A Longitudinal Analysis of the Causal Factors in Major Aviation Accidents in the USA from 1976 to 2006

Chris.W. Johnson (1) and C.M. Holloway (2)

(1) Department of Computing Science, University of Glasgow, Glasgow, UK.
Johnson@dcs.gla.ac.uk

(2) NASA Langley Research Center, Hampton Roads, VA, USA.
c.m.holloway@larc.nasa.gov

Abstract
This paper forms part of a long term analysis to understand the causes of aviation accidents across US air space. The intention is to understand the role that organisational issues, human error, technical failures and environmental factors play in adverse events. This is important because the recommendations that are intended to avoid future mishaps are determined by the causes that are identified in accident and incident reports. We are also concerned to determine whether these causal factors have changed over time either as a consequence of changes in the aviation industry, such as the introduction of more advanced safety management practices, or as a result of changes in the way in which accidents are investigated. In previous work, we have identified patterns in the causes of aviation accidents between 1996 and 2004. This interval was chosen because the relevant reports were made available via the NTSB web site. In this paper, we extend our analysis to include all major US aviation accidents between 1976 and 1984. We also consider the most recent series of reports up to 2006. We conclude by identifying significant differences in the causes of these accidents across these different samples.

Keywords: Accident Analysis; Causal Factors; Aviation.

Introduction
Accident reports play an important role in the development of safety-critical systems. They provide a key feedback mechanism that helps to ensure previous weaknesses are not replicated in future systems. However, the findings in these documents can be influenced by a number of factors. For example, the nature of accidents can vary over time as new technologies and working practices are introduced into an industry. For example, the development of automated control systems can reduce the opportunity for direct human error as a cause in many accidents. Similarly, changes in market structure can create problems as organisations work to establish safety management systems within new companies. These can be called ‘primary factors’ because they lead directly to changes in the causes of accidents. There are also ‘secondary factors’ that can influence the causes that are identified in accident reports. The last decade has seen significant changes in the ways in which investigators are trained. For instance, the NSTB has recently established an academy to provide a focus for many of its career development activities. Similarly, there have been significant changes in the way in which we distinguish between the immediate or catalytic causes of adverse events and the latent or underlying causes. This has stemmed from a realisation of the need to look beyond operator errors to consider the organisational causes of accidents and incidents (Reason, 1997).

There have been very few studies into the primary and secondary changes that affect the causes identified in major accident reports. Many investigatory agencies, including the US National Transportation Safety Board (NTSB), provide detailed statistical summaries of the frequency of accidents over time in a number of different categories, including type of operation, aircraft type etc. However, we have been unable to find any previous longitudinal study of the ways in which the causes cited in major accident reports change over time. This is a significant omission. If we can identify changing patterns in the distribution of causes then this will help to provide important insights both into the changing safety record of particular industries and into the impact of changing investigatory practices. In other words, it will provide important feedback on a principle feedback mechanism for lessons learned in safety-critical systems.

The following pages present the findings from a longitudinal study of the causes of aviation accidents in the United States for three sample periods between 1976 and 2006. This period was chosen because the mid-seventies saw the initial rise in mass commercial aviation transport as new levels of affluence reached many communities. This period also saw significant technical innovation in aircraft design and development, for instance with the introduction of the Boeing 747 at the start of the decade. Taking such a 'long view' creates a number of logistical problems. The NTSB provides electronic access to its major accident reports via their web site but only, at the time of writing, for reports from 1996. Earlier accident investigations are archived by Embry-Riddle Aeronautical University and we are indebted both to the NTSB and to Embry-Riddle for providing access to these important resources. The appendix to this paper includes the NTSB reference numbers for all of the reports used in this analysis.

Methodology

Each major accident report can refer to several different causal and contributory factors. For example, one of the most recent reports, AAR-05/02, contains the following summary:

> "The National Transportation Safety Board determines the probable cause(s) of this accident as follows: the pilots' failure to follow established procedures and properly conduct a non-precision instrument approach at night in IMC, including their descent below the minimum descent altitude (MDA) before required visual cues were available (which continued unmoderated until the airplane struck the trees) and their failure to adhere to the established division of duties between the flying and non-flying (monitoring) pilot. Contributing to the accident was the pilots' failure to make standard callouts and the current Federal Aviation Regulations that allow pilots to descend below the MDA into a region in which safe obstacle clearance is not assured based upon seeing only the airport approach lights. The pilots' unprofessional behavior during the flight and their fatigue likely contributed to their degraded performance".

