FAA Civil Aerospace Medical Institute
Aerospace Accident- Injury and Autopsy Database System
AA-IADS

Final Project Report
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1.0 INTRODUCTION

The purpose of this document is to describe the results of activities accomplished under the grant entitled "Development of Specifications for an Interactive Aircraft Accident Data Collection and Analysis System," (No. 04-G-034). Dr. Jennie J. Gallimore, from Wright State University was the principal investigator. The Federal Aviation Administrator (FAA) technical monitor was Dr. Charles DeJohn, from the Aeromedical Research Team of the Aerospace Medical Research Division (AAM-600), Civil Aerospace Medical Institute (CAMI) in Oklahoma City, OK.

This research plan supported the FAA CAMI by providing a Ph.D. research graduate student to support the development of an Aircraft Accident Injury and Autopsy Database System (AA-IADS) to improve the FAA's ability to classify and study aircraft occupant injuries to better understand the types and mechanisms of injuries caused by aircraft accidents. The proposed duties and responsibilities are summarized as follows:

1. Provide scientific research expertise for the development of the Aircraft Accident Injury and Autopsy Database.
2. Perform a literature search on the study of injury pattern investigation in aviation-related aircraft accidents and preventive strategies.
3. Evaluate alternative system hardware and software for database development.
4. Develop a system for collecting, classifying, and posting injury data into the AA-IADS.
5. Develop a method to migrate autopsy data currently contained in the CAMI Autopsy Database into the AA-IADS.
6. Develop a research plan to study the mechanism of injuries and methods to reduce passenger and aircrew injuries so as to increase survival rate.

7. Collaborate with software developers to assist in overseeing the development of the database.
8. Coordinate findings with the Aeromedical Research Team Lead, Protection and Survival Laboratory Manager, and Aerospace Medical Research Division Manager.
9. Publish the results of the findings in an Office of Aerospace Medicine (OAM) report and/or in the open literature.

The overall goal of this research is to develop systems requirements and conceptual design toward the development of the AA-IADS.

This final report is divided into the following sections: 1.0 Introduction, 2.0 Background, 3.0 Research and Development of the AA-IADS Concepts, and 4.0 Current Research Progress on the Development of CAMI AA-IADS.

2.0 BACKGROUND

Since 1985, The Federal Aviation Administration (FAA) Civil Aerospace Medical Institute (CAMI) has received and processed autopsies from fatal aircraft accidents that occurred in the U.S. CAMI established an Autopsy/Injury Database in 1997. The primary objective of the CAMI autopsy database was to "develop a system of collecting and organizing information regarding injuries and the causes of death in aviation accidents, so that this information could be applied to operational recommendations and research tasks" [1].

The requirements supporting the development of the FAA CAMI database (see Appendix A) are based on: 1) International Civil Aviation Organization (ICAO) Standards & Recommended Practices, Annex 13; 2) The Aviation Safety Research Act of 1988 [2]; and 3) FAA orders 8020.11B and 8025.11B [3]. In addition, one of the major goals described in the FAA Flight Plan 2006-2010 [4] is to increase safety, specifically to reduce fatalities in commercial and general aviation accidents. As related to the Office of Aerospace Medicine (OAM), the FY 2006 Performance Plan's number-one priority is to reduce the commercial aviation fatal accident rate. To accomplish this goal, CAMI needs to conduct three main research activities: 1) investigate injury and death patterns in civilian flight accidents, along with meticulous analysis to determine causation and prevention strategies; 2) develop recommendations for protective equipment and procedures; and 3) evaluate options, addressing all aircraft cabin occupants. The above mentioned research program identifies human tolerance, capabilities, and failure modes both in uneventful flights, and during in-flight incidents and accidents.

CAMI receives but does not generate autopsy or injury reports. Autopsy reports produced as part of an accident investigation are generally submitted to the FAA regional flight surgeon's office for the region in which the accident occurred. Copies of these reports are forwarded to

CAMI. In some cases, CAMI might request autopsy reports directly from the Medical Examiner office. Clearly, CAMI's AA-IADS depends on how accurately, completely, and comprehensively these data have been collected. Once the data have been received, to code it CAMI must rely on: 1) standardization of injury terminology; 2) injury classification and a severity assessment scoring system; 3) information available to the data entry coders; and 4) the consistency of the coders.

The two Federal agencies primarily involved with the source of data entered into the CAMI AA-IADS are the FAA and the National Transportation Safety Board (NTSB). The latter is the agency responsible for determining the probable cause (s) of a civilian aviation accident. The FAA Civil Aerospace Medical Institute in Oklahoma City performs toxicological tests of biological samples from fatal accidents to determine the presence –or absence– of alcohol, drugs, or other substances that might have degraded pilot performance or –equally important– to determine if the occupants died as a result of smoke inhalation. In addition, the CAMI Toxicology Laboratory helps to determine if a pilot was taking medication for a known medical condition or if he or she was taking a particular medication for a medical condition that was unreported to the FAA.

As shown in Table 1, from 1985 through 2005, CAMI has received approximately 4,000 autopsies of pilots injured in aircraft accidents, which represented 46% of all pilots' fatalities, according to the National Transportation Safety Board (n= 8,755) [5]. Figure 1 and Table 1 also shows that the number of pilot fatalities has been steadily decreasing during the last 20 years. The number of autopsies received at CAMI has also steadily decreased during the same period, from 51% in 1985 to 19% in 2005. Although few epidemiological analyses have been conducted using the current CAMI autopsy database, it has been utilized to support various certification issues, to determine most frequent fatal injuries by body regions, and to respond to aviation safety recommendations or questions asked of the FAA.

Table 1 U.S. Pilot Fatalities and Autopsy Reports Processed at CAMI, 1985-2005. (Source: NASDAC and CAMI Autopsy Database, 2006). [2]

Year	NTSB Pilot Fatalities	CAMI Pilot Autopsies	Percentage Received	Missing Pilot Autopsies	Percentage Missing
1985	542	276	51%	266	49%
1986	500	237	47%	263	53%
1987	486	174	36%	312	64%
1988	483	186	39%	297	61%
1989	471	89	19%	382	81%
1990	474	67	14%	407	86%
1991	475	215	45%	260	55%
1992	466	192	41%	274	59%
1993	423	168	40%	255	60%
1994	416	177	43%	239	57%
1995	431	209	48%	222	52%
1996	394	219	56%	175	44%
1997	375	299	80%	76	20%
1998	383	280	73%	103	27%
1999	345	272	79%	73	21%
2000	378	279	74%	99	26%
2001	348	224	64%	124	36%
2002	355	168	47%	187	53%
2003	360	144	40%	216	60%
2004	338	60	18%	278	82%
2005	312	59	19%	253	81%
Total	**8755**	**3994**	**46%**	**4761**	**54%**

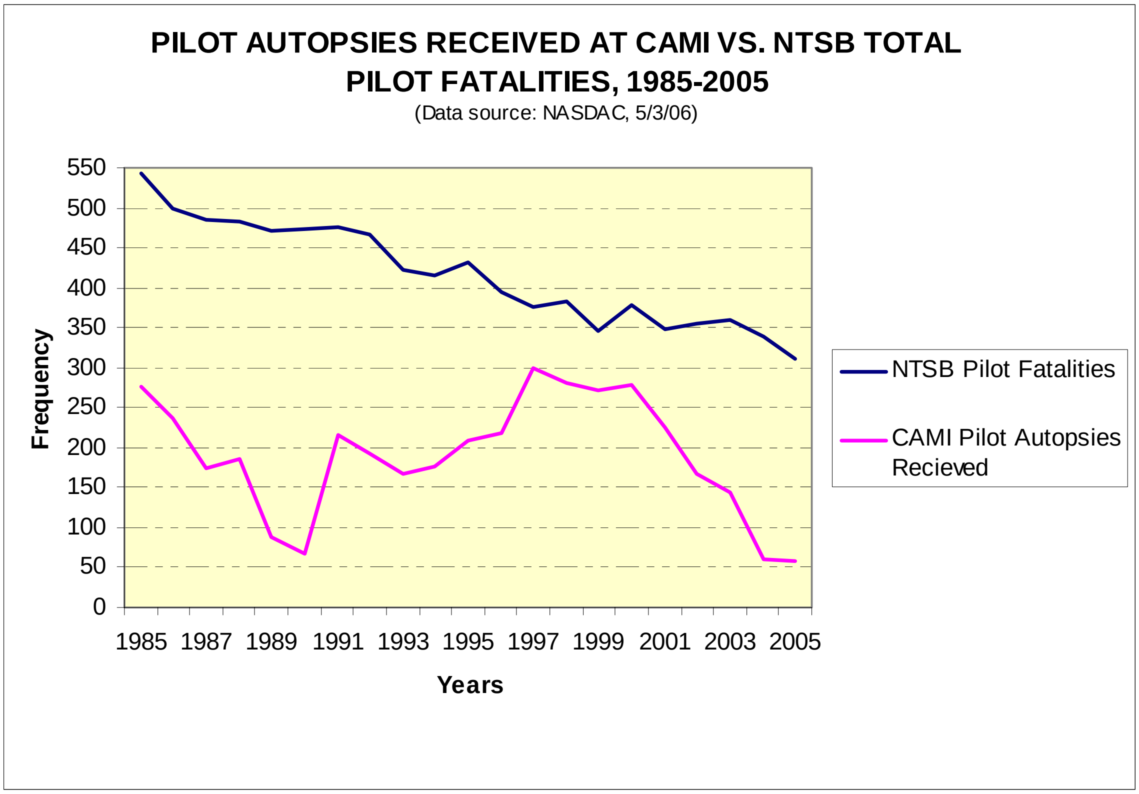


Figure 1. Pilot Autopsies Received At CAMI vs. NTSB Total Pilot Fatalities, 1985-2005 (Source: NASDAC and CAMI Autopsy Database, 2006)

2.1 Current Limitations in Collecting and Analyzing Injury Data

An interesting study to identify injury mechanisms and to prioritize the technologies that could mitigate these mechanisms of injury in 11 partially survivable major accidents [6] revealed that: 1) available accident data are more focused on the cause of the accident and not necessarily the cause of injury. As a result, data and analysis related to occupant survivability are often limited; and 2) it appears that, although the type of information needed to perform injury mechanisms analysis has been collected, it is not fully conveyed in each accident's final report. This information includes:

- Detailed injury and autopsy information
- Detailed seat damage and deformation measurements and photographs

- Damage and deformation information for other interior structures
- Detailed description of structural deformation in the fuselage
- Passengers and witness interviews, and egress issues, including the exit used for each person

The bottom line of these findings appears to be the lack of data to “develop differential, quantitative conclusions about the efficacy of various safety technologies” [6].

Injury researchers [7] agree that an important limitation in analyzing injury data is that injury-related information collected by each federal agency under the Department of Transportation’s umbrella varies in:

1) The way the data are collected, coded, and analyzed;

2) The definitions of events and classification of injuries, including their severity; and

3) The statistical methods used to analyze the data.

Indeed, there is a lack of standardized definitions (i.e., event, fatalities, and injuries), detail of injury data and severity, as well as the non-use of a universally accepted injury classification and coding system among the Department of Transportation’s agencies. Clearly, it is critical to establish a common injury criteria-reporting and classification system.

One concern is the lack of civil aviation injury databases in the international community, particularly the need for: 1) a detailed injury description and classification system; 2) the documentation of the damage to the aircraft interior components, 3) the documentation of damage to the occupant’s restraint systems; 4) the documentation of exit methods used; and 5) the documentation of the post-crash environment. All of this information should be readily available in one linked data system. Without such data integration, an accurate determination of mechanisms of injury and subsequent formulation of intervention measures to significantly improve survivability in aircraft accidents will be difficult to achieve.

2.2 Major Limitations of the Current FAA CAMI Autopsy/Injury Database

The limitations encountered in the current CAMI Autopsy database are summarized as follows:

1. Lack of a standardized injury scoring system.
2. Lack of injury data for survivors.
3. Injury severity has not been classified for fatal injuries.
4. Keywords used to classify injuries are vague and confusing. For instance the keyword “body fragmentation” includes a variety of injuries that cannot be classified under a single keyword, with different severity levels. As a result, querying for a specific injury type is very challenging, and the outcome may be inaccurate.
5. Information related to occupant restraint systems, exits used, biomechanics of the impact, impact vectors, injury mechanisms, and/or correlations and detailed medical information from hospital records is absent in the majority of accidents.
6. Relevant accident information, although collected, cannot be entered manually into the database due to the lack of data fields available.

3.0 RESEARCH AND DEVELOPMENT OF THE AA-IADS CONCEPT

Development of the Civil Aerospace Medical Institute Aerospace Accident—Injury and Autopsy Database (AA-IADS) concept was based on the following research questions:

1. Why is an autopsy/Injury database needed in civil aviation?
2. What type of medical data must be collected for both fatal and non-fatal accidents, particularly related to crewmembers?

