Aviation Recorders
--Their use by safety investigators in the 21st Century

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Let me say first how pleased I am to be with you again. This is the fifth opportunity for me to speak with you on aviation safety from the perspective of a manufacturer of regional, business and amphibious aircraft.

Bombardier Aerospace places a very high value on aviation safety in general and, in particular, on the work of organizations such as this one. We believe that our interests—as well as the interests of our customers and operators, and their customers—are best served with a significant and continuing investment in safety.

Although we work in an industry that already enjoys a very good safety record, there is always room for improvement. As a manufacturer's representative, I am pleased to see that our industry's approach to safety includes not just the way aircraft are designed and built, but that it extends to the way aircraft are operated and maintained.

For our part, Bombardier Aerospace offers extensive training and customer support resources to help our customers and operators perform safely and efficiently.

Improved aviation safety is our common objective. David Learmount, writing in *Flight International* magazine's annual review of air safety notes—correctly, I think—that the travelling public's confidence in aviation safety is **not** driven by accident rates, but simply by the number of accidents.

The big, black headlines that occur when an aviation safety failure results in tragedy have a much greater influence on public perceptions than any statistical trend line on a chart. That observation tells us that we're on the right track. There is no such thing as an 'acceptable' accident rate...

I think it must be apparent to just about everyone, that electronic instruments with non-volatile memory, and equipment capable of recording information from a wide range of sources—including maintenance diagnostic systems and Flight Data Recorders—are now the pre-eminent tools for aircraft accident and incident investigation.

The cockpit voice recorder also plays an important investigation role, although to be fair, the flight deck crew's subjective impressions and reactions are not always as useful as the large quantities of data recovered from the data recorder.

When the FDR and CVR are recovered after an accident—and the data can be recovered—the results often lead investigators directly to the major contributing factors and causes.

There are exceptions to this general rule, of course, and two cases come immediately to mind. Here I refer to the continuing investigations of Swissair flight 111 and EgyptAir flight 990. In the case of Swissair, both the FDR and CVR ceased functioning within a second of each other, about six minutes before the impact with the sea.

Incidentally, this resulted in a Transportation Safety Board of Canada safety recommendation to have these units powered by an independent power source.

Although the EgyptAir investigation has not concluded, the U.S. National Transportation Safety Board has indicated the FDR data revealed no mechanical problems with the aircraft.

At the same time, however, the many conflicting stories about the contents of the cockpit voice recorder should alert us all to the potential conflicts that arise when interpreting this information.

More often, however, the FDR and CVR provide a clear picture that includes both what happened and why it happened.

Incidentally, through the work of its Engineering Laboratory, the Transportation Safety Board of Canada has achieved an international reputation for displaying aircraft behavior and instrument panel readouts, based on recovered flight data recorder information.

In these recreations, the cockpit voice recorder tracks are synchronized to the digital flight data recorder information.

These techniques have been used following many accidents and incidents to help show investigators just what was going on at the time of the events. This technology has been employed in the Swissair investigation and, more recently, for the Crossair event.

The use of FDRs and CVRs in aircraft accident and incident investigation has been greatly assisted by improvements in system survivability and in their ability to acquire large quantities of data from a very large number of parameters.

According to L-3 Communications, the manufacturer of the Fairchild FDR product line, today's top-end data acquisition systems can record data from hundreds of parameters.

Current Bombardier aircraft, including the Canadair Regional Jet Series 100 and 200 airliners, the Dash 8Q turboprop Series 100, 200 and 300 airliners and the Challenger 604 business jet, all employ Fairchild solid state CVRs and FDRs.

The new-generation Q400 turboprop—which entered revenue service with SAS Commuter in February this year—is equipped with a solid state digital flight data recorder manufactured by the Allied Signal division of Honeywell.

The CRJ Series 700 regional jet—now in test flight—employs the Fairchild FA2100 SSCVR and FDR.

I'd like to turn the focus, now, to how manufacturers can use information from flight data recorders to support their products and their operators.

The first is a mirror-image of the accident investigator's use of this information in determining precisely what happened in the investigation of an aviation accident or incident.

Manufacturers can also use flight data recorder information 'pro-actively' for product improvement, to develop and implement updates, and to respond to reports of operator issues or concerns with the in-service fleet.

Let me tell you about several events and how we at Bombardier Aerospace used the information from the Flight Data Recorders to understand each event in detail.

Single-engine performance

The first event occurred in March 1995 to a Dash 8 on a routine flight. The flight became non-routine when the captain observed the Number-2 engine oil pressure gauge indicating 50 pounds of pressure per square inch (psi)—which is significantly below the normal operating range, and indicative of a powerplant anomaly.

