TECHNOLOGY WHITEPAPER

Mandatory and Recommended Parameters and Data Storage Requirements for Flight Data Recorders

CURTISS-WRIGHT
DEFENSE SOLUTIONS

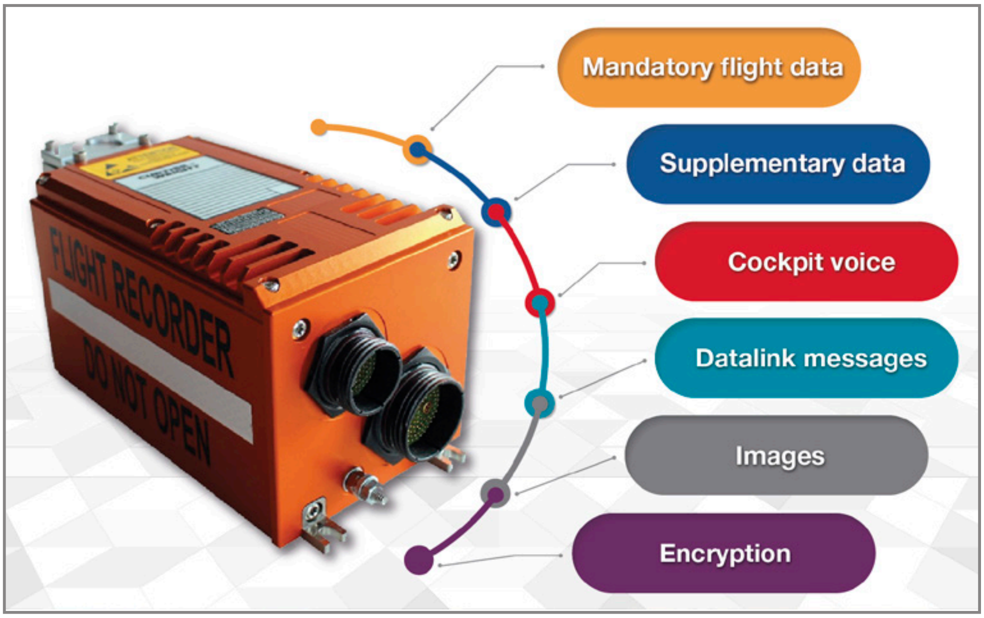
Read About

- Flight Data Recorders
- Electronic Code of Federal Regulations
- ED-112A
- Data Recorder Requirements

Introduction

Flight recorders have helped improve aviation safety since their introduction in the 1950s, providing vital information to ensure that, in the event of an accident or incident, investigators can learn more about the chain of events leading up to it. Flight recorders have evolved over time to meet new regulatory mandates, new military needs, to exploit new technologies, and to increase the amount of information available to accident investigators.

The increase in information includes parametric data, voice, image, and datalink messages. This white paper examines what parametric data is required by regulatory bodies, and other interested parties, and how flight recorders can store this valuable information.



Modern flight data recorders can acquire and store large amounts of data from several sources

Regulation Categories

For the air transport market, flight recorders are typically separate products functioning as flight data recorders (FDR) and cockpit voice recorders (CVR). These functions can also be combined into a single crash protected flight recorder, sometimes called a 'combi' or CVFDR for lighter aircraft, military jets, or rotorcraft. The air transport market now allows the installation of combined recorders. This white paper mainly addresses the requirements of FDRs as CVRs are typically more "straightforward".

The FAA stipulates the requirements for FDRs in title 14 of its code of federal regulations, known as the federal aviation regulations (FAR), defining operating and flight rules under which aircraft operate. These include parts 91, 121, 125, 129, 133, and 135 that segment aircraft into different groups depending on their application (as shown on the x-axis in figure 1). For example, an aircraft being used for cargo transport falls under part 129, whereas an aircraft engaged in carrying passengers falls under part 135. What, if any, FDR they must carry depends on aircraft type and what 'Airworthiness Standard' applies (the y-axis in figure 1).