3. What are the legal issues regarding the collection of medical information from health care providers in the case of survivors?
    i. Which guidelines are necessary to comply with the Health Insurance Portability and Accountability Act (HIPAA) to protect the Privacy of personal health information?
    ii. What kind of training in injury mechanisms analysis should be provided to FAA physicians involved in medical aspects of accident investigation?
4. What injury scoring system should be used?
5. What functional requirements must be implemented?
    i. What injury, accident (event), medical and toxicology data must be collected and linked?
6. What type of visualization techniques might be used to:
    i. Speed up the process of entering and editing injury data?
    ii. Better understand and analyze injury causation?

3.1 Objectives of the AA-IADS

The main objectives of the AA-IADS can be described as follows [8]

1. Introduce effective data analysis and visualization tools that will provide CAMI injury researchers with a better understanding of the relationships among the many factors that lead to injuries and fatalities. The ultimate objective of the system is to provide data that will help users to develop intervention measures that will reduce injuries and fatalities resulting from aircraft accidents.
2. Provide data entry and query capabilities for autopsy reports and hospitals records (injury reports).

3. Provide a relational database that delivers composite views of accidents and the injuries they caused. In other words, provide integrated data from the NTSB Accident Database, the Toxicology database and the CAMI Data Imaging Workflow System (DIWS).
4. Provide researchers with the ability to rapidly create custom data sets and query capabilities that allow injuries to be explored from multiple perspectives.
5. Improve and extend the analytical methods used to provide aviation safety information.
6. Allow researchers to visualize seat position and the injuries sustained by the seat occupants.
7. Provide on-line metadata for database elements.
8. Allow data quality to be measured and reported. Quality characteristics will include data accuracy, validity and completeness (percentage of fields that actually contain data).

Drs. DeJohn and Webster [8], research physicians on the Aeromedical Research Team, suggested that a research-oriented CAMI Injury and Autopsy Database should meet the following criteria:

1. Data Security and Privacy Issues:
    i. Enable secure recording of injury and autopsy data, linked directly to up-to-date accident records, to enable accurate evaluation of aircrew and passenger injuries and injury mechanisms.
    ii. Provide data source that ensures compliance with privacy act requirements and Health Insurance Portability and Accountability Act of 1996 (HIPAA)

and provides a tool for aviation safety and public health analysis to ensure the safety of the civil aviation

2. Automatic integration and evaluation of data for use in making data-driven decisions

   i. Integrate automated recording of airman certification information following an accident into a single secure accident data record. This will provide an efficient, accurate tool for evaluation of airman certification status of accident victims and provide information to develop data-driven safety decisions in future aeromedical certification requirements, as well as special issuance cases.

   ii. Provide the FAA and aerospace industry with an accurate injury analysis tool for developing data-driven aircraft design and cabin safety improvement recommendations.

3. Understanding mechanism of injuries and reduction of injuries and fatalities.

   i. Provide the public, engineers and safety professionals with better understanding of the mechanisms of injuries in aircraft accidents in order to better protect the occupants, during the pre-crash, crash and post-crash sequence.

3.2 AA-IADS Process

The new AA-IADS system concept is displayed in Figure 2. Injury mechanisms analysis in civil aviation accidents typically begins with on-site data collection, including carefully gathered medical evidence. The NTSB is the Federal agency responsible for investigating civilian aircraft accidents in the U.S. In addition, CAMI often conducts a detailed medical history review of the crewmembers. This review includes verifying the airman's medical certificate and previously reported medical conditions to evaluate any medical aspect that might have contributed to the accident. Biological samples of fatal accident victims are analyzed at the CAMI Toxicology Laboratory to detect the presence of any substance or medication that could have affected the pilot's performance. Also, the absence of a prescribed medication could indicate that the pilot was not taking a necessary medication and therefore an underlying incapacitating or impairing medical condition must be considered. Injury descriptions from autopsy reports and hospital records will be coded, entered into a digital format and stored for further analysis and queries.

By following the above recommended process, a better understanding of the mechanism of injury and sequence of events leading to an injury, including the interactions between the occupant, vehicle, and environment will be achieved. As a result, data-driven prevention and mitigation strategies to reduce injuries and increase survivability rates in aircraft accidents become possible.

Figure 2. AA-IADS Process (Courtesy of the FAA Media Solution Group, 2006)

As implied in Figure 2, AA-IADS typically would start with:

1. ***NTSB* event data**, with the following main elements:

    a. *Event Information*: NTSB-assigned aircraft accident number and status of the investigation, accident location, time, type of operation, flight number, purpose, phase of operation, narrative history, probable cause, flight conditions, light condition, turbulence etc.

    b. *Aircraft Information*: aircraft registration and serial number, aircraft make, type, and model, aircraft damage, ditching status, collision indicator, biohazard indicator, overhead storage detachment status, fuselage rupture, number of seats, homebuilt indicator, ELT indicator, fire, explosion, accident classification, cockpit/cabin condition.

    c. *Airman information*: pilot's demographics, seat occupied, pilot certificate number, aircraft ratings, instrument ratings, instructor ratings, medical certificate, date of last medical exam, person at controls.

    d. *Restraint systems*: seatbelt, shoulder harness, and helmet use, flight suit condition, flight gloves use, boot condition, etc.

    e. *Evacuation methods*: evacuation assistance, method of exit, evacuation injuries, escape difficulties, rescue date, time, and type of vehicle used during evacuation.

    f. *Impact information*: magnitude and direction of vertical, longitudinal, and lateral impact vector.

2. **Medical information related to (see Table 2):**
    a. CAMI Aeromedical Certification Division (AMCD, AAM-300) Data Imaging Workflow System (DIWS) Data Elements.
    b. CAMI Toxicology laboratory.
    c. Hospital Records
    d. Autopsy Records

Table 2. Summary of Data Elements containing medical information from DIWS, TOX lab, Hospital Records, and autopsies

Data Imaging Workflow System (DIWS)	1. Date of birth 2. Height 3. Weight 4. Medical class issued 5. Path codes 6. EKC code 7. Restriction codes 8. Medications
CAMI Toxicology Lab Data Elements	1. Tox ID 2. Specimen Drug Name 3. Concentration and units
Hospital Records	Including injury information gathered on medical treatment records, clinic records, etc.
Autopsy records	Including injury description and severity.

As shown in Figure 3, injury information received at CAMI comes from autopsy reports and hospital records for fatalities and survivors. Text description of injuries needs to be coded and entered into the AA-IADS using injury score systems, such as the Abbreviated Injury Score System (AIS) version 98 and the Medicode International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9- CM). AA-IADS will link relevant data from NTSB, DIWS, TOX with injury causation in a way that analysis and outcome would be applicable to aeromedical certification, biodynamic research, aircraft industry, academy, and international regulatory organizations.

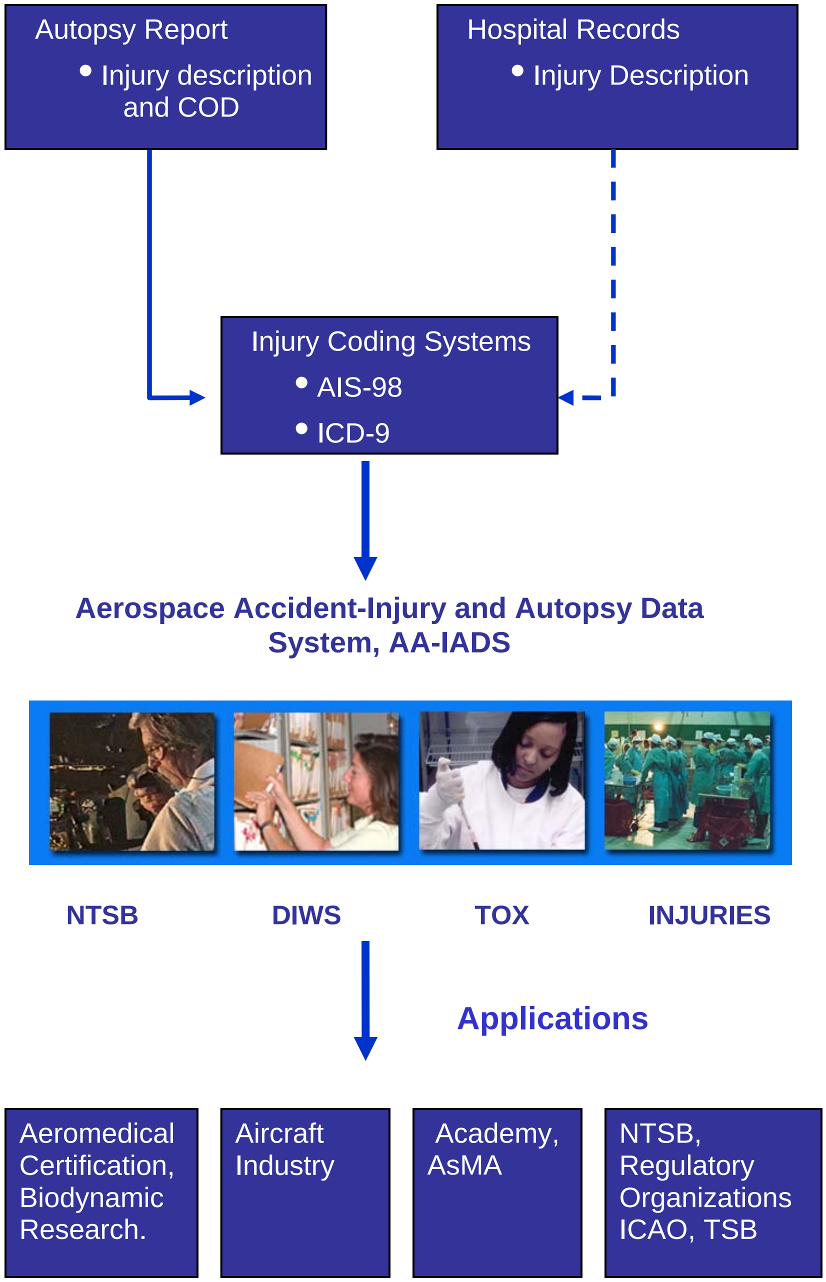


Figure 3 AA-AIDS Medical Information Flowchart (Courtesy of MMAC Media Solutions Group).

4.0 Current Research Progress on the Development of CAMI AA-IADS.

The purpose of this report is to summarize the research completed under this grant toward the development of the AA-IADS. Table 3 lists the tasks, carried out during the research project. Results for each task are described in the following sections.

Table 3. Tasks, Duties and Responsibilities

1. Provide scientific research expertise for the development of the Aircraft Accident Injury Database.
2. Perform literature search on the study of injury pattern investigation in aviation-related aircraft accidents and preventive strategies.
3. Evaluate alternative system hardware and software for database development.
4. Develop a system for collecting, classifying and inputting injury data.
5. Develop a method to migrate autopsy data currently contained in the CAMI Autopsy Database into the Aircraft Injury Database.
6. Develop a research plan to study the mechanism of injuries and methods to reduce passenger and aircrew injuries and increase survival.
7. Collaborate with software developers to assist in overseeing the development of the database.
8. Coordinate findings with the Medical Research Team Lead, Protection and Survival Laboratory Manager, and Aerospace Medical Research Division Manager.
9. Publish the results of the findings as an OAM report and/or in the open literature.

4.1 Task 1: Providing scientific research expertise for the development of the CAMI AA-IADS.

Eduard Ricaurte, M.D., has worked directly with CAMI in the research and development of the AA-IADS. With his aeromedical and human factors engineering expertise, he has provided support for understanding issues related to injury analysis in civil aviation accidents. His specific tasks are those listed in Table 3.

4.2 Task 2: Perform literature search on the study of injury pattern investigation in aviation-related aircraft accidents and preventive strategies.

As part of this task, an EndNote (version X) library was created with more than 90 references. The literature review related to this research is presented in the background section (2.0) and below. For the purpose of this document, *injury pattern* and *injury mechanism* definitions are used interchangeably.

The main purpose of an aircraft accident investigation is to determine the sequence of events, conditions, and the circumstances that led to an accident in order to prevent similar occurrences in the future. Similarly, aviation safety has been consistently improved due to the ultimate findings in several accident investigations wherein determinations have been made relative to the cause of death of each passenger, the relationship between body parts and the aircraft, as well as the mechanisms of injury [9, 10].

Medical examinations of occupants in crashed aircrafts have provided valuable information about the presence or absence of disease, drugs, or other substances that may have affected either occupant survivability or pilot performance. The value of injury patterns sustained by the occupants in the reconstruction of the sequence of events and circumstances of accidents, as well as the provision or design of safety equipment has been widely recognized by accident investigators and aviation safety officers. Autopsy and toxicological analyses of the fatally injured in an aircraft accident have been successfully used to identify of safety shortfalls in aircraft design, safety equipment effectiveness, and the development of strategies to improve the survival of the occupants [11-14].

Previous injury pattern studies in airline crashes have played an important role not only in identifying critical safety concerns such as inadequate restraint systems, but also in the reconstruction of an accident, as well as the deceleration forces and crash dynamics involved [12, 14, 15]. Furthermore, injury patterns, toxicology analysis, and cause of death of each occupant have provided important insights into the post-crash environment.

