TECHNOLOGY WHITE PAPER

History and Future of Flight Data Recorder Regulations

CURTISS-WRIGHT

DEFENSE SOLUTIONS

Read About

Flight Data Recorders (FDR)

International Civil Standards

National Regulations

ED-112A

GADSS

Introduction

Flight Data Recorders (FDR) help accident investigators determine the reasons for accidents and, in turn, enables authorities to recommend changes to help mitigate future incidents. FDRs are themselves subject to regulations to ensure they can deliver the information needed. FDR regulations have evolved over the years from their inception and they continue to evolve today in response to new technologies and unfortunate incidents that highlight areas for improvement in their design or recoverability. This white paper looks at the history of FDRs, their regulations and how these regulations are formulated. It also discusses regulations due in the near term and postulates upon what the future may bring.

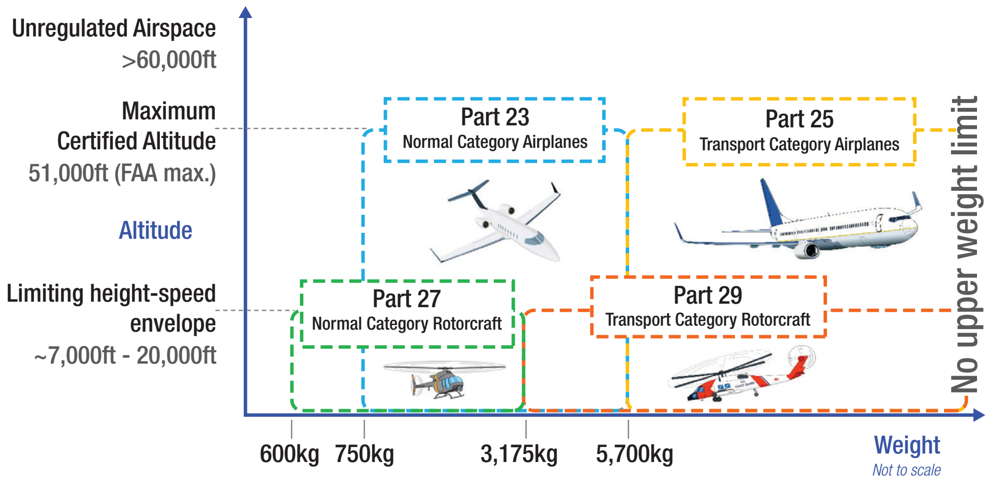

Figure 1: Different regulations apply to different classes of aircraft

The History of Flight Data Recorders

The Wright-Brothers made the first powered flight in 1903 and spent the following few years attempting to evolve their Wright Flyer into a reliable flying platform. Their process involved many test flights with frequent design alterations and repairs following their observations and some hard landings. In 1905, Orville Wright was nearly killed in a particularly hard landing that led to further developments that ultimately led to sustainable and controllable flights later that year.

As aircraft evolved over the years, the focus for safety of the pilot and any passengers moved beyond ensuring an aircraft was designed to be capable of controlled flight. The aircraft themselves were expected to fly over long distances for many years and

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became more and more complex. With complexity comes more points of failure, and a method was required to learn from incidents. The most complex system on any aircraft – the pilot – is also a potential point of failure, and it became important to assess pilot actions in normal and extraordinary circumstances.

It was in the 1930's that the first recorders began to be used in test flights to preserve data in the event of an incident. More modern recorders, typically using metal wire or foil, emerged during World War II, but it wasn't until the 1950's that devices that could also record audio would begin to be designed and built. In 1953 Australian Scientist, Dr. David Warren, conceived the idea for the first "Black Box", developing a prototype in 1958, while investigating a jet-powered commercial aircraft. In 1955 Curtiss-Wright (known then as Penny & Giles) developed their first FDR followed by the first aircraft accident recorder based on magnetic recording. Please note, that for convenience, all types of crash protected recorder will be generally referred to as FDRs unless otherwise specified.

