An Internet-based, Searchable Database of Air Accidents

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Abstract

Despite improvements in the safety of individual aircraft, a steady growth in the volume of air travel is producing an overall increase in serious aircraft accidents. One of the weapons in the fight against this trend, is the use of accident analysis to detect patterns within these accidents and to identify areas where improvements are required. This paper describes the Warwick Air Accident Database (WAAD), which has been established specifically to facilitate this process of accident analysis.

The WAAD contains details of over 2700 major accidents over a 21-year period. It covers accidents involving passenger and freight aircraft of over 5700 kg maximum takeoff weight, and includes jet, turboprop and piston aircraft (but excludes helicopters and military aircraft). Being Internet-based, WAAD can be accessed from anywhere in the world and is available free of charge to anyone working or researching in this area. One of the strengths of the database lies in its range of powerful search facilities that permit accidents to be selected to match any combination of a wide range of characteristics.

The paper outlines the characteristics and use of the Warwick Air Accident Database and describes some significant accident trends that have been identified using its data.

Introduction

Over the past few decades, great improvements have been made in the safety of air travel. This has resulted in a fall from about 30 fatal accidents per million departures in 1959, down to between 1 and 3 fatal accidents per million departures in 1999, depending on the region of the world (ref.1). However, although the probability of an individual flight being involved in an accident is falling, a steady increase in the volume of aircraft traffic means that the actual number of fatal accidents each year is increasing.

While knowledge of the total number of accidents in a given year may give an indication of the magnitude of the problem, it does not in itself help to reduce this number. In order to reduce accidents we need to understand the reasons why aircraft crash, and to take steps to tackle them. Many countries have aviation accident investigation authorities (such as the US National Transportation Safety Board and the UK Aircraft Accident Investigation Branch) that look into aircraft accidents and attempt to determine their causes. Where a specific problem is identified within a particular aircraft this will normally be tackled to prevent further accidents from this cause. However, most aircraft accidents are not so clear cut.

Because of the severe consequences associated with accidents, the aircraft industry is extremely safety conscious. All critical systems have a very high level of integrity, and fault tolerance is used extensively to reduce the rate of system failures. This fault tolerance extends to the use of two pilots who check each other's operations to reduce undetected human error. A result of these measures is that few aircraft accidents are the result of a single component or human failure. Most are caused by an unfortunate combination of events, which individually would not have caused a major problem. Such a combination of events is referred to as an 'accident scenario' and experience shows that these will often consist of 3 causal and 2 circumstantial factors (ref.2).

The complexity of many accident scenarios makes the analysis of accidents very involved. It also makes it very difficult to detect common contributory factors between accidents. Accident reports are normally extremely long and contain a great deal of information. The detection of similarities between one accident and another may rely simply on the memory of engineers who have been associated with both events.

The Warwick Air Accident Database aims to help this situation by providing a simple means of identifying accidents with common causal factors, and by simplifying the identification of trends within accident data.

One of the objectives of this paper is to publicize the air accident database and to encourage those working or researching in this area, to make use of it. The database can be found at:

http://www.air-accidents.warwick.ac.uk/

This URL points to a registration page where applicants can request a username and password by completing an online form.

The Warwick Air Accident Database

WAAD is an Internet-based database of major aircraft accidents, developed with funding from GAPAN – The Guild of Air Pilots and Navigators. It covers the period from 1977 to 1997 and includes accidents involving commercial fixed-wing aircraft that seat at least 15 passengers or have a maximum take-off weight of greater than 5700 kg (12,500 lbs). Details of accidents related to passenger, cargo, positioning and ferry flights are included for jet, turboprop and piston aircraft. The database does not include accidents involving helicopters or military aircraft, except where these involve aircraft covered by the database.

The database includes information on many aspects of the aircraft and the flight(s) concerned, and on factors that may have contributed to the accident. Clearly this database is not unique in providing such information via the Internet. Indeed, many aircraft accident investigation reports are now available online. The uniqueness of the Warwick database lies in its range of powerful search facilities that permit accidents to be selected to match any combination of a wide range of characteristics. This allows accidents to be selected, for example, by their time, place, airline, aircraft, aircraft manufacturer, aircraft type, severity, weather conditions, phase of flight, nature of flight, ground facilities available, or any of several hundred accident factors.