Subpart F of the standards in title 14 (aeronautics and space), part 23 (airworthiness standards: normal, utility, acrobatic, and commuter category airplanes), describes what equipment is required for the respective part. Specifically, section 23.1459 details the requirements for flight data recorders. It specifies that each FDR required must be installed so that it is supplied with various data, for example airspeed, altitude, and directional data obtained from sources that meet the accuracy requirements of section 23.1323, 23.1325, and 23.1327, as appropriate.

Military aircraft typically are not required to meet such stipulations, or indeed even have a flight recorder, although they are increasingly implementing them for safety reasons.

				Operating Regulations					
				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: eVTOL		EASA	CS-VTOL Special Condition	< 9 seats and MCTOM <3,175kg					
		FAA		FAA following Part 23					
Part 23		Normal, Utility, Acrobatic and Commuter Airplanes	Normal, Utility, Acrobatic (NUA) < 9 seats + TOW<5700kg	EASA NPA 2017-03 Commercial Operations MCTOM >2,250kg ED-155 compliant acceptable > 6 passenger seats= 2h CVR	Turbine engine craft 2h CVR; > 25,000ft 25h FDR EASA reg: MCTOM>27,000kg manufactured after 1 Jan 2021: 25h CVR 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 EASA reg: MCTOM>27,000kg manufactured after 1 Jan 2021: 25h CVR 25h FDR			> 10 seats= FDR
Part 25		Transport Category Airplanes	Not classified NUA						> 6 seats= 2h CVR
Part 27		Normal Category Rotorcraft	< 9 passenger seats and TOW<3180kg	> 6 seats = 2h CVR.	NA	NA	FDR and CVR regs match part 135	NA	> 6 seats= 2h CVR
Part 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

Figure 1: A matrix of operating regulations and airworthiness standards that illustrates what FDRs are required

Subpart F also specifies a number of other stipulations, summarized below as

+ Vertical acceleration sensor installation
+ Electrical power delivery
+ Aural or visual means for preflight checking of the recorder
+ An automatic means to simultaneously stop a recorder and prevent any data eraser features from functioning within 10 minutes of a crash
+ Prevention of a single external electrical failure disabling both the CVR and FDR
+ The FDR and CVR are in separate containers, unless functions are combined and only complying with FDR requirements, in which case the CVR must also be a combined unit
+ Locate non-deployable recorders to limit the impact and fire effects of a crash
+ The FDR readings of airspeed, altitude, and heading should correlate with the first pilot's instruments
+ Recorder containers must be either bright orange or bright yellow, have reflective tape and have an underwater locating device
+ Any non-standard aircraft designs or operational characteristics may require additional parameters

There are near identical details available for part 25, 27, and 29, any differences being slight and due to minor practical differences, e.g. with rotorcraft vs fixed wing. While other aerospace organizations, such as EASA, don't have identical requirements, they are very similar. Figure 2 gives a visual representation of how airworthiness standards are applied in relation to weight and operating altitude.

Required Parameters

The airworthiness standards dictate, in broad terms, criteria the FDR must meet. These refer out to other parts, such as part 135.152, to specify the key parameters an FDR must record in order for a particular aircraft to be flown. The aircraft type also determines the necessity for some parameters, for example, a fixed wing aircraft does not need to log rotor speed. Similarly, measurements of sideslip (latitudinal or longitudinal) would be uncommon on a rotorcraft.

The number of parameters is dependent on when the aircraft was certified, if the aircraft is turbine powered, and if it carries a certain number of passengers.