In 1958, following the Munich air disaster, the UK Ministry of Aviation mandated that all civil carriers be equipped with a flight data recorder. Since then, FDRs have become mandatory equipment on certain commercial aircraft, and their specifications are subject to strict regulations.

Aircraft Classes

A significant factor that decides what aircraft must have FDRs, and what functionally it must have is defined by the class of the aircraft. Aircraft class depends on a number of factors, chiefly how large it is (e.g. its maximum take-off weight and how many passenger seats) and its purpose (e.g. crop dusting, flying passengers, etc.). Table 1 outlines which operating regulations an aircraft is subject to. For example, a transatlantic airliner is a Part 23 craft subject to Part 125 regulations as it is a commuter craft that exceeds 6,000 lb in weight and has more than 20 passenger seats. This means it currently requires a 25-hour FDR and a 2-hour Cockpit Voice Recorder (CVR). A small rotorcraft with only 2 seats is likely to require no FDR.

Figure 2: FDRs have evolved over the years from wire based to solid-state systems

				Operating Regulation					
				Part 91	**Part 121**	**Part 125**	**Part 129**	**Part 133**	**Part 135**
				General Operating and Flight Rules. All craft except Ultralight	Operating Requirements: Domestic, Flag, and Supplemental	Certification + Operations: 20+ seats or TOW >2730kg	Foreign Air Carriers + Ops. Of U.S.-Reg. Craft Engaged In Common carriage	Rotorcraft External-Load Operations	Operating Requirements: Commuter And On Demand Operations
Airworthiness Standards Part	23	Normal, Utility, Acrobatic and Commuter Airplanes	Normal, Utility, Acrobatic (NUA) < 9 seats + TOW<5700kg	> 6 passenger seats= 2h CVR	Turbine engine craft 2h CVR; > 25,000ft 25h FDR	NA	As part 121, 125 or 135.	NA	> 6 seats= 2h CVR
			Commuter: < 19 seats, TOW <8600kg	As above; > 10 seats = 25h FDR		>6,000lb, 25h FDR; 2h CVR			> 10 seats= FDR > 6 seats= 2h CVR
	25	Transport Category Airplanes	Not classified NUA.						
	27	Normal Category Rotorcraft	< 9 passenger seats and TOW<3180kg	> 6 seats = 2h CVR.	NA	NA	FDR and CVR regulations match part 135	NA	> 6 seats= 2h CVR
	29	Transport Category Rotorcraft	Category A: >10 seats or TOW>9090kg	> 10 seats, 25h FDR > 6 seats = 2h CVR					> 10 seats, 25h FDR > 6 seats= 2h CVR
			Category B: < 9 seats + TOW<9090kg	> 6 seats = 2h CVR					6 seats= 2h CVR

Table 1: Different aircraft need to meet certain regulations depending on the category of aircraft and how it is used

FDR Regulations

Regulations governing FDRs have been in place for a long time and generally arise from the need to understand why an incident occurs so that future such scenarios can be avoided. The Munich air disaster is one such example. It took some 10 years for the real cause of the crash to become apparent, during which the captain was largely held responsible[1]. Erroneous claims that he had failed to deice the wings rather than the airport's failure to clear the runway of slush could have been better informed with data recorded from the aircraft. Table 2 shows how, over the years, different technical standing orders (TSO) have introduced new regulations to ensure FDRs can cope with certain levels of hazard.

Regulation formulation

Today, there are different reasons why new regulations come into force, but there is generally a similar scenario whereby this happens. If air accident investigators discover a shortcoming in retrieving information from a recorder, then this will be reported to the International Civil Aviation Organization (ICAO). Similarly, a government agency may recognize an issue and report it to ICAO.

Such shortcomings are generally due to needed information not being available to accident investigators. It could be the information wasn't recorded because it wasn't mandated as standard (so perhaps more parameters need to be captured), the FDR's media itself was too badly damaged to recover information (so the storage media may need more protection) or the FDR itself can't be located (implying a better tracking system is required).