Accident data has been gathered from a number of sources including the US National Transportation Safety Board, the UK Aircraft Accident Investigation Branch, the Canadian Transportation Safety Board and the Australian Transportation Safety Board. Wherever possible multiple data sources have been used to improve the reliability of the information stored, although the amount of information available varies considerably. In all cases the sources of the information are listed. Links are also given to official accident reports, where these are available on-line.

Database Fields

Fields within the database may be divided into a number of broad categories, namely:

- Date
- Aircraft Details
- Environmental Details
- Ground Facilities
- Official Information
- Accident Factors

Within each of these categories there are a number of fields. For example, within the 'Aircraft Details' category there are fields covering: the airline; the aircraft registration; the aircraft manufacturer; the aircraft model; the aircraft type (jet, turboprop or piston); the number of crew on board at the time of the accident; the number of passengers on board; the total number of fatalities; the number of any third party fatalities; the number of engines on the aircraft; the nature of the flight (scheduled passenger flight, ferry flight, etc.); the phase of flight in which the accident occurred; the configuration of the aircraft; the level of damage (total loss or major partial loss); whether the aircraft is missing; whether the aircraft was on an illegal flight; whether TCAS was installed; and whether GPWS was installed.

The category containing the largest number of fields is that relating to accident factors. This contains over 250 potential factors that might relate to a particular accident. These are divided into 6 major groups (collisions; equipment failures; military and criminal; environmental factors/fire; human factors; and flight failures) which are then divided into 20 sub-groups. Each of these sub-groups then contains a number of individual accident factors. For example, the human factors group contains a sub-group related to 'flightdeck crew' issues, which contains 51 individual accident factors. These include factors such as 'misunderstanding ATC instructions' and 'crew incapacity'. The major data fields within the database are shown in Tables 1 and 2.

Table 1 - Accident Data Fields

Date of accident
- Month:
- Year:

Aircraft Details
- Airline:
- Registration:
- Aircraft Manufacturer:
- Aircraft Model:
- Aircraft Type:
- Aircraft Fatalities:
- No. of Engines:
- Nature of Flight:
- Phase of Flight:
- Level of Damage:
- Aircraft Missing:
- Illegal Flight:

Environmental Details
- Mercator Slice:
- Region:
- Country:
- State:
- Town/City:

Ground Facilities
- Specific Approach and Landing:
- General Approach and Landing:

Official Information
- Source:
- CVR Transcript Available:
- Official Report Available:
- Reporting Agency:
- Report Reference:
- Synopsis Reference:

Table 2 - Accident Factors

Collisions
- Controlled Flight Accidents:
- Mid-air Collisions:
- Collisions on the Ground:
- Uncontrolled Collisions:

Equipment Failures
- Engine Failures:
- Systems Failures:
- Ground Equipment Failures:

Military and Criminal
- Military:
- Malicious and Criminal Acts:

Environmental Factors/Fire
- Environmental Factor Accidents:
- Accidents Involving Fire:

Human Factors
- Flightdeck Crew Related:
- Maintenance Related:
- Other Human Factors:
- ATC Issues:
- Airport Infrastructure:

Flight Failures
- Take-off and Landing Accidents:
- Disruption of Structure:
- Loss of Aerodynamic Control:

Searching the Database

The database can be searched to find those accidents that have any particular value within any of the data fields, or to find accidents that match any combination of these fields. Thus a simple search might select all accidents that involved a certain kind of aircraft and were related to engine fires, while a more complex search might select those accidents that involved a two or four engined aircraft; that occurred during landing and involved windshear.

Search parameters are normally selected from lists of the values present within the database to prevent problems associated with typing errors.

