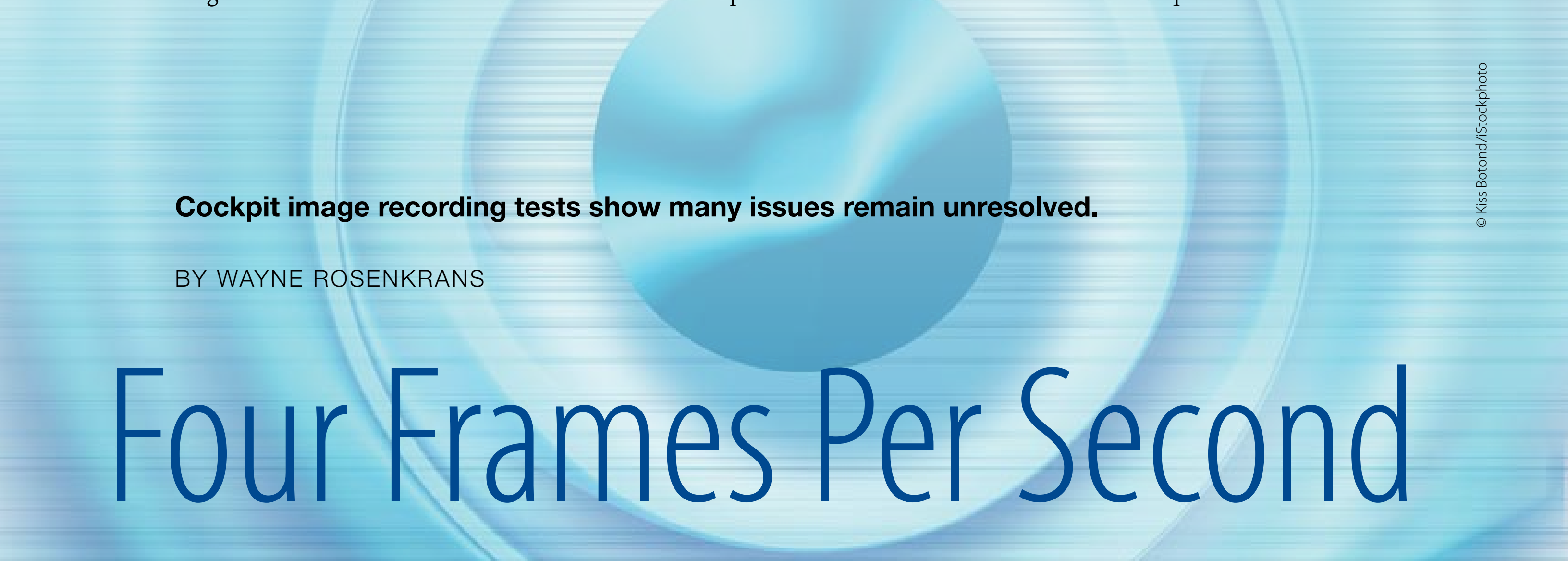
Four Frames Per Second

Cockpit image recording tests show many issues remain unresolved.

BY WAYNE ROSENKRANS



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Proposals to enhance accident investigation with imagery from cameras in the cockpit show a combination of strengths and weaknesses, according to U.K. Civil Aviation Authority (CAA) research. "The results of the research were mixed," the CAA's report said. "Although image recorder systems do provide some benefits, this research has not found them to be as effective as has been postulated by some accident investigation agencies. … Image recording systems can gather large amounts of data that may assist accident investigation without providing explicit identification of the flight crew."[1]

Accident investigators have imagined many benefits if cameras continuously captured action on the flight decks of large commercial jets to supplement flight data recorders (FDRs) and cockpit voice recorders (CVRs), or to see what preceded an event involving a small turbine-powered airplane or helicopter not equipped with an FDR or CVR.

Guesswork about the technical feasibility has been reduced by the CAA report. However, the long-running controversy about these proposals has not been resolved to the satisfaction of airline pilot associations, aircraft operators or regulators.

