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Collaborative Biomechanics Data Network (CBDN): Promoting Human Protection and Performance in Hazardous Environments Through Modeling and Data Mining of Human Centric Data Bases

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14. ABSTRACT
This report is a comprehensive but synoptic overview of the 711 HPW/RHPA Collaborative Biomechanics Data Network (CBDN). The CBDN is a working (i.e. operational) concept for how the collective wisdom of years of systematic DoD research into human response and tolerance should be archived and made accessible for future investigations and for principled operational safety policy. The intent of this report is to give a guided-tour of the CBDN contents, along with its data archiving methods and philosophy. This is done mainly through extended quotes from important source materials from the major contributors to the CBDN.

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SUMMARY

The Air Force Research Laboratory has integrated decades of human response and measurement research data into the world's most comprehensive collection of web-based, searchable databases called the Collaborative Biomechanics Data Network (CBDN). This network is now available to the public. The CBDN contains thousands of records from tests and surveys in impact acceleration, rocket sled ejection, blast, anthropometry, multi-axial vibration, wind tunnel, and high altitude. New data sets are continually being added through participation of active collaborators. It also contains analysis tools including the Generator of Body Data (GEBOD), Altitude Decompression Computer (ADRAC), and BURNSIM models, and a 3-D Human Shape Search tool [a web application built on ARIS] that can be used directly with the databases for injury risk prediction and bio-signature analyses. The CBDN is used extensively by researchers in the Air Force, Army, Navy, NASA, NHTSA, as well as by universities, industry, and international research organizations. The CBDN will continue to improve its user features to allow more efficient sharing of bioscience data across remote networks. When these improvements are combined with analysis tools that evolve to address the needs of mission planners, risk assessment for humans working in hazardous environments should be greatly facilitated.

1.0 Collaborative Biomechanics Data Network (CBDN)

1.1 CBDN Overview and History

The Collaborative Biomechanics Data Network (CBDN) is a group of databases and web applications developed and maintained by the Vulnerability Analysis Branch of the Air Force Research Laboratory (AFRL) at Wright-Patterson AFB, Dayton, Ohio. Its primary mission is to provide a data repository and research utilities for both DoD and public access in the human-centric areas (e.g., anthropometry, biomechanics), and in domains of human performance occurring in hazardous environmental conditions (e.g., low atmospheric pressure).

The CBDN started with the Biodynamics Data Bank (BDB), which was established in 1984 by a team of researchers at the Armstrong Aerospace Medical Research Laboratory Wright-Patterson AFB [Abrams, Kaleps, and Brinkley, 1988]. This database consolidated decade's worth of research formalizing and predicting the effects of impact and acceleration on human operators. The BDB has been later joined by other database archiving/access efforts as the air, sea, land warrior is subject to a broad range of hazards in addition to acceleration. Therefore, a central access point to DoD research on military operations hazards is both a well-motivated and timely project [https://biodyn.istdayton.com/CBDN/aboutCBDN.aspx].

1.2 CBDN Objectives and Tactics

A prototypical database encompasses 1) the results from many studies executed in some empirical domain (e.g., impact damage, burn damage, decompression sickness) and 2) an archiving method of such results (i.e., schematizing, "marking up"), such that easy extension and search of the data base is possible by later investigators. All databases in the CBDN have conformed to this ideal over time (specifics given in the methods section).

A database is constructed to support the following general kinds of goals: allow on-line data analysis & simulation, promote sharing of published human-centric research data, develop common architectures which allow data sharing (but allowing partners to maintain their own data), and perform on-line knowledge discovery. Additionally, the tools developed to extract data from a database and the models derived from the database are important parts of the database proper. These are also archived and made accessible in the CBDN.

CBDN Databases are extensible both within and across domains and are expected to grow in both respects over time. Therefore, laying out a flexible infrastructure for extending and accessing databases is essential. Commercial-off-the-shelf information-technology helps maintain flexibility and security. In addition, knowledge and engineering techniques enhance user access and meaningful digestion of data. In particular, multiple search and visualization techniques have to be built-in to selected databases. These consist of cross links and searching capability among all types of data. Where rich auxiliary data, such as video recordings exist, these are archived and accessed conveniently. These techniques are applied in a consistent fashion among the databases in the CBDN, which originate not only from in-house (historically first) databases but also from other Air Force, Navy, Army, and possibly industry-based functions. For each database hosted, some amount of regularization or adaptation is required for hosting to be conducted in consistent way. CBDN has evolved in such a consistent way over time.

1.3 CBDN Databases

To date CBDN hosts eight diverse databases relating to operationally-relevant and/or hazardous performance conditions. These are hosted (or mirrored) at one central (but distributed) location at Wright-Patterson AFB. The databases as shown in Figure 1 are the Biodynamics Database (BDB, the original Air Force repository of impact and acceleration effects for the modeling of human injuries), Naval Biodynamics Laboratory Database (a complementary database to the BDB), Rocket Sled and Ejection Database (Air Force), Human Vibration Database (Air Force), Wind Tunnel Database (Air Force, developed by JayCor), Air Crew Performance and Protection (Altitude) Database (Air Force), Anthropometry Research Information System (Air Force and Army), and Blast Database (Army). These databases are discussed further in the "Contents" section of this report.

