

COCKPIT IMAGE RECORDING SYSTEMS

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ABSTRACT

This paper will discuss some of the results and successes that can be achieved with different low-cost FDRs, but will focus specifically on the benefits of Cockpit Image Recording Systems over the more traditional 'hard-wired' FDRs.

Low-cost FDRs are appropriate for General Aviation as they can still provide a wealth of useful information; to operators about their day to day operations, to flight instructors and their students regarding training progress, to maintenance engineers in the form of diagnostic information, and to accident investigators in the event of an incident.

It is not being suggested that General Aviation aircraft should be burdened with further compulsory regulation and costs from the Aviation Authorities, but it is being suggested that there could be positive benefits for the operators of some General Aviation aircraft to choose to invest in such devices.

The research project behind this paper has produced a number of flight-tested designs for low-cost light aircraft (Helicopter or Aeroplane) solid-state FDRs utilising modern technologies and has produced some relevant flight data storage, processing and presentation software tools.

INTRODUCTION¹

Since their introduction in the 1950's the Flight Data Recorder (FDR) and the Cockpit Voice Recorder (CVR) have played a critical role and proven themselves to be valuable tools in the determination of the probable causes of all sorts of aircraft accidents.

The FDR and CVR can provide information that may be difficult or impossible to obtain by any other means and with a better understanding of the factors that may have caused an accident, changes can be made to designs and/or processes to prevent a repeat of that type of accident.

Compulsory for some time on large commercial jet aircraft such devices can now be found in most aircraft other than those typically categorized as light aircraft / General Aviation (GA). Unfortunately that constitutes rather a lot of unprotected aircraft.

Providing 'black box accident investigation' functionality is the most well known reason for having an FDR but it is in fact not the only one. Other uses include predicting maintenance and debriefing after training flights.

The National Transportation Safety Board (NTSB) describes "black boxes" thus (Ref. 1):

"Currently large commercial aircraft and some smaller commercial, corporate, and private aircraft are required by the Federal Aviation Authority (FAA) to be equipped with two "black boxes" that record information about a flight. Both recorders are installed to help reconstruct the events leading to an aircraft accident. One of these, the Cockpit Voice Recorder, records radio transmissions and sounds in the cockpit, such as the pilot's voices and

engine noises. The other, the Flight Data Recorder, monitors parameters such as altitude, airspeed and heading. Older analog units used one-quarter inch magnetic tape as a storage medium and the newer ones use digital technology and memory chips. Both recorders are installed in the most crash survivable part of the aircraft, usually the tail section.

Each recorder is equipped with an Underwater Locator Beacon to assist in locating in the event of an overwater accident.

Following an accident, both recorders are immediately removed from the accident site and transported to NTSB headquarters in Washington D.C. for processing. Using sophisticated computer and audio equipment, the information stored on the recorders is extracted and translated into an understandable format. The Investigator-in-Charge uses this information as one of many tools to help the Safety Board determine the Probable Cause of the accident.

Both the FDR and the CVR have proven to be valuable tools in the accident investigation process. They can provide information that may be difficult or impossible to obtain by other means. When used in conjunction with other information gained in the investigation, the recorders are playing an ever increasing role in determining the Probable Cause of an aircraft accident."

The FAA Revisions to CVR and Digital Flight Data Recorder (DFDR) Regulations; Proposed Rule (Ref. 2) states that they are applicable only to aeroplanes and helicopters certificated for ten or more seats and so are not immediately relevant to any type of DFDRs for smaller helicopters, which unfortunately, is the majority of them. Also, military aircraft are exempt from this rule. While not mandatory, these rules do however suggest some sensible criteria for any size or type of DFDR.

1. Presented at 34th European Rotorcraft Forum, Liverpool, September 16-19, 2008. Copyright © 2008 by Alan Barclay. All rights reserved.

Key points for CVRs are;

- Minimum 2 hours recording time.
- Solid state only - no magnetic tape.
- Minimum 10 minute operation after a loss of aircraft power.

