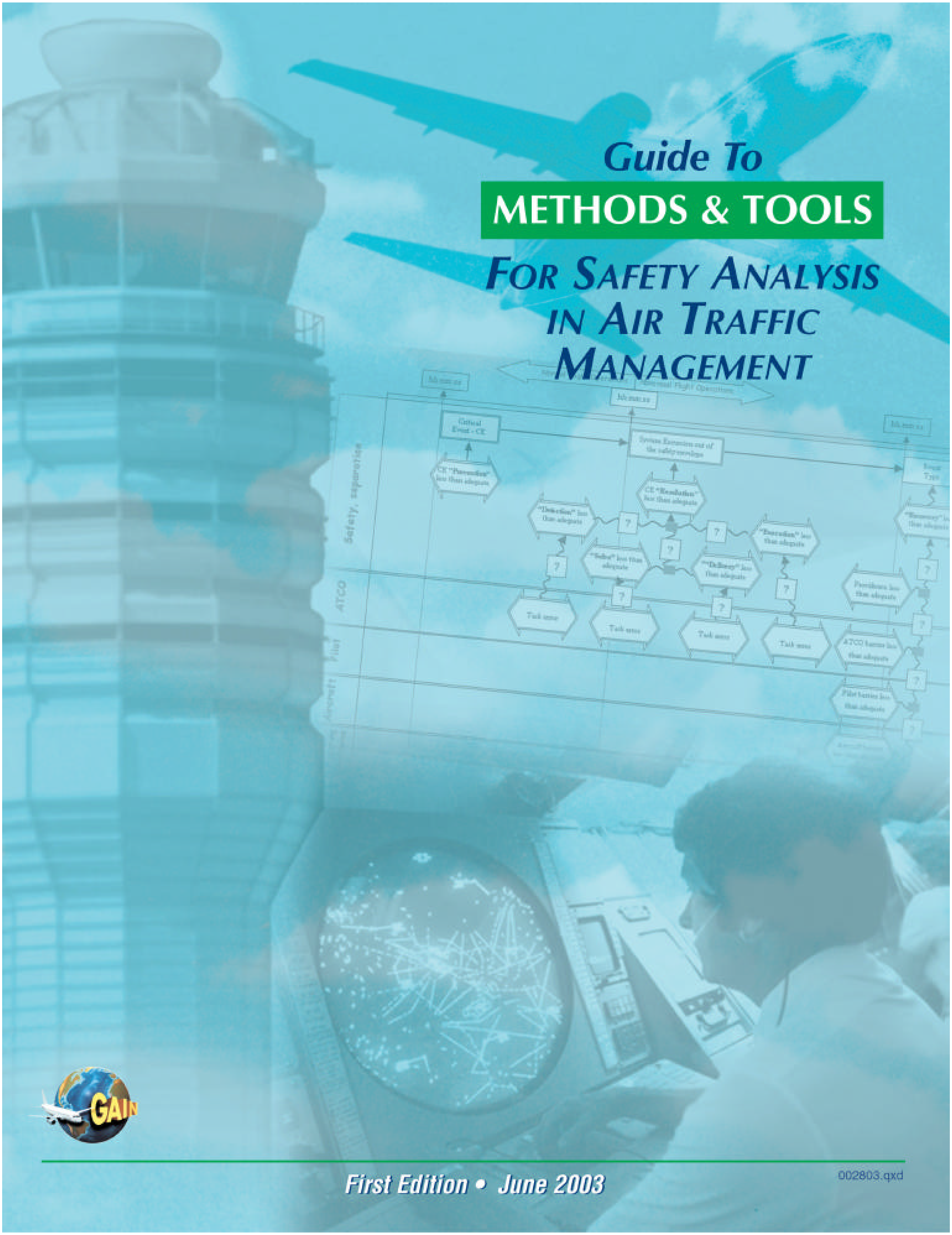

Guide To METHODS & TOOLS FOR SAFETY ANALYSIS IN AIR TRAFFIC MANAGEMENT

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Guide to

METHODS & TOOLS

FOR SAFETY ANALYSIS
IN AIR TRAFFIC MANAGEMENT

Prepared by: GAIN Working Group B, Analytical Methods and Tools

First Edition – June 2003

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Foreword

This guide to methods and tools is intended for air traffic control/management service providers, air traffic system developers, air traffic rules and procedures specialists, or air traffic safety managers. It is the second in a series that the Global Aviation Information Network (GAIN) Working Group B (Analytical Methods and Tools) is issuing. In the first guide, Working Group (WG) B focused on airline flight safety. In the future, the WG may address analytical methods and tools to support other aviation segments such as airline maintenance safety and airport safety.

This guide is not a comprehensive inventory of analytical methods and tools that could be used in air traffic safety analysis, but only a guide to those that WG B is aware of. It's certain that many other tools that are just as useful or even more qualified exist. Also, there are many other methods and tools that are intended for the analysis of air traffic system capacity, delay, efficiency, etc. Only those tools that address safety or factors related to safety (e.g., controller task load) are included. WG B would like to receive feedback on the experience that the aviation community has had with the methods and tools included in this issue as well as suggestions for additional methods and tools to be included. The reader should view this guide as a living document that will be updated periodically with improved coverage of methods and tools.

Acknowledgements

The following GAIN WG B members were primarily responsible for the preparation of this guide:

Ken Geisinger, FAA Air Traffic Resource Management Program

Carolyn Edwards, FAA Office of System Safety
Geoff Gosling, University of California at Berkeley
Andy Muir, FAA Office of System Safety
Grant Schneemann, Abacus Technology Corporation
Don Weitzman, Northrop Grumman Mission Systems

Ken Geisinger was the principal author of this guide and led the working group task team that developed the guide. Don Weitzman contributed the section on human factors tools.

Others who generously contributed ideas and comments on this guide or who assisted in the review and documentation of specific methods and tools are as follows:

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1.0 Introduction

1.1 Purpose of Guide

The purpose of this guide is to provide information on analytical methods and tools that could be used by air traffic management service providers, air traffic system developers, air traffic rules and procedures analysts, air traffic safety managers, etc. to conduct analyses aimed at improving or assessing safety. Summaries are presented for a sample of the many methods and tools that are available.

This report was produced by the Global Aviation Information Network (GAIN) Working Group (WG) B on Analytical Methods and Tools. It is hoped that this guide will help increase the awareness of available methods and tools within the air traffic community and assist members of that community as they consider which tools to incorporate into their safety analysis activities.

1.2 Scope

This Guide addresses both analytical tools that were developed specifically for air traffic safety analysis applications as well as other tools that were not developed for this purpose but could potentially be applied to air traffic safety analyses. The efforts of WG B to date have identified a large number of air traffic management safety tools of many types. However, it is recognized that this is not a complete list and other relevant tools exist that are not included in this Guide. Their omission does not imply that they are less deserving of inclusion than those that are included, only that WG B has not been able to obtain sufficient information on them to include them in this edition of the Guide.

Some tools have been deliberately excluded; for example, tools that address air traffic system capacity, delay, and efficiency, but not safety. On the other hand, some tools developed for airspace design or controller training, for example, could have a safety application and are included. Operational tools, such as URET and AMASS are not included; but tools that might be used to assess the efficacy of such tools are included.

This guide contains some tools that are not available outside the organizations that developed them. Some are in the prototype or early development phase. Information on these tools might still be useful to those interested in developing their own tools. Some tools are commonly used while others are infrequently used. Some of the tools are fairly straightforward and easy to use while others are more advanced and may require specialized analytical expertise.

1.3 Air Traffic Risks

As used in this report, *air traffic control (ATC)* relates to the direction and assistance provided to aircraft operators by agents of an authority set up to serve this purpose. *Air traffic management* (*ATM*) includes air traffic control, air traffic rules and procedures, airspace design, etc. This report discusses the wider scope of air traffic management, but the term air traffic control will be used where appropriate.

The major purposes of air traffic management is to facilitate the safe and expeditious movement of aircraft by providing guidance to aircraft operators in order to keep controlled aircraft safely separated from other aircraft, airspace that they are not authorized to enter, hazardous weather or other conditions, obstacles, vehicles and pedestrians, and the ground (other than intended operating surfaces). The air traffic controller or manager must identify aircraft and establish communication with them, and also assist in flight planning, air and surface navigation, and sequencing. The air traffic control system contains air traffic control specialists, air traffic flow managers, meteorologists, weather observers, communications devices and networks, air traffic radar, weather radar, air traffic computer systems (hardware and software), navigation aids, flight plans, air traffic rules and procedures, etc.

Any failure within the air traffic management system that endangers an aircraft, its occupants, its cargo, or persons and/or property outside the aircraft, constitutes an air traffic risk. This Guide contains a description of analytical tools that address these risks.

Since the purpose of the Guide is to increase the awareness of analytical tools that can be used to support analyses of air traffic safety, it may be relevant to ask what types of accident have occurred in recent years due to failures of the air traffic control system, and how frequently these different types of accident have occurred. According to data obtained from the US Federal Aviation Administration (FAA) National Aviation Safety Data Analysis Center (NASDAC), there were 32 accidents in the US civil airspace in the last eleven years in which a failure in the air traffic control system was a contributing factor. The particular contributing errors and the kind of accident are summarized in the following table.

Accidents in US Civil Airspace Involving ATC as a Causal Factor (1992-2002)

Note: Each letter represents one accident with the error cause and consequence type for the cell.

- "A" indicates that an air carrier aircraft (FAA Part 191) was involved.
- "T" indicates that a commuter aircraft (FAA Part 135), but no air carrier aircraft involved.
- "M" indicates a military aircraft, but no air carrier or commuter aircraft were involved.
- "G" indicates that only general aviation aircraft were involved.
- *CAPITAL LETTERS* indicate a fatal accident. *lower case letters* indicate a non-fatal accident.

Type / Cause	MAir Coll	Surf Coll	Coll w Terrain	Coll w Vehicle	W V Damg	Flt Atd Injury	Jet Blast	Rwy Obstcl	Total
Alt clnc			GGGG						4
Rwy adv				g				g	2
Coordtn	gGM	g							4
FSS adv								g	1
Sequenc	gGG				g				4
Taxi clr		t					g		2
Terr adv			G						1
Trfc adv	gGGG	tg				aa			8
Trfc sep		G							1
WV adv					gg				2
Wx adv			gGA						3
Total	10	5	8	1	3	2	1	2	32

Source: WG B analysis based on data from the FAA's NASDAC (see Section 2.1.4)

The abbreviations for causes are the following:

1. Alt clnc = aircraft cleared to altitude below minimum safe altitude
2. Rwy adv = failure to advise aircraft of hazard on runway or taxiway
3. Coordtn = failure of controllers to properly coordinate with or brief each other
4. FSS adv = inadequate flight service advisory
5. Sequenc = aircraft improperly sequenced for landing
6. Taxi clr = aircraft cleared to taxi into hazard
7. Terr adv = aircraft advised it was safe to descend into terrain hazard
8. Trfc adv = aircraft not advised of traffic hazard where required
9. Trfc sep = aircraft separation maneuver ordered too late
10. WV adv = aircraft not advised of wake vortex hazard
11. Wx adv = aircraft not advised of weather hazard

The resulting accident type codes are:

1. MAir Coll = midair collision
2. Surf Coll = collision between aircraft on the airport surface
3. Coll w Terrain = collision with terrain or surface obstacle while in flight
4. Coll w Vehicle = collision with a vehicle while operating on the surface
5. WV Damag = aircraft damaged or destroyed due to collision with wake vortex
6. Flt Atd Injury = flight attendant injured (due to abrupt maneuver)
7. Jet Blast = aircraft damaged by jet blast
8. Rwy Obstcl = aircraft collided with an obstacle on a runway

The table shows that the accidents were almost evenly divided between fatal and nonfatal, with 15 fatal and 17 nonfatal. Three accidents involved air carrier aircraft; 1 fatal (at Charlotte /Douglas Intl. in July 1994) and 2 nonfatal. Two accidents involved commuter aircraft, both nonfatal. There was one accident involving a military aircraft and it was fatal. Nine of the 32 accidents occurred on the airport surface; 1 was fatal.

About half the cases were collisions between aircraft (10 midair and 5 on the airport surface). The one fatal accident involving an air transport aircraft was a collision with the ground. Thus, the perception of ATC causing midair collisions involving an air carrier transport as a common occurrence is not borne out in actual data. (The last such accident in the US occurred at Cerritos, CA in 1986 and inadequate ATM procedures was cited as one of the causal factors.) In fact, the kinds of errors that occur and the kinds of accidents that result are rather surprising. For example, almost all the accidents occurred either in terminal airspace or on the airport surface. About 60 to 65 percent of the reported controller errors involve en route airspace.

It should be noted that in 80 percent of the cases, ATC was not the sole causal factor. In most cases the pilot could have been aware of the hazard through published material or visual observation, and/or should have been able to maintain control of the aircraft. The FAA handles about 141 million aircraft operations (an aircraft handled by an ATC facility) a year. One accident was partly the result of a flight service station briefing oversight. The FAA delivers about 900,000 flight services per year.

The great majority of errors do not result in accidents, but they do involve a situation in which safety standards or procedures were violated. These occurrences, referred to here as air traffic safety events, are indicators that a breakdown in the system occurred. In the US, there are two kinds of errors attributed to the air traffic control system: operational errors (violations of aircraft separation minima) and operational deviations (all other errors, such as violations airspace restrictions). According the National Airspace Information Monitoring System (see section 2.1.4) there are about 1,000 operational errors and about 265 operational deviations reported each year in the US.

These errors are not synonymous with risk. Most of these occurrences involve little or no risk, and perhaps there are instances where a risk is engendered without one of these occurrences. Nevertheless, keeping these occurrences to a minimum seems a good way to reduce air traffic risk.

Some of the tools examine these occurrences (safety events) as if eliminating them were an end in itself. Some look at risks with little regard to whether or not a safety event is involved. Others assess the risks associated with a particular error. All have a place in ATM safety analysis.

An analysis of safety events in the UK can be found in:

Majumbar, A. and Ochieng, W. (2003), "A Trend Analysis of Air Traffic Occurrences in the UK Airspace," in The Journal of Navigation, May 2003, pp 211-229.

The benefits of reducing air traffic risks go beyond the benefits of eliminating harm to persons and property. For one thing, safety events, let alone accidents, require time and effort in investigations and documentation. When an air traffic controller is responsible for a safety event, usually the controller must be taken off duty and put through a re-certification process. The individual might even have to be replaced. If this can be avoided, say through an improvement in procedures or technology, it would be an economic benefit that is frequently overlooked.

1.4 Definitions of Methods and Tools

This Guide addresses both analytical methods and tools. WG B has adopted the following definitions for distinguishing between methods and tools.

> **Method:** An analytical approach or process that may or may not be automated.
>
> **Tool**: A software-based/computerized application of one or more methods.

The only requirement is that the method or tool has an application to aviation safety. The emphasis is on tools, as the large volume of data and/or the amount of detail involved will usually require the use of computers.

The term "tool" is viewed rather broadly in this guide. It includes devices for analyzing data, obtaining and managing data, retrieving and displaying data, producing data from artificial sources, extrapolation and interpolation of data, etc. In general, anything that might help in the study of aviation risks associated with air traffic management is considered as a tool.

1.5 Classes of Methods and Tools for Safety Analysis in Air Traffic Management

Because air traffic management errors are a complex problem and cover a wide spectrum of activities, a large variety of tools are needed. The air traffic methods and tools are organized into seven classes. This classification is based on the function of the tool, but other means of classification could be adopted, and many tools could have been placed in more than one class, as they perform multiple functions. The types of tools one might use in an analysis depend on the question to be answered, and the time and funds available to perform the analysis.

1. <u>Safety Event Data Systems</u>

   The first step might be to look at historical data on safety events (accidents and incidents) related to the type of situation of interest. These tools are designed to collect, manage and/or analyze data on events that imply a compromise of the margin of safety desired in air traffic management. Such tools might be used to retrieve data on a single event, or on a collection of events.

2. <u>Air Traffic Replay and Non-interactive Simulation</u>

   Sometimes, radar and voice tapes recorded during the time of an incident of interest might be available. In this case, it would be nice to have a tool that replays these data so that one could augment the written reports with recorded data. If these aren't available, it might be possible to get recordings made during an operation that approximates that situation. Or it might be of interest to create a hypothetical situation based on actual data.

   Tools for real-time (or fast-time) replay or static display of recorded aircraft tracks and/or air traffic controller actions for the purpose of helping an analyst determine how an actual or hypothetical event, or series of events, might have occurred. These tools also include simulations to analyze proposed or hypothetical AT equipment and/or human performance under various traffic loads, routings, procedures, etc. These tools do not provide for real-time human interaction, which are included in the next class.

3. <u>Human Interactive Simulation Tools and Facilities</u>

One can create actual or hypothetical track data, but it is not possible to see how a real controller would or possibly did react. There is devic e that simulates a real human being: a real human being. The problem is to provide a device that provides the human participant with a sufficiently realistic environment.

These are real-time simulation tools for involving one or more humans acting as air traffic control specialists and possibly as aircraft pilots. These are useful in studying human factors relating to actual or hypothetical events. They could also be used to evaluate proposed changes in equipment, operating rules, procedures, etc. These range from standalone tools that operate on a single personal computer (PC) to complex simulation laboratories with sophisticated hardware and software, and many human participants

4. <u>Risk Analysis</u>

Human-in-the-loop simulations are very expensive; it is cost prohibitive to run very many of them. As we saw in the Section 1.3, that accidents resulting from ATC errors are very rare and varied events. Even reportable controller errors are very rare. Most controllers don't have one in their entire career. Thus, it would not be feasible to run interactive simulations anywhere long enough to get statistical data on the probability of a particular error or accident. Those tools have a place in getting some sample data. But to estimate risk one would have to resort to a risk analysis tool that could simulate many, many replications of a risk scenario in order to get an estimate of what the probability of a failure might be. These replications might be done through many computerized replications, or through mathematical calculations.

These tools estimate risk associated with a specified event, procedure, or action. Risk analysis looks at hazards to determine what can happen, and the combination of factors leading to an ATC-related accident.

5. <u>Human Factors Analysis</u>

Data presented in Section 1.3 showed that all of the actual ATM-related accidents in the last 10 years involved a controller error, although a few involved an ATM equipment problem as well, and almost all could have been prevented by the pilot. It seems safe to say that the bulk of ATM risk is the human operator. Thus part of the solution would lie in the study of human factors.

Human Factors Analysis refers to the study of human performance (e.g., cognitive, perceptual, physiological, motor) and the human-machine interface. This includes tools for investigating, estimating, or predicting human error, capacity, capability, and task loads under various situations.

6. <u>Text/Data Mining and Data Visualization</u>

While the probability of an error occurring during any particular air traffic control operation is miniscule, so many operations are performed, that a large database of accidents and events has been accumulated. Analysis of these data might yield clues on relationships between certain types of errors and the situations in which they occur. But the problem is that the kinds of errors and the situations in which they occur are quite varied. Some errors occur in situations were other errors can't happen. Actions that might reduce the likelihood of certain errors or accidents will have no impact on preventing others. This problem is not unique to ATM safety and much work is being done to develop automated tools to help analyze volume data.

Text mining tools are designed to automatically extract structured information from text. Data mining tools process large volumes of structured data to extract potential cause and effect relationships, patterns, trends, etc. Data visualization tools portray volume data in visual schemes that facilitate the human operator discovering relationship that would not be apparent in tables and graphs. Most of these tools were not developed for aviation safety, but could potentially help analyze air traffic safety event data.

7. General Tools for Data Analysis
   Dealing with data often requires the construction of databases. There are many tools commercially available. This includes general tools for creating databases, and for retrieving and processing electronic data. They facilitate computerized detection of potential relationships and trends.

It is recognized that these categories are somewhat arbitrary and that some methods and tools could fall into more than one class. The only purpose in defined separate categories is that some questions about methods and tools in one group would not apply to those in other classes. Some of the same tools contained in the airline compendium are contained here with potential air traffic applications addressed.

1.6 Organization of this Guide

The remainder of the guide contains two sections. Section 2 is organized into seven sub-sections, one for each of the major classes discussed above. A brief discussion of each tool is presented. Section 3 contains an overview and conclusion. It discusses how these various classes of tools tie together and might be used in conducting a safety analysis. It also mentions some of the general drawbacks and limitations of the tools in each class, so that the reader will be aware of them.

The guide also contains a list of acronyms and abbreviations, as well as two indexes of tool summaries, one sorted by tool name and one sorted by the acronym or abbreviation commonly used for each tool.

1.7 Overview of GAIN & WG B: Analytical Methods and Tools

GAIN is an industry and government initiative to promote and facilitate the voluntary collection and sharing of safety information by and among users in the international aviation community to improve safety. GAIN was first proposed by the Federal Aviation Administration (FAA) in 1996, but has now evolved into an international industry-wide endeavor that involves the participation of professionals from airlines, employee groups, manufacturers, major equipment suppliers and vendors, and other aviation organizations. To date, five world conferences have been held to promote the GAIN concept and share products with the aviation community to improve safety. Through 2002, nearly 900 aviation safety professionals from 49 countries have participated in GAIN.

The GAIN organization consists of an industry-led Steering Committee, four working groups, a Program Office, and a Government Support Team. The GAIN Steering Committee is composed of industry stakeholders that set high-level GAIN policy, issue charters to direct the working groups, and guide the program office. The Government Support Team consists of representatives from government organizations that work together to promote and facilitate GAIN in their respective countries. The working groups are interdisciplinary industry and government teams that work GAIN tasks within the action plans established by the Steering Committee. The current GAIN working groups are: Working Group B--Analytical Methods and Tools, Working Group C--Global Information Sharing Systems, and Working Group E--Flt Ops/ATC Ops Safety Information Sharing. The Program Office provides technical and administrative support to the Steering Committee, working groups, and Government Support Team.

Working Group (WG) B was formed in response to the need expressed by many in the aviation-user community for better analytical methods and tools to help convert data into useable safety information. Members of the community have said that the need to manage and analyze ever-larger amounts of safety-related data will require the use of increasingly sophisticated tools and techniques. These methods and tools will help safety analysts discover patterns and extract lessons learned in order to identify emerging safety issues and support safety decision-making. Responding to these needs the GAIN Steering Committee chartered WG B to foster the use of existing analytical methods and tools and the development of new methods and tools. The WG has four main focus areas:

- Gather requirements for analytical methods and tools from the aviation-user community
- Identify and increase awareness of existing methods and tools
- Assess the usefulness and usability of existing tools in partnership with the aviation community
- Facilitate the development of enhanced or new analytical tools.

This guide was prepared specifically to address the second focus area.

1.8 Guide Update and Feedback

WG B plans to update this guide periodically to include information on additional methods and tools as appropriate. The WG encourages readers to provide feedback regarding their experience with any of the methods and tools contained in the guide and to nominate others for possible inclusion. Suggestions for improving the usefulness of this guide are also requested. A feedback form for this purpose is included at the end of this guide.

1.9 Disclaimer

Inclusion of a tool in this report does not indicate an endorsement of the tool by GAIN, or by the compilers of this guide, nor does exclusion indicate that the tool is less worthy than those that were included. The reader and potential users of these and other tools must judge for themselves. Some of the tools that are included have gaps or defects that are obvious, and probably many others that are not. Even a tool that is useful for some purposes will be a flop in other circumstances. And, of course, even a well-designed tool depends on the quality of input data given to it and proper interpretation of its outputs.

Much of the information was obtained from websites and brochures and is already outdated. An attempt was made to contact vendors/developers/owners of the tools to get more up-to-date information, but for many of the tools no one could be found by the time the guide went to press. Either way, most of the information in this report was provided by the developers and/or promoters of the particular tool being described, and was not verified. The GAIN organization and the producers of this report cannot take responsibility for its accuracy. A point of contact is provided (where one could be found) for each method and tool so that the reader may obtain further information.

2.0 Summaries of Selected Methods and Tools for Safety Analysis in Air Traffic Management

This section contains a summary of methods and tools that might be useful in conducting an analysis of air traffic management safety. This is by no means all of the tools that exist, but it is an attempt to represent a selection from the variety of tools that are available. Which of these tools, if any, one would use depends on the issues being considered. It should be noted that these tools are not the answer in themselves. They only provide data that an analyst could employ, along with a careful examination of the problem and the results provided by the method or tool.

There is not enough space available for a full discussion. The intent is to provide enough information so that an analyst can determine if the method or tool might be of interest. A contact for further information is provided. Information provided in these summaries include:

1. <u>Name</u>
2. <u>Purpose</u>: the primary objective.
3. <u>Description</u>: Some of the results produced, input data required, how it works, limitations
4. <u>Aviation Usage</u>: Examples where the tool has been used for aviation or ATM analyses
5. <u>Potential Benefit to Air Traffic Safety Analysis</u>: Potential, especially for tools not developed for ATM analysis
6. <u>Tool Cost</u>: Purchase price, what is required to use the method or tool
7. <u>Documentation</u>: sources for more information about the method or tool
8. <u>References</u>: source of information in the summary (if not reviewed by owner/vendor
9. <u>Vendor/owner support</u>: name, address, and web-site of vendor or owner, kind of support offered
10. <u>Related Tools</u>: other tools that are derived from, or required to use the method or tool
11. <u>Point of contact</u>: name, phone number, e-mail address of person(s) who can provide more information.

The following is a discussion on each method or tool.

2.1 Air Traffic Safety Event Data Systems

This section contains summaries of tools that could be used to obtain and/or analyze selected information about safety events. These tools generally contain capabilities and features to assist the user in event information storage and management as well as report generation and querying. Some also have analysis capabilities as well as features to facilitate action assignment, monitoring, and data exchange. Most of these systems include events having to do with other aspects of aviation, but all include air traffic control/management events. This list does not include, for example, systems designed exclusively for use by airlines. Still this list is only a small sample of the systems that exist around the world. Some additional safety event data systems are documented in the report, “Major Current or Planned Government Aviation Safety Information Collection Programs” prepared by the GAIN Government Support Team and available at *www.gainweb.org.*

Some of these systems provide data (properly redacted to maintain privacy) to the public; others are designed to maintain private information and allow very limited access. Some have existed for years; others are in the planning stage. These tools have been sub-categorized as: 1) automatic reporting tools, 2) voluntary reporting tools, 3) mandatory reporting tools, and 4) miscellaneous data sources.

This discussion is intended to serve two purposes. First, as a source of data for ATM safety analysis, and second as a source of information for those who would like to institute or upgrade a safety event reporting system.

2.1.1 Automatic Reporting Systems

Most safety reporting systems require a human to detect and report the occurrence. This invites under-reporting, as the human could miss the incident, or fail to report it for a number of reasons. Automatic systems could also miss events, but could also report as safety events situations that do not qualify. Thus purported incidents must still be subject to review.

Automatic Safety Monitoring Tool (ASMT)

Purpose
ASMT provides an automatic monitoring facility for safety related occurrences based on operational data. It detects and categorizes each occurrence for assessment by trained operational experts. The tool will help determine causes and assist in the evolution of local procedures, airspace design, equipment and techniques.

Description
ASMT collects proximity-related occurrences. It will begin collecting ACAS occurrences through Mode-S stations, altitude deviations, runway incursions, airspace penetrations, and route deviations. ASMT supports the following trackers: MADAP, ASTERIX, Aircat500, and FAA.

Aviation Usage
ASMT was developed by the EUROCONTROL Experimental Centre (EEC), in cooperation with the Maastricht Upper Airspace Centre, for pilot operational use in 2000. It is also being used as part of the Real Time ATM Simulation facilities at the EEC.

Potential Benefits to Air Traffic Safety Analysis
It will provide ATM providers with more accurate reporting, data to support investigations, a learning tool, a safety indicator tool, and a trend analysis tool.

Tool Cost
Not Applicable

Documentation

References
This summary is based on a brochure published by EUROCONTROL in September 2000.

Vendor/owner Support
EUROCONTROL Experimental Centre, Brétigny: BP 15, F-191222 Brétigny-sur-Orge, CEDEX, France

Point of Contact
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Tony Joyce, EUROCONTROL Experimental Centre, +33-1-6988-7487, Anthony.joyce@eurocontrol.int

2.1.2 Voluntary Reporting Systems

Some reporting systems are based on voluntary reporting and others on mandatory reporting. It is important to know which type one is obtaining data from as each type has advantages and disadvantages over the other. A voluntary system is intended to encourage those who committed an error to file a report and frankly relate details that might not otherwise be revealed. It is hoped that this might produce more information about causal factors, assuming that the reporter will be honest and accurate. Incentives, such as immunity from penalties, are often offered to encourage reporting. Because many individuals might still be reluctant to report, the system might be subject to under-reporting.

Aviation Safety Reporting System (ASRS)

Purpose
The ASRS collects, analyzes, and responds 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, and to support policy formulation and planning.

Description
Pilots, air traffic controllers, and others involved in aviation operations are encouraged to submit reports when they are involved in, or observe, a situation in which aviation safety was compromised. All submissions are voluntary, and are confidential. ASRS de-identifies reports before entering them into the incident database.

The ASRS was established in 1975 under an agreement between the US Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA). The FAA provides most of the funding and NASA administers the program. In order to encourage participation, the FAA has committed to not use ASRS information against reporters, and to waive fines and penalties, subject to certain limitations, against those who voluntarily report the incident to the ASRS.

Each report received is read by a minimum of two subject matter experts with experience as a pilot and/or air traffic controller. If a hazard is identified that requires immediate attention, an alerting message is sent to the appropriate authority. Then the reports are examined and classified to help identify causal factors.

Information in the ASRS database is available to interested parties. The individuals and organizations wishing access may contact ASRS with a statement of need. The ASRS staff will conduct a search and mail the results to the requestor.

Aviation Usage
Over 300,000 reports have been submitted to date. More than 3,000 searches have been accomplished. In addition, ASRS has conducted and published over 56 research studies of its own.

Potential Benefits to Air Traffic Safety Analysis
The ASRS acts on the information it receives, identifies system deficiencies, publishes a newsletter and a journal, and conducts research studies. Its database is a repository that serves the needs of organizations worldwide which are engaged in research and the promotion of safe flight.

Tool Cost
Information is provided at no cost to requestors.

Documentation
This summary was prepared by WG B based on data on the ASRS website.

References
Web site: http://asrs.arc.nasa.gov/

Vendor/owner Support
ASRS is operated under contract by Battelle Memorial Institute.

Point of Contact
NASA Aviation Safety Reporting System, P.O. Box 189, Moffett Field, CA 94035-0189, USA, asrs-program@lists.arc.nasa.gov

Confidential Aviation Incident Reporting (CAIR)

Purpose
CAIR was instituted by the Australian Transport Safety Bureau (ATSB) in 1988 as a supplement to their mandatory reporting system, the Air Safety Incident Report (ASIR). The program's focus is on systems, procedures and equipment, rather than on individuals. It was founded to gather data that would not be reported under a mandatory system. It covers flight crews, maintenance workers, and even passengers, as well as air traffic service officers.