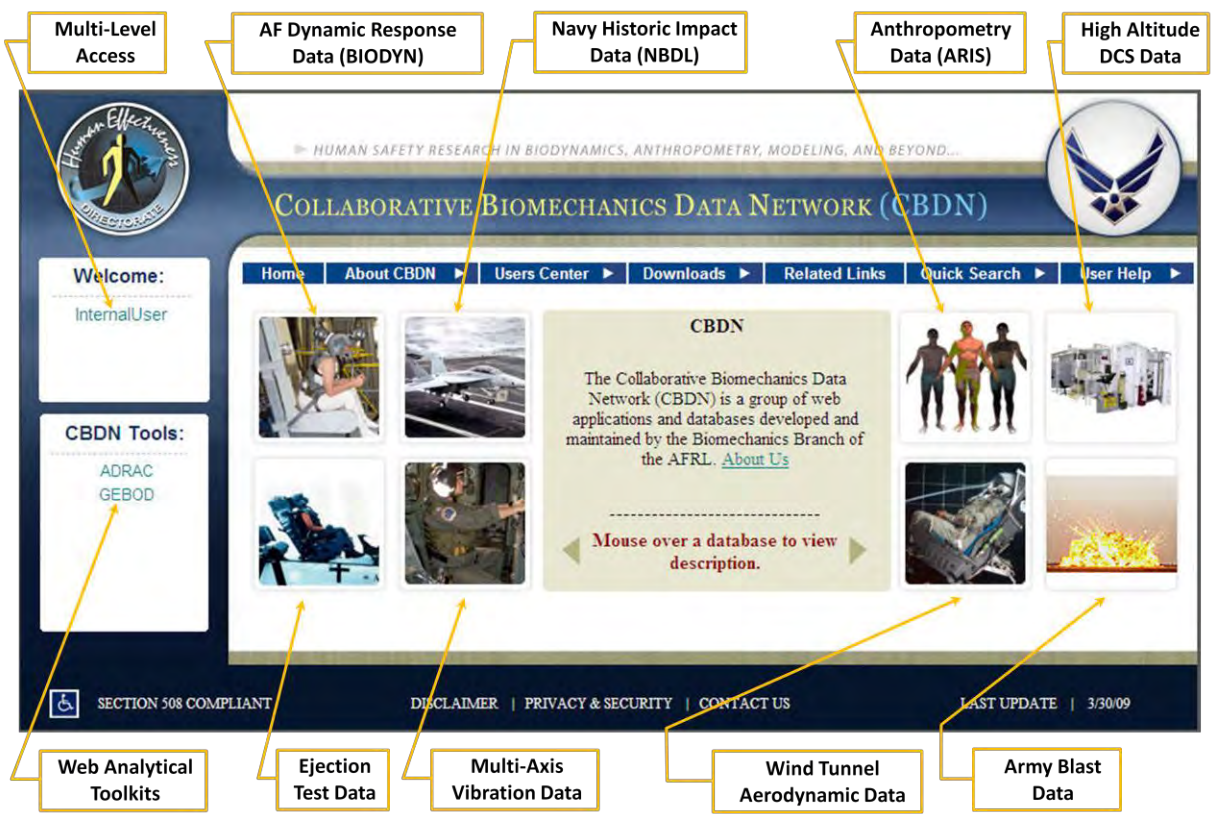

Figure 1. Collaborative Biomechanics Data Network (CBDN)

1.4 CBDN Models and Tools

CBDN also provides central access to mission-relevant modeling tools, which are mathematical formalizations of the domain results relevant to mission-relevant hazards or constraints. A model is often the major application of a relevant database. In this report, four such models and/or tools will be described using their primary sources: Altitude Decompression Sickness Risk Assessment Computer (ADRAC) model, GEnerator of BODY Data (GEBOD) program, a heat exposure burn/damage extrapolator (BURNSIM), and finally a data mining tool (ABMiner).

2.0 METHODS

2.1 Platform

2.1.1 Conceptual organization

The six impact/acceleration databases (BDB, NBDL, Ejection, Vibration, Blast, and Wind Tunnel) were all designed using the same general structure organized at the top level by test programs and/or individual tests. The organization of the CBDN biodynamic response data contained in the Biodynamics Database (BDB) is centered on test programs, or studies/experiments, designed to answer particular questions in the areas of human dynamic response (e.g., to impact acceleration associated with aircraft ejection equipment). The BDB is the most developed template for a data archiving scheme. It contains summary information for each test program and all specific test parameters, as well as the actual collected test data. The tests conducted under each study are grouped into cells. A cell defines a set of 18 parameters or test conditions, a number which could vary with different domains, which are identical among all tests within the cell. For each test, there are up to one hundred data channels including subject/seat forces, accelerations, and displacements in multiple axes. Such data channels are the mission-relevant changes in forces or accelerations applied to a human or manikin (hypothesized to be relevant toward causing human injury). These data channels provide the basic telemetry (or time-history) throughout an experimental trial [Cheng and Buhrman, 2000]. The Ejection, NBDL, and Blast databases all contain the same type of impact acceleration data as the BDB, and therefore all use the same general structure. However, the tests contained in these databases were not conducted under discrete test programs or studies. The data are therefore organized by individual tests which can be searched for by the various test parameters which vary for the databases. Organizational structures for the other two databases were developed based on their unique data requirements. For an excellent primer on the CBDN process see Keller and Plaga [2010]. This report shows an example of a database, in the ejection-seat / rocket-sled domain, stood up for rapid assimilation of new studies and rapid extraction of specific data meeting query constraints.

