Workshop on Flight Crew Accident and Incident Human Factors

June 21-23, 1995

Office Of System Safety

PROCEEDINGS

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EXECUTIVE SUMMARY

On June 21 - 23, 1995, the Federal Aviation Administration's (FAA's) Office of System Safety, as part of its Human Factors Data Project, convened the Workshop on Flight Crew Accident and Incident Human Factors at The MITRE Corporation in McLean, Virginia. The workshop provided a forum for discussing and documenting activities that aviation accident investigators, safety analysts, data specialists, and human factors professionals are involved in relative to flight crew accident and incident human factors. The following were the objectives of the workshop:

- *Identify the relevant human factors data elements, or types of data, required for appropriate analysis of flight crew error contributing to aviation accidents and incidents.*

- *Define how various models of human performance and human error can be incorporated into a process for analyzing human factors data in aviation accidents and incidents.*

- *Define the conceptual interface between users, data systems, and analytical models/taxonomies.*

Each objective was discussed at round tables of approximately seven attendees with diverse affiliations, expertise, and interests. A total of 60 individuals attended the meeting. Government agencies, industry, and academia were represented, as were both foreign and domestic interests.

Based on the discussions reported by the round tables, there were four primary items identified for the first objective.

1. *Provide a "history of actions by crew" that enabled the crew to resolve operational problems.*
2. *Commuting/deadheading is an area of concern regarding crew operations in commercial aviation.*
3. *Decision making processes of the flight crew are not traceable in a reliable manner.*
4. *Normative data should be collected from line flying.*

The second objective provided eight primary discussion items.

1. *When available, utilize the flight crews' knowledge to explore the event.*
2. *Develop aviation community partnerships.*
3. *Develop airline organizational models.*
4. *Develop an automated analytical support capability.*
5. *Develop analytical process based on user's needs and understanding.*
6. *Develop a process, not the process.*

7.

8. Define measures of human factors data.

9. Define measures of human factors models.

There were five primary discussion items for the third objective.

1. Define the users as having fundamental interest in aviation operations and safety.

2. Develop a system for classifying the type of data observation.

3. The user interface must be based on the types of users identified by the round tables.

4. On-line access of accident and incident data.

5. Narrative descriptions of events are required.

A large amount of detailed information was provided at the workshop. This information is being evaluated by the members of the Human Factors Data Project and will be incorporated into the planning of future project activities.

The quantity and diversity of the attendance and the enthusiasm displayed throughout the workshop was overwhelming, clearly demonstrating the need for the Office of System Safety to continue its focus on improving the processing of flight crew accident and incident human factors data. The workshop was also a successful beginning in that it brought together for the first time, leaders in the field from government, industry, and academia to discuss their ideas and concerns about accessing, integrating, and analyzing flight crew accident and incident human factors data. Another workshop is being planned for the Spring of 1996 to discuss the progress made on the Project and to revalidate the user requirements established at this workshop.

1WORKSHOP SUMMARY

1.1INTRODUCTION

A workshop to discuss and document industry activities related to flight crew human factors in accidents and incidents was convened by the Federal Aviation Administration's (FAA's) Assistant Administrator for System Safety, Mr. Christopher Hart. Opening remarks were also provided by Dr. Mark Hofmann, the FAA's Chief Scientist and Technical Advisor for Human Factors. Held June 21-23, 1995 at The MITRE Corporation in McLean, Virginia, the workshop focused on three objectives:

¥ *Identify the relevant human factors data elements, or types of data, required for appropriate analysis of flight crew error contributing to aviation accidents and incidents.*

¥ *Define how various models of human performance and human error can be incorporated into a process for analyzing human factors data in aviation accidents and incidents.*

¥ *Define the conceptual interface between users, data systems and analytical models/taxonomies.*

1.2SCOPE

The background and organization of the workshop are briefly summarized. Following these sections are the summaries of the primary discussion items for each workshop objective. Due to the large amount of diverse comments and in-depth discussion at each of the eight round tables of the workshop, a detailed analysis of each round table is not within the scope of this summary, therefore, only the topics and points on which there were prevailing opinions are summarized. The total collection (125+) of objective templates completed by each round table is available electronically in an un-edited format. Workshop attendees may request these templates by sending either an electronic mail message to *jblancha@MITRE.org* or a self-addressed stamped mailer (10" x 14") and a formatted diskette (High density only) to: Jim Blanchard, The MITRE Corporation, 7525 Colshire Drive, McLean, Virginia, 22102.

1.3BACKGROUND

The workshop was designed to provide guidance and expertise to the FAA's Office of System Safety to define a process to support industry and government users of aviation safety data systems. To implement this process, the project team is designing and developing an integration tool to access and integrate various data archives relative to aviation accident and incident human factors. In the future, additional resources available within the FAA and other aviation organizations may also be included in the process and subsequently implemented through the integration tool.

To provide a strong foundation for the functional requirements of the process and integration tool, the project team conducted a one year study and analysis of the users of aviation safety data. The results of this study, presented in the background research report dated October 1994, identified a number of functional requirements for accessing, integrating and analyzing flight crew human factors in accidents and incidents. Three of these requirements are embodied in the objectives of the workshop. To further understand the needs of the users of aviation safety data and human factors related to flight crews, the project team elected to conduct the workshop as a planning step in the design and development of the process and integration tool. Involving the users from the outset was thought to be the best method of defining and designing an automation capability for the limited number of users known to require human factors data on flight crews. Air carriers known by the project team to be currently publishing and practicing aviation safety data analysis were invited. Academic leaders in the field, as well as interested government and industry professionals were also invited. The workshop had representatives from all qualified user populations within the United States, as well as a small international representation. The attendance distribution by company or government organization (many organizations/divisions representing the same agency) indicates the breadth of the workshop.

¥   Government representatives totaled 20 organizations/divisions
¥   Industry representatives totaled 18 different companies, including associations
¥   Academia representatives totaled 4 different institutions

*1.4*WORKSHOP ORGANIZATION

The attendees were welcomed, heard opening remarks and were provided with background information on the objectives and structure of the workshop during the first half of day one. The second half of day one was spent in randomly selected teams of five to seven attendees working as "round tables" on the first objective. Templates were provided to guide the reporting and participants discussed freely the objectives and their implications on the aviation community. The second and third objectives were the focus of day two. Round table participants were organized by the staff to ensure a balanced team of five to seven attendees was present at each table, relative to their personal experience and interest. Again, templates were used to guide the reporting of the discussions. A summary of the workshop and facilitated discussion was held on day three. Following closing remarks from the Assistant Administrator of System Safety, Mr. Christopher Hart, the workshop adjourned at noon on day three.

1.5OBJECTIVE 1 DISCUSSION ITEMS

Objective 1. *Identify the relevant human factors data elements, or types of data, required for appropriate analysis of flight crew error contributing to aviation accidents and incidents.*

Provide a "history of actions by crew" that enabled crew to resolve operational problems. Flight crews often develop solutions to problems as they occur in-flight. Too many times these solutions are "not reported" or "not described adequately" in the post flight analysis and therefore they are not part of the record or solution published for others to consider. Data relevant to event reconstruction is needed for "successful outcome events" as well as those where the outcomes result in an accident and incident.

Commuting/deadheading is an area of concern regarding crew operations in commercial aviation. A large percentage (unknown but estimated by the air carriers at greater than 40 percent) of the commercial pilot population commutes to work in an environment where the commute itself is mentally and physically taxing. Some of these commutes include cross-country flying and jump seat rides that take the better part of a day. While not recognized as a factor in the majority of accidents and incidents, most of the round tables commented that more data about the pilot's activities prior to flight might be helpful in advancing the understanding of flight crew human factors.

Decision making processes of the flight crew are not traceable in a reliable manner. The process by which a crew member arrives at a decision is a major "missing link" in the existing investigative techniques of the accident and incident process. Understanding *how* a crew member arrives at a decision is a critical component of understanding and predicting flight crew performance.

Normative data collected from line flying. There exists a lack of understanding and documentation about what pilots do when they are *flying safely*. Rarely is a normal or safe flight reviewed for what went right. Collecting sample data about *normal operations* would be useful in understanding the effectiveness of training operations and safety concerns of the operators. Such data should be collected both in a measured capacity, such as Flight Operations Quality Assurance (FOQA), and observed process, such as Computer-Aided Debriefing Stations (CADS), and post-flight analysis systems designed to highlight practices and procedures where training and performance are observed as predicted.

Other significant discussions centered around:

¥   The use of a *multi-level criticality ranking scale* for incidents which "flags" single occurrences that should (1) not be allowed to escalate or (2) be treated as a single, isolated event.

¥   The need for a *flexible dictionary* of terms which supports the integration of safety data systems and facilitates the discussion of human performance among operators and users having dissimilar backgrounds or goals.

¥   A *save button* which allows the crew to mark the flight data recorder and cockpit voice recorder for post-flight analysis upon arrival at a destination.

¥   A *fast review capability* for analyzing post-flight data in faster-than-real-time modes.

¥   A system capable of detecting *patterns and trends* in data that is being monitored in programs such as FOQA or Save Button.

¥   A capability to *control the reporting bias* (inter-rater reliability is one type of bias which was discussed). Some round tables discussed the need for data collection training at the source of the data, such as an investigator course designed for human factors data collectors. Others reported the need for users to be trained.

¥   Develop and support a more effective and widespread use of the *call-back procedures* developed by the team at the Aviation Safety Reporting System (ASRS). Include commercialization development of this process for non-governmental parties interested in the procedure.

¥   Devise an *incentive program* to entice and ensure contribution of the operator in the safety reporting systems of the future.

¥   Develop a general aviation digital flight data recorder to support incident and accident reconstruction and understanding of pilot performance.

¥   Review the investigative and analytical procedures used by insurance companies for understanding human performance and the sharing of information between operators and insurers.

¥   The use of continuous video recording and voice recording to support the identification and analysis of pilot perceptions in flight.

1.6 OBJECTIVE 2 DISCUSSION ITEMS

Objective 2. *Define how various models of human performance and human error can be incorporated into a process for analyzing human factors data in aviation accidents and incidents.*

When available, utilize the flight crews' knowledge to explore the event. The Federal Aviation Administration and the industry need to focus on the development of "Talk to the Pilot" models. These models of analyzing flight crew human factors should elicit information about the event under study and be non-punitive towards participants.

Develop aviation community partnerships. The Federal Aviation Administration and the industry, along with academic and government scientists, need to work together to develop teams

of expertise in next-generation human performance analysis. Two significant comments surrounding this issue centered on (1) the need for teaming as a method for tackling an analytical problem that is beyond any one organization's ability to resolve, and (2) the need for partnerships as a way to gain a significant amount of information about flight crew activities in normal operations over a shorter period of time than would be possible if only one carrier collected data on/for themselves and did not share it with other interested parties.

Develop airline organizational models. The influence of the organizational leadership, operations management, and corporate culture has been cited recently (and increasingly) as a factor in a flight crew's ability to operate the aircraft. Without detailing the value of such an influence (the workshop did not suggest a viewpoint as a prevailing opinion), an understanding of the influence of corporate culture on the crew's performance is critical to the development of effective human performance and error models relative to flight crews. This would include identifying and collecting data to support the models. Organizational factors are *external influencers* known to be observable in flight crew performance analytical models. Further development of analytical models describing the influence of the organization on the crew is needed to advance in this area of flight crew human factors.

Develop an automated analytical support capability. There are certain activities that computers do well, and others that are clearly the role of the human operator. Many operators have desktop computers linked to information systems in their organization. Most of those who have these technologies collect data and analyze it, sometimes producing poor quality and useless analytical results. Developing an automated process would help alleviate *errors of analysis* and improve usability by suggesting areas requiring further investigation or attention. Most operators' analytical capabilities are based on a human analyst's ability to reason and apply common sense to a mountain of data. These human reasoning skills must not be destroyed in the process of developing analytical technology and systems designed to support aviation safety analysts. Correctly using the available data systems *and* analytical tools is a major requirement of any process to access, integrate or analyze flight crew human factors in accidents and incidents.

Develop analytical process based on user needs and understanding. Similar to the point immediately above, the need to have the human expert developing and overseeing the analytical process was stressed by the round tables as critical to the process of studying human factors in flight crews. Specifically focused on the reasoning and declarative abilities of the human mind, this issue remains a strong underpinning of the entire workshop. Next-generation analytical systems and models (such as those envisioned in the Automated Performance Monitoring System - APMS and the Computer Aided Debriefing Station - CADS) must be centered on the human user's needs and operate as tools to support the analytical process. This workshop issue implies the use of the human experts *and* automation tools in a systemic process, not the automation of all analysis process steps.

Develop *a* process, not *the* process. The task of developing a process to support various users who require access, integration or analytical capabilities relative to flight crew human factors in accidents and incidents *should* be declared by the Federal Aviation Administration as *only one of many* industry "stepping stones" on the way to new and improved processes. The FAA's

continued support for other parties (working outside the participants of the workshop) should be given recognition for their attempt to advance the understanding of the aviation community relative to flight crew human factors.

Define measures of human factors data. Similar to the need for a data dictionary in understanding and accessing various data systems is the need for a clear description of the *measures* being used to assess human performance in flight crews. Related to flight crew activities, the need to clarify the measures precedes any legitimate attempt to define collection and analytical processes whereby different sources of data (collection activities and archiving) can be used to create *super-sets* or *homogeneous data bases* for large-scale analysis.

Define measures of human factors models. A second trend emerged in the workshop regarding the application of next-generation data.   Most round tables agreed that the industry has a lack of understanding about the development of a hypothesis and methods of experimental inquiry which attempt to measure the outcomes of flight crew performance. Models and processes rely on the clarity of the hypothesis to define what data should be collected to use the models and processes. Most of the analytical models in use today are based on a non-scientific prevailing opinions of post-event analytical methods. The future of predicting and preventing flight crew performance will be based on some method which has yet to be developed defining "What measures are reasonable and valid in *predicting* flight crew performance?"

Other significant discussions centered around:

¥   The need for the Federal Aviation Administration to support a limited amount of *outside development of human factors research* relative to predicting flight crew performance.
¥   Recognition of the *lack of verifiable and valid models* for use in the industry has caused many operators to develop internal analytical techniques which may or may not be useful.
¥   Developing a *next-generation analytical model* designed for measuring flight crew performance should be explored in the FOQA program (including supporting the tools of FOQA such as APMS, CADS and other next generation flight crew analysis projects).
¥   The Federal Aviation Administration should attempt to *provide specific guidance* in how to use the models which it might provide in future data systems.

1.7OBJECTIVE 3 DISCUSSION ITEMS

Objective 3. *Define the conceptual interface between users, data systems and analytical models/taxonomies.*

Define the users as having fundamental interest in aviation operations and safety. Further descriptions of the users of aviation safety data emerged from the round tables, with the following list as the primary types of aviation operations and safety-oriented users (in frequency of occurrence order): Pilots, Technical/Professional Certificated Airmen, Engineers, Lawyers, Managers, Journalists, and Researchers (from academia, government and industry).

Develop a system for classifying the type of data observation. Many of the data systems do not specify the type of collection technique used to gather or archive the data contained in the data system. This lack of a published classification scheme interferes with usability, quality and "trust" of the value of the data system contents. To move towards integrating many sets of information gleaned from smaller data systems, the user's trust must be maintained by ensuring that the data was collected for use in such queries as flight crew human factors. Any interface into a data system should identify the source(s) of the data and provide a detailed description of the data for traceability. To support longitudinal study, data systems should provide users with a notation (or some on-line description) of the analytical methods to be used in the application of source data. Round tables suggested this description as a technique to reduce mis-use of questionable results.

The user interface must be based on the types of users identified by the round tables. A critical short-coming of the past data access projects is the lack of utility and friendliness of the interface to the types of users actually attempting to operate the systems. Examples ranged from having a search process that requires a skilled data base analyst, to the need for human factors experts "on the spot" to interpret the results. Any interface must eventually lead to output (a result) which is usable.

On-line access of accident and incident data. Almost unanimously, the workshop attendees agreed that all the accident and incident data that is suitable/appropriate for use by qualified users should be made available on-line. A strong point of concern was voiced that this does not mean simply posting it to the internet. Developing a secure interface for use by authorized personnel is needed in the near future.

Narrative descriptions of events are required. Access to the record of an event should include a narrative description of the event as documented by the investigative team or flight crew (in the case of self-reporting), and both forms of reporting if available. The user's interface should refer to all events in the system that may be related according to the search/query parameters the user provided. Additionally, a narrative search capability using key words *and* context-level searching should be provided.

Other significant discussions centered around:

¥   The development of a process to ensure the *level of de-identification* is appropriate to the user's authorization.
¥   *Protection of both the individual and the operator* must be maintained if the intended purpose of safety data analysis and dissemination is to be possible.
¥   *Data sharing schemes* and a system of "depositors only" access should be explored. [Editorial comment: Some legitimate users of this data are not depositors. Future workshops will explore this further to resolve "appropriate users" and applications of the data.]
¥   Legislation and rules for the *protection of the users* and depositors should be developed.
¥   The user's interface should strive to *prevent misinterpretation and unintentional misuse* of the data and results by compelling correct analysis and results.

¥   A *system level standardization* for depositors and users should be implemented through a
     well-designed interface.

1.8 CAUTIONS AND PITFALLS HEARD AROUND THE WORKSHOP

¥   The use of subjective data for the analysis of flight crew human factors is very difficult and
     should be carefully studied before being implemented.
¥   The scope of the Federal Aviation Administration's role in the furtherance of flight crew
     human factors data analysis should emphasize a proactive role through innovative applied
     research projects and support of the industry practitioners who seek to advance the sciences
     of human factors in aviation.
¥   Inappropriate uses of the data must be prevented in the early stages of any safety data
     "network" or participants may not be willing to continue to be involved.
¥   A clear demonstration of commitment by the FAA to the operational and fiscal stability of a
     safety data exchange (or other process operated by the FAA) must be made clear before
     operators and researchers will make contributions of data, fiscal resources or time.

1.9 SUMMARY

The workshop objectives provided a structure for the attendees on which to focus their attention.
In doing so, the templates elicited a large set of points that need attention and further definition.
The results of the workshop clearly indicate a set of "next steps" and directions for advancing the
human factors analysis potential of the aviation community. These next steps should be taken as
a partnership between the industry and the FAA.

Follow-on workshops will address the use of the integration tool, and the clarification of data
required to conduct meaningful analysis and prediction of flight crew performance. Specific
focus will be on the next generation data systems and programs where users share data between
themselves in the interest of aviation safety.

2 HUMAN FACTORS DATA PROJECT SUMMARY

The Flight Crew Accident and Incident Human Factors Project is a major effort by the FAA's Office of System Safety to accomplish the primary goal of the aviation community to substantially reduce aviation accidents and incidents. A summary of the project activities conducted to date and those planned is provided below.

2.1 BACKGROUND

To address the high incidence of human factors related accidents and incidents, the Office of Aviation Safety, predecessor to the Office of System Safety, initiated the Human Factors Data Project in August 1993. This project is included in FAA's Strategic Plan under Goal 3: Eliminate accidents and incidents caused by human error. The goal of the Human Factors Data Project is to identify causes of human error that contribute to accidents and incidents in order to develop prevention strategies. The general approach to satisfy this goal is twofold: (1) Increase the Office of System Safety's capabilities to access, integrate, and analyze human factors data relating to accidents and incidents, and (2) Facilitate efforts of the aviation community to improve aviation safety through the application of human factors data and analytical models.

The initial focus of the project is to develop and implement a process to access, integrate, and analyze flight crew human factors data relevant to safety.   In the future, the process will be extended to include aircraft maintenance and air traffic control human factors data. The Flight Crew Accident and Incident Human Factors Project has four phases; background research, process development, process verification/validation, and process implementation.

2.2 ACTIVITIES TO DATE

During FY94, teams from the Office of Aviation Safety performed a search of available and emerging data systems that contain flight crew accident and incident human factors information. An investigation was also conducted on the models or techniques that are used or are being developed to analyze these data. In addition, a significant sample of human factors and safety experts were interviewed to determine what human factors data and analyses are being used to understand the causes and prevention of aviation accidents and incidents. The major finding from the background research was that there are individual accident and incident data systems that contain adequate information on "what happened" but very little information on "why it happened." In order to develop effective prevention strategies, as much contextual and causal information as possible needs to be gleaned from all available sources of accident and incident data. The major recommendation from the background research was to develop a standardized and relatively easy process for safety analysts, accident investigators, and human factors professionals to access and integrate information contained in various accident and incident data systems and perform analysis of this information to determine the important human factors involved. A report was prepared by the Office of Aviation Safety documenting the activities and results of the background research.

Based on the background research, it was decided that an initial process would be developed and demonstrated during FY95 that would permit an FAA safety analyst to apply either of two human error models to an accident database or an incident database to identify significant human factors patterns and trends across accidents and incidents. Although there are other relevant human error models that could be applied, the models proposed by Norman-Reason and Laing-Graesser-Hemphill were selected for the initial process. The databases selected were the National Transportation Safety Board (NTSB) Accident/Incident Data System and National Airspace Information Monitoring System (NAIMS)/Pilot Deviation System (PDS). These databases are resident in the Office of System Safety's National Aviation Data Analysis Center (NASDAC).

In order to associate the flight crew human factors information contained in the selected accident or incident database with the selected human error model in a context that will help the safety analyst to interpret the results, a human factors framework or categorization scheme was needed. The scheme proposed by Senders and Moray, was selected for the initial process. Senders and Moray recommend that all investigations of error should explicitly be included in their four levels of taxonomy as a descriptive system before deeper analysis. Generally, this taxonomy divides human error into two broad categories; the situation and the consequences. The situation is comprised of two main factors: Who and Why. The consequences are comprised of; Where/When, and What. For the initial process, this general categorization scheme will be decomposed into specific subcategories that support the two selected human error models and relate directly to data fields in the NTSB and NAIMS/PDS databases.

In order to efficiently and reliably connect different accident and incident databases, human error models, and the users of safety and human factors data, a computer-based integration tool is being developed. Neuron Data's Smart Elements, introduced in 1994, was selected as the software development environment. Smart Elements supports rapid prototyping and meets our development requirement of combining a graphical user interface (GUI), an object oriented and rule-based expert system, and database interface. For our application, objects represent data elements within the human error models and accident/incident databases and the decision (If-Then-Else) rules connect the objects and display the results in accordance with the categorization scheme of Senders and Moray. The GUI permits real-time creation of user-friendly input, intermediate, and output display screens and the data access element makes access to a wide variety of outside databases transparent to the user.

For the initial process, the user will select either or both the NTSB accident or the NAIMS/PDS database and one of the two human error models. For each query of the database(s), the output derived will show the number of accidents or incidents in the database(s) that contained a human error as defined by either Norman-Reason or Laing-Graesser-Hemphill and interpreted by human factors professionals assigned to the project. The accident or incident report numbers associated with each human error can be accessed if desired. By clicking on any of the report numbers, the analyst can call up the narrative extract from the report to verify the presence of the human error and to understand more about the context and causality of the accident or incident. The entire process, from entering a query to receiving an output, takes only a matter of a few minutes. Currently it takes days to obtain the same information and that's assuming the analyst has a working knowledge of the selected database and human error model.

In June 1995 the Office of System Safety sponsored a 2 1/2 day workshop on Flight Crew Accident and Incident Human Factors in McLean, VA. The purpose of the workshop was to hear from potential users of the process, i.e., human factors professionals, safety analysts, and accident investigators, concerning their human factors data collection and analysis activities and needs. Sixty representatives from government, industry, and academia attended the workshop. Inputs from the workshop will be used to refine the initial process and prioritize FY96 project activities within the Office of System Safety. Attendees agreed that the workshop was an important milestone towards standardizing human factors data and analysis requirements to support accident and incident prevention. The workshop also provided a unique opportunity for those attending to become familiar with other related human factors and safety data initiatives being conducted within the aviation community.

2.3 ACTIVITIES PLANNED

During the 4th Quarter of FY95, Version 1 of the integration tool software, which will be used to demonstrate the operation of the initial process or "proof of concept," will be completed. Version 1 will contain decision rules to connect a subset of the objects or data elements contained within the two selected human error models and accident and incident databases. The queries permissible will include time period, airspace user type, referenced to flight crew member, aircraft make/model, phase of flight, and weather conditions. Version 1 will only access the fixed fields within the NTSB and NAIMS/PDS databases. Version 1 software will run on a stand-alone PC with the NTSB accident and NAIMS/PDS incident data loaded into the hard disk. Also during this period, a demonstration of Version 1 will be provided to FAA safety and human factors management and technical personnel, the proceedings from the June Workshop will be distributed, and a bulletin board will be established on the Internet to permit those attending to continue the dialog begun at the workshop. A report providing a detailed definition of the initial process and the prototype integration tool will be prepared.

During the 1st quarter of FY96, operational testing of Version 1 of the integration tool software will be conducted by the project team and selected individuals from government, industry, and academia. During the first 2 quarters of FY96, Version 2 will be developed which will contain additional decision rules to associate the remaining objects or data elements contained within the two selected human error models and accident and incident databases. Version 2 will also permit remote users to access the NTSB accident and NAIMS/PDS databases in the NASDAC via Internet with textual retrieval capability to process the narrative data contained in the accident and incident reports. Operational testing of the additional capabilities will be accomplished by the project team with selected participants from the aviation community. Version 2 software and documentation will be completed during the 3rd quarter of FY96.

The Office of System Safety is planning to have a contractor outside the project team conduct an independent verification and validation (V&V) of Version 2 of the integration tool software. A V&V plan will be prepared during the 2nd quarter of FY96, V&V will be completed during the 3rd quarter, and a V&V report will be prepared during the 4th quarter. Another user workshop

will be held during the Spring of 1996 to review the design and operation of the initial process based on Version 2 of the integration tool software and to discuss the preliminary results of the independent V&V. User requirements obtained from the workshop and the changes identified during the V&V will be incorporated into Version 2 of the integration tool software. Version 2.1 software and documentation will be released by the end of FY96, at which time, the Office of System Safety will begin using Version 2.1 to access, integrate, and analyze flight crew accident and incident human factors data.

It is expected that as additional databases (e.g., ASRS) are incorporated into the NASDAC, the Office of System Safety will integrate them into the process. Human Factors data from the Flight Operational Quality Assurance (FOQA) Program, Automated Performance Monitoring System (APMS), the Advanced Qualification Program (AQP), and emerging industry safety programs will also be integrated as these data are made available. As resources permit additional human error models and statistical analysis techniques will be evaluated and integrated into the process. It is also expected that the integration tool will be enhanced to provide the user with references to sources of human factors research data to better understand the causes and prevention of the human errors identified. Throughout this period, the Office of System Safety will maintain contact with the users of the process to discuss improvements in collecting and analyzing flight crew accident and incident human factors data and the means of implementing them.

