EVOLUTION OF THE DOUGLAS FLIGHT-TEST DATA SYSTEM

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Summary. The process of developing new techniques and systems for the purpose of flight-test data acquisition, communication, and processing is, in fact, an evolutionary one. It is filled with potential mutations formed when an orderly or direct path is not taken in any of supporting disciplines or when the capabilities of one link greatly exceed those of another.

The rigid design philosophy that made the Douglas system so successful in support of numerous test programs has had both a negative and positive effect of limiting, or at least slowing, the future growth in flexibility. Upgrading the system with new hardware and software must be accomplished in a manner that does not degrade the existing performance and throughput capabilities while making room for the new species to evolve.

Problems have been minimized by placing the development of the acquisition and processing systems under common management and, in turn, having this group accountable to the project users of the system. Constant feedback between system developers and users has ensured a degree of adaptability to the hostile environment of test program costs and schedules.

Introduction. The Douglas Flight-Test Data System was designed to provide a new approach to data acquisition, communications, and processing. In order to ensure success for the DC-10 program, these three elements were developed and integrated simultaneously to obtain maximum compatibility. The resulting system has performed very well and according to design specifications. It has been successfully utilized in the development and certification of the DC-10 (Series 10, 30, and 40), DC-9 and DC-8 commercial aircraft, the A-4N military development and demonstration programs and many miscellaneous laboratory programs, including seat ejection development tests.

Since its initial implementation in 1970 the most challenging efforts have been in developing and/or accepting inputs from new acquisition systems with formats different from the original and in interfacing these sources to the communications and data processing system. During this process, the ground station hardware has not changed significantly, but the software has been continually expanded.

In addition to the new input sources, the next most challenging effort is in terms of increasing the level of data processing. This involves improvements in real-time and post-test data analysis capability by combining the basic data processing task with special analysis programs and interactive computer graphics. The goal of adaptability/flexibility is being met by tempering the requirements for improvements with the data throughput sufficient for a multiproject operation.

Airborne Data Acquisition

Baseline Digital Data System (DDS). The baseline airborne data acquisition system was procured in 1968 and 10 of these systems are in use today. The system, shown in Fig. 1, uses PCM encoding techniques and contains 400 data channels, 90 channels recorded at prime sampling rates, 290 channels recorded at a 10:1 subcom rate, and 20 channels at 20:1 subcom rate. The prime and subcom allocations are made up of 320 analog, 60 digital, and 20 frequency input channels. The prime channel sampling rate can be controlled in flight from 400 to 10 samples-per-second in six stages.

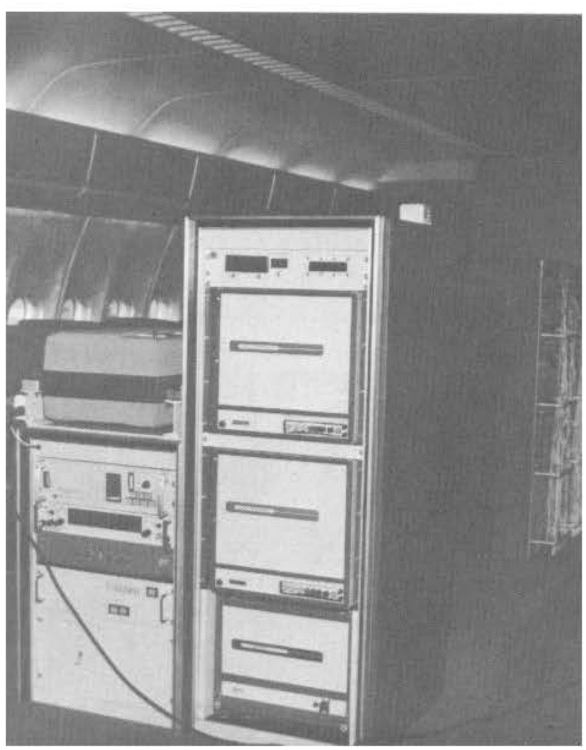

FIGURE 1. 400 CHANNEL DATA SYSTEM - DDS

Test information is resolved into a 10-bit data word for a ±511-count range. The maximum data stream rate is 500,000 bits-per-second. Recording is in Manchester I code (serial) with a maximum tape packing density of 8333 bits-per-inch. Telemetry transmission uses NRZ-M code. An IRIG time code generator is integrated into the system to provide system clock, remote time displays for the flight-test engineer, clocking pulses to drive auxiliary equipment, group binary time in the data stream, and serial BCD time with a 1-KHz carrier on a separate tape search track.