The role of fire in aircraft crash fatalities remains a major safety problem affecting post-accident survivability. It has been reported that fire occurs in 47% of commercial aircraft accidents, 32% of military accidents and 26% of general aviation crashes [13]. In a study correlating injuries, toxicological findings and cause of death in Galaxy Flight 203, it was found that 60% of the decedents and those who survived the impact ultimately died as a result of smoke inhalation and burns [15]. These findings are consistent with reports published by the NTSB in which fire was responsible for 65% of all aircraft accident fatalities [15, 16]. An analysis of cause of death in U.S. Army aircraft crashes from 1965 to 1969 published by Berner and Sand [17] revealed that 51% of the aircraft occupants killed in survivable or partially survivable accidents died as a result of post crash complications such as fire and drowning, while 44% died as a result of crash impact trauma. Analyzing the post crash factors only, burn and their complications were the most frequent single cause of death, accounting for 80% of the cases, followed by drowning in 9% of the deaths. Recent studies reported burns as the immediate cause of death in 7% of fatal general aviation accidents [18] and 4% of commercial aviation-related fatalities in 1980 and 1990 [14]. In terms of survivability, it has been estimated that there is a 90-95% chance of survival if there is no post crash fire as opposed to only 60-65% chance of survival if there is a fire [16].

Unfortunately, there is a lack of detailed injury-related data in civil aviation accidents, including: 1) classification and severity of injuries using standard score systems; 2) injury mechanisms analysis and the biodynamics of impact; and ultimately 3) a system that allows the linkage of injury data with accident data, medical data, and toxicological data. This lack of specific injury and impact data in civil aviation has been reported numerous times in scientific publications and government reports. Leading injury researchers have identified this lack of injury data as one of the major limiting factors in the goal of improving accident survivability [7, 14, 19, 20].

Although little aeromedical research and few epidemiologic investigations have been devoted to describe postmortem examinations of aircraft accident victims in the context of injury mechanisms analysis, it is widely accepted that injury pattern studies in commercial airline accidents have played an important role not only in identifying critical safety concerns such as inadequate restraint systems and poor seat design but also in the reconstruction of an accident, as well as the deceleration forces and biodynamics involved [12, 14, 15]. For example, it has been reported that from 1975 to 1985 there were approximately 30 commercial airline crashes with more than 2,500 fatalities; however, only two articles were published on the subject of autopsy findings and injury patterns [15].

A comprehensive list of coded injuries sustained by each occupant, along with injury mechanisms, toxicological analysis, and cause of death, could provide important insights into the sequence of the accident, as well as the occupant-aircraft-environment interaction during the pre-crash, crash, and post-crash environments.

The U.S. Department of Transportation (DOT) *Safety Data Action Plan* published in September 2000 [21], clearly determined the goal of providing the (DOT) with "data of a quality sufficient to identify, quantify, and minimize risk factors in U.S. travel." Under this initiative, the Injury Classification and Coding Working Group was created and recommended:

1. The development of an injury reporting system patterned after the NASS CDS, with at least the following elements:

1.1. source of injury data,

1.2. complete AIS 90 code, including severity code,

1.3. aspect of injury 1,

1.4. aspect of injury 2, and

1.5. injury source (one or more data fields).

2. The foundation for developing prevention/mitigation strategies based on:

2.1. identification of injury (injury description) and

2.2. mechanism of injury.

4.2.1 Injury Mechanism Analysis in Aircraft Accidents

Injury mechanisms analysis is a critical step necessary to implement intervention measures aimed at mitigating the severity and consequences of injuries. A determination of how, when, and why injuries are caused in aircraft accidents is complicated, particularly the sequence of events leading to injuries. Several reasons have been cited in an attempt to explain the complexity of injury mechanisms analysis in aviation accidents [6, 22, 23]. It has been recognized, for example, that aircraft accident investigation has been traditionally more focused on the cause of the accident, spending minimal or no effort on the causes of injuries. As a result, studies conducted to identify mechanisms that produce injuries and fatalities in otherwise survivable accidents have been limited by: 1) the scarcity of data related to occupant survival and 2) lack of detailed injury and autopsy information, in relation to aircraft damage, egress patterns, exits used, and other safety issues. Although the information needed to reconstruct an injury sequence is sometimes collected by on-site investigators, it is not generally reported in the accident report. It is clear that a comprehensive injury-oriented data collection and analysis system is needed to better understand the interaction between the individual and the aircraft components leading to injury causation.

Most injury researchers agree that the types of injuries in aviation accidents can be classified as follows: 1) decelerative, 2) impact, 3) intrusive, and 4) thermal. Hill [22] classified the causes of injuries in most aircraft accidents from a pathological standpoint as: 1) crushing within a collapsing frame, typically caused by high-velocity impacts; 2) entrapment within the wreckage caused by non-accessible exits due to either the fuselage deformation or post-crash environment, i.e. fire, water, or simply because occupants are trapped directly by wreckage; 3) the absence or failure of restraints, i.e. the harness itself or its attachment, the seat, floor, or a combination of these; 4) being struck by loose objects, particularly heavy objects placed in overhead compartments; 5) injuries associated with escape; and 6) explosive decompression. Hill acknowledges the complexity and difficulties in determining the sequence of events producing injuries based on the fact that a force applied to one part of the body is transmitted to another. For example, medical accident investigators are familiar with acetabular fractures caused by the transfer of energy from the impacted knee through the longitudinal axis of the femur up to the femur head and to the femur acetabular joint. The picture is even more complex because abdominal compression has been associated with cardiothoracic injuries produced when viscera displacement and intravascular pressure increase [22]. In a study of 331 fatalities in 72 fatal aircraft accidents, Hill reported a definite correlation between hepato-splenic, lower chest, and head injuries. The basic principle appears to be an underlying relationship between intra-abdominal injury and trauma elsewhere in the body.

In an attempt to improve crash survivability through crashworthy design, engineers developed the “CREEP” concept. Crashworthiness is defined as the ability of an aircraft and its internal systems and components to protect occupants from injury in the event of a crash [16]. The acronym "CREEP" has been used as a meaningful tool to organize the important aspects of crash survivability as follows:

C = Container

R = Restraint

E = Energy absorption

E = Environment

P = Postcrash factors

A detailed analysis of these factors is beyond the scope of this report; however, it is worth mentioning the similarities to the epidemiological approach postulated by William Haddon Jr. The Haddon Matrix was developed in an effort to develop a strategy for injury identification and control. Such a matrix "provide(s) a means for identifying and considering, cell by cell: a) prior and possible future allocations and activities, as well as the efficacies of each; b) the relevant research and other knowledge - both already available and needed for the future; and c) the priorities for countermeasures, judged in terms of their costs and their effects on undesirable injury results, that is on the problems to be reduced." [24].

In its simplest form, the matrix (Table 4) has two dimensions: The first is what Haddon called *phases*. In the case of aircraft accidents, the phases are: "Pre-crash," "Crash," and Post-crash." The second dimension of the matrix is divided into three *factors*: The "Human," (or host, i.e. the person susceptible to injury; the specific agent), the "Vehicle" (or "vector"), and the "Environment," (which can be subdivided into "physical" and "sociocultural"). Injuries caused by vehicle accidents might be better understood as an interaction similar to the epidemiological triad: the host (occupant), the specific agent (i.e., mechanical energy), and the environment (i.e., the impacted structure) [6].

The Haddon matrix has proven to be a useful tool when planning and evaluating the benefits of intervention measures to reduce injuries [25]; however, due to the volume and complexity of data in aircraft accident investigation, it is necessary to develop a database system to process and analyze data in a meaningful way.

Table 4. Haddon matrix

Phases	**Factors**		
	Human	**Vehicle**	**Environment**
Pre-Crash			
Crash			
Post-Crash			

To determine an injury pattern [26], it is necessary to correlate injury information with the following basic information:

1. The impact forces (direction and magnitude of accelerative forces).
2. The time, duration, and direction of the applied forces.
3. The cockpit or cabin configuration.
4. The nature of the accident and subsequent occurrences.
5. The occupant kinematics in the accident, particularly relating to restraint systems and evacuation methods.

Unlike motor vehicle accidents, victims of aircraft accidents are usually exposed to more than two axes of deceleration. The probability of injuries increases dramatically with the addition of one more axis. In addition, during impact there are simultaneous rotational and translational movements of the different body parts (i.e., head, neck, thorax, abdomen, and upper and lower extremities). The biodynamics of these moving body parts during impact forces are very complex and not well understood [22]. Collection and analysis of good quality injury data in real aircraft accidents and modeling with slide crash test data should answer questions concerning injury patterns. For example, a detailed evaluation of seat damage, including cross validation using injury data from the AA-IADS, has been proposed [27]. Seat structural performance can indicate the appropriateness of existing dynamic test severity levels and can assist investigators in estimating crash severity. In addition, injury patterns can be used to evaluate the adequacy of occupant injury assessments made during dynamic tests. Integration of seat structural performance and injury data is crucial to form a basis for developing new safety standards and refining existing standards

The unique nature of injury data constitutes a real challenge to injury researchers in reference to methodological issues, etiology, and the impact of interventions in the field of injury prevention and control [24, 28]. Some examples of the complicated characteristics of injury data are summarized as follows:

- Injuries occur in the context of a sudden transfer of physical energy, either mechanical, thermal, radiant, chemical, or electrical. In the case of aircraft accidents, moving objects are vehicles of mechanical energy.
- Injuries might occur more than once to the same individual.
- A single event such as an aircraft accident might result in multiple types of injuries to multiple body sites with different severities.
- Knowledge, attitudes, and behaviors play a major role in determining the etiology of injury.

Determining the mechanisms of injuries is a critical step in developing injury prevention and mitigation strategies in aviation accidents. Developing an automated Aircraft Accident Injury and Autopsy Data System, AA-IADS to categorize and classify aircraft accidents is the next step needed to answer fundamental questions related to injury causation.

4.3. Task 3: Evaluate alternative system hardware and software for database development.

During the development of this project, existing software for injury database development was evaluated. One of the most important criteria during this evaluation was to identify a system able to link injury, aeromedical, toxicological, accident, aircraft, and environmental data, i.e., post-crash fire, ditching, etc.

The systems we evaluated for civil aviation applications are summarized below:

4.3.1 National TRACS® [29]

- Outcome-based Trauma Care Research.
- Developed by the American College of Surgeons.
- Used by trauma centers.
- Calculates Abbreviated Injury Score (AIS) 90, Injury Score System (ISS), and New Injury Score System (NISS).
- Not appropriate for fatalities.
- The objective of NATIONAL TRACS® is to improve injured patient care.

4.3.2 Tri-Code Collector® [30]

- A medical coding system that automatically converts text into ICD 9 CM and AIS 98 injury codes.
- Originally designed to interface with hospital systems, such as Emergency Department, Med-Flite®, billing and admission systems.

- The following sections are applicable to CAMI database:
    - I: Demographic data
    - II: Prehospital data
    - VI: Anatomical diagnosis
- It is possible to conduct nine different query selections at the same time.
- Contains a basic statistical analysis capability.
- Some limitations included:
    - No “body aspect” defined (i.e., right, left, center, anterior, posterior, etc).
    - Not clear how the software handles injury descriptions that are not easily coded.

4.3.3 U.S. Army Combat Readiness Center (USACRC) Transaction Database and Data Warehouse [24]

- This database is located in Fort Rucker, Alabama. Three types of information are collected and analyzed: scene, vehicle, and occupant. The platform used is Oracle/Structured Query Language (SQL). It takes 6 weeks on average to complete the accident data input. A staff of 24 people is required for this database to function, including: 1) quality controllers, 2) injury coders, 3) scanners, 4) developers (computer programmers), 5) query analysts (data helpers and statisticians), and 6) managers.

4.3.4 National Center for Statistics and Analysis (NCSA) of the National Highway Traffic Safety Administration (NHTSA) [31]

- The National Automotive Sampling System (NASS) is composed of two systems: The Crashworthiness Data System (CDS) and the General Estimates System (GES).
- Both systems are based on cases selected from a sample of police motor vehicle accidents (MVA).
- CDS (started in 1979) data focus on passenger vehicle crashes and are used to investigate injury mechanisms to identify potential improvements in vehicle design.
- GES data focus on the overall accident picture and are used for problem size assessments and tracking trends.
- The Crashworthiness Data System (CDS)
    - KLD Associates, Inc. is an Injury Coding Center (contractor) for the National Automotive Sampling System (NASS), located in San Antonio, TX.
    - The Department of Transportation (DOT) National Highway Transportation System (NHTSA) owns the software, which was developed by the Volpe Center in Washington, D.C.
    - The Abbreviated Injury Score System (AIS 90) is used for injury description and severity coding. ”
    - Search Criteria for Queries applicable to the CAMI database include:
        - *Crash criteria* (accident event: year, month, mortality/injury severity)

    - *Vehicle criteria* (aircraft type, manufacturer, year, etc)
    - *Occupants* (crewmembers and passengers): demographics
- Relevant medical information.
- Seat position.
- Injury classification by body region and severity: AIS-98 Coding, Maximum AIS and ISS.
- Restraint use (crash worthiness data).
- On average, injury researchers complete 1.5 cases per week.
- Injury coders are trained through courses and conferences.
- Injury coding is considered a very specialized project by NHTSA, requiring different areas of expertise, such as biomechanics and injury analysis.
- The CDS system might be very adaptable to aviation.

