD
Publications	Perry C.E, Nguyen T., and Pint S.M., "Evaluation of Proposed Seat Cushions to Vertical Impact," SAFE Proceedings, October 2000.
Distribution	ASC-00-1861, ASC-01-1990 (Content), ASC 03-2843 (Videos) - Distribution Unlimited

Figure 14. The First Page of Study Information for Study 200001



BIODYNAMICS DATABASE

Cell Information of Study No. 200001
RAM SEAT CUSHION STUDY (RSC)

Main Menu

Home

Click cell
to see tests

6 cells

More...

Cell	Axis	NEG-G	Cushion	FACIL	Harness	H Rest	Helmet	Iner Reel	Lap Belt	Lap ADJ
A	+Z	NONE	NONE	VDT	MB-6	0° C	HGU-55/P	SINGLE-T	HBU-Std	E/W
B	+Z	NONE	ACES II	VDT	MB-6	0° C	HGU-55/P	SINGLE-T	HBU-Std	E/W
C	+Z	NONE	APECS I/C	VDT	MB-6	0° C	HGU-55/P	SINGLE-T	HBU-Std	E/W
D	+Z	NONE	APECS I/P	VDT	MB-6	0° C	HGU-55/P	SINGLE-T	HBU-Std	E/W
E	+Z	NONE	DYN SYS I	VDT	MB-6	0° C	HGU-55/P	SINGLE-T	HBU-Std	E/W
F	+Z	NONE	Confor C-47	VDT	MB-6	0° C	HGU-55/P	SINGLE-T	HBU-Std	E/W

Figure 15. The First Page of Cell Information for Study 200001

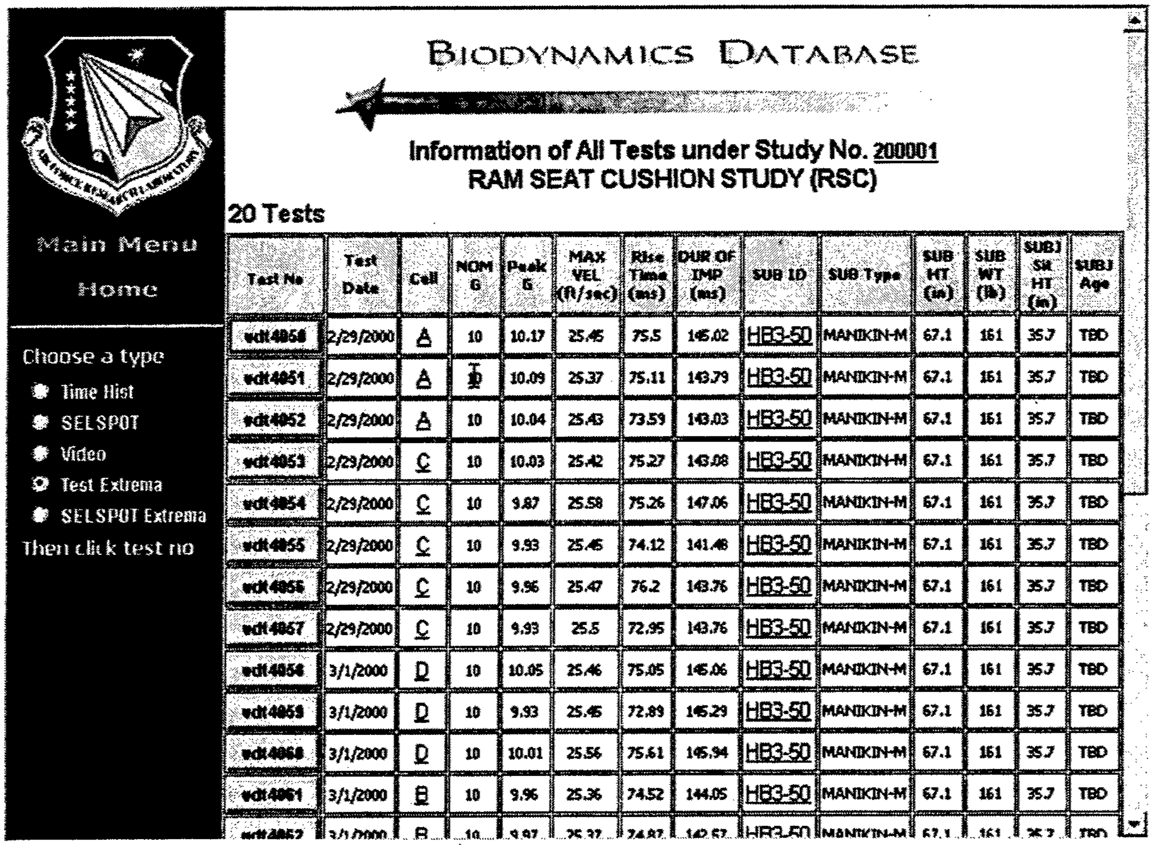
- H Rest: type of head rest and extension angle.
- Helmet: type of helmet.
- Iner Reel: inertial reel used in the test fixture.
- Lap Belt: type of lap belt.
- Lap ADJ: type of lap belt adjuster.
- Limb Rest: additional straps used.
- Misc: information not covered in listed parameters
- NVG/HMD: night vision goggles/helmet-mounted systems.
- Oxygen Mask: type of oxygen mask.
- PIN: metering pin number for test facility
- PLOAD: harness tension pre-loads
- Seat Fix: seat fixture.
- SP/SB: seat pan angle/seat back angle

Clicking on a cell button brings up the test information page that lists only those tests conducted with the configuration specified in the cell.

3.4.4 Test Information and Test Extrema Pages

Figure 16 shows the screen capture of the Test Information page for Study 200001. This page contains the complete list of tests conducted in the study. Using the web browser, the user can view all the tests by scrolling down the page. The total number of tests listed is shown at the top of the table. This page may contain several hundred tests and therefore take a few seconds to load. Below are brief definitions for the fields in the Test Information page:

- Test No: Test number of the test. It normally consists of three characters representing the test facility followed by a number assigned to the test.
- Test Date: Date on which the test was conducted.
- Cell: Cell to which the test belongs. A link is attached to the cell number and leads to the cell information page.
- NOM G: Nominal or approximate G level of the sled or carriage acceleration designed for the test.
- Peak G: Actual peak G of the sled or carriage acceleration measured in the test.
- MAX VEL: Maximum velocity in ft/sec of the sled or carriage during the test.
- Rise Time: Rise time of the acceleration impact pulse.
- DUR of IMP: Duration of the acceleration impact pulse.
- SUBJ ID: Test subject ID. A link is attached to the Test Information page that leads to the subject information page.
- SUBJ Type: Type of test subject (human or manikin and gender).
- SUBJ Ht: Standing height of the test subject in inches.
- SUBJ Wt: Weight of the test subject in pounds
- SUBJ Sit Ht: Sitting height of the test subject in inches.
- SUBJ Age: Age of the test subject in years.



Test No	Test Date	Cell	NOM G	Peak G	MAX VEL (ft/sec)	Rise Time (ms)	DUR OF IMP (ms)	SUB ID	SUB Type	SUB HT (in)	SUB WT (lb)	SUBJ SIt HT (in)	SUBJ Age
vdt4050	2/29/2000	A	10	10.17	25.45	75.5	145.02	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4051	2/29/2000	A	10	10.09	25.37	75.11	143.79	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4052	2/29/2000	A	10	10.04	25.43	73.59	143.03	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4053	2/29/2000	C	10	10.03	25.42	75.27	143.08	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4054	2/29/2000	C	10	9.87	25.58	75.26	147.06	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4055	2/29/2000	C	10	9.93	25.45	74.12	141.48	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4056	2/29/2000	C	10	9.96	25.47	76.2	143.76	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4057	2/29/2000	C	10	9.93	25.5	72.95	143.76	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4058	3/1/2000	D	10	10.05	25.46	75.05	145.06	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4059	3/1/2000	D	10	9.93	25.45	72.89	145.29	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4060	3/1/2000	D	10	10.01	25.56	75.61	145.94	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4061	3/1/2000	B	10	9.96	25.36	74.52	144.05	HB3-50	MANIKIN-M	67.1	161	35.7	TBD
vdt4062	3/1/2000	B	10	9.97	25.37	74.87	142.57	HB3-50	MANIKIN-M	67.1	161	35.7	TBD

Figure 16. Test Information for Study 200001

The design of the Test Information page is similar to other web pages displaying tabular data. The "Test No" field has buttons bearing the test number and functioning in several ways depending on the radio button selection on the left menu bar. If "Time Hist" or "3-D Motion" is selected, clicking the button will start time history chart plotting (see section 3.4.6). If "Video" is selected, clicking the button will access the video display page (see section 3.4.5). If "Test Extrema" or "3-D Extrema" is selected, clicking the button will display tables of extrema (or peak) data.