3LIST OF ATTENDEES

Ludwig Benner
Ludwig Benner & Associates
12101 Toreador Lane
Oakton, VA 22124
703-758-4800

Ben Berman
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594
202-382-6574
bermanb@ntsb.gov

* Jim Blanchard
 The MITRE Corporation
 CAASD/MW-W195
 7525 Colshire Drive
 McLean, VA 22102
 703-883-6758
 jblancha@mitre.org

Sue Bogner
Food & Drug Administration
1350 Piccard Road, HFZ 230
Rockville, MD 20850
301-594-3877
msb@fdadr.cdrh.fda.gov

Joseph Bracken
AirLine Pilots Association
P.O. Box 1169
535 Herndon Parkway
Herndon, VA 22070
703-689-4208

* Jim Cieplak
 The MITRE Corporation
 CAASD/MS-W273
 7525 Colshire Drive
 McLean, VA 22102
 703-883-5292
 jcieplak@mitre.org

Sherry Chappell
NASA/ASRS
NASA Ames Research Center
MS 262-4
Moffett Field, CA 94035
415-604-6909
sherry@cos.arc.nasa.gov

Tom Chidester
American Airlines, Incorporated
P.O. Box 619617
MD 891 GSWFA
Dallas/Ft. Worth Airport, TX 75261
817-967-5182

Rebecca Chute
NASA Ames Research Center/San Jose State University
MS 262-4
Moffett Field, CA 94035-1000
415-604-0771
rchute@gmgate.arc.nasa.gov

Linda Connell
NASA/ASRS
625 Ellis Street
Suite 305
Mountain View, CA 94043
415-604-3969
linda_connell@abbott.arc.nasa.gov

Rich Dieckhans
Federal Aviation Administration
ASA-100, Rm 2322
400 7th Street, SW
Washington, DC 20590
202-366-2125
rdieckhans@mail.hq.faa.gov

* Flight Crew Human Factor Project Team

* Nancy Dolan
Galaxy Scientific Corporation
2500 English Creek Avenue
Building 11
Egg Harbor Township, NJ 08234
609-645-0900
galsci@acy1.digex.net

Jack Fearnsides (Opening Remarks)
The MITRE Corporation
7525 Colshire Drive
McLean, VA 22102

Mark Fischer
AeroKnowledge, Incorporated/ASRS
2425 Pennington Road
Trenton, NJ 08638
609-737-9288
pa24aero@ao1.com

Chuck Fluet
Federal Aviation Administration
400 7th Street, SW
Washington, DC 20590
202-366-4466
charles_fluet_at_asa@mail.hq.faa.gov

Stephanie Frank
Battelle/ASRS
625 Ellis Street
Suite 305
Mountain View, CA 94043
415-969-3969
stephanie_frank@gmgate.nasa.arc.gov

Larry Ganse
Northwest Airlines
5101 Northwest Drive
MS-N7180
St. Paul, MN 55111-3034
612-726-0916

* Wrensey Gill
Federal Aviation Administration
400 7th Street, SW
Washington, DC 20590
202-366-6166

Curt Graeber
Boeing Commercial Airplane Group
P.O. Box 3707
MS 9W-AA
Seattle, WA 98124-2207
206-237-1610
grarcb00@ccmail.iasb.ca.boeing.com

Scott Griffith
American Airlines Safety Action Partnership
960 Breakwater Drive
Annapollis, MD 21403
410-263-8235

John Hansman
Department of Aeronautics & Astronautics
MIT Aeronautical Systems Laboratory
Rm 33-115
77 Massachusetts Avenue
Cambridge, MA 02139
617-253-2271
rjhans@mit.edu

Steve Harper
CSERIAC Program Office
AL/CFH/CSERIAC
Building 248
2255 H Street
Wright-Patterson AFB, OH 45433
513-255-4842
sharper@desire.wright.edu

* Christopher Hart (Opening Remarks)
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591
202-267-3611

* Flight Crew Human Factor Project Team

Chuck Hedges
Federal Aviation Administration
400 7th Street, SW
Washington, DC 20590
202-366-4466

* Lloyd Hitchcock
Hitchcock & Associates
2520 Pleasant Hill Road
Hatboro, PA 19040
215-675-2419
71250.1556@compuserve.com

Mark Hofmann (Opening Remarks)
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591
202-267-7125

Beverly Messick Huey
National Research Council, Marine Board
Suite HA250
2101 Constitution Avenue, NW
Washington, DC 20418
202-334-3119
bhuey@nas.edu

Pierre Huggins
AirLine Pilots Association
535 Herndon Parkway
P.O. Box 1169
Herndon, VA 22070
203-689-4211

Sharon Jones
NASA-UT
P.O. Box 981064
Houston, TX 77098-1064
sharon.jones@mail.utexas.edu

George Kaseote
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591
202-267-8541
george_kaseote_at_air100@mail.hq.faa.gov

Thomas Lilli
Air Line Pilots Association
P.O. Box 1169
535 Herndon Parkway
Herndon, VA 22070
703-689-4208

George Lyddane
Federal Aviation Administration
3960 Paramount Boulevard
Lakewood, CA 90712
310-627-5206

Callum MacGregor
British Airways, Safety Services
The Compass Centre (S742)
P.O. Box 10
Heathrow Airport
Hounslow TW-6 2JA
0815622925

Vincent Mancuso
Delta Air Lines
Department 024
Atlanta Hartsfield International Airport
Atlanta, GA 30320
404-209-1654
70232.1005@compuserve.com

Vincent Mellone
Battelle/ASRS
625 Ellis Street
Suite 305
Mountain View, CA 94043
415-969-3969

* Flight Crew Human Factor Project Team

Rowena Morrison
Battelle/ASRS
625 Ellis Street
Suite 305
Mountain View, CA 94043
415-969-3969
rowena_morrison@abbott.arc.nasa.gov

* Eric Neiderman
Galaxy Scientific Corporation
2500 English Creek Avenue
Building 11
Egg Harbor Township, NJ 08234
609-645-0900

Lou Nemeth
USAir
P.O. Box 7543
Charlotte, NC 28241-7543
704-588-0863
ususa32b@ibmmail.com

Hop Potter
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591
202-267-3723
hop_potter_at_afs200@mail.hq.faa.gov

* Phil Prasse
Records Management Systems, Inc.
11166 Main Street
Suite 200
Fairfax, VA 22030
703-218-1400

Larry Randall
Federal Aviation Administration
400 7th Street, SW
Washington, DC 20590
202-366-6003

Ira Rimson
Validata Corporation
P.O. Box 1015
Springfield, VA 22151
703-978-2944
73700.3376@compuserve.com

Mark Rodgers
Civil Aeromedical Institute (CAMI)
P.O. Box 25082
Oklahoma City, OK 73125
405-954-6848
mark_rogers@mmacmail.jccbi.gov

* Barbara Sada
Federal Aviation Administration/NASDAC
400 7th Street, SW
Washington, DC 20590
202-366-6003

Nadine Sarter
The Ohio State University
210 Baker Systems Building
1971 Neil Avenue
Columbus, OH 43210-1210
614-292-6287
nsarter@magnus.acs.ohio_state.edu

* Stew Schreckengast
Advanced Systems Technology Incorporated
2121 Crystal Drive
Suite 514
Arlington, VA 22202
703-218-1400

Ronald Simmons
Federal Aviation Administration
400 7th Street, SW
Washington, DC 20590
202-267-7058
rsimmons@mail.hq.faa.gov

* Flight Crew Human Factor Project Team

Barry Strauch
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594
202-382-6642
strauch@ntsb.gov

Robert Sumwalt
Air Line Pilots Association
P.O. Box 1169
535 Herndon Parkway
Herndon, VA 22070
800-442-9007 (7216)

Michal Tamuz
University of Texas
School of Public Health
2100 Herman Presler
Houston, TX 77030
713-792-4364
tamuz@utsph.sph.uth.tmc.edu

Stan Trollip
SR Trollip & Associates
2200 East 22nd Street
Minneapolis, MN 55404
612-332-5725
70732.2431@compuserve.com

John Wise
Embry Riddle Aeronautical University
Center for Aviation/Aerospace Research
Embry Riddle Aeronautical University
Daytona Beach, FL 32114
904-226-6384
wise@db.erau.edu

* John (Jack) Wojceich
Federal Aviation Administration
400 7th Street, SW
Washington, DC 20590
202-366-6431
jwojciech@mail.hq.faa.gov

* Flight Crew Human Factor Project Team

4APPENDIX A - POSITION PAPERS

*Editor's Note: Some papers submitted were not included due to their late submission.

4.1SUMMARY OF POSITION PAPERS - LLOYD HITCHCOCK

Preface

The attempt to summarize the position papers submitted by workshop attendees for consideration posed a significant challenge. Each of the position paper authors presented points of consideration that were both important and insightful. However, their very diversity makes any attempt at general summarization extremely difficult. While an earnest effort was made to capture the key concepts from each paper in the summary which follows, there may be some ideas which were inadvertently left out; for this the authors are given sincere apologies. While the source of most of the ideas included in the summary are cited, it did not prove to be practical to identify all the material included through the routine use of paragraph separation or the use of quotation marks. The original unedited and unabridged position papers remain the best source of comprehensive coverage and proper attribution of the author's ideas. In the course of searching for a framework which could serve as a basis for organizing the varied contributions of the position paper authors in a way that would facilitate the deliberations of the workshop, the following categories were chosen:

- *Where are we now?*
- *How did we get here?*
- *Where do we want to be (Objectives)?*
- *How do we get there?*
- *What obstacles must we overcome enroute?*
- *How will we know when we have arrived?*

While the labels which have been given to these categories are admittedly somewhat informal, it is hoped that both their basic meanings and their potential significance to the workshop goals are apparent.

Where Are We Now?

Current attempts to study the contributions of the human component to overall aviation system safety are fraught with difficulty. Much has been made of the fact that from 2/3rds to 3/4ths of our aviation mishaps involve some element of human failing.

One aspect which fosters confusion is the extreme breadth of the many system elements which are frequently included under the rubric of "Human Factors" as pointed out by Benner and Rimson (1995), the Federal Aviation Administration's current definition of Human Factors is:

> *"....a multidiciplinary effort to* **generate** *and* **compile** *information about human capabilities and limitations and* **apply** *that information to equipment, systems, facilities, procedures, jobs, environments, training, staffing, and personnel management for safe, comfortable, effective human performance."*

(AAR-100 Pamphlet, March 1995)

Many of the databases used to identify human error were originally developed to simply document the event without consideration to accident prevention. Thus, many of the current safety data collection practices lack methodological standardization and, as a consequence are not susceptible to controls on either their validity or their quality. Typical investigation methodologies tend to accept, uncritically, all kinds of data inputs and formats with little attempt at quality control, verification, corroboration, or scientific validation. There exists no viable methodology for normalizing, or otherwise recasting, anecdotal or episodic "rare event" data into a scientific format which could allow/support their use in statistical inferences (Benner and Rimson, 1995).

Furthermore, as pointed out by Corrie (1995), there are vast differences in the investigation cultures and capabilities between the 183 Contracting States of ICAO which result in marked differences in both the nature and utility of the human factors information which they generate.

How Did We Get Here?

The current mishap investigation approaches, objectives, and methodologies were, for the most part, originated in the 1930's by the Civil Aeronautics Board. They evolved to fulfill statutory and regulatory requirements derived from legalistic issues of culpability and liability (Benner and Rimson, 1995). The current negative investigational focus on "what went wrong", with its implicit attention on "who's to blame", serves to discourage candid witness participation in a positive process to develop accident prevention strategies, particularly in today's climate of litigation (Benner & Rimson, 1995). Furthermore, while accident reports usually depict "what" happened and "when", in too many instances they stop short of fully explaining the "why" and "how" which led to the accident (Sumwalt, 1995). Callum MacGregor, Senior Air Safety Investigator with British Airways, also emphasizes the need for "*an open, penalty-free, culture* [to] *inspire staff to report high quality safety information*".

Much potentially valuable data on "incidents" has been routinely lost because of a common, though mistaken, attitude that such events as inappropriate touchdown point or improper rotation rate are too minor to be perceived as significant (Ganse, L. R, 1995). Graeber (1995) concurs, noting that "*many events which would be of interest to a Human Factors investigator are not reported because pilots either don't see them as potential infractions or don't think they are important enough to bother filling out the paperwork*". In addition, incident data provide first-hand information from participants directly involved at a level of detail often not available following an accident. Incident data are "ecologically valid" in that they were generated within the operational environment and are not merely laboratory phenomena. However, such data are often difficult to validate and face the potential hazards posed by reporter biases (Chappell, 1994). Errors that are near misses (incidents) should be considered in error analyses since what proves to be a near miss for one may well be a fatal error for others (Bogner, 1995).
The study of aviation errors has also been hampered by the tendency to view problems as residing either in the human or in the engineering world. A more enlightened approach would

recognize the synergism between the man and machine which sees errors as breakdowns not only in communications between humans but between man and machine as well (Moll van Charante et al., 1992, Sarter and Woods, 1994, Wiener, 1989).

We have tended to focus on the safety implications of flight crew errors because they are listed more frequently as primary accident causes. This approach ignores the well recognized multiple-cause etiology of most accidents and incidents (Greaber, 1995). Ganse (1995) cites the importance of a consideration of the interactions between flight crew, flight attendants, mechanics, station personnel, air traffic controllers, and airline policy and procedure mandates to a full understanding of the origin of an accident. Wise and Wise (1995) compellingly illustrate the criticality of this interdependence by citing the case of the loss of a DC-10 because a cargo door, which could not be locked properly by the unskilled ground crew (because of the complexity of the required operation), blew open in flight. This event, coupled with a design deficiency which prevented adequate pressure compensation when the door was lost, the placement of control cables under the section of floor that buckled from the over pressure, and the resultant jamming of the control system created a sequence of events whose end product was a major accident which cost many lives. Unfortunately, most human factors specialists lack the operational background needed to assess many of the more subtle nuances of such interfaces. With such an interactive pattern in mind, Corrie (1995) reminds us that the "*causes of human error can be complex and any examination must include the entire scenario in which the accident occurred*". To really understand what caused a particular mishap, an investigation must dig beneath the surface - look beyond the obvious - to determine what systemic factors may have served as the root causes of the ultimate error. Investigations should include management philosophy and practice, regulatory influence, and the corporate culture (Sumwalt, 1995). Additionally, seemingly unrelated issues, such as corporate policies, family relationships and language/communication exchange are difficult to qualify or quantify.

Where Do We Want To Be?

We need to establish standardized techniques of data collection which yield comprehensive and valid answers to the questions "*What was supposed to happen*?" and "*What actually did happen*?" These techniques should be fully applicable to both accidents and to the potentially more data rich investigation of incidents. The techniques adopted must be compatible with, and support, a rapid, user friendly methodology for the exchange of data and information between all parties and agencies with an interest in the human factors aspects of aviation safety.

The aviation safety community must come to an agreement on the logical context, or model(s), which will be used to proceed from data acquisition and summarization to the development of causal inferences and, subsequently, to recommendations for techniques for enhanced safety. The model(s) selected must be equally sensitive to issues of "what went wrong?" and "what went right?" if they are to generate meaningful insights into how to prevent similar incidents in the future.

In short, those interested in establishing ways in which the aviation community can successfully reduce the human error component of aviation incidents and accidents must work together to

reach a well documented prevailing opinion on the answers to at least the following primary issues and the questions they generate:

Data Issues:

- What is an "error"?
- What data should be collected?
- How should the data be collected?
- How do we control data quality?
- How do we validate the data?
- How do we code the data?
- How do we standardize these processes?
- How do we handle questions of confidentiality and liability?

Analysis Issues:

- How do we generate hypotheses?
- What framework (models) do we use to organize our analyses?
- How do we determine the statistical significance of "rare events"?
- Who adjudicates disagreements in analytic interpretation?

Information Exchange Issues:

- How do we integrate existing data bases?
- How do we meet the needs of almost 200 separate agencies?
- How do we facilitate and support rapid data transfer?
- How do we manage the combined data base and who does it?

Perhaps the greatest challenge still remains. The aviation human factors community must then build the "bridges" needed to transform analytic exercises into compelling arguments for what may well be the significant, and potentially costly, changes in flight equipment, training, personnel, practices, procedures, and operational climate that are necessary requisites to a meaningful impact upon future safety.

What Do We Have To Do To Get There?

Simply developing a new arsenal of analytic models is not sufficient to meet the safety research challenge. These models must be made compatible with, and integrated into, the analysis process itself. There are a variety of human performance and human error models that have become popular among aviation human factors professionals, These include Norman's separation of errors into slips, lapses, and mistakes Jim Reason's concept of latent failures and "resident pathogens", Rasmussen's concepts of skill-based, rule-based, and knowledge-based behavior, and Edwards' SHEL (**S**oftware, **H**ardware, **E**nvironment, **L**iveware) model (Bogner, 1995; Graeber, 1995; Sumwalt, 1995). Ongoing efforts to identify the strengths and weaknesses of

these, and all other similar approaches, should be evaluated as part of the development of a prevailing opinion regarding the model to be used in forthcoming investigations. In addition, the wealth of experience of both NASA and Battelle Memorial Institute, gained through their cooperative efforts to develop a human factors taxonomy and attempts to apply human error models and human performance models to the data contained in the Aviation Safety Reporting System (ASRS) data bases, should be used as a source of practical counsel in the development of any new model(s) (Morrison, 1995). Effort should be made to draw upon the NTSB's experience in applying extensive safety issue taxonomies to accident data (Ellingstad and Mayer, 1995). The taxonomy of data elements should be focused, unambiguous, and designed for ease of coding yet possess the flexibility needed to allow for elaboration and the coding of unique circumstances (Bogner, 1995).

Benner and Rimson (1995) argue that successful reduction in human factors related accidents mandates a change in investigation philosophy from a focus on "post-accident" analyses which emphasize what went wrong ("What went wrong to 'cause' the accident?") to a study of "pre-accident" incidents which can yield data on what was done right and, as a consequence, kept an accident from ultimately unfolding ("What went right to prevent it?"). Redirecting attention from accidents, which identify only operational failures, to incidents, which identify both operational failures and successful strategies, is seen as essential to reducing the likelihood of future accidents. The current "sound of one hand clapping" tendency to look only at what human failure(s) led to a given accident tells us all too little about how to avoid such accidents in the future. This position is supported by MacGregor (1995) who states that "*the approach is not just to gather data but to use empirical data in a predictive manor to identify future problems and take remedial action before the incident occurs*".

More work must be done to separate issues of accident cause, effect, and prevention. For example, automation is frequently proffered as a remedy for workload induced human error(s). However, as pointed out by Potter (1995), errors in the keystroking activities associated with inputs to the Flight Management Systems (FMSs), touted as palliatives for human failings, tend to increase as the pilot workload they are designed cure increases. Such a tendency toward error could be critical since one FMS, currently certified by the FAA, requires 164 keystrokes to program a single IFR approach (Kasseote and Lyddane, 1995). Thus, the "cure" could prove to be "cause" as well. What is needed is a philosophy of automation that is based not on anecdote and assumption but on hard data gathered on both the specific features of automation hardware and software and the subtleties of automation interaction with other cockpit processes. This philosophy must be incorporated into a clear statement of the issues, and their supporting standards, which govern the testing associated with the certification of automated systems.

British Airways has initiated the British Airways Safety Information System (BASIS) which has now become the medium for the world-wide exchange of safety information between airlines of all sizes, aviation authorities and aircraft manufacturers. Based upon data gathered in a non-punitive collection climate, the information contained in BASIS provides the user with a targeted risk management matrix, and provides the user with user-defined graphic presentations of analyses of trends in accident/incident quantity, probability, delay impact and cost. This information is both managed and distributed by a reliable, user-friendly, paper-free computer

system which is networked to all sections of the Company for use by line managers. In addition, the BASIS has been interfaced with other aviation agencies such as IATA, ATA, UK Air Safety Committee, ALPA, and the European Regional Airlines Association. The experience and expertise of such agencies as the Crew System ERgonomics Information Analysis Center (CSERIAC), Wright-Patterson Air Force Base, should also be called upon to aid in the development of data exchange methodologies and the human-computer interface (HCI) techniques, such as Graphical User Interfaces (GUIs) which can serve to make the exchange methodologies more user friendly. The exchange methodology developed should be fully integrated with the approach developed by the international aviation safety community (Graeber, 1995).

Those concerned with the role of human error in aviation safety must develop a philosophy which recognizes such errors as a "symptom" rather than a "cause" (Sarter and Woods, 1995). When viewed as a symptom of a breakdown in crew coordination, communication, organizational pressure, or the introduction of faulty technology, the emergence of an error should call forth more in-depth investigations of how the total system involved both functions and malfunctions (Rasmusson, et al., 1987; Reason, 1990; Hollnagel, 1993). Such an approach should be both future and prevention oriented and go beyond phenotypical description of the processes involved in the evolution of a single, potentially unique, accident/incident and would look for the genotypical patterns in safety data.

What Obstacles Can We Expect To Have To Overcome On The Way?

Currently, there exist significant disagreements over even the basic nature of the sources of human error and, as a consequence, differing interpretations of how best to reduce their likelihood. As pointed out by Woods and Sarter (1995), "*the label human error is prejudicial and unspecific and...retards rather than advances our understanding of how complex, man-machine systems fail and how the same operator behavior can contribute to both success and failure*".

We must develop a better and more complete understanding of the human factors related causes of accidents and incidents than can be derived from the current accident data bases which capture only a small portion of the problems occurring in the National Airspace System. Such programs as the *Airline Safety Action Partnerships* should be explored as a possible way to broaden the scope of safety data collection (Chidester and Griffith, 1995; McGarry, 1995).

Currently, task-oriented human factors information about accident scenarios is often missing or unusable in transportation accident databases. This category of information is often overlooked because the investigators involved lack an adequate understanding of, and sensitivity to, human factors issues. Furthermore, these data are often not gathered because they do not leave the same kind of tangible physical evidence as that provided by damaged structural components (Ellingstad and Mayer, 1995).

Techniques must be developed to generate estimates of the cost of the human factors analysis program to the airline industry, the government, and the passenger. Without such a foundation of

fiscal justification, it will be difficult, if not impossible, to successfully implement any new safety initiative.

Perhaps the most formidable hurdle which must be overcome is the fact that the very nature of scientific inquiry argues against the ability to extrapolate knowledge derived from the past to the vagaries of the future. The scientific method rests upon the empirical testing of hypotheses and, as Wise and Wise point out (1993, 1994), "How do we formulate reasonable hypotheses about the future?". While it is clear that any major change(s) in aviation technology and its operational environment will serve to render the knowledge gained from the past less useful, it is reasonable to assume that, for the immediate future at least, pilots and support crews will continue to have to contend with many, if not all, of the problems and challenges that plague them today.

How Will We Know When We Get There?

None of the position papers submitted for this workshop addressed directly the issue of quantification of progress. However, in view of today's heightened concern for fiscal prudence, it would seem appropriate that some thought be given to setting criteria which would define when the system has reached maturity, when it still has a way to go, and when it has gone beyond the minimum necessary to insure successful implementation. Statistical minimums for levels of significance should be considered for such attributes as validity and reliability. How will we know when we have moved far enough away from a punitive investigation philosophy toward a positive climate of free exchange of accident avoidance data collection? Is it possible to establish benchmarks which can assess the adequacy of the taxonomy established and/or the model(s) selected as the analytic framework? How much predictive power is enough? Sooner or later it is highly likely that such issues will require, perhaps even demand, answers.

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4.2 DATABASES FOR EFFECTIVE SAFETY ENHANCEMENT - *AIR LINE PILOTS ASSOCIATION*

We must work with our databases to identify incident trends in order to prevent future accidents. Past studies have concluded that human factors issues are prevalent in nearly every accident. We must recognize those issues prior to experiencing a catastrophe in order to avoid accidents. This can be accomplished through the use of air safety databases. These databases may contain not only basic information about incidents but also details of past accidents, information regarding mechanical discrepancies, and uneventful hazards avoided by luck and/or skill.

Many organizations have established and maintain databases to track and analyze occurrences of specific interest. Efforts must be made to standardize the information recorded with the goal of sharing database information among many organizations. This would result in the development of a master database which could then be used to identify trends by many organizations. Of course, prior to the implementation of such a master database, sever hurdles must be overcome, including confidentiality, security, and legal issues.

Introduction

The Air Line Pilots Association was founded in 1931 under great secrecy, with fear that discovery of a pilotÕs membership in the Association could cost the pilot his job. Now, membership is displayed proudly with the ALPA pin, and we now have membership in 38 airlines of over 42,000 pilots. Since its early years, our AssociationÕs motto has been, ÒSchedule with Safety.Ó

The Air Line Pilots Association has an extensive safety organization that works to support each individual airline as well as the airline pilot in general. Each airline has a Central Air Safety Chairman (CASC) that has been designated by that airlineÕs elected officers. This CASC forms a safety network within his or her airline that is responsive to their membersÕ individual needs. Also, the CASC participates in meetings with the Central Air Safety Chairs from the other airlines represented by ALPA, to discuss and make recommendations for safety issues common to all airlines.

At the top of this group of Central Air Safety Chairs is the designated Executive Central Air Safety Chairman. As with each Central Air Safety Chair, the Executive Central Air Safety Chair (ECASC) is also a full-time line pilot. Within the scope of the ECASC is the formation of Technical Committees that address issues of national scope. These include the following committees:

> Accident Investigation Board
> Accident Survival Committee
> Air Traffic Control Committee
> Airport Standards Committee

Airworthiness & Performance Committee
All Weather Flying Committee
Aviation Weather Committee
Charting and Instrument Procedures (CHIPS) Committee
Dangerous Goods Committee
Human Performance Committee
New Aircraft Evaluation/Certification Committee
Noise Abatement Committee
Pilot Training Committee
Regional Airline Committee

These committees work on issues common to all the pilot membership. Members are assigned to the committees from the airlines to ensure broad representation. There is a technical staff in Herndon, Virginia at the main ALPA offices that assist these technical committees to interface with the government and industry.

In addition, there is a Regional Safety Chair structure that addresses issue common to geographic regions. These regions generally match the FAA regions, and within their scope is the oversight of the airports and the Air Traffic Management in the region.

The Association has an award winning magazine, _Air Line Pilot_, that is distributed monthly to its membership. The contentÕs focus emphasizes advances in air safety and flight technology; industry developments; labor union information; and regulatory and economic issues affecting the airline industry and the airline piloting profession.

An Air Safety Hotline is provided for the membership to use in calling in accident, incident, enforcement events, as well as any other pilot reports of safety problems. This is the link between the line pilots and the technical staff. It serves the caller having been involved in a safety incident, and the technical committees and staff as a communications channel.

The ALPA Air Safety Structure is complex interwoven network of expert pilots and staff that coordinate to advance air safety. The efforts of this structure go towards solving both day-to-day issues and advancing the state-of-the-art within the aviation community. In support of these efforts, ALPA has available for members use numerous aviation databases. These databases are constantly evolving, and are used to assist in developing documentation for our proposals for safety improvements.

ALPA believes that good use of databases can greatly aid in reducing the number of aviation accidents that occur. ALPA feels that it is critical to input as much information as possible into, and review these databases on a regular basis. Such activity will assist the Department of Transportation in reaching its goal of, ÒZero Accidents.Ó We suggest that the way to prevent accidents is to investigate incidents. An incident is a potential accident where the crew did something to avoid the accident. The information from the incident investigations, if stored in a database with sufficient detail and an extensive set of keywords, should serve to identify issues for changes before they cause an accident.

In order to be successful in achieving this goal, air safety databases must be standardized and refined. The databases need as many accident and incident reports as possible to be an effective tool in spotting trends. The databases will need to be user friendly enough to have reports entered easily. A common set of variables and their formats will also aid greatly in increasing the number of reports. This will make the data available for sharing among collection points. Also, there will always be a need for the data recording to be objective and uniform in its description of an event.

With these issues in mind, however, there also needs to be work done to remove some of the barriers that hold back database utilization. These barriers include the exclusion of data submitted to these databases in the discovery process of litigation, and the de-identification of the data sufficiently to prevent application of the data for purposes of competitive advantage.

Proactive utilization of comprehensive incident databases could lead to preventing numerous accidents, improving safety for all in aviation.

Databases Utilized By Alpa

The use of databases within ALPA is for the purpose of supporting the air safety activity. In this realm, this includes discussions involving the government and industry on proposed regulatory changes. Databases are also used in the process of identifying past trends and documenting accident investigation causes. Finally, air safety databases are used to resolve pilot reports of safety problems. The databases function in support of explaining reasons for recommended safety improvements.

The databases used within ALPA for air safety span numerous sources. The Aircraft Information Services Limited (AISL) database covers accidents where the airframe was destroyed or substantially damaged, and begins with the introduction of jet aircraft. It is an international set of data and is focused on airframe histories. This database is often useful in tracking a particular aircraft, or identifying trends associated to the hardware design of the aircraft.

The Service Difficulty Reports (SDR) are also used by our Association. These are reports from the mid 70Õs to present, and focus on hardware anomalies among national (flag and domestic) carriers. The purpose of this data is also to identify trends in aircraft hardware failures.

The Civil Aviation Authority (CAA) of the United Kingdom provides data on accidents from the mid 70Õs. This scope includes international flights involving all commercial aviation. This data is beneficial for its thorough documentation of the accident event.

Also used within ALPA is the recently acquired NASA Aviation Safety Reporting System (ASRS) Database. This is a large dataset, consisting of approximately 40,000 full event descriptions over the last five years, and over 140,000 abbreviated event reports. The reports can span all of aviation, but are mostly focused on issues of regulatory nature, as the program includes a feature providing for immunity from penalty for most regulatory violations. The purpose of this database is to provide candid reporting of safety hazards without fear of backlash that could cost the pilot their job.

ALPA also uses a database to manage the calls made to the ALPA Air Safety Hotline. This program utilizes the British Airways Safety Information System (BASIS). The reports in the database date from the mid 80Õs to present, and involve events and reported problems that are identified during line operations. The database is utilized to identify trends that may lead to accidents and incidents, and to resolve repeating issues without having to retrace all the steps discovered in prior efforts. This data is useful for problem resolution at the local, regional and national level.

4.2.1.1A new database that may be used in the future involves the Flight Operations Quality Assurance (FOQA). This data is in-flight recorded data from onboard monitoring systems. It could be used to analyze trends, and improve air safety. It could influence accident investigation, pilot and crew inflight performance, training, performance, air transport operations efficiency, air traffic control enhancement, and aircraft and airport design.

Suggested Evolution of Features in Air Safety Databases

ALPA recognizes that the industry is changing, but on the other hand, some aspects seem to remain the same. Thus, we must be able to use our databases in both aspects, examining both the long term and the short term, as appropriate. In order to do so effectively, we must make efforts to improve our databases, so they can perform effectively. We suggest a review of air safety databases by their users should consider changes to improve standardization, data sharing, and protecting data from inappropriate use.

