SPACELAB SYSTEM ANALYSIS

MARSHALL AVIONICS SYSTEM TESTBED (MAST)

CONTRACT:

NAS8-36717

FINAL REPORT

10/31/89

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16. Abstract

A synopsis of the visits to avionics test facilities is presented. A list of recommendations for the MAST facility is also included.

17. Key Words (Suggested by Author(s)) LAN - Local Area Network MAST - Marshall Avionics Testbed FDDI - Fiber Distributed Date Interface	18. Distribution Statement

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1.0 Introduction

To take advantage of past research that has been performed in distributed architecture systems and the current research work in progress, it was necessary to seek out information from other facilities that have also been studying distributed architectures. It was beneficial to see what systems these facilities had installed and found useful, as well as, to discuss their conceptual ideas for the future. Visits were made to five facilities: U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Northrup Corporation Hawthorn, General Dynamics San Diego, General Dynamics Ft. Worth and NASA JSC. An attempt to visit the Bell helicopter facility in Dallas was not allowed by the Bell marketing department. Attempts to visit the Boeing facility in Seattle, NASA Langley and other facilities were unsuccessful due to timing, budget or other causes.

2.0 Waterways Experiment Station Vicksburg

On January 18, 1989 J. K. Owens, F. M. Ingels, and S. P. Daniel visited with Mike Ellis of the U.S. Army Corps of Engineers Waterways Experiment Station (WES).

Mike Ellis
Department of the Army
Waterways Experiment Station, Corps of Engineers
P.O. Box 631
Vicksburg, Mississippi 39180–0631
(601)–638–0670

At this facility, a Facility–Wide Fiber–Optic Communications Network is being installed. The goal of this facility is the connection of a widely distributed campus of 108 buildings spread over 600 acres by an all digital communications network. There are also plans to add a super computer to the facility and the network would serve as the primary means of access to most users. A diagram of the WES backbone network is shown in Figure 1.

The design goals for the network were connectivity and the ability to upgrade easily as new hardware became available. The Information Technology lab at WES performs compatibility (connectivity) test but few performance experiments for delay and throughput.

This facility is a good model for the Marshall campus area network that will be part of MAST or that will connect to MAST.

3.0 Northrup Corporation Hawthorn Facility

During the month of February J. K. Owens, F. M. Ingels, and S. P. Daniel visited the Northrup facility in Hawthorn, California. The engineers at the facility are involved in the design and test of avionics and therefore are knowledgeable in the area of avionics testbeds.

At the Northrup plant Peter Shaw, Tom Winfrey, Nareh Shah, Jim Evans and Leo Stein were visited. Mr. Shaw can be reached at (213) 332–6110. Northrup's address is

One Northrup Ave
Hawthorne, CA 90250–3277.

At the Northrup facility, we were especially interested in the Vehicle Management System (VMS) lab. In this lab a ProNET–80 is used to connect several Force 68020 computers. At present they have 12 computer systems connected but they plan to connect 48 Force Motorola 68020 computer systems together over a ProNET network in the near future. This system is used to simulate the flight control subsystem of an aircraft. Their eventual goal is to have many of the aircraft subsystems modeled in the various computers and combine these to deter-