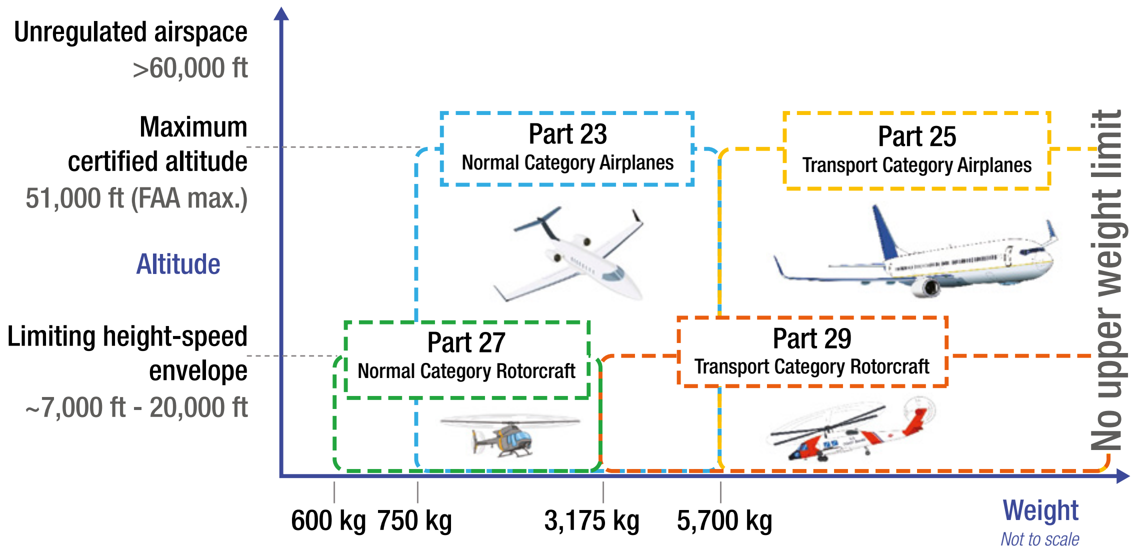


Figure 2: A visual guide to how airworthiness standards are applied to different aircraft types

If the initial certification was before 1969 then 11 parameters are required, after this, 18 must be recorded. If the aircraft is turbine-engine powered with between 10 to 30 passenger seats, then more operational parameters are required, depending on when it was manufactured, as noted in table 1 (a complete table is available in the appendix).

Table 1 **Required parameters (1-28) for FDRs**

				Turbine 10-30 seats	
ID	Parameter	< 1969	> 1969	< 8/18/00	> 8/19/02
1	Time	✓	✓	✓	✓
2	Pressure altitude	✓	✓	✓	✓
3	Indicated airspeed	✓	✓	✓	✓
4	Heading, primary flight crew reference (if selectable, record discrete, true or magnetic)	✓	✓	✓	✓
5	Normal acceleration (Vertical)	✓	✓	✓	✓
6	Pitch attitude	✓	✓	✓	✓
7	Roll attitude	✓	✓	✓	✓
8	Manual radio transmitter keying, or CVR/DFDR synchronization reference	✓	✓	✓	✓
9	Thrust/power of each engine—primary flight crew reference	✓	✓	✓	✓
10	Autopilot engagement status			✓	✓
11	Longitudinal acceleration	✓	✓	✓	✓
12	Pitch control input			✓	✓
13	Lateral control input			✓	✓
14	Rudder pedal input		✓	✓	✓
15	Primary pitch control surface position	✓	✓	✓	✓
16	Primary lateral control surface position		✓	✓	✓
17	Primary yaw control surface position			✓	✓
18	Lateral acceleration			✓	✓
19	Pitch trim surface position or ID 82 if currently recorded		✓	✓	✓
20	Trailing edge flap or cockpit flap control selection (except when ID 85 applies)		✓	✓	✓
21	Leading edge flap or cockpit flap control selection (except when ID 86 applies)		✓	✓	✓
22	Each Thrust reverser position (or equivalent for propeller airplane)		✓	✓	✓
23	Ground spoiler position or speed brake selection (except when ID 87 applies)			✓	✓
24	Outside or total air temperature			✓	✓
25	Automatic Flight Control System (AFCS) modes and engagement status, including autothrottle			✓	✓
26	Radio altitude (when information source installed)			✓	✓
27	Localizer deviation, MLS Azimuth			✓	✓
28	Glideslope deviation, MLS Elevation			✓	✓

Once you know the parameters you need, you can get more information about their required accuracy and resolution by referring to Appendix F of the part 135 standard. Similar information can be found in the European Organisation for Civil Aviation Electronics (EUROCAE) ED-112A standards document. A sample of the information in Appendix F is shown in Table 2.