The system is given wide flexibility for recording instrumentation inputs through the use of a signal conditioning subsystem. This subsystem consists of an identical processing network for 320 analog input channels packaged in two 160-channel modules. Each one provides amplification (gain), zero adjustment, active filtering, common mode isolation, shunt calibration, and standard instrumentation excitation power distribution. All elements except amplifiers may be bypassed if desired. Transducer bridge, thermocouple, or other electrical signal inputs of 5 millivolts to 30 volts full-scale can be accepted on any of these universal analog channels. In addition, the system will accept pure parallel digital inputs on both prime and subcom channels.

The 14-track tape recorder has 2 MHz bandwidth response at a tape speed of 120 inches-per-second. It operates at any one of six run speeds to match the selected digital data sampling rates. Data are recorded on one track of magnetic tape which is 1 inch wide, 9200 feet long, and carried on a 14-inch reel. Other tracks on the magnetic tape are used to record IRIG B time and FM data.

New Airborne Equipment. Several changes and additions have been made to the airborne data acquisition equipment. All of these changes have retained overall compatibility with the existing communication and ground station systems.

(1) Mini Digital Data System (MDDS) - Uses the same format as the baseline 400-channel data system. This version has 125 channels all of which are prime. The MDDS (see Fig. 2) is physically smaller and is designed for quicker installation for large aircraft where fewer parameters are required and for small aircraft such as the A-4 series where it fits into an external instrumentation store.

(2) Asychronous Buffer System (ABS) - Many data requirements for today’s complex avionics systems require the acquisition of signals from airborne computers that output a serial data stream which is asychronous to the basic test data system. In order to capture these data and utilize the existing ground station hardware and software, the ABS system was designed to accept these high-burst rate signals, then buffer, reformat, and clock these data into a compatible data stream.

(3) Hybrid Thick Film Micro Circuitry - The advent of the new film technology has made possible the updating of test equipment to improve reliability, decrease power requirements and reduce the size and weight of equipment. Douglas has been very active in this area and has done in-house design, development and fabrication of several

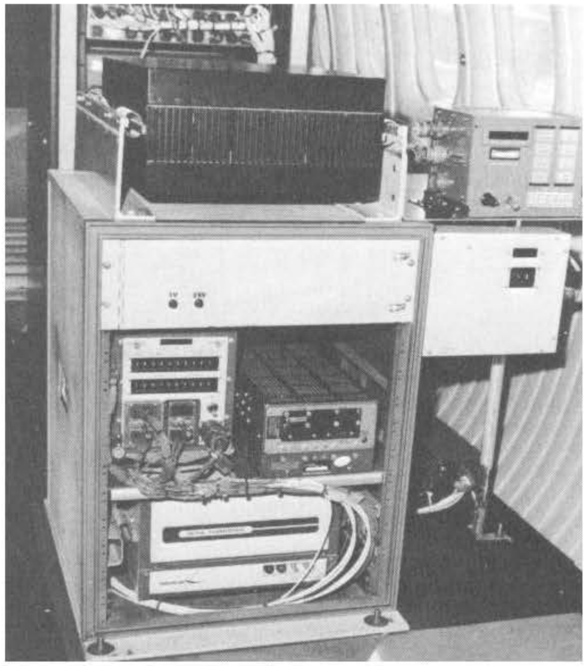

FIGURE 2. 125 CHANNEL DATA SYSTEM - MDDS

components including signal conditioning amplifiers, time code generators and special signal conditioning units for discrete measurements. A comparison of a discrete component version of a signal conditioning card with a thick-film, microcircuit version containing variable gain-step amplification, zero adjustment, active filtering, common-mode isolation, shunt calibration and excitation power is shown in Fig. 3.

