Institute of Transportation Studies
University of California at Berkeley

Development of the Flight Crew Human Factors Integration Tool

PHASE II SUMMARY REPORT

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Preface and Acknowledgments

This report documents research undertaken by the National Center of Excellence for Aviation Operations Research, under Federal Aviation Administration Research Contract Number DTFA03-97-D-00004, Delivery Order DTFA03-97-F-UC007, *Human Factors Support to the FAA Office of System Safety for the Global Analysis and Information Network*. Any opinions expressed herein do not necessarily reflect those of the Federal Aviation Administration (FAA) or the U.S. Department of Transportation.

This report summarizes the results of the various tasks in the Delivery Order relating to the development of the flight crew human factors Integration Tool, that are documented in more detail in three supporting reports: *Implementation of Analysis Methods and Training Needs Assessment* (Blanchard *et al.*, 1998); *Improving the Representation of Human Error in the Use of the Flight Crew Human Factors Integration Tool* (Gosling, Roberts & Jayaswal, 1998); and *Proposed Functional Enhancements for the Flight Crew Human Factors Integration Tool* (Gosling, 1998).

The maintenance of the Integration Tool website and the work on implementing analysis methods and performing the training needs assessment described in chapter 3 of this report was performed by Dr. Jim Blanchard and Dr. Deborah Osborne of Embry-Riddle Aeronautical University under a subcontract from the University of California at Berkeley. The development of the flight operations risk management questionnaire discussed in chapter 4 has been adapted from prior work by Carolyn Libuser of the University of California at Los Angeles and Karlene Roberts of the University of California at Berkeley.

The authors wish to acknowledge the support and suggestions provided by Jack Wojciech of the FAA Office of System Safety, as well as the assistance and input received from a large number of FAA and industry personnel involved in aviation safety.

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Executive Summary

In May 1996, the FAA announced a new and innovative approach to reach a goal of "zero accidents," known as the Global Analysis and Information Network (GAIN). This would be a privately owned and operated international information infrastructure for the collection, analysis, and dissemination of aviation safety information. It would involve the use of a broad variety of worldwide aviation data sources, coupled with comprehensive analytical techniques, to facilitate the identification of existing and emerging aviation safety problems.

A major component of the GAIN approach is the application of innovative analysis capabilities to identify the types of human error that contribute to aviation accidents and incidents in order to develop prevention strategies. As part of its Flight Crew Accident and Incident Human Factors Project initiated in 1993, the FAA Office of System Safety has developed a new process that uses a prototype website-based Integration Tool (IT) to access, integrate, and analyze flight crew human factors data relevant to safety. In September 1996, the FAA Office of System Safety funded the National Center of Excellence for Aviation Operations Research to initiate a program of research to provide human factors support for the GAIN concept. The first phase of this research performed a technical review of the results achieved to date by the flight crew human factors project and developed a strategic plan to lay the foundations for a sound scientific approach to the analysis of human factors issues within the framework of the GAIN concept. This report documents follow-on research activities directed at continued development of the Integration Tool and developing better ways to identify error reduction strategies.

Enhancement of the Prototype Integration Tool

The prototype Integration Tool was developed by a team that included the FAA Office of System Safety, the MITRE Corporation, Abacus Technology Corporation, and Galaxy Scientific Corporation. By 1996, this work had resulted in Version 2.1 of the prototype IT. As part of the research performed during this

contract, two separate sets of enhancements to this version of the prototype Integration Tool were implemented.

The University of California at Berkeley (UCB) developed a number of enhancements to Version 2.1, that allow the values in the IT master or sub-query matrices to be downloaded to a spreadsheet, as well as the values of the data fields for the database records identified by a cell in a master or sub-query matrix. The data fields currently downloaded for each record correspond to the non-narrative fields that are displayed by the IT when the user selects the list of record numbers for the values in a matrix cell, then selects one of the records to display the brief report. This enhanced version of Version 2.1 has been termed Version 2.2.

In addition, researchers at Embry-Riddle Aeronautical University (ERAU) developed a modified version of the IT, with a significantly different user interface, that allows the user to select a much wider range of subsets of the data than is possible with Version 2.1, obtain cross-tabulation counts, and download them to a spreadsheet. This version has been termed Version 3.0.

Demonstration of Analysis Methods and Training Needs Assessment

In addition to maintaining and enhancing the functionality of the Prototype IT, a major focus of the research was the development and demonstration of analysis techniques that could take advantage of the information provided by the IT to improve the understanding of flight crew human error and help develop strategies to reduce these errors. With this objective, researchers at ERAU examined the application of a risk assessment technique to identify training targets of opportunity to reduce the occurrence of flight crew error, and undertook a flight crew training needs assessment.

The risk assessment analysis involved the application of a mathematical technique known as the Analytical Hierarchy Process that makes use of expert opinion to develop importance weights to apply to different criteria in a decision process. This technique was applied to data in the National Transportation Safety Board Accident and Incident Database, and used to define a model intended to provide the user with the ability to identify the combination of conditions that are most likely to be involved in an accident or incident involving flight crew error.

A second analysis was performed by researchers at UCB in order to demonstrate the application of the IT to a specific category of flight crew human error incidents, using the FAA Pilot Deviation System (PDS) database. This analysis built on a prior study that had been performed by the FAA Office of System Safety to examine the causal factors behind one of the most serious safety issues currently being faced by the FAA, namely the growing frequency of runway incursion incidents. The results of this analysis largely confirm the findings of the earlier FAA study, and show that inadequate or inappropriate pilot-controller communications and lack of airport familiarity are the principal causal or contributing factors to general aviation runway incursions.

The training needs assessment was undertaken at five flight training centers, and examined three aspects of the training process: procedural compliance, systems knowledge, and decision making related to weather. Data was collected on the percent of the training time devoted to each of these three factors and the number of times that the factors were addressed in the curriculum. In addition, a questionnaire administered at each site to collect data on the opinions of the training staff regarding such aspects as the information used to measure the effectiveness of the training program, the flexibility allowed to flight crew to apply individual practices, and the adequacy of the training program to develop in-flight decision skills.

Based on the information obtained, it was found that there is a need to develop standardized procedures to collect operational data on flight crew performance that can be correlated with data collected in the course of training programs to measure the effectiveness of the training. It was recommended that training needs assessements should be conducted using a common process across similar types of training activity and that further efforts are needed to improve the classification of types of flight crew error to better identify how to improve flight crew training and recertification. It was also suggested that attention needs to be given to the evolving use of cockpit automation and changing procedures within the National Airspace System.

Improving the Representation of Human Error in the Use of the IT

The current version of the IT applies two different classifications of human error to records in accident or incident databases to construct matrices that crosstabulate the number of errors of each type against a classification of the accidents or incidents on the basis of the flight conditions or year during which the accident or incident occurred. It provides the capability to select subsets of the data and to display detailed information for each record for a selected cell of the matrix. The classification of the errors is performed through the use of two human error models that apply a set of defined rules to the information in the database. The first model distinguishes between slips and mistakes, where slips are execution errors in which the action does not go as planned and mistakes are errors where the action goes as planned but fails to achieve the desired outcome. The second model broadens this classification to distinguish between errors that are knowledge-based, rule-based, or skill-based.

In order to provide a richer characterization of human error that can help identify the causal factors behind these errors, it has been increasingly recognized that errors need to be understood in the context within which they occur. Efforts to understand how errors get made, and what can be done to reduce this, need to address the way in which information is processed by the flight crew and how this is influenced both by their training and experience, as well as the sequence of events that precede each decision. The approach to these issues in this phase of the research consisted of an examination of the recent literature on human error to identify how to better characterize the context of such errors, including how to address individual, team, and organizational behavior, as well as the development of a survey instrument for collecting empirical data on these behavioral constructs and incorporating them in aviation safety databases.

Proposed Functional Enhancements to the IT

The fourth component of the research was directed at identifying potential functional enhancements to the prototype Integration Tool that address the safety data access and analysis needs of potential users and would be supported by them. The approach adopted during the study consisted of three components: a review of potential enhancements to the prototype IT identified in prior work and other tasks of the current project; a survey of potential users of the IT to identify their data access needs and views on the potential usefulness of different features; and discussions with FAA offices that would be involved in the use of the IT or the provision of data accessed by it.

The results of the user needs survey demonstrate a high level of support for the type of data access and analysis capability provided by the Integration Tool, as well as a clear need for almost all the functional enhancements identified in the survey. While some enhancements were perceived as somewhat more useful than others, the differences in the assessment were not great. This suggests that it would contribute to the value of the IT to implement as many of the proposed enhancements as soon as possible.

Based on the assessment of the survey respondents, there appears to be a very promising opportunity for the FAA to enter into a partnership with the potential users in the industry, in which those organizations would share in the cost of further development of the IT. However, for this to occur the capabilities of the current version of the IT need to be enhanced, so that the tool provides many of the features that respondents identified as desirable. It will also be necessary to continue to support an operational website and promote the use of the IT among the user community.

Conclusions and Recommendations

The current version of the Integration Tool provides a useful initial capability to analyze aviation accident and incident databases, by identifying specific records in a large database that meet certain criteria, and then allowing the user to display the contents of the database records for further review. The concept of using human error models to assist in selecting records for events that conform to a particular type of error allows the user to focus on a subset of the data of particular interest, and may facilitate the identification of strategies to reduce the occurrence of particular types of error.

The challenge of reducing the fatal accident rate in U.S. aviation by 80 percent by 2007, established as a goal in the latest FAA Strategic Plan, will require a sustained commitment to developing effective tools to integrate, manage and analyze the growing volume of aviation safety data. The success of the Global Analysis and Information Network will depend not only on the ability to address the concerns over sharing proprietary or sensitive data, but also the availability of tools to manage and analyze those data.

The current version of the Integration Tool provides a useful platform from which to address these issues. However, for this to occur, further enhancements to the structure and logic of the IT are needed, so that it can provide users with greater functionality and access to a broader array of aviation safety data. Central to this are two capabilities:

- the provision of the ability for users to define their own human error models, using a rule-based format that can access any desired field in the underlying databases;
- the ability to access other databases over the Internet using secure methods for the transmission of sensitive data.

It is recommended that these enhancements be pursued as soon as sufficient resources can be made available.

In addition, the FAA should maintain an active research program directed at improving the understanding of the causal factors underlying flight crew error and developing effective intervention strategies. In order to begin to collect quantitative data on the role of safety culture in aviation organizations, as well as to obtain experience in adapting survey techniques that have been found to be useful in other safety-critical organizations and to establish their value and effectiveness, the FAA should consider sponsoring a demonstration program in cooperation with one or more airlines to begin collecting data on a trial basis. This would require appropriate protection for those involved, and could serve as a useful proof-of-concept study for the GAIN concept. While the availability of data from such programs would enhance further research into strategies to reduce flight crew human error, it is equally important to continue current research efforts based on the use of existing data sources.

1. Introduction

On May 9, 1996, the FAA announced a new and innovative approach to reach the Administrator’s goal of “zero accidents,” known as the Global Analysis and Information Network (GAIN). GAIN would be a privately owned and operated international information infrastructure for the collection, analysis, and dissemination of aviation safety information. It would involve the use of a broad variety of worldwide aviation data sources, coupled with comprehensive analytical techniques, to facilitate the identification of existing and emerging aviation safety problems.

A major component of the GAIN approach is the application of innovative analysis capabilities to identify the types of human error that contribute to aviation accidents and incidents in order to develop prevention strategies. As part of its Flight Crew Accident and Incident Human Factors Project initiated in 1993, the Office of System Safety has developed a new process that uses a website-based prototype Integration Tool (IT) to access, integrate, and analyze flight crew human factors data relevant to safety. The initial process applies two human error models to the NTSB accident database and the FAA Pilot Deviation System (PDS) incident database and generates human factors patterns and trends. Safety analysts in the Office of System Safety began to use the initial process in October 1996.

In September 1996, the FAA Office of System Safety funded a research grant to the National Center of Excellence for Aviation Operations Research to initiate a program of research to provide human factors support for the GAIN concept. The first phase of this research, consisted of two tasks: first to continue the application and improvement of the IT and lay the foundations for a sound scientific approach to the analysis of human factors issues within the framework of the GAIN concept; and second to review the results achieved to date by the flight crew human factors data project and integrate recommendations from this technical review into a strategic plan.