Key points for DFDRs are;

- Time, Airspeed, Altitude, Heading, Acceleration, Attitude and Outside Air Temperature.
- Engine and Rotor speed.
- Cockpit controls at 4x per second.

A brief summary of proposed rules can be found in FAA Press Releases (Ref. 3) and Fact Sheets (Ref. 4).

SMALL HELICOPTERS

Small helicopters are very commonly used for (initial) flight training, personal/private transport and many varied types of Air Operator Certificate (AOC) work, but typically not mass passenger transport or heavy lifting. And having less than ten seats there is no compulsory requirement for any type of DFDR.

Whilst there are many initiatives to improve flight safety there has previously been little emphasis on the recording and analysis of generic flight data for small helicopters, and any existing 'black box' solutions typically are too cumbersome and expensive for this segment of the industry. There is a definite limit to the size and weight of a DFDR that would be sensible to install in a common type such as the R22. Providing cost effective and good solutions for this segment of the industry is therefore quite challenging.

The most common small helicopters; Enstroms, Robinsons, Schweizers as well as the smallest Bells and Eurocopters constitute far more than 70% of the U.K. Civil Registered Helicopter Fleet (Ref. 6) (Table 1) (Figure 1) (Snapshot taken May 2008). Figures for North America are similar (Ref. 8). The three biggest manufacturers, with almost 70%, currently do not install any standard 'generic' recording device into their production aircraft. Suitable devices from a couple of manufacturers typically are very aircraft type specific or offer few overall benefits, for a reasonable cost.

Exploring the number of helicopters in the U.K. fleet in more detail, it was found that only 104 from the 1483 had ten or more seats. Therefore it can be deduced that over 90% have no CVR / DFDR type device installed.

In order to support the International Helicopter Safety Team's goal of achieving a reduction in the helicopter accident rate by 80% by 2016 it is proposed that increased data collection is essential to better understand what is causing the current problems / accidents.

Figures being compiled by IHST (Ref. 7) show that the most prolific causes of problems / accidents are;

- Instructional / Training
- Personal / Private Transport
- Aerial Application
- Emergency Medical Service
- Commercial Operator (AOC)
- Law Enforcement
- Air Tour / Sightseeing
- Off-Shore
- External Load

The commercial airline industry undoubtedly benefited from the widespread use of FDRs and the challenge for the helicopter industry (manufacturers and operators) will be to implement low-cost FDRs with appropriate functionality, in the near future, to contribute towards this goal of improving flight safety.

Also, the FAA states in Flight Plan 2005-2009 (Ref. 9) that its goal is to "*achieve the lowest possible accident rate and constantly improve safety*" and a specific objective is to "*reduce the number of fatal accidents in general aviation*". According to their draft Flight Plan 2008-2012 "*Goal: To achieve the lowest possible accident rate and constantly improve safety*".

As such, this area is extremely worthy of additional flight safety research.

Table 1: Helicopters in U.K. Fleet

Manufacturer	No. of aircraft	Percentage of total
Aérospatiale	52	3.51%
AgustaWestland	63	4.25%
Bell Textron	181	12.20%
Brantly	7	0.47%
Enstrom	75	5.06%
Eurocopter	275	18.54%
Hiller	1	0.07%
McDonnell Douglas	64	4.32%
Robinson	574	38.71%
RotorWay International	50	3.37%
Sikorsky	59	3.98%
Schweizer	61	4.11%
Westland	21	1.42%
Total in fleet	1483	

Helicopters in U.K. Fleet (per manufacturer)

