A Historical Perspective on Aviation Accident Investigation

C. W. Johnson† C. M. Holloway*,

† Dept. of Computing Science, Univ. of Glasgow, Glasgow, G12 8RZ, johnson@dcs.gla.ac.uk

*NASA Langley Research Center, 100 NASA Road, Hampton VA 23681-2199, U.S.A., c.m.holloway@nasa.gov

When the editor suggested that we write a piece for this 50th edition of the newsletter, it seemed appropriate to reflect on the longer term history of our field and, in particular, to focus on the topic of accident investigation which has been the focus of our previous work[1]. In early 1928, the Assistant Secretaries for Aeronautics in the Departments of War, Navy, and Commerce in the United States, asked the National Advisory Committee for Aeronautics (N.A.C.A.) to develop a common approach for the analysis and reporting of aircraft accidents. In response to this request, the N.A.C.A. organized the Special Committee on the Nomenclature, Subdivision, and Classification of Aircraft Accidents. The following paragraphs review the work of this special committee and reflect on the changes that have taken place since this early initiative to learn from adverse events in aviation.

The N.A.C.A. committee published an initial report in August 1928 [1]. This was "undertaken in recognition of the difficulty of drawing correct conclusions from efforts to analyze and compare reports of aircraft accidents prepared by different organizations using different classifications and definitions." It, therefore, proposed a method of investigation both to the US representatives and to the representatives of four foreign governments (Britain, France, Italy, and Japan). The 1928 report began with a series of definitions; "An aircraft accident is an occurrence which takes place while an aircraft is being operated as such and as a result of which a person or persons are injured or killed, or the aircraft receives appreciable or marked damage through the forces of external contact or through fire." The report notes that "a collision of two or more aircraft should be analyzed and reported statistically as one accident." This can usefully be compared to the International Civil Aviation Organisation's (ICAO) definition of an aviation accident as "An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which: a) a person is fatally or seriously injured as a result of: — being in the aircraft, or — direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or — direct exposure to jet blast, *except* when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or b) the aircraft sustains damage or structural failure which: — adversely affects the structural strength, performance or flight characteristics of the aircraft, and—would normally require major repair or replacement of the affected component, *except* for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips, antennas, tires, brakes, fairings, small dents or puncture holes in the aircraft skin; or c) the aircraft is missing or is completely inaccessible" [2]. The difference in complexity between the 1928 and the current definitions illustrates the increasing diversity of modern aviation operations.

The 1928 N.A.C.A. report goes on to present a methodology for analysing "two or more distinct causes and makes possible, by the use of percentages, the indication of the relative weight of each cause in any particular accident." The report does not define these causes and the subsequent reports delete this section. Most modern investigatory techniques do not attempt to quantify the weight or importance of particular causal factors. Organisations such as the National Transportation Safety Board (NTSB) and Canadian Transportation Safety Board (TSB) will distinguish between causes and contributory factors but percentages are not used. There is a recognition that it may not be possible to derive an objective priority over the role played by, for instance human error or managerial failure compared to problems in system engineering. The report goes on to present an Aircraft Accident Analysis Form. This provides four broad categories of causes: personnel, material, miscellaneous, and underdetermined and doubtful. The first three of these are further divided into additional categories, with the first two having a third subdivision. The committee argued that a line should be drawn with the "operating personnel of the aircraft." That is, the Personnel category includes only those people directly operating the aircraft. "Errors due to personnel other than those immediately accessory to the operation of the aircraft are shown in the 'Underlying causes' or 'cross analysis' … rather than in the main headings of immediate causes."

As an example of an immediate cause, consider the carelessness or negligence subdivision of the errors of pilot division of the personnel category. The 1928 report describes this category as including "all accidents resulting from the absence of care on the part of the pilot according to circumstances or the failure to use that degree of care which the circumstances justly demand,

[1] This article is an abridged version of a paper that originally appeared in the IET 2nd Conference on System Safety, 2007.

either on the ground, or in the air, such as careless manipulation of the controls of an aircraft, failure to ascertain the amount of gasoline on board before taking off, failure to ascertain the conditions of the instruments, etc." These distinctions remain applicable. In the United States, for instance, there is no special law of aviation negligence; the same provisions apply as they do in any other spheres of activity. Pilots must, however, exercise a greater standard of care because of the potential harm that could be caused by any mishap.

As an example of an underlying cause, consider the deteriorated materials subdivision of the faulty materials division of the materiel failures category. This causal category "includes all accidents traceable to faulty materials where the defects of such materials occurred through deterioration after delivery." The importance of this category of causal factors cannot be underestimated in modern aviation. Composite materials are being introduced into areas that were conventionally only fabricated using metal, for example in the A380 and the B-787. These composite structures may well create particular challenges for accident investigators, as illustrated by the recent NTSB investigation into the possible failure of components in the composite vertical stabilizer involved in American Airlines flight 587, which eventually showed that there was no such failure.

