Airborne Recording and Its Future with the Airlines

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In recent years, airborne recording systems for commercial airlines have become a reality. These systems now offer accuracy, reliability, recording capacity, and versatility. A wide range of building blocks are available to meet the particular needs of any airline. Initial investment is discouraging, but the potential gain will force airlines to face up to the application of airborne automated data recording. When complexity of the present and next generation of commercial airplanes or space shuttle vehicles is considered, there is good reason to believe this new system will offer the most effective solution to a number of problems faced by aviation.

Introduction

ONE of the pioneers of aviation, who is dedicated in the true sense of a silk scarf aviator, has likened commercial aviation progress to his favorite sport—professional football. In some respects, this phase of aviation has followed the same pattern as professional football, which has been developed to the point where it is frequently considered a science in itself. Certainly, professional football has adopted some of the most modern tools of science, striving for the highest degree of perfection in any sport. The game started in 1875 and in the early years, improvement was gained primarily through observation, trial, error, and adjustment. However, demands of the complex 20th Century have forced professional football to adopt precise techniques and tools in support of the game. All professional football teams use the latest in visual and aural recording devices coupled with computers to maintain their competitive position. A similar parallel can be drawn in the aircraft industry. In the late 1920's, pilot training, all too often, consisted of a ground explanation of the aircraft followed by an immediate solo flight. If the pilot came back, he passed the test. Similarly, the aircraft engine mechanic got his experience repairing automotive engines —if he was fortunate. However, modern aircraft are far more demanding in their support requirements. Here again, as in football, trial and error have given way to complex techniques and some of the most precise support tools. For example, most commercial pilot training is done in computer-driven, dynamic simulators which reproduce the cockpit environment to an almost unbelievable degree of realism. Maintenance support of aircraft, especially the engines, has experienced a similar advance in state-of-the-art, and most of this progress has occurred within the past ten years. It is in this area of continuous effort to advance support of aircraft and flight operational performance that airborne recording offers a significant contribution, and ultimately will become quite common as a maintenance and training tool.

Need for Improved Data

The need for improved data occurs primarily in three areas: 1) engine analysis, 2) aircraft subsystems, and 3) aircraft operational performance studies. Engine analysis will be considered first.

In the late 1950's, some of the major airlines, such as American Airlines, began to look with renewed vigor for techniques to drastically refine methods of engine maintenance support to achieve improved reliability and cut costs. This was first done using cockpit instrument data recorded by the flight engineer and then manually plotted to study trends and identify potential engine faults. The analysis portion of this process was later automated by fitting a model of the engine into a computer where much more sophisticated diagnostics could be applied, but this approach was then limited by accuracy, repeatability, the number of parameters available and frequency of sampling. The computer was capable of performing much more thorough analysis if improved data were available. Automation of the airborne data gathering system improves both quality and quantity of data for engine analysis. Generally speaking, there is even less data available for aircraft subsystem analysis. The recent trend of including BITE (Built In Test Equipment) circuitry in the more complex systems has somewhat reduced the need for airborne recorded data in this area, but the technique has not proved to be the cure-all that was expected. It now appears that airborne recording can be advantageously applied to some of these systems, provided the systems are designed for computerized maintenance analysis. The APU exemplifies this application since it is similar to the aircraft engines, and there are other areas as well which may benefit from an automated data acquisition system, especially those areas where the effects of physical or thermal stress are cumulative such as landing gear, structure, or possibly brakes. As the aircraft systems become more complex, the need for timely, accurate maintenance support data will become more significant. A similar need will exist to support the reusable space vehicle. The third area where improved data is frequently desirable relates to aircraft performance. In recent years, very little improvement has been made in data available to refine management techniques related to aircraft performance. Improved fuel management and customized pilot training present a challenge in this area. There is some potential for further extension of existing techniques in the above three areas, but the next major step must result from an improved data base. Automated airborne recording is one way of achieving this new, higher quality, more inclusive data base.