4.3.5 Services of the FAA Aviation Safety Information Analysis Sharing (ASIAS) formerly National Aviation Safety Data Analysis Center (NASDAC) [32]

- The organization is part of FAA's Office of Aviation Safety (AVS)
- It would provide architectural design and maintenance of an injury database at "no cost" to CAMI
- ASIAS is very familiar with:
    - NTSB and FAA Aviation Accident Investigation (AAI) Data Systems
    - FAA CAMI's mission and needs
- It has had previous experience working with secure data systems

- Examples of ASIAS-supported databases are:
    - NTSB Accident and Incident Data System
    - NTSB Safety Recommendations
    - FAA Accident/Incident Data System
    - Aviation Safety Reporting System
    - Bureau of Transportation Statistics Air Registry
    - Air claims
    - Event Monitoring System
    - Enhanced Airworthiness Data Mart
    - National Airspace Incidents Monitoring System
    - Service Difficulty Reporting System
    - World Aircraft Accident Summary
    - Wildlife

4.3.6. Recommendation

After careful evaluation and comparison with other database designs, we determined that ASIAS (NASDAC) could provide comprehensive access to accident information and advanced analytical tools, at no cost to the FAA. In addition, ASIAS normally updates NTSB data monthly or weekly, which is a great advantage to CAMI.

4.4. Tasks 4 & 5: Develop a System for Collecting, Classifying and Inputting Injury Data and Develop a Method for Migrating Autopsy Data

As indicated in the introduction section, the primary purpose of this research effort was to develop functional requirements for the AA-IADS systems. The functional requirements document (FRD) provides information needed for future data input and migration. The purpose of the FRD is to serve as the official document for the software requirements associated with the AA-IADS (See Appendix A). As the system is developed, it will also provide the foundation for the system design document and support the testing and system acceptance processes.

After the FRD was developed, a Concept of Operations for the AA-IADS was prepared. A detailed description of the AA-IADS Concept of Operation is included as a draft document at the end of this report (See Appendix B) and was developed through the FAA Research Grant No. 2004-G-034 to Wright State University and a partnership with the National Aviation Safety Data Analysis Center (NASDAC).

A logical system description describing the AA-IADS from a business logic perspective, along with the business rules, the structural relationships between these entities, the Logical Screen References, and the AA-IADS Data Map has been attached to this report (See Appendix C).

Appendix D contains a draft of the AA-IADS Software Design Document. Appendix E portrays the new CAMI AA-IADS Data Entry Process.

As previously mentioned, current information related to occupant injuries and aircraft accidents is dispersed among multiple databases. Additionally, accident and particularly injury information is stored in non-standard formats, using non-standardized injury classification systems. Many critical data elements, such as aircraft makes and models, are not captured in a standardized manner, metadata is often sparse, and data access issues make it difficult to retrieve and analyze the data. Once the data is retrieved, it is difficult to consolidate and analyze in a manner that facilitates a better understanding of the sequence of events leading to an injury. Again, understanding the nature and mechanisms of injuries inflicted during an aircraft accident is essential to develop interventions to increase occupant survivability.

4.5. Task 6: Develop a Research Plan to Study The Mechanism of Injuries and Methods to Reduce Passenger and Aircrew Injuries and Increase Survival.

The main purpose of a research-oriented injury database is to be able to assess and improve crash survivability by organizing and integrating relevant information related to occupant injuries (including toxicology), crash forces, occupiable space, and post-crash environment. Simply stated, AA-IADS's contribution will be the determination of injury outcome as related to "CREEP" factors: container, restraint system (including types), environment, energy absorption, and post-impact factors/hazards.

Our approach is to have a "one-stop shopping," injury-oriented database able to answer questions related to:

1. *Injury Codes* in *Fatal* and *Non-fatal Accidents*
2. *Incidental Medical Findings*
3. *Estimated Deceleration Forces (i.e., Injury Mechanisms Analysis)*

The above data will be correlated with the following specific circumstances of the accident listed in Table 5:

Table 5. Data Elements for an Injury-Oriented Database System

1. Demographic	2. DIWS Information	3. Toxicological Information	4. NTSB Information
• Name, SSN, Cert. No., PI No. • Age • Sex • Height • Weight • Cause of death	• Medical Class • Restrictions • Path Codes • Date of last medical exams	• Drug name • Concentration and units • Specimen	• NTSB Injury Classification • Total Flight Time • Time of Crash • Day of Week • Phase of Flight • CFR part • Flight Rules • Aircraft Make, model, and type • Aircraft damage • Aircraft Fire • Aircraft Collision • Biohazard • Floor failure indicator • Overhead Storage Detachment • Fuselage Rupture • NTSB's Probable Cause • Survival analysis • Seatbelt used • Shoulder harness • Seat failure • Helmet • Flight suit • Flight Gloves • Boot • Method of exit • Evacuation injuries • Rescue • Estimated deceleration forces

Some basic examples of the type of aeromedical and aviation safety issues that AA-IADS may be able to address:

1) The correlation, if any, between injuries (Decelerative, Impact, Intrusive, and Thermal), cause of death, incidental medical findings, and:

    a. Demographics
    b. Medical Certificate and path codes
    c. Toxicological findings (i.e., prescribed medications, illegal drugs, carbon monoxide, etc.)
    d. Type of aircraft, including make and model
    e. Type of operation
    f. Aircraft damage
    g. Restraint systems
    h. Post crash-environment (fire, ditching, other)
    i. Floor failure
    j. Overhead storage detachment
    k. Seat failure
    l. Fuselage rupture
    m. Method of exit
    n. Rescue
    o. Estimated deceleration forces

Finally, to reduce passenger and aircrew injuries and increase occupants survival, a detailed evaluation of seat damage has been proposed in conjunction with the Biodynamics Research

Team, Aeromedical Research Division, AAM-600 [27]. Such effort is based on the following facts:

a. Damage patterns can be cross-validated with injury data from the AA-IADS
b. Seat structural performance can indicate the appropriateness of existing dynamic test severity levels and can assist investigators in estimating crash severity.
c. Injury patterns can be used to evaluate the adequacy of occupant injury assessments made during dynamic tests.
d. Integration of seat structural performance and injury data is crucial to form a basis for development of new safety standards and refinement of existing standards.

4.6 Task 7: Collaborate with software developers to assist in overseeing the development of the database.

During the course of this grant, Dr. Ricaurte has continually collaborated with software developers from ASIAS (NASDAC) in the development of functional requirements.

NASDAC provided the technical support necessary: 1) to determine functional data requirements based on current collected data, 2) to determine the software requirements associated with the AA-IADS, 3) for the foundation of the system design document, and 4) to support the testing and system acceptance processes.

The capability of visualizing occupant injury in 3-D is currently being discussed with Transportation Safety Board of Canada Engineering Branch Software Designer/Developers, Mr. Louis R. Landriault and Mr. John Garstang.

Research on injury risk in the context of spatial variation has been made possible in part because of advances in Geographic Information Systems (GIS), combined with powerful statistical software. GIS are automated systems for the capture, storage, retrieval, analysis, and display of spatial data. As its definition implies, the functional capabilities of GIS range from data capture, including entering and editing data, as a regular database; storage of both map and attribute data; and data retrieval based on features attributes and/or space retrieval. GIS's spatial analysis and display capabilities facilitate the analysis of associations between location, environment, and disease [33].

A GIS application into injury analysis in aerospace accidents is possible because of the spatial analysis capabilities, i.e., the ability to manipulate spatial data into different forms and extract meaningful results. Three general types of spatial analysis tasks have been cited by Clarke and colleagues [33] as described by Gatrell and Bailey: 1) visualization, 2) exploratory data analysis, and 3) model building. In the case of injury mechanism analysis in aerospace accidents, visualization techniques offer the advantage of showing injury causation patterns and severity over space and time. Injury causation in aviation accidents is a dynamic process. An essential goal of GIS is to better understand the sequence of events leading to an injury. One of the most active areas in GIS/spatial analysis research is exploratory spatial analysis. Exploratory spatial analysis and GIS have been previously used in aviation safety research, particularly in the analysis of the geographic characteristics of pilot fatality rates in general aviation accidents within the continental United States [34]. By plotting aircraft accident sites on a digital map, computing rates at regular grid intersections and interpolating the data using GIS, and employing Monte Carlo simulations, the authors were able to compare low, medium, and high rate areas in relation to pilot characteristics, aircraft characteristics, and accident circumstances.

Accident Investigation Geographic Information System (AIGIS) is an existing prototype software application developed by John Garstang, Louis Landriault (See Appendix D), and colleagues at the Transportation Safety Board of Canada with the goal of providing a standard common interface for accessing key accident investigation data and reference material from different sources [35]. AIGIS is similar to conventional GIS with respect to some of the spatial data applications associated with the geographic information for an occurrence site or scene. However, AIGIS differs from conventional GIS in that it also contains custom applications associated with investigating spatially related data for the occurrence vehicle (i.e., aircraft), both in its intact and post-accident condition (i.e., wreckage). Similarly pre- and post-accident data for each victim onboard that aircraft can also be displayed using AIGIS. 3-D CAD and GIS computer models, including land mass and ocean floor DTMs, can be integrated with other information to provide investigators with a powerful accident investigation analysis tool [35].

The goal of this collaborative effort with TSB's Engineering Branch software designers/developers is to build an injury-oriented visualization system applicable to multi-modal accident/incident investigations, leveraged by the existing AIGIS, focused on occupant injuries, and integrated with the AA-IADS. A special plotting technique would allow 3D mannequins to be placed in a CAD model depicting vehicle's interior and correlating individual injuries (body regions) with aircraft damage (see Figure 3). A better analysis of injury patterns would be achievable (for more details see Appendix D)

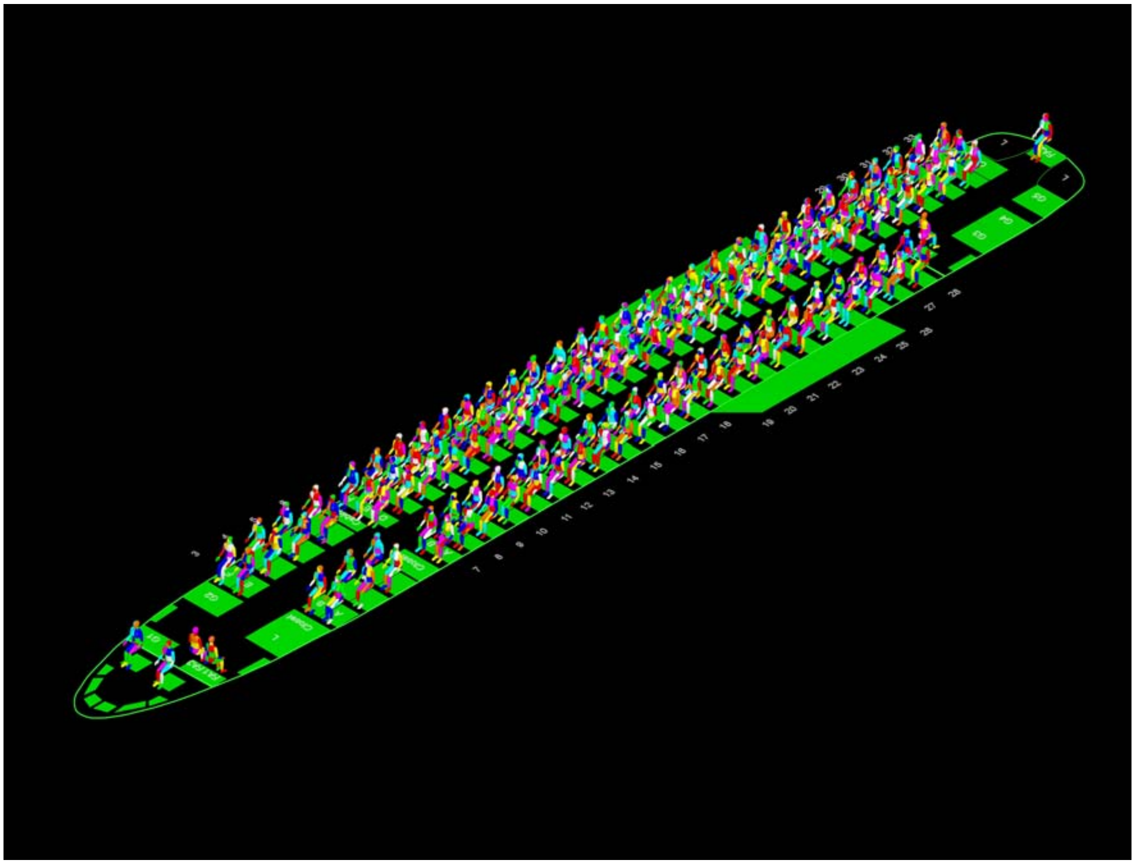


Figure 3. Visualization Technique Depicting Occupants Injuries by Body Regions and Aircraft's Interior. (With permission of Landriault and Garstang, Trasnportation Safety Board of Canada, Systems and Engineering Services Division, Ottawa, Ontario, 2006).