Table 2 Appendix F to part 135 that details the Airplane Flight Recorder Specification

Parameters	Range	Accuracy (sensor input)	Seconds per sampling interval	Resolution	Remarks
1. Time or relative time counts	24 Hrs, 0 to 4095	±0.125% per hour	4	1 sec	UTC time preferred when available. Counter increments each 4 seconds of system operation.
2. Pressure altitude	–1000 ft to max certificated altitude of aircraft. + 5000 ft	±100 to ±700 ft (see table, TSO C124a or TSO C51a)	1	5' to 35"	Data should be obtained from the air data computer when practicable.
3. Indicated or calibrated airspeed	50 KIAS or minimum value to Max Vso≠ and Vso to 1.2 V.D	±5% and ±3%	1	1 kt	Data should be obtained from the air data computer when practicable.
4. Heading (Primary flight crew reference)	0–360° and Discrete "true" or "mag"	±2°	1	0.5°	When true or magnetic heading can be selected as the primary heading reference, a discrete indicating selection must be recorded.
5. Normal acceleration (Vertical)	–3g to + 6g	±1% of max range excluding datum error of ±5%	0.125	0.004g	

Every parameter has a defined range, an accuracy and resolution requirement, and a minimum sampling interval. Taking Heading, as an example, the sampling interval is 1 second. The reading from the sensor, when digitized, shall have an accuracy of ±2° and a resolution of 0.5° therefore a minimum of 9 bits will be required to sample this parameter over the range 0 to 360°.

Thus, once you know the required parameters, you can reference a source such as table 2 to establish how much data you need to acquire from your aircraft and send to your FDR. The system integrator has the responsibility of knowing what parameters will be acquired from where, implementing a system to store the data and verifying that it can be played back across the specified range, and to a minimum resolution. It is important to note that the FDR does not typically determine the resolution and accuracy of the data. Typically, a Digital Flight Data Acquisition Unit (DFDAU) achieves this goal and packages the data into a suitable format, however, some FDR provide this function through an integrated data acquisition function. Regardless of where the acquisition function is implemented, the requirements are the same.

Feeding FDRs

A common approach to gathering and packaging data for FDRs is to use an intermediary unit to gather and send it to the recorder in a compatible data stream. Such a unit is commonly called a digital flight data acquisition unit (DFDAU) and it acts as a translator between the aircraft data sources and the FDR.

DFDAUs have a proven track record of meeting application requirements but they are stand-alone units and thus take up space, add weight, and increase installation and logistics overheads. This is especially problematic in military jets and small aircraft, where space is at a premium. Thus, it is advantageous to use existing systems onboard the aircraft to accomplish the data gathering and processing for the FDR if possible. The standard data format used for passing data between the DFDAU and FDR is either ARINC-573 or ARINC-717, but there is no reason other data formats can't be used.

Although the regulations specify what parameters must be gathered, they do not specify the source i.e. the avionics bus, sensor type, etc. As modern aircraft are more 'bus based', where all the sensors and systems are connected to a single common bus, an FDR may be able to exploit this architecture to gather all the data it needs, without requiring a separate DFDAU. This assumes the FDR has an interface capable of reading the data. If so, then the FDR can become a node on that network and extract information addressed to the FDR. This simplifies the system, removes a box, lowers weight and power requirements, reduces logistics and maintenance overheads, and potentially reduces system costs.

The ARINC-429 avionics bus is common on commercial aircraft and a common standard for sending data to a glass cockpit. MIL-STD-1553 is similarly common in military aircraft. Glass cockpits are a natural data concentrator as they need to display detailed information to the pilots and are thus a potential source of data for an FDR. Deterministic Ethernet, in the form of ARINC-664 part 7, is also becoming a popular avionics bus and an Ethernet enabled FDR can easily gather data from it by becoming an ARINC-664 end system.

Increasing Data Needs

How much data needs to be recorded has changed over time, from 11 parameters before 1969 to over 80 today, depending on aircraft type. Some 25 years ago, it was not uncommon that one could fit all the required parameters, with their respective resolution and sampling rate requirements, in an ARINC-717 frame of 64, twelve bit words per second (wps). Today, some aircraft are recording 512 or even 1024 wps – although this only includes the mandatory parameters.

