Log 1984

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: June 19, 1987

In reply refer to: A-87-77 through -89

Honorable Donald D. Engen
Administrator
Federal Aviation Administration
Washington, D.C. 20591

Since the Safety Board issued its last flight recorder recommendations in August 1982, a number of significant events have occurred, the most notable of which were the Federal Aviation Administration's (FAA) March 25, 1987, rule changes. Other events such as the technological development of solid-state flight data recorders (SFDR), the continued growth of the commuter air carrier industry, the 14 CFR Part 23 changes to provide for the definition and certification of a commuter category airplane, and the adoption of revised flight data recorder (FDR) and cockpit voice recorder (CVR) standards by the International Civil Aviation Organization (ICAO), have necessitated an update of the Safety Board's flight recorder recommendations. We believe it essential that future recorder requirements represent the best compromise among needs, design feasibility, and economic constraints. The Safety Board also believes its views, which are based on years of experience as the ultimate user of flight recorder information for accident investigation purposes, satisfy the safety objectives of both government and industry. As a result, all existing Safety Board recommendations to the FAA regarding flight recorders will be "Closed—Superseded" or "Closed--Superseded/Unacceptable" by the new recommendations. The existing recommendations and their new classification are contained in the appendix to this letter. This will hopefully clarify the Safety Board's position on this very complex issue.

The new recommendations propose two distinct recorder groups--one for large airplanes used in air carrier operations and one for a commuter category and selected smaller aircraft operated under 14 CFR Part 91. The recommendations pertaining to large airplanes would expand the current requirements to include the Safety Board's parameter list as contained in table I on newly manufactured airplanes and existing airplanes equipped with an Aeronautical Radio, Inc., (ARINC) 429 digital data bus or its equivalent. In addition, the large airplane recorder requirements would be extended to include 14 CFR Part 135 operations with aircraft capable of carrying 20 passengers or more. The second recorder group would include requirements for an 8-hour FDR and a 15-minute CVR. The 8-hour FDR requirements would apply to newly manufactured multiengine, turbine-powered aircraft capable of carrying 10 passengers or more and not currently required by 14 CFR Parts 121, 135, and 127 to have an FDR. The recommendation would require a 15-minute CVR on existing and newly manufactured multiengine, turbine-powered aircraft capable of carrying six passengers or more and requiring two pilots by certificate or operating rule and not currently required under 14 CFR Parts 121, 135, and 127 to have a CVR.

4660/860-15

Flight Recorder Requirements, 14 CFR Part 121

Although the Safety Board is pleased with the March 25, 1987, 14 CFR Part 121 rule changes that will eliminate the foil-type flight recorders, it is still concerned with the adequacies of the minimum standards for expanded recorders as set forth in 14 CFR Part 121, Appendix B, which was not affected by the March rule changes. The current list of required parameters was undoubtedly selected with the foresight available in 1969 when this portion of the rule was last amended. The experience acquired during the intervening 17 years has permitted the Safety Board to evaluate the usefulness of the required parameters and the potential significance of some parameters that are not required. Safety Recommendation A-82-66 addressed the need to update the mandatory parameter list and defined new parameters, improved accuracies, ranges, and sampling intervals. This recommendation is, in fact, a reaffirmation of Safety Recommendations A-78-27 through -29 issued April 13, 1978, which, in part, proposed specific changes to Appendix B. The Safety Board presented its specific concerns regarding the inadequacies of Appendix B in its formal response dated April 8, 1985, to NPRM "Flight Recorder and Cockpit Voice Recorder" and in a followup letter to the Administrator of the FAA on April 25, 1985.

The international aviation community has also become aware of the need for improved flight recorder standards as exemplified by ICAO's adoption of new flight recorder standards that would require 32-parameter FDR systems. These 32 parameters and associated accuracies and recording intervals are consistent with those recommended by the Safety Board. In addition, the European Organization for Civil Aviation Electronics (EUROCAE) has concluded its March 23, 1987, meeting of Working Group 21 (flight data recorders) that was tasked to produce a document which defines minimum operational performance standards for FDRs. The minimum standards will provide guidance material for installation, parameters recorded, data compression, data retrieval, and crash survivability testing for the next generation of recorders, and will give the European's the lead in recorder development.

The technological changes that have occurred since 1969 have had a significant effect on the information needed to properly analyze an accident or incident. The current lists of flight recorder parameters, whether required by the FAA or recommended by the Safety Board or ICAO, has always been a compromise between desired parameters and economically feasible parameters. The new electronic display systems (i.e., "glass cockpits"), however, provide some relief to the economic constraints and, at the same time, introduce additional investigative requirements. The ARINC 429 digital data bus which is on Boeing 757, 767, and 747-400, as well as the Airbus A300-600, A310, and 320, can provide a wealth of additional data. In fact, the amount of data is so extensive that the only constraint to the FDR system appears to be the recording capacity of the FDR. On the other hand, the new electronic displays pose new investigative challenges by the nature of their operational and physical characteristics. The video display units will supply little useful information in the postaccident environment and limited information to the flightcrew whose system monitoring function has been taken over by the electronic centralized aircraft monitor (ECAM) on the airplane or the engine indication and crew alerting systems (EICAS) on the Boeing 757 and 767 airplanes. With the expanded role of technology in the operation of modern aircraft, a thorough knowledge of the interaction of man and machine in accident investigations has become even more critical. The introduction of the Airbus A320 with its fly-by-wire technology will present new challenges in accident investigation that will require postaccident information of the quantity and quality that goes far beyond the current minimum standards of Appendix B.

Therefore, the Safety Board believes there is a definite need for additional flight recorder parameters; that the core requirements be increased to include those recommended by the Safety Board and ICAO; and that the minimum parameter list for a particular make and model aircraft be based on any unique design or operational capability defined at the time of certification.

The economic constraints to the acquisition of the additional data are minimal. As long as the additional data are on the ARINC 429 data bus or its equivalent, they can be readily and easily recorded. The three leading manufacturers of digital flight data acquisition units (DFDAU) are producing microprocessor-based devices. Therefore, the parameters selected for recording need only be programmed into the programmable read-only memory (PROM). The one-time cost of programming the DFDAU for the recording of selected parameters could be amortized over an operator's entire fleet of a particular make and model of aircraft. One DFDAU manufacturer placed this one-time cost at between $10,000 and $15,000 per fleet.

