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**NASA JOHNSON SPACE CENTER
LIFE SCIENCES DATA SYSTEM**

**Hasan Rahman
Martin Marietta Services
Houston, Texas**

**Jeffery Cardenas
NASA/JSC
Houston, Texas**

ABSTRACT

The Life Sciences Project Division (LSPD) at JSC, which manages human life sciences flight experiments for the NASA Life Sciences Division, augmented its Life Sciences Data System (LSDS) in support of the Spacelab Life Sciences-2 (SLS-2) mission, October 1993. The LSDS is a portable ground system supporting Shuttle, Spacelab, and Mir based life sciences experiments.

The LSDS supports acquisition, processing, display, and storage of real-time experiment telemetry in a workstation environment. The system may acquire digital or analog data, storing the data in experiment packet format. Data packets from any acquisition source are archived and meta-parameters are derived through the application of mathematical and logical operators. Parameters may be displayed in text and/or graphical form, or output to analog devices. Experiment data packets may be retransmitted through the network interface and database applications may be developed to support virtually any data packet format. The user interface provides menu- and icon-driven program control and the LSDS system can be integrated with other workstations to perform a variety of

functions. The generic capabilities, adaptability, and ease of use make the LSDS a cost-effective solution to many experiment data processing requirements. The same system is used for experiment systems functional and integration tests, flight crew training sessions and mission simulations. In addition, the system has provided the infrastructure for the development of the JSC Life Sciences Data Archive System scheduled for completion in December 1994.

INTRODUCTION

Understanding the physiologic changes that occur in space requires detailed physiologic measurements before, during, and after spaceflight. This generates large amounts of pre-, in-, and post-flight data in a variety of data formats. Traditionally, different data systems have been implemented to deal with different phases of the investigation, each system responsible for inflight data and another (or perhaps several) systems handling pre- and post-flight data. As a result, there are varied data formats and computer systems, with little or no resulting standardization.

The LSDS provides a portable, self-contained unit capable of data acquisition,

monitoring, analysis, archival, playback, and network transmission. The LSDS can acquire RS449 synchronous serial Non-Return-to-Zero (NRZ) formatted RF-downlink data or Consultative Committee for Space Data Standards (CCSDS) packetized data from a network interface.

The LSDS system was designed to handle, in real-time, data from any phase of spaceflight and store it in a readily accessible and flight compatible format. The system allows for easy access to data files, implementation of mathematical functions, and portability to other support sites. The LSDS system has been tested and used on all Spacelab missions with a life sciences complement, and it has been adopted by university laboratories. In addition, the LSDS system will be used to store and display the continuous data entered into the NASA Life Science Data Archive.

Overall, the LSDS software has proven to be useful, practical, and powerful. Although the development of this software began to address problems specific to space research, the software is being used to solve ground-based command and control data issues.

DESIGN

Design Considerations

The original design specifications for the LSDS were created to support the NASA Life Sciences experiments and investigations. During the early design phase, it became clear that by selecting the proper hardware and using a modular, object-oriented approach to software development, the LSDS could become a flexible, powerful system capable of operating in a wide range of data acquisition environments. Some of the design goals implemented during the development of the LSDS are as follows:

- Ease of use
- Ease of maintenance and modification
- Real-time, multifunction capabilities
- Acquisition of data from several sources

- Support to multiple experiment data streams
- Generic data displays to handle a wide variety of data types
- Utilization of existing software and off-the-shelf (COTS) hardware where possible
- Real- and playback data analysis capabilities
- Distributed architecture
- Client/Server capability

Input Data Format

The original design specifications for the LSDS required that it support the acquisition and processing of a synchronous serial NRZ-formatted data stream generated by an experiment payload microcomputer at a minimum bandwidth of 256 kilobits per second. The data stream is formatted into NASA Standard 630 High-Rate Multiplexer (HRM) and NASCOM frames. In this format the data bits are formatted into 12 or 16 bit words, and the words are grouped into minor frames. A minimum of four minor frames are grouped into major frames. Each minor frame begins with a standard 6-byte header. The first 32 bits of the header are a 24 bit sync word and 8 bit minor frame number used for frame synchronization. Data parameters are stored in the remainder of the minor frames. Data parameters may or may not be major-frame repetitive; ones that are not repetitive are indicated by bits set to indicate the presence or absence of particular parameters in the major frame. Upon acquisition by a ground system, major frames are grouped into packets of one or more major frame per packet.