4.7 Task 8: Coordinate findings with the Medical Research Team Lead, Protection and Survival Laboratory Manager, and the Aerospace Medical Research Division Manager.

Dr. Ricaurte has coordinated his research and findings with Dr. Charles DeJohn, the Research team lead, Mr. Robert Shaffstall, Manager of the Protection and Survival Laboratory, and Dr. James Whinnery, Manager of the Aeromedical Research Division.

4.8 Task 9: Publish the Results of the Findings in an OAM Report and/or Open Literature.

The present document along with a report of the research outcomes will be published as an Office of Aviation Medicine (OAM) report. In addition, CAMI's autopsy and injury data has been already presented at the Aerospace Medical Association’s Annual Scientific Meeting in 2005 and 2006.

5.0 CONCLUSIONS

The overall objective of this research was to develop a conceptual model for a research-oriented AA-IADS. Collaboration with database architecture designers and software engineers will ensure the effectiveness in addressing scientific queries. This database will allow the scientific community to better understand injury production and causation in aircraft accidents. A desirable outcome of this research would include the application of existing Accident Investigation Geographic Information System (AIGIS) prototype software application to produce the required injury data plots for injury analysis purposes. Application of this system will be used in the aviation safety domain to reduce the severity of aircraft accident injuries and increase the probability of survival. Results of this research might also contribute to improve aeromedical certification standards, as well as aircraft certification requirements.

APPENDIX A. Application Software Functional Requirements

System Transition Functions

The AA-IADS system will replace the current Autopsy/Injury Database. For that reason, the application software must acquire existing records and augment those records with data from the other AA-IAD systems.

Requirement Title	Requirement Description
Extract/Load Autopsy Data	The system shall perform a one-time extraction of existing autopsy data and load it to the AA-IADS database.
Build AA-IADS Records	The system shall perform a one-time extraction and append function to complete AA-IADS records. The most recent DIWS data will be used.

Aircraft Seating Configurations

A source for seating configuration must be located and acquired. A key requirement of the system is to provide analysts with the ability to visualize seat/injury relationships.

Requirement Title	Requirement Description
Aircraft Seating Configuration	The system shall allow the user to select an aircraft make/model and display a general seating configuration.

Autopsy Data Entry

The system shall allow the following data elements to be manually entered from an autopsy report or an injury report from a hospital. Once entered, all fields can be edited. The initial entry will begin the integrated record construction process that relates data from the Toxicology Database, DIWS and NTSB accident reports.

Requirement Title	Requirement Description
Subject Role	The system shall allow the user to enter one of the following roles: Captain, first officer, second officer, licensed passenger, crew member, passenger, ground, jump seat, GA pilot left seat, GA pilot right seat, or undetermined.
Fatal / Non-fatal	The system shall allow the user to indicate whether or not the injuries sustained were fatal or non-fatal.

Requirement Title	Requirement Description
Subject Record ID Number	The system shall allow the entry of an 11 char. Alphanumeric code. If not unique, alert user.
Cause of Death	The system shall allow the user to enter the cause of death.
Manner of Death	The system shall allow the user to enter the manner of death.
Autopsy/injured Subject's Date Of Birth	The system shall allow the user to enter the subject's date of birth.
Autopsy/Injured Subject's Last Name	The system shall allow the user to enter the subject's last name (50 char)
Autopsy/Injured Subject's First Name	The system shall allow the user to enter the subject's first name (50 char)
Autopsy/Injured Subject's Age	The system shall allow the user to enter the age of the subject. (Autopsy Report)
Autopsy/Injured Subject's Gender	The system shall present the user with indicators for male and female. (Autopsy Report)
Autopsy/Injured Subject's Social Security Number	The system shall allow the user to enter the subject's Social Security Number (***-**-****).
Case Start Date	The system shall automatically enter the date the report was first worked on. (Note: not all cases will start with an autopsy report).
Case End Date	The system shall allow the user to enter the date on which the case is complete. (Note: this date will not always be driven by work related to the entry of autopsy report information).
Injury Body Region Descriptions and Codes	The system shall allow for the entry of multiple injury descriptions, multiple regions. The system shall assess the descriptions and automatically insert the appropriate AIS90/ICD9 body region codes. If a code is not selected, the system shall allow the user to display a pull down menu of body region codes.
Injured Body Parts Descriptions and Codes.	The system shall allow for the entry of multiple injury descriptions, multiple body part and their related codes. The system shall assess the descriptions and automatically insert the appropriate AIS90/ICD9 body part codes. If a code is not selected, the system shall allow the user to display a pull down menu of body part codes.
Incidental Medical Findings	The system shall allow the user to enter incidental medical findings from the autopsy report, or in the

Requirement Title	Requirement Description
	case of an injured subject, from other medical reports.

DIWS Data Elements

The DIWS extraction process will begin when a record is initiated. Using a SSN or Cert. #, the system will be queried and the following data elements will be extracted and loaded into the AA-IADS database. The DIWS data associated with an autopsy/injury report will be accessed and loaded once. DIWS data is not to be updated.

Requirement Title	Requirement Description
Medical Class	The system shall automatically access DIWS. The system will then retrieve and load the medical certification information.
Social Security Number	The system shall automatically extract and load the subject's SSN.
DIWS Extract Date	The system shall load the date on which data was extracted from the DIWS.
Medication Restriction Code	The system shall automatically access DIWS to retrieve and load the medication/restriction code (Y or N)
Pilot ECG Code	The system shall automatically access DIWS to extract ECG codes. Three numeric code.
Pilot ECG Description	The system shall automatically access and load DIWS ECG description associated with the ECG code. 100 alpha/numeric characters.
Contact Lenses in Use	The system shall extract and load contact lens use data (Y or N)
Path codes	The system shall automatically extract and load DIWS path codes.
ICD 9 Codes	The system shall allow the user to manually enter ICD 9 codes.
Date of Birth	The system shall extract and load the subject's DOB.
Height	The system shall extract and load the subject's height.
Weight	The system shall extract and load the subject's weight.

Toxicology Data Elements

The following data elements shall be extracted from the toxicology database and loaded to the AA-IADS database. After loading, all elements will be editable.

Requirement Title	Requirement Description
TOX ID	The system shall allow the user to automatically link to the Toxicology Database, extract the TOX ID and load it to the AA-IADS database.
Drug Name	The system shall allow the user to automatically link to the Toxicology Database, extract the drug name and load it to the AA-IADS database.
Concentration and Units	The system shall allow the user to automatically link to the Toxicology Database, extract the concentration and units and load it to the AA-IADS database.
Specimen	The system shall allow the user to automatically link to the Toxicology Database, extract the specimen source and load it to the AA-IADS database.
Social Security Number	The system shall allow the user to automatically link to the subject's SSN. The SSN is the unique key that relates information from the multiple systems.

NTSB Data Extraction Requirements

The data elements that follow will be automatically extracted and loaded to the AA-IADS database when a record is opened.

Requirement Title	Requirement Description
NTSB Number	The system shall extract and load NTSB # (25 alphanumeric char).
NTSB Status	The system shall extract and load the NTSB status indicator (preliminary, factual, final or unavailable).
Accident Region	The system shall extract and load the region in which the accident occurred.
Accident State	The system shall extract the name of the state in which the accident occurred.
Nearest City to Accident	The system shall extract and load the name of the city closest to the accident.
Accident Zip Code	The system shall extract and load the zip code of the city closest to the accident.
Accident Time Zone	The system shall extract and load the time zone of the city closest to the accident.
Airport Proximity of Accident	The system shall extract and load the proximity of the accident to the nearest airport.
Local Time of Accident (24 hour clock)	The system shall extract and load the local time of the accident.
Flight Plan Filed	The system shall allow the user to enter the flight plan filed indicator.
Flight Plan Type	The system shall extract and load the type of flight plan filed by the subject.
Flight Number	The system shall extract and load the flight number associated with the accident.
Purpose of Flight	The system shall extract and load the purpose of the flight.
Phase of Operation	The system shall extract and load the phase of operation. A drop down menu will be used to display phases from Form 6120.1/2
Aircraft Registration #	The system shall extract and load the N # (6 alphanumeric chars).
Aircraft Serial #	The system shall extract and load the serial number of the aircraft (up to 10 alphanumeric char)
Aircraft Make	The system shall extract and load the name of the aircraft manufacturer. (NASDAC Std.field). In the event that a make is not found, a suspense file will be created that can be reviewed and used

Requirement Title	Requirement Description
	to add new makes to the NASDAC standard.
Aircraft Model	The system shall extract and load the model of aircraft. (NASDAC Std. field) In the event that a model is not found, a suspense file will be created that can be reviewed and used to add new makes to the NASDAC standard.
Aircraft Type	The system shall extract and load the type of aircraft from a pull-down menu. The field will also allow types to key entered if they are not in the list.
Aircraft Damage	The system shall extract and load the degree to which the aircraft was damaged.
Aircraft Ditched	The system shall extract and load the aircraft ditched indicator (Y or N).
Aircraft Collision Indicator	The system shall extract and load the indicator for whether or not the aircraft collided with another aircraft (Y or N).
Aircraft Collision location	The system shall extract and load the air or ground location indicator.
Second collision Aircraft N #	The system shall allow the user to enter the N# of the second aircraft involved in the collision.
Biohazard Indicator	The system shall extract and load the biohazard indicator.
Biohazard Type	The system shall extract and load biohazard types.
Floor Failure Indicator	The system shall extract and load Y or N indicator for floor failure. (Future capability)
Overhead Storage Detachment	The system shall extract and load the Y or N indicator for overhead storage detachment. (Future)
Fuselage Rupture	The system shall extract and load the Y or N indicator for fuselage rupture.
Aircraft Sequence #	The system shall extract and load the Seq. #
CFR Part	The system shall extract and load valid CFR Part #.
Scheduled Flight indicator	The system shall extract and load the scheduled flight indicator.
Light Condition	The system shall extract and load the light conditions at the time of the accident.
Turbulence	The system shall extract and load the type of turbulence present at the time of the accident.
Number of seats	The system shall extract and load number of seats on the aircraft.
Homebuilt Indicator	The system shall extract and load the homebuilt indicator.

Requirement Title	Requirement Description
Aircraft Fire	The system shall extract and load fire indicator.
Aircraft Explosion	The system shall extract and load the indicator that denotes the presence of an explosion.
Accident Classification	The system shall extract and load the classification of the accident.
First Pilot Seat Occupied	The system shall extract and load the seat occupied by the first pilot.
First Pilot Cert. Number	The system shall extract and load the subject's cert. Number.
Subject Aircraft Ratings	The system shall extract and load the subject's aircraft ratings.
Subject Rotorcraft/glider/ LTA	The system shall extract and load the subject's ratings for rotorcraft, Glider LTA.
Subject Instrument Ratings	The system shall extract and load the subject's instrument ratings
Subject Instructor Rating	The system shall extract and load the subject's instructor rating.
Subject Type Rating	The system shall extract and load the subject's rating type.
Subject Medical Cert. Status	The system shall allow the user to manually enter the cert. Status of the subject.
Subject's Date of Last Medical Exam	The system shall allow the user to manually enter the date of the subject's last medical exam.
Subject Seatbelt Used	The system shall extract and load the indicator that denotes the use of the seatbelt.
Subject Shoulder Harness in Use	The system shall extract and load the indicator that denotes use of the shoulder harness.
Narrative History of Flight	The system shall extract and load the narrative textual history.
Probable Cause of Accident	The system shall extract and enter the probable cause of the accident as reported by NTSB.
Flight Rules in Affect	The system shall allow the user to enter the flight rules in affect at the time of the accident.
Flight Conditions	The system shall extract and load the flight conditions at the time of the accident.
Subject's Social Security Number	The system shall extract the subject's social security number. Only one instance of the SSN will be loaded to the database. It's primary purpose is to serve as a unique identifier that is required to associated data from multiple sources.
Pilot in Command	The system shall extract and load the indicator that identifies the subject as the PIC.