Commuter Air Carrier/General Aviation Flight Recorder Requirements, 14 CFR 135/91

The Safety Board has long been concerned by the substantial growth of the commuter air carrier fleet and the lack of FDR and, until recently, of CVR requirements. The number of passengers enplaned by commuters between 1981 and 1986 grew by 84 percent and is expected to grow at an annual rate of 8.3 percent during the next decade. 1/ This growth has required the acquisition of newly manufactured aircraft designed specifically for the commuter market. The maximum takeoff weight of most of these new airplanes is in excess of 12,500 pounds, but since a significant number carry less than 30 passengers and have payloads of 7,500 pounds or less, they can be operated without flight recorders under the commuter rules of 14 CFR Part 135. Indeed, some airplane manufacturers have gone so far as to advertise this fact in their sales literature.

A number of these newly manufactured airplanes employ state-of-the-art avionics and control systems, such as the so-called "glass cockpit." As with their larger air carrier counterparts, these new digital systems will present some unique and potentially insurmountable problems to accident investigators. Much of the postaccident cockpit documentation, such as switch and instrument positions, that have proven so vital in past investigations will no longer be available. On the more positive side, the availability of vast amounts of pertinent information on digital data buses will greatly improve the technological and economical feasibility of installing FDRs on airplanes of this size.

The commuter air carrier industry is currently undergoing technological and operational changes comparable to that faced by the certificated air carrier industry some 17 years ago when wide-bodied jets were introduced. At that time, the existing flight recorder requirements were determined to have been inadequate, and a new set of standards was developed. Unfortunately, the new recorder standards applied only to airplanes with a type certification date subsequent to September 30, 1969, regardless of the date of manufacture of the airplane. The March 25, 1987, flight recorder rule changes are testimony to the inappropriate application of the 1969 standards. The additional expense associated with a retrofit as opposed to installation during manufacture is apparent; what is not apparent is the loss of vital accident data due to the lack of an adequate recorder system during the intervening years. It is not possible to

1/ "Regional Airline Association 1986 Annual Report," published by the Regional Airline Association, 1101 Connecticut Avenue, N.W., Washington, D.C. 20036.

estimate how many lives or millions of dollars could have been saved had the changes adopted on March 25, 1987, been implemented 17 years earlier. The FAA is now in a position to make a similar decision concerning CVR and FDR requirements for commuter air carriers.

The Safety Board believes that the January 15, 1987, change to 14 CFR Part 23, that defines the "commuter category" as airplanes having a seating configuration, excluding the pilot seats, of 19 or less, and a maximum certificated takeoff weight of 19,000 pounds or less, is consistent with a logical division point for the complexity and type of recorder required. An examination of commuter fleet indicates that only three airplane models have a seating capacity of from 20 to 30 passengers, 2/ and a maximum payload of 7,500 pounds or less. Two of the three airplanes, the Embraer EMB-120 and Shorts 330, have a seating capacity of 30 passengers, while the third, the CASA 212, has a seating capacity of 26 passengers. The Safety Board believes that these airplanes are of sufficient size and complexity to warrant the installation of flight recorders that meet the requirements of 14 CFR Part 121. In the case of two models, the addition of a single passenger seat would require the installation of a CVR and FDR under the existing Part 121 rules. At least two models, the EMB-120 and Shorts 330 are being operated in Europe with complete FDR and CVR systems. In fact, the first Shorts 330 delivered to the United States were required by U.S. standards at the time to have an FDR and CVR.

Therefore, the airplanes that fall into the designation of commuter category, 19 or less passengers and 19,000 pounds, are distinctly different from their larger Part 135 counterparts, the maximum seating capacities of which are some 7 to 11 seats larger. The Safety Board believes that a more logical division for those airplanes requiring compliance with 14 CFR Part 121 flight recorder rules would be 20 passengers or more and not 31 as currently required. This would be more consistent with the distinct division that currently exists in the commuter fleet and would align those few airplane models of larger capacity with the intent of the 14 CFR Part 121 recorder rules.

The technological feasibility of a flight recorder for the commuter category aircraft (19 passengers or less) is no longer in question. In fact, one recorder manufacturer has developed a recorder for the general aviation market that meets the technical standards of SAE 8039.3/ In addition, the U.S. Army has just embarked on a prototype program to install 200 FDRs in its UH-64 Blackhawk helicopters. These recorders are a standard off-the-shelf version of a digital data recorder currently in use by a number of U.S. and foreign air carriers. This prototype program is a prelude to a much larger program which specifies that SFDRs be installed on the U.S. Army's entire fleet of aircraft. Also, the U.S. Air Force is currently flying F-16 and B1 airplanes equipped with SFDRs. In addition, a solid-state version of the 25-hour air carrier FDR has been proposed by one recorder manufacturer and is under development by others. Consequently, the Safety Board believes that a technological spinoff for general aviation/commuter category recorders is highly probable and that these small lightweight recorders can be retrofitted into aircraft with systems similar to those generally found in the commuter air carrier fleet.

The investigations of commuter airplane accidents that have occurred since the Safety Board's last recommendations continue to emphasize the need for CVRs and FDRs. On December 6, 1984, a Provincetown Boston Air (PBA) Embraer EMB-110 crashed shortly after taking off from Jacksonville, Florida. All 11 passengers and 2 crewmembers

2/ "Regional Airline Association 1986 Annual Report," Ibid.
3/ Society of Automotive Engineers, Inc., "Minimum Performance Standards General Aviation Flight Recorder."

were killed and the airplane was destroyed. Although the evidence of an in-flight structural failure was obvious, the reason for the failure was not. In fact, the investigators had so few clues to work with that Emergency Airworthiness Directive 85-01-51 was issued on January 10, 1985, which essentially grounded the U.S. EMB-110 fleet until an inspection of remaining airplanes could be completed. The investigation continued for 18 months, far longer than most comparable air carrier accident investigations. In addition, the degree of certainty as to why the accident occurred would have been significantly more positive had CVR and FDR information been available. The Safety Board was able only to conclude that a pitch control problem occurred but was unable to determine the precise malfunction that caused the problem. The Safety Board is confident that, had CVR and FDR information been available, the cause would have been determined in a much more timely manner and with a precise identification of the malfunction.

