The Black Box: An Australian Contribution to Air Safety

With jet aircraft now a common sight, it is hard to think back to the days of the world's first commercial jet aircraft. Following the rapid development of jet fighters during the Second World War, the British began to develop the first jet-powered airliner, the famous Comet, which first flew in the 1950s. But the Comet seemed to be cursed, and in 1953 a number of the aircraft crashed inexplicably, putting doubt in the public's mind about the safety of jets.

Aircraft engineers and scientists all round the world were also perplexed. The cause of the crashes had to be found or the Comet would be doomed to failure. Many professional committees discussed the possible causes at endless meetings. Dr David Warren of the Aeronautical Research Laboratories in Melbourne, a chemist specialising in aircraft fuels, was one of those involved with some of these meetings, his role being to consider whether a fuel explosion could account for the crashes.

Unfortunately, there were few clues to be found. There were no witnesses, no survivors, and all that was left of the aircraft were massive tangles of bent metal.

As David Warren listened to the frustrating discussion of possible causes, he began to conceive the idea of some sort of recording of the flight crew's conversation, and of protecting the record so that it would survive the crash. He reasoned that while the technical committees found it difficult to trace the cause of the crash, there was a good chance that that the flight crew might have known, and it might well have been revealed in their conversation in trying to deal with the emergency.

Warren discussed his concept openly, but found it raised very little interest. So, in 1954, he outlined his ideas in a report entitled "A Device for Assisting Investigation into Aircraft Accidents". This was circulated widely to aviation authorities and the aircraft industry, but also appeared to evoke little interest.

It was decided that "show and tell" would be more effective than "tell", so a demonstration unit was needed. With the enthusiastic support of his Superintendent, Mr Tom Keeble, and an Instrument Engineer, Mr T. Mirfield, such a unit was designed and built using steel wire as the recording medium. It was fully automatic for fit-and-forget operation with a "memory" mechanism that would store four hours of pilot voice and instrument readings at the rate of eight per second up to the moment of any accident, but would automatically erase older records for the wire to be re-used. It was given the project name of "The ARL Flight Memory Unit" and the original (Figure 1) is now displayed in the Science Museum, Melbourne.

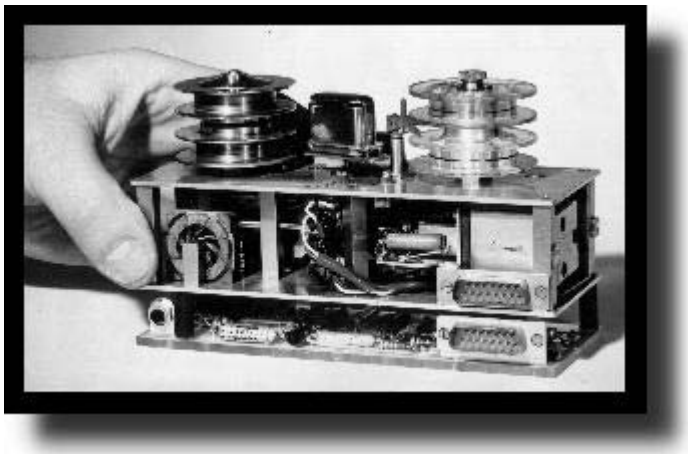

Figure 1: The original (1958) ARL Flight Memory Recorder, capable of storing the cockpit speech and eight instrument readings at rate of four per second for the four hours prior to an accident.

After being successfully tested in the air, assessment by the various aviation authorities was formally requested. The response was far from encouraging. Civil authorities replied that "Dr Warren's instrument has little immediate direct use in civil aircraft". The RAAF considered "such a device is not required ... the recorder would yield more expletives than explanations". The Australian Aeronautical Research Council recommended "in view of the difficulties involved no action should be taken". The Federation of Air Pilots declared that it would be like "a spy flying alongside ... no plane would take off in Australia with Big Brother listening".

The reason for this widespread local disinterest may well have been that Australia had not experienced a major air accident for many years and, indeed, was recognised as having the world's best safety standard at that time. "We don't have accidents any more" seemed to be the general feeling.

This stalemate was finally broken in 1958 when the Secretary of the UK Air Registration Board, Sir Robert Hardingham, happened to see the recorder while on an informal visit to ARL. His enthusiasm was instantaneous. He arranged for Warren to take the "Flight Memory" to England to demonstrate it. The response to the demonstration in the UK was most encouraging. The BBC featured the recorder on evening television and Radio Newsreel. Many UK manufacturers and operators offered their support, and the British authorities began a move to make recorders mandatory in British civil aircraft.