The LSDS system can be configured to acquire packetized digital data in other formats.

Up to sixteen analog channels from a single workstation can be input into the LSDS system. Samples of the signals are digitized and stored in digital data packets.

Hardware

The LSDS was initially developed on a VAX/VMS platform. The Server of the LSDS software will run on VAX or AXP systems. The Client application software is available in multiple platform architecture (e.g. Macintosh, MS-DOS and VAXStation).

Digital telemetry is supported with Commercial Off-The-Self (COTS) hardware manufactured by Simfact Associates. An ICP3222 and /or FreeWay I/O box is used to receive data directly from a telemetry interface at the JSC Mission Control Center. An ICP3222 provides up to 4 input channels with an aggregate rate of 1 MB/Sec.

The FreeWay I/O box is used to support data acquisition and transmission over Ethernet and FDDI using TCP/IP protocol. This methodology provides a complete open system distributed architecture to provide services within the Life Sciences user community. An external magneto-optical Disk is used for data storage and archival. A Graphtec 32-channel analog strip chart recorder can be used to provide hardcopy strip charts. Any printer connected on a Local Area Network (LAN) can be used for printed output.

See Figure 1 for a representation of the architecture of the LSDS.

Work Stations

The system environment provides a consistent user interface regardless of the underlying operating system or hardware platform. The LSDS II VAX workstation display subsystem is based on the X-Window System™ and the Motif Graphical User Interface (GUI). This system provides portability and interoperability of displays across various platforms (e.g., Macintosh, MS-DOS PC, and any X-Window System Terminal/Server).

The workstation environment supports a variety of functions, from initial loading of experiment requirements into a database,

acquisition and display of test and simulation data, timeline and activity plan development, real-time flight operations monitoring and control, to preflight and postflight biomedical baseline data collection. Applications software resident in the workstations is developed in-house from COTS applications. The system allows the user to define and build custom displays of processed experiment data.

The Macintosh-based workstation Microsystems Integrated Real-time Acquisition Ground Equipment (MIRAGE) was designed and developed to provide a portable, self-contained desktop unit capable of real-time acquisition, processing, monitoring, analysis and storage of experiment data. User Interface and Data Visualization and Representation tools were designed and developed on the MIRAGE workstation.

Software

The LSDS Server software was developed on VAX/VMS, AXP OpenVMS, and on the Macintosh platform using Apple's Macintosh Programmers' Workshop C. A modular, object-oriented approach to software design was used to assure ease of modifiability and maintainability. The LSDS Client software uses the X-Window (Motif) DataView™ toolbox, establishing the capability to transport the LSDS Client software directly to other systems such as UNIX, Macintosh, and DOS-based Personal Computers.

The LSDS Server software makes use of the VMS system services provided by the operating system to support real-time functionality. The LSDS Server software uses the VI Corporation's DataView™ library of function calls to control the display system. TCP/IP and DECnet network protocol is used to provide interface to the Ethernet and/or FDDI controller hardware.

The software uses a new feature of the OpenVMS and Macintosh system 7.0 operating system. In Macintosh environment

the application uses the Time Manager to create a multitasking environment within an interrupt-driven operating system. By using Time Manager, the user can archive, acquire and display data simultaneously. In addition, LSDS has built-in utilities that allow the user to manipulate archived data. With the "extract and convert" command the user can convert a section of data (or the entire archive) to a different data format (e.g. Motorola or Intel). With the "frame editor" command, the contents of a major frame or block of frames can be modified. The "packet lim scan" utility will scan the data for a particular event that occurred during data collection. The "gapper" utility generates a report about the gaps that occurred in the data.

See Figure 2 for an illustration of the LSDS software architecture.

Configuration Database

The LSDS configuration database is created using Microsoft Excel. The database consists of several tab-delimited text spreadsheets, arranged into folders on the disk the LSDS software resides on. The LSDS database is used to define the system defaults (fonts, colors, etc.), experiment-specific hardware configuration, data stream format (stream data rate, packet frequency, etc.), acquisition defaults, experiment parameter format (packet location, extract masking information, etc.), display format, and analog input and output characteristics.

Due to the design of the databases supporting the software, the type of data, format of the data, and displays for the data can be modified quickly and easily. By using the DataView Draw and Macintosh ResEdit 2.1 software, a display can be modified in a matter of minutes and new parameters can be added to the display by modifying a database.

