MEASURING SAFETY WITH FLIGHT DATA

Sheryl L. Chappell
National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California

ABSTRACT

For over two decades, airlines outside of the US have measured safety by routinely screening flight data for deviations from prescribed procedures. NASA is developing a prototype system using a two-pronged approach, to further automate these labor-intensive event-measurement systems and to analyze the complete distributions of the flight parameters. The premise for the latter approach is that, in addition to deviations, much can be gained by analyzing all the flight data on a routine basis. The statistical analyses enable the evaluation of normal as well as extreme flight conditions. Valid operational baselines can be established. Trend analyses make it possible to foresee a potential unsafe operation and intervene before it occurs. In addition to measuring the safety parameters, this research program will develop techniques for determining why an unsafe event occurs. Pilot performance will be measured in terms of error patterns, human limitations, and specific operational implications.

INTRODUCTION

In the United States, flight data have been used extensively for accident investigations. However, in other countries, these data are also used to detect safety problems before accidents occur. Flight Operational Quality Assurance (FOQA) programs have been providing critical safety information to non-US airlines for over two decades. A FOQA program has been defined as "a program for obtaining and analyzing data recorded in flight to improve flight crew performance, air carrier training programs and operating procedures, air traffic control procedures, airport maintenance and design, and aircraft operations and design" (Flight Safety Foundation, 1992, p. 1). Currently, more than 25 non-US airlines screen flight data for deviations from prescribed operations. Some airlines perform these analyses on data from all flights. (For an extensive review of existing FOQA programs, see Flight Safety Foundation, 1992.)

The National Aeronautics and Space Administration (NASA), with support from the Federal Aviation Administration, is addressing the safety needs of the US air transport industry with a program titled Automated Performance Measuring System (APMS). The program has the challenge of converting flight data into useful safety information. This information must provide needed feedback to the airlines and to the flight crews. This research effort addresses the practical problems in implementing currently-available flight data safety programs. In addition, this research program takes the unique approach of applying robust statistical methods to evaluate the distributions of flight data parameters.

Once the level of safety is appraised, the causes of safety problems must be determined. Many of those causes stem from the interaction of the pilot and the aircraft, the air traffic system, and other crew members. Techniques will be explored to identify these causes and assess remedial measures.

Presented at the Eighth International Symposium on Aviation Psychology, Columbus, Ohio, April 24-27, 1995.

APPROACH

Current FOQA Programs

The APMS team has surveyed the safety programs in use at airlines around the world. These programs carefully track events that exceed operational tolerances. For example, if the flaps/slats are extended at an excessive airspeed, the event detection software will produce a report of this occurrence. These events are counted and reports generated, typically by aircraft type. Training and flight standards personnel use this information to continually track the level of safety. Problems with an individual pilot's rotation technique, a flight director algorithm, an aircraft's fuel system, and individual engine anomalies have been detected by these programs. The event detection and tracking systems developed by these airlines would, if implemented, provide valuable safety information to US carriers.

Unfortunately, this approach currently requires a great deal of human analysis for many of the events found in the flight data. The NASA team is undertaking a feasibility study to determine whether an additional level of software analyses could automate this process, with minimal loss of safety information. These analyses would draw upon state-of-the-art knowledge-based-engineering techniques. Emphasis is being placed on eliminating many of the false positives that are currently detected by the human analysts. In addition, further clarification of the correctly identified events may be possible with advanced knowledge-based systems. For example, one type of event may have several causal roots that are determined by the analyst. This classification process may be a candidate for automated analysis.