There is a significant need for the databases that can be shared with other air safety organizations. In order to accomplish this, the data must fit a common format and use a common set of keywords. Those keywords must mean the same thing to the parties exchanging the data. We suggest that to accomplish this, there should be a convergence of safety database representatives under the guidance of experts in intelligent systems, to establish a system for event description that combines the conflicting goals of simple-to-use and thorough-and-objective. The results of such a meeting could be made available in an Advisory Circular or other guidance material. A depository could be established that allowed participants to tap into the database for their evaluation of safety issues, as necessary.

ALPA suggests that provision of a depository for air safety data is the best way to get more data. Getting more data can be beneficial by making trends more clear. But the trend only becomes clear if the description is lucid. A vague or inappropriate description will not aid in establishing a set of supporting documentation to an expected safety problem. So there is a tradeoff again, between getting more data and having the data be of sufficient detail and clarity to assist by being applicable to the situation at hand.

There is a chance that there also will be a chasm between the need for sharing data and the need for protecting proprietary data. In our organizationÕs pilot report database, we de-identify the airline identifier. There may be reason to know the carrier is the same if a trend caused by their procedure or training caused the trend. Yet, this could be addressed within the airline. Finally, another way to address this issue could be to trade refinement in one area for increased vagueness in another area. For example, the request to group the data by common carriers could be made to be limited to training events, or to non-specific aircraft. Overall, what this discursiveness comes down to saying, is that we must restrain our use of this data to only address safety issues.

Flight Operations Quality Assurance (FOQA)

The use of the data from line operations as proposed in FOQA is a critical activity, with great potential, according to some advocates. We can understand such excitement, but wish to have it clear that there are also great concerns over the use of this data. Such data, if applied maliciously, could easily be career threatening. The intent of FOQA clearly is to improve safety and prevent accidents. Thus, it should be limited to improving and not destroying careers.

ALPA sees a need for FOQA to ensure any event that is evaluated is compared to a valid facsimile of the comparable events. It is essential that the data collected from the sampling in FOQA is determined by law to be unusable in the discovery process. The data itself explains what happened, but also needed is an explanation of why the event happened. As such, a mechanism for prompting the submission of ASRS reports to go with flight data sampling would aid in providing this. Absence of such linkage will probably cause the reasons behind performance anomalies to remain unexplained.

Conclusion

There is a definite need for proactive use of incident data in identifying ways to prevent further similar incidents before an accident occurs. Data needs to be gathered in a format that will be uniform and objective, detailed and clear, that can be used to determine if a proposed fix will resolve the problem. Sharing of data will increase the chance of discovering the trends, but sharing needs to be done in a way that we do not mix unlike events. Security of the data needs to be a priority.

4.3 INCIDENT INVESTIGATION: PARADIGM SHIFTS TOWARD EXPLOITING SUCCESSFUL HUMAN FACTORS INTERVENTION STRATEGIES TO PREVENT AIRCRAFT ACCIDENTS - Ludwig Benner, Jr., P.E. and Ira J. Rimson, P.E.

Ludwig Benner & Associates
12101 Toreador Lane
Oakton, VA 22124
(703)758-4800

The Validata Corporation
P.O. Drawer 1315
Springfield, VA 22151
(703)978-2944

*"Admittedly, most crashes these days are blamed on pilot error; an analysis two years ago showed the behavior of the flight crew as the dominant cause of 60% of crashes. But this is somewhat misleading since **it includes crashes which the crew failed to avert after something else had gone wrong first**."* (Emphasis added) *Ñ The Economist*, April 8th, 1995, p. 71.

Position

Specific incidents, analyzed scientifically, will immediately identify successful interventions which have averted accidents, from which effective prevention strategies can be directly derived.

Problem

The objective is to reduce the incidence and severity of aviation accidents and incidents by formulating changes to human behavior which contribute to those adverse outcomes. Historical approaches have failed to achieve enduring modification of errant behavior. Traditional paradigms must be altered to overcome the inherent inadequacies of prevailing mishap origination concepts and investigation methodologies.

> *"If you do what you did,*
> *you're gonna get what you got!"*
> - Yogi Berra

I. Background

A. Current mishap investigation approaches, objectives and methodologies:

- ¥ Originated in 1930's by U.S. Civil Aeronautics Board, based on legalistic concepts of culpability and liability.
- ¥ Evolved to fulfill statutory and regulatory demands rather than scientifically-based accident prevention requirements.

¥ Mandate finding of "probable cause(s)" as the primary goal for mishap investigation, which diminishes prevention initiatives.

¥ Focus on problems rather than on actions which overcame problems, failing both to prevent recurrence of old causes or emergence of new problems.

¥ Define "accident" or "incident" in terms of relative outcomes, which are irrelevant for identifying data significance or analyzing processes leading to the outcomes.

¥ Trivialize mishaps in which surviving participants could describe the process by which they prevented catastrophic outcomes.

¥ Lack investigative standardization, therefore lack the capability to measure or control either internal quality or inter-investigation consistency.

¥ Accept uncritically all data sources and formats without applying standards for verification of individual data elements, corroboration among data elements, or validation by scientific testing.

¥ Discourage candid, objective contributions by subjecting surviving participants to negative judgmental evaluation.

¥ Lack methodology for recasting anecdotal or episodic data into scientific format, therefore lack ability to discriminate among variables with sufficient certainty to verify statistical inferences.

B. Current analytic approaches, objectives and methodologies:

¥ Do not require variables to be normalized.

¥ Accept data at least four levels abstracted from observation as statistically valid:
   1. Investigator's descriptions of observed data
   2. Report format and statistical category designers' assumptions
   3. Investigator's interpretations of descriptive data to fit undefined format criteria ("Fill out the Form")
   4. Data analyst's reinterpretations of formatted data to fit undefined statistical category criteria

¥ Render reliable statistical inference and productive safety recommendations virtually impossible because of high level of abstraction of safety data.

II. Human Factors/Human Error Models

A. Traditional

   1. Prospective
          ¥ Probabilistic Risk Assessment
          ¥ Fault Tree
          ¥ Error-tolerance Limit

    2. Retrospective
        a. Qualitative
            ¥ MORT
            ¥ "Root Cause"
        b. Quantitative
            ¥ Epidemiology

B. Innovative

    1. Reason: Latent vs. Active failures
       ¥ "Windows of opportunity"
    2. Perrow: "Normal" accidents
       ¥ System complexity vs. coupling density
    3. Ratner: Enhanced Safety Net
       ¥ Facilitating Operational Situations/Predisposing Underlying Factors
    4. Benner: Multilinear Events Sequencing
       ¥ Event Pairs and Logic Testing

C. Common requirement of all models: A scientifically accurate description of
      WHAT HAPPENED? - *what people did* to produce the outcome Ð
          is seldom formulated by current post-facto investigations.

Investigations must provide data from incidents or accidents to determine:

    ¥ Who did what, when, where, how and why?
    ¥ What specific behavior increased the likelihood of an undesired outcome?
    ¥ What specific behavior mitigated or prevented the undesired outcome?
    ¥ What behavior is preferred within the operational context?
    ¥ How can the preferred behavior be achieved?

III. Real-World Problems of Data Relevance, Quality, Quantity and Accessibility

A. Relevance. Investigation outputs must, at minimum, include compatible descriptions of:

    ¥ What was supposed to happen?
    ¥ What did happen? -- yet frequently do not.

B. Quality and quantity.

    ¥ Post-accident investigation data rely principally on second-hand (or more abstract) sources, inferences or opinions, and rarely exist in sufficient quantity or quality to fulfill requirements without interposing abundant unverifiable conjecture.
    ¥ Incident investigation affords opportunities to obtain first-hand data directly from partici-pants, including how they perceived deviations from plans, diagnosed effects of devia-

tions, evaluated and selected among alternatives, and evaluated consequent intervention actions and their results; in short, the entire process by which the incipient accident was mitigated to achieve an acceptable outcome. [ref. "DECIDE" Model - *see Hendrick, Benner & Lawton (1987) and Lawton, Benner, Clarke, et al (1987)*]

C. Accessibility. Two mutually exclusive problem areas exist:

  1. Accessibility of data possessed by mishap participants:
  ¥ Current "Attitude" paradigm focuses on error, blame and liability, providing little motivation for survivors' willing cooperation. "Parties" to post-accident investigations commonly restrict participant employees from candid interviews, and interpose strict legal oversight to protect their perceived vulnerability as potential litigants.

  2. Accessibility of information/data possessed by investigation agencies:
  ¥ Judgmental "Attitude" paradigm leads to restrictive covenants between investigation agencies and participants/witnesses which inhibit flow of data needed to fulfill current statistically-driven database approach to problem definition.

As a result of both problem areas, numerous independent incident-derived data bases have been established and are maintained by manufacturers and operators for "proprietary" internal risk management programs, which are rarely shared for prevention purposes.

IV. Alternative Approach, Objective and Methodology

A. The aviation community's quest for a reality-based initiative designed to reduce the incidence and severity of aviation accidents involving human factors will be better served by:

  1. Adjusting the "Opportunity" paradigm from "Post-accident" to "Pre-accident"; i.e., redefine "accident" and "incident" from mere outcome attributes to functional process descriptors: e.g., *"...an incident is an incipient accident which failed to attain its full potential because of successful intervention by persons, things or fortuity within the system."*

  ¥ Redirect data acquisition concentration from accidents (which identify "causes" or operational failures) to incidents (which identify both operational failures and successful recoveries therefrom).

  2. Adjusting the "Attitude" paradigm from Negative: "What Went Wrong to 'Cause' the accident?" to Positive: "What Went Right to Prevent it?"
  ¥ Acknowledge both the ubiquity of human error, and human capability to recover from errors. Redirect resources toward successful intervention processes which thwart accident progression, thereby focusing on adaptation to error rather than error perpetuation.
  ¥ Expand investigations' focus to include positive factors. Encourage witnesses to provide accurate data for constructing effective prevention strategies, in contrast to defensive

"CYA" strategies fostered by current judgmental perspectives which emphasize failures and errors.

3. Adjusting the "Investigation Methodology" paradigm from "Investigator's Option" to standardized investigation techniques which generate scientific data formats, permit critical data analyses, and allow data to be evaluated against measurable quality standards.

¥ Institute data input, process and product quality standards and controls.

¥ Solicit, document and collect actions during actual successful anecdotal and episodic experiences to obtain timely source data for defining prevention initiatives which actually worked.

4. Adjusting the "Data" paradigm from unscientifically-defined statistically-driven data base fulfillment to direct observation, recasting the raw data into scientific formats accessible to quality control, verification and confidence-testing procedures.

¥ Use observed data both to devise and validate models of successful error compensation. Current theoretical models employing abstract data categories or forms as templates drive investigation data selection and analysis, and are rarely (if ever) subjected to validation or verification testing.

¥ Compile participant-sourced data from intervention-focused investigations which identify successful accident mitigation tactics immediately and accurately, and are self-verifying. Current error-focused investigation data deficiencies beget unverifiable assumption and conjecture about opportunities for error avoidance or response.

¥ Require accurate process timing data to support time-sensitive modeling methodologies; e.g., Perrow's "coupling density" and Benner's STEP/Multilinear Events Sequencing.

5. Adjusting the "Analysis" paradigm from current styles which are incapable of identifying defective data and rely on normal statistical methods, to techniques which enable investigators to define and describe interactions and interfaces accurately and reliably.

¥ Recognize necessity for "Rare-Event" statistical treatment, including techniques for recasting anecdotal and episodic data to permit valid statistical treatment.

¥ Measure "What happened?" against "What was supposed to happen?" to establish disciplinary relevance boundaries, and identify when incipient accident-processes begin, not merely where they end.

V. Recommendations

1. Redirect FAA investigative resources to develop more useful data about successful intervention actions during incidents, rather than investigating relatively data-poor NTSB-delegated mishaps.

2. Standardize investigation methodology to facilitate exercising objective quality controls on data and analyses.

3. Require that investigation methodology include accurate chronological data to define events and relational logic within the mishap process.

4. Establish a reporting process which
   a. encourages operational level persons to submit their incident experiences and anecdotes directly and immediately, and
   b. captures their data in a format that enhances the data's accuracy and utility with minimal need for editing or manipulation.
   (This could easily be an enhancement of the current NASA/ASRS.)

5. Establish a centralized repository through which participants worldwide can contribute and extract data and information.

7. Conduct prompt triage on anecdotal and episodic data to identify incidents which hold high potential for producing useful intervention actions. Analyze those incidents and provide priority feedback to operators who can benefit therefrom.

8. Enhance the accuracy and quality of scientific investigations to improve the efficacy of their outputs by establishing a single independent government-sponsored National Investigative Agency to replace the myriad organizations currently conducting unstandardized investigations which fail to achieve established quality management objectives. A dedicated national agency, staffed by professionally educated and trained investigators intimately acquainted with quality management, could overcome parochial bias and enhance investigations' effectiveness in preventing recurrence of mishaps of national influence. Core investigative expertise would be reinforced on a case-by-case basis by technical specialists from appropriate regulatory and operational agencies.

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4.4 HUMAN ERROR IDENTIFICATION: DESIGNING FOR THE USERS - Marilyn Sue Bogner, Ph.D.

Food and Drug Administration

Even though human factors efforts have been directed to reducing the likelihood of human error in **a** number of domains, accidents attributed to human error persist. If human factors efforts can affect the incidence of error, then the lack of their effectiveness may He the identification of the factors contributing to error. This paper addresses that possibility by presenting a human factors approach to the identification of factors that contribute to error and the development of error prevention strategies whether they involve training, design of new equipment, equipment modification, or policy change.

The following discussion describes an error data collection effort designed to provide sufficient information to identify the problem and target prevention strategies to specific factors that contribute to the problem. This involves two techniques: grounding the data collection effort in the perspectives of the user populations, and applying a systems model to the design of the data collection, analysis, and applications of the findings..

It should be noted that although this paper discusses the human factors approach in terms of developing a data collection effort, the approach also can be used to structure and analyze existing data collection activities. The effectiveness of the approach in existing activities is limited, however, because the perspectives of the user populations almost certainly were not considered in the development of the effort. The importance of those perspectives is addressed in the next section of this paper.

A number of steps are involved in developing an error data collection effort and identifying preventive strategies based on the findings from the data. For the purpose of this paper, the steps include: defining the problem, decomposing it into its constituent parts, determining the appropriate data to collect, devising a means for collecting data that will address the concerns of the users, and analyzing the data to provide meaningful findings. Those steps organize the following discussion of an empirically based, domain-free set of data elements which can be augmented to address the idiosyncratic issues of any specific domain.

Problem Definition

The definition of human error for the purpose of this paper is an amalgam of dictionary definitions of error: *Human error is an act, assertion, or decision that deviates from a norm and results in an actual or potential adverse incident. That incident may or may not eventuate in an adverse outcome. The norm which defines an error is consensually accepted by the constituents of the domain under consideration An error may reflect a number of factors or may, be the final act in a series of contributing errors, i.e., a cascade of errors.*

There have been a number of refinements of the term human error. The rubric of error has been differentiated into slips and mistakes (Reason, 1990) as well as being linked to a level of performance as in AM-based, rule-based, or knowledge-based activity (Rasmussen 1986). To have a simple definition of error for ease of conceptualization and discussion in this paper, those refinements although admittedly useful for more detailed considerations, are not addressed.

Human error is not unique to any one domain. There is ample documentation of human error in industries such as aviation, nuclear power, and health care. The observation that error is ubiquitous and has been over time is confirmed, albeit only for a certain class of error, by the existence of a mechanism in the human brain that is dedicated to monitoring a person's performance and compensating for errors (Dehaene, Posner, and Tucker, 1994). The class of errors which activates this mechanism is that of errors detected in time for a correction to be attempted, i.e., near misses.

Errors that are near misses should be considered in an error data collection activity because what is a near miss for one individual may be a fatal error for others. Information on near misses can only be captured from the person experiencing the error. Similarly, information about what actually occurred in any error can best be provided by the person experiencing the error. The perspective of those who experience errors, i.e., those who use the data collection instruments by responding to them is rarely considered. Typically, the users of data collection activities are presumed to be the professionals who collect and analyze the data.

The data collection and analysis activities described in this paper, consider the perspective of two groups of users: those who report the information and those who use the information. If the information from the former group of users isn't viable, then the products from the latter group may not be accurate and lead to ill conceived preventive strategies. Because the perspective, of the information providers is central to the success of a data collection effort, the data collection activity should be designed and organized for relevance and acceptability by the respondents as well as providing the necessary information to the data collectors. The inclusion of the perspectives of both groups of users throughout the ensuing discussion is implicit when not explicit.

Errors are broadly categorized by their outcome: an adverse incident which nearly occurs, i.e., a near miss; an adverse incident which occurs, but its impact is immediately reversible; an adverse incident with an adverse outcome lasting 3 months or less; an adverse incident with a long term (more than 3 months) adverse outcome; and an adverse incident resulting in death. This paper addresses only errors which are quantifiable either directly or indirectly. Near misses are quantifiable via the report of the person involved. Although efforts to reduce the likelihood of an error and reluctance to report an error are related the severity of its outcome, outcome is only tangentially considered in this discussion of error identification. The focus of the paper is error, not outcome.

Human error is considered as having two components: behavior that is determined to be erroneous, and the conditions in which the error occurred. The broad categories of behaviors consist of acts, assertions, and decisions which may lead to near misses, adverse incidents, or

adverse outcomes. There also are two components to the conditions in which the error occurs: the contributing factors, both proximal and distal and the preceding or anticipated circumstances. This consideration of error inducing conditions is structured by decomposing them into categories of contributing factors.

Problem Decomposition -- Contributing Factors

Given the vagaries of human beings, it is unlikely that error ever will be eradicated. The incidence of error, however, can be reduced by targeting preventive activities to the factors that contribute to it. Those factors can be identified by decomposing the problem through analyzing the conditions in which the error occurred and developing data elements to reflect those factors. Determination of categories of contributing factors can aide this process by focusing the analysis.

An error involves more than the person associated with the error even in the apparent solitary act of decision-making. It is necessary for an individual to have something about which to make a decision. Decision-making entails at a minimum, the psychological cognitive, and perceptual facilities of the decision maker and an entity or set of circumstances to stimulate those factors. Even the most intra-personal/intra-psychic error involves extra-personal factors. This diad can be conceptualized as a system of the individual and the extra-personal factor(s). Thus, error reflects an event of a system. If the basic unit of consideration meets the criteria for a system then it is reasonable that a systems approach be applied to the problem of error identification.

Moray (1994) has proposed a domain-free systems approach that consists of a hierarchy of levels of description. The hierarchy starts with equipment, followed by the physical ergonomics of the equipment, the behavior of the individual using the equipment, team and group behavior, organizational and management behavior, legal and regulatory rules, and finally societal and cultural pressures under which all else operates. These levels assist the analysis of the problem of error identification by providing structure for the decomposition of human error into broad categories of contributing factors.

The literature suggests that there is a core of factors that contribute to error regardless of the domain in which the error occurs. Those empirically based findings are included in the decomposition of problem of error. The well documented error-contributing factor of fatigue (Kreuger, 1994) provides an example. That factor is induced by the conditions such as consistently working extended hours or varying shifts. A preventive strategy directed to the individuals might be to instruct them to spend more of their off-work hours steeping. This is not necessarily a realistic admonition. Using the systems approach, fatigue is considered in terms of its cause, the work schedule, which is within organizational and management behavior. Thus, preventive strategies to reduce the likelihood of fatigue induced error would be directed to the organizational and management component.

In addition to the classes of contributing factors within the hierarchical categories that are common across domains, there are idiosyncratic characteristics of each of the domains. These characteristics are domain-specific foci for the common contributing factors. For example, the

organizational and management behavior category, there is the class of delegation of responsibilities. Delegation of responsibilities for an airline cabin crew with respect to the cockpit crew has different foci from that for personnel in a hospital's intensive care unit with respect to the emergency room staff. To best represent the actual nuances of the contributing factors, the foci should be developed from the respondents' perspective as well as that of the data collectors,

Data Element Determination to Capture Acts and Circumstances

To be relevant, data must reflect the problem being addressed, i.e., human error. This involves capturing information about the erroneous act or behavior and the circumstances, the context of the situation in which the act occurred from the perspective of the respondent. For the purpose of this discussion, the situation in which the error occurs can be envisioned as a vertical representation of the contributing factors within the categories of the systems approach. The circumstances are factors in preceding or anticipated situations which contribute to the error. Circumstances can be represented on a horizontal time line.

The circumstantial factors do not directly affect the person, yet they contribute to the error. The influence of circumstances is intra-psychic; however, the contributing circumstantial factors can be documented by records of previous activities or schedules of future ones. For example, a person omits a critical step in an operational procedure for no apparent reason, i.e., the work conditions are as usual with no observable stress or fatigue and the equipment being operated equipment is familiar. Analysis of circumstances finds that the person observed a fatal incident the previous week and is scheduled to use the equipment that was involved in that incident during the next day. This could be pre-occupying the person and contribute to the omission. Further information should be gathered and preventive strategies developed.

To provide as complete a picture as possible of what leads to human error, the elements of an error data reporting activity should tap into the respondents' experience with the erroneous acts and the contributing factors in the specific situation and circumstances in which the error occurred. The elements should be designed so the respondents provide sufficient detail about the error and the context in which it occurred to identify all contributing factors. Those factors then can be organized into the system categories for analysis and use in targeting preventive strategies.

Because every aspect of human endeavor evidences behavior that is judged erroneous, it can be assumed that some consistency in characteristics of erroneous behavior exists across domains. This consistency can be found in ongoing research and training activities in various domains as well as in the empirical literature. Similarly, because the conditions in which errors occur are finite and even similar across domains, it can be assumed that classes of factors that contribute to that behavior might be identified. In addition, there are intra-personal consistencies across errors and situations. For example, some people tend to blame themselves for an error when the contributing factors actually are external to them These people are considered to be intrapunitive rather than extra-punitive (Sellen, Senders, and Russell in press). Data elements should be designed to address this tendency as well as other consistencies.

Given that the purpose of the data collection activity is to develop prevention strategies to reduce the likelihood of the error, it is imperative that the data elements elicit information which after appropriate analysis, indicates the conditions in which the error occurred and the contributing factors. It is not uncommon that data collected by a problem reporting system reflect the occurrence of a problem with only the readers' imagination to determine the contributing factors. An example of such a report is: "Person X experienced **a** severe injury when person Y raised widget Q on which X was standing. Widget Q was inspected and found to be functioning in accordance with its specifications." Such a report would be interpreted as indicating that human error was the cause because the equipment, widget Q, was functioning according it its specifications. What prevention strategies might be developed from this information?

Numerous comparable reports may be received from a reporting system which collects data as in the previous example. From such data, it can be stated that human error with Q caused severe injury in Z number of instances. Although providing information for summary statistics, these data provide no viable information to address the problem. That is, no information is provided to identify: what aspect of Q might contribute to the problem any deficiencies in the skills and abilities of Y, circumstances of the work environment that affect Y's behavior, or contributing factors in the process of using Q that contributed to the error.

The example underscores the importance of data elements that provide sufficient, appropriate information to accomplish the purpose of the data collection activity, i.e., develop prevention strategies. In addition, data elements should be designed in a way to elicit information from the respondents, i.e., the data elements should be acceptable to the users of the data collection instrument. The phrasing of the elements should be unambiguous, the elements should be simple and concise, but not preclude detail. The elements within the categories of contributing factors should stimulate the respondent to address all aspects of the situation. The elements should elicit extra-punitive contributing factors from intra-punitive respondents.

In striving to develop data elements from the perspective of the respondents, it is necessary to consistently consider the issues of quality and quantity of data elements from the perspective of the other group of users -- those who will code and analyze the data and ultimately use the findings to develop strategies to prevent error. The elements should be designed for ease of coding yet be amenable to the respondents. The elements should allow the response to be focused, yet allow for elaboration that can be readily coded.

Both groups of users should be involved in the final determination of the data elements. Previous data collection efforts in the domain under consideration and other domains to the extent possible, should be analyzed and lessons teamed, both positive and negative, applied to the current activity. This provides an expanded empirical basis for the data elements.

Data Collection

To optimize the effectiveness of the data collection for both groups of users, it is necessary to design and implement that activity in accord with its purpose of obtaining information about error. Collecting error data has particular problems; there is a major accessibility issue of the repercussions from reporting errors. Given the current. propensity of our society to solve all problems through litigation, the possibility of personal liability from error reporting is a non-trivial factor in collecting error data. Common parlance is that the Aviation Safety Reporting System (ASRS) has successfully circumvented that concern to a considerable degree. Thus, the ASRS provides lessons teamed that are valuable to all domains involved in collecting error data.

Another facet of effective data collection is that of accessibility of the data reporting instrument to the respondent. If the means for reporting data is not available or is inappropriate for the task, then it won't be used and even the most sensitive data elements are for naught. A paper form has high accessibility to the user whereas a computer terminal may be relatively inaccessible. Information from the paper form particularly a written narrative, may be very difficult to read, resolve ambiguity, and code. Direct entry into a computer is readable, however, coding of a narrative remains a problem.

For accuracy and completeness, data pertaining to an error should be collected as close to the time and location of the error occurrence as possible. These qualifications argue for collecting data via a palm-top computer or possibly a small lapel-mounted tape recorder from which the data would be transcribed and coded to conform to the data elements. The miniature computer and the transcription and coding of audio recorded error descriptions probably are not feasible due to fiscal constraints. An affordable alternative might be for the respondents to reply to the elements presented on a written form via audio tape which could be computer coded.

How representative the number of errors reported is to what actually occurs within a given domain is of tantamount concern. Under-reporting leads to inappropriate representation of the magnitude of the problem. Preventive efforts based on under-reported information although well conceived and directed, may not be effective because the portion of the problem addressed is insufficient. This could lead to an effective preventive effort being considered ineffective.

Skewed reporting, i.e., data collected which disproportionately represent one among many contributing factors could lead to preventive activities-'ties that appear to be ineffective for the problem while actually being effective for the aspect of the problem identified, These examples emphasize the importance of thoroughness in data collection and suggest that the process of data analysis be carefully executed so that its potential can be realized.

Data Analysis

Issues to be addressed by the analysis of data should be determined prior to the development of the data elements. Data elements typically address a narrowly defined problem; however,

additional information for a nominal increase in effort might be provided by further analysis of responses to some data elements.

The analysis of data for the development of preventive strategies is driven by the identification of what constitutes error, factors both proximal and distal that contribute to the error, and sources of those factors. Another purpose of the interpretation of the findings from the data analysis could be an explicit as well as implicit evaluation of current preventive activities. That would provide lessons learned information which can be particularly useful for a domain's geographically distributed activities. The information could be applied to a planned activity that is comparable to one implemented elsewhere.

The analysis of data can produce findings which are applied to the purpose of the activity. It also can produce findings that contribute to the research literature. This dual use of data analysis, that of application and research, is iterative (Bogner, 1994). Findings from the data analysis can be used to direct the development of preventive strategies activities to a specific error, and contribute to the, refinement of the data collection activity and elaboration of the models upon which it is based. Those refinements when reported in the research literature can be integrated into the development of other data collection activities within the specific domain or across domains. The process is repeated with further refinement of data collection activities and enrichment of the literature that may be have a number of applications both within and apart from error data collection activities. Such uses of data multiply the impact of resources.

Summary

Rather than error being considered a shameful act to be buried for fear of being punished, error should be considered a flag, an occurrence indicating a problem to be solved. From the systems perspective, an error will persist regardless of the individuals involved until the circumstances that induced the error are remedied. The problem is in the system not the individual so shame and blame are not appropriate. Efforts directed to reducing the likelihood of the recurrence of an error should be directed not just to reducing the error *qua* error, but to redressing the conditions that caused it

There are several audiences for the reports of the findings from the data analysis which are represented by the categories of contributing factors in the hierarchical systems model e.g., organization and management personnel and those concerned with legal and regulatory issues. From those findings, each audience can affect preventive strategies which synergistically can impact the problem In some instances, format organized activity may not be necessary; performance can improve in a performing unit when that unit is given a report of its activity together, with comparison data for comparable units (Barbour, 1994).

Two approaches to error identification were presented in this paper both of which represent the application of a human factors approach to error identification. One approach is that the perspective of each of the groups of users should drive every aspect of the error data collection

activity. The second approach is that a systems model is an effective guide for the development and implementation of the data collection activities and preventive strategies. These approaches not only are parsimonious as advocated by OccamÕs s razor, they are good business because they enhance the impact of scarce resources by building on previous work and affording multiple uses of the findings.

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4.5 FLIGHT CREW ACCIDENT AND INCIDENT HUMAN FACTORS - OBJECTIVE 1

Identify the relevant human factors data elements, or types of data, required for appropriate analysis of flight crew error contributing to aviation accidents and incidents.