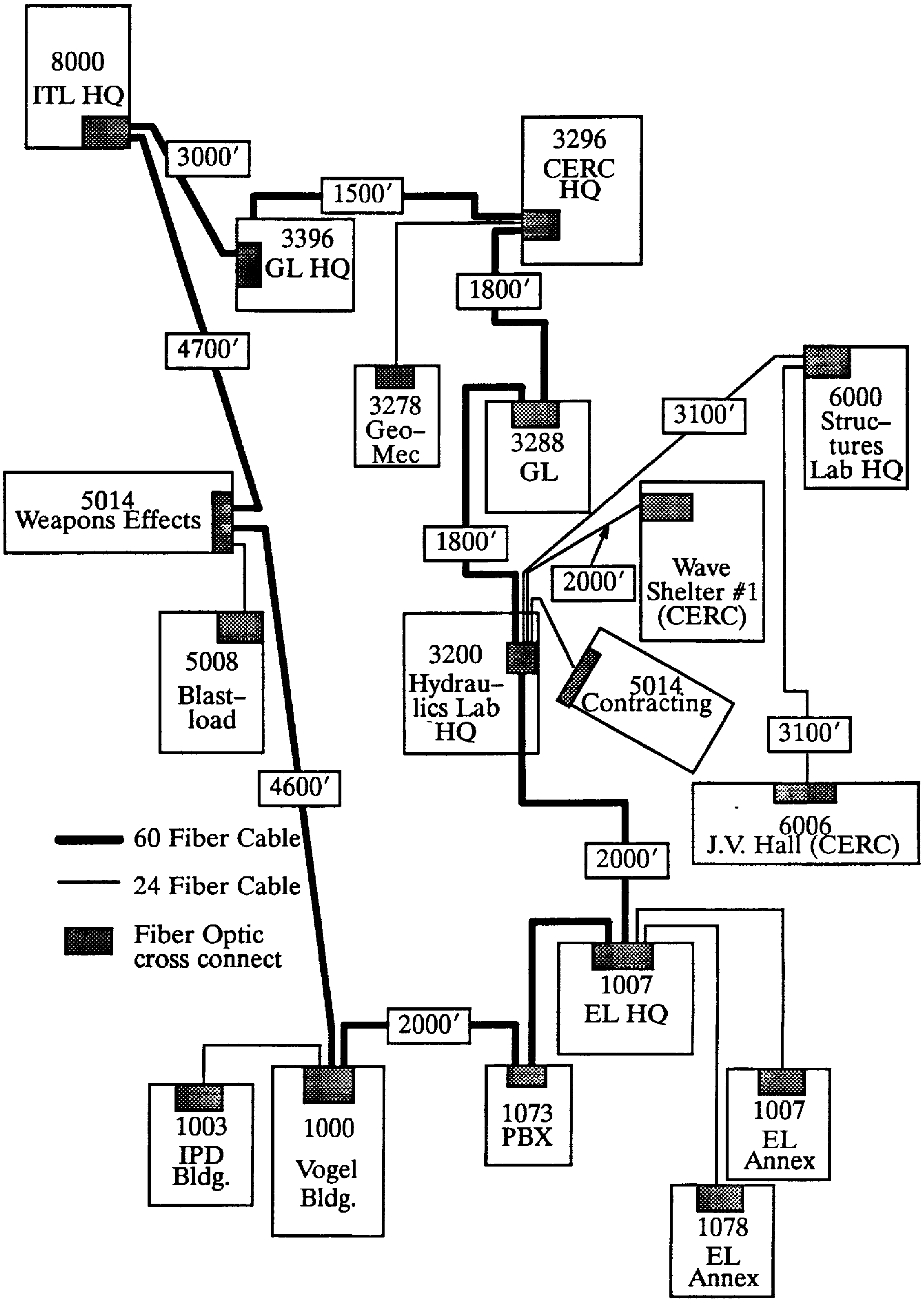


Figure 1 WES Backbone Network

mine performance and compatibility. The system is designed to allow a pilot in the loop.

The installation of the ProNET has resulted in the staff developing expertise with ProNET drivers for several computers. ProNET drivers for VAX systems are available from Proteon but support for other systems is lacking. One of the problems that was encountered was the need for software delays in the driver. If two consecutive packets are sent to the same address they can over–run the receive buffer resulting in lost packets. This occurs without any error indications. The problem was alleviated by looking at the Sun ProNET driver that had software delays built–in. These delays were added to the Northrup drivers and cured the error. One point of interest at the lab is that software is written directly in Ada.

Another problem with ProNET–80 is that the system is protocol dependent. The internal protocols between two lower level networks using a ProNET backbone must be the same. A method of packet encapsulation should be added to the protocol so that an Ethernet packet bound for a station on a token passing bus can easily be transported over the ProNET backbone.[TREL88]

The wire center nodes of the ProNET system are used extensively at this facility. If at all possible new connections are added at an existing wire center instead of adding a new node to the ring.