General Concepts

A typical airborne recording system installation is illustrated in Fig. 1. The three units shown above the dotted line through the airplane are installed to meet Government regulations. These consist of a Flight Data Entry Panel (FDEP), Flight Data Acquisition Unit (FDAU),

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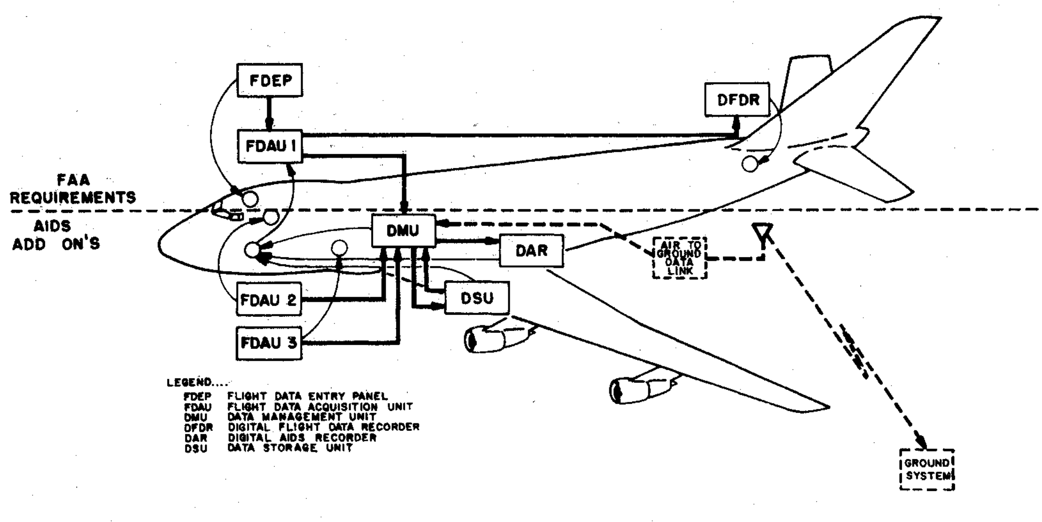

Fig. 1 AIDS airborne recording system.

Data Storage Unit (DSU), and a Digital Flight Data Recorder (DFDR). The FDEP is used to insert documentary information such as date, trip number, gross weight, and other information related to a particular flight leg. Information from this FDEP is fed into the Flight Data Acquisition Unit together with signals from other sources such as flap or rudder position. In Table 1 a typical set of FAA required data is indicated (see footnote "a"). For a large jet aircraft, 18 to 25 parameters will be required; the actual number depending on control surface configuration. In the FDAU, input signals are conditioned, converted from analog to digital values, arranged in serial format, and then sent to the Digital Flight Data Recorder located in the tail area of the airplane. The DFDR is a continuous recorder which preserves the last 25 hr of recorded information. That portion of the recorder which contains the magnetic tape is protected to withstand both the thermal and physical crash environment as specified in FAR Rules and Regulations, Pt. 31.150, Aircraft Flight Recorder TSO C51a. Data from this recorder are not normally processed unless an airplane incident or crash has occurred.

Again referring to Fig. 1, the units shown below the dotted line are optional electronic boxes added to perform those functions desired by an airline. In this case, two additional signal conditioners (FDAU's) have been included to process other parameters listed in Table 1. The output data streams from these three units are fed into a Data Management Unit for additional processing. The DMU processes the data from the three FDAU's and also accepts some unique parameters directly from aircraft sensors for analog to digital conversion. Any computations required of the airborne recording system are also accomplished in this unit. Some of the more common requirements include detection of excessive exhaust gas temperature, engine speed, bank angle, or turbulence exceedances which initiate a recording cycle in addition to the routine periodic recordings that occur at specified time intervals. In addition, some installations may include more sophisticated computations such as engine diagnostics or flight path calculations. The DMU also provides all recording system management, such as control of intervals at which data is recorded in the Digital Aids Recorder (this will be discussed later in more detail), and control of data contained in the Data Storage Unit (DSU). The DSU will either be a continuous loop recorder or solid state buffer in which, for example, 2 min of data is preserved, should the DMU call for it. This assures that 120 sec of continuous data are available before any exceedance, where it is desirable to obtain history just prior to the exceedance, and the Digital Aids Recorder (DAR) may not have been in a routine recording mode at that time. In this case, the DMU initiates a dump of the history data from the Data Storage Unit into the Digital Aids Recorder. The DAR is the airborne system primary recorder and receives data at specified intervals controlled by the Data Management Unit. This unit must have a recording capacity of from 10

