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OAO/TR-81/0058

STUDY PHASE 2
RELATION OF NEEDS TO OSTA

FINAL DOCUMENT

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ABSTRACT

This document provides the results of a study by OAOCO on the relationship of the NEEDS program to OSTA. The purpose of this phase of the study was to examine the NEEDS program and identify the interfaces between OSTA and NEEDS and furthermore to assess the responsiveness of the NEEDS program to OSTA technological requirements.

Section 2 includes a discussion of existing and planned NEEDS elements. Section 3 includes a definition of the relationship between NEEDS and future OSTA programs and includes an identification of potential benefits or impacts to OSTA through the implementation of NEEDS concepts/elements. Section 4 identifies possible OSTA demonstration systems or pilots for the NEEDS technology.

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SECTION 1. INTRODUCTION

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In order to meet the data processing requirements for NASA missions in the 1980 to 1989 time frame, the concept for a composite data management system known as the NASA End-to-End Data System (NEEDS) has been developed. By definition, NEEDS will be an ensemble of NASA data and information systems. Figure 1-1 depicts a functional diagram of the NEEDS. It is anticipated that the development of the NEEDS will provice NASA with an organized, efficient data management and processing structure which can fulfill the data processing and dissemination requirements of future missions.

This study will examine components of the NEEDS program. An "end-to-end data system" is defined as the total data system from the sensor to the end user. At the spacecraft a sensor makes observations (measurements) which produce raw data. These data, or processed versions of them, flow through a sequence of processors/facilities used to transform, process and transmit them. The data is either stored in archival form and made available to users or ultimately reduced to information products which are disseminated to end users. The means of allowing for feedback of control information for management of earlier stages of the system is also considered part of the end-to-end data system.

The NEEDS program has been structured into distinct phases to provide for comprehensive and unified planning, management review and approval of each phase, and a systematic and cost-effective technology transition in the mid-1980's to new end-to-end systems. Each phase provides specific incremental gains toward overall improvement in capability.

The Phase 1 program focussed on the development and demonstration of five technology elements that would provide cost-effective solutions

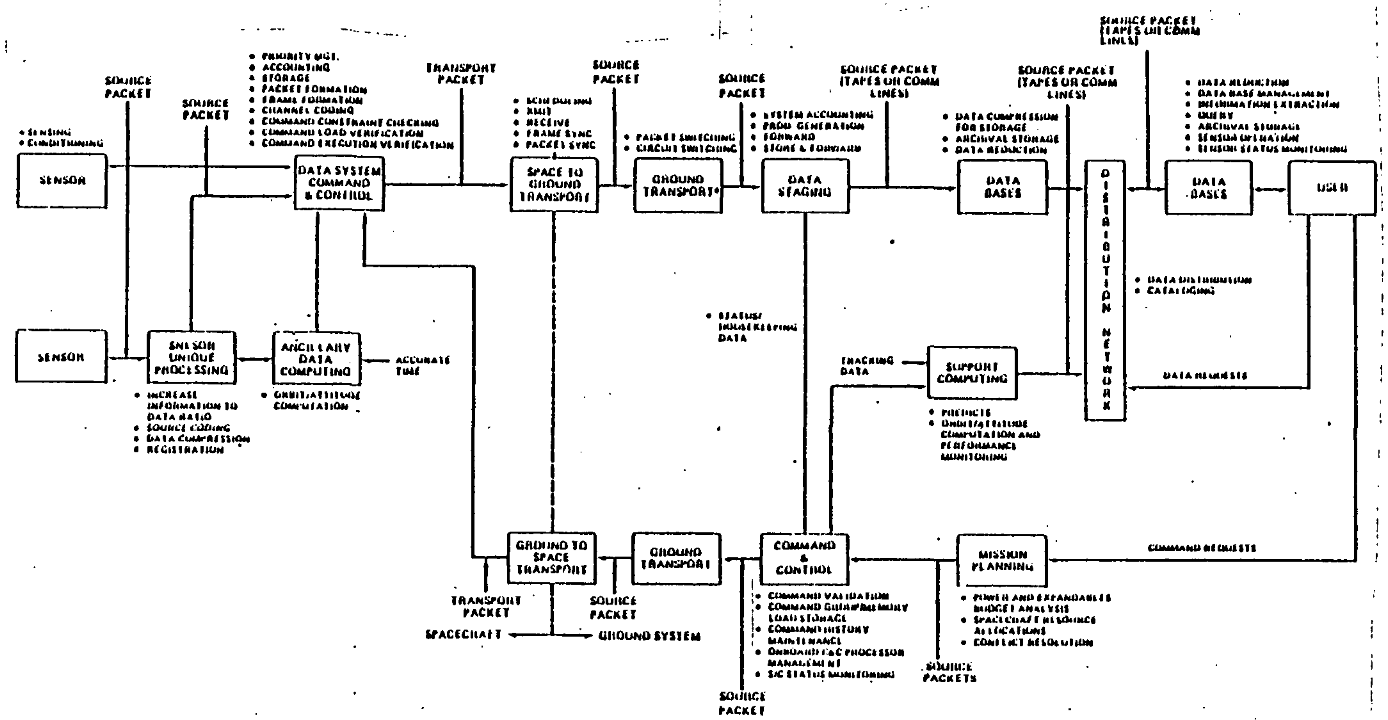

Figure 1-1. NEEDS Functional Elements

for several of NASA's very-near-term, high-data-rate processing problems, for software proliferation, and for the identification of data handling systems needed to satisfy future user requirements. These five technology elements were:

a. Synthetic Aperture Radar Data Processor
b. Multispectral Data Processor
c. Digital Data Systems
d. Multipurpose User Oriented Software Technology
e. Resource Effective Data System Definition

The specific objectives of NEEDS Phase 2 are:

a. To provide the systems concepts, techniques, and technology which could increase the systems responsiveness:

(1) So that the time between sensing an event and presentation of useful information to the user is reduced by two orders of magnitude where appropriate.

(2) So that the time between a user obtaining information and the conditioning of a sensor for a new data collection is reduced by two orders of magnitude where appropriate.

(3) So that appropriate and timely reduction of data to information occurs as it progresses through the system.

(4) So that the time required to exchange information (i.e., store, retrieve, and transmit) among users is reduced by two orders of magnitude.

b. To provide the system concepts, techniques, and technology which could reduce the relative cost of extracting information from space data.

(1) Such that the unit cost of sensing an event and transmitting the useful data/information to the user is reduced by an order of magnitude.

(2) Such that the unit cost for extracting useful information from the data is reduced by an order of magnitude, and

(3) Such that the unit cost for storage and retrieval of data/information is reduced by an order of magnitude.

c. To provide the systems concepts, techniques, and technology which could increase the degree of standardization throughout the system.

(1) So that the increased efficiency of using industry standard protocols, formats, and subsystems throughout the entire system would be established.

(2) So that increased efficiency would be demonstrated in the storage retrieval, and exchange of data, information, and knowledge (e.g., as is required by the user in the macrocorrelation problems such as Weather and Climate and by some of the major elements such as the Space Transportation System).

(3) So that concepts for the efficient use of complimentary ensembles of sensors used in space would be established.

The broad objectives of Phase 2 are to continue to conduct systems analysis to guide and evaluate the program, to develop new technology and techniques concepts, test and demonstrate at the brassboard level these new subsystems and demonstrate them in an integrated system configuration. The following is a partial list of developing concepts and technologies relevant to the goals of the NEEDS Phase 2 and the overall NASA future space missions:

a. VLSI Technology
b. Fault Tolerant Computing Systems
c. Fiber Optic Data Bus Integration
d. Archival Mass Memory Technology
e. Massively Parallel Processing
f. Onboard Attitude Determination
g. Improvements in Algorithmic Development
    (1) Radiometric Calibration
    (2) Geometric Correction
h. Packetizing
i. Packet Queuing
j. Data Capture, Data Staging Techniques
k. Multi-Megabit Data Processing Architecture

The major program elements of the NEEDS Phase 2 program are:

a. Information Adaptive Systems (IAS)
b. Massively Parallel Processor (MRP)
c. Modular Data Transport Systems (MDTS)
d. Data Base Management Systems (DBMS)
e. Archival Mass Memory (AMM)
f. Ancillary Data and Support Computing (ADSC)

The relationship of these elements to the NASA data handling and data management system is shown in figure 1-2.

The long range goals of the NEEDS program are to increase the data/information throughput of the NASA end-to-end data system by a factor of 1,000, reduce the system access time for space-acquired data by a

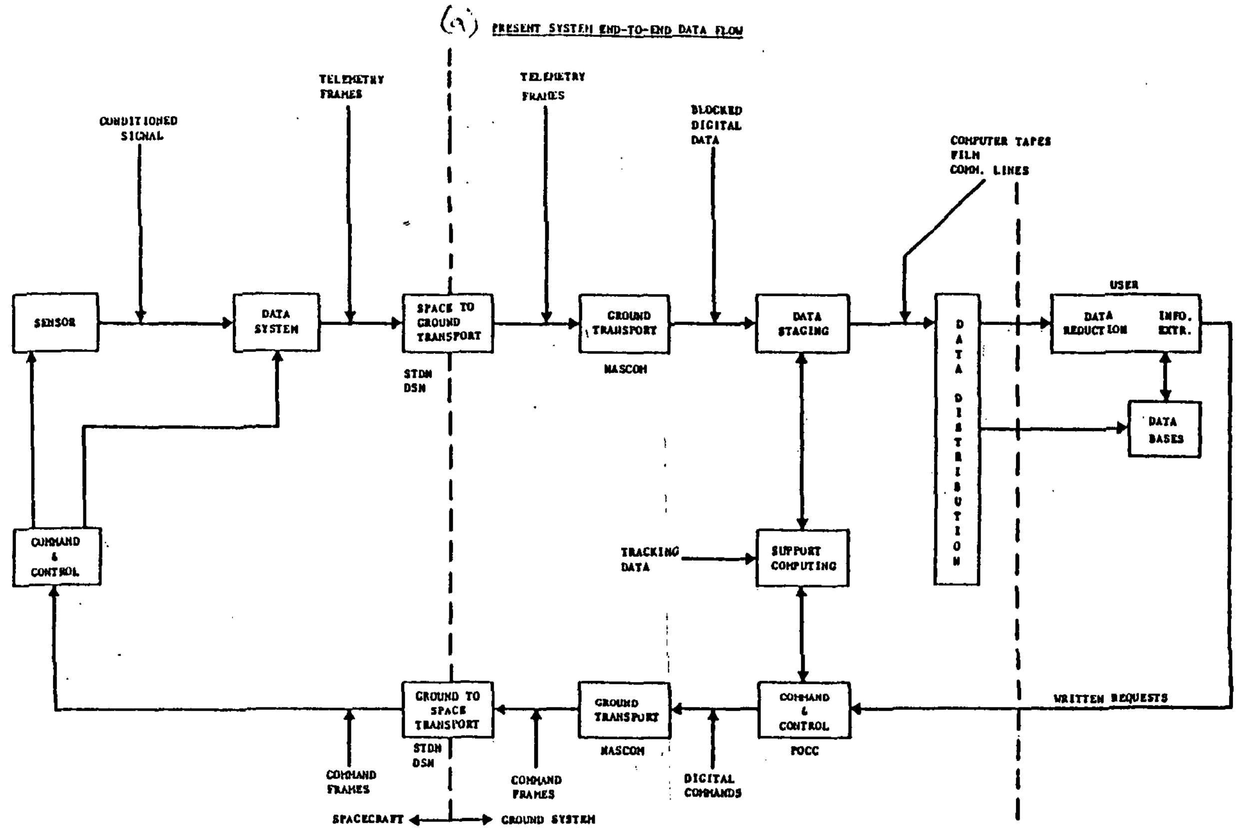

Figure 1-2. Relationship of NEEDS Elements to NASA Data Handling and Management System (Sheet 1 of 3)

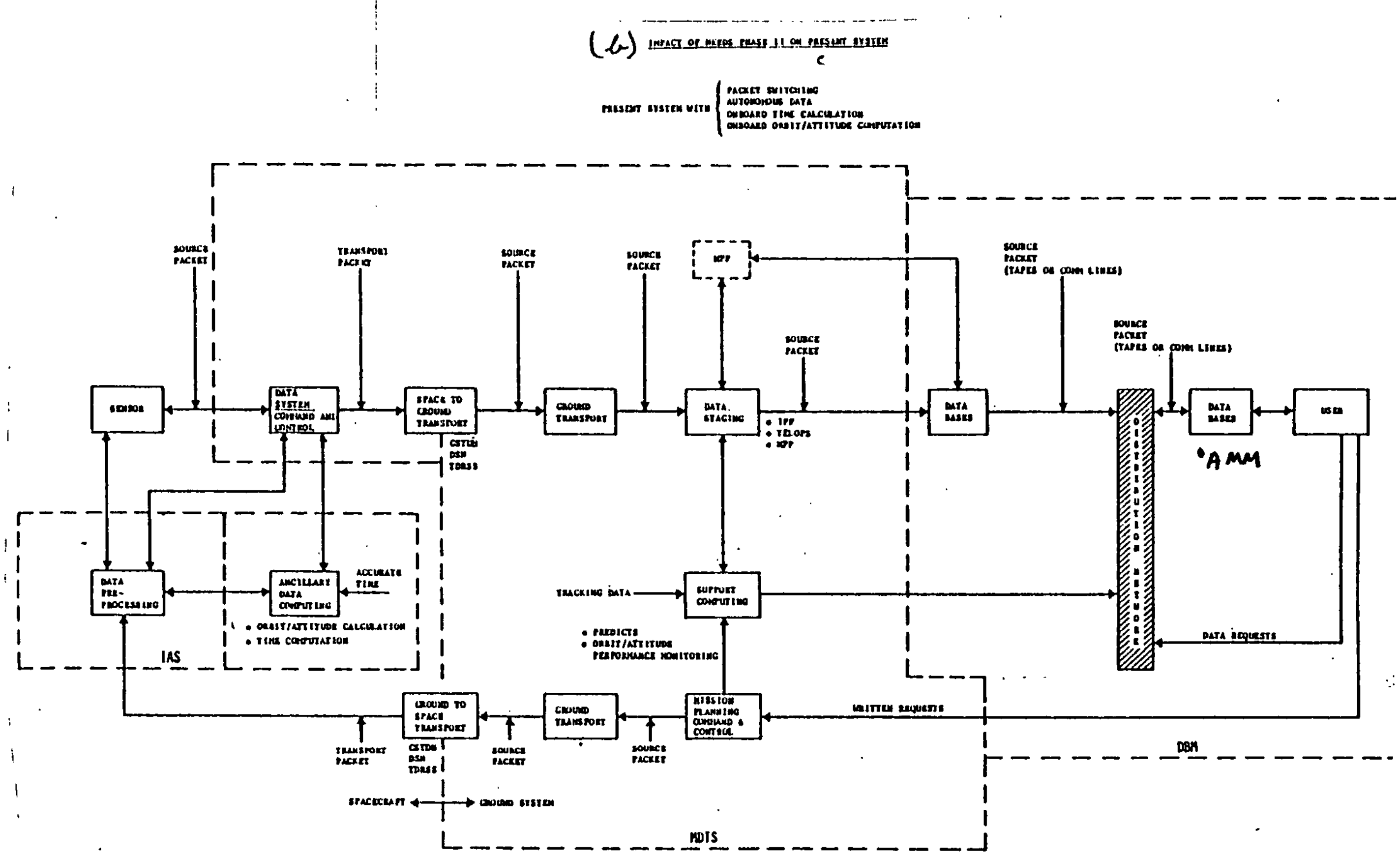

Figure 1-2. Relationship of NEEDS Elements to NASA Data Handling and Management System (Sheet 2 of 3)