The AOPA Air Safety Foundation (ASF) works frequently in concert with various offices of the FAA and other aviation entities to further everyoneÕs goal of reducing aviation accidents. For instance, we are actively involved in producing safety reviews of accidents involving general aviation aircraft. Accidents for specific aircraft models or specific hazards to general aviation flight operations are studied to help other pilots avoid the same problems, whether they are human, mechanical, or environmental factors. In addition to the accident t analyses, each review includes an extensive training outline for instructors and pilots to use in incorporating risk management techniques into their transition and recurrent training. Emphasis is given to those specific areas that the studies have been shown to have a high risk factor.

As extensive as these studies are, however, there are some risk factors that we have not been able to identify because the supporting data is not available. Here are the additional data items that the Air Safety Foundation would like to see collected during investigations of general aviation aircraft accidents. While we realize that it may not be practical to expect NTSB/FAA investigators to be able to obtain all this data, it represents our ideal for research and analysis into accident causes and their prevention.

> Type of weather avoidance equipment installed (radar, stormscope, etc.).
>> Was is functional, in use, helpful?
>
> Type of deicing equipment installed (boots, fluid, electric, etc.).
>> Was it functional, in use, helpful?
>
> Type of ground proximity warning device installed (radar altimeter, etc.).
>> Was it functional, in use, helpful?
>
> Aircraft ÒhomeÓ base.
>
> PilotÕs Training:
>> Year of first solo flight.
>> Date and type of training for each certificate/rating.
>>> (Part 141 school, university, FBO, free-lance instructor, etc.)
>> Date and type of any refresher/transition training.
>> Date and type of any simulator-based training.
>> Date of last BFR and make and model of aircraft flown.
>> Date and type of any safety seminar attended.
>> Level of participation in FAA Pilot Proficiency Award Program.
>
> PilotÕs Flight Activity:
>> Flight times in the last year.

Instrument flight time in the last year and last six months.
Night flight time and time in make/model, last year, last six months, and last 90
and 30 days.
Multi-engine flight time and time in make/model, last year, last six months, and
last 90 and 30 days.

PilotÕs Background:
Marital status.
Highest level of formal education received.
Aircraft accident history.
FAR violations.
Automobile license suspensions/revocations.
Alcohol/drug arrests.
Automobile accidents.

However, any data about specific accidents will become really useful only when corresponding data about the pilots who do not have accidents is also available. A recent joint conference with the FAA investigating general aviation pilot proficiency requirements identified a compelling need for more timely and comprehensive general aviation exposure data. The present FAA annual survey that collects data and estimates statistics has several serious shortcomings that limit its overall value to the FAA and to industry safety organizations.

The FAA estimates the number of hours flown in general aviation aircraft only on an annual basis. The estimate is typically released anywhere form nine months to a year after the fact. Currently, there is no official estimate for the number of hours flown in general aviator for 1994, much less for the early par t of 1995. There are only projections and forecasts for that time period. Although there are some monthly estimates of general aviation activity in the IFR arena and at FAA control towers, in reality general aviation conducts much of its flight activity outside of these environments. In effect, the national has no reliable estimate of how much flying is actually being conducted by general aviation until almost a year has passed. Even then it has only annual data - monthly data is just not available.

Thus a void exists in reliable, timely exposure data with which to relate the more frequently reported safety measures (i.e., accidents, incidents, fatalities, near mid-air collisions, etc.). Analyses conducted without a reliable basis for comparison can lead to erroneous or misleading conclusions. The ASF has consistently found that due to a lack of exposure data in several categories of general aviation activities, many desired studies and analyses cannot be performed. Studies which are done are often based on imperfect data and with too high a reliance on intuition. Our FAA colleagues have acknowledged similar frustrations.

Despite the lack of current exposure data for all of general aviation, the FAA, and to some extent the NTSB and other national aviation safety organizations, continues to release a variety of safety information about general aviation on a monthly basis. These range form NMACs and runway incursions, to accidents and fatalities. In many cases, government entities must make informed decisions based on this data. However, any conclusions drawn form such data must remain

suspect until they can be weighed against how much flying is actually being done. As an example, if the number of fatal accidents declines compared to a hear ago, does this mean that the system is getting safer, or does it mean that less flying is being conducted? Until reliable, current exposure data is available for all of general aviation, we just do not know.

The requirement for current activity data against which to compare accident and other failure data is essential for the production of effective programs to reduce the general aviation accident rate. It is obvious that exposure data is needed on a monthly basis with perhaps more comprehensive data in certain areas.

4.6HUMAN FACTORS RESEARCH INTO COCKPIT/CABIN CREW PERFORMANCE - REBECCA D. CHUTE

San Jose State University and Ames Research Center

The cabin crew on board the commercial aircraft of today are an essential component in pilot decision-making and the prevention of aviation accidents. However, government and industry have persisted in the perception of the primary roles of the flight attendant as service and survivability. Moreover, the cockpit and cabin crews of today have evolved into two distinct cultures (Chute & Wiener, 1994). These factors have resulted in communication and coordination problems which have jeopardized flight safety.

In 1989, 24 people died when an Air Ontario jet crashed on takeoff from Dryden, Ontario due to wing contamination. Despite concern on the part of the flight attendants, they did not notify the pilots because they had been trained to trust the judgment of the pilots and not to question it. Additionally, past experience had shown that pilots treated operational concerns expressed by the cabin crew with disdain. The Board of Inquiry cited the organizational policy of Air Ontario that reinforced the suppression of operational information by the flight attendants (Moshansky, 1992).

In 1988, on approach into Nashville, an American Airlines flight attendant and an off-duty first officer notified the cockpit of smoke in the cabin. The captain was skeptical of their report of smoke as there had been a problem with the auxiliary power unit (APU) on a prior flight which resulted in fumes. This time the problem was the result of improperly packaged hazardous materials. Even when informed that the floor was becoming soft and passengers had been reseated, the cockpit crew persisted in refusing to acknowledge that there was serious jeopardy to the aircraft and their passengers. No in-flight emergency was declared. Consequently, the aircraft was not evacuated immediately on landing, exposing the crew and passengers to the threat of smoke and fire longer than necessary. The NTSB determined the cabin crew used CRM techniques well; however the cockpit crew did not. The NTSB found a "deficiency in communication between the cockpit and cabin crews and expressed concern about the reluctance by the captain to accept either crew member's report as valid or to seek additional information." (NTSB, 1988).

Our past research has shown that crews do not see themselves as one team, but rather as two crews with separate responsibilities This division can result in territorial, and even hostile, attitudes. For example, when on a flight conducting field research, I observed a situation where the refusal of the flight engineer to check out an inoperational lav resulted in the cabin crew withholding food from the pilots. Food seemed to be the only currency the flight attendants had to express their frustration. However, both crews brought the aircraft in on a five-hour leg, and I picked it up on a subsequent five-hour leg. During that flight, the pilots were only given nuts for sustenance out of retaliation. Is it reasonable to assume that in an abnormal situation the crews would have transferred information to each other without hesitation? Moreover, in an emergency would those crew members have instantly united and trusted one another?

We have identified five factors which either created or perpetuate barriers between the two cultures: Historical background, physical separation, psychosocial issues, regulatory factors, and organizational factors (Chute & Wiener, in press). Some manifestations of these influences are: discrepancies in manuals and procedures; attitudes such as distrust, alienation, and skepticism; withholding important safety of flight information due to fear of rebuke or disciplinary action; an unawareness of the otherÕs duties during flight; and insufficient technical knowledge on the part of the cabin crew to communicate with optimal effectiveness and timeliness regarding aircraft anomalies.

It should be emphasized that, in addition to survivability duties post-crash, flight attendants also have a significant *preventive* role which has been discounted. This is where effective bi-directional communication becomes vital. Flight attendants are sometimes privy to abnormal sights and sounds in the aircraft of which the pilots are unaware. Automated flight decks and the two-pilot crew have accentuated the role of the flight attendants in the detection and reporting of mechanical anomalies aft of the cockpit door which was formerly the province of the flight engineer. On long flights, especially at night, flight attendants can play a significant role in aiding pilotsÕ vigilance with periodic checks and conversation. Additionally, the serving of food to the pilots can, and should, be viewed as a safety duty (as evidenced by my flight experience related earlier). It is the safety, rather than the service, duty of the cabin crew to ensure that the pilots are as alert and properly nourished as possible. The cabin crew can also ameliorate potentially serious situations, such as fires, troublesome passengers, and medical emergencies by timely and coordinated actions. Any impediment in the teamwork of the cockpit and cabin crews can lead down a slippery slope to an unmanageable crisis. Currently, the types of data collected (primarily post-crash and survivability data) do not reflect the preventive responsibilities of the cabin crew nor the nature of interactions between the crews and the proactive role of the flight attendants.

In addition to generating our own data, we review accident and incident reports from the NTSB and ASRS. Yet there is a dearth of information collected in any systematic manner on the interface between the cockpit and cabin crews. The NASA Aviation Safety Reporting System has developed, with the assistance of the Cabin Safety Issues Identification Team (Nora Marshall, Pat Coleman, and myself), a cabin crew reporting form that will greatly enhance our knowledge of the safety issues that transpire aft of the cockpit (e.g. turbulence injuries, mechanical malfunctions, passenger disruptions, etc.). Additionally, this information would supplement cockpit/cabin communication reports that are already being received from pilots by giving a more complete picture instead of the limited view currently available. For example, Vicki Hoang and I recently conducted an analysis of cabin turbulence injuries by categorizing and analyzing 79 ASRS reports (Hoang & Chute, in press). However, not one report was a first-person account by a witness in the cabin. Data is also needed that illuminates any flight attendant reluctance or pilot resistance in the information-transfer system.

The importance of the focus of human factors research for the next decade moving into cockpit and cabin crew coordination was underscored in the following statement by Chidester (1993): " The unit of analysis should become the flight deck and cabin crew. Almost every safety problem encountered on one side of the cockpit door soon becomes a problem for the other. Coordination between these parts of the crew has been assumed in the operational community and unstudied by the research community." Additionally, the National Plan for Civil Aviation Human Factors (1995) cites Òcoordination between the flight deck and cabin crews in abnormal situationsÓ as a specific research need. The research begun by Chute and Wiener, necessarily scratches the surface of the deeper investigation needed in

these critical areas. Increased emphasis on the importance of the interface between the two crews, the preventive responsibilities of the cabin crew, a corresponding increase in available, relevant data, and support for future studies will ensure that cockpit/cabin deficiencies do not continue to jeopardize flight safety.

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4.7ICAO VIEWS ON THE APPLICATION OF HUMAN ERROR MODELS TO ACCIDENT AND INCIDENT DATA - STEPHAN J. CORRIE

Chief, Accident Investigation and Prevention Section, ICAO

Summary

Human factors data pertaining to flight crew error is obtained by ICAO primarily from reports of accident and incident investigations conducted by Contracting States. In return, this data is provided to all Contracting States for their use in preventing accidents. The international provisions which deal with the investigation and reporting of aviation occurrences is provided in *Annex 13* to the Chicago Convention and in the *Manuals Of Aircraft Accident Investigation* and *Accident/Incident Data Reporting (ADREP)*. Human factors data elements were upgraded and incorporated into the ADREP computer data base system in 1984. The work reflected the state-of-the-art of investigation authorities in the early 1980's. This initiative resulted from recommendations from the 1979 Accident Investigation and Prevention Divisional Meeting and the ADREP Study Group formed after the meeting.

While many models of human error have been developed for various purposes, there are limitations in the ability to conduct error analyses from human factors data in accident/incident data bases. The causes of human error can be complex and any examination must include the entire scenario in which the error occurred. As a result, it can be very difficult to select a common error model to cover all conditions and circumstances under which error will occur and from which it can be analyzed.

The quantity and quality of human factors information produced in an investigation is dependent on the methodology used to, collect, organize and analyze the data gathered. Of the 183 Contracting States in ICAO, there are vast differences in their investigation capabilities and cultures, and thus in the extent of human factors information contained in their reports. Furthermore, inconsistent ADREP reporting has resulted in ICAO placing more emphasis on human error associated with known accident/incident precedents and scenarios, from which to learn how to mitigate human error, rather than on attempting to look for trends and conduct research using such data.

In 1993, ICAO established the ADREP 2000 Study Group to assist the Secretariat in making several enhancements to the present system. One of these areas pertains to human factors which will involve reviewing the present classifications for adapting it to advances in the human factors field. This work has stagnated and ICAO is eager to obtain the additional support needed from those States which nominated the members on the study group in order to successfully complete the work.

 ICAO will continue to improve its ADREP system and is interested in any further progress made by States and the industry to improve the reporting, collection and classification of human performance data for understanding the nature of human error and for accident prevention

purposes. In view of the limitations of data models, ICAO must emphasize the importance of activities leading to the development of standardized methods of exchanging safety data as a means to improve international capabilities to identify hazards and safety deficiencies and for formulating accident prevention strategies.

ICAO Safety Activities

Accident Prevention

Of the many issues facing the air transport field, the relationship between economics and safety is enduring. While governments and the aviation industry strive to ensure that commercial air transport operations are conducted in a manner that does not adversely affect safety, economics inescapably plays an important role in the major decisions of organizations in their pursuit of this endeavor. The task of balancing the production goals of an organization against safety considerations is difficult. Yet, managers are in control of finances and resources and, therefore, are directly responsible for managing safety. Accordingly, ICAO has tried to emphasize the need for decision makers to be continually aware of the risks involved in their decisions and of the overall impact these decisions have on the safety of their operations. In this context ICAO established the Flight Safety and Accident Prevention and Flight Safety and Human Factors programs designed to educate and influence the decision makers into becoming better safety managers.

In 1984, ICAO published the *Accident Prevention Manual* to assist States and their industry, to understand the concepts and activities involved in accident prevention and to develop a system and programs designed to identify, eliminate or control aviation hazards before they result in accidents. Attempts are being made to update this manual based on successful prevention initiatives in States. In addition, a draft Assembly Resolution has been prepared calling on States to improve accident prevention and it will be on the Assembly agenda for its meeting this September.

Human Factors

As a result of Assembly Resolution A26-9 in 1986, ICAO implemented the Flight Safety and Human Factors program. The objective of the program is to improve aviation safety by making States more aware and responsive to the importance of human factors in civil aviation through the publication of practical human factors material and the successful measures developed and taken on the basis of experience in States. It focuses on the organizational aspects of the aviation system and on the essential role played by management in fostering a system tolerant to unavoidable human errors. In this regard, ICAO recently published Digest No. 10 - *Human Factors, Management and Organization*. ICAO is also fostering the development and use of practical tools which will help management balance effectively production goals and safety considerations. The program has developed several other digests which provides additional guidance for enhancing the examination of human factors stemming from accidents and

incidents. The program complements the guidance material in the *Accident Prevention Manual* and helps to integrate current human factors knowledge in prevention methodology.

Accident and Incident Investigation

ICAO published many years ago the *Manual Of Aircraft Accident Investigation* to assist States in conducting investigations in accordance with the provisions in Annex 13. The manual outlines the procedures for organizing and conducting an accident investigation and contains detailed information on how to apply many of the specialized areas of investigation. While the manual has been amended, its last major edition was in 1970. Based on recommendations of the 1992 Accident Investigation and Prevention (AIG) Divisional Meeting, an expert group called the Accident Investigation Methodology Study Group (AIMSG) was formed to assist ICAO in improving the format of the final written report, an appendix to *Annex 13*, in order to encourage examination of the deeper, systemic causes of accidents. The group is also tasked with updating the investigation manual. The study group met in April of this year and made substantial progress in these two areas. A complete new edition of the investigation manual is expected to be drafted by the end of 1996 and published in 1997.

ADREP System

The implementation of the ADREP system in 1976, was designed to provide computer-generated information routinely on the circumstances and causes of accidents and incidents, as determined by national authorities, for use in the technical work program of ICAO and for dissemination to Contracting States for prevention purposes. The success of this program is dependent on the consistent reporting of aviation occurrences and on the dissemination of the ADREP bi-monthly Summary reports from ICAO to Contracting States and the industry.

An upgrade of the human factors data elements in the ADREP computer data base system was made in 1984. It reflected the state-of-the-art by investigation authorities in the early 1980's and resulted from recommendations from the 1979 AIG Divisional Meeting and the ADREP Study Group formed after the meeting. As a result of recommendations from the 1992 AIG Divisional Meeting, ICAO established the ADREP 2000 Study Group in 1993 to assist the Secretariat in developing an expanded, integrated incident information system, based on ADREP classifications.

ICAO has co-operated with selected States, through the informal International Data Exchange for Aviation Safety (IDEAS) Group, in the development of a standardized data exchange interface with its members. ICAO has consulted with this group and members of the ADREP 2000 Study Group (ADREPSG) to determine the scope and structure of the additional incident data to be collected. It is envisaged that an integrated accident/incident data base will be created by the end of 1996, but this new data base will require additional support from the study group members to achieve this objective.

It is essential that an integrated system for collecting and disseminating accident and incident information be developed in order to address more effectively safety hazards and deficiencies in

the air transportation system. The study group is reviewing existing accident and incident data bases, on-line access and statistical methods as the basis for developing this new integrated system. One of the other areas under consideration is human factors which will involve reviewing the present classifications for adapting it to advances in the human factors field.

The ADREP system has recently been upgraded with new hardware and software which will provide it with the capability to furnish better access to timely integrated safety information. The AIG Section, which operates ADREP, is now linked to the Internet mail system and is an effort to improve the section's capability to communicate with States more efficiently. This system has been used for about one year on a trial basis. Results are encouraging. States wishing to communicate with AIG are requested to send their communication to: **"rmenzel@icao.org"**.

Data Issues In Analyzing Human Error

Data Relevance

The method of determining the relevance of human factors data as it applies to causes of accidents and incidents is linked to the entire investigation process and the quality of the evidence available. How the available evidence is gathered and examined in an investigation is central to that process and occasionally is an issue among aviation investigator circles. Not only can the investigation results differ from what is needed to satisfy the questions on the ADREP system data base forms, but widespread differences between the investigation capabilities of the 183 Contracting States of ICAO results in difficulties in capturing relevant data on the causes of human error.

The prominent accident model used by Contracting States is the chain-of-events, single to multiple cause. The investigation attempts to identify all the causes that contributed to the chain of events that culminated in the accident. There are limitations to this model and the data provided often tends to describe what happened in the accident, but not why nor why it was not prevented. It should be noted, however, that improvements have been implemented to eliminate the single cause concept and to stress the need for identifying systemic causes as a result of the 1992 AIG Divisional Meeting and publication of Amendment No. 9 to *Annex 13*.

In an attempt to provide better guidance to investigators for investigating and reporting on relevant human factors data from accidents and incidents, ICAO produced Digest No.7, *Investigation of Human Factors in Accidents and Incidents*. The digest focuses on using the model developed by Professor James Reason as a means to help guide investigators in the identification of systemic factors. It also mentions the SHELL model, developed by Captain Frank Hawkins, as a means to help the investigator analyze detailed factors which may underlie human error. An example of an analysis method used by a particular State is included in Digest No.7 and the example involves a test for the existence, influence and validity of the human factors evidence for causal determinations.

Use of Human Error Models

It is difficult to identify all of the foreseeable human factors issues which may require future research. Consequently, it is difficult to design a data base system to answer all potential questions concerning these future issues. The ADREP system contains a wide variety of data elements to satisfy a variety of needs. However, experience has shown that the amount of human factors details presently in ADREP is not adequate for in-depth research into human error. At the same time, it is capable of providing the entire context in which errors occur and can indicate where human factors deficiencies exist in any occurrence. However, the amount of detail found in the ADREP data and final written reports can only reflect the thoroughness and depth of the investigation.

If a human error model is used to develop a data structure for a computer data base, then the data elements needed are collected in an investigation of accidents/incidents to fit the structure required by the model. Consequently, in order to ensure the validity of the data structure, an investigation must be performed so that the expected level of detail concerning human error in an accident/incident sequence can be determined with some level of confidence. This model approach, however, may make it difficult to use the data collected for other purposes and for applying it to other models. More importantly, the model may not provide a full understanding of the accident.

If a model is to be used by ICAO, it must be compatible with the ADREP multi-event causal model and useable by the Contracting States of ICAO. It is essential that data models be kept simple so that they can be easily understood and applied by investigators. Otherwise, investigators may find it difficult to obtain the data elements required by the model. The lack of adequate resources, legal and financial constraints can also preclude collecting all desirable human factors information.

The *ADREP* manual provides guidance to investigators on how to code the evidence gathered in the investigation for input into the computer data base. In addition to the numerous codes that have been developed for gathering routine statistical information, the ADREP system incorporates a multi-event causal model with descriptive and explanatory factors which can describe how and why the accident occurred. As the model applies to the coding of human factors, a variety of subject codes, under the descriptive category, can be used to identify general causal factors. These factors can then be explained further under the category of organizations and persons by using various other subject factors and modifiers. For example, flight crew performance could be identified as a general causal factor by using the ADREP classification, *flight crew procedures/crew co-ordination/inadequate* which could be further explained by using the classification , *operator-training staff-instructor/experience-competence/unacceptable*. The ADREP model is flexible enough to allow for further detail depending, once again, on the depth and methodology used in the investigation. It is only limited to the number of factors which can be developed based on objectives and experience.

The ICAO ADREP causal model is similar to the existing NTSB model. However, NTSB data must be converted using software programs and the results reviewed before the data is added to

the ADREP data base. The ability to use the ADREP system effectively requires training and practice. The manual needs to be updated because of the numerous improvements that have been made since it was published in 1987.

Data Quality and Quantity

In addition to the factors mentioned previously, another fundamental issue affecting quality and quantity of human factors data is whether safety specialists take a statistical approach to identifying safety problems or consider the value of known precedents as more suitable. Depending on which approach is taken will determine, in part, the quality and quantity of data. We do not favor a statistical approach in all cases for reasons mentioned earlier. The use of accident data for statistical purposes is not very helpful because of the limited amount of information available. Moreover, the industry cannot rely on the use of accident data to identify adverse trends. Inconsistent ADREP reporting has resulted in ICAO placing more emphasis on human error associated with known accident/incident precedents and scenarios, from which to learn how to mitigate human error, rather than attempt to look for trends and conduct research using such data. However, the prevalence of incident data is more valuable for prevention purposes and suitable for trend analyses.

There may be limited resources for investigating incidents and minor accidents, thus any data model must also allow for some classification of very general findings so that this limited information is available for analyses. Simplicity is favored. This also helps to ensure that the data collected contains fewer errors.

Identifying Performance

Any taxonomy or model of human error must encompass the psychological, situational and organizational factors which can affect individual behavior. The model should permit assessing the effectiveness of the different controls used by organizations to foster safe and compliant individual behavior. Such controls may be administrative, technical or social in the nature. Errors can be a consequence of inherent human limitations and can result from inadequate communications, policies and procedures. Violations, on the other hand, can either be deliberate or unintentional and occur within a regulated environment. An examination of performance must consider the adequacy of rules and regulations in conjunction with compliant behavior. The objective of assessing human performance should be to encourage and assist organizations to develop controls which are suitable for guiding safe and productive individual behavior within which the organizations operate. This objective should be a part of any accident prevention program. The program will reduce violations by including motivational and organizational remedies, and will foster a safety-oriented corporate culture.

Accessibility

Privacy legislation in several States prohibits the exchange of personnel related information between States. Thus provisions are needed to de-identify the data for international exchange.

Another important problem is the question of whether access should be given to the public at large. Efforts underway to encourage "penalty free" reporting could be jeopardized if the information in human factors related data bases is used for purposes other than accident prevention. In addition, the potential for litigation during the course of an accident investigation can stifle a free exchange of information and prevent access to valuable data.

ICAO is proceeding carefully on the question of making its data publicly available on the "information highway". Information will continue to be provided to authorized officials in ICAO, Contracting States and international organizations in a form suitable for their needs. However, ICAO will have to review its policies on ADREP data dissemination in order to provide more efficient access to this data by the industry.

Conclusions

The relevance, quantity and quality of human factors information from accidents and incidents is dependent on the methodology used and depth of the investigation, and the capabilities of States. Legal and financial factors also play a role. The potential value of human factors information from incidents versus accidents for prevention purposes is unquestionable. ICAO moved forward to stress the importance of incident investigations through Amendment No. 9 to *Annex 13*.

Insofar as this idea is accepted, it must be recognized that there are limitations to conducting error analyses from human factors data found in final written reports and accident/incident data bases from accident and incident investigations. Difficulty in obtaining consistent reporting from Contracting States is another factor in the quantity of human factors information made available from official government sources.

Additional efforts to develop a human error model that is flexible enough to accommodate all error situations and simple enough for investigators internationally, to use to satisfy the data requirements of the model, is a significant challenge to States and the aviation industry. ICAO is not optimistic about success in developing such a model. In view of the fact that extensive knowledge about human error is already available, there appears to be more justification for applying it to mitigate error and limited value in pursuing further attempts to model and study human error in the short term. Although the causes of human error can be complex, any examination must take into account the complete environment, conditions and circumstances under which error occurred before it can be understood. Thus, ICAO will continue to emphasize and encourage the improvement of investigation and prevention processes in States and the industry.

ICAO will continue to improve its ADREP system through the support of the ADREP 2000 Study Group, coordination with the IDEAS Group and the support from States. Thus, ICAO will appreciate the additional support needed to successfully complete the work on the study group agenda from those States which nominated the members. It is very interested in any further progress made by States and the industry to improve the reporting, collection and classification

of human performance data for understanding the nature of human error. In the long term, such efforts as this workshop, could prove beneficial.

Inasmuch as ICAO recognizes the present limitations of investigations and data models, it must reemphasize the importance of activities leading to the development of standardized methods of exchanging safety data as a means to improve international capabilities to identify hazards and safety deficiencies and for formulating accident prevention strategies.

Recommendations

1)   Emphasize the importance of improving investigation and prevention methodologies, processes and skills.

2)   Apply existing human error knowledge aggressively through prevention processes to improve the effectiveness of hazard identification, elimination and control.

3)   Continue developing knowledge about the causes of human error on a long term basis, consistent with technological and operational changes and integrate this knowledge into operations.

4)   Develop easy to use human error data models giving consideration to the difficulties in obtaining human factors data through investigations and to their international application and compatibility with the ICAO ADREP system.

5)   Continue to actively support and participate in the development of standardized methods of exchanging safety data through the IDEAS Group.

4.8 ASSESSMENT OF HUMAN ERROR FROM TRANSPORTATION ACCIDENT STATISTICS - VERNON S. ELLINGSTAD AND DAVID L. MAYER

National Transportation Safety Board

Introduction

Baker and Lamb (1992) have recently reported on a study of commuter and air taxi accidents during the period from 1983 through 1988 they obtained data from the National Transportation Safety Board's Aviation Accident Data Base on a total of 719 fixed wing aircraft involved in 122 commuter and 597 air taxi accidents and subjected these data to an extensive process of analysis. They identified twelve major crash categories (as well as an "other" and an "undetermined" classification) that provided useful groupings of the Part 135 accidents for more focused analysis. They also evaluated each accident record to determine whether factors associated with (a) the pilot, (b) ground personnel, (c)air traffic control, (d) aircraft malfunction, (e) airport conditions, and (f) weather had contributed to the accidents. Pilot condition or pilot error was identified in about 74 percent of these accidents. Human factors issues such as fatigue, improper procedures, and decision errors were observed for individual cases and emerged as safety issues when the cases were aggregated. The Baker and Lamb study provides a useful description of an important class of aircraft accidents.

At last year's Transportation Research Board meeting Hegwood (1992) presented an analysis of general aviation accidents from 1988. She attempted to evaluate the prevalence of human factors issues in these accidents by applying a modification of Feggetter's (1982) checklist to a sample of 50 general aviation accident records in the NTSB data base.   She coded cognitive, social and situational human factors in these accidents after inspecting the NTSB factual reports, briefs of accident and accident narratives. Her analysis identified human factors as contributing to 90 percent of the 50 accident sample, as compared to 82 percent that had been originally identified by the NTSB as caused or contributed to by human factors flaws in information processing (80 percent of the accident sample) and errors in judgment or decision making (66 percent of the sample) were particularly notable findings. Again, this study provides useful descriptive information to the aviation safety and human factors communities by examining aviation accidents in the aggregate.

On October 14, 1992 the Safety Board adopted a study of alcohol and other drug involvement in fatal general aviation accidents during the period from 1983 through 1988. This study revealed a small decline in the number and percent of alcohol related general aviation accidents over the study years, to a rate of about 6 percent in the late 1980s. A slightly higher proportion of alcohol related fatal (to the pilot) crashes occur at night than is the case for fatal to the pilot crashes that do not involve alcohol. Disappointingly, no strong evidence of differential causation between alcohol involved and non-alcohol involved accidents emerged from the study -- that is to say we did not discover human failures that were clearly associated with alcohol impairment in these accident records. This study depended, of course, on factual and analytic data derived from the NTSB Aviation Accident Data Base.