Data Flow

Figure 3 gives a representation of the data flow through the LSDS system. There are three external sources: the Macintosh user

interface, the experiment database, and the experiment data source. The user enters experiment stream, parameter, and display data into the experiment database. Through the Macintosh interface to the LSDS Server application, the user controls at runtime the experiment data source and other application functions. The user can choose multiple acquisition functions. Data can also be played back from an archived disk file.

The data acquisition portion of the program reads data from the specified external data source and, based upon the contents of the stream database, extracts and stores the major frames in the primary buffers. If the user has the archival function turned on, the primary buffers are read by the archival process, a header is generated, and the data packet is written to the archive file.

The parameter extraction function then extracts the data values for each parameter specified in the display databases from the primary buffers. The parameter database is used to locate and process the data values. The extracted and processed data values are stored in the parameter buffers.

If analog output is enabled, the data values for the parameters to be output are extracted from the parameter buffers and stored in the analog output buffer. The buffer is then passed to the analog output process.

The LSDS Client software for each display and graph window defined in the display databases, the data values to be displayed are extracted from the parameter buffers and output in the specified window in textual or graphical form based upon input from the display databases.

IMPACT OF SOFTWARE

Value and Utility

The LSDS is used at NASA/JSC Life Sciences Project Division Science Monitoring Area (SMA) for a variety of applications. Real-time data from Spacelab missions are acquired, displayed and stored by this software. During acquisition and

playback, LSDS can display, archive, and transmit analog data to a strip chart recorder, or other display device. This allows investigators to view and get a hard copy of their data.

In addition, the Life Sciences Data Archive (LSDA) Project is underway at JSC. The archive will allow for the storage, preservation, and access to the biomedical information obtained during life science investigations. Data entering the LSDA will be stored, retrieved, and analyzed using LSDS.

At the Ames Research Center (ARC), the Space Life Sciences Project Office will be using LSDS Server system. A recent contract from Ames to Martin Marietta specifically called for four LSDS Server capable systems. At the Medical College of Virginia, Dr. Dwain Eckberg uses the system to help with the analysis of his studies on the carotid-cardiac baroreflex. At the University of Texas-Southwestern Medical Center, LSDS Server is also used for analysis of pre- and post-flight biomedical data.

Recent work with the Russian Space Agency will also use LSDS Server configuration. The Macintosh systems in Houston and Moscow are being used to quality test the Standard Interface Rack Controller in support of the Shuttle-Mir Science Program joint missions. The LSDS Server is also being used to test the Mir Interface to Payload Systems (MIPS) Controller flight software. Four LSDS Server/Client systems will be established in Russia to support Mir-18.

Enhanced Productivity

Prior to LSDS Client/Server, biomedical data from spaceflight was collected on dedicated VAX-based systems. These systems were not portable and were only used during simulations or actual spaceflight. By using the portable LSDS Client/Server systems, data is collected during a mission or a simulation, and the same system is utilized to support baseline

data collection, science verification tests, data analysis, and data archival, both pre- and post-flight.

Data from life sciences missions and ground studies come in a variety of formats (analog, digital, High Rate Multiplex, CCSDS). Before the implementation of the LSDS Client/Server architecture, a separate system dealt with each kind of data. This required different software, with the attendant documentation, training, etc. Currently, only LSDS Client/Server need be used to deal with all the data and to provide a common format for retrieval. The ability to deal with multiple data types provides a savings to the LSDA, now under development, to handle the data from life sciences flights experiments. Rather than have multiple systems, LSDS will be used to view all continuous data from the flights, regardless of its initial format.

For future flights the time required to configure the data acquisition system and displays for new experiments and data has been drastically reduced. The LSDS Client/Server system uses spreadsheets to set the data acquisition parameters for a new experiment. In the spreadsheets the user can set LSDS system defaults (fonts, font sizes, display colors, etc.), experiment-specific hardware configuration, data stream format (stream data rate, packet frequency, etc.), acquisition defaults, experiment parameter format (packet location, extract masking information, etc.) display format, and analog input and output characteristics. Once this is complete, the spreadsheets are saved in a folder and can be retrieved upon demand.