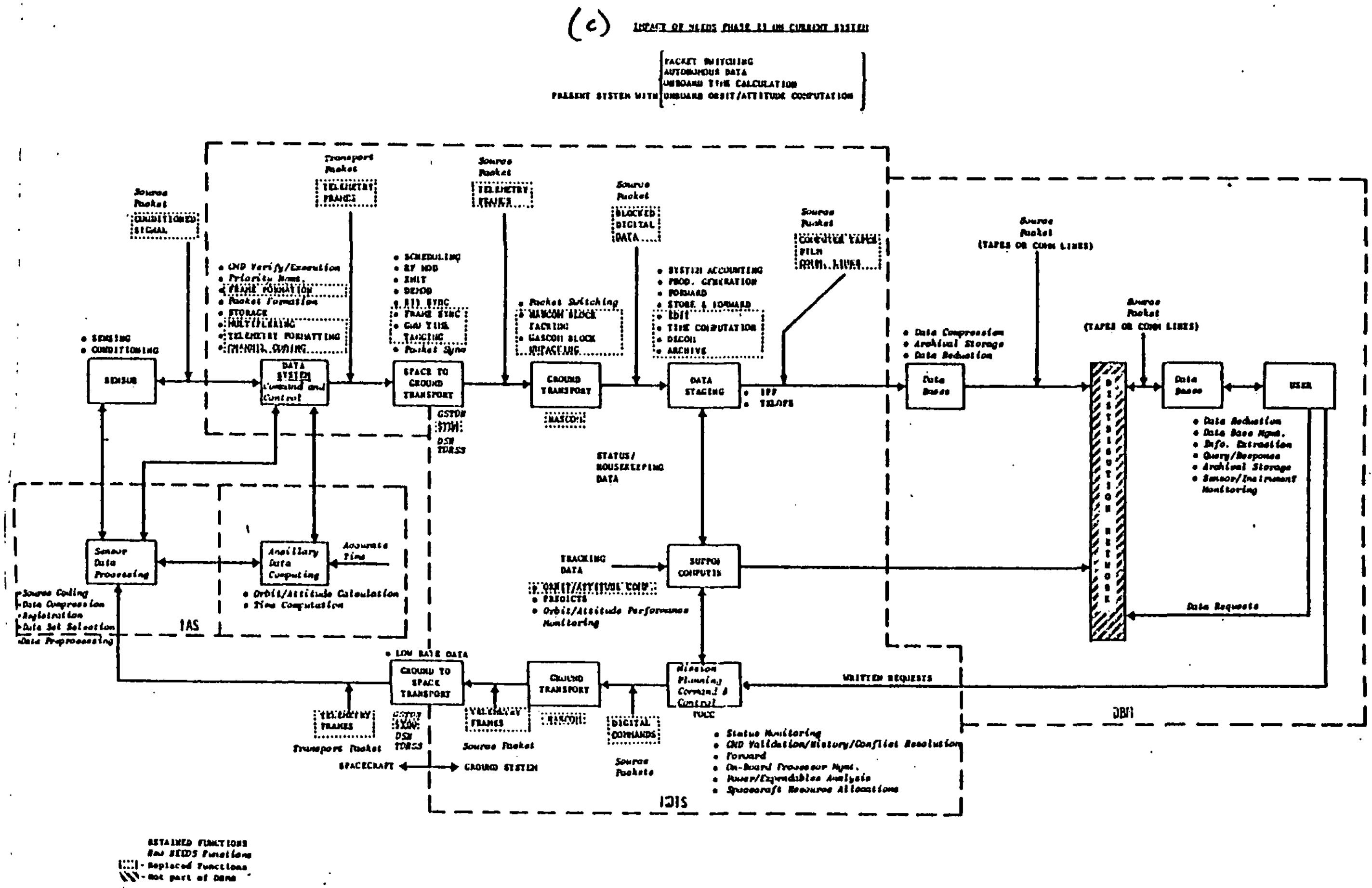

Figure 1-2. Relationship of NEEDS Elements to NASA Data Handling and Management System (Sheet 3 of 3)

factor of 100, and reduce the support costs for the system by a factor of 10. Successful accomplishment of these goals is essential to NASA's ability to support missions planned for the future.

SECTION 2. NEEDS PHASE 2 SURVEY

SECTION 2. NEEDS PHASE 2 SURVEY

2.1 SURVEY OVERVIEW/METHODOLOGY

The Systems Analysis and Integration Team, part of NEEDS, is performing a continuing analysis and evaluation of the data/information system in order to assess and monitor progress of the NEEDS program and isolate problem areas which need special attention from management, systems considerations, or technology development. This activity provides the systems analysis and performance evaluation of the present system, systems under development, or proposed end-to-end data/information systems. The analysis will be used to guide the program toward the development of advanced techniques and technology solutions. Systems definition and integration and demonstration plans required between any of the other program elements will be provided by this element. These other program elements are:

a. Information Adpative Systems (IAS)
b. Massively Parallel Processor (MRP)
c. Modular Data Transport Systems (MDTS)
d. Data Base Management Systems (DBMS)
e. Archival Mass Memory (AMM)
f. Ancillary Data and Support Computing (ADSC)

2.2 NEEDS ELEMENT EXAMINATION

This subsection presents the results of the NEEDS element examination. For each of the elements the following four broad categories were used to assemble the data:

a. Program Objective
b. Technology Activities

c. Element Interface

d. Demonstration Activities

Table 2-1 provides a brief look at the results.

In the preparation of this section of the report on the existing and planned NEEDS elements the following criteria were used to guide the examination and assessment efforts:

a. The objective and approach of this element.

b. Relevant technology, requirements, existing candidate technologies, trade-offs made and advancements needed.

c. Available survey or comparison data, and other related NASA efforts underway.

d. Conclusions reached and what future plans exist.

e. Inter-element association.

f. Capabilities demonstrated.

g. Element status.

Although all of these were applied to each area of study, some characteristics remain unknown due to the immature nature of some elements and lack of available documentation for others. The final draft of this report will incorporate any new information developed in the interim.

2.2.1 INFORMATION ADAPTIVE SYSTEMS

2.2.1.1 Program Objective. The primary objective of this technology element is to develop and demonstrate onboard capability for data sets selection and adaptive processing of sensor data. Electronic and optical processing components will be explored as candidate technologies for implementation of the concept. Figure 2-1 presents an IAS conceptual view.

Table 2-1. NEEDS Element Status

	IAS	MPP	MDTS	DBMS	AMM	ADSC	SOFTWARE TECHNOLOGY*
CONTACT	GSFC Tom Taylor LaRC Bill Howle	GSFC Dave Schaefer	GSFC Ray Hartstein JPL Don Lord	GSFC Pat Gary MSFC Doug Thomas Al Bailey	MSFC Al Bailey	GSFC Art Fuchs	GSFC Tom Taylor LaRC Ed Fundriat
CONTRACTS	Kenyon CSC 11/1/80	Goodyear 1979	JPL 1979	N/A	Harris 1979	N/A	N/A
CONCEPTUAL DOCUMENT	BTS Study (Interim)	Goodyear MPP Final Report Phase I	Incomplete	4/1/80 In review	Preliminary AMM/DBMS ICD AMM Doc. Plan	Concepts DOC May 1980	N/A
FIRST DEMONSTRATION CAPABILITY	7/82 Radiometric Calibration Geometric Correction	9/82 NASA Reqs (5)	12/80 Packetizing Packet Queuing Frame Gen. Data Capture Data Staging	1982 50 MBS Data Flow w/AMM Archiving	6/81 Measure: BER File access Storage transfer rate Data replication	Concepts Demo No Date	N/A

*Interelement developments.

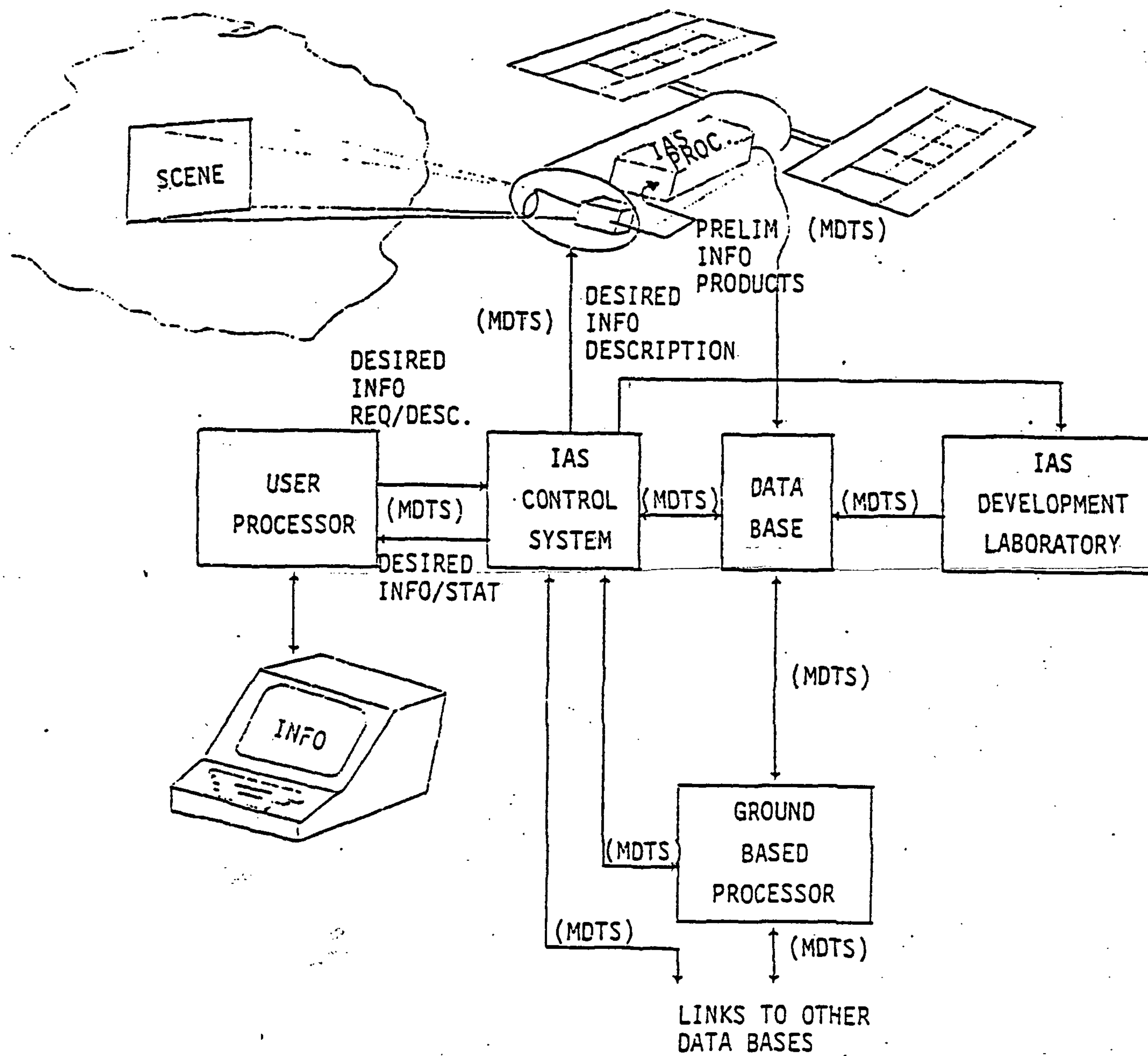

Figure 2-1. IAS Conceptual View

2.2.1.2 Technology Activity. There are five major contributions which IAS can provide for NEEDS. These are:

a. Data volume reduction.
b. Timeliness in response.
c. Adaptation to events which occur during sensing.
d. Adaptation to the changing requirements of the user community.
e. System modularity and standardization.

These factors provide the basis for the following system requirements:

a. Radiometrically and geometrically correct data to be generated by the sensor system.
b. Onboard emphemeris determination and maintenance is to be achieved.
c. The facilities of MDTS are to be utilized wherever possible.
d. Data sets are to be selected through geographical region specification.
e. Autonomous algorithmic image processing is to be utilized to the greatest extent permitted by the state-of-the-art.
f. There is to be a flexible user interface to the system via MDTS.
g. There is to be onboard cloud detection and data deletion.
h. There is to be onboard pixel classification at Levels I and II.
i. The system will perform the signature tracking necessary to permit autonomous classification to take place.
j. The system will provide for target identification and tracking between periods of observation.
k. The system will provide an on-line long and short term data base.

Additionally, there are four long term IAS requirements:

a. Adaptive resolution sensor.
b. Efficient autonomous image processing algorithms.

c. Relational data base management system to support a base of 10^{15} bits.

d. Dialect tolerant image processing language.

A study was conducted by IBM of four architectural approaches capable of implementing the IAS functions. The approaches include:

a. Custom Designed Computer
b. Federation of Functional Processors (FFP)
c. Distributed Microprocessor System
d. Distributed Signal Processor System

The last three approaches all represent a distributed architecture with the FFP having a high level of logic integration at the processor level. Much interest is currently focused on the last two distributed approaches due to a potential for lower overall system cost coupled with high system fault tolerance.

The distributed signal processor system best suits the IAS high throughput requirements. Key to the design of any distributed architecture is the interconnection or busing structure and the available system functions among several processing elements. The Future Signal Processor (FSP) is representative of the system architecture best suited to IAS requirements.

GSFC is studying various algorithms suitable for best demonstrating IAS concept development in radiometric calibration and geometric correction. Kentin and CSC contractors are working in support of the in-house software.

Langley Research Center (LaRC) is studying hardware concepts needed for radiometric calibration and geometric correction. Texas Instruments, Inc. is studying charge coupled devices approaches to radiometric correction. TRW is continuing to develop geometric correction software.

A breadboard table look-up approach to radiometric calibration was completed and tested at 5 megasamples per second. Design goal is 15 megasamples per second.

Future actions include the following:

a. A restructuring of GSFC IAS efforts is underway.

b. The IAS conceptual document will be completed.

c. A contractor selection for the IAS demonstration will be made about November 1, 1980.

d. A recommendation for extending IAS demonstration into FY83.

e. Current goals are to design a brassboard hardware applying state-of-the-art technology within a 2-year implementation period.

Figure 2-2 presents an IAS spacecraft implementation block diagram.

2.2.1.3 Element Interface. The IAS developed technology will be integrated with that of MDTS, MPP, and DBMS. Because of slips in the MPP element schedule, the 128 x 128 version will not be available for an integrated demonstration. However, GSFC is proposing the use of an in-house developed 32 x 32 version.

2.2.1.4 Demonstration Activities. An engineering model demonstration is planned for July 1982 (see figures 2-3 and 2-4) at LaRC. It will feature radiometric calibration and geometric correction concepts including data set selection and packetization functions. It will be a closed-loop data system in that test support and demonstration equipment will simulate both multispectral sensor output and output buffers interfacing.

At the current time no significant technological advancements are expected at the demonstrations, only technological concepts will be validated.