During a 7-month period from August 25, 1985, to March 13, 1986, the commuter air carrier industry suffered three fatal accidents:

- On August 25, 1985, Bar Harbor Flight 1808, a Beech Model 99, crashed during an instrument landing system (ILS) approach to Auburn-Lewiston Airport, Auburn, Maine. The airplane struck trees at an elevation of 345 feet mean sea level (msl) in a wings level attitude 4,000 feet from the end of the runway threshold and 440 feet to the right of the extended runway centerline; all eight persons aboard were fatally injured. 4/

- On September 23, 1985, Henson Airlines Flight 1517, a Beech B99, crashed during an ILS approach to Shenandoah Valley Airport, Weyers Cave, Virginia. The airplane struck trees at an elevation of 2,400 feet msl in a wings level attitude about 6 miles east of the airport; all 14 persons aboard were fatally injured. 5/

- On March 13, 1986, Simmons Airlines Flight 1746, an Embraer EMB-110P1, crashed during an ILS approach to Phelps Collins Airport, Alpena, Michigan. The airplane struck trees at an elevation of 725 feet msl in a wings level attitude about 1.5 miles from the end of the runway threshold and about 300 feet to the left of the extended runway centerline; three of the nine airplane occupants were fatally injured. 6/

In all three accidents, the flightcrews were involved in precision instrument approaches in instrument meteorological conditions. The recorded air traffic control (ATC) communications in all three instances gave no indication that the flightcrews were experiencing any mechanical or ILS navigational problems. The ensuing examinations of

---

4/ For more detailed information, read Aircraft Accident Report—"Bar Harbor Airlines Flight 1808, Beech B-99, N300WP, Auburn-Lewiston Airport, Auburn, Maine, August 25, 1985" (NTSB/AAR-86/07).

5/ For more detailed information, read Aircraft Accident Report—"Henson Airlines Flight 1517, Beech B-99, N339HA, Shenandoah Valley Airport, Grottoes, Virginia, September 23, 1985" (NTSB/AAR-86-07).

6/ For more detailed information, read Aircraft Accident Report—"Simmons Airlines, Flight 1746, Embraer Bandeirante EMB-110P1, N1356P, Near Alpena, Michigan, March 13, 1986" (NTSB/MAR-87/02).

the airplane wreckages and navigational aids did not disclose any problems that would have caused or would have contributed to the flightcrew's wings level controlled crashes. Therefore, with the lack of any evidence to suggest mechanical malfunctions, the investigations focused on flightcrew performance.

Unfortunately, the lack of flight recorder information severely limited the scope of the flightcrew performance investigations. As a result, the investigators were confined to areas such as interviews with fellow crewmembers, training records, FAA surveillance, cockpit standardization, and a number of additional operational factors. Although the investigative efforts produced a number of significant safety recommendations based on sound evidence of potentially hazardous conditions and practices, the specific flightcrew actions, inactions, environmental conditions, heretofore undetermined equipment failures or combinations thereof that caused the accidents could not be positively identified. Further, the lack of a definitive accident cause diminishes the effectiveness of the Safety Board's recommendations to improve safety. However, the Safety Board is confident that, had flight recorder information been available, the specific deficiencies in flightcrew performance or some heretofore unknown failure or malfunction would have been determined for these accidents.

Two more recent incidents further exemplify the need and benefits of FDRs and CVRs. The first incident involved a regional air carrier, operating a 42-passenger turboprop airplane. 7/ During an ILS landing approach in icing conditions, control was lost and the airplane rolled abruptly to the right and left and descended 600 feet before the flightcrew could regain control. On the same day, a second airplane of the same type operated by the same operator had a similar but far less severe encounter. The FAA acted promptly to prohibit operations into forecast icing conditions until the airworthiness of the airplane could be further evaluated. The FDR from both airplanes and the CVR from the first airplane were removed and analyzed. The recorded data clearly identified the cause of the loss of control as operational rather than anything related to airworthiness and thus allowed for a prompt implementation of corrective action and the removal of the icing prohibition. This all took place within a matter of days.

In stark contrast is the March 4, 1987, fatal accident in Detroit, Michigan, involving a regional air carrier operating a 26-passenger CASA 212 that crashed inverted while on final approach to the airport. Because this airplane is certificated to carry less than 30 passengers and has a maximum payload of less than 7,500 pounds, CVR and FDR information was not available nor was it required. Without the CVR and FDR information, the investigation is limited to witness statements, ground impact marks, badly damaged and burned wreckage, limited air traffic control radar data, and flight test data. During the week of March 16 through March 20, an FAA flight test team was dispatched to Madrid, Spain, to conduct a flight test in the area of stall characteristics, stall warning, directional stability, and engine-out controllability. The team determined that the natural stall warning was inadequate. An NPRM was issued on April 10 that would require the installation of an artificial stall warning system in the CASA-212. However, even with the information obtained from this flight test program, a positive determination of factors that caused the accident may never be made. The possibility of an additional flight test program in currently under review. In the interim, however, there are 29 CASA 212s in the United States and over 300 worldwide operating without restriction and without a determination as to what caused the accident or even what happened.

7/ For more detailed information read, Aircraft Accident/Incident Summary Investigation No. DCA-87-IA015.

On May 8, 1987, another CASA-212 in scheduled commuter operation crashed on the final approach to the airport in Mayaguez, Puerto Rico. Both pilots were killed, and the four passengers aboard were injured. The airplane was destroyed. There was no CVR or FDR aboard the airplane, and Safety Board investigators are limited to information similar to that available in the Detroit accident.

As the accident record shows, the need for FDRs and CVRs on commuter category airplanes has not diminished since the last recorder recommendations were issued by the Safety Board in 1982.

Cockpit Voice Recorder "Hot Mic," 14 CFR Parts 121, 135, 25, and 23

The Safety Board has found the performance of CVR installations where the audio signal from the boom microphone of each flight crewmember is continuously recorded on a dedicated channel, often referred to as a "hot mic," to be far superior to the standard cockpit area microphone (CAM). This conclusion was reached after the Safety Board investigated a number of accidents/incidents involving both U.S. and foreign registered airplanes equipped with CVR "hot mics." In fact, the "hot mic" has proven to be a most significant technological improvement in CVRs. The level of improvement far surpasses any technological improvement that could be achieved by state-of-the-art recording or signal processing equipment.