From this excerpt we can identify human error on the part of the pilot as a causal factor. We can also identify regulatory issues amongst the contributory factors towards this accident. In the following analysis it is, therefore, important to recall that there will typically be many more causal factors than accident reports given that adverse events are rarely the result of single failures. There may be interdependencies between causes. For instance, an initial human error might make subsequent mistakes more likely. However, these dependencies are not always apparent in the synopses and so are not considered in this initial study. The one to many relationship between accidents and causal factors created further logistical issues that, in turn, influenced our choice of methodology. Given limited resources and the potentially large number of candidate reports across the period being considered we decided to compare all major accident reports from two eight year periods. We chose 1976-1984 as the starting point. This yielded 137 investigations from the NTSB archive held at Embrey-Riddle. We then selected a second eight-year sample using the most recent complete set of reports that were available when the study started, this period from 1996 to 2004 yielded only 27 major accident reports. Recall that it can take several months after an initial report for the full report to be published and so there are several reports relating to previous years that are still under consideration. All reports for 2004 were finalised hence we focused on this as the end point for the second sample. For completeness, however, the closing sections will consider a final small sample of 5 major accidents that were investigated between 2004 and 2006.

From this brief summary it should be apparent that the decision to base samples on eight year intervals creates some problems for our study. Continual safety improvements have resulted in a significant fall in the frequency of major aviation accidents over this thirty year period. Hence our initial sample contains over four times as many reports as the second one. The summary statistical analyses must therefore focus on the proportion of causes in particular categories rather than simple numerical comparisons. The decision to proceed in this way was justified by the difficulty of selecting further samples from within the data set. However, further work intends to reconsider this sampling strategy in order to support more sophisticated statistical comparisons. This will support an extension of our work from major accident reports to consider the much larger mass of low consequence or near-miss incident reports that have been archived by schemes such as NASA's Aviation Safety Reporting System (ASRS). However, this further work must also consider the problems of under reporting and bias that can affect these systems. The protection and immunity offered by the ASRS arguably makes it more likely that aircrews will document instances of human error through this scheme than, for instance, technical failure. In contrast, our focus on major incidents leading to hull loss or fatalities helps to avoid problems of under-reporting (Johnson and Holloway, 2004).

The previous quotation from a 2006 report illustrates further issues that complicate the analysis of causal factors in major accident reports. It is possible to identify several different forms of human error in this account. The subsequent analysis could proceed by simply identifying all accident reports that involved any form of human error. Hence, in any subsequent statistical analysis we would only refer to a single case of human error for AAR-05/02. In contrast, we chose to distinguish between several instances of the same general cause. In consequence, we would record one human error for the pilots' failure to "follow established procedures and properly conduct a non-precision instrument approach at night in IMC" and another for their "failure to adhere to the established division of duties between the flying and non-flying (monitoring) pilot". This approach creates problems of subjectivity. The analyst must consider the prose in the NTSB report in considerable detail in order to distinguish between different instances of a particular cause. This subjectivity becomes even more problematic when attempting to distinguish between different causal factors. For example, one of the early NTSB reports in our samples, AAR-76-02, argued that the "overweight condition of the aircraft may have contributed to the pilot's actions". This contributory factor can be classified in a number of ways. At first sight, it might simply be interpreted as an aircraft or equipment problem. However, it might also be classified as a further form of human error because the pilot took the decision to take off with the overweight condition. Alternatively, this contributory factor can be interpreted as the result of managerial failures for creating a situation where the aircraft was above the relevant weight limits in the first place.