After such is reported, ICAO will then direct a working group to look further into the matter. This may then produce recommendations which they pass on to the regulatory authorities (EASA, FAA etc.). These regulatory authorities can then choose to adopt these recommendations into their local laws. This means, for example, that an EASA registered aircraft must comply with these recommendations in order to fly legally.

Implementing regulations

In theory, a national air agency could decide not to enforce a regulation from ICAO, but this may have an impact on the national fleet's ability to operate internationally. An example of this is airport security, which ICAO also makes recommendations on. There are some airports, for example, which do not implement thorough security screening of persons or baggage (scanning and random check for example). The result is aircraft from those airports are banned from inbound flights into US airspace.

In practice, therefore, while ICAO cannot legally produce regulations, if it produces recommendations then these will

TSO Hazard	C51	C84	C51a	C123/ C124	C123a/ C124a	C123b/ C124b	C123C/ C124C
Effectivity Date	1958	1964	1966	1992	1996	2010	2015
MOPS	TSO-C51	TSO-C84	TSO-C51a	ED-55 / ED-56	→	ED-112	ED-112A
Impact Shock	100g	→	1,000g, 5ms	3,400g, 6.5ms	→	→	→
ULB Sheer & Tensile Strength	X	X	X	X	X	X	6000lb in each direction, 1 min
Penetration Resistance	X	X	500lb, 10ft, ¼" Spike	→	→	→	→
Static Crush	X	X	5,000lb, 5 min /face	→	→	→	→
Fire Resistance	1100°C, 30 min 50% coverage	→	→	1100°C, 30 min, 50% coverage, 50,000 BTU/Hr/ft²	→	→	→
Heat Resistance	X	X	X	X	10 hrs @ 260°C	→	→
Deep Sea Pressure	X	X	X	20,000ft, 24 hrs	→	→	→
Salt Water Corrosion	48 hrs	36 hrs	30 days	9ft, 30 days	→	→	→
Corrosive Fluids	X	X	Specified fluids, 24 hrs	→	→	→	→

Table 2: Regulations have changed over the years from the introduction of C51 in 1958

be acted on by the national air agencies and all the major aircraft OEMs. Legal enforcement will usually take the form of issuing a TSO or a minimum operational performance standard (MOPS). A period will then be given for implementation that gives the aircraft OEMs and operators a realistic amount of time to assess and implement the relevant changes.

It's important to note that ICAO is not a standards organization, instead it is more focused on producing performance-based requirements. For example, when Malaysian Airlines MH370 "disappeared," various agencies put forward recommendations into ICAO, which called a working group from the International Air Transport Association (IATA) to put a study paper together.

This group was called the Air Tracking Task Force which subsequently came back with their report. This resulted in ICAO releasing recommendations called the global aeronautical distress safety system (GADSS). A key aim of this system is to maintain an up-to-date record of an aircraft's progress and, in case of a crash, forced landing or ditching, the location of survivors, the aircraft and recoverable flight data[2]. This includes a performance metric that, for certain classes of aircraft, means you must have a tracking system installed.

This tracking system has two modes –routine and abnormal tracking. The routine mode is where reports are sent on a periodic basis (<15 minutes). The abnormal tracking is where a report is sent to an emergency response group if certain conditions are encountered. For example, if there is a high bank angle in the cruise or other abnormal flight patterns. The details of how this system is implemented isn't mandated, but overseas at least, it's likely that communication will need to use satellites.

There is another route to achieving this second recommendation though – using a deployable recorder. Such a recorder needs to be fitted with a so-called second generation beacon that transmits at frequencies that can be picked up by Cospas-Sarsat satellites. This will alert first responders to the fact an incident has occurred, and thus they can quickly get to a location where they can rescue any survivors.

