AN INTEGRATED SOLUTION FOR FLIGHT TEST DATA HANDLING

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ABSTRACT

An integrated airborne/ground data acquisition and processing system is being implemented for McClellan AFB. This Flight Data Acquisition and Processing System is capable of gathering large amounts of varied types of instrumentation data during F-111 test flights and providing general purpose computer processing of the test data results. A programmable PCM data acquisition system was developed along with companion acquisition systems for monitoring the F-111 SRAM, MARK II, PAVETACK, ad MIL-STD-1553 on board computer busses. The information is stored on an IRIG instrumentation recorder for subsequent processing and display by a DEC VAX 11/780 computer in the ground station. The VAX in the ground station is supported by multiple programmable preprocessors for data compression/engineering unit conversion and a specially developed software system provides a unique integration of the airborne/ground system capabilities via a parameter data base. A special capability of the system is the ability to process a typical flight tape utilizing a single playback of the instrumentation tape at the recorded speed.

INTRODUCTION

FDAPS, an acrynonym for Flight Data Acquisition and Processing System, is a powerful new telemetry system developed for McClellan AFB to aid in their F-111 flight test program. The system includes on board airborne equipments to condition and store measurement information on the F-111 and a DEC VAX computer based ground telemetry station which provides for rapid an efficient analysis of the stored airborne information. The FDAPS program was a two year effort from its inception and involved more than twenty four man years of engineering manpower in development and implementation of the system. The initial application of the FDAPS is planned for support of the F-111 Avionics Modernization Program (AMP), a billion dollar program for upgrade of F-111 avionics systems. Following and in conjunction with AMP flight tests, FDAPS is to support an ongoing McClellan AFB test program to enhance reliability of avionics systems aboard the various models of the F-111.

Performance requirements of the FDAPS at the time of contract award in October of 1982, presented formidable challenges to the FDAPS program team in a number of areas. The system was required to interface a large number of different measurement sensors on board the F-111 as well as a large number of high speed asynchronous serial digital data signals and record all available measurement information on a standard magnetic tape recorder. Additionally, as the FDAPS package would not be a permanent installation on the F-111, the airborne system was required to be capable of being easily installed in or removed from a specified compartment area in the aircraft. The specified compartment area was an area normally occupied by ECM equipment and did not provide sufficient space to allow a system to be configured using currently available equipment. FDAPS was also to provide a computer ground station compatible with he airborne system and capable of supporting data analysis of the stored measurement information utilizing a single pass of the airborne tape. The single pass requirement necessitated the use of multiple sets of Telemetry Front Equipment (TFE), including decommutation and preprocessor hardware, due to the high aggregate system data rates encountered during this playback. Software to be provided in support of the FDAPS requirement was to include a menu oriented user interface which would allow the normal telemetry user without a software background to set up and use the ground station. A fundamental challenge of the software task was the requirement to manipulate and display measurement data from the various data sources together and in a consistent manner. even though the data sources presented widely varying formats and data identification techniques.

SYSTEM REQUIREMENTS

Although not an all inclusive list, the following are highlights of the capability requirements for FDAPS.

Airborne Subsystem

- Provide flexible programmable data acquisition system for acquisition of up to 300 traditional flight test data measurements.

- Provide control and display of selected PCM data measurements in the F-111 cockpit in an engineering unit format.

- Provide conditioning and recording to capture all data fro twenty serial digital data busses, including MIL-STD-1553, MARK II, and SRAM data types.

- Provide 90 minutes of data recording time while utilizing a standard IRIG airborne instrumentation recorder.

- Provide ground support equipment capable of downloading format setups to the flight hardware and monitoring flight readiness status of the flight hardware under preflight conditions.

Ground Station Subsystem

- Provide computer controlled ground data processing station capable of processing an entire airborne tape with a single playback pass of the airborne tape.

- Provide parameter data base oriented software system which enhances user friendliness via use of operator assignable aircraft ID names and parameter measurement names.

- Provide sufficient microcodable preprocessing capability to allow data compression algorithms and floating point engineering unit conversions to be performed on all data parameters during tape playback while storing data on computer disk at 300 KB simultaneously for each of three disks.

- Provide quick look displays in alphanumeric and graphic format during transfer of measurement data from instrumentation tape to disk storage.

- Provide event, limit, and parity reporting options at the conclusion of a data run for the purpose of supporting quick look and subsequent disk data analysis.

- Provide alphanumeric and graphic data analysis of data parameters stored on disk. Crossplots as well as time history plots are provided by the graphic display.

FDAPS OVERVIEW

FDAPS includes an Airborne Subsystem and a Ground Station Subsystem. Ground Support Equipment (GSE), in addition to the Ground Station, is described as a part of the Airborne Subsystem along with the Flight Hardware. The FDAPS Flight Hardware is a set of specially developed acquisition equipment to be mounted on board test F-111 aircraft and used for recording in flight conditions. Inputs to the Flight Hardware are derived from F-111 avionics data busses, such as MIL-STD-1553 and Mark II, as well as a large number of individual data measurement sensors. The large number of individual measurement inputs provide the capability for monitoring a varying array of typical telemetry information such as voltage levels, temperature conditions, vibration, etc. Each individual measurement is conditioned as required for that sensor and digitized for recording along with the conditioned avionics data signals. Displays are available in the cockpit of PCM data channels in engineering unit format along with the current time. The Flight Hardware produces a fourteen track instrumentation tape which contains all available measurement data along with a header record. The header record identifies the setup of the Flight Hardware formats during the recorded flight test and is furnished as one of the functions of the GSE.