Multiple tests can be included for time history and 3-D motion data charting as well as for extrema data comparison. Therefore, clicking the test number button first displays a message box asking whether or not to select another test. The user can click "OK" to add another test or "Cancel" to proceed. Using the "Test Extrema" option as an example, once the user selects tests, the next page, "Select Channel", is loaded and lists all the recorded data channels used by these tests. The user can then select multiple channels from the list and click "Continue" to view test extrema data for all these channels. Note that some channels may not be present in every selected test or group of tests. Figure 17 shows the test extrema comparison for three data channels among three selected tests of Study 200001.

Because the plotting and comparison are conducted for the same channels among selected tests, the test subjects in these tests have to be comparable, i.e. human to human or manikin to manikin; the web interface will prevent users from mixing different subject types together.

Test Extrema Data for 3 Tests

CHEST X ACCEL (G)

Test No	Subj Type	Max	Time of Max	Min	Time of Min	Preimpact Avg
VDT4050	MANIKIN-M	9.28	76	-4	86	-0.01
VDT4052	MANIKIN-M	6.98	75	-2.74	87	0.01
VDT4054	MANIKIN-M	15.29	82	-5.74	176	0.04

CHEST Ry ANG ACCEL (RAD/SEC2)

Test No	Subj Type	Max	Time of Max	Min	Time of Min	Preimpact Avg
VDT4050	MANIKIN-M	1225.38	75	-1933.67	86	5.83
VDT4052	MANIKIN-M	803.58	100	-1429.09	86	-2.95
VDT4054	MANIKIN-M	1842.49	83	-1611.13	92	-6.45

INT LUMBAR X FORCE (LB)

Test No	Subj Type	Max	Time of Max	Min	Time of Min	Preimpact Avg
VDT4050	MANIKIN-M	361.84	78	-45.7	337	-22.56
VDT4052	MANIKIN-M	323.05	77	-28.88	306	-5.21
VDT4054	MANIKIN-M	458.38	86	-10.86	364	-10.77

Figure 17. Test Extrema Data Comparison Among Three Tests for Study 20001

3.4.5 Handling of Multi-Media Data and File Downloads

The BDB has a large collection of different types of data. Besides those data stored in the SQL Server database, there are other types of individual data files stored on the file server and organized by a set of folders and naming rules. These files are:

- DAS/3-D motion analysis time history data files in Microsoft Excel format (.xls).
- Study reports in Adobe PDF format (.pdf) or Microsoft Word format (.doc).
- Study photos scanned and saved in JPEG format (.jpg).
- Test video in Windows streaming video format (.wmv and .asx).
- Images of pre-1970's tests' oscillograph charts digitized in JPEG format (.jpg).

<u>Time history and 3-D Excel data files</u>

Each test produces one DAS time history and one 3-D motion analysis time history file. There are tens of thousands such files. Users can view and chart these data (see section 3.4.6) or download the Excel file. The number of files that can be downloaded is set to 100 by the BDB user management system at the initial user registration but can be increased upon request by the user. SQL Server stored procedures were developed to perform these tasks and to keep track of user download activities, such as the names of downloaded files, the time of downloading, the balance on the user's download quota, and the IP address of the user's computer.

Because these files are stored in physical folders on the file server, users do not have direct access to the files. The downloading is performed through a third-party component designed for file/data uploading and downloading. The component serves as middleware, and server-side script was developed to locate the data file and transfer it from the file server to the user's computer. This process is transparent to users.

Referring to Figure 16, after the user selects "Time Hist" and a set of tests, the next page (Select Channel for Web Charting) displays a set of "Download" buttons at the bottom of the page. Each download button corresponds to the time history file of one selected test. Clicking it begins downloading the file and consequently the user's download quota is reduced by one.

For pre-1970's tests, the time history data may be in the form of oscillograph charts. These charts are displayed as regular image files.

<u>Study Reports and Photos</u>

Each study may contain multiple reports and documentation photos that can be accessed through the Study Information page by checking the radio button "Photos" or "Reports." Because these files are placed in virtual directories, they are directly accessible to users and can be viewed or saved. The study photos are listed in two columns and displayed in small sizes (see Appendix D). Clicking each individual photo opens another window with the full–size, high-resolution picture.

<u>Streaming Test Videos</u>

Many tests have more than one slow-motion video file since there are often two cameras deployed at different shooting angles. The BDB contains several thousand video clips, most of which are several megabytes in size. Users can view test videos by checking the radio button "Video" and then clicking the test number button on the Test Information page (see Figure 16). If the test has multiple video clips, a list of these clips is shown first instead of the video playing page.

For streaming videos, the video starts playing when the first part of the video clip has been received by the client computer and keeps playing while follow-on parts are arriving one by one. This is achieved through Microsoft Windows Media Service technology. The streaming video is served by the Windows Media Server and played by the Windows Media Player embedded in the web page. Because user computers may use different versions of Windows Media Players, script was developed to detect the client version and embed the correct one. The streaming video files are created using a Visual Basic program that searches for any new AVI files and automatically converts them to streaming video files.

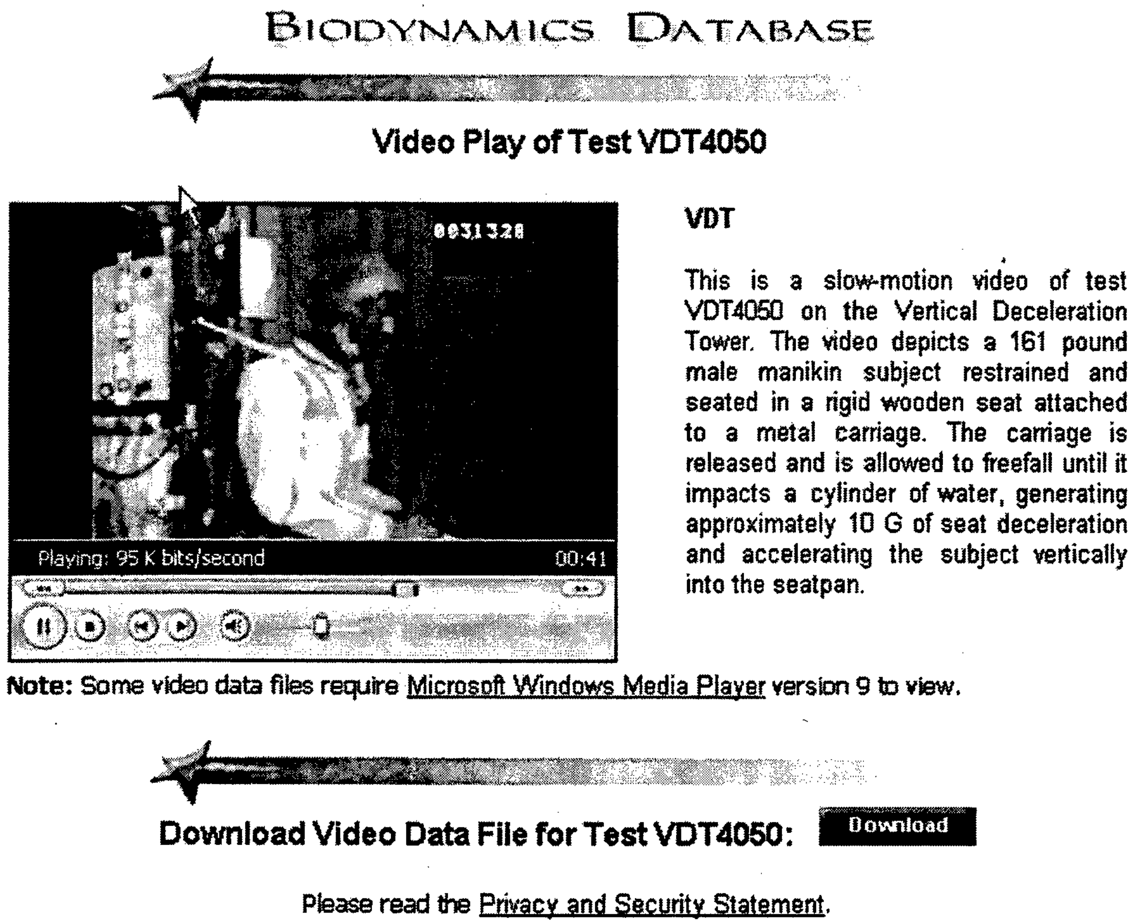


Figure 18. Embedded Web Video of Test VDT4050 in Study 20001

Figure 18 shows the streaming video page of test VDT4050 in Study 200001. The text to the right of the video window depicts the video in terms of subject information, test configuration, and peak acceleration data. This narrative is generated dynamically for each test through server script and database stored procedures. The stored procedure extracts information from the database, and server script forms the narrative string based on this information and plugs in necessary numbers. Different test configurations usually require different narratives. The user can also download the video clip by clicking the "Download" button. Downloading a video file requires user registration and counts toward the user account's download quota.