One way of reducing these problems of interpretation is to develop a classification script or protocol that can be used to guide the analyst and, therefore, help to replicate the results of any study (Holloway and Johnson, 2004). Such protocols, typically, also include taxonomies that enumerate the categories to be used in any classification. This creates considerable problems when analyzing a broad range of causes across several hundred accident reports. The taxonomy must consider everything from wildlife demographics that contribute to bird strikes through to particular meteorological factors that can lead to runway accidents. There is also no guarantee that such protocols will achieve the desired levels of consistency (Johnson, 2003). In contrast, we chose to develop a method of independent, free classification with moderation. In other words, both analysts independently considered all of the accident reports in our sample. They did not use any predefined classification scheme and were free to group causal or contributory factors in any way that seemed to be appropriate. We then held a moderation meeting where the different classes identified by each analyst were grouped into the same higher level classification: Equipment; Organizational; Human Error; Other. During this moderation process, each analyst was given the opportunity to revise their assessment. However, there was no attempt to ensure absolute agreement between the individual interpretations of the NTSB findings.

Results For First Eight Year Sample: 1976 to 1984 (N=137)
After the initial analysis of the 137 major accident reports in the NTSB archive from 1976 until 1984, both analysts identified 396 different causal and contributory factors. As might be expected, there were significant differences between their more detailed classifications. These are illustrated in table 1.

Analyst M	
Human error	198
Equipment	53
Environment	46
Management	39
Regulator	25
Maintenance	22
Undetermined	13
Total	396

Analyst J	
Human error	197
Equipment	11
Environment	4
Management	46
Regulator	24
Maintenance	24
Undetermined	18
Design	25
Air Frame	2
Meteorological /wild life	45
Total	396

Table 1: Inter-Analyst Comparison of Initial Classification for 1976 to 1984

From these initial figures we can derive a higher level classification. In the case of analyst M, management, regulatory and maintenance issues can be combined under 'organisational causes'. Similarly, we can group environmental causes with undetermined factors in another category. For analyst J, Air Frame, equipment and design can all be grouped under equipment related causes. Organisational causes can be captured by combining managerial and regulatory causes. Environmental factors, meteorological and wild life issues and undetermined causes can be grouped under others to yield the combined results illustrated in Table 2.

Causal Factor	**Analyst M**	**Analyst J**

Human Error	198	197
Organisational Issues	86	94
Equipment Problems	53	38
Other	59	67
Total	396	396

Table 2: Inter-Analyst Comparison of Higher-Level Classification for 1976 to 1984

Although there remain some differences between the interpretations of the individual analysis from the high level classification, it is possible to identify a similar pattern to these findings. Individual human error accounts for the majority of causes identified by both analysts. Organisational issues, including regulation and management, form a second major group of causes in aviation accident reports between 1976 and 1984. Equipment related issues can be seen in third place within both rankings illustrated in Table 2.

Results for Second Eight Year Sample: 1996 to 2004 (N=27)
Table 3 continues the analysis for the second sample of NTSB major accident reports between 1996 and 2004. As can be seen, the high level groups reveal considerable differences in comparison to the previous sample with an increasing emphasis on organisational issues compared to the causes and contributory factors that can be associated with more direct forms of human error. As mentioned previously, these results do not necessarily indicate an actual reduction in the instance of human error in major accidents between the two samples. Our source material is based on the recommendations and findings in the NTSB reports. This apparent change in emphasis may, therefore, also be due to institutional and organisational factors within the investigatory agency, including changes in the methods used by and the training offered to investigators.

Causal Factor	Analyst M	Analyst J
Human Error	33	32
Organisational Issues	48	46
Equipment Problems	12	11
Other	2	3
Total	95	92

Table 3: Inter-Analyst Comparison of Higher-Level Classification for 1996 to 2004