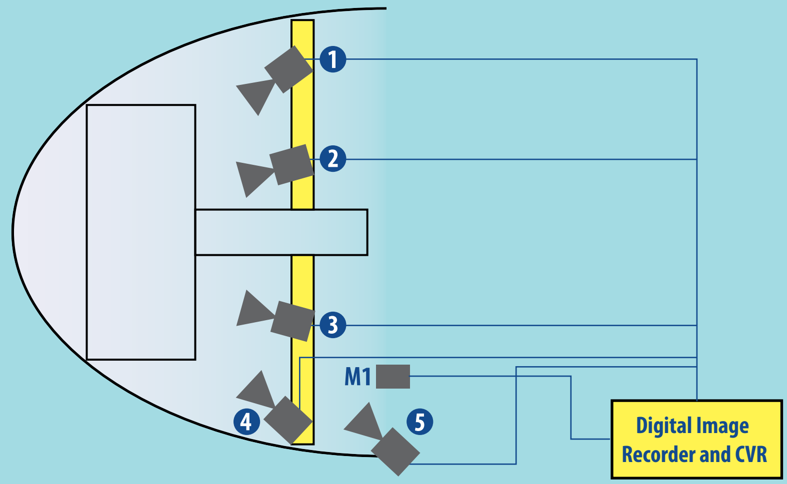
Anyone familiar with video camcorders and digital cameras — but not closely following this issue — readily could become lost in the semantics. For example, what some proponents now envision is not full-motion video but sequences of still photos.

A March 2003 European Organisation for Civil Aviation Equipment (EUROCAE) specification — adopted by the U.S. Federal Aviation Administration (FAA) for a technical standard order in July 2006 — actually calls for color images more like those from intermittent closed-circuit surveillance at a bank than the approximately 30 frames per second required for full-motion video in the United States. The minimum EUROCAE-specified data — effectively 12,600 compressed images in two hours — requires about three gigabytes of crash-protected solid-state storage per camera, a much greater amount than required by current-model CVRs and FDRs. The specification also calls for dual-password encryption of images, designed to prevent unauthorized viewing.[2]

The specification essentially calls for installing cameras only behind and/or above the flight crew and facing forward so that instruments, flight controls and the pilots' hands can be seen clearly but the pilots' heads and shoulders are not recorded while they are in their normal seating positions.

EUROCAE said that key factors affecting visual quality include frame rate, resolution, camera position, ambient lighting, lens type and the software algorithm used to compress data output by an imaging sensor. Its specification describes five uses of cameras, called Type A, B, C, D and E. In a Boeing 737 simulator, the CAA study used one Type A camera (Figure 1), covering a general area, including workstations, instruments and controls; and four Type C cameras covering instruments and control panels, including the forward instrument panel, overhead panel, center pedestal and displays. Types B, D and E would record datalink messages, head-up displays and non-cockpit images such as cabin or cargo views, respectively. The Type A camera would be "required to capture data supplemental to conventional flight recorders" at a rate of four images per second for the most recent 30 minutes and one image per second for the period 30 minutes to two hours older. The Type C camera would provide a "means for recording flight data where it is not practical or [is] prohibitively expensive to record on an FDR, or where an FDR is not required." This camera

Camera Placement in Boeing 737 Simulator



CVR = Cockpit voice recorder   M1 = Cockpit area microphone for CVR

Notes:

1. Type C camera with 8-mm lens covering pilot main displays
2. Type C camera with 6-mm lens covering engine instruments
3. Type C camera with 6-mm lens covering throttles and center panel
4. Type C camera with 8-mm lens covering copilot main displays
5. Type A camera with 3.5-mm lens covering cockpit general area

Cameras were mounted on a bar, just behind and above the pilot seats.

Camera uses (types) are specified by the European Organisation for Civil Aviation Equipment.

Source: U.K. Civil Aviation Authority

Figure 1

would capture one image per second for the most recent 30 minutes and one image per two seconds for the period 30 minutes to two hours older.

In each simulator scenario, the researchers induced system failures, problems and excessive workload intended to lead to a serious incident. FDR-equivalent data and recordings from CVR equipment installed in the simulator were studied by a German accident investigator from the Bundesstelle für Flugunfalluntersuchung/Federal Bureau of Air Accident Investigation (BFU), while images from a cockpit image recording system were studied by a French accident investigator from the Bureau d'Enquêtes et d'Analyses (BEA); neither initially had access to the other investigator's data. The investigators then compared all sources to determine if their conclusions would change.

Images showed that instruments had gone blank, the presence of smoke, and hand movements reflecting attempts and failures by the crew to resolve a problem — actions that might not be discernible from FDR and CVR data. They could intrude into flight crew privacy, however, if cameras were not installed in accordance with the EUROCAE specification. The images also could be misleading when seen in isolation.