3.4.6 Web Charting of Time History Data

Before the development of the BDB web interface, the plots of DAS and 3-D motion analysis time history data were created through an Excel customer add-on developed in Visual Basic. Therefore, the earlier web interface development modified the code into server script. A mechanism was developed to copy the Excel data file requested by the user into a working folder for plotting and to assign an ID number for tracking and deleting once the user exited. To generate a plot, the server script started an Excel application, opened the data file (workbook), and called the Excel charting functions. There were some drawbacks to this approach because copying/deleting files was slow and running multiple Excel applications was resource-intensive. Therefore, the number of users doing concurrent time history plotting was limited. Later when the pubic server was updated, Microsoft Office was removed from the server and time history plotting was disabled temporarily.

To obtain true web plotting capability, the software plotting package "WebChart 8" from ComponentOne LLC was integrated into the BDB web interface. WebChart 8 allows development of sophisticated X-Y charting routines for Active Server Pages (ASP). The charts are served as JPEG images to client browsers. Users can access time history or 3-D motion data web charting from the test information page (see Figure 16) by checking radio button "Time Hist" or "3-D Motion" and then selecting one or multiple tests by clicking on the corresponding "Test No" buttons. The next page displays "Select Plotting DAS/3D Motion Analysis Channels," as shown in Figure 19.

In Figure 19, the channel names of selected tests (VDT4050 and VDT4051) are retrieved by querying the Test Extrema table in the database. The names are listed in a cluster pattern with similar channels grouped together. Because there are usually several dozen channels in an Excel data file, this kind of cluster listing helps the user quickly locate the channels of interest. There are two plot type choices including "Overlay," which allows the user to compare different channel data in a single large size plot, and "Multiple," which draws one plot per channel and allows the user to compare the same channel data among different tests.

Clicking the "Submit Chart" button brings up the time history plots. Figure 20 shows an overlaid plot of two channels from two tests (total of four). It also demonstrates the capability of making two plots with different scales and units using the left and right Y-axes. Figure 21 shows four plots with one plot per channel for the same two tests. The curves in both Figures 20 and 21 are in different colors when viewed with a web browser.

The creation of a chart involves two steps, the first of which is to extract data from the Excel data file. Inside the file, the first column on the left is Time and the following columns to the right are Channel Data columns. The first row has the channel names as the column headings. A data range has been defined in each Excel file to encompass the cell region that has the time history data. Microsoft ADO (ActiveX Data Objects) is used to query the Excel workbook and retrieve selected columns' data into an ADO Recordset. In this approach, the workbook is treated as a database and the data region is treated as the data table for the query search. The column headings are used as the selection fields in the query.

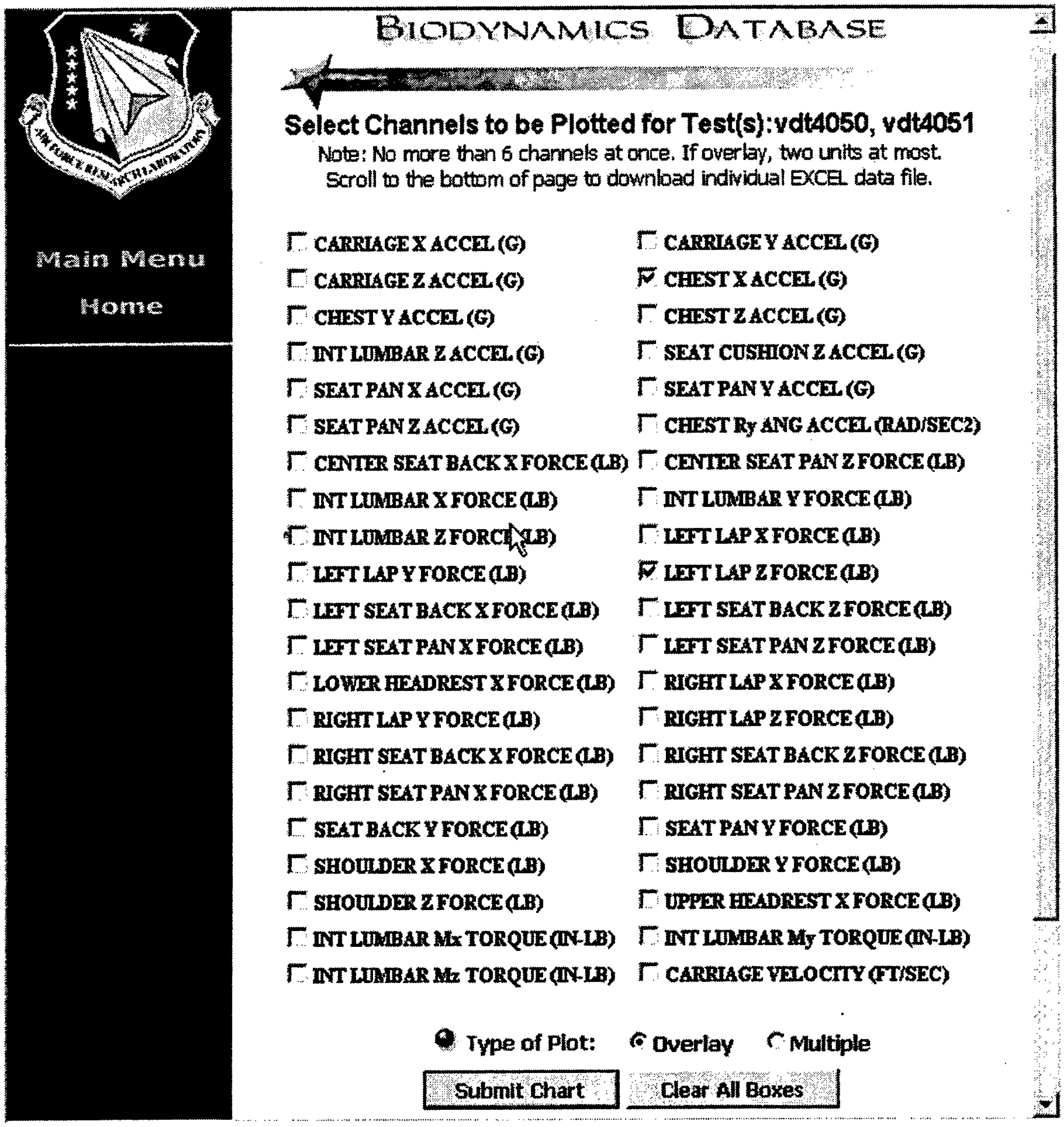


Figure 19. Channel Selection for Two Tests in Study 200001

The second step is to produce the plots. Because the number of plots and plotting contents are not pre-known, the setup, drawing, and display of plots have to be dynamically generated. These tasks are accomplished through server script developed in the ASP page of the time history plots.