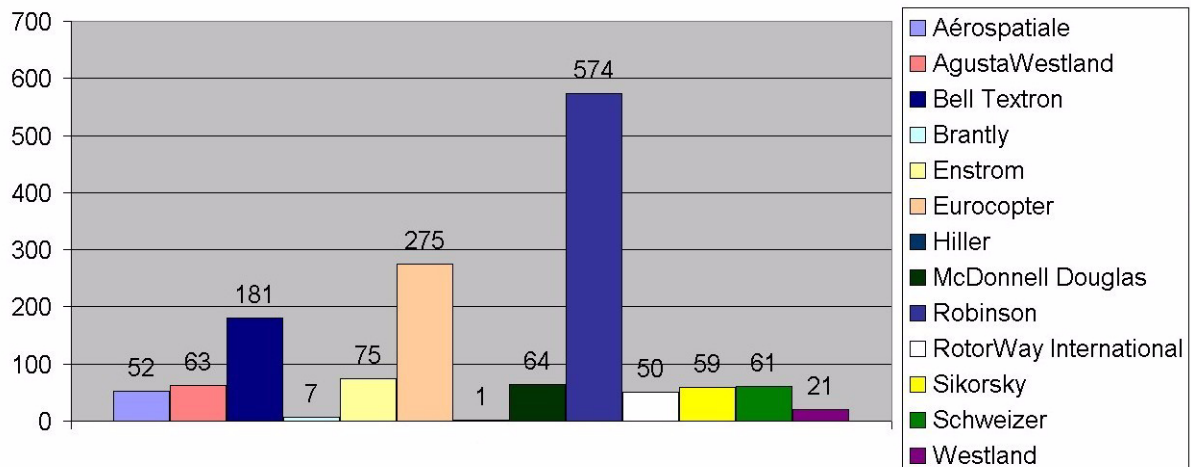


Figure 1

RESEARCH

At the University of Aberdeen, a research project has been working to produce flight-tested designs for various light aircraft (Helicopter or Aeroplane) solid-state FDRs, incorporating appropriate HUMS/HOMP concepts, utilising new technologies and has produced new corresponding flight data analysis and presentation software tools. It is envisaged that such devices and software tools would contribute to flight safety through improvements in flight training and providing pro-active aircraft maintenance data, while lowering operating costs. They would also provide valuable extra information to accident investigators.

All of the resulting designs / devices, which might be thought of as mini-HUMS devices, are typically similar in capabilities to current commercial flight data, engine monitoring and voice recorders but of a size, weight and cost appropriate to GA light aircraft.

The associated database / software would be capable of displaying flight data using a variety of graphical techniques and would make use of statistical data analysis to automatically determine various stages of flight and engine / airframe limit exceedances.

One of the key challenges with this will be to provide user interfaces that are extremely simple to use and yet will provide all of the essential information that is required by the user. It is through the statistical data analysis software tools that it should be possible to deduce and report on the salient points in each data set (whether about the status of the airframe or the capabilities of the pilot).

SOLUTIONS

Any black box or DFDR device incorporating HUMS/HOMP functionality would also need to offer some additional “value-for-money” in everyday operations.

For example;

- Flight Training Organizations;

In conjunction with “flight path re-creation and statistical analysis” computer software it would become a tool for examining pilot technique, whether during dual flight exercises or solo cross-country flights, such that further training could become more focused on any area identified as causing specific problems to that student pilot. Such automatic statistical analysis computer software could automatically determine various stages of flight (for example; take-off, level flight, banked turns, descents) and compare against published flight test acceptance criteria. This analysis could measure the progress of a trainee pilot and help their flight instructor identify manoeuvres which were repeatedly carried out unsuccessfully or in an unsafe manner. Figure 2 shows a training flight (sky blue line) overlaid within the GoogleEarth (Ref. 13) application.
- Maintenance Organizations and Aircraft Re-Sale;

It could produce a ‘tech. log’ record of all airframe / engine activity such that any limitation exceedances could be immediately indicated. Also, analysis of airframe and engine related data might predict and highlight future maintenance issues. A permanent life-time record could be achieved either by downloading data from the device during each regular maintenance cycle into a database or by ensuring that the device contains sufficient storage capacity to hold all data that would ever be generated (between rebuilds). Such a life-time audit trail of airframe / engine activity could be useful during the re-sale of an aircraft as evidence of prior ‘one careful owner’