The N.A.C.A. report provides an example to illustrate the application of their investigation methodology:

Pilot John Doe was flying a seaplane at 200 feet altitude over a point of land between a bay and the open sea when the engine stopped. Pilot Doe had an opportunity to land either directly into the wind in the open sea or cross wind in the bay. He started to land in the ocean, but at 100 feet altitude he changed his mind and attempted to turn so as to land in the bay. In turning, Doe held the nose of the seaplane up, stalled it, and spun into the land. The seaplane was demolished, the pilot was seriously injured, and the passenger was killed. Doe, according to his record, was an experienced aviator with 30 hours flying during the preceding month and with recent experience in stunting seaplanes. Examination of the engine showed that one of the teeth in the magneto timing gear had stripped, the broken tooth having been drawn into the other teeth, causing the eventual stripping of all teeth. The original break was determined to be a visible hardening crack.

The N.A.C.A. method begins by classifying the nature of the accident; Class C: tail spin following engine failure. The results to personnel are Class BA (that is, one major injury and one fatality). Finally, the destruction of the seaplane means that the results to materiel classification is A. The report allocates 75% of the immediate causes to personnel and 25% to materiel by stating "that the account of the accident shows that the pilot had two chances to make a safe landing and took advantage of neither of them." For the personnel immediate causes, the report reasons "it is obvious that this is chargeable neither to 'errors of supervisory personnel' nor to 'errors of other personnel,'" so the entire 75% goes to 'errors of pilot.' To explain the 35/40 allocation, the report explains: "It appears further that the errors of the pilot involved errors of judgment in that he lost altitude while wavering indecisively between landing in the ocean and attempting to land in the bay. It appears that poor technique was the most important single factor in that he continued to pull the nose up, still further stalling the seaplane, when he should have sensed the approaching stall. It is considered that a charge of 35 per cent to 'error of judgment' and 40 per cent to 'poor technique' represents as near an approximation as can be arrived at in this case." This analysis illustrates considerable differences between modern investigatory practices and the N.A.C.A. methodology from the 1920s and 1930s. In particular, human factors experts and psychologists are now well integrated into the teams that analyze the causes of aviation accidents. Rather than simply identifying 'errors in judgement' and 'poor technique', today's reports often spend many pages identifying the cognitive and perceptual factors that contribute to such adverse events. Hence, the simple interpretation of these early N.A.C.A. forms has led to more sustained multi-disciplinary investigations that are rooted deeper in the social sciences than might be apparent from the early investigations.

A major criticism of the 1928 report was that the weighting process was likely subject to considerable individual variation. The response given to this criticism in subsequent N.A.C.A. reports was to discuss a test conducted by the original special committee, but not mentioned in the first report. Each member of that committee was given 6 identical accident reports, which each person analyzed independently. The results were then averaged and compared with the individual weightings. Today, similar trials have been conducted into the impact of subjectivity in the application of accident investigation techniques. For instance, we have conducted a number of studies in previous work to analyse the role of subjectivity across several hundred investigations published by the National Transportation Safety Board and similar organisations around the world. It is ironic to find that the criticisms of the original N.A.C.A. report raise concerns that continue to be the topic of workshops and research papers even today.

Subsequent N.A.C.A. reports presented the results obtained from the application of the method for a little over a year by the Army, Navy, and Department of Commerce. The accidents analyzed all occurred before January 1929, and extended back in time for several years. There were 1432 military accidents and 1400 civil accidents that were analyzed. The report presents two tables, one of which shows the percentages of accidents in each of the 14 'nature of accident' categories, and the other of which shows percentages according to immediate causes. For the immediate causes, slightly less than 50% of the military and civil accidents were attributed to pilot error, a result which corresponds fairly well to recent studies of major civil aviation accidents in the United States.

The N.A.C.A. led a pioneering initiative to establish common approaches to the investigation and analysis of aviation accidents. Their reports in 1928, 1930 and 1936 laid the seeds that in 1967 led to the establishment of the US National Transportation Safety Board. By studying these early attempts to establish common methods of investigation, we can see the generic nature of many of the issues that continue to complicate accident investigations. For example, there is a common concern to develop objective analytical techniques that enable lessons to be shared between different investigators across a number of different organisations. There is also a common concern to identify multiple causes that consider both engineering and human factors issues. A common misconception today is that considering such issues is a relatively recent innovation. Our study of these early investigatory procedures shows this not the case, as the reports illustrate a degree of sophistication in the analysis of pilot interaction.

There are, however, some important differences between the N.A.C.A. reports and current investigatory practices. In particular, the committee was anxious to develop common techniques that could be used in both civilian and military reporting systems. This is very far from being achieved in the US or Europe. In consequence, it can be extremely difficult to ensure that lessons learned in military accidents are transferred to civil systems and vice versa. Similarly, the N.A.C.A. focus on establishing the weighting of causal factors has largely been abandoned, although it persists in civil litigation where the courts may assign civil liability to individuals and organisations in proportion to their involvement in an accident. An important conclusion from our study is that some changes that have taken place since the publication of the N.A.C.A. reports in the 1920s and 1930s have not been for the better. It can be argued that recent court judgements following the Linate and Ueberlingen accidents might have been informed and supported by engineering processes that did not shy away from the difficult issues of blame and responsibility in the aftermath of major adverse events.

References

[1] National Advisory Committee for Aeronautics. Aircraft Accidents: Method of Analysis. Report No. 308. Washington, D.C. (1928).

[2] International Civil Aviation Organization. Annex 13 to the Convention on International Civil Aviation: Aircraft accident and incident investigation (Ninth Edition). Montreal. (2001).