As a final example of what I am sure that you have guessed by now to be illustrations of the application of accident data bases (and their associated accident statistics) I would like to mention a study that is currently in progress in the Safety Studies Division at the Safety Board. This study is an assessment of flight crew performance in Part 121 air carrier accidents determined by the Board to have involved flight crew error. Ben Berman and his colleagues are now in the process of refining taxonomies of flight crew errors that were identified through a detailed analysis of accident data, including factual and analytic records, as well as cockpit voice recorder transcripts and other investigative information. They are also deriving, from the same data sources, empirical characterizations of operational factors such as workload, situational awareness and communication flow whose relationships to flight crew error can then be assessed. We hope that this analysis, in the aggregate, of a fairly large collection of major air carrier accidents will reveal some of the human performance issues that may not be readily apparent in a single accident.

The balance of this paper will explore a couple of issues that affect the usefulness of accident databases for safety research generally, and human factors research in particular. Mayer and Ellingstad (1992) note a number of problems in the use of accident data bases designed for purposes other than research and analysis, including: treatment of missing data; database structure and design; and representativeness of the records in the database. These are important technical considerations that will influence the quality and usefulness of accident research, but they are outside the scope of our discussion today. Instead, I would like to concentrate on two issues: (a)the importance of examining accidents in the aggregate, and (b)the need for improving our measurements of "cause."

Why Bother With Accident Statistics?

The National Transportation Safety Board (NTSB) is a premier accident investigation agency and it produces definitive analyses of individual transportation accidents. These analyses are based on extensive field and laboratory investigations, a party system that ensures the consideration of widely differing points of view, and very extensive deliberation. They produce, in most cases, a formal statement of the Òprobable cause,Ó of the accident, and, where appropriate, recommendations for action to correct safety defects. You will shortly have evidence from my colleagues Jim Danaher and Jerry Walhout of the impressive scope and quality of these investigations. Why then do we bother to collect and analyze collections of accident data stored in our computers?

The first answer to this question has to do with seeing the forest, in addition to all of the individual trees that are represented by the separate accidents. Assessment of accident trends requires the aggregation of data from all of the individual accidents that are investigated. Standardization of data elements and methods of data collection have obvious importance in accounting for the patterns of accidents over time, as do considerations of reliability and validity of the data that these trends are based on.

A second, and perhaps even more important rational for aggregate analyses (accident studies) is that accident causes are not always evident, even to the most extensive, well organized, and professionally conducted single investigation. Sometimes this is due to the presence of what we might call "weak causes," influences which, in a statistical sense, account for only a modest (but reliable) proportion of the variance. other accidents, or classes of accidents, may be produced by multiple causes that interact in complex ways. It should not be surprising that the kinds of causes that we are focusing on today -- the human factors -- are often (if not usually) both weak and multiple.

Finally, transportation accidents always occur in a context that must be understood and accounted for. The influence on accidents of factors such as operator workload, hours of service, task complexity, and the like can probably only be understood statistically -- that is, on the basis of aggregate studies of accidents for which the requisite human performance data has been collected.

Measuring Accident Causes

The Safety Board makes an important formal distinction between "fact" and "analysis" in its investigation of accidents. The investigative process of yields a body of "fact" that describes and documents the accident circumstances and that supports "analysis" intended to yield an assessment of probable cause. Similarly, in addition to a collection of factual information, the accident database may include analysis and some representation of the cause(s) of accidents.

One of the implicit assumptions of accident analysis has always been that if the *cause* of an accident is known, similar accidents can be prevented in the future. This notion has its roots in fault tree analysis. If specific accident-producing modes of failure can be identified, then accidents can be prevented by strengthening these weak links. Some modes (e.g., metal fatigue or tire failure) are relatively well understood and, more importantly, they leave identifiable physical traces that survive the accident, however, generally leave little direct evidence for later analysis. Consequently, accident databases usually capture more information representing hardware failures and other directly observable phenomena, than human errors.

Grouping similar accidents by type or category is perhaps the simplest and most common representation of causation in accident data bases. While it is often possible to classify accidents as belonging to a specific type (e.g., mid-air collision, VFR into IMC, loss of control, etc.), this rarely explains why an accident occur. Accidents -- even relatively simple ones -- often result from multiple causes.

Some accident data bases address this issue by recording a narrative statement of accident causation, generally produced by a trained analyst, using a somewhat structured vocabulary. The Aviation Safety Reporting System (ASRS) maintained by NASA (Rosenthal and Mellone, 1989) utilizes this kind of text-based key-word system. The NTSB Aviation Accident System also contains a 200 work narrative statement of probable cause, although this is not the primary method of recording accident causes in the NTSB database. While this approach provides the

opportunity for rich expression of causal relations, methods of analysis for text data are, at present, limited.

The current NTSB aviation database uses a somewhat more complex coding system that identifies from one to five *"occurrences"* (see Figure 1) that make up the accident Sequence *of Events* Associated with each occurrence is a "Phase of Flight" code (see Figure 2).

For each occurrence/phase of flight recorded the accident investigator also records a set of coded explanations or "findings" that account for that occurrence. A primary set of findings consisting of a "subject" (23107 - Altimeter), a "modifier" (3121 - Misread), and a "person" (4000 - pilot in command) can be entered to account for the occurrence. An underlying explanatory factor (e.g., 33130 - physical impairment, alcohol; pilot in command) can also be associated with this occurrence. The sequence of events system is intended to comprehensively represent the events in a single accident in a formal coding structure that permits the examination of common patterns across accidents of particular types.

This approach is complicated somewhat by the fact that more than one "sequence of events" may be necessary to account for a particular accident. In many accidents a simple chronological listing of occurrences in the order in which they occur is sufficient to account for accident causation. In other circumstances the causal sequence of events may be different from the temporal sequence of events. This is particularly true when factors that significantly pre-date the accident sequence of occurrences (e.g., maintenance failures, pilot sleep loss, etc.) must be causally associated with accident events.

An additional complication in attempting to capture the details of accident causation in a sequence of events coding structure concerns the assessment of relationships between multiple accident factors or findings. It would be useful, for example, to assess the extent to which the pilot's sleep loss contributed to his vigilance decrement, and how much that in turn contributed to failure to detect a critical signal. Current database redesign efforts at the Safety Board are directed to the incorporation of such information in the sequence of events data system.

A related issue in quantifying accident causation is the assessment of the strength of the relationship of each separate occurrence or factor in the sequence of events to the accident itself. Military aviation investigation systems have, for example, indicated which event in the sequence made the accident inevitable.   The Safety Board does not presently code that information.

While possessing great potential explanatory and analytic power, coded representations of causal chains such as that just described can be very complicated to use. Current efforts to improve the Safety Board's database are directed to improvements in this area as well.

Additional Information Needed To Account For Human Causes

In addition to documentation of the factual aspects of an accident and an assessment of causation; a human factors analysis is an important component of a full investigation. In this context

"human factors information" must be understood to refer to a complete accounting of human-equipment interaction in the accident situation, and not the "mental state" or disposition of the people involved in the accident. There must, for example, be a thorough accounting of task demands placed on the operator as well as the operational requirements of the task(s). Preferably, this analysis should be standardized across all accidents in the database. In effect, what is needed is a retrospective task analysis which helps to identify and code system failures. Drury (1983) detailed several such alternatives for coding consumer product accidents, but no such method has emerged for transportation accidents. The need for standardization and the realization that not all accident investigations will be conducted by professionals trained in human factors, suggests that checklists or other "cookbook" methods may be needed.

Conclusions

Transportation accident databases will continue to provide the primary basis for most empirical diagnoses of safety problems and evaluations of safety countermeasures. Improvements in database technology as well as database design can be expected to make these sources of information increasingly useful but significant attention must be directed to improving both the collection and analysis of relevant data regarding the circumstances, contexts and causes of accidents -- and particularly the human factors.

Task-oriented human factors information about accident scenarios is often missing or unusable in transportation accident databases. This kind of information is sometimes overlooked because of an inadequate understanding of human factors by accident investigators. More often, however, these data are not collected because human failings do not leave the same kind of permanent physical traces that broken vehicular components do.

Sometimes human factors information, and other analytic findings, are collected but not coded well or completely. Improved methods of quantifying causality, and representing relationships between multiple causes are needed to render databases more useable in this regard.

Human factors researchers should and need to use accident databases in their work, but great care must be taken to use these tools effectively. Greater participation by researchers in the design of databases and the collection of data will increase their suitability for our work.

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Figure 1

NTSB OCCURRENCE CODES

100	ABRUPT MANEUVER
110	ALTITUDE DEVIATION, UNCONTROLLED
120	CARGO SHIFT
130	AIRFRAME/COMPONENT/SYSTEM FAILURE/MALFUNCTION
140	DECOMPRESSION
150	DITCHING
160	DRAGGED WING, ROTOR, POD, OR FLOAT
170	FIRE/EXPLOSION
180	FORCED LANDING
190	GEAR COLLAPSED
200	HARD LANDING
210	HAZARDOUS MATERIALS LEAK/SPILL
220	IN FLIGHT COLLISION WITH OBJECT
230	IN FLIGHT COLLISION WITH TERRAIN/WATER
240	IN FLIGHT ENCOUNTER WITH WEATHER
250	*LOSS* OF CONTROL - IN FLIGHT
260	LOSS OF CONTROL - ON GROUND
270	MIDAIR COLLISION
280	NEAR COLLISION BETWEEN AIRCRAFT
290	NOSE DOWN
300	NOSE OVER
310	ON GROUND COLLISION WITH OBJECT
320	ON GROUND COLLISION WITH TERRAIN/WATER
330	ON GROUND ENCOUNTER WITH WEATHER
340	OVERRUN
350	LOSS OF ENGINE POWER
360	PROPELLER BLAST OR JET EXHAUST/SUCTION
370	PROPELLER/ROTOR CONTACT TO PERSON
380	ROLL OVER (Helicopter)
390	UNDERSHOOT

400   UNDETERMINED
410   VORTEX TURBULENCE ENCOUNTERED
420   MISSING AIRCRAFT
430   MISCELLANEOUS/OTHER

Figure 2

NTSB PHASE OF OPERATION CODES

500	STANDING
510	TAXI
520	TAKEOFF
530	CLIMB
540	CRUISE
550	DESCENT
560	APPROACH
570	LANDING
580	MANEUVERING
590	HOVER
600	OTHER
610	UNKNOWN

4.9 PRACTICAL ISSUES IMPACTING HUMAN FACTORS INVESTIGATIONS AT THE AIRLINE LEVEL - CAPTAIN L. R. GANSE

Director Flight Safety
Northwest Airlines

In the world of the air safety investigator data on human performance can be difficult to obtain. Most of us have been trained very well on the technical aspects of incident or accident investigation. However, our education on human performance issues is mostly gained from experience and from some outside reading or seminars such as this. To the best of my knowledge, in the airline world, no one has the luxury of keeping a trained human performance expert on the very small safety staffs currently employed. One overseas carrier has attempted to do this with additional off line pilots, but the results have been mixed, at best.

Let's look at the principle limitations that impact today's airline safety investigator.

I. Limitations on Data Acquisition

Today's investigator must depend primarily on voluntary inputs from the individuals who are involved in an incident or accident. This poses a series of problems:

1/ Some "incidents" may be so minor that they are not even perceived as such by the crew. Examples may be inappropriate touchdown point on the runway or improper rotation rates on takeoff.

2/ When an incident is of a "minor" nature and only the participants are aware of it, there is no incentive for them to come forward and report it. Examples might be minor altitude or navigation deviations or mis-programming an FMS. In addition to the natural desire to avoid exposure to a possible disciplinary action, there is also a reluctance to inform on a fellow crew member.

3/ When a flight crew is involved in a major incident or even a minor accident the fear of punitive action will inevitably deter a candid discussion of the events leading up to it.

II. Limits on the Investigator.

1/ In addition to the lack of training noted in the opening paragraph and the lack of data outlined in section I above, the ordinary airline safety investigator suffers from a lack of time. Most airline safety departments are very small, and effective human factors investigation tends to be very time consuming. Consequently, the press of more obvious problems tends to preclude any effective human factors work on a routine basis.

2/ Most human factors specialists/researchers lack the operational background required to assess many of the more subtle nuances of the interface between cockpit crews and:
- Flight Attendants
- Mechanics
- Station Personnel
- Air Traffic Control
- Airline Policy/Procedures development

The upshot of (1) and (2) is that it normally takes a major accident to bring together the combined expertise of the air safety investigator and the human factors specialists and the lessons from precursor incidents escape the system.

The Real World of Today's Airline Safety Investigator

Given the constraints outlined above, I shall illustrate how one airline's safety division is functioning today.

At Northwest we have two air safety investigators that deal with 5500 pilots operating approximately 1600 flights a day to more than 150 airports over a route network spanning 2/3 of the globe. Our primary source of incident information is the pilot submitted Air Safety Report (ASR). Although NWA offers immunity from company discipline for any information submitted through the ASR, our inability to protect the confidentiality of those documents or to provide similar immunity from FAA certificate action seriously compromises our ability to obtain meaningful incident information during routine operations.

However, when an incident rises above a certain threshold of noticeability, we do have a process that allows us to conduct more meaningful investigations into all aspects of the incident. We call it our flight crew debrief.

As with the ASR, NWA will provide immunity to the affected crew for all information divulged during the debrief. The big difference between the ASR and the debrief is that the latter is a face to face meeting with the crew (often including the flight attendants) and confidentiality can be afforded the participants since no document obtainable by the FAA is produced.

When a debrief is conducted we attempt to uncover every causal factor leading up to the incident as well as the consequences of the manner in which it was handled. We use as a basis for the debrief James Reason's model since many incidents also include issues of organizational structure and its affect on flight crew behavior. The following incident outlines how the process was applied to an incident where there were serious injuries and aircraft damage after an unanticipated encounter with turbulence over the Pacific. The incident was somewhat unique in that all but one of the flight attendants were Asian nationals based at our various far eastern crew domiciles.

The flight crew was initially debriefed upon their return to the U. S. three days following the incident. During that debrief it became apparent that numerous difficulties had occurred in dealing with the flight attendants. Consequently, the flight attendants and the captain were reconvened at a subsequent debrief back in Tokyo the following week. Together, the two debriefings allowed us to ascertain the following:

- There were differences in the training provided to U.S. based flight attendants and their Asian counterparts which led to misunderstandings between the lead flight attendant (a U. S. national) and his working crew.

- There were cultural issues involving attention to assigned duties vs. passenger care.

- Company emphasis on "Service" lead to a disregard for observation and enforcement of the "Fasten Seat Belt" sign.

- Northwest had become lax in teaching and enforcing good discipline with respect to operation of the "Fasten Seat Belt" sign.

- There was no standard language for communicating turbulence information between the flight deck and the flight attendants. Consequently, the flight attendants were left to their own interpretation of terms such as "light", "moderate" or "severe".

- There were no appropriate guidelines in place for flight attention actions when advised of varying levels of turbulence.

- Existent Northwest procedures for interphone communication (no requirement for the speaker to identify her/himself) led to ambiguities and assumptions that exacerbated the difficulty of handling the situation.

A more complete discussion of these issues is contained in Appendix A, the analysis section of the incident report prepared by the flight safety division.

The total time to complete this investigation, including the trip to Tokyo, was in excess of 75 man hours. Additional time was spent writing the report and working with other divisions within the company to devise and implement remedies to the problems discovered.

A Look To The Future
Finding The Means To Improve Human Factors Investigations

If we are to truly mine the field of human factors incidents we must necessarily find a way to address the concerns enumerated at the outset of this paper.

Perhaps nothing has been more difficult and frustrating as the inability to have ready access to the minor incidents that are often the precursors to the more serious incidents or accidents.

At the heart of the problem in the U. S. has been the legal and regulatory climate. It may be an oversimplification, but a _very_ human factor is to avoid exposing oneself to any circumstance that can or will adversely affect either your livelihood or professional status. Although there are the glimmerings of hope on this front in the form of the Secretary of Transportation/FAA encouragement of such programs as digital flight data recorder monitoring (FOQA) and the experimental ASAP program at American Airlines, we are a long way from the actual regulatory and legislative foundation required for full implementation.

Another major hurdle that will need to be overcome here in the U.S., given the economic state of most of our air carriers, will be the cost justification of these programs, especially FOQA. The recent FAA proposed rule making on additional flight recorder parameters will remove the cost of updating the recorders from the cost/benefit studies since it will be mandated. However, FOQA programs also require additional resources in terms of handling, processing and analyzing the data. This cost will vary depending on the size of the airline and the level of automation introduced but, at our airline it is estimated that the initial cost of hardware and software will be $250,000 and at least three analysts (one air safety, one engineering and one information services) will be required at a recurring annual cost of $150,000± The challenge will be to justify the need for those resources.

In summary, if we are to make any meaningful strides at improving the human factors analysis here in the U.S., it will require major changes in the regulatory climate, more and better trained investigators and a method for cost justifying the effort. The latter may be the biggest challenge since, historically, accidents have only been priced _after_ the fact. No credit is given for avoiding one.

APPENDIX A

[Excerpt from Flight Safety Division Accident Report]

2. ANALYSIS

2.1 General

The flight crew was current and qualified in accordance with all FAA and NWA regulations. There was no evidence of non standard operation either in the testimony of the flight crew or in the flight data recorder readout.

The airplane was certificated, equipped and operated according to applicable regulations. The airplane was properly loaded and the cg was within the normal operating range.

2.2 Meteorological Factors

The area of the turbulence encounter lies along the northern boundary of the Intertropical Convergence Zone. This is the area where cooler air from the Northeast Tradewinds is mixed with the warm moist equatorial air mass. Weather in this area is characterized by nearly continuous but mostly scattered to broken areas of thunderstorm activity with individual cells often attaining heights in excess of 50,000 feet. This thunderstorm activity is in a continuous life cycle process of building, maturing and dissipating. However, due to the spacing between and among the cells these thunderstorms do not present the hazard to enroute navigation often found associated with closely spaced frontal thunderstorms.

On the day of this incident the crew was totally reliant on the aircraft weather radar due to the absence of ground based radar at the Guam center and real time satellite imagery at the NWA meteorology office in Tokyo. Based on the flight crew's observation of the heavy thunderstorm near the north end of Saipan during their departure and the issued NWA TP for scattered thunderstorm activity it is probable that there were developing as well as dissipating thunderstorms in the area of the planned flight back to NRT. NWA meteorology believes that the most likely cause of the turbulence was undetected convective activity at a lower altitude, probably beneath the aircraft's radar coverage owing to its tilt adjustment.   However, absent the record that could be provided by satellite imagery this cause cannot be definitively proven.

2.3 Air Traffic Control

Air traffic control is not considered to be a factor in this incident.

2.4 Operational Factors

2.4.1 Thunderstorm Avoidance Procedure

The flight was operating in an area of scattered thunderstorm activity. The activity had been continuous throughout the daytime hours and the flight crew had operated through the area upon their arrival approximately 2 1/2 to three hours earlier. During the arrival the captain had observed that the storms appeared to be "old and dying" with no lightning or convective activity. The aircraft weather radar showed only wear or no returns in both the 'normal' and 'contour. modes. Nevertheless, he advised the flight attendants to stow the service carts, turned on the "Fasten Seat Belt" sign and advised the inbound passengers to remain seated with their seat belts on. Subsequently the flight encountered only "minor bumps" during its descent and arrival to SPN.

Based on his experience during the arrival to SPN the captain decided that it was not necessary to request the flight attendants to remain seated during the climb out of SPN. Indeed, no turbulence was encountered during the climb out and initial level off. Nevertheless, the captain elected to keep the "fasten Seat Belt" sign illuminated until they had exited the thunderstorm area.

The encounter took place about two minutes after the airplane leveled off in a thin layer of cirrus clouds. According to the flight crew's statements they were following published NWA thunderstorm avoidance procedures while navigating their way through the area of

thunderstorms. As the airplane was being established in the cruise configuration with an indicated airspeed of 289 knots, the DFDR indicates that the airspeed began to fluctuate (+9/-4) knots. Within seconds the airplane began to experience minor vertical acceleration oscillations (+.2G/-.15G). Twenty-eight seconds later, the airplane began experiencing significant vertical acceleration oscillations ranging from +1.83G to -0.56G. During the significant vertical acceleration oscillations the airplane experienced pitch attitude oscillations ranging from +4.0 degrees to -0.8 degrees and roll attitude oscillations ranging from 12.8 right wing down to 12.7 left wing down. The major oscillations lasted for thirty seconds with the maximum positive to negative G reversal confined to a 2 second interval. Minor oscillations continued for anther 20 seconds.

At the time of the severe turbulence encounter the captain estimated that they were ten miles to the upwind side of the nearest cell off the left side.   The first officer, who was flying, estimated the distance as closer to twenty miles. These distances are in accordance with the guidance in the FOM (7.31.2 & 3).

The impact of the encounter caused the cockpit to fill with flying debris, the autopilot and autothrottles to disengage and engine "Low Oil Pressure" lights to flash on.

2.4.2 Cockpit to Cabin Coordination

Within one minute after ascertaining that the aircraft was still in controlled flight the second officer attempted to contact the cabin to ascertain the situation. He was answered by what he believed to be a "male Chinese" flight attendant but was unable to understand what he was saying. At the direction of the captain he then proceeded downstairs to the cabin. The second officer conducted a rapid walk through of the cabin during which he spoke briefly with several of the flight attendants, but not all of them. He returned to the flight deck and reported to the captain that there numerous injuries to passengers and crew and that one passenger appeared to be unconscious and that their was debris everywhere in the cabin.

Following some discussion with both the cockpit crew and the lead flight attendant the captain decided to continue toward NRT. His decision was based on the following:
  - Uncertainty about the weather in either Saipan or Guam.
  - Uncertainty about the availability of hospital on Saipan.
  - A return would require penetrating the area of thunderstorms which caused the problem.
  - A minimum time of one hour would be required to clean up the cabin suitably for a landing.
  - The unconscious passenger had regained consciousness.
  - There did not appear to be any life threatening injuries to either passengers or crew.

Subsequent to the arrival at NRT it was determined that a number of misunderstandings had developed relating to the manner in which the cabin and flight crew had handled their respective roles following the turbulence encounter. Therefore, a subsequent meeting was arranged in Tokyo on December 9 between the cabin crew and the Captain to more fully discuss these issues. The results of that meeting indicate that their are some fundamental problems that have arisen

from the policies and procedures for staffing flights south of Narita, the so called "interport" flights. These impact both safety and customer service.

2.4.2.1 Cabin Crew Composition

Flights beyond Narita are normally staffed with a U.S. lead flight attendant and the balance of the crew is composed of Asian nationals. The latter may be based in Bangkok, Hong Kong, Narita, Seoul or Singapore. Normally there is a mix of the various bases in order to accommodate the numerous languages of our Pacific rim customers. However, this cross cultural combination can cause problems with both intra and inter cabin communications.

It was noted during the debriefing that some U.S. lead flight attendants exercise very firm control over the interport flight attendants while others frequently almost defer to them. This leaves the Asian flight attendant with a lack of standards in their operation. This phenomena is, in part, attributable to lack of standardized training for the lead flight attendant position and/or the lack of a permanent bid lead flight attendant position which frequently facilitates a low experience level in that job. It can also arise out of the lack of joint training which precludes the U.S. and Asian flight attendant groups from developing any mutual understanding.

During the instant flight a misunderstanding arose between the lead flight attendant and one of the Asian flight attendants over the expectations concerned with handling the injured passengers and flight attendants. The Asian flight attendant was expecting some instructions from the lead as he had been trained. The lead, meanwhile, was expecting the other flight attendants to immediately deal with the emergency as <u>he</u> had been trained.

Because the lead flight attendant became engrossed with directing the cabin response he was not available at the L1 interphone when the flight deck made its initial inquiries as to the status in the cabin. An Asian flight attendant was the first to be contacted and, due to difficulties with the technical questions, could not reasonably communicate with the flight deck.

2.4.2.2 Language

With the exception of the lead flight attendant, English is normally the second language of the interport cabin team. Their degree of fluency varies widely but, in nearly all cases, they are unfamiliar with both slang and much of the technical jargon associated with flying our airplanes. Therefore conversation between these flight attendants and either the lead or the flight deck crew is ripe for misunderstandings.

During the debriefing the point was made by several of the Asian flight attendants that their role as interpreters was very difficult because they had to listen for the words of the flight deck crew or the lead flight attendant, often in the midst of a service or in a noisy part of the aircraft, try to get the gist of the message and then make the announcement in their native tongue. Lengthy PA announcements or those dealing with technical matters such as speed, altitude, or malfunctions

can be nearly impossible to handle. Although not an issue in this incident, there are certain situations involving unanticipated problems with only a short time where this could be significant.

2.4.2.3 Passenger Communication

This flight was operated with one Japanese speaking flight attendant/interpreter. Unfortunately, she was one of the injured parties. This caused a good deal of confusion and misunderstanding on the part of the cockpit and cabin crews since the entire passenger load were Japanese nationals. The interpreter was initially unable to make any announcements in her native language although she later proceeded to a passenger seat from which she could use a PA handset.

All of the flight attendants were anxious for some information from the flight crew. The captain wanted very much to provide this information to the passengers and made several attempts to secure the interpreter's presence on the flight deck believing, as he did, that there was little point in an English language announcement to a group of passengers who would not understand him. No one from the cabin team conveyed to him the message that any sort of announcement from the cockpit would help to assuage both passenger and flight attendant concerns over the turbulence encounter.

During the course of these efforts he spoke several times with one Asian flight attendant who he assumed was the interpreter. When he finally ascertained that she was not, he sought her assistance in bringing the interpreter to the flight deck. When he finally discussed the issue with the lead flight attendant he was distressed that the captain did not initially contact him, however, he did not discuss this with the captain.

This flight had aboard only 117 passengers, virtually none of whom were seated in the aft (E) zone of the aircraft. However, it is interesting to note that the two most seriously injured passengers had moved themselves to that zone. It is also interesting to speculate on what the situation might have been if this zone had been more fully occupied and the services of the lone interpreter were lost.

2.4.2.4 Crew Communication

As noted in nnnnn and 2.4.2.3 (above) there were several areas of breakdown in communications between the flight deck and cabin crews. In discussing this issue with both groups it is clear that many of our current operating practices militate against clear and effective communications between the tow groups. Of particular import is the declining incidence of full crew briefings.

As illustrated in the foregoing, the lack of definitive information leads to both parties making assumptions about the other's actions. It also can lead to critical gaps in the information exchange. A gap that developed in this incident was the flight attendant's concern about the structural integrity of the airplane. Moreover, the lead flight attendant was concerned with how

to deploy his remaining three able flight attendants for the landing, especially since he was unsure of the aircraft's status. The exact reasons for no one on either side of the question initiating this discussion are not certain but, clearly, the lead flight attendant's assumption that the captain had elected not to deal with him earlier must have been a factor.

2.4.3 Fasten Seat Belt Sign Discipline

A fundamental question arising from this investigation is, "why were all of these people injured when the 'Fasten Seat Belt' sign was illuminated?" A corollary question must also be, "What does the 'Fasten Seat Belt' sign mean to our flight attendants in terms of service initiation or interruption?"

The former question would seem to be the easier to answer. The flight attendant manual states specifically that, "Flight attendants shall visually and individually check to ensure that all customers are seated with their seat belts fastened whenever the seat belt sign is illuminated and as long as it remains on." (Ref. p14.10.4)

However, and especially on long haul flights, it is common for the flight crew to overlook the "Fasten Seat Belt" sign and allow it to remain on for extended periods of time even in calm air. Consequently, enforcement of the illuminated instructions has become lax. It can reasonably be assumed that the cabin crew's perception of the lack of danger during the departure was nearly the same as the captain's, both of which were based on their arrival experience several hours earlier.

The second issue is far more complex and requires some research and discussion that exceeds the scope of this report. Suffice it to say that the "fasten Seat Belt" sign, of its own accord, offers little guidance to our flight attendants unless its illumination is accompanied by specific instructions from the flight deck. The Flight Safety division and Inflight have undertaken a cooperative effort to reduce the level of flight attendant turbulence injuries. Although we are only beginning to get a data base of some significance, one salient point emerging from the information is that a large number of the injuries occur during flight attendant attempts to maneuver and/or stow serving carts. This casts some doubt on the current procedures (or lack thereof) for protecting the welfare of our flight attendants.

4.10 FLIGHT CREW ACCIDENT AND INCIDENT HUMAN FACTORS - R. Curtis Graeber

Chief, Human Factors Engineering
Boeing Commercial Airplane Group

The following comments are offered in relation to the Workshop's goals from the perspective of a Human Factors professional with both NASA and airframe manufacturing experience. The focus is on data acquisition, analysis, and application based on airline flight crews and does not address other potential activities which may provide equal or greater benefit for improved safety.