Where multiple search criteria are used these are combined using conventional Boolean operators (AND and OR) adopting logical rules. For example, if a user selects both 'two-engined' and 'four-engined' aircraft it is clear that he or she wishes to see those accidents involving either 'two-engined' aircraft OR 'four-engined' aircraft (since no aircraft can simultaneously have both two engines AND four engines). However, if a user selects the year '1990' and the aircraft manufacturer 'Boeing', the database will display those accidents that occurred in 1990 AND involved Boeing aircraft. In practice, the rules are very intuitive and it is not normally necessary to worry about the association rules. A small section of the search page is shown in Figure 1.

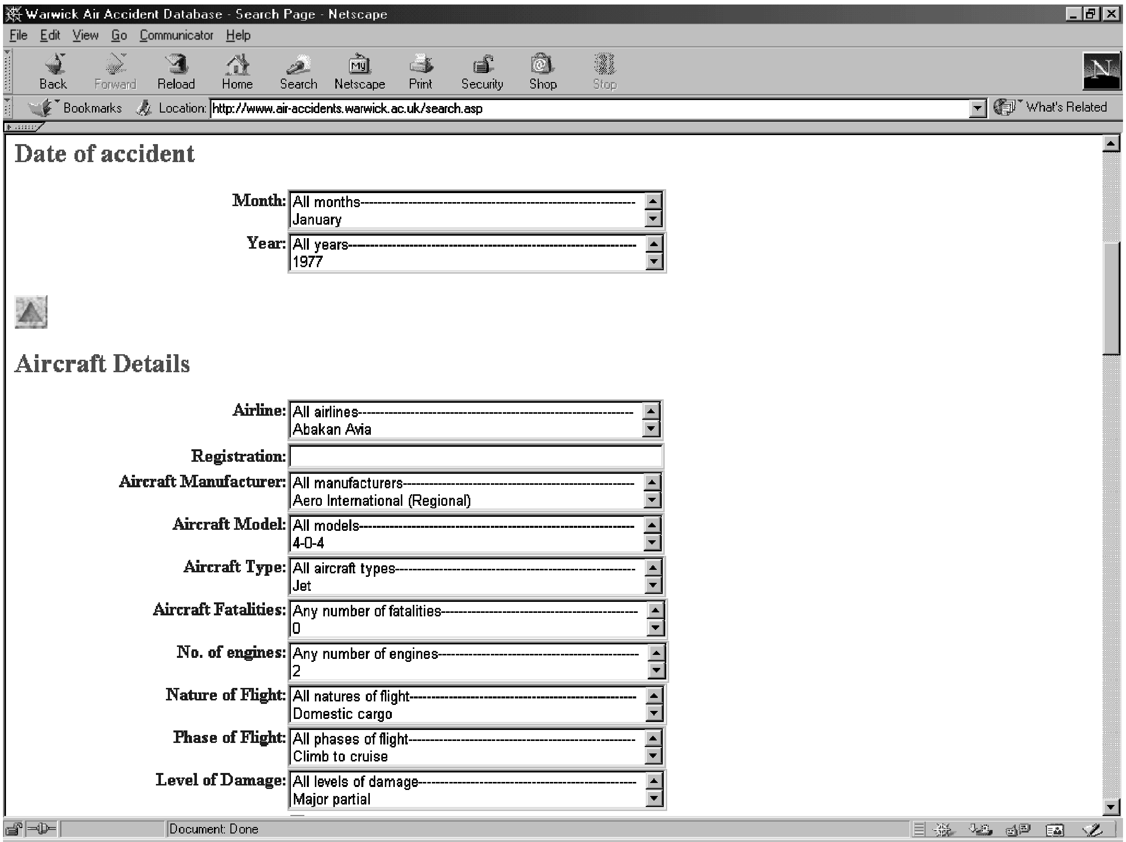

Figure 1 - A Section of the Search Criteria Selection Page

When the search criteria have been selected the user can initiate a search by clicking on the 'submit' button at the bottom of the search page. In response the system will return a page which indicates the total number of accidents that match these criteria. If the number is too large, or perhaps too small, the user can return to the search page to refine the search requirements. Alternatively, the user can opt to display a list of the selected accidents.