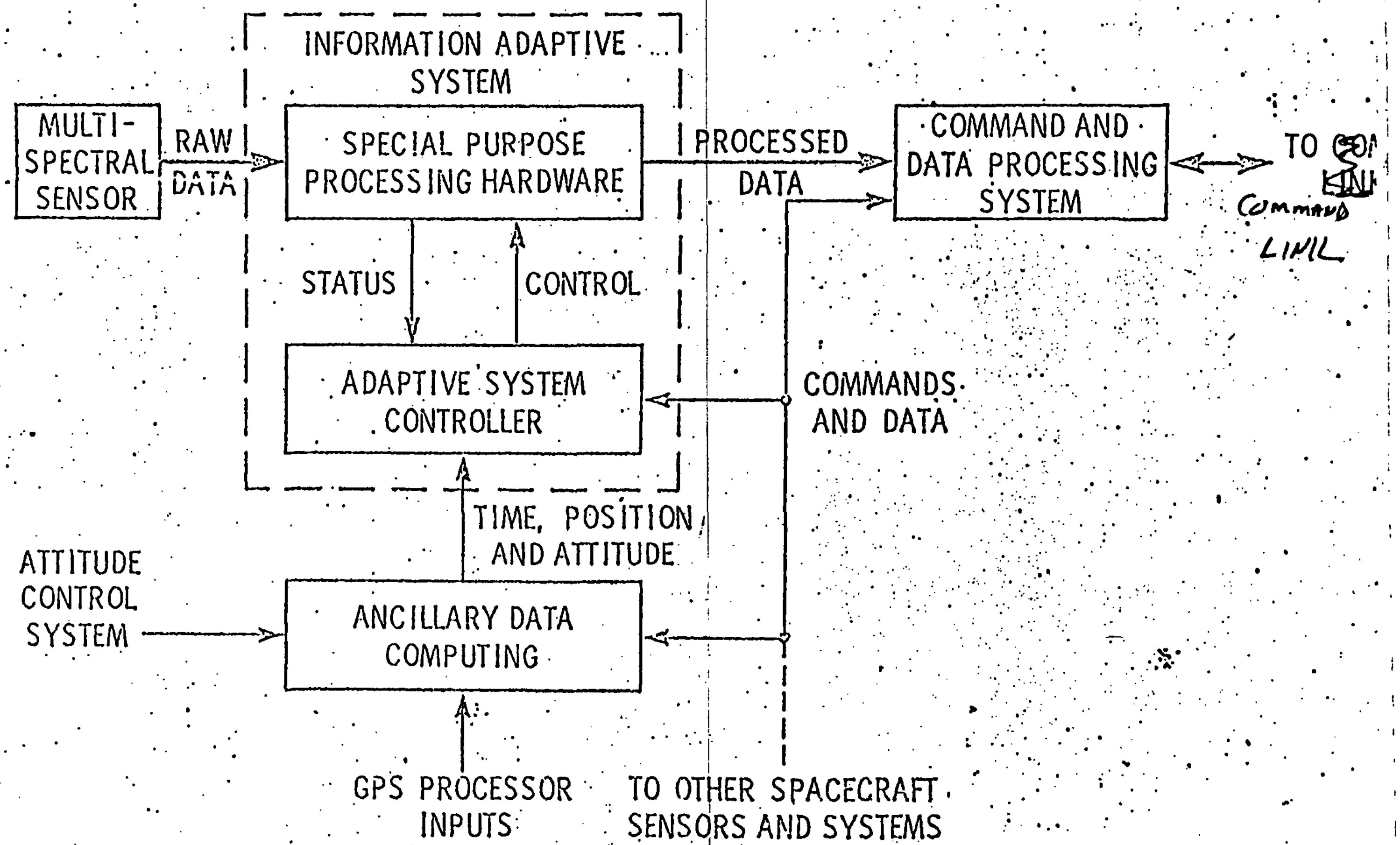

Figure 2-2. IAS Spacecraft Implementation Block Diagram

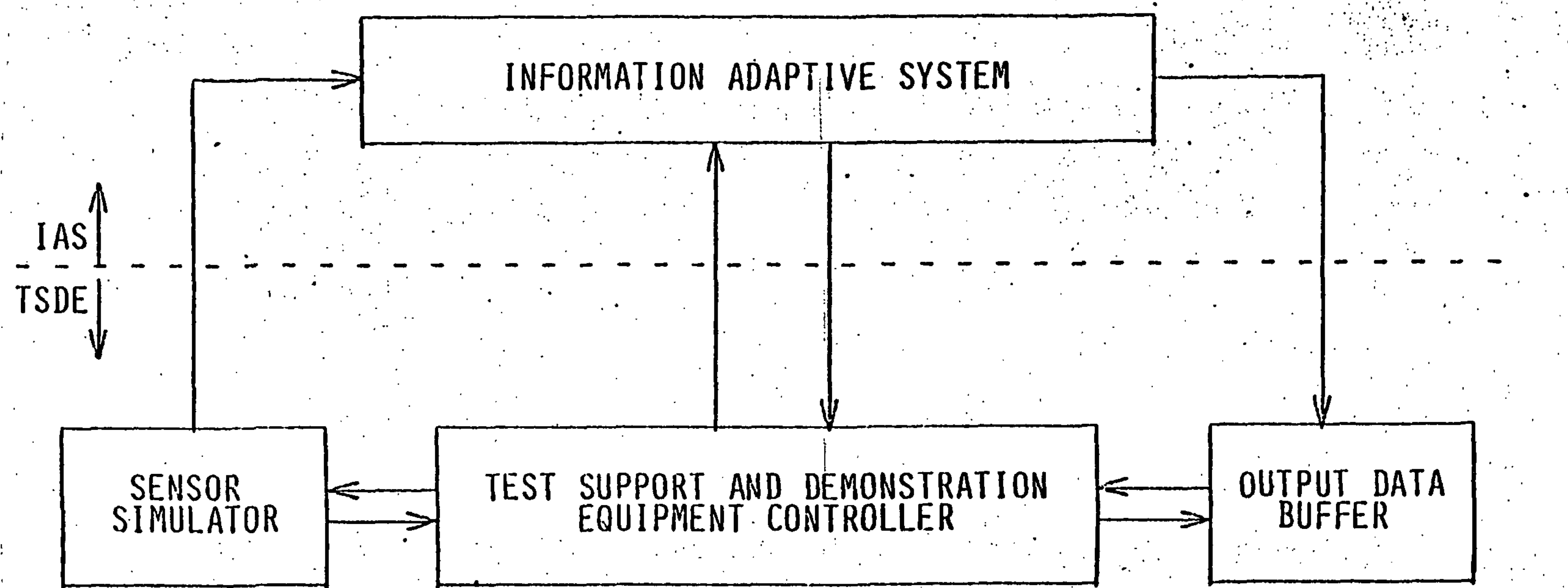

Figure 2-3. Information Adaptive System Demonstration Configuration

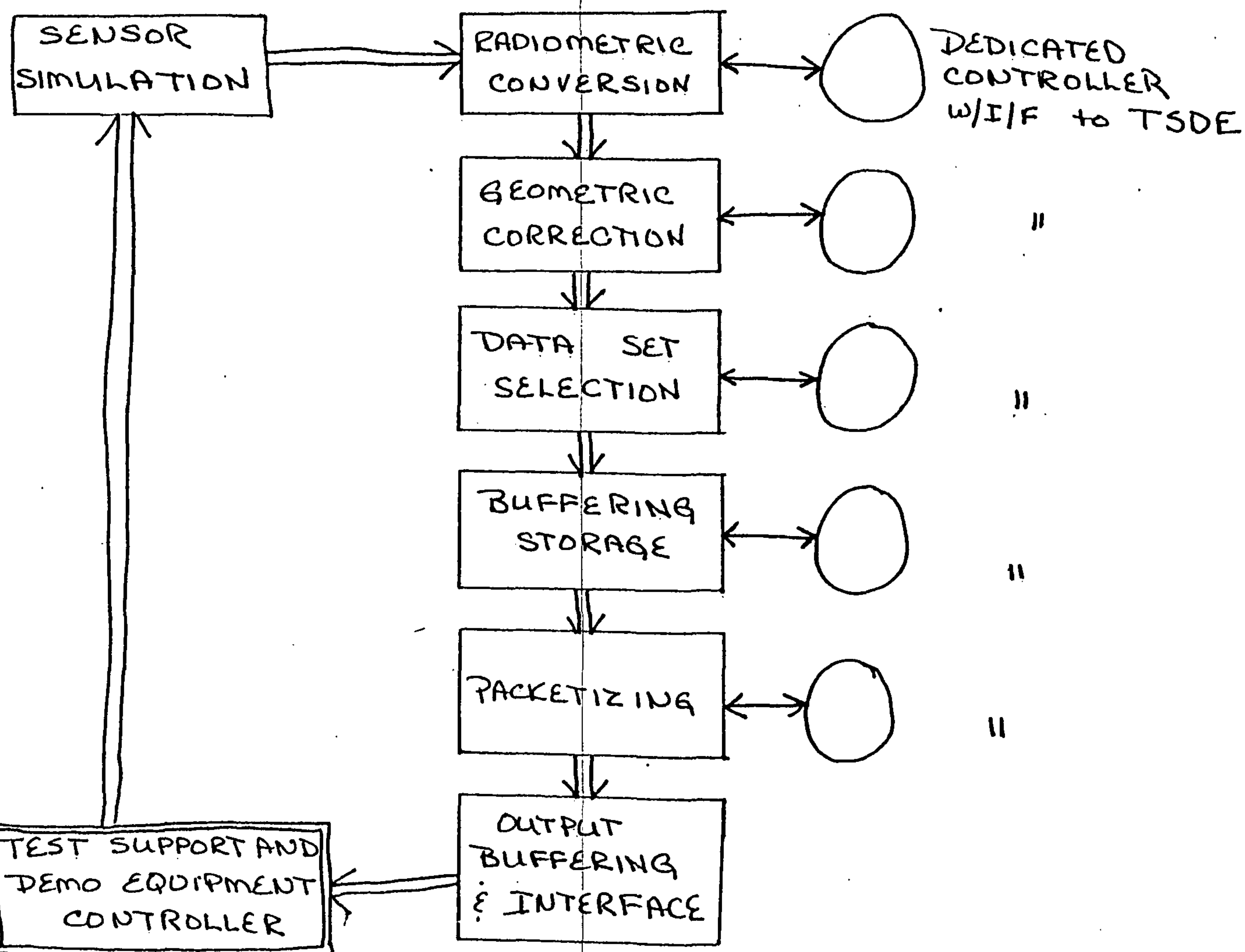

Figure 2-4. IAS Demonstration Functional Configuration

The demonstration will be a ground demonstration in a laboratory environment. However, engineering model hardware will be used which will take flight requirements into consideration but will not be flight-qualified hardware. Although complete end-to-end data flow in real time with other NEEDS Phase II hardware elements will not be possible with this demonstration, the high data rate throughput and processing capability of the IAS will be demonstrated.

The simulated sensor input will be a high-speed disk/high-speed semiconductor RAM buffer, which can be loaded with data from Landsat tapes and/or special simulated data input. These data are then output to the other IAS hardware through the sensor electrical interface at high data rates consistent with planned multispectral sensors of the mid to late 1980's.

2.2.2 MASSIVELY PARALLEL PROCESSOR

2.2.2.1 Program Objective. The objective of this program element is to build an image processing system known as the massively parallel processor that will perform logical operations at an effective rate of 10^9 operations/second with potential to 10^{10} operations/second.

These high speeds will be attained by simultaneously operating with 16,384 modular computers that are arranged in a 128 x 128 array. As many as four modular computers will be fabricated on one silicon chip.

Each processing element will contain a 1024 bit array memory. The MPP is expected to perform the following arithmetic operations:

a. Six billion 8-bit additions and subtractions per second.
b. Two billion 8-bit multiplications per second.
c. 430 million 32-bit floating point adds/sec.
d. 216 million 32-bit floating point multiplies/sec.

2.2.2.2 Technology Activity. For requirements, NASA has developed five algorithms which are used to provide an indication of machine types needed but which is technically feasible: They are:

a. Cross correlation
b. Extraction of maximum value
c. Multispectral classification
d. Nearest neighbor binary rotation
e. Image resampling

The only commercial product competing in MPP technology is built by International Computers Ltd. (ICL); they have 32 x 32, 64 x 64, and claim to have a 128 x 128 capability soon.

The GSFC/Goodyear MPP has two serious drawbacks:

a. It cannot do serial problems.
b. It does not handle long word lengths well.

Goodyear has researched the feasibility of applying the MPP to Synthetic Aperture Radar (SAR) digital processing (see subsection 2.3).

Interim results of the Goodyear study on the MPP for SAR digital processing indicate that the MPP could easily become the most cost-effective solution for NASA SAR applications.

Goodyear's effort indicate that:

a. The MPP can service multiple sensors.
b. The MPP is easy to reconfigure.
c. The MPP/SAR implementation is well adapted to subsequent image processing including image enhancements techniques, target detection and classification.

Table 2-2 illustrates via comparison the uniqueness of MPP technology.

Table 2-2. MPP Comparison

PROCESSOR	DEVELOPED BY	SPEED (MI/S)	MEMORY (MBITS)	DEVELOPMENT TIME (YEARS)	TECHNOLOGY DATE
SAPPHIRE	GOODYEAR	4300	36	3	74
HIRSADAP	GOODYEAR	1000	3.5	3	71
FLAMR	HUGHES	1	0.2	6	66
PROTEUS	IBM	50	2	3	72
STARAN 4 ARRAY	GOODYEAR	64	9.6	3	70
ILLIAC 4	U OF ILLINOIS AND BURROUGHS	1000 256 15	24 8 8	5 TO 6	66 – OBJECTIVE 70 – REVISED OBJECTIVE 76 – ACCOMPLISHMENT
STAR	CDC	256	8	6	70
7600	CDC	5 TO 10	16	3 TO 4	70
MPP	GOODYEAR	4000	16	2	80

A comprehensive study on array processors is available from Mitre Corporation (Document No. MTR-79W00305). This is the only NASA-sponsored study/development effort underway.

The MPP is initially aimed at demonstrating a ground-based state-of-the-art image processing system. The ultimate effort from a NEEDS prospective is its applicability to image processing aboard the S/C. This is expected by the late 1980's. Studies have considered MPP use on Landsat-D but no current implementation plan exists.

2.2.2.3 Element Interface. The in-house (GSFC) 16 x 16 version will not be available for the IAS demonstration.

2.2.2.4 Demonstration Activities. A demonstration will be conducted by the contractor, Goodyear, in September 1982. The demonstration will address the requirements stated above. Figures 2-5, 2-6, and 2-7 represent the various components of MPP technology.

2.2.3 MODULAR DATA TRANSPORT SYSTEMS

2.2.3.1 Program Objective. This program element will develop and demonstrate an integrated modular data transfer system which will provide onboard adaptive sensor sequence control, computational capability for onboard data handling, processing, and simplified spacecraft data control and data transfer interactions for multipurpose, multisensor experiments and payloads. The onboard data system utilizes a distributed microprocessor LSI architecture. The ground data transfer and processing portion of the data transport system will be developed, to take advantage of the special capabilities of the onboard portion of the system.