This report documents follow-on research activities directed at continued development of the Integration Tool and developing better ways to identify error reduction strategies, that have been undertaken to implement the recommendations of the technical review.

Research Approach

The research activities during this phase of the project comprised two broad tasks: (1) continued implementation and demonstration of IT applications; and (2) research to begin to implement the recommendations of the technical review performed during the first phase of the project.

The approach to the first task consisted of four activities:

- Maintenance of the Prototype IT on a computer website at Embry-Riddle Aeronautical University (ERAU) for the duration of the contract. In addition to the version of the IT developed by the FAA Office of System Safety, a modified version developed by ERAU was also supported that provided additional data retrieval functionality.
- Application of a technique known as the Analytical Hierarchy Process to the analysis of data in the National Transportation Safety Board database in the IT, and a demonstration of its application to identifying targets of opportunity to reduce the occurrence of flight crew error.
- Conduct of a multi-site demonstration of the IT at four flight training centers, operated by two airlines, Boeing and ERAU, and the US Navy Safety Center. A training needs assessment process was developed and implemented at each site.
- A case-study approach to the analysis of the data presently included in the FAA Pilot Deviation System (PDS) database, that built on a prior study that had been undertaken by the FAA Office of System Safety to examine the causal factors behind the growing frequency of runway incursion incidents.

The first three activities were undertaken by Embry-Riddle Aeronautical University under a subcontract from the University of California (Blanchard, *et al.*, 1998). Additional functional enhancements to the Prototype IT were developed and implemented by the University of California at Berkeley (UCB) on a developmental website that was established at Berkeley.

The case study analysis of the PDS data on runway incursions was undertaken by UCB in order to demonstrate how the IT can be used to gain a better understanding of the possible causes of flight crew error, to examine the utility of the IT in performing this analysis, and to identify how enhanced functionality of the IT could improve its usefulness.

The approach to the second task consisted of the following activities:

- A review of the recent literature on human error to identify how to better characterize the context of such errors, including variables addressing individual, team, and organizational behavior. This effort included the development of an instrument for collecting empirical data on these behavioral constructs and incorporating them in aviation safety databases.
- A review of the findings of two prior workshops that had been conducted by the FAA Office of System Safety to discuss the analysis of flight crew human factors, present the development of the IT, and obtain feedback. This was supplemented by the recommendations from the first phase of this study, and the results of the research into improved representation of human error undertaken as part of the current phase of the research.
- A survey of potential users of the IT, to identify their data access needs and views on the potential usefulness of different features.
- Discussions with FAA offices that would be involved in the use of the IT or the provision of data accessed by it.

Although not a formal part of the research to identify user needs, the multi-site demonstration and training needs assessment that was performed by Embry-Riddle Aeronautical University as part of the first task provided an opportunity to solicit informal feedback from potential users of the IT on desired enhancements.

Structure of this Report

The remainder of this report consists of five chapters. Chapter 2 describes the activities performed during the current phase of the research to maintain the

Prototype Integration Tool website and provide additional functional capabilities. The following chapter discusses the analytical techniques that were developed and demonstrated in the course of the research and reviews the training needs assessment that was conducted. Chapter 4 describes the research into ways to improve the representation of human error that was undertaken during the current phase of the research. The following chapter reviews the proposed functional enhancements that were identified during the first phase of the research, summarizes discussions that were held with potential users of the Integration Tool, and describes the design, conduct and findings of a survey to identify safety data access needs of potential IT users, their perception of the usefulness of different potential IT features, and their assessment of the likely willingness of their organization to financially support the continued development of the IT. Finally chapter 6 presents the conclusions and recommended future course of action for the continued development of the IT and supporting research.

2. Enhancement of the Prototype Integration Tool

The prototype Integration Tool is an Internet (World Wide Web) based data access and analysis tool that permits safety analysts, accident investigators, human factors professionals, and others to remotely apply two human error models to the NTSB accident/incident and FAA National Airspace Incident Monitoring System (NAIMS)/Pilot Deviation System (PDS) incident databases in a consistent manner. For the NTSB database, the prototype IT produces a cross-tabulation matrix of Type of Flight Crew Error (e.g. slips and mistakes) and the Domain of Flight Crew Error (e.g. aircraft system and weather conditions) during which the error occurred. For the PDS database, the prototype IT produces a matrix of Type of Flight Crew Error and year of the PDS event. For each database-model pair selected the IT will generate a Master Matrix. The user can then create sub-matrices from the master matrix by selecting any combination of year, weather condition, airspace user, aircraft manufacturer (make), phase of flight, and pilot's total hours flown. Further details of the IT are given in Appendix A.

The prototype Integration Tool was developed by a team that included the FAA Office of System Safety, the MITRE Corporation, Abacus Technology Corporation, and Galaxy Scientific Corporation. By 1996, this work had resulted in Version 2.1 (Schreckengast, Fogle & Tax, 1996). This version is currently running on a computer in the FAA Office of System Safety, and copies have been established on computers at the University of California at Berkeley (UCB) and Embry-Riddle Aeronautical University (ERAU).

As part of the research performed during this contract, two separate sets of enhancements to Version 2.1 of the prototype Integration Tool were implemented. UCB researchers developed a number of enhancements that allow the values in the IT master or sub-query matrices to be downloaded to a spreadsheet, as well as the values of the data fields for the database records identified by a cell in a master or sub-query matrix. This enhanced version of the prototype IT has been termed Version 2.2, and has been maintained on a website at *http://skylark.its.berkeley.edu*.

In addition, ERAU researchers developed a modified version of the IT, with a significantly different user interface, that allows the use to select a much wider range of subsets of the data than is possible with Version 2.1, obtain cross-tabulation counts, and download them to a spreadsheet. This version has been termed Version 3.0.

Integration Tool Version 2.2

This enhanced version of the IT adds buttons to the screen display of a master or sub-query matrix that allow the values in the matrix to be downloaded to a spreadsheet, or the values of the data fields in the records represented by the count of records in a cell of the matrix to be downloaded to a spreadsheet. This provides the user with the capability to perform statistical analysis on the values in the master or sub-query matrices, without having to manually enter the values from the screen display, as well as perform statistical analysis on the values in the data fields of selected database records identified by the IT.

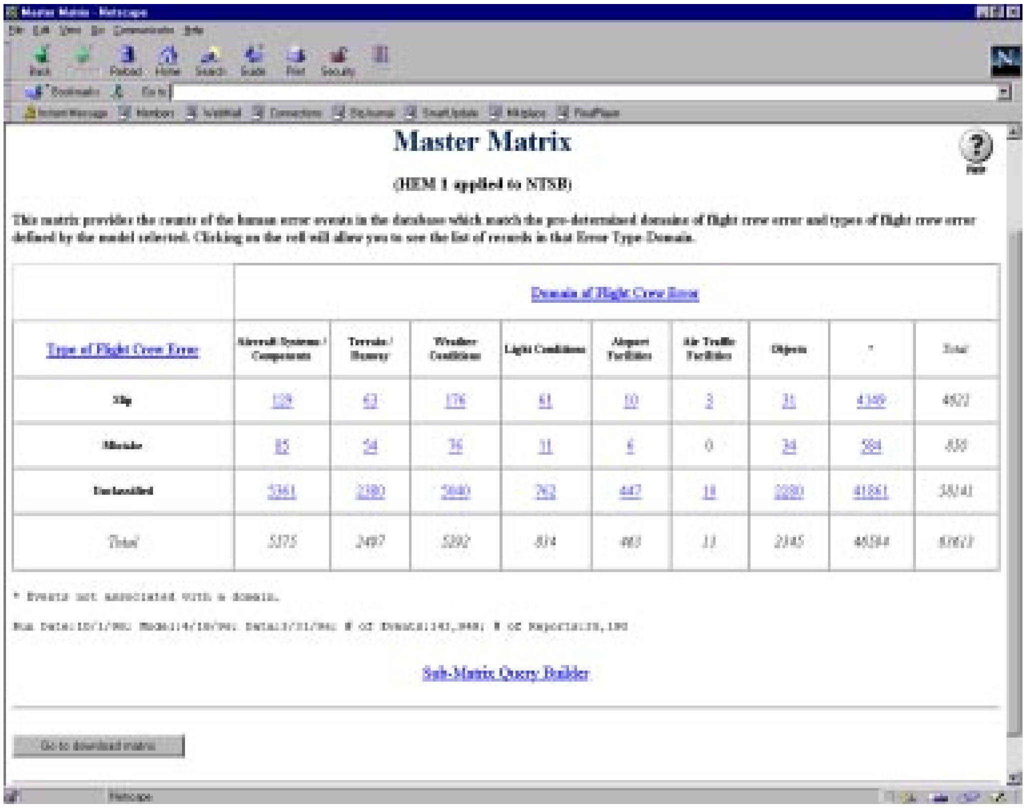
The data fields currently downloaded for each record correspond to the non-narrative fields that are displayed by the IT when the user selects the values in a matrix cell to display the list of record numbers, then selects one of the records to display the brief report. The narrative fields are not included due to their length, and the fact that they are not likely to be used for statistical analysis.

The user interface for Version 2.2 is intuitive. The master or sub-query matrix screen contains a button to download the information in the matrix, as shown in Figure 2-1. This creates a modified version of the matrix screen that contains instructions on downloading either the values in the matrix or the data field values for one cell of the matrix, as shown in Figure 2-2. Each cell of the matrix contains a button to download those records. The resulting files are in tab-delimited format that can be imported by most common spreadsheet, statistical analysis, or database management programs.

Integration Tool Version 3.0

Version 3.0 of the IT was developed by ERAU to provide the capability to perform crosstabulation of selected data fields in the IT databases, either for the entire database or for records that represent particular types of human error as classified by the IT. The user interface presents the user with the possible values for each step in defining the database query, allowing the user to select the desired values by clicking on them with the mouse.

The user initially selects a database and type of error defined by one of the two human error models in the IT, by choosing from a list that shows the available combinations of database and error type. Selecting a table from this list displays the available database fields (column headings), as shown in Figure 2-3. The user then selects one or more of these database fields.



Master Matrix

(HEM 1 applied to NTSB)

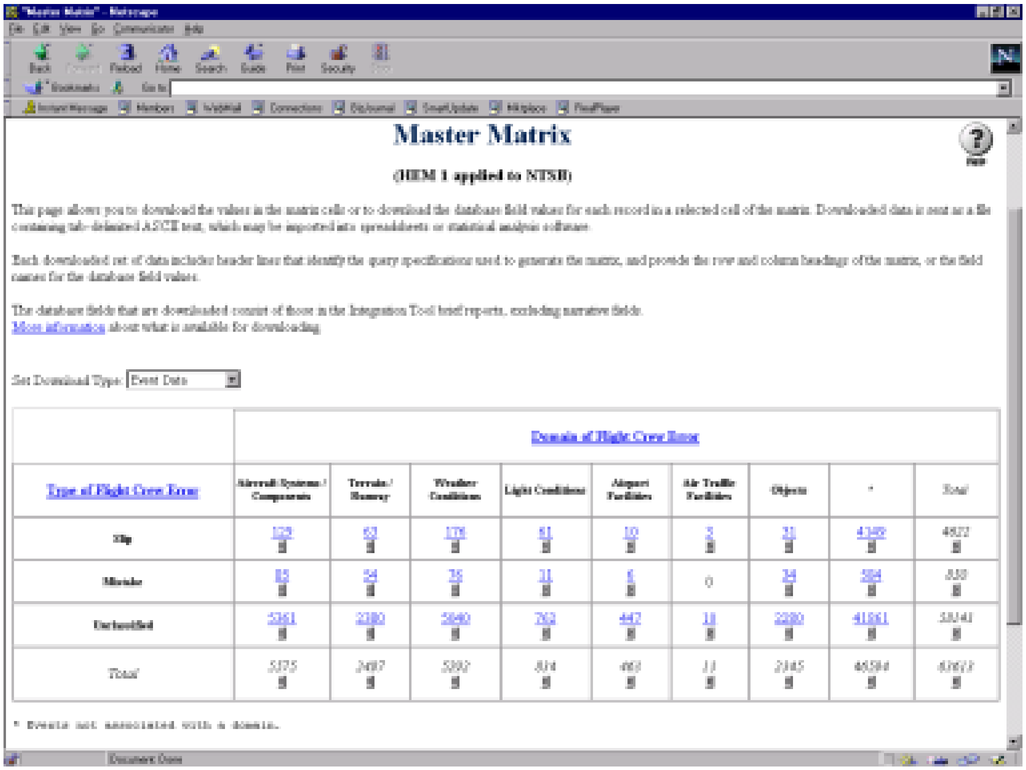
This matrix provides the counts of the human error events in the database which match the pre-determined domains of flight crew error and types of flight crew error defined by the model selected. Clicking on the cell will allow you to see the list of records in that Error Type Domain.