Requirement Title	Requirement Description
Visibility	The system shall extract and load the visibility distance (statute miles).
Restriction to Visibility	The system shall extract and load the nature of the visibility restriction (haze, dust, smoke, fog, ice fog, etc.)
Type of Precipitation	The system shall extract and load the type of precipitation (rain, snow, hail, rain showers, drizzle,etc.)
Intensity of Precipitation	The system shall extract and load the intensity of precipitation (light, moderate heavy)

Information Gathered On-Scene

The AA-IADS database will accommodate the following data elements that may be gathered by investigators at the scene of an accident

Requirement Title	Requirement Description
Biohazard Type	The system shall allow the user to enter the biohazard type.
Floor Failure Indicator	The system shall allow the user to indicate floor failure. (Y or N)
Overhead Storage Detachment	The system shall allow the user to indicate overhead storage detachment. (Y or N)
Fuselage Rupture	The system shall allow the user to indicate fuselage rupture. (Y or N)
Occupant Seat Failure	The system shall allow the user to indicate seat failure. (Y or N)
Helmet Retained	The system shall allow the user to indicate the retention of the subject's helmet. (Y or N)
Helmet Dislodged	The system shall allow the user to indicate whether or not the subject's helmet was dislodged. (Y or N)
Helmet Type	The system shall allow the user to display and enter valid helmet types from a pull-down menu.
Flight Suit fire Retardant	The system shall allow the user to enter Y or N to indicate whether or not the designated occupant's flight suit was fire retardant.
Flight Suit Condition	The system shall allow the user to display a dropdown menu of valid conditions of the flight suit.
Flight Gloves Fire Retardant	The system shall allow the user to enter Y or N to indicate whether or not the designated occupant's flight gloves were fire retardant.
Flight Gloves Condition	The system shall allow the user to enter the condition of the flight gloves.
Boot Fire Retardant	The system shall allow the user to indicate whether or not

Requirement Title	Requirement Description
	the subject's boots were fire retardant.
Boot Condition	The system shall allow the user to enter the condition of the subject's boots.
Evacuation Assistance	The system shall allow the user to display a dropdown menu of valid types of assistance. (Form 6120.1/2)
Method of Exit	The system shall allow the user to display a dropdown menu of valid methods of exit. (Form 6120.1/2)
Evacuation Injuries	The system shall allow the user to enter Y or N to indicate whether or not injuries occurred during the evacuation.
Cockpit/Cabin Condition	The system shall allow the user to display a dropdown menu of valid conditions. (Form 6120.1/2)
Escape Difficulties	The system shall allow the user to enter types of difficulties associated with the escape
Rescue Date	The system shall allow the user to enter the date of the rescue.
Rescue Time	The system shall allow the user to enter the time of the rescue. (24 hour clock)
Rescue Vehicle	The system shall allow the user to enter the types of rescue vehicle used.
Rescue Elapsed Time	The system shall allow the user to enter the number of minutes required to complete the rescue.
Estimated G Forces	The system shall allow the user to enter the estimated G Forces experienced by the subject. The estimates will be based on observations of the subject's eyes. The user shall be presented with a pull down menu and series of ranges such as >100.
Subject Impact Vector	The system shall allow the user to enter the direction the subject was traveling upon impact. A pull down menu will offer the following options: X,Y,Z, combined or unknown. The direction will be based on observations of the subject's eyes.

Analysis and Search Requirements

Requirement Description
The software shall provide fully integrated statistical analysis capabilities.
The software shall provide integrated text search and text mining capabilities.
The software shall provide fully integrated data mining capabilities.
The software shall support a fully integrated thesaurus development capability.
The software shall support an ad hoc reporting tool.
The system shall support desktop access to the Canadian AIGIS system.

Software Access and Performance Requirements

Requirement Description
The system must be available 24 hours per day seven days per week. A fail-over capability must be available to continuously monitor system availability and compensate automatically. Down time must be limited to scheduled software upgrades.
Simple web queries must be responded to in less than 10 seconds using a high-speed internet connection.
The software shall support multiple web sites operating concurrently with different level of access permissions.

Database Management System and Operating System

The system shall be developed using Oracle 10g to support the use of the Portal based (Oracle Application server 10g) web application architecture.

Hardware and Communications Requirements

The Operating system to be used will be Windows 2003 Enterprise edition. The Application server will require a minimum of 6 gig of RAM. A minimum of 8 gig of RAM will be required by the Database Server . Intel Xeon 4 processors, RAID drive arrays are recommended.

Communications and Security policies shall conform to the AVS Policies.

APPENDIX B. AA-IADS CONCEPT OF OPERATIONS

1. Project Description

1.1 **Preparation of Concept of Operations Document**

The Aerospace Accident Injury and Autopsy Data System (AA-IADS) Concept of Operations Document was prepared by the Federal Aviation Administration's Civil Aerospace Medical Institute (CAMI). It was developed through the FAA Research Grant Number 2004-G-034 to Wright State University and a partnership with the National Aviation Safety Data Analysis Center (NASDAC). The purpose of the document is to serve as the official document of the Concept of Operations for the AA-IADS System.

1.2 AA-IADS System Concept

1.2.1 Summary of AA-IADS System Concept

The purpose of the new AA-IADS system is to provide CAMI researchers with an integrated database and data-marts that facilitates efficient analysis of injury data. Data will be coded with standardized injury classifications and include non-fatal injury data. The new system will integrate multiple CAMI data tables with NTSB data in a new integrated database with data-marts.

1.2.2 Detailed Database System Concept

Currently, information related to occupant injuries and aircraft accidents is dispersed among multiple databases. Additionally, accident and particularly injury information is stored in non-standard formats, using non-standardized injury classification systems. Many critical data elements are not captured in a standardized manner, metadata is often sparse, and data access issues make it physically difficult to retrieve and analyze the data. Once the data is retrieved, it is difficult to consolidate it and analyze it in a manner that facilitates a better understanding of the sequence of events leading to an injury or simply how an injury was caused. Understanding the nature and mechanisms of injuries during an aircraft accident is essential to develop interventions to increase occupants' survivability.

The AA-IADS is being developed to provide CAMI with an improved injury analysis capability. The system will replace the current Autopsy Database. It will also provide users with an integrated view of: 1) autopsy and injury data; 2) information related to occupants extracted from the NTSB Accident Database (NASDAC version); 3) the CAMI Toxicology Database; and 4) the CAMI Document Imaging and Workflow System (DIWS). The new system will also provide new data visualization capabilities, improved query functions, and provide access to the Canadian Accident Investigation Geographic Information System (AIGS).

The major purpose of the AA-IADS is to provide researchers with the ability to efficiently analyze injuries within the broad context of the accident or event that caused the injury. In other words, AA-IADS will integrate data from multiple systems, provide metadata, standardize key data elements, and allow researchers to correlate an injury with multiple variables. The system will also provide advanced data visualization capabilities and allow for the rapid development of custom data sets that can address specific research questions.

1.3 Current Situation

CAMI established an Autopsy/Injury Database in 1997. The requirements supporting the development of the current database are based on: 1) International Civil Aviation Organization (ICAO) Standards & Recommended Practices, Annex 13; 2) The Aviation Safety Research Act of 1988; and 3) FAA orders 8020.11B and 8025.11B. In addition, one of the major goals described in the FAA Flight Plan 2005-2009, is to increase safety, specifically reducing the fatalities in commercial and general aviation accidents. As related to the Office of Aerospace Medicine (OAM), the FY 2006 Performance Plan's objective number one is to reduce the Commercial Aviation Fatal Accident Rate. To accomplish this goal, CAMI needs to conduct three main research activities: 1) investigation of the injury and death patterns in civilian flight accidents along with meticulous analysis to determine cause(s) and prevention strategies; 2) development of recommendations for protective equipment and procedures; and 3) evaluation of options, addressing all aircraft cabin occupants. This research program identifies human tolerance, capabilities and failure modes both in uneventful flights, and during civilian in-flight incidents and accidents.

CAMI receives, but does not generate, autopsy or injury- related data from Medical Examiner offices across the U.S. Clearly, CAMI's Autopsy/Injury Database depends on how accurately, completely, and comprehensively these data have been collected. Once the data have been received, to code it CAMI must rely on: 1) standardization of injury terminology; 2) injury classification and its severity assessment score system; 3) information available to the data entry coders; and 4) the consistency of the coders.

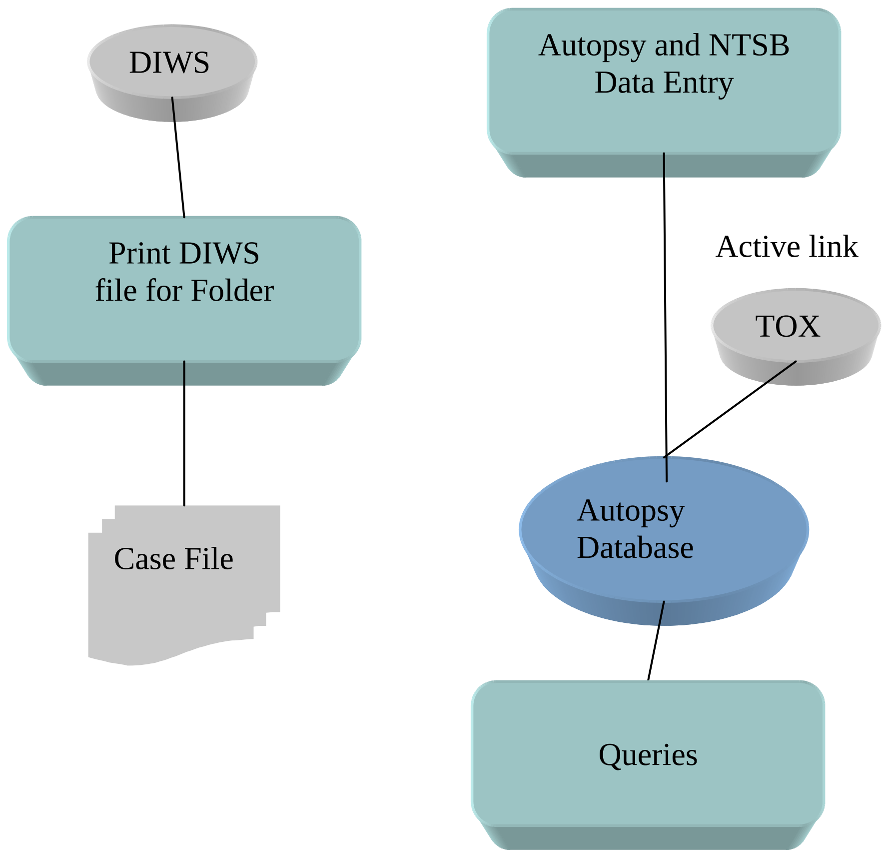
The two federal agencies primarily involved for the source of data entered into the CAMI Autopsy/Injury Database are the Federal Aviation Administration (FAA) and the National Transportation Safety Board (NTSB). The latter is responsible for determining the probable cause of civilian aviation accidents and collects information on scene when an accident occurs. CAMI performs toxicological tests of biological samples from fatal accidents to determine the presence or absence of alcohol, drugs, or other substances that might have degraded pilot performance, or equally important to determine if the occupants died as a result of smoke inhalation.

The current fatal, severe, minor and non-injury classification do not allow for any detailed research that could result in aeromedical recommendations to improve survivability in an aircraft accident. In the civil aviation sector, an interactive AA-IADS is needed to improve the FAA's ability to classify and analyze aircraft occupant injuries. This research-oriented database is necessary to better investigate and understand the types and mechanisms of injuries caused by aircraft accidents. As a result, the FAA will be able to formulate data-driven intervention strategies to reduce the number of aircraft accident-related fatalities, increase survivability rates, and ultimately reduce the severity of injuries.