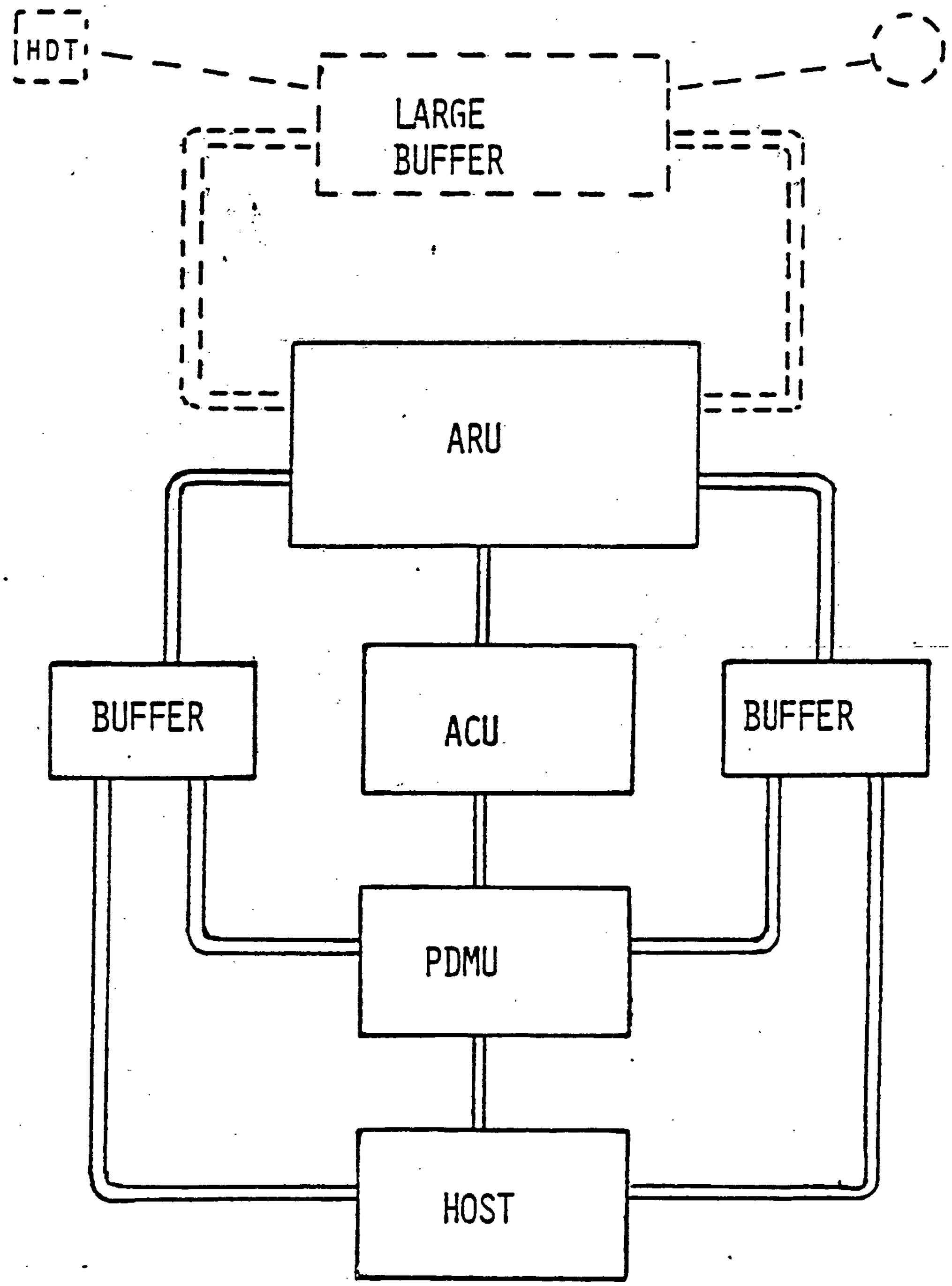

Figure 2-5. Basic MPP System Structure

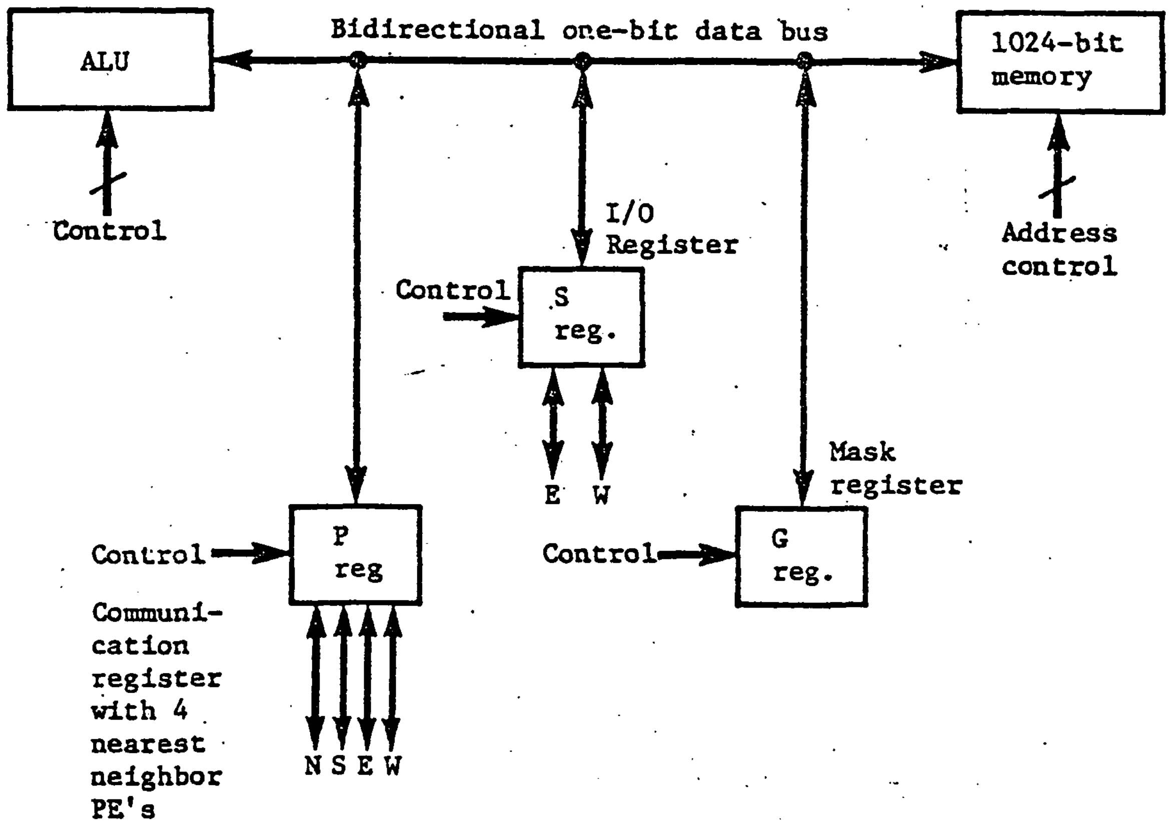

Figure 2-6. Single MPP Processing Element

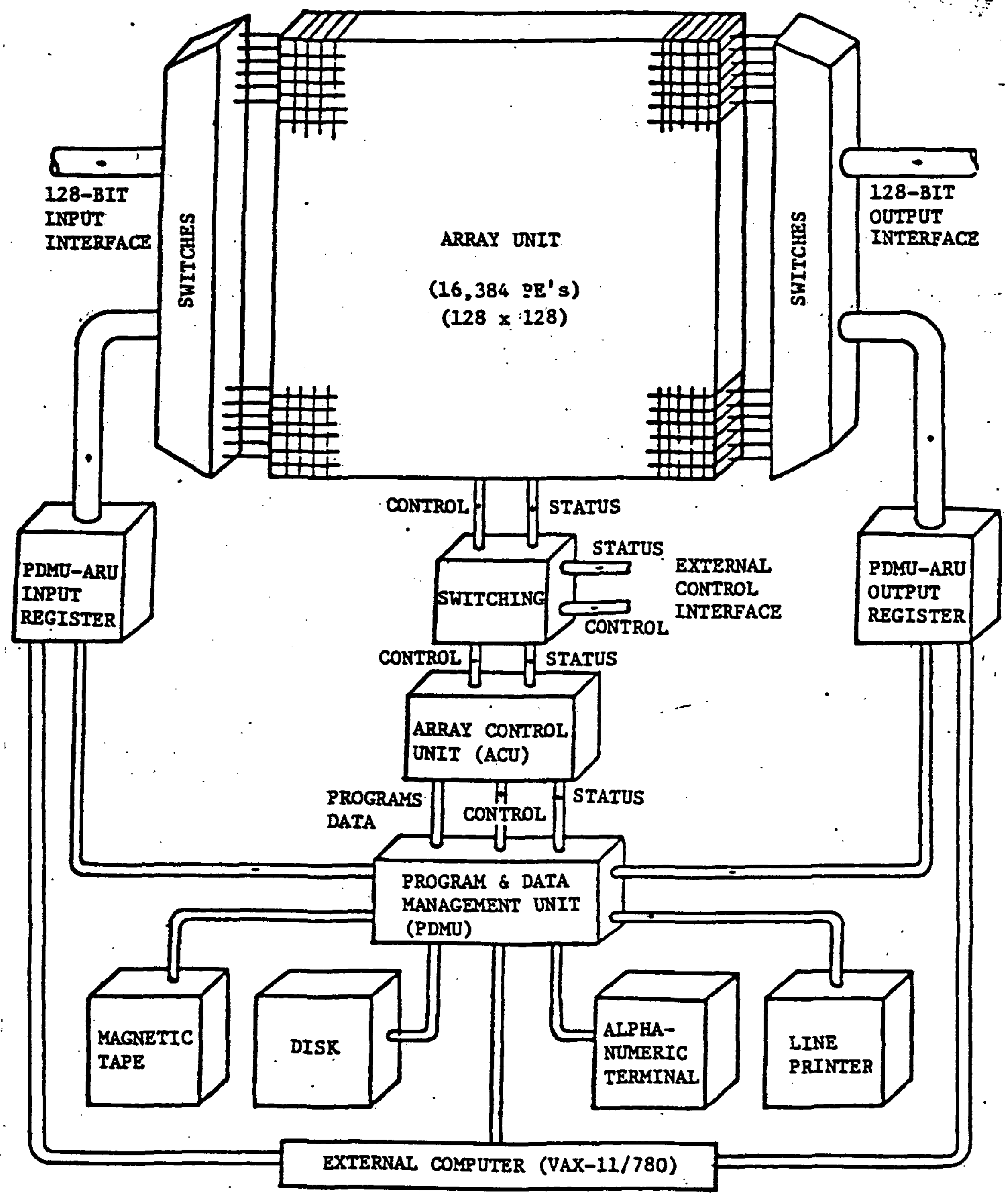

Figure 2-7. Basic Goodyear/NASA Design

2.2.3.2 Technology Activity. At the time of this report, a concepts document was not available, however, some concepts supporting this element include:

a. Instrument Telemetry Packet (ITP)
b. Packetizing
c. Data Staging
d. Packet Queuing
e. Fault Tolerant Building Blocks

The MDTS includes the following functional elements:

a. A downlink consisting of:

    (1) Command and Control/Data System (onboard)
    (2) Space-to-Ground Transport
    (3) Ground Transport
    (4) Data Staging (includes data accounting)

b. Uplink consisting of:

    (1) Ground Transport
    (2) Ground-to-Space Transport

Figure 2-8 shows MDTS functional elements.

a. Instrument Telemetry Packet (ITP). As a replacement for the conventional mtuliplexed telemetry frame approach, the ITP concept basically requires that the telemetry data from a single spaceborne instrument or spacecraft subsystem be temporarily assembled containing only the data from a single instrument along with any required ancillary data (spacecraft clock, reference voltages, spacecraft and instrument control states, parity check bits, etc.) necessary for the validation, calibration, and cross-linking of this data

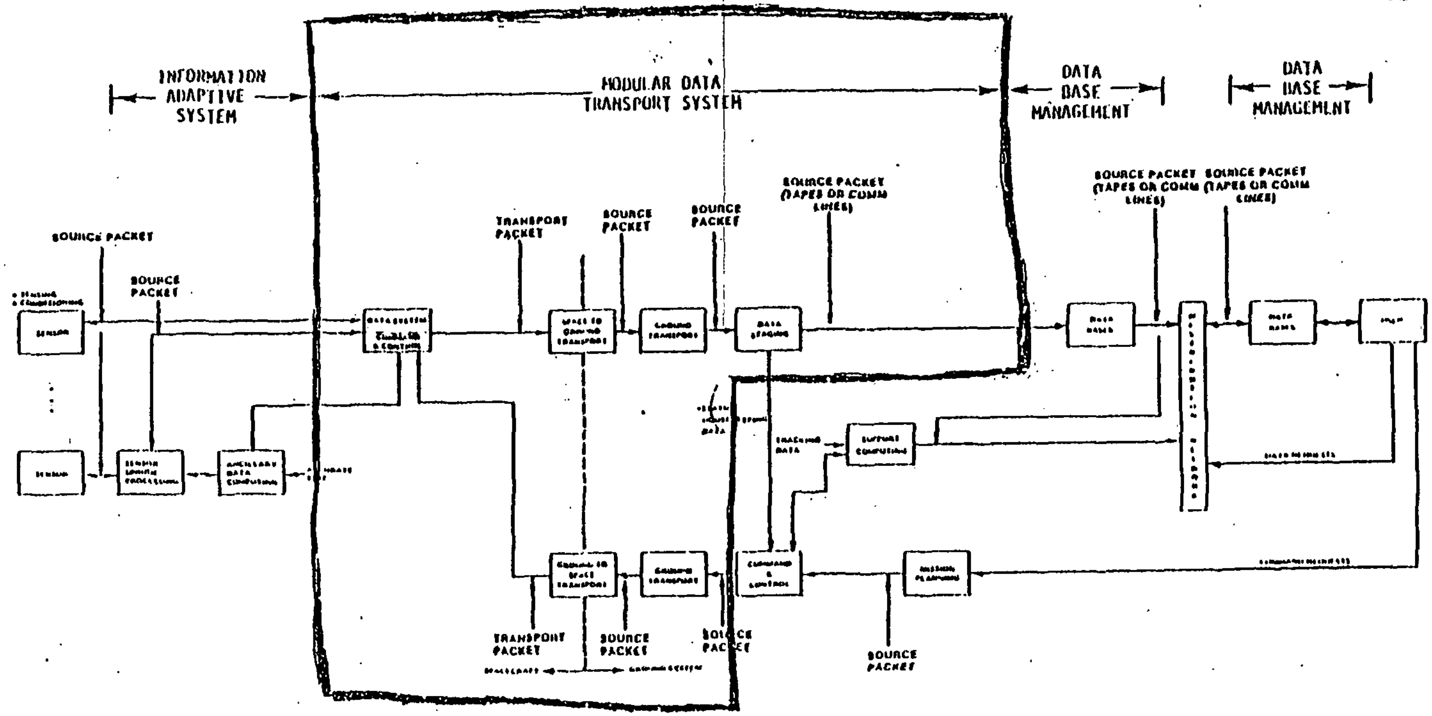

Figure 2-8. MDTS Functional Elements

with other subsequently derived data sets (i.e., corrected time, position, and attitude). In the not too distant future it will be possible to generate and insert corrected time, position, and attitude directly into an ITP. Each ITP should be a stand-alone element containing all the data necessary for the validation, calibration, reduction, and interpretation of one or more experimental observations from a single instrument. Even a few years ago the ITP concept described herein would have been impractical due to the resulting complexity, cost, and power requirements. Now, with the emergence of powerful low-cost microprocessors and associated semiconductor memories, this concept is technologically feasible.

The need for such a technique centers around the principle that the integrity of the observational data can best be ensured by encoding this data into a reliable transmission unit immediately at the source. Many of the problems and frustrations experienced within the telemetry data processing operations originate because the basic integrity of the sensor data is compromised before it reaches the processing site, thus necessitating complex andussually only partially successful recovery procedures.

Three important advantages of the ITP concept:

(1) A high-level source encoding function is provided to improve the integrity and autonomy of the resulting observational data.

(2) For the first time it frees the instrument designers from the shackles imposed by a synchronous telemetry system.

(3) The need to perform any mission and/or instrument-unique processing at any intermediary step within the overall processing cycle is eliminated.

Each of these features will have a profound effect on the overall mission data management.

b. Packetizing. A packet telemetry system employing correction by retransmission control is believed to be a viable candidate for telemetry transmission from near-Earth satellites operating through the TDRSS in the 1980's.

A packetized telemetry system's unit of transmission of space acquired data to the ground would be a telemetry packet containing sensor data from only a single instrument along with the possible inclusion of the ancillary data (time, position, attitude, etc.) needed for the interpretation of this instrument data. This is in contrast to the conventional mode of telemetry operation in which sensor data from all instruments and spacecraft subsystems are word-multiplexed within a telemetry frame format, and subsequent ground processing is required to demultiplex this data into the individual data sets associated with each source.

Some of the principal advantages of this system are:

(1) Improved source encoding of instrument data.

(2) Better bandwidth allocation on the basis of current instrument requirements.

(3) Improved communications efficiency while virtually eliminating all errors in the telemetry link.

(4) Faster distribution of instrument data to the users.

(5) A significant reduction in the ground processing and distribution costs relative to that required by a continuation of present methods.

While the system requires an increase in the onboard data system complexity, the system is well within the current state-of-the-art of digital system technology.

c. Data Staging. Data staging in the NEEDS/MDTS concept is an identified grouping of functions all or some of which must be performed for/by each data user. Physical association of these functions is not a requirement; that is, data staging may be centralized, distributed, mission unique, or some combination of these options.

Data staging is the interface between the data acquisition network and the user (or main data base) distribution network. As such it provides user data selection and rate smoothing (so that user links do not have to be sized to the peak transmission rate of the spacecraft), and communications protocol conversion between the two networks.

Data staging includes a data capture function which provides a short term (nominally 48 hours) data base to provide a major point of protection against data loss (the first point, in the TDRSS mode) and to support the other data staging functions of data preparation (tape recorder data reversal, redundant data deletion and data cataloging), product generation and system accounting.

A ground-based data staging effort to support the MDTS demonstration (see below) is being developed at GSFC under B. Jones.

d. Packet Queuing. The concept of adaptive packet queuing with bandwidth selection is being examined with the JPL activities mentioned below.

e. Fault Tolerant Building Block. The primary constraints on the onboard computing system are the requirements for long unattended life and severe restrictions on power, weight, and volume. Reliability is the most severe constraint which affects the computer architecture in several ways. In most cases, only proven (5 to 10-year old) technology can be used to minimize the chance of unexpected failure modes. Parts are extensively tested and screened for reliability, driving their cost to 10 or more times those in commercial market place. Redundant processors, memories, and input/output (I/O) circuits double or triple the amount of hardware that is used. Thus, reliability requirements induce the majority of costs for onboard computing.

The JPL program (a major contributor to NEEDS technology) in fault tolerant computing has had two major parts. The first was the development of a fault tolerant uniprocessor designated the JPL self-testing and repairing (STAR) computer (1961 to 1972). It was aimed at the flight technology of the early 1970's (e.g., bipolar SSI/MSI and plated-wine memory). A breadboard STAR computer was constructed and tested in 1970 to 1972.

The second part of this program was started in 1973 to develop fault-tolerant distributed processing systems, and is a continuing program. The development of low-power high density microprocessor technology has allowed the replacement of an expensive shared computing resource with small computers placed where they are needed in a number of subsystems and science experiments.

The problems of complexity, software reliability and hardware fault tolerance have been addressed, and a breadboard distributed computing system has been constructed and used to emulate a number of spacecraft computing functions.

Today both the knowledge and the technology exist to build highly reliable computers at only small penalties of size, weight, and cost. The reliability of these computers is achieved through a redundant or fault-tolerant architecture. VLSI technology provides the capability of putting large amounts of circuitry in small and inexpensive packages. By using a standby redundant architecture in which unpowered elements of the computer are spare, computer system reliability can be improved in increments by adding spares. The long term potential result is systems which are sufficiently reliable, that they do not require technician or logistic support for the life of their mission. In the shorter term, systems can be built which utilize a highly reliable core computer which can significantly aid in the diagnosis and maintenance of the entire system.

Fault tolerance is the ability to continue correct operation in the presence of failures. Self-checking circuits are capable of detecting their own malfunctions. Study has resulted in the definition of four VLSI circuits which allow the construction of a single or a distributed fault-tolerant computer system. The four building-block circuits are: (1) an error detecting (and correcting) Memory Interface, (2) a programmable Bus Interface, (3) a core Building Block, and (4) an I/O Building Block. These circuits interface with two commercial microprocessors and commercial memory to form a Self-Checking Computer Module (SCCM).

In short, the important attributes of this building-block approach to fault-tolerant computing are:

(1) Using the four VLSI building blocks, Self-Checking Computer Modules can be constructed from a variety of commercial microprocessors and memories.

(2) The self-checking property of the SCCM allows these machines to instantly detect and signal internal faults, thus, allowing straightforward implementation of automated recovery by backup spares.