The GSE is a single rack of equipment designed to be mounted in a Van and used near the aircraft in support of pre-flight checkout activities. A basic function of the GSE is also to provide the facility for creating a telemetry setup format for the Flight Hardware data acquisition system and to then download the setup format into non-volatile memory in the acquisition system. The GSE also provides the capability for ‘quick look’ displays of the data streams being recorded on the flight tape by the Flight Hardware. This function is to be used during pre-flight operations to provide assurance of proper operation by the Flight Hardware. Another feature of the Flight Hardware is the ability to record calibration sequences on the airborne tape which may be analyzed by the Ground Station to detect gain and offset shifts in the PCM data acquisition system. The calibration functions are controlled from the cockpit control panel along with selection of run ID and event markers for merging with the PCM data stream.

The FDAPS Ground Station is a DEC VAX 11/780 controlled subsystem which is capable of processing large amounts of high speed telemetry data. The Ground Station utilizes a new specially developed software system to simplify the user interface and minimize the risk of incorrect system setups. Inputs to the Ground Station include off-line operator setups of the parameter data base and telemetry equipment setup files. After the airborne tape is mounted on the instrumentation recorder, playback of the tape may be accomplished under control of an operator from any VAX CRT terminal. Playback of a header on the airborne tape is used by the Ground Station to compare the actual setup format of the airborne system to the current data base to be used for tape processing. Differences are identified to the system operator via a printer report output. This eliminates the necessity to maintain a documentation record identifying the contents with each airborne tape. Calibration records on the airborne tape may be utilized by the Ground Station software to detect first order inaccuracies in the PCM data. Automatic correction of this data during processing is accomplished by adjusting engineering unit coefficients to compensate for the detected error. All measurement data is subjected to selected compression algorithms via a system of EMR 715 preprocessors whereby redundant data or data types/ranges not pertinent to the test are eliminated. Compression algorithms are performed individually on each measurement in each data stream as selected by off-line operator inputs to the parameter data base.

The preprocessors also perform engineering unit conversions on each data point as the data points are provided to the VAX CRT's for display and to the VAX 300MB disk system for storage and subsequent analysis processing. FDAPS analysis software retrieves measurement data from the 300MB disk system and presents alphanumeric and graphic displays of selected time slices. The analysis displays reference the current parameter data base along with the stored disk data to simplify the process of data retrieval for the operator. The operator typically needs only to be aware of the aircraft ID mnemonic and the names of the desired measurements for display. Also, the Ground Station utilizes cassette tape to transmit a copy of the current parameter base and telemetry equipment setup file for PCM to the Ground Support Equipment. This feature minimizes the requirement for operator input of the Ground Support Equipment setup for the airborne system and thereby reduces the possibility for errors.

AIRBORNE SUBSYSTEM DESIGN

Block Diagram

A block diagram of the Airborne Subsystem is shown in Figure 1. Signals to be monitored by FDAPS are interfaced to conditioning and data acquisition circuits mounted on the left side compartment of the F-111. After preparation by the FDAPS conditioning equipments, the resultant synchronous data streams are recorded on a 14 track instrumentation recorder mounted in a right side compartment. Units mounted in the F-111 cockpit provide control over the airborne system and feature displays of PCM measurement channels in engineering units as well as a display of the current test time. The Ground Support Equipment includes PCM decommutation and MIL-STD-1553 simulation equipment supported by a microprocessor system. A unique binary bus data display unit allows a quick look by the GSE at words from the conditioned serial digital data bus streams prior to recording on tape.

PCM Data Acquisition System

FDAPS provided the impetus for development of a new PCM airborne data acquisition system. The new PCM system was conceived with the design goal of eventually producing a set of airborne products which would compete in the general marketplace for a small, high performance distributed PCM system. In the FDAPS package this new 5000 Series design is incorporated in two chassis assemblies in the instrumentation case located on the left hand side of the aircraft. The system is a flexible, general purpose data system for handling analog, digital and synchro signals. The system was designed to support a distributed signal conditioning capability and utilizes an intelligent controller in support of that function. The controller stores downloaded setups from the GSE in its internal Electrically Erasable Read Only Memory, a non-volatile storage medium. Programmable format parameters include format word assignments, word length on an individual word basis, frame/subframe rate, channel gain/offset setting, and engineering unit conversion information for cockpit display. The system includes flexible signal conditioning to allow interface to a variety of measurement sensors such as resistive bridges, temperature devices, voltage sources and synchros. The output of the PCM system is a randomized NRZ-L data stream to be recorded on a single tape track.