Table 1 Typical recorded parameters

Time—GMT[a]	Oil inlet temperature	Autopilot ILS mode
Pressure altitude[a]	Oil quantity	Autothrottle on/off
Radio altimeter alt.	P_t3-Low comp dischg total press.	Marker beacon
Vertical speed	P_s4-High comp dischg static press.	Flap load relief
Airspeed[a]	P_s5-Turb. cooling air static press.	Mach warning
Fuel quantity	Oil pressure	Stick shaker
Flap angle[a]	Oil breather pressure	Glideslope deviation
Stabilizer position[a]	Start air pressure	Localizer deviation
Speed brake position	N_1 Low press. comp speed	Lateral acceleration[a]
Pitch angle[a]	N_2 High press. comp speed	Aileron position[a]
Roll angle[a]	Variable stator angle	Rudder position[a]
Magnetic heading[a]	Power lever angle	Comm. mic on/off[a]
Elevator angle[a]	Vibration	Angle of attack[a]
Mach number	Bleed flow	Ldg. edge flap posn.[a]
Vertical acceleration[a]	Total air temp	T_t3-Low comp dischg total temperature
Fuel flow	Bleed duct pressure	T_t4.5-High comp dischg total temperature
Exhaust gas temp.	Eleven switch positions	Nacelle temperature
Eng. press. ratio[a]	Reverser lights[a]	

[a] FAA required data.

Table 2 Typical recording schedules

System 1

Documentary—ignition on.	Climb—30 sec after lift off
Start—if exhaust gas temperature exceeds 580° C. squat switch on, N_1 80%.	Cruise—above 5000 ft, 250 knots, and altitude and airspeed stabilized for 4 π in
Takeoff—airplane moving 50 knots, squat switch on, N_1 80%	Touch down—squat switch on
Lift off—squat switch off	Manual record—on command of the flight crew by push-button

In the cruise mode, ten samples of each engine parameter are taken and averaged to obtain one set of data points for engine analysis.

System 2

Documentary—on command
Takeoff—continuous from 110 knots to flaps retracted
Cruise—one frame data each 30 min
Landing—continuous from flaps extend to reversers applied
Manual—on command from the crew
Continuous—when flap/altitude limits exceeded
90 sec of pre-exceedance stored data and continuous for following exceedances:

Exhaust gas temp	Flap speed
High press. comp. RPM (N_2)	Vertical speed
Stick shaker	Pitch angle
Turbulence	Roll angle
Speed brake	

to 25 hr, depending on tape handling procedures, route structures, mission, or data requirements of the ground support organization. This capacity requirement assumes periodic recording rather than continuous. A fleet of 100 airplanes with an average utilization of six hr per day would produce in the order of 300×10^6 bits of data per day if the recording system ran continuously. There are a number of methods or techniques to reduce this volume of data. One method is periodic recording which requires the Data Management Unit to control the times at which recordings are made, in addition to exceedance recording previously discussed. Table 2 lists two recording schedules which have been used successfully in commercial jet transport data acquisition systems.

New Recording Systems Available

In 1960, American Airlines installed one of the first commercial jet aircraft production recording systems designed specifically for support of aircraft maintenance and performance management. Other systems were being designed at about this same time. Although the general purpose of all of these recording systems was very similar, the hardware configuration was quite different both in electronic circuitry and physical characteristics. This rather disorganized progress continued until 1968. By this time, the airlines had begun to recognize the need for standardization and, at the same time, the Government regulatory agencies began to see the need for additional airborne recorded data to support safety requirements. The outgrowth of these conclusions was the formation of an industry committee, under the guidance of ARINC, to develop a standard for modular Aircraft Integrated Data Systems (AIDS). This committee developed an industry specification, ARINC Characteristic 573, Mark 2 Aircraft Integrated Data System, which has become the base for all newly designed recording systems now available for airborne recording, other than those special data acquisition systems used for flight test or other short-term airborne recording purposes. This specification uses a modular concept providing a base to meet Governmental agency requirements for airborne recording and, at the same time, allows the user to take economic advantage of this hardware, adding as many building blocks as required to meet his own particular needs. Standardization of the building blocks also makes possible the pooling of expensive support equipment and spare units between fleets, airlines, or other users.