Description
The program is designed to capture information, no matter how minor the incident. While confidentiality is maintained, the report must not be anonymous or contain unverifiable information. The ATSB supplement in the 'Flight Safety Australia' magazine is the primary method of publishing a report and obtaining feedback on CAIR issues. Publication of selected CAIR reports on the Internet is planned.

Aviation Usage
CAIR already covers all aspects of Australian civil aviation. Air safety investigations are performed by ATSB independent of the Civil Aviation Safety Authority (CASA) (the regulator) and AirServices Australia (the air traffic service provider). The ATSB has no power to implement its recommendations.

Potential Benefits to Air Traffic Safety Analysis
CAIR reports have helped identify deficiencies and led to safety enhancements.

Tool Cost: Not Applicable

Documentation
See www.atsb.gov.au/atsb/facts/cair_program.cfm or www.atsb.gov.au/atsb/indxf/air_invest.cfm

References
This report was prepared by WG B from information on the ATSB web-site.

Vendor/owner Support
Australian Transport Safety Bureau, PO Box 967, Civic Square ACT 2608, Australia

Related Tools
The Fiji Islands maintains their own version of CAIRS, referred to as FCAIRS. See website: http://www.caafi.org.fj/airsafety.htm

Point of Contact
CAIR Manager, Phone (in Australia) 1 800 621 372 or 1 800 020 505, cair@atsb.gov.au

Confidential Human Factors Incident Reporting Programme (CHIRP)

Purpose
CHIRP provides a totally independent confidential (not anonymous) reporting system for all individuals in the civil aviation industries, including air traffic control officers. CHIRP compliments the UK CAA Mandatory Occurrence Reporting (MOR) system by allowing individuals to raise concerns without being identified.

Description
CHIRP was formed in 1982 as a result of a joint initiative between the Chief Scientific Officer Civil Aviation Authority (CAA), the Chief Medical Officer CAA and the Commandant Royal Air Force Institute of Aviation Medicine (IAM). CHIRP is based on the US Aviation Safety Reporting System (ASRS). In 1996, a registered charitable company (The CHIRP Charitable Trust) was established to operate the system.

Aviation Usage
CHIRP has been in operation since 1982. It was expanded to include air traffic control officers in 1986.

Potential Benefits to Air Traffic Safety Analysis
These data cover a very long time period and thus could be particularly useful in studying trends, and how changes over the years might have affected these trends.

Tool Cost
Not Applicable

Documentation

References
http://www.chirp.co.uk/air/what_is_chirp.htm

Vendor/owner Support
The CHIRP Charitable Trust, Building Y20E, Room G15, Cody Technology Park, Farnborough GUI4 OLX, UK

Point of Contact:
Peter Tait, The CHIRP Charitable Trust, +44 1252 395013, PeterT@chirp.co.uk

2.1.3 Mandatory Reporting Systems

Mandatory reporting systems typically require that a report be submitted by a responsible party (usually not the person who committed the error). This helps reduce under-reporting, but it might produce less information about the cause of the event.

Aviation Safety Monitoring System (ASMS)

Purpose
To provide the New Zealand aviation community with safety information as determined from accidents and incidents. It is also used to track corrective actions against non-compliances that are detected during proactive surveillance.

Description
ASMS is a relational database that links information on aviation document holders with safety failures (occurrences and non-compliances) and tracks corrective actions. It is fully integrated with CAA's management information system and contains tools for creating and maintaining a database, customizing and creating occurrence reports, tracking safety investigations, analyzing data, and tracking corrective actions. Risk management is facilitated though the use of severity and likelihood codes. Automated Occurrence Report forms provide assistance in entering data and provide an audit trail of changes made. Investigation reports support full multimedia, including pictures. The analysis package is based on Prof. Reason's causal factor philosophy. It is linked to Microsoft Office packages for graphing, charting, and statistical analyses.

Aviation Usage
ASMS is used by the New Zealand Civil Aviation Authority to keep a record of all reportable civil aviation accidents and incidents, including those involving ATM. A specific set of cause codes was adopted, and can be selected from a drop-down list when the incident report is prepared. Queries have been set up to facilitate extraction of reported incidents by numerous criteria. A clone of ASMS, the Aviation Quality Database (AQD), is used by several airlines and other organization in New Zealand and other countries to gather occurrence data, track corrective actions, analyze the data and (for NZ organizations) report their safety performance directly to the NZ CAA via an electronic interface.

Potential Benefits to Air Traffic Safety Analysis
Over 8,500 reports of ATM-related accidents and incidents are on file. They are available for research purposes, subject to confidentiality agreements where appropriate.

Tool Cost
See vendor for information on obtaining and using AQD.

Documentation
CAA website: http://www.caa.govt.nz
AQD Software vendor website: http://www.superstructure.co.nz

Vendor/owner Support
On-line support is available for reporting and resolving problems, suggestions, etc.

Point of Contact
ASMS: Peter Nalder, New Zealand CAA, +64-4-560-9424, NalderP@caa.govt.nz
AQD: Sue Glyde, Director, Superstructure, +64-4-570-1694, sue@superstructure.co.nz

Civil Aviation Daily Occurrence Reporting System (CADORS)

Purpose

CADORS is a national data reporting system that is used to collect timely information concerning operational occurrences within the Canadian National Civil Air Transportation System and is used in the early identification of potential aviation hazards and system deficiencies.

Description

Under the Aeronautics Act, there is a mandatory requirement for ATS certificate holders to report items listed in the CADORS Manual. CADORS reports are collected from a number of sources. The main information provider is NAV CANADA, which supplies close to 80% of all reports. Other information providers include, Transportation Safety Board, airports, police forces, public, etc.

Aviation Usage

CADORS captures a wide scope of safety related events including ATC operating irregularities; communication, navigation, surveillance, and other air traffic systems failures; controlled airspace violations; etc. Included in the collection are occurrences related to aircraft, aerodromes, security (e.g. bomb threats, strike actions) and environment (e.g. fuel spills)

Potential Benefits to Air Traffic Safety Analysis

Keeping in mind that the information in CADORS is considered preliminary and unsubstantiated, the system acts as early notification to alert of trends and developing problems ahead. As an analytical tool, CADORS data are used as input for safety studies, planning purposes (e.g. audits and inspections), ministerial briefing notes and ad-hoc data requests.

Tool Cost

There is no cost associated with this tool, as it is only available on Transport Canada's internal web site.

Documentation

The official CADORS manual is the fourth edition and is referenced TP 4044. It should be noted that this document is currently in the process of being revised. Dissemination is limited.

References

Information from CADORS is currently shared with a limited number of aviation stakeholders, with access available through either daily e-mail subscription or query privileges. The whole issue of sharing / release of information is currently under review by the Department. Requests for CADORS information are assessed on a 'case-by case' and 'need-to-know' basis. Requests can be made at:

Website: http://www.tc.gc.ca/quebec/en/aviationSafety/cadors.htm

Vendor/owner Support

CADORS was developed to address the needs of Transport Canada senior management and has been modified over time to serve broader interests. A combination of internal and external (consulting) resources was used in its development. All on-going maintenance is the responsibility of Occurrence Data Analysis Unit of Transport Canada (AAEO), Tower C, Place de Ville, 330 Sparks St., Ottawa, Ontario, K1A 0N5, Canada

Point of Contact

Peter Wesley, Transport Canada, (613) 993-8234, wesleyp@tc.gc.ca

Identifying Needed Defenses in the Civil Aviation Transport Environment (INDICATE)

Purpose
INDICATE is a proactive safety program that was developed by the Australian government for use by Australian airlines. But it has been adapted to cover air traffic and other components of the civil aviation system. It provides a simple, but structured, process to ensure consistent and high-quality safety feedback. Because it is a generic safety program, it can be tailored to the requirements of any industry or organization.

Description
INDICATE was developed to be used by individual airlines and be installed on a company computer. The system:

- Records the nature of each safety hazard
- Records any action (or lack of) taken on each hazard
- Maintains the confidentiality of the submitter
- Generates a recommendation

INDICATE offers a formal communications channel (the Electronically Submitted Incident Reporting (ESIR) system) to report to appropriate outside organizations weaknesses found in regulations, policies and standards. Any safety issues reported externally are at the discretion of the company, but certain reports, particularly those involving air traffic services must be reported to the Australian government.

Aviation Usage
An eight-month trial of the program within a major Australian regional airline revealed that it could have a positive influence on safety performance. It is currently operational within a number of Australian and international companies.

Potential Benefits to Air Traffic Safety Analysis
Based on the trial with an airline, potential benefits to an air traffic organization could include:

- Improved staff confidence in how safety is managed
- Increased staff willingness to report safety hazards and incidents
- Improved safety communications between departments and management and staff
- Safety performance can be assessed in a rigorous and scientific way
- It actively involves staff in safety management

Tool Cost
Available free to qualified parties.

Documentation
This summary was derived by WG B from The INDICATE Safety Program Implementation Guide, Version 2.0, published January 2001 by the Australian Transport Safety Bureau.

References: Web site: http://www.atsb.gov.au

Vendor/owner Support
Australian Transport Safety Bureau (ATSB), PO Box 967, Civic Square ACT 2608, Australia

Point of Contact
Ted Smith, Team Leader, Safety Support, ATSB, 1-800-621-372, atsbinfo@atsb.gov.au

Mandatory Occurrence Reporting Scheme (MORS)

Purpose
MORS was established by the United Kingdom Civil Aviation Authority (CAA) following a fatal accident in 1972. Its primary purpose is to secure free and uninhibited reporting, and dissemination of the substance of the reports, where necessary, in the interest of flight safety. It covers operators, manufacturers, maintenance, repair and overhaul, air traffic control services, and aerodrome operators.

Description
Only certain kinds of incidents, namely, those that are "endangering" or "potentially endangering," are subject to mandatory reporting; others are not. Reporting of "day-to-day defects/incidents, etc" is discouraged. These are left to the CAA's Occurrence Reporting Scheme.

The CAA will not disclose the name of the person either reporting or reported to the scheme unless required to do so by law, unless those persons authorize disclosure. It is not CAA policy to institute proceedings in respect to unpremeditated or inadvertent breaches of the law which come to its attention only because they have been reported under the Scheme, except in cases involving dereliction of duty amounting to gross negligence. If a report indicates that a license holder may not be a fit person to exercise privileges of the license, the fact that he/she has reported the occurrence will weigh heavily in their favor.

Aviation Usage
MORS is in active use thought the civil aviation community in the U.K. and is supported by the CAA at a cost of over a million euro per annum. Today, some 12,000 reports are submitted each year.

Potential Benefits to Air Traffic Safety Analysis
Having a single system to cover air traffic service and aircraft operators has potential benefits. The CAA article contains an example where it was found that insufficient preparation of air traffic controllers was a factor in a fatal accident. This led to emergency response training which later prevented an accident.

Tool Cost: Not applicable.

Documentation
CAP 382, The Mandatory Occurrence Reporting Scheme, Information and Guidance, CAA, June 1996
Available on the web at: http//www.caa.co.uk/docs/33/CAP382.pdf

References
The information in this summary was derived by WG B from an article written by Ian Weston, Head of Safety Investigation and Data Department, CAA, "United Kingdom Mandatory Occurrence Scheme." Website: http:/www.italianflightsafetycommittee.org/varie/convego-aprile02/svt/10.pdf

Vendor/owner Support: Information not available.

Related tools
1. New Zealand has adopted MORS. See www.caa.govt.nz and go to "Accidents and Incidents"
2. Fiji has adopted MORS, referred to as the Fiji Confidential Aviation Incident Reporting (FCAIR). See http://www.caafi.org.fj/airsafety.htm

Point of Contact
Tim Whittle, Safety Regulation Group, UK CAA, +44 1293 57 3211, Email: sdd@srg.caa.co.uk, Website: www.caa.co.uk

2.1.4 Miscellaneous Data Sources

There are a number of data resource tools that provide data on safety events and that do not fall into the above categories. This includes a planned multi-national reporting system (ECCAIRS), an experimental reporting system (EPOQUES), and programs that provide access to information from a number of different reporting systems (NAIMS and NASDAC).

European Co-Ordination Centre for Aviation Incident Reporting Systems (ECCAIRS)

Purpose
ECCAIRS is a European Union initiative to harmonize the reporting of aviation occurrences by Member States so that so that the Member States can pool and share data on a peer-to-peer basis. Although the proposed data sharing has not yet been implemented, the potential benefits appear sufficiently promising that it is included here.

Description
Each Member State will enforce the procedures for collecting and processing the reports. The reports will be placed in an electronic database together with safety relevant information derived from confidential reporting. An electronic network will allow any CAA or AAIB in the EU to have access to the integrated information. It will facilitate independent analyses and plans include having tools for trend and other analysis tools built-in.

Aviation Usage
The proposed harmonized system would cover all aspects of civil aviation in 15 Member States, possibly enlarged to as many as 15 more.

Potential Benefits to Air Traffic Safety Analysis
The inclusion of air traffic safety events will provide a coherent source of information on such events in all participating states.

Tool Cost
The ECCAIRS Reporting System is available free of cost to authorities and investigation bodies of the European Union. The software can be used, after authorisation, by non-EU authorities and investigation bodies on an as-it-comes basis.

Documentation
http://eccairs-www.jrc.it
http://204.108.6.23/Conferences/GAIN5/briefings/Henrotte.pdf
http:// www.italianflightsafetycommittee.org/ftp/varie/convegno-aprile02/svt/15.pdf

References
This summary was prepared by WG B from information on the web, including a briefing by Jean-Paul Henrotte, Direcorate-General, Energy and Transportation, EU, at the Fifth GAIN World Conference.

Vendor/owner Support
Basic support like help-desk and training facilities is available at no cost to authorities and investigation bodies of the European Union. Support to non-EU authorities and investigation bodies is limited to available resources.

Point of Contact
Wietse Post, EU's Joint Research Center, +39 0332 789896, wietse.post@jrc.it

EPOQUES (Tools and Methods to Treat Air Traffic Management Safety Occurrences)

Purpose
EPOQUES is a research project to propose methods and tools to treat safety occurrences at the French air traffic service provider. Participatory design and iterative prototyping are being used to define a set of investigative tools, involving the five French en-route centers and two approach facilities.

Description
Two complementary methods are being conducted in parallel. One is to study the existing work practices so that the initial prototype is grounded in current every day use. The second is to involve participants and designers to work together to iterate, refine, and extend the design, using rapid prototyping and collective brainstorming. The results show that the user-centred approach is useful to design safety tools. It allows designers to integrate non-technical aspects in tool design such as relationships between investigators and air traffic controllers, the context of incident investigation in air traffic en-route centres.

Safety units have officially formulated the need for an integrated safety tool based on the project results. The French air traffic control provider has decided to integrate this need in its business plan, in order to begin the development of the product in year 2003. The product should be developed for both en-route centres and airports. The CENA team is involved in this transfer to industry through a support for detailed function analysis

Aviation Usage
EPOQUES is still in the prototyping phase, but important findings based on practical experience have been noted. First, the proposed reconstruction tools should allow the investigators to save time in the data gathering and reconstruction phases of the occurrence investigation, so that they will have more time for the analysis and dissemination phases. The environment that has been built facilitates this and will incorporate a timeline to show how each occurrence develops over time. It will be designed to spot trends and common features. A PC environment will facilitate report constitution and briefing construction for lesson dissemination. An output for simulators is planned to integrate non-nominal situations in training.

Potential Benefits to Air Traffic Safety Analysis
The resulting tool should allow air traffic service providers to:
- Select and analyse relevant occurrences;
- Disseminate lessons learnt from incidents via a PC environment for experience feedback, which is the main objective of safety units;
- Integrate in the same tool different sources of information, with synchronised restitution;
- Limit repetitive tasks for investigators, shorten investigators' learning period with easy-to-use interfaces;
- Recreate what air traffic controllers have seen on their working position.

Tool Cost
Not Applicable

Documentation
Not known

References
This summary was prepared by WG B based on an article by Helene Gaspard-Boulinc, Yannick Jestin, and Lionel Fleury in a summary by C.W. Johnson in 2002.

Vendor/owner Support
Not available.

Point of Contact
Hélène Gaspard-Boulinc, e-mail: helene@cena.fr

National Airspace Information Monitoring System (NAIMS)

Purpose
NAIMS is a Federal Aviation Administration program to collect, maintain and analyze aviation statistical information based on reports of accidents and incidents in the US national airspace system. NAIMS produces a monthly report available to the public, supplies data to NASDAC, and responds to public inquiries for safety information.

Description
Reported incidents are:

1. near midair collisions (NMAC's)
2. operational errors (OE's)
3. operational deviations (OD's)
4. pilot deviations (PD's)
5. vehicle/pedestrian deviations (VPD's)
6. surface incidents (SI's)
7. runway incursions (RI's)
8. flight assists (FA's)

The NAIMS monthly report monitors trends in and apportionment of each of these indicators. For example, operational error rates (OE's per 100,000 operations) are shown for each ATC facility. The original forms are maintained for five years. A database containing an electronic copy of each form is maintained indefinitely.

Aviation Usage
NAIMS reports and queries are used throughout the US aviation community.

Potential Benefits to Air Traffic Safety Analysis
Analysis of trends and apportionment of the indicators can signal where attention needs to be focused. The detailed data on each accident or incident can lead to potential solutions for reducing risk.

Tool Cost
Reports and query results are provided at no cost.

Documentation
See *The Aviation Safety Statistical Handbook* published monthly by the FAA's Air Traffic Resource Management Program; Planning, Information and Analysis Division (ATX-400). The March edition is an annual report.

References
Web site in preparation

Vendor/owner Support
ATX-400, Federal Aviation Administration, 800 Independence Ave., SW, Washington, DC 20591 USA

Point of Contact
Theresa Payne, FAA, +1 202-385-4802, theresa.payne@faa.gov

National Aviation Safety Data Analysis Center (NASDAC)

Purpose
NASDAC's mission is to enhance system safety decision-making by providing high quality safety information, analysis, services, and technology to the aerospace community.

Description
NASDAC is located at the U.S. Federal Aviation Administration headquarters, but it can be accessed either in person, by telephone, or on the web. Its services are available to anyone with a need or desire for aviation safety information, including foreign governments, manufacturers, airlines, etc. It allows retrieval from a variety of US and foreign databases. Many of these data are available elsewhere, but the NASDAC databases often have an advantage in having gone through a cleansing process and being linked to related databases.

The capabilities of the NASDAC system recently were enhanced significantly. The NASDAC system now has the capability to construct customized data marts. Data marts enable the user to integrate and view data in ways the previously were technically impossible to do. For example, historical aircraft activity data has been integrated with aircraft maintenance records to enable the user to view the maintenance history of aircraft over time by aircraft make/model, fleet, operator, etc. This provides aircraft engineers with a new tool to monitor the safety performance of aging aircraft.

NASDAC data can be accessed directly by the requestor. An easy-to-use data retrieval system has been developed. An expert staff is available to assist in determining the data that is needed and how to retrieve and analyze it.

Aviation Usage
NASDAC contains data on accidents, incidents, air traffic facility information, air traffic control regulations and procedures, aviation safety studies, etc.

Potential Benefits to Air Traffic Safety Analysis
NASDAC provides data, information, and tools to help in safety decision-making.

Tool Cost
No charge

Documentation
See web site (below).

Vendor/owner Support
Support is readily available.

Point of Contact
NASDAC +1 202-493-4247 Website: http://www.nasdac.faa.gov

Tool Kit for ATM Occurrence Investigation (TOKAI)

Purpose
TOKAI was designed to support the EUROCONTROL member states in implementing a reporting system compliant with EUROCONTROL Safety Regulatory Requirements (ESARR 2). It assures that reports submitted by the various providers are of uniform quality and format to allow aggregated data to remain meaningful.

Description
TOKAI is more than a database management system for incident data. It contains imbedded tools that permit: 1) Air traffic management staff to report occurrences, 2) local investigators to investigate, analyze and assess occurrences, to develop safety recommendations, 3) safety departments to investigate, exchange data and develop statistics on groups of occurrences, 4) regulators to develop remedial policies.

TOKAI 's occurrence notification form is the ATS Occurrence Reporting Form developed by EUROCONTROL. The data gathered is based on EUROCONTROL ATM occurrence data taxonomy called HEIDI.

TOKAI analysis is facilitated through the Sequentially Outlining and Follow-up Integrated Analysis (SOFIA) tool. This tool helps the reconstruction of the occurrence, its analysis and safety recommendation elaboration by creating a chart that plots critical events and conditions in time sequence and shows linkages between them. Another analysis tool is called Human Error in ATM (HERA). It helps investigating the human errors by a non-human factor specialist, offering guidance through a series of flowcharts. SOFIA (providing the system perspective) and HERA (providing the human factors perspective) are fully integrated tools.

Assessing the severity of an occurrence is accomplished with the Occurrence Incident Evaluation Mark-sheet. This is a question driven marksheet which looks at both the separation achieved and how much the ATC was in control of the situation. A complete risk (and severity) assessment scheme will be in place by the end of 2003.

TOKAI also contains tools for selecting suggested safety recommendations and following-up on their implementation. It also has an export function for selecting and grouping reports of interest (depending on the particular recipient and automatically disabling selected fields and de-identifying specific data).

In short, TOKAI is designed to support the entire process of collecting, analyzing, assessing and disseminating occurrence data. It also assists in developing and managing remedial actions.

Aviation Usage
The tool is being developed by EUROCONTROL. The tools are already implemented in a number of EUROCONTROL member states. Other states are in the process of implementing it.

Availability
EUROCONTROL is willing to share TOKAI with other ATM organizations at no cost.

Documentation
A presentation is available on the web at: http//www.eurocontrol.int/src/html/tokai.html

Vendor/owner Support
Not Applicable

Potential Benefits to Air Traffic Safety Analysis
TOKAI is a complete package useful to an ATM organization that has no automated tool for establishing and maintaining a database on ATM occurrences. TOKAI can exchange data with other databases through SHIELD (also developed by EUROCONTROL). The module to export data to the European Union system ECCAIRS is already in place.

Total Cost:
Free to any air traffic management organization.

Other Comments:
TOKAI is still under development, but it is already a mature product, with a history of real life usage in ATM organizations, and is well on its way to be a complete tool for ATM occurrence investigation.

Point(s) of Contact
T. Blajev Phone: + (32) 02 729 3965 email: tzvetomir.blajev@eurocontrol.int

2.2 Air Traffic Replay and Non-interactive Simulation

This section describes tools for replay and simulation of air traffic data (radar, etc.). This includes real-time, fast-time, and cumulative freeze-time replay. It includes replay of actual recorded data, display of hypothetical data, and combinations of the two. It does not include tools that allow a human operator to interact with the tool while it is in operation, acting as an air traffic controller or pilot, which are discussed in the following section.

Such tools might be used to display events where an error occurred, to augment the written report. Or they might be used to test a hypothetical situation. There are many air traffic simulation tools that are not included because they have no safety implications (e.g., required separations are automatically enforced), which are designed to compute capacity and/or delay.

These tools have been subcategorized as: 1) tools for replay of ATC data concerning specific safety events, 2) replay and simulation of ATC data for general purposes, and 3) other data replay.

2.2.1 Replay of ATC Data on Safety Events

Some replay tools are designed to replay ATC track data and voice communication recorded during the time leading up to the occurrence of a safety event for the purpose of gathering additional data for analysis of the accident or incident. A good example of this is RADS.

Radar Analysis Debriefing System (RADS)

Purpose
RADS is a PC-based, real-time, tool for playback of radar and voice in a highly intuitive, three-dimensional format. It can be used for analysis of incidents and/or training and is adaptable to any ATC environment.

Description
RADS is based on Flightscape's Recovery, Analysis and Presentation System (RAPS). It is adaptable to any air traffic control environment. It accepts digital audio files. It displays multiple windows and is configurable.

Aviation Usage
RADS is used by NAV CANADA, which has the exclusive rights to market RADS worldwide.

Potential Benefits to Air Traffic Safety Analysis
RADS can be used to analyze incidents on a low-cost, easily transportable hardware system.

Tool Cost
See vendor

Documentation
See NAV CANADA for more information.

References
Web site: www.navcanada.ca

Vendor/owner Support
Sponsor: NAV CANADA, 77 Metcalf Street, Ottawa, Ontario, K1P 5L6, Canada

Vendor: Flightscape, 36 Antaras Drive, Suite 850, Ottawa, Ontario, Canada K2E 7W5

Point(s) of Contact

NAV CANADA: 1-800-876-4693, service@navcanada.ca
Flightscape: +1 613 225 0070, info@flightscape.com

2.2.2 General Replay and Simulation of ATC Data

There are a host of tools available to replay actual or simulated flight track data. Some have a function of studying traffic patterns and loading. Some are constructed to analyze proposed changes in airspace design, traffic routing, or procedures. A few of them are mentioned here.

Future ATM Concepts Evaluation Tool (FACET)

Purpose
FACET is an air traffic management (ATM) modeling and simulation capability. Its purpose is to provide an environment for the development and evaluation of advanced ATM concepts.

Description
FACET can model system-wide airspace operations over the entire US. It uses flight plan data to determine aircraft routing. As options, the routes can be automatically modified to direct routes or wind-optimal routes. FACET then uses aircraft performance characteristics, winds aloft, and kinematic equations to compute flight trajectories. It then computes sector loading and airspace complexity. As an option, FACET can compute and simulate advanced concepts such as: aircraft self-separation and National Playbook rerouting. FACET also has simple algorithms that can be used to model the en-route impact of ground delay programs and miles-in-trail restrictions.

FACET has been designed with a modular software architecture to facilitate rapid integration of new ATM concepts. It is written in the “C” and “Java” programming languages, and is platform independent.

Aviation Usage
FACET has been used at NASA, the FAA, Northwest Airlines, and several other aviation organizations.

Potential Benefits to Air Traffic Safety Analysis
FACET might be useful to determine the impact of proposed future ATM concepts on controller task load, sector loading, and workload on automated self-separation systems.

Tool Cost
FACET is available to any U.S. company upon completion of a Non-Disclosure Agreement.

Documentation
A FACET Orientation Manual is available on request.

References
Web site: www.asc.nasa.gov/aatt/wspfs/Billimoria_FACET.pdf

Vendor/owner Support
NASA Ames Research Center, Moffet Field, CA USA

Point of Contact
Dr. Banavar Sridhar or Dr. Karl Bilimoria, NASA, Banavar.Sridhar-1@nasa.gov or Karl.D.Bilimoria@nasa.gov

GRaphical Airspace Design Environment (GRADE)

Purpose

The Graphical Airspace Design Environment (GRADE) provides aviation analysts with a powerful and flexible tool with which to conduct complex analyses on a variety of aviation-related applications. GRADE enables analysts to visually examine radar track and flight plan data from multiple angles.

Description

GRADE provides advanced visualization capabilities including three dimensional static as well as dynamic (replay) views of airspace and air traffic. The user has easy, flexible access to the underlying airspace/traffic data and to a set of functional tools for visual and quantitative analysis, model preparation of current or proposed operations for use in simulations, replaying radar data and animating simulation results in three dimensions, for actual or simulated air traffic operations.

In addition, GRADE can manipulate a number of independent data layers that may be utilized individually or in combination. These include:

- En route, oceanic and terminal radar tracking data and flight plans
- Airport layouts and CAD drawings
- Navigational aids and fixes
- Standard aircraft departure and arrival procedures
- Airways and route structures
- Terrain and obstructions
- Political boundaries, land use maps, street maps and census data
- Controller video maps
- Pilot and controller voice recordings
- Weather cell boundaries

Aviation Usage

GRADE has been used in numerous airport and airspace design and analysis studies over the past 12 years. In addition, it has been licensed for installation at several FAA and EUROCONTROL sites.

Potential Benefits to Air Traffic Safety Analysis

GRADE calculates traffic density, separation distances, deviation from flight plan, and controller workload measures, based on either real radar tracks or simulated tracks. The tool can also be used for accident investigation analysis, as it was for the Avianca accident approaching JFK in 1990.

Tool cost

GRADE is the property of and is licensed by ATAC Corporation.

Documentation

Further documentation is available upon request and with approval of ATAC Corporation.

Vendor/owner support

ATAC Corporation, Sunnyvale, CA., USA

Point of contact

Mr. Don Crisp, ATAC Corporation, +1 (408) 736-2822, Email: DonCrisp@atac.com

Performance Data Analysis & Reporting System (PDARS)

Purpose
PDARS provides air traffic control facility managers a tool for monitoring day-to-day operations. PDARS enables processing and extracting data from complex and extremely large datasets.

Description
The PDARS system routinely and continuously collects radar track and flight plan data from Automated Radar Terminal System (ARTS) and Air Route Traffic Control Center (ARTCC) HOST gateways. These data are further translated into performance and safety measurements. The results are available early the following morning.

The BirdWatch Reporting System (BWRS) component of PDARS is a Microsoft Excel-based application that allows users to design custom reports, graphs, and tables giving managers access to the performance and safety measures. The GRaphical Airspace Design Environment (GRADE) component of PDARS provides advanced visualization capabilities, including 3-D static or dynamic (replay) views of airspace and air traffic.

PDARS installations are linked together with a secure Wide-Area-Network (WAN) managed by NASA, which greatly streamlines the administration of the distributed system and allows for data to be shared between facilities. A PDARS Intranet site allows authorized users to access specific report pages containing facility performance measures and facilitates exchange of information and data between facilities.

PDARS operates on Windows, Solaris, and Linux operating systems. The Federal Aviation Administration and the National Aeronautics and Space Administration (NASA) jointly sponsored its development.

Aviation Usage
PDARS is currently operationally deployed at 18 FAA facilities, including: 10 ARTCCs, 5 Terminal Radar Approach Control (TRACON) facilities, 2 Regional Offices, and the ATC System Command Center.

Potential Benefits to Air Traffic Safety Analysis
Having a rich data source such as PDARS on hand opens the doors to a wide array of safety analyses that could be performed. One example is the test of Time Based Metering (TBM) for LAX arrivals. The implementation team identified a scenario where conflicting arrival flows over the Ventura (VTU) VOR combined with TBM testing could increase sector workload. PDARS was used to assess the potential for conflictions between aircraft on these flows.

Usability for Air Traffic Safety Analyses
PDARS data and analytic tools have been used in safety-oriented studies. PDARS components are also being used to evaluate real time simulation results produced by NASA Langley's Air Traffic Operations Simulation. PDARS allows for relatively easy integration and adaptation to suit many air traffic safety analyses.

Tool cost
PDARS is currently only available to authorized FAA users at FAA ATC facilities.

Documentation
Further documentation is available upon request and with FAA permission.

Vendor/owner support
ATAC Corporation in Sunnyvale, CA, is the primary contractor providing full support to the PDARS program.