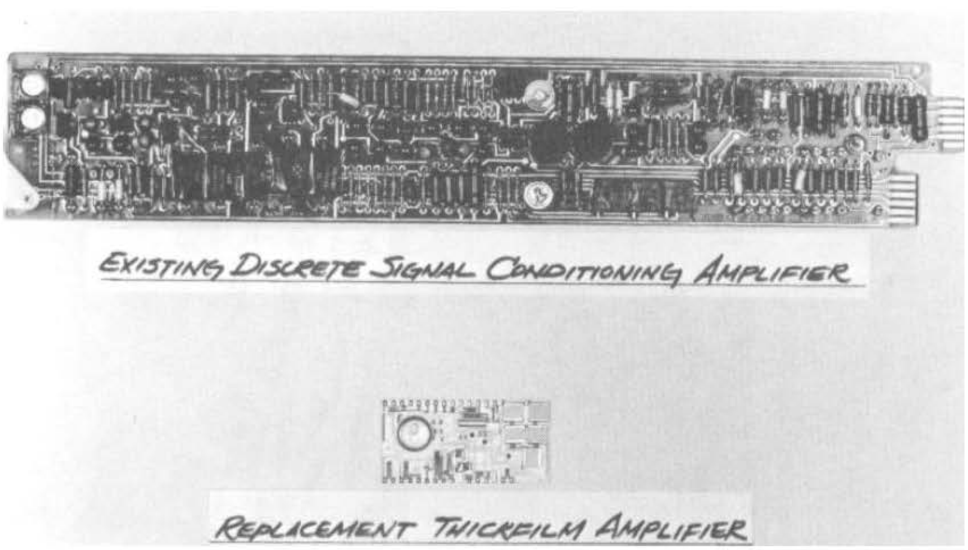

FIGURE 3. SIGNAL CONDITIONING AMPLIFIERS

Future Airborne System Plans. Airborne data acquisition systems will continue to evolve as new requirements arise and technology permits. Douglas is active in the design/development cycle or in the procurement phase of many new systems associated with acquisition and recording. Among these are the following:

(1) Digital Subcom Unit (DSU) - When the original DDS was designed, fixed limits were set as to how many analog and digital parameters, both prime and subcom, could be input to each system and exactly where these signals would be sampled in the PCM frame. Parameter types were grouped together in blocks of channels such as digital subcom, analog subcom, analog prime, and digital prime. The great majority of these channels were reserved for analog inputs. The digital inputs were reserved for a few digital transducers, encoders, counters, and discretes. New avionics equipment, however, abounds with bi-level discretes that indicate modes of operation. In order to handle additional discretes or parallel digital inputs the new DSU currently in development will replace prime digital channels with subcom channels. This will be done in module of 3 prime or 30 subcom. channels. Since each channel contains 10 bits a subtotal of 300 bi-level discretes will be handled by each DSU. Up to three DSUs may be added for a total of up to 900 discretes.

(2) Digital Add- on Unit (DAU) - Like the DSU above the DAU will extend the capability of the basic DDS to handle more digital inputs. The DAU will permit serial or parallel digital channels to replace analog channel in the serial data stream. This will be accomplished external to the existing system by clocking the replacement data into the serial word string at the proper location. Both prime and subcom positions may be used. The DAU will incorporate features similar to the ABS previously discussed in that it will merge serial asychronous burst data with standard parallel inputs.

(3) Remote Multiplexor Data System (RMDS) - One of the more significant costs of instrumenting an aircraft such as the DC-10 with its multitude of parameters and physical size, is in the stringing of wire from the end item transducers to the data acquisition system (see Figs. 4 and 5). The cost of material and labor for installation prior to first flight and for the refurbishment after the last test flight of an aircraft provides a strong incentive for the implementation of a new type of data acquisition system. The RMDS which is in the procurement phase is ideal for this application since it allows for many smaller remote multiplexor units (RMU) to be located at strategic points in the aircraft rather than a single centralized location. These acquisition units are tied to a “mother” data management unit (DMU) which merges all remote units into a serial data stream for recording and/or transmission (see Fig. 6). It is estimated that a forthcoming DC-10 test program will use only 24,000 feet of wiring using the multiplexor system as compared to 205,000 feet (40 miles) if the DDS were used. A direct savings of 3900 man-hours for installation, $55,000 in wire costs and a 7000-pound reduction in weight will be realized. These savings do not include the reduction in refurbishment costs.