In the study, images also successfully showed pilot adherence to checklist procedures; checklist actions and silent communication, such as hand gestures; and visible aircraft motions caused by simulated turbulence. Some images did not show the desired information, such as "status of systems which have no display."

Reports by the investigators varied in describing crewmember actions — one omitting mention of the preflight checks seen in images. "The differing analyses of the image data clearly show that the investigator's focus or 'slant' has a definite effect on the amount of useful information that can be obtained from an image recorder," the report said. For example, one investigator concentrated more on describing what was observed without explanation, and the other explained why actions occurred with less descriptive detail.

In one scenario, investigators could see what alerts were displayed to the flight crew and that pilots had attempted to perform physical tasks without success, such as trying but failing to deploy thrust reversers. "This means that it may be possible to determine that a flight crew were unable to perform necessary mitigating actions rather than simply failing to take them," the report said. Another scenario showed that the investigators could substantiate each other's observations of a hydraulic system failure with images and the FDR/CVR data. Similar corroboration occurred for an electrical system failure. "It is also interesting to note that this scenario shows that there are some forms of information that cannot be obtained using any type of flight recorder (e.g., what the flight crew are looking at)," the report said.

Analysis of one scenario raised the possibility that information normally displayed to the flight crew and recorded on the FDR actually was not displayed to them. "As this may lead to a reduction in the number of accidents that are deemed to result from pilot error, it is a significant result," the report said.

Smoke Could Be Overlooked

Smoke particles dense enough to be visible to the crew also were visible in images. But one investigator identified smoke in images while the other did not. "Whether or not the investigators see it will depend upon how dense the smoke is and whether another source of information has led them to look for it," the report said. "[Researchers] agreed [that] … guidance needs to be drafted for the analysis of image data."

The report concluded that investigator training would be just as important as the technological solution proposed. "As images can be especially compelling — and this research has shown that image data can be misleading, even when analyzed by specialists in accident investigation — it is recommended that the analysis and interpretation of image data should only be performed by those specifically trained in this discipline," the report said.

Imaging Technology Evolves Quickly

In the EUROCAE specification, the cameras covering a general area would have sufficient resolution to enable accident investigators to study "ambient conditions on the flight deck (smoke, fire, lighting, etc.); general crew activities such as use of checklists, charts, etc.; health and well-being of the crew; nonverbal communications (hand signals, pointing, etc.); [and] cockpit [control] selections within crew reach while seated at duty station (switch/throttle/flight controls, etc.)."

Manufacturers of other types of digital imaging systems — already used by hundreds of airlines for purposes such as remotely viewing cabins and cargo areas, cockpit-door security and simulator training — say that the key enabling technology for the proposed systems is crash-protected solid-state storage modules. Modules holding 48 gigabytes, for example, would enable time-stamped sequences from multiple cameras to be stored in compressed data formats. Systems would have bulk-erase capability and independent power supply.

Around 2003, EUROCAE expected cameras either to be able to take a series of still photos comparable to a six-megapixel digital camera or to convert a stream of digital video data into a series of still photos. According to Mike Horne, managing director of AD Aerospace and a contributor to the EUROCAE specification, imaging technology already has advanced farther. Significantly higher-resolution charge-coupled device (CCD) sensors and complementary metal oxide semiconductor (CMOS) sensors, the types commonly used now in consumer cameras, are available to consider, he said. The EUROCAE specification intentionally limited the image recording required to match digital cameras available at that time, but the level of detail possible in newly designed cameras would require even more storage to take advantage of their sensors.

International Context

The origins of the CAA study can be traced to a fatal Boeing 737 accident at Kegworth, United Kingdom, in 1989. As a result of the investigation, the U.K. Air Accidents Investigation Branch (AAIB) recommended rapid research into cameras for cockpits because of accident investigators' difficulty determining the crew's interpretation of engine instruments. The U.S. National Transportation Safety Board (NTSB) has said that it "first formally dealt with the issue of crash-protected image recorders in February 2000, following … investigation of the 1997 crash of a Cessna 208B Caravan near Montrose, Colorado, that resulted in nine fatalities."[3]

Accident-investigation agencies generally began proposing cameras for cockpits during the 1990s, based on the occasional insufficiency of information from FDRs and CVRs and the financial cost, delay and uncertainty of some investigations. Defining, in engineering and regulatory terms, exactly what gaps a cockpit image recording system should fill has been difficult despite the EUROCAE specification. Airline pilot associations have said that they will not support proposed systems without acceptable safeguards on data use and evidence that cameras would reduce accident risk more effectively than increasing FDR parameters and funding more programs for routine flight data monitoring.