Objective 1

Relevant data elements or types of data required for analysis.

The aviation industry has historically encountered considerable difficulty in attempting to analyze flight crew error in a manner which demonstrably contributes to safety improvements. There are several reasons for this state of affairs. These include limited data scope, incomplete reports, inconsistency in content and format, skewed reporting, and lack of accurate baseline error rates. For the purposes of this effort it is worthwhile to explore each of these before offering a "solution."

The issue of *limited data scope* arises primarily from the fact that the only data assured of collection are those related to accidents or major incidents. While even these are often insufficient for sound human factors analysis, they represent low probability events that usually arise from the joint influence of multiple contributory factors of which one or more may legitimately be designated a human factor. They provide little beneficial insight into those human factors that are responsible for raising the risk of aviation mishaps on a daily basis.

If anything, this overall situation is the outcome of an aviation system that holds the flight crew accountable for safely operating the airplane. In some cases, this practice translates into the crew being more exposed to blame because they are the last line of defense when unsafe situations threaten flight operations. Their positive contribution to safety is rarely recognized except when pilots are seen as "superhumans" overcoming insurmountable odds caused by other factors (e.g., Aloha 737, United DC-10 at Sioux City).

It is well recognized that this situation also results in the reluctance of many crew members to be forthcoming after an incident, hence the success of ASRS's immunity provision for encouraging direct input from crew members. However, such a reporting system necessarily encourages pilots to report any perceived infraction, thereby providing a *skewed* estimate of the actual frequency of certain types of events and an inability to estimate *error rates*. Conversely, many events which would be of interest to a Human Factors investigator are not reported because pilots either don't see them as potential infractions or don't think they are important enough to bother filling out the paperwork.

Regardless, ASRS reports can provide valuable insights into the whys and wherefores of well described incidents; however, most of the data is *incomplete* especially for attempting to carry out a behavioral analysis of a set of events. Such analyses often require consistent information about situational factors, organizational issues, and other behavior modifiers, and not just operational facts which are easier to gather. When in-depth data is required, it is often obtainable by the use of the costly CALLBACK process to interview flight crews involved in a particular type of incident. I raise these issues not because ASRS is not a valuable tool for understanding flight crew error, but because it is sometimes viewed as having solved the data problem. It has not.

While more accurate and consistent data is needed on incidents, major and minor, it is my belief that in order to focus our limited safety resources effectively, we must not limit our data search to the negative side of the human factors equation. The industry could obtain valuable insights from those occasions where flight crews have successfully dealt with unexpected operational events. Crews have always been willing to share their successes among comrades. The traditional importance of "hanger talk" in promoting safety is well recognized by flight crew oriented publications. It is perhaps the quickest, but albeit the most limited, way to address previously unrecognized latent failures. The industry needs to raise this proven approach to a new level which enables wider communication and a greater consistency in information content than that offered through anecdotes. By obtaining a balanced view of flight crew human factors we will greatly improve our ability to determine the critical issues that need to be addressed. It will also encourage greater participation by the professional pilot community, provide better insight as to why crews sometimes do the things they do, and help us develop practical countermeasures to human factors related issues.

At the same time we must be careful not to limit such data collection to flight crews. Attending more to flight crew error because it is listed more frequently as a primary cause of accidents ignores the well recognized multiple-cause etiology of most accidents and incidents. Similar efforts on other safety fronts have done little to change the consistently low baseline accident rate over the past two decades. If we are to accomplish a reduction in the overall accident rate, Human Factors must be viewed as a system wide issue and any proposed database must do more than is currently being done to capture the performance of other professionals who interact with flight crews in daily operations.

The future success of any expanded effort to gather human factors data regarding flight crews will require much more open cooperation by their professional associations and the airlines for which they work. Recently there have been renewed calls for the sharing of such information among the carriers. At the IATA Human Factors Seminar in Bahrain in March, this was one of the major conference conclusions. The IATA Flight Operations Directorate is exploring how this might be encouraged. The ICAO Human Factors Program has expressed similar desires. I strongly recommend that the U.S. FAA not develop a scheme independent of the international aviation community. Too often in the past the FAA and the U.S. in general has chosen a "go-it-alone" approach. We can no longer afford to adopt such an isolationist view. Airlines are becoming multinational with rapidly increasing potential for mixed U.S. and non-U.S. crews. The presence of foreign registered airplanes is rapidly increasing within U.S. airspace while U.S. carriers continue to expand their global operations. If we really want to understanding the human factors issues surrounding accidents and incidents, we must take much more of an international perspective which other authorities and non-U.S. carriers can "buy into" and which will enable the sharing of similarly structured data across boundaries.

Objective 2

Incorporating models of human performance and error into the analysis process.

There are a variety of human performance and human error models that have become popular among aviation human factors professionals. These include Jim Reason's concept of latent failures and resident pathogens, Elwyn Edwards' SHEL model, Jens Rasmussen's model of skill-based, rule based, or knowledge-based behavior, and Don Norman's sorting of errors into slips, lapses, or mistakes. While both Reason's and Edwards' models can be particularly helpful after an accident to determine whether or not all the potential areas of concern have been investigated, they are not particularly helpful except at the most elementary level in analyzing incident data. Of the two, Edwards' model is the most parsimonious and may at least provide some basic categories for data reduction.

As part of an ATA Human Factors Task Force effort, Boeing has been developing an analysis of accidents in an attempt to better understand why crews do not follow procedures. The data utilized is the same as described in our recent publication on Multiple Prevention Strategies. The structure of this analysis is based on a cognitive approach and has led us to include both Rasmussen's and Norman's schemes for attempting to categorize particular errors by the crew. At the same time it includes the following general categories: Cultural Effects, Context Variables, Stressors, Type of Behavioral Trigger, Situational Awareness, Information Acquisition and Processing, and Crew Communications. We have also obtained some preliminary indications that the approach we have developed may be beneficial in developing a structured way to analyze air crew related incidents within an airline and hence provide a framework for structured data collection.

Obviously, our approach is not a model but rather a behaviorally based practical strategy for organizing data in a way that is compatible with current cognitive science. Whether any incident database could include such a comprehensive scheme may be a challenge, but there is no doubt that, if a human factors database is to prove useful, it must provide some degree of consistency across reports which will support statistical and behavioral analysis. Human Factors is a science which requires a richer database than most activities in aviation. Of course, the plague of databases is that their usefulness is usually limited by their format and completeness which can usually withstand very little tampering once put in place.

Objective 3

Conceptual interface.

This is a difficult subject which ought to be approached from a Human Factors Engineering standpoint, that is, let's first define and validate the interface requirements. My greatest fear is that a great deal of effort and resources will go into major software development without careful examination and testing of what is really needed.   We believe that a great deal of data is already available from different

sources in a wide variety of formats and quality. While we need to improve the quality of these data, the need to improve our ability to share such data may be even greater.

At Boeing we currently utilize a wide variety of safety data to analyze the factors which contribute to flight crew error. These sources include official accident reports, ASRS, CHIRP, and airline incident reports concerning Boeing airplanes. At times, when a particular design or training issue arises within the company, we have contracted for CALLBACK interviews by the ASRS staff in which we help them structure a carefully designed set of questions targeted at understanding the issue at hand.

We have periodically utilized these and other data obtained from our training activities and airline support visits to assess the potential contribution that specific design options might make to improving safety or to assure ourselves that design features will not increase the potential for flight crew errors. We have also used such data to help us better understand crew factors in the course of accident investigations. These techniques can prove extremely helpful when sufficient data is available, but the paucity of reliable data can be extremely frustrating. While simulator studies can provide important data on human error potential, they take considerable effort and time and lack the real-world validity of operational events encountered by line crews.

4.11HUMAN FACTORS ISSUES ASSOCIATED WITH FLIGHT CREW ACCIDENTS AND INCIDENTS - STEVEN D. HARPER AND MARK J. DETROIT

Introduction

The Crew System ERgonomics Information Analysis Center (CSERIAC) was established in 1988 as a national source of human factors information. CSERIAC is a Defense Technical Information Center/Department of Defense (DTIC/DoD) organization, hosted by the Human Engineering Division at Wright-Patterson Air Force Base, and operated by the University of Dayton Research Institute. CSERIAC supports all facets of Human Factors Engineering and Ergonomics for human operated systems.

CSERIACs mission is to provide a quick and reliable source for analytical services, topical publications, software programs, and data bases pertaining to human factors. We collect, analyze, and disseminate information and technologies to support all parties within the government, industrial, and academic sectors concerned with human-machine systems.

Historically, CSERIAC has provided its customers with a broad variety of services and products. Products range from the *Gateway* newsletter (a free periodical published six times per year with a readership exceeding 10,000), to State-of-the-Art Reports (SOARs), covering a variety of areas of high interest to human factors practitioners, to sophisticated human factors engineering and analysis support for short and long term projects.

The aviation experience base at CSERIAC is extensive. In addition to our traditional Air Force customer base, CSERIAC has supported NASA and FAA with human factors analysis of aviation related projects. CSERIAC has experienced pilots and staff (ATP rated, Flight Instructors, military) with accident investigation experience and exposure to state-of-the-art military and commercial flight control and navigation systems. In addition, our staff (and the faculty at the University of Dayton) have extensive operational and research experience with aircraft and simulators covering general aviation, airline, and military operations. CSERIAC is also fortunate to have a member of FAA, Dr. Mark Hofmann, serving on our steering committee.

Discussion

Objective 1: Relevant human factors data

The identification of human factors data relevant to the investigation, and, more importantly, the prevention of aircraft accidents and incidents has been an issue since the birth of aviation. However, it wasnÕt until the late 1970s that the FAA and the NTSB began to formally recognize the limitations and performance capabilities of human operators as factors in accidents and incidents. Even now, after nearly 30 years of recognizing this important element, there are few computer-based tools or models available for human factors practitioners responsible for the identification of the causes of aircraft accidents. The development of new databases and access

to existing human factors information is an important step toward providing tools that can facilitate credible analysis of human performance.

In order to meet the needs of the users of the data, CSERIAC recommends conducting analysis to identify the information needs of the user population as well as investigating existing procedures and analysis methods. All factors relevant to accident and incident data could then be categorized according to a user's specialty (pilot, investigator, engineer, psychologist, etc.). Potential sources for this data include: NTSB, FAA, NASA, Military, Airline Pilots Association, Aircraft Manufacturers, Airlines, Insurance companies, etc. This analysis effort should also investigate other data sources and strive to uncover missing data elements. The results of this analysis will provide an understanding of current requirements for information and technologies available for accessing and processing it, identify areas of common interest, and facilitate the development of algorithms to tailor information searches for accident/incident investigators. It is important for the designer of any system to have a thorough grasp of the requirements of the user before attempting to implement a solution. It is equally important to assess the current methods for analyzing the data in order to build upon them. CSERIAC has extensive experience in determining and refining user requirements and analyzing technologies which can then be synthesized into design solutions. CSERIAC methods result in a design approach that is based on the needs of the user and aided by technology, rather than an approach which is solely driven by technology.

Objective 2: Human performance and error models

The principles of human information processing theory (Wickens, 1992) and some of the various mental workload assessment techniques may be useful in the analysis of aircraft incidents and accidents. Information processing theory provides a scientific framework for modeling strategies and methods humans use to process information. Human Reliability Analysis (HRA) techniques facilitate the probabilistic risk assessment (PRA) process for predicting when humans are likely to commit errors. Information from the human factors databases could be used to determine the inputs and outputs of the human and system. Fault Tree Analysis (FTA), Event Tree Analysis (ETA), and Root Cause Analysis might be adapted to model the throughput (or processing) of the human, within the context of system characteristics and environmental conditions. This approach would enable various scenarios to be evaluated and yield a higher confidence in identification of probable human causes of accidents or incidents.

This approach could be taken further with the current state-of-the-art of computer technology. Low fidelity (non-motion, part-task) simulations can be developed which would allow investigators to use the human factors data in conjunction with or without Subject Matter Experts (SMEs) (e.g., flight crews) to recreate accident or incident scenarios. The approach using SMEs would be much like that which is used today to recreate an accident scenario in a motion based simulator. The approach without the SMEs would basically use a computer optimized profile based upon either information processing models or queuing theory and would provide a capability to conduct some preliminary analyses before calling in the SMEs.

A side benefit of such a development effort would be the use of tools such as these to design of

new aircraft systems. Designers could get a better allocation of functions between the human operator and the system than is currently capable with a static design environment. In addition, the creation of lessons learned databases (accidents, design, maintenance, Crew Resource Management, etc.) would also influence future designs and greatly aid in determining flight crew error contributions to aviation accidents and incidents.

Objective 3: Conceptual interface

In order to develop an effective user interface for any system, the needs, capabilities, and limitations of the user must be fully understood. CSERIAC has considerable experience with Human-Computer Interface (HCI) from designing Graphical user Interfaces (GUIs) for accessing computer databases and to providing usability guidelines for software tools. CSERIAC's experience includes the development of an extensive internal database of human factors information, database development guidance and support for the US Air Force, creation of a CSERIAC "Home Page" on the World Wide Web, and extensive experience with a variety of databases to support our function as an Information Analysis Center for DTIC.

The need to access information is not much different for accident/incident investigators than it is for many other scientific disciplines. Most of the necessary data exists in one form or another. What is required is an integrated, computer based solution. Users of the data need the ability to access it from one place. A problem that has existed in the past is that much of the data is not text based. The text based data is relatively easy to process and store with electronic methods. The data that is not text based (photo, video, audio, among others) has been much more difficult to store in a central database. Further, data collection procedures in the field do not readily support traditional databasing methods.

The technology to create an integrated, computer based data collection, storage and retrieval system is mature. Many of the needed elements are grossly grouped within multi-media computer-based technology. CSERIAC has much experience with this new technology. To take advantage of multi-media technology, the current process for data collection, dissemination, and usage will have to be analyzed and modeled. This process often results in a number of changes in the process due to new capabilities made available by the technologies. One such change might be the streamlining of field collection procedures using electronic checklists and data input with Laptop PCÕs. Further changes would include the storage of photo, video, audio, etc. data on electronic media. Access could be provided nationwide via the World Wide Web. The technology to display and work with the data in this manner exists today. Going a step further, human error prediction models, simulation tools, etc. could also be made available. Levels of access to the data would be controlled by an editable user profile that would be filled in automatically during the initial login phase. The user would provide background information and be granted access to information and tools at a level appropriate for his or her needs.

Conclusion

CSERIACÕs charter is to provide human factors support and analysis for projects such as the FAAs initiative to provide accident and incident data to aviation professionals. CSERIAC is staffed with human factors professionals with experience in aviation operations, training, and accident investigation as well as in the access and display of computer based information. CSERIAC is capable of tailoring solutions to meet the unique human factors problems of our customers. In addition, CSERIAC can create a multidisciplinary team of professionals from government, industry, and academia to provide solutions based upon systems engineering principles.

We believe that the intent to provide easy access to human factors data relevant to accidents and incidents will greatly aid the analysis of aircraft accidents. Further, such a database, coupled with human performance models, will facilitate a better, more expedient understanding of the role of the human operator in an aircraft accident or incident. Finally, this initiative may be eventually provide cockpit design personnel with information that will enable the design of cockpits that reduce the probability of accidents and incidents. CSERIAC would be pleased to work with FAA to further develop this initiative and help to integrate it with the national plan for Civil Aviation Human Factors.

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4.12 HUMAN FACTORS CONSIDERATIONS TO BE USED BY CERTIFICATION TEST PILOTS IN THE FAA APPROVAL OF CERTAIN ELECTRONIC SYSTEMS IN VARIOUS AIRCRAFT - GEORGE KASEOTE AND GEORGE LYDDANE

FAA Test Pilots

The Aircraft Certification Service approves many type of Flight Management Systems (FMS), Navigation Systems, Radios, etc. at the request of an applicant for a Type Certificate or a Supplemental Type Certificate for various aircraft. The tests for these systems are conducted by twelve different offices and over forty different individual test pilots; however, there is very little guidance or standardization relative to human factors issued for those individuals to approve a particular item

The Type Inspection Authorization (TIA), is a document that outlines various tests (among other things) that the test pilot should conduct in order to approve an installation of a piece of electronic equipment. The TIA generally has a "boiler-plate" item that loosely says "Evaluate the controllability and accessibility of the (FMS)". That leaves a large area for individual interpretation. For example, one specific certified FMS requires 164 key punches to program one IFR approach. Some pilots may feel that is too many key strokes and requires much too much time. That time spent programming a system is time spent away from other activities involved with the overall conduct and safety of the flight.

There should be studies and data available from the Human Factors community that could be used to issue guidance for standardization throughout the Certification Service as to a reasonable number of key strokes required for a function, the amount of time that is reasonable for various functions, the shape of knobs and dials, etc.

Another consideration that requires study is the annunciations required to certificate a particular item.

These are some of the things that we would like addressed in this workshop.

4.13HUMAN FACTORS IN AVIATION SAFETY DATA AND ACCIDENT INVESTIGATION - THOMAS LILLI

Consultant to ALPA Human Performance Committee

On January 9th and 10th the FAA hosted an unprecedented working session in Washington DC to address safety in the aviation industry. This Safety Summit was comprised of six workshops one of which concentrated on safety data collection and use. The safety data which the Workshop addressed includes: The Safety Partnership Program data, FOQA Program data, and Safety Data from different domestic and international data bases. This particular workshop also addressed issues such as improving the quality and availability of safety data, addressed ASRS's future needs and addressed concerns associated with the sharing of data.

The concept in which the FAA, a commercial airline company, and a pilot association could form a partnership to improve safety is unprecedented. Many carriers in the US and abroad are beginning to form alliances like these. Data collected as a result of these alliances should prove to be a keystone to future safety enhancements and offer the opportunity to provide immediate response to safety issues. This is due to the high level of participation from interested groups. FOQA (Flight Operational Quality Assurance) should prove to add further to the benefits gained through a program such as The Safety Partnership Program due to even higher levels of participation in pilot labor organizations and the amount of data being collected. The topic of FOQA can not be broached without raising two ongoing concerns. They include anonymity and relief from the Freedom of Information Act. The consequences resulting from abuse of enforcement policies, and public reaction to news media interpretation of this information could have a catastrophic effect on this program and an even greater effect on the morale of the participants in industry.

Historically, aircraft accidents and incidents have provided the aviation industry with much of its safety data. Unfortunately, up until the recent past, the identification of a specific pilot error was the main protocol for most accident investigations. The introduction of highly educated human factors experts taking part in accident investigation and applying sophisticated human factors models to the accident investigation process helped redirect probable cause statements. Previous protocols resulted in determining *who* committed *the* error which caused to *why* did a *chain of errors* occur which may have ultimately lead to an accident. When we view accident investigation in this fashion, we can begin to ask what can we do to prevent future accidents of this nature? We must continue to support policies that ensure the continued refinement of human factors models and the application of their results in the accident investigation process.

One does not have to wait for an accident, however, to see trends of errors which could ultimately cause an accident. There is a vast resource of aviation safety data domestically and around the world which may have valuable information to provide evidence of increased risk and ultimately tear the safety net. The governers of these data sources should be encouraged to

participate in a global coalition such as an international ASRS in which a "Single Event Issue"[1] could be distributed in a high priority. An electronic network type media would be most efficient. Along with the formation of this alliance, there should be strict standards put in place for human factors type input. This would help give credibility to data and provide a more accurate assessment of specific human factors type systemic problems.

For many years, the goal of increasing safety by reducing accidents through individual efforts has resulted in the leveling in the reduction of accidents. For the first time the Civil Aviation Community is uniting to decrease the number of accidents to zero through unique and synergistic efforts. The success in the application of safety data to help in this process can be effective only with serious commitment to assure that there is proper protection from enforcement, and legislation to protect data from the Freedom of Information Act. This data must further be made available on an international basis for Single Event Issues, and there must be a convention for collating human factors issues when compiling human factors data. Attention paid to these issues now will help make the quest for zero accidents a reality tomorrow.

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[1] A "Single Event Issue" is the issue of an event that, if discovered, could result in the avoidance of an accident. Such an event might be the discovery that an airport Minimum Descent Altitude was not appropriate on a chart. For example, if the MDA at airport XYZ was stated as 863' MSL instead of 1863' on an airport with a field elevation of 1463' MSL, it is obvious this discovery could save some one from possibly having a controlled flight into terrain accident.

4.14FLIGHT CREW ACCIDENT AND INCIDENT HUMAN FACTORS AND ANALYSIS - RONALD C. MCGARRY

Aviation Safety Inspector

Subject

Partnership for Safety Programs

Background

One of the most challenging responsibilities for the FAA and the air transportation industry is to ensure that airlines operate safely and in compliance with the Federal Aviation Regulations (FARS). The FAA, other government agencies, trade organizations, manufacturers, airlines and labor organizations alike are constantly looking for new and innovative ways to make the aircraft operating environment safer. Within the past few years a safety strategy has been developed primarily by the airline industry in conjunction with their labor union(s) that encourages airmen to report incidents they observe that are of a safety concern. While that in itself is not new, what is new is these programs are in partnership with the FAA and do not carry the threat of reprisal by the company or legal enforcement action by the FAA provided certain conditions are met. These programs are referred to as "Partnership for Safety Programs"

Compliance with the FARS is based on voluntary actions by the airlines and their employees. In addition, the FAA conducts inspections and testing on a daily basis on the airline aircraft, safety equipment and their safety personnel such as pilots, mechanics and flight attendants. Non compliance with the FARS detected by an FAA inspector requires an investigation and corrective action. The degree of corrective action is dependent upon how adversely safety was affected and whether or not the violation was intentional or inadvertent. The sanction for an airline or airman that violates an FAR can range from civil penalties (fines), license and certificate suspension or revocation, to administrative action in the form of a warning notice or letter of correction. These safety tools used by the FAA have been effective in gaining compliance however, they do create an unwillingness (fear) for the airmen to come forward voluntarily and report noncompliance not detected by the FAA. This causes a gap in safety data. In other words a number of safety issues occur without safety analysis or preventative action.

Issue

The theory behind partnership for safety programs is that airmen who operate in the air transportation system on a daily basis would be more likely to bring safety concerns forward for analysis and correction if they were assured that there would not be reprisals taken against them from their employer or FAA.

Since these programs are relatively new there are only a few in operation today. Some programs are very focused on a particular safety area such as the reporting of altitude deviations and others

are more general in scope such as the reporting of any safety of flight item that may be of concern to a flight crew member. These programs have been brought about through a Memorandum of Understanding (MOU) between the FAA, an airline and its labor organization(s). The MOU is of a limited duration and may be renewed if the program is achieving its safety objectives.

An example of how the most complex program in existence today works is as follows:
A FAA Flight Standards Certificate Holding District Office (CHDO) engaged in a partnership for safety program with a major airline and its pilot union to develop a system where the pilots could voluntarily report any safety issues they believed were important to a review committee. The review committee is made up of safety experts comprised of a member from the FAA CHDO assigned oversight responsibilities for that airline, airline management and the pilot union. Certain parameters were established by the review committee to screen out reports that were not related to safety and obvious, serious, safety problems that would be detected by the FAA through normal procedures. In addition, any intentional infraction of the FARS is not be covered by the program. The committee would review the report and make recommendations for corrective action to the airline, the union and/or the FAA. However, the FAA has reserved the right to make its own decisions in the enforcement arena. The corrective action could range from remedial training for a pilot to the airline changing a procedure or way of doing business that precipitated the safety problem. The committee could also recommend enforcement action by the FAA. All flight crew members are given feedback on the outcome of each report submitted to the committee through an electronic bulletin board. The partnership program does not replace any existing methods the FAA uses to ensure compliance with the FARS and there are no provisions for immunity from FAA enforcement action. The program is an additional safety tool for the FAA, the airline and its pilots to use. Mitigation is given by the FAA to the airmen that report safety concerns under this program. Most cases handled by the FAA under this program have resulted in no action or administrative action reports.

This program is unique because the reports made by the flight crew members must be made within 24 hr's of the safety event. Each report is reviewed and safety recommendations are made and in many cases implemented. A number of the reports involve safety issues that are not infractions of the FARS.

This particular program has been in existence for eleven months and over 2600 reports have been made. They range over a broad base of safety issues including incidents that would not have been discovered and corrected by airline management or the FAA in the past. The reporting and analysis of these incidents have caused several positive safety changes within the airline.

The traveling public as well as the employees and management of the airlines have benefited from the safety changes that have occurred because of this program. The FAA has gained additional valuable insight into the day to day problems that occur during actual operations that had not surfaced previously. This type of partnership for safety program is being studied by other airlines and the FAA to see if it could provide the same benefits on a larger scale.

Recommendations

1. It is recommended that partnership for safety programs be studied more closely by a group of safety experts to see what safety benefits are being achieved and how these programs can be improved.

2. Have the FAA prepare standardized guidance material for FAA and industry to use in developing and administering these programs.

3. Develop an industry clearing house where safety information and solutions to problems reported through partnership for safety programs at different airlines can be shared with other airlines.

4.15 ISSUES RELATED TO USE OF ASRS INCIDENT DATA WITH HUMAN PERFORMANCE AND ERROR MODELS - DR. ROWENA MORRISON[2]

An Overview of the Aviation Safety Reporting System

The Aviation Safety Reporting System (ASRS) was established in 1975 under a Memorandum of Agreement between the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA). ASRSÕs primary mission is to collect, analyze, and respond to voluntarily submitted aviation safety incident reports in order to lessen the likelihood of aviation accidents. ASRS data are used to identify deficiencies and discrepancies in the National Aviation System (NAS) so these can be remedied by appropriate authorities; to support policy formulation and enhancements to the NAS; and to strengthen the foundation of aviation human factors safety research.

Pilots, air traffic controllers, flight attendants, mechanics, ground personnel, and others involved in aviation operations submit reports to the ASRS when they are involved in, or observe, an incident or situation in which aviation safety was compromised. All submissions are voluntary. Incident reports are read and analyzed by ASRSÕs staff of aviation safety analysts, whose experience covers the full spectrum of aviation activity: air carrier, military, and general aviation operations; and air traffic control in towers, TRACONS, Centers, and military facilities. The analysts perform two primary functions. They identify the aviation safety hazards discussed in reports and flag this information for alerting message action; and they classify reports and diagnose the causes underlying each reported event. Their observations, and information from the original de-identified report, are then entered into the ASRS database.

The ASRS database provides a foundation for specific products and subsequent research addressing a variety of safety issues. Full-form database records include the narratives submitted by reporters after these have sanitized for identifying details. The narratives provide a rich source of information for policy development and human factors research. The database also contains coded information from the original report which is used for data retrieval and statistical analyses.

Background on ASRS Human Factors Taxonomy

The ASRS had a formal taxonomy for coding human performance prior to 1986, but coding categories were too generalized (e.g., Òpilot technique,Ó Òcontroller vigilance,Ó) for many research applications. In 1986 the formal coding of human factors diagnostics ceased as a matter of practical necessity. This change came about as the result of several years of sharply increased

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[2] This paper is based on conceptual materials provided by the following individuals: Loren J. Rosenthal, the Battelle Program Manager of ASRS, and Vice President of the Aviation Operational Safety and Efficiency Business for BattelleÕs Transportation Division; Susan J. Mangold, a Principal Research Scientist and aviation human factors specialist with BattelleÕs Transportation Division ; and Linda J. Connell, a NASA Ames Research Psychologist and ASRS Staff Scientist. Dr. Morrison is a Battelle Principal Research Scientist and ASRS Research Coordinator.

report intake, coupled with a stagnant funding situation. ASRS no longer had the resources to process incident reports as it had previously. Under new procedures adopted to expedite the coding process, the amount of analyst time devoted to coding each report was slashed from an average of 1 hour and 28 minutes per report, to approximately 45 minutes of analyst attention. Differential report processing was also introduced, and coding structures were streamlined. As the result of these measures, it became easier to reliably code the external descriptive aspects of events than their underlying causal dynamics. It was determined that human factors coding would not be done at all.

The decision made in 1986 still seems to be sound given the constraints that existed then. However, the absence of hard-coded human factors information has hampered ASRS research and decreased the utility of the ASRS database. A significant minority of search requestsÐboth external and internalÐseek reports that relate to human factors issues. It is difficult to extract these from the ASRS database as it is now configuredÐmuch less perform meaningful statistical profiles of human factors issues in the database.

The ASRS is in the process of revamping and computerizing its report processing procedures. Computer support is being inserted at new points in the production process to increase efficiency and enhance quality. If computers can be used to facilitate human factors coding, ASRS can reintroduce hard-coded human factors diagnostics to the database. The ASRS and research community would benefit greatly.