Tables 4 and 5 provide a more sustained analysis for this second sample. As can be seen, these provide the more detailed classifications used by each analyst. The tables also distinguish between causes and contributory factors in the NTSB reports on a year by year basis. There is no apparent bias towards ‘blaming the operator’. The frequency of human error being identified by analyst J is: 3 probable and 3 contributory (1996), 6 probable and 4 contributory (1997), 0 probable and 1 contributory (1998), 0 probable and 0 contributory (1999), 5 probable and 2 contributory (2000), 2 probable and 3 contributory (2001), 0 probable and 0 contributory (2002), 2 probable and 0 contributory (2003). The frequency of distribution for analyst M is similar: 3 probable and 4 contributory (1996), 7 probable and 5 contributory (1997), 0 probable and 1 contributory (1998), 0 probable and 0 contributory (1999), 3 probable and 2 contributory (2000), 3 probable and 3 contributory (2001), 0 probable and 0 contributory (2002), 2 probable and 0 contributory (2003). The apparent peak in 1997 is not due to any single incident with a high number of human errors. Instead, it is explained by a series of reports that both analysts identified as being due to human error.   These are AAR 97-05, 04, 03, 02 and 01. A similar rise in human error identified during 2000 makes it likely that these are semi-random artifacts stemming more from the types of incidents that occurred in those years. The rise in human error is largely explained by two incidents in 2000, these are documented in AAR 00-01 and 00-02.

	1996		1997		1998		1999		2000		2001		2002		2003		Total	
	J	M	J	M	J	M	J	M	J	M	J	M	J	M	J	M	J	M
Human Error	3 (3)	3(3)	6 (5)	7(5)	0	0	0	0	5 (2)	3(2)	2 (1)	3(1)	0	0	2 (2)	2(2)	18 (13)	18(13)
ATM Failure	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance Problem	1 (1)	1(1)	0	0	1 (1)	0	0	0	0	0	0	0	1 (1)	1(1)	1 (1)	1(1)	4 (4)	3(3)
Company Management	2 (2)	1(1)	3 (2)	3(2)	2 (1)	3(2)	0	0	0	0	0	0	0	0	0	0	7 (5)	7(5)
Regulation	2 (1)	0	1 (1)	1(1)	3 (1)	3(1)	0	0	0	0	0	0	0	0	0	0	6 (3)	4(2)
Equipment Failure	0	0	0	0	0	1(1)	1 (1)	1(1)	1 (1)	1(1)	0	0	0	0	0	0	2 (2)	3(3)
Aircraft Design	0	1(1)	0	0	0	0	0	1(1)	0	0	0	0	0	0	0	0	0	2(2)
Manufacturing	0	0	0	0	1 (1)	1(1)	0	0	0	0	0	0	0	0	0	0	1 (1)	1(1)
Environment	0	1(1)	1 (1)	1(1)	0	0	0	0	0	0	0	0	0	0	0	0	1 (1)	2(2)
Undetermined	0	0	0	0	1(1)	0	0	0	0	0	0	0	0	0	0	0	1 (1)	0
Total	8	7	11	12	8	8	1	2	6	4	2	3	1	1	3	3	40	40

Table 4: Frequency of NTSB Probable Causes over Time (Analysts J and M, figures in parentheses represent number of different incidents)

	1996		1997		1998		1999		2000		2001		2002		2003		Total	
	J	M	J	M	J	M	J	M	J	M	J	M	J	M	J	M	J	M
Human Error	3 (3)	4(3)	4 (3)	5(4)	1(1)	1	0	0	2(2)	2(2)	3 (1)	3(1)	0	0	0	0	13 (10)	15(11)
ATM Failure	1 (1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 (1)	0
Maintenance Problem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Company Management	6 (4)	8(5)	3 (3)	3(3)	2(2)	2(2)	0	0	1(1)	1(1)	0	0	2(1)	2(1)	0	0	14 (11)	16(10)
Regulation	3 (2)	6(3)	4 (3)	4(3)	2 (1)	2(1)	0	0	4(2)	4(2)	0	0	2(1)	2(1)	0	0	15 (9)	18(10)
Equipment Failure	0	0	2 (1)	2(1)	0	0	0	0	0	0	0	0	0	0	1(1)	0	3 (2)	3(2)
Aircraft Design	0	0	2 (1)	1(1)	0	0	0	0	2(1)	1(1)	1(1)	0	0	1(1)	0	1(1)	5 (3)	3(3)
Manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Environment	1 (1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 (1)	0
Undetermined	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	14	18	15	15	5	5	0	0	9	8	4	3	4	5	1	1	52	55

Table 5: Frequency of NTSB Contributory Causes over Time (Analysts J and M, figures in parentheses represent number of different incidents)

Results for the Most Recent Sample Reports: 2004 to 2006 (N=5)

As mentioned, the initial samples were chosen to provide accident reports covering two eight year periods at the start and at the end of the last three decades. However, there are a number of recently completed and provisional major accident reports that have not been considered in the previous analysis. It is important to consider the results from these investigations because if they are confirmed then they have the potential to significantly alter our findings. Table 6 summarises the high-level results for this most recent group of reports.