Distribution Analyses

Current FOQA programs only address events that are in the extreme tails of the frequency distributions of flight parameters. The nature of these distributions is currently not known. It is impossible, for example, to determine how closely the mean airspeed on approach resembles the target airspeed (V_{ref}). The amount of variability under normal conditions is not known. Operational procedures prescribe tolerances, e.g., approach airspeed within five knots. However, is the standard deviation greater, perhaps 10 knots? Do pilots allow a greater deviation above the target speed than below? At what altitude do pilots generally attain a stabilized approach? Does this vary with different airports or air traffic procedures? Are company procedures being applied in a consistent way across all fleets? When on an automatically controlled descent profile, how do pilots implement a temporary level-off demanded by the controller? Do they use the keyboard, the altitude dial on the mode control panel, or manually level the aircraft? None of these questions can be addressed by current flight data safety programs.

Technological improvements in data compression, storage, and computation allow much more functionality for flight data safety systems being developed today. A major enhancement to event detection programs comes from the ability to retain data from all the flights. The full population can be determined for most flight parameters. For example, the approach speed can be measured every second for every flight. This is a luxury seldom possible in statistical analyses. It enables the use of powerful statistical techniques.

From these data, a baseline can be established for each important parameter in each phase of flight. These baselines can be used by flight standards departments to establish procedures that are realistic, i.e., the pilot can maintain these standards in most flight conditions. The baselines can be used by airframe manufactures to create displays that allow the pilot to easily determine if the parameter has exceeded tolerance. These baselines can be used to develop safe air traffic procedures that allow for normal variability in flying accuracy. A very important advantage to measuring baselines is that current data can be compared against the baseline to test statistically for the existence of trends, both in the direction of operations becoming less safe and in safety improvements. Training and operations personnel can readily make use of this valuable feedback to determine the efficacy of safety programs and the need to take immediate remedial action.

Quantifying the distributions of flight parameters also allows the prediction of events before they occur. This includes the ability to assign a probability to the occurrence of multiple failures, which, when compounded, may have serious safety consequences.

Pilot Feedback

Most of the current FOQA programs concentrate on providing feedback to the airline to determine the level of safety across the fleets. This feedback is viewed by the airlines as invaluable for maintaining a safe airline operation. An important feedback loop, that must not be overlooked, is the need of the individual pilot for information regarding flying skills. The richness of actual flight data is not available through any other mechanism. Feedback of both positive and negative experiences can greatly improve the performance of a pilot. Timely access to the data from flights that were exceptionally well flown and ones that were less well conducted can provide specific information that immediately addresses pilot performance at its source. Bad habits can be squelched quickly. Good techniques can be further perfected. For example, a pilot may wish to review the response made to a collision avoidance system command on a recent flight. An aggressive response to climb may have resulted in an excessive vertical speed, causing a greater altitude change than desired.

METHOD

User-Needs Study

A user-needs study is being conducted as part of the NASA APMS program, to determine the requirements for safety information within the different departments of an airline. Input will be solicited from personnel involved with pilot training, corporate safety, flight standards, pilot labor organizations and individual pilots. Once it is determined what safety questions need to be answered by each group, the statistical analyses will be mapped to the appropriate parameters and the optimum presentation method and user interface will be explored. The user-needs study will take an iterative approach; the user will have input into the design and will be asked to provide feedback on the usability of the prototype in successive stages of development.

System Design

Based on the findings of the user-needs study, the APMS program will develop a set of prototype tools for the airlines to evaluate safety using flight data on a routine basis. These tools will have many components, including commercially available software and hardware and additional capabilities developed by NASA. These components will be accessed through a common graphical user interface. Flight data will be input directly into the system. Deidentification will occur immediately. A link between the data and a flight crew will not be possible. The data retrieval system will be secure; only company-authorized personnel will have access to the raw data.

The capabilities developed by airlines with long-standing FOQA programs, for detecting and tracking safety events, will be incorporated in the prototype. Additional analyses will further automate the event verification. Selected flight parameters will be statistically analyzed to determine the measures of central tendency and variability. The data will be analyzed for the presence of trends across time, in either a positive or negative direction. The results of the analyses will be presented to the user in a concise form designed to minimize the risk of misinterpretation. Hard copy reports will be generated in real-time, as requested by the user.