A more detailed look at the VMS concept is appropriate. The Northrup philosophy is to combine all flight–critical control sub–systems into a single fault–tolerant system. The typical sub–systems for a launch vehicle are shown in Figure 2.[CHEN88] The use of VMS is part of the Integrated Control Law Evaluation program (ICLE) and the flow of evaluation and refinement is shown in Figure 3. The expected benefit of this approach is the functional and physical integration

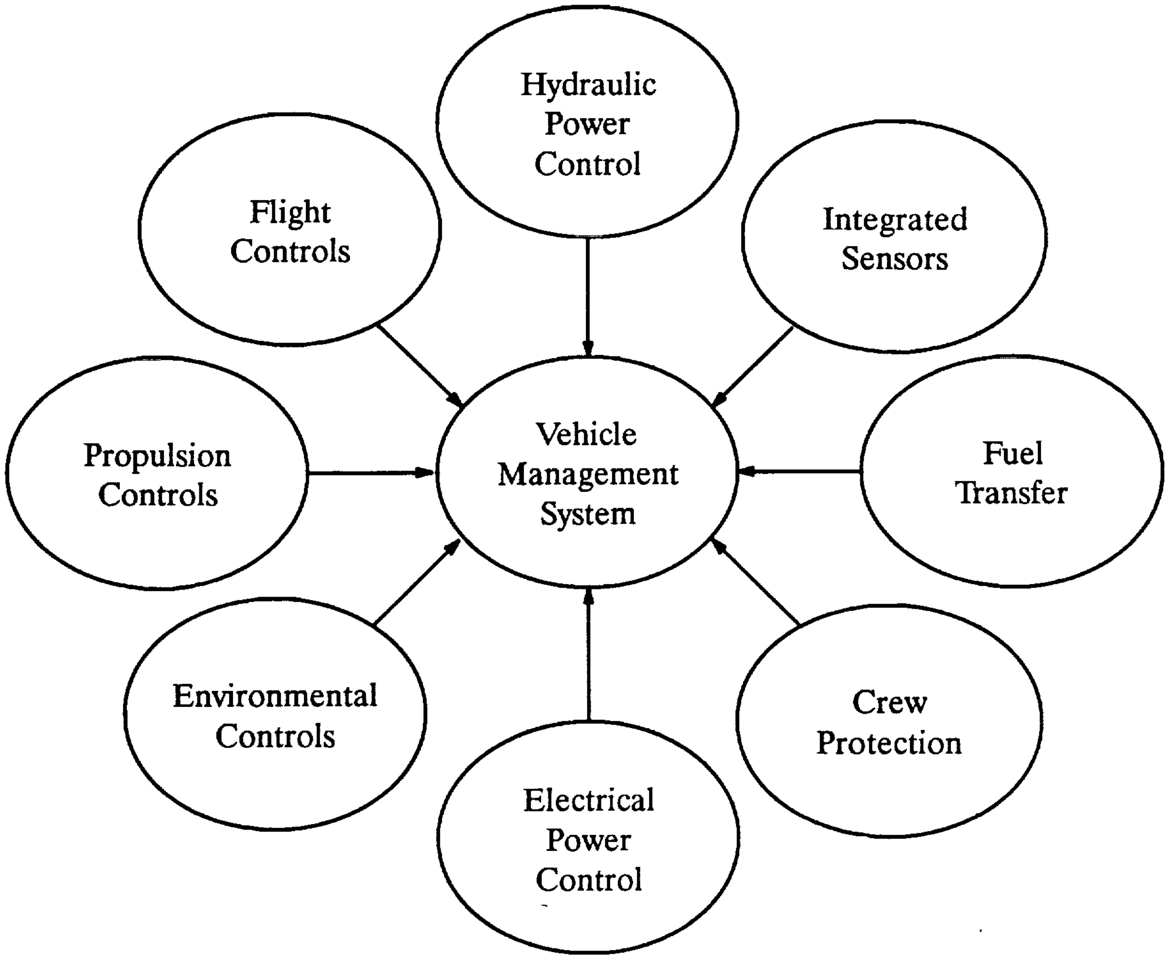
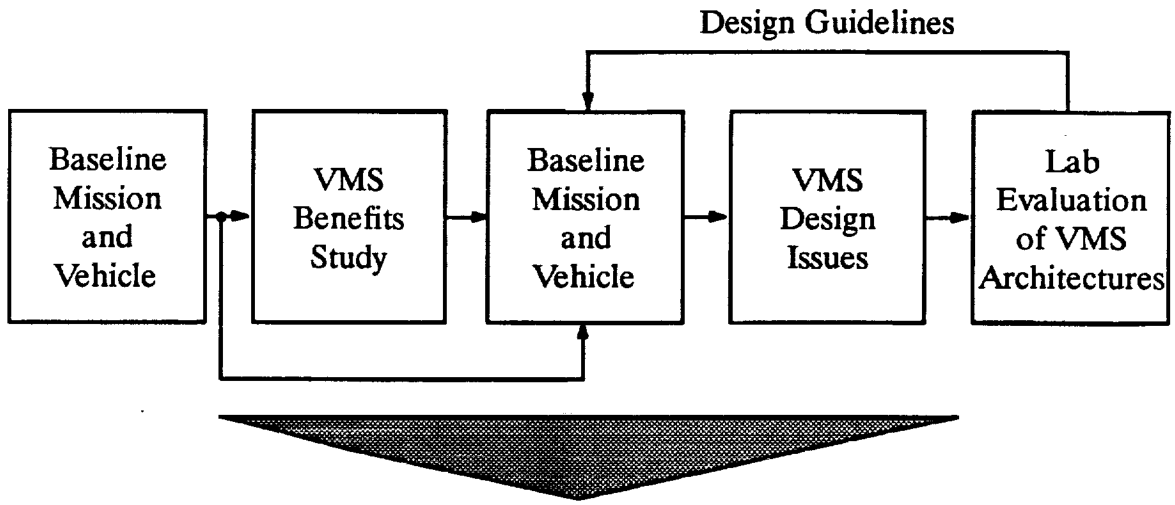