(3) Using the SCCM's as building blocks allows the system designer to choose from a wide variety of system architectures. He is allowed full flexibility in the tradeoff between redundancy and performance in adding or deleting computers in the system.

A typical Self-Checking Computer Module is shown in figure 2-9. It provides a computer building block with a great deal of computing power. A 16-bit processor with instruction cycles in the range of 1 to 2 microseconds would be provided along with 32 thousand words of memory.

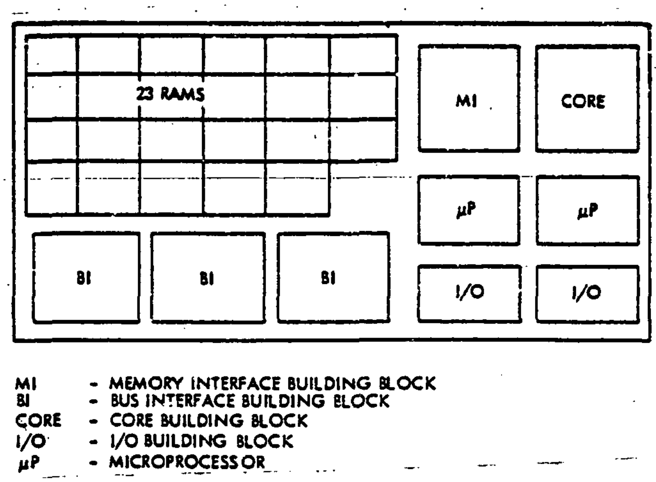

Figure 2-9. A Self-Checking Computer Module

Typical packaging would be a 50-square inch multilayer board containing 23 commercial RAM's and two commercial microprocessors. The building-block circuits are one Memory Interface (MI), one Core circuit (C), three Bus Interfaces (BI), and two I/O devices (IO).

Through the use of LSI, the cost of hardware has dropped to the point where a fault-tolerant computer costs much less than a non-fault-tolerant computer did only a few years ago. Using LSI circuits, the intrinsic reliability of computer systems has improved greatly, but not enough to provide fault-free operation. This is achieved by fault-tolerant, i.e., self-repairing, architectures which offer fault-free operation of a year or more with current technology. The current cost of fault tolerance is on the order of the an extra $10,000 to $20,000 per computer. This is largely due to the cost of the additional high reliability parts which are many times more expensive than commercial quality devices. Current costs may be significantly reduced in two ways: (1) the use of self-testing logic should make them much more easily tested, thus reducing a large production cost, and (2) using fault tolerance less component screening is required since an occasional failure is automatically corrected.

VSLI circuit development is not static and by the mid-1980's there should be major improvements in this fault-tolerant computer technology. For example, we can expect an SCCM to be packaged on one or two chips at a cost of less than $1,000. Components can be expected to be several times more reliable, producing an equivalent increase in the reliable life of the fault-tolerant configurations. One can project conservatively that fault-tolerant machines can be built in a few years which provide 5 to 10 years of maintenance-free operation at less than $1,000 in increased costs.

f. Additional Efforts. An onboard mass memory study is underway at GSFC. The requirements for this device include:

(1) 10^{10} bit capacity memory.
(2) 20 megabit playback to ground.
(3) 20 megabit maximum record rate.

The candidates for this technology study include:

(1) Magnetic bubble
(2) Magnetic disk
(3) Optical Disk
(4) Semi-conductor (CCD, MNOS)
(5) Tape recorder

The conclusions of this study and future actions proposed are summarized below:

(1) All solid state or high potential options to tape recorder involve high risk today.

(2) Technology survey and development.

(a) Complete 10^7 to 10^8 bit survey (1980)
(b) Initiate MNOS unit evaluation for 10^7 -10^8 bit storage (1981)
(c) Complete 10^{10} bit survey (1981)
(d) Initiate development of technology for 10^{10} bit storage (1982)

(3) Continue magnetic bubble research.

(4) Expand optical disc research into onboard applications.

(5) Continue onboard processing research and technology to reduce raw data storage by:

(a) Perform preprocessing (radiometric and geometric)
(b) Data editing and instrument control (eliminate redundant, useless, or unwanted data)
(c) Provide onboard information extraction.

The results of a preliminary data storage survey are shown in table 2-3.

Table 2-3. Data Storage Survey

	MAGNETIC BUBBLE	MAGNETIC DISC	OPTICAL DISC	CCD	MNOS
GROUND-BASED COMMERCIAL	INTEL NAT'L SEMI. ROCKWELL TEXAS INST. FUJITSY	IBM SHUGART PCC MEMOREX CDC CAL COMP OTHERS	DISCOVISION RCA HARRIS PHILLIPS-MAGNAVOX MCA NV PHILLIPS	TEXAS INST. FAIRCHILD	NATIONAL CASH REG. GENERAL INSTRUMENTS NITRON PLESSEY
RESEARCH FOR COMMERCIAL	IBM BELL LABS	NUMEROUS	SAME	FAIRCHILD TI	TI ROCKWELL FAIRCHILD
RESEARCH FOR DOD & SPACE APPLICATIONS	LaRC DOD ROCKWELL SPERRY	DOD	RCA	NONE	DOD WESTINGHOUSE SPERRY UNIVAC ROCKWELL SANDIA LABS

g. Other NASA data storage technology efforts underway include:

(1) Magnetic bubble device research at LaRC for the IAS element.

(2) Optical disk system (for a ground-based archives) research for the AMM element at MSFC.

(3) A survey of memory technology at GSFC.

Once the memory technology study is complete, a recommendation on one or two approaches will lead to a contract award for development.

Associated with these conceptual efforts is a team at GSFC (under IAS leadership) studying protocols and architectures of file optics data bus implementation. The design goal is a 200 megabit bus data rate. A contract will be let soon but no demonstration is envisioned. The technology developed will be applied to packet switching.

Additional developments in spatial data management software and hardware technology include a study being conducted on video and optical disk advancements. Present conclusions imply a capability for a 10^{12} bits capacity with a much improved interactive feature resulting from the optic supported user interface. An immediate application is seen for the shuttle missions. A commercial product is available from Discovision however, it is an analog version.

In digital disk technology, a very low cost media (a write once method) RCA and Philips are developing versions.

In a related element, IAS algorithms are being studied for suitability in developing channel coding technology.

2.2.3.3 Element Interface. Presently no information is available in this element's integration with other demonstration systems.

2.2.3.4 Demonstration Activities. Overall demonstration plans have been determined and documented. A joint GSFC and JPL demonstration is currently scheduled for December 1980 (see figure 2-10). Originally planned as an integrated system demonstration with technological elements from both the IAS and ADSC the necessary interfaces with these elements will be simulated. Features to be demonstrated at the JPL facility test site include:

a. Packetizing using real instrument data provided by tape recorder.
b. Packet queuing.
c. Frame generation.

This packetized experimental data will have frame header generation and be sent over the 56 kbs NASCOM lines to GSFC.

At GSFC, the demonstration will feature data capture and data staging functions. Although not part of the demonstration of December 1980, the data path would conceptually be transferred to the DBMS element at this point for data reduction, compression, and archival storage.

2.2.4 DATA BASE MANAGEMENT SYSTEMS

2.2.4.1 Program Objective. This technology element is responsible for developing and demonstrating a brassboard model of a data base management system with the following features:

a. Improvement in data access time through the use of high speed secondary storage hardware.
b. Distributive processing utilizing microprocessors programmed for data base management functions only.
c. Simpler user-to-data-base interactions through the use of relational data base structure software.

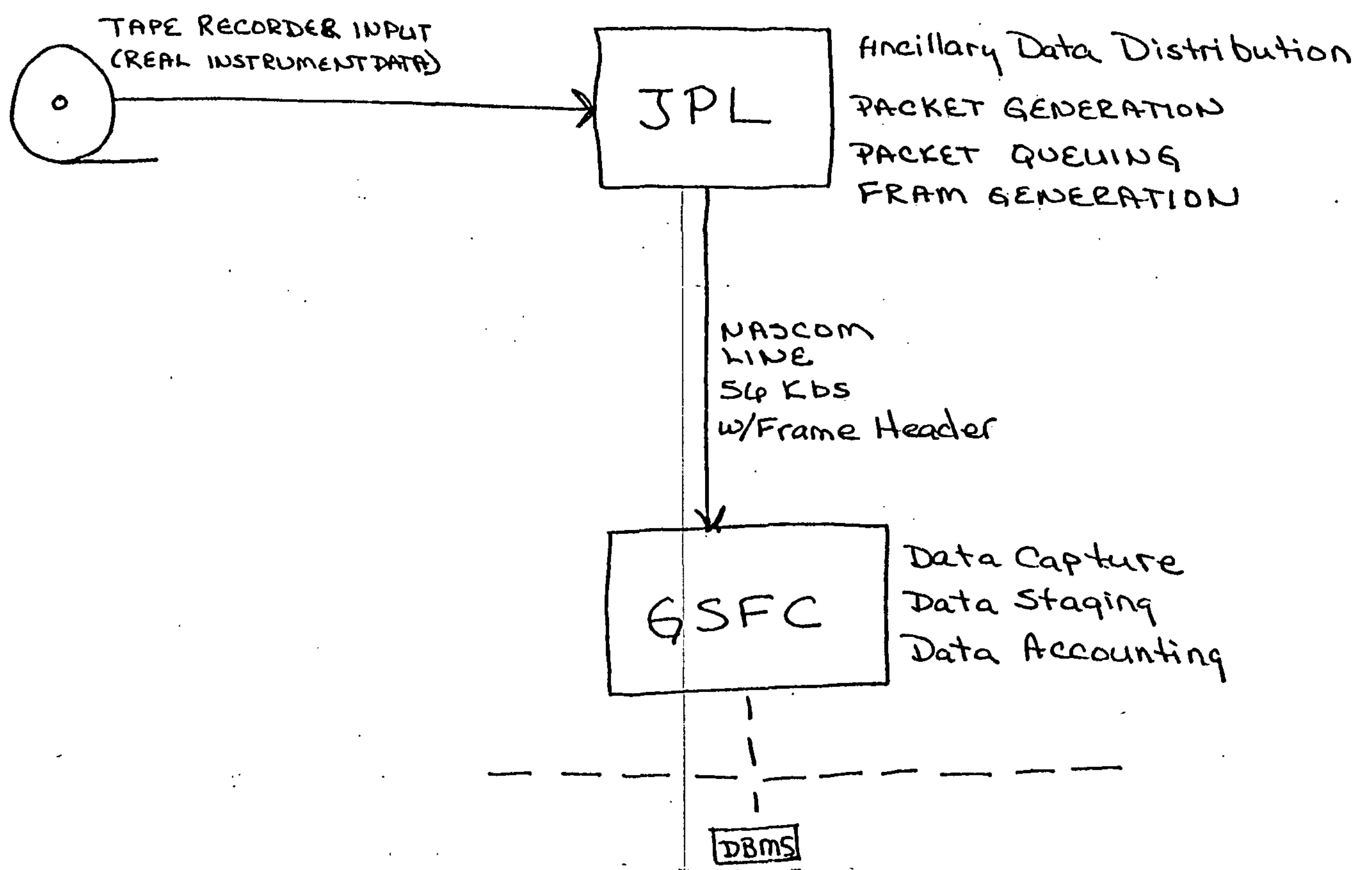

Figure 2-10. MDTS Demonstration Configuration and Capabilities

2.2.4.2 Technology Activity. The technology being developed within this element falls into three distinct areas: (1) GSFC is responsible for the development of a relational data base structure; (2) MSFC is responsible for the development of hardware including fiber optic research for high speed secondary storage (AMM); and (3) distributed processing on advanced microprocessors supporting data base management functions.

The requirements on the data base structure phase include:

a. Flexibility in both off-line and on-line support of user queuing functions.

b. In addition to being a commercially available product the software must be ameneable to modifications required to interface with AMM hardware and software to be developed at MSFC. This includes the DEC VAX 11/780 processor.

Lastly, the DBMS must support access to user data files without format conversion on many storage systems such as tape, disk, or memory.

Towards these goals a survey of commercial packages was initiated and interim results find the number of candidates reduced from an original list of 77 to 16.

The final selection of a DBMS including trade-offs and mods required to implement is to be completed.

A technological test bed will be conducted (prior to the integrated demonstration with elements of MSFC) using as an application the Pilot Climate Data Base Management System. It will be used to resolve technical problems associated with providing unified data management support for multi-parameter, multi-source climate-related data. It will be used to investigate interactive capabilities needed to interface with users and producers of climate data. As a pilot system, it will permit the development of DBMS capabilities that can evolve into a broader NASA climate DBMS.

The PCDBMS will provide comprehensive capabilities but initially will support a limited quantity of data which will be periodically updated and expanded. One aspect of the PCDBMS will be the development and on-going maintenance of a catalog, for system users, describing data sets and their data products.

The technology involved in the development/use of a fiber optics element is that heretofore they have been used in a point-to-point implementation whereas this will be the first application of a fiber optics bus in a computer environment. The fiber optics bus is expected to operate at 100 megabits.

The technological requirements for the AMM are stated in the description of that element (see paragraph 2.2.5).

Presently, the MFSC distributed processing concept hardware configuration includes the use of a triport memory providing two data paths to the AMM, minimizing user access delay time during high rate input of sensor data, and allowing for DBMS/AMM exchange (see figure 2-11).

Planned activity includes the IDBMS selection, the analysis of data sets (OSS) and implementation tradeoffs, the definition of DBMS/AMM interface protocols and physical connection and the definition of all X.25 parameters and packet header formats for the data staging interface.

2.2.4.3 <u>Element Interface</u>. A demonstration of AMM integrated with DBMS is planned for September 1981 although some of the DBMS support will be simulated.

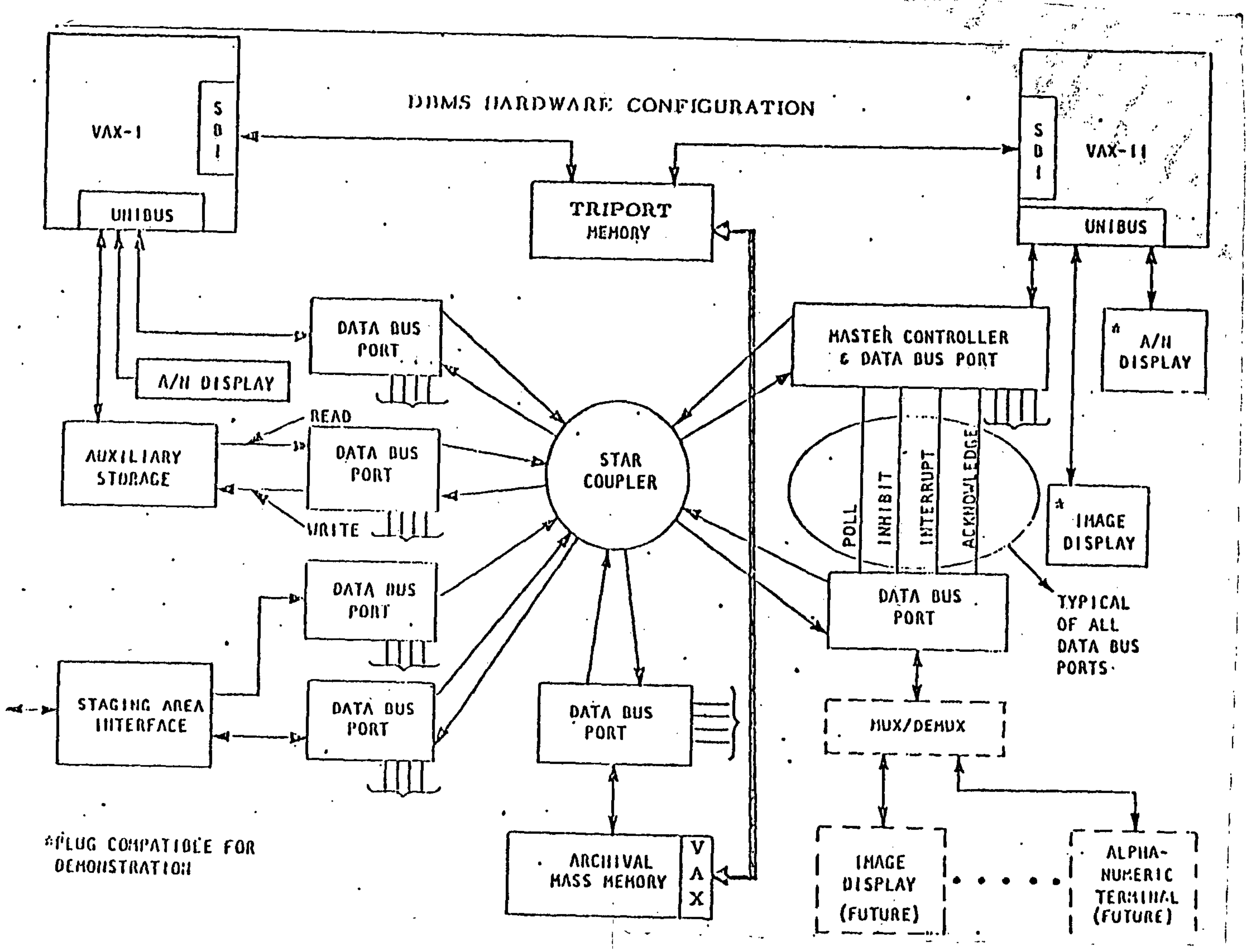

Figure 2-11. DBMS Hardware Configuration

2.2.4.4 Demonstration Activities. A demonstration of the following capabilities is scehduled for the second quarter of 1982.

a. Move data at 50 mbs through the system.
b. AMM integration.
c. Accept sensor data, archive it, create directives with primary and secondary headers and make available to users in a finite period of time.
d. Build a comprehensive directory of all data including ancillary and allow users to interact with.