In contrast, the quality of the audio signal recorded by the standard CAM can generally be described as poor, which requires considerable time and effort to produce a transcript. Frequently, the tape contains unintelligible dialog that is important to the determination of causal factors. The high quality audio signal available from the "hot mic" would eliminate this problem for the most part, and at the same time, provide additional benefits, as follows:

a. positive crewmember identification,

b. redundant multichannel recordings,

c. a potential for the evaluation of crewmember incapacitation by monitoring respiration rates, and

d. improved accuracy in determining which pilot was controlling the aircraft.

The Civil Aviation Authority (CAA) of the United Kingdom (UK) has required CVR "hot mic" since 1974. The UK Accident Investigation Branch's nearly 13 years of experience in analyzing CVR "hot mic" recording has prompted it to promote the adoption of CVR "hot mic" standards by the international aviation community. As a result, both ICAO and EUROCAE have adopted CVR "hot mic" standards. In addition, the Board of Directors of the Air Line Pilots Association voted in May 1987 to adopt a resolution to promote the use of CVR "hot mics."

The use of CVR "hot mic" may be the only means of producing an adequate CVR recording of pilot conversation for some airplanes. A good example of this was the standard CVR installation in the deHavilland Dash 7, which was found by the FAA's Flight Standards District Office in Milwaukee, Wisconsin, to be unsatisfactory. As a result, deHavilland engineers found that the only satisfactory solution was to install a "hot mic."

Although the benefits of CVR "hot mic" are numerous, the economic penalties are slight. In fact, most if not all major airplane manufacturers are now offering CVR "hot mic" as standard equipment. Therefore, a CVR "hot mic" requirement would not pose an economic penalty for operators purchasing new equipment.

General Aviation, 14 CFR Part 91 8/

The general aviation fleet is undergoing a technological evolution similar to, and in some respects greater than, that occurring in the air carrier and commuter fleets. The technological advances in the general aviation fleet have been numerous and varied, with the introduction of composite structures, digital data buses, and advanced automatic flight control systems. An indication of how pervasive the introduction of state-of-the-art technology has become was the November 1986 release by the General Aviation Manufacturers Association (GAMA) of three digital data bus standards for general aviation aircraft. As discussed earlier, these digital systems offer both an opportunity and a challenge to future accident/incident investigations. The opportunity stems from the relative ease by which vast amounts of significant information can be accessed and recorded. The challenge will come if this opportunity is not taken, for without crash-protected information, future investigations will have even less evidence than is currently available on conventional aircraft from cockpit instruments, light bulbs, switch settings, etc. Unfortunately, it is not merely an investigative challenge that is at stake--the lives and property of future passengers and owners are also at stake.

The accident record continues to present evidence that this challenge has been formidable and costly, both in lives and property. For example, the accident/incident histories of the Mitsubishi MU-2 and the Gates Learjet Models 24 and 25 airplanes provide an appreciation for the consequences of not having flight recorder information. The accident/incident records of the Learjet and MU-2 have been well documented in previous Safety Board recommendations 9/ and, therefore, need not be reiterated in detail. Briefly stated, however, both airplanes have a history of experiencing a sudden loss or reduction of control, which in many instances resulted in uncontrolled, high speed collisions with the ground.

In a recent MU-2 accident of this type, shortly before the fatal uncontrolled ground collision, the pilot radioed that the autopilot was pitching the airplane nose-down and that he could not control it. Because of this information, the Safety Board has been able to focus its investigative efforts in this accident, and other MU-2 accidents, on specific components of the Bendix M-4 autopilot system. This was accomplished by the correlation of the service difficult reports and accident/incident histories of the MU-2s and Learjet airplanes. Although these most recent investigative efforts appear to be providing some answers, it has been much too long and costly in terms of lives and property. The very long time taken to reach this point in the investigative process stems directly from the lack of information of the type provided by modern recorders. It is safe to say that had data similar to that proposed in the attached recommendation been available, a much more timely resolution of the serious safety problems could have been made which might have prevented all subsequent occurrences.

8/ In the context of this letter, the term "general aviation" means multiengine turbine-powered aircraft.

9/ Safety Recommendations A-81-106 through -111, issued August 31, 1982, and A-86-132 through -134, issued January 9, 1987.

The benefits of flight recorder information are becoming apparent to elements of the general aviation community as voluntarily installed recorders begin to yield valuable information. An indication of this was the recent National Business Aircraft Association (NBAA) change of policy that now encourages its members to consider voluntary installation of CVRs. In stating this policy change, Mr. Jonathan Howe, president of NBAA, cited the value of CVR information in the recent investigation of a collision between a corporate jet and a small plane. 10/

Summary

The aviation community and the commuter airlines in particular cannot afford to identify its safety problems by an accumulation of accidents in which the cause cannot be determined in a timely and definitive manner. The public expects and deserves a prompt and accurate determination of cause and should never be subjected to a repeat of unresolved accidents. The Safety Board is confident that, in the cases previously cited, the recommended CVR/FDR systems would have provided data of sufficient quality and quantity to determine in a much more timely manner the specific safety problems with a much higher degree of certainty.

The FAA has repeatedly cited cost as the main reason for not requiring FDRs and a retrofit of CVRs on commuter airplanes and general aviation aircraft. Although the FAA recognized the benefits of recorders, as evidenced by NPRM 85-1 "Flight Recorders and Cockpit Voice Recorders," which encouraged the voluntary installation of approved flight recorders and the soon-to-be-adopted Technical Standard Order (TSO) C-111, "General Aviation Flight Recorders," it has not seen fit to make them mandatory. The problem of implementing the Safety Board's recommendations, however, comes with the FAA's approach to determining the cost-benefit requirement as specified by Executive Order 12291. The Safety Board believes that the FAA's cost-benefit evaluation is dated and, therefore, does not truly reflect the state-of-the art in aircraft and recorder technologies. Fortunately, the aviation industry has not been waiting for the FAA's leadership in the area of flight recorders. Technology has progressed, and there are a number of SFDRs in operation on military aircraft which could be adapted for use in the commuter and general aviation fleets with little difficulty or cost.

In the past, the Safety Board recommended the prewiring of newly manufactured aircraft pending the development of a general aviation recorder which the Safety Board acknowledged was not commercially available. The Safety Board now believes that it is no longer necessary to go through the prewiring phase while waiting for the industry to develop a recorder for airplanes that have no mandatory compliance date. The Safety Board believes hat the technology currently exists ɔ permit the recorder industry to develop suitable and economically feasible flight recorders. This is not to say that a prewire phase shculd not precede the mandatory compliance date, thus insuring the most comprehensive coverage without requiring a retrofit.