FIGURE 4. WIRING BUNDLES - DC-10 CARGO BAY

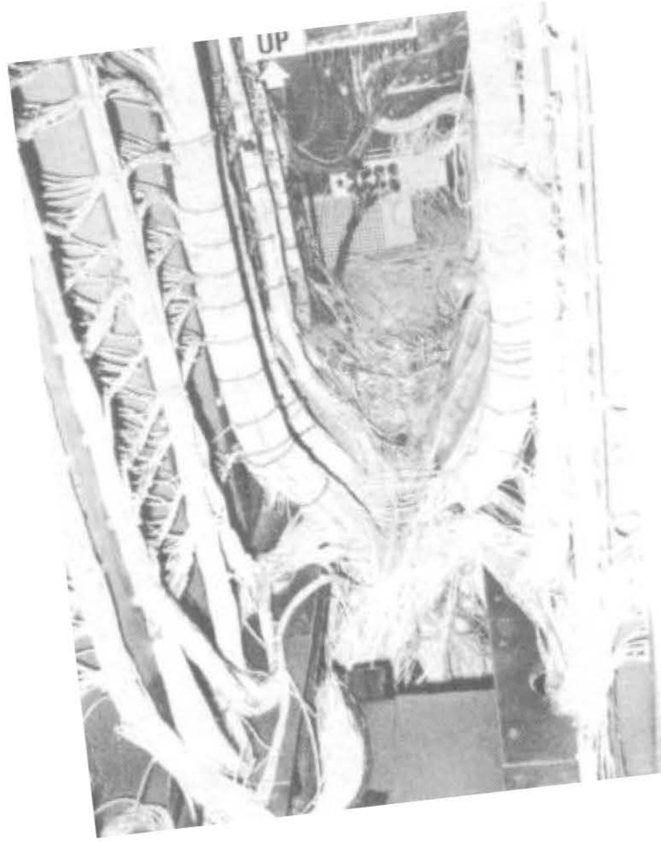

FIGURE 5. WIRING BUNDLES - DC-10 PATCH PANEL BAYS

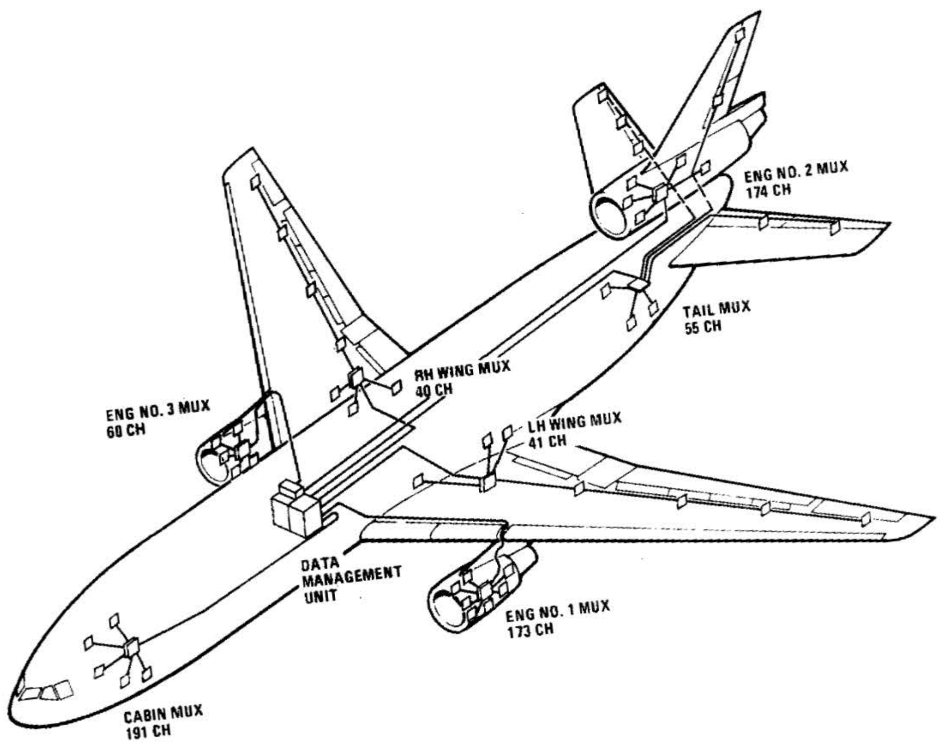

FIGURE 6. REMOTE MULTIPLEXER DATA SYSTEM INSTALLATION

In addition to its appeal to management as a cost savings technique, the RMDS will give the instrumentation engineer a much greater capability in data acquisition. One of the main features of the RMDS is its flexibility in terms of parameter inputs and sampling rates. Where the present DDS uses fixed prime/subcom and analog/digital channel assignments, the RMDS does not. The instrumentation engineer may mix parameters in a variety of ways. He may have several different subcommutation ratesand may supercommutate as well (all of which are unavailable in the existing DDS system). He may add or subtract remote MUX units and vary the length of the major and minor frames.

However, all of this flexibility has its price. Operational procedures will become more complex. With the fixed-format DDS system there is no confusion about the DDS configuration of today's flight relative to yesterday's or two years' previous. Channel 360 is, was and will be an analog prime channel, regardless of what aircraft it appears on or at what point in time it occurs. Not so with the RMDS. (Some modification to this simplification may occur with the use of the add-on units previously described.) Greater control and coordination must be evolved to monitor and communicate system changes such that data processing is not unduly complicated or data throughput reduced. As such Douglas will initially use the RMDS in a fashion similar to the present DDS. As operational procedures and data processing capabilities permit, the system will be given more and more freedom of format.

Since the RMUs are independent data systems they may be used standalone without the DMU for lessor applications. The DMU is actually a mini-computer and some of the excess bandwidth will probably be used to enhance on-board processing and display of test parameters.

(4) Hybrid Thin-Film Microcircuitry - Douglas is actively pursuing the development of thin-film microcircuit technology. Although still in the development stage, these techniques will play a big part in the future of instrumentation components. Applications at Douglas are beginning with the utilization of these techniques for a PCM decommutation unit to provide on-board display of test data directly from the serial data stream of DDS or RMDS units.