The demonstration data sets will be selected from both scientific and applications areas. In science, DE, ICEE and Weather/Climate data will be accepted and primary/secondary headers will be constructed. The PI's will do extraction of DE and ISEE data sets.

The Weather/Climate data will have been already processed at GSFC (Pat Gary) and most information extraction will be accomplished here.

Also, the DBMS element staging areas will be transmitting to MSFC. This demonstration may include image display functions.

2.2.5 ARCHIVAL MASS MEMORY

2.2.5.1 Program Objective. The development of an optical mass memory system modularly expandable to a storage and retrieval capacity of 10^{15} bits will be undertaken in this technology element. This system is intended to replace the use of magnetic tape and microfilm used in the archival storage facilities of large data base centers. The system will feature secure archival storage, lower overall storage cost, simplified design and operation, greater reliability, minimization of data maintenance requirements, simplified replication and dissemination, modular software tailorable to meet needs of multiple users, simplified data base management keyed to user needs, compatibility with existing systems, and expandable and cost-effective design and implementation.

2.2.5.2 Technology Activity. The requirements for an archival mass memory device include:

a. 10^{12} bits on-line storage
b. 10^{13} bits off-line expandable
c. Max access time for on-line 15 sec
d. Max access time for off-line 3 min
e. Read/record rate-50 mb/sec
f. Bit error rate 10^{9}
g. Recording density 30 mb/in^{2}
h. Archivability 10 yr
i. Unit record replication

AMM is high capacity 10^{13} photographic film device the only storage medium guaranteed to be archival, uses optical digital spots 2.5 microns each and 1 fiche 160 x 160 mm each of 10^{9} bits.

The anticipated development is the ability to read/write on fiche large amounts of storage data.

AMM provides a large storage system through the VAX systems, 2, VAX 1, and VAX 2 (see figure 2-11) and a resident VAX in the AMM. The concept is to build modular components which can be added on. The AMM interfaces through the triport system and can communicate through a shared memory system.

AMM does own file management but DBMS puts headers on, but AMM can operate independently of DBMS since a constraint on the VAX is the inability to operate at 50 megabits/sec rate.

Harris is developing AMM. They were chosen because they already had sub-components in house from other development areas and so AMM presented a "system problem" but required no new technology breakthroughs.

They had conducted a survey of industry needs which included type, usage rate, and data formats for massive storage requirements. This is why AMM is on-schedule.

Because of the aforementioned, the NEEDS program was timely in providing an application (demonstration) for MSFC technology.

2.2.5.3 Element Interface. A demonstration of AMM integrated with DBMS is planned for September 1981.

2.2.5.4 Demonstration Activities. A factory test is scheduled by contractor in June 1981. A demonstration of AMM integrated with DBMS (September 1981) will verify the design criteria of the hardware, compatibility of hardware and overall system performance requirements. As a minimum, the tests will include:

a. Measurement of corrected BER.
b. Measurement of data file access time.
c. Measurement of system storage capability.
d. Measurement of data transfer rates.
e. Measurement of accuracy of data replication.

2.2.6 ANCILLARY DATA AND SUPPORT COMPUTING

2.2.6.1 Program Objective. To design, develop, and demonstrate Ancillary Data and Support Computing techniques to support the NEEDS program and be consistent with NEEDS fundamental concepts. The ancillary data elements are to include spacecraft orbit, attitude, and universal time for near-Earth and deep space missions. The emphasis is the onboard computation of these parameters. The support computing function is to include the validation and maintenance of data necessary to support the ancillary data module in the spacecraft, and related ground support functions such as the generation of other derived ancillary data and the formatting of that data into standard data packets for distribution by the MDTS.

2.2.6.2 Technology Activity. The technology to be developed within this element includes improved packing densities in LSI architecture, receivers, and advanced microprocessors. Requirements involve the use of all plug-in type ROM's so as to reconfigure for different mission requirements. This adaptability is necessary because of the large spectrum of potential users.

Another requirement is a highly partitioned system which will allow a selection of various RF's with less noise.

Available in November 1980 are four prototype versions of a GPS receiver/processor assembly. Two will fly on Landsat-D and two will go to the DOD. GSFC will study the packing density and miniprocessor technology architectures with an emphasis on modularity and adaptability.

Advancement needed includes development by DOD of improved packing density of LSI technology.

Ground Support Processing for Onboard Ancillary Data, a study conducted by ORI for this element sought to:

a. Define the requirements of forthcoming identifiable missions for ancillary data; timing, orbit and attitude data.
b. Identify the ground processing functions required to support the general onboard timing, orbit, and attitude computation operation.
c. Identify alternative concepts for onboard ancillary data computation and describe the effects on ground support computing.

The following is a summary of suggested conclusions:

a. Attitude history tapes would be eliminated.

b. Less frequent attitude determinations required.

c. For semi-autonomous attitude determination systems (SMM, Landsat-D S/C) ground augmentation of OBC computations will be retained.

d. But for fully autonomous systems (with sufficient memory to store star catalogs) the ground support task would be one of validation only.

e. Orbit data will not have to be merged on the ground with sensor data.

f. With orbit, attitude, and time computed onboard, ground support will no longer have to merge ancillary data with experimenter and spacecraft engineering data.

The future actions of this element will include:

a. Complete draft of ADSC concepts document by April 30, 1980.

b. Initiate design of modular GPS unit in spring/summer of 1980.

c. Initiate top-level microprocessor design and definition studies for onboard attitude computations in April/May of 1980.

d. Continue coordination of onboard TDRSS orbit determination activity with onboard GPS activity.

e. Continue coordination of timing modular with the network time and synchronization activity and the GSFC data systems requirements committee, including JPL personnel in coordination activity.

2.2.6.3 Element Interface. Presently no information is available in this elements integration with other demonstration systems due to a lack of a concepts document defining data protocols, etc.

2.2.6.4 Demonstration Activities. A demonstration will feature a brassboard receiver cumulation which will attempt to illustrate key architectural concepts only. Figures 2-12 and 2-13 show impact of onboard processing on attitude ground support elements.

2.3 SOFTWARE TECHNOLOGY

2.3.1 SOFTWARE VERIFICATION AND VALIDATION - LaRC

As a support effort to ensure highly reliable flight software for ever more autonomous spacecraft and instruments, an integrated verification and validation system for flight software in the HAL/S language is being developed. The system will be based on the most recent research results in verification and validation and will select applicable techniques such as data flow analysis, symbolic execution, dynamic analysis, and executable assertions.

A contract award for this effort will be made in August 1980, with a proposed system demonstration about April 1982.

The MUST system (see figure 2-14) is a conceptual arrangement of compatible software development tools and methodology designed to reduce developmental time and costs, and to enhance the quality and reliability of research flight software production.

The MUST system is being developed by the LaRC and will be hosted initially on the CDC 6000/CYBER machines of the LaRC computer couples (under the Network Operating System - NOS). The system is intended to be generally applicable to NASA flight software development projects and may be installed at other NASA centers on other ground-based host computers.

The V&T system will be applied primarily to flight code written in the HAL/S language. The HAL/S language has been selected and established as an NASA standard language for flight code programming.

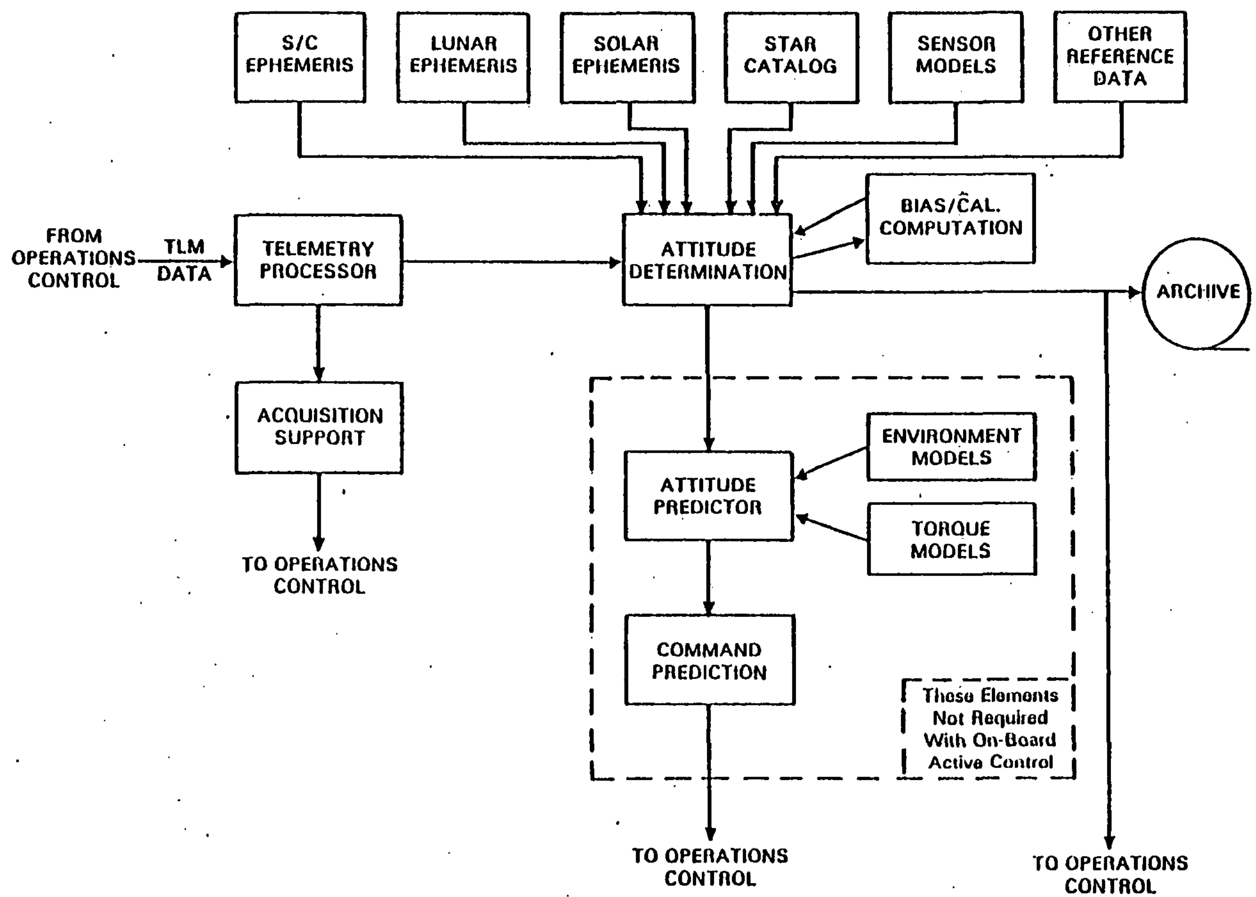

Figure 2-12. Generalized Attitude Ground Support Elements W/O On-Board Processing