2.1.2 Database infrastructure

Figure 2 shows a big-picture view of the CBDN present and future hosting tactics. The left side of the picture addresses the options for participating in the network. In particular, those who are stakeholders in the database community have the option of either tight or loose integration in the CBDN. Tight integration involves Wright-Patterson AFB hosting and maintaining a physical copy of the database, thus freeing the database contributor from this overhead. Loose integration, on the other hand, puts more of the responsibility (autonomy) on the stakeholder. In this case, CBDN acts as a kind of mirror for the partner's data, via XML web services which are jointly agreed on by CBDN and the partner.

XML offers a method of data description that is both well formatted and open to a high degree of manipulation. Further, XML files are text-based, so they can pass over firewalls through the standard http protocol. This resolves a common security obstacle for organization-to-organization data integration. The partner must maintain its own database and be consistent with (and also maintain) the agreed-upon web service interface. In principle, such practices once perfected make database manipulation much easier for a widely distributed set of stakeholders. As an incentive to the loose-integration approach, at least in the domain of anthropometry, RHPA is developing a unique ontology for querying and constraining data search in the ARIS database (e.g., WEAR, World Engineering Anthropometry Resource working group).

The right side of Figure 2 illustrates applications of the database. These include data visualization and analysis capabilities on the raw data as well as access to model simulation. Some of these applications are discussed in more detail below. Other applications include bibliographic search interfaces for the research literature, where research documents archived have been marked up to allow parameterized search (e.g., tagged, and therefore filterable for, special populations, equipment, and experimental manipulations).

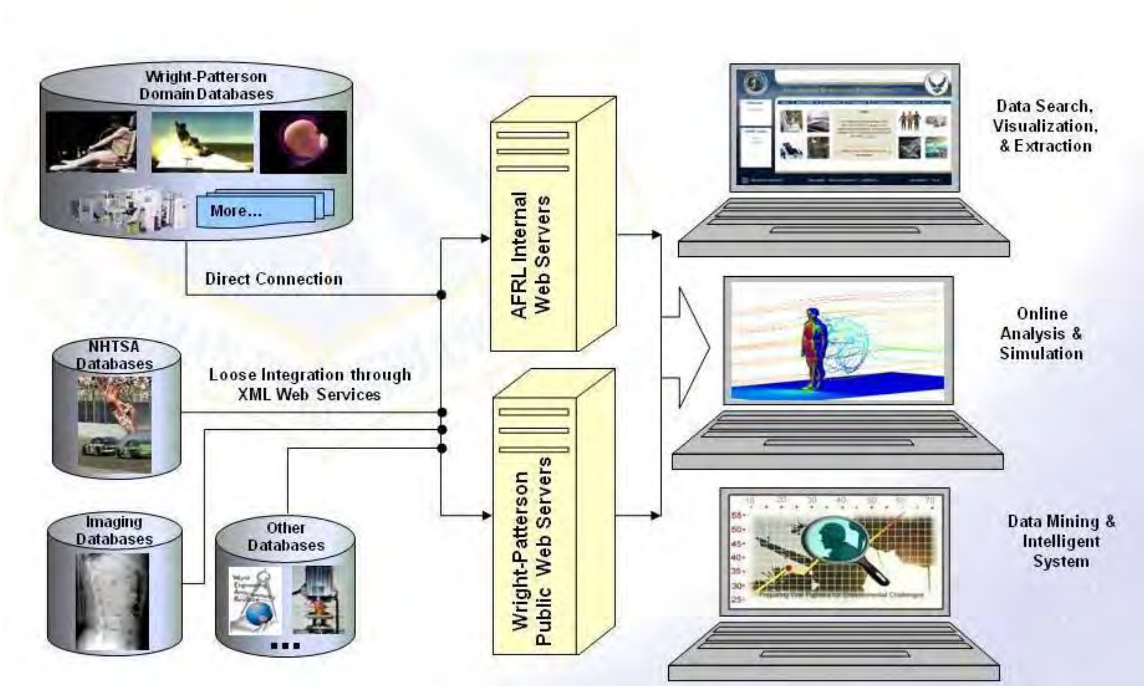

Figure 2. CBDN Infrastructure

2.1.2.1 Database software

The database is implemented as a relational database, with Microsoft Access used as the database tool and Microsoft SQL Server as the database engine. All the text and numerical type data are stored in tables. Relationships and integrity constraints are enforced between tables to prevent erroneous input and keep consistency among data [Buhrman, Plaga, Cheng, Mosher, 2001].

2.1.2.2 Web application development

All technologies are based upon and run on top of the .NET Framework (or will be migrated to that in the future). "CBDN was developed using Microsoft Active Server Page (ASP) technology. In ASP.NET, a web page typically consists of a group of web control classes with event handling and functional logics. The ASP.NET web controls are server-side controls which have much richer functionalities than those of traditional HTML controls. This makes the development of complex web GUI features possible." [Cheng, Buhrman, Webb, Pilmanis, 2008]. In particular, for the Biodynamics database (which is the template that other databases will follow), a user-friendly front-end, created using Visual Studio 2005, is used to view a tabular webpage (e.g., Excel compatible format), for which one can easily sort, query and search the data. Sortable fields include study title, facilities, and subjects (not only human, but equipment and manikin-type employed). Once a desired study has been identified, one can follow different types of information links by pressing the study-button/study-number field. The type of link followed is determined by a radio-button setting to the left of the table, namely: study information (synopses and more general information), test information (access to experimental dependent variable data, e.g., x, y, z, accelerations, as a function of time, with plotting and download capability), cell information (access to experimental device descriptions and other aspects of the experimental manipulations), photos (access to still photos depicting experimental setups), videos (showing trial execution), and finally reports (downloadable papers and technical reports in .pdf format).