Data Transmission/Communications

Baseline Telemetry/Microwave Link. Developed and procured at the same time as the airborne acquisition systems the baseline telemetry and microwave link provides real-time data and voice communications for Douglas flight-test operations in Southern California. The telemetry section originally utilized dual, 10-watt, L-band transmitters in the aircraft operating on different frequencies in the 1435 to 1485 MHz band. An automated ground tracking antenna is located atop 8400-foot Frost Peak (42 air miles from Long Beach) and provides a test radius of up to 250 miles at 30,000-foot altitude. The mountain-top facility uses four receivers for frequency and polarity diversity monitoring of signals to minimize signal dropout during aircraft maneuvering. The entire data stream and IRIG time of day is received and relayed to Long Beach via a single-leg microwave link. In addition to the 500-KHz data stream the microwave link provides active radio communication on several bands between test aircraft and the Long Beach facility. Automatic microwave fault isolation monitoring is also carried on the link.

New Facilities and Capabilities. The following improvements have been made in the T/M microwave link:

(1) Telemetry Transmission - One of the earliest updates to the telemetry section was to improve the reliability and bandwidth capabilities of the airborne transmitter. Twenty-watt transmitters have replaced the 10-watt units and have improved the overall operation considerably.

(2) Yuma Remote Terminal - Shortly after the start of the DC-10 test program the bulk of the test operation was moved to Yuma, Arizona which is 190 air miles from Long Beach. Initially test flights from this facility were monitored with telemetry from the Frost Peak antenna only after the aircraft had reached an altitude of 20,000 feet. Today the operation is quite different. The Yuma facility has its own telemetry tracking system and is connected to Long Beach via a 5-leg microwave link. Test operation range from Long Beach is greatly extended (see Fig. 7) and now covers airspace from above Fresno, California into Baja, California where the Mexican government has given permission to operate.

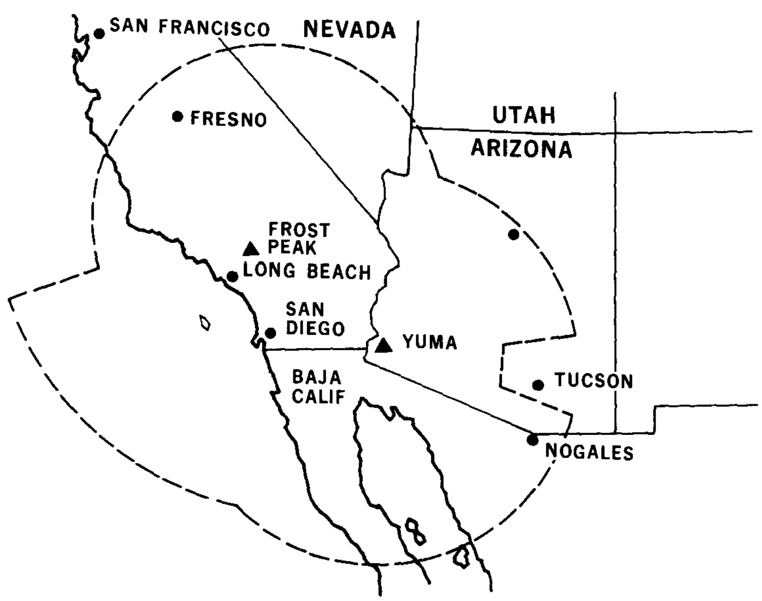

FIGURE 7. TELEMETRY/MICROWAVE COVERAGE - AIRCRAFT AT 30,000 FT

(3) Data Dump - Operating from Yuma necessitated an improvement in the transportation of high-priority airborne recorded tapes to the Long Beach facility. Instead of waiting for air or ground shipment of these tapes they are now dumped via the microwave link to Long Beach and duplicated on similar tape equipment. Playback rates of up to 1 MHz are used to expedite this transmittal providing a speedup of 2 to 64 times the real-time record rate.

(4) Closed-Circuit TV - The Yuma microwave link provides 24 channels of telephone lines in addition to the data transmittal. The adage "a picture is worth 1024 words" justifies the newest use of this link in support of a closed-circuit TV system. Management and engineering personnel at Long Beach and their counterparts at Yuma now communicate (pre- and post-flight meetings, etc.) from conference rooms and offices equipped with camera and monitors.

(5) Laser Modem - Although not a basic part of the Flight-Test Data System the Mobile Laser Tracking System must communicate with the Long Beach facility to expedite data processing. This is accomplished by transmitting the laser data via a dual modem and the microwave link to the Long Beach facility. The microwave link eliminates many problems associated with commercial telephone networks.

Future Expansion. Since communication of information expedites decision making, new developments are always required to narrow the time gap from acquisition to analysis. Some of these are listed below:

(1) Laser Computer Uplink - As previously mentioned the laser tracking data are currently transmitted to Long Beach via modem. These are raw polar coordinate data and must then be processed into x, y, z space positioning data and merged with the appropriate measured aircraft data. The newest laser system will incorporate a computer in the laser van to process the raw data in a format which is directly usable. In order to eliminate the need for a post-flight merge of the laser and aircraft data, it is currently planned to uplink the laser data to the aircraft and merge into the DDS data stream for recording and/or transmittal to the ground data processing facility via the microwave link. In addition this uplink permits the installation of flight guidance data displays for the flight crew.