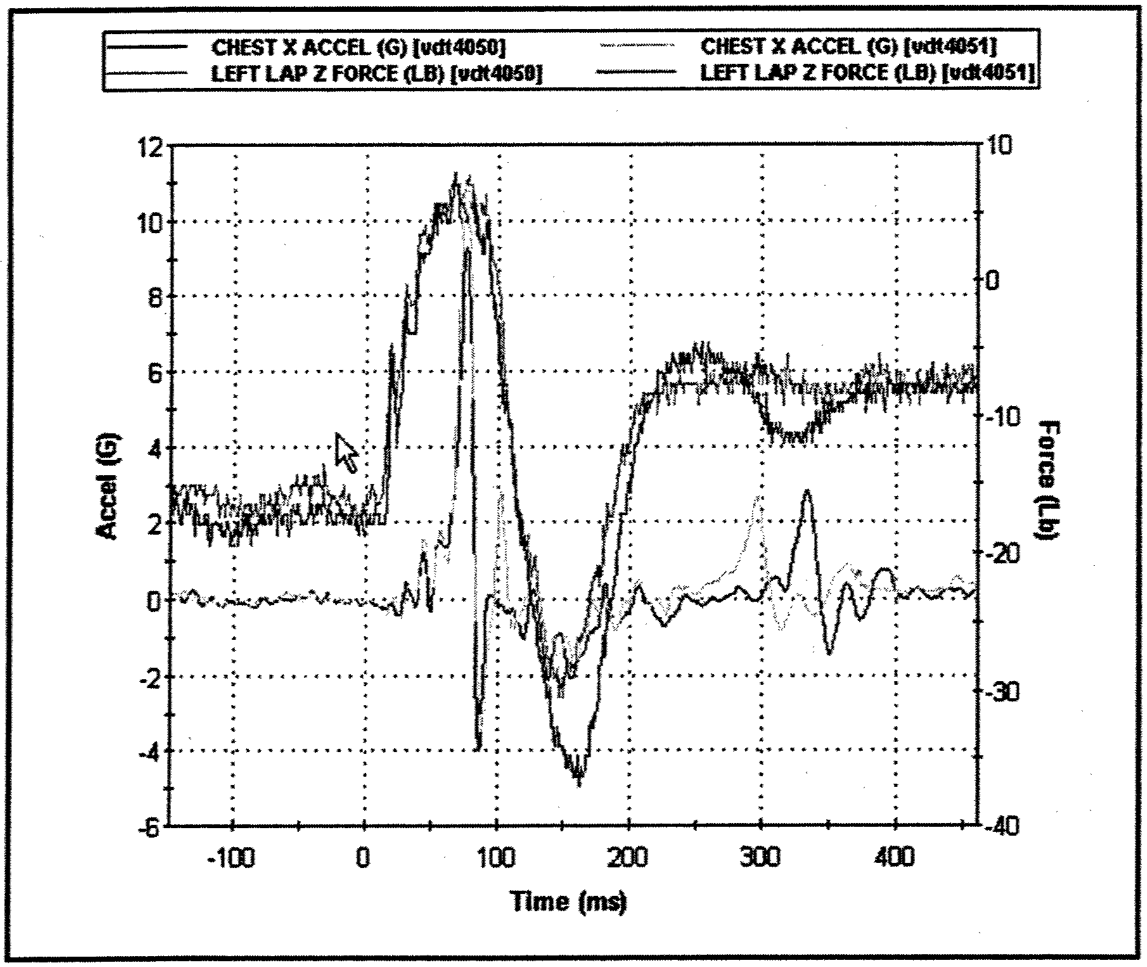


Figure 20. Overlaid Time History Plot of Two Channels Each from Tests VDT4050 and VDT4051

The server VBScript:

- Creates chart objects using WebChart's server-side component with each chart object representing one plot.
- Creates data series in the chart object and loads data from the record set. Because there may be multiple tests each having different time scales and Y axes, the data series have to be in general layout format with independent X and Y arrays. The number of data series in a chart object also depends on whether the plot is overlaid or not. In addition, certain channels may not be present in every test and this in turn will affect the number of data series in the chart object.
- Sets up corresponding axes, labels, colors, and legends.
- Sets up size and position for each plot depending on the number of plots.
- Draws the X-Y plots and saves them as JPEG images.

Compared to the old approach of running an Excel application, this new approach requires minimum system resources, has fast performance, and is very flexible. It offers a way to visualize DAS and 3-D motion analysis time history data.

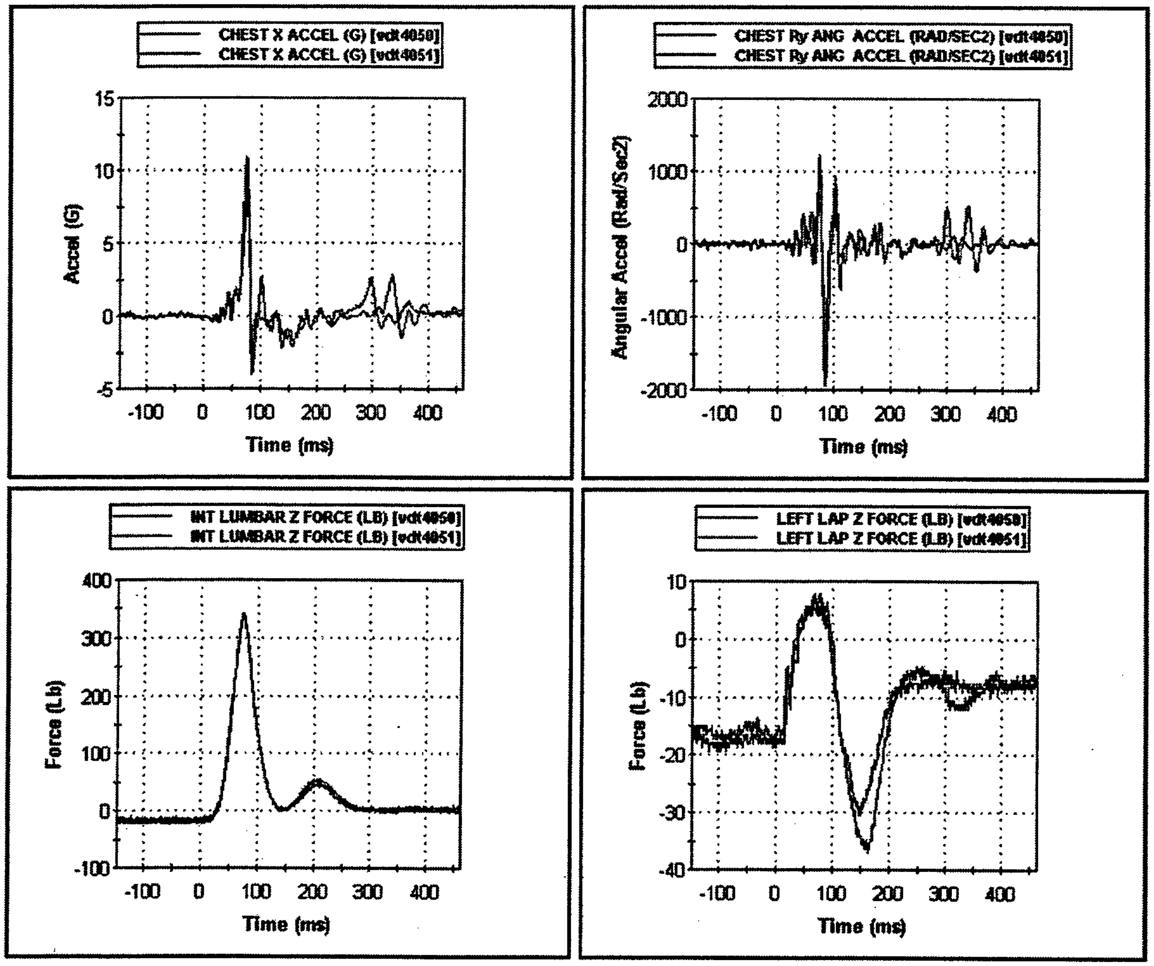


Figure 21. Four Separate Time History Plots of Tests VDT4050 and VDT4051

3.5 Integration of GEBOD Program

3.5.1 GEBOD Program and Lahey FORTRAN for .NET compiler

GEBOD is a FORTRAN 77 program that is used to compute human and dummy body data sets for rigid body dynamics modeling and simulation, such as the ATB (Articulated Total Body Model) simulation. The program uses a few basic measurements such as age, weight, and/or height as inputs. A GEBOD-generated body data set divides the body into 15 or 17 segments, joins them at locations representing the physical joints of the human body, and assigns them mass properties based on segment volumes. The computation is based on a set of regression equations developed from several anthropometric surveys and stereophotometric data. For more detailed information on GEBOD, please refer to references 7 and 8.

The objective of integrating GEBOD into BDB is to give users a tool to evaluate models of the BDB's test subjects or other user-specified subjects for possible applications in biomechanical modeling and simulation. The focus is typically on the large number of human test subjects, and therefore the BDB's GEBOD interface is used to generate human data sets. In addition, joint mechanical properties are not listed because they are not complete at this time and need further validation.

The introduction of ASP.NET simplified the integration of GEBOB into the BDB web interface because .NET technology allows coding in mixed languages. In 2003, Lahey Computer Systems, Inc released Lahey/Fujitsu FORTRAN v7.1, a FORTRAN for .NET compiler integrated with Microsoft Visual Studio.NET 2003. It allows developing an ASP.NET web application with mixed programming and compiling between Visual Basic.NET and FORTRAN 2003.

3.5.2 GEBOD Web Pages

All GEBOD related web pages are developed in ASP.NET, which is very different from ASP in that it has an object-oriented structure, uses server controls, and is programmed in VB.NET and therefore pre-compiled. These features are very beneficial to the web page development. For example, the object-oriented structure enables the development of user controls for page heading and footing. The page heading user control groups the standard BDB title bar and left menu bar into one ASP.NET page. It was also used in other ASP.NET pages. In the future, adding a link to the menu bar will only need to change the user control page rather than modify all the other web pages. The introduction of server control allows programming Window-style the interactive user interface. The pre-compiled code increases performance compared to the ASP's slow runtime interpretation of VBScript code. Because an ASP.NET web application runs separately from the ASP web application and BDB's GEBOD requires user registration, a mechanism was developed to track users between ASP and ASP.NET sessions by assigning and saving a random UserID number.