MIL-STD-1553 Conditioning System

In order to satisfy the requirements for recording data from F-111 MIL-STD-1553 data busses, a new technique was required. Most conventional PCM monitoring schemes for this data bus utilize a technique of capturing only selected words and merging these words into a PCM stream produced by a standard data acquisition system. This approach requires prior knowledge of the content of the data on the bus to allow proper setup of the monitoring system. FDAPS required a system which would capture all information appearing on the bus without requiring any knowledge of bus activity. Additionally, the requirement existed to record this information on no more than two tracks of the recorder while operating at a tape speed which produced 250khz response per track. The concept devised and implemented for FDAPS performs this monitoring function for two independent MIL-STD-1553 data busses. Each FDAPS 1553 conditioner is a passive monitoring device on the MIL-STD-1553 data bus and creates two synchronous 400KHz data streams. The conditioners each perform functions of insertion of filler/sync words for creation of synchronous data streams, resolution of command/status word ambiguity, selection between primary and secondary bus connections and data randomizing. Each FDAPS conditioner spreads alternate bus data words across two tape tracks, thereby providing a total bandwidth of approximately 800KHz for a single bus. The MIL-STD-1553 data bus, although operating at a 1 MHz bit rate, is asynchronous and seldom experiences activity levels in excess of 80% duty cycles for long periods. The conditioner relies on this fact and utilizes a First In-First Out buffer in the conditioner to provide a smoothing effect across periods of peak bus activity. The conditioner also provides error messages in the data stream which indicate received bus parity error, invalid received bus message sequence, or overflow of the input buffer.

MARK II Conditioning System

The conditioning system designed to handle MARK II serial digital data bus formats was similar to the system developed for MIL-STD-1553. The concept of using FI-FO circuits and fill words to create synchronous serial data output streams containing all data words from the incoming asynchronous data streams was again employed. However, each MARK II data stream was a 100 KHz bit rate signal and sixteen total MARK II streams were to be recorded. In order to optimize use of recorder bandwidth, the MARK II conditioner was designed to merge four incoming signals into a single synchronous output for recording on a single tape track. Therefore the total of 16 serial MARK II signals require 4 total tape tracks of storage space, each providing bandwidth for a 400KHz randomized NRZ-L signal. The conditioned MARK II data streams, like the conditioned MIL-STD-1553 data streams, are each synchronous signals with standard telemetry formats and frame synchronization patterns to allow playback of the recorded tape by a ground station utilizing standard PCM decommutator front end equipment.

SRAM Conditioning System

The SRAM data handling system required another unique design to handle this unusual data stream. F-111 SRAM data is presented to the FDAPS conditioner along with data gate and data clock signals. The format utilizes 25 bit words and provides for multiple unique formats on the same input line. This 50 KHz asynchronous data stream is conditioned by the FDAPS conditioner to also provide a synchronous output data stream for recording. This data stream contains fill words when no data is present and inserts periodic frame synchronization patterns to enable data retrieval by the Ground Station.

PAVETACK Conditioning System

PAVETACK data is received by FDAPS as a 100 KHz serial NRZ-L PCM signal. FDAPS conditioning for this stream consists of converting the signal to a BIØ-L code to provide the most reliable means of recording. The Ground Station may also process this signal using a standard PCM decommutator.

Ground Support Equipment

The GSE is designed to support the Flight Hardware during setup and checkout operations. Included in the GSE is a standard PCM decommutation and display system along with a binary bus data display unit. The bus data display provides a ‘logic analyzer’ like capability for binary display of captured blocks of data from the various conditioned data streams being recorded on tape by the Flight Hardware. The PCM decommutator selected for use in the GSE was the EMR EXPRT series, a unit which contains an LSI-11/2 microprocessor. The microprocessor was upgraded to an LSI-11/23 with 256 KB of memory and two additional functions were added to its list of responsibilities. The first function was support of a plug-in MIL-STD-1553 bus tester system. The bus tester allows the GSE to be used as a bus controller, remote terminal or simply as a bus monitor. The second additional function was support of the program format download for the 5000 series data acquisition system in the Flight Hardware. A new software package was necessarily developed to enable this setup to be accomplished on the GSE microprocessor. The setup software presents a menu interface to the user and utilizes a data base approach for storage of format and parameter information. The GSE setup software is capable of reading a format and parameter data base setup previously stored on cassette tape by the Ground Station and automatically preparing the necessary setup for download of the Flight Hardware based on this information. The GSE also generates a tape header record, via an RS-232C modulated FM VCO, to be recorded on a tape track providing feedback to the Ground Station of the final Flight Hardware setup configuration.

GROUND STATION SUBSYSTEM

Block Diagram

A block diagram of the FDAPS Ground Station functional layout is shown in Figure 2. The primary purpose for the Ground Station is one of engineering support for flight test activities by providing data manipulation and display of flight test data measurements stored on instrumentation tape. The system provides acquisition, engineering unit conversion, processing, display and hard copy outputs of data retrieved during playback of the tapes. The system is capable of performing all of its operations under control of a single operator, or multiple operators may call up and display multiple sets of data simultaneously. Referring to the block diagram maximum use was made of readily available standard telemetry and computer products in the system design. The Ground Station front end design is relatively conventional, featuring standard PCM and FM telemetry front end equipment for processing the various tap tracks. Sufficient hardware is included in the system design to support playback of all 14 tracks of an instrumentation tape simultaneously. A set of three EMR 715 preprocessors is utilized to perform data compression/engineering unit conversions on the data as it is prepared for entry into the VAX 11/780 computer system via multiple sets of EMR computer interface units. The VAX computer system is supported by a full complement of standard peripherals, such as disk, tape, and CRT subsystems. Processed data is stored on the UNIBUS 300 MB disk drives while simultaneously being displayed on the alphanumeric or graphic display system. After storage on a 300 MB disk, selected time slices of the data may be retrieved and analyzed in detail by analysis software, which also provides CRT displays in alphanumeric and graphic format.