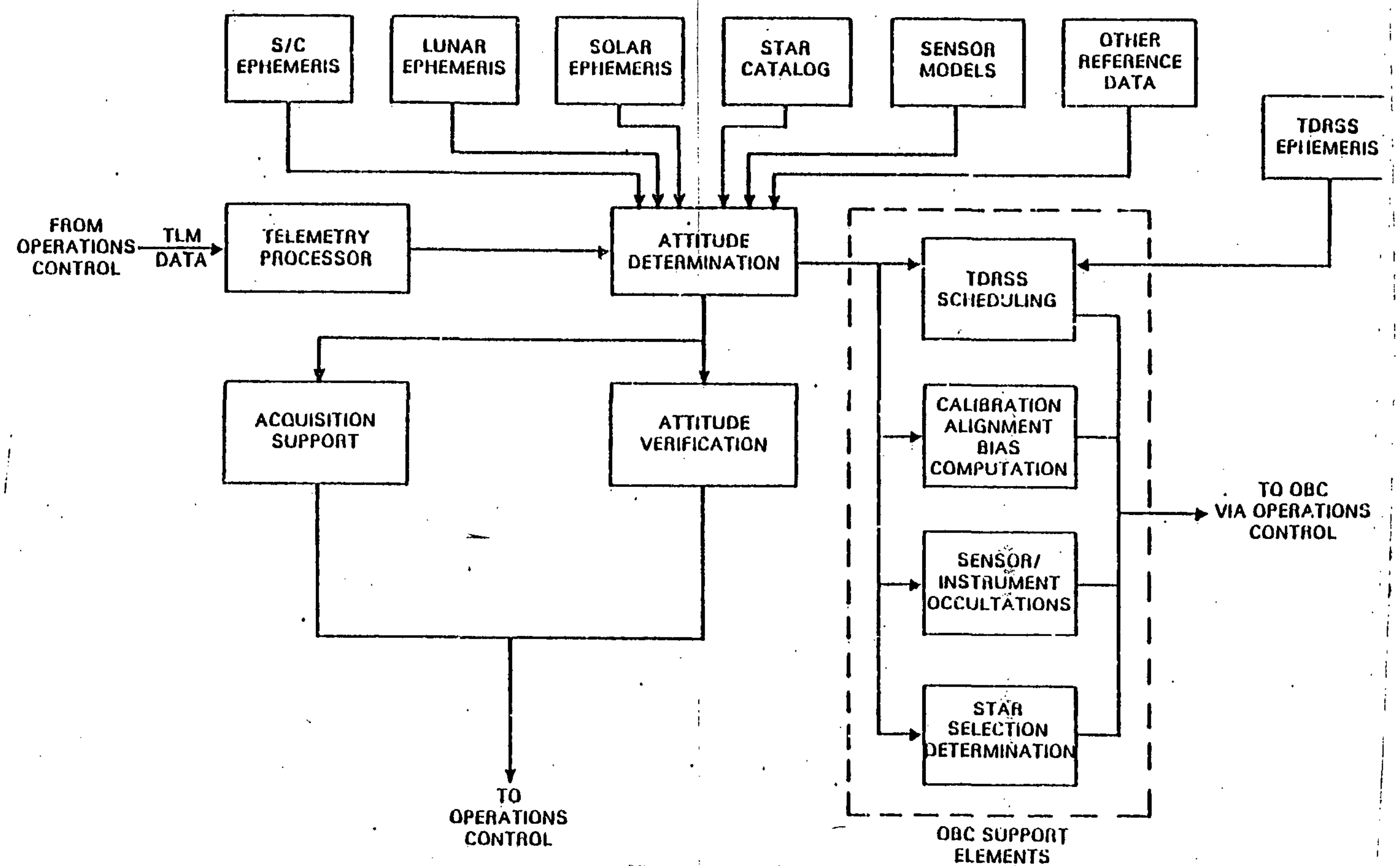

Figure 2-12. Generalized Attitude Ground Support with On-Board Processing

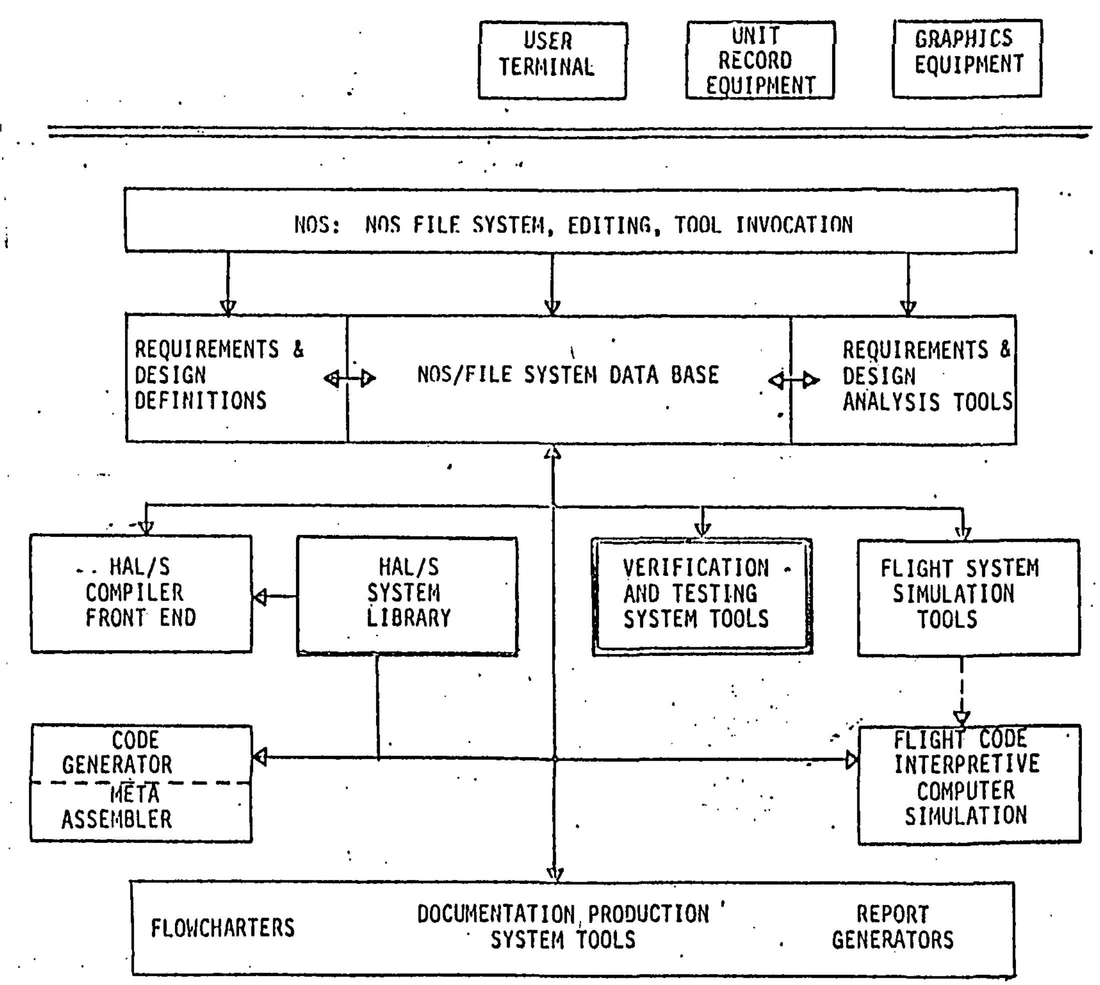

Figure 2-14. MUST System Configuration

The Verification and Testing (V&T) system will be developed and installed on the LaRC computer complex as a set of invokable flight software analysis tools within the MUST system environment. The fundamental purpose of the V&T system tools is to provide the flight code developer (user) with analysis capabilities and assistance in the conduct of code verification and testing.

2.3.2 SYNTHETIC APERTURE RADAR PROCESSOR

An advanced SAR processor is being developed to provide more efficient processing of space-acquired SAR data. Currently available digital processors required approximately 10 hours to process 100 x 100 km Seasat-A SAR image which was acquired in a few minutes. A ground-based SAR processor is to be developed which, by FY85, will increase the processing speed by 2000 times over currently used methods of SAR processing. The plans for this activity include the initiation of a competitive industry design contracts in FY80, the start of an industry design ground-based SAR processor in FY81 with hardware and software delivery in 1985. The preliminary performance parameters are:

a. 700 km altitude
b. 75^{o} incident angle
c. 50 km swath width
d. 15 m resolution
e. 2 looks (range and azimuth)
f. L and X band with two polarizations each

A ground-based design will be demonstrated in 1985.

A long range goal is the development of a second generation system by the early 1990's capable of use onboard a spacecraft for direct processing of space-acquired SAR imagery.

2.3.3 C^2 - COMMAND/CONTROL

A new GSFC team called C^2 for Command and Control headed by B. Bartlette is studying systems packet technology for command handling concepts and procedures for system analysis of TDRS command environment in the future.

2.3.4 CHANNEL CODING

A study is being conducted by W. Miller of GSFC in channel coding for the TDRS with emphasis on the evaluation of present and future TDRS links.

2.4 SUMMARY

Although it can be projected that NASA's advanced onboard processor technology activities supported by the dynamic R&D of the electronics industry will enable complex onboard computing functions such as multispectral classification, SAR processing and information extraction by the 1990's, an examination of the foregoing material on the various NEEDS Phase 2 elements yields an immediate breakdown of the efforts into two distinct classes. The programs under IAS, ADSC, MDTS, and DBMS are somewhat immature and definite technological advances seem to be distant. On the other hand, the MPP and AMM elements seem to be well advanced in concept, goal, and potential for well-defined new technology. This is due in part to the advanced stages of these elements and to the fact that their respective interfaces to the other elements (integration) are well-defined. They can be developed rather independently of the others. Both are well into contractual development phases.

Table 2-4 depicts the anticipated improvements resulting from NEEDS elements technologies. The IAS effort seems to be in a reevaluation phase at GSFC, the ADSC element lacks a concepts document at this time, the MDTS concepts document is incomplete and unavailable but it should ne noted that JPL is well into the technology required for demonstration of this element.

Table 2-4. Anticipated Improvements Resulting from NEEDS Technology

CURRENT PROBLEMS/ LIMITATIONS \ ANTICIPATED IMPROVEMENTS	DATA AUTONOMY	S/C ONBOARD INSTRUMENT AUTONOMY	EFFICIENT BANDWIDTH UTILIZATION	STANDARDIZATION	SYSTEM MODULARITY	SYSTEM ACCT/QUALITY CONTROL	INTEGRATED DATA/INFO BASES	ONLINE DATA BASE ACCESS	REMOTE USER CONTROL CONCEPT	TIMELY REDUCTION OF DATA TO INF
TRANSFER OF USELESS DATA INEFFICIENT BANDWIDTH UTILIZATION	IAS	IAS	IAS							
DATA LACKS AUTONOMY	IAS MDTS	IAS	IAS	MDTS	MDTS					
LACK OF STANDARDIZATION	MDTS			DBMS MDTS	MDTS	DBMS	DBMS	DBMS		
EXCESSIVE DATA THROUGHPUT TIME	MDTS			MDTS	MDTS					MPP
LACK OF ACCT/QUALITY CONTROL				DBMS		DBMS	DBMS	DBMS		
LACK OF INTEGRATED DATABASES				DBMS		DBMS	DBMS	DBMS		
LIMITED CAPABILITY FOR USER CONTROL OF S/C & INSTRUMENTS									DCC	
EXCESSIVE TIME TO REDUCE DATA TO INFORMATION										MPP

Overall, there exists a lot of contracts to be let and a lot of concepts which have to find technology in order to be implemented for NEEDS Phase 2 goals.

SECTION 3. OSTA/NEEDS INTERFACE ASSESSMENT

SECTION 3. OSTA/NEEDS INTERFACE ASSESSMENT

3.1 INTRODUCTION

After careful consideration of the results of Phase I of this study and an investigation of the potential thrusts of ongoing technological developments an identification of two major impacts to the NEEDS concepts and technology can be made. The first results from instrument requirements which will satisfy the need to detect data and transfer it into a useable form. The second is a more integrated or disciplined need which will disseminate user required data.

A discussion of the impacts of instruments and disciplines to the NEEDS evolution follows. A chart summarizes the critical technological impacts (refer to table 3-1).

3.2 INSTRUMENTS

The major drivers for the instrument impact on NEEDS results from the functional capabilities being pursued to process, store and deliver data. Representative generic classes of instruments have been chosen for consideration because of their unique and sufficient impact on developing NEEDS technologies. They represent sufficient conditions in the sense that their impact to the NEEDS concept is critical and if not met will cause significant over-all system failure in the delivery of space acquired data. They present a single point failure potential.

Likewise they are unique in that they represent the first of the new technology of the future.

Table 3-1. Technological Impacts and NEEDS

TECHNOLOGIAL IMPACTS	SATISFIED BY NEEDS	SATISFIED BY MODIFIED NEEDS	SATISFIED OUTSIDE NEEDS
VLSI Technology			X
Fault Tolerant Computing Systems			X
Fiber Optic Data Bus Integration			X
Archival Mass Memory Technology	X		
Massively Parallel Processing	X		
Onboard Attitude Determination		X	
Improvements in Algorithmic Development			
(1) Radiometric Calibration		X	
(2) Geometric Correction		X	
(3) Software Developments			X
Packetizing	X		
Packet Queuing	X		
Data Capture, Data Staging Techniques	X		
Multi-Megabit Data Processing Architecture			X
Networking		X	
Data Distribution Systems (S/W)		X	
Cataloging		X	
Disciplined Users Needs		X	
Data Integration Technology		X	

The following instruments represent impacts to the NEEDS concepts and developing technologies:

a. SAR
b. LIDAR
c. MMLA

3.2.1 SAR

Synthetic Aperture Radar (SAR) is an active microwave sensor sometimes called coherent radar or sidelooking radar. As with conventional radars, the area of interest is flooded with microwave radiation of controllable characteristics and the return reflections are operated upon. The synthetic-aperture radar, a unique type of active sensor, differs from a conventional "real" aperture radar primarily in the method for achieving azimuthal resolution along the track. The real-aperture radar uses an antenna of maximum practical length to produce a narrow beam. The synthetic-aperture device employs a relatively small sidelooking antenna that transmits a moderately broad beam. Due to the relative motion of the target with respect to the antenna, the target is synthetically resolved at a substantially narrower beam in the azimuth, as if it had been observed with a much longer antenna.

The spatial resolution, which in a focused synthetic-aperture radar is independent of the target's range, is of course, a very critical parameter for all types of active sensors. Another important parameter, which sometimes has to be traded off against resolution, is the signal-to-noise ratio after averaging a large number of return pulses. A radar's signal-to-noise ratio is the counterpart of temperature resolution in passive sensors. Improving that radio requires averaging a number of independent signal returns from the same resolution cell.

For the synthetic-aperture radar, the averaging requirement reduces the spatial resolution, because the available integration time is divided by multiple looks over the same resolution cell. For example, the best achievable azimuth resolution of Seasat's synthetic-aperture radar was 6 m. But after four looks were averaged to improve the speckle effect, the resulting resolution was 24 m.

Synthetic Aperture Radar systems proposed for the 1990's are currently under investigation by a number of NASA centers, contractors, and a few of the larger universities throughout the U.S. The primary focus is on data processing because of the impact on present data systems, i.e., Seasat-A SAR, and more importantly the effect on future systems by the volume of imagery to be generated by free-flyers (automated payloads) and Spacelab in the future.

Synthetic Aperture Radar systems perceived for free-flyer applications in the 1990's will include a digital processing capability. Free-flyers will be particularly useful in monitoring the dynamic features of our environment, such as sea state, soil moisture, biological growth, etc. These applications rely on timeliness of the image product so that near real-time processing and subsequent transmission to an appropriate site represents a highly desirable system capability.

Although the SAR data rates are nominal ($\leq$ 250 MBPS) the major impact is on ground processing. L. Holcomb (NASA Headquarters) has two studies underway to investigate SAR processing technologies. The requirement exists for real-time SAR processing in the near future.

Optical processing has been used in many previous SAR systems. This is not performed in real-time and therefore requires the radar data to be stored on film for subsequent processing. When the amount of data collected by the SAR is not too large digital processing in real-time may be more convenient than optical processing.

Digital processing can be performed on board with the processed data relayed to ground, or the radar output can be relayed directly to ground processing centers.

The use of parallel processors in reducing SAR data is being actively studied by several groups. The results of a MITRE study on this area are presented in section 2.2.2.

A cursory examination of the SIR-A radar and the intended applications indicates that it will have a rather limited capability. Further study and experience with the data should indicate whether a SIR-A type radar should be considered for "routine" sensing as a "free-flyer" for the continuing acquisition of data or whether it can only be considered as the first step in the development of a more sophisticated radar with enhanced capabilities.

The objective of the Spaceborne Imaging Radar-B (SIR-B) experiment is to develop the technical base and evaluate the application potential of spaceborne radar imagers for Earth resources observations. Present imagers (on LANDSAT) cover a very small arange of the electromagnetic spectrum (visible and near-infrared). The extension of the spectral coverage to the microwave region would provide additional information on the properties of the Earth's surface. This information would help in the monitoring, managing, and evaluating of Earth resources. The SIR-B experiment is an applications proof-of-concept experiment for the imaging radar, which is a natural candidate for the payload of the Global Resources Monitoring System (GRMS).

The SIR-B is a flexible sensor that allows changes in the observation parameters. It consists of a dual frequency (C- and X-band) synthetic aperture radar. The X-band will have direct and cross-polarized channels. The incidence angle is selectable anywhere between 15^{o} (from straight down) and about 65^{o}. The combination of the SIR-A and SIR-B experiment would provide sufficient information to define the parameters of the required operational spaceborne radar sensor.

The data from a typical 7-day mission are returned to the ground and played back, through a tape recorder similar to that in the spacecraft, into a ground digital processor. The processor provides both range and azimuth correlation and also performs a first-order geometric correction. Outputs from the correlator are produced in film and in high-density digital tape (HDDT). The film is probably most useful as an indicator of data regions deserving more quantitative analysis. The HDDT's, on the other hand, contain the full complement of radiometric and geometric correction information for use with subsequent user algorithms.

The final step in data usage and application rests with the users. The special processing, including specific algorithm development, is best performed as a set of more or less independent developments. It is anticipated, for example, that the requirements of geological users regarding radiometric and geometric accuracy might differ significantly from those of agricultural users. The "standards" product supplied to the users is, therefore, as application-independent as possible.

The development of processing algorithms should parallel ground and onboard SAR data-processor-hardware development. Electronic processing of SAR data into images appears superior to the optical processing used to date. The state of the art for ground-based electronic processing is well advanced. Hence, development of a system for SIR-B can be started at an appropriate time to make it available for use with the Shuttle tape-recorded data for that system.

Radar systems with modest resolution can use on-board processing of signals into images. The telemetry bandwidth for the processed image will be significantly less than that required for the signal itself. However, for systems that achieve the finest possible resolution and have multiple channels, on-board data processing is complicated and needs development. Consequently, the testing of these sytems on the Shuttle and use of them on early free-flying spacecraft should be an integral part of the microwave remote sensing for Earth observation.

3.2.2 LIDAR

First conceived on in 1963, "lidar" stands for light detection and ranging. It can be throught of as laser radar using light in place of radio waves. Radiation from a laser is pulsed into the atmosphere. As the light passes through various atmospheric regions, particles, liquid droplets and gaseous molecules scatter or absorb it in different ways.

Some portion of the scattered or emitted light returns to its point of origin, where a telescope-like receiver channels it to a photodetector. The photodector produces an electrical signal proportional to the optical radiation received by the telescope. The length of time between transmission and reception indicates from what distance the light was scattered, and the intensity of the electrical signal indicates the concentration of the particles or molecules being monitored.

In practice, these time and intensity readings require more elaborate processing to fully describe the atmospheric conditions. When this is done, however, they can be used to establish profiels of various atmospheric components. For instance, if laser light tuned to scatter from aerosols is scanned across a given portion of the atmosphere, a cloud cover profile may be constructed by lidar. Or, if tuned to an absorption frequency of a certain pollutant, a ladar can map out the presence and intensity of that polutant over a given area.

Lidar has been used for a number of years in a variety of configurations. Profiles can be produced by scanning radially from a fixed location or by mounting a unit on a moving vehicle, such as a van or airplane. But not existing technique fully realizes the global potential of lidar, which could cover broader geographic areas and more regions of the atmosphere.

As backscatter data accumulates during a Shuttle Lidar run, it will be digitized and stored on tapes. When the shuttle comes into range of a tracking and data relay satellite (TDRS), data will be "dumped" at high rates to the satellite, which will then transmit it to a ground station. Goddard Space Flight Center will process the digital data and will make it available to principal investigators in the program, who will do their own interpretation and analysis.

An interesting arrangement of lidar and MSS (Multispectra Scanner) can be envisioned on one platform which would potentially enhance resolution through more efficient error checking.

3.2.3 MMLA

The Multispectral Multilinear Array (MMLA) will utilize the multilinear array technology with multiarrays covering the spectral range of 0.4 to 2.5 μm at bandwidths as small as 20 nm. The MMLA will eventually replace the MSS and TM. The high data rate of the MMLA and the processing required to use it will have a major impact on NEEDS. Adaptive bandwidth, autonomous data packing, ground processing and data distribution/integration techniques will be needed. Additionally, the area of user needs (by discipline) will have to be examined and even perhaps some priority established on the selection and use of algorithm processes.

3.3 DISCIPLINE SYSTEMS

Several discipline or integrated system thrusts on evolving NEEDS technologies can be identified. They fall into several of the following areas:

a. Data systems
b. Networking
c. Distributed cataloging systems

Components of each are discussed and a chart (table 3-1) summarizes their impacts.