Using Lahey FORTRAN v7.1, GEBOD was converted to FORTRAN 95. The body data set is computed in ASP.NET pages by calling different GEBOD subroutines. The results are exposed as properties and displayed directly in the pages. The inputs are handled by server controls, and corresponding event-handling routines are programmed in VB.NET. Figure 22 illustrates a complete sample input for an adult human subject with known weight and height. Because there are several options along each step of the input, the initial loading of the page only shows the dropdown box "Subject Type". With the progress of selecting or entering values, more dropdown and input boxes are shown one by one depending on the user's selection and input from the previous step.

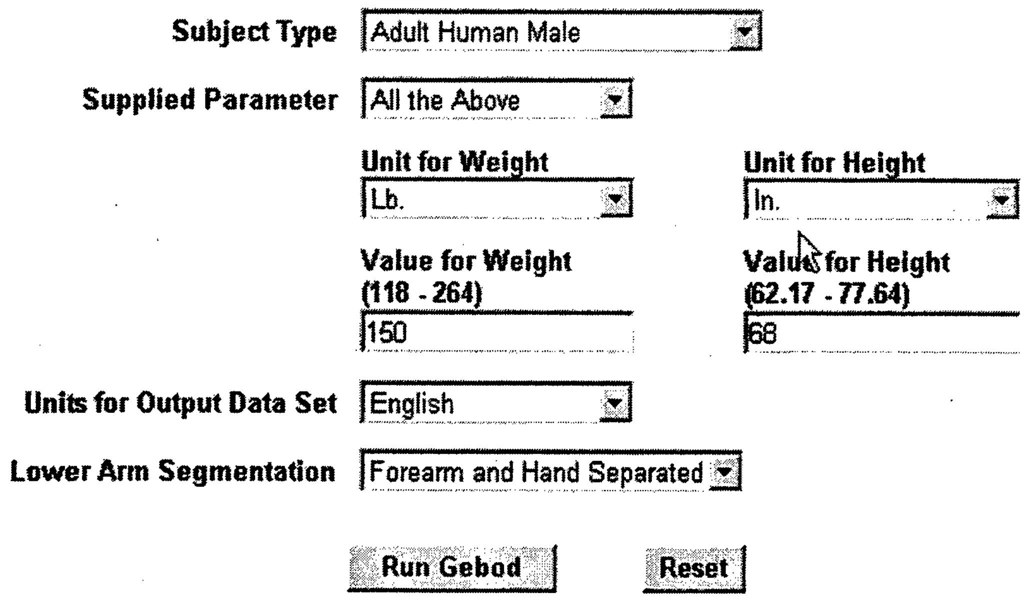


Figure 22. BDB GEBOD Input of an Adult Human Male Subject

The major options for subject types are:

- Child (2-19 years)
- Adult human male
- Adult human female
- User-supplied body dimensions

The input parameters for the child option are age, weight, and/or standing height. The input parameters for adult human are weight and/or standing height. The units for weight and height can be English, metric, or percentile. If the "User-Supplied Body Dimensions" option is selected, the page will be redirected to the 32-body-dimension input page, as shown in Figure 23. In this page, the dropdown list "Select BDB Subject" allows the user to select a BDB test subject, and the web interface then extracts the anthropometry measurements for these 32 body dimensions from the BDB database. Clicking the button "GEBOD 32-Dim Input File" produces a formatted FORTRAN input file consisting of the 32 body dimensions of the subject. This input file can then be used as an input to a stand-alone GEBOD program to generate a complete body data set. The output of a GEBOD iteration consists of three web pages, including information on 32 body dimensions, segment mass properties, and joint connectivity and locations. Appendix E depicts the result set for the input values shown in Figure 22. The integration of GEBOD successfully introduces the latest .NET technology into the BDB web interface development and will be the platform for future enhancements of the interface, especially in the area of adding sophisticated data analysis modules, particularly since most of these modules already exist in various stand-alone programs.

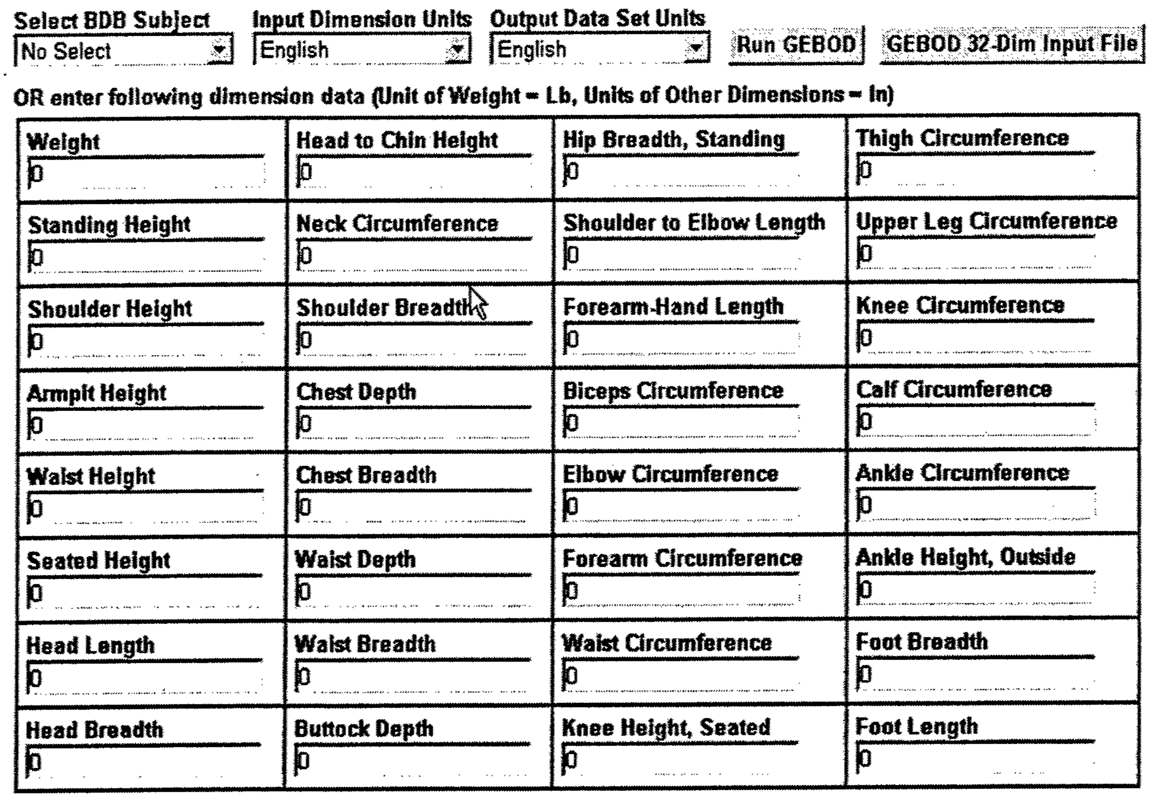


Figure 23. BDB GEBOD Page for User-Supplied 32-Body-Dimension Option

4. REGISTRATION AND NAVIGATION OF THE BDB

4.1 User Registration

On the BDB home page, the "View Sample Data as Guest" provides an overview of the BDB's structure and capability for new users. Accessing all other data, searching the BDB, and downloading data files require user registration. The registration information is used only for site user management and is kept solely in the BDB's user management system. It is not stored in any other databases for commercial uses or any other data gathering purpose.

The user registration page can be directly accessed from the BDB home page (see Figure 7). After the registration is submitted, a new user account is created in the BDB but the account status is in a holding state. The account has to be reviewed and approved by the BDB administrator. This usually takes one or two days. Once the account is approved, it is activated and the user is notified through e-mail. A new user account usually has a one-year expiration time and a 100 file download quota. If either of the numbers is exceeded, a notice will be sent to the user through e-mail and the user can submit a renewal request for approval. After the user account is activated, the user can login with their selected UserID and password. Clicking the "Login as Registered User" label on the BDB home page (see Figure 7) takes the user to the login page. Once the user logs in, a link to the Main Menu is provided.

4.2 Navigating the BDB

The web interface of the BDB is intuitive and easy to use. On the home page, the links "About the Data Bank" and "Laboratory Test Facilities" give an overview of the BDB. The "Glossary" link on the blue left menu bar area gives a complete list of definitions of many terminologies and abbreviations used in the BDB.

The sections from 3.2 to 3.5 of this technical report present detailed information on important pages and features of the BDB web interface and can be used as a User's Guide. In addition, Figure 24 depicts the major navigation paths of the BDB that can be used as a site map.