Telemetry Front End Equipment Design

The telemetry front end (TFE) equipment in the Ground Station consists of a Sabre X instrumentation recorder, a set of 10 EMR EXPRT PCM decommutators, an EMR 287 FM subsystem with 3 companion EMR 429 multiplexer/encoders, an EMR 741/743 time system, a set of 3 EMR 715 Multiplex preprocessors and a set of special interface designs to off-load dedicated tasks from the processing system. All of the TFE, with the exception of the special interfaces (SRAM, PAVETACK, MARK II, MIL-STD-1553) are controlled from the VAX 11/780 UNIBUS system via EMR 760 computer interface channels. Digital playback data from the instrumentation recorder is accepted in serial form by each of the EXPRT decom systems where bit synchronization, frame synchronization and word alignment functions are performed. Parallel 16 bit outputs from the decom systems are then routed to the three 715 preprocessors. PCM system data is the only recorded digital data provided directly to the preprocessor. All other digital data streams in the system require special interfaces. These interfaces perform repetitive bit manipulations and data organization tasks to provide relatively uniform data formats to the three 715 preprocessors. This approach allows the preprocessors to operate with essentially identical microcode and concentrate on tasks they are particularly suited for, such as high speed data compression, floating point engineering unit conversions and limit checking. FM playback data in the system is supported by the set of EMR 287 discriminators. The discriminator outputs are multiplexed and digitized by three EMR 429 units. The digitized data is provided in parallel form to inputs of the three preprocessors for merging with other measurement data into the VAX system for display and analysis. The EMR 429 multiplexer encoders are also utilized as system simulators to allow automatic diagnostic tests to be performed on the overall Ground Station. The ability of the unit to output programmed octal patterns is a feature used in this application to facilitate implementation of an extensive system self test diagnostic program. A serial output from the EMR 429 simulators is connected to an auxilary input of each PCM decom in the system to facilitate this test.

VAX Computer System

The DEC VAX 11/780 selected for use in the Ground Station is a powerful 32 bit machine manufactured by Digital Equipment Corporation and the VAX/VMS operating system, included with the VAX, provides a flexible virtual memory addressing, multi user environment for support of the FDAPS software. The VAX system also includes 3 MB of interleaved main memory and is equipped with three UNIBUS interface systems. Each UNIBUS is used to interface an EMR 715 preprocessor and one of the 300 MB disk drives. The preprocessor and disk systems are evenly distributed across the three Unibusses to allow the system to achieve optimum aggregate throughput data rates to the disk drives. In this configuration the system will achieve a rate of approximately 30 KB to each of the three 300 MB disks simultaneously. Other computer peripherals such as the CRT and magnetic tape drive systems are also distributed among the UNIBUS systems. A 300 MB RM05 system disk drive is provided utilizing a separate MASSBUS to maintain separation between the system device and the high speed telemetry data disks.

FDAPS Software

A unique new software system was developed and implemented on the FDAPS Ground Station. This software system represents the culmination of more than a decade of experience in the field of computer controlled telemetry data acquisition and data processing systems. A functional overview of the software is illustrated in Figure 3. During the design and development phase of this program particular emphasis was placed on the requirement for simplifying the user interface and minimizing the amount of operator input required for system operation. As shown in the referenced figure, the operator will interface the system in one of the following ways. These include the file maintenance tasks, analog tape header tasks, acquisition tasks, and analysis tasks. The analog tape header tasks consists of reading and analyzing the information stored in the tape header record on the airborne tape. Also included in this category is the function of reading the calibration sequences stored on the airborne tape and performing adjustments to processing coefficients for the active calibration channels. The second major operator interface area is that of file maintenance. In this mode the operator is provided with the ability to readily alter the disk files that identify setup configurations for the front end hardware as well as the parameter data base which contains all information describing the individual data parameters. The setup files for each hardware setup configuration as well as each unique parameter data base are stored in disk files segregated according to an operator assignable alphanumeric identifier (typically an aircraft ID). Operator interface during input of this file maintenance information is simplified by a structure of well organized system menus with supplemental support from an extensive set of help messages. Once the necessary setup information has been entered via the file maintenance tasks the system operator interface will shift to the acquisition tasks. The acquisition tasks allow the operator to initiate a download sequence to transfer setup information, stored in disk files under the operator ‘alphanumeric identifier’, into the telemetry font end hardware. Also under acquisition, the operator is then provided the options of starting and stopping the flow of telemetry data into the VAX UNIBUS system and into the 300 MB disk system. Data streams to be active during this acquisition task are automatically selected by an active/inactive stream list previously set up during the file maintenance tasks. Additionally, during the acquisition tasks the system operators may obtain graphic and alphanumeric displays of selected parameters from the processed data streams. At the end of each acquisition data cycle the operator is presented with a set of reports describing the conditions during the run. These reports include a report of out of limit violations, a report of system events, and a report of parity error rates on each of the digital data bus tape tracks. The analysis task is utilized after an acquisition pass has written processed data to the disk storage system. The analysis task accesses information in the parameter data base to minimize operator input during the analysis process and allows the operator to display selected time slices in time history or crossplot formats on a graphic CRT. Alphanumeric displays during analysis feature a variable speed scrolling function which is capable of reversing directions. Hard copy outputs of both acquisition and analysis displays are available.