(2) CRT Image Transmission - Remote test sites such as Yuma require feedback of data for test planning purposes. Since all data processing is accomplished at Long Beach a means of relaying this information must be developed. Current plans include the installation of equipment to scan and transmit CRT display images and transmit these to Yuma in video format via the microwave link for display on a high-resolution TV monitor and/or hardcopy output unit. With the use of a TV camera this system will be used for high-speed facsimile transmission of images from any source such as listings, sketches, photographs, etc.

(3) Acoustic Data Transmission - With the emphasis on noise abatement, more testing than ever before is being done in this field and the testing is done again at remote locations. The Douglas installation at Yuma has extensive facilities to measure and record acoustic noise levels. Current operation requires these FM recorded data to be sent to Long Beach for the process of performing 1/3-octave-band filtering, digitizing, and processing to obtain standardized perceived noise levels. In order to expedite this procedure and provide improved field monitoring and test direction, some of the noise data processing will be accomplished at Yuma in real time and transmitted via the microwave link for final data reduction in Long Beach. This approach simplifies and expedites the merging of the aircraft and space positioning data (from the laser uplink) with the noise measurements.

Test Monitor and Data Processing

Baseline Flight Control and Data Center. The Flight Control and Data Center serves as both a data reduction center and a flight control monitor station for flight-test aircraft. It provides the equipment and environment to allow multiple-test vehicle data processing and monitoring of test data, both in graphical and tabular forms, with strip chart backup for redundancy independent of the computer. To accomplish these objectives, the approach diagrammed in Fig. 8 was provided. The data processing consists of handling the multiple, high-rate input data, making engineering unit displays of selected test data, and obtaining hardcopy and/or high-quality microfilm outputs of the finished display. Fig. 9 and 10 are views of the data center.

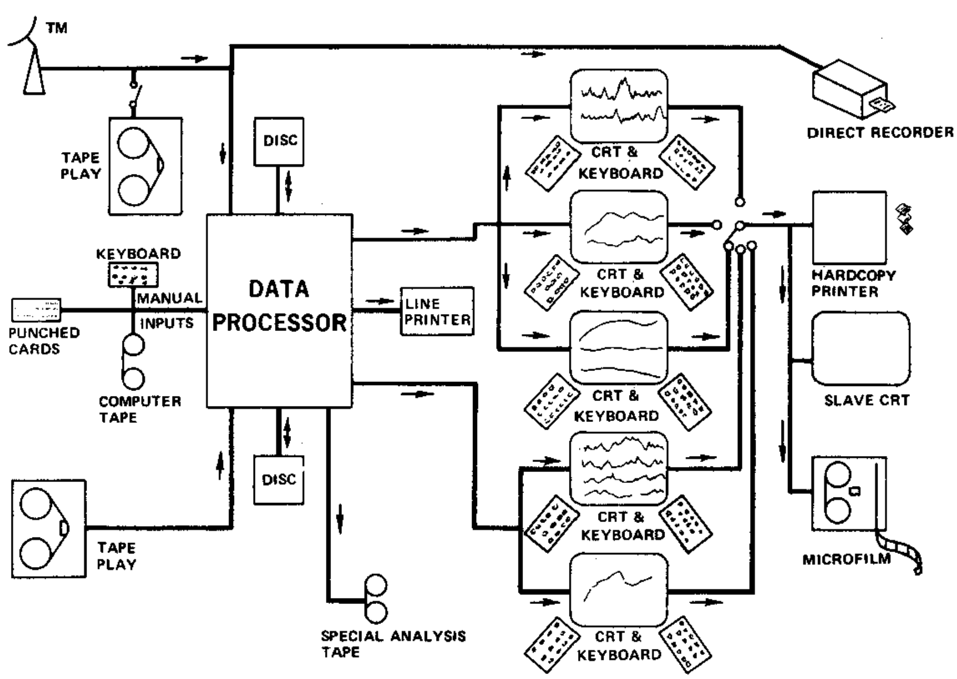

FIGURE 8. DATA PROCESSING SYSTEM - OPERATIONAL SCHEMATIC

FIGURE 9. FLIGHT CONTROL AND DATA CENTER

FIGURE 10. CRT GRAPHIC DISPLAYS

The heart of the Flight Control and Data Center is a Sigma 7 computer with 131K words of memory. The computer receives test information either from the telemetry microwave link or from the tape recorded onboard for post-flight analysis, converts the raw data to engineering units, and displays the results in corrected time history or tabular form on CRTs. Through a special-function keyboard designed specifically for flight development, and a standard alphanumeric keyboard, a CRT operator (a flight-test engineer) is able to call for any parameter over any time span. Through these keyboards and a light pen, the operator is capable of adding, deleting, or replacing parameters, changing scales in both the X and Y axis, adding notes or titles, and producing on the CRT a final annotated engineering-unit tabulation, or time-history plot. This can be accomplished during the flight or after the flight. When the operator is satisfied with the results, he can make a hardcopy or microfilm copy, or both, by actuating a key on the special function keyboard. The hardcopy is available in approximately 10 seconds.