2.1.2.3 Security

ASP and .NET technology afford industry standard security and encryption (e.g., https: protocols for web sites). In addition, the following security measures are taken:

a). All online data are cleared for public release. Two separate web sites & database servers are maintained: 1) a DoD internal site where complete data collections on the AFRL internal servers are kept, and 2) a public accessible site (http://biodyn.istdayton.com/CBDN) where public releasable data collections are kept, residing on an off-base server maintained by an engineering support contractor.

b). Access to the DoD internal site requires both DoD Common Access Card (digital authentication) and user login (and can therefore be made available from the AF PORTAL).

c). The public website requires user registration and login only.

d). Daily security updates & backups are conducted on both sites.

3.0 CONTENTS

3.1 Biodynamics Database

"The Air Force Research Laboratory's Biodynamics Data Bank (BDB, or Biodyn) is the world's largest repository of human biodynamic response data. The contents include data from research efforts that include more than 12,000 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, Horizontal Impulse Accelerator, Vertical Impact Device, Body Positioning and Restraint Device, and Horizontal Decelerator. Currently there are study summaries encompassing 168 test programs from 1958-2010. Each summary contains information such as study title, objective, investigators, test facility, test numbers, test matrix, instrumentation, and test results. Slow motion videos and documentation photographs of the tests provide enhanced analysis capability [Cheng, Mosher, & Buhrman, 2004].

"BIODYN is the first component in an expanding group of databases, and has the most comprehensive data collection including information on research studies, test data including multi-channel time histories, subject anthropometry, manikin measurements and drawings, literature of biomechanics research, test photos, and high-speed videos. It also contains web toolkits such as the Generator of Body Data (GEBOD) program [Gross, 1991; Cheng, Obergefell, & Rizer, 1994] for generating human and manikin mass and inertial properties data sets based on subject height and/or weight or percentile. Multiple search and visualization techniques have been built into BIODYN.

They consist of cross links and searches among all types of data; web plotting of data time histories; and video streaming of high-speed videos. These techniques were later applied in similar styles to other databases in the group." [https:// biodyn.istdayton.com/CBDN/aboutCBDN.aspx, retrieved March 18, 2011]

3.1.1 Biodynamics Database Applications

Researchers in the areas of occupant crash protection and aircraft ejection seat safety have used data from the BDB extensively. 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 [Buhrman, 1998] such as the Articulated Total Body (ATB) model [Fleck, Butler, Deleys, 1982; Obergefell, Gardner, Kaleps, Fleck, 1988], which 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 Dynamic Response Index (DRI), which has been used extensively by the Air Force to predict the probability of spinal injury during aircraft ejection [Brinkley and Shaffer, 1970; Cheng & Buhrman, 2000].

The BDB has also provided data that have been used to provide guidelines on determining the effects of head-supported weight on fatigue and comfort during extended missions [Gallagher and Caldwell, 2008].

3.2 Naval Biodynamics Laboratory (NBDL) Data Bank

"The Naval Biodynamics Laboratory (NBDL) Data Bank contains human response data similar to the BDB. The data were collected at the Naval Biodynamics Laboratory in New Orleans, which was closed in the 1990s. These data include information from over 4,000 human and manikin impact acceleration tests along with 287 time histories and the anthropometry measurements from 200 of the test subjects. A portion of the data has been transferred to the CBDN, although the complete data set now resides with the U.S. Army Aeromedical Research Laboratory (USAARL) located at Ft. Rucker, AL." [https://biodyn.istdayton.com/CBDN/aboutCBDN.aspx, retrieved March 18, 2011]

3.3 Altitude Database (AFRL Air Crew Performance and Protection Data Bank)

"The AFRL Air Crew Performance and Protection (Altitude) Data Bank represents over 17 years of research and experiments in high altitude decompression sickness (DCS), conducted by the Aircrew Performance and Protection Branch at Brooks City-Base, Texas [Pilmanis, 1995]. It consists of the DCS research database, the DCS bibliographic database, and the Altitude Decompression Sickness Risk Assessment Computer (ADRAC) model. Data from over 3,000 exposures with both male and female human volunteer subjects were deposited into the AFRL DCS research database. From these test data, ADRAC (discussed in greater detail below) was developed and validated for predicting DCS risk during altitude exposures [Pilmanis, Petropoulos, Kannan, & Webb, 2004]. In addition, over 1,700 publications related to DCS research have been compiled in the DCS bibliographic database." [https://biodyn.istdayton.com/CBDN/aboutCBDN.aspx , retrieved March 18, 2011]

The Altitude Database structure was based on separate individual "exposures." Each exposure was accomplished in a pressure chamber under a unique set of conditions that typically included simulated altitude, pre-breathe time, exercise level, etc., all of which are notated as fields in a spreadsheet type format. Various measurements such as oxygen consumption and other physiological symptoms were also recorded after each test. The physiological experimental measurements taken include EKG, oxygen saturation, and inspiratory demand.

Each exposure record has a discrete number, the automatically-assigned Man-Flight-Number (MFN), which may be associated with many or few Bubble records and several or no Symptom records. Each MFN will also have associated records describing the pressure changes and may have several breathing Gases listed" [Cheng et al., 2008].