New Recorder Technical Standards, 14 CFR Parts 91, 121, and 135

There are a number of recorder manufacturers interested in developing SFDRs to replace the existing electromechanical digital recorders, but they are finding their efforts stymied by the lack of a suitable TSO. The existing flight recorder TSO was issued in 1958 and does not address many significant features of an SFDR. EUROCAE, currently operating under the same TSO, also has recognized the shortcomings of TSO C-51 and plans to have a new standard in about a year. The SFDRs radical departure from

10/ Aviation Daily, April 15, 1987.

existing recorder technology while offering many advantages will also feature survivability requirements never envisioned by the drafters of TSO C-51. For example, the requirements to hydrostatically test a recorder have never been a problem because the memory mediums currently in use are not as vulnerable to crushing. Crush-testing, however, is important to an SFDR, because its memory chip could crush at extreme ocean depths. The recorder industry needs to know soon the crush load which the unit must be designed to withstand. To properly determine the design crush load criteria about ocean depths, as related to the probability of recovery within the life span of underwater locator beacons, recovery capabilities and costs of recovery must be established.

The new TSO must also address items such as sampling intervals, accuracies that reflect state-of-the-art sensors, and recording resolution. Recording resolution is of particular importance in defining data compression techniques and memory size. The Safety Board believes that any data compression techniques must record changes to the least significant bit, but at the same time acknowledges that the current standing for digital recorders, ARINC 573 and 717, places word size at 12 bits which for a number of parameters is larger than necessary. Therefore, the minimum word size should be determined on a parameter by parameter basis.

The verification that a recorder can retain the most recent 25 hours (14 CFR Part 121) or 8 hours (14 CFR Parts 91 and 135) of recorded data is also causing concern among recorder manufacturers. In the past, the capacity of the recorder was determined by the size of the memory medium. With an SFDR employing data compression, it is no longer a function only of memory size but also of the activity of the flight—the more active the flight the more memory required. Therefore, a standard by which a recorder's ability to retain 25 or 8 hours of data must be established. The Safety Board is willing to accept a standard that would permit the retention of less than 25 or 8 hours under extreme conditions, but not to exceed 10 percent of capacity.

Expanded Flight Recorder Requirements for New Airplanes, 14 CFR Parts 23 and 25

The technological advancements in recent years and those envisioned for the future have made it impractical to require only a minimum parameter list for all new airplanes. Therefore, the Safety Board believes that any unique design or operational characteristics that affect the performance of the airplane, in the form of handling qualities and performance limitations such as take off and stopping distances or any critical autopilot configurations and, particularly, any expert artificial intelligence dedicated to a monitoring function deemed critical to airplane operation, must be evaluated at the time of airplane certification to ensure that sufficient information will be recorded from which airplane performance can be determined. Specific language must be written into the rules to address these requirements.

In past discussions between staff on this subject, the FAA has insisted that the current rules are adequate to ensure that this will be done. The Safety Board finds that this interpretation of the rule is not shared by all regions. For example, the Boeing 757s sold to Delta Air Lines and Northwest Air Lines do not record angle of attack although it is readily available on the digital data bus. The current rule lists angle of attack as a mandatory parameter "(if recorded directly)" which is somewhat confusing and subject to misinterpretation.

As a consequence of this comprehensive review of the status of flight recorders, the National Transportation Safety Board recommends that the Federal Aviation Administration:

Amend 14 CFR 121.343 to require that, after a specified date, all airplanes equipped with a 429 digital data bus or equivalent (i.e., "glass cockpits") be retrofitted to record sufficient data to determine the parameters in table I. (Class II, Priority Action) (A-87-77)

Amend 14 CFR 121.343 to require that, after a specified date, all airplanes manufactured after that date be equipped with an approved flight recorder that records data from which the information listed in table I can be determined. (Class II, Priority Action) (A-87-78)

Amend 14 CFR Part 127, Subpart H, to require that all existing and newly manufactured rotorcraft, regardless of the date of original type certificate, be equipped with one or more approved flight recorders that record data from which the information listed in table II can be determined. The recorder should retain no less than the last 8 hours of aircraft operation. (Class II, Priority Action) (A-87-79)

Amend 14 CFR Part 135 to require that, after a specified date, all multiengine turbine-powered aircraft (both fixed-wing and rotorcraft) capable of carrying 10 to 19 passengers, brought onto the U.S. register, be equipped with an approved flight recorder that records data from which the information listed in tables III and IV can be determined, and at a date to precede the above date, that all subject aircraft be prewired to accept a flight data recorder capable of recording data from which the information in tables III and IV can be determined. The recorder should retain no less than the last 8 hours of aircraft operation. (Class II, Priority Action) (A-87-80)

Amend 14 CFR 135.151 to require that, after a specified date, a cockpit voice recorder be installed on all currently certificated multiengine turbine-powered aircraft (both fixed-wing and rotorcraft), which are certified to carry six or more passengers and which are required by certificate or operating rule to have two pilots, used in any type of operation not currently required by 14 CFR 121.359, 135.151, and 127.127 to have a cockpit voice recorder. The cockpit voice recorder should have at least one channel reserved for voice communications transmitted from or received in the aircraft by the radio and one channel reserved for audio signals from a cockpit area microphone, and should record at least the last 15 minutes of aircraft operation. (Class II, Priority Action) (A-87-81)

Amend 14 CFR 135.2 to require that those aircraft (both fixed-wing and rotorcraft) capable of carrying 20 passengers or more to be equipped with flight data recorders that comply with 121.343 flight recorder requirements as changed to conform to Safety Recommendations A-87-77 and -78. (Class II, Priority Action) (A-87-82)

Amend 14 CFR 135.151 to require that those aircraft (both fixed-wing and rotorcraft) capable of carrying 20 passengers or more, and not currently required by 14 CFR 121.359 or 135.151 to have a cockpit voice recorder, be equipped with a cockpit voice recorder that meets 14 CFR 121.359 requirements. (Class II, Priority Action) (A-87-83)

Amend 14 CFR Part 91 to require that, after a specified date, all multiengine turbine-powered aircraft (both fixed-wing and rotorcraft) capable of carrying 10 or more passengers brought onto the U.S. register, be equipped with an approved flight recorder that records data from which the information listed in tables III and IV can be determined at a date to precede the above date, and that all subject aircraft be prewired to accept a flight data recorder capable of recording data from which the information in tables III and IV can be determined. The recorder should retain no less than the last 8 hours of aircraft operation. (Class II, Priority Action) (A-87-84)