	Domain of Flight Crew Error								
Type of Flight Crew Error	Aircraft Systems / Components	Terrain / Runway	Weather Conditions	Light Conditions	Airport Facilities	Air Traffic Facilities	Objects	*	*Total*
Slip	129	63	176	61	10	3	31	4349	4822
Mistake	85	54	76	11	6	0	34	384	*650*
Unclassified	5361	2380	5040	762	447	18	2280	41861	*58149*
Total	*5575*	*2497*	*5292*	*834*	*463*	*21*	*2345*	*46594*	*63621*

* Events not associated with a domain.

Run Date:10/1/98; Model:4/10/98; Data:3/31/98; # of Events:143,948; # of Reports:28,180

Sub-Matrix Query Builder



Master Matrix

(HEM 1 applied to NTSB)

This page allows you to download the values in the matrix cells or to download the database field values for each record in a selected cell of the matrix. Downloaded data is sent as a file containing tab-delimited ASCII text, which may be imported into spreadsheets or statistical analysis software.

Each downloaded set of data includes header lines that identify the query specifications used to generate the matrix, and provide the row and column headings of the matrix, or the field names for the database field values.

The database fields that are downloaded consist of those in the Integration Tool brief reports, excluding narrative fields.
More information about what is available for downloading.

Set Download Type: Event Data

	Domain of Flight Crew Error								
Type of Flight Crew Error	Aircraft Systems / Components	Terrain / Runway	Weather Conditions	Light Conditions	Airport Facilities	Air Traffic Facilities	Objects	*	*Total*
Slip	129	63	176	61	10	3	31	4349	4822
Mistake	85	54	76	11	6	0	34	384	*650*
Unclassified	5361	2380	5040	762	447	18	2280	41861	*58149*
Total	*5575*	*2497*	*5292*	*834*	*463*	*21*	*2345*	*46594*	*63621*

* Events not associated with a domain.

Figure 2-1 **Integration Tool Version 2.2 - Master Matrix with Download Option**

Figure 2-2 **Integration Tool Version 2.2 - Download Instructions**

For each database field selected, the program displays possible values of the field and allows the user to select the values to be included in the resulting tabulation, as shown in Figure 2-4. Once the user has defined all the database fields and their associated values to be included in the query and requested that the query be submitted to the database server, as shown in Figure 2-5, the specification is converted into Structured Query Language (SQL) and the program then tabulates the count of records in the database for each combination of the selected values, as shown in Figure 2-6. The resulting table can be downloaded to a spreadsheet. The download files are in comma-separated value format, which can be imported by most common spreadsheet programs. Depending on the Web browser being used and its settings, the download file may be automatically loaded into Microsoft Excel.

Further details of Version 3.0 are described in the technical report *Implementation of Analysis Methods and Training Needs Assessment* (Blanchard *et al.*, 1998). As part of the contract, ERAU personnel maintained a website at *http://astor.caar.db.erau.edu* that supported both the original Version 2.1 of the prototype IT and the revised Version 3.0.

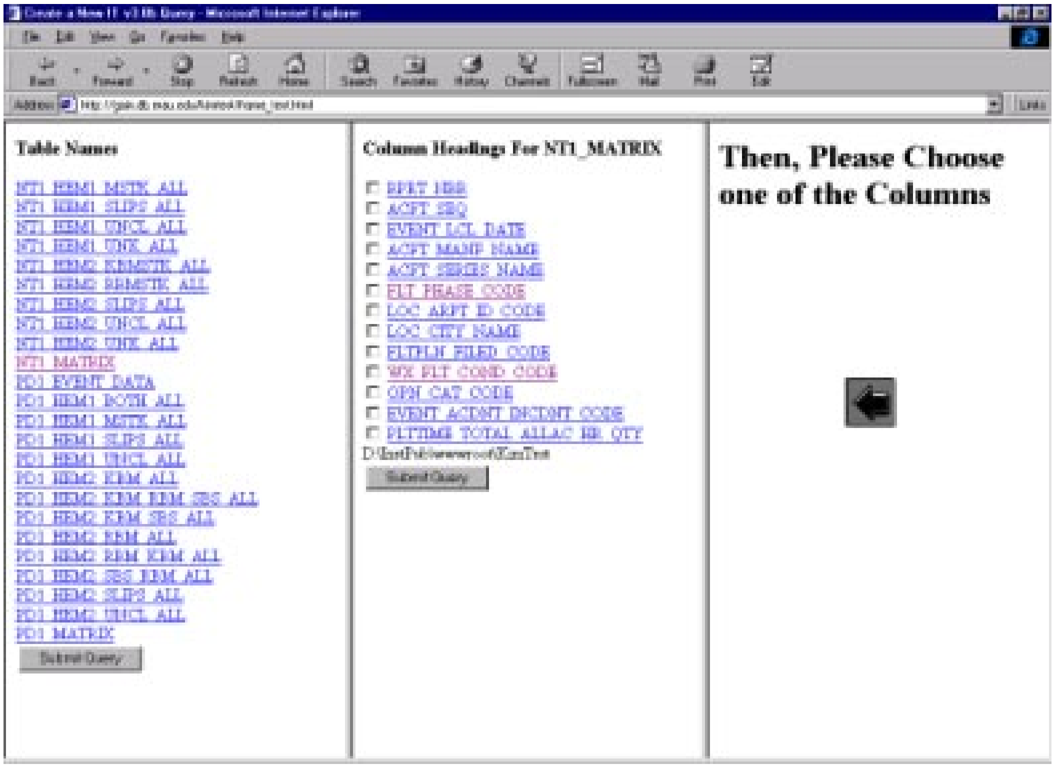


Table Names

- NT1_HEM1_MSTK_ALL
- NT1_HEM1_SLIPS_ALL
- NT1_HEM1_UNCL_ALL
- NT1_HEM1_UNK_ALL
- NT1_HEM2_KRMSTK_ALL
- NT1_HEM2_RRMSTK_ALL
- NT1_HEM2_SLIPS_ALL
- NT1_HEM2_UNCL_ALL
- NT1_HEM2_UNK_ALL
- NT1_MATRIX
- FD1_EVENT_DATA
- FD1_HEM1_BOTH_ALL
- FD1_HEM1_MSTK_ALL
- FD1_HEM1_SLIPS_ALL
- FD1_HEM1_UNCL_ALL
- FD1_HEM2_KRM_ALL
- FD1_HEM2_KRM_RRM_SRS_ALL
- FD1_HEM2_KRM_SRS_ALL
- FD1_HEM2_RRM_ALL
- FD1_HEM2_RRM_KRM_ALL
- FD1_HEM2_SRS_RRM_ALL
- FD1_HEM2_SLIPS_ALL
- FD1_HEM2_UNCL_ALL
- FD1_MATRIX

Column Headings For NT1_MATRIX

- ☐ RPRT_NBR
- ☐ ACFT_SEQ
- ☐ EVENT_LCL_DATE
- ☐ ACFT_MANF_NAME
- ☐ ACFT_SERIES_NAME
- ☐ FLT_PHASE_CODE
- ☐ LOC_ARPT_ID_CODE
- ☐ LOC_CITY_NAME
- ☐ FLTPLN_FILED_CODE
- ☐ WX_FLT_COND_CODE
- ☐ OPN_CAT_CODE
- ☐ EVENT_ACDNT_INCDNT_CODE
- ☐ FLTTIME_TOTAL_ALLAC_HR_QTY

D:\InetPub\wwwroot\KimTest

Then, Please Choose one of the Columns

Figure 2-3 **Integration Tool Version 3.0 - Selecting Database Fields**

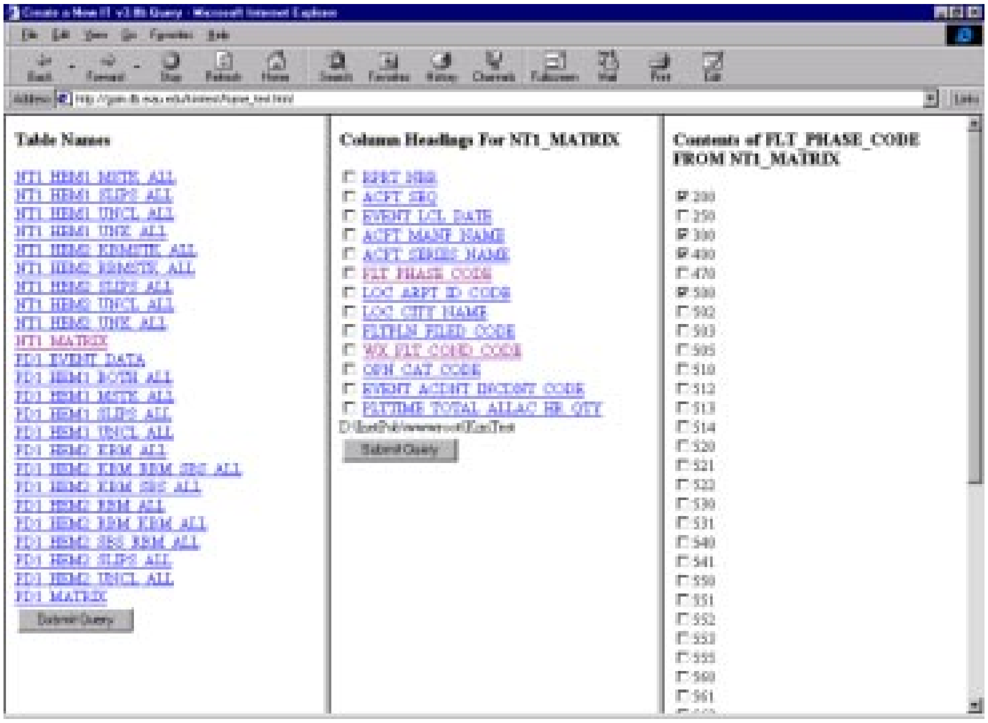


Table Names

- NT1_HEM1_MSTK_ALL
- NT1_HEM1_SLIPS_ALL
- NT1_HEM1_UNCL_ALL
- NT1_HEM1_UNK_ALL
- NT1_HEM2_KRMSTK_ALL
- NT1_HEM2_RRMSTK_ALL
- NT1_HEM2_SLIPS_ALL
- NT1_HEM2_UNCL_ALL
- NT1_HEM2_UNK_ALL
- NT1_MATRIX
- FD1_EVENT_DATA
- FD1_HEM1_BOTH_ALL
- FD1_HEM1_MSTK_ALL
- FD1_HEM1_SLIPS_ALL
- FD1_HEM1_UNCL_ALL
- FD1_HEM2_KRM_ALL
- FD1_HEM2_KRM_RRM_SRS_ALL
- FD1_HEM2_KRM_SRS_ALL
- FD1_HEM2_RRM_ALL
- FD1_HEM2_RRM_KRM_ALL
- FD1_HEM2_SRS_RRM_ALL
- FD1_HEM2_SLIPS_ALL
- FD1_HEM2_UNCL_ALL
- FD1_MATRIX

Column Headings For NT1_MATRIX

- ☐ RPRT_NBR
- ☐ ACFT_SEQ
- ☐ EVENT_LCL_DATE
- ☐ ACFT_MANF_NAME
- ☐ ACFT_SERIES_NAME
- ☐ FLT_PHASE_CODE
- ☐ LOC_ARPT_ID_CODE
- ☐ LOC_CITY_NAME
- ☐ FLTPLN_FILED_CODE
- ☐ WX_FLT_COND_CODE
- ☐ OPN_CAT_CODE
- ☐ EVENT_ACDNT_INCDNT_CODE
- ☐ FLTTIME_TOTAL_ALLAC_HR_QTY