Thus, while ICAO produces recommendations, different aircraft OEMs can decide to take different approaches to meeting the requirement. There are also some nuances to implementation. Sometimes OEMs will adhere to regulations when they aren't legally obliged to. For example, EASA has mandated that some aircrafts FDRs should be able to record cockpit audio for 25 hours (i.e. a 25 hour CVR), but the FAA has not. This means OEMs like Airbus and Boeing don't need to install a 25 hour CVR on their aircraft that will be flown in the US. But, it is easier just to design for the highest common denominator as it is simpler and lower cost to certify a single FDR model for an aircraft type rather than create variants for different customers. There will be, for example, Boeing 737 MAXs being flown in a couple of years by SouthWest Airlines that only need a 2 hour CVR but will have a 25 hour CVR installed despite the fact they won't ever fly outside of North America.

The Future

What the future will bring for FDR regulations is unknowable, although there is a reasonable amount of certainty around the next few years, as a number of regulations are already in the pipeline to address the problems encountered with Air France Flight AF 447 and Malaysian Airways MH370 (which highlighted a weakness in being able to reliably locate aircraft quickly or at all).

Short term

In the next few years, there are three principal regulations – one around underwater locator beacons (ULB), another for lengthening CVR duration and one regarding the tracking system discussed earlier (contained within GADSS).

In 2018, new ULB must transmit for 90 days. This is an increase from 30 days and was a direct reaction to how long it took to locate the FDR on the AF 447. Larger airliners will need to retrofit older ULBs, although in time, all aircraft will have 90 day ULBs as 30 day ones are no longer being manufactured.

Similarly, the aircraft tracking recommendations arose from the loss of flight MH370. If such a tracking system was installed, search and rescue teams would have known where to start their search rather than spending some 4 years, at the time of writing, trying to find out what happened.

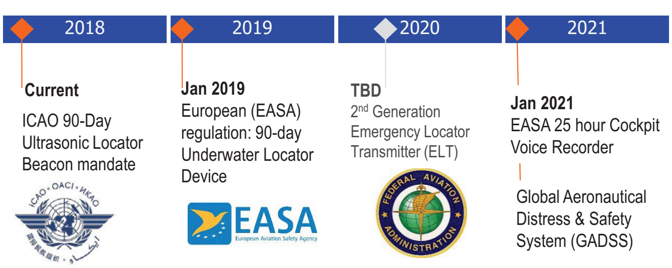

Figure 3: In the next few years, the regulations being introduced are aimed at more rapidly and reliably locating aircraft and their FDRs

By December 2018, aircraft with a MCTOM of more than 27,000 kg and 19 passengers (and cargo aeroplanes with a MCTOM of over 45,500 kg) will need a tracking system if such can't be done by air traffic control (ATC). These aircraft types manufactured from 2021 will need an automatic system to alert authorities of the location of an accident.

There is also a requirement that from January 2021, for EASA registered aircraft with a maximum certified take-off mass (MCTOM) of over 27,000 kg and more than 19 passenger seats and cargo aeroplanes over 45,500 kg performing transoceanic flights should be capable of recording 25 hours of audio[3]. This only applies to aircraft produced from 2021 and is not retroactive. As alluded to previously, although this only applies to EASA regulated aircraft, it is likely most OEMs will adhere to this as well, regardless of operating region.

Gazing into the crystal ball

While it is always difficult to predict the future, there are some regulations that can be subjected to educated speculation. The following are a selection of possibilities that may occur given technological advances or because of future unfortunate incidents.

Expanding the net

The requirements for a given category of aircraft as noted in table 1 could be altered so that more aircraft are required to carry an FDR. For example, it may happen that all aircraft with an occupant would need to carry an FDR regardless of its operational profile.

Increasing qualifications

It is likely that various tests that FDRs must pass, as shown in table 2, will become more stringent and more test could be added. This will further increase the likelihood that FDRs will survive crash events.