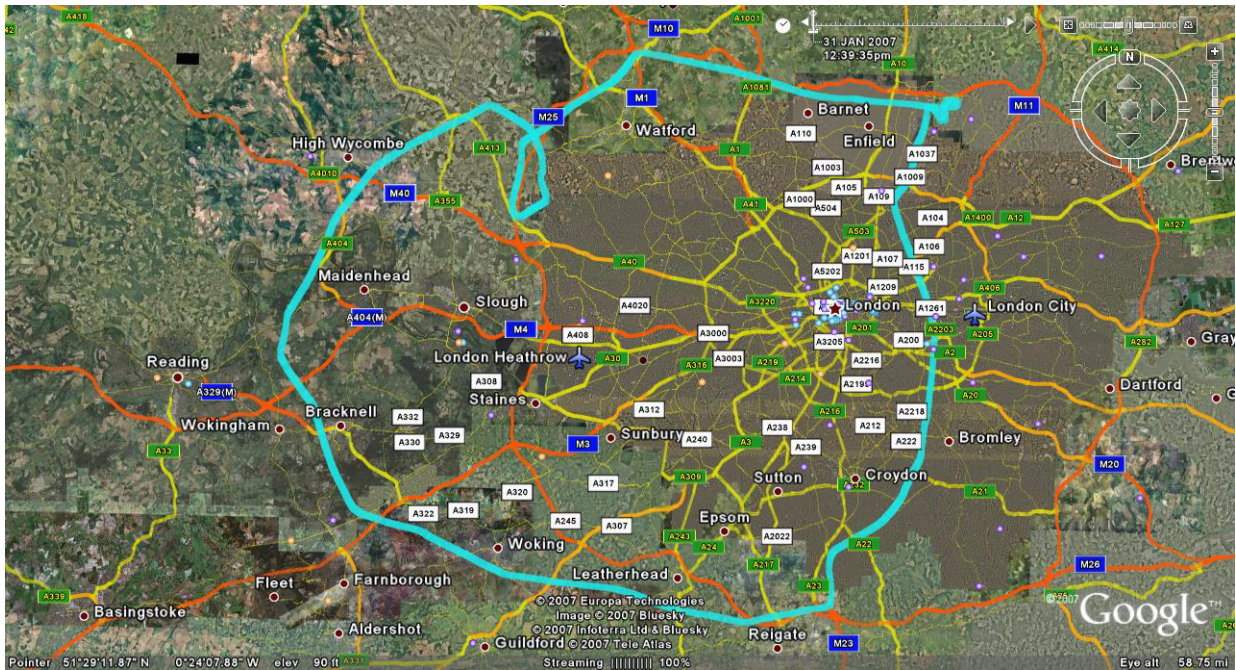


Figure 2 - Training Flight shown using GoogleEarth

handling and actually increase the re-sale value of the helicopter.

Figure 3 shows prototype computer software for displaying various engine and rotor system data parameters.

- Operators - Tracking / Limitations;
The device could phone home with regular position update information or only if / when a certain airframe limitation has been exceeded.

Some of these concepts are neither particularly new or innovative but typically have not been made available for small helicopters at a size / weight / cost which was attractive enough to be of interest to a large segment of the industry.

During the course of this research, designs / solutions or actual working prototype devices (nicknamed Jemma and EMMA) have been created covering these example application areas and the majority of the FAA key points for CVRs and FDRs.