Point(s) of contact
Mr. Richard Nehl, FAA, +1 (202) 267-8788, rich.nehl@faa.dot.gov
Dr. Irving C. Statler, NASA, +1 (650) 604-6655, istatler@mail.arc.nasa.gov
Mr. Wim den Braven, ATAC Corp., +1 (408) 736-2822, WimdenBraven@atac.com

Reorganized ATC Mathematical Simulator (RAMS Plus™)

Purpose
The RAMS Plus™ air traffic control fast-time simulator offers a high fidelity simulation using rich ATM functions to carry out a range of micro to macro studies.

Description
RAMS Plus™ is a PC-based simulation tool that allows the users to create a complete model of an air traffic control system, including controller actions. It offers high-fidelity modeling of ATC procedures, 4D performance of over 300 aircraft, 4D conflict detection and rule-based conflict resolution, and controller actions based on the current demand. It includes controller workload assignment based on dynamic system conditions, TMA runway sequencing and holding stack operations, airspace routing, free flight and Reduced Vertical Separation Minima zones, stochastic traffic generation, and graphical animation. The tool produces a detailed list of events created in text form for analysis.

The current RAMS Plus™ version 4.00 runs on a desktop PC with Windows NT, Windows 2000, or Windows XP. Its open architecture design facilitates integration with other simulation tools. Some of the tools now working within the interoperability framework include: ATMOS, to calculate wind effects, the Augmented Flight Deck Model, and FAA's OPGEN to model the optimization of flight trajectories from an airlines business perspective.

The complementary post-processing tool, the ATM Analyser, is included with the RAMS Plus tool. The ATM Analyser includes a wide-range set of easily-extensible standard reports that recognize, among other tools, RAMS Plus outputs.

Aviation Usage
The RAMS simulation engine has been used in many studies since 1993. RAMS Plus is currently installed in over 25 client sites around the world, including the FAA and EUROCONTROL research facilities.

Potential Benefits to Air Traffic Safety Analysis
RAMS Plus is somewhat unique in that it considers both aircraft movements and controller actions in one simulation. The tool provides flexibility in many of its features (along with extensive outputs and the extensible ATM Analyzer reports) to allow the modeling and study of many future concepts and abstractions. Therefore, it might be able to predict controller overload or flawed procedures.

Tool Cost
The vendor is currently licensing RAMS Plus as community-supported tool. As such, there is an initial licensing fee, and yearly continuing support fees which allow access to support and new releases/patches. The 2003 pricing is $15,000 for a single-machine license, and includes the ATM Analyser, and continuing support is currently priced at $5000 per year.

There are current arrangements with the FAA and the vendor such that FAA installations receive licenses for RAMS Plus and the ATM Analyzer for no charge.

Documentation
Full documentation, including an extensive User Manual and Data Manual, are available in PDF format from the vendor upon request. Contact ramssuppport@isa-software.com.

References
Web site: http://www.ramsplus.com/

Vendor/owner Support
Support is available from the vendor, as indicated above in Tool Cost**.** Training courses and consultation in the use of the tool are also available from the vendor:
ISA Software, 38 rue des Gravilliers, 75003 Paris, France

Point of Contact
Carolyn Sorensen, ISA Software, +33 1 44 54 87 80, ramssupport@isa-software.com
Ian Crook, ISA Software, ian@isa-software.com

Sector Design Analysis Tool (SDAT)

Purpose
SDAT is a high-end visualization and analysis tool for use by airspace offices at the local, regional and national levels. SDAT uses a variety of metrics to evaluate the effect of airspace and traffic changes that characterize sector capacity and traffic complexity. One metric is an estimate of the number of times per hour that a controller would have to intervene, or consider intervening, in order to prevent loss of safe separation between aircraft. Early studies using SDAT showed that there was a strong correlation between its prediction of separation workload and actual number of operational errors experienced.

Description
SDAT supports nearly all airspace and traffic data sources used within the FAA and overlays the traffic data on the airspace environment. The user is able to select from menus the portions of the data to display and how the data are displayed. SDAT permits the user to postulate changes in the airspace and/or traffic data to compare the analysis results to those with the original. SDAT analysis tools include measures of traffic loadings within control sectors or within a given radius of a specified fix. SDAT also contains a unique feature that performs a calculation of the expected number of ATC aircraft separations per hour in each airspace sector. This allows the user to see in advance how a proposed change could impact controller task load, particularly separation assurance task load, and possibly prevent errors resulting from excessive demands on the controllers' attention.

Aviation Usage
SDAT is deployed at all major FAA AT facilities and is the primary tool used in airspace design. The recently released PC version of SDAT has expanded the scope of SDAT's original capabilities by providing traffic animation, controller familiarization tools, connections to the NAS Resources database and direct connections to archives of historical traffic data. SDAT supports analysis of proposed changes in airspace design, traffic loading, and/or routing in US en route airspace. SDAT has been expanded to visualize and analyze interactions between traffic and airspace in terminals, one or more Air Route Traffic Control Centers (ARTCCs), regional, and National Airspace System (NAS) environments.

Potential Benefits to Air Traffic Safety Analysis

SDAT is intended to lessen the potential for AT errors, not to analyze them. However, SDAT can display AT occurrences as preserved in the radar recording. It can show cumulative radar track positions or a time step display and thus show the traffic and airspace considerations at the time of the error. SDAT has a feature that allows it to compute the number of times per hour a sector controller team will have to consider separating aircraft, based on recorded flight tracks. Thus can be used to determine the relative risk of an error, assuming that the risk is proportional to the demands placed on the AT system.

Tool Cost

The new version of SDAT, SDAT Enterprise, runs on high-end Windows 2000 workstations. SDAT is the property of the FAA and is available upon request to the ATALAB manager in FAA's Air Traffic Airspace Management (ATA200) office.

Documentation

Documentation on SDAT is available from the FAA (ATA200). This includes brochures, a user manual, and a training guide/tutorial. The SDAT manual is kept up-to-date and is available on the world-wide-web.

References

Web site: http://atalab/sdat/

Vendor/owner Support

SDAT is an FAA-owned tool that is currently supported by CNA Corporation, Crown Consulting and Unitech contractors who work in support of the ATA-200 ATALAB. CNA Corporation provides analytical and project management support; Crown Consulting provides software development support; and Unitech provides subject matter expert and user support.

Point of Contact

Barry C. Davis, ATA-200, FAA, 202-267-9201, barryCdavis@faa.gov

Other Comments

SDAT is continually being improved and deployed. SDAT is relatively easy to use having full documentation, on-line support, built-in help menus and a user support team.

2.2.3 Replay of Other Data

There are other recorded data of potential interest in safety analysis. One of the most interesting incidents is a cockpit collision alert. While this is not an ATM function, it is important to understand how systems that back-up the ATM system work in order to estimate the bottom-line risk of collision.

InCAS

Purpose
InCAS is a PC-based interactive simulator for replaying and analyzing Airborne Collision Avoidance System (ACAS) during close encounters between aircraft. It is designed for case-by-case incident analysis by investigators.

Description
InCAS reads radar data and provides an interface to examine these data in detail, removing any anomalies that may be present. The cleaned data are used to simulate trajectories for each aircraft at one-second intervals and these data are fed into a full version of the logic in the Traffic Alert and Collision Avoidance System, TCAS II (versions 6.04A or 7). TCAS provides both a visual and audible signal to the pilot when another aircraft crosses protected outer and inner boundaries around the TCAS-equipped aircraft. The pilot is advised of a suggestion to climb or descend, and how fast.

Many different displays of the resulting simulation can be provided –technical views (plan view, horizontal view, TCAS event summary, TCAS logic parameter graphs, TCAS logic decision text), cockpit views (using EFIS or IVISI), or a controller view (pseudo radar picture).

The tool simulates the reaction of TCAS, using radar data, and cannot provide precisely the same alerts as occurred in reality. Nevertheless, it provides a simulation analysis of high fidelity that gives a good understanding of what was likely to have happened. The tool flexibility allows adjustment of parameters, if necessary, to correspond to a known sequence of events. It provides valuable insights into the geometry of incidents.

InCAS recreates these (visual and aural) alert signals (based on the MOPS logic), the radar display as might have been visible to the air traffic control specialist, plots of the aircraft tracks, and hard-copy reports containing an analysis of the event (including plots of the aircraft tracks in the horizontal and vertical planes). The user can select from a number of different views and have them displayed simultaneously. The ACAS parameters view describes textually the behavior of TCAS at critical points in its logic.

The user can replay the event in different views and at different speeds (real-time, fast-time, or at a customized clock speed). The user can edit the track information and replay the edited version.

Aviation Usage
InCAS is currently used by nine organizations (including air traffic service providers, ATS regulators and an airline) to analyze ACAS events.

Potential Benefits to Air Traffic Safety Analysis
This is a very useful tool for gathering data on near midair collisions, TCAS effectiveness, controller and pilot reaction times, etc. It can also be used to test proposed changes in the TCAS logic, but this capability is not provided to the general user.

Tool Cost
InCas is available free of charge, subject to EUROCONTROL approval and license agreement.

References
Web site: http://www.eurocontrol.fr/ba_saf/acas/InCAS/Index.htm

Vendor/owner Support
On-line support is available for reporting and resolving problems, suggestions, etc.

Point of Contact
Garfield Dean, EUROCONTROL +33 1 6988 7587, garfield.dean@eurocontrol.int

Replay Interface for TCAS Alerts (RITA)

Purpose
RITA 2 is an experience feedback tool for the training of air traffic controllers and to reinforce the training of flight crews. It shows on the same screen what both pilots and controllers could see and a transcript of what was said.

Description
RITA was initially developed by Centre d'Etudes de la Navigation Aérienne (CENA) in 1995 for the ACAS training of French controllers. RITA2 is a new PC-based European version whose main objectives are to include TCAS II Version 7 events and to implement modern radar and TCAS displays. A library of TCAS alert events are being assembled, selected based on their relevance to training needs.

Although individual use is possible, RITA is best used by instructors in briefing sessions with small groups of pilots and controllers. It's display is divided into three main parts: 1) a visual display simulating the radar display provided by radar recordings, 2) a visual display of the pilot's view on either an Instantaneous Vertical Speed Indicator (IVSI) or an Electronic Flight Instrument System (EFIS), with the associated aural alarms, 3) display of the transcript of voice communication between controller(s) and pilots.

Aviation Usage
RITA has been used in France for several years. It is now being used by EUROCONTROL and several European States.

Potential Benefits to Air Traffic Safety Analysis
Beyond its benefit in improving understanding between flight crews and controllers at one of the times it is most needed, RITA 2 should be a useful source of information on pilot and controller reactions and times required in the last few seconds of a potential collision, for input into a collision risk analysis tool.

Tool Cost
RITA is available on request from the EUROCONTROL ACAS Support Unit (ASU) or CENA ACAS division.

Documentation
This report is based on a brochure produced by CENA

References
Web site: http://www.cena.dgac.fr/ and http://www.eurocontrol.int/acas/

Point of Contact
Jean-Marc Loscos at CENA, Toulouse, France, contact_sas@cena.fr

2.3 Air Traffic Human Interactive Simulation Tools and Facilities

This section presents simulation tools that allow a human to interact with the tool in real-time while it is executing. Such tools can be used to train air traffic controllers/managers, or to test new concepts for ATC equipment, controller aids, air traffic rules and procedures, airspace designs, etc. They might be used to replay events leading up to an actual incident to see how another controller would react given the same information. They can be used to introduce a simulated pending air traffic control emergency to test the ability of the human to respond in time.

There is a wide-variety of such tools, ranging from tools like AT Coach, where a single person acts as the controller and the personal computer does everything else, to huge research facilities, e.g., NARSIM, where numerous people interact simultaneously. In between, are simulators that can be purchased assembled on-site and be made to duplicate the environment and traffic experienced at a particular facility. Some of these tools can be purchased or leased, some can be used as part of an outside research program, and some might not be available for outside use but offer a information on the state of the art in air traffic simulation.

2.3.1 <u>Standalone Systems</u>

The least costly way of incorporating a human operator is with a standalone system. The aircraft are simulated by computer generated voices and displays. This might suffice when a single controller and predictable aircraft responses are to be simulated.

AT Coach™

<u>Purpose</u>
ATCoach™ is a family of precision products supporting standalone training, ATC Automation system based training and testing, airspace modeling, and voice recognition based simulation control.

<u>Description</u>
There are two simulation systems: the AT Coach™ Standalone Simulation and the AT Coach™ Embedded Simulator.

AT Coach™ Standalone Simulation workstation based systems can range from a desktop training system to s full fidelity console based simulation environment. Each replicates several automation systems, including FAA ARTS, FAA ARTCC, as well as systems in use internationally. The system contains voice recognition software that is used to make the simulated aircraft respond realistically to the controllers spoken instructions, both in aircraft display and with simulated voice responses.

The AT Coach™ Embedded Simulation provides the highest simulation fidelity as it merges the simulated target generation with an operational ATC automation system. This system produces real time radar and flight data messages exactly as the controller would see them. In addition, the Embedded Simulation provides an extensive automation system test capability.

<u>Aviation Usage</u>
AT Coach™ Embedded Simulation is currently in use as a research tool in Germany at the DFS Deutsche Flugsicherung GmbH. Raytheon Systems Company has incorporated AT Coach™ Embedded Simulation in the FAA STARS program. Lockheed Martin has used this technology in a DSR/NAS training system, and in a new Korean automation system under development. The FAA used Coach™ Standalone Simulators in verification of the design of the Potomac TRACON Consolidation Project.

Potential Benefits to Air Traffic Safety Analysis
AT Coach™ could be used to conduct experiments in cases where the controller is acting alone and target simulation is adequate.

Tool Cost
Contact vendor

Documentation
Contact vendor

References
Web site http://www.atcoach.com/

Vendor/owner Support
UFA Inc., 18 Commerce Way, Suite 4000, Woburn, MA 01801 USA

Point of Contact
Email: ufa@atcoach.com

2.3.2 Training Systems

There are a large number of training simulators with various capabilities. These systems allow a group of participants to work as a team of controllers. Some allow another group to act as pseudo-pilots. While they are designed as training tools, they have the ability to postulate hazard situations, and can serve as research tools. They vary in the ability to simulate postulated equipment, situations, and procedures.

Aviation Research and Training Tools (ARTT)

Purpose
ARTT was developed to provide a low-cost entry to air traffic and aviation simulation. It provides optimal performance, flexibility, affordability, and scalability. The ARTT product series can be used for training or as a research tool.

Description
ARTT is an integrated family of products: ARTT Tower (control tower cab), Radar (approach control), Driver (airport vehicles), and Coms (radio and telephone). Each ARTT simulator can be installed on a single laptop computer or at a network of desktop computers to provide scalability, portability, and flexibility. Visual display can be on the computer screen using graphics cards or can be projected onto large screen displays.

Aviation Usage
ARTT has been adopted by aviation universities, education and research organizations, and by airports for air traffic and airfield research and training.

Potential Benefits to Air Traffic Safety Analysis
The ARTT product series can be used in aircraft and vehicle runway incursion analysis, airport operations analysis and airport operational procedures studies.

Tool Cost
Cost depends on the particular configuration and series.

Documentation
Adacel can provide electronic user guides. For more information contact vendor.

References
This information is based on vendor's sales brochure and additional guidance, including web site: http://www.adecelinc.com/

Vendor/owner Support
Adacel Inc., Columbia House, Columbia Drive, Worthington, West Sussex BN13 3HD UK
Adacel, Inc., 7900 Taschereau Blvd., Building E, Brossard, Quebec J4X 1C2 Canada
Adacel Systems, Inc., 6200 Lee Vista Blvd., Suite 100, Orlando, FL 32822 USA

Point of Contact
England: +44 1903 268 169, Canada: +1 450-672-3888, info@adacelinc.com

BEST Air Traffic Control Simulators

Purpose
BEST training tools and software are included in some of the other training systems mentioned in this guide. They cover a wide range of ATC simulation needs, with full integration.

Description
The BEST product family of ATC simulators includes:
1. Area Radar & procedure Control Simulator
2. Approach Radar& Procedural Control Simulator
3. Controller and Pseudo-Pilot Self-Teach Trainer
4. Tower and Ground Control Simulators with 2D displays
5. Tower and Ground Control Simulators with 3D displays
6. Multi-role Tower + Ground + radar trainers

Some of the features BEST tools offer:
1. Voice recognition and output with user tools to accommodate accents, names, and phraseology
2. Full-color, multi-window, radar displays
3. Emulation and simulation of operational ATC equipment
4. Fast, easy pseudo-pilot commands
5. Full networking for ease of expansion
6. Comprehensive data preparation suite
7. Modern object-oriented software design

Aviation Usage
Some examples are:
- UK National Air Traffic Services Ltd is using BEST ATC simulators at the UK's new en-route center at Swanwick, in Hampshire.
- BEST radar approach simulators are used at the UK NATS College of ATC.
- BEST has been selected by the Deutsche Flugsicherung to provide part task training.

Potential Benefits to Air Traffic Safety Analysis
BEST's full range of integrated products might allow creation of risk scenarios that stretch across several layers of ATC.

Tool Cost
Contact vendor

References
Website: http://www.micronav.co.uk

Documentation
See vendor

Vendor Support
MICRO NAV Ltd, Gild House, 64-68 Norwich Ave. West, Bournemouth, Dorset BH2 6AW, UK
MICRO NAV provides training, ongoing maintenance, and user help services.

Point of Contact
Tom Howard-Jones, MICRO NAV, +44 (0) 1202 764444, sales@micronav.co.uk

Controlled Airspace Synthetic Environment (CASE)

Purpose
CASE is a training system that can be purchased and installed on one's own site. It models the complete airspace system from gate-to-gate.

Description
The CASE simulator is capable of recording every single event that occurs within the scenario that has been defined. In addition to modeling the performance/profiles of any number of aircraft and ground vehicles, CASE is also able to evaluate and analyze events such as congestion, sector loading, the number of times a separation threshold has been violated the number of aircraft controlled by each control station, etc.

The core elements are: 1) a Central Processing Suite, 2) up to thirty-five Pilot, Controller. and Supervisor) Operator Workstations, 3) an Exercise Preparation System, and 4) Voice and data communications networks. Each operator workstation is fitted with two PCs, two 21-inch rectangular color displays, and keyboard and mouse. Each workstation is a standard multi-function, multi-airspace position that can be configured as a Controller, Pilot or Supervisor position.

CASE uses industry standard components and interfaces in a modular way to maintain an open design that can be adapted and updated. It is largely based on the ADA language, the UNIX operating system and a number of PC workstations and servers.

Aviation Usage
CASE was used by the Swedish air traffic service academy (SATSA) to study the implementation of a third runway at the Stockholm Airport.

Potential Benefits to Air Traffic Safety Analysis
This is a very flexible tool that could be used to study the interface between gate, runway and airspace control operations including multi-sector and international operations.

Tool Cost
Depends upon precise configuration and scope.

Documentation
See the web site below.

References
Web site: http://www.amsjv.com/html_eng/search/prods/product_keyword.asp

Vendor/owner Support
Alenia Marconi Systems, ATM & Airport Systems
Ty Coch Way, Cwmbran, NP44 7XX United Kingdom
On-line support is available for reporting and resolving problems, suggestions, etc.

Point of Contact
Christopher Wilson, Director, International Sales, ATM & Airport Systems, AMS; +44(0)1633-835-039, Christopher.wilson@amsjv.com

Durable Aviation Trainer Solutions - Tower and Radar (DATS)

Purpose
DATS aims to cover all the needs of the aviation sector: ATC, airport, air combat control, pilot procedures, all interacting in a common simulation environment. DATS Tower is a simulator for local and ground controllers. DATS Radar is a simulator for area and approach control. Both will interact with each other and with other components of the DATS simulator community.

Description
DATS simulators are all produced based on concepts and specifications developed by simulator instructors. Functions for radio, direct intercom and phone communication plus voice and data recording and playback complete with the set-up. The tools can be run on a standard PC with any of the commonly used operating systems.

DATS Tower can be integrated with real tower hardware or with "behind-glass" hardware. It offers a 3D out-the-window view ranging from 60 to 360 degrees, special visual weather effects, pseudo pilot functions, and more than 50 visible moving targets. It includes Surface Movement Radar, and will include ADS-B, VHF Data-Link, and the Runway Incursion Warning System.

DATS Radar features multi-radar or single radar emulation, PC –based communication system and interface, real-time dynamic simulation with more than 100 visible moving targets. It includes functions for Short Term Conflict Alert, Minimum Safe Altitude Warning, and Reduced Vertical Separation Minima.

DATS pseudo pilot workstations allow hot key or mouse operation, built-in take-off/approach and landing procedures, holding patterns, and handovers between pseudo pilots.

Aviation Usage
DATS tools are used extensively in Sweden, Russia, Lithuania, Portugal, Slovenia and Saudi Arabia.

Potential Benefits to Air Traffic Safety Analysis
DATS tools could prove useful in human pilot and controller human-in-the-loop simulations.

Tool Cost
See vendor

Documentation
See vendor

References
Web site: http://www.c-its.com/

Vendor/owner Support
C-ITS, Cardellgatan 1, Box 5676, SE-114 86 Stockholm, Sweden

Point of Contact
Phone: +46 8528 026 00, info@c-its.com

Evans & Sutherland Tower Trainer

Purpose
The E&S Tower Trainer - A safe controlled environment where tower and ground controllers can develop skills.

Description
The E&S Tower Trainer includes a full 3D, 180-degree, modular tower simulation system that can be set up in an office and be easily moved. It includes a PC-based visual display system. It incorporates the Micro Nav BEST™ air traffic control simulation software that provides full ATC functionality, including programmable voice recognition. It can vary training scenarios from normal to complex with only a few keystrokes.

Aviation Usage
Over 400 Micro Nav BEST ATC training seats installed worldwide. Thousands of channels of E&S visual systems installed worldwide.

Potential Benefits to Air Traffic Safety Analysis
The E&S Tower Trainer's ease of use and mobility should make it easy to use in a research setting to postulate hazards and study reactions. It is networkable; it can be linked to flight simulators to facilitate ATC-to-flight-crew coordination training. It is also valuable in re-creation of mishap situations/scenarios to permit identification and elimination of mishap causal factors. It could be a valuable tool for ground incursion analysis.

Tool Cost
Largely dependent on display requirements – Scalable from laptop use to full 360 degree tower cabs. See vendor

Documentation
See following web site: http://www.es.com/products/simulation+systems/atct/index.asp

Related Tools
BEST Air Traffic Control Simulators

References
Web site: http://www.es.com

Vendor/owner Support
Evans & Sutherland, 800 Komas Drive, Salt Lake City, UT 84108 USA
http://www.es.com/support/support+home.asp, Spares availability within minutes of fault isolation, rapid-replacement of failed parts, protection against obsolescence.

Point of Contact
Bill Roberson, E&S, +1 801-588-1535, broberso@es.com

MaxSim

Purpose

The MaxSim is an advanced simulation system for aviation training and research.

Description

MaxSim consists of two separate tools: 1) MaxSim Tower, a control tower simulation, and MaxSim Radar, a radar control simulation that includes PAR (Precision Approach Radar). The MaxSim Tower and MaxSim Radar can be used independently or they can be seamlessly integrated into the MaxSim Tower Radar. The MaxSim Tower Radar provides combined research training. It can be used in traffic flow studies, training, procedures development, disaster management planning, etc.

MaxSim Tower has a 360-degree field of view, customizable visual display. It has voice recognition software for control of computer-generated aircraft or allows for pseudo pilots. MaxSim Radar is fully scalable from a single-seat approach control to a multi-seat en route facility. It can interface with either FAA ARTS IIIA or the European Operational Display and Input Device (ODID).

Aviation Usage

MaxSim has been adopted by leading FAA and ICAO aviation facilities around the world, including NASA, the United States Air Force (USAF), the United States Army, Nav Canada, ENAV (Italy), INFRAERO (Brazil), Embry-Riddle Aeronautical University and the University of North Dakota, just to name a few.

Potential Benefits to Air Traffic Safety Analysis

MaxSim can be used to test proposed changes in airport and radar procedures or human reaction to simulated emergencies. MaxSim can also be used for runway incursion studies and runway separation studies.

Tool Cost

See vendor for pricing, which depends on the specific configuration.

Documentation

Adacel provides CBI (Computer Based Instruction), maintenance guides and training guides.
See http://www.adacelinc.com/

References

This summary is based on a sales brochure produced by the vendor and with helpful comments from the vendor. For more information contact the vendor.

Vendor/owner Support

Adacel Inc., Columbia House, Columbia Drive, Worthington, West Sussex BN13 3HD UK
Adacel, Inc., 7900 Taschereau Blvd., Building E, Brossard, Quebec J4X 1C2 Canada
Adacel Systems, Inc., 6200 Lee Vista Blvd., Suite 100, Orlando, FL 32822 USA

Point of Contact

England Phone: 044 1903 268 169   Canada Phone: (450) 672-3888
E-mail info@adacelinc.com

2.3.3 Full Scale Simulation Laboratories

The most expensive and presumably the most accurate means of incorporating a human-in-the-loop is the full-scale simulation laboratory. These are usually capable of incorporating a considerable number of participants and simulating a large variety of postulated equipments and procedures.

EUROCONTROL Simulation Capability Platform for Experimentation (ESCAPE) and Derivatives

Purpose

The EUROCONTROL Experimental Centre (EEC) caries out research and development to improve ATM in Europe. It supports the European Air Traffic Management Programme (EATMP) through simulations, field trials, and various studies. The ESCAPE platform was launched in 1996 as the 6th generation of the EEC ATC real time simulation facility.

Description

ESCAPE is the biggest ATC real-time simulator in Europe. It uses the Raptor 2500 FPS display technology, using LCD flat panel displays, each with a 170-degree viewing angle. The Centre has the capability to simulate a host of different en route scenarios.

By 2000, it became very difficult and costly to satisfy both real time (RT) simulations and R&D simulations with the same ESCAPE platform. RT simulation and training requires a very stable and robust platform. R&D requires a very flexible but not so robust platform. As an interim step, the decision was to split ESCAPE into two platforms:

1. The Experimentation And Trial (EAT) platform for R&D and pre-operational validation
2. The Real Time Simulation (RTS) platform, always derived from an EAT platform, providing a stable and reliable simulator for RT simulation and training

The next step is for the new AVENUE compliant ESCAPE (ACE) platform to replace the EAT platform and become the next generation of ESCAPE during 2003. These three platforms (RTS, EAT, and ACE) are based on ESCAPE and are hosted within the EUROCONTROL Simulation Capability and Platform for Experimentation (ERIS) project. ESCAPE remains the ERIS core product.

Aviation Usage

The Centre has more than 60 programmes and projects in its business plan, ranging from future airspace management activities to environmental assessment and safety studies. It has an annual budget of 60 million euros. One of the key activities is an investigation into the amount of ATC responsibilities that can be safely transferred into the cockpit.

Potential Benefits to Air Traffic Safety Analysis

This high-fidelity simulation capability for R&D, training, and validation should make a considerable contribution to ATM safety.

Tool Cost

Information not available

References

This summary was prepared by WG B based on the article, "Bringing the Future to Life," by Stefan Marx in the brochure: ECAC and EUROCONTRL: Serving European Aviation. And the Web site: http://projects.eurocontrol.fr/

Vendor/owner Support
EUROCONTROL Experimental Centre, Brétigny: BP 15, F-191222 Brétigny-sur-Orge, CEDEX, France

Point of Contact
David Young, +(33) 1-69 88 7655, dave.young@eurocontrol.int

FAA Center for Aviation Simulation

Purpose
The Center is equipped to conduct simulations that encompass every aspect of air traffic control: airport, terminal, en route, and oceanic; airway facilities; flight deck; navigation; communications; security; etc. It can simulate current and proposed systems and procedures,

Description
The Center for Aviation Simulation is located at the FAA's Howard J. Hughes Technical Center. The laboratory contains exact duplicates of hardware and software located at FAA facilities, and has access to current air traffic personnel to participate in studies, and have all linked together in a highly realistic simulation.

Aviation Usage
The center has been used to study air traffic control automation-related technologies, reduced vertical separation, traffic alert and collision avoidance systems, proposed new air traffic control work stations, data link communications, new oceanic air traffic management systems, final approach spacing aids, etc.

Potential Benefits to Air Traffic Safety Analysis
The ability to test new equipment and/or procedures with actual working air traffic control specialists is extremely valuable to expose and eliminate problems that might otherwise occur in the real world.

Tool Cost
Not determined

Documentation
Not determined

References
Web site

Vendor/owner Support
ACT-5, FAA Technical Center, Atlantic City International Airport, New Jersey 08405

Point of Contact
Not determined

FAA Research and Development Human Factors Laboratory (RDHFL)

Purpose

The RDHFL is a state-of-the-art facility designed specifically to support research into human factors. It is dedicated to providing new insights into human performance, and assisting in the design of aviation systems that bring people and technology together.

Description

The RDHFL is located at the FAA's William J. Hughes Technical Center. It contains approximately 10 thousand square feet of laboratory space, including four experiment rooms that can be used independently or together. Links are provided between the RDHFL and some other government laboratories, including the NASA Ames Research Center. The RDHFL also contains a Virtual Reality (VR) capability where researchers can interact with three-dimensional, computer-generated representations of concepts, designs, and data sets that might otherwise be difficult to visualize.

Aviation Usage

The RDHFL has been used in human factors research in support of:

1. Display System Replacement (DSR)
2. Host and Oceanic Computer System Replacement (HOCSR)
3. User Request Evaluation Tool (URET)
4. En Route Integration & Interoperability Facility (I2F)
5. Voice Switching and Control System (VSCS)

Potential Benefits to Air Traffic Safety Analysis

By examination of the human factors implications of new designs, potential safety problems could be uncovered and corrected before field implementation.

Tool Cost

The RDHFL is the property of the FAA and is available for studies.

Documentation

Documentation is available from the FAA.

References

Web site: no longer available

Vendor/owner Support

See point of contact

Point of Contact

ACT-5, William J. Hughes Technical Center, Atlantic City International Airport, Atlantic City, NJ 08405

FutureFlight Central

Purpose
FutureFlight Central is a fully interactive control tower simulator located at NASA 's Ames Research Center. It is designed to allow virtual reality tests of new tower procedures, airport designs and technologies. It's design and development was a joint NASA and FAA supported project. NASA maintains and operates the simulator for a nominal fee to benefit both government research and commercial applications.

Description
FutureFlight Central combines the communication and coordination of tower cab, TRACON, ramp and pilots. It is customizable to an actual or proposed airport, tower, fleet mix, and operating procedure. The tower cab features a 12-screen, 360-degree high fidelity 3D representation. It can simulate weather and time-of-day effects. Humans interact as pilots, air traffic controllers, ramp controllers, and airport operators, connected by a digital voice communication system. Video and audio playback is available from any controller position. Standard output data includes measurements of airport efficiency, controller task load, voice frequency congestion, and cumulative airport noise profile.

NASA Ames has two flight simulators that can be operated in conjunction with the tower simulation for simultaneous evaluations from the pilot and controller point of view.