The list of accidents indicates: the year of each accident; the airline company involved; the aircraft model and the location of the accident. For example, a search for accidents in 1997 in which more than 100 people were killed yields the following list:

1. 1997-Silkair B737 in Palembang
2. 1997-Garuda Indonesia A300 in Medan
3. 1997-Korean Air B747 in Agana

If the list contains more than 25 accidents then these are divided into pages, each with 25 entries. Each line of the list is a hyperlink and clicking on the accident details will fetch a full report for the accident. This contains not only the values of the various data fields described above, but also an accident summary and pointers to the official report where this is available.

The ability to select accidents to match complex profiles is of great benefit when performing accident analysis and looking for accident trends. The remainder of this paper describes analyses performed using the database.

Worldwide Accident Trends

One of the simplest analyses that can be performed using the accident data is to produce a summary of the number of major air accidents worldwide over a given period. Figure 2 shows such a summary for the period covered by the database. A trendline has been added, using a least squares approximation, which shows that the number of accidents has increased by about 14% over the time period. However, further analysis shows that this increase is not evenly distributed over different forms of accident.

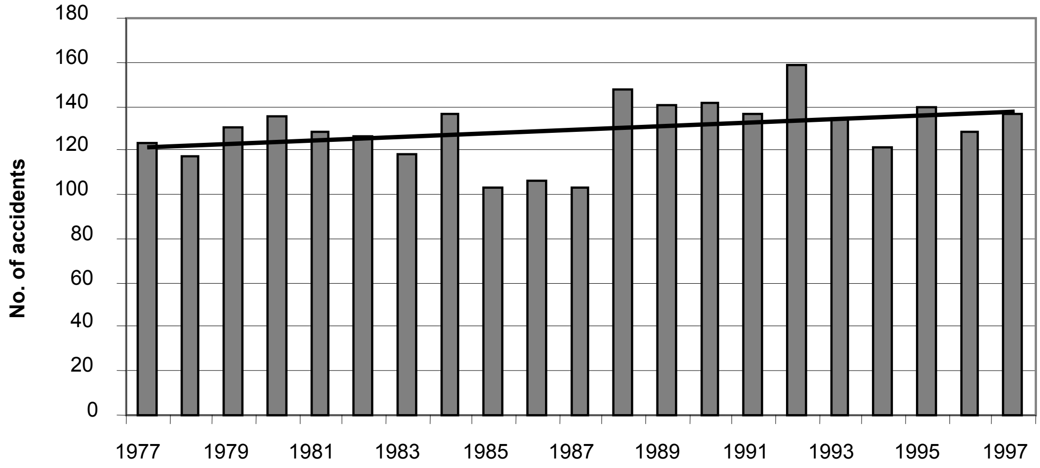

Figure 2 - Worldwide Major Air Accidents 1977-1997

The database includes both total loss and major partial loss accidents. Total losses are those accidents that result in aircraft being destroyed or where the estimated repair costs render the aircraft a total loss under the terms of the insurance contract. Major partial losses are those accidents where the repair cost is believed to have been 10%, or more, of the insurance value but did not result in a total loss (ref. 3).

Total losses account for 65% of the total number of accidents in the database and Figure 3 shows the number of such events for each year from 1977 to 1997. This illustrates how the annual number of such accidents has fluctuated over the 21-year period, the annual average over this period being 84.

A trendline has again been added to the data, and shows that the number of total loss accidents has decreased by about 13% over the time period. During the early 1980's the number of total loss accidents was falling steadily and it seemed that air safety was improving dramatically. However, this trend was not to continue and over the period of the database as a whole we see a more modest fall in accident rates.

Extending the trendline forward we would expect to see 75 losses in 2000. Since accident reports may take several years to produce, at the time of writing this paper exact figures for the number of total loss accidents in 2000 is not available.