A major application of the Altitude Database is the Altitude Decompression Sickness Risk Assessment Computer (ADRAC) model [Cheng et al., 2008]. This model (see Model section below) is available on-line at the CBDN website. The model has two interface options for allowing quick estimation of decompression sickness likelihood, given a user-provided set of expected working conditions (e.g. altitude, amount of physical activity). Specifications analyzed through the ADRAC model have been used to guide simulation of U-2 flights and high altitude parachute operations [Cheng et al., 2008].

3.4 Anthropometry Research Information System (ARIS)

The Anthropometry Research Information System (ARIS) Database contains measurements from an extensive list of surveys conducted with large numbers of human subjects. The measurements were taken using traditional measurement tools such as calipers and tape measures, and in some cases taken using a 3-D body scanner. The primary focus of this database is to allow the user to quickly conduct searches and display measurements from subjects with specified dimensions.

"ARIS contains anthropometry measurements and demographic information from 70 surveys conducted on more than 100,000 subjects worldwide. The contents include one of the most extensive surveys ever conducted, the Civilian American and European Surface Anthropometry Resource data (CAESAR) [Robinette et al., 2002]. CAESAR is the first large anthropometry survey that used 3-D full body laser scanning extensively in addition to traditional anthropometric measurements. It is comprised of over 4,000 subjects ages 18 to 65 from North America and Europe. The use of laser scans allows capture and analysis of individual shapes instead of just traditional summarized statistics. Therefore, ARIS has become a valuable resource for fitting and designing clothing and personal equipment, work stations, and digital human models. Eventually, ARIS will connect a group of anthropometry databases around the world through XML Web Services [through the World Engineering Anthropometry Resource (WEAR) Working Group]" [https://biodyn.istdayton.com/CBDN/aboutCBDN.aspx, retrieved March 18, 2011].

Current applications include realistic design of manikin head and bodies based on data archived from subsets of operational personnel (e.g., dimensions recorded by gender and by short, medium, and tall builds). Better manikin design leads to better assessment of personnel equipment under acceleration [such as helmet systems, see Plaga and Boehmer, 2003].

Possible future applications of the ARIS database, achievable through data-mining and development of suitable models, are human-ISR (intelligence, surveillance, reconnaissance) capabilities. Information and threat discovery afforded from various data sets (1-D, 3-D, posture, motion, and other recordable behavior) can be the basis of semi-automated video-stream analysis for target body signatures (e.g., specific agents of interest) or distorted body shapes and gait (indicative of concealed weaponry/explosives).

3.5 Rocket Sled and Ejection Database

"The Rocket Sled and Ejection Database includes 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. These tests were conducted with instrumented manikins at speeds and trajectories comparable to actual emergency aircraft ejections. The database includes variables such as forebody, seat type, seat velocity and trajectory, and manikin neck loads. Data from these tests have been used to establish the safety and reliability of ejection seats, restraint devices, and instrumentation systems" [https://biodyn.istdayton.com/CBDN/aboutCBDN.aspx, retrieved March 18, 2011].

Keller and Plaga [2010] provide the best overview of this database. See also the first synopsis in Appendix 1.

3.6 Human Vibration Database

The Human Vibration Data Bank includes human data collected during multi-axis vibration exposures in the laboratory on the Six Degree-of-Freedom Motion Simulator (SIXMODE), and vibration data collected during aircraft operations over the last 20 years. Other data not yet entered in the CBDN include exposures on the laboratory's Single-Axis Electrodynamic Vibration Facility and the Single-Axis Servo-Hydraulic Vibration Facility. Laboratory exposures include sinusoidal and quasi-random vibration, as well as operational vibration collected on selected aircraft and recreated in the facilities [https://rhepws002.wpafb.af.mil/CBDN/aboutCBDN.aspx, retrieved March 18, 2011]. The Vibration Database is similar to the BDB with respect to its designated test programs and test numbers, but since vibration parameters can be varied on the fly, the data are divided into "Sessions" with multiple "Runs" in each session. Also, since the vibration input is typically a simulation of an actual signature of an aircraft or other vehicle, additional information is provided to describe both the input pulse and vehicle conditions (aircraft type, altitude, velocity, etc.).

"A major portion of the data bank includes tri-axial accelerations collected at the seat/occupant interfaces using a variety of seating systems and components, tri-axial accelerations collected at various anatomical locations, and both translational and rotational accelerations and displacements collected at the head (via a bitebar) and helmet. Other data will include targeting performance (tracking error and time-on-target), task performance, workload assessment, and comfort evaluations. These data were collected to quantify human body multi-axis vibration responses, to evaluate the effects of seat design on the transmission of vibration to the occupant, and to investigate the effects of operational exposure on human perception and performance. Operational exposures include seat/occupant interface accelerations and helmet accelerations at selected operator and passenger locations. These data were used to conduct exposure assessments in accordance with current human vibration standards and to recreate the operational environment in the laboratory." [https://biodyn.istdayton.com/CBDN/aboutCBDN.aspx, retrieved March 18, 2011].

3.7 Wind Tunnel Database

The Wind Tunnel Database is actually a separate linked database developed by Jaycor, Inc. for the Air Force Research Laboratory (AFRL) and is operated and displayed in MS Access.