Amend 14 CFR Part 91 to require the installation of a cockpit voice recorder in all multiengine turbine-powered aircraft (both fixed-wing and rotorcraft) capable of carrying six passengers or more, which require two pilots by certificate or operating rule, and which currently are not required by 14 CFR 121.359, 135.151, and 127.127 to have a cockpit voice recorder. The recorder should have at least one channel reserved for voice communications transmitted from or received in the aircraft by the radio and one channel reserved for audio signals from a cockpit area microphone, and should record during the last 15 minutes of aircraft operation. (Class II, Priority Action) (A-87-85)

Develop a technical standard order (TSO) for solid-state flight data recorders (SFDR) specifying resolution, sampling intervals, accuracies, and specify crash/fire survivability requirements to accommodate the unique design characteristics of the SFDR not currently covered by TSO C-51A. Also provide specific criteria by which the ability of the recorder to retain the most recent 25 or 8 hours of recorded data can be verified. (Class II, Priority Action) (A-87-86)

Amend 14 CFR Parts 23, 25, 27, and 29 to require that all newly type-certificated aircraft be evaluated to determine any dedicated parameters that must be recorded on flight data recorders because of the unique design or operational characteristics of the aircraft. (Class II, Priority Action) (A-87-87)

Amend 14 CFR Parts 23 and 25 to require that all newly manufactured aircraft and new cockpit voice recorder installations be designed such that an uninterrupted recording from the boom or mask microphones and headphones for each flight crewmember's position and from an area microphone can be made on dedicated channels of the CVR. On those aircraft requiring only two flight crewmembers, the unused channel should record the passenger address audio signal when available. A sidetone shall be produced only when the transmitter or interphone is selected, and, in addition, all audio signals received by hand-held microphones shall be recorded on the respective crewmember's channel when keyed to the "ON" position. (Class II, Priority Action) (A-87-88)

Amend 14 CFR Parts 121 and 135 to require the use of boom microphones by all flight crewmembers below 18,000 feet mean sea level on those aircraft equipped to record the uninterrupted audio signals received by a boom or mask microphone. (Class II, Priority Action) (A-87-89)

BURNETT, Chairman, GOLDMAN, Vice Chairman, and LAUBER, NALL, and KOLSTAD, Members, concurred in these recommendations.

Jim Burnett

By: Jim Burnett
Chairman

TABLE I

PARAMETER LIST (14 CFR 121)

PARAMETERS	RANGE	ACCURACY (SENSOR INPUT TO DFDR READOUT)	SAMPLING INTERVAL (PER SECOND)
Time (GMT)	24 Hrs	±0.125% Per Hour	0.25 (1 per 4 seconds)
Altitude	-1,000 ft to max certificated altitude of aircraft	±100 to ±700 ft (See Table I, TSO-C51a)	1
Airspeed	50 KIAS to Vso, and Vso to 1.2 V_D	±5% ±3%	1
Heading	360°	±2°	1
Normal Acceleration (Vertical)	-3g to +6g	±1% of max range excluding datum error of ±5%	8
Pitch Attitude	±75°	±2°	1
Roll Attitude	±180°	±2°	1
Radio Transmitter Keying	On-Off (Discrete)		1
Thrust/Power On Each Engine	Full Range Forward	±2%	1 (per engine)
Trailing Edge Flap Or Cockpit Control Selection	Full Range Or Each Discrete Position	±3° Or As Pilot's Indicator	0.5
Leading Edge Flap Or Cockpit Control Selection	Full Range Or Each Discrete Position	±3° Or As Pilot's Indicator	0.5
Thrust Reverser Position	Stowed, In Transit, And Reverse (Discrete)		1 (per engine)
Ground Spoiler/Speed Brake Selection	Full Range Or Each Discrete Position	±2% Unless Higher Accuracy Uniquely Required	1
Marker Beacon Passage	Discrete		1
Autopilot Engagement	Discrete		1

LE 1 (2)

PARAMETERS	RANGE	ACCURACY (SENSOR INPUT TO DFDR READOUT)	SAMPLING INTERVAL (PER SECOND)
Longitudinal Acceleration	±1g	±1.5% Max Range Excluding Datum Error of ±5%	4
Pilot Input And Surface Position-Primary Controls (Pitch, Roll, Yaw)	Full Range	±2° Unless Higher Accuracy Uniquely Required	1
Lateral Acceleration	±1g	±1.5% Max Range Excluding Datum Error of ±5%	4
Pitch Trim Position	Full Range	±3% Unless Higher Accuracy Uniquely Required	1
Glideslope Deviation	±400 Microamps	±3%	1
Localizer Deviation	±400 Microamps	±3%	1
AFCS Mode And Engagement Status	Discrete (5 Bits Necessary)		1
Radio Altitude	-20 ft to 2,500 ft	±2 Ft Or ±3% Whichever Is Greater Below 500 Ft And ±5% Above 500 Ft	1
Master Warning	Discrete		1
Nav 1 and 2 Frequency Selection	Full Range	As Installed	0.25
DME 1 and 2 Distance	0-200 NM;	As Installed	0.25
Main Gear Squat Switch Status	Discrete		1
Angle of Attack (If Recorded Directly)	As Installed	As Installed	2
Outside Air Temperature	-90°C to +50°C	±2°C	0.5

TABLE I (3)

PARAMETERS	RANGE	ACCURACY (SENSOR INPUT TO DFDR READOUT	SAMPLING INTERVAL (PER SECOND)
Hydraulics, Each System Low Pressure	Discrete		0.5
Groundspeed	As Installed	Most Accurate System Installed (INS Equipped Aircraft Only)	1

TABLE II

PARAMETER LIST (14 CFR 127)