Current System Architecture

Source Documents

Written autopsy reports and NTSB web pages

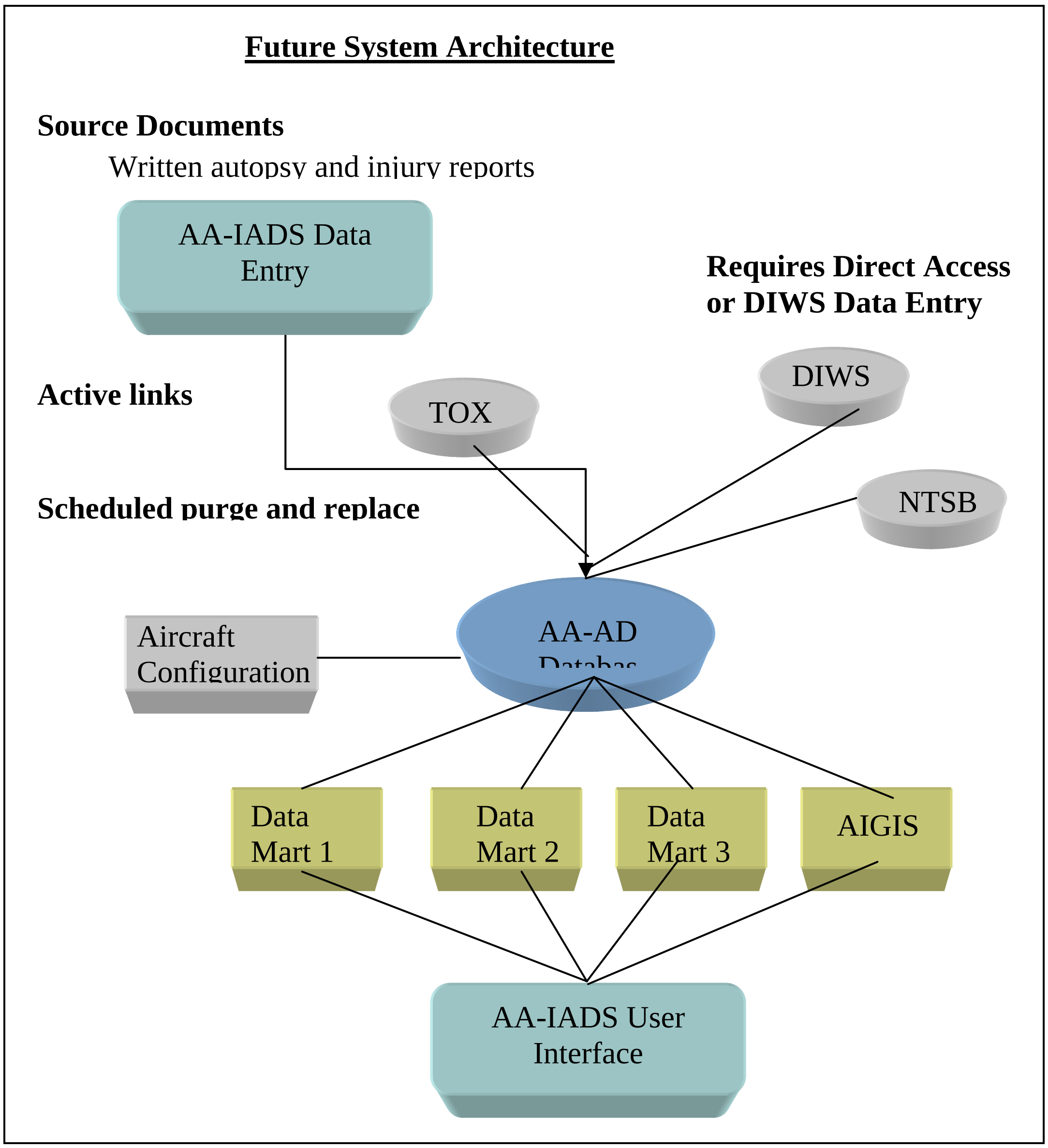


1.4 System Users

The AA-IADS will support research efforts undertaken to reduce injuries and fatalities caused by aircraft accidents. The system will only be accessed by CAMI researchers working at the CAMI facility in Oklahoma City. The system will follow AVR, NTSB and CAMI security procedures.

2. Future System Architecture

The AA-IADS will be based on an architecture featuring a centralized database supporting a series of subject oriented datasets (data marts). When the central database is updated, the application software will also dynamically update the data marts. The diagram below shows the future system architecture.



3. Justification

Transportation and motor vehicle accident related fatalities rank third as the cause of lost years of life in the U.S., after heart disease and cancer [21], and are the leading cause of all injury deaths, as well as all occupational injury deaths [36].

A recent review of the NTSB Data System revealed that in the United States from January 1985 to December 2004 a total number of 43,738 aircraft accidents occurred involving all types of civilian operations. Fatal accidents accounted for 8,427 (19%) of these events. Based on the number of aircraft involved, 17,643 people died on-board and 8,913 suffered serious injuries. Passengers accounted for approximately half of the total fatalities. During the same period, a total of 5,034 autopsy reports were sent to CAMI by Medical Examiners from all across the United States and entered into the CAMI Autopsy database [5, 37].

Injury mechanism analysis is a process that requires, in addition to the injury description, a detailed analysis of the environment in which the injury occurred; an analysis of protective equipment (e.g., seats and restraints) to determine its function (or lack of it) and use; and a knowledge of the crash dynamics, incident circumstances, and related structural failure modes [7]. In other words, an injury mechanism analysis helps to answer the questions: how and why the injury occurred in terms of the sequence of events or actions involved during the transfer of energy and the “contact” surface, i.e. the vehicle itself or its environment (aircraft structure, fire or water environment, trees, etc.)

Traditionally, aircraft accident investigations have been more focused on the cause and circumstances of the accident, spending minimal effort on the cause and mechanisms of injury, particularly during the process of collecting critical data in the field. As a result, research conducted to identify mechanisms that produce injury and fatalities in otherwise survivable accidents, have been limited by: 1) the scarcity of data related to occupant’s fatal and non-fatal injuries and 2) lack of correlation between autopsy and toxicological findings, injury severity, demographic variables, restraint systems, aircraft damage, method of exit, evacuation injuries and other safety issues. It appears that although the information needed to reconstruct the sequence of events leading to an occupant’s injury might be collected by on-site accident investigators, it is not completely reported in each accident’s official report. It is clear that a comprehensive injury-oriented data collection and analysis is needed in order to better understand the interaction between the individual and the aircraft components leading to injury causation.

Summarizing, occupants’ injury descriptions along with injury mechanisms analysis, i.e. correlations of injuries, toxicological levels, and causes of death provide valuable insights into the reconstruction of events leading to the air disaster and helps to identify areas where future research may reduce the severity of injuries, increase occupants’ survival, and ultimately improve aviation safety.

4. Concept of Operations

The objectives of the AA-IADS are to:

- Provide standardized data entry services for autopsy reports and medical injury reports. Injury data will be enhanced with NTSB and DIWS databases.
- Introduce effective data analysis and visualization tools that will provide CAMI researchers with a better understanding of the relationships among the many factors that lead to injuries and fatalities.
- Reduce injuries and fatalities resulting from aircraft accidents.

The new system will:

- Provide data integration services that deliver composite views of accidents and the injuries they cause.
- Provide integrated views of the NTSB Accident database, the Toxicology database and the CAMI DIWS database.
- Provide analysts with the ability to rapidly create custom data sets and query capabilities that allow subjects to be explored from multiple perspectives.
- Improve and extend the analytical tolls used to provide safety information,.
- Provide on-line metadata for database elements.
- Allow analysts to visualize seat position and the injuries sustained by the seat occupants.
- Allow data quality to be measured and reported. Quality characteristics will include data validity and completeness (percentage of fields that actually contain data).

4.1 System Transition Functions

The AA-IADS system will replace the current Autopsy Database. For that reason, the application software must acquire existing records and augment those records with data from the other AA-IADS systems. The system will perform a one-time extract of existing autopsy data and load it to the AA-IADS database. The most recent DIWS data as related to the accident date will be used.

4.2 Data Availability and Constraints

A source for seating configuration must be acquired. A requirement of the system is to provide analysts with the ability to visualize seat/injury relationships. The system will allow the user to select an aircraft make/model and display a general seating configuration. Licenses for desktop access to the Canadian AIGIS system will be required.

4.3 Autopsy Data Entry

The system will standardize data elements to be manually entered from an autopsy report or an injury report from a hospital. Once entered, all fields can be edited. The initial entry will begin the integrated record construction process that relates data from the Toxicology Database, DIWS and NTSB accident reports.

4.4 Analysis and Search Concept

The software will provide integrated statistical analysis capabilities, text search and text mining capabilities, data mining capabilities, a full thesaurus capability, an ad hoc reporting tool, and desktop access to the Canadian AIGIS system.

4.5 Software Access and Performance Concept

The system must be available 24 hours per day seven days per week. A fail-over capability must be available to continuously monitor system availability and compensate automatically. Down time must be limited to scheduled software upgrades. Simple web queries must be responded to in less than 10 seconds using a high-speed Internet connection. The software will support multiple web sites operating concurrently with different levels of access permissions.

4.6 Database Management System and Operating System

The system will be developed using Oracle 10g to support the use of the Portal based (Oracle Application server 10g) web application architecture.

4.7 Hardware and Communications Concept

The Operating system will be Windows 2003 Enterprise edition. The Application server will require a minimum of 6 gig of RAM. A minimum of 8 gig of RAM will be required by the Database Server. Intel Xeon 4 processors, RAID drive arrays are recommended. Communications and Security policies will conform to the AVS, CAMI and NTSB Policies.

APPENDIX C. AA-IADS LOGICAL SYSTEM DESCRIPTION

Introduction

The purpose of this document is to describe the Aerospace Accident Injury and Autopsy Database System (IADS) from a business logic perspective. It is intended for the owners and users of the system and is not to be confused with any formal technical documentation. Logical entities and their major attributes will be defined and described from a business perspective. The business rules and the structural relationships between these entities will be addressed as well. The goal of this document is to clarify and verify the basic operation function of the system before actual construction begins.

Logical Entities and Attributes

The logical entities of any database system describe categories of data elements grouped together that have a meaning and a purpose specific to the scope of the project. Physically entities are expressed as tables in a database. Attributes are used to define the meaning and purpose of the entities. For example, an AIRCRAFT entity would have the attributes for the Serial Number, Registration Number, Make, Model and Series that define an Aircraft. Physically an attribute is expressed as a column or field in a table in a database. A *primary attribute* is an attribute the uniquely distinguishes one instance of an entity from another. An *instance* of an entity would be a row in the table, a unique entity.
Defining attributes are the minimum amount of information needed to create a unique entity.

The IADS system has 5 primary logical entities as follows;

- USERS
- CASES
- AIRCRAFT
- SUBJECTS (People)
- INJURIES

USERS

A user is a person who enters, manipulates and retrieves data from the database via the application. All users are people and therefore have a first and last name, so a persons name is a defining attribute of a user. Because some people have the same names, a unique identifier has to be generated to distinguish one user from another. Users are defined to control access to the system (due to the nature of the sensitive information) and to define rights on manipulation of the data. So each user is assigned a role, also a defining attribute.

The primary attribute for the user will be a user id, a system generated attribute to guarantee uniqueness of user.

The defining attributes for a user will be

- User Name
- User Role

User Roles

There are 3 types of user roles to the system:

- Application administrator
- Data Entry
- Analyst/Report User

The **application administrator** is has all power over the other users and has the rights of all other users. He is not to be confused with the Database Administrator or the Network Administrator. He cannot change the way the software works. His responsibilities will include:

- Creating, Deleting, Modifying all other users of the application
- Granting access rights to the application to all other users
- Updating Injury Codes and new Aircraft configurations when necessary

The application administrator role may be disseminated to other based on the implementation strategy to be defined. Or, a specific 'named user', will be called out and the role eliminated.

The **data entry** user collects and enters data into the system via the application. His is responsible for the data collection of all Cases he is assigned. His responsibilities include.

- Creating, Deleting, Modifying all instances of entities owned by him
- Entering, Editing applicable attributes of all instances of entities owned by him.
- Initiating automatic data loads from NTSB, DIWS and TOX for all cases assigned to him
- Close cases that belong to him.

The **analyst/report User** has read only access to the data collected. This user will usually access data via an ad-hoc reporting tool, have download capability or through pre-canned reports created by the developers.

The users access to the system most likely will defined by the network environment to a reporting database or through the web portal product.

CASES

A case is defined as a collection of all information associated with an event where a person (people will be referred to as subjects from this point on) was injured on an aircraft. An event takes place in time and space, so the event date and location are primary attributes of a case. An aircraft was involved, and all operating US aircraft have a unique registration number at any given point in time, so registration number becomes a primary attribute of a case. A subject was injured, and all subjects have a name, so a subject's name becomes a primary attribute. Some subjects have the same name, so we have to come up with a unique identifier for each individual subject. A case has a data entry lifespan, a start date and a closed date. A case closed date is the date when the data in the case is completed and will no longer be modified.

The primary attribute for a case will be a system generated case number to guarantee uniqueness of each case.

The defining attributes for a case are:

- Event Date
- Event Location
- Aircraft Registration Number
- Subject Identifier (a unique person)
- Case create date
- Case closed date

Cases and Users

- A case has to be created by a user. The user that creates the case is called the case owner. Only users that have the Data Entry role (as defined in the Users entity) can create a case.

- A case can only be deleted or edited by the Case Owner.
- A user can be responsible for more than one case.
- A case can be closed by the case owner under the condition that the NTSB data for that case is in its final state.

AIRCRAFT

An aircraft is defined in this a system as a combination of the event environment around the vehicle and the vehicle itself. The event environment attributes define location, conditions and characteristics of the event. The vehicle attributes of the aircraft entity define the type, configuration and individual identifiers of the vehicle.

Because an aircraft is a part of the definition of a case, a case cannot exist without an aircraft. An aircraft instance is automatically created on the creation of a case and the case id becomes the primary attribute of an Aircraft. The reverse is true as well, when a case is deleted, all aircraft associated with that case are deleted.

The primary attribute of an Aircraft Entity is the Case Id.

The defining attributes of the aircraft are:

- Aircraft Registration Number
- Event Date
- Event Location

Cases and Aircraft

- When a case is created, an Aircraft instance is created as well. A case must have at least one Aircraft. This is called a *parent child relationship*. A child (aircraft) cannot exist without the parent (case), and a parent, by definition, must have a child.
- A case can have more than one Aircraft. An example of this would be 2 aircraft colliding with injuries on both planes
- If a case is deleted, all aircraft information associated with that case are deleted as well.
- The Aircraft inherits the rules associated with the case users. All Aircraft attributes can only be modified by the Case Owner.