Systems designed by several vendors are now flying in some of the major airlines, and have demonstrated accuracy, reliability, recording capacity and versatility. Some of the prestandardization systems were marginal or even deficient in one or more of these important areas. It can now be said that AIDS is a reality, and that the airlines have a challenge to develop this tool to extend aircraft engine and system maintenance support techniques, together with refinement of aircraft and fuel management.

Requirements for AIDS Implementation

Implementation of an AIDS program within the operating structure of an airline is an involved process for two major reasons. First, AIDS is a complex system because of its own electronics, and secondly, support and application of the airborne recorded data supplied by AIDS cuts across so many areas of responsibility within an airline. These observations should not discourage the use of airborne recording, but merely indicate the need for thorough planning to achieve the highest efficiency in the use of AIDS.

There are twelve major steps involved in implementation of an airborne recording system on a fleet of complex jet airplanes such as the 747, DC10, or L1011 aircraft: 1) applications study, 2) economic study and funding document, 3) hardware and software specification, 4) hardware selection, 5) development of a hardware maintenance support program, 6) development of a software maintenance support program, 7) detailed program for application of the data, 8) installation design, FAA certification, and functional certification, 9) debugging of the installed hardware, 10) debugging of the computer software, 11) operational system on a fleet basis, and 12) expansion of the recording system application. If these twelve steps are not followed, the airline will find it has a very expensive system installed, not working very well, but producing pounds of data that a group of engineers are trying to determine how to use. In this respect, AIDS is similar to the computer field. It's a fascinating subject, easy to talk about, but takes much hard work and vision to be used effectively.

Unless handled carefully, AIDS will have marginal first success, and thus retard its successful future in the airline industry. The twelve steps leading to successful implementation of airborne recording require strong technical participation and active management support to insure success.

The applications study is the most important step since it provides the raw material for the economic study and also defines the scope of the project. The major application of airborne recording, other than safety, relates to aircraft engines, since this represents a high cost area where maintenance support decisions have a strong, direct influence on the resultant costs. The applications study must include a joint airline, engine manufacturer, airframe manufacturer effort to determine the most desirable parameters necessary to diagnose engine problems or establish significant trends. A proper balance of quantity and quality of engine parameters measured must be achieved to describe the most efficient system. This type of analysis was accomplished to develop the parameter list previously mentioned and shown in Table 1. The applications study must be expanded to consider other uses for the AIDS system. However, the first application of AIDS should be directed at two major areas—engine support and operation performance as it relates to pilot control of the aircraft—with capacity built into the system to later add monitoring of hydraulics, pneumatics, life support systems, etc., which the applications study has shown to be of value. Implementing AIDS and then extending it in steps will avoid being overwhelmed with data and, as a result, becoming discouraged or confused, which will in the long run actually retard or even defeat the program.

The second major application of AIDS mentioned above relates to operational performance and requires clarification since it is not as obvious as engine diagnostics. This subject and the related economics are treated in detail in Ref 1. A portion of that discussion is included here to define the operation performance application. In this application, operational performance relates to pilot control of the aircraft. "There can be variations in operational performance which have both significant safety and economic impact on the airline operation. Improved control of these characteristics offers impressive cost reductions. For example, the data can be used to support the flight crew in maintaining a safe operation. Airborne recording raises the effective level of check flights from about 0.6% to very nearly 100%. This will aid pilots in minimizing unintentional habits which may tend to degrade quality of the flight. Secondly, the specific need for training can be identified and tailored to fit each pilot."

The next step of implementation, economic study and preparation of a funding document for company approval, will be based on cost of the required AIDS equipment compared to the applications benefits which will be available from the applications study. Preparation of an AIDS hardware specification is not difficult since it can be the specification of the vendor selected, revised to meet ARINC 573, if necessary, and also requirements of the using airline. However, the airline will find development of a software specification much more difficult, even if