CONCLUSION

A documentary of significant portions of the eventual design configuration for FDAPS is offered in the system photographs included as Figures 4, 5, 6, and 7. A program such as FDAPS has many side benefits to the performing organization in areas of new product developments as well as assimilation of new techniques for handling unique system problems. The FDAPS program was a highly successful program in this respect as well as providing very effective solutions to the overall FDAPS program requirements. New product developments spawned during FDAPS development included significant enhancements to the EMR EXPRT PCM decommutator system, a new 5000 series of high performance programmable airborne data acquisition equipment, and a powerful new parameter data base oriented software system which greatly simplifies the user interface in a large telemetry data processing system environment. Technologies were also advanced with development of reliable techniques for storage and subsequent processing of various types of digital bus data.

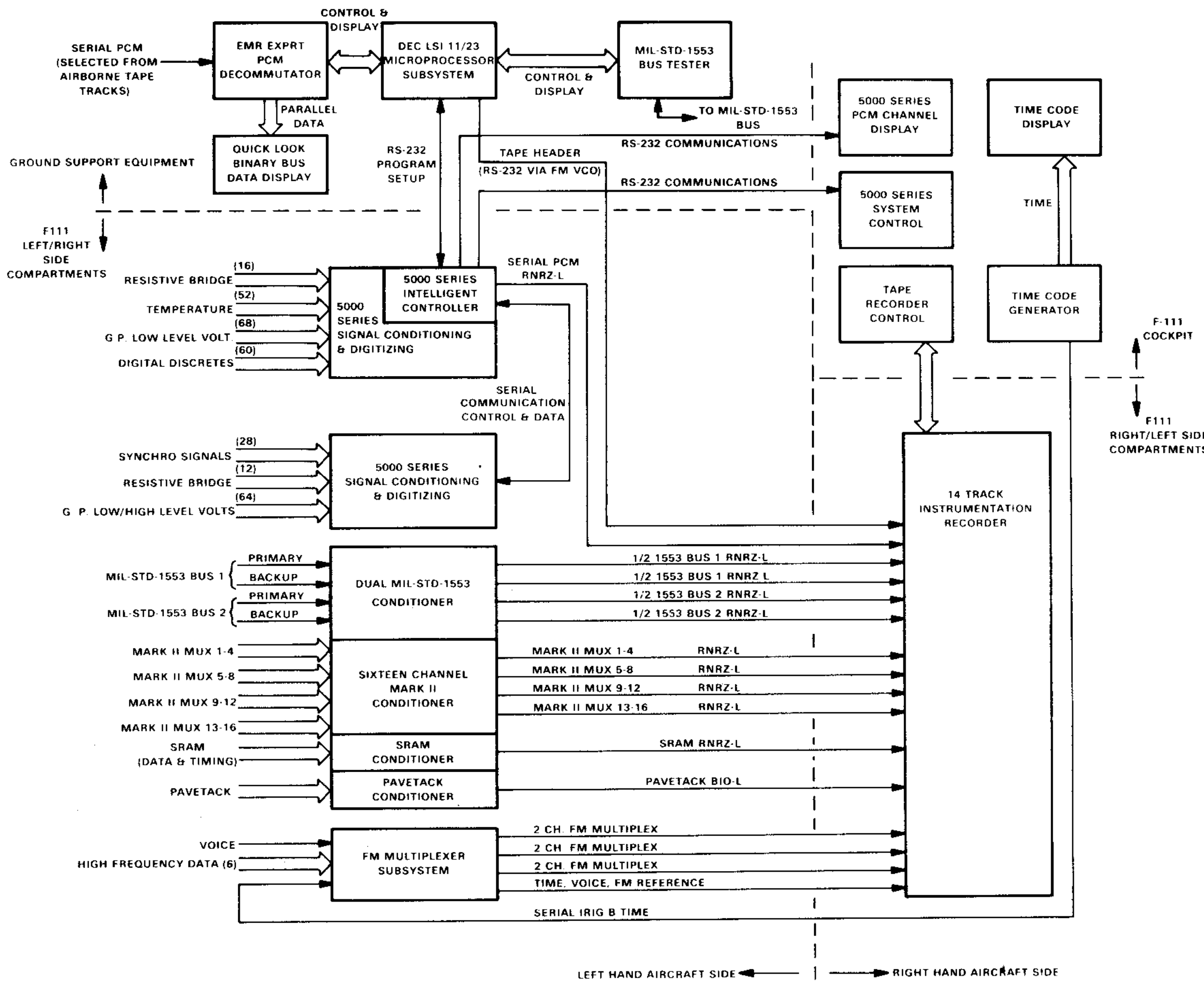

FIGURE 1. FDAPS AIRBORNE SUBSYSTEM BLOCK DIAGRAM