PARAMETERS	RANGE	ACCURACY (SENSOR INPUT TO DFDR READOUT)	SAMPLING INTERVAL (PER SECOND)
Time (GMT)	24 hrs	±0.125% per hr	0.25 (1 per 4 seconds)
Pressure Altitude	-1,000 ft to max certificated altitude of aircraft	+100 to +700 ft (See Table I, TSO-C51a)	1
Airspeed	As the installed measuring system	±3%	1
Heading	360°	±2°	1
Normal Acceleration (Vertical)	-3g to +6g	±1% of max range excluding datum error of ±5%	8
Pitch Attitude	±75°	±2°	2
Roll Attitude	±180°	±2°	2
Radio Transmitter Keying	On-off (Discrete)		1
Power on Each Engine: Free Power Turbine Speed and Engine Torque	0-130% (Power Turbine Speed) Full range (Torque)	±2%	1 speed 1 torque (per engine)
Main Rotor Speed	0-130%	±2%	2
Altitude Rate	±6,000 ft/min	As installed	2
Pilot Input - Primary Controls (Collective, Longitudinal Cyclic, Lateral Cyclic, Pedal)	Full range	±3%	2
Flight Control Hydraulic Pressure Low	Discrete, each circuit		1

TABLE II (2)

PARAMETERS	RANGE	ACCURACY (SENSOR INPUT TO DFDR READOUT)	SAMPLING INTERVAL (PER SECOND)
Flight Control Hydraulic Pressure Selector Switch Position, 1st and 2nd Stage	Discrete		1
AFCS Mode and Engagement Status	Discrete (5 bits necessary)		1
Stability Augmentation System Engage	Discrete		1
SAS Fault Status	Discrete		0.25
Main Gearbox Pressure Low	As installed	As installed	0.25
Main Gearbox Temperature High	As installed	As installed	0.5
Controllable Stabilator Position	Full range	±3%	2
Longitudinal Acceleration	±1g	±1.5% max range excluding datum error of ±5%	4
Lateral Acceleration	±1g	±1.5% max range excluding datum error of ±5%	4
Master Warning	Discrete		1
Nav 1 and 2 Frequency Selection	Full range	As installed	0.25
Outside Air Temperature	-90°C to +50°C	±2°C	0.5

TABLE III

PARAMETER LIST (FIXED WING AIRCRAFT)

PARAMETERS	RANGE	INSTALLED SYSTEM 1/ MINIMUM ACCURACY (TO RECOVERED DATA)	SAMPLING INTERVAL (PER SECOND)
Relative Time (from recorder on prior to takeoff)	8 hrs. minimum	±0.125% per hour	1
Indicated Airspeed	V_{SO} to V_D (KIAS)	±5% or ±10 kts., whichever is greater. Resolution 2 kts. below 175 KIAS	1
Altitude	-1,000 ft. to max cert. alt. of A/C	±100 to ±700 ft. (see Table I, TSO C51-a)	1
Magnetic Heading	360^0	$\pm5^0$	1
Vertical Acceleration	-3g to +6g	±0.2g in addition to ±0.3g maximum datum error	4 (or 1 per second where peaks ref. to 1g are recorded)
Longitudinal Acceleration	±1.0g	±0.05g in addition to max. datum error of ±0.1g	2
Pitch Attitude	100% of usable range	$\pm2^0$	1
Roll Altitude	$\pm60^0$ or 100% of usable range, whichever is greater	$\pm2^0$	1
Stabilizer Trim Position	Full range	±3% unless higher accuracy uniquely required	1
OR			
Pitch Control Position	Full range	±3% unless higher accuracy uniquely required	1

1/ When data sources are aircraft instruments (except altimeters) of acceptable quality to fly the aircraft, the recording system excluding these sensors (but including all other characteristics of the recording system) shall contribute no more than half the values in this column.

T III (2)

Engine . ower, Each Engine			
Fan or N_1 Speed or EPR or Cockpit Indications Used for Aircraft Certification	Maximum range	$\pm 5\%$	1
OR			
Prop. Speed and Torque (Sampled Once/Sec as Close Together as Practicable)			1 (prop speed) 1 (torque)
Altitude Rate 2/ (need depends on altitude resolution)	$\pm 8,000$ fpm	$\pm 10\%$. Resolution 250 fpm below 12,000 ft. indicated	1
Angle of Attack 2/ (need depends on altitude resolution)	-20^0 to $+40^0$ or 100% of usable range	$\pm 2^0$	1
Radio Transmitter Keying (Discrete)	On/Off		1
TE Flaps (Discrete or Analog)	Each discrete position (U,D,T/O,APP)		1
	OR		
	Analog 0-100% range	$\pm 3^0$	1
LE Flaps (Discrete or or Analog)	Each discrete position (U,D,T/O,APP)		1
	OR		
	Analog 0-100% range	$\pm 3^0$	1
Thrust Reverser, Each Engine (Discrete)	Stowed or full reverse		1
Spoiler/Speedbrake (Discrete)	Stowed or out		1:
Autopilot Engaged (Discrete)	Engaged or Disengaged		1

2/ If data from the altitude encoding altimeter (100 ft. resolution) is used, then either one of these parameters should also be recorded. If, however, altitude is recorded at a minimum resolution of 25 feet, then these two parameters can be omitted.

TABLE IV

PARAMETER LIST (ROTORCRAFT)

PARAMETERS	RANGE	INSTALLED SYSTEM 1/ MINIMUM ACCURACY (TO RECOVERED DATA)	SAMPLING INTERVAL (PER SECOND)
Relative Time (from recorder on prior to takeoff)	4 hrs. minimum	±0.125% per hour	1
Indicated Airspeed	V_{min} to V_D (KIAS) (minimum airspeed signal attainable with installed pitot-static system)	±5% or ±10 kts., whichever greater	1
Altitude	-1,000 ft. to 20,000 ft. pressure altitude	±100 to ±700 ft. (see Table I, TSO C51-a)	1
Magnetic Heading	360°	±5°	1
Vertical Acceleration	-3g to +6g	±0.2g in addition to ±0.3g maximum datum error	4 (or 1 per second where peaks ref. to 1g are recorded)
Longitudinal Acceleration	±1.0g	±0.05g in addition to maximum datum error of ±0.1g	2
Pitch Attitude	100% of usable range	±2°	1
Roll Attitude	±60° or 100% of usable range, whichever is greater	±2°	1
Altitude Rate	±8,000 fpm	±10%. Resolution 250 fpm below 12,000 ft. indicated	1

1/ When data sources are aircraft instruments (except altimeters) of acceptable quality to fly the aircraft, the recording system excluding these sensors (but including all other characteristics of the recording system) shall contribute no more than half the values in this column.