The Captain directed the co-pilot to reduce the Number-2 engine power lever to flight idle and, shortly thereafter move the propeller condition lever to the feather position. The Number-2 engine 'low oil pressure' red warning light then illuminated, and the captain elected to shut down the engine. The pilot requested radar vectors to a nearby airport for an immediate landing.

The flight became more unusual still—when descending through 1,000 feet—the nose landing gear would not extend. After circling the airfield three times at 125 knots, and an altitude of less than 500 feet, the pilot requested that the runway be foamed.

During the single-engine manoeuvring, the crew had difficulty managing the aircraft and complained about the aircraft's single-engine performance. Ultimately, the aircraft was landed on the main landing gear alone, without injuries or major damage occurring.

An investigation revealed that the nose landing gear pivot tube assembly was broken, which prevented lowering the nose landing gear using either the normal or alternate landing gear extension procedures.

Ultimately, a post-occurrence inspection of the aircraft by maintenance personnel confirmed the presence of an engine anomaly. The crew became aware of the engine oil pressure problem by observing a low oil pressure reading on the oil pressure gauge during flight. The Number-2 engine oil pressure anomaly was corroborated when the low pressure warning light illuminated.

An interesting fact was that the crew elected to perform a zero-flap landing. Although zero flap is permitted, it's intended only for situations in which the flap system is inoperative. This is an abnormal configuration for landing with an engine inoperative and resulted in a higher landing speed, and that itself is inappropriate given the nose landing gear extension anomaly.

Perhaps the greatest concern to us as the aircraft manufacturer was the pilot's report that the aircraft would not maintain altitude on one engine, following the in-flight shut down.

In this incident, the information retrieved from the digital flight data recorder indicated that after the initial discovery of the oil pressure problem and the shut down of engine Number-2, power was never increased on the Number-1 engine.

In addition, the Number-1 propeller condition lever was not selected to the maximum RPM—full increase position—which would have been necessary to achieve maximum available power.

This situation—with regard to engine management—was further complicated by the crew's intent to conduct the zero-flap landing.

In this case, the flight data recorder pointed out the absence of actions that should have been taken by the flight crew. In turn, this lack of action suggests serious deficiencies in basic airmanship and procedures training. Unfortunately, this isn't an uncommon finding…

Rejected takeoffs

The second instructive incident I'd like to describe relates to a pair of rejected takeoffs experienced by one of our Dash 8 customers in December 1997 and January 1998.

In these incidents, the flight crews were attempting takeoff from a minimal length runway. They reported that when they had pulled back on the control column to rotate the elevator to the full-trailing-edge-up position, the aircraft had not rotated as they expected.

Examination of DFDR data indicated that at the time of the crews' decision to abort the takeoffs, the aircraft had initiated rotation, and had in fact, rotated to approximately two degrees nose-up.

Analysis of the digital flight data recorders also revealed that in both instances, the crews had pulled up-elevator for rotation significantly sooner—at a speed at least 10 knots slower—than is mandated in those circumstances.

What the two events had in common was the application of Type IV anti-icing fluid shortly before takeoff.

In these instances, aircraft series-specific Service Letters entitled *Icing Precautions and Procedures & Performance Adjustment for Ground De-icing/Anti-icing Fluids* clearly spell out that the target speed of V_r +10 knots, or about 105 knots—appropriate to the aircraft being operated—must be used.

By attempting to rotate at 94 or 95 knots, the crew~~s~~ pulled on the elevator before it was aerodynamically effective. As a result, they pulled the control column until it reached its spring-tab stop, which gave the crew an unexpected stick-force gradient. Considerable added effort would have been required to move the elevator further towards the full-trailing-edge-up position for rotation and takeoff.

As a result, the crew experienced an unfamiliar stick force—or control force—at rotation and achieved much less elevator response than they expected. They interpreted this as indicating a serious problem and, hence their decision to abort the takeoffs.

The performance of the aircraft under these conditions was subsequently verified during Type II and Type IV anti-icing fluid testing on a Dash 8 at Montréal's Mirabel Airport in March 1998, undertaken by us and at our expense.

Here again, the flight data recorder information identified a serious operational problem that was <u>initially</u> believed to be a problem with the aircraft itself.

However, the DFDR clearly indicated the <u>in</u>appropriate crew procedures operating the aircraft following the fluid-application operation.

The Mirabel testing confirmed aircraft performance and handling characteristics following the application of anti-icing fluids, when the appropriate aircraft operating procedures and fluid handling and application procedures are respected.