"The Wind Tunnel Database … contains wind tunnel tests employing instrumented manikins, ejection seats, and various pieces of test equipment. These tests were conducted at wind tunnel facilities at Vought, Calspan, and Arnold Engineering Development Center (Air Force, AEDC). The test data include measurements of aerodynamic forces and pressures on the ejection seat and manikin. The results are used to investigate the influence of seats, helmets, and other flight gear on the forces experienced by the crewmembers, and to reduce the potential of injury due to limb flail, head rotation, and other injury producing mechanisms. The tests are also used to quantify the degree of protection offered by flow diverting and flow stagnation devices mounted on the ejection seat or on the occupant's flight equipment" [https://biodyn.istdayton.com/CBDN/aboutCBDN.aspx , retrieved March 18, 2011].

3.8 Blast Database

"This database contains the data from blast tests conducted in 2007 by the University of Virginia and sponsored by the U.S. Army. The blasts were from C-4 explosions at various distances from 3 instrumented manikin heads. The heads were left either unprotected, protected with a helmet, or wearing a Helmet Mounted System (HMS). The Blast Database contains parameters based on the charge type and distance from the blast event. The data also include time histories of accelerations, pressures, & angles measured at various locations on the head as well as event data from the HMS system." [https:// biodyn.istdayton.com/CBDN/aboutCBDN.aspx].

3.9 Future Database

3.9.1 Dynamic Environment Simulator (DES) (or Centrifuge) Database

This CBDN area will house research reports and eventually data from Wright-Patterson's dynamic flight simulation facility as this facility comes on line. It is expected that the legacy work conducted by Brooks (both the earlier Armstrong and the Air Force Research laboratory) will be archived there as well. The DES was used for both sustained acceleration and spatial disorientation research. This allows for the evaluation of crew technologies including personal protective equipment, helmet mounted systems, and cockpit systems. Physiological and experimental measures include ECG, EOG, EMG, oximetry, optical digitizer (precise head movement measurements), and recording of real-time flight simulation performance under acceleration and closed-circuit video/audio monitoring. Applications of such a research facility include evaluation of anti-G garments, helmets and helmet mounted systems under high G, as well as oxygen-delivery systems [https://biodyn.istdayton.com/CBDN/des.aspx].

3.10 Models

3.10.1 Altitude Decompression Sickness Risk Assessment Computer (ADRAC)

"The purpose of the AFRL ADRAC Program is to provide the capability for Department of Defense personnel to predict the incidence of altitude decompression sickness (DCS) symptoms when exposed to a specific altitude exposure profile. The program is designed primarily for predictive applications such as mission planning, design of aircraft pressurization systems, design of space suits, design of DCS countermeasures, research and other pre-altitude exposure applications. In addition, real-time applications are possible. ADRAC predictions are based on four input parameters: altitude, time at altitude, pre-oxygenation time, and level of physical activity [at the altitude]. ADRAC cannot predict the DCS incidence in a single individual; rather it predicts DCS for a population of people that reflect the USAF flying personnel with respect to gender, age, physical fitness, height, weight, and general health. The vital element of this program is the combination of two models: 1) a statistical DCS model based on the results of human altitude exposure research [originally] stored in the AFRL DCS Research Database at Brooks City-Base, TX, and 2) a mathematical bubble growth model. The Database contains the results of over two decades of AFRL DCS research [currently hosted by the CBDN]. The model has been validated with a series of human exposures in an altitude chamber. A detailed description of the model and the validation results can be found [Pilmanis, et al., 2004]." [https://biodyn.istdayton.com/CBDN/Aircrew/ADRAC/Main.aspx, retrieved March 28, 2011].

3.10.2 Generator of Body Data (GEBOD)

GEBOD (GEnerator of BODY Data) program … takes a few basic dimension parameters and computes human body data sets using geometric relationships and regression equations from anthropometric surveys and stereophotometric data. It models the body into 15 or 17 individual rigid segments joined at locations representing the physical joints of a human body. A GEBOD generated body data set includes 32 body dimension data, segments' mass properties, and joints locations. Non-anthropometry related data such as segment contact ellipsoids and joint mechanical properties are not listed in the body data set. To compute those data as well as Hybrid II and III dummy data sets, please use standard GEBOD or ATB 3I program [see Cheng, Rizer, & Obergefell, 1998].

There are four major options in generating body data sets of different types:

Child Option. The input parameters are age, weight, and/or standing height. Regression equations are based on child and youth anthropometric survey data.

Adult Human Male and Female Options. The input parameters are weight and/or standing height. Regression equations for 32 body dimensions are based on adult anthropometric survey data, and regression equations for mass properties and joint locations are based on stereophotometric study.

User-Supplied Body Dimensions Option. The input parameters are 32 body dimension measurements. No regression equations are involved. Other data are directly computed from input using geometric equations. [https://rhepws002.wpafb.af.mil/CBDN/gebodIntro.aspx, retrieved March 21, 2011].

3.10.3 Burn Simulation (BURNSIM)

BURNSIM is a computer model that calculates heat flow through the skin represented as eighty-nine 25 micron thick slices using finite difference equations developed by Crank-Nicholson. The local temperatures are converted to damage estimates using a first order kinetics relationship developed by Arrhenius and first employed by Moritz and Henriques (1948 [cited in Knox, Mosher, McFall, 2008]) to describe burn damage.