T. IV (2)

Engine Power, Each Engine			
Main Rotor Speed	Max. range	$\pm 5\%$	1
Free or Power Turbine Speed	Max. range	$\pm 5\%$	1
Engine Torque	Max. range	$\pm 5\%$	1
Flight Control Hydraulic Pressure			
Primary (Discrete)	High/Low		1
Secondary-if applicable (Discrete)	High/Low		1
Radio Transmitter Keying (Discrete)	On/Off		1
Autopilot Engaged (Discrete)	Engaged/Disengaged		1
SAS Status-Engaged (Discrete)	Engaged/Disengaged		1
SAS Fault Status (Discrete)	Fault/OK		1
Flight Controls			
Collective	Full range	$\pm 3\%$	2
Pedal Position	Full range	$\pm 3\%$	2
Lat. Cyclic	Full range	$\pm 3\%$	2
Long. Cyclic	Full range	$\pm 3\%$	2
Controllable Stabilator Position	Full range	$\pm 3\%$	2

APPENDIX

With the issuance of Safety Recommendations A-87-77 through -89, the following recommendations have been classified as "Closed—Superseded."

A-78-28

Draft specifications and fund research and development for a low cost FDR, CVR, and composite recorder which can be used on complex general aviation aircraft. Establish guidelines for these recorders, such as maximum cost, compatible with the cost of the airplane on which they will be installed and with the use for which the airplane is intended.

A-82-64

Amend 14 CFR 121.343 so that, after a specified date all turbojet aircraft manufactured before that date and type-certificated before September 30, 1986, be required to have installed a suitable digital recorder system capable of recording data from which the minimum following information may be determined as a function of time within the ranges, accuracies, and recording intervals specified in Table I—altitude, airspeed, heading, radio transmitter keying, pitch attitude, roll attitude, vertical acceleration, longitudinal acceleration, stabilizer trim position, engine thrust, and pitch control position.

A-82-65

At an early date and pending the effective date of the recommended amendment of 14 CFR 121.343 to require installation of digital flight data recorder systems capable of recording more extensive parameters, require that operators of all aircraft equipped with foil flight data recorders be required to replace the foil recorder with a compatible digital recorder.

A-82-66

Amend 14 CFR 121.343 so that, after a specified date, all aircraft manufactured after that date, regardless of the date of original type certificate, be equipped with one or more approved flight recorders that record data from which the information listed in Table I can be determined as a function of time. For newly type-certificated aircraft, any dedicated parameter which may be necessary because of unique features of the specific aircraft configuration and the design should also be required.

A-82-67

Amend 14 CFR 127, Subpart H, to require that all rotorcraft manufactured after a specified date, regardless of the date of original type certificate, be equipped with one or more approved flight recorders that record data from which the information listed in Table II can be determined as a function of time. For newly type-certificated rotorcraft, any dedicated parameter which may be necessary because of unique features of the specific configuration and type design should also be required.

A-82-106

Encourage timely adoption of Society of Automotive Engineers (SAE) standard for "general aviation" flight recorders (intended for installation in multiengine, turbine-powered fixed-wing aircraft and rotorcraft in any type of operation not currently required by CFR 121.359, 135.151, and 127.127 to have a cockpit voice recorder and/or a flight data recorder), and issue a Technical Standard Order (TSO) covering such recorders immediately after the SAE document is approved. Include in the TSO requirements that:

a) specify a cockpit voice recorder (CVR) of high enough audio quality to render intelligible recorded data on each of two channels which reserves one channel for voice communications transmitted from or received in the aircraft by radio, and one channel for audio signals from a cockpit area microphone;

b) specify all flight data recorder (FDR) parameters, ranges, accuracies, and sampling intervals cited in Tables I and II (attached);

c) specify crash and fire survivability standards for CVRs and FDRs which are at least as stringent as those of TSO-C51a for Type I (nonejectable) and Type III (ejectable) recorders as appropriate.

A-82-108

Require that all multiengine, turbine-powered, rotorcraft certificated to carry six or more passengers, manufactured on or after a specified date, in any type of operation not currently required by 14 CFR 121.127 to have a cockpit voice recorder and/or a flight data recorder, be prewired to accept a "general aviation" cockpit voice recorder (if also certificated for two-pilot operation) with at least one channel for voice communications transmitted from or received in the aircraft by radio, and one channel for audio signals from a cockpit area microphone, and a "general aviation" flight data recorder to record sufficient data parameters to determine the information in Table II (attached) as a function of time.

The following recommendations have been classified as "Closed—Superseded/Unacceptable."

A-82-107

Require that all multiengine, turbine-powered, fixed-wing aircraft certificated to carry six or more passengers manufactured on or after a specified date, in any type of operation not currently required by 14 CFR 121.343, 121.359, and 135.151 to have a cockpit voice recorder and/or a flight data recorder, be prewired to accept a "general aviation" cockpit voice recorder (if also certificated for two-pilot operation) with at least one channel for voice communications transmitted from or recieved in the aircraft by radio, and one channel for audio signals from a cockpit area microphone, and a "general aviation" flight data recorder to record sufficient data parameters to determine the information in Table I (attached) as a function of time.

A-82-109

Require that "general aviation" cockpit voice recorders (on aircraft certificated for two-pilot operation) and flight data recorders be installed when they become commercially available as standard equipment in all multiengine, turbine-powered fixed-wing aircraft and rotorcraft certificated to carry six or more passengers manufactured on or after a specified date, in any type of operation not currently required by 14 CFR 121.343, 121.359, 121.151, and 127.127 to have a cockpit voice recorder and/or flight data recorder.

A-82-110

Require that "general aviation" cockpit voice recorders be installed as soon as they are commercially available in all multiengine, turbine-powered aircraft (both airplanes and rotorcraft), which are currently in service, which are certificated to carry six or more passengers and which are required by their certificate to have two pilots, in any type of operation not currently required by 14 CFR 121.359, 121.151, and 127.127 to have a cockpit voice recorder. The cockpit voice recorders should have at least one channel reserved for voice communications transmitted from or received in the aircraft by radio, and one channel reserved for audio signals from a cockpit area microphone.

A-82-111

Require that "general aviation" cockpit voice recorders be installed as soon as they are commercially available in all multiengine, turbojet airplanes which are currently in service, which are certificated to carry six or more passengers in any type of operation not currently required by 14 CFR 121.343 to have a flight data recorder. Requiring recording of sufficient parameters to determine the following information as a function of time (see Table I attached) for ranges, accuracies, etc.):

altitude
indicated airspeed
magnetic heading
radio transmitter keying
pitch attitude
roll attitude
vertical acceleration
longitudinal acceleration
stabilizer trim position
or pitch control position