D:\InetPub\wwwroot\KimTest

Contents of FLT_PHASE_CODE FROM NT1_MATRIX

- ☑ 200
- ☐ 250
- ☑ 300
- ☑ 400
- ☐ 470
- ☑ 500
- ☐ 502
- ☐ 503
- ☐ 505
- ☐ 510
- ☐ 512
- ☐ 513
- ☐ 514
- ☐ 520
- ☐ 521
- ☐ 522
- ☐ 530
- ☐ 531
- ☐ 540
- ☐ 541
- ☐ 550
- ☐ 551
- ☐ 552
- ☐ 553
- ☐ 555
- ☐ 560
- ☐ 561

Figure 2-4 **Integration Tool Version 3.0 - Selecting Values for the Database Fields**

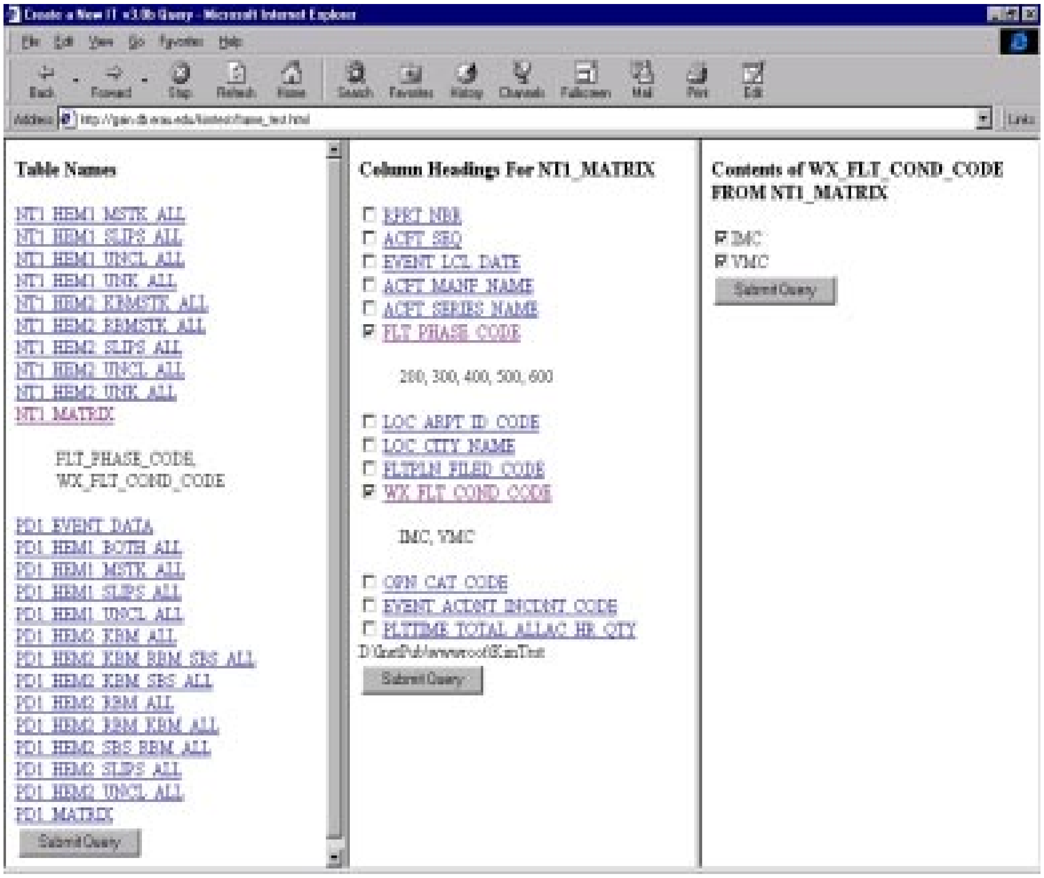


Table Names

NT1_HEM1_MSTK_ALL
NT1_HEM1_SLIPS_ALL
NT1_HEM1_UNCL_ALL
NT1_HEM1_UNK_ALL
NT1_HEM2_KRMSTK_ALL
NT1_HEM2_RRMSTK_ALL
NT1_HEM2_SLIPS_ALL
NT1_HEM2_UNCL_ALL
NT1_HEM2_UNK_ALL
NT1_MATRIX

FLT_PHASE_CODE,
WX_FLT_COND_CODE

PD1_EVENT_DATA
PD1_HEM1_BOTH_ALL
PD1_HEM1_MSTK_ALL
PD1_HEM1_SLIPS_ALL
PD1_HEM1_UNCL_ALL
PD1_HEM2_KBM_ALL
PD1_HEM2_KBM_RBM_SBS_ALL
PD1_HEM2_KBM_SBS_ALL
PD1_HEM2_RBM_ALL
PD1_HEM2_RBM_KBM_ALL
PD1_HEM2_SBS_RBM_ALL
PD1_HEM2_SLIPS_ALL
PD1_HEM2_UNCL_ALL
PD1_MATRIX

Column Headings For NT1_MATRIX

☐ RPRT_NBR
☐ ACFT_SEQ
☐ EVENT_LCL_DATE
☐ ACFT_MANF_NAME
☐ ACFT_SERIES_NAME
☑ FLT_PHASE_CODE

200, 300, 400, 500, 600

☐ LOC_ARPT_ID_CODE
☐ LOC_CITY_NAME
☐ FLTPLN_FILED_CODE
☑ WX_FLT_COND_CODE

IMC, VMC

☐ OPN_CAT_CODE
☐ EVENT_ACDNT_INCDNT_CODE
☐ FLTTIME_TOTAL_ALLAC_HR_QTY

Contents of WX_FLT_COND_CODE FROM NT1_MATRIX

☑ IMC
☑ VMC

Figure 2-5 **Integration Tool Version 3.0 - Submitting Query to the Database Server**

This is what the NT1 query will look like

```
SELECT Count(*) as Count, NT1_MATRIX.FLT_PHASE_CODE, NT1_MATRIX.WX_FLT_COND_CODE

FROM NT1_MATRIX

WHERE ((NT1_MATRIX.FLT_PHASE_CODE=200) or (NT1_MATRIX.FLT_PHASE_CODE=300) or (NT1_MATRIX.FLT_PHASE_CODE=400) or
(NT1_MATRIX.FLT_PHASE_CODE=500) or (NT1_MATRIX.FLT_PHASE_CODE=600)) and ((NT1_MATRIX.WX_FLT_COND_CODE='IMC') or
(NT1_MATRIX.WX_FLT_COND_CODE='VMC'))

GROUP BY NT1_MATRIX.FLT_PHASE_CODE, NT1_MATRIX.WX_FLT_COND_CODE;
```

Count	FLT_PHASE_CODE	WX_FLT_COND_CODE
1	200	VMC
1	300	VMC
3	400	VMC
12	500	IMC
432	500	VMC
2	600	IMC
48	600	VMC

This is what the PD1 query will look like

Nothing selected from the PD1 database

To see your results file, click here

Figure 2-6 **Integration Tool Version 3.0 - Display of Query Results**

3. Demonstration of Analysis Methods and Training Needs Assessment

In addition to maintaining and enhancing the functionality of the Prototype IT, a major focus of the research was the development and demonstration of analysis techniques that could take advantage of the information provided by the IT to improve the understanding of flight crew human error and help develop strategies to reduce these errors. With this objective, researchers at ERAU examined the application of a risk assessment technique to identify training targets of opportunity to reduce the occurrence of flight crew error.

A second analysis was performed at the University of California at Berkeley in order to demonstrate the application of the IT to a specific category of flight crew human error incidents, using the FAA Pilot Deviation System (PDS) database. This analysis built on a prior study that had been performed by the FAA Office of System Safety to examine the causal factors behind one of the most serious safety issues currently being faced by the FAA, namely the growing frequency of runway incursion incidents (Wojciech, *et al.*, 1997).

In addition to the analysis of accident and incident data, a demonstration of the prototype IT and flight crew training needs assessment was undertaken at four flight training centers and the U.S. Navy Safety Center by researchers at ERAU.

Application of Risk Assessment Techniques

This activity addressed the use of risk assessment techniques as one means of improving the FAA’s capability to assess flight crew error. Using the Prototype Integration Tool and a technique involving expert opinion known as the Analytical Hierarchy Process, a model was developed that may improve the understanding and prevention of flight crew error contributing to aircraft accidents and incidents. The model provides the user with the ability to identify training targets of opportunity to reduce the occurrence of flight crew error and therefore improve aviation safety. The application of the process was demonstrated through an analysis of data from the National Transportation Safety Board (NTSB) accident and incident database.

Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is a mathematical technique developed by Thomas Saaty (Saaty, 1990; Saaty, 1995) to provide a structured way to perform multiple criteria evaluation of alternative decisions. In a typical application there are a number of alternatives to be evaluated using several different criteria. For example, an airport site selection study might have identified a large number of possible sites and several different airport configurations on each site.

The Analytical Hierarchy Process (AHP) is a mathematical technique developed by Thomas Saaty (Saaty, 1990; Saaty, 1995) to provide a structured way to perform multiple criteria evaluation of alternative decisions. In a typical application there are a number of alternatives to be evaluated using several different criteria. For example, an airport site selection study might have identified

a large number of possible sites and several different airport configurations on each site. Evaluation of these alternative options would typically address such issues as construction costs, noise impacts, air pollutant emissions, access travel times, loss of wetlands and wildlife habitat, and so forth. The relative performance of each alternative can be determined for each criterion, but the difficulty comes when the decision-makers have to select a preferred alternative. Except in the rare case where one alternative is superior on all counts, the choice will require trade-offs to be made, such as how much additional noise impacts should be accepted in order to avoid filling an acre of wetland, or how much additional access travel time can be incurred in order to save a million dollars of construction cost.

According to the thinking behind the AHP, what is needed is a way to express the relative importance of each criterion. If a relative weight can be determined for each criterion, then these weights can be used to combine the results of the evaluation of a given alternative against each criterion into an aggregate score for that alternative, and these aggregate scores can be used to select the preferred alternative. The AHP provides a technique to obtain these relative weights from a pairwise comparison of every criterion.

The decision-makers are asked to assess the relative importance of each criterion compared to every other criterion using a scale from 1 to 9. Criteria that are judged of equal importance are assigned the value 1. A criterion that is judged to have extreme importance compared to another is assigned the value 9 and the other criterion is assigned the inverse value. In this way a square matrix can be completed that contains the results of all the pairwise comparisons. The AHP then provides a mathematical technique to reduce this matrix to a set of weights for each criterion, such that the weights are normalized to sum to 1 across all the criteria.

Naturally, different decision-makers will have different relative values for the criteria and thus will produce different weights. How these get combined into a common set of weights, or how the aggregate scores for each alternative using each decision-maker's weights get combined into a common score, is not simply a matter of mathematics, but raises complex issues of relative technical expertise, institutional relations, and control over the process, which are beyond the scope of this discussion.

Application to Flight Crew Incident Analysis

The application of the AHP process to the data in the NTSB accident and incident database used the term importance in a rather different sense. In this application the relative importance of different factors relate to their respective contribution as causal factors. Thus if the phase of flight is considered to be more important than pilot flight time, this is saying that being in a phase of flight associated with a high proportion of accidents or incidents involving a particular type of error is a more important contribution to the risk of making such an error than having pilot flight time that is also associated with a high proportion of such accidents or incidents.

Normally the contribution of factors such as phase of flight or pilot flight time is assessed by comparing the frequency of incidents associated with that factor to the exposure to those conditions or the relative occurrence of that particular factor. Thus if a higher proportion of incidents occur during landing than during taxi, it would be reasonable to assume that landing involves more risk of an accident. Similarly, if a much higher proportion of pilots with less than 1,000 hours flight time are involved in incidents than those with more than 1,000 hours, it would be reasonable to infer that low flight time increases the risk of an accident.

However, the difficulty with this approach is that while detailed information exists about the pilots and flight conditions involved in accidents and incidents, information on the comparable exposure of those not so involved is much harder to come by. Furthermore, there is significant, but unknown, correlation between such factors as the phase of flight and pilot flight time. Student pilots spend a large amount of their flight time practicing take-offs and landings, thus if these phases of flight contribute to a high proportion of accidents, it would not be surprising that low-time pilots would experience more accidents that more experienced pilots who spend less of their flight time in these phases.