Aviation Usage
One particular use cited is the evaluation of the Surface Management System (SMS) where the Dallas/Ft. Worth International Airport (DFW) east side traffic was simulated with participation of DFW controllers. Another case is the evaluation of candidate changes at the Los Angeles International Airport (LAX) designed to reduce runway incursion incidents.

Potential Benefits to Air Traffic Safety Analysis
Such a full-scale simulation tool could possibly reveal benefits or deficiencies in a new piece of technology or a new procedure and prevent a future accident from happening.

Tool Cost
NASA charges on a project-by-project basis, a fee for development of the simulation and facility usage. The cost varies depending on the complexity and duration of the simulation, but typically ranges from $50,000 to $300,000.

Documentation
This summary was prepared by WG B based on information in a FutureFlight brochure and on information on the FutureFlight web site.

References
Web site: http://ffc.arc.nasa.gov/

Vendor/owner Support
FutureFlight Central, NASA Ames Research Center, Mail-stop 262-8, Moffett Field, CA 94035-1000.

Point of Contact
Nancy Dorighi, Manager, +1 (650) 604-3258.
General information: Nancy Tucker, +1 (650) 604-5577, ntucker@mail.arc.nasa.gov

The NLR Air Traffic Control Research Simulator (NARSIM)

Purpose
NARSIM is a research simulator built by Netherland's National Aerospace Laboratory (NLR). Its main goal is to support ATM research within NLR. This includes evaluating new operational procedures, new controller assistance tools, and the human/machine interface for the new Amsterdam Advanced ATC system. In the past several years, NARSIM has been used for research programs for a variety of customers.

Description
NARSIM is located in the NLR building in Amsterdam. There are six AT consoles and up to 12 pseudo pilot positions, each of which can control up to 15 aircraft. The AT consoles and pseudo pilots are connected by a voice communication net. The computers driving each station are connected to the main NARSIM computer, which is also connected to an external NLR network. The NARSIM software simulates most important aspects of a real air traffic control system, including less than ideal radar information. It has the capability to use actual recorded radar data, computer generated data, pseudo pilot generated data, or combinations of the three. Scenarios can be constructed based on a set of initial flight plans (both real and hypothetical).

Aviation Usage
NARSIM can accommodate investigations on several ATM topics:

- Human machine interface (HMI)
- Development and/or validation of ATM concepts and procedures
- Development and/or validation of advanced air traffic controller assistance tools
- Support of qualitative safety assessments

NARSIM is being used to support several EUROCONTROL projects as well as the US Free Flight research program sponsored by NASA.

Potential Benefits to Air Traffic Safety Analysis
NARSIM can serve to avoid ATC problems generated by inadvisable ATC procedures, man/machine interface glitches, etc., which could lead to ATC errors in the future.

Tool Cost
NARSIM is not in production. Its use would be negotiated with NLR.

Documentation
Extensive documentation can be found on NLR's web site (below) or by contacting NLR.

References
Web site: http://www.nlr.nl/public/narsim2/facilities.html

Vendor/owner Support
National Lucht- en Ruimtevaartlaboratorium (NLR), Postbus 905002, 1006 BM Amsterdam, The Netherlands

Point of Contact
Hugo W. G. de Jonge, +31 20 511 31 95, jongehw@nlr.nl

Pseudo Aircraft Systems (PAS)

Purpose
Pseudo Aircraft Systems (PAS) is an air traffic control (ATC) simulator with a high-fidelity piloting system designed to simulate the flight dynamics of aircraft in controlled airspace. Realistic air traffic scenarios can be created for advanced automated ATC system testing and controller training. With PAS, researchers can examine air traffic flow in real time.

Description
PAS gives researchers the ability to provide air traffic control instructions to simulated aircraft, and receive verbal feedback from PAS operators ("pseudo-pilots") on a simulated radio network and visual feedback through a simulated radar display. PAS consists of three major software components: Simulation Manager, Pilot Manager, and one or more Pilot Stations. They combine to provide dynamic real-time simulations, robust piloting capabilities, and realistic aircraft modeling.

The Simulation Manager runs the simulation in real time, monitors aircraft flight modes, determines the type of route being flown. Aircraft follow rules and procedures based on aircraft type, altitude, and location. During flight, they respond realistically to commands received from the Pilot Stations.

The Pilot Manager manages simulation network traffic, supports automated command functionality, and provides a "super-user" pilot station.

The Pilot Station is where pseudo-pilots "fly" the aircraft. Each station has a radar situation display an instrument panel. Communicating with air traffic controllers over radio-type headsets, pseudo-pilots respond to controller instructions by using the extensive command set to alter heading, speed, altitude, and other important flight commands.

Aviation Usage
PAS is the primary simulation support system for the Center/TRACON Automation System (CTAS). It is also used at the FAA's William J. Hughes Technical Center to validate and verify new ATC systems.

Potential Benefits to Air Traffic Safety Analysis
PAS might be used to detect operational problems that could lead to compromises in the level of safety.

Tool Cost
Not determined

Documentation
Not determined

References
Not determined

Vendor/owner Support
Not determined

Point of Contact
William Chan, wchan@mail.arc.nasa.gov

SMGCS Airport Movement Simulator (SAMS)

Purpose
The SAMS project was commissioned by the European Commission (EC) to perform human-in-the-loop simulations of the air/ground environment, including a platform that simulates Advanced Surface Movement Guidance and Control System (A-SMGCS) tools and technologies under all weather conditions.

Description
SAMS consists of the following major components:

1. The LATCH cockpit simulator, located in Bedford, UK
2. The DLR Tower Visual Simulator, located in Braunschweig, Germany
3. An A-SMGCS simulator, located in Amsterdam, The Netherlands
4. A datalink facility, between the A-SMGCS simulator and LATCH
5. A voice channel between LATCH and the DLR Tower Visual Simulator

Additional components include:

1. A Human machine Interface (HMI) for the pilot in the cockpit simulator
2. An HMI for the controller team
3. Linked environment simulators in the tower and cockpit display drivers
4. Pseudo pilot workstations
5. Traffic generator software
6. Common Object Request Broker Architecture (CORBA) middleware to connect devices

As in real-life, both pilots and controllers operating the SAMS simulation receive the major part of their information from visual observation supplemented by automated displays. The simulation tools offer highly realistic outside views and working environments.

Aviation Usage
SAMS was used in the ATOPS project, in which operations at Schiphol (Amsterdam) and Heathrow (London) were simulated in an A-SMGCS environment to determine the impact of this equipment on efficiency and safety. During the simulation, both "real" and false-alarm intrusion alerts were posed to controllers to test their ability to react. See: ATOPS/P/DERA/2000/025 available at website: http://europa.eu.int/comm/transport/extra/reports/air/atops.pdf

Potential Benefits to Air Traffic Safety Analysis
The SAMS platform could be used to test operation of proposed surface movement alerting and display devices at other airports.

Tool Cost
See the EC for availability.

Documentation
See: C/NLR/00/D06, website: http://europa.eu.int/comm/transport/extra/final_reports/air/SAMS.pdf

References
Websites mentioned above.

Vendor/owner Support
Not determined

Point of Contact
Not determined

2.3.4 Other Simulation Tools

There are many other similar tools that could be mentioned, including:

1. The SMART simulator at the Swedish Air Traffic Control Academy, SATSA
2. Raytheon of Canada's FIRSTplus™ simulator
3. Environmental Tectonics Corporation "National Center for Simulation"
4. The Embry-Riddle Aeronautical University simulation laboratory
5. The Mitre Corporation simulation laboratory

2.4 Risk Analysis

Risk analysis refers to the process by which hazards are identified and analyzed for their likelihood of occurrence and their potential severity. Risk is defined as the expected loss per unit time or activity. This is computed as the product of the severity times the probability of the loss event. Risk analysis looks at hazards to determine what can happen, when it could happen, and the factors associated with their occurrence. Some of these tools are for general risk analysis and some have been constructed specifically for air traffic applications.

The risk analysis tools have been sub-categorized as: 1) Safety Engineering, 2) Causal Analysis, and Risk Prediction tools.

2.4.1 Safety Engineering

Many analytic methods developed for the field of Reliability Engineering were adapted and expanded into Safety Engineering methods. These include fault trees, cause-consequence diagrams, etc. Users and developers of these methods include the nuclear power industry and its regulators, NASA, and aircraft manufacturers. These too, are applications where the probability of a failure is small, but the potential consequences are large. Many of these methods have been applied to ATM safety analysis.

These methods and tools portray the controller and the ATM system as a complex system, with numerous failure modes and chains of causal factors. These are related to many of the human factors tools discussed later. Only a small sample of these tools is shown.

Fault Tree+ (Event Tree Module)

Purpose
To organize, characterize, and quantify potential accidents in a methodical manner by modeling the sequence of events leading to the potential accident that result from a single initiating event.

Description
As a built-in Markov analysis module for integration dependencies in fault tree analysis, Event Tree Analysis (ETA) uses "inductive" logic and is helpful in understanding the consequences of an initiating event and the expected frequency of each consequence. ETA is similar to Fault Tree Analysis, but is more general in that events may comprise not only failures, malfunctions, and errors, but also proper operation. ETA involves selecting initiating events, both desired and undesired, and developing their consequences through consideration of system/component failure-and-success alternatives. Identification of initiating events may be based on review of the system design and operation, the results of another analysis such as a Failure Modes and Event Analysis, a Hazardous Operation Analysis, etc., or personal operating experience acquired at a similar facility. The FTA postulates the success or failure of the mitigating systems and continues through all alternate paths, considering each consequence as a new initiating event.

Fault Tree + is capable of analyzing large and complex event tree models originating from different initiating events, CCF events and consequence tables. Multiple branches are also handled to allow for partial failures. Fault Tree + provides a flexible import/export facility (32-bit operating system) which allows the user to transfer data to and from MS Access databases, MS Excel spreadsheets, text delimited and fixed length files. It is capable of analyzing complex event trees and provides users the capability to construct a single project database containing generic data and event tables, event trees originating from different initiating events, and consequence tables.

Aviation Usage
No airlines are known to be using this tool.

Documentation
This tool is well documented. See product website: http://www.isographdirect.com/.

Vendor/owner Support
Isograph presents workshop-training courses that provide users with an in-depth understanding of the methods and theory behind systems reliability methods as well as providing practical instruction on the use of the computer programs. The course instructors have over 18 years experience in providing systems reliability training worldwide.

Potential Benefits to Air Traffic Safety Analysis
Event tree analysis could be helpful to the FSO in pre-incident or post-accident modeling and aid in understanding where safety improvements should be focused. The Fault Tree+ report generator allows the user to select from a range of standard reports and quickly design their own customized repots. This is a systems reliability analysis tool, which allows event tree analysis to be performed in an integrated environment.

Tool Cost
Purchase Price: $6895

(Purchase price does not include installation, operation, maintenance, or training costs.)

Other Comments
ETA is universally applicable to systems of all kinds, with the limitation-unwanted events (as well as wanted events) must be anticipated to produce meaningful analytical results. Successful application to complex systems cannot be undertaken without formal study over a period of several days to several weeks, combined with some practical experience. Methodology is enormously time consuming and, therefore, should be reserved for systems wherein risks are thought to be high and well concealed (i.e., not amendable to analysis by simpler methods). Additional Reference: Lewis, H.W., and "The Safety of Fission Reactors, " Scientific American, Vol. 242, No. 3, March 1980, Fullwood RR., "Probabilistic Safety Assessment in Chemical and Nuclear Industries," Boston: Butterworth-Heinemann, 2000(ISBN 0-7506-7208-0).

References
Demonstration version of Fault Tree+ from the web, Fault Tree+ user's manual, website: www.isographdirect.com, System Safety Analysis Handbook, System Safety Society, No.26 P3-93 2nd Edition, July 1997.

Point of Contact
Isograph Inc., 4695 MacArthur Court, 11th Floor, Newport Beach, CA, 92660, (949) 798-6114, fax (949) 798-5531. Website: http://www.isographdirect.com/. In U.S., email: sales@isographdirect.com. International address, Isograph Ltd. Malt Building, Wilderspool Park, Greenalls Ave., Warrington, United Kingdom, WA46HL, +44 1925 43 7001, fax +44 1925 43 7010. Email: sales.uk@isograph.com.

Fault Tree+ (Fault Tree Module)

Purpose
To assess a system by identifying a postulated undesirable end event and examining the range of potential events that could lead to that state or condition.

Description

As a built-in Markov analysis module for integration dependencies in fault tree analysis, Fault Tree Analysis is a graphical method commonly used in reliability engineering and systems safety engineering. It is a deductive approach that documents qualitatively the potential causal chains leading to a top (head) event, but it also accommodates quantitative analysis when probability or "rate" information is adjoined to the graphical tool.

Starting with the top event (typically undesirable), the safety engineer goes through causal chains systematically, listing the various sequential and parallel events or combinations of failures that must occur for the undesired top event to occur (a static picture of system failures). Logic gates (AND, OR) and standard Boolean algebra allow the engineer to quantify the fault tree with event probabilities, and lead to the probability (or rate) of the top event. Not all system or component failures are listed, only the ones leading to the top event. Only credible faults are assessed, but may include hardware, software, human failures and/or environmental conditions. Fault Tree + running under a 32-bit operating system is capable of analyzing large and complex fault trees producing the full minimal representation for fault tree TOP events. Fault Tree + provides importance analysis, uncertainty, and sensitivity analysis.

Aviation Usage

No known airlines using this tool.

Documentation

This tool is well documented. See product web site: http://www.isographdirect.com/.

Vendor Support

Isograph presents workshop training courses that provide users with an in-depth understanding of the methods and theory behind systems reliability methods as well as providing practical instruction on the use of the computer programs. The course instructors have over 18 years experience in providing systems reliability training worldwide.

Potential Benefits to Air Traffic Safety Analysis

Fault Tree + is a systems reliability analysis tool, which allows fault tree analysis to be performed in an integrated environment. There is a very large potential benefit of this program to increase knowledge about the probability of hazard occurrence, however a moderate to extensive amount of R&D time is required as well as expert assessment of probabilities for the various faults. There are scenarios in the Flight Safety Office where Fault Tree Analysis could be useful in assessing where safety improvements could be most needed for a particular type of accident/incident. Fault Tree + provides a sophisticated report generator, which allows the user to design, preview and print high quality customized reports. The report generator allows graphs and charts to be designed and displayed individually or as a group.

Tool Cost

Purchase Price: $6895

(Purchase price does not include installation, operation, maintenance, or training costs.)

Other Comments

Fault Tree Analysis is universally applicable to systems of all kinds, with the following ground rules: (1) Events that are to be analyzed/abated, and their contributors, must be foreseen. (2) Each of those system events must be analyzed individually. Primary limitations of the technique are: (1) The presumption that relevant events have been identified. (2) The presumption that contributing factors have been adequately identified and explored in sufficient depth. Apart from these limitations, the technique as usually practiced is regarded as among the most thorough of those prevalent for general system application. Significant training and experience is necessary to use this technique properly. Application, though time-consuming, is not difficult once the technique has been mastered.

References
System Safety Engineering and Risk Assessment: A Practical Approach, Nicholas J. Bar, Taylor & Francis, Washington, D.C., 1997. Fault Tree Handbook (NUREG-0492 ERR), website: http://www.nrc.gov/NRC/NUREGS/ABSTRACTS/sr0492err.htm; Demo version of Fault Tree + from the web, Fault Tree + user's manual, website (www.isographdirect.com)

Point of Contact
Isograph Inc., 4695 MacArthur Court, 11th Floor, Newport Beach, CA, 92660, (949) 798-6114, fax (949) 798-5531. Website: http://www.isographdirect.com/. In U.S., email: sales@isographdirect.com. International address, Isograph Ltd. Malt Building, Wilderspool Park, Greenalls Ave., Warrington, United Kingdom, WA46HL, +44 1925 43 7001, fax +44 1925 43 7010. Email: sales.uk@isograph.com.

FaultrEASE

Purpose
To facilitate creation, calculation, and display of fault trees, which are a graphical method commonly used in reliability engineering and systems safety engineering

Description
FaultrEASE allows the user to create, edit, and draw fault trees with minimal effort. It performs elementary fault tree mathematics, including mixed probability and frequency calculations, Boolean reduction, and cut sets. When drawing trees with FaultrEASE the user only need be concerned with the tree's content, as its form is adjusted automatically. After each edit is made, FaultrEASE will balance the tree, center labels, and place statistics, transfers and tags.

FaultrEASE also simplifies fault tree editing with the use of cells. A cell is a rectangular region that contains the graphical representation of an event. An event is defined as an atomic unit of fault tree construction, consisting of either a gate or a leaf. Gates logically consist of the gate symbol, itself and the box above it. In FaultrEASE both parts share a single cell. The result is that any tree built with FaultrEASE will always be a proper tree--it is impossible to violate the "no gate-to-gate" rule. The user can save the work to a file, and retrieve it later. The file contains descriptions of the symbols in the fault tree, as well as the values of all changeable parameters. When the user loads the next tree, all of these parameters will be set to the values set for that tree.

Aviation Usage
No airlines are known to be using this tool.

Documentation
The tool is sufficiently documented to give the user confidence in its validity, but all questions may not be thoroughly answered in the documentation. See the FaultrEASE User's Manual, Version 2.0, by ICF Consulting.

Vendor Support
ICF Consulting offers technical and customer support services.

Potential Benefits to Air Traffic Safety Analysis
FaultrEASE is a program for creating, editing and computing fault trees. FaultrEASE performs fault tree mathematics including mixed probability, frequency calculations and cut-sets. For trees with repeated events, reduction is achieved using direct evaluation. FaultrEASE also permits easy tree surgery in which entire branches can be pruned, cloned and grafted. Statistics can also be entered in the form of probabilities, frequencies or multipliers.

Tool Cost
Purchase Price: $1150 as of early 2003

(Purchase price does not include installation, operation, maintenance, or training costs.)

Other Comments
FaultrEASE is available both for the Windows and Macintosh platforms. FaultrEASE for Windows runs on Windows 3.x, 95, 98, NT, 2000, or XP and FaultrEASE for Macintosh runs on OS X and previous versions. FaultrEASE also permits multiple window creation and performs fault tree mathematics including mixed probability, frequency calculations, and cut sets. Most graphical attributes can be modified to produce a variety of custom effects for reports, presentations and overheads.

References
FaultrEASE User's Manual, Version 2.0, May 1996. Version 2.2 planned for release in early 2003.

Points of Contact
ICF Consulting, 33 Hayden Avenue, Lexington, MA 02421, web site: www.icfconsulting.com, email: faultrease@icfconsulting.com, Susan Ferola, 781-676-4036, email: sferola@icfconsulting.com.

SafEty and Risk Evaluation using bayesian NEts (SERENE)

Purpose
SERENE is a tool for quantifying the safety of a complex system using Bayesian Networks.

Description
SERENE method is concerned with the functional safety of complex systems. Functional safety is the ability of a system to carry out the actions necessary to achieve or maintain a safe state. This must take into account both systematic and random failures. This could relate to both design-caused and operator-caused errors.

The Bayesian Network (BN) allows the specification of risk models that represent the key factors and their inter-relationships (qualitative model) with probability distributions based on expert judgment or from observed data (quantitative model). SERENE helps the analyst build large-scale risk models quickly and efficiently. It allows the analyst to draw cause-effect BN graphs using an intuitive visual editor, specify probability tables using either deterministic or theoretical distributions, execute the algorithm using fast evidence propagation algorithms, perform what-if and sensitivity analyses on the results, and export the results in HTML format for inclusion in reports.

Aviation Usage
None known

Potential Benefits to Air Traffic Safety Analysis
It seems that it should be possible to construct a model of the air traffic control system using this tool, and perform a risk analysis combining both hardware and human risk factors.

Tool Cost
See vendor for purchase price. Obtaining "expert judgment" will be a problem.

Documentation
See the vendor for more information.

References
Web site: http://www.hugin.com/

Vendor/owner Support
Hugin Expert A/S, Aalborg, Niels Jernes Vej 10, 9220 North Jutland, Denmark

Point of Contact
Neils Jernes, Hugin Expert, +45 9635 4545, info@hugin.com

2.4.2 Causal Analysis

The first step in risk analysis might be to examine historical reports of accidents and incidents to ascertain the contributions of known and unknown risk factors, so that the prediction of future risks might have some basis in fact. The first tool specializes in taxonomy problems, which is a fruitful area for investigation. The other tools take a broader look.

Quantitative Risk Assessment System (QRAS)

Purpose
QRAS is a PC-based software tool for conducting a Probabilistic Risk Assessment (PRA) on a system. The tool helps in modeling deviations from the system's nominal functions, the timing and likelihood of such deviations, potential consequences, and scenarios leading from initial deviations to such consequences. It was designed for use by NASA for space missions, but could be adapted to other uses, e.g., the air traffic control system.

Description
QRAS provides a user-friendly graphical interface and structured guidance to the user. Elements of the model can be accessed using point-and-click. It includes direct use of Event Sequence Diagrams (ESD), supported by linked Fault Trees. The system hierarchy consists of a structural or functional breakdown of the system, which is not limited in the number of levels. The mission time-line is a representation of the different operational phases that the system goes through during its mission. Different modes of failure exist in each Operational Time Interval (OTI). QRAS has an extensive set of standard reliability models built-in, and allows the user to construct his own, or input existing models designed specifically for the particular system component in question. QRAS also has common cause failure logic, which covers system dependencies.

Once a risk model is completed, it can be analyzed in two stages: First an ESD linking step creates Boolean expressions for each scenario and each end state. Then the results of individual ESD's are aggregated to compute risk levels at the next higher level of the hierarchy. A Reduced Order Binary Decision Diagram (ROBDD) handles the occurrence of the same basic events in multiple fault trees.

The modeling and analysis capabilities are integrated into a single software application that runs as a stand-alone application on a Microsoft Windows platform.

Aviation Usage
None known of as of yet, but the FAA Airways Facilities service is interested.

Potential Benefits to Air Traffic Safety Analysis
The potential application to the physical portion of an air traffic control system is clear. Whether or not this tool could be used to analyze human failure modes has yet to be investigated.

Tool Cost
This tool was developed by the University of Maryland under a US government contract and its availability would depend on US government permission. If granted, the cost would be nominal.

Documentation

References
This information was derived by WG B from "Quantitative Risk Assessment System (QRAS) For Space Mission PRA", by Ali Mosleh, Pete Rutledge, and Frank Groen of the University of Maryland.

Vendor/owner Support
The University of Maryland

Points of Contact
Prof. Ali Mosleh, Dept. of Materials and Nuclear Engineering, University of Maryland at College Park, +1 301-405-5215, Mosleh@eng.umd.edu, Pete Rutledge, NASA, prutledg@hq.nasa.gov

TapRooT

Purpose
To facilitate incident reporting, collect incident information, identify root causes, develop effective corrective actions, provide a standard incident report, trend incident information, and track corrective action.

Description
The TapRooT System (process and techniques) are packaged in a computerized tool that helps investigators focus on what happened and why it happened, and help investigators find the real, fixable root causes of accidents, incidents, near-misses, quality and productivity problems. Although it was not specifically designed for aviation, TapRooT has been applied to airline safety. This tool builds on the Root Cause Tree with an interface that helps an investigator use the tree more consistently for root cause analysis. TapRooT is a complete incident investigation tool applied to a database that includes customizable fields so the user can add information that they think is important. Two standard and five optional techniques are built into the TapRooT Software. The two standard techniques are SnapCharT and the Root Cause Tree. The five optional techniques are Safeguards Analysis, Change Analysis, Critical Human Action Profile, Equifactor, and the Corrective Action Helper Module. The software user can add an unlimited number of custom fields to the database to record items of interest. The software has a number of standard reports and one can use Access to develop custom reports. Drawing a SnapCharT is an essential part of the TapRooT process for finding root causes. When the user enters the corrective actions they are automatically entered into their standard report and into the corrective action-tracking database. The application links the corrective action to the corresponding root cause or one can manually link one corrective action to more than one root cause. The database has a built-in capability for approval of reports and corrective actions in separate, secure on-line approval sequences. The database can be used to track the corrective action, the person responsible, and the due date. The user can print reports of what is complete, what is outstanding, and what is overdue. There is also a validation and verification option for corrective actions. Some of the TapRooT tools are available in additional languages beyond English.

Aviation Usage
Four airlines are using this tool for a variety of investigation types (air and ground safety, audit root cause analysis, and worker safety issues). Several others have attended TapRooT training but the extent of their usage of the technique is not known. Also personnel from the FAA, NTSB, and Canadian NTSB, as well as Australian military aviation safety personnel have attended TapRooT training. Also the Medallion Foundation (a group working to improve aviation safety in Alaska) is in the process of licensing TapRooT for the use of all its members in Alaska. There is also a video about the use of TapRooT at an airline available at the vendor's web site.

Documentation
TapRooT is well documented in a hardbound book that has 12 chapters and one appendix. There is also a laminated Root Cause Tree and Root Cause Tree Dictionary that comes with the book. The user can also

find information on the company web site. The first TapRooT manual was published in 1990 making the current book, published in 2000, the fifth version of the documentation.

Vendor/owner Support

TapRooT offers extensive support to its customers. The support includes a help line; user support; two newsletters; initial training, continuing education program for users, expert facilitators to assist with investigations or implementation, and a Summit every 18 months to keep users up to speed. TapRooT uses interactive training to get new users up to speed. There is also advanced training to enhance expertise and a licensing and 'train-the-trainer' program for companies that want to teach their own course. To enhance productivity, TapRooT has optional software including the Corrective Action Helper Module and a relational root causes database with a report generator and corrective action tracking. The company sponsors an annual (once every 16 months) summit to promote the advancement of root cause analysis and the sharing of information among many TapRooT users. Training is supported worldwide with instructors located in the US, Canada, Mexico, UK, and Australia. The Root Cause Tree and Root Cause Tree Dictionary have been translated into French and Spanish and a German version is in the process of translation. Also Spanish, French, and German versions of the software are planned. Also, course materials have been translated into Spanish and Spanish speaking instructors are available.

Potential Benefits to Air Traffic Safety Analysis

Although the investigators must enter all of the incident information manually, TapRooT provides a Root Cause Tree report as well as identifying each incident and listing corrective action for that incident. TapRooT provides the investigator with a structured format for consistency investigating incidents. Users state that they explore deeper into human performance problems; and they recognize ways to improve performance that are better than the old techniques of incident identification and analysis. The techniques associated with TapRooT are effective and result in time savings because the reports and presentations the investigators give are more efficient and they are required to do less reinvestigating of the incident because they are able to answer all of management's questions the first time. By giving the corrective actions associated with each incident, the number of incidents (and therefore the number of investigations) will decrease over time, which saves the investigator's efforts. All investigators are interested in root causes and latent errors in organizations, and TapRooT can assist with identifying them.

Tool Cost

Purchase Price: $1495 for a single user version of the TapRooT Software. 2-day TapRooT Course attendees can obtain the software for only $795. The software is included in the price of the 3-day TapRooT/Equifactor Training and the 5-day Advanced TapRooT Investigation team Leader Training. There is also an option for a server-based software for multiple simultaneous users. Public courses are offered in the US, Canada, Australia, and Europe. The 2-day TapRooT Incident Investigation and Root Cause Analysis Course is $995. The 3-day TapRooT/Equifactor Equipment Failure Analysis Course is $1890 (includes TapRooT Software). The 5-day Advanced TapRooT Investigation Team leader Training is $2195 (includes TapRooT Software). On-site courses are also available throughout the world.

(Purchase price does not include installation, operation, maintenance, or training costs.)

References

TapRooT software brochure, TapRooT web site http://www.taproot.com/

Point of Contact

Edward Skompski, System Improvements, (865) 539-2139, skompski@taproot.com

2.4.3 Risk Prediction

Risk prediction is an estimation of the probability that an accident will happen, given a certain set of assumptions. One general tool (@RISK) is listed, along with several that were developed specifically for air traffic safety analysis. The later tools differ from the safety engineering tools, which consider the system as a hardware component, and the human factors risk models, which consider the system as a human/machine interface, in that they consider the geometry of aircraft movement along with time delays and errors in human responses.

@Risk

Purpose
@Risk is a risk analysis and simulation add-in (software tool) for Microsoft Excel or Project intended to facilitate quantification and analysis of uncertainty.

Description
@Risk recalculates spreadsheets hundreds of times, each time selecting random numbers from the @Risk functions entered. This not only tells what could happen in a given situation, but how likely it is that it will happen. It is a quantitative method that seeks to represent the outcomes of a decision as a probability distribution. The techniques in an @Risk analysis encompass four steps: (1) Developing a Model – by defining problem or situation in Excel spreadsheet format, (2) Identifying Uncertainty – in variables in Excel spreadsheets and specifying their possible values with probability distributions, and identifying the uncertain spreadsheet results that are to be analyzed, (3) Analyzing the Model with Simulation – to determine the range and probabilities of all possible outcomes for the results of the worksheet, and (4) Making a Decision – based on the results provided and personal preferences @Risk helps with the first three steps by providing a powerful and flexible tool that works with Excel to facilitate model building and Risk Analysis. The decision-maker to help choose a course of action can then use the results that @Risk generates.

@Risk uses the techniques of Monte Carlo simulation for risk analysis. In @Risk, probability distributions are entered directly into Excel as standard worksheet formulas (ex. =RISKNormal(10,2)) using custom distribution functions, or through myriad graphical interfaces such as RISKView and BestFit. For each iteration, the spreadsheet is recalculated with a new set of sample values and a new possible result is generated for output cells - new possible outcomes are generated with each iteration. Advanced analyses in @Risk allow sophisticated analysis of simulation data. One-way and multi-way Sensitivity analyses identify significant inputs relative to the fluctuation of the outputs. Scenario analysis identifies groups of combinations or inputs that lead to output target values. Goal seek enables you to determine starting conditions that lead to a certain result.

Aviation Usage
Palisade customers include the US Air Force, Northwest Airlines, Cessna Aircraft Company, Lockheed Martin, Boeing, NASA, Air New Zealand, Kuwait Airways, Transasia Airways, LOT (Polish Airlines)

Documentation
The tool is well documented. See product web site: http://www.palisade.com/.

Vendor/owner Support
Palisade Corporation offers free, unlimited technical support to all registered DecisionTools software users for 30 days. Maintenance contracts are available.

Potential Benefits to Air Traffic Safety Analysis

@Risk is an add-in for Microsoft Excel. It facilitates a quantitative method for assessing the impacts of risk decisions and determining all possibly outcomes to a model. Since most airline FSOs will have Excel, @Risk seems to be a valuable add-in. Only a basic knowledge of probability theory is required. A new graphical interface makes it easier to decide which distribution to use. Also, reviews of the software note that some learning investment is required to use @Risk. On balance, @Risk seems to be a likely candidate for an analyst to "partner" with an airline FSO to develop a case study.

Tool Cost

Purchase Price: $795 (varies depending on version)

(Purchase price does not include installation, operation, maintenance, or training costs.)