SUBJECTS

A subject is defined as a person on an Aircraft injured in an event. Because a subject is a part of the definition of a case, a case cannot exist without a subject. Part of the definition of a subject calls out an Aircraft, so a subject cannot exist without an associated aircraft. The same is true of an Aircraft, an aircraft cannot exist without at least one subject. A subject instance is automatically created on the creation of a case and the case id becomes one of the primary attributes of a subject. A subject is dependent of an Aircraft. When an aircraft is deleted, all associated subjects are deleted as well. The relationship carries down from the case as well. When a case is deleted, all aircraft associated with that case are deleted and as a result, all the subjects associated with those aircraft are also deleted. An Aircraft can have many subjects (people) at the time of the event. These subjects (names are not unique) are distinguished in the system by a unique identifier name the Subject Record Identifier and it becomes the second part of the primary attribute.

The primary attribute of a subject entity is a combination of:

- Case ID
- Subject Record Identifier

Each subject on the plane has a name

Each subject on the plane plays a role (Pilot, Passenger, Flight Officer). Based on the role played, different data will be collected about the subject (DIWS). As a result, subject role is added to differentiate the subjects.

Each plane must have at least a Pilot flying the plane.

Each subject must have an injury type (Fatal, Non-Fatal). Based on the type of injury, different data will be collected about the subject (Autopsies). As a result, an injury type is added to differentiate the subjects

The defining attributes of a subject are:

- Subject Name
- Subject Role
- Subject Injury Type

Cases and Subjects

- A case must have at least one subject, so when a case is created a subject is created as well

Aircraft and Subjects

- An aircraft must have at least one subject
- A subject is a child of aircraft, so when an aircraft is deleted the associated subjects are deleted as well. An Aircraft cannot exist without a subject.
- An aircraft can have more than one subject
- An aircraft must have a subject that plays the role of pilot (pilot in charge)

INJURIES

An injury is defined as damage or harm done to or suffered by a subject that was received as a result of an event on an aircraft that can be classified by the ICD9 and/or AIS coding manuals. By definition an Injury cannot exist without a subject, so the subject's primary attributes carry as one of the primary attributes of an injury. Injuries are defined as and/or an AIS or ICD9 code, so an injury must have one of these codes as part of it's primary attributes. There may be other aspects of the primary identifier for an injury that are as a result of the coding process for ICD9 and AIS.

The primary attributes of an injury are

- Case ID
- Subject Record Identifier
- Injury Code Type
- Injury Code

In the case of injury, the defining attributes are embedded in the primary attributes because the structures of the codes for AIS and ICD9 contain detailed references to information on location, aspect, etc of the injury.

Subjects and Injuries

- A subject must have at least one injury
- An injury is a child of a subject, so when a subject is deleted all associated injuries are deleted as well
- A subject may have more than one injury.

APPENDIX D. Draft AA-IAD Software Design Document

1. Project Description

1.1 Preparation of Software Design Document

The Aerospace Accident Injury and Autopsy Data System (AA-IADS) Software Design Document was prepared by the Federal Aviation Administration (FAA) Civil Aerospace Medical Institute (CAMI). It was developed through the FAA Research Grant Number 2004-G-034 to Wright State University and a partnership with the National Aviation Safety Data Analysis Center (NASDAC). The purpose of the document is to serve as the official document for the Software Design Document for the AA-IADS.

1.2 AA-IAD System Objective

1.2.1 Summary of AA-IAD System Objective

The purpose of the new AA-IAD system is to provide CAMI researchers with an integrated database and data-marts that facilitates efficient analysis of injury data. Data will be coded with standardized injury classifications and include non-fatal injury data. The new system will integrate multiple CAMI data tables with NTSB data in a new integrated database and data-marts.

2. Software Inputs

See the attached diagram labeled “CAMI Autopsy System Data Entry Process” for an explanation of the current CAMI autopsy software data input flows.

See the attached diagram labeled “CAMI Injury and Autopsy System Data Entry Process” for an explanation of the new AA-IAD software data input flows.

The table below shows the side-by-side comparison of old and new system data acquisition sources.

Old System	New System
NTSB Website	NTSB Database
DIWS Website	DIWS Database
Toxicology Database	Toxicology Database
Autopsy Reports	Autopsy Reports
	Injury Reports
	On Site Reports

3. Software Outputs

The AA-IAD system produces an integrated database and data mart structure to support the analytical functions of the CAMI staff. The Entity Relationship Diagrams (ERD) shown in the next sections explain the database structure and content.

The AA-IADS integrates data from the NTSB Database, DIWS Database, Toxicology Database, Autopsy Reports, Injury Reports, and On Site Reports. Data-Marts will be produced from the AA-IAD Database. The Data-Marts will facilitate ad-hoc analytical queries and data mining. The Data-Mart content will be defined at a later time.

4. Database ERD

See the attached ERWIN ERD.

5. Software Relationships

The linkage to existing database and data entry will be developed in Oracle Portal, the Database will be Oracle 10g, and Oracle Discoverer and other Portal components will be used for queries. Oracle views of the databases will be used to define the Data-Marts.

6. Concept of Operation

The attached Concept of Operation Document explains of the system operation. The Operations Manual, still to be developed, will further explain the operation of the system.

7. Traceability of Requirements

The attached requirements spread sheet traces the system requirements to the design.

8. Reuse Element Identification

The new AA-IADS links to the NTSD, DIWS and Toxicology Databases for data reuse and integration without re-entry of data. Data from the CAMI Autopsy Database will be migrated to the new AA-IAD system.

APPENDIX E. Accident Investigation Geographic Information System (AIGIS)

Introduction

Experience has demonstrated the need for an accident investigation tool that can be used in the collection, storage, retrieval, analysis and display of spatially referenced data. Research revealed that the best approach to accomplish this task would be to use a non-conventional Geographic Information System (GIS)[1]. Since an appropriate "off the shelf" tool could not be found it was decided to develop a prototype Accident Investigation Geographic Information System (AIGIS).

The AIGIS tool would be similar to conventional GIS in that it would allow the mapping of occurrence sites/scenes. In addition it must also be capable of collecting, analyzing and displaying data associated with both pre and post occurrence structures. These would include vehicles, buildings and human anatomy.

AIGIS Primary Components

The AIGIS prototype is divided into two primary components, a relational database[2] and a two and three dimensional (2D & 3D) Computer Aided Design (CAD)[3] application. The relational database that was selected was Microsoft (MS) Access. This database management system was chosen because of its availability (i.e. it comes standard with MS Office Professional), because it has a productivity enhanced development environment and because it can be used to store and retrieve any ODBC[4] compliant data. The CAD application that was chosen was Bentley Microstation. It was chosen because of its availability, because it's GIS capable and because it can be manipulated by an external program (e.g. MS Access).

In order to make AIGIS a multi-user application the database and user interface would be separated into two MS Access applications. One, the "back-end", would host the relational tables and the collected data and the other, the "front-end" would host the user interface. This separation will allow multiple users, each possessing their own copy of the front-end, to access a shared back-end.

AIGIS Framework

The AIGIS framework is divided into three main categories:

1. Developmental
2. Database (MS Access) / CAD (Bentley Microstation) communications.
3. User Interface

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[1] The United States National Science Foundation defines a GIS as a computerized database management system used for the capture, storage, retrieval, analysis, and display of data that is spatially referenced. GIS is typically used in mapping environments.

[2] A relational database is a means of structuring data as a collection of tables that are logically associated to each other by shared attributes.

[3] A CAD system is a computer system used in the design, drafting and display of graphically oriented information.

[4] Open Database Connectivity (ODBC) is a standard or open application programming interface (API) for accessing a database.

The developmental aspect of the AIGIS framework consists of data table and user form templates from which new tables and user forms can be rapidly developed and deployed. These templates have reusable custom code associated with them which, among other things, facilitates data entry, data querying and data display. Consequently AIGIS can be quickly deployed and new tables and forms can be rapidly added, removed or modified to adapt to new circumstances and rapidly changing priorities.

Because the database (MS Access) and CAD (Microstation) applications are separate programs they can function independently of one another. However the true power of any GIS is its ability to graphically display spatially referenced data. Consequently the AIGIS framework includes custom code that facilitates two way communications between MS Access and Bentley Microstation. This means that, through the framework, MS Access can send information and commands to Microstation causing it to selectively and systematically generate 2 and 3D plots depicting things such as occurrence site maps and pre and post crash structures (e.g. vehicles, buildings and human anatomy). Similarly Microstation can send information and commands to MS Access causing it to query and display data from its database. For example the selection of a graphic element depicting anything from a map location to an object in a structure (e.g. engine component, human body part, etc.) can trigger Microstation to send information and commands to MS Access causing it to query the database and display all information associated with that graphic object. It is however important to note that for this aspect of the AIGIS framework to work a previously established link must exist between a graphic object and the database.

The user interface framework is designed to simplify user interaction with the database. The interface consists of a variety of sub forms which are all embedded in one “master” form. All data is entered, edited and displayed through this “master” and its sub forms. In addition, through the selecting of a menu option, these forms are transformed into a database querying interface. Both simple and complex SQL[5] queries, based on any available field or combination of available fields, can be easily created by filling in the same forms that are used for data entry. Once the query forms are filled in the selection of another menu option will cause the template code to produce properly formatted SQL commands which are then used to query the database (Operators do not require any knowledge of the SQL language in order to effectively query the database.). The results of these queries are automatically displayed back into the “master” and its sub forms. The user interface framework also allows queries to be modified, saved and restored.

The user interface framework also simplifies CAD plotting. Plots can be systematically built up, saved and restored. They can be created in steps, each step representing the results of a database query. These steps can be saved and later recalled to either recreate the plot or to be used as the foundation of additional plots.

AIGIS Wreckage and AIGIS Pathology

To date the AIGIS foundation software has been used to create two variations of AIGIS. They are AIGIS Wreckage and AIGIS Pathology. As the names imply AIGIS Wreckage is used to collect, store, retrieve, analysis and display data associated with vehicle wreckage components and AIGIS Pathology is used to collect, store, etc. data associated with the occurrence victims. Both variations have some common tables and forms. For example each has “Photo” tables and forms that host the photographs associated with the wreckage component or victim. Among other

[5] SQL is a standard computer language for accessing and manipulating databases.

information a “thumbnail” of each image is shown, which when selected, will launch a high resolution version of the image located in near line storage (i.e. a jukebox).

AIGIS Wreckage was adapted to include tables to host among other things pre and post crash component descriptions, locations (i.e. where the component was located on the pre-crash vehicle and where it was found in the wreckage field) and multi-media data (e.g. object models, panoramic images, video and audio). For one specific investigation this variation of AIGIS was used to host and analyze over 20,000 exhibits, over 160,000 images and was used to track and plot over 35,000 CAD graphic objects.

AIGIS Pathology was also adapted to host victim data, which among other things, included, victim statistics (e.g. age, sex, etc.), next of kin, personal effects, exhibits (i.e. body parts), injury and toxicology. In addition a special plotting utility was added that allowed 3D mannequins to be placed in a CAD model depicting a vehicle’s interior (i.e. a mannequin for each victim). These mannequins, one male and one female were scaled to indicate whether they were an infant, a child or an adult. Each mannequin was divided into sixteen segments (i.e. left and right for – head, face, neck, chest, arms, abdomen, pelvis and legs) and each segment was linked to the database allowing manipulation of the individual segments and allowing the database to be queried from the CAD application. In addition human anatomical CAD models were added which would allow a detailed analysis of an individuals injuries. These models, which were on loan from Visible Productions (http://visiblep.com), included a complete human skeleton, the major organs (both male and female) and the major portions of the central nervous system (i.e. different sections of the brain and spinal column). They were also linked to the database which allowed them to be programmatically manipulated. AIGIS Pathology was used to in a wide range of applications. The list includes but is not limited to, victim recovery and identification, selecting of victims for toxicology purposes and the analysis of injury patterns. In one occurrence the system was used to collect, track and analysis data for 229 fatalities. During one four hour session approximately 80 different questions (e.g. where were the people with tibia or fibula fractures seated?) were answered. This included the creation of approximately 80 different 3D mannequin seating plan plots, one for each question asked.

Conclusion

AIGIS has proven to be a very powerful tool and the prototype has exceeded expectations. However there are areas that need improvement and additional features that should be added.

The use of MS Access has proven to be a limiting factor. It has a file size limitation of 1 Gigabyte which, in one case, required the database “back-end” to be separated into multiple “back-ends”. MS Access also has performance issues when operating in a multi-user environment. The programming language used in MS Access (Visual Basic for Applications) limits AIGIS framework and user interface development.

The use of AIGIS in real world applications has identified areas where additional features would be useful. The AIGIS prototype is limited in that it can only deal with one occurrence at a time. An ability to query across multiple occurrences would be beneficial. Both AIGIS Wreckage and AIGIS Pathology need to be combined into one product. This would allow a better analysis of the human – machine environment. AIGIS should also be expanded to include statistical analysis and charting modules.

In conclusion it is recommended that AIGIS be redesigned to:

1. Use a more powerful multi-user relational database "back-end".
2. Query across multiple occurrences.
3. Combine AIGIS Wreckage and AIGIS Pathology.
4. Include statistical analysis and charting modules.
5. Use a more powerful development environment (e.g. MS Visual Studio .NET).

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