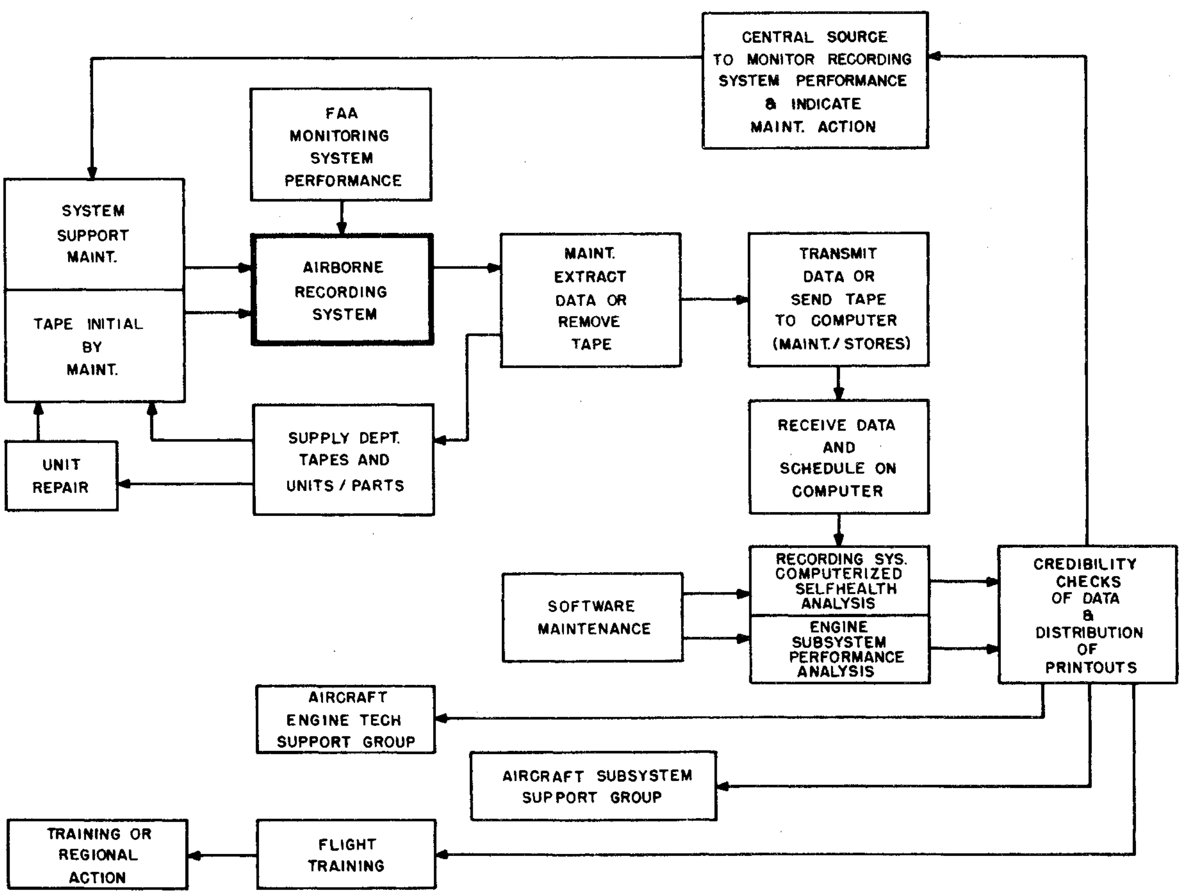

Fig. 2 Data acquisition and application.

completely prepared by the vendor. The best software specification is one which has been prepared with careful understanding of the project objectives, but recognizing the need for 20% refinement after the first hardware has been activated and with appropriate allowances in the schedule for these necessary changes. The following lists some important considerations which should be observed in preparation of the software:

1) Programs should be modular in construction. Each parameter's credibility testing, threshold testing, and conversion to Engineering Units should be separate and distinct insofar as practical. Where parameter dependencies exist, the results of previous tests should be made available to subsequent parameter testing as a consequential but independent result.

2) All programs should reflect uniform and consistent results. A single set of tables, conversion routines, etc., should be maintained for use by all programs requiring them. Ideally, they would be dynamically invocable.

3) All tables or other variables should be designed for ease and accuracy of change. Especially at the outset of a new program, it will be desirable to change some limits applied to a given set of data. This is particularly helpful when sufficient data has accumulated to verify theoretical parameter boundaries.

4) In the interest of conserving computer time, the data should be processed in "raw counts" until it becomes necessary to convert to engineering units for output display.