Flight spoiler extensions
A more serious incident concerns an operator's report of difficulty retaining control of an aircraft following takeoff, in August 1998.

In this episode the inboard roll spoilers stopped tracking their respective ailerons shortly after takeoff. As the aircraft accelerated and was cleaned up, the inboard roll spoilers extended symmetrically—without being commanded by the pilots. The event lasted for about 12 seconds. A second un-commanded extension occurred a few moments later, but this event was non-symmetrical.

On the first occasion the spoiler extension resulted in the aircraft's altitude increase by about 100 feet, while the second un-commanded extension resulted in an altitude increase of about 60 feet. Both altitude excursions were the result of the pilot responding to the lift loss.

The pilots immediately recognized that they had a serious situation on their hands and elected to return to the departure airport. During the flap extension to 15 degrees for landing, the inboard roll spoilers extended, floating up to about eight degrees, over a period of 25 seconds. Following flap extension the spoilers operated appropriately in response to lateral control inputs.

The pilots reported decreased aircraft controllability during this sequence of events, and we were naturally very concerned, and decided to investigate the incident thoroughly—including analyzing data recovered from the aircraft's flight data recorder.

Here again, the information from the flight data recorder provided a virtual reconstruction of the incident sequence.

First, I should note that at no time during this incident did the aircraft even approach an 'uncontrollable' state. Specifically, the lateral and directional control inputs indicated no controllability problems with the aircraft.

This is confirmed by the flight data recorder, which indicates that control deflections were minimal throughout the sequence, and that at no time were the crew attempting to overcome an engaged autopilot, which was initially postulated.

The Dash 8 aircraft has been extensively flight-tested and shown to be fully controllable with one engine inoperative, or with an inoperative hydraulic system—including spoiler float associated with the loss of spoiler hold-down pressure.

The flight data recorder provided a more complete picture of the sequence of events, which—for purposes of this discussion—began with the pilots' pre-flight preparations.

As part of their pre-flight checks, the crew had pulled both "Pull Fuel Off" handle**s** on the aircraft's fire protection panel, which closes the fuel and hydraulic shutoff valves for each engine. The "Emergency Shut Off Valve" for the Number-1 hydraulic system had remained in the closed position after the crew reset the "Pull Fuel Off" handle at the completion of this check. In turn**,** following engine start-up**,** the "Number-1 engine Hydraulic Pump" caution light remained illuminated.

Despite the illumination of this caution light, or a provision permitting continued operation with either engine-driven hydraulic pump inoperative on the approved Dash 8 Master Minimum Equipment List, the aircraft was dispatched.

Dispatch with the Number-1 engine-driven pump inoperative exposed the flight to the possibility—however remote—of a second failure which could have seriously jeopardized the safety of the flight to a point that recovery may have been much less certain.

Generally, the aircraft and system behavior described by the operator is consistent with the Number-1 engine-driven hydraulic pump being inoperative for take-off, with the Number-1 hydraulic system being supplied by the electrically powered Number-1 Standby Power Unit, or SPU.

In this instance, the illumination of a hydraulic system low-pressure caution light should have alerted the crew of a problem with the Number-1 hydraulic system. The take-off should not have been attempted.

The reduced efficiency of the hydraulic system did not seriously degrade the aircraft's performance or controllability, but it would account for the abnormal handling characteristics experienced by the flight crew during flap retraction and extension.

In the three cases I have described, the information from the Flight Data Recorder completely cleared the aircraft and the way it performed. In fact, in each case the full picture has identified some serious operational issues.

While that is very gratifying for the manufacturer, it also underlines the validity of a point I have made before in this and other forums.

While our aircraft are built to the same certification requirements as the biggest and most complex large jet transport aircraft, we sometimes find that the operating and maintenance environments do not reflect the same standards.

This can be due to the fact that regional airlines have experienced rapid growth, or because they are often younger organizations and haven't had time to develop the same depth of experience and resources as their big-carrier counterparts.

As I have suggested before, investing in training offers the fastest and most cost-effective path to eliminate these operational and maintenance shortcomings.

Leading-edge loss

The final incident I'd like to describe for you had a very different outcome from the three events I have already discussed.

It didn't have a tragic outcome. Yet it was the most serious of the incidents I am using—and it might well have resulted in an accident. In some ways this is also the most unsatisfactory event—from the manufacturer's perspective—because of the way it turned out.

Immediately after takeoff—in January 1998—a Dash 8 with a crew of four and 32 passengers suffered the loss of the inboard leading-edge of the right wing—a segment about nine feet long. Fortunately, the crew selected an appropriate direction to turn the aircraft and immediately performed an uneventful precautionary landing on an adjacent runway.