BURNSIM, v3.0.2, adds the capability to use data from standard fabric test methods like the Thermal Protective Performance (TPP) test. In this test a fabric in single or multiple layers is exposed to a 50/50 convective/radiant heat source until a copper slug calorimeter placed behind the fabric indicates that sufficient heat has passed through the fabric to cause a threshold second degree burn. The test itself was based on earlier work by Alice M. Stoll and M. A. Chianta (1969 [cited in Knox, Mosher, McFall, 2008]) and the procedure is embodied in ISO Standard 17492 and in ASTM Std D4108-82, NFPA 1971, 2000 edition and NFPA 2112, A2006.

BURNSIM is designed to accommodate any shape pulse and can use a time series of thermal measurements to describe a dynamically changing thermal input. By using BURNSIM, the TPP results and a fabric model it should be possible to define a fabric insulation factor that BURNSIM can use to assess the protective effect [for] any thermal input so long as the fabric system remains intact [Knox, Mosher, & McFall, 2008]. For excellent source material on BURNSIM concerning history, model specifics, and practical applications, see Knox, Reynolds, Conklin, Perry [1998].

3.11 Tools

3.11.1 ABMiner (data mining software)

This is a data exploration / visualization utility most directly employed with the ARIS database at CBDN. However, in principle, the utility can be adapted to and exploited in any multi-variable database. "ABMiner can be used to develop data mining models for classification, numerical prediction, and clustering. The knowledge models are accessed using the ABMiner Model Base. The model base website was originally developed by DIS (Distributed Intelligent Systems) group of Intelligent Automation, Inc. (IAI). The development was assisted by IAI's academic partner Dr. Jiawei Han, commercial partner Infoscitex Inc., and sponsor AFRL's Biomechanics Branch. [https://biodyn.istdayton.com/CBDN/ModelBase/StartDataMiningModels1.aspx, retrieved April 7, 2011 [also see Tang, 2007, citation below].

Several classification models have been developed from ABMiner as notional tests of the predictive utility of CAESAR [Robinette, et al. 2002]. In particular logistic regression models of the following classification models can be found at the web source citation given just above: 1) Gender classification models: male or female (based on 20 measurements, accuracy = 99%); based on four measurements (accuracy = 97%). 2) Ethnicity classification: White or African-American (based on 17 measurements, accuracy = 88%); based on 5 measurements (accuracy = 85%). 3) Ethnicity classifier: Persian or White (based on 16 measurements, accuracy = 98%).

Each data model has a "view" page which gives the model's meta data. The most important of these are the general description and the explicit (logistic) regression equation. Variables (measurements) used in the model are noted by structured abbreviation (e.g., **HIP-CIR-MAX/HT,** which refers to [hip circumference maximum] divided by height. A "visualize" page allows pair-wise scatterplots of the variables of a model of interest to be inspected as well as histogram plottings of single variables. A "query" page allows input of specific values into the model's variable slots (i.e., textfields). When a query is made with inputs that are not the default ones, the expected outcome of the updated input is reported (e.g., the model classifies the measurements as "female"). Additionally, multiple model inputs can be individually "scrolled" quickly along their allowable range by slider controls to the left of each input slot for very rapid model queries.

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Tang, K., Buhrman, J., and Phadke A. Biomechanics Data Mining to Support Human Performance and Injury Prevention, INFORMS Annual Meeting, WAID Workshop, Seattle, 2007.

Appendix 1: In depth illustration of materials stood up at CBDN under WU 71840220 funding

Databases stood up:

Keller, K., Plaga, J. [2010]. The Ejection Seat Test Database: A Resource for Enabling Aircrew Safety and Survivability. AFRL-RH-WP-TP-2010-0003, Air Force Research Laboratory, Wright-Patterson AFB, OH.

Synopsis: Documents the archiving at the CBDN of over 30 years of ejection-simulation studies and describes CBDN methods. These methods allow 1) rapid searches for studies (write-up and data) meeting constraints, 2) rapid induction of a new study into the database via user-friendly form entries, 3) auto-plotting of significant ejection-relevant telemetries (e.g., lumber force along x, y, z axis separately against time). Applications include what-if extrapolations to related domains, such as extreme accelerations during ground landing of space capsules and race-car crash events. Such extrapolations proceed by formalizing extant ejection (and rocket sled) data into dynamic injury models, where the acceleration characteristics of an event (e.g. an accident event) can be mapped into a most-similar manikin study of ejection (or horizontal acceleration), and thereby provide a prognosis for human injury estimated by measurements taken on manikin subjects.

Data studies assimilated:

Cote, M.D., & Buhrman, J.R. [2008]. Human vertical impact testing of auto-separation night vision goggle helmet systems. Proceedings of the 46th Annual Survival and Flight Equipment (SAFE) Association Symposium, Reno, 2008

Synopsis: Night-vision goggle (NVG) systems can be added to pilot helmets; however, these change cervical torque and load while undergoing high-G maneuvering. Such goggles should stay fixed and not unduly strain pilots' necks during such maneuvering; however, during an aircraft ejection, which has a specific high-G profile, NVGs systems need to "auto-detach" to avoid dangerous torque and load on the neck during windblast and parachute-open phases of an ejection. Using a vertical deceleration tower, humans and manikins (body stature varied within each category) were compared for the tendency of NVG systems (two types) to detach during simulated ejection. Additionally, conditions comparing NVG to no-goggles controls (human and manikin) assessed specific changes in head accelerations owing to NVG helmet augmentation during simulated ejection. Auto-detachment was more likely with manikin tests than human tests and this was attributed to different neck dynamics for humans (i.e., they brace themselves for expected high-G). Hence, extrapolations from manikin studies with respect to auto-detaching require caution. More design work in NVG-augmentation of helmets is needed to ensure detaching, given the pilot is normally unable to manually detach the NVG prior to ejection.