5) Comment cards should be used generously. Every module or routine should contain sufficient comment cards to concisely describe what happens in the routine. The cards should be religiously kept up to date since tentative program changes will be made long before flow charts, etc., are updated if, indeed, they are not forgotten.

Planning in the development of hardware and software maintenance support procedures requires more than the usual attention for electronics or computer software support. First of all, AIDS will not be a dispatch requirement for aircraft safe flight. This means that the maintenance support priority will be inherently lower and require closer monitoring to assure thorough maintenance support. Secondly, system reliability is the summation of the AIDS hardware reliability plus that of all the other aircraft systems from which the recording system receives data, and this may be 35 or more input systems. It will be rare if the total system on a given airplane is completely operative at any one time. The maintenance program must recognize and accept this as normal, but at the same time, minimize the degree of system failure. All modern airborne recording systems include Built In Test Equipment (BITE), which monitors 60 to 85% of the circuitry exclusive of input signal sources. Unlike an autopilot or radar, for example, there is little to indicate system failures in the airborne recording system other than BITE. It is this characteristic that dictates the need for a different approach to AIDS maintenance. This technique will be called system health, and means that system condition will be determined by computer analysis of the data recorded in the airborne hardware. More will be said of system health later. It is sufficient to say here that the system health analysis is used to dictate day-to-day maintenance requirements, and that through a developed organization, which is a function of the airline's particular maintenance support structure, the total AIDS support must be centrally controlled. An airborne recording plan for a large fleet must consider that the computer software is a dynamic program requiring more than the customary software maintenance. Implementation should include an annual budgetary allowance of approximately $30,000 to maintain the software. These required changes result partly from new engine maintenance policies or support techniques, experience with engines, modification programs, aircraft operational performance changes, and partially from application of AIDS to support new aircraft subsystems as the need is recognized.

A detailed program for application of the recorded data was indicated as a major implementation step. One might assume that if data is collected, the uses will become obvious from the applications study, and possibly this is true, but it will not be done unless a detailed program is developed and accepted by all affected departments. This is generally true for any project, but is more significant for application of an airborne recording system because so many departments within an airline are involved, as illustrated in Fig. 2.

Another stumbling block in the implementation of AIDS can be the installation, certification, and debugging process. If the system is added after the airplane has been built, 1000 to 2000 man-hours may be involved, depending on system complexity, with an out-of-service time of four to eight days. Certification is not difficult, provided ARINC 573 electrical isolation specifications have been followed, but debugging of the installed system and the related computer software is very difficult. Every major installation to this date has exceeded the airline's schedule to achieve a fully operational recording system with functional software to meet the application's intent. The schedule for implementation should recognize that up to 12 months may be required before the hardware and software will be fully operational, and then a continuous process of software refinement and hardware applications must begin to achieve the most cost effective use of this tool. Careful planning and detailed attention to these 12 steps are necessary to assure a successful airborne recording and applications project.

Major Areas of Application

There are two primary viewpoints on the most significant application of an automated airborne data acquisition system; one is purely safety, and the other is safety and economy. There is general agreement that a certain amount of data is desirable for accident investigation. Beyond this point, one view concludes that additional recorded data may expedite an accident investigation and, at the same time, reduce the cost of investigation from figures in the order of $300,000 to $75,000. The other viewpoint indicates that any recorded data beyond that necessary to establish flight path, indicate aircraft primary control performance and engine thrust, should be of economic benefit. This cost effective expansion of the basic system should be directed at one or more of four major areas: 1) engine management, 2) operational performance as it relates to pilot control of the aircraft, 3) fuel management, and 4) other aircraft subsystems.

The application of airborne observed data has been a significant tool in the management of aircraft engines for many years, and computerized techniques have further extended the effectiveness of this procedure. Within the last three years, improvements in engine design to further utilize the modular concept of assembly have opened a new area for extension of engine management effectiveness. Through strategic location of additional temperature and pressure sensors along the gas flow path, it is possible to more precisely identify defective engine modules and direct maintenance to a particular area. As engine designs become more maintenance oriented in the future, a system of automated in-flight data collection will become much more attractive.