Causal Factor	Analyst M	Analyst J
Human Error	9	9
Organisational Issues	1	1
Equipment Problems	0	0
Other	0	0
Total	10	10

Table 6: Inter-Analyst Comparison of Higher-Level Classification for 2004 to 2006

As can be seen, the prominence of human error is striking in comparison both to the first and second samples. If this trend is sustained then it seems clear that there are important changes either within the North American commercial aviation industry or in the manner is which accidents are being investigated. He strong agreement between both analysts reflects both the relatively small sample size being considered here but also the unambiguous nature of the reports. For example, the causal factors cited in report AAR-06-03 include:

> "The National Transportation Safety Board determines that the probable cause of this accident was fuel starvation resulting from the captain's decision not to follow approved fuel crossfeed procedures. Contributing to the accident were the captain's inadequate preflight planning, his subsequent distraction during the flight, and his late initiation of the in-range checklist. Further contributing to the accident was the flight crew's failure to monitor the fuel gauges and to recognize that the airplane's changing handling characteristics were caused by a fuel imbalance".

It is difficult to underestimate the significance of such findings if the trend towards identifying individual human error is sustained beyond this most recent sample of accident reports. Initial discussions with representatives from US airlines have suggested that there may be long term changes in the demographics of aircrews as more junior pilots are being given responsibilities at an earlier age. They may, therefore, lack some of the experience that has guided previous generations of aircrew. However, such interpretations remain anecdotal. It is, therefore, critical that resources are allocated to monitor the changing patterns of causal factors in major accident reports.

Conclusions and Further Work

This paper has presented a longitudinal analysis of the causes of aviation accidents across US air space. The study has focussed on major accident reports published by the NTSB. The intention is to understand the role that organisational issues, human error, technical failures and environmental factors play in adverse events. This is important because the recommendations that are intended to avoid future mishaps are determined by the causes that are identified in accident and incident reports. We are also concerned to determine whether these causal factors have changed over time either as a consequence of changes in the aviation industry, such as the introduction of more advanced safety management practices, or as a result of changes in the way in which accidents are investigated. In previous work, we have identified patterns in the causes of aviation accidents between 1996 and 2004. In this paper, we have extended our analysis to include all major US aviation accidents between 1976 and 1984. We also considered the most recent series of reports up to 2006. Our results indicate that the proportion of incidents related to direct human error was higher in the first sample (1976-1984) than in the second interval (1996-2004). Conversely, there was a greater emphasis on organisational and regulatory causes from 1996-2004 than in the interval from 1976-1984. We have suggested that this may be explained by changes in investigatory practices within the NTSB. However, further work is required to validate this tentative conclusion. We, therefore, propose to conduct a series of interviews with present and former NTSB staff. It should also be noted that initial results from the most recent sample of major accident reports seems to suggest a renewed focus on individual human error. Again, additional work is required to determine whether this trend is sustained.

This research has profound implications. It is often argued that human error is the most significant cause of adverse events across many different industries (Johnson, 2003). This argument is used to justify considerable investment in human factors research. Our findings do not undermine the justification for such expenditure. However, it does suggest that additional work is needed to better understand the ways in which managerial and regulatory intervention help to create the preconditions for adverse events. Conversely, the prominent role of human error in the causes of incidents and accidents has also been used to justify attempts to engineer operators out of safety-critical systems, principally by development autonomous modes of control. The findings from our work suggest that while these initiatives may address some of the causes of adverse events in North American airspace, there remain a significant number of accidents that are not addressed by such initiatives.