3.3.1 DATA SYSTEMS CONCEPTS

Two components of this are user directed targeting in a near real-time mode and a multidisciplined instrument payloads. These concepts are not new but with the proliferation of new radar imagery and microprocessor technologies it seems almost inevitable that some form of these will make themselves felt on developing NEEDS technologies. Direct unloading of experimented data to the user is a strong contender for aleviating the bottleneck at the ground processing phase of NASA's system. Furthermore, the use of many different types of instruments on one platform will present real problems in data autonomy procedures.

The following is a brief presentation of these data system concepts which will have an important impact to NEEDS developments.

3.3.1.1 User Control (Near Real-Time). This concept has been studied for nearly 20 years at NASA and waited for by many space research oriented groups. With communications and networking technologies as advanced as today there is strong compelling justification for near real-time user control of experimental equipment in space. Although a "joy sticking" capability may be somewhere in the future a virtual-type "by target" selection is possible and safe now. The major impact will be in ground software capabilities. Command and verification protocols, massive distribution data dump capabilities, both transmission and processing, archival storage and multiuser data base management technologies will have to be developed.

3.3.1.2 BUSS Packing Concept. This many disciplined mission concept would allow diverse instruments requiring a common orbit to be flown together. The impact of a many to many instrument to user mapping would impact the MDTS element most. Again, a virtual target - virtual user concept and technology will have to be developed. Of an equally important positive impact is the TDAS. With acquisition possible, user routing protocols can be developed so as to allow a broadcast capability.

3.3.2 NETWORKS

Although there are a few valued-added networks in operation including Telemet, Tymnet, Datapac, Transpac, Saponent, NDN, NTT-DDX and perhaps at least half a dozen more, the reality is that the average user has not much benefited from existing advanced networks unless he happened to be tied to Dataroute or DDS.

The concepts of technology have changed. Packet switching and circuit switching have come to look more alike. Packet switching has largely dispensed with the concept of self-routing datagrams for the moment, adopting instead a circuit switching method of setting up a fixed link or virtual circuit between sender and receiver for the duration of a call.

Internetwork connections have also been made possible in the last 10 years, and made to work. Telenet and Tymet both link to Datapac, for instance, and Telenet links to Hawaii's Dasnet II interisland network.

In the area of network management we can expect a strong trend toward decentralized control of switching and value-added functions but centralized control of network management functions.

More intelligent, circuit switching will gain in applicability and may well take precedence over pack switching for general purpose networks by the end of the decade. The support X.20 and X.21 standards by computer manufacturers will be a major factor in causing this to happen.

The fact that it is not known how the protocol translation and other problems are to be solved in future networks should not be an excuse for a "wait and see" attitude.

The single most important fact that has been learned over the last 10 years is that the only low risk approach to networking is one that separates some of the key network functions into clearly distinct network entities. The most important separation must be between the "network transport function" (the fundamental transmission, switching, and network management functions which all networks must provide) and "value added functions" (such as protocol conversion, message storage, formatting, and what is now called "communication processing").

3.3.3.1 Data Distribution Network. This system (shown in figure 3-1) will function as a switch between GSTDN/TDRSS communications link and users, space centers and research centers. Its design will facilitate the S/C BUSS packing concept discussed above and augment through conceptual integration with the MDTS element of NEEDS.

3.3.3.2 Distributed Catalogue Concept. Essential for the future requirements of data base management and independent of any data systems concept is a cataloging scheme. As depicted in figure 3-2 a central data processing facility (unseen by users) supplies data to data distribution network which controls the dissemination of requested data through a data base management structure. This concept allows disciplined cataloging and archiving functions to occur transparently and thereby broaden the potential spectrum of users.

3.3.3.3 TDAS Distribution. This data system concept (figure 3-3) utilizes the TDAS to broadcast space data directly to the user.

Primary advantage here is that user unique data handling/processing functions do not broaden processing facilities and that users establish their own catalogue protocols.

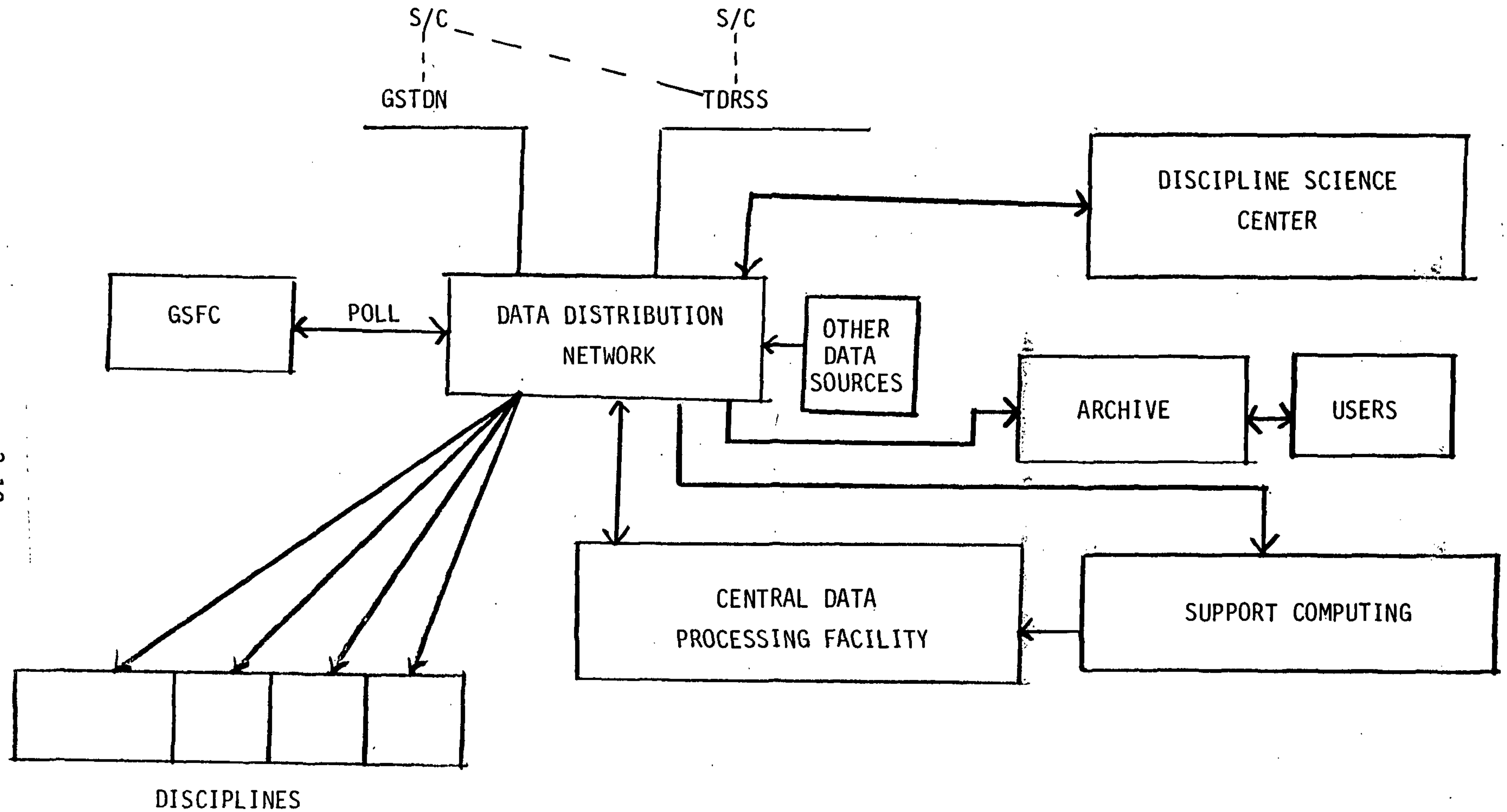

Figure 3-1. Data Distribution Network

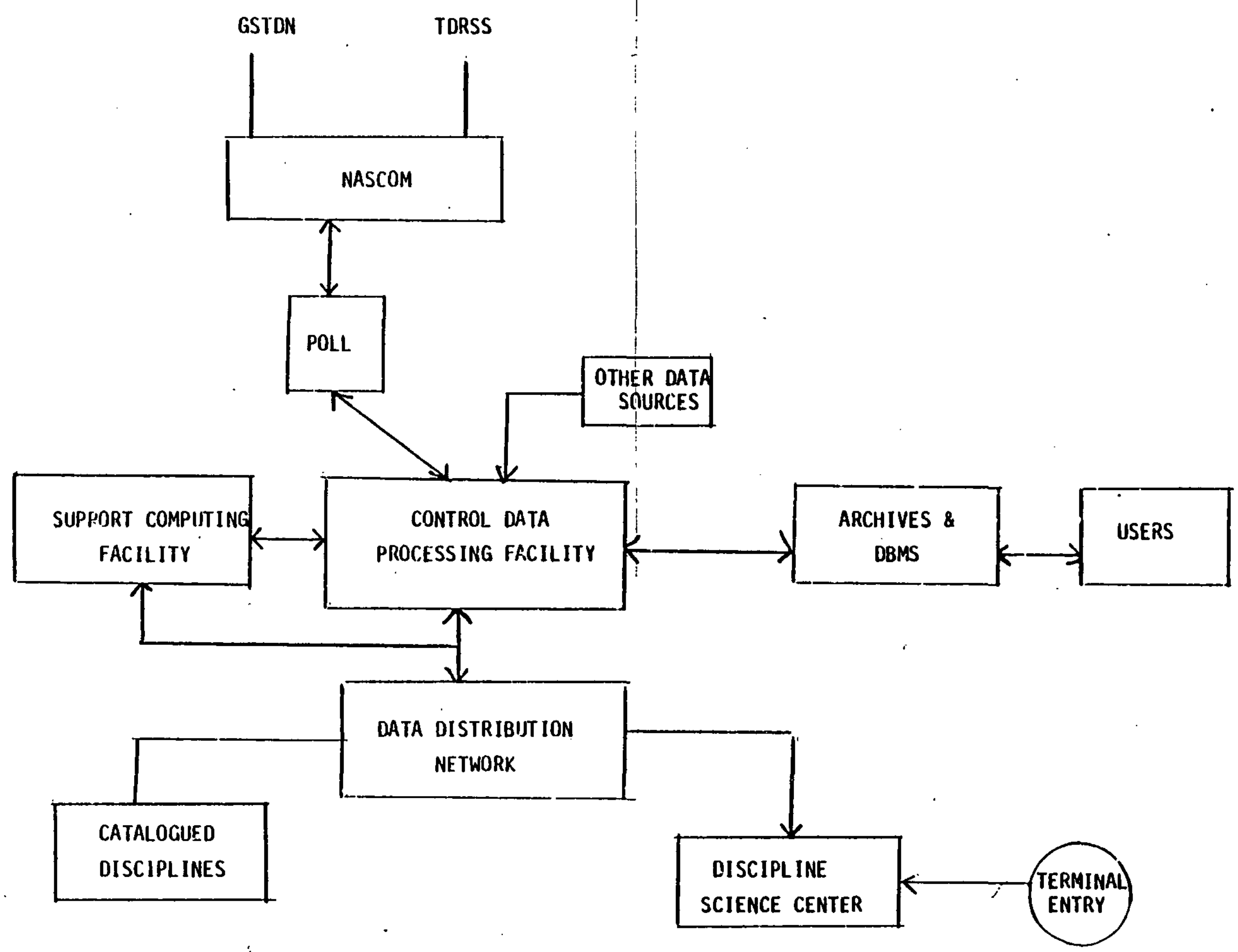

Figure 3-2. Distributed Catalogue System

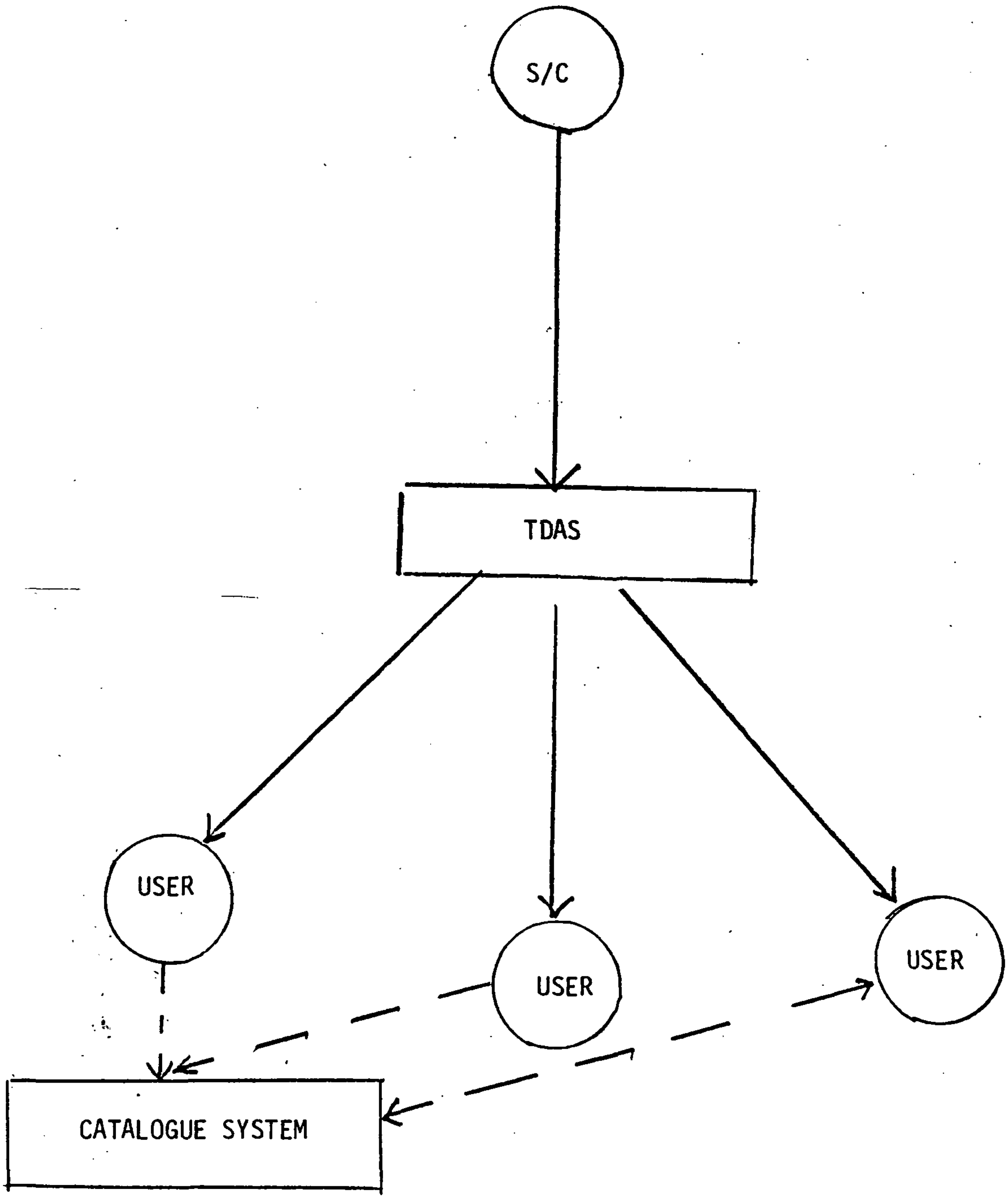

Figure 3-3. TDAS Distribution

SECTION 4. POTENTIAL OSTA DEMONSTRATIONS AND PILOTS

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This section contains an outline of several pilot studies or demonstrating though to be of extreme relevance to the concepts and future goals of NEEDS. The first three are an obvious tie between the OSTA technology thrusts upon NEEDS while the last would provide an assessment tool for measuring NEEDS effectiveness now and planned capabilities for the future.

4.1 SOFTWARE ALGORITHM REDUCTION

This study would identify commonly used software algorithms, perform some analysis and attempt to reduce the amount of time required to execute them. A demonstration of several critical processing functions (SAR data processing) would follow.

4.2 CATALOGUING MODEL

This study/demonstration would develop a model of a small scale data distribution system utilizing DBMS concepts and include at least two levels of user protocol (access) across several disciplines. Taped data would suffice as input. Various cataloguing concepts could be demonstrated.

4.3 USER NEEDS

This pilot would establish guidelines and techniques required to assess the data system needs of the various disciplines. In addition to data type, frequency, and processing requirements potential data integration technologies would be identified.

4.4 NEEDS ASSESSMENT

This pilot study and demonstration would develop parameters for a S/W model of NEEDS through the year 2000. Simulation would be developed on data storage, data processing and data distribution capabilities over the next 20 years and include as inputs the impacts of instrument technology and disciplines as identified and forthcoming.

REFERENCES

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