The next most significant area of application relates to operational performance, which was defined in the discussion on requirements for AIDS implementation. This is one of the most difficult applications because of the "big brother is watching" connotation which can offend some pilots. It is true that this application monitors how the airplane is being controlled, just as FAA check pilots periodically monitor each pilot. However, it can be done with adequate safeguards to protect flight crews. The purpose should be to aid pilots in minimizing development of unintentional habits which may tend to degrade quality of flight, and secondly, to assist in tailoring recurrent training to the specific needs of each pilot. There must be no intent to use this data to penalize a crew member, but merely to help him become a better pilot. This purpose should be clearly understood, with a well-defined, written agreement prepared jointly by Government agencies, the pilot organization, and the airline. The third major area of application of airborne recorded data combines some of the engine data with aircraft performance data to evaluate fuel consumption and provide a tool for improved fuel management. The fourth area concerns expansion of the recording system to include certain aircraft subsystems. There are dynamic airborne conditions which cannot be simulated on the ground under normal airline conditions, where airborne data are valuable in analyzing system faults. As discussed before, BITE can be used, but its value remains to be truly proven in wide-scale application. In considering the future of AIDS with the airlines, it is reasonable to conclude that as far as subsystems such as hydraulics or autopilots are concerned, the major application of airborne recording will occur when the system has been designed to utilize AIDS. That is, the subsystem has been developed to include adequate sensors located to permit isolation of faults to a removable unit more efficiently than could be done by alternate methods.

Costs of Airborne Recording

The 1972 economics are not significantly different from that of 1970, which was discussed in detail in Ref 1. Hardware costs are down about 5%, but the cost to install a system and prepare computer software has increased to the extent that the total required investment remains about the same, or possibly 2 to 5% higher. Hardware, installation, test equipment, spares, programming, etc., total about $135,000 per airplane depending on system complexity and wiring provisions installed during assembly of the airframe. The major elements of annual recurring costs include airborne system maintenance and overhaul, technical application of data, software maintenance and computer data processing costs. These recurring costs amount to $514,000 annually for a fleet of 16 airplanes. For the same size fleet, the initial investment to install a system capable of recording the parameters listed in Table 1 is about $300,000, including ground support. These figures include requirements to meet FAA regulations for an expanded crash recorder.

Economic Benefits of Airborne Recording

This high initial investment presents a major obstacle that most airlines have been unable to overcome. There are two basic reasons for this difficulty. First, extensive airborne recording is still pioneer territory and the savings are largely theoretical. There are no large fleet installations to substantiate the potential economic value of Aircraft Integrated Data Systems. Secondly, the economic climate in the airline industry for the past two years has very nearly eliminated funds available for developmental projects other than those associated with safety or short-term cost effectiveness. In evaluating financial benefits, the areas relating to engines, performance, and fuel offer the greatest potential. Engine potential payback includes: 1) extension of the modular maintenance concept, 2) early detection of impending faults, 3) reduction in consequential damage, 4) reduction in catastrophic damage, 5) improved management of engine removals, 6) flight interruption avoidance, 7) more efficient inspection procedures, 8) rapid evaluation of cost effectiveness of modification programs, 9) reduction in spares inventory, 10) minimized engine ground runups, and 11) extended useful life of the engine. Performance and fuel management economic considerations include: 1) more efficient use of simulator, 2) reduced actual aircraft expense for flight training, 3) less hours required for crew training, 4) eliminate all training where exceptional proficiency is demonstrated, 5) assure that flight planning achieves maximum fuel efficiency, and 6) assure that aircraft performance achieves maximum fuel efficiency Although these areas offer a potential annual cost reduction in the order of $2,500,000 for a fleet of 16 airplanes, the actual figures are, to a large extent, theoretical and acceptance is difficult to achieve.

The electronic industry can help in overcoming this obstacle. As a general rule, AIDS manufacturers have offered hardware to perform a theoretical need, and it has been up to the customer to justify the investment. Since airborne recording represents an unusually large first cost, the electronic industry could participate in the justification. In addition, the strain of initial investment could be eased through deferred payment based on actual payback achieved. As an alternative, the electronics vendor could develop a hardware system with the required computerized diagnostic programs, retain ownership and lease the package to an airline. Innovative thinking in the electronic industry could advance the airborne recording program two years or more.