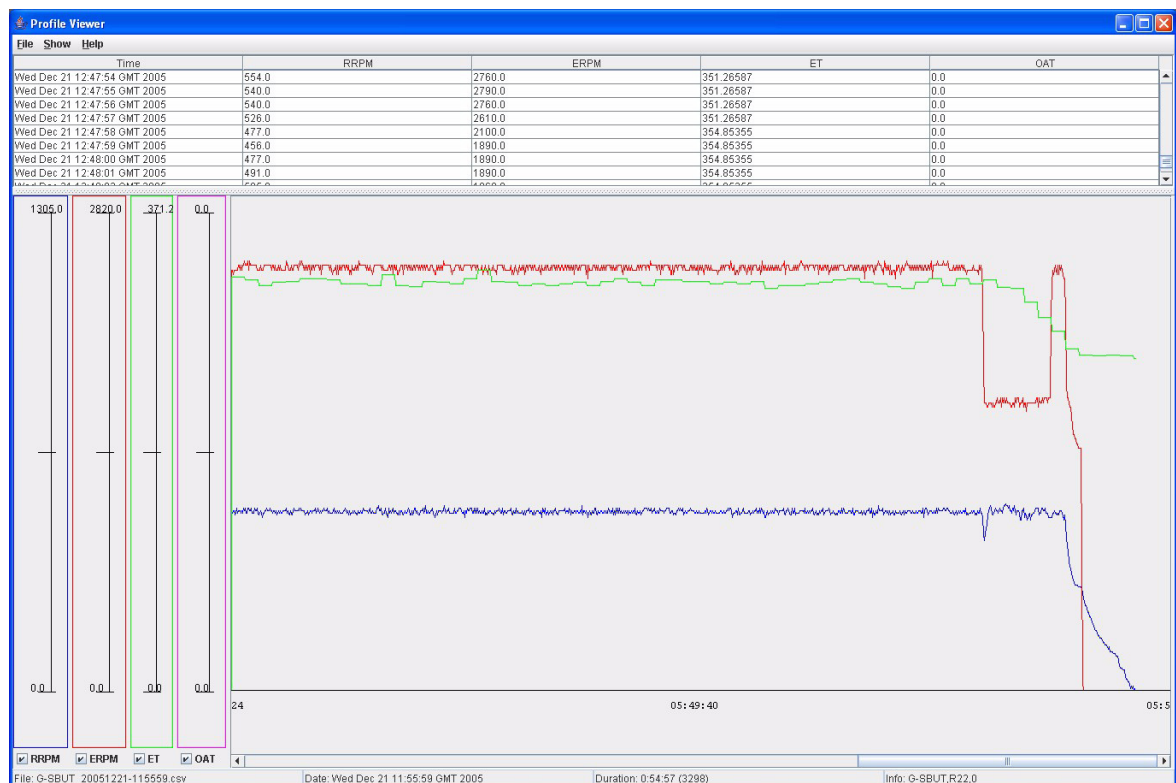


Figure 3 - Recorded Engine and Rotor Speeds

It is important to note that these prototype devices have been designed to be as small, light and low-cost as possible. They have not been specifically designed to be fully crash-proof (or fire-proof). This is partly because they are just prototypes and partly because it is considered that the only component which needs to survive an impact is the postage stamp sized removable solid-state memory device and if sensibly installed in the target aircraft then survival of this is very likely.

Since such FDRs would be useless without comprehensive associated software tools, some work in this area has also been carried out. It is extremely important that any such software would be readily usable by engineers and flight instructors with only average computer experience as opposed to requiring extensive training.

JEMMA PROTOTYPES

The first device in this range was a very simple straightforward engine and rotor speed monitor and has already had a few 100 hours of successful flight testing. The manufacturing cost of this device is around \$250, is about the size of a cigarette packet (not carton), weighs under 200g (without its external sensors), and can store upto 100 hours of data (which is the maintenance interval for an R22 or R44). Figure 4 shows a view of its tiny circuit board. Other devices in the range add GPS and Attitude recording, multiple analogue and digital data channels, and extend the data storage capacity to 1000's of hours but remain approximately the same size and weight, and still have a manufacturing cost below \$1,000.