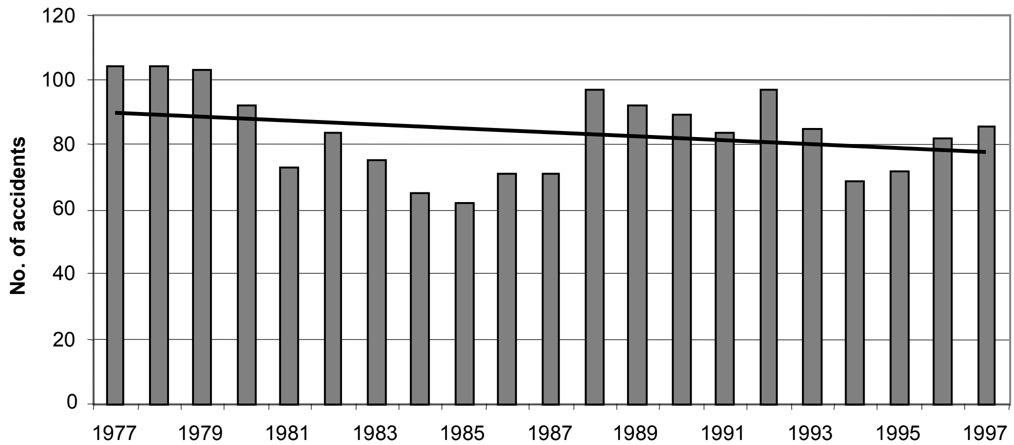

Figure 3 – Worldwide Total Losses 1977-1997

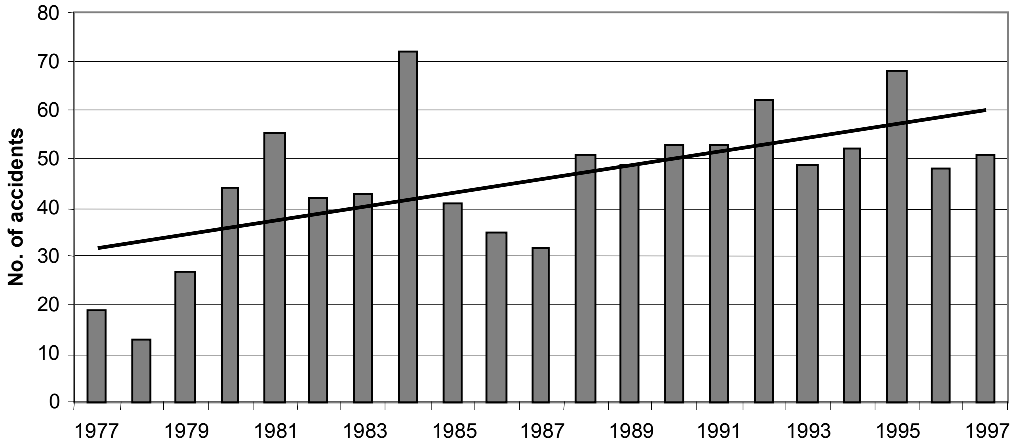

Figure 4 – Worldwide Major Partial Losses 1977-1997

Major partial losses account for 35% of the accidents in the database, and while the number of total loss accidents fell over the 21-year period, the number of partial loss accidents increased. Figure 4 shows the annual number of such accidents from 1977 to 1997.

Figure 4 shows that there were particularly high numbers of major partial losses in 1984 and 1995, which can be attributed to hailstorms in Munich and Dallas respectively. Both hailstorms caused severe damage, but did not write off any aircraft. The least squares approximation trendline shows that the number of major partial losses increased by 94% between 1977 and 1997. However, the number of accidents in the late seventies is remarkably low and perhaps gives a distorted view of the increase over the time period. Discounting the first 3 years of the period, where the levels are exceptionally low, and using another linear trendline, the number of major partial losses shows an increase of about 21%, which would seem a more reasonable figure. Using this increase, we would expect that there would have been 56 major partial loss accidents in 2000.

Regional Variations in Accident Rates

Another area of interest is the variation of accident rates between different parts of the world. The database's ability to select accidents by region makes it easy to compare total accident rates, or rates for particular types of aircraft or accident. Figure 5 shows the distribution of total loss accidents between eleven geographical regions, over the period from 1977 to 1997.