Other Comments

As an add-in to Microsoft Excel or Lotus, add-in appears to be a versatile tool capable of supporting a quantitative risk assessment. Applications to the FSO need to be developed and evaluated.

References

@Risk Advanced Risk Analysis for Spreadsheets, Palisade Corporation, 2003

Point of Contact

David Bristol, Palisade Corporation, 31 Decker Road, Newfield, NY 14867 Tel. (607) 277-8000 Fax: (607) 277-8001, e-mail: sales@palisade.com, web site, http://www.palisade.com/

Analytic Blunder Risk Model (ABRM)

Purpose

The ABRM estimates the collision risk inherent in a reported (or hypothetical) air traffic controller error or pilot deviation. While some other tools predict the probability of an error occurring, ABRM computes the probability that a particular error will result in a collision.

Description

The ABRM computes the probability of a collision, given a particular blunder (controller error, pilot error, equipment malfunction) between one aircraft involved in the error (the "blunderer") and another aircraft (the "evader"). For example, suppose an error occurred resulting in loss of required separation between aircraft, but no collision occurred. But what if the position, heading, or climb/descent angle of the aircraft involved would have been different (within a given range of possible values)? What if the pilot or controller took longer to perform? ABRM considers all these possibilities within parameters specified by the user and estimates the probability that the error could have resulted in a collision.

ABRM is a 3-D model. Either or both aircraft can be climbing or descending at an angle that can be specified as a range of values. Both aircraft are assumed to be flying at a constant speed in a constant direction immediately prior to the potential collision. (See References.)

ABRM considers both the probability of a collision assuming no intervention, and then the probability of timely intervention by pilots or controllers. It uses empirical probability distributions for reaction times and a closed form probability equation to compute the probability that a collision will occur. This permits it to consider combinations of events with small probabilities efficiently and accurately. It is programmed in Excel (with macros).

The tool could also be used for collisions on the airport surface where one of the aircraft could be a surface vehicle.

Aviation Usage
Used only in exercises to date.

Potential Benefits to Air Traffic Safety Analysis
The ABRM could be used to compare the relative risk between various types of blunders in order to weigh the importance of investment in efforts to prevent certain types of blunders from happening.

Tool Cost
No cost for use of the tool, but gathering the necessary data could involve some cost.

Documentation
Documentation is available from the developer/sponsor.

References
Web site: none
Geisinger, K.E. (1985), "Airspace Conflict Equations", Transportation Science, Operations Research Society of America, Vol.19, No. 2, May 1985

Vendor/owner Support
See point of contact

Point of Contact
Ken Geisinger, FAA Air Traffic Service. Phone: (202) 385-4749 Email: kenneth.geisinger@faa.gov

Reduced Aircraft Separation Risk Analysis Model (RASRAM®)

Purpose
RASRAM® is used for quantitative assessment of the increase in risk of aircraft operations due to reduced separation requirements, and/or reduced risk due to new surveillance or navigational technology.

Description
RASRAM (a registered trademark of Rannoch Corporation) is a PC-based tool that is based on a large database of aircraft data, incorporating aircraft and air traffic controller data. It was developed under contract with NASA and in cooperation with the FAA's Office of System Safety. The overall organization of RASRAM is a fault-tree analysis of the major failure modes in specific operational scenarios. The approach includes time-budget analyses of dynamic interactions among multiple participants in a scenario, each with defined roles, responsibilities, information sources, and performance functions. Examples are response times for pilots and air traffic controllers. The methodology works directly with the functional form of probability distributions, rather than relying on Monte Carlo simulation techniques. The probability of a Near Mid-Air Collision (NMAC) is computed, and from this, the probability of a collision, using a factor of collisions/NMAC. Probability distributions of lateral miss distance and simultaneous runway occupancy are also computed.

Aviation Usage
RASRAM has been used to study a variety of issues involving air traffic management, including the safety impact of free flight procedures, new technologies, and reduced wake vortex and reduced lateral separation requirements.

Potential Benefits to Air Traffic Safety Analysis
RASRAM can be used to consider air traffic controller response times in combination with other impacts on the time available for an air traffic controller to respond.

Tool Cost
Contact vendor

Documentation

1. "A Risk Assessment Model for Free Flight – Terminal Area Reduced Separation", Rick Cassell, Alex Smith, and Roger Shepherd, Rannoch Corporation, 1996
   website: http://www.rannoch.com/PDF/dascrso.pdf
2. *A Reduced Aircraft Separation Risk Assessment Model,* Roger Shepherd, Rick Cassell, Rajeev Thapa, Derrick Lee, American Institute of Aeronautics and Astronautics
   website: http://www.rannoch.com/PDF/AIAA_Final_3_.pdf

References
Web site: www.rannoch.com/RASRAMMain.html

Vendor/owner Support
Not determined

Point of Contact
Rannoch Corporation, 1800 Diagonal Road, Suite 430, Alexandria, VA 22314, USA
(703) 838-9780, info@rannoch.com

Traffic Organization and Perturbation AnalyZer (TOPAZ)

Purpose
TOPAZ is a safety assessment methodology and tool set for evaluation of existing or newly developed ATM operational concepts. TOPAZ accounts for both the nominal and non-nominal events and dynamics of ATM operations, including interactions between human operators, technical systems and procedures. TOPAZ facilitates quantitative safety assessment and provides safe spacing criticality feedback to developers.

Description
The TOPAZ risk assessment methodology is based on a stochastic modeling approach towards risk assessment and has been developed to provide designers of advanced ATM with safety feedback, following on a redesign cycle. The assessment cycle consists of four sequential stages:

- *Stage 1: Identification of operation and hazards*
  Information about nominal and non-nominal behavior of the ATM concept or procedure is gathered, through hazard identification sessions with a variety of experts. For a new operation it is common practice to also perform a qualitative hazard analysis.
- *Stage 2: Mathematical modeling*
  A stochastic dynamical model of the operation is developed that incorporates both the nominal and non-nominal events of the operation. All model assumptions are specified.
- *Stage 3: Accident risk assessment*
  A multi-step procedure is followed to quantify the accident risk. In addition, a bias and uncertainty assessment for all model parameters and model assumptions is performed.
- *Stage 4: Feedback to operational experts*

The results of the quantitative safety assessment are fed back to and discussed with the designers and operational experts, who can use the results to redesign the proposed ATM design, if necessary.

For the second and third stages use can be made of TOPAZ tool sets, such as:

- SIMULATOR is a tool set that allows to specify and implement the mathematical model and to subsequently run Monte Carlo simulations with that implementation.
- COLLIR is a methodology and tool set that supports the evaluation of collision risks in the Terminal Maneuvering Area (TMA) and en-route.
- TAXIR is a methodology and tool set that supports the evaluation of accident risks at the airport.
- CRITER is a risk criteria framework that supports the judgment of the acceptability of the risks that are assessed by COLLIR, WAVIR and TAXIR.

The methodological parts of COLLIR, WAVIR and TAXIR incorporate the evaluation of statistical data that are obtained either through empirical data collections or Monte Carlo simulations (e.g., SIMULATOR). For each of the tool sets further extensions are ongoing at NLR.

Aviation Usage

TOPAZ has been operational at the NLR since 1992. Principal applications include:

- Converging and parallel landings for ATC and CAA of the Netherlands and EUROCONTROL
- Assessment of wake vortex induced accident risk, for DFS and the European Commission
- Safety-based design of ASAS, for NASA/FAA and EUROCONTROL
- Modelling conventional en-route ATC, for EUROCONTROL and the European Commission
- Capacity/safety performance of data link, for the European Commission
- Modelling of accident risks at airports, for the European Commission and NASA
- TOPAZ methodology and toolset is the property of the NLR

Documentation

1. M.H.C. Everdij, G.J. Bakker and H.A.P. Blom. Estimating safe separation criteria. Report WP 3 of CARE/ASAS Activity 3: Airborne Separation Minima. January 2002
2. M.H.C. Everdij and H.A.P. Blom. Bias and uncertainty in accident risk assessment. EUROCONTROL Report for project TOSCA-II, December 2001
3. H.A.P. Blom, K.C. Corker, S.H. Stroeve and M.B. Klompstra. Study on the integration of Air-MIDAS and TOPAZ, Phase 2 Final Report. Report NLR-CR-2001-528, November 2001
4. H.A.P. Blom, S. Stroeve, J. Daams, H.B. Nijhuis. Human cognition performance model based evaluation of air traffic safety. Proc. 4th International Workshop on Human Error, Safety and System Development, Linköping, Sweden, June 2001
5. H.A.P. Blom, J. Daams and H.B. Nijhuis. Human cognition modelling in ATM safety assessment. 3rd USA/Europe Air Traffic Management R&D Seminar, Napoli, 13-16 June 2000, http://atm-seminar-2000.eurocontrol.fr/
6. M.H.C. Everdij and H.A.P. Blom. Piecewise Deterministic Markov Processes represented by Dynamically Coloured Petri Nets. NLR Report TP-2000-428, December 1999
7. H.A.P. Blom, M.H.C. Everdij and J. Daams. ARIBA consolidation report part II: Modern safety cases for a new operation in air traffic. NLR Report TR-99587, 1999, http://www.nlr.nl/public/hosted-sites/ariba/
8. M.H.C. Everdij, H.A.P. Blom and M.B. Klompstra. Dynamically Coloured Petri Nets for Air Traffic Management Safety purposes, Proc. 8th IFAC Symposium on Transportation Systems, pp 184-189, 1997
9. M.H.C. Everdij, M.B. Klompstra and H.A.P. Blom. Development of mathematical techniques for ATM safety analysis, MUFTIS ATM Safety Study Final Report Part II, NLR report TR 96197, 1996.
10. G.J. Bakker and H.A.P. Blom. Air Traffic Collision risk modelling. Proc. 32nd IEEE Conference on Decision and Control, pp. 1464-1469, 1993.

Vendor/owner Support
TOPAZ is supported by the NLR. Licenses of toolsets are possible, including the provision of the necessary specific training.

Potential Benefits to Air Traffic Safety Analysis
TOPAZ enables safety and spacing criticality analysis of ATM operations. As such, it may be used to analyze the effect of changes to accident risk and separation criteria by comparison of scenarios. The TOPAZ methodology enables accident risk/separation assessment for existing or new air traffic management operations concepts. The TOPAZ tool set already supports accident risk evaluation for a wide range of specific operations, including en-route, in TMA, and at airports. The required expertise on the development of stochastic models and the instantiation within the TOPAZ tool set is high. Hence this is typically done at NLR. However, for using previously developed TOPAZ applications the expertise requirements are less demanding.

Total Cost:
Cost is high for modeling a new operational concept, medium for an instantiated operational concept. TOPAZ is very sophisticated and requires specialists to apply it.

Vendor/owner Support
National Aerospace Laboratory NLR, Postbus 90502, 1006 BM Amsterdam, The Netherlands

Point of Contact:
Henk.A.P. Blom, PhD., NLR, +31 20 5113544, blom@nlr.nl

2.5 Human Factors Analysis

The great majority of ATM safety occurrences and accidents attributed at least in part to air traffic management are the result of controller error. On the other hand, untold many more incidents are avoided by timely human intervention on which the air traffic control system depends. One recent study suggests that without pilot or controller intervention, there would be a mid-air collision in each of several of the U.S. en-route center's airspace each month. The rate in terminal airspace would most likely be even higher. (See: Geisinger, K.E. (1998) "The Role of ATC in Mitigating Collision Risk," The Journal of Air Traffic Control, Jan-Mar, 1998). Thus the study of human factors could play an important role in ATM risk analysis.

Human Factors (HF) Analysis refers to the study of human performance and human error as the cause of incidents, accidents, and other safety-related events. HF Analysis tools might yield insight into the cause of controller errors and how changes in air traffic loading, procedures, operating environment, technology, etc., might reduce or mitigate errors. This section covers four areas of the study of human factors: causal analysis, error prediction, human behavior, and measurements. Causal analysis deals with historical safety-related events to determine probable causal factors. Error prediction deals with the probability that a controller error would happen under certain set of conditions or contexts. Human behavior analysis generally looks at the capability of a human operator to deal with a complicated series of tasks when multi-tasking is required. Finally, some methods of measuring abstract concepts, such as workload, and situation awareness are discussed.

The tools described below represent only a small sample of those available. Some were designed for other process control fields, such as nuclear power, and some were designed specifically for air traffic management. More complete discussions can be found in:

1. "Performance Prediction in Air Traffic Management: Applying Human Error Analysis Approaches to New Concepts"; Steven Shorrock, Barry Kirwan, and Ed Smith
2. "Flight into the Future: Human Factors in Air Traffic Control," C.D. Wickers, A.S. Mavor, and J.P. McGee, National Academy Press, 1997.
3. "Modeling Human and Organizational Behavior: Application to Military Simulations" Richard W. Pew and Anne S. Mavor, Editors; Panel on Modeling Human Behavior and Command Decision Making: Representations for Military Simulations, National Research Council, National Academies Press, 1998.

2.5.1 Causal Analysis Tools

These are tools for analyzing safety-related events to determine contributing causes related to human factors. Some of the tools are designed to analyze a single incident and others are designed to look at more general design issues.

Aviation Topics Speech Acts Taxonomy Tool (ATSAT)

Purpose

ATSAT is a tool for categorizing pilot/controller voice communication according to their purpose, identifying communication problems, and developing time based performance metrics. The tool can be used in the investigation of a particular accident/incident/mishap, to evaluate pilot and controller proficiency or in operational evaluations of new and emerging technologies.

Description

ATSAT provides a method for encoding air-ground voice communication in a systematic and consistent fashion. Messages are arranged hierarchically and can be used to measure operator and task performance associated with departures, approaches, clearances, and transfer of communications. Once encoded, messages are entered into a spreadsheet and imported into SPSS or similar statistical package. Both descriptive and inferential statistics can be performed on the data.

Each transmission (or operation) can be analyzed according to speaker/receiver/aircraft, type of message (clearance/instruction, advisory, report, request), content (altitude, heading, speed, route/position, frequency change, etc.), and problems (omission, substitution, transposition, excessive verbiage, equipment).

Aviation Usage

ATSAT uses the phraseology standard contained in *FAA Order 7110.65 Handbook of Air Traffic Control*. It can be used to track the number and type of messages transmitted by speaker to facilitate an aircraft's movement through the controller's sector/position.

Documentation

Documentation on ATSAT is available from the FAA.

Vendor/owner Support

FAA Civil Aerospace Medical Institute, AAM-510, Oklahoma City, OK 73125

Potential Benefits to Air Traffic Safety Analysis

It could be used to analyze communications either as a check on routine communications, baseline current operations, document change introduced into the system by new procedures or technical capabilities, or to analyze incidents/accidents to determine if communications was a factor. ATSAT could be a useful tool to check that necessary information was conveyed in the proper format. This might catch errors or omissions that might otherwise be missed. As mentioned in the documentation, there might be situations where the indicated missed information was not really necessary, based on a further analysis by the user.

Total Cost

ATSAT is the property of the FAA and is available to anyone.

Other Comments

The documentation used in preparing this summary shows the verbal analysis, but does not show how an SPSS statistical analysis would be conducted. But the spreadsheet could be used for any purpose.

References

1. *Development of a coding form for approach control/pilot voice communications*, N95-28540. Prinzo, O.V., Britton, T.W., and Hendrix, A.M. http://www.cami.jccbi.gov/aam-400A/Abstracts/1996/am96-20.html
2. *Automatic Dependent Surveillance -Broadcast Cockpit Display of Traffic Information: Innovations in Pilot-Managed Departures.* Prinzo, O.V. http://www.cami.jccbi.gov/aam-400A/Abstracts/2002/am02-05.htm

Point of Contact

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Human Error Reduction in ATM (HERA)

Purpose

HERA was developed by EUROCONTROL to identify human errors involved in air traffic management incidents or events. Its purpose is to provide *retrospective* identification of cognitive failures and other causal factors that contribute to the loss of required separation between aircraft.

Description

In HERA, human performance is the consequence of complex mental operations based on information perceived from the environment. These operations are a sequence of information processing stages (e.g., perception, decision making, response selection and execution, and control via feedback) that are modified by mental processes, procedural knowledge, and expectations. While this conceptualization is highly simplified, it nevertheless has been found useful in incorporating most relevant ATC activities and behavioral requirements (e.g., situation awareness, planning) as well as detail the psychological error mechanisms involved in an airspace incident or event. A HERA analysis examines the human error event in relation to contextual factors such as the nature of the task engaged in at the time of the error and the equipment being used.

HERA allows the analyst to identify the context through use of appropriate information keywords. Each of the information processing stages provides a structure by which to identify a particular error associated with a particular event. Each stage, once identified, is further analyzed in terms of the nature of the error (e.g., missed or late detection of the problem, misdiagnosis of the problem, ineffective planning) and the psychological mechanism (e.g., premature commitment to an incorrect hypothesis, lapses in attention or memory) that caused the error. Analysis of each error also includes the identification of factors that may have contributed to the occurrence of the error.

Analysts using HERA work from the narrative description of an airspace incident to identify each human error considered to be a contributing factor in the incident. *(Note, European "Airprox" reports are typically more descriptive/detailed than operational error reports in the US).* Each human error is analyzed consecutively as a separate unit of analysis using HERA's information processing model as a template. The analyst is encouraged to avoid assumptions, whenever possible, and to make explicit all assumptions in the analysis. Clear stopping rules *minimize* assumptions and speculation. For each air traffic incident, a description of each individual human error is entered into the HERA analysis form, including how the error was detected and, if it occurred, how the error was mitigated before it became a safety threat. The extent to which the error(s) was causal, contributory, or compounding is also recorded. Contextual factors associated with the error(s) (e.g., the task, equipment, input information available) are identified from a checklist. After the errors are identified, the analyst is aided by the technique to identify the nature of the error, the psychological mechanisms that underlies the error and other factors that may have contributed to that error (e.g., traffic load, failures in communications and coordination, procedural errors, organizational or supervisory factors).

Aviation Usage

HERA remains a model-based research program whose goal is to identify and reduce human error as a cause in ATC incidents and events. The extent of its usage and the degree to which it has been validated is described under Documentation (below).

Potential Benefits to Air Traffic Safety Analysis

HERA was specifically designed for air traffic safety analysis. Accordingly, it can be used and extended more systematically to understand the significant causal factors of an air traffic incident or accident. HERA not only attempts to identify significant substandard and flawed human performance and the mechanisms and processes that underlie it but also the context in which such performance occurs. HERA may well prove to be an effective tool for improving human performance, reducing or eliminating erroneous actions, and increasing system safety.

HERA requires the careful review of available documents and reports, interviews with controllers and supervisors and, perhaps, site visits. Thus, the systematic application of HERA (as with HFACS and SLM) will be labor intensive and require analysts who are not only familiar with the particular format and checklists employed by HERA, but who are also subject matter experts on human error and air traffic management.

Tool Costs
There is no purchase price, but it involves team specialists to apply it.

Documentation
1. EATMP (2000). *Validation of the Human Error in ATM (HERA) Classification System*, Draft report. Brussels: EUROCONTROL.

Vendor/owner Support
Not Determined

Point of Contact
EUROCONTROL, Brussels, Belgium, Anne Isaac, EUROCONTROL, +32 2 729 3957, Isaac@eurocontrol.int

Human Factors Analysis and Classification System (HFACS)

Purpose
HFACS was specifically developed as a taxonomic system to categorize both the latent and immediate causal factors that have been identified in aviation accidents. Its purpose is to provide a framework for use in aviation accident investigations and as a tool for assessing accident trends.

Description
HFACS was developed and refined by analyzing hundreds of aviation accident reports containing thousands of human causal factors. Although designed originally for use within military aviation, HFACS has been shown to be effective for the identification and analysis of causal factors in civil aviation as well. HFACS uses four levels of failure. These include: (1) unsafe acts, (2) preconditions for unsafe acts, (3) unsafe supervision, and (4) organizational or cultural influences.

Unsafe acts include the willful violation of rules, regulations, and procedures that govern the safety of flight and the human errors associated with well-learned, repetitive, and routine responses (e.g., mental lapses), perceptual errors associated with the lack or loss of situational awareness, and decision errors associated with planning and problem solving. The remaining three tiers attempt to get at why the unsafe acts occurred. For example, preconditions for unsafe acts involves analyzing the conditions of the operator (both physical and mental), the conditions of the both the physical environment and the human-computer interface including automation, and the level and quality of teamwork (e.g., communications and coordination). Unsafe supervision includes such factors as inadequate supervision and supervisory violations. Finally, organizational influences include analyzing the quality of organizational decision making regarding such factors as staffing and resource allocation, formal rule making, work scheduling, etc.

Using the above framework, analysts can get beyond attributing an accident (or incident) simply to operator human error. Instead, HFACS permits the analyst to identify specific types of human error at various levels in the organizational hierarchy, thereby increasing the likelihood that meaningful and successful mitigation strategies can be developed, implemented, and tracked. HFACS does not require a reinvestigation of an accident or incident. It simply regroups causal factors into a different and perhaps more meaningful set of categories. This means that accidents and incidents can be analyzed post hoc, allowing for the analysis of trends, if a sufficient sample is available. However, given its (checklist) approach to analyzing accidents and incidents, its major shortcoming is that it still relies on the overt actions and sequence of actions of the operator, supervisor, or manager rather than the deliberations (the intentions and expectations) that underlay them. Error analyses schemes that can tap into these deliberations need to be carefully considered.

Aviation Usage

None known. However some preliminary attempts have been made by researchers at the FAA's Civil Aerospace Medical Institute (CAMI) to apply HFACS to air traffic operational error reports.

Potential Benefits to Air Traffic Safety Analysis

HFACS holds great promise for the analysis of controller errors and for failures in ATM. It would appear to be an effective analytical tool for understanding the antecedents of operational errors and ATM failures for air traffic safety analysis. HFACS provides a systematic framework for the analysis of operational errors and failures, but it is labor intensive and dependent on the availability of detailed quality data, and requires knowledgeable human factors safety analysts to use it

Total Cost

Contact tool owner

Documentation

1. Shappell, S. A. and Wiegmann, D. A. (2000), The Human Factors Analysis and Classification System (HFACS). Report Number DOT/FAA/AM-00/07, Federal Aviation Administration: Washington, DC.
2. Wiegmann, D. A. Shappell, S. A., Cristina, F. and Pape, A. (2000), "A human factors analysis of aviation accident data: An empirical evaluation of the HFACS framework," Aviation Space and Environmental Medicine, 71, 328-339.

Vendor/owner Support

http://www.cami.jccbi.gov/AAM-400A/, http://ssi-inc.com/HFACS.html

Point(s) of Contact

Dr. Scott Shappell, FAA Civil Aerospace Medical Institute, Oklahoma City, OK 73126, +1 405-954-4082, scott.shappell@faa.gov

Dr. Douglas A. Weigmann, Aviation Research Laboratory, University of Illinois, Savoy, IL 61874

Step Ladder Model (SLM)

Purpose

SLM is a descriptive decision making model developed from the study of process control operators' decision making activities. It provides insight into the decision making process of operators in situations analogous to those that occur in air traffic control.

Description

SLM models the decision making process, developed from an understanding of the behavior of nuclear power plant operators. While providing for the standard serial stages of human decision-making and problem solving, this model explicitly recognizes short-cut paths by which one or more steps can be skipped. Decision-making is conceived as a series of tightly coupled and iterative steps, proceeding from simple problem detection and information acquisition tasks to more knowledge-based diagnostic and planning tasks. These steps are followed by selection of a strategy or procedure and then by the execution of that strategy or procedure. The model also suggests that at each level of decision-making, the more complex intellectual processes may be bypassed by rule or skill-based behavior. These paths include stereotyped processes, in which the process of observation and detection leads to a direct inference of the system state (e.g., the air traffic situation) and to the immediate selection of a task or procedure, as well as cross connections in which certain tasks are connected with certain system states, and vice versa.

A "skill-based" decision is one that proceeds directly from detection to the execution of the relevant response with little, if any, conscious thought, following a preset pattern of responses that are not individually planned. A "rule-based" decision involves conscious recognition of a pattern of observed variables that may or may not be processed mentally to form a representation of the present system state (e.g., the air traffic situation), and the selection and execution of appropriate procedures based on that recognition. In short, rule-based decisions involve one of the intermediate short-cut paths, such as selecting a task or procedure based directly on the detection of a problem. A substantial majority of air traffic control actions fall within this category. Finally, a "knowledge-based" decision involves the full range of human decision-making skills, including diagnosis, planning, and the evaluation of alternative plans. Thus, knowledge-based decisions proceed through the full chain of causal reasoning. They would arise within the air traffic control room environment whenever there is ambiguity or uncertainty about air traffic conditions and the procedures to be employed (e.g., unexpected, novel, or under-specified conditions). Decision-making at this level demand substantial knowledge of the characteristics and dynamics of the air traffic and air traffic control system.

Aviation Usage

SLM has been employed to identify the causal factors associated with tower controller errors whose consequence was a "near-collision" runway incursion. See, "Runway Incursions and Critical Controller Decision Making in Tower Operations," Journal of Air Traffic Control, April-June 2000, pp 26-31.

Potential Benefits to Air Traffic Safety Analysis

SLM may be an effective model for the purposes of gaining insights into the underlying decision-making elements associated with controller errors and the consequence of those errors. It may be effective because: (1) it is a model that incorporates behavioral elements (e.g., detection, plan generation and testing etc.) common to a wide variety of decision-making activities, (2) it was developed within a process control context that is very similar to that of ATC, (3) the behavior elements of the model accord well with common sense, and are relatively easy to communicate to others, and (4) it appears to be robust enough to deal with a wide variety of decision-making sequences, not just those that can be assumed to proceed in an orderly fashion from detection through diagnosis and planning to execution.

These characteristics would appear crucial for the analysis of controller errors because it is generally not possible to treat complex decision making simply as a branching process along a tree structure. The fact that the model can deal with a wide variety of decision-making sequences, not just those assumed to proceed through a series of standard steps, makes it attractive for the analysis of safety related human errors in ATM.

ATM safety analysis has generally focused on human errors associated with traffic events and controller actions. Thus it fails to address the importance of more complex decision-making tasks. So, for example, most analyses of controller errors have emphasized display, control, and task management problems associated with the observation/detection and execution tasks. Yet, it is clear that the more complex the incident and the more unfamiliar the circumstances, the more the controller must depend upon higher, knowledge-based activities. SLM seems well suited to identify the potential sources of error for each level of decision-making activities.

SLM requires new methods to capture the temporal sequence of events and the related decision-making processes of the controller. New methods will require much greater emphasis on documenting the intentions and expectations of the controller when making decisions. Reviews of operational error (OE) reports and interviews with a controller(s) familiar with a particular incident will be necessary to describe the circumstances preceding and surrounding key controller actions and decisions. From interviews and an analysis of the OE report, a group of critical decisions associated with a given incident should be identified along with information relating to the context of the decision, e.g., immediately preceding activities, competing activities, communication/coordination activities, traffic and equipment factors, etc.

Tool Cost
No purchase price.

Documentation
1. Rasmussen, J. (1986), “Information Processing and Human-machine Interaction: An Approach to Cognitive Engineering. North-Holland: New York.
2. Weitzman, D. O. (2000), “Runway Incursions and Critical Controller Decision Making in Tower Operations,” Journal of Air Traffic Control, 42(2), pp 26-31.

Vendor/owner Support
Riso National Laboratory, Fredericksborgvej 399, P.O. 49, DK-4000, Roskilde, Denmark

Point of Contact
Jens Kruse Rasmussen, + 45 4677 4310, jens.rasmussen@risoe.dk

2.5.2 Error Prediction Models

Error prediction deals with the probability of a human error occurring under a given set of conditions or contexts. These models only predict that a human error will occur, not that a safety event or accident will result. Just as very few reportable errors result in an accident (and some ATC-related accidents occur without a reportable error), an untold number of ATC errors occur that are not reportable. There are many mitigating factors, including: detection by the one who made the error, a supervisor or fellow controller, or the flight crew(s); or what some controllers call "The Big Sky Theory," i.e., the chance of an encounter with another aircraft is quite small.

Nevertheless, almost all ATM-related accidents are at least partially caused by a controller error (e.g., a delayed reaction to a threat, an incorrect instruction, bad advice, failure to catch an incorrect read-back, etc.). Therefore, anything that can be done to better understand and reduce them should be a positive benefit.

Confusion Matrix

Purpose
The confusion matrix was devised as a means of evaluating errors of operators responding to off-normal (nuclear) plant conditions. Its relatively unique feature is that it seeks to identify various modes of misdiagnosis for a range of possible off-normal events.

Description
The Confusion Matrix relies on the judgments of experts as to the likelihood of different misdiagnoses of specific critical events in nuclear power plants. These judgments are solicited in a structured and systematic fashion, allowing for the evaluation of probabilities at different times during a given incident sequence. Thus, its outputs represent the probabilities that operators will fail to respond correctly to events A, B, C, etc. at times t_1, t_2,...,t_n after the initiation of the sequence. In giving their judgments, the experts are encouraged to take account of such factors as the interdependence or correlation of symptoms between different events, the operators expectations based on their previous experience, the effect of time stress, and the general ergonomic quality of the workstation. The principle advantage of this technique is that it provides a simple structure for helping analysts to identify critical situations in the sequence of events not so easily identified by other risk assessment techniques. Nevertheless, it appears to have more value as a qualitative analytical tool than as a quantitative one. Considerable disagreements have been reported between the probability estimates of different experts. It also shares the weakness of being based on simplistic manipulations of subjective data.

Aviation Usage
None known.

Potential Benefits to Air Traffic Safety Analysis
The Confusion Matrix often provides considerable variability and hence, uncertainty, in the quantitative results achieved. This creates practical problems in determining how to assess and deal with, first, the uncertainty itself, and second, estimates of risk (or misdiagnosis) that necessarily embody great uncertainty. The Confusion Matrix technique does not appear capable of getting us any closer to the truth regarding the assessment of risk in air traffic control.

Total Cost
No cost to purchase, but finding true "experts" could be a challenge.

Documentation
1. Potash, L. M., Stewart, M., Dietz, P. E., Lewis, D. M. and Dougherty, E. M. (1981), "Experience in Integrating the Operator Contributions in the PRA of Actual Operating Plants" in Proceedings of the ANS/ENS Topical Meeting on Probabilistic Risk Assessment, Port Chester, N. Y., American Nuclear Society: La Grange Park, Ill.

Vendor Support
Not determined

Point of Contact
Not determined

Human Error Assessment and Reduction Technique (HEART)

Purpose
HEART is a cost-effective tool for predicting human reliability and identifying ways of reducing human error. HEART can be applied to any industrial operation, as its methodology is centered upon the human operator rather than the technical process.

Description
HEART computes the probability of a human operator error on a combination of numerical factors provided by expert opinion. It allows consideration of HEART Generic Tasks, and Tasks developed to be specific to the industry or situation under consideration. The HEART methodology has been implemented in a PC version, called HEART-PC. It uses standard Windows technology to provide a user-friendly interface. It provides help to the users providing data on expert judgments upon which the HEART methodology depends. It allows the user to store these data, as well as the results, separately or in a single project database. It provides output reports at various levels of detail throughout the project.