Thus the ERAU study used one of the members of their research team with a background in aviation human factors to assess the relative importance of four variables in contributing to the risk that a particular set of circumstances will result in an error of a given type (mistake or slip). The four variables chosen were the domain of flight crew error, the phase of flight, the prevailing meteorological conditions (instrument or visual flight rules), and the pilot flight time. The domain of flight crew error deserves some discussion, since this variable describes factors other than the flight crew that contributed to the accident or incident, such as a failure of aircraft systems or an icy runway, while the other three variables describe attributes of the flight crew or the flight at the time the accident or incident occurred. Unlike the other three variables, the domain of flight crew error is not a mutually exclusive set of conditions, one of which must apply to the accident or incident. Indeed, in the great majority of cases analyzed no domain was indicated in the NTSB data. The ERAU analysis excluded the cases in which no domain was indicated from the proportions calculated for each category. Thus it was implicitly assumed that such cases resulted from a failure of the investigations to identify a domain, but had they done so, the proportions would have been approximately the same as the cases where a domain was identified. If this assumption is not correct, this would result in the contributing factors associated with the various domains playing a larger role in the analysis than they should.

Analysis Results

Based on the pairwise assessments of the ERAU expert, the weights shown in Table 3-1 were determined.

Table 3-1
AHP Importance Weights

Variable	Mistakes	Slips
Domain of Flight Crew Error	0.102	0.091

Pilot Flight Time	0.362	0.455
Phase of Flight	0.454	0.354
Meteorological Conditions	0.082	0.101

These weights were then used in a series of examples to show how they can be combined with the proportions of accidents and incidents found in the NTSB data for a specific outcome of each variable to define a measure of the likelihood that a given combination of conditions would result in an accident or incident involving a specific type of flight crew error. This measure was termed by the ERAU researchers the flight crew error risk, and consisted of the sum of the proportion of accidents or incidents involving an error of the specific type (mistake or slip) for the relevant value of each variable, multiplied by the relative importance weight for that variable:

$$Y(e) = \Sigma (P_i * W_i)$$

where $Y(e)$ is the flight crew error risk for error type *e*
P_i is the proportion of accidents and incidents with error type *e* for the particular value of variable *i*
W_i is the importance weight for variable *i*

Since both P_i and W_i have values between 0 and 1, and the values of W_i sum to 1, the value of Y(e) must lie between 0 and 1. It should be noted that Y(e) is not a measure of risk in the usual sense of the probability of an accident occurring.

Recommendations

Based on the results of this analysis the ERAU researchers concluded that use of the algorithms developed during this phase of the research make it possible to identify the combinations of circumstances that are most likely to result in an accident or incident involving human error. This information can be used to target training experiences that will prepare pilots to respond successfully to potentially risky situations. The ERAU researchers recommended that several further activities are necessary to strengthen the approach developed in the research. Improvements in the consistency and accuracy of data in aviation accident and incident databases are needed, together with further work in classifying types of errors to facilitate the use of human factors information to improve pilot training and re-certification. They also suggested that the analysis approach developed in this part of the research needs to be refined to address dependencies between the variables and to utilize additional data sources to validate the findings obtained in the research.

Analysis of Flight Crew Human Error

In order to demonstrate the application of the prototype Integration Tool to the analysis of flight crew human error, and to identify how enhanced functionality of the IT could improve its usefulness, researchers at the University of California undertook a case-study analysis of the data on runway incursion incidents presently included in the PDS database. The objective of this analysis of the causal factors behind the growing frequency of runway incursion incidents was to demonstrate how the IT can be used to gain a better understanding of the possible causes of flight crew error, and to examine the utility of the IT in performing this analysis.

The current analysis expanded on the prior FAA study in two ways. First, the FAA study had based its findings on a 28 percent random sample of general aviation runway incursion incidents. The current study examined all general aviation runway incursion incidents to determine if the pattern of causal or contributing factors was consistent with the earlier results. Second, the current study examined the trend in the pattern of causal and contributing factors over the period of analysis to determine whether particular factors were accounting for the increase in incidents.

Runway Incursion Trends

The PDS database accessible with the prototype IT contains 328 reports on runway incursion incidents for the period 1992 through early 1996, of which only three were from 1996. The number of runway incursion (RI) reports by type of operator for each year during the period 1992 to 1995 is shown in Table 3-2. After declining from 1992 to 1994, the total number of reports jumped dramatically in 1995. General aviation (GA) operations accounted for about 70 percent of the RI incidents, 14 percent resulted from U.S. air carrier operations while each of the other operator types accounted for 4 percent or less of the RI incidents. Although the relatively low number of incidents for each category of operator other than GA and U.S. air carrier make any apparent trends in these data statistically insignificant, the data appear to show two noteworthy trends for GA and U.S. air carrier operations. The first is the progressive increase in U.S. air carrier incidents between 1992 and 1996 and the second is the sharp increase in GA incidents in 1995, following a progressive decrease during the previous three years.

However, it should be noted that if foreign air carrier incursion incidents are combined with those for U.S. air carriers, the increase from 1992 to 1995 is less and in fact there was no change from 1994 to 1995. Including commuter air carriers as

Table 3-2

Runway Incursion Pilot Deviation Reports

	1992	1993	1994	1995	Total
Type of Operator					
U.S. Air Carrier	8	9	13	16	46
Foreign Air Carrier	3	3	4	1	11
Commuter Air Carrier	5	4	1	3	13
Air Taxi		1	6	3	10
General Aviation	63	58	37	71	229
Other Operator	4		1	6	11
Unknown	1	2		2	5
Total	84	77	62	102	325

well further reduces the increase from 1992 to 1995, but still suggests a progressively increasing trend over the period.

Although the prototype IT does not allow runway incursion incidents to be specifically selected to classify the type of human error involved, by accessing the underlying PDS database, it was possible to classify the runway incursion incidents. The prototype IT uses two human error models. The first (Human Error Model 1) is based on a classification of human error that distinguishes between slips and mistakes, where slips are execution errors in which the action does not go as planned and mistakes are errors where the action goes as planned but fails to achieve the desired outcome. Using Human Error Model 1, it was found that almost all the errors were classified as slips, as shown in Table 3-3. Furthermore, almost all the runway incursion reports were able to be classified by the criteria used in the error model.

Causal and Contributing Factors

The previous FAA analysis identified 38 causal and contributing factors that may have contributed to the runway incursions, based on a survey of airline pilots by the MITRE Center for Advanced Aviation System Development (Adam *et al.*, 1994, Adam & Kelley, 1996). These were grouped by the FAA study into six major

Table 3-3

Classification of Pilot Deviation Runway Incursion Errors

All Airspace Users

	1992	**1993**	**1994**	**1995**	**Total**
Human Error Model 1					
Slips	78	74	62	96	310
Mistakes	-	-	-	-	-
Slips and Mistakes	2	2	-	2	6
Unclassified	4	1	-	3	8
Total	84	77	62	102	325

categories: orientation, communication, memory, attention, FAR/compliance with ATC, and other. The three most common causal or contributing factors were found to be:

- inadequate or inappropriate pilot-controller communications
- lack of airport familiarity
- inadequate or ineffective use of cockpit procedures for maintaining orientation.

Each of these factors could be identified from the data fields in the PDS records, based on the criteria established in the previous study. The relevant data were extracted from the prototype Integration Tool PDS database using Microsoft Query running within Excel to interface with the Oracle Workgroup Server software used to access the data tables comprising this database. The required data fields from these tables were imported and merged into a Microsoft Excel spreadsheet for subsequent analysis.

The number of records in the 328 runway incursion reports extracted from the PDS database (including the three reports for incidents in early 1996) that were found to involve these three factors are shown in Table 3-4. One or more of these factors were present in about 40 percent of the GA incursion reports and in about 28 percent of the U.S. air carrier incursion reports. Perhaps not surprisingly, pilot-controller communication problems were identified as a factor in almost half of the runway incursion reports involving foreign air carriers. Pilot-controller communication problems were also the most frequent of the three factors identified for GA incursion incidents.

The change in the number of GA incursion incidents involving the three factors from 1992 to 1995 is shown in Table 3-5. The proportion of reports identifying at least one of these factors increased from 30 percent in 1992 to about 51 percent in 1994, before decreasing to about 42 percent in 1995. Whether this decrease is due to an increase in the proportion of other factors, or simply an increase in the proportion of incidents for which causal and contributing factors could not be assigned, cannot be determined without further analysis. However, the data do

Table 3-4

Occurrence of Major Causal or Contributing Factors

	Pilot Communication	**Airport Familiarity**	**Cockpit Procedures**	**One or More Factors**
Type of Operator				
U.S. Air Carrier	5	5	7	13
Foreign Air Carrier	5	3		8
Commuter Air Carrier	3	1	1	4
Air Taxi		3		3
General Aviation	60	36	15	93
Other Operator	4			4
Unknown	2			2
Total	79	48	23	127

Table 3-5

Change in Major Causal or Contributing Factors

General Aviation Runway Incursion Reports

	1992	1993	1994	1995	Total
Total GA Runway Incursions	63	58	37	71	229
Causal or Contributing Factor					
Pilot Communication	11	17	10	20	58
Airport Familiarity	10	7	8	11	36
Cockpit Procedures	4	5	3	3	15
One or More Factors	19	23	19	30	91
Percent of Total GA Reports	*30*	*40*	*51*	*42*	*40*

appear to suggest that inadequate or inappropriate pilot communications was a significant contributing factor to the increase in GA runway incursions from 1994 to 1995.

Conclusions

The results of this analysis largely confirm the findings of the earlier FAA study, particularly the importance of effective pilot communication and airport familiarity in reducing runway incursions. Since airport familiarity depends on the prior use of the airport by the flight crew, which generally is not something that can be changed, it is important that appropriate procedures are developed and followed to compensate for this when flight crew are using unfamiliar airports. Similarly, effective pilot communication comes from both training and habit. While it may be easy to identify a failure of effective communication as a contributing factor to a runway incursion, it is much harder to determine why that failure occurred and thus what can be done to reduce the likelihood of such errors in the future. This is limited by the information currently available in the PDS database. Therefore efforts to reduce pilot surface deviations need to address the information available to be analyzed as much as the results of the analysis that can be performed.

In addition to confirming the earlier findings, the analysis of the runway incursion reports in the PDS database demonstrated how enhanced functionality of the Integration Tool could improve the ability to analyze the aviation safety data accessible with the tool. The ability to select specific types of incidents for analysis on the basis of any database fields and to analyze the information contained in the report narratives would have been of particular value. In the event, the analysis resorted to direct access to the underlying database and then combined this information with the human error classification obtained from the prototype IT.

Training Needs Assessment

The ERAU team conducted a multi-site demonstration of the Integration Tool at the following locations: USAirways, Flight Training Center, Charlotte, NC; TWA Flight Training Center in St. Louis, MO; Embry Riddle Aeronautical

University, Daytona Beach, FL; US Navy Safety Center, Norfolk, VA; and Boeing Flight Training Center, Seattle, WA. In addition, a training needs assessment was conducted at ERAU for the primary flight training course FA-110. A training needs assessment process was developed, based on an examination of three aspects of the training process:

- Procedural compliance,
- Systems knowledge,
- Decision making related to weather.

Data was collected on the percent of the training time devoted to each of these three factors and the number of times that the factors were addressed in the curriculum. In addition, a questionnaire was developed that was administered at each site to collect data on the opinions of the training staff regarding such aspects as the information used to measure the effectiveness of the training program, the flexibility allowed to flight crew to apply individual practices, and the adequacy of the training program to develop in-flight decision skills. These data were analyzed and used to develop a number of findings addressing the use of statistical data to improve the training process:

- There is a need for additional models that are suitable for the analysis of human error causal factors and context as they relate to aviation training systems;

- Most current training systems do not track trainee performance at a level that would allow a correlation to be developed between the structure and content of the training system and the infrequent occurrence of accidents and incidents;

- There is a need to separate the regulatory activities of the FAA from its role in promoting operational practices that improve aviation safety by supporting research efforts and developing techniques to enhance the sharing of information;

- There is a need to collect operational data on flight crew performance through such programs as Flight Operations Quality Assurance (FOQA) that can be correlated with data collected in the course of training programs to measure the effectiveness of the training programs;
- Existing FOQA programs tend to focus on the physical operation of the aircraft, since that is what is recorded by the flight data recorders, rather than aspects of flight crew behavior;
- There is a need for standard procedures on the conduct of training effectiveness analysis.