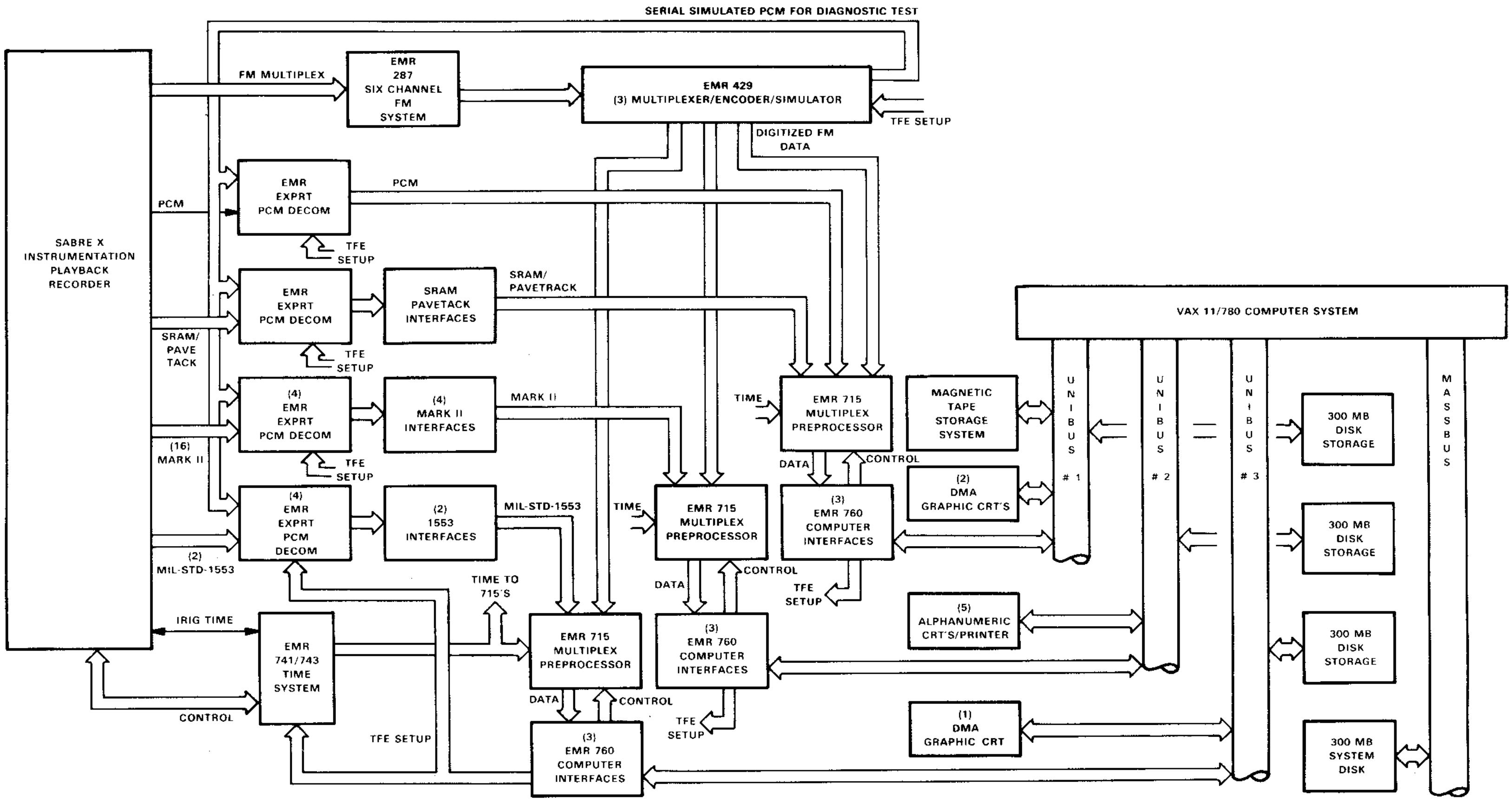

FIGURE 2. FDAPS GROUND STATION BLOCK DIAGRAM

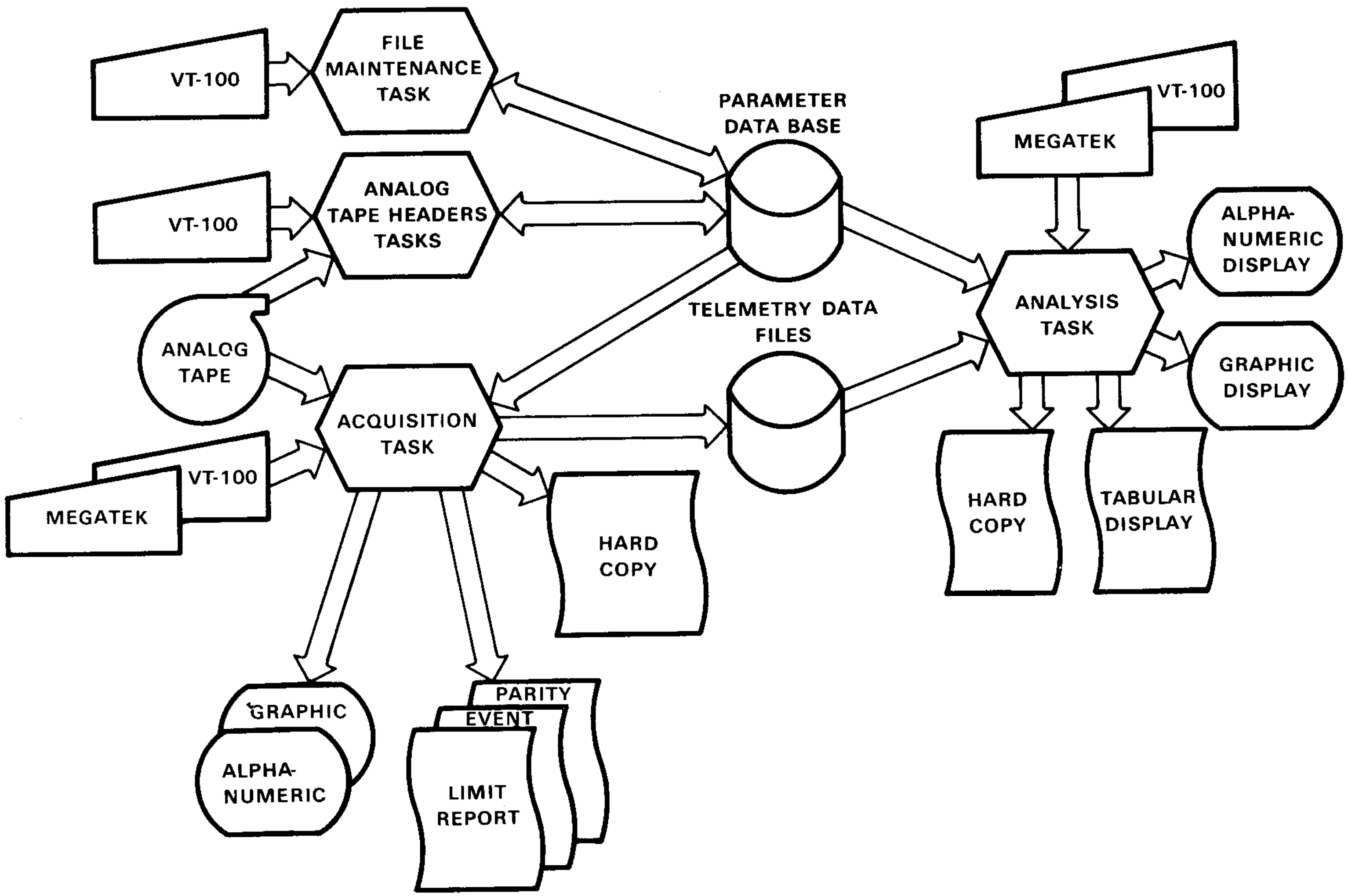

FIGURE 3. FDAPS SOFTWARE

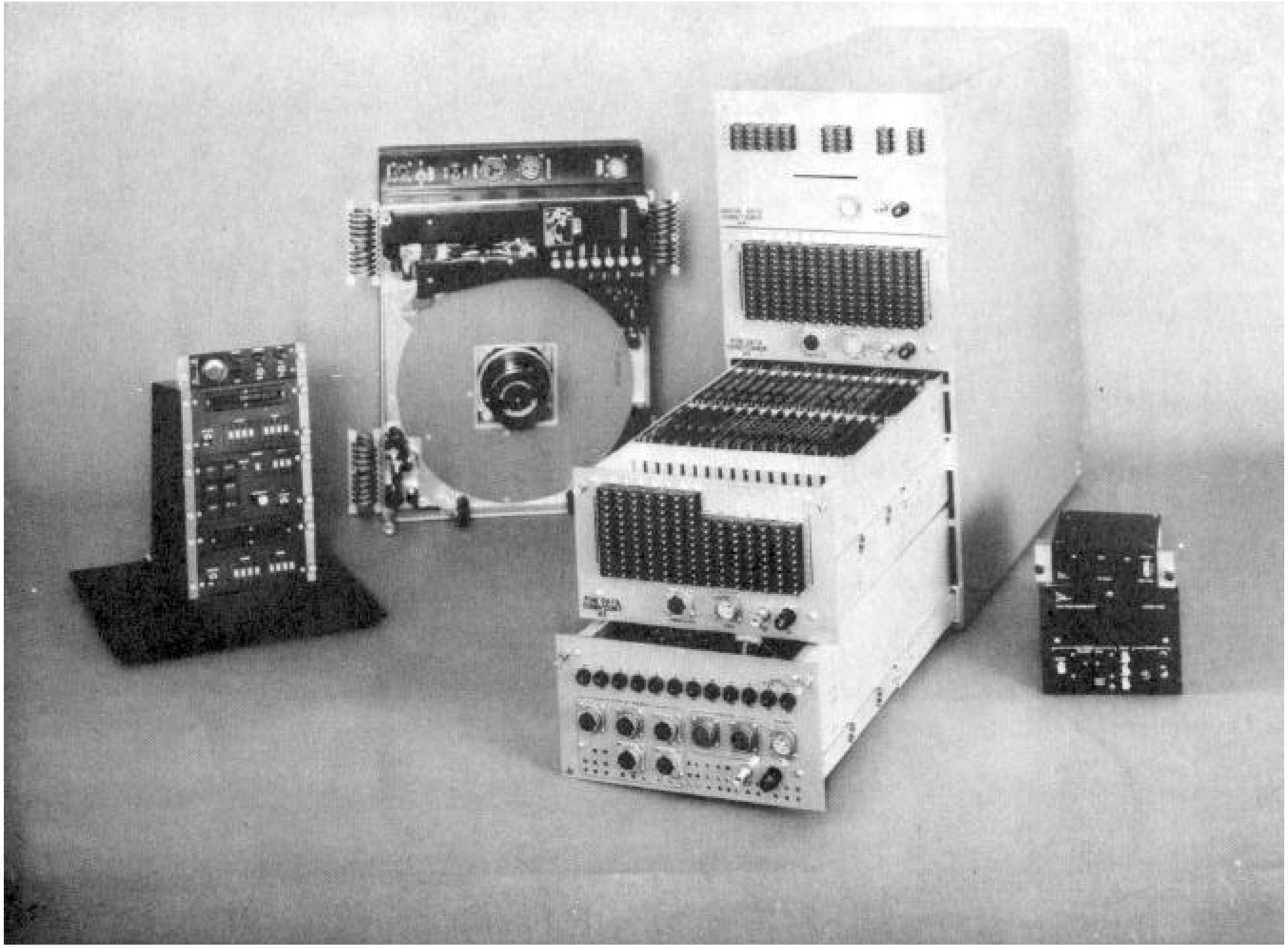

FIGURE 4. FDAPS FLIGHT HARDWARE

FIGURE 5. FDAPS GROUND STATION TFE

FIGURE 6. FDAPS GROUND STATION COMPUTER SYSTEM

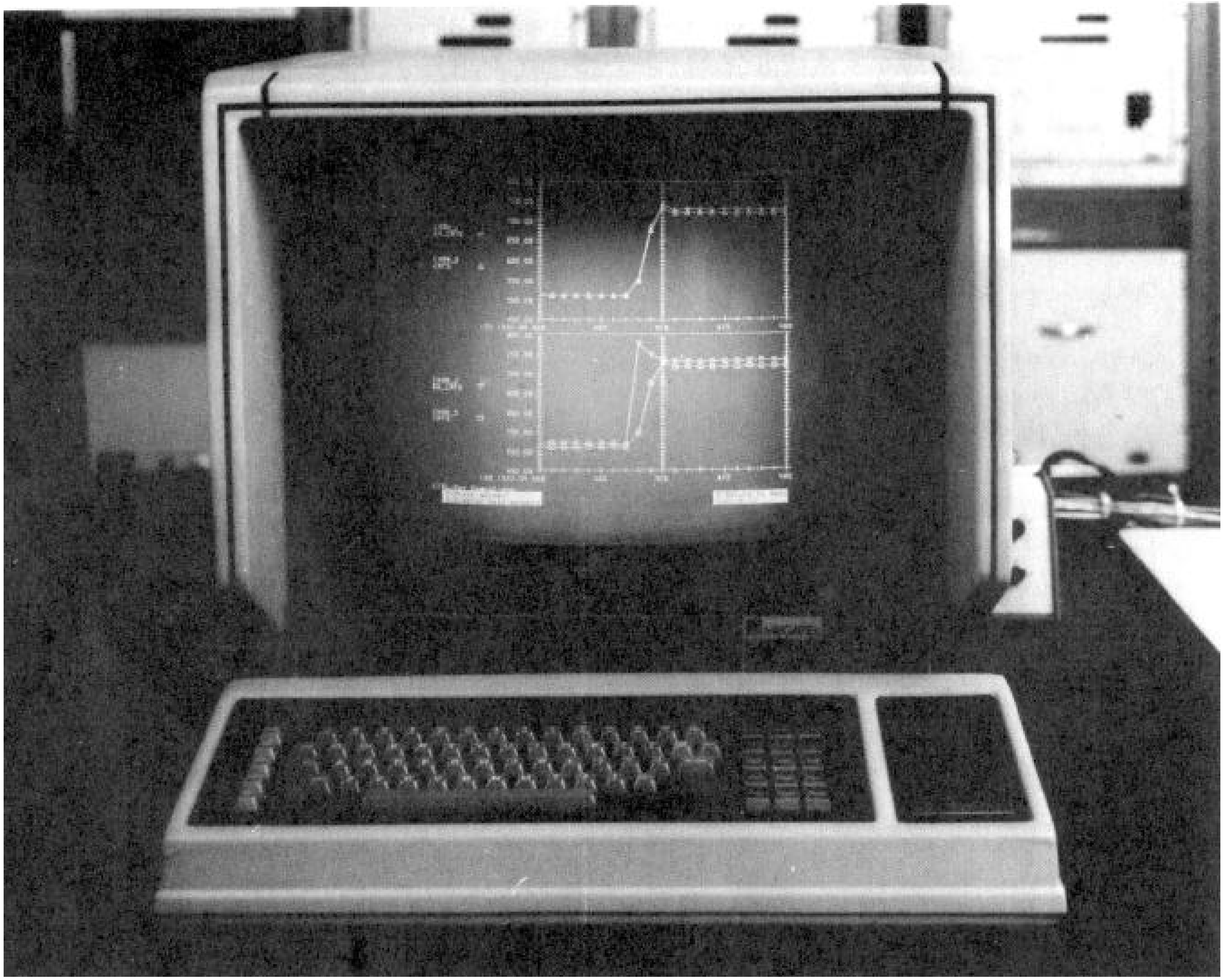

FIGURE 7. FDAPS ANALYSIS DISPLAY (TYPICAL)