The ground system includes five active CRTs, each completely independent of the others, a large random-access disc file used primarily for temporary raw-data storage, and two PCM decommutators which permit post-flight analysis on two separate flights or a combination of post-flight analysis in conjunction with real-time flight monitoring. For easy access and fast data processing, all calibrations for all channels and all flights for each of the test aircraft are also stored on the random-access disc. A standard line printer and a 1/2-inch magnetic tape output are also available for analysis and for standard batch programs not requiring the graphic display output. The data center also includes a complete communications system, operating through the microwave relay station, that permits direct aircraft communications for the flight director and/or the individual CRT users.

Modifications to Date - Hardware. Few changes have been made in the ground station hardware since, for the most part, the operation has been satisfactory and the system and personnel have been too busy to afford the opportunity for change. Areas that have been modified include:

(1) Hardcopy/Microfilm - The one area of the data system which has been less than satisfactory has been in the reproduction of CRT displays. The hardcopy and microfilm units have required more maintenance than any of the units in the system. Accordingly, Douglas had to procure a second hardcopy unit for backup purposes and modify the camera installation in the microfilm unit to improve reliability and provide better status indications to the controlling software. Several vendor updates were made to the hardcopy units to improve the paper handling mechanism and dust removal from the optical section.

(2) Multiplexor/Digitizer (MD-40) - Since its inception the system as described in this paper has been limited to the processing of PCM data. Due to the high sampling rates of the airborne acquisition system it was possible to handle most test requirements in this manner except for vibration and acoustic information utilizing FM recording techniques. This type of data has been handled separately in an adjacent facility. As applications of the Data Center and the CRT displays have spread to other areas in flight and laboratory development so has the need for handling high-frequency data. Accordingly, the Data Center now contains sufficient FM electronics, a high-speed multiplexor and analog-to-

digital converter to enter these data into the Sigma 7 for processing and display in the same manner as PCM data.

(3) Flight Recorder Playback/Transcription Electronics - All commercial passenger-carrying aircraft carry some form of a flight recorder, measuring pertinent variables for the investigation of accidents or incidents. The newest versions of these systems are digital PCM and they acquire many more parameters than their predecessors. It requires special equipment to play back data from these recorders so it may be processed. Douglas has procured and installed sufficient equipment to handle this requirement for all configurations of recording systems currently in use on the DC-10 aircraft.

Modifications to Date - Software. A full-time staff of at least seven programmers has been involved with supporting the Flight Control and Data Center. Although some of these programmers have concentrated on batch analysis programs the greater percentage have dealt directly with system software maintenance and new capabilities. The major areas of new capabilities include:

(1) Normalize - In addition to the basic task of producing engineering unit time-history data in tabular, time-plot or cross-plot formats, the system can output another level of processed data. This capability is termed "Normalize" and is available via the CRT function keyboard either through the CRT operator or via the keyboard simulate mode. Basically, this mode allows the user to further process the engineering unit data through various equations or chains of equations to output calculated parameters. These equations permit combining the engineering unit output of one or more data channels along with appropriate constants to form a new output value. The normalize process is a powerful tool that permits on-line computation and display in time plot, cross plot, or tabulations of many values that would normally be processed in a batch mode with special analysis programs.

(2) Background Batch Capability - During the first two years of operation, batch programs could not be input when the system software was resident. All batch jobs had to be run on second or third work shifts or system operation had to be suspended while batch jobs were run on the first shift. Since that time, the concurrent foreground (system) and background (batch) operation has been implemented which greatly improves overall efficiency and data turnaround time.

(3) Variation of Input Data Formats - With the first deviation from the format or configuration of the baseline data acquisition system, software changes were required in two major areas: 1) those required to handle the unique format in the individual routines comprising data acquisition, file management and data selection and 2) those necessary to distinguish one configuration from another during system log-on (initialization procedure

for each user) such that the appropriate routines would be utilized. Changes were required for all input configurations where such parameters as frame sizes, sampling rates, subcom ratios, word size or negative number notation were changed or where the tape density (i.e., 8000 vs 16000 bits /inch), PCM code (i.e., BI-PHASE, NRZ, DM) were different from the baseline configuration.