Data Modeling and Data Mining Applications

Tang, K., Buhrman, J. R., Phadke, A. (2007). Biomechanics Data Mining to Support Human Performance and Injury Prevention, INFORMS Annual Meeting, WAID Workshop, Seattle.

Synopsis: Presents research efforts on the data mining methodologies to handle unique properties of biomechanics datasets. Classification and numerical prediction models that connect experimental manipulations to some operationally useful predictive concern are a main interest. The input factors include motion conditions, anthropometric features, and choices of injury prevention devices; operational concerns include estimation of injury probability, as indexed by a dependent measure such as lumbar force. For instance, injury prognostication is optimized by assessing the best vantage point (e.g., sensor position on seat-assembly equipment) from which to measure Z accelerations. This is done by assessing a measuring method's predictive ability with respect to lumbar force directly measured on a manikin's body across multiple studies. Other data mining excursions include "attributization" of continuously measured properties (e.g., body height) to simplify descriptions of input factors for the generation predictive rules based on coarser descriptions.

Appendix 2: Broadly described materials (adapted from webpage summary and query-entrance page) stood up at CBDN under WU 71840220 funding

Biodynamics Database:

200914	Assessment of the Head/Neck Restraint System (HNRS) Using the Horizontal Impulse Accelerator (HIA) and Vertical Deceleration Tower (VDT)	Horizontal Impulse Accelerator (HIA)	LARD and LOIS manikins
200913	Vertical Impact Testing of the MACH Helmet System and New NVG Banana Mount	Vertical Deceleration Tower (VDT)	LOIS and LARD Manikins
200911	Impact Test Procedure, GEN-II HMD	Helmet Drop Tower (HDT)	P55, TPL and X-LINER
200909	Impact Test Procedure, 55/P Helmet	Helmet Drop Tower (HDT)	P55 Helmet
200908	Vertical and Horizontal Impact Tests of the Joint Service Aircrew Mask (JSAM)	Vertical Deceleration Tower (VDT), Horizontal Impulse Accelerator (HIA)	LOIS and LARD manikins
200907	Comparison of Manikin Impact Responses to Predicted Numerical Model Impact Responses - Tare Load Assessment	Horizontal Impulse Accelerator (HIA)	HB3-50 manikin
200906	Parachute Opening Shock Evaluation of the Army Improved Outer Tactical Vest and Releasable Body Armor Vest	Vertical Deceleration Tower (VDT)	ADAM-L manikin
200905	Vertical and Horizontal Impact Tests of A-10 Monocular Helmet Mounted Cueing System	Horizontal Impulse Accelerator (HIA), Vertical Deceleration Tower (VDT)	AERO-95 Manikin
200904	Comparison of Manikin Impact Responses to Predicted Numerical Model Impact Responses - EuroSID2 Impact Response	Horizontal Impulse Accelerator (HIA)	EUROSID2 and HB3-50 auto manikins
200903	Parachute Opening Shock Evaluation of the Army Parachutist Oxygen Mask Bail-Out System	Vertical Deceleration Tower (VDT)	ADAM-L Manikin
200901	Vertical Impact Tests of Prototype Seat-pan Cushions and the Standard ACES II Seat-pan Cushion: (Goodrich and Oregon Aero)	Vertical Deceleration Tower (VDT)	AERO-95, LARD, LOIS, HB3-50 Manikins
200810	Vertical and Horizontal Impact Tests of the Scorpion Helmet System	Horizontal Impulse Accelerator (HIA), Vertical Deceleration Tower (VDT)	AERO-95 Manikin

200808	JSF sled tests	HIA	LOIS manikin
200807	Vertical Impact Testing of the Eyeball Helmet System: Phase II	Vertical Deceleration Tower (VDT)	LOIS, HB3-95 auto Manikins
200806	BICNS	DTB	
200805	Orion Crew Impact Attenuation Energy Absorber Tests	Vertical Deceleration Tower (VDT)	Strut
200804	Comparison of Manikin Impact Responses to Predicted Numerical Model Impact Responses	Horizontal Impulse Accelerator (HIA)	HB3-50 aero and HB3-50 auto manikins
200803	Impact Evaluation of Orion Crew Seat Concept Using the Horizontal Impulse Accelerator (HIA)	Horizontal Impulse Accelerator (HIA)	HB3-50 auto Manikin
200802	Impact Evaluation of Miniature Triaxial Accelerometer for Ear Plugs	VID	
200801	Advanced Combat Helmet Impact with Modified Padding	Helmet Drop Tower (HDT)	Magnesium Headform
200705	MTS Testing		
200704	Seat Cushion Testing		
200703	Orion Planetary Suit Impact Evaluation Using the Horizontal Impulse Accelerator (HIA)	Horizontal Impulse Accelerator (HIA)	HB3-50 Auto Manikin
200702	Measurement of the High Altitude Low Opening (HALO)/High Altitude High Opening (HAHO) Oxygen Bail-Out System Retention, and Manikin Dynamic Response During Simulated Parachute Opening Shock	VDT	ADAM-L and ADAM-S manikins
200701	Vertical Impact Tests of the Panoramic Night Vision Goggle (PNVG) Auto-Separation Capability (NVCD AS Study)	Vertical Deceleration Tower (VDT)	Human volunteers, LOIS, HB3 50 Aero, and HB3 95 Aero manikins