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The National Aviation Operational Monitoring Service: Development of a Survey Methodology

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The National Aviation Operational Monitoring Service (NAOMS) was a research project designed to develop a methodology for acquiring information on changes over time in safety-related events occurring in the National Airspace System. A scientifically designed survey was used to measure the experiences of front-line operators and to evaluate trends that could compromise safety. Information from NAOMS could be the first indication of a developing situation, providing the basis for further investigation using other sources. This paper reports on a demonstration of the NAOMS concept through development and conduct of a survey of air carrier pilots. Data from over 18,000 randomly selected pilots were taken over a three-year period. Results of this demonstration provide evidence that the NAOMS survey methodology can reliably identify changes over time in the rates of occurrence of safety-related events.

The National Airspace System (NAS) is an exceptionally safe system. However, it is constantly buffeted by technological, procedural, and other changes which may affect the safety of the system. Implementation of the Next Generation Air Transportation System (NextGen, FAA, 2012) will significantly increase the rate at which these changes occur. Several approaches are currently available to assess the impact on the NAS of technological and other innovations. One approach is to compile voluntary reports of safety-related events. This approach, exemplified by the Aviation Safety Reporting System (ASRS), is able to obtain data from across the system. However, because potential respondents choose what and when to report, the accumulated data may not reflect the operation of the system as a whole. Another approach is to use automatically recorded flight data. This approach, exemplified by the Flight Operational Quality Assurance (FOQA) program, can provide statistically reliable data but only some factors can be recorded and only from some users of the airspace system. Several organizations, (White House Commission on Aviation Safety and Security, 1998; Government Accounting Office, 2000; National Transportation Safety Board, 2000,) recognized the gaps in information and called for better data to effectively monitor the status of the NAS. The National Aviation Operational Monitoring Service (NAOMS) project (conducted during the years 2000 to 2005) was established to determine if this need could be addressed through a comprehensive statistically sound survey of NAS operations.

The central purpose of NAOMS was to develop the methodology for a reliable, comprehensive and coherent evaluation of the safety-related experiences of operators of the airspace system – pilots, controllers, maintenance personnel, and cabin attendants. It was hypothesized that a well-designed survey could provide the needed data by relating operator experiences to their corresponding exposure opportunity. This paper briefly describes the NAOMS concept and summarizes the methods developed, the design of the survey instrument for air carrier pilots, the conduct of the air carrier pilot survey, and the results of the analyses of the data obtained. For a more complete report of the NAOMS project, see Connors, Mauro, and Statler (2012)

Concept

The primary goals of NAOMS was to: 1) determine if survey data could be collected in a systematic and objective manner with sufficient statistical power to allow meaningful interpretation, 2) determine the limitations of this approach, and 3) lay the foundation for a future continuing monitoring service. NAOMS was designed to be a reliable pointer to potential safety events that could be further evaluated through other means; it was not designed to provide explanations for these events or to identify appropriate interventions. The NAOMS concept envisioned collecting data from various operators – pilots, air traffic controllers, mechanics, and cabin crews. For this research effort, one group – air carrier pilots – was selected to assess the feasibility of the method. However, the concept could be applied to other operator groups, though the details of the application would need to be specific to each group.

Methods

Because the primary purpose of NAOMS was to determine the feasibility of using a statistically sound survey to obtain information that was unavailable through other means, substantial effort was devoted to resolving methodological issues. The key issues that had to be resolved before the survey could be conducted are described briefly here.