Aviation Usage
None known

Potential Benefits to Air Traffic Safety Analysis
This is one of several methods for predicting controller errors based on a relatively simple mathematical combination of input data based on "expert opinion." So little seems to be known at this point about what factors go into causing a controller error that the usefulness these techniques is questionable.

Tool Cost
2,000 pounds sterling per copy, as of March 2001.

Documentation
Not Determined

References
Web site: http://www.electrowatt-ekono.co.uk/product/heart-pc/heart-pc.html

Vendor/owner Support
Electrowatt-Ekono, Ltd, Horsham Head Office, Century House, 100 Station Road, Horsham, West Sussex RH13 5UZ UK. Hardturmstrasse 161, P.O. Box CH-8037, Zurich, Switzerland

Point of Contact
Dave Carey of Electrowatt-Ekono Ltd. Phone +01 403 22 4200, dave.carey@hrh.ewe.ch

Operator Action Trees (OATS)

Purpose
OATS was devised specifically for predicting human errors during an impending safety threat or during off-normal conditions, and is designed to provide error types and associated probabilities to be used in probabilistic risk assessment.

Description
OATS employs the basic fault tree, to identify possible operator failure modes or errors. OATS emphasizes cognitive error types that involve mistakes in higher-level cognitive processes, such as in situation awareness, diagnosis or interpretation, strategy selection or planning, and response execution to mitigate a safety threat. These errors are quantified by applying an analytical tool called the time-reliability curve that generates probabilities for these errors. The probabilities represent the likelihood of a non-response or, conversely, a successful action by an operator or team of operators. For example, the major input to the quantification curve is the time available for diagnosing or interpreting an impending problem:

$$T(d) = T(o) - T(i) - T(e)$$

where T(d) is the time available for diagnosis, T(o) is the overall time from the initiation of a safety threat to a point by which operator actions have to be completed to mitigate the threat, T(i) is the time after initiation after which an appropriate alert or warning is given, and T(e) is the time taken to carry out a planned action or mitigation strategy.

As a result, OATS can predict the probability that a response will or will not be made to a safety alert as a function of the time since the threat occurred. The time-reliability curves have provided reasonable estimates of speed-accuracy trade-offs in fault diagnosis among nuclear power plant operators. However, these estimates are generally "best guesses", that are usually derived from expert opinion or extrapolated from laboratory studies. OATS does not predict when or how often an error will occur, or if how much of the delay was due to time to detect the problem vs. time to process the information, only the probability that a no response will occur in the time available.

Aviation Usage
None known.

Potential Benefits to Air Traffic Safety Analysis
It might be possible to generate different time-reliability curves on the basis of time to task completion for various air traffic scenarios. Given that different kinds of cognitive activity (e.g., situation awareness, diagnosis) take different times to execute, time-dependent non-response probabilities of air traffic controllers confronting different off-normal situations using operational data. There are a number of useful features to OATS: (1) it appears to be a quick and relatively convenient analytical tool to apply, (2) it will take into account the time dependent nature of controller activities, including cognitive activities, (3) good fits have already been found between the predictive capability of OATS and observed completion times in simulator studies with nuclear power plant operators, (4) some input data (time available from the onset of a "problem") might be inferred in the data base for air traffic management errors.

Tool Cost
No cost.

Documentation

1. Hall, R. E., Fragola, J .R. and Wreathall, J. (1982). "Post-Event Human Decision Errors: Operator Action Tree/Time Reliability Correlation." NUREG/CR-3010, U. S. Nuclear Regulatory Commission: Washington, D. C.
2. Hannaman, G. W., Spurgin, A. J. and Lukic, Y. D. (1984). "Human Cognitive Reliability Model for PRA Analysis." NUS-4531, Electric Power Research Institute: Palo Alto, CA.
3. Senders, J. W., Moray, N. and Smiley, A. (1985) "Modeling Operator Cognitive Interactions in Nuclear Power Plant Safety Evaluation," Report prepared for the Atomic Energy Control Board, Ottawa, Canada.
4. Wreathall, J. (1982) "Operator Action Trees: An approach to quantifying operator error probability during accident sequences." NUS-4159, NUS Corporation: Gaithersburg, MD.

Vendor/owner Support
Not determined

Point of Contact
Not determined

Success Likelihood Index Methodology (SLIM)

Purpose
SLIM was designed to elicit and structure expert opinion in order to connect error probabilities in generalized situations with suspected performance influencing factors.

Description
SLIM assumes that the likelihood of an error occurring in a particular situation depends upon the combined effects of a relatively small number of performance influencing factors (PIF's). A success likelihood index (SLI) is derived from a consideration of the typical variables known to influence error rates (e.g., level of experience, workload, time stress, procedures). It is assumed that experts can provide a numerical rating of how influential these PIF's are in a given situation. The numerical ratings are multiplied by each PIF's assigned weight for each PIF and the products are summed to give the success likelihood index. This index is presumed to relate to the probability of success that would be observed over the long run in the situation of interest.

SLIM is available in two interactive software packages. One calculates the success likelihood indices and the other performs additional sensitivity and cost-benefit analyses. In order to establish the independence of the PIF's (an important assumption of the methodology), the software packages check the ratings provided by the experts to see if the ratings of two or more PIF's are correlated. In addition, up to 10 tasks can be evaluated within a single SLIM session. This substantially reduces the amount of the experts' time needed to utilize SLIM.

At present, there are some difficulties with the calibration of SLIM. In theory, error probabilities can be calibrated against reference tasks whose error probabilities are objectively known. However, the success of calibration has turned out to be highly specific to the choice of the reference task and the mathematics underlying the calibration procedure is not widely accepted. More importantly, SLIM has not fared well in independent validation studies.

Aviation Usage
The basic SLIM methodology has been applied to assess the risks associated with the acquisition of candidate systems within the FAA's Investment Analysis process. It has not been applied to the assessment of risks associated with aviation safety.

Potential Benefits to Air Traffic Safety Analysis
The validation studies of SLIM's human reliability assessments have had very limited success. The combined generic weightings and task rankings have showed little or no relationship to actual data. In addition, it was also found that group consensus values offered no advantage over individual estimates of absolute probability judgments in which judges assign a likelihood of failure directly to the task being assessed. In short, SLIM does not seem to offer many benefits for the analysis of air traffic safety.

Usability for Air Traffic Safety Analysis
Although simple to implement and use and its application might result in the quantification of operator success, it is less likely to generate useful insights and understanding about the potential for controller errors in specific situations because, ultimately, it still relies on the adequacy of informed guess work rather than on hard data.

Tool Cost
No cost.

Documentation
1. Embrey, D. E., Humphreys, P. C., Rosa, E. A., Kirwan, B., and Rea, K. (1984) "SLIM-MAUD: An Approach to Assessing Human Error Probabilities Using Structured Expert Judgment," NUREG/CR-3518; Brookhaven National Laboratories: Upton, N.Y.

Vendor/owner Support
Not available.

Point of Contact
Not available.

Technique to Estimate Operator's Errors (TESEO)

Purpose
TESEO derives estimates of the likelihood of operator failure through the combined application of five error likelihood parameters, namely, the type of activity, the degree of time stress involved in that activity, operator experience and training, the degree to which the activity represents a safety threat, and an ergonomics factor.

Description
TESEO was developed from interview data collected in petrochemical process plants, but it might also have application in other areas. TESEO yields the likelihood (or odds) of operator errors through the combined application of five error likelihood parameters:

K1 = type of activity (routine vs. off-normal activities): 0.001 to 0.1.
K2 = temporary time stress: routine activities: 0.5 to 10; non-routine activities: 0.1 to 10.
K3 = operator experience and training: 0.5 to 3.
K4 = safety threat factor (dependent upon the situation):1 to 3.
K5 = ergonomic factor (interface and workspace environment): 0.7 to10.

The values assigned for each of the above parameters are combined multiplicatively to provide a predicted error rate for any given activity or task. Although relatively simple in concept and easy to use, its numerical basis is derived from informed guesses, rather than from hard data. Nevertheless, where it has been used, TESEO's output has compared reasonably well with the assessments of expert judges. Accordingly, it might be useful for quantifying human reliability in very specific situations where no hard data are available.

Aviation Usage
None known.

Potential Benefits to Air Traffic Safety Analysis
This technique will require that new parameter estimates be developed for the air traffic control environment. New parameters (e.g., the requirement for intellectual teamwork) might be added. An example of how this may be applied in practice to ATC is as follows: Suppose a highly experienced controller is working five well separated aircraft all in level flight and all at different altitudes and hands them off in sequence to the adjoining sector. The task is a relatively simple one, giving his full attention to the task and with little to distract the controller. Assigning values for the five parameters in this situation, we get, as an example: K1 = .001; K2 = 0.5; K3 = 0.5; K4 = 1; K5 = 1; giving a predicted error rate of 1 in 4000 similar situations (a probability of approximately 0.0001). Nevertheless, this technique involves nothing more than the simplistic manipulation of subjective data, which in most cases, would be difficult to interpret and perhaps be quite meaningless.

Tool Cost
Not determined

Documentation
1. Bello, G. C. and Colombari, V. (1980), "Empirical Technique to Estimate Operator's Errors (TESO)." Reliability Engineering, 1,3.
2. Hannaman, G. W., Spurgin, A. J. and Lukie, Y. D. (1984), "Human Cognitive Reliability Model for PRA Analysis." NUS-4531, Electric Power Research Institute: Palo Alto, CA.
3. Kletz, T. A. (1985), "An Engineers View of Human Error" The Institution of Chemical Engineers, Rugby, UK.

Vendor Support
Reliability Research Group, ENTE Nazionale Idrocarburi, Italy.

Point of Contact
Not determined

Technique for Human Error Rate Prediction (THERP)

Purpose
THERP provides human reliability data for probabilistic risk assessment studies; namely, to predict human error probabilities and to evaluate the degradation of human-computer systems likely to be caused by human errors alone or in connection with equipment malfunctioning, operational procedures, or other system and human characteristics that influence complex system (i.e., joint human-machine) behavior.

Description
The basic assumption of THERP is that the operator's actions can be regarded in the same way as the success or failure of a piece of equipment. The theory is that the reliability of the operator can be

assessed in essentially the same way as an equipment item. The operator's activities are broken down into task elements and estimates of the probability of an error for each task element is made, based on data or expert judgment. The procedural steps involved in applying THERP are as follows:

1. Identify those system functions that can be influenced by human error.
2. List and analyze related human tasks via a detailed task analysis.
3. Estimate the relevant error probabilities for each task using a combination of expert judgment and available data on the effects of such factors as workload, the CHI, operator skills and the like on those tasks.
4. Estimate the effects of specific human errors on system failure.

From these four steps, one could also try out different modifications or improvements and recalculate the probabilities in order to gauge the effects of these modifications. THERP includes an event tree. Each branch represents a combination of a particular human activity and presumed influences upon that activity. All the human task elements depicted by the tree are conditional probabilities based on expert judgment on the effects of workload, the quality of the CHI, the skills, experience, motivation, and expectations of the individual operator, and the degree of time stress likely to be present in various situations.

The core of THERP is contained in a number of tables of human error probabilities (the probability that when a given task element is performed, an error will occur) and some upper and lower bounds of the given probability, reflecting uncertainty. These numbers are generic values, based on "expert opinion" and data obtained from activities similar to nuclear power plant operators. Each of the tables deals with particular errors associated with specific activities (performed by nuclear power plant operators): for example, errors of commission in reading information from a display, execution errors, and so on.

Aviation Usage

There is no known use of THERP in ATC safety analysis.

Potential Benefits to Air Traffic Safety Analysis

THERP, like most event tree analyses, is designed to predict performance in order to identify possible weaknesses of a system; that is, to find out what could possibly happen in a given context, e.g., an equipment failure, time stress, or lack of situation awareness. However, the path of an event tree can present so many possibilities for a given context, that the analysis can become quite unmanageable very quickly. So event trees, such as THERP, can become misleading because the sequence of events and tasks cannot be assumed to remain the same under all conditions.

THERP is based upon the assumption that human activity is composed of distinct tasks which are summative and can be arranged into one pattern or another without affecting the character of any single task. This atomistic notion of human behavior is open to serious criticism. For example, a controller working at a task, however simple, integrates all the part activities into a whole: therefore the changing of any part activity, however small, might change in some degree the pattern of the larger task.

Usability for Air Traffic Safety Analysis

Because of the inherent unreliability of the underlying human performance numbers using the THERP technique it is not likely to be very usable even for performance prediction except in very limited ways. For all its technical sophistication, THERP remains an art form – useful perhaps when employed by highly experienced people, but of doubtful validity in the hands of others.

Tool Costs

Not Applicable

Documentation

1. Bell, B. J. and Swain, A. D. (1983), "A Procedure for Conducting a Human Reliability Analysis for Nuclear Power Plants." NUREG/CR-2254, Albuquerque, N.M.: Sandia National Laboratories.
2. Swain, A. D. and Guttmann, H. E. (1983), "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications." NUREG/CR 1278, Sandia National Laboratories.
3. Swain, A. D. and Weston, L. M. (1988), "An Approach to the Diagnosis and Misdiagnosis of Abnormal Conditions in Post-Accident Sequences in Complex Man-Machine Systems." In L. Goodstein, H. Andersen, and S. Olsen, eds., Tasks, Errors, and Mental Models. London: Taylor & Francis.

Vendor/owner Support

Web site: http://www.pitt.edu/~cmlewis/therp_1052.html

Point of Contact

email: rmcranw@sandia.gov

TRACEr lite

Purpose

TRACEr *lite* is a human error identification tool for air traffic management applications. It is a reduced version of TRACEr (Technique for the Retrospective and Predictive Analysis of Cognitive Errors in ATM) which was designed for Human Factors (HF) specialists.

Description

TRACEr was developed in 1999 in NATS (National Air Traffic Services, UK), as a means of classifying human errors and their causes in air traffic incident reports. TRACEr is based on the Human Factor Information Processing paradigm, but draws extensively from a range of Human Factors and error causation models. It was based on a task analysis of the controller activities via Hierarchical Task Analysis. TRACEr contains a number of flowcharts to help the analyst determine what errors could occur, what their causes might be, and their relative recovery likelihood.

TRACEr *lite* was created to make core TRACEr techniques accessible to incident investigators and ATC specialists.

Aviation Usage

TRACEr *lite* has been applied to a number of design projects (e.g. the Final Approach Spacing Tool used in NATS) and airspace procedure changes (including reduction of separation in unclassified airspace in the UK). It has more recently been applied within EUROCONTROL to an design and concept projects in the areas of ASAS (delegation of certain tasks to the pilot), Time-Base Separation (an approach tool), and to the Conflict Resolution Assistant (CORA 2) project, the EUROCONTROL equivalent of the US PARR tool for conflict resolution advice to controllers. It is about to be applied to the Mediterranean Free Flight (MFF) project.

Potential Benefits to Air Traffic Safety Analysis

TRACER *lite* offers a means of systematically identifying human errors for future systems. It is compatible with HERA and other retrospective analysis techniques, so that learning can go in both directions (the so-called JANUS concept, meaning that we can translate information from past incidents easily into insights for future system design and assessment). Since human error and human performance remain a critical element, if not the critical element in ATM safety, this is a useful function.

Tool Cost
The tool is free.

Documentation
1. Shorrock, S.T. and Kirwan, B. (2002) "The Development and Application of a Human Error Identification Tool for Air Traffic Control" *Applied Ergonomics*, **33**, 319-336.
2. Shorrock, S.T., DNV "Error Classification for Safety Management: Finding the Right Approach."
3. Shorrock, S.T., DNV "The Two-Fold Path to Human Error Analysis: TRACEr *lite* Retrospective and Prediction."

Documentation is currently limited outside of the papers that have been produced on the tool. TRACEr *lite* exists as an Excel spreadsheet. The original developer (Steve Shorrock) is developing a more accessible website (below). It is hoped that in the near future reports showing in more detail the application of the technique will become available from the EUROCONTROL Experimental Centre.

References
Website: http://tracer-lite.co.uk

Vendor/owner Support
For support, see: Steven T. Shorrock, Det Norske Veritas (DNV), Highbank House, Exchange Street, Stockport, Cheshire, SK3 0TE, UK.

Point(s) of Contact
Steven Shorrock, Det Norske Veritas (DNV), +44-161-477-3818, steven.shorrock@dnv.com
Barry Kirwan, EUROCONTROL Experimental Centre, +33-1-6988-7886, barry.kirwan@eurocontrol.int

2.5.3 Models of Human Behavior

Human behavior refers to the ability of the human operator of a device to behave as required, often when faced with the need to perform a number of tasks nearly simultaneously (multi-tasking). This involves cognitive and psychomotor tasks, and decision-making. This is certainly true of the air traffic control specialist's job, as well as many others. Again, this section contains only a small sample of the methods tools available.

A source for much of the information in this section, and for information on other tools, is:
Pew, R. and Mavor, A.S. (1998), "Modeling Human and Organizational Behavior: Application to Military Simulations", Panel on Modeling Human Behavior and Command Decision Making: Representations for Military Simulations, National Research Council. Available on the web at http://www.nap.edu/

Cognition as a Network of Tasks (COGNET)

Purpose
COGNET is a framework for creating and exercising models of human operators engaged in primarily cognitive (as opposed to psychomotor) tasks. Its primary purpose is to develop user models for intelligent interfaces. It has been used to model surrogate operators (and opponents) in submarine warfare simulations.

Description
The most important assumption behind COGNET is that humans perform multiple tasks in parallel. These tasks compete for attention, but ultimately combine to solve a problem. COGNET assumes rapid attention switching with attention focusing first on one task and then another depending upon the priority of the task for a given problem context. At any given time, the task with the highest priority is the focus of attention.

A COGNET model of an antisubmarine warfare simulation received limited validation against both the simulated information processing problems used to develop it and four other problems created to test it. COGNET correctly predicted 92% that a real human operator would perform a certain task for the given set of problems. Also, the mean time that COGNET executed tasks preceded actual task performance was about 5 minutes. Note that antisubmarine warfare is much slower paced that ATM work; situations typically evolve over periods of hours rather than minutes or seconds.

Potential Benefits to Air Traffic Safety Analysis
COGNET appears to be a plausible framework for representing cognitive multitasking behavior in ATM. A development environment for creating such models for ATM simulations would be of benefit to developers of ATM simulations for safety analysis. Although validation of COGNET has been limited, the results appear to be promising.

Total Cost
No cost.

Documentation

1. Zachary, W., Le Mentec, J. C., and Ryder, J. (1996), Interface agents in complex systems.
2. In Human Interaction with Complex Systems: Conceptual Principles and Design Practices, (C. N. Ntuen and E. H. Park, eds.), Kluwer Academic Publishers

Vendor/owner Support
Not available

Point of Contact
Not available.

Micro Saint

Purpose
Micro Saint is a tool used to construct (network) models for predicting human behavior in complex systems. These models are designed to yield estimates of times to complete tasks and task accuracies; they also generate estimates of human operator workload and task load (i.e., the number of tasks an operator has to perform over time).

Description
Micro Saint is a modern commercial version of a network modeling and simulation language long used in the design and analysis of complex human-machine systems. Micro Saint is not so much a model of human behavior as a simulation language and a collection of simulation tools that can be used to create human behavior models to meet user needs. It provides a conceptual framework for representing human-machine systems that consist of discrete task elements, continuous state variables, and interactions between them. It is designed to facilitate an assessment of the contribution that human and machine components make to overall system performance.

Micro Saint assumes that human behavior can be modeled as a set of interrelated tasks (a task network), the sequence of which is determined by experience, objective criteria, or priorities. Thus modeling starts with a detailed analysis of the assumed sequence of actions down to elementary operator functions, including time and accuracy parameters. Subsequently, a task network is synthesized from these elements. The simulation is initialized when internal and external events are scheduled. As events are processed, tasks are initiated, accuracy data are computed, workloads are computed, and task termination events are scheduled. Linkages and transition probabilities between tasks are selected in such a way that the model behaves realistically under dynamic conditions.

Aviation Usage
None known

Potential Benefits to Air Traffic Safety Analysis
Micro Saint has been widely employed in simulations used for analysis to help increase military system effectiveness. It is one of the few simulation engines that have gone through the U.S. Army verification, validation, and accreditation process. Accordingly, there is nothing in principle that prevents Micro Saint from being applied to ATM safety analysis. On the other hand, since Micro Saint is a tool, not a model, the user is responsible for providing the behavioral modeling details. Micro Saint lacks psychological validity, which the user must therefore be responsible for providing. There is no built-in mechanism with which to develop detailed models of complex human cognitive processes; such features must be built from scratch.

Nevertheless, Micro Saint has already shown merit through at least limited validation and accreditation and has further potential as a good tool for building models of human behavior in ATM simulations. Being a commercial product, it is general purpose and ready for use on a wide variety of computer platforms. It offers the advantage of vendor support, and its software support environment provides tools for rapid construction and testing of models.

Tool Cost
Contact vendor

Documentation
LaVine, N. D., Peters, S. D., and Laughery, K. R. (1996), "Methodology for predicting and applying human response to environmental stressors. " Report DNA-TR-95-116. Defense Special Weapons Agency, Alexandria, VA.

Vendor Support
Micro Analysis & Design, 49-49 Pearl East Circlr, Suite 300, Boulder Co., USA
Website: http://www.maad.com/MaadWeb/microsaint/msaintma.htm

Point of Contact
Phone: 303-442-6947, info@maad.com

Man Machine Integrated Design and Analysis System (MIDAS)

Purpose
MIDAS is a system for simulating one or more human operators in a simulated world. The primary purpose of MIDAS is to evaluate proposed human-machine system designs and to serve as a test bed for a variety of behavioral models. NASA, the U.S. Army and Sterling Software, Inc. jointly developed it to model pilot behavior, primarily in support of helicopter crew station design.

Description
The overall architecture of MIDAS comprises a user interface, an anthropometric model of the human operator, symbolic operator models, and an environmental model. The user interface consists of an input side (an interactive GUI, a cockpit design editor, an equipment editor, a vehicle route editor, and an activity editor) and an output side (display animation software, run-time data graphical displays, summary data graphical displays, and 3D graphical displays.

MIDAS is an object-oriented system consisting of objects (grouped by classes). Objects perform processing by sending messages to each other. More specifically, MIDAS consists of multiple, concurrent, independent agents. There are two types of physical agents in MIDAS: equipment agents are the displays and controls with which the human operator interacts; environmental "world" agents are the distal environmental factors critical to performance. The human operator agents are the human performance representations in MIDAS – cognitive, perceptual, and motor. The idea is that the human operator agents interact with the equipment agents and, in combination with the distal environmental agents, results in observable behavioral activities (e.g., scanning, decision making, reaching, and communicating). A number of rule-based cognitive models, each specific to a particular design case and mission, have been developed to support these interactions.

MIDAS relies on either a pattern-matching approach to trigger reactive behavior, based on internal perceptions of the outside world, or a more global assessment of the situation in terms of external events. Prior to a MIDAS simulation, the environmental "world" representation is preloaded with such things as mission scenario, procedure, and equipment information. During the simulation, the "world" is constantly updated by activities of the human operator agents. The representations for human operator activity consists of the following attributes: the preconditions necessary to begin an action, the satisfaction conditions, that define when an action is complete, constraints on activities, interruption specifications, that define how an activity can be interrupted, workload, the duration of an activity, and the fixed priority of the activity. Activities can be forgotten when interrupted.

Aviation Usage
None known.

Potential Benefits to Air Traffic Safety Analysis
MIDAS is an integrative, versatile model that appears consistent with current psychological and psychomotor theory and data. MIDAS explicitly models communication and situation awareness with respect to the external "world" representations. There has been some validation of MIDAS.

On the other hand, MIDAS has some limitations for air traffic safety analysis. For example, MIDAS does not generate human errors; they are not emergent features of the model, but must be explicitly programmed. Accordingly, programming real-life scenarios and potential human error(s) in order to predict an error is of dubious value at this stage in its development. Also, MIDAS may be too big and too slow for most ATC simulation applications. In addition, it is very labor intensive, and it seems to contain many details and features not needed in ATC simulations.

Usability for Air Traffic Safety Analysis
Nevertheless, MIDAS could have some potential for use in ATC simulations. The MIDAS architecture would seem to provide a good base for controller representation. Components of MIDAS could be used selectively and simplified to provide the level of detail and performance required to evaluate alternative human-machine designs and procedures. Furthermore, MIDAS might be a good test bed for ATC behavioral research.

Tool Cost
Not Applicable

Documentation
1. Banda, C. et al (1991), Army-NASA Aircrew/Aircraft Integration Program: Phase IV AI Man-Machine Integration Design and Analysis System (MIDAS) Software Detailed Design Document. NASA Contractor Report 177593. NASA Ames Research Center, Moffett Field, CA.
2. Laughery, K. R. and Corker, K. M. (1997), "Computer Modeling and Simulation of Human/system Performance"; Handbook of Human Factors, 2nd edition; G. Salvendy, ed. ; New York, NY: John Wiley & Sons.
3. NASA Ames Research Center (1996), MIDAS Core Redesign: Release 1.0 Documentation. Unpublished report; NASA Ames Research Center, Moffett Field, CA.

Vendor Support
NASA Ames Research Center, Moffett Field, CA.

Point of Contact
Web site: http://caffeine.arc.gov/midas/Overview.html

Programmable User Modelling Applications (PUMA)

Purpose
Programmable User Model (PUM) is a model of human behavior relating to operating a device to obtain a desired result. A PUM Application (PUMA) is an analysis performed using PUM. The purpose is to gain

a better understanding of how the operator will respond, and under what circumstances the operator's performance could be incorrect or insufficient.

Description

PUM models a human operator ("user") and a device being operated on ("device"). The device responds in some predictable (but not completely predictable to the user) way to user operations by changing its state. PUM assumes that the user is a "rational agent." A PUMA involves 'programming' a cognitive architecture that implements rational problem-solving behavior with knowledge. The analyst must define knowledge and (user/device) interactive behavior. For complex architectures, this could be an iterative process. Once the main problem areas are identified, a further analysis can be conducted.

Some of the types of knowledge considered are:

1. the user's task
2. the user's knowledge of the device state
3. various operations that can be performed, their purpose and expected result.
4. actions to be performed to execute the operation
5. domain and device concepts that the user must deal with

PUM models the decision process by which the user selects an operation to be performed, the operation, the device's response, and the user's response to the device's perceived new state. Construction of a PUM model generally proceeds in several stages, starting with a description and working through to (hand-simulating) a running model. *PUMA Footprints* is a lightweight version of the approach which is less time-consuming to apply, and therefore more cost-effective for large systems, but correspondingly lacking the detailed rigor of traditional PUMA.

Aviation Usage

None known.

Potential Benefits to Air Traffic Safety Analysis

This is a sophisticated approach. It seems obvious that it could be applied to air traffic management, but to do so realistically will take a considerable effort. It probably will not be able to predict or analyze specific errors, but might lead to devices and/or procedures that might reduce the chances for error.

Tool Cost

PUM Analysis is currently a manual process.

Documentation

1. Blandford, A., Butterworth, R., and Curzon, P. (2001) "PUMA Footprints: Linking theory and craft skill in usability evaluation" Interaction Design Centre, School of Computing Science, Middlesex University, London. (Available on the web site below.)
2. Blandford, A.E., Buckingham Shum, S., and Young, R.M. (1998), "Training Software Engineers in a Novel Usability Evaluation Technique." *International Journal of Human-Computer Studies* 45, 245-279.

References

Website: http://www.cs.mdx.ac.uk/puma/ - See in particular Working Paper WP11, which is a tutorial on PUMA, Website: http://www.uclic.ac.uk/annb/I2001footorintscrc.pdf

Vendor/owner Support

None.

Point of Contact

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Situation Awareness Model for Pilot-in-the-Loop Evaluation (SAMPLE)

Purpose
SAMPLE models the behavior of operators (individuals or crews) of complex human-machine systems. It has been applied to several complex domains, including combat aviation, commercial aviation and air traffic control, battlefield command and control, and Military Operations on Urban Terrain (MOUT). Recent variants have been applied to the study of the effects of individual differences and environmental stressors on cognitive performance.

Description
SAMPLE assumes that the behavior of an operator is guided by highly structured standard procedures and driven by detected events and assessed situations. Some variants assume a multitasking environment. In all cases, the operator (or crew) is concerned primarily with performing situation assessment, continuous control and communication, and discrete procedure execution.

SAMPLE is a domain-independent architecture for modeling situation awareness (SA) centered decision-making in high-stress, time-critical environments. Information is drawn from a world model and processed via a suite of information processing algorithms, which includes sensory processing and perceptual processing to generate a set of identified events of interest to the human behavior model. A situation assessment process then translates the low-level events into high-level situation assessments, which are finally processed by a decision-making module to produce actions or communications affecting the world state. Each of the component cognitive modules draws from a suite of internalized mental models of the external world, stored in long-term memory, and used to interpret the world state, identify events and situations, and select appropriate responses. Additionally, each module both draws from and populates a short-term memory representation with identified events, situations, and selected tasks and procedures, which combined, models the individual's real-time interpretation of the world state. Each of the cognitive processes within SAMPLE are modeled computationally through several AI technologies, including fuzzy inferencing for information processing, Bayesian reasoning for situation assessment, and expert systems for decision-making and procedure selection.

SAMPLE is accompanied by a suite of graphical tools that: 1) guide developers through the task hierarchy, 2) step through and check the model, and 3) collect generated events for after-action review by the analyst.

Aviation Usage
The SAMPLE model has been applied within a modeling and simulation environment, using NASA's Future ATM Concepts Evaluation Tool (FACET), to investigate the potential for a Principled Negotiation-based approach to the distributed air traffic management problem. This study incorporated an advanced multi-agent system modeling the situation assessment and decision-making behavior of individual commercial pilots, air traffic controllers, and airline dispatchers as well as the interactions between these modeled players to support distributed, cooperative ATM concepts.

Potential Benefits to Air Traffic Safety Analysis
SAMPLE provides a general framework for constructing models of human operators of complex systems, particularly in cases in which the operators are engaged in information processing and control tasks quite similar to those that engage air traffic controllers. Given that the majority of air traffic control actions involve procedure selection and execution, SAMPLE might be able to provide much detail about the effectiveness of ATM procedures, the consequences of inappropriate procedure selection and/or execution, and the strategies necessary to mitigate controller errors.

Tool Cost
No cost.