In a study of this nature, it is only possible to hint at the causes of the changes that we observe in the causes of major accident. In previous paragraphs we have argued that these changes are likely to be the result of different investigatory techniques. However, it is worth considering the alternate argument that these changes in the causes of adverse events may be the result of structural changes within the aviation industry that led to a reduction in the role of individual human error in our two initial samples. This can be explained in terms of changes in flight crew training, such as JAR-OPS requirements for Crew Resource Management, or the introduction of glass cockpits with additional pilot information systems as well as new ‘safety net’ applications for Air Traffic Management. These changes not only reduce the likelihood of individual error but they can also help to detect and mitigate those errors that do occur so that they do not lead to the accidents that trigger the reports in our samples. Conversely, the increasing prominence of organisational causes can be traced back to changes in the aviation market structure. The 1990’s saw the vertical and horizontal disintegration in many areas of the industry. Large commercial operators began to outsource many of their activities under pressure from new market entrants and low cost carriers. Changes in energy prices created further pressures that were compounded by events such as the terrorist attacks of 9/11. These factors combined to force changes in organisational and managerial structures, which in turn may explain the apparent rise in the prominence of these issues in the causes of major accidents. One way to confirm these hypotheses would be to conduct a more detailed analysis of particular major accidents to trace in detail the way in which market pressures may have influenced the organisational failures that have been identified in the NSTB reports. Similarly, if our initial results for 2005 and 2006 are sustained then it will be imperative to understand the reasons for this apparent rise in human error as a direct cause of major aviation accidents. Initial discussions with investigators have suggested that this may be due to the changing demographics of commercial aircrews as companies begin to recruit younger pilots with less of experience in previous generations of cockpit technology and operational conditions.

As mentioned, this paper focuses on major accident reports published by the NTSB. This decision is justified by the decision to conduct a longitudinal study with a method that enables inter-analyst comparisons to be made. By focussing on major accidents, we can focus on several hundred reports rather than the thousands of incident reports that are received via schemes such as NASA's Aviation Safety Reporting System (ASRS). We also avoided many of the problems of bias that affect the reporting of lower consequence events. By focussing on incidents that involve hull loss or fatalities, we can be relatively sure that there is no problem of under-reporting. In contrast, the immunity and protection offered to respondents within the ASRS increases the likelihood that aircrews will use it to 'confess' incidents that involve some element of individual human error. It is important to acknowledge, however, that our focus on major accidents does create a number of important limitations. In particular, the relatively low frequency of these events can lead to a situation where an individual accident can skew our results, for instance if it was the result of a combination of organisation causes or human errors. Further work intends to extend our analysis by examining the causes of a sample of the thousands of incident reports that have been compiled during the years considered by this study.

We are currently compiling the necessary major accident reports to extend our study across the entire interval from 1976 to the present. This will involve replicating the analysis for the years between 1984 and 1996. The decision to focus on an initial comparison between the samples in this paper was motivated partly by resource constraints, including the availability of the reports from previous decades, and partly by the decision to conduct inter-analyst comparisons to increase confidence in our classifications. However, the initial analysis of the differences in our samples motivates the additional work that is required to examine all of the reports across the intervening period. It is also important to reiterate that this is intended to be a scientific study, which others can replicate in order to support or question our findings. We have included an appendix enumerating the reports that were used in the various samples and we would encourage others to repeat our methods so that we can increase our understanding of the causes of major aviation accidents.

References

C.M. Holloway and C.W. Johnson, Distribution of Causes in Selected U.S. Aviation Accident Reports Between 1996 and 2003. In Proceedings of the 22nd International System Safety Conference, 2-6 August 2004, Providence, Rhode Island, 2004.

C.W. Johnson and C.M. Holloway, 'Systemic Failures' and 'Human Error' in Canadian TSB Aviation Accident Reports between 1996 and 2002, Proceedings of HCI in Aerospace 2004, 29 September - 1 October 2004, Toulouse, France, 2004.

C.W. Johnson, A Handbook of Accident and Incident Reporting, Glasgow University Press, Glasgow, UK, 2003.