5. CONCLUSIONS

The BDB incorporates several decades of biomechanics research data compiled at the Air Force Research Laboratory (AFRL). With the use of modern database technology, these data are maintained securely and managed efficiently. In its current capacity, the BDB contains an impact test database, ejection research database, and biomechanics bibliographic database. New test data and publications are continuously being added into these databases. Plans are also being made to integrate other types of research data into the BDB, including vibration, wind tunnel and anthropometric data.

The development of the BDB web user interface offers researchers and engineers a user-friendly and readily available way to access, search, visualize, and analyze the vast amount of information in the BDB. It was developed with the latest Internet technology and is capable of delivering targeted data to users in multiple formats including multi-media files. The interface is being continuously improved with the planned addition of more analytical modules to facilitate in-depth mining of the data. Web pages will also be developed for the planned new databases. It is envisioned that the BDB will be the center of data management and analysis for biomechanics research in DoD and a valuable tool for outside researchers and engineers in the application of AFRL's research data.

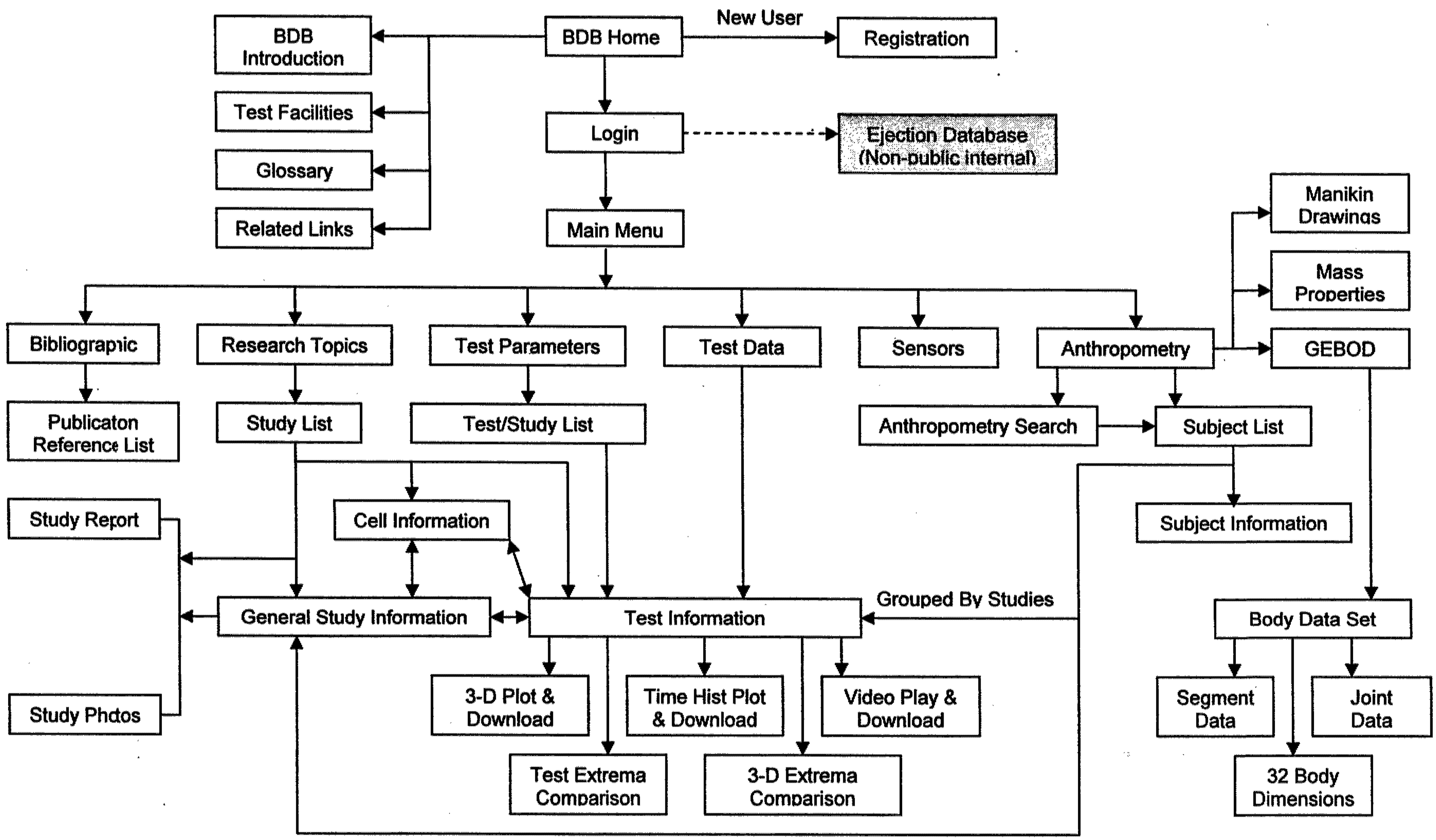


Figure 24. BDB Site Navigation Map

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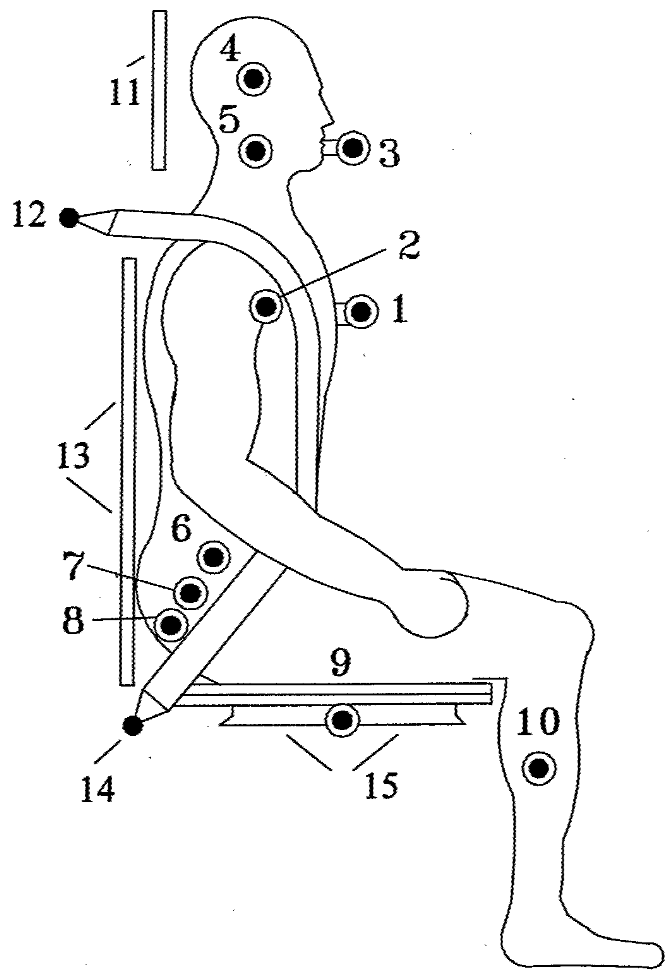
Appendix A

List of Test Data Sensors

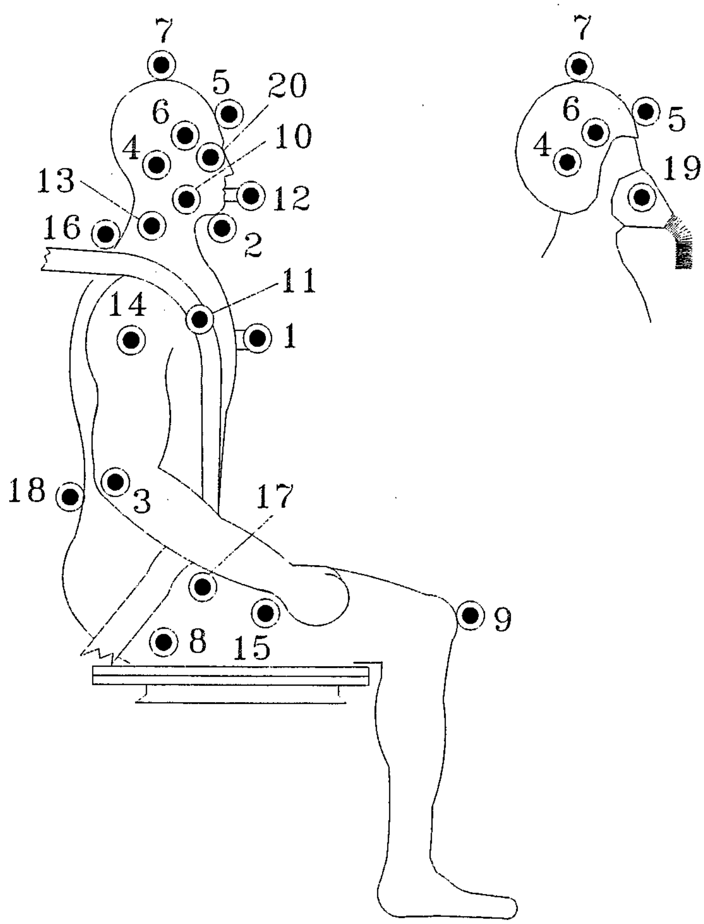
1. Primary Acceleration / Force Sensors



Primary Acceleration / Force Sensor Locations and Designations

1	Chest Acceleration	9	Seat Pan Acceleration
2	Int Chest Acceleration	10	Tibia Force
3	Head Acceleration	11	Head Rest Forces
4	Int Head Acceleration	12	Shoulder Force
5	Neck Force	13	Back Rest Forces
6	Lumbar Acceleration (ADAM)	14	Lap Force
7	Lumbar Force	15	Seat Pan Forces
8	Lumbar Acceleration (Hybrid III)		