Recommendations

Based on the training needs assessment, the ERAU researchers made a number of recommendations to strengthen the application of analytical techniques to improve the effectiveness of training programs in reducing the occurrence of flight crew error:

- Training needs assessments should be conducted using a common process across organizations conducting similar training activities (initial, transition, recurrent);
- The FAA needs to identify whether existing training programs are adequately addressing the evolving use of cockpit automation and changing procedures within the National Airspace System;
- Further efforts are needed to improve the classification of types of flight crew error in accidents and incidents to better identify how the information can be used to improve flight crew training and recertification.

4 Improving the Representation of Human Error in the Use of the IT

The current version of the IT applies two different classifications of human error to records in accident or incident databases to construct matrices that crosstabulate the number of errors of each type against a classification of the accidents or incidents on the basis of the flight conditions or year during which they occurred. It provides the capability to select subsets of the data and to display detailed information for each record for a selected cell of the matrix. While this performs a useful function by identifying specific records in a large database that meet certain criteria, and then allowing the user to display the contents of the database records for further review, its usefulness in analyzing the underlying causes of flight crew error and hence identifying strategies to reduce the frequency of occurrence of those errors is presently limited by several constraints.

These constraints may be addressed in one of two ways: by improved functionality of the IT itself, and by a richer representation of human errors and how they occur. These two aspects go hand in hand, since the ability to support a richer representation of human error depends on improved functionality of the IT, while enhanced functionality of the IT will be of greater use if it can support a better representation of how errors are committed. As part of the current project, enhancements to the prototype version of the IT have been made, that provide additional capabilities to download the information presented by the prototype version of the IT, in order to perform more extensive statistical analysis. It is of course not necessary for an improved understanding of the causal factors behind human errors to be encoded in the logic of the IT, as long as the analyst has the capability to specify how the IT will select records for further analysis. Indeed, the more flexibility that the IT gives the analyst to specify the search criteria, the more useful the tool is likely to be. However, this requires the analyst not only to have a clear idea of what to look for, but also to know how to express this to the IT. Therefore the more that can be done to incorporate an improved representation of human error in the logic of the IT, the more useful it is likely to be to the analyst.

The approach to these issues in this phase of the research consisted of an examination of the recent literature on human error to identify how to better characterize the context of such errors, including how to address individual, team, and organizational behavior, as well as the development of an instrument for collecting empirical data on these behavioral constructs and incorporating them in aviation safety databases.

Understanding the Context of Human Error

In order to provide a richer characterization of human error that can help identify the causal factors behind these errors, it has been increasingly recognized that errors need to be understood in the context within which they occur. Flight crew decisions are recognized as the result of information processing activities. Thus efforts to understand how errors get made, and what can be done to reduce this, need to address the way in which information is processed by the flight crew and how this is influenced both by their training and experience, as well as the sequence of events that precede each decision. According to a four-stage model of information processing described by Wickens and Flach (1988), input from external stimuli are retained in a short-term sensory store, and examined using a process of pattern recognition that organizes the information into a meaningful structure. This structure informs a decision process and selection of an appropriate response, which is then executed. These four stages are further divided in a sequential algorithm for classifying information processing failures proposed by O'Hare *et al.* (1994) that defines the following six types of pilot error:

- information error
- diagnostic error
- goal error
- strategy error
- procedure error
- action error.

Comparing this algorithm to the four-stage model described by Wickens and Flach suggests that the first two types of pilot error correspond to the pattern recognition stage, while the next three correspond to the decision process. Finally the last type of error corresponds to the response execution stage. It should be noted that while the last type of error may be viewed as a slip or lapse in Reason's classification of unsafe acts (Reason, 1990), and the previous three types of error can be viewed as mistakes, the first two are not really acts at all, but rather the results of the environment within which the cockpit crew were operating, the completeness of the information available to them, and their training at interpreting that information.

In order to account for the effect of supervisory practices and operating conditions, Shappell and Wiegmann (1997) have defined a *Taxonomy of Unsafe Operations*, illustrated in Figure 4-1. In their paper, the authors point out that failures at any of the three levels shown in the figure can lead to accidents or mishaps, and expand on each of the elements shown in the figure.

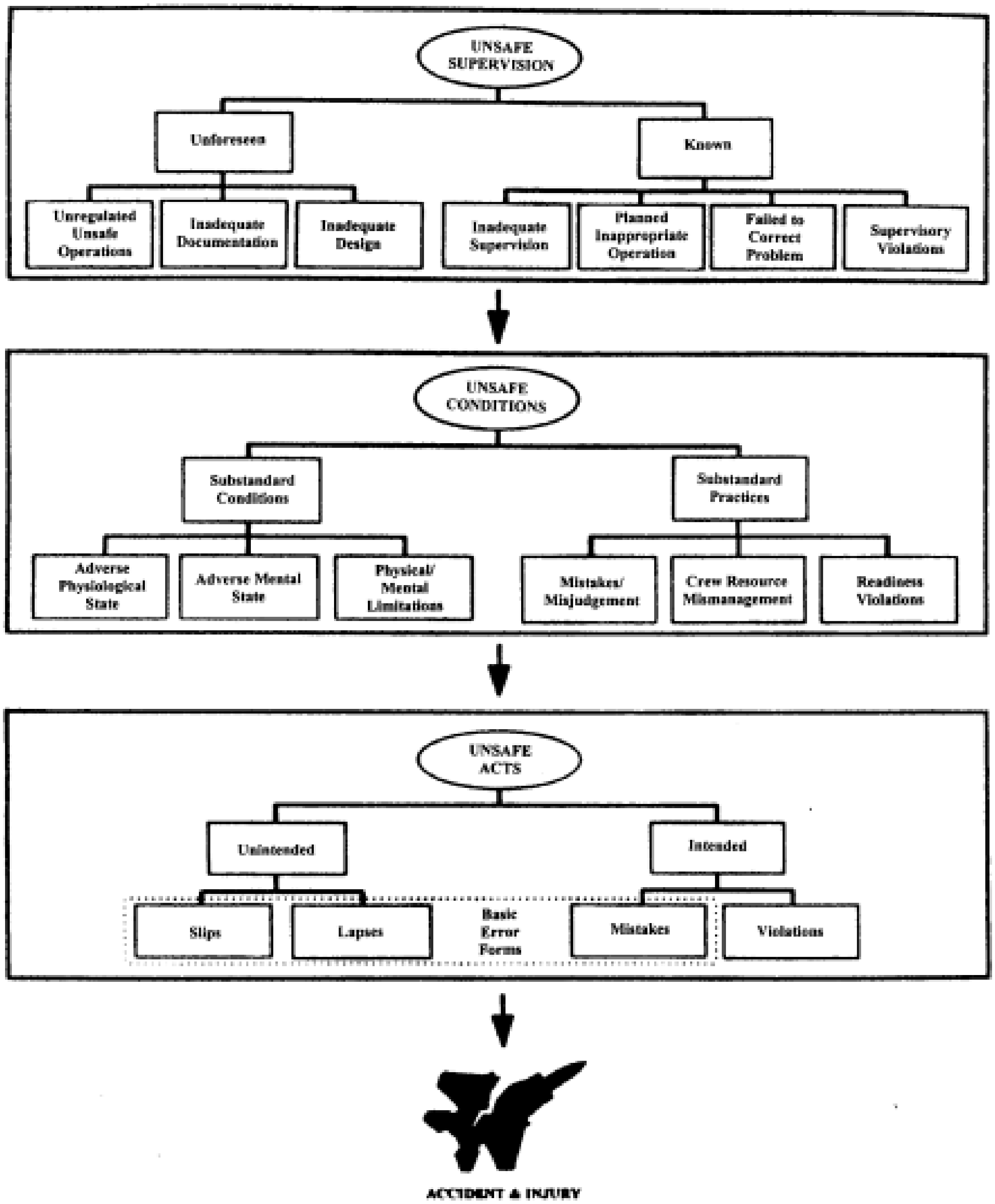
Individual, Team and Organizational Factors

As suggested by the work of Shappell and Wiegmann, a fuller understanding of flight crew human error requires that the actions of the flight crew be understood in the context of the culture of the organization of which they are part, as well as their training, experience, and supervision. These issues are important not only to obtain a better explanation of why errors are made, but also because they address the means by which these errors can be reduced.

Interactions between members of the flight crew, between the flight crew and the aircraft systems, and between the flight crew and the external environment are all recognized as important determinants of flightdeck performance. Timely response to change and surprise by individuals as well as organizations is required in any system that seeks to mitigate risk. As numerous National Transportation Safety Board investigations show, a large percentage of aircraft accidents happen when flight crews lose situational awareness.

Previous research into ways that large-scale organizations attempt to mitigating risk has found that four processes present major challenges. They are variations in organizational structures, challenges to developing strong cultures and barriers to communication and trust. However, to date very little research has been undertaken on how these issues relate to flight crew errors, and how they can be appropriately represented in aviation accident and incident databases in order to be considered within the overall framework of causal factors behind these errors.

Understanding these issues is critical to the success of future efforts to improve aviation safety. As safety levels in the industry improve, achieving further improvements will require an increasingly sophisticated understanding of the causes of human error, and the analytical tools to support this. It is unrealistic to expect that this can be accomplished without a solid foundation of basic research upon which to build. It is equally unrealistic to expect that this research can be "fast-tracked" to make up for lost time, if these issues are ignored until circumstances force them to be recognized. Thus a balanced development strategy for the IT would include an appropriate



SOURCE: Shappell & Wiegmann, 1997.

Figure 4-1 **The Taxonomy of Unsafe Operations** allocation of resources between fundamental research to improve the understanding of the causal factors involved in human error and the continued development of analytical techniques to take advantage of the results of that research.

Development of Data on Organizational and Regulatory Factors

The effectiveness of the use of the Integration Tool to analyze flight crew human error ultimately depends on access to data that captures the full range of factors that shape flight crew decisions and actions, and hence the likelihood of error. There is a growing recognition of the need to integrate cognitive analysis of the actions of those involved in accidents and incidents with the organizational and regulatory context within which their decisions are made. However, much of the information on this broader context is not available in current accident and incident databases, nor is likely to become so in the foreseeable future.

In order to understand the role of individual, team and organizational factors in flight crew errors, and how to develop programs to reduce the risk of such errors, it is necessary to develop appropriate databases of relevant information that can be applied to the analysis of safety-related events, that can span the spectrum from accident investigations to monitoring an individual's progress in training programs. Without such data, efforts to understand how these factors have influenced the outcome of the event become speculative and subjective. What is needed is a framework for collecting and managing such data, together with an instrument that can be used to measure the safety posture of an organization and identify issues that may need further investigation.

Following the approach developed by Libuser (1994), the issues that contribute toward the safety posture of an organization engaged in flight operations can be grouped in five categories:

- Process Auditing
- Reward System
- Quality of Operations

- Risk Perception
- Management Procedures.

In order to provide a means to collect quantitative data on these issues, the survey instrument shown in Appendix B has been designed to obtain the perceptions of employees at all levels on the importance of a range of risk management factors in the operations of the organization. Although the survey questions have been designed with the functions of airline flight crews in mind, they can be fairly easily adapted to other operational functions that impact flight safety.

The sensitivity of this type of information should not be overlooked. People are not going to make honest assessments if they think that they may be punished for it. Similarly, organizations will not willingly make such information on their operations available to others if this information may be used against them in the future. Yet only by collecting data on their own performance and comparing their performance to that of others can organizations hope to learn where to focus their efforts to improve their performance.

The use of a risk management questionnaire, tailored to the issues of importance in the organization being studied, has been found in other organizational contexts to be an effective way to assemble quantitative data that address these issues. While this technique has not yet been adopted in civil aviation, the U.S. Navy has recently commenced a program to apply this approach to Navy aviation and Marine Corps units (Ciavarelli & Figlock, 1997). As part of the research under the current project, discussions have commenced with several airlines and other industry organizations to explore the application of a similar approach within civil aviation.

The challenge in a competitive airline industry is to figure out how to share this information in a way that contributes to improving safety without creating undue risk of unintended economic or legal consequences. One way may lie in sharing deidentified data through the Global Analysis and Information Network, combined with making appropriate analysis tools available within the organizations to take advantage of the deidentified data.

Role of the Integration Tool

In principle, the design of the Integration Tool could permit analysts to combine information on organizational and regulatory factors with the data typically available from accident or incident investigations, provided the former information is structured in a form that can be related to specific events. This will require both enhanced capabilities within the Integration Tool to merge data from different datasets, including data at the level of organizations rather than incidents, as well as a significant effort to develop appropriate techniques to document the organizational and regulatory environment within which an accident or incident occurred.