During the March 2006 conference of the world's directors general of civil aviation, NTSB discussed U.S. consideration of mandatory cockpit image recording systems. After a 2004 NTSB hearing on this issue, some opponents said that retrofitting these systems probably could not be cost-justified; recommended efforts to strengthen international safety data protection laws; urged a shift of focus to aircraft for which little or no objective accident data sources exist; doubted that objective data could be provided by proposed systems; and said that current protections against potential misuse and abuse of images remained unsatisfactory.

The AAIB, BEA, BFU, Transportation Safety Board of Canada (TSB) and other counterparts have continued their advocacy of cameras in the cockpit.[4] But the FAA has said, "Recorder recommendations present unique challenges, including difficulties in cost/benefit analysis, technical hurdles, retrofit problems, issues about use of data and privacy concerns." FAA has not initiated rule making to mandate the installation of cockpit image recording systems.

Most recently, the agency has been analyzing its own proof-of-concept test, conducted in June 2005, to determine if a cockpit image recording system could be used to collect specific parametric data — details of operating parameters shown on instruments — and other flight information before considering performance-based regulatory requirements like those applied to FDRs and CVRs. During the test, several imaging systems were installed in an FAA-operated Raytheon King Air and in a flight simulator; the aircraft was flown in various operational and environmental conditions to determine if operating parameters such as altitude, attitude and airspeed derived from images would be accurate, compared with FDR data. The TSB said that Transport Canada has been anticipating results of this FAA study, and that harmonization of proposed regulations by the Flight Recorder Panel of the International Civil Aviation Organization was necessary before rule making.

The FAA's other related action was to publish the 2006 Technical Standard Order TSO-C176, *Aircraft Cockpit Image Recorder Systems.* The agency said, "Should an applicant, either an aircraft operator or original equipment manufacturer, wish to install a camera or video recording system voluntarily either in the cockpit or in the aircraft cabin, the FAA would work with the applicant to approve such an installation."

So the industry remains in a holding pattern on this issue. The research by the CAA and the FAA could rekindle discussions around a narrower scope of technically feasible proposals that — combined with investigator training, technology to aid interpretation of digital images and relevant procedures — still might depend on overcoming the remaining global deficiencies in image protection. "The goal is to develop a balance between the legitimate security, privacy and confidentiality concerns of labor and operators with the needs of investigators and regulators," said the final report issued in December 2001 by the RTCA Future Flight Data Collection Committee. "The committee recommends that issues regarding security, privacy and confidentiality be resolved and acceptable protections be put in place prior to any action mandating image recording." ●

During research and development, prospective manufacturers of airline cockpit image recording systems have difficulty excluding pilots' heads and shoulders.

Notes

1. Safety Regulation Group, U.K. Civil Aviation Authority. *CAA Research Project: The Effectiveness of Image Recorder Systems in Accident Investigations.* Civil Aviation Publication (CAP) 762. Nov. 10, 2006.
2. European Organisation for Civil Aviation Equipment (EUROCAE). ED-112, *Minimum Operational Performance Specification for Crash Protected Flight Recorder Systems.* March 2003. Cited in CAP 762.
3. For commercial aircraft operators, the U.S. National Transportation Safety Board in 2006 reiterated its recommendation that "all aircraft operated under [U.S. Federal Aviation Regulations] Part 121, 125 or 135 and currently required to be equipped with a cockpit voice recorder and digital flight data recorder be retrofitted by Jan. 1, 2005, with a crash-protected cockpit image recording system. The cockpit image recorder system should have a two-hour recording duration, as a minimum, and be capable of recording, in color, a view of the entire cockpit including each control position and each action … taken by people in the cockpit. The recording of these video images should be at a frame rate and resolution sufficient for capturing such actions."
4. The Transportation Safety Board of Canada (TSB) said, "While Canada treats [sensitive cockpit] recordings as privileged, all nations do not. If image recordings are to be universally accepted, worldwide protections need to be put in place for all cockpit voice and image recordings. … [TSB recommends that] regulatory authorities harmonize international rules and processes for the protection of cockpit voice and image recordings used for safety investigations."