Figure 2 Subsystems for Launch Vechicle VMS study

of the sub–systems. Functional integration implies that control functions are implemented with respect to the whole system as opposed to sub–systems. This allows the inherent couplings between sub–systems to be dealt with directly. Physical integration implies that either resources are shared or that sub–systems are physically combined.

The key to realizing the benefits of this approach is to design a system architecture that not only meets the functional requirements, but also achieves a good balance between minimizing the technology risks and optimizing various performance metrics such as weight, cost, supportability, etc. As system characteris-



- VMS Benifits
- VMS
- VMS Design Guidelines

Figure 3 VMS Analysis in ICLE Program

tics vary widely, no single VMS architecture is expected to be optimal for all systems.

The VMS architecture allows a trade–off analysis between central and distributed processing to be performed. This is especially important to NASA as smart sensors and other intelligent subsystems are augmenting the central flight controller. Another area for study is data communications within the vehicle. Data rates in excess of the capabilities of MIL–STD–1553B are being required and a VMS type testbeb would be useful in studying the application of advanced protocols. Two other areas that may be studied with this facility are control task partitioning and function synchronization. The study of control tasks partitioning is to determine the optimal way to divide task that run on several processors. Function synchronization is the study of the effects of asynchronus operation and how to minimize its undesirable effects. There are several other system design considerations that may be studied in the lab. These include: fault detection and isolation, reconfiguration, redundancy, maintainability, and supportability.

Two configurations of the VMS lab are presented in Figures 4 and 5. The major differences between the configurations is task partitioning and communications. Configuration one uses a central processor that can preform all control tasks or may allow a subsystem processor to control the subsystem. Configuration two does not contain a central processor, this requires that any operation involving two or more systems must be distributed among the subsystem controllers. Another configuration is a hierarchical approach that allows data bus requirements to be reduced. The resulting trade–off in delays between subsystems and overall performance may be studied. A configuration to study the performance trade–offs of smart sensors would include additional processing and control at the sensors and effectors.

A problem with the VMS lab is that there are few diagnostics available in either software or hardware to pinpoint errors or system faults. This is a problem with any new system of a complex nature. Using hardware with self–test features greatly reduces debug and maintenance time. The basic VMS lab including system under test, simulation and instrumentation units and a software development facility is presented in Figure 6.