Improved Efficiency, Reliability, Quality

The LSDS system provides real-time data quality checks and creates log files automatically indicating when LOS (loss of signal) periods occurred. In addition, data drop outs and the times when particular displays were activated, are also logged. Previously, the user had to wait until the disk was full (1-2 hours) before a data products analysis could be provided.

Formal Recognition

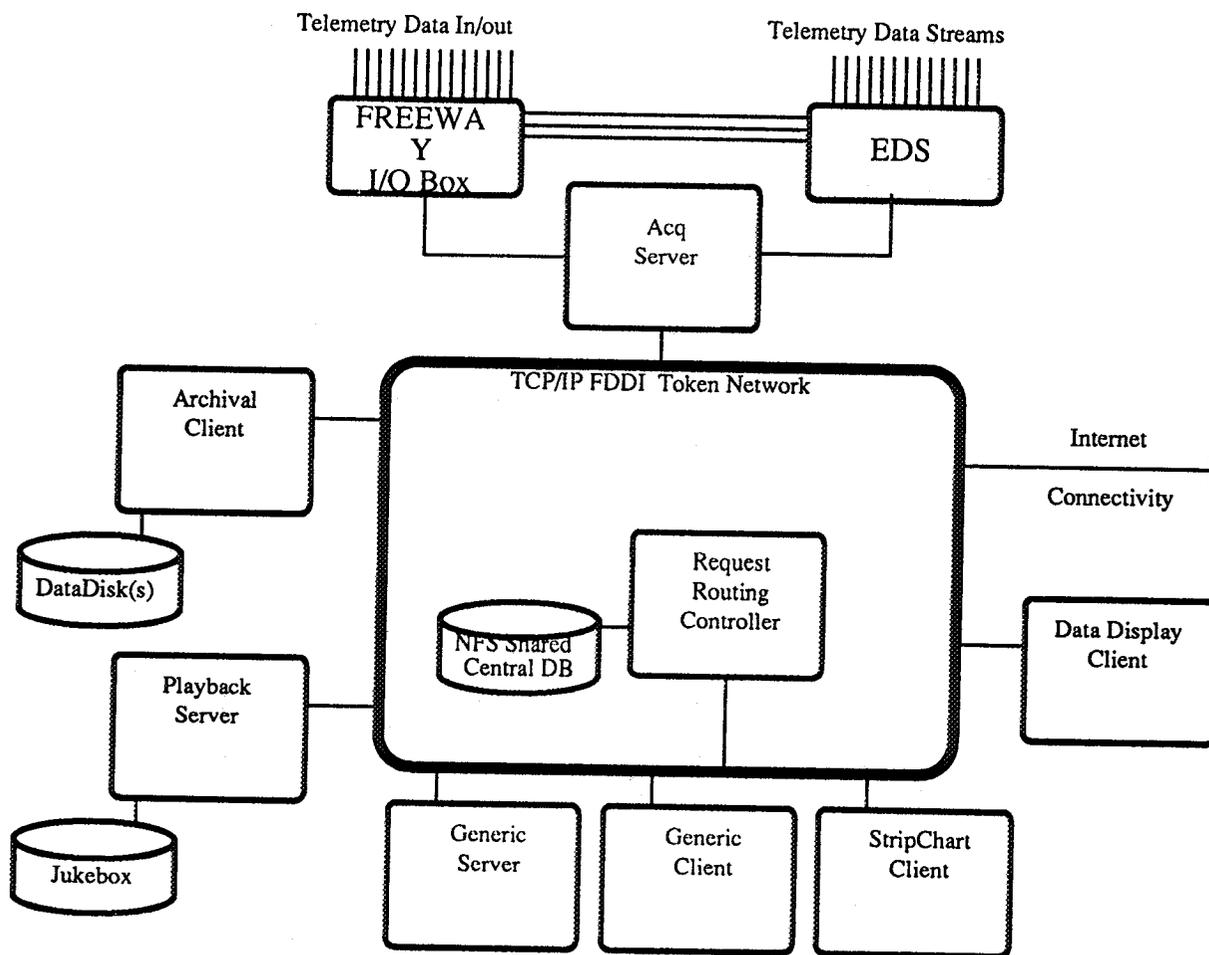
The LSDS Macintosh based Client/Server system has been presented at Technology 2002, the Third National Technology Transfer Conference and Exposition. The Macintosh based development team also won the NASA Public Service Group Achievement Award in March 1991, "... in recognition of their outstanding contribution to the design, integration, test and fabrication of the technologically advanced portable MIRAGE system."