The memory capacity required depends on the quantity, size, and frequency of the recorded parameters. In an ARINC-717 data stream, for example, you have a repeating series of frames, in each frame you have four subframes, each typically containing 1 second of data. The acquired information is organized into words (or slots) where you can put data. The data 'size' can vary from a single bit up to a typical maximum of 21 bits distributed over a number of word slots. An example of a long sequence is latitude and longitude which is a 21 bit number. Another is altitude, that has a range of –1.5k to 70k feet (depending on the category of aircraft) and a resolution of within 5 feet means a minimum of 14 bits are required (71,500 / 5 = 14,300) to define the altitude parameter.

There is a lot more information available on the aircraft beyond the mandatory parameter set which aircraft OEMs may wish to record. For example, while they may only be required to record one or two power levels on the aircraft, there are many more available that could be used for future troubleshooting. There are also operational requirements that traditionally use quick access recorders (QAR) that record a superset of data, including data sent to the FDR. QARs are not crash protected, but gather additional data useful for maintenance and planning, such as fluid levels in bathrooms to best calculate the required weight of fluid needed to flush toilets for different journey profiles. Many military missions will also tend to be shorter than a long-haul commercial flight, and thus record durations will be limited.

Modern FDRs can integrate this QAR functionality. All that is needed is sufficient memory, access to the data, and a means to conveniently download it. One method for data transfer is automatic wireless download – something that is made easier if the FDR has an Ethernet interface with a built in webserver. Utilizing the FDR for the QAR function will remove the need for a separate QAR, and like removing the need for an FDAU, lower weight, simplify installation etc.

This is already happening on modern FDRs which are being tasked with recording increasing amounts of data as OEMs recognize that they can eliminate a separate QAR. Curtiss-Wright has seen examples of aircraft installations that, while only needing the mandatory 88 parameter set, implemented a recording system capturing in excess of 2,500 parameters. Thus the kind of acquisition and recording system that an aircraft OEM may want needs to be designed to accommodate much larger amounts of data than is minimally required by regulators.

The storage capacity of the latest FDRs is unlikely to be a limiting factor, at least for parametric data (longer voice recording durations and the increasing desire for image recording are far more demanding). It is actually more difficult to obtain lower capacity memory devices as very few, if any, memory fabrication plants are interested in mass producing low capacity, memory chips. This can actually present FDR designers with more challenges due to component obsolescence and the decreased thermal robustness of higher capacity devices (a detailed discussion of which is outside the scope of this paper). The more immediate limit for new and next generation FDRs is being able to process the higher rates of data and meet modern interface needs.