J. Reason, Managing the Risks of Organizational Accidents. Ashgate Publishing Company, London, UK, 1997.

Acknowledgements

This research described in this paper was conducted as part of a travelling scholarship funded by the

European Office of Aerospace Research and Development, Air Force Office of Scientific Research, United States Air Force Laboratory.

Appendix

As can be seen from the following list of reports included in our study, the sample size is inevitably effected by the falling number of major accidents over the period studies. Hence, there are relatively few accidents per year towards the end of the study and a comparatively higher number at the start of the study period. The NTSB aviation accident reports included in the sample from 1976 to 1984 are as follows: AAR-76-01, AAR-76-02, AAR-76-03, AAR-76-04, AAR-76-05, AAR-76-06, AAR-76-07, AAR-76-08, AAR-76-09, AAR-76-10, AAR-76-11, AAR-76-12, AAR-76-13, AAR-76-14, AAR-76-15, AAR-76-16, AAR-76-17, AAR-76-18, AAR-76-19, AAR-76-20, AAR-77-01, AAR-77-02, AAR-77-03, AAR-77-04, AAR-77-05, AAR-77-06, AAR-77-07, AAR-77-08, AAR-77-09, AAR-77-10, AAR-77-11, AAR-77-12, AAR-78-01, AAR-78-02, AAR-78-03, AAR-78-04, AAR-78-05, AAR-78-06, AAR-78-07, AAR-78-08, AAR-78-09, AAR-78-10, AAR-78-11, AAR-78-12, AAR-78-13, AAR-78-14, AAR-78-15, AAR-79-01, AAR-79-02, AAR-79-03, AAR-79-04, AAR-79-05, AAR-79-06, AAR-79-07, AAR-79-08, AAR-79-09, AAR-79-10, AAR-79-11, AAR-79-12, AAR-79-13, AAR-79-14, AAR-79-15, AAR-79-16, AAR-79-17, AAR-79-18, AAR-80-01, AAR-80-02, AAR-80-03, AAR-80-04, AAR-80-05, AAR-80-06, AAR-80-07, AAR-80-08, AAR-80-09, AAR-80-10, AAR-80-11, AAR-80-12, AAR-80-13, AAR-80-14, AAR-80-15, AAR-81-01, AAR-81-02, AAR-81-03, AAR-81-04, AAR-81-05, AAR-81-06, AAR-81-07, AAR-81-08, AAR-81-09, AAR-81-10, AAR-81-11, AAR-81-12, AAR-81-13, AAR-81-14, AAR-81-15, AAR-81-16, AAR-81-17, AAR-81-18, AAR-82-01, AAR-82-02, AAR-82-03, AAR-82-04, AAR-82-05, AAR-82-06, AAR-82-07, AAR-82-08, AAR-82-09, AAR-82-10, AAR-82-11, AAR-82-12, AAR-82-13, AAR-82-14, AAR-82-15, AAR-82-16, AAR-83-01, AAR-83-02, AAR-83-03, AAR-83-04, AAR-83-05, AAR-83-06, AAR-83-07, AAR-83-08, AAR-84-01, AAR-84-02, AAR-84-03, AAR-84-04, AAR-84-05, AAR-84-06, AAR-84-07, AAR-84-08, AAR-84-09, AAR-84-10, AAR-84-11, AAR-84-12, AAR-84-13, AAR-84-14, AAR-84-15.

The NTSB aviation accident reports included in the sample from 1996 to 2004 are: AAR-96-01, AAR-96-02, AAR-96-03, AAR-96-04, AAR-96-05, AAR-96-06, AAR-96-07, AAR-97-01, AAR-97-02, AAR-97-03, AAR-97-04, AAR-97-05, AAR-97-06, AAR-98-01, AAR-98-02, AAR-98-03, AAR-98-04, AAR-99-01, AAR-00-01, AAR-00-02, AAR-00-03, AAR-01-01, AAR-01-02, AAR-02-01, AAR-03-01, AAR-03-02, AAR-03-03, AAR-04-01, AAR-04-02, AAR-04-03, AAR-04-04.

Our sample from 2004-2006 included: AAR-05-01, AAR-05-02, AAR-06-01, AAR-06-02, AAR-06-03.