4.0 General Dynamics San Diego Facility

At the GD plant Ed Jones, Delbert Ingalls, Eric Hogan, John Sessions, Kelly Wallace and Andy Schicking we visited. Mr. Jones can be reached at (619) 547–4581. The GD Address is

General Dynamics
Space Systems Division
MZ 24–8710
PO Box 85990
San Diego, CA 92138–85990

The GD facility includes four avionics testbeds. They have Atlas, Centaur, Titan and general purpose testbeds. The main emphasis for these labs is

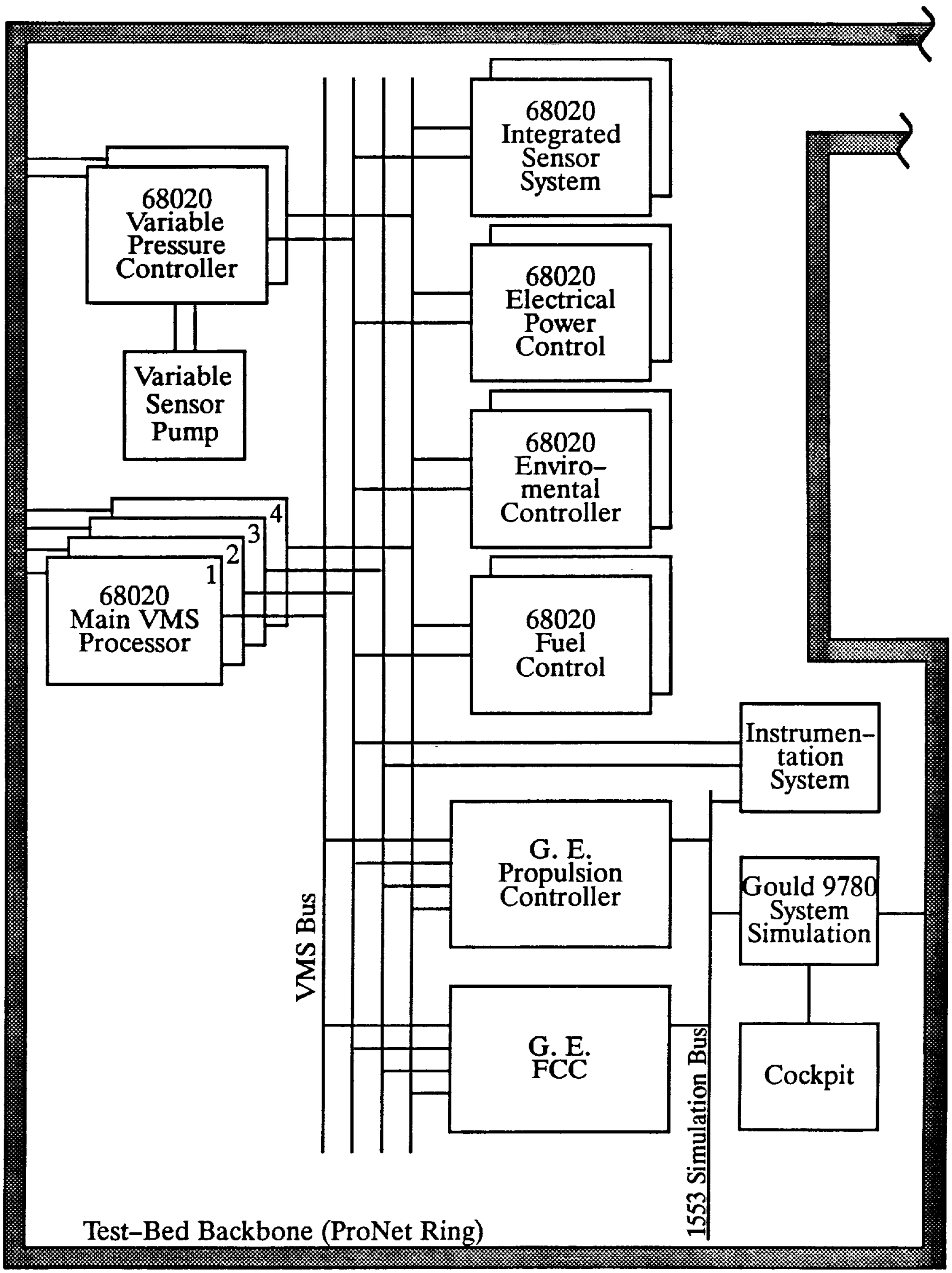


Figure 4 Implementation of VMS Configuration 1

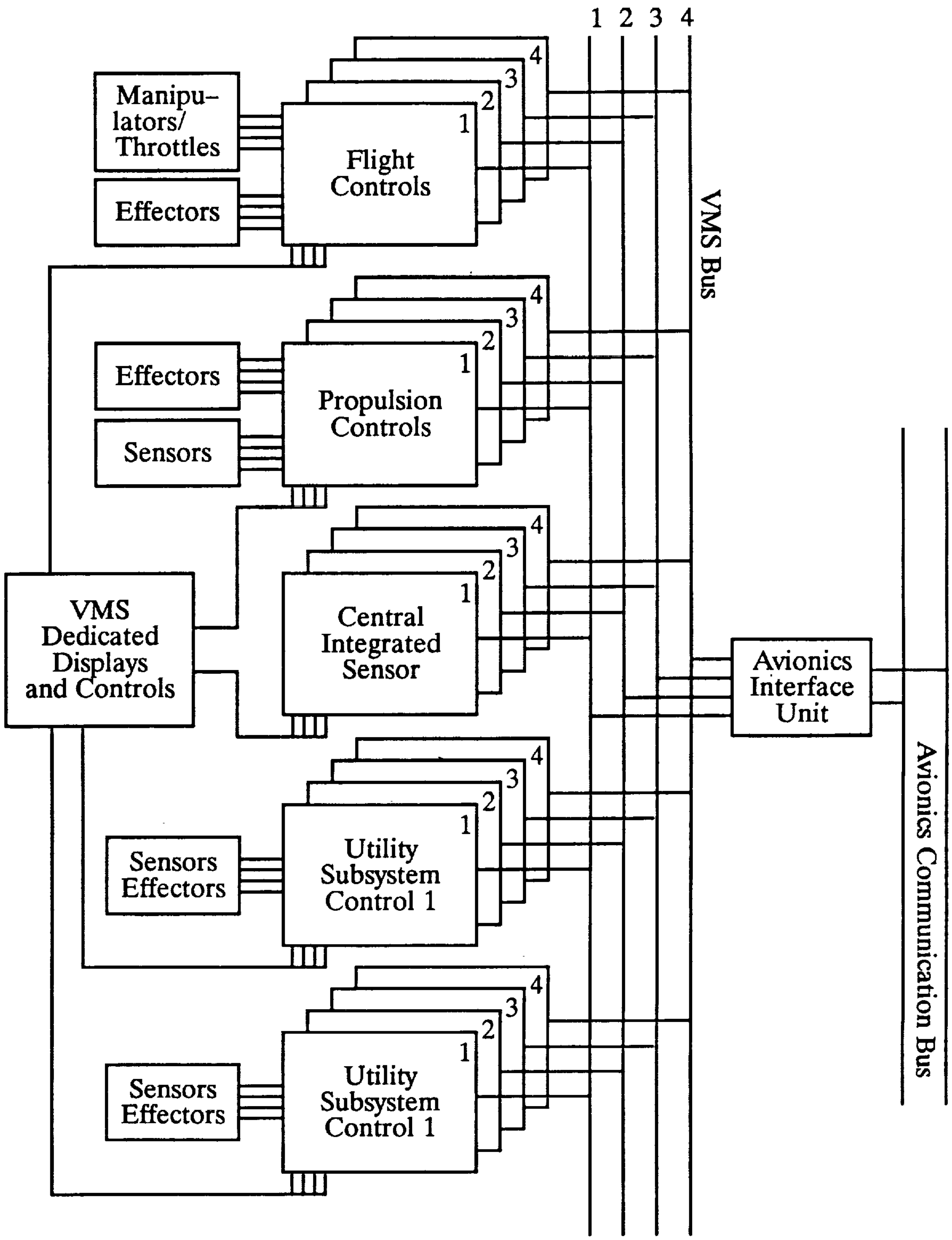


Figure 5 Implementation of VMS Configuration 2