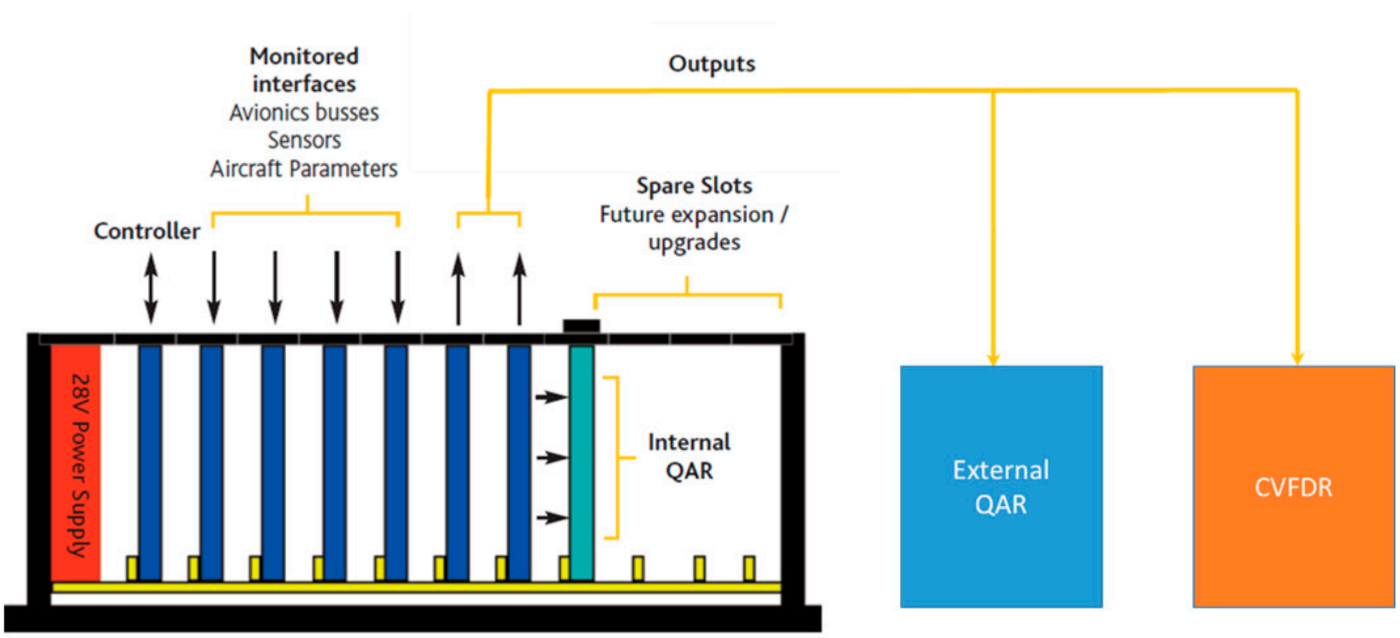


Figure 3: FDAUs can feed both QARs and FDRs

Designing a Future Proofed FDR

Curtiss-Wright has been designing cockpit voice and flight data recorders for over 65 years and has recently introduced the Fortress, a compact and lightweight combined cockpit voice, flight data, datalink, and image recorder. It meets all FAA and EUROCAE requirements and has been designed to be able to process and store the vast amounts of data available on modern aircraft.

Fortress is the most modern multi-function flight recorder on the market and has been designed with a high speed interface and multiple gigabytes of storage capacity. We believe Fortress has the most capacity and the highest record rate of any FDR on the market with 4,096 wps (ARINC-717) for a minimum of 25 hours. When compared to older generation recorders, Fortress can record in excess of 34,000 hours of FDR data when recording at 64 wps. This is significantly greater than any other FDR and facilitates future data needs as well as functioning as a QAR.

It can also record up to four channels of ARINC-429, either as separate data channels or as dual redundant recording channels and has an interface for ARINC-664 pt7, for which it supports up to 14 virtual links and 60 kB/s for a 25 hour recording duration.

Fortress was also designed to accommodate plug-in modules. This modularization facilitates additional functionality to help lower weight and free up space by integrating into modern avionics busses. This makes it future proof as it can implement additional functionality, such as MIL-STD-1553, encryption, and so forth, in the recorder itself to protect against obsolescence due to unanticipated future regulatory changes.

Conclusion

FDRs have been providing data to accident investigators since their introduction in the 1950s. The amount of required information has risen over the years and this trend is likely to continue. OEMs and operators are also increasingly looking to store more data in order to remove the need for a separate QAR. Modern avionics busses make it easier than ever to send data directly to an FDR without the need for an DFDAU. Thus modern flight recorders will ideally support high data rates, have large storage capacities, and be able to connect to a variety of avionics busses. Curtiss-Wright has developed the Fortress flight data, voice, datalink, and image recorders to address these needs and continue our long history of industry firsts with Fortress being the first fully ED-112A qualified FDR providing class 6 CVR capability.

Reference docs

Electronic Code of Federal Regulations (e-CFR), 2019, Title 14: Aeronautics and Space: part 23—airworthiness standards: normal category airplanes, available online, accessed November 10, 1029

Electronic Code of Federal Regulations (e-CFR), 2019, Appendix F to Part 135—Airplane Flight Recorder Specification, available online, accessed November 10, 1029

EUROCAE ED-112A - Minimum Operational Performance Specification for Crash Protected Airborne Recorder Systems, September 2013

Figure 4: Fortress is the most modern and capable multi-function crash protected flight recorder in the industry

The Fortress CSR has been developed specifically for the military market, with an inbuilt QAR and integrated data acquisition

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