Future System Improvements - Hardware. Except for core-size limitations within the computer, the system as it is currently configured, is adequate for its original goal of handling flight-test data monitoring and processing. However, efforts are currently underway to extend the interactive processing capability to areas in laboratory test and acoustic/vibration data processing support. Many of these tasks involve remote locations which will necessitate communications of both input and output data. Some of the planned improvements are:

(1) Digital Electrostatic Plotter - Certain test requirements necessitate output data formats that are either not compatible with CRT displays or would result in a waste of resources if CRTs were used. As such, Douglas is implementing a high-speed electrostatic printer/ plotter which will be interfaced to the Sigma 7 and will provide this alternative to data output.

(2) Interface to Other Data Sources - The acquisition and processing capabilities of the Flight-Test Data System have been used for a variety of applications for laboratory tests. For the most part these requirements have been fulfilled by using an airborne data system to acquire the data. Future uses will interface existing laboratory equipment directly to the Sigma 7 for processing and output to the CRTs or digital plotter.

(3) System Resource Allocation Console - The current method of assigning a data source to the system preprocessing equipment, computer, and output devices is too complicated, time consuming, and is subject to human errors. A new approach will be taken to consolidate all of these functions in a centralized resource allocation console, from which an electronic switching matrix and direct computer interface would be activated to set up the appropriate data path and equipment assignment.

(4) Hardcopy/Microfilm Unit Replacement - The existing hardcopy and microfilm output devices for CRT data are analog driven and utilize a small CRT and optical translation to produce an image on chemicallytreated paper. As previously mentioned, this equipment requires extensive maintenance and produces copies of marginal quality. Current plans at Douglas are to replace and/or augment these units with a device which improves quality, reduces maintenance and is suitable for use in remote locations via a digital link. Candidate systems for this replacement include the implementation of a high-speed, fine-

resolution, electrostatic printer/plotter with software required to convert the existing random CRT refresh commands to an ordered raster scan digital output.

It is disappointing to say the least, that the industry has not perfected a means of producing high-quality hardcopies of CRT display images that may be produced quickly and inexpensively. The continued development and utilization of CRT displays and interfacing equipment seems to have left a void in this area.

(5) Basic Computer Update - The existing Sigma 7 computer is fully expanded with 131K words of core memory and all six memory ports are in use. In addition, the batch processing monitor can only accommodate one batch job concurrent with the foreground operation. With the increase in I10 required to handle new data sources, as discussed above, and increasing number and size of batch jobs, it will be necessary to update the Sigma 7 with a Sigma 9 or equivalent. The final system must be Sigma compatible as far as software is concerned and must permit additional core, ports, and virtual memory features.

Future System Improvements - Software. The requirements for software updates is an ongoing one that is involved with most improvements to the acquisition and processing hardware discussed previously. In addition, two major areas of software development will be accomplished in the near future:

(1) Analysis Program - The existing interactive CRT data processing permits real-time, intermaneuver and post-flight display of data in graphical or tabular format. Displayed data may be simply converted to engineering units or may involve the use of a series of equations to output special computer values. In order to provide a more powerful analysis and interactive graphics capability, the following improvements are currently being made:

- Allow batch analysis programs to be initiated from the CRT keyboards.
- Permit these programs to operate in the backbround but be able to use data from the real-time foreground acquisition.
- Implement a user-oriented, general-purpose graphic package to allow the user to communicate with the operating program and to output the data in any customized display format (not limited to plots and tabulations).

The first phase of the development is now operational and the others are scheduled for completion near the end of the year. These features, in conjunction with the basic system capabilities, should greatly improve the level of data analysis capability and reduce the turnaround time for final processing.

(2) Flexible Format - Up to this point in time, software modifications have been required each time the basic frame format or quantitizing technique has varied from that of the original data acquisition system. The task of making these modifications is time consuming, expensive, and complicates the software greatly. In order to take full advantage of the Remote Multiplexor Data System (RMDS) capabilities previously described, it will be necessary to take a new approach to this problem. The major requirements in this area are three-fold:

- Permit dynamic redefinition of these formats or configurations.
- Be able to accept data acquisition system formats with a wide range of frame sizes, frame rates, word sizes, supercom and and subcom ratios, LSB or MSB first, magnitude only, sign and magnitude, 2's complement, auto ranging gain notation, etc.
- Accomplish these improvements in a manner such that current processing and analysis capability is not impaired and operational procedures are not unduly complicated.

Conclusions. The basic character of the Douglas Flight-Test Data System remains unchanged from its 1970 operational date. However, its capabilities have been expanded through new data acquisition systems and improved communications links. Major improvements in system reliability have been realized in the operation of hardware and software. Continued development is foreseen in areas that improve the adaptability to handle new input requirements and those that expand the interactive data processing and display capabilities.