2. Primary 3-D Motion Analysis Targets



Primary 3-D Motion Analysis Target Locations and Designations

1	Chest	11	Shoulder Strap
2	Chin	12	Mouth
3	Elbow	13	Neck
4	Ear / Helmet Ear	14	Shoulder
5	Forehead / Helmet Forehead	15	Thigh
6	Temple / Helmet Temple	16	Upper Spine
7	Top of Head / Helmet Top	17	Waist
8	Hip	18	Lower Back
9	Knee	19	Oxygen Mask
10	Cheek Bar	20	Orbitale

Appendix B

Keywords for Research Topics

- ☐ ACCELERATION LEVEL/DURATION
- ☐ AUTOMOTIVE RESTRAINT
- ☐ CHILD MANIKIN TESTING
- ☐ CREW ESCAPE MODULE
- ☐ DYNAMIC PRELOAD
- ☐ FLIGHT GEAR
- ☐ HARNESS SUSPENSION
- ☐ HEAD INITIAL POSITION
- ☐ HEADREST IMPACT
- ☐ HELICOPTER CREW SEAT
- ☐ HELMET-MOUNTED DEVICE
- ☐ INERTIA REEL PERFORMANCE
- ☐ LAP BELT TESTING
- ☐ LATERAL IMPACT
- ☐ MANIKIN CENTER-OF-MASS
- ☐ MANIKIN EVALUATION
- ☐ METERING PIN PROFILES
- ☐ MULTI-AXIS RESPONSE
- ☐ PARACHUTE OPENING SHOCK
- ☐ SEAT CUSHION PROPERTIES
- ☐ SEAT PAN/BACK ANGLE
- ☐ SHOULDER STRAP ANGLE
- ☐ THIGH IMPACT
- ☐ UPPER EXTREMITY BRACING
- ☐ WEBBING MATERIAL
- ☐ ANGULAR ACCELERATION MEASUREMENT
- ☐ CATAPULT EVALUATION
- ☐ CHILD RESTRAINT SEAT
- ☐ DATA ACQUISITION SYSTEM
- ☐ EJECTION/CREW SEAT
- ☐ GENDER/SIZE EFFECTS
- ☐ HARNESS/RESTRAINT SYSTEM
- ☐ HEAD/NECK RESPONSE
- ☐ HEADREST POSITION
- ☐ HELMET TESTING
- ☐ HELMET-MOUNTED DEVICES
- ☐ INFLATABLE RESTRAINT
- ☐ LAP BELT TIE-DOWN
- ☐ LIMB RESTRAINT
- ☐ MANIKIN COMPOSITE LIMB
- ☐ MANIKIN HEAD/NECK RESPONSE
- ☐ MOTION ANALYSIS SYSTEM
- ☐ OXYGEN MASK TESTING
- ☐ PSYCHOMOTOR PERFORMANCE
- ☐ SEAT PAN LENGTH
- ☐ SEAT REPOSITIONING
- ☐ SIZE/GENDER EFFECTS
- ☐ THORACIC SPINE SENSOR
- ☐ UPPER TORSO RETRACTION

Appendix C

Study Information Pages for Study 200001

1. Page One

General Study Information - Study No. 200001

Study Title	Investigation of Proposed Ejection Seat Cushions (RSC)
Starting Date	2/28/2000
Ending date	3/1/2000
Facilities and Labs	Vertical Deceleration Tower (VDT)
Subjects	Hybrid III 50
Peaks and Ranges	TBD
Data Availability	Test data accessible on optical disk or BDB by study & test number; video accessible on tape cartridges by facility and test number.
Project/Task Number	62202F-7231-3101
Tech Report Number	TBD
Publications	Perry C.E, Nguyen T., and Pint S.M., "Evaluation of Proposed Seat Cushions to Vertical Impact," SAFE Proceedings, October 2000.
Distribution	ASC-00-1861, ASC-01-1990 (Content), ASC 03-2843 (Videos) - Distribution Unlimited

2. **Page Two**

More General Study Information - Study No. 200001

- **Study Title Abbreviation**
  RAM SEAT CUSHION STUDY (RSC)

- **Investigators**
  Thao Nguyen, Steven M. Pint, Chris E. Perry

- **Objectives of the Study**
  1. To compare compressive loads of various seat cushion configurations during vertical impacts. 2. To provide data that can be used by designers to achieve optimal comfort without compromising ejection safety.

- **Test Matrix Cells**

Test Cell	Accel Level	Cushion Configuration	Backpad & Lumbar Support
A	10	None	No
B	10	ACES II	No
C	10	APECS I (Confor)	Yes
D	10	APECS I (Poron)	Yes
E	10	DYN SYS I	No
F	10	C47 Confor w/Stimulite	No

- **Test Number Used for Study**
  VDT4049-VDT4070

- **Measured Variables**
  Carriage velocity and acceleration; seat, seat cushion, head, chest, and lumbar accelerations; head and chest angular accelerations; lumbar force and moment; lap belt and shoulder strap loads; headrest, seat back, and seat pan loads.

- **Instrumentation**
  Endevco 200 series and Entran EG series linear accelerometers; Endevco 7302BM2 angular accelerometers, Denton 1914 tri-axial internal lumbar load cell, Strainsert single-axis load cells (FL series), Michigan Scientific 4000 triaxial strain gage load cells, Dyncorp AAMRL/DYN custom-made load links, Globe 22A672 velocity tachometer, on-board Pacific Instruments (PAC) model 5600A data acquisition system (sample rate 1,000/sec) with 120 Hz low-pass 8-pole Butterworth filter, AT-GPIB interface board in PC (for data collection) and DEC PB-80D-XC Alpha NT computer (for data processing), Kodak Ektapro 1000 high-speed on-board video system.

- **Incidental Equipment**
  VIP seat fixture mounted on VDT carriage with seat back angle 0 degrees with respect to vertical and seat pan angle 0 degrees with respect to horizontal;

contoured headrest in-line with seat back; conventional MB-6 double shoulder strap harness and HBU lap belt (preloaded to 20 +/- 5 lbs); HGU-55/P flight helmet; flight suit; ACES II cushion (flat with multiple foam layers including C47 Confor foam), C47 Confor cushion (2" thick Confor foam with 0.5" Stimulate cover), DYN SYS 1 cushion (flat with 1" layer of medium Sunmate foam on 1" layer of firm Sunmate foam), Oregon Aero APECS I cushion (contoured with either Confor or Poron rate-dependent foam, and including APECS backpad and lumbar support pad), VDT plunger #102; Velcro thigh and ankle restraints with manikin's hands placed under thigh restraints.

- **Results and/or Conclusions**

  The DYN SYS 1 and the APECS I seat cushions transmitted the least energy to the occupant compared to the other cushions, and were comparable to the test configuration using no cushion.

- **Interpretation Remarks**

  1. All transducers (except carriage accelerometers) are referenced to the seat coordinate system. The z-axis is parallel to the seat back and positive in the direction of the subject's head. The x-axis is perpendicular to the z-axis with positive eyes-forward from the subject. The y-axis is perpendicular to the x and z axes according to the right-hand rule. 2. The origin of the seat coordinate system is at the midpoint of the line segment formed by the intersection of the seat pan and seat back. 3. REFERENCE MARK is the start of the event processing window. It represents a voltage pulse corresponding to a flash on the film and is used to synchronize the electronic and photometric data. 4. START TIME (or start of impact) is defined as the time at which sled acceleration exceeds 0.5 G for 5 ms (at 1000 samples/sec) on VDT tests and 0.2 G for 5 ms on HIA tests. All times are referenced to this point (T=0). 5. MAX VELOCITY occurs at the start of impact for VDT, and at the end of impact for HIA tests. Due to problems with the velocity tachometer, MAX VELOCITY was calculated by integrating the carriage acceleration. However, the integrated acceleration is probably slightly higher than the actual velocity due to friction in the rollers.