Database Mining

When measuring flight safety, it is not sufficient to merely answer the questions generated by even the most knowledgeable aviation experts. Safety demands the prediction of problems that were not imagined possible. The data must portray unsafe events that the analysis system was not specifically designed to illuminate. To facilitate database mining, three features are important: easy access to the data, extensive data visualization, and vast statistical capabilities. The APMS is designed to get the data in the hands of many people with different operational perspectives. An engine specialist will look at different parameters and will see the same parameters differently than a chief pilot. Easy access to the data by all these individuals is an important characteristic of a flight data analysis system.

Once the appropriate data are retrieved, the capability to manipulate the data graphically is imperative. This feature is the second element of the APMS that promotes database mining. Taking many cross-sections through the data can reveal anomalies that are not discoverable by even an ambitious repertoire of analyses. The users will be able to select any parameter or combination of parameters to be presented using a host of data visualization techniques. One powerful data visualization tool will enable the animation of flight parameters such that the user will be able to watch an aircraft model as it flies, observing flight control movements, instrument indications and the outside scene. The aircraft trajectory can be compared with navigational information, e.g., localizer and glide slope. The perspective viewing angle can be manipulated, as well as zooming in and out, e.g., to see ground features such as the runway.

The third characteristic is a complement of traditional and advanced numerical analysis methods. An extensive library of statistical procedures is available in the APMS from standard statistical packages, accessed through a custom graphical user interface. For example, a fleet manager may suspect that a new noise abatement procedure at a hub airport is the cause of an increased number of 'rushed approaches' found by the event detection routines. An analysis of variance can easily be performed on the parameters for approaches before and after the procedure was implemented. Additionally, advanced research methods can be applied to the data. These techniques will systematically reveal safety issues, based on the values of the data, not hypotheses generated in advance. Cluster analysis and pattern recognition are pivotal to these advanced database mining methods. By arming operational experts from many different perspectives with powerful data retrieval, analysis and presentation capabilities, the chances of safety problems being detected at the earliest possible opportunity are maximized.

IMPLICATIONS FOR FURTHER RESEARCH

The first step in improving safety is to determine the existence of safety problems. The second step is to determine what caused the problems. An increasing proportion of the causes of safety problems lies in the area of pilot performance. To improve pilot performance, evaluations of flight deck procedures, air traffic procedures, aircraft interface design, and pilot training must be conducted in the context of basic human characteristics. Laboratory research in this field is useful in illuminating specific effects of various components of the operational environment. However, many findings in the laboratory change or disappear when tested in the real world. The acquisition of actual flight data will provide a quantum improvement in our understanding of how pilots interact with their aircraft and the airspace system. Baseline operational performance has never been available, resulting in a void in knowledge of how systems are used and how accurate aircraft control is under normal circumstances. When the normal variability is known, it can be taken into account in designing aircraft interfaces and airspace procedures that are robust.

The third step in improving safety is to construct solutions for the problems, after they are identified. The availability of flight data will greatly enhance this process and serve to focus research on relevant operational issues. The efficacy of changes in procedures can be directly evaluated. Negative side effects of those changes can be immediately discovered and corrected. The system as a whole can be made more error-tolerant once errors can be better measured.

CONCLUSION

Flight data analysis has profound potential for raising the level of safety in air travel. The APMS will combine event detection systems and statistical analyses based on flight parameter distributions to create a feedback mechanism that is revolutionary. The feedback can directly improve the individual pilot's performance as well as the airline's safety record. While human error remains the number one contributor to accidents, the measurement of human performance in the context of the operational environment can lend tremendous insight to underlying problems that prevent a pilot from conducting a safe flight.

REFERENCES

Flight Safety Foundation (1992). *Air Carrier Voluntary Flight Operational Quality Assurance Program.* Arlington, VA: Flight Safety Foundation.