Challenges in Developing a Human Factors Taxonomy for ASRS Data

Applying Human Error Models. Human error models provide taxonomic systems based upon types of error. In the attempt to make these taxonomies applicable to a broad range of situations (aviation, nuclear, assembly line), they must be translated so as to apply to the area of interest. Even if an appropriate human factors taxonomy is developed for ASRS incident data, it would be an unrealistic expansion of ASRSÕs mission to analyze the types of errors made in each of the more than 30,000 incident reports submitted annually. This undertaking would also be intensely resource consumptive, since ASRS analysts currently lack the human factors background and training necessary to make these determinations. ASRSÕs primary role, historically, has been to provide data as efficiently as possible. While development of a human factors taxonomy is consistent with this role, detailed error analysis of ASRS data belongs more appropriately to the research and user community.

Applying Human Performance Models. The attempt to integrate human performance models with incident/accident databases has a long and difficult history. There are inherent problems in basing any database on just one, or even a few, such models. For example, in considering just the workload domain, one would have to choose among a variety of performance models varying along such dimensions as single versus multiple, and structural versus resource features. How would the model most appropriate for ASRS data be determined? ASRSÕs main responsibility is to provide the best possible data in the most accessible form possibleÐhence the need for a

useful human factors taxonomy. It is the responsibility of experts in the many different areas of human performance to apply ASRS data to models of interest.

Selecting Terms and Creating Definitions. One of the most critical issues for any proposed ASRS taxonomy is the level of aggregation at which terms are selected. There is an obvious tradeoff between breadth and quantity. To limit the number of human factors diagnostic terms, it is tempting to use broad categories (e.g., Òsituation awareness,Ó ÒworkloadÓ). However, broad categories can become meaningless in some practical applications. For example, it may be impossible to judge, on the basis of information supplied in an ASRS incident report, whether a specific event reflects a breakdown in situational awareness, or a failure to apply good decision making skills.

An effective ASRS taxonomy should employ terminology that can be used by both ASRS analysts and human factors specialists. To achieve this optimal level of aggregation, it is necessary to provide *operational definitions* of traditional human factors terms. For example, Òsituational awarenessÓ is a broad term susceptible to conflicting expert interpretations. Rather than using such a broad term, an attempt might be made to determine the flight deck activities that are performed to maintain or achieve situational awarenessÐfor example, mode control panel settings. Such operational translations would bring human factors issues to a level that ASRS analysts could use accurately and consistently. Parallel efforts are currently underway to translate Crew Resource Management (CRM) terms in this fashion for the Advanced Qualification Program (AQP).[3]

Regardless of the level of aggregation employed in an ASRS taxonomy, the research and user community must agree on standard definitions for the terminology employed. Without such standardization, it will be impossible for users to select salient variables for human factors investigation.

Proposed Steps Toward Developing an ASRS Human Factors Taxonomy

Several problems must be solved if a human factors taxonomy is to be tailored to ASRS needs: (1) a taxonomy must be defined that is meaningful to the human factors community; (2) report processing tools and techniques must be developed that will enable ASRS analysts to rapidly code reports for human factors information, at an acceptable level of quality. *No matter what method is devised, its application by ASRS analysts must be formally tested to ensure that the taxonomy is a practical tool, and that quality goals are actually being met by analysts during routine report processing.*

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[3] The FAA has tasked the Battelle Memorial Institute with development of a Model AQP Program which will identify innovative ways in which scenario-based training can be applied to LOFTs, LOEs, ground school curricula, field training devices, and simulator training (Mangold & Neumeister, 1995).

Adopt a Structured Research Approach. Development of an ASRS human factors taxonomy should consist of the following tasks[4]:

Task 1   Review existing human factors taxonomies and lexicons, including those developed by ICAO, NTSB, British Airways[5], and other organizations.

Task 2   Synthesize and enhance pre-existing taxonomies to create a new ASRS human factors taxonomy for database coding.

Task 3   Run tests to determine whether ASRS analysts can code reports at acceptable levels of speed and quality using the new taxonomy.

Task 4   If the coding tests fail, develop alternate approaches to accomplish the second research objective.

Develop Computerized Tools. The ASRS reporting form currently asks reporters to provide information on the chain of events (how the problem arose; how it was discovered; contributing factors; corrective actions) and human performance considerations (perceptions, judgments, decisions; actions or inactions; factors affecting the quality of human performance). Reporters do not always, or even usually, give equal attention to these human performance topics. Additional structure imposed on narrative descriptions might help some reporters provide information of value to the human factors researcher. If ASRS report submission *via* the Internet becomes a reality, a simple expert system with guided queries could support the collection of human factors information. Such a system could be set up (in theory) as a BBS or web page to which reporters could connect.

As various elements of report processing become computerized, coding of human factors information in ASRS reports may be accomplished by use of an electronic thesaurus of search terms. This feature would be particularly useful with a taxonomy that incorporates operational Òtranslations Ó of human factors concepts (i.e., both top-level and lower-level terms). An electronic thesaurus would allow ASRS analysts to insert one or more words and access a set of matching candidate terms. A specific term could then be selected from the candidate set.

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[4] This task definition was excerpted from a research proposal, ÒHuman Factors Taxonomy,Ó prepared by Loren J. Rosenthal in June 1993.

[5]

   British Airways has tested several human factors coding schemes, including one developed by John Chappelow of the RAF Institute of Aviation Medicine.

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4.16 NEEDED: A SYSTEMATIC APPROACH FOR A COCKPIT AUTOMATION PHILOSOPHY - HOP POTTER

Air Carrier Training Branch
Flight Standards Service, FAA

Background

At just about any meeting involving aviation human factors, cockpit automation is one of the hottest topics. It is a hot topic for a number of reasons. Perhaps the most important single reason is that technology is advancing too fast for us humans to assimilate its new products. This assimilation problem is even greater in respect to the FAA's ability to make appropriate regulatory policy.

There is an uneasy feeling among many in the aviation world that automation has a dark side. Anecdotal evidence points insistently at the automation element, in hangar-flying conversations about close calls and in safety articles and newsletters. Accident reports issued by the National Transportation Safety Board (NTSB) are also pointing at automation.

The Cockpit Automation Philosophy Gap

Still, the FAA has been unable to take a clear position in respect to cockpit automation. And there are many voices on this complex topic. What is desperately needed is a unifying cockpit automation philosophy, one that is universally accepted and faithfully applied in every activity of every aviation stakeholder. Those stakeholders include aircraft designers and manufacturers, aircraft customers, pilots, the travelling public, and the FAA.

One Example Of The Problem

Consider just one unresolved issue concerning cockpit automation, selecting an appropriate level of cockpit automation near a terminal area:

- ¥ Keystroke (input) errors generally run about 1 in 10 (10%) regardless of age, proficiency, and most other variables.

- ¥ One variable does affect keystroke error rate: WORKLOAD. Keystroke errors increase as workload increases.

- ¥ Workload is linked to confusion. If an FMS input operation is interrupted, confusion results, and crews typically START OVER AGAIN with the entire FMS input routine.

¥ Seems to say that use of the FMS for flight guidance is not desirable when workload is already heavy -- heads-down, more keystroke errors.

¥ Workload is heaviest in the terminal area. Seems to say that FMS use is not desirable in the
terminal area.

¥ A further reasonable inference seems to be the reverse of bullet #2: If keystroke errors start to pile up, it is probably caused by workload and confusion.

¥ An effective "human-centered" automation system would recognize when erroneous keystrokes are starting to signal that the human is getting overloaded (confused) and would fail -- drop off -- to a low- or zero-automation state.

¥ At present, automation systems fail into a kind of passive-aggressive state where they simply fail to accept appropriate input until the pilot unscrambles the egg. Meanwhile, clearances are busted -- altitudes, airspeeds, intercepts, holding clearances, etc.

¥ The overriding message seems to be: THE MORE THE CONFUSION, THE LESS SHOULD BE THE AUTOMATION IN USE BY THE PILOT.

¥ IF THE PILOT CAN'T RECOGNIZE THE MESS THAT'S DEVELOPING (and drop back to a lower level of automation by choice), THE SYSTEM SHOULD (and drop back to a lower level of automation on its own).

The line of reasoning flows. Anecdotal evidence seems to support the line of reasoning. Safety wags (writers) and safety experts (NTSB) are starting to point to automation's dark side. But there the remedial process bogs down.

The Missing Piece

What is missing is a way to get to an overarching cockpit automation philosophy that is based not on inference but on hard data -- a philosophy that is simple and irrefutable. The data gathering process needs to be broad enough to comprise human errors associated with specific features of cockpit automation hardware and software, and with the integration of automation with other cockpit processes.

Once appropriate data are collected, analysis should follow which culminates in practical principles regarding cockpit automation, principles for every aviation stakeholder. Those principles may then be packaged into a simple, usable cockpit automation philosophy statement that will show the way into the next century.

4.17BASELINE ASSESSMENT OF THE NATIONAL AIRSPACE SYSTEM: AN APPROACH TOWARD MODELING OPERATIONAL ERRORS - MARK D. RODGERS AND CAROL A. MANNING

Federal Aviation Administration's Civil Aeromedical Institute
Oklahoma City, OK

Introduction

In the history of the Federal Aviation Administration, no aircraft have collided while under positive control in En Route airspace. However, aircraft have violated prescribed separation minima and approached in close proximity. This event can occur as a result of either a pilot deviation or an air traffic control (ATC) operational error (OE).   In Air Route Traffic Control Centers (ARTCCs), also called En Route facilities, Air Traffic Control Specialists (ATCSs) primarily handle aircraft traveling between the terminal facilities across the nation. A system (SATORI: Systematic Air Traffic Operations Research Initiative) was recently developed that utilizes routinely collected radar and computer data from these facilities to re-create the air traffic situation, allowing for the graphic representation of situational dynamics (Rodgers & Duke, 1993). This paper discusses a method for utilizing SATORI input data with the POWER (Performance and Objective Workload Evaluation Research) system (Rodgers, Manning, & Kerr, 1994) to investigate the relationship between OE occurrence and measures of sector dynamics, aircraft proximity, and sector activity.

An ATC OE can occur as a result of either an equipment malfunction or an error on the part of an ATCS. ATCSs are required to maintain certain separation minima between aircraft under their control. Standards for separation minima are described in the Air Traffic Control Handbook (7110.65H), and associated supplemental instructions. While there is considerable complexity in those standards, at flight levels between 29,000 and 45,000 feet, ATCSs at En Route facilities are required to maintain either 2,000 feet vertical separation or 5 miles horizontal separation between aircraft. At flight levels below 29,000 feet with aircraft under Instrument Flight Rules (IFR) conditions, En Route ATCSs are required to maintain either 1,000 feet vertical separation or 5 miles horizontal separation. An ATCS OE takes place when a controller allows less than these prescribed minimum separation distances between aircraft (or between an aircraft and an obstruction).

In order for Quality Assurance (QA) specialists who investigate OEs to make more definitive determinations of the factors involved in OEs, they require an accurate representation of the dynamics associated with a given error situation (i.e., using SATORI), and access to objective (machine-based) measures of the ATC situation. Within the context of the current investigation/reporting procedure, it is not possible to determine the extent to which OEs are a result of traffic density, airspace configuration, local operating procedures, workstation design, poor technique, or any of a number of other possible factors. In fact, since normative information is not available for many relevant variables, as mentioned above, one must settle for a descriptive view of the factors associated with the error process. However, the POWER system

was developed to allow for the analysis of routinely collected radar and computer data. The POWER system objectively measures factors that may be related to the incidence of operational errors. POWER computes several sets of numerical measures, including airspace characteristics, aircraft dynamics, aircraft proximity, and sector activity.

POWER allows for the calculation of facility level normative data, and several measures currently made subjectively by QA specialists. The addition of objectively computed quantitative (i.e., number of aircraft worked, extent of separation loss) and qualitative (i.e., workload, complexity) measures to the current error investigation process may prove invaluable in determining causal relationships associated with the occurrence of OEs. This study addresses the impact of aircraft dynamics, aircraft proximity, and sector activity on situations in which an OE occurred. It is hypothesized that indices of aircraft dynamics, aircraft proximity, and sector activity vary systematically during the time periods before, during, and after an OE. In this study the period immediately preceding the occurrence of an OE is compared to the time period during which the error occurred. With POWER it should be possible to model the error process in ATC. OE modeling depends on the ability to develop measures sufficiently sensitive to distinguish between periods when OEs occur and when they do not. However, in this study, there were too few observations and too many variables to achieve this result. Therefore, these analyses were considered exploratory and thus were used to provide general indications about variables of interest that might be explored further.

Method

Routinely Collected ATC Data. En Route facilities record all data associated with air traffic control operations on a System Analysis Report (SAR) tape. Several data types on a SAR tape can be extracted on the ATC Host Computer System (HCS) using the National Track Analysis Program (NTAP) and the Data Analysis and Reduction Program (DART). Three DART files were extracted for this analysis: Log, Track, and Conflict Alert. One NTAP file was extracted: Beacon. The Log file contains information on all ATCS interactions with the HCS and information displayed in the aircraft data blocks (i.e., altitude, speed, and handoff messages). The Track file contains information about the number and type of aircraft tracks (i.e., free, flat, coast, block, hold, unknown) in each sector. The Conflict Alert file contains information regarding the conflict alert notices (notifications of potential conflicts between pairs of aircraft occurring within one's sector of control) sent to each radar display in the facility. The Beacon file contains information about aircraft location within the facility's airspace.

Apparatus.   The calculation of dependent measures was performed by the POWER software routines which were written to analyze the extracted DART and NTAP data used by the SATORI system. The POWER workstation is a DEC 3000-600 Alpha using the DEC/AXP 6.1 operating system with 44 gigabytes of striped (RAID Level 5) storage and 128 Megabytes of RAM.

Design and Procedure. Data were analyzed for 12 OEs that occurred at Atlanta Air Route Traffic Control Center between 1992-1994. Each of the 12 errors involved only one sector. Eight of the sectors were low altitude sectors, and four were high altitude sectors. In six of the errors, a single

controller was working the sector; in five errors, two controllers worked the sector; and in one error, three controllers were working the sector. Seventeen minutes of data were associated with each error. The data for each error were split into two parts: the first 8 1/2 minutes preceding the error, and the second 8 1/2 minutes during which the error occurred. The error occurred approximately 2 1/2 minutes after the start of the second time period.

A within-subjects design was used to analyze the data for the two time periods. MANOVAs were performed on the 2 sets of sector activity measures, 3 sets of aircraft proximity measures, and 3 sets of aircraft dynamics measures. The 2 sets of sector activity measures included 4 measures associated with handoff activity (Number of Aircraft Transiting Sector, Average Sector Transit Time, Number of Handoffs Accepted, and Latency to Accept Handoffs), and 2 measures associated with HCS interactions (Number of HCS Inputs, and Number of Input Errors). The 3 sets of aircraft proximity measures included 2 measures of conflict alert (Number of Conflict Alerts, and Duration of Conflict Alerts), 4 measures of proximity (Average Horizontal Separation, Average Vertical Separation, Number of Aircraft Pairs Within a Criterion Distance of Each Other, and the Average Time Aircraft Pairs Spent Within a Criterion Distance of Each Other), and Number of Aircraft in the Sector by track type. The 3 sets of aircraft dynamics measures included speed, heading, and altitude dynamics. Four measures were calculated for each: Average Change, Number of State Changes (A state is defined as a continuous change in position. For instance, if an altitude update for an aircraft increases for 5 updates, then remains stable for 5 updates, and then decreases for 5 updates, a total of 3 state changes occurred; however, average change over the time period could be zero.), Number of Aircraft Changing State, and the Number of Changes Over a Criterion Level. The criterion values chosen for this analysis were 50 knots for speed changes, 1000 feet for altitude changes, 15 degrees for heading changes, and 10 miles and 1000 feet for the proximity criterion.

Results

Each set of measures was calculated by POWER for each OE. The resulting data files were appended into a single data set for each type of measure. These measures were then examined using MANOVA to evaluate any change that might be attributable to the within-subjects factor of time period. Since this was an exploratory study, an alpha level of $p < .1$ was selected to protect against the commission of Type II error.

Sector Activity Measures. Table 1 details the means, standard deviations, and significance levels of the sector activity measures associated with handoffs. The Average Sector Transit Time was significantly longer during the error period, $F(1,11) = 57.86$, $p < .001$, as was the Average Latency to Accept Handoffs, $F(1,11) = 23.74$, $p < .001$. The Number of Handoffs Accepted was significantly less during the error period, $F(1,11) = 26.95$, $p < .002$. The Number of Aircraft Transiting the Sector was not significantly different across time periods. Neither of the measures associated with HCS Interactions (Number of Inputs and Input Errors) was significant.

Table 1
Sector Activity

Handoff				Overall $\underline{F}(4,8)$=17.16, p<.001
Average Sector Transit Time	t1 t2	$\underline{M}$ = 263.41 $\underline{M}$ = 547.27	$\underline{SD}$ = 79.30 $\underline{SD}$ = 151.83	$\underline{F}(1,11)$ = 57.86, p < .001
Average Latency to Accept HO	t1 t2	$\underline{M}$ = 44.57 $\underline{M}$ = 116.17	$\underline{SD}$ = 32.42 $\underline{SD}$ = 65.16	F (1,11) = 23.74, p < .001
Number AC Transiting Sector	t1 t2	$\underline{M}$ = 3.58 $\underline{M}$ = 4.42	$\underline{SD}$ = 2.11 $\underline{SD}$ = 2.71	F (1,11) = 2.57, p > .13, N.S.
Number of HO Accepted	t1 t2	$\underline{M}$ = 5.00 $\underline{M}$ = 2.67	$\underline{SD}$ = 2.67 $\underline{SD}$ = 1.88	$\underline{F}$(1,11) = 26.95, p < .001

Aircraft Proximity Measures. Table 2 details the means, standard deviations, and significance levels of the aircraft proximity measures. For the aircraft proximity measures, average vertical separation was greater for the error period $\underline{F}$ (1,11) = 6.51, p < .027, as was the Average Time Aircraft came within a Criterion Distance of Each Other $\underline{F}$ (1,11) = 17.24, p <.002. Neither of the measures of conflict alert nor the measures of Aircraft Tracks were significantly different across time periods.

Table 2
Aircraft Proximity

Proximity				**Overall** $\underline{F}(4,8)=7.51$, $\underline{p} < .008$
Average Horizontal Separation (mi)	t1	$\underline{M} = 4.18$	$\underline{SD} = 4.41$	$\underline{F}\,(1,11) = 2.74$, $\underline{p} > .12$, N.S.
	t2	$\underline{M} = 6.33$	$\underline{SD} = 2.31$	
Average Vertical Separation (ft x100)	t1	$\underline{M} = 391.69$	$\underline{SD} = 427.26$	$\underline{F}(1,11) = 6.51$, $\underline{p} < .027$
	t2	$\underline{M} = 701.01$	$\underline{SD} = 265.67$	
Average Time AC within 10 Miles & 1000 Ft. (Sec)	t1	$\underline{M} = 33.88$	$\underline{SD} = 60.46$	$\underline{F}(1,11) = 17.24$, $\underline{p} < .002$
	t2	$\underline{M} = 68.99$	$\underline{SD} = 52.94$	
Number of AC Pairs within 10 Miles & 1000 Ft.	t1	$\underline{M} = 2.42$	$\underline{SD} = 4.32$	$\underline{F}(1,11) = 3.37$, $\underline{p} < .09$
	t2	$\underline{M} = 4.08$	$\underline{SD} = 3.50$	

Aircraft Dynamics Measures. None of the overall MANOVAs for the three sets of dynamics measures (speed, heading, and altitude changes made by aircraft) indicated differences between time 1 and time 2.

Discussion

It should be stated at the outset that this analysis was an exploratory study that cannot be interpreted as defining the causes of OEs. However, it was a first attempt using the POWER system to compare situations in which OEs occur with situations in which they did not occur. While several measures were significant in the expected direction, many failed to reach significance. Those that did reach significance suggest that the controller was busier during the error period than the period prior to it. For instance, there were longer sector transit times, longer latencies to accept aircraft, and fewer aircraft accepted during the error period. In fact, it took nearly twice as long for approximately the same number of aircraft to transit the sector during the error period. The question as to whether these characteristics caused the errors or resulted from the errors can not be ascertained from this analysis.

Another interesting finding was related to aircraft density. As expected, during the error period more aircraft pairs were within the criterion distance (10 miles & 1000 feet) for a significantly longer duration. However, mean vertical separation between aircraft was also significantly greater during the error period, and mean horizontal separation appeared greater during the error period, but the difference failed to reach statistical significance. That is, although more aircraft pairs were within the criterion distance from each other for a longer duration during the error

period, in general, those aircraft had greater vertical and horizontal separation during the error period. This indicates that aircraft density was temporarily increased during the error period. It would be interesting to look at the distribution of aircraft density within a sector for several criterion distances and track the density transitions to determine their relationship to losses in separation.

The events associated with this analysis occurred within the same sector over two closely spaced time periods. The focus of further analyses will be to look at different time periods, using the same data set to better understand the temporal sensitivity of these measures. By analyzing the temporal characteristics of these measures, it is hoped that it will be possible to more accurately identify the time period that defines the error. Many of these measures may also be highly correlated; by reducing the number of measures, namely those less sensitive in identifying error situations, a more predictive set of measures should become available.

POWER has many potential applications, including performance and taskload measurement, description of factors that influence complexity in ATC, evaluation of alternative ATC display designs and configurations, and evaluation of the productivity of controllers utilizing new automated systems. In order to model the operational error process using POWER, further analyses will be required, and larger data sets and fewer variables will be requisites. Once profiles of selected variables have been developed and applied to operational data sets it may be possible to predict the occurrence of an operational error, aside from the fact that separation between aircraft has been lost. Such models, if validated and appropriately applied to conflict resolution algorithms, should eliminate/reduce the occurrence of operational errors. It is to this end that this research is directed.

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4.18 THE QUEST FOR AVIATION SAFETYÕS HOLY GRAIL: FINDING UNDERLYING CAUSES OF ACCIDENTS AND INCIDENTS OR IF YOU REALLY WANT TO IMPROVE AVIATION SAFETY, YOU MUST FIRST IDENTIFY SYSTEMIC PROBLEMS - CAPTAIN ROBERT L. SUMWALT, III

Working Group for Human Factors in Accident Investigation
Air Line Pilots Association

The goal of the FAAÕs Human Factors Data Project is to identify causes of human error that contribute to accidents and incidents in order to develop prevention strategies. The Air Line Pilots Association, representing 42,000 professional airline pilots flying for 37 airlines, has long supported efforts to improve flight safety by addressing and resolving the real and potential threats to safety. Many sources of data indicate that human error is the largest single cause of aviation accidents across all types of flight operations. For example, the *FAA's National Plan for Civil Aviation Human Factors: An Initiative for Research and Application* states that human error has been identified as a causal factor in 60 to 80% of air carrier, commuter, and general aviation accidents and incidents (FAA, 1995). Because such a large percentage of accidents involve human factors, ALPA believes that proper and thorough investigation of aviation human factors is an essential element in preventing future accidents.

ALPA is committed to thoroughly investigating all areas of potential significance in an accident investigation, including human factors. Recently we formed a Working Group for Human Factors in Accident Investigation, a committee comprised of experienced airline pilots who have received advanced training in human factors in accident investigation techniques. *ICAO Human Factors Digest Number 7* states that combining an understanding of human factors with an accident or incident investigation can provide Òa greater opportunity to identify root causes which may not have been recognized previouslyÓ (ICAO, 1993).

Why Investigate Accidents and Incidents?

A personÕs answer to this rhetorical question may depend on his or her perspective. A lay person, for instance, may simply want general answers to what caused the accident. For a trail lawyer the goal of an investigation may be to find fault or assign blame. However, to those persons truly dedicated to improving aviation safety there is only one overriding objective of each investigation: identifying and correcting causal factors to prevent future mishaps.

Although the goal of Òidentifying and correcting causal factors to prevent future mishapsÓ may sound a bit obvious, the outcome of some investigations reveal that this objective is not clearly understood. ICAO says, ÒAccident investigation reports usually depict clearly **what** happened and **when**, but in too many instances they stop short of fully explaining **how** and **why** the accidents occurred.Ó Until the industry consistently addresses the ÒhowÓ and ÒwhyÓ, the watch-words for accident prevention, efforts will be ÒreactiveÓ rather than Òproactive.Ó It is ALPAÕs intention to continually improve the processes that lead to more proactive accident

prevention. This proactive approach includes a systemic review of human factors in accidents and incidents. This is approach is akin to a person who discovers a slow leak in one of his car tires. There are essentially two options to resolve the dilemma: continue indefinitely to fill the empty tire, or find the nail that caused the leak and correct the problem. Accident reviews that do not look at systemic issues are simply Òfilling the tireÓ rather than repairing it.

Looking Beyond the Obvious

Indeed, several investigations have concluded that the mishapÕs cause was some performance failure or error by a Òfront line operatorÓ such as a pilot, air traffic controller or mechanic. While the cited individuals may have been the last person(s) to have made an error prior to the accident, it must be clearly understood that people do not make errors in a vacuum; they are merely one element in a very complex system. To really understand what caused a particular mishap the investigation <u>must</u> dig beneath the surface - look beyond the obvious - to determine what systemic factors may have caused or led an individual(s) to act inappropriately. An investigation that looks beneath the surface Òhelps identify the underlying deficiencies that might cause other incidents or another accident to happen,Ó according to ICAO. Developing a framework for systemic review provides a roadmap (a process and a focus) for unfamiliar territory. The complexity and unique context inherent in every accident suggests that each review is uncharted territory.

A Òsystems approachÓ to accident and incident investigation acknowledges that *all* elements of the system may have a role to play in the occurrence. These elements include, but are not limited to, airline management philosophies and practices, regulatory influence and corporate culture. Adopting a systems approach helps to identify the underlying causes through a better understanding of how various components of the system interacted and integrated to result in a mishap.

ALPA strongly believes that all accident and incident investigations must strive to review systemic factors leading to the accidentÕs root cause(s). Because a systems approach aids in the discovery of underlying system deficiencies, it allows energies to be clearly focused when offering recommendations for corrective actions. Without a clear understanding of the mishapÕs root cause(s), recommendations are likely to be Òband aidÓ solutions, not true solutions.[6] For example, two often cited ÒsolutionsÓ are *increased training* and a call for *added vigilance*. While these items may be necessary and appropriate in some cases, oftentimes they compensate for, rather than correct underlying system deficiencies. Resource management training teaches crews how to leverage available resources. While a highly resourceful and well rested crew may not fall prey to a systemic deficiency, another crew may. The more important question is ÒAre the resources sufficient or appropriate for the operational requirements?Ó For example, a review

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[6] By suggesting that investigations look at root causes, ALPA is not suggesting that front line operators are never to blame. However, the Association recognizes that if any appreciable improvements are to be made in aviation safety, they must be done through a comprehensive systems approach directed towards getting at the root cause of mishaps. We see little benefit in investigating accidents and incidents without a commitment to investigate all elements of the system.

of operator action without a review of available resources and/or situation context is a deficient process that will likely lead to a band aid solution. It is necessary to define methodologies that focus investigative efforts beyond the surface indicators. The development of systemic human factors investigative methodologies will focus review activities on a deeper level.

A system as complex as the air transportation system requires real solutions. While band aid solutions may provide short term fixes, they are faulty by virtue of their failure to actually correct the real problems. In order to make real improvement in aviation safety, it is necessary to first identify systemic problems. Unless the underlying systemic deficiencies are identified, it is not likely that corresponding corrective actions and recommendations will prevent future mishaps. To illustrate, in February 1979 an Nord 262 air carrier crashed at Clarksburgh, WV. The National Transportation Safety Board (NTSB) determined that the probable cause of the accident was Òthe captainÕs decision to takeoff with snow on the aircraftÕs wings and empennage surfaces ...Ó (NTSB, 1979). By pointing their finger at the crew, what did the NTSB accomplish? Did their probable cause statement eliminate takeoff icing-related accidents? Sadly, it should be no surprise that in the 13 years that succeeded this accident, there were 10 air carrier accidents worldwide attributed to takeoff attempts with ice on wings.

In March 1992 a Fokker F28 air carrier crashed during attempted takeoff from New YorkÕs LaGuardia Airport. The focus of this investigation centered on wing icing, but unlike others, it also looked at the entire system in which the flightcrew operated. The NTSB then determined that the probable cause of the accident was Òthe failure of the industry and the Federal Aviation Administration to provide flightcrews with procedures, requirements, and criteria compatible with departure delays on conditions conducive to airframe icing...Ó (NTSB, 1993). It must be noted that the NTSB also cited the crewÕs performance, but by citing the system as the foremost cause, the catalyst for change was set. The systemic investigative approach that surrounded this accident directly influenced widespread improvements to Federal Aviation Regulations pertaining to takeoff in icing conditions, as well as massive overhauls to air carrier operating procedures. Had the NTSB merely pointed the finger of blame at the flightcrew, what corrective action, if any, could have been gleaned from this investigation? Based on the fact that 10 air carrier accidents occurred worldwide due to icing in the previous 13 years, it is suspected that very little safety improvement would have been realized had the NTSB failed to take a systemic approach. Remember: in order to improve aviation safety, you must first identify systemic problems.