Questionnaire Design

The NAOMS team obtained external reviews of the concept and the desired approach during focus group sessions with air-carrier pilots, consultations with aviation safety and survey methodology experts, and multiple briefings with peers in the FAA and NASA. The opinions of the aviation community were elicited on the events to be addressed, question formats for each event, the order of the questions, and the structure of the survey instrument. Emphasis was placed on identifying the safety topics appropriate for a longitudinal survey designed to reveal changes over time in the rates of potentially threatening events. In its final form, the survey was divided into four sections: Section A obtained information on the respondent's flying during the reporting period. This included information on the hours and legs flown by make and model of aircraft, type of operation – cargo or passenger, and crew position. Flight hours and legs flown are measures of risk exposure; i.e., the opportunity the pilot had to experience a safety event during the time investigated. This "risk opportunity" formed the denominator of the event rates used in the analyses. In addition, some background information (e.g., the interviewee's life-time total commercial flight hours) was obtained. Section B consisted of 96 safety-related questions

that elicited information on the number of events experienced by the interviewee during the reporting period. This "risk experience" formed the numerator of the event rates used in the analyses. Section C was included to provide quick looks at topics of interest to the aviation community. Section D asked the respondent about the questionnaire and the survey process.

Survey Mode

To determine the most appropriate way of interacting with respondents, the NAOMS team initially compared in-person, telephone, and mail modes of conducting the survey. Later, the use of an Internet-based survey was explored. It was concluded that telephone interviews represented the best compromise between achieving high response rates and keeping costs within project limits.

Recall Period

One of the most important methodological decisions dealt with the recall period, i.e. the period for which the pilot respondents would be asked to recall safety events. Based on previous research, it was clear that the recall period would affect the accuracy of the recall -- the shorter the recall period, the more accurate the information recalled. However, the longer the recall period, the greater the number of events that are likely to be captured in a single interview. Determining the best compromise between accuracy and the amount of information obtained required substantial investigation. This issue was studied through experiments and small-scale field tests of prototype surveys. The NAOMS team compromised on a 60-day recall period. The general form of the questions posed to the pilot subjects was "How many times during the last 60 days have you experienced [insert specific event.]"

Sample Composition

Obtaining an appropriate pool from which to sample air carrier pilots was a significant challenge. Eventually, it was decided to use the public FAA Airmen Certification database and to randomly select from those United States based pilots who possessed an airline transport pilot certificate, a current first-class medical certificate, a multi-engine rating, and a flight engineer certificate.

Sample Size

Some events happen very rarely and achieving statistical reliability for these events would require an investigation that far exceeded the limits of the NAOMS project. Estimates indicated that 8,000 interviews per year could detect 20% rate shifts with 95% confidence for about half the questions of Section B (Battelle, 2007). The NAOMS team determined that this would be adequate to assess the applicability of the methodology and established 8,000 interviews per year as a goal

Random vs. Panel Sampling

It was decided relatively early in the design process that direct random sampling (without replacement for one year) offered more advantages than did panel sampling.

Interview Procedure

Procedures recommended by Dillman (1978) were followed to engage the pilots and increase participation. Experienced, professionally trained interviewers conducted all interviews. The combination of the factors employed to identify, contact, and engage the respondents resulted in an 81% response rate for those identified and located.

Analyses and Results

The NAOMS air carrier interviews were conducted evenly from January 2002 through December 2004. Data from 18,377 air carrier pilots who met the inclusion criteria were analyzed. (See Connors, Mauro and Statler (2012) for a full description of the limits for inclusion.) Of the 96 questions in Section B, 43 questions captured sufficient numbers of events to allow reliable statistical analysis. The remaining events were too infrequent to allow reliable analysis over the three years of the study. If the study were conducted over a longer period, it is likely that additional questions could be reliably analyzed.

To assess changes over time for the 36-month data collection period, data were grouped into 3 years with 4 quarters in each year. The data were then analyzed to detect linear changes over these 12 quarters. In additional analyses, year-to-year changes and seasonal effects were examined. Because the type of operation can also affect the likelihood of encountering safety-related events, the effects on event rates of aircraft category and cargo/passenger operation also were examined alone and in conjunction with the changes over time.

A series of Negative Binomial regressions were conducted to detect the effects of the predictors described above. Of the 43 questions analyzed in the air-carrier study, 16 questions showed linear trends over the 12 quarters. Fourteen of these events showed reductions in event rates over the time investigated, two showed increasing rates of events. These results indicate that, during this time period, when linear trends were observed, they were predominantly in the direction of greater safety.