Results/Conclusions

The LSDS II design provides data processing functions according to specifications set by users, in this particular case experiment investigators. The processed data will be distributed to locally- and remotely-based users and also stored on magnetic media for the future use of the investigators. The data processing functions use state-of-the-art workstation technologies, and analysis tools which may be developed by investigators and/or operations personnel at LSPD operations facilities or at remote locations.

Applications of the LSDS II and lessons learned by the JSC Project have already been made to the International Space Station Alpha Program, the Joint NASA RSA Shuttle MIR Science Program, and the NASA Life Sciences Flight Experiment Program. Utilization in the commercial and private sector has been coordinated through the NASA Technology Utilization Office.

LSDS SYSTEM OVERVIEW



Overall control starts in the middle of the diagram, with reliant tasks/resources branching off from their respective controllers. Connections are not necessarily representative of the physical layout.

Figure 1 Open Life Sciences Data System

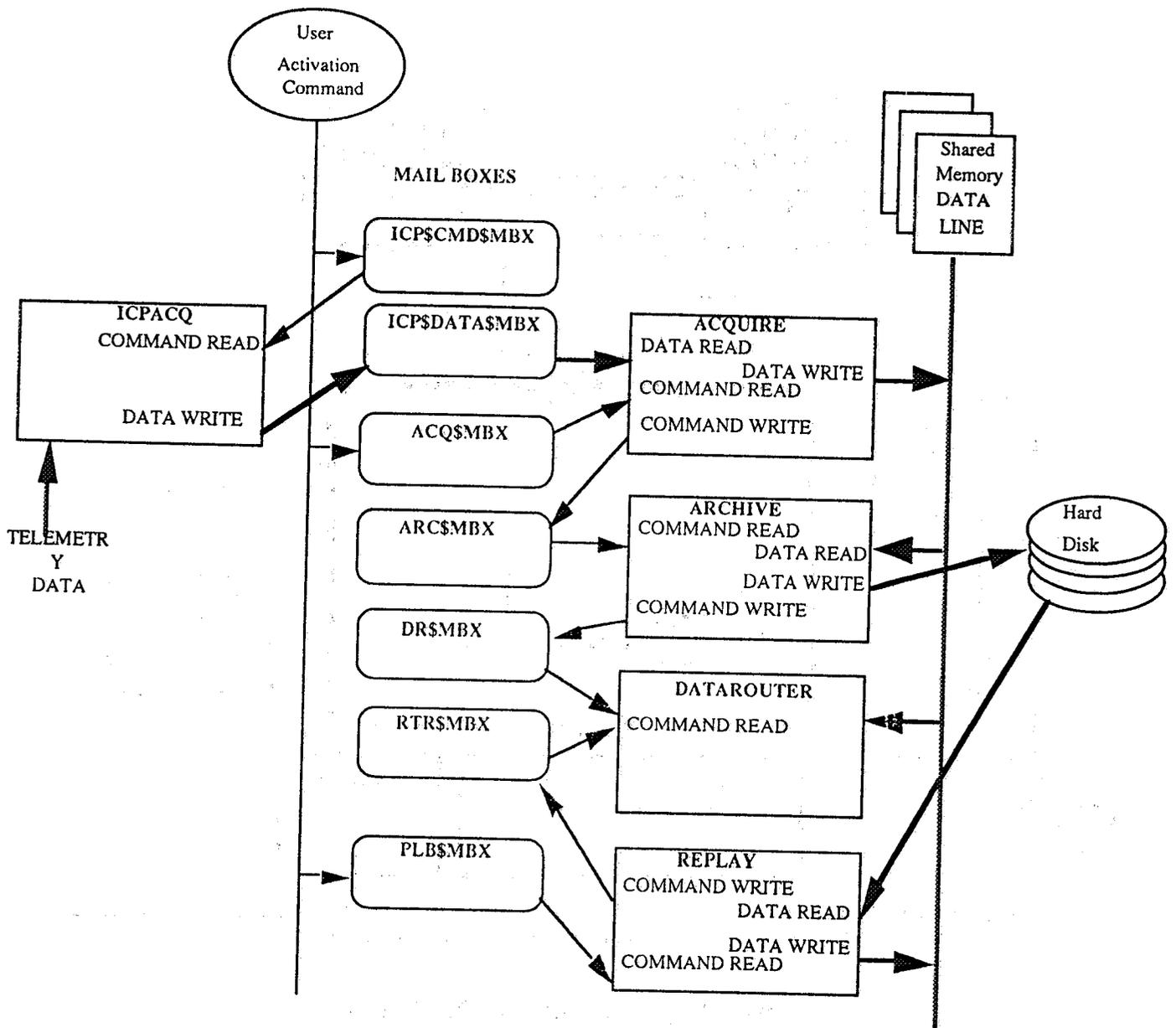


Figure 2 LSDS Software Architecture

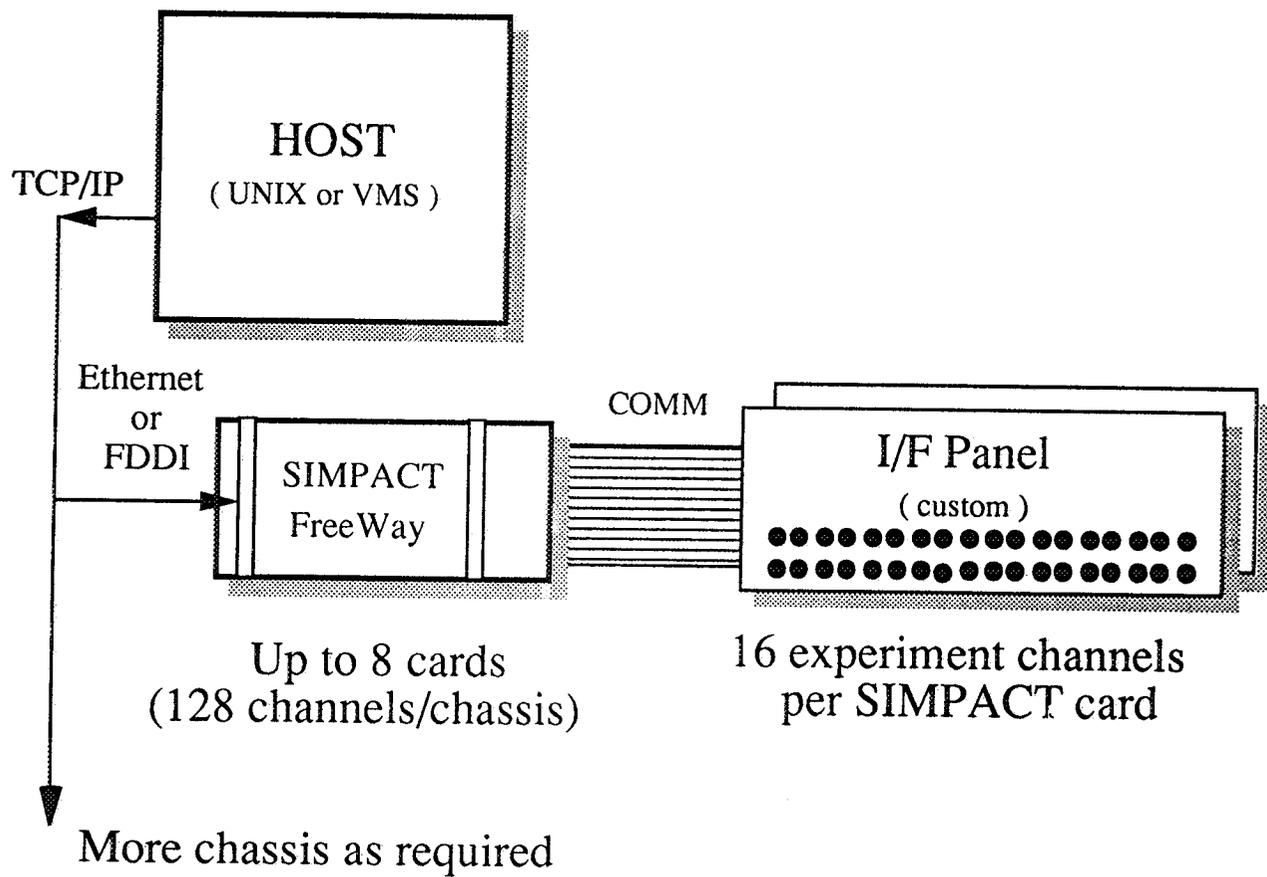


Figure 3 LSDS Data Flow