- **Protocol Numbers**

  N/A

- **Verified by**

  JRB, SMP

- **Key Words**

  SEAT CUSHION PROPERTIES, ACES II SEAT CUSHION, APECS I SEAT CUSHION, CONFOR FOAM SEAT CUSHION, PORON FOAM SEAT CUSHION, DYN SYS I SEAT CUSHION, MB-6 HARNESS, HBU LAP BELT, HGU-55/P HELMET, LUMBAR SUPPORT, HYBRID III MANIKIN

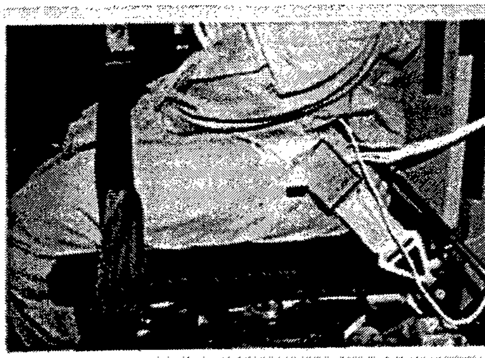
Appendix D

Study Photo Pages for Study 200001

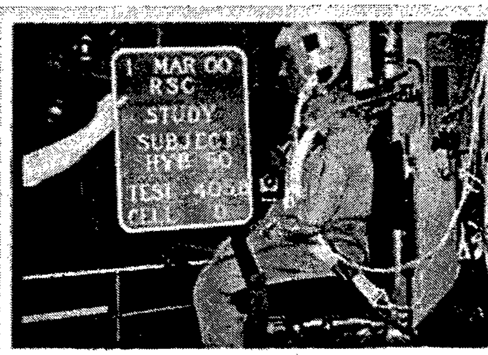
BIODYNAMICS DATABASE

Photographs - Study 200001

Note: Click on photograph for high resolution image. To save an image, right-click on the image and choose "Save Picture As...".



Photograph 200001_7



Photograph 200001_8

Photograph 200001_9

Photograph 200001_10

Appendix E

Sample GEBOD Output

1. Body Information

Subject Type: Human Male, Weight - 150 Lb., Height - 68 In.

No.	Body Dimension	Value	Unit	No.	Body Dimension	Value	Unit
0	WEIGHT	150.0000	Lb.	18	FOREARM-HAND LENGTH	18.9406	In.
1	STANDING HEIGHT	68.0000	In.	19	BICEPS CIRCUMFERENCE	11.6681	In.
2	SHOULDER HEIGHT	55.4131	In.	20	ELBOW CIRCUMFERENCE	11.8352	In.
3	ARMPIT HEIGHT	49.6391	In.	21	FOREARM CIRCUMFERENCE	10.6037	In.
4	WAIST HEIGHT	40.7375	In.	22	WRIST CIRCUMFERENCE	6.6862	In.
5	SEATED HEIGHT	35.8892	In.	23	KNEE HEIGHT, SEATED	21.2284	In.
6	HEAD LENGTH	7.7402	In.	24	THIGH CIRCUMFERENCE	21.5999	In.
7	HEAD BREADTH	6.0700	In.	25	UPPER LEG CIRCUMFERENCE	18.0645	In.
8	HEAD TO CHIN HEIGHT	8.8801	In.	26	KNEE CIRCUMFERENCE	14.4650	In.
9	NECK CIRCUMFERENCE	14.5432	In.	27	CALF CIRCUMFERENCE	13.9070	In.
10	SHOULDER BREADTH	15.6279	In.	28	ANKLE CIRCUMFERENCE	8.4475	In.
11	CHEST DEPTH	9.0558	In.	29	ANKLE HEIGHT, OUTSIDE	5.2584	In.
12	CHEST BREADTH	12.2421	In.	30	FOOT BREADTH	3.7377	In.
13	WAIST DEPTH	8.1174	In.	31	FOOT LENGTH	10.3539	In.
14	WAIST BREADTH	11.3395	In.	32	HAND BREADTH	3.4125	In.
15	BUTTOCK DEPTH	8.7540	In.	33	HAND LENGTH	7.3455	In.
16	HIP BREADTH, STANDING	13.2235	In.	34	HAND DEPTH	1.0612	In.
17	SHOULDER TO ELBOW LENGTH	12.6200	In.				

2. Segment Information

Subject Type: Human Male, Weight – 150 Lb., Height – 68 In.

Note: All coordinate data are described with respect to the segment local reference axis systems

I	Segment Name	Weight (Lb.)	Principal Moment of Inertia (Lb-Sec**2-In)			Principal Axes (Deg.)		
			X	Y	Z	Yaw	Pitch	Roll
1	Pelvis	20.5167	0.6662	0.6031	0.7627	0.00	0.00	0.00
2	Abdomen	4.3428	0.1073	0.0575	0.1592	0.00	0.00	0.00
3	Thorax	44.7422	3.3356	2.4325	2.0262	0.00	14.40	0.00
4	Neck	1.9890	0.0124	0.0150	0.0183	0.00	0.00	0.00
5	Head	9.0813	0.1755	0.1997	0.1296	0.00	36.00	0.00
6	Right Thigh	18.3619	1.1333	1.1909	0.2951	0.00	0.00	0.00
7	Right Calf	7.3317	0.4255	0.4319	0.0484	0.00	0.00	0.00
8	Right Foot	1.8589	0.0339	0.0321	0.0061	-4.00	8.40	-6.10
9	Left Thigh	18.3619	1.1333	1.1909	0.2951	0.00	0.00	0.00
10	Left Calf	7.3317	0.4255	0.4319	0.0484	0.00	0.00	0.00
11	Left Foot	1.8589	0.0339	0.0321	0.0061	4.00	8.40	6.10
12	Right Upper Arm	3.5454	0.0872	0.0913	0.0168	0.00	0.00	0.00
13	Right Forearm	2.5644	0.0616	0.0629	0.0086	0.00	0.00	0.00
14	Right Hand	1.0018	0.0101	0.0083	0.0031	-14.00	6.00	-7.70
15	Left Upper Arm	3.5454	0.0872	0.0913	0.0168	0.00	0.00	0.00
16	Left Forearm	2.5644	0.0616	0.0629	0.0086	0.00	0.00	0.00
17	Left Hand	1.0018	0.0101	0.0083	0.0031	14.00	6.00	7.70

3. Joint Information

Subject Type: Human Male, Weight – 150 Lb., Height – 68 In.

Note: All coordinate data are described with respect to the segment local reference axis systems

J	Joint Name	Connecting Segments		Location in Segment A (In.)			Location in Segment B (In.)		
		Segment A	Segment B	X	Y	Z	X	Y	Z
1	Pelvis-Abdomen	Pelvis	Abdomen	-1.2786	0.0000	-2.1909	-2.1908	0.0000	2.1562
2	Abdomen-Thorax	Abdomen	Thorax	-1.5158	0.0000	-0.8195	-0.1662	0.0000	6.9265
3	Thorax-Neck	Thorax	Neck	-0.1209	0.0000	-7.0070	-0.7733	0.0000	1.5577
4	Neck-Head	Neck	Head	0.9543	0.0000	-2.4494	-0.8112	0.0000	2.0254
5	Right Hip	Pelvis	Right Thigh	-0.6090	2.0414	1.3751	-0.5902	-1.8237	-7.3317
6	Right Knee	Right Thigh	Right Calf	-0.2583	0.3148	9.4011	0.5738	-0.5155	-6.7644
7	Right Ankle	Right Calf	Right Foot	0.3693	-0.7341	9.3442	1.3158	-0.2838	-2.6831
8	Left Hip	Pelvis	Left Thigh	-0.6090	-2.0414	1.3751	-0.5902	1.8237	-7.3317
9	Left Knee	Left Thigh	Left Calf	-0.2583	-0.3148	9.4011	0.5738	0.5155	-6.7644
10	Left Ankle	Left Calf	Left Foot	0.3693	0.7341	9.3442	1.3158	0.2838	-2.6831
11	Right Shoulder	Thorax	Right Upper Arm	-0.8535	6.3704	-3.9323	0.4893	-0.2378	-4.9458
12	Right Elbow	Right Upper Arm	Right Forearm	-0.6580	-0.3437	4.9461	-0.5128	0.2334	-4.1368
13	Right Wrist	Right Forearm	Right Hand	0.3715	-0.0512	5.7180	0.1310	0.5508	-2.5650
14	Left Shoulder	Thorax	Left Upper Arm	-0.8535	-6.3704	-3.9323	0.4893	0.2378	-4.9458
15	Left Elbow	Left Upper Arm	Left Forearm	-0.6580	0.3437	4.9461	-0.5128	-0.2334	-4.1368
16	Left Wrist	Left Forearm	Left Hand	0.3715	0.0512	5.7180	0.1310	-0.5508	-2.5650