Removal or increased reliability of deployable recorders

As mentioned previously, some of the requirements in GADSS can be met with a deployable recorder rather than a data transmission system. However, the ED-112A MOP for an inadvertent deployment of a recorder is only 1 in 10^{-5} per flight hour. There are viewpoints in the airline world that the design standard for inadvertent deployment is unacceptable when you consider how many aircraft are flying. Estimates are that some 22,000 airliners are flying today (which is currently growing by over 1,000 per year). Taking this into consideration, the math works out that if every airliner has a deployable recorder, there would on average be five inadvertent deployments per day. Given these recorders are essentially tough metal boxes, there could be a number of unfortunate incidents happening every year.

Image recording

While data and cockpit audio can tell investigators a lot about what has happened, it would be very useful to see what pilots did and what the instrumentation was showing. There have been moves to mandate image data, although this has faced opposition from pilot unions under privacy concerns, and such capability is not available yet from all FDR manufactures.

Encryption

Encrypting data on FDRs is common on military platforms, but there is also some concern with the privacy and integrity of FDR data for civilian aircraft. One issue is if an FDR is recovered by someone other than an official accident investigator, then voice data could be leaked to the media, violating pilot privacy and negatively affecting loved ones, for example. Another issue – if somewhat conspiratorial sounding – is if someone were to alter the data to cover up an aircraft flaw. It sounds like the plot of a Hollywood movie, but given that an alteration could save an organization a great deal of money to avoid a product recall, for example, such is conceivable if highly unlikely. Encryption would guard against such incidents.

Collecting structural health data

There are aerospace applications that assess the structural health of an airframe. These generally use a relatively small set of sensors to gather data which is then analysed to check for tell-tale signs that a structural problem may be developing. Such data could become mandatory following an incident where a structural failure leads to an accident.

Removing FDRs

It could become standard to have every aircraft streaming all the data that would go to an FDR to an operations centre. A good reason a recorder may always be needed however, is the aircraft could lose the data link before an incident. Data links are also relatively expensive and operators may wish to limit such constant broadcasting. There are also privacy concerns, in particular regarding cockpit audio – encryption may be a prerequisite to such data transmission. Another reason that an FDR may always be a requirement is it will add redundancy.

CURTISS-WRIGHT

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Conclusion

FDRs are valuable tools for authorities to help increase flight safety for everyone. Since their inception, FDRs have provided information to investigators, but incidents over the years have highlighted their shortcomings. These incidents have helped shape regulations that have improved the survivability of FDRs and the ease of their location.

Curtiss-Wright has witnessed this from the beginning of FDR regulations in the 1950's and to this day is closely involved with regulatory bodies to ensure we are developing FDRs that can meet the upcoming regulations. This is precisely what we have done with our Fortress recorder which meets all current and anticipated ED-112A requirements. For example, Fortress is ready to meet 25 hour CVR requirements and is capable of acquiring image data and interfacing with transmission systems to help aircraft be GADSS compliant.

Learn More

White Paper

- New Paradigms for Crash Protected Recorders

Video

- The History of Flight Data Recorders

Case Study

- Replacing an Obsolete Custom Flight Data Recorder with an Off-the-Shelf Solution

[1] Leadbeater, 2018, The story behind the Munich Air Disaster – and its aviation safety legacy, website, available from https://www.telegraph.co.uk/travel/comment/the-munich-air-disaster-and-its-safety-legacy/

[2] ICAO GADSS Advisory Group, 2017, Global Aeronautical Distress & Safety System (GADSS) – concept of operations, online, available from https://www.icao.int/safety/globaltracking/Documents/GADSS%20Concept%20of%20Operations%20-%20Version%206.0%20-%2007%20June%202017.pdf

[3] EASA, 2016, New regulation, new timings, On Air, Issue 9 - Flight Tracking, online, available from https://www.easa.europa.eu/newsroom-and-events/news/new-regulation-new-timings