Warren was given a team, comprising Lane Sear, Ken Fraser and Walter Boswell, to update the early model Flight Memory to a pre-production standard. It was improved (Figure 2) in a number of ways, including a method of recording instrument readings with greater accuracy and at an increased rate of 24 readings per second. In anticipation of the coming mandatory requirement, the British firm of S. Davall & Son approached ARL for the production rights and their "Red Egg" crash recorder was developed from it, winning a large part of the British and overseas market at that time.

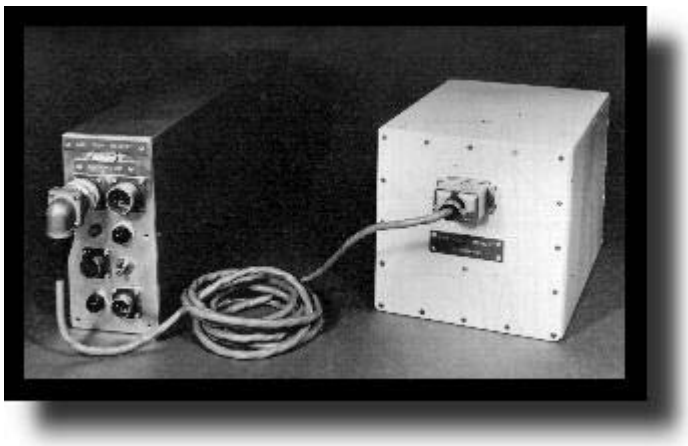

Figure 2: The "pre-production" prototype ARL Flight Memory Recorder (1962) with the recording mechanism in a separate crash-and-fire-proof container for mounting in the tail of the aircraft.

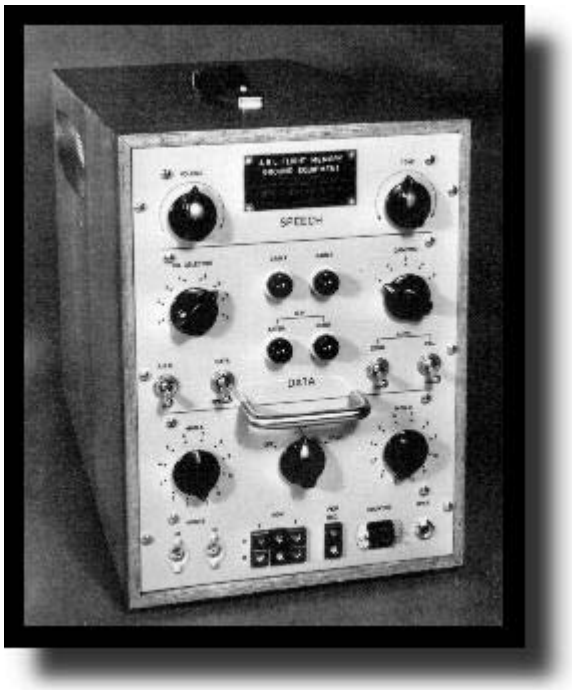

Figure 3: The playback station used for separating the cockpit speech and analysing the instrument readings.

Progress in Australia had to wait until the unexplained crash of a Fokker Friendship in Mackay, Queensland, in 1960. The judge inquiring into the mysterious crash was told of the development of the crash recorder and, as a result, made a judicial order that all Australian airliners should carry recorders for pilot speech from January 1963. A decision was made to ask an American company, United Data Control (UDC), to develop a cockpit voice recorder to meet the new Australian requirement. UDC chose to use magnetic tape, which was harder to make fireproof than wire, leading to delays in its development. When Australia's next aircraft accident occurred in Winton, Queensland, voice recorders had still not been fitted, and questions were asked at the inquiry about the failure to comply with the judicial requirement. However, soon afterwards, in 1967, the difficulties were overcome and, while the UK and other countries had adopted the recording of flight instrument data, Australia became the first country to make both flight data and cockpit voice recording mandatory.

Voice-plus-data recording is now mandatory for all major civil aircraft throughout the world and has proved to be of inestimable value in finding the causes of many aircraft accidents, just as its inventor, Dave Warren, had foreseen.

Technical details

The ARL pre-production prototype ARL Flight Memory Unit (1962) comprised an ARL Flight Memory Recorder, an associated ARL Flight Memory Electronics Unit which did not have to survive a crash, and a ground station unit named the "ARL Flight Memory Ground Equipment", which was used to unscramble the recorded data. The Recorder was essentially a small, light-weight recorder capable of storing the cockpit conversation and flight data for an aircraft during a period of four hours before an accident. Speech and eight channels of flight data were recorded together on magnetic wire using a combination of frequency and time multiplexing. The wire was made of special steel and was 0.005 mm in diameter. The flight data signals were taken from transducers and time-multiplexed at a rate of 24 readings per second by means of a solid-state sampling switch that switched bursts of a recordable carrier frequency. The different frequency bands for speech and flight data allowed them to be separated by the ground station equipment (Figure 4).