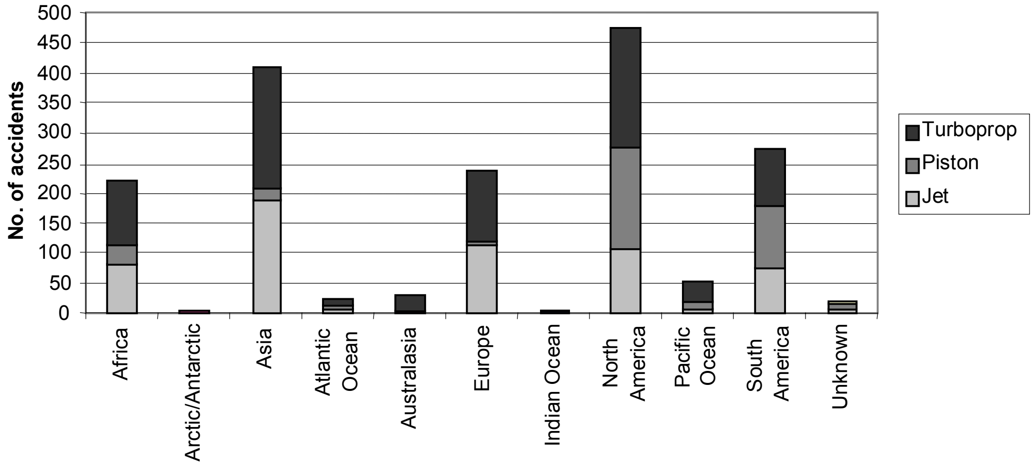

Figure 5 - Total Loss Accidents 1977 - 1997 by region

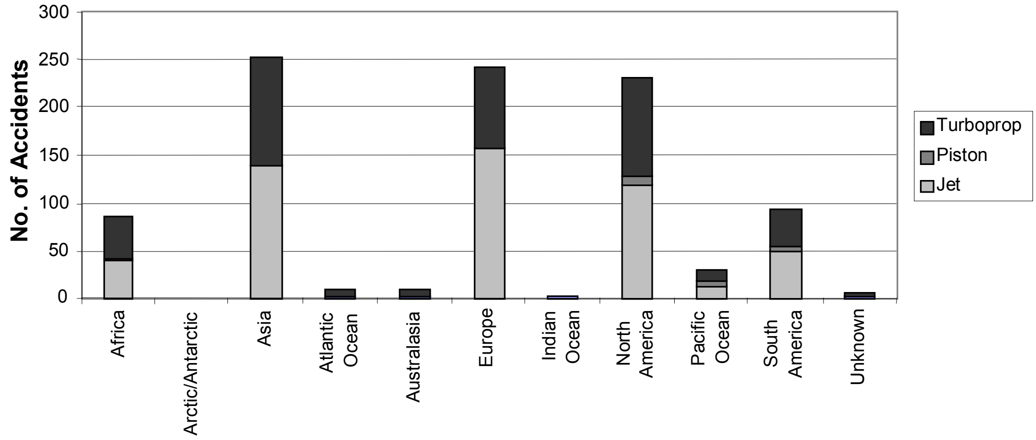

Figure 6 - Major Partial Loss Accidents 1977 - 1997 by region

From Figure 5 it is clear that the vast majority of total losses occur in five main regions of the world, namely: Africa; Asia; Europe; North America and South America. These five areas account for approximately 92% of all total loss accidents.

A similar analysis can be performed for major partial loss accidents, and this is shown in Figure 6. Again the majority of such accidents are concentrated into the same five regions which account for about 94% of the accidents.

From Figures 5 and 6 it is clear that Asia, Europe and North America see large numbers of both total loss and major partial loss accidents.

Asia is a rapidly expanding aviation market and had an increasing number of operators in the latter period of the database. For example, there was a 23% increase in the number of scheduled airline flights by operators in Asia and the Pacific between 1994 and 1997 (ref. 4). By comparison, over the same period there was an increase in flights by North American operators of only 10%. This growth in Asian air travel has inevitably led to an increase in the number of accidents occurring in this region, and the database shows a 60% increase in accidents in Asia over the 21 year period.