It has been designed primarily to provide a mechanism for identifying and quantifying (unreported) over-speeds to maintenance engineers.

Engine and Rotor overspeeds are relatively common occurring in perhaps around 10% of an operator's Robinson fleet, each year, when being used for Flight Training and Rental purposes. Careful inspection after an over-speed event, and repair as necessary, is essential to keeping the aircraft airworthy.

Typically an overspeed event must be reported by the Pilot In Command (PIC) to the aircrafts owner / maintenance organization but this might not always occur - especially if the person responsible was concerned that they would receive a potentially large bill for the repair.

It records date and time, rotor RPM, engine RPM, engine Cylinder Head Temperature (CHT) and outside air temperature and has an overspeed indicator lamp which comes on, at the start of the next flight, if either the rotor or engine RPM limit has been exceeded.

The potential advantages offered by this device;

- Data and time of every engine start / stop are recorded.
- Exceeding a set engine or rotor speed limit will result in the overspeed indicator lamp becoming lit - which can only be turned off by a maintenance engineer.
- Data traces show whether certain pre-flight checks are being carried out - such as the Sprag Clutch disengage check and the Low Rotor RPM Horn / Light check.
- Data traces showing whether correct engine warm-up and shutdown procedures are being followed.
- Data traces showing actual engine and rotor RPMs being maintained during practice auto-rotations (in Flight Training).
- In the event of an accident the data traces would show any engine or rotor RPM decay / overspeed as well as the order in which these actually occurred.



Figure 4 - Jemmal Circuit Board

This “black box” information might greatly assist accident investigators to understand the cause.

Figure 5 shows the most recent Jemma incarnation. Almost exactly the same size and weight at the first Jemma device, but featuring more generic analogue and

digital channels, an internal 12-channel GPS, internal solid-state magnetic compass and XYZ accelerometers, an ARINC429 input channel, support for external gyro and a fast USB data download capability.