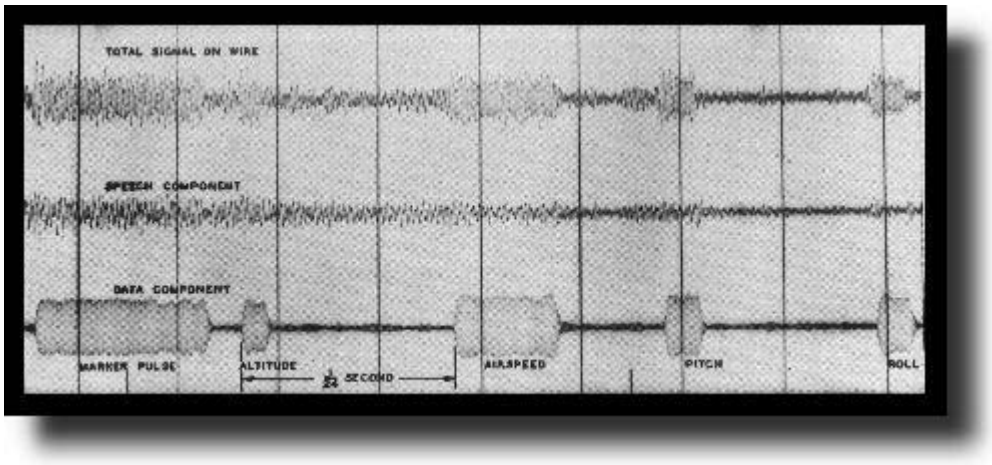

Figure 4: Cockpit speech and instrument-readings separated by the playback station.

The choice of the recording method presented a scientific challenge. Basically, magnetic wire is a single channel medium (compare with the multi-track possibilities for magnetic tape) and, unlike the tape recorder, the wire recorder does not have a capstan to feed tape past the recording head at constant speed as the spools turn. There was no guarantee that the layering of the wire when recording and when reproducing would be the same and fluctuations in signal frequency between recording and reproducing were apparent. The method adopted was to convert the pulse duration for each flight data channel into the number of cycles of a sinusoidal carrier. The number of cycles remained invariant even if the carrier frequency fluctuated between recording and reproducing. This was a pseudo-digital recording method for the flight data and provided remarkably good accuracy. The pre-production prototype was installed in the Department of Civil Aviation Fokker Friendship aircraft, VH-CAV, and the maiden test flight took place on 23 March 1962 departing from Essendon airport (in Melbourne, Australia). A sample of the instrument readings recorded during that flight and decoded by the playback station is shown in Figure 5.

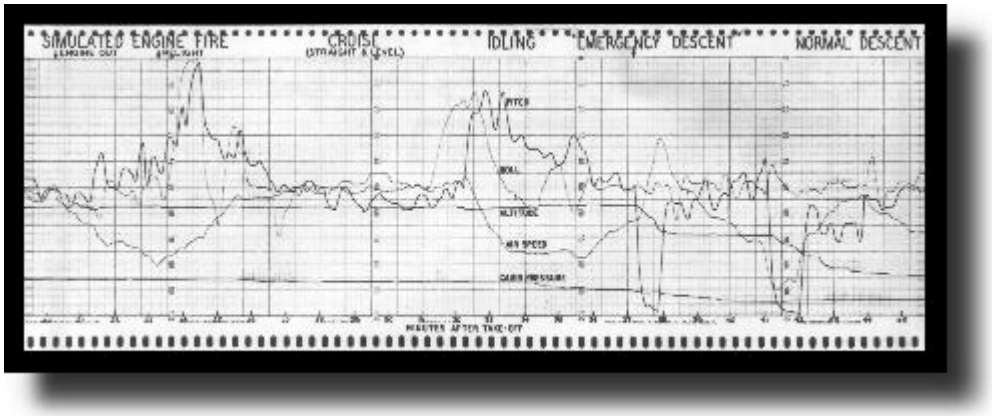

Figure 5: Chart printout of instrument readings recorded during the test flight of the pre-production prototype and decoded by the playback station.

Wire was chosen as the recording medium because it could withstand a higher temperature than tape during any post-crash fire and, at the time of the development of the system, it was superior to tape in terms of storage capacity per unit volume of magnetic medium. Even so, the wire spools were protected against fire and impact damage via a protective box. In subsequent years there was a world trend to switch from magnetic wire to tape as the preferred recording medium. Magnetic tape has, in recent times, been superseded by computer-style technology using solid-state memory chips.