A systems approach to investigation must be clearly defined and methodically used in each and every investigation. While the NTSB may have used a systems approach in determining probable cause of the 1992 New York icing accident, it failed to use this methodology when determining the cause of a 1994 windshear accident at Charlotte, NC (NTSB, 1995). Had the crew been made aware of the severe windshear conditions that existed that evening, they would have not initiated their approach for landing. However, a series of systemic failures prevented the crew from acquiring this information: a sophisticated terminal Doppler weather radar (TDWR), a weather-alerting system with proven results, should have been installed in Charlotte, but was plagued with FAA bureaucratic problems including land acquisition difficulties; air traffic controllers were required, but failed to provide the crew with timely weather information; and, the aircraftÕs

on-board windshear detection system had a design flaw that prevented the flightcrew from receiving a timely windshear alert. In spite of these weather dissemination deficiencies, the NTSB cited crew errors as accidentÕs foremost probable cause. It was speculated that upon entering the windshear, the crew could have successfully flown through the encounter had the aircraft been flown differently. While that may have been the case, a systems approach would have revealed that the crew probably would have never initiated the approach had they been warned of the serious nature of the weather. In essence, had the crew been properly forewarned, the accident opportunity would have been eliminated.

The National Center for Atmospheric Research states that there have been 30 air carrier windshear-related accidents from 1964-1989. Following the Charlotte windshear accident the NTSB had an excellent opportunity to highlight the need for improvements in weather dissemination practices. Because they failed in that endeavor, no real change is likely to significantly reduce windshear-related accidents. As indicated in the above-cited icing analogy, until investigations focus on the underlying causal factors that contributed to the mishap, it is difficult to appropriately focus corrective actions.

How Do We Get There?

To conduct a systemic investigation of a mishap, it is necessary to properly collect and analyze human factors data. Human factors cognitive models provide a framework for the scope and focus for review efforts. Two well known models are EdwardÕs SHEL model and ReasonÕs model. Below is a very brief description of these models. *ICAO Human Factors Digest Number 7* contains a more extensive explanation of each.

The SHEL model is useful for human factors data collection because it allows exploration of many (hopefully all) factors that may have acted upon the individual in question. This model removes focus from the individual, instead highlighting that individuals do not operate on their own, but rather interact directly with many other components in the system.

A systemic analysis follows the data collection process. Dr. James ReasonÕs model is helpful because it establishes a framework for investigators to use when looking beyond the actions of front line operators. Imagine for a moment the task of trying to get to the core of an onion. Envision peeling back layer after layer of the onion, all the while getting closer and closer to core. To apply this analogy back to the context of an aviation mishap investigation, ReasonÕs model helps investigators peel back the various layers of the system in order to find the root cause of the event. As one works through all layers of the system it is possible to identify how latent failures[7] interacted with the front line operators to create the Òwindow of accident opportunity.Ó Reason states that front line operators are the Òinheritors of a systemÕs defects.Ó

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[72] Latent failures are flaws in the system that are lying dormant, waiting to become manifested. An example of a latent failure is the design problem with the on-board windshear detection system that was cited in the Charlotte accident. The problem existed for many years but did not become manifested until combined with a series of other flaws, such as FAA problems with implementing TDWR, ATCÕs non-adherence to prescribed weather dissemination practices, and crew procedural errors.

Because the quality of data collected and analyzed may be limited by the models and protocols used, and because these tools are limited in number, ALPA challenges the industry to advance development of human factors investigation protocols and models.

Needed: Emphasis On Incident Investigation

The value of investigating incidents must not be underestimated. It is widely believed that incidents are precursors of accidents. To support this notion, industry-wide estimates suggest that there are approximately 360 minor safety incidents that underlie each fatal accident (Ganse, 1994). Therefore, it is important to investigate incidents and analyze trends that may point to potential accidents.

It is commendable that many air carriers are developing in-house incident reporting systems. However, this implementation is not without danger. If each air carrier develops its own incident reporting system, how does this affect the utility of a national or centralized incident reporting system such as NASAÕs Aviation Safety Reporting System (ASRS)? Is it possible that encouraging airline employees to submit incident reports to their own in-house incident reporting systems may effectively decrease the emphasis on submitting these reports to ASRS?

To realize an inherent danger of decreasing emphasis on ASRS usage, one only must look at an event that triggered formation of ASRS. In December 1974, a Boeing 727 airliner descended prematurely and crashed into a mountainside while on approach to WashingtonÕs Dulles International Airport. The investigation uncovered widespread ambiguity concerning flightcrew actions following receipt of approach clearances (NTSB, 1975). Ironically, only six weeks earlier a United Air Lines crew very narrowly escaped the same fate while conducting the same approach to the same airport (Hardy, 1990). The United crew reported the event to their company Flight Safety Awareness Program, a program where crew members were encouraged to report to the company any incidents they felt involved a safety problem. This report resulted in safety bulletins being issued to United crews to warn them of this trap; however there was no clear avenue to disseminate this information to crews of other air carriers.

There is tremendous, undisputed value of having air carriers collect and analyze their own incident data. However, philosopher George Santayana stated, ÒThose who cannot remember the past are condemned to repeat it.Ó The reasons for forming ASRS must not be forgotten, lest accidents and incidents of the past will be repeated. It is essential that a system be developed to encourage reporters to dual report incidents to company incident reporting systems, as well as to ASRS. ASRS has capability to quickly disseminate safety concerns to appropriate authorities to ensure timely corrective actions. Also, ASRS offers Òpower in numbersÓ when looking for hazard trends. For instance, if each carrier received only one report of a particular problem it may be difficult, perhaps impossible, to determine the level of threat posed by this seemingly isolated event. However, if ASRS also received a copy of each of these reports, then it is considerably more likely that the hazard would be detected. Obviously it is easier to detect trends with an increased number of data points.

Conclusions

The goal of the FAAÕs Human Factors Data Project is to identify causes of human error that contribute to accidents and incidents in order to develop prevention strategies. It must be clearly understood that it is not possible to prevent humans from making errors. What is possible, however, is better management of human error. By conducting investigations that focus on finding and correcting systemic problems, it is possible to reduce the frequency of these errors and to limit their adverse consequences.

In order to make an appreciable improvement in aviation safety, it is essential that systemic problems be identified and corrected. Knowledge of aviation human factors and an understanding of how to apply this knowledge in accident and incident investigations will offer a greater opportunity to accomplish this goal.

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4.19ASSESSING THE QUANTITY AND QUALITY OF AVIATION SAFETY INCIDENT REPORTS: TWO STUDIES - MICHAL TAMUZ

University of Texas
School of Public Health
Houston Health Science Center

In this paper, I draw on the findings of two studies that relate to one of the workshop goals, assessing the quality and quantity of information provided by aviation safety information systems. These studies were conducted as a part of a larger, ongoing research project that seeks to understand how organizations collect information about (Tamuz, 1988) and learn from near accidents. The main argument is that while the number of incident reports does not provide a reliable indicator of aviation safety, the contents of the reports can provide valid safety-related information.

The first is a study of pilot reports filed with the Near Midair Collision System (NMAC System) operated by the Federal Aviation Administration, as part of the National Airspace Information Monitoring System (NAIMS). It explores how the midair collision over Cerritos affected the reporting of near midair collisions (NMACS) by pilots in California (Tamuz, 1988). The study examines the content validity of NMAC reports filed in the wake of heavily-publicized accidents.

The second, a study of the Aviation Safety Reporting System, examines changes in pilot incident-reporting behavior following the implementation of the automated surveillance of air traffic controllers (Tamuz, 1987). The research focuses on some of the consequences of offering limited immunity in exchange for information on potential dangers.

The studies examine changes over time in the reporting of incidents or near accidents to safety information systems. The definition of a near accident is drawn from the National Research Council's definition of an air traffic incident; it is defined as an event in which "...no significant damage or injuries occurred, but which, under other circumstances, could have been an accident...."(NRC, 1980). In this paper, the terms "incident" and "near accident" are used interchangeably.

The quantity and quality of data is affected by how the information was collected. Because safety reporting systems rely on individuals as the primary source of information, the factors that influence individual reporting behavior can also confound efforts to use incident data to monitor safety conditions. Indeed, safety analysts often have observed that counting the number of potentially hazardous events reported by individuals does not provide a reliable safety indicator.

Observations on the Quantity of Incident Reports

As aviation safety experts have long realized, variations in the number of incident reports are not only affected by changes in the underlying safety conditions but also by factors, often unrelated to safety, that influence individual reporting behavior. The Aviation Safety Reporting System

(ASRS) routinely cautions data-users about the reporting bias that can confound their data analysis. Indeed, an increase in the quantity of reports may reflect improvements in reporting rather than an erosion in safety conditions. For example, an aviation safety information system experienced an abrupt increase in the number of incident reports following the distribution of new reporting forms. The increase in reporting can also result from the influence of external events or internal changes in the safety information system. While monitoring near midair collisions in California, FAA safety analysts observed a dramatic increase in the number of NMACs reported after the Cerritos midair collision, on August 31, 1986 (FAA, 1987b). Similarly, in a footnote to NMAC statistics, FAA safety analysts explain that the remarkable increase in the number of NMAC reports filed during 1968-71 corresponds with the time period in which the FAA experimented by offering immunity to those who filed NMAC reports (FAA, 1987a; Tamuz, 1994).

The evidence from aviation suggests that the number of incidents reported to a safety reporting system is not a reliable safety indicator. Drawing on the cumulative experience of aviation safety experts, a series of studies confirmed this conclusion. The research findings indicated that the number of near accidents reported varied with changes in publicity, politics, and perceived incentives (Tamuz, 1988).

Although the confounding effects of reporting biases on incident-reporting trends is widely-recognized by aviation safety analysts, less is known about the relationship between the quantity of reports filed and the quality of the data provided by them.

Questions about the Quality of Information

Questions remain about the validity of information contained in the near accident reports. Consider the near midair collision (NMAC) reports submitted to the Federal Aviation Administration. If a pilot perceives that a near midair collision occurs and files a report with the FAA, the FAA must gather and investigate each report, even if after further investigation, the report is found to be mistaken. It is commonly thought that since the number of NMAC reports filed is sensitive to external events, such as highly-publicized accidents, that these "extra" reports are likely to be mistaken or trivial. In the ASRS, limited eligibility for immunity is offered in exchange for providing information about potential dangers. Understandably, a common assumption is that most incident reports are filed in order to benefit from the immunity provisions. The following studies address these two sets of common assumptions.

A Study of Near Midair Collision Reporting before and after the Cerritos Midair Collision

Drawing on safety analysts' observations of the effect of the Cerritos accident on NMAC reporting, this longitudinal study monitors whether highly publicized accidents influenced the number of NMACs reported in California (Tamuz, 1988). The findings tentatively suggest a "geography of risk", in which pilots perceptions of risk were increased by accidents close to home but were left unaffected by accidents that occurred in far away places. Thus, as noted earlier, tracking the number of incidents did not appear to reflect changes in underlying safety conditions.

Although the number of NMAC reports filed was influenced by publicity over recent local accidents, the contents of most of these reports provided valid information about safety concerns. Using data provided by FAA investigators, the study examined the validity of the near accident reports filed in response to publicity over the Cerritos accident and other California-based accidents. As part of their investigation, FAA flight safety investigators categorized each NMAC report as "critical", "potential", or "no hazard". If, as one might assume, the accident encouraged individuals to file an NMAC report over any trivial event, one would expect a greater proportion of non-hazardous reports filed after a highly-publicized accident than before it.

The findings of this study suggest the contents of incident reports provide valid information about potentially hazardous events despite their lack of reliability as a safety indicator. The findings indicate that there is no significant difference in the proportion of valid to non-hazardous NMAC reports submitted in California, before and after the Cerritos accident, and other highly-publicized, local accidents.

Perceived Changes in Reporting Incentives: A Natural Experiment

This study of the Aviation Safety Reporting System (ASRS) examined some of the effects of immunity provisions on the voluntary reporting of potentially hazardous situations (Tamuz, 1987). One of common concerns about offering immunity from punishment in exchange for information about potential dangers is that individuals will focus their attention on rule violations and report only those events for which they can benefit from the immunity provisions (e.g., Lawler and Rhode, 1976).

In 1983, a natural experiment occurred when the FAA, as part of its Quality Assurance Program, began to install a computerized system for the surveillance of controllers working in air traffic control centers. Although the system was designed to monitor the performance of controllers, one of its indirect effects was an intensified surveillance of pilots, albeit under limited conditions. With the implementation of this new surveillance system, pilots apparently perceived that the chances of detection had increased; and consequently, they perceived greater incentives to seek immunity by reporting possible air traffic violations to the ASRS.

Building on this natural experiment, the study examines pilot reports to the ASRS before and after the implementation of the QAP computerized surveillance of controllers. The study

compares the reporting of "monitored events" (i.e., possible air traffic violations that could be detected by surveillance, such as altitude deviations, heading or track deviations) to the reporting of "non-monitored events" (i.e., safety-related incidents, unrelated to air traffic violations and the quest for immunity). With the increase in the perceived incentives for seeking immunity, it was expected that pilots would focus their attention solely on protecting their interests by filing reports of possible air traffic violations to the ASRS. Thus, it was predicted that the reporting of monitored events would increase while the reporting of non-monitored events would decrease.

Contrary to expectations, the findings demonstrated that pilot reporting of incidents to the ASRS could not be explained solely as a means of seeking immunity. As expected, following the implementation of the QAP computerized surveillance, the findings indicated a dramatic increase in the number of pilot reports of monitored events, or possible violations. Surprisingly, there also was an increase in the number of reports of non-monitored events, or safety-related incidents, which could not be detected by the surveillance system. Despite the perceived increase in the incentives for seeking immunity, pilots continued to file reports of safety-related incidents that were unrelated to rule violations and thus, unrelated to gaining benefits from the immunity provisions.

Conclusions

While counting the incident reports gathered from individuals does not produce a reliable measure of aviation safety, pilot reports of potential dangers can provide a valid source of information about potential hazards.   Consider the Near Midair Collision System operated by the FAA. Although variations in the number NMAC reports can be affected by highly-publicized local accidents, the increase in the number of reports also yields valid descriptions of actual and potentially hazardous near midair collisions. Similarly, while the possibility of gaining immunity gives pilots an incentive to file reports with the Aviation Safety Reporting System, it is not the only motivating factor. Pilots reported many safety-related incidents to the ASRS that did not involve immunity provisions. Thus, in both systems, counting incident reports does not provide a reliable safety indicator, but the contents of the reports can contain valuable descriptions of potential dangers.

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4.20IN SEARCH OF ANSWERS WITHOUT QUESTIONS: OR, HOW MANY MONKEYS AT TYPEWRITERS WILL IT TAKEÉ - JOHN A. WISE AND MARK A. WISE

Embry-Riddle Aeronautical University   University of Central Florida
Daytona Beach, FL   Orlando, FL

Abstract

It is argued that it will be difficult to identify potential problem areas in new technology areas *a priori* because of the lack of theory and/or hypotheses to tell one were to look. Random searches, or searches based on theory relevant to old technology, will be of limited value. Some non-standard approaches to the problem area are discussed.

ÒAll men by nature desire to know.Ó
Aristotle, *Metaphysics*, (p.1)

Introduction

Rapid advances in technology and software have provided the capability to develop very complex systems that have highly interdependent components. While this has permitted significant increases in system efficiency and has allowed the development and operation of systems that were previously impossible (e.g., negative stability aircraft), it has also brought the inherent danger of system induced catastrophes. Perrow (1984), in his book *Normal Accidents*, has demonstrated that highly-complex systems with highly interdependent components have an inherent disposition toward massive failure.

Systems that have high intradependence often create new types of failures. Interrelated components that were previously independent can cause unpredicted failures in each other. For example, the tests of wide-bodied aircraft initially used the same criteria for cabin depressurization as older narrow bodied aircraft. As a result, when the DC-10 lost a cargo door in flight (an unskilled ground crew could not lock it properly because of the complexity of the procedure), the insufficient means of depressurizing the cabin caused the floor to buckle jamming the controls. The unpredicted intradependence between ground personnel skill, procedure complexity, cabin pressure, and flight controls resulted in a crash and the loss of many lives.

As complex systems become more intradependent, interdisciplinary issues become more critical. Nowhere is this more true than in the person-machine interface. It is likely that new operational interface problems will reside in locations where disciplines (and the system components relevant to their domain) meet and interact. It is in these intellectual intersections that most new compromises and cross-discipline trade-offs are made. And it will be in these intersections, that new interface induced failures will emerge that will probably not have been anticipated. It is also in these intersections that it will be the most difficult to determine where to look for potential faults *a priori*.

Given the above issues, it is difficult to argue against the goal of this meeting: to identify ways of predicting where problems will exist Ð before they occur Ð so as to mitigate their consequences. However, we will argue that the odds of such an undertaking being successful are low.   The history of science is ripe with debates on this issue, but it is generally accepted today that any search is always guided by some theory or hypothesis.   Pirsig (1974) in his classic book *Zen and the Art of Motorcycle Maintenance* debated the origin and value of knowledge and quality. He noted that there has been a long debate within the philosophy of science of how science and scientific theories develop. Pirsig was describing the arguments of the French philosopher and mathematician Henri PoincarŽ when he wrote:

Which facts are you going to observe? he [PoincarŽ] asked. There is an infinity of them. There is no more chance that an unselective observation of facts will produce science than there is that a monkey at a typewriter will produce the LordÕs prayer. (Pirsig, 1974, p. 237)

The equivalent in the current discussion would be that Òthere is no more chance that the unselective observation of aviation data will produce insight into future accidents than there isÉ Ó So one needs to ask the following basic questions/.   How do we develop selective observations in areas where little theory or other insight exists? How do we know where to selectively look when we are using a new technology or when we are using a procedure that has never been applied?

How About Science?

The scientific model, as PoincarŽ has noted, is particularly weak at making predictions without an underlying theoretical base. As a matter of fact many philosophers of science have argued that it is impossible for science to work at all without theory to guide the search. The scientific method itself is rooted in the empiricist philosophy of the John Locke, George Berkeley, and David Hume. These philosophers maintain that all knowledge is gained through empirical, *a posteriori* experience or observation. These scholars have taught us that step one of the scientific method is the statement of the problem and step two involves developing hypothesis. Scientific research involves the testing of the hypotheses, without a statement problem or hypothesis, inquiry can not proceed within the scientific method.

The analysis and prediction of future errors or events is based primarily on the ability to infer from those which have previously occurred, and a belief that there is justification for believing that these events will or could happen again (Hume, 1748). However, to predict those events which have no historical correlate, requires something much more Ð foresight. If, as the old adage states Òhindsight is 20/20,Ó then foresight would be at least functionally blind. History suggests that no matter how diligently and methodically a system is tested *a priori,* there still exists a possibility for failure. Take for example ÒThe Unsinkable Ship,Ó the Titanic Ð it sank. Thus, the question becomes, ÒHow do we form reasonable hypotheses about future?Ó

Even if it were possible to identify the hypotheses, the scientific method would still be extremely difficult to apply. To address the current inquiry within the scientific paradigm, the following problem statement might be established: ÒWhat events will lead to undesirable situations within the aviation system?Ó However, further attempts to break this problem down into more manageable tasks, proves

laborious, if not futile. The complexity of the interface between human and machine provides a number options which, when analyzed mathematically approach infinity, especially when coupled with time and highly unpredictable environmental factors (both physical and psychological).

Hume (1748), Mason and Mitroff (1973), and others have also argued that science is basically a consental method of inquiry. That is, the ÒtruthÓ of a scientific theory is based on the amount of prevailing opinions for the theory exists among the scientists of that field (i.e., does it win a referendum vote?). If the topic area is new (e.g., new technologies or new procedures) there will not be many prevailing opinions, there will be much disagreement and debate. Mason and Mitroff observed that if the consental position is at all suspect (i.e., there is not a large majority supporting a given theory) then something other than traditional science may be needed.

How About Simulation Or Modeling?

Unfortunately modeling and simulation, while they are extremely powerful tools in structured problem spaces, have problems when it comes to new technologies and/or procedures. Modeling and simulation use a formal (often mathematical) representation of the problem space by starting from a set of basic ÒtruthsÓ and then systematically build a network of more formal propositional truths.

Modeling and simulation normally have high value because they can be tested by the exacting tests of logic and mathematics, such as internal consistency, completeness, comprehension. Mason & Mitroff (1973) have argued that simulation and modeling are extremely powerful when working on well structured problems for which an analytic solution exists.   Their weakness however, overlay the area of the proposed inquiry: The future of relatively unknown technologies. For example, if one had used a formal model to investigate the impact of the automobile on pollution when it was originally introduced, the result no doubt would have been that the automobile would drastically reduce pollution. (The principal pollutant at the time was horse manure which was ubiquitous and a serious health hazzard in most large cities.) The modelÕs basic truths would have probably not included anything issues associated with air pollution, and thus it would not have been predicted.

Is There A Solution?

Several non-traditional methods of inquiry have been suggested in the literature. For example, some (e.g., Mitroff & Betz, 1972) have argued that dialectical inquiry may be the best method of investigation into future events. Dialectical inquiry (which involves an dynamic argument over common data by persons holding two polar worldviews) has the advantage that the participants will always attack the assumptions on which the oppositionÕs predictions are made. The attacks on assumptions are critical when addressing the future. Assumptions about the future can often be treated dogma (e.g., they will never change), because it is often difficult to imagine alternative models of the world based on not yet evolved systems behaviors. For an example of this phenomenon, one only need remember a few years ago, when the real estate purveyors were telling everyone that real estate prices could only increase. A dialectical inquiry would have attacked that assumption, and at least made the public aware that a fall was possible and should be considered.

Dialectical inquiry does not guarantee any better conclusions, but it does maximize the chance that the results obtained are held with caution. As a matter of fact, dialectic inquiry would demand that an antithesis to the conclusion be immediately formed and begin to attack its weaknesses.

An other approach is to Ògo with what you know.Ó Use data and knowledge that is *generalizable to all systems.* Following the path of experience, examine possibilities that can be reasonably inferred from the past, even if they fall upon the outer edge of the path. Additionally, it often helps to examine systems, however new or complex in a top-down manner (Wise & Wise, 1994). That is go from the systems level to the directly applied. Both of these approaches allow one to build on relevant experiences from other domains (e.g., computer science, space exploration) and form reasonable hypotheses and identify successful methods of inquiry.

Conclusions?

Hume (1748) has argued that:

All inferences from experience suppose as their foundation, that the future will resemble the past, and that similar powers will be conjoined with similar sensible qualities. If there be any suspicion, that the course of nature may change, and that the past may be no rule for the future, all experience becomes useless, and can give rise to no inference or conclusion (p. 24).

If Hume is correct and human knowledge about the probability of future aviation accidents is based on experience or data (e.g., Aviation Safety Reporting System) will be limited to current systems and procedures. However, if there is a situation, such as the development of highly complex and intradependent systems, which have no correlate to data that we have on the past, then no conclusion can possibly reached which would lead one to discover or predict future events.

The underlying problem, with the sort of inquiry desired by the aviation community (i.e., predicting future problems), is that it is a process of searching for an answer where no question has been (or can be) defined. Additionally, the complexity and intradependence of current and future systems, coupled with the unpredictable nature of a human operator, creates an near infinite number of contingencies, making a search of all possibilities impossible. The desired inquiry is analogous to a pathologist trying to predict diseases that will occur twenty years from now. Who would have predicted the genesis and spread of HIV 30 years ago? All of the leads and clues were there, but they were impossible to perceive, to piece together. In much the same way that the clues which would lead to the prediction of future pilot and system errors do exist, however they will be virtually impossible to see without the gift of hindsight.

It should be noted that the arguments being posed here are NOT arguing that the proposed effort not be undertaken Ð in fact, the authors would argue in its favor (see Wise & Wise, 1993; 1994). The aim of this paper has been to point out the weaknesses of traditional inquiring methods in dealing with future events. Especially, when it is anticipated that these events may have no necessary connection to past or previously examined events.

In order not to fall into an inquiry trap, in which the search for an answer is limited or defeated by using an inappropriate inquiry method, the approach that will be taken during this probe is equally as important (or more so) than the probe itself.

The cautious words of Confucius may best summarize the proposed inquiry.

ÒTo know that you know what you know;
and that you do not know what you do not know Ð
that is true knowledge.Ó
Confucius

Addendum

A major question at the workshop was ÒWhat data should be included in an accident prevent database? Ó Given the above arguments about not being able to predict future questions *a priori*, it follows that one cannot predict *a priori* the data will be needed to answer those questions. There will always be a need for some set of fundamental data (e.g., basic flight parameters), but new technologies and new operational paradigms (e.g., free flight) will generate their own problems that will have specific data needs that will not be obvious until the problems surface. Thus, the most important data goal for the system must be flexibility! Flexibility to quickly adapt its data acquisition tools to collect new types of data in an effective and efficient manner. Flexibility to acquire relative large amounts of data on a new topic in a short period of time. Flexibility to develop new tools to collect data that has no current acquisition device.   If the system is not flexible in its data acquisition capabilities, it will only help solve problems for which we already have solutions.

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4.21LEARNING FROM ACCIDENTS: THE NEED TO LOOK BEHIND HUMAN ERROR - DAVID D. WOODS AND NADINE B.SARTER

<div align="center">

Cognitive Systems Engineering Laboratory
The Ohio State University

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Human error is often cited as the cause or a contributing factor to accidents and incidents in domains such as aviation where operators perform their duties in cooperation with advanced technological systems. The implication is that problems reside either in the human or in the engineered side of the equation (Woods, 1990). The perception of a human error problem then leads to proposals to minimize people's involvement in overall system operations through the introduction of more and more automation of functions.

The situation is far more complex, however, as indicated by the results of research on human-automation interaction in a variety of domains (Wiener, 1989; Sarter and Woods, 1994, 1995; Moll van Charante et al., 1992). These studies show that most incidents and accidents are the result of breakdowns in the communication and coordination between human and machine agents -- breakdowns which are related to design flaws and inappropriate training, both of which fail to support the formation of a human-machine team. This research illustrates that the label human error is prejudicial and unspecific, and that it retards rather than advances our understanding of how complex man-machine systems fail and how the same operator behavior can contribute to both success and failure. Labeling undesirable actions and faulty assessments as human error identifies a symptom, not a cause; the symptom should call forth more in-depth investigations of how a system comprising people, organizations, and technologies both functions and malfunctions (Rasmussen et al., 1987; Reason, 1990; Hollnagel, 1993).

Most incidents and accidents involve a conjunction of several failures or factors such as breakdowns in crew communication and coordination, organizational pressures, or the introduction of clumsy technology (see Sarter and Woods, 1995). It is not possible nor helpful to single out one individual agent or aspect of the event as the critical causal factor.

The Cognitive Systems Engineering Laboratory (CSEL) approach to analyzing incidents and accidents emphasizes this inseparability of human, machine, and environment in their contribution to overall system performance (Woods et al., 1994). The focus of this approach is not on any one individual system component but on the interaction and (in)compatibility of the various elements. The goal is to identify, analyze, and eliminate mismatches between human, machine, and operational environment in order to prevent the (re-)occurrence of observed problems and to correct predictable problems before they occur.

The CSEL approach is future- and prevention-oriented as it goes beyond phenotypical descriptions of processes involved in the evolution of an incident and instead looks for genotypical patterns in incident and accident data (Hollnagel, 1993). We attempt to identify lawful factors that govern different types of erroneous actions or assessments in order to be able to predict and prevent problems. These lawful factors involve cognitive factors -- e.g.,

knowledge, attention or mindset, and goal conflicts, clumsy use of technology, mode awareness, and organizational pressures. These patterns are verified and further explored in the context of empirical research. Based on these patterns, generic conceptual frameworks are being developed that allow for the application of findings in one domain to other fields of practice that involve similar forms of human-machine interaction.

One important step in this approach is to build a model of how operators behave in a locally rational way given the knowledge, attentional, and strategic demands at work in that particular field of activity. It is critical to adopt the position of the practitioner in a given context rather than that of a detached omniscient observer in order to understand and not condemn behavior. Normative models of practitioner behavior usually are not helpful in this context.

In summary, it seems important to view incident and accident investigations as an opportunity to learn, not as a means to assign blame and responsibility. To learn we must avoid the biasing effect of knowledge of outcome (the hindsight bias) and we must go beyond the search for absolute single causes. If the goal of accident investigations is to improve the reliability of distributed human-machine systems, we must try to learn about vulnerabilities to failure, about effective strategies for change, and about the prioritization of investments. The potential for constructive change lies behind the label human error -- it is the starting point, not the ending point of any investigation.

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