For the purposes of the database Europe is defined as mainland Europe, the UK, Northern Ireland and those parts of Russia (plus the ex-CIS states) that are to the West of the Ural Mountains. The remainder of Russia is classed as Asia. Further breakdown of the European accidents shows that approximately 40% of both total losses and major partial losses occurred in Russia or the ex-CIS states.

The volume of air traffic in North America is higher than any other region and so, statistically, we would expect there to be a greater number of aircraft accidents in this region. A large proportion of the total loss accidents in North America involved Piston driven aircraft. (there are only piston major partial loss accidents from 1990 onwards from Airclaims which was the major source of major partial loss accident data)

Further Observations from the Data

A high proportion (46%) of total losses occurred during the approach and landing phases of flight. The approach and landing phases involve the highest workload for the crew and therefore provide the highest risk of mistakes occurring. A large number (46%) of major partial loss accidents occurred during landing although there was also a significant number (about 23%) of accidents during ground operations. Nearly 40% of major partial losses on the ground involved a collision with objects such as aircraft, trees or buildings.

A majority (60%) of both total losses and major partial losses occurred on domestic flights, while approximately (20%) of both types of accidents occurred on international flights. Also, the majority of total loss accidents (55%) and major partial loss accidents (65%) occurred on passenger flights. 21% of total loss accidents occurred on cargo flights (14% of major partial losses) and 6% occurred on ferry flights (4% of major partial losses).

Analysis shows that the majority of the database accidents had between 1 and 3 factors attributed to them, while 8% of accidents had no factors attributed because of a lack of information. The greatest number of factors allocated to a single accident was 15. Accidents normally involve a chain of events. In many cases these events are not documented in the accident information used to create the database and this is reflected in the low number of factors commonly attributed. Accidents for which more information is available, are likely to have a higher number of factors associated with them. There were 29 accidents that had 10 or more factors allocated to them. Of these, 9 occurred prior to 1988 and 20 after 1988. This would suggest that the amount of information pertaining to an aircraft accident has increased over the time period of the database.

One of the most important uses of accident data is in determining whether particular forms of accident are becoming more or less common. This allows money and effort to be directed at areas where there is greatest need. To investigate such variations, accidents within the database were divided into two ten-year time periods, from 1978-1987 and from 1988-1997. Accidents within these two groups were then compared to detect changes in the patterns of contributory factors.

Figure 7 shows the percentage change in the number of accidents associated with particular causal factors, between the two time periods. In each case the change is shown separately for jet and turboprop aircraft. The number of piston driven aircraft is decreasing rapidly and such aircraft are excluded from this analysis.

Because of the statistical nature of the data, small differences between the two time periods are of little significance. However, several factors stand out, and would seem to indicate significant changes. Potential problem areas would seem to be: *malicious acts* involving turboprops, *maintenance errors* and *other human errors* involving jets and *ground equipment failures* involving both jets and turboprops. On the other hand, large improvements would seem to have been made in jet aircraft accidents involving the *military*, *ATC* and *mid air collisions*. It should, however, be noted that although some categories have seen large increases or decreases, these may be based on small numbers.