Seventeen events revealed significant year-to-year changes. For most of these events, the changes mirrored the linear trends by quarters. However, for three events for which there were no significant linear trends across quarters, there were significant year-to-year non-linear effects.

Statistically significant seasonal effects were observed for 21 of the 43 questions analyzed. The time period represented by each quarter approximated a season of the year, providing an opportunity to assess factors related to seasonal weather (e.g., icing, thunderstorms) or other factors (e.g., tourist travel) that vary regularly across the year.

The operation in which an aircraft is engaged is a major factor affecting the number of specific events encountered and whether some events are experienced at all. The effects of differences among aircraft categories are complex, reflecting the specific types of operations for which these aircraft are used. Significant main effects for aircraft category were found for 36 of the 43 events analyzed. Interactions between aircraft category and year/season were observed for 16 events, indicating that the temporal patterns in these event rates differed by aircraft category.

The survey data were further analyzed according to whether the reporting pilot was engaged in cargo or passenger transport. Of the 43 questions analyzed, four were specific to events involving passengers, and therefore resulted in very few, or no, reports of those events from cargo pilots. For 13 events, there were no differences between operation types. For 20 events, rates were higher in cargo operations than in passenger operations. For six events, rates were higher in passenger operations than in cargo operations.

Full descriptions of the analyses for the 43 questions are reported in Connors, Mauro and Statler (2012).

Considerations for Future Implementations

For any survey to yield valid inferences about a population, it must be based on an appropriate sample. For any method to be practical, it must be cost effective. Before the NAOMS methodology can be implemented on a regular basis, both issues must be addressed for each intended target population.

To obtain a sample of air carrier pilots for the NAOMS survey, pilots were drawn from the public FAA Airmen Certification database. This database does not include employment information. Although all air carrier pilots must have either a Commercial or Airline Transport Pilot certificate, possession of one of these certificates does not guarantee that the pilot is employed by an air carrier. Many pilots obtain these certificates but do not use them. To narrow the pool before attempting to contact potential participants, additional selection criteria were imposed (see Methods above). These requirements resulted in the exclusion of some air carrier pilots. Furthermore, during the NAOMS survey period, the FAA was instructed to allow pilots to "opt-out" of the public Airmen Certification database. This too resulted in the exclusion of some air carrier pilots from the sample. Although there was no reason to expect that the pilots excluded from the sample would experience events at different rates from those included in the sample, analyses were conducted to test this hypothesis. Little evidence of any effect of the exclusions was found. However, similar concerns could arise in selecting samples for other segments (e.g., air traffic controllers, mechanics) of the NAS. In any future implementation of a NAOMS-like system, we expect that all segments of the pilot population would be included and recommend that the most complete databases for every segment be used so that no sample selection issues would arise. Obtaining a simple or stratified random sample would eliminate the need to evaluate the samples for potential biases.

The costs of conducting a telephone-based survey are quite high compared to alternative methods. The NAOMS team recognized that a web-based survey could substantially reduce

costs and, near the end of the project, conducted a small study that evaluated this mode. In contrast with the very high response rate obtained in the telephone survey, the web-based approach resulted in a low response rate. However, there may be ways to improve the response rate of the Internet-based survey. It is also possible that a response rate lower than that achieved by the NAOMS telephone-based survey may be adequate. Additional research should be conducted to identify ways in which the integrity and reliability of the survey system can be maintained while lowering costs.

Conclusions

The NAOMS project demonstrated that a scientifically sound survey could provide a statistically reliable method for routinely assessing the status of the National Airspace System along across a range of dimensions. The use of a computer-supported, telephone interview methodology proved highly effective in addressing the main NAOMS objective - identifying changes in event rates over time. It also demonstrated the ability to identify some characteristics of the aircraft and the operations in which the respondents are engaged that are associated with increased vulnerability to encounter specific events. Demonstrated here for air carrier pilots, there is every reason to believe that the NAOMS concept may be applied with similar success to other operational user groups. When combined with information from ASRS, FOQA, and other data sources, a richer, more complete picture of the entire system can be obtained and this knowledge can be used to enhance safety.

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