Documentation

1. Zacharias, G. A., Miao, C., Illgen, J. Y., and Siouris, G. (1996), "SAMPLE: Situation awareness model for pilot in the loop evaluation." First Annual Conference on Situation Awareness in the Tactical Environment. Naval Air Warfare Center, Patuxent River, MD.
2. Mulgund, S. S., Harper, K. A., Zacharias, G. L., & Menke, T. (2000). "SAMPLE: Situation Awareness Model for Pilot-in-the-Loop Evaluation". 9th Conference on Computer Generated Forces and Behavioral Representation, Orlando, FL.
3. Harper, K., Guarino, S., White, A., Hanson, M. L., Bilimoria, K., & Mulfinger, D. (2002). "An Agent-Based Approach to Aircraft Conflict Resolution with Constraints". AIAA Guidance, Navigation, and Control, Monterey, CA.
4. Hanson, M.L., Harper, K.A., Endsley, M., & Reszonya, L. (2002). "Developing Cognitively Congruent HBR Models via SAMPLE: A Case Study in Airline Operations Modeling". 11th Conference on Computer Generated Forces and Behavior Representation, Orlando, FL.
5. Harper, K.A. & Zacharias, G. (2002). "Modeling Attention Allocation and Multitasking in Computational Human Behavior Representations". 11th Conference on Computer Generated Forces and Behavior Representation, Orlando, FL.
6. Harper, K., Ton, N., Jacobs, K., Hess, J., & Zacharias, G. (2001). "GRADE: Graphical Agent Development Environment for Human Behavior Representation". 10th Conference on Computer Generated Forces and Behavior Representation, Norfolk, VA.
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8. Aykroyd, P., Harper, K. A., Middleton, V., & Hennon, C. G. (2002). "Cognitive Modeling of Individual Combatant and Small Unit Decision-Making within the Integrated Unit Simulation System". 11th Conference on Computer-Generated Forces and Behavior Representation (CGF-BR), Orlando, FL. pp.597-604.

Vendor Support
Not available

Point of Contact
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2.5.4 Tools for Measurement of Workload and Situation Awareness

Two of the human factors aspects that are critical to human performance, and have been mentioned in many of these tools, are: (1) workload (the perceived demand placed on the human operator), and (2) situation awareness (the awareness of the human operator of what is going on in the environment in which he/she is operating). These (too much of the former and two little of the latter) have been named as causes in many accidents, especially lack of situation awareness. But these are somewhat abstract, and not easily observable. Methods for quantifying them should play an important part in at least some ATM safety studies.

There are basically two types of measurements: (1) subjective, i.e., based on subjective opinion and (2) objective, i.e., based on either an observer's judgment or objective data. One of each kind is presented for both workload and situational awareness. This is only a small sample of some of the better-known tools.

Performance and Objective Workload Evaluation Research (POWER)

Purpose

POWER is designed to provide objective measures of ATC task load and relate them to controller workload and performance. Specifically, it is a research program designed to investigate the relation between a set of task load measures (e.g., traffic count, traffic variability, number of handoffs, number of conflict alerts, number of data entries and so on) and controller mental workload and performance.

Description

POWER has identified a set of measures describing different aspects of ATC activity that are objective, routinely recorded and therefore, relatively easy to obtain. POWER utilizes recorded ATC data, to estimate controller task load in situations in which workload measurement is of interest. POWER measures encompass activity attributes such as traffic volume, the average heading, speed, and altitude changes, the number of handoffs, data entries, route displays, point-outs, data block offsets, conflict alerts, and so on. The rationale behind POWER is that if some of these measures are strongly related to measures of mental effort and/or the reliability of controller performance, it may then be possible to use them in situations where it would not be otherwise possible to evaluate mental workload or performance.

Aviation Usage

POWER was developed to provide a research platform for investigating the relationship between en route ATC activity and controller task load and mental workload. Several studies have been completed both to evaluate the current set of POWER measures and to provide guidelines for the addition of new measures. The studies that have been completed have shown that some POWER measures were related to mental workload but only weakly related to controller performance. Accordingly, there is little empirical evidence to suggest that POWER is sufficiently rigorous as a tool to predict either controller workload or controller performance in its present state. More research is clearly needed.

Potential Benefits to Air Traffic Safety Analysis

Controller workload generally refers to the interaction between the controller and his or her task, insofar as the controller's limited information processing capacities are concerned. When workload is exceeded one can expect that performance will decline in some fashion and in some cases reduce safety. The primary potential benefit of POWER would be in its ability to predict controller workload based on the ATC task environment both in terms of breakdowns in performance and in the subjective experience of high or low mental workload. The issue of activity-based prediction of workload is still very much a hot research topic and is joined by the more recent concerns of POWER. While total task load does not seem to be a useful predictor of controller errors, certain kinds, combinations, and timing of tasks, which could be studied using POWER, might be.

Usability for Air Traffic Safety Analysis

The practical implications of POWER as a measuring tool for controller workload and performance is that it utilizes unobtrusive, readily available ATC activity data. Such measures, if empirically validated, would be immediately useful in predicting performance and workload for existing systems and perhaps, even future ones.

Tool Costs

Not determined

Documentation

1. Manning, C. A., Mills, S. A., Fox, C., Pfleiderer, E., and Mogilka, H. J. (2001), "Investigating the validity of performance and objective workload evaluation research (POWER)". DOT/FAA/AM-01/10, Office of Aerospace Medicine, Washington, DC 20591 USA
2. Mills, S. H., Pfleiderer, E. M., and Manning, C. A. (2002), "POWER: Objective activity and taskload assessment in en route air traffic control"; DOT/FAA/AM-02/2, Office of Aerospace Medicine, Washington, DC 20591 USA

Vendor/owner Support

Not determined

Point of Contact

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Situation Awareness Global Assessment Technique (SAGAT)

Purpose

SAGAT is a method that provides an objective measure of situation awareness (SA) during a simulated operation. It is not intended for use during an actual operation.

Description

Measures of SA provide an index of how well operators are able to acquire and integrate information in a complex environment where a lot of data may vie for their attention. SAGAT employs periodic randomly-timed freezes in a simulation scenario during which all of the operator's displays are blanked and a series of questions are provided to the operator to assess his or her knowledge of what was happening at the time the freeze occurred. The queries typically cover all three levels of SA (perception, comprehension, and projection). The main advantage of SAGAT is that it allows an objective, unbiased index of SA that assesses operator SA across a wide range of elements that are important for SA in a particular system.

The relationship between SA, workload, the probability of an error, and the probability of an accident are left to other tools and other studies. But SA is critical, and this method is a practical and unbiased way to measure it.

Aviation Usage

SAGAT was used in a number of studies. One of the most interesting was conducted by the Massachusetts Institute of Technology in which various proposals for Free Flight were simulated with actual controllers and SAGAT was used to assess the impact of Free Flight on SA. See http://atm-seminar-97.eurocontrol.fr/endsley.htm.

Potential Benefits to Air Traffic Safety Analysis

Lack of SA is cited as a major causal factor in many error and accident reports. SAGAT could be useful in testing proposed changes in the ATC system, including new equipment, procedures, or traffic loads.

Tool Cost

There is no purchase price, but there is a cost to set-up the scenarios and design the queries.

References

1. "A Comparative Analysis of SAGAT and SART for Evaluations of Situation Awareness", Endsley, M.R.; Selcon, S. J.; Hardiman, T.D.; and Croft,D.G. ; available on the web at: http://www.satechnologies.com/papers/pdf/HFES98-SAGATvSART.pdf

Documentation

1. Endsley, M.R. (2000) "Direct Measurement of Situation Awareness: Validity and Use of SAGAT" in M.R. Endsley and D. J. Garland, Eds. (2000), Situation Awareness Analysis and Measurement, Mahwah, NJ, Lawrence Erlbaum http://www.erlbaum.com
2. Endsley, M.R. (1997) "Situation Awareness, Automation and Free Flight", FAA/Eurocontrol Air Traffic management R&D Seminar, Saclay, France. Available on the web at: http://atm-seminar-97.eurocontrol.fr/endsley.htm
3. Endsley, M.R. Smolensky, M.(1998), "Situation Awareness in Air traffic Control: The Picture" in Human Factors in Air Traffic Control, M. Smolensky and E. Stein. New York, Academic Press: pp 115-154

Many additional references are available on the web at http://www.satehnologies.com

Related Tools

SART

Vendor/owner Support

SAGAT is in the public domain, but expert advice is available (example below). A ready-built software package for administering an ATC version of SAGAT is commercially available from SA Technologies (see below) for $499.

Point of Contact

Dr. Mica Endsley, SA Technologies, 4731 East Forest Peak, Marietta, GA 30066 USA
Phone: (770) 565-9859 Email: Inquiries@satechnologies.com

Situation Awareness Rating Technique (SART)

Purpose

SART is a technique for rating of situation awareness (SA) of operators of complex human-machine systems. It is an index of how well operators are able to acquire and integrate information. It has been applied to several complex domains, including air traffic control.

Description

SART is used in conjunction with a human-in-the-loop simulation in which the operator must perform tasks based on sensory evidence provided by the simulation tool. SART relies on operator ratings of their own subjective opinion of their situation awareness. Operators rate on a bi-polar ("low" to "high") scale how they perceive three domains: 1) the demand for their attentional resources, 2) the supply of attentional resources, and 3) their understanding of the situation. These scales are then combined to provide an overall SART score for a given scenario.

The scales can be continuous (of a constant length) or discrete (e.g., 1 through 7). The three domains can be further subdivided. For example a ten generic construct version has for demand: 1) instability of the situation, 2) variability of the situation, and 3) complexity of the situation; for supply: 1) arousal, 2) spare mental capacity, 3) division of attention; and for understanding: 1) information quality, 2) information quantity, and 3) familiarity.

The advantage of SART is that the scales are universal and do not have to be tailored to a specific application. A disadvantage is that SART ratings are based on how well the operator thinks he/she is doing (without knowing that his/her perception might be incorrect), as opposed to how good his/her SA really is. SAGAT takes the opposite approach; the tests attempt to measure actual SA, but the questions must be tailored to the particular situation.

As an alternative, SART can be used with a trained observer to rate operator SA. The observer is given a more complete knowledge of the situation and thus the rating is less subjective. However, the observer must rely on the operator's overt indications to determine SA.

Air Traffic Usage

SART has been used to evaluate cockpit and ATC displays.

Potential Benefits to Air Traffic Safety Analysis

SART could be used to evaluate new display systems, procedural changes, etc.

Tool Cost

No cost. However, some training is advisable.

References

1. Jones, Debra (2003), "Subjective Measures of Situation Awareness", in Endsley, M.R. and Garland, D.J., Eds. (2000) Situation Awareness Analysis and Measurement**,** Mahwah, NJ, Lawrence Erbaum. Available at http://www.erlbaum,.com/
2. Endsley, M.R., (1998) "A Comparative Analysis of SAGAT and SART for Evaluations of Situation Awareness." Available at:
   a. http://www.satechnologies.com/papers/pdf/HFES98 -SAGATvsSART.pdf
3. Selcon, S.J. and Taylor, R.M. (1991). "Workload or Situational Awareness?: TLX vs. SART for Aerospace Systems Design Evaluation", Human factors Society 35th Annual Meeting, Santa Monica, CA, Human Factors Society.

Documentation

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2. Taylor, R. M. (1990). "Situation Awareness Rating Technique (SART): the development of a tool for aircrew systems design. In Situation Awareness in Aerospace Operations (AFARD-CP-478; pp. 3/1-3/17). Neuilly Sur Seine, France: NATO-AGARD
3. M. Endsley, R. Sollenberger, A. Nakata, E. Stein. "Situation Awareness in Air Traffic Control: Enhanced Displays for Advanced Operations", FAA ACT-530

Vendor Support
SART is in the public domain, but expert advice is available (see example below).

Related Tools
SA-SWORD, SAGAT

Point of Contact
Mr. Robert Taylor, Dstl Avionics and Mission Systems, Air Systems Concepts and Performance Group, A2 Bldg., Room G007, Ivey Gate, Ivey Road, Farnborough, Hants GU14, 0LX, UK
Phone: 44 (0) 1252 455784 email: rmtaylor@dstl.gov.uk

Subjective Workload Assessment Technique (SWAT)

Purpose
SWAT is a technique to assess the workload placed on operators of complex human-machine systems. SWAT is designed to be easy to use, low cost, non intrusive, valid, and sensitive to workload variations. It has been applied to several complex domains, including air traffic control.

Description
SWAT is composed of subjective operator ratings for three orthogonal dimensions of workload: time load, mental effort load, and psychological stress load. For time load, the question is about how much spare time does the operator have. For mental effort load, the question is how much mental effort or concentration is required. For psychological stress load, the question is about confusion, risk, frustration, and anxiety. Each dimension is represented on a three-point scale with verbal descriptors for each point. Individual assessments are scaled and conjoint analysis is carried out on the results to convert them to a single metric of workload. There are 27 possible combinations; the user can decide how to rank order these values.

Although the technique was intended for use in the operation of actual systems, or in human-in-the-loop simulations, it can be applied to predict operator workload prior to a system being built. In such applications, it is referred to as Projective SWAT.

SWAT is a non-diagnostic technique in that it will not distinguish among use of perceptual, central, or motor resources.

The SWAT scale has been used extensively, some practitioners claim that it is insensitive (not able to discriminate statistically between different load conditions) when the workload is low. An attempt to improve this by adding more rating levels, but this makes the scoring more difficult, more error prone, and more time consuming. Another suggestion was to make the scale continuous, thus allowing for an essentially infinite range of possible scores. This has been called the Continuous Subjective Workload Assessment technique, or C-SWAT.

Air Traffic Usage
None known.

Potential Benefits to Air Traffic Safety Analysis
SWAT could be used to evaluate new display systems. It could be used to test new airspace designs, air traffic rules and procedures, etc.

Tool Cost

No cost. However, some training is advisable and a rating scheme must be selected.

References

1. Human Engineering Appendix to INCOSE SE Handbook, pp 79-81, US Navy Office of Naval Research, (2000). Available at: http:// www.manningaffordability.com/S&tweb/PUBS/Man_Mach/part1.html
2. Subjective Workload Assessment Technique (SWAT), VNET Resources, available at: http://www.vnet5.org/reg/mfs/mfs_swat.html

Documentation

1. Nygren, T.E. (1982) "Conjoint Measurement and Conjoint Scaling: A User's Guide." (AFAMRL-TR-82-22). USAF Aero Medical Research Laboratory, Wright-Patterson Air Force Base

2. Reid, G.B., Shingledecker, C.A., and Eggemeir, F.T. (1981) "Application of Conjoint Measurement to Workload Scale Development." Proceedings of the Human Factors Society 25th Annual meeting (pp 552-526). Rochester, NY Human Factors Society

Related Tools

Multiple Resources Questionnaire (MRQ)
Continuous Subjective Workload Assessment Technique

Vendor Support

SART is in the public domain, but expert advice is available (see example below).

Point of Contact

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2.6 Text/Data Mining and Data Visualization

This section deals with tools that look at a collection of safety events to determine patterns that might indicate common causal factors, which might lead to effective solutions to reduce the number of these events in the future. This is not an easy task. There are many different kinds of errors and many different combinations of causes for them. The number of events is huge and the data on each of them is considerable. Some of the data are numeric and some (often the most informative) is textual. Some automated means of looking through this large volume of data would be very desirable.

Many automated tools have been and are being developed to automate the examination of large databases. There are three major kinds of tools. Some of the tools perform more than one of these approaches.

2.6.1 <u>Text/Data Mining Tools</u>

Data Mining refers to the process of analyzing a large amount of data in which automated algorithms are used to identify patterns and trends in data as a first step prior to further analysis or examination of the patterns, trends, and associations identified by the data mining process.

Text Mining refers to the process of analyzing freeform text using automated algorithms to identify specific concepts or ideas in the text. These concepts or ideas may be translated into standardized terms in predetermined fields in the database from which the text was taken, in order to provide more structured information for analysis in place of the freeform text.

Aviation Safety Data Mining Workbench

<u>Purpose</u>
To provide a software application that an aviation safety officer can use to search a collection of incidents or aviation related events to find those most similar to a selected event, to find subsets of data that have interesting correlations, and to determine the distribution of selected incident/event attributes.

<u>Description</u>
The Aviation Safety Data Mining Workbench developed by the MITRE Corporation consists of three data mining techniques for application to aviation safety data. The first technique, FindSimilar, uses both information retrieval and data mining methods to analyze text and structured data. FindSimilar is most often employed to search a collection of incidents to find those most similar to a selected incident. This is useful in determining if similar incidents have occurred before, and if so, how they were addressed.

The second technique is called FindAssociations. This technique searches the collection of incidents to find subsets that have interesting correlation. For example, this tool can identify a set of incidents that occur at a common location, for the same or similar aircraft type and for the same problem. Knowing such a subset exists and what factors are in common may help in determining what action to take to reduce or eliminate those incidents in the future.

The third technique is called FindDistributions. This technique focuses on a selected field or attribute of the incidents. It determines an overall distribution for this field. Subsets of the data are then obtained and the distribution of the selected field is calculated for each subset. Those subsets that differ most from the overall distribution are identified as the most interesting. This technique helps in identifying anomalies that may be candidates for action.

In the workbench, data mining is included with other data manipulation and reporting tools to give the aviation safety officer a more complete suite of useful analysis tools. Because it is built within Microsoft

Access, the workbench has capabilities for querying, selecting and reporting data. Access also provides On-Line Analytical Processing (OLAP) capability that complements the 'data-driven' techniques described above. The application is also complementary to certain incident tracking, or data sharing tools.

Aviation Usage
One airline experimented with an evaluation version of the Aviation Safety Data Mining Workbench. MITRE partnered with another airline and tailored the Workbench to analyze some of their air safety reports. A third airline has been using the Workbench to analyze their safety reports in a proof-of-concept effort sponsored by GAIN.

References
Information gathered in Working Group B meetings and at GAIN conferences, with additional information provided by vendor.

Point of Contact
Zohreh Nazeri, MITRE Corporation, phone: 703-883-5841, e-mail: nazeri@mitre.org, web site: http://www.mitre.org/tech_transfer/

FERRET Q

Purpose
To enhance the effectiveness and productivity of decision making, problem solving, and learning in aviation.

Description
Q is the knowledge engine in FERRET. Q technology is a rapid and potentially accurate strategy for identifying information of value (IOV) in electronic text. Q reads electronic files in a wide variety of formats (e.g., Word, Excel, Access, PDF) and identifies IOV using a network of concepts constructed to simulate human understanding. The network of concepts forms a Topic Map stored in XML. Q incorporates a "knowledge engineering" tool that enables user-friendly construction of the concept network. It is written in a modular JAVA format, hence, it is essentially platform independent and it can be used as a "plug-in" in support of a broad spectrum of applications.

The original application of Q was to identify sensitive weapons information in electronic text. It has been applied to provide real-time checking of electronic mail, "intelligent" distribution of electronic files and classification (categorize/catalogue) of documents. It is presently being extended to provide fast, accurate (query-based) search of electronic files. Q promises to be useful in pattern recognition, e.g., associated with human factors analysis of safety data, and in expert-guided education.

Aviation Usage
No airlines are known to be using this tool.

References
Demonstrations and discussions at BWXT Y-12 l.l.c (BWXT Y-12 l.l.c is the Department of Energy management contractor for the Y-12 facility in Oak Ridge).

Points of Contact
Simon D. Rose, 865-574-9494, email: sdr@ornl.gov, Dr. Charles Wilson, 423-263-4983, email: areteq@bellsouth.net, Al Klein, BWXT Y-12 LLC, 865-576-5881, email: ajk@y12.doe.gov

NetOwl

Purpose

SRA's text mining product, NetOwl, provides a tool that analyzes free text, whether contained in newspapers or in mission-critical database records. It automatically analyzes the important events expressed in free text, including such facts as the time of an event, its cause, and other important information. The tool normalizes this information, allowing its insertion in structured format into a database. This enables a user to pose very sophisticated queries and to analyze trends much more easily and accurately.

Description

Traditionally, text or narrative data has been difficult to analyze. SRA's text mining product, NetOwl, is particularly suitable for analyzing such unstructured contexts. NetOwl is based on a technology called Information Extraction, which finds and classifies key phrases in text, such as personal names, corporate names, place names, dates, and monetary expressions. It finds all mentions of a name and links names that refer to the same entity together. Rather than relying on static lists of previously known names, SRA's extraction technology relies on dynamic recognition to achieve high accuracy and coverage at very high speed.

NetOwl also analyzes events in texts. These are more complex than names. For an event, NetOwl identifies the time, the cause, any relevant circumstances (such as, in the case of airplane repair records, the piece of equipment involved). It puts all this information extracted from free text into a structured database format. Once inserted in a database, a user such as an airline safety officer can pose questions that they previously could not. For example, an officer can ask questions—using a standard database query capability—such as how many events with a given cause occurred during a certain time span. In addition, such extracted events can be fed directly to data mining or visualization tools for deeper analysis.

Underlying NetOwl is a general-purpose, extremely fast pattern-matching engine combined with a highly flexible pattern specification language. NetOwl allows the extraction—with minimum effort—of a whole range of events of interest.

Aviation Usage

NetOwl has been applied to a major commercial airline's narrative descriptions of safety incidents and events. The application identified the factors leading up to the reported event, the event itself, and the results of the event. The information extracted included the airport involved; the aircraft's altitude, airspeed, the type of approach; weather conditions; the type of event; and the consequences of the event.

References

Web site: http://www.netowl.com/

Point of Contact

John Maloney, SRA International, phone: 703-803-1553, e-mail: john_maloney@sra.com, web site: http://www.netowl.com/

PolyAnalyst

Purpose
PolyAnalyst is a universal data mining system from MEGAPUTER Intelligence that automates knowledge discovery in large volumes of either structured data or free form text. PolyAnalyst can identify key patterns of terms in text fields and relations between them, extract domain-specific terms and visualize the main correlations between extracted terms and individual values of structured attributes. This enables the user to proactively make informed decisions based on an objective and accurate analysis of *all* available data.

Description
PolyAnalyst is designed to be a comprehensive and user-friendly data and text mining system. It can access data stored in any major commercial database and some proprietary data formats (Excel, SAS), as well as popular document formats. PolyAnalyst offers a broad selection of semantic text analysis, clustering, prediction, and classification algorithms, link analysis, transaction analysis, and powerful visualization capabilities.

PolyAnalyst is built on a conglomerate of powerful and scalable analytical methods including morphological, syntactic and semantic techniques for analyzing free form text; and decision tree, neural network and correlation analysis techniques for processing structured data. This synergetic combination of machine learning and semantic text analysis algorithms allows the user to extract and synchronize the maximum of knowledge hidden in all available data. PolyAnalyst can automatically build semantic taxonomies from text and categorize data records accordingly, extract from textual fields key terms and relations between them, and perform clustering and link analysis for identifying the main patterns in causes and consequences of incidents. For its text processing, PolyAnalyst utilizes a comprehensive semantic dictionary of English, which can be further expanded with user-defined add-on dictionaries.

PolyAnalyst was designed for both business users and data analysts. The user of PolyAnalyst is shielded from the complexities of the performed analysis. Data analysts communicate with the system through a collection of standard dialogs and reports and flexible visualization functions equipped with drill-down capabilities. Business users can receive the results of the analysis over the Internet in a preset reporting template. Reusable analytical scripts can be created and scheduled to execute on new batches of data at a given time.

PolyAnalyst has been used at one airline against a dataset of pilot reports consisting of both structured attributes and textual narratives. The analysis revealed strong correlations between certain incident types, places and aircrafts involved, and specific patterns of values of different attributes. For example, PolyAnalyst helped automatically extract faulty equipment from pilot narratives, map these incidents to the corresponding aircraft, time of the day and flight phase, and visually compare the distribution of problems for different aircraft types. It demonstrated typical patterns of entities and actions associated with different incidents and allowed simple drill down to the original records supporting the discovered patterns.

Aviation Usage
PolyAnalyst has been applied to the analysis of safety incident data at one airline as a proof-of-concept demonstration.

References
Web site: http://www.megaputer.com/

Point of Contact
Richie Kasprzycki, MEGAPUTER Intelligence Inc., phone: 812-330-0118, e-mail: r.kasprzycki@megaputer.com.

QUORUM Perilog

Purpose
QUORUM Perilog methods and tools enable exploratory analysis of large collections of aerospace incident narratives.

Description
QUORUM Perilog (also known as Perilog) exploits the situational structure of "unstructured" narrative incident reports. By modeling the contextual structures of incident narratives, it models the structures of the incidents themselves. This makes it possible to explore narrative databases in an entirely new way. The new methods are patent pending and have been commercially licensed. Perilog is currently being used by the ASRS, and by the ASAP office of a major U.S. airline.

Numerous studies have been conducted since 1995 to develop the methods and to demonstrate their effectiveness. In one key study (McGreevy & Statler 1998), Perilog automatically found incidents relevant to the crash of a Boeing 757 jet in commercial service near Cali, Colombia in December 1995. The accident involved controlled flight into terrain, over-reliance on automation, confusion during descent and approach, problematic operations in foreign airspace, and a number of other factors. All of the text of two accident reports, one from the Colombian government and one from the National Transportation Safety Board, were used as a single query in a QUORUM Perilog search to retrieve relevant incidents from the ASRS database. Experienced analysts judged the relevance of a collection of narratives that included both randomly selected narratives and narratives identified as relevant by Perilog. The analysts independently judged that 84% of Perilog's narratives were relevant to the Cali accident. Subsequent review showed that 92% were actually relevant. Not only were the narratives relevant, they were relevant to the various factors of the accident.

Perilog exploits the situational structures of narrative incident reports to provide capabilities for search by example, keyword-in-context search, flexible phrase search, phrase generation, and phrase discovery (McGreevy 2001). Search by example uses text such as accident or incident narratives as a query to find relevant incident narratives. Keyword-in-context search converts individual query words into detailed topical models and finds relevant narratives. Flexible phrase search accepts any number of phrases of any length as a query to find narratives containing the query phrases and near matches to the query phrases. Phrase generation is a tool for finding phrases in the database that contain a particular word. Phrase discovery finds phrases that are relevant to a query. For example, a query consisting of words like "fatigue" and "sleep" can retrieve hundreds of contextually associated phrases such as "crew duty", "crew rest", "crew scheduling", and "continuous duty overnight". Additional tools include vocabulary review, extraction of phrases from subsets of narratives, and searching within subsets of narratives.

The Perilog tools work together to support exploratory narrative analysis. For example, vocabulary review can suggest words to use as queries in phrase generation or keyword search. Phrases can be extracted from the narratives retrieved by a search, and some or all of those phrases can be used as a query in phrase search. From the narratives retrieved by a keyword or phrase search, narratives of interest can be used as a query in search by example. Further, the results of any search can be defined as a subset, given a name, and used as the scope of any subsequent searches. These interactive and integrated search tools make Perilog particularly useful for investigating problematic situations described in collections of incident narratives, for finding and elaborating operational concepts for taxonomies, and for obtaining a contextual view of incidents for comparison with categorical analyses.

Aviation Usage
A research version of the Perilog software is currently being used by the ASAP office of a major U.S. airline.

Other Comments

The Perilog methods can be licensed from NASA Ames. An example of software to implement the methods is provided as part of the license package. License fees are negotiated on a case-by-case basis. Further information about licensing can be obtained from David Lackner, NASA Ames Commercial Technology Office, Moffett Field, CA 94035-1000. Tel: (650) 604-5761. E-mail: dlackner@mail.arc.nasa.gov.

References

Michael W. McGreevy and Irving C. Statler, *Rating the Relevance of QUORUM-Selected ASRS Incident Narratives to a "Controlled Flight Into Terrain" Accident*, Report NASA/TM-1998-208749, Ames Research Center, Moffett Field, California, September 1998.
Website: http://human-factors.arc.nasa.gov/IHpublications/mcgreevy/ASRS.Cali

Michael W. McGreevy, *Searching the ASRS Database Using QUORUM Keyword Search, Phrase Search, Phrase Generation, and Phrase Discovery*, Report NASA/TM-2001-210913, Ames Research Center, Moffett Field, California, April 2001.
Website: http://human-factors.arc.nasa.gov/IHpublications/mcgreevy/ASRS.search

Point of Contact

Dr. Michael W. McGreevy, System Safety Research Branch, NASA Ames Research Center, Moffett Field, CA 94035-1000. Tel: (650) 604-5784. E-mail: mmcgreevy@mail.arc.nasa.gov.

2.6.2 Data Visualization Tools

Data Visualization refers to the process of arraying data in visual schemes that allow human analysts to draw conclusions about possible patterns, trends, or associations.

PV-WAVE™

Purpose
PV-WAVE is a family of tools designed to do mathematical, statistical, financial, and scientific computations, and to deliver high level 3D interactive visualization.

Description
The PV-WAVE family of products (PV-WAVE, TS-WAVE, and JWAVE) delivers off-the-shelf solutions to data analysts, designers, statisticians, etc. PV-WAVE is oriented toward visualization using OpenGL. This includes advanced modeling techniques such as iso-surfaces, streamlines, implicit modeling, cutting planes, hedgehogs, glyphs, texture mapping, clipping transparency, and Delauney triangulation. TS-WAVE is oriented toward time series analysis with extensions to user-supplied or selected mathematical or statistical functions. JWAVE is a package of Java routines, including an extensive set of predefined JavaBeans, Java classes, and Java applets.

Aviation Usage
PV-WAVE was developed with the aerospace industry in mind, but applications to air traffic management are not known of at this time.

Potential Benefits to Air Traffic Safety Analysis
Air traffic control incidents are very numerous and very varied. We have a little data on most of them, but not much data on very many of them. Perhaps some visualization scheme would allow a look at a lot of the data that we have in order to gain some insights about what trends and relationships are hidden in the mass of data.

Tool Cost
Contact vendor

Documentation
Users manuals and examples are available on the vendor's web site.

References
Web site: http://www.vni.com/products/wave/

Vendor/owner Support
Visual Numerics, Inc., 2000 Crow Canyon Place, Suite 270, San Ramon, CA, 94583, USA

Point of Contact
Email: info@vni.com

Spotfire™

Purpose
Spotfire™ is a data retrieval, visualization, and analysis software package. It allows the user to select combinations of various data elements for analysis to quickly reveal trends, patterns, and relationships that would otherwise be very difficult to identify.

Description
Spotfire is a tool for visual display of data in many dimensions, using 3-d projections and various sizes, shapes, and colors. This allows the user to spot multi-dimensional relationships that might not be detectable through looking at raw numbers or more limited presentations.

Spotfire's visualization technology provides a unique way of examining data relationships. It has a series of built-in heuristics and algorithms to aid the user in discovering alternative views of data.

Aviation Usage
The FAA National Aviation Safety Data Analysis Center (NASDAC) has used Spotfire for over four years as a data visualization tool and as a data integration application to assist in the rapid identification of trends, anomalies, outliers and patterns in aviation safety data.

Documentation
Spotfire is very well documented and comes with an extensive on-line help feature and a 267-page user guide. Spotfire's website provides additional up to date support information.

Potential Benefits to Air Traffic Safety Analysis
The tool is extremely user friendly and is database independent. It can extract a large volume of data from practically any electronic data source. However, the key is the user's knowledge of the data and expertise in the subject matter that allows him/her to suggest possible combinations to examine. The user's skill and the quality of the data will determine the potential benefit achieved.