In addition to the need for improved representation of the context of human error, and the inclusion of appropriate data in safety databases, the utility of the prototype Integration Tool will be greatly enhanced by additional functionality that provides the users with the capabilities to define their own categories of error, merge data from multiple databases, and make greater use of the information in those databases to select the records for analysis. While ultimately it is the insight and experience of aviation safety experts that will identify effective strategies to reduce the occurrence of flight crew error, the availability of effective tools to search and organize the information will enhance their ability to focus on the critical issues, and recognize the relevant patterns amid the vast amount of data that can potentially be generated by recent advances in information technology.

The challenge of reducing the fatal accident rate in U.S. aviation by 80 percent by 2007, established as a goal in the current FAA Strategic Plan (FAA, 1998), will require a sustained commitment to developing effective tools to integrate, manage and analyze the growing volume of aviation safety data. The success of the Global Analysis and Information Network will depend not only on the ability to address the concerns over sharing proprietary or sensitive data, but also the availability of tools to manage and analyze those data.

Recommendations

The current version of the Integration Tool provides a useful platform from which to address these issues. However, further enhancements to the structure and logic of the IT are needed, so that it can provide users with greater functionality and access to a broader array of aviation safety data. Central to this are the capability to allow users to define their own human error models, using a rule-based format that can access any desired field in the underlying databases, and the ability to access other databases over the Internet using secure methods for the transmission of sensitive data. It is recommended that these enhancements be pursued as soon as sufficient resources can be made available.

In addition, the FAA should maintain an active research program directed at improving the understanding of the causal factors underlying flight crew error and developing effective intervention strategies. In order to obtain experience in adapting the risk management techniques discussed in this chapter to civil aviation and to establish their value and effectiveness, the FAA should consider sponsoring a demonstration program in cooperation with one or more airlines to begin collecting data on a trial basis. This would require appropriate protection for those involved, and could serve as a useful proof-of-concept study for the GAIN concept. While the availability of data from such programs would enhance further research into strategies to reduce flight crew human error, it is equally important to continue current research efforts based on the use of existing data sources.

5. Proposed Functional Enhancements to the IT

The fourth component of the research was directed at identifying potential functional enhancements to the prototype Integration Tool that address the safety data access and analysis needs of potential users and would be supported by them. The approach adopted during the study consisted of three components: a review of potential enhancements to the prototype IT identified in prior work and other tasks of the current project; a survey of potential users of the IT to identify their data access needs and views on the potential usefulness of different features; and discussions with FAA offices that would be involved in the use of the IT or the provision of data accessed by it.

Proposed Functional Enhancements

The prior phase of the study included a review of the findings of two prior workshops that had been conducted by the FAA Office of System Safety to discuss the analysis of flight crew human factors, present the development of the prototype Integration Tool, and obtain feedback from potential users. As part of the current phase of the study, these enhancements were organized into five categories:

- data access
- data interpretation and use
- analysis functions
- integration with human error models
- application support.

The specific enhancements in each category not already supported by the prototype IT are shown in Table 5-1.

User Needs Survey

In order to identify the views of current and potential users of the Integration Tool as to the usefulness of the various proposed functional enhancements, as well as the provision of access to additional databases, a survey of safety data access and analysis needs was undertaken. In addition to data access needs and the functionality of data access and analysis tools, the survey

Table 5-1

Potential Functional Enhancements to the Integration Tool

Data access	Access to data maintained on internal corporate databases Access to risk exposure data
Data interpretation and use	On-line glossary of abbreviations On-line definitions for database codes
Analysis functions	Capability to download record count and search criteria for off-line analysis Capability to download database records matching search criteria Capability to specify search in terms of **events** or **reports** Capability to specify search in terms of **accidents** or **incidents** Capability to tabulate count of search results using user-defined categories of events Capability to tabulate count of search results as relative frequency (percent of all such events) Capability to tabulate search results in terms of exposure (events per unit of activity) Capability to search text in narrative fields and flag records for subsequent analysis Capability to analyze the sequence of events
Integration with human error models	Provision of expanded explanation of the theory behind human error models used by the system Capability for users to specify their own human error model
Application support	Access to on-line documents describing the theory behind the use of human error models in flight crew safety data analysis Detailed examples of how the IT can be used to better understand causes of human error

was also designed to investigate how familiar the aviation safety analysis community is with the prototype IT, and their willingness to financially support the future development of the IT.

The survey was distributed to about 150 aviation safety professionals, comprising members of the GAIN Working Group 1, participants in the first and second FAA Workshop on Flight Crew Accident and Incident Human Factors, held in June 1995 and June 1996 respectively, and selected participants at the FAA Safety Roundtable on Runway Incursion Prevention held in October 1997. These recipients were supplemented by other selected FAA and industry experts identified by the project sponsor or the research team.

Some 29 responses were received, representing about 19 percent of the survey recipients. The respondents form a fairly broad sample of the various sectors of the industry, as shown in Table 5-2.

Table 5-2

Distribution of Survey Responses

Industry Sector	Responses	Percent
Federal Aviation Administration	7	*24*
Other Government	6	*21*
Industry Associations	2	*7*
Airlines	3	*10*
Manufacturers	3	*10*
Research Centers / Contractors	6	*21*
Universities	2	*7*

Survey Results

The survey results provide a useful insight into the data access and analysis needs of the aviation safety community, as well as the extent to which the respondents were already familiar with the Integration Tool. Most respondents had some level of awareness of the prototype IT, although only about 24 percent had actually used it. A further 17 percent had seen it demonstrated. At the other end of the scale, 34 percent were aware of it but had no knowledge of its capabilities, while 21 percent had never heard of it. All but one respondent had access to the World Wide Web from the computer on which they perform safety analysis.

Respondents were divided fairly evenly between those for whom aviation safety analysis occupies most of their time and those for whom it is an occasional or intermittent activity. Some 76 percent of all respondents needed access to the National Transportation Safety Board Accident and Incident Database and the same proportion needed access to the NASA Aviation Safety Reporting System data (although not necessarily the same respondents). About 41 percent needed access to the FAA Pilot Deviation System database. Some 62 percent identified other databases that they needed to access. The most widely reported of these databases was the National Aviation Safety Data Analysis Center (NASDAC).

Half of all respondents identified specific safety data access and analysis tools that they used or to which they had access, including NASDAC (which can also be regarded as a data access system). The British Airways Safety Information System (BASIS) was used by 17 percent of respondents, while another 14 percent had access to it. The Airbus Aircrew Incident Reporting System was used by 10 percent of respondents. The various other systems mentioned were each used by only one respondent.

Respondents were asked to assess the usefulness of a range of possible features for a data access and analysis support environment, using a five level scale from “highly desirable” to “no use foreseen.” These features included the proposed enhancements shown in Table 5-1, as well as some already implemented in the Integration Tool, in order to determine the respondents perception of the value of the basic concept behind the IT. A clear majority of respondents found all the proposed features highly desirable or potentially useful. There was less perceived need for access to internal corporate databases, than to public data and risk exposure data. Well over half the respondents found the concept of integrating safety data with human error models highly desirable or potentially useful. However, respondents appeared to feel that these capabilities were somewhat less useful than enhanced functionality to work directly with the data. Similarly, although a majority found the proposed on-line application support features desirable or potentially useful, these were perceived as less important than the analytical capabilities.

The survey asked respondents whether they felt that their organization would be likely to provide financial support for continued development of data access and analysis tools that provide the features addressed in the survey. While a significant number of respondents felt that it was most unlikely that their organization would contribute financially to the development of safety data access and analysis tools, a reasonable number felt that it was possible or even quite likely. As could be expected, respondents felt that the likelihood declined at higher contribution levels. They also seemed to feel that their organizations would prefer paying an annual license fee to a higher one-time license fee. There also seemed to be a preference for a lower license fee per registered user than a higher fee per organization to subscribe to a user consortium.

Using these findings, the expected revenue for each option was calculated, as shown in Table 5-3. Obviously, the total revenue depends on the number of organizations participating. Since the survey was not sent to all possible users of the tool, it was assumed that there are 100 potential user organizations, with an average of two users in each in the case where users must be individually registered. It should be noted that this is not the number of organizations contributing, since only a proportion of the *potential* users will actually participate, as indicated by the survey responses. While this estimate of the potential market may be conservative, the survey was directed at those organizations most likely to be interested, and any assessment of the potential interest of other organizations becomes rather conjectural.

It can been seen that the greatest revenue is generated by the highest fees

Table 5-3

Potential Level of Industry Support

Option	Potential Users	Expected Users	Total Revenue
Subscribe to a user group consortium			$
$5,000 per year	100	33	165,000
$10,000 per year	100	20	200,000
$25,000 per year	100	10	250,000
Pay an annual license fee			
$1,000 per registered user	200	75	75,000
$5,000 per registered user	200	33	165,000
$10,000 per registered user	200	18	180,000
Pay a one-time license fee			
$10,000	100	23	230,000
$25,000	100	12	300,000
$50,000	100	8	400,000

scale. The smaller number of organizations participating is more than offset by the higher fee. However, the increase in total revenue from the middle fee scale to the highest fee scale is very sensitive to the assumptions about the probability of organizations contributing where the respondents felt that it was not very likely or most unlikely. It can also been seen that the highest revenue on an annual basis would be generated by fees that were paid on the basis of the organization rather than individual users, although this conclusion is very sensitive to the assumption about the average number of users in each organization. One strategy would be offer two scales: a lower one for individual registered users and a higher one for an organizational subscription. Smaller organizations would typically choose the former, while larger organizations would find it more economical to choose the latter.

Although the one-time license fee would generate the most revenue initially, it is clear that annual license fees would quickly generate more revenue over subsequent years. This would also provide a consistent source of revenue to pay for technical support, system maintenance, and continuing upgrades.

Recommendations

It is clear from the results of the survey of user needs that there is widespread support for all of the enhancements identified in the survey, as well as for the availability of data access and analysis tools with the type of capabilities provided by the Integration Tool. Some of the enhancements were perceived as more useful than others, which provides a basis for prioritizing their implementation. In addition, there appeared to be an encouraging degree of support among the potential users for having their organization contribute financially to the development and support of the Integration Tool. However, it should be noted that to date the prototype Integration Tool has only been available to a limited number of users, and that therefore most of the respondents were assessing their potential use of the IT without any direct experience.

This suggests that the FAA should pursue a threefold course of action:

1. Implement an initial set of enhancements identified by the user needs survey;
2. Promote the use of the Integration Tool by maintaining an operational Web site, establishing an active user group, and conducting training courses;
3. Develop a cost-sharing mechanism to allow non-FAA users to support the on-going use and development of the Integration Tool.

Some of the capabilities addressed by the survey have already being implemented as part of the current phase of the research, as discussed in chapter 2. The research into improving the representation of human error undertaken as part of the current phase of the research has identified a need for three other capabilities discussed in the survey:

- the capability to allow users to define their own human error models, using a rule-based format that can access any desired field in the underlying databases;
- the ability to access other databases over the Internet using secure methods for the transmission of sensitive data;
- the ability to search text in narrative fields and flag records for subsequent analysis.

Depending on the availability of appropriate databases, the combination of the first two of these capabilities could also allow users to implement some of the other capabilities discussed in the survey, such as expressing search results as relative frequency or performing the analysis in terms of exposure. However, these capabilities are sufficiently fundamental to the way that the IT is used that it is probably worth building them into the tool directly.

Since the combination of the three capabilities described above would provide such a major enhancement to the value of the IT, it is recommended that they form the basis of the next significant upgrade of the enhanced prototype IT, which would become the production version of the IT. This version could also include a number of the other analysis functions identified in the survey, where these could be implemented relatively easily through minor modifications of the database access routines.

Based on the assessment of the survey respondents, there appears to be a very promising opportunity for the FAA to enter into a partnership with the potential users in the industry, in which those organizations would share in the cost of further development of the IT. However, for this to occur the capabilities of the current version of the IT need to be enhanced, so that the tool provides many of the features that respondents identified as desirable.

6. Conclusions and Recommendations

The current version of the Integration Tool provides a useful initial capability to analyze aviation accident and incident databases, by identifying specific records in a large database that meet certain criteria, and then allowing the user to display the contents of the database records for further review. The concept of using human error models to assist in selecting records for events that conform to a particular type of error allows the user to focus on a subset of the data of particular interest, and may facilitate the identification of strategies to reduce the occurrence of particular types of error.