Post-event investigation by the carrier's own maintenance personnel revealed that the lower row of screws securing the inboard leading-edge segment onto the wing, had not been replaced following a routine maintenance check.

Although the operator initially indicated it would make the digital flight data recorder available to us, the data never came. When we enlisted the help of the FAA to obtain the recording, the operator indicated that the data was no longer available.

We can only speculate on the reasons for this response. Perhaps the best explanation is that the operator feared further embarrassment, or that providing the FDR information might provoke new investigations of its operations and maintenance functions. We won't ever know.

Similarly, we won't ever know how the aircraft performed without a major piece of its leading edge. We do know that the flight crew experienced difficulty maintaining control. Initially, the leading-edge section may have flipped upwards, exposing the front edge of the spar and the open side of the leading-edge section to the airflow, prior to being released from the aircraft.

Our aerodynamics experts tell us that the Flight Data Recorder information would have provided crucial data on what kind of safety margin remained between controlled flight and catastrophe.

The loss of a leading-edge segment isn't a scenario we can accommodate in even the most sophisticated flight simulator, and it is far too hazardous to replicate in flight testing aboard an aircraft.

So, as a result of the operator's decision not to provide data, we remain uninformed about the performance of the aircraft in that condition, although we know that the crew had difficulty. And yet forgetting to re-install the securing screws or the crew missing the problem during the pre-flight walk-around isn't so bizarre or far-fetched that we can reasonably think that it probably will never happen again in our fleet.

The aerodynamic performance of the aircraft in this unique event is now irretrievably lost and that is a tragedy in itself. The message for us should be that Flight Data Recorders are invaluable tools for enhancing and improving aviation safety—but like every other tool in our inventory, they are useless without the proper attitudes and the willingness to use them properly.

Jim Burnett, former chairman of the U.S. National Transportation Safety Board likened the Flight Data Recorder to a blood pressure monitoring device. He said:

> "Diagnosis is the first step to a solution. What the Board wants is to stop using accidents as a diagnostic device."*

Burnett's thoughts were echoed by Robert Francis, a former US NTSB vice-chairman, who said:

> "It is time—now—to move beyond recorders as accident investigation tools. We must move to the use of modern recorders as pre-emptive tools to monitor the day-to-day safety of airline operations to keep ahead of incidents that can lead to accidents."*

Looking at the future of Flight Data Recorders we can see their capabilities enhanced by making their operation even more reliable—perhaps through some form of self-powering capability. This might eliminate those few cases in which some information is lost because of a power interruption.

We can also expect further increases in the capacity of Flight Data Recorders. That would provide even more information from more sources over a longer period.

Ultimately, this might even include some form of real-time data transfer from aircraft in flight, thereby bypassing the aircraft-mounted 'black boxes' entirely.

Yet another direction for in-flight information gathering is the prospect of flight deck videos, complete with multiple audio sources. Here again, the intended use of technology is to develop a fuller picture of what was going on in the aircraft—in this case a literal picture.

Flight information—when it's available and acted on—provides a powerful tool for enhancing aviation safety.

As with operational and maintenance data, making the best use of information resources depends, first and foremost, on a willingness to make tough decisions.

These decisions aren't intended to cast blame for operational or maintenance shortcomings, but to establish and maintain that safety is and must always be our first priority. It's the right thing to do and it's good business.

Jim Donnelly began his aviation career flying commercial helicopters in the Canadian Arctic in the early 1970s. In 1979 he was employed by the de Havilland Aircraft of Canada as a Field Service Representative and lived for six years in various locations worldwide, including: Monterey, California, Port Moresby, Papua New Guinea, Sana'a, North Yemen and Barranquilla, Colombia. In 1986 he joined the Air Safety Group of Boeing Canada, de Havilland Division. Jim is currently Manager, Product Safety, Bombardier Aerospace, Regional Aircraft, based in Toronto, Ontario Canada. His responsibilities include providing assistance to government authorities investigating aircraft accidents involving de Havilland Canada aircraft (DHC-2 Beaver, DHC-3 Otter, DHC-4 Caribou, DHC-5 Buffalo, DHC-6 Twin Otter, DHC-7 Dash 7 and DHC-8 Dash 8) as well as those involving the Canadair Regional Jet airliner (CL600-2B19).

* *Both cited in* Air Safety Week *Vol. 13, No. 13 March 29, 1999 re NTSB report on USAir Flight 427 Boeing 737 accident at Pittsburgh, Pa.*