Tool Cost
Purchase Price: $300-$3000 (various software configurations; one-time cost)

Other Comments
Spotfire provides a collaborative repository through which analysts not only share the results of visual analysis with their peers but also provide access to the underlying data.

Vendor/owner Support
Spotfire, Inc., 212 Elm Street, Somerville, MA 02144 USA (There are also offices in Sweden and Japan.) website, http://www.spotfire.com. Spotfire provides an extensive support network through its offices in Europe and U.S.

Point of Contact
David Bailey, Spotfire, (800)-245-4211, dbailey@spotfire.com

Starlight

Purpose
Starlight is an R&D platform developed for the intelligence community. Starlight uses visual metaphors to depict the contents of large datasets.

Description
Starlight is an information system that couples advanced information modeling and management functionality with a visualization-oriented user interface. This makes relationships that exit among the items visible, enabling powerful new forms of information access, exploitation and control. Starlight is both a powerful information analysis tool and a platform for conducting visualization research.

Starlight marries a variety of different types of "conventional" and novel information visualization capabilities into a single, integrated, information system capable of supporting a wide range of analytical functions. Further, Starlight visualization tools employ a common XML-based information model capable of effectively capturing multiple types of relationships that might exist among information of disparate kinds. Together, these features enable the concurrent visual analysis of a wide variety of information types. The result is a system capable of both accelerating and improving comprehension of the contents of large, complex information collections.

Starlight's integrated GIS system enables time and location analysis to be integrated with data content analysis.

Aviation Usage
None as of yet

Potential Benefits to Air Traffic Safety Analysis
Starlight might reveal unsuspected relationships between selected data elements of selected data sets that could lead to a new understanding of the importance of certain causal factors, linkages, similarities, etc. This might lead to novel approaches for attacking the causes behind certain types of errors.

Tool Cost
Starlight was developed using US government funds and is free for US government clients. However, it contains five proprietary software packages, each of which requires a software license. The Starlight developer has rights to bundle and distribute these licenses. The cost is approximately $13,000.

Documentation
Starlight has embedded help and user's guides and reference materials.

References
website: http://starlight.pnl.gov

Vendor/owner Support
Battelle Memorial Institute, Pacific Northwest Laboratory, P.O. Box 999, Richland, WA 99352 USA
Training classes are available in the Washington, DC area and at the developer's site in Richland, WA.
On-site training and support are available.

Point of Contact
John Pinto, Battelle, (888)-375-7665, john.pinto@pnl.gov

2.7 General Tools for Data Analysis

This chapter contains the summaries of tools not specifically developed for aviation use but could possibly be used for air traffic safety analyses. Many of these tools possibly could be used for airline safety analysis and were included in the WG B's Guide to Methods and Tools for Airline Flight Safety Analysis. They are included here with their potential application to air traffic safety addressed.

Descriptive statistics refers to the treatment of data that summarizes or describes important features of a data set (such as measures of variability and central tendency). Trend Analysis refers to statistical techniques that identify trends in a set of data. These techniques can be used to identify the existence of a trend, its statistical significance and its consistency over time.

There are many other commercially available tools similar to the ones shown that may well be superior in significant respects. It would be impossible to include them all. The reader is encouraged to look further. The ones included were selected only because they are among the most common and are known to be used by an air traffic safety organization.

2.7.1 Database Tools

The following is a brief summary of three kinds of tools: a spreadsheet (Microsoft Excel), a relational database management system suitable for a limited number of simultaneous users (Microsoft Access), and a relational base management system suitable for very large databases and large numbers of simultaneous users (Oracle Discoverer). While these tools are by no means designed specifically for aviation use, anyone considering building a database for air traffic safety data storage and analysis should be aware that these tools and many others like them exist.

Microsoft Access™

Purpose
Microsoft Access™ is the relational database management application in Microsoft Office.

Description
A relational database stores data records in connected tables, enabling data that are common to many records to be placed once in another table, rather than be repeated in multiple records in the first table. For example, if several records of safety events refer to the same ATC facility, information about this facility could be contained in a single record in a table of facility data.

Access allows six kinds of objects:

1. tables – stores data in row-and-column format (similar to a spreadsheet)
2. queries – extracts data from related tables based on user-supplied criteria
3. forms - displays data from a table or query in a user-defined format
4. reports – displays and prints data from a table or query
5. macros – automates common database actions based on user-specified commands
6. module – automates complex data processing operations using a reduced version of the Microsoft Visual Basic language

Access communicates with other Microsoft Office products. For example, Access can export the results of a query as a Microsoft Excel spreadsheet.

Access allows a database of up to gigabytes minus space needed for system objects. It can be accessed simultaneously by a number of users, but performance suffers with more than 5 to 10 users.

Aviation Usage
Access is used by several applications by the Federal Aviation Administration.

Potential Benefits to Air Traffic Safety Analysis
Access allows storage and manipulation of air traffic safety data.

Tool Cost
Contact vendor

Documentation
Many good users guides are provided by Microsoft and other publishers.

References
Web site Microsoft Office Web Site, http://www.microsoft.com/office/access/default.htm

Vendor/owner Support
Microsoft Corporation provides various support and training.

Point of Contact
Web site Microsoft Office Web Site, http://www.microsoft.com/office/access/default.htm

Microsoft Excel

Purpose
Microsoft Excel is a powerful general-purpose spreadsheet program that provides a wide range of capabilities to manage, analyze and chart data.

Description
Microsoft Excel stores data in tabular worksheets of rows and columns, each cell of which can contain textual or numerical data. Multiple worksheets can be stored in a single file termed a workbook. Excel provides a large number of built-in functions and data analysis capabilities to manipulate the contents of these cells and define the contents of cells in terms of the contents of other cells on the same or different worksheets, including worksheets in different workbooks. These functions include mathematical and statistical operations and text-manipulation capabilities.

Excel provides a range of capabilities to chart the data contained in the worksheets in a number of different formats, such as trend lines, bar charts, or pie charts. These capabilities allow users to customize the appearance of the charts and add annotations and drawings to the charts. A ChartWizard function simplifies the creation of charts, which can then be modified with the other built-in capabilities. Excel is designed to be seamlessly integrated with other Microsoft Office products, including the Word (word processing) and Access (data base management) programs. Word documents can incorporate charts and tables that have been created in Excel and the contents of which change if the source data is changed in the Excel file. Similarly, data can be easily imported and exported between Access databases and Excel worksheets. Excel also includes capabilities to access other external databases that support Sequential Query Language (SQL) queries, and supports access to web-based data sources through the inclusion of Unified Resource Locators (URLs) in formulae.

In addition to the statistical functions that are included in the basic capabilities of Excel, Microsoft provides a set of more advanced data analysis tools for use with Excel called the Analysis ToolPak that can be used to save steps when developing complex statistical or engineering analyses. The appropriate statistical or engineering macro function displays the results in an output table. The statistics feature includes: linear best-fit trend, exponential growth trend, FORECAST function, fit a straight trend line by using the TREND function, fit exponential curve by using the GROWTH function, plot a straight line from existing data by using the LINEST function, plot an exponential curve from existing data by using the LOGEST function, and a Descriptive Statistics analysis tool.

More advanced customization is possible through the use of built-in programming capabilities using the Visual Basic programming language.

Aviation Usage
A large number of airlines are known to be using this tool for the analysis of flight safety data and for presenting the results in the form of charts.

Documentation
A very well documented tool. Microsoft provides thorough documentation together with an extensive built-in user "Help" function. A large number of third-party user guidance books are available. Numerous training courses are also widely available, although these usually address general capabilities of the software rather than specific airline applications.

Vendor/owner Support
Microsoft provides various support and training.

Potential Benefits to Air Traffic Safety Analysis
Microsoft Excel provides a wide range of general analytical capabilities, but the successful application to flight safety analysis requires the user to develop the detailed elements of the specific analysis desired.

Tool Cost
Purchase Price: $400

(Purchase price does not include installation, operation, maintenance, or training costs.)

References
Microsoft Office Web Site, http://www.microsoft.com/office/archive/x197brch/default.htm

Point of Contact
Microsoft Office Web Site, http://www.microsoft.com/office/excel/default.htm

Oracle Discoverer™

Purpose
Oracle9iAS Discoverer is a key component of the Oracle9i Application Server. It is an intuitive ad hoc query, reporting, analysis, and Web-publishing tool that empowers users to create, modify, and execute queries and reports.

Description
Some of the features of the current version, Oracle9iAS discoverer are:

Discoverer's intuitive user interface guides the user through the entire process of building sophisticated charts and graphs. Report builders can easily create exception reports to highlight data meeting certain user-specified criteria. Users can perform drills on data or graphs to view and analyze underlying data in order to identify trends and anomalies. Discoverer also includes many advanced analytical functions.

Discoverer's End User Layer (EUL) allows end users to interact with their data in their own terminology. Discoverer's single metadata repository enables all users to access the same metadata. Reports can be interchanged between client/server and web users. This eliminates the need to save multiple versions of the same report or data.

Most query tools, including Discoverer, allow users to set an upper threshold on query execution times. But Discoverer provides an estimate an estimate the retrieval time before a query is run. It also queries the database directly without first moving the data to a proprietary dataset, as does some other systems, and is tightly integrated with the database and so is able to support new database features that become available.

It is imperative that the system performs as well as the first thousand users as the next thousand. Discoverer uses a round robin method to balance the load across all available servers, and stores the metadata in the database that is designed to scale for just that kind of load.

Aviation Usage
Oracle Discover is used by the FAA's Air Traffic Service (ATX-400) to produce its monthly Aviation Safety Statistical Handbook

Potential Benefits to Air Traffic Safety Analysis
Discoverer is particularly well suited for application where many users wish to access a database simultaneously.

Tool Cost
Contact vendor

Documentation
This summary is based on information on the website:
http://otn.oracle/products/discoverer/htdocs/Oracle9iAS20_Disco_FOV.html

References
Web site: http://otn.oracle.com/products/discoverer/content.html

Vendor/owner Support
Oracle, Inc., 1910 Oracle Parkway, Reston, VA 20190 USA

Point(s) of Contact
See the website: http://www.oracle.com/corporate/contant/ or Phone:1-800-ORACLE-1
John Brideweser and Dan Davis at (703) 364-2500, john.brideweser@oracle.com and dan.davis@oracle.com

2.7.2 Statistical Analysis Tools

There are numerous statistical analysis tools available. The following is a sample of these tools.

*SAS*Ò

Purpose
SAS offers an integrated suite of modular products designed to meet a range of focused information needs. The functionality includes: data access, data management, data analysis, and data presentation.

Description
SAS software includes many organization management tools, besides the data management tools.

SAS can access most major databases and sources, including: Microsoft Excel, Oracle, Paradox, HTML, Accesso Lotus 123, and delimited or fixed width text files.

SAS can help manage data by: a Query Builder, a Sort Interface, MDDB/OLAP cubes,

SAS can help analyze data using; correlation analyses, distribution analysis, summary tables, and categorical summaries. All of the standard statistical tests and functions are included.

This is just a small selection of the tools available.

Aviation Usage
Various

Potential Benefits to Air Traffic Safety Analysis
SAS could be useful in analysis of large aviation statistical databases.

Tool Cost
Contact vendor

Documentation

References
Web site: http://www.sas.com/products/guide/all_features.html or
http://www.sas.com/success/industry.html#public

Vendor/owner Support
SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513-2414 USA

Point of Contact
Phone: (800) 727-0025 or (919) 531-4396 or Jim Barillaro, jim.barillaro@sas.com

STATGRAPHICS Plus

Purpose
STATGRAPHICS *Plus* is a statistical analysis package that provides a wide variety of analyses, procedures, and capabilities, ranging from basic statistics to highly advanced and sophisticated techniques.

Description
STATGRAPHICS *Plus* has more than 200 powerful statistical analyses to choose from and a host of innovative features. It guides the user through every statistical analysis or graphics choice they make. It has the look and feel of Microsoft Windows, and is compatible with Windows NT, Windows XP, Windows 2000, Windows 98, or Windows 95. STATGRAPHICS *Plus* allows the user access to graphics in every procedure. The product is available in three different configurations: STATGRAPHICS *Plus* Standard Edition, STATGRAPHICS *Plus* Quality and Design, and STATGRAPHICS *Plus* Professional.

The Professional version includes basic statistical analyses and processes, Quality Control, Design of Experiments, Time Series, Multivariate Statistics and Advanced Regression. Several of the main features of STATGRAPHICS *Plus* include: StatAdvisor, gives the user instant interpretations of results; StatFolio, a revolutionary new way to automatically save and reuse analyses; StatGallery, allows the user to combine multiple text and graphics panes on multiple pages; StatWizard, guides users through a selection of data and analyses; StatReporter, allows the user to publish reports from within STATGRAPHICS *Plus*; StatLink, allows the user to poll data at user-specified intervals. These are just a few of the many features available in STATGRAPHICS *Plus*.

Aviation Usage
No airlines are known to be using this tool.

Documentation
The tool is well documented and comes with on-line help that includes statistics-related resources, information about training courses, technical specifications that list the recommendations for the current version of the software, software patches, and tutorials.

Vendor/owner Support
Always available – In addition to STATGRAPHICS help documentation and on-line help there is 24 hours technical support.

Potential Benefits to Air Traffic Safety Analysis
STATGRAPHICS contains extensive statistical inference and analytical procedures. All available procedures are listed in icons on the toolbar, and their implementation is as easy as point-and-click. This simple set-up makes the tool particularly user-friendly. All analysis results are presented in both graphs and written summaries, which should be very helpful for flight safety analysis. The two built-in features—StatGallery and StatFolio, provide simple and organized report formats for analysis results. These features should help reduce the safety department's labor and also support the safety monitoring process. However, the designs of some of the analysis procedures are somewhat confined to a special type of data and require additional statistical knowledge in its users to make proper modifications.

Tool Cost
Purchase Price: $749 (Standard Edition - U.S. Customer Cost).

(Purchase price does not include installation, operation, maintenance, or training costs.)

References
STATGRAPHICS *Plus*, User Manual, Version 5

Point of Contact

STATGRAPHICS Plus web site http://www.statgraphics.com, 1-800-592-0050, ext. 900 or e-mail: gsales@manu.com

3.0 Observations and Conclusions

3.1 The Challenge of Air Traffic Management Safety Analysis

Analysis of air traffic management (ATM) safety faces the same difficulty as that facing efforts to improve airline safety; the system is so safe that there is very little accident data. Unlike, for example, motor vehicle traffic which every day produce many more accidents than can be analyzed, there are relatively very few aviation accidents to analyze. Those that do occur are studied thoroughly and many useful lessons are learned. However, of these, very few are related to air traffic management. The analysis presented in Section 1.3 of this Guide showed that only about three accidents per year in the United States involve a failure in the air traffic control system as a contributing factor. Air traffic control is the sole contributing factor in few, if any, of these accidents.

Thus we attempt to learn from accidents that didn't happen. We look at cases where the margin of safety was reduced below desired levels by an error, defect, or design. Some refer to these situations as "accident precursors," but most have little or no risk that an accident could have resulted. In order to analyze air traffic safety and estimate the impact that a proposed change or an observed problem might have on safety, we must resort to analysis. We cannot wait for accidents to happen.

3.2 Air Traffic Safety Analysis Tools

This document presents a list of tools of a variety of types. There are many possible ways to organize these tools. No matter which way is tried, it seems that some tools won't fit into any category and others will fit into more than one. This volume presents one way that these tools could be grouped. One reason for this grouping is that it helps make clear the various steps that an analyst in general should go through to study a question on air traffic management safety.

This is by no means a complete list, but an attempt was made to provide a representative cross-section of the available tools. It is hoped that the reader will learn about the existence of some tools of potential interest through this effort. Readers are also encouraged to bring other tools to the attention of the authors, and a feedback form has been provided at the end of this document to facilitate this.

This document views tools in a broad context. Any analytical device that is potentially useful in identifying, defining, or solving a problem relating to air traffic management safety is considered a tool. In order to conduct an analysis, one might need a variety of tools. Which ones are needed will depend on the problem.

The first thing one will almost certainly need is data. Data on past events are available from a wide variety of sources, some of which can be accessed through the tools included in Air Traffic Safety Event Data Systems. These tools have selection and sorting capabilities. There are other systems that contain aviation safety events not related to an air traffic management problem, but only those that contain events of interest to air traffic safety are included.

Reported data on past events must be viewed with caution. They are usually subject to under reporting, contain mistakes and/or subjective opinions, are sometimes incomplete, and can be subject to misinterpretation, to name a few problems. Yet they do have the advantage that they at least have one foot in reality. The reports can sometimes be supplemented with operational data collected at the time, e.g., controller/pilot voice recordings and recorded radar or other flight track data. Tools for processing and displaying these data are discussed under Air Traffic Replay and Non-interactive Simulation Tools.

But data on past events, even if they can tell what happened and why, can't tell what would have happened, if…. For example, if the pilot had begun the descent five seconds sooner, if the controller's radio call had been stepped on, if some new device had been available, etc. This is covered in Risk Analysis Tools.

Some tools use recorded radar or other flight track data collected at times when no incident occurred. These are also presented as Air Traffic Replay and Non-interactive Simulation Tools. These tools usually allow the analyst to change the flight trajectories to simulate new air traffic rules, routings, traffic densities, etc. These capabilities are generally designed to assess operational effects of proposed changes, such as their effect on throughput or delays, although they may also be used to generate measures of interest to safety analysis, such as controller task load or traffic density.

It is tempting to see how close aircraft come to each other as a measure of safety. But as long as safe separation is maintained, it is not necessarily the case that closer proximity implies greater risk. Some situations might look risky, but are not. For example, the pilots might be providing self-separation. No matter how good the recorded data, one does not know what was happening in the pilot's or air traffic controller's mind or what would have happened had there been an actual threat.

There is one way to determine what might go on in the human mind: employ humans in the simulation. We can simulate hazards in the laboratory and see how the human operator, perhaps along with a new automated aid, will react. The Air Traffic Human Interactive Simulation Tools and Facilities section includes a number of human-interactive simulation tools, from simple single-player tools to laboratories where a number of actual pilots and controllers can interact. Which is appropriate will depend on the question to be answered, the precision needed, and the funds available.

One should be cautious about the conclusions that can be drawn from such experimental data. No matter how real the simulation seems to the participants, it is not real. They know it and that might affect the way they react. They know that they are being watched. They know that, sooner or later, a very unusual situation will be presented to them. Perhaps a situation that they are unlikely to see in a lifetime will be presented (because of the cost of paying the human participants every half hour or so, reducing the element of surprise that is crucial to the experiment). These are a few of the problems with human-interactive simulation.

When sufficient data are obtained, the answer might be apparent, or some tool for estimating risk might be required. There are various kinds of Risk Analysis Tools. The field of reliability estimation has produced analytical techniques such as fault trees, event trees, event sequence diagrams, etc., which attempt to reflect the fact that an aviation accident requires the linkage of a long chain of unlikely events. Some of these tools explore these chains with probability analysis. Some just do a sensitivity analysis by running through ranges of parameters. Others drill down into various contributing causes to determine causal factors.

Some are easy to use, but are not very informative. Some are very complex and require expertise and much effort to use. But all are only "best guesses." To be anywhere close to providing accurate results, a large volume of accurate data is required. Even with a reasonably accurate representation of the system, along will come an unlikely chain of events that no one ever imagined.

Almost all failures of the ATC system that have safety implications involve human operator errors. Thus reducing the number of accidents due to an ATM failure is best achieved through reducing the chance for a human error. There have been numerous studies of how to predict and overcome lapses or limitations in human performance. Many tools developed for doing this are discussed in the Human Factors Analysis section. Despite a tremendous effort in this vital and extremely complex area, each has limitations mentioned in the discussion.

Although accidents due to ATM failures are rare, reported errors (the so-called "precursor events") are relatively numerous. They are also very varied. Factors that relate to some kinds of failures will not be significant in others. For example, air traffic control errors on the airport surface and those in the high-altitude en-route airspace will probably have some different and some similar elements. Two incidents that look similar might have resulted from quite different circumstances.

Text/Data Mining and Data Visualization tools provide automated assistance to processing large amounts of data on a large number of records. Most event data records contain both numerical and text data. The numerical data sometimes summarize the information in the text data, but in many cases important information is contained only in the text fields. Data Mining refers to looking for patterns in numerical data. Text mining refers to looking for patterns in text fields. The later is much more difficult because written data usually do not follow rigid formats and taxonomy.

Data visualization refers to graphical display of data in a representation that allows the viewer to see a large number of key variables from different records simultaneously. For example, one variable in the x-direction, another in the y-direction, another in the z-direction, another by color, another by shape, another by texture, etc.

These different kinds of tools are grouped together for two reasons. They all attempt to help the viewer detect and comprehend relationships in a large volume of data with little or no special knowledge of the subject matter built into the tool. And some of the tools perform more than one of the processes.

These tools depend heavily on the user to suggest which of the many data items in these records to examine, and which ways to combine them. Interpretation of the results is always dependent on the skill of the user and the adequacy of the data in the first place. Both leave plenty of room for misleading results.

The final category of tools is General Tools for Data Analysis. These include common off-the-shelf general data processing and analysis tools. There are many other such tools in addition to those mentioned. Those listed are known to been used in the analysis of data relating to air traffic management safety. Their ability to select, sort, and group records, and to perform mathematical and statistical analyses on sets of data have sometimes been sufficient in themselves to answer a question or provide an insight.

3.3 Conclusion

The foregoing discussion has presented samples of seven different types of methods and tools that provide a wide range of capabilities to support air traffic safety analysis. All the types have a place. Probably no one tool will be sufficient. Which tools are useful will depend on the question to be answered. All have shortcomings and pitfalls, only some of which were mentioned in Section 3.2.

Much more work needs to be done to develop improved tools. Much work is underway. One should be aware of the EUROCONTROL programmes HYBRIDGE, ARIBA, and EATMP, to name just a few examples. This report will require considerable revision. But doubtlessly even future tools will have limitations.

All of these tools require considerable skill and knowledge of air traffic management procedures to use effectively, as well, of course, as access to suitable data. Air traffic management issues are often complex and the underlying factors are frequently not well understood, so it is hardly surprising that the results of analysis are sometimes questionable or inconclusive.

In the last analysis, expert judgment has to be used in deciding how much weight to place on any particular result. However, careful analysis provides a framework within which such expertise can be applied, and good analysis requires good tools. It is hoped that this guide will help those undertaking such analysis select the most appropriate tools, and encourage others to become more familiar with the tools that are available.

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List of Acronyms and Abbreviations

ABRM	Analytic Blunder Risk Model
ACAS	Airborne Collision Alert System
ACC	Area Control
ACPA	Air Canada Pilots Association
ADS-B	Automatic Dependant Surveillance - Broadcast
AISG	Accident Incident Safety Group
ALPA	Air Line Pilots Association, International
ANS	Air Navigation System
ANSNAC	Air Navigation System National Advisory Committee
ANSP	Air Navigation Service Providers
ANSR	Air Navigation System Requirements
AOGA	Aircraft Operations Group Association
APP	Approach Operation
AQD	Aviation Quality Database
ARTCC	Air Route Traffic Control Center
ARTT	Aviation Research and Training Tools
ASMT	Automatic Safety Monitoring Tool
ASRS	Aviation Safety Reporting System
ATAC	Air Transport Association of Canada
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATOCC	Air Transport Operations Consultation Committee
ATS	Air Traffic Services
ATSAC	Air Traffic Specialist Association of Canada
ATSAT	Aviation Topics Speech Acts Taxonomy Tool
ATSB	Australian Transport Safety Bureau
BN	Bayesian Net
CAA	Civil Aviation Authority
CAD	Computer Aided Design
CADORS	Civil Aviation Daily Occurrence Reporting System
CAIR	Confidential Aviation Incident Reporting
CAMI	Civil Aerospace Medical Institute
CASE	Controlled Airspace Synthetic Environment
CATCA	Canadian Air Traffic Control Association
CBI	Computer Based Instruction

List of Acronyms and Abbreviations
(continued)

CENA	Centre d'Etudes de la navigation aérienne
CFIT	Controlled Flight Into Terrain
CHI	Computer Human Interface
CHIRP	Confidential Human Factors Reporting Programme
CNS/ATM	Communication, Navigation, Surveillance/Air Traffic Management
COGNET	Cognition as a Network of Tasks
COMM	Communications
CORA	Conflict Resolution Assistant
CTAS	Center/TRACON Automation System
DAT	Director of Air Traffic Services
DATS	Durable Aviation Trainer Solutions
DFS	Deutsche Flugsicherung GmbH
EATMP	European Air Traffic Management Programme
EC	European Commission
ECCAIRS	European Coordinated Centre for Aviation Incidence Reporting
ECFTSG	East Coast Flight Training and Safety Group
EEC	EUROCONTROL Experimental Centre
EFIS	Electronic Flight Instrument System
ETA	Event Tree Analysis
EMS	Emergency Medical Service
EOSID	Engine Out Standard Instrument Departure
EPOQUES	Proposed Tools and Methods
ESCAPE	EUROCONTROL Simulation Capability Platform for Experimentation
ESD	Event Sequence Diagram
ETG	Enhanced Target Generator
FA	Flight Assist
FAA	Federal Aviation Administration
FACET	Future ATM Concepts Evaluation Tool
FSDO	Flight Standards District Office
FSS	Flight Service Station
FTA	Fault Tree Analysis
GA	General Aviation
GAIN	Global Aviation Information Network
GRADE	Graphical Airspace Design Environment
GUI	Graphical User Interface
HEART	Human Error Assessment and Reduction Technique
HERA	Human Error Reduction in ATM
HF	High Frequency

List of Acronyms and Abbreviations
(continued)

HF	Human Factors
HFACS	Human Factors Analysis and Classification System
HMI	Human Machine Interface
HOCSR	Host and Oceanic Computer System Replacement
HTML	Hyper Text Mark-up Language
I2F	Integration and Interoperability Facility
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
IOV	Information of Value
IPAT	Incursion Prevention Action Team
INDICATE	Identifying Needed Defenses in Civil Aviation Transport Environment
IVSI	Instantaneous Vertical Speed Indicator
KG	Kilograms
LFT	Lufthansa Flight Training
LTRACON	Large Terminal Radar Approach Control
MIDAS	Man Machine Integrated Design and Analysis System
MOR	Mandatory Occurrence Reporting
MSAW	Minimum Safe Altitude Warning
NAIMS	National Airspace Information Monitoring System
NARSIM	NLR Air Traffic Control Research Simulator
NASA	National Aeronautics and Space Administration
NASDAC	National Aviation Safety Data Analysis Center
NATCA	National Air Traffic Controllers Association
NATS	National Air Traffic Services
NMAC	Near midair collision
NRL	National Lucht-en Ruimtevaartlaboratorium
NZALPA	New Zealand Airline Pilots Association
NZCAA	New Zealand Civil Aviation Authority
OATS	Operator Action Trees
OCC	Operational Control Center
OD	Operational Deviation
ODID	Operational Display Input Device
OE	Operational Error
OEP	Operational Evolution Plan
OPI	Office of Primary Interest
Ops	Operations
OTI	Operational Time Interval

List of Acronyms and Abbreviations
(continued)

PAR	Precision Approach Radar
PAS	Pseudo Aircraft Systems
PC	Personal computer
PD	Pilot Deviation
PDARS	Performance Data Analysis and Reporting System
POI	Principal Operating Inspector
POWER	Performance and Objective Workload Evaluation Research
PRA	Probabilistic Risk Assessment
PUM	Programmable User Model
PUMA	Programmable User Modeling Applications
QAM	Quality Assurance Management
QRAS	Quantitative Risk Assessment System
RADS	Radar Analysis Debriefing System
RAMS Plus	Reorganized ATC Mathematical Simulator
RASRAM	Reduced Aircraft Separation Risk Analysis Model
RDHFL	Research and Development Human Factors Laboratory
RITA	Replay Interface for TCAS Alerts
RNAV	Area Navigation
RNP	Required Navigation Performance
RI	Runway Incursion
RVSM	Reduced Vertical Separation Minimum
SAGAT	Situation Awareness Global Assessment Technique
SAMPLE	Situation Awareness Model for Pilot-in-the-Loop Evaluation
SAMS	SMGCS Airport Movement Simulator
SART	Situation Awareness Rating Technique
SATSA	Swedish Air Traffic Service Academy
SCRI	Transport Canada Sub-Committee on Runway Incursions
SDAT	Sector Design Analysis Tool
SERENE	Safety and Risk Evaluation using Bayesian Nets
SI	Surface Incident
SID	Standard Instrument Departure
SLIM	Success Likelihood Index Methodology
SLM	Step Ladder Model
SMGCS	Surface Movement Guidance and Control System
SOE	State Owned Enterprise
SQL	Sequential Query Language
STAR	Standard Terminal Arrival
SWAT	Subjective Workload Assessment Tool

List of Acronyms and Abbreviations
(continued)

TAIC	Transport Accident Investigation Commission
TBM	Time Based Metering
TCAS	Traffic Alert and Collision Avoidance System
TESEO	Technique to Estimate Operator's Errors
THERP	Technique for Human Error Rate Prediction
TOKAI	Tool Kit for Occurrence Reporting and Analysis
TOPAZ	Traffic Organization and Perturbation Analyzer
TMA	Terminal Maneuvering Area
TRACON	Terminal Radar Approach Control
TRM	Team Research Management
TTP	TCAS Transition Program
UHF	Ultra High Frequency
URET	User Request Evaluation Tool
URL	Unified Resource Locator
VFR	Visual Flight Rules
VHF	Very High Frequency
VPD	Vehicle/Pedestrian Deviation
VSCS	Voice Switching and Control System
WG	Working Group
WG B	(GAIN) Working Group B, Analytical Methods and Tools

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Feedback Form

GAIN Working Group B encourages the submittal of any comments and/or suggestions that will improve the content of future issues of this guide. Please submit this form to:

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or complete this form at:
http://www.gainweb.org

Name: ______________________________

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1) How useful is this guide on air traffic methods and tools to your organization?
(Please circle one)

not useful - 1 2 3 4 5 - very useful

Comments:______________________________

____

2) What information contained in this guide is most useful to your organization?

____

____

____

3) Which tools shown in this guide have you or your organization used?

____

____

____

4) What tools or other information would you like to see added to this guide?

____

____

____

____

5) What methods or tools does your organization need but does not have now?

____
____
____

6) What are the most significant challenges your organization faces in using or implementing air traffic methods & tools? *(please circle all that apply)*

Management Support	Money
Time	Resources
Knowledge of Existing Tools	Experience
Training	Software/Hardware Limitations

Other:____

7) What activities should WG B undertake in the area of safety analysis in air traffic management that would be most useful to you and your organization? ____________________

____
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8) Would you or someone in your organization be interested in participating in WG B activities? **YES / NO** Would you like to be added to our mailing list? **YES / NO**

Other Comments/Suggestions: ____

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