Automated Testing of AIDS

Built-in test circuits will be included in any recording system to aid in maintaining the airborne hardware. However, there is an additional capability inherent to the system which should be utilized. The technique which takes advantage of this capability is generally called System Health, or Self Health Analysis. It is a method whereby the data produced by the recording system is computer analyzed to determine serviceability of the system itself and then produces a printed report of hardware condition.

System health consists of a computer program which evaluates data performance and applies the results of this analysis to a logic tree where through a process of elimination the probable location of each fault is determined. A series of computer tests are defined for each parameter recorded to determine its validity. The type of test used is determined by the parameter signal characteristics. Fixed high and low signal limits may be used to evaluate some parameters. These limits for a given parameter are varied as a function of aircraft flight mode, recording mode if pertinent, or other related parameters. For example, in the takeoff recording mode, with the aircraft airborne, a particular set of fuel flow limits may be applied which will be different from the cruise mode limits. Similar logic exists for other parameters from that same engine. If only one parameter is out of limits, the fault generally lies within the instrumentation. If two or more parameters from that same engine are out of limits, the problem generally is within the engine. Another check for invalid numbers used in conjunction with the above check is to compare like signals from different engines, but which are processed through the same electronic circuits, and then apply the results to a logic tree.

Aircraft performance data is much more difficult to evaluate since parameters are not generally duplicated as they are between engines. There are some credibility checks which can be made. Logic can be written for two conditions which cannot exist at the same time. For example, constant altitude and a sustained increase in vertical speed. Fixed limit checks may be used to confirm performance faults in the recording system, but not necessarily to recognize the existence of a fault. A bank angle within the fixed limits, but whose rate of change is impossible for continued normal flight, obviously indicates a recording system fault. A combination of fixed and dynamic limit checks for a given set of performance modes or engine conditions will generally identify 90% of the recording system faults. Application of this analysis to a logic tree will pinpoint the fault to a specific electronic box or signal source in most cases.

Following this method, it is possible to automate 95% of the recording system analysis for maintenance support. The system health technique does assume availability of sufficient data to perform an analysis and repeat the analysis for validity. This means that any onboard data compression or data elimination techniques applied must still make available adequate information for system health analysis. The analysis should also be located at the beginning of the computer program so that erroneous data can be identified and discarded early in the process to conserve computer time. It should, of course, be acknowledged that the system health method is not a cure-all, and there will always be those cases that require on-site troubleshooting to correct difficult system problems.

Spin-Off Benefits of AIDS

Unanticipated benefits already have been realized from the flying airborne recording systems, and other benefits will undoubtedly occur. Probably one of the most significant was the early experience with digital circuits regarding voltage levels, noise and transient voltage suppression required in the recording systems. This information was useful in preparing industry standards for other systems using digital circuitry. The industry standard characteristic for digital air data systems, for example, utilized this experience. As a secondary benefit, AIDS has been used to evaluate performance of instrumentation on new airplanes and proposed multimillion dollar engine modifications before the investment was committed. One additional satisfying contribution of airborne recording relates to analysis of crew performance. In almost every case, these studies have shown that pilots manage airplanes in a highly professional manner consistent with requirements of the moment. There are other spin-off benefits of airborne recording which could be cited, and others will be experienced. However, these will illustrate the incidental contribution of AIDS, in addition to its prime function, and also support the contention that ultimately, AIDS will be a common tool of the larger airlines.

Conclusions

In recent years, airborne recording systems for commercial airlines have become a reality. Both quality and quantity of data can be reliably recorded to meet the particular needs of any airline. Using a building block concept and the industry standard specification, ARINC 573, a system can be tailored to an airline functional specification and still maintain a high level of interchangeability between airlines. Implementation is quite involved. It requires exceptionally good planning and coordination both within the company and with outside agencies. The initial investment is high, but the potential savings will make it difficult to ignore this new tool. As aircraft engines and subsystems become more expensive, and pilot training costs rise, there is good reason to believe this new system will offer the most effective solution to a number of problems faced by commercial aviation. The ultimate achievement of AIDS will be to schedule the needed part and right skill to correct problems in the more complex aircraft systems before the airplane reaches the airport.

Reference

[1] Wise, F. D., "AIDS - Benefits and Costs to Users - Why Use It," *Instrument Society of America,* Vol. 16, May 1970, pp. 164–169.