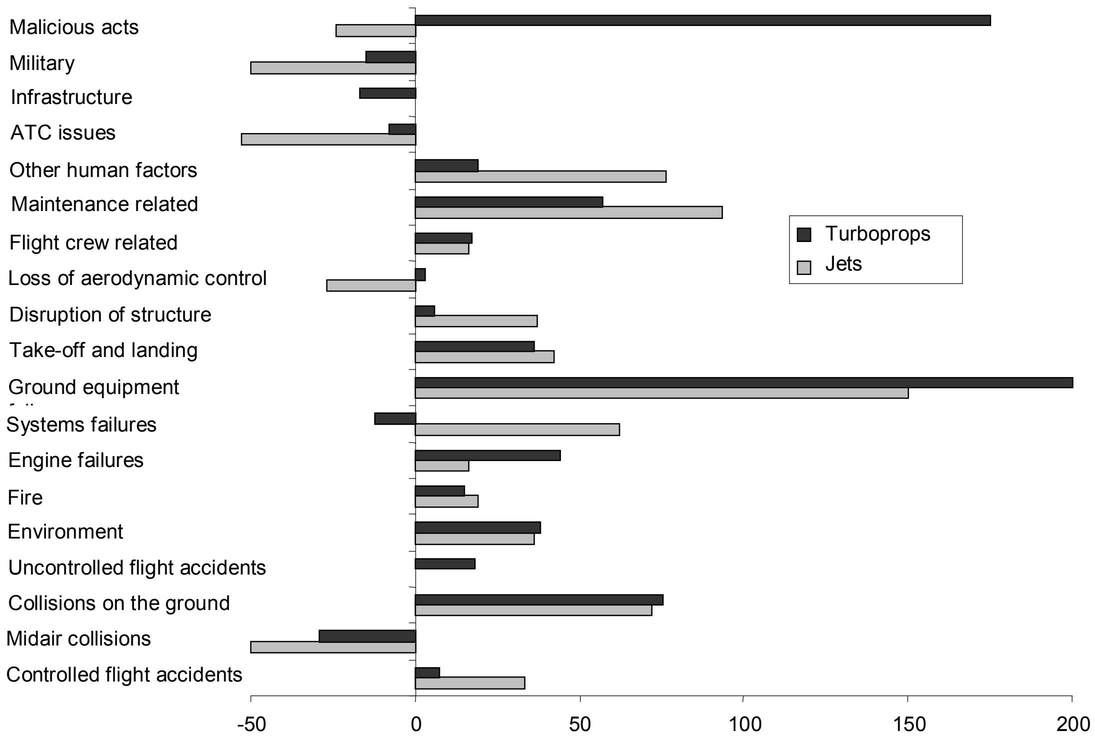

Figure 7 - Percentage Change Between Two Ten-year Periods (1978-1987 and 1988-1997)

One of the limitations of the database is related to the assessment of the human factors element. It should be emphasized that the various causal factors were allocated to a particular accident only when they were specifically mentioned in the accident information. Human factors involvement in accidents does not tend to be specifically stated in accident information other than in detailed reports, such as those produced by the NTSB. Unfortunately, a relatively small percentage of accidents worldwide are investigated with this level of rigor. Consequently, it is certain that the number of accidents involving human error is vastly understated. Boeing suggests that 70% of jet accidents involve flight crew error (ref. 5), while only 24% of accidents within the Warwick database are shown as involving crew-related factors

One of the strong points of the database is the large list of causal factors that are used to classify accidents. Unfortunately, this strength also has potential problems, in that the number of factors available can be overwhelming. This can be a particular problem for new users of the database. Hopefully, with experience, users are able to use the power of the search tools to refine and hone their accident research.

More information on the structure and form of the database, together with more detailed analysis of the accident data, can be found in Reference 6.

Discussion and Conclusions

The Warwick Air Accident Database is available free of charge to anyone working or researching in areas related to the aircraft industry. Being Internet-based, it can be accessed from around the world, and it is currently being used by engineers, pilots, managers and academics from many countries.

The database has combined accident information from a range of sources in an attempt to produce a database of high integrity. Over 50% of the accidents entered were derived from two or more sources of information.

One of the strengths of the database is its ability to select accidents that match a given set of characteristics, enabling researchers to identify patterns, and trends, within the data.

Analysis of the accident data shows that:

- The number of major aircraft accidents increased over the time period from 1977 to 1997. This period has seen a dramatic increase in the volume of air travel and it is therefore not surprising that the total number of accidents has also increased.

- North America had the highest number of total loss accidents and Asia had the most major partial loss accidents. Europe and North America had similar overall numbers of accidents.

- Accidents occurred mainly during the approach and landing phases, although there were a significant number of major partial loss accidents that involved ground operations.

- The majority of accidents occurred on domestic, and on passenger, flights.

- Examining the factors involved in accidents between 1978-1987 and 1988-1997, it can be seen that there were large increases in: *malicious acts* involving turboprops; *maintenance errors* and *other human errors* involving jets; and *ground equipment failures* involving both jets and turboprops. Also, there were increases in total loss accidents resulting from *ground collisions* and *ground equipment failures*, and in major partial loss accidents involving *maintenance errors* and *military* activity.

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