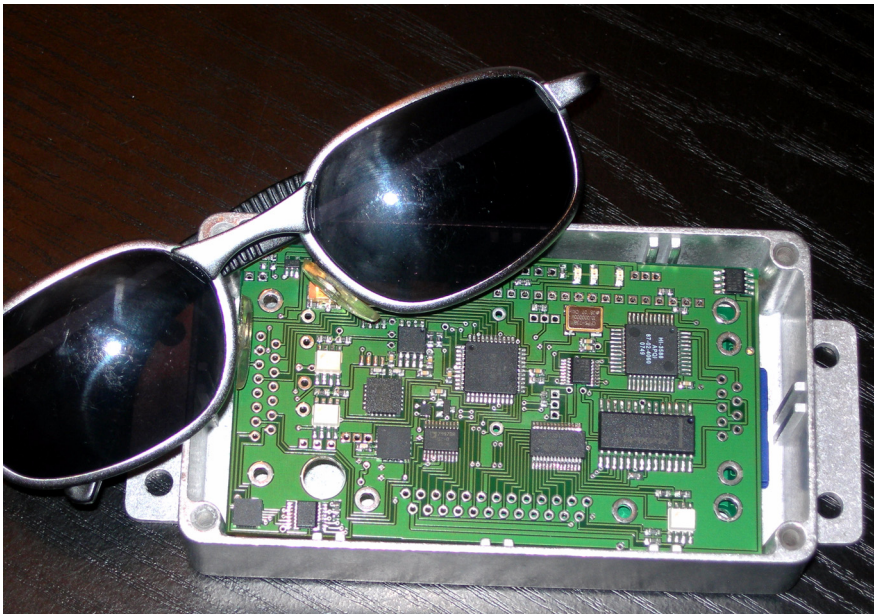
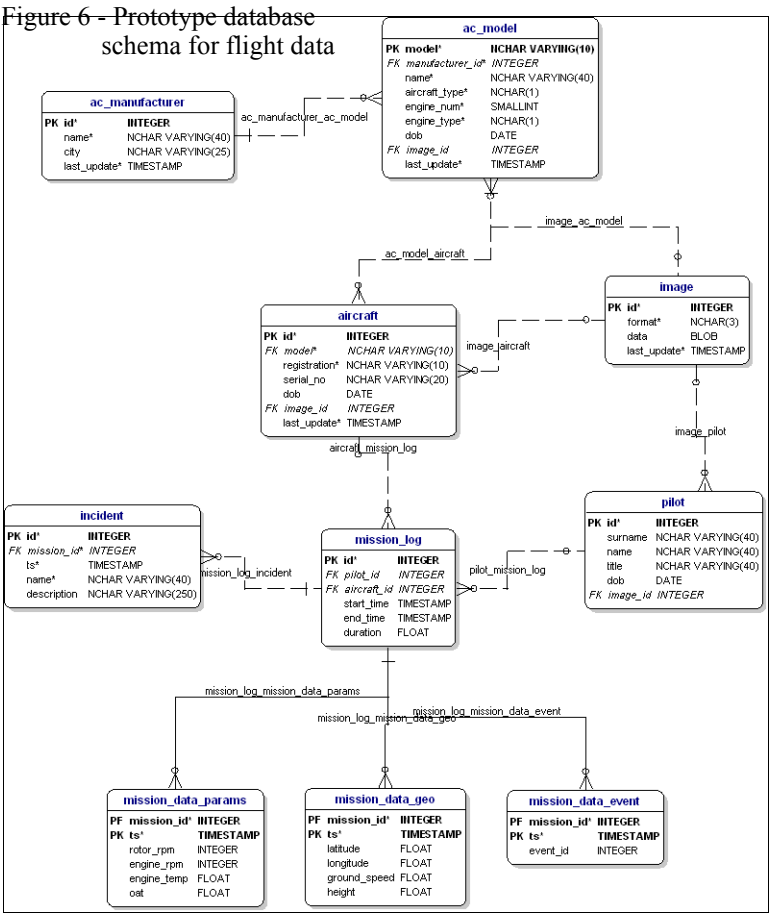


Figure 5 - Latest Jemma Circuit Board

Figure 6 shows a prototype schema for a database which was designed for storing data resulting from both Jemma and CIRS devices. The database itself runs on a small inexpensive self contained ‘Network Computer’ that can

just be turned-on and requires minimal administration, with data uploading, access and reporting via a simple web browser interface.



COCKPIT IMAGE RECORDING SYSTEM

Installing an FDR into an aircraft requires connecting the device to the various sensors and systems from which data is desired to be gathered.

Even for a simple FDR, such as Jemma1, this can involve a significant amount of additional wiring and installation of sensors, which may prove to be both a time consuming and costly exercise. Often this will also lead to complex certification issues, depending on which aircraft systems the device is being connected to.

For a complex HUMS system in a large mass passenger transport helicopter, such as EC225, the installation effort is quite considerable.

Where the data gathering exercise is being done just to identify a single issue, perhaps just one pilot that is having an obscure issue, then all of this effort would be rather disproportionate. And sometimes that obscure issue just never occurs when someone else is observing.

A radically different approach to the standard FDR, which is intrinsically linked to the aircraft systems, is a Cockpit Image Recording System (CIRS) which uses only a high resolution camera, an area microphone and a

collection of internal sensors to build a picture of the activities of the aircraft. (Ref. 14)

The 'EMMA' device is far more comprehensive in terms of its input capabilities than 'Jemma' and should be considered to be a general purpose CVR/FDR with a size about that of a small shoe box. It is capable of being configured to record dozens of input channels, including GPS-derived flight path information (for example; position, altitude, speed and heading), attitude, magnetic heading, outside air temperature, engine and rotor system parameters, airframe vibration, audio and video, for up to thousands of hours. Although, in the CIRS form it is constrained specifically to GPS and camera.