However, the human error models currently implemented in the IT provide limited guidance as to what might be done to address these errors. Furthermore, the human error models as currently implemented are only able to classify a small proportion of the records in the two databases accessible with the tool, due partly to the limited amount of human factors information in these databases and partly to the limitations of the models themselves. What is needed is a richer characterization of human error, that identifies not only the type of error, but the context within which the error was made and the contribution of organizational and environmental factors to the error. The research described in this report has reviewed the recent literature on human error and strategies to reduce the risk of such errors. It is increasingly recognized that both the sequence of precursor events, as well as the institutional environment within which the flight crew operate, are important factors in shaping whether an error is made, and in determining whether errors are rapidly detected and corrected, or whether they are allowed to escalate into an accident.

For these ideas to be applied in the context of an analysis tool such as the IT, it is necessary to be able to access a broader range of information than is currently available in the databases accessible by the IT. Some of the required information exists within the databases, such as in the narrative fields, but is not currently accessible to the user of the IT except by reading the content of each record. Other information exists in other databases, which the IT currently has no way to access. Finally, some of the required information is not currently collected at all. In particular, data on the safety culture of the organization, and the perceptions of those in the organization of the importance placed on eliminating the possibility of error, is increasingly being recognized as a useful complement to traditional incident investigation in a broad range of safety-critical organizations. The use of a risk management questionnaire, tailored to the issues of importance in the organization being studied, has been found in other organizational contexts to be an effective way to assemble quantitative data that address these issues. These techniques are beginning to be applied in military aviation. The FAA should consider sponsoring a demonstration program in cooperation with one or more airlines to obtain experience in adapting the techniques to civil aviation and to establish their value and effectiveness. While the availability of data from such programs would enhance further research into improving the understanding of the causal factors underlying flight crew error and developing effective intervention strategies, it is equally important to continue current research efforts to utilize existing data sources.

Based on information obtained from a training needs assessment performed at five flight training centers as part of the research, it was concluded that there is a need to develop standardized procedures to collect operational data on flight crew performance that can be correlated with data collected in the course of training programs to measure the effectiveness of the training. It was recommended that training needs assessements should be conducted using a common process across similar types of training activity and that further efforts are needed to improve the classification of types of flight crew error to better identify how to improve flight crew training and recertification. It was also suggested that attention needs to be given to the evolving use of cockpit automation and changing procedures within the National Airspace System.

In addition to the improved representation of the context of human error, and the inclusion of appropriate data in safety databases, the utility of the Integration Tool will be greatly enhanced by additional functionality that provides the users with the capabilities to define their own categories of error, merge data from multiple databases, and make greater use of the information in those databases to select the records for analysis. While ultimately it is the insight and experience of aviation safety experts that will identify effective strategies to reduce the occurrence of flight crew error, the availability of effective tools to search and organize the information will enhance their ability to focus on the critical issues, and recognize the relevant patterns amid the vast amount of data that can potentially be generated by recent advances in information technology.

The challenge of reducing the fatal accident rate in U.S. aviation by 80 percent by 2007, established as a goal in the latest FAA Strategic Plan, will require a sustained commitment to developing effective tools to integrate, manage and analyze the growing volume of aviation safety data. The success of the Global Analysis and Information Network will depend not only on the ability to address the concerns over sharing proprietary or sensitive data, but also the availability of tools to manage and analyze those data.

The current version of the Integration Tool provides a useful platform from which to address these issues. However, for this to occur, further enhancements to the structure and logic of the IT are needed, so that it can provide users with greater functionality and access to a broader array of aviation safety data. Central to this are two capabilities:

- the provision of the ability for users to define their own human error models, using a rule-based format that can access any desired field in the underlying databases;

- the ability to access other databases over the Internet using secure methods for the transmission of sensitive data.

It is recommended that these enhancements be pursued as soon as sufficient resources can be made available.

As part of the current study, a survey was performed of the data access and analysis needs of potential users of the IT, and the prospects for cost-sharing support for developing functional enhancements for the IT (Gosling, 1998). This survey found that an enhanced version of the Integration Tool, incorporating the features discussed above, might be able to attract significant financial support from the user community.

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Appendix A

Introduction to the Prototype Integration Tool

FEDERAL AVIATION ADMINISTRATION

Office of System Safety

Prototype Integration Tool

The prototype Integration Tool (IT) permits safety analysts, accident investigators, human factors professionals, and others to remotely apply two human error models to the NTSB accident/incident and FAA National Airspace Incident Monitoring System (NAIMS)/Pilot Deviation System (PDS) incident databases in a consistent and timely manner. For the NTSB database, the prototype IT produces a cross-tabulation matrix of Type of Flight Crew Error (e.g. slips and mistakes) and the Domain of Flight Crew Error (e.g. aircraft system and weather conditions) during which the error occurred. For the PDS database, the prototype IT produces a matrix of Type of Flight Crew Error and year of the PDS event. For each database-model pair selected the IT will generate a Master Matrix. The user can then create sub-matrices from the master matrix by selecting any combination of year, weather condition, airspace user, aircraft manufacturer (make), phase of flight, and pilot's total hours flown

Each NTSB and PDS cross-tabulation matrix is considered to represent a pattern of human factors across accidents and incidents for a specific population. By comparing population matrices for the same database-model pair, differences or similarities in accident and incident human factors patterns can be observed. By comparing matrices for the same population over time, trends can be detected.

The number in the cells of a matrix represents the frequency of error events. By clicking on an error type-domain matrix cell, the associated report numbers will be displayed. NTSB report numbers include the date of occurrence and airport location. The PDS report numbers indicate the FAA region and facility location along with the date of the incident. By clicking on any one of the report numbers, the analyst can call up the actual report to verify the presence of the type of human error, and to understand more about the context and causality of the accident or incident.

Human Error Models

Two human error models were chosen from the available literature and adopted by the project team for the prototype Integration Tool. The object of these models is to identify and classify human error events in the databases. A series of If-Then decision rules corresponding to the HEM selected look at *all* database records contained in the selected database. The rules are based on coded fields, i.e. fixed data formats, in each database. An accident or incident record may have more than one human error event.

Human Error Model One (HEM1) classifies accident and incident events as either *slips* or *mistakes* resulting from the intent to act. If the data does not identify intent, and there is human error present, the event is designated as *unclassified*. Slips occur when the actions do not go as planned and are therefore considered execution errors. Mistakes result when the actions go as planned, but fail to achieve the desired outcome. Thus, mistakes are categorized as planning errors.

Human Error Model Two (HEM2) classifies accident and incident records as either *knowledge- based*, *rule-based*, or *skill-based* errors. If the data does not identify these errors, and there is human error present, the event is designated as *unclassified*. If the data does not show human involvement, the event is classified as *unknown* and do not appear on the matrices. Skill-based slips represent failures with automatic, routine, and familiar behaviors often resulting from the lack of attention or distraction. Rule-based mistakes occur upon the selection of an inappropriate rule set that dictates or governs behavior. Knowledge-based mistakes result from behavior that requires real-time planning in an unfamiliar situation, often occurring when there is incomplete or incorrect knowledge.

Domain of Flight Crew Error

Seven domains of flight crew error have been identified for the NTSB database. These domains are the subjects for the primary non-people related findings associated with the human error event. They include:

- Aircraft System/Components
    - Structure (flight controls, rotors, fuselage)
    - Systems (electrical, hydraulic, oxygen)
    - Powerplant (engine, fuel system, propeller)
    - Miscellaneous (Fluids, Misc. Equipment, Lights, Aircraft Performance, Aerial Application Equipment, Tow/Advanced Equipment, Balloon Equipment)
- Terrain/Runway Conditions (icy, tundra, wet)
- Weather Conditions (fog, tailwind, rain)
- Light Conditions (dawn, dusk, sunglare)
- Airport
    - Facilities

    - Fire/Rescue
- Air Traffic Facilities
    - Navigational Aids
    - Radar
    - Approach Aids
    - Procedures
    - Weather
- Objects (aircraft parked, hangar, animal)

The human error events were not assigned a domain if they do not have one of the primary non-people related findings associated with them.

A PDS report addresses a single human error event (pilot deviation) but may have multiple error types and domain values. Therefore, for the PDS database the year in which the incident occurred was assigned as the domain of flight crew error.

Databases

The National Transportation Safety Board (NTSB) database reflects all the final accidents and incidents in the NTSB files which are releasable to the public. Since the NTSB database contains over 700 data elements, many of which are clerical in nature, the number of useful data elements was reduced to a subset of approximately 200 elements including the narratives in order to minimize the required time to complete a data query. Privacy Act considerations have been made to remove the identity of individuals, both involved with and investigating the event. The IT presently contains 35,190 records from the NTSB database from 1983 through March 1996.

The FAA National Airspace Incident Monitoring System (NAIMS) Pilot Deviation System (PDS) database reflects pilot deviation incidents which are releasable to the public. These include altitude excursions, unauthorized entry into controlled airspace, and failure to follow command. Privacy Act considerations have been made to remove the identity of the individuals, both involved in and investigating the incident. Prior to 1992, the fields for human factors were not available. The IT presently contains 5,840 records from the NAIMS-PDS database from January 1992 through March 1996.

Databases are provided through the FAA, Safety Data Services Division, ASY-100, National Aviation Safety Data Analysis Center (NASDAC). The data is updated periodically, and the results are annotated with the date when the data was received from NASDAC.

Appendix B

Flight Operations Risk Management Questionnaire

NOTE: The Flight Operations Risk Management Questionnaire included in this appendix is intended to provide sample questions to illustrate the concept, and would need to be expanded and tailored to the needs of a specific organization before being used. The sample questions and format are based on copyrighted material by Carolyn Libuser, and should not be reproduced without permission.

FLIGHT OPERATIONS RISK MANAGEMENT QUESTIONNAIRE

National Center of Excellence for Aviation Operations Research
Institute of Transportation Studies
University of California
Berkeley, CA 94720

Please answer the following questions using a 5 point scale:
Strongly Agree; Agree; Neither Agree nor Disagree; Disagree; Strongly Disagree

PROCESS AUDITING:

Q1. The company makes it hard for flight crew to cover-up or hide mistakes

Q2. The company takes recommendations of the pilot association safety committee very seriously

Q3. Flight crew are discouraged from reporting incidents to the NASA Aviation Safety Reporting System

Q4. The airline safety committee generally does a good job of identifying safety problems

Q5. Company safety bulletins contain valuable and timely information

Q6. The company does a good job of identifying flight crew who tend to make mistakes or take risks

REWARD SYSTEM:

Q7. The company does not reward flight crew who identify safety problems or report mistakes

Q8. Flight crew often feel pressured to achieve an on-time departure against their better judgment

Q9. Flight crew who make serious mistakes are usually punished

Q10. I feel comfortable reporting a serious mistake or safety problem to the airline safety committee

Q11. Flight crew with good cockpit resource management skills are promoted faster

Q12. I personally know of flights that took place with inoperative equipment that in my view should have been canceled or delayed until the problem was fixed

QUALITY OF OPERATIONS:

Q13. This airline is one of the safest to fly

Q14. Compared to our competitors, this airline cares more about making money than the quality of service it provides

Q15. I am proud to tell my friends which airline I work for

Q16. Safety is the most important consideration in every flight crew decision

Q17. The company makes every employee feel that their efforts contribute directly to its success

Q18. Compared to our competitors, this airline devotes more resources to safety programs

RISK PERCEPTION:

Q19. Flight crew are well aware of the risks involved in flying

Q20. Flight crew receive good information about hazardous weather that they might encounter

Q21. Information about safety incidents is rapidly disseminated to flight crew

Q22. Regular training adequately prepares flight crew to handle emergency situations

Q23. I personally know of at least one pilot that I would not want to fly with

Q24. The company takes active steps to identify and minimize risks

MANAGEMENT PROCEDURES:

Q25. Company safety policies, rules and procedures are written down in a manual that I can refer to at any time

Q26. I think that this airline has too many rules, procedures and protocols.

Q27. Many of the company rules get in the way of safe operations.

Q28. Senior management is well informed about safety problems

Q29. When flight schedules get disrupted by bad weather, the company has adequate reserve flight personnel to operate safely

Q30. I think that I am trained well enough to do my job.