The device contains a relatively powerful embedded computer (sufficient to also drive an external character or graphical information display for the pilot and to support a real-time communications up/down link) as well as extensive solid state data memory and an internal backup power source (so that the system can continue to record even after an aircraft power failure).

Figure 7 shows the front panel of the 6" by 8" by 3" self-contained prototype unit which has been tested in four or five different helicopter types, to date.



Figure 7 - Prototype (EMMA) CIRS unit

The camera is directed at the aircraft instrument panel where it can 'see' the information being presented to the pilot whether via steam gauges or glass panel displays, and to also observe the pilots operation of switches / controls. The microphone records background noise, rather than CVR type pilot audio, from which it is typically possible to determine engine and drive-train / rotor-system health. An internal GPS receiver provides information about the location and speed of the aircraft.

All of the recorded data is stored onto durable capacious Compact Flash cards (USB devices including memory sticks and iPods may also be used) for later processing with a software suite on a regular desktop computer. Readily available 8GB Compact Flash cards can store over 4 hours of data which is typically long enough to exceed the fuel endurance of such helicopters.

The camera records megapixel resolution images (at approximately four times television camera resolution) in order to accurately capture the detail of instrument needle positions, dials, etc. in what is after all a rather high vibration environment.

It should be highlighted that such a system exists to record what is happening in the cockpit of the aircraft. It should make no difference to the pilot / crew that a camera is being used rather than a myriad of FDR sensors on every part of the aircraft.

Where a pilot is following the standard operating procedures of the aircraft then they should not be concerned about being 'watched'. If their equipment fails on them, then all of the evidence to support that they did nothing wrong will have been recorded and indemnify them of blame.

The associated software suite includes capabilities for flight profile data analysis, generating overlay files for the GoogleEarth application (see Figure 1) and for producing DVD-like movies of the flight (which are excellent for training flight evaluation and debriefing).

Further enhancements for this system include;

- an external Gyro (Attitude / Orientation Sensor).
- an external (cockpit mounted) LCD display.
- an Iridium based real-time data feed, for example, 'tracking' information or emergency reports.

- internal magnetic compass and XYZ accelerometers.
- ARINC429 input (from other equipment).

Figure 8 shows a test camera mounted on the ceiling of a Robinson R44, courtesy of HeliAir Ltd. (Ref. 15). Data and power cables are required to connect the camera to the main unit.

Figure 9 shows the typical camera view of the console, stick & pedals and some external, in a Robinson R44. Figure 10 shows a view of the much larger and more complex AS350 console with its 'digital' glass displays.



Figure 8 - Test installation of CIRS camera in a Robinson R44



Figure 9 - Camera view in a Robinson R44



Figure 10 - Camera view in an AS350

CONCLUSION

It is not being suggested that GA aircraft should be burdened with further compulsory regulation and costs from the Aviation Authorities, but it is being suggested that there are positive benefits for the operators of some GA aircraft to choose to invest in these types of devices. These benefits include improving the efficiency of training through the ability to debrief using actual flight data and to enhance maintenance through the ability to bring data trends and peaks to the engineers attention.

It is also expected that the wider use of DFDRs could contribute to the goal of the International Helicopter Safety Team.

Black box FDRs and HUMS, etc. have proved invaluable to other segments of the aircraft industry over many decades and similar improvements in flight safety across the large fleet of small helicopters would likely be achieved if there existed suitable black box FDRs even with modest data acquisition capabilities.

It is suggested that devices like Jemma and EMMA CIRS can make such a contribution.

You just can't fix what you don't know. But if you have a recording of what was going on just before the event then you have something to work with and should ultimately speed up the determination of causes of the event and allow corrective action to happen much faster. The CIRS, in particular, offers a simple and relatively low-cost approach to getting a recording of what was going on.

The benefits of using such devices include providing useful airframe diagnostics for maintenance engineers as well as providing information on pilot performance to flight instructors and aircraft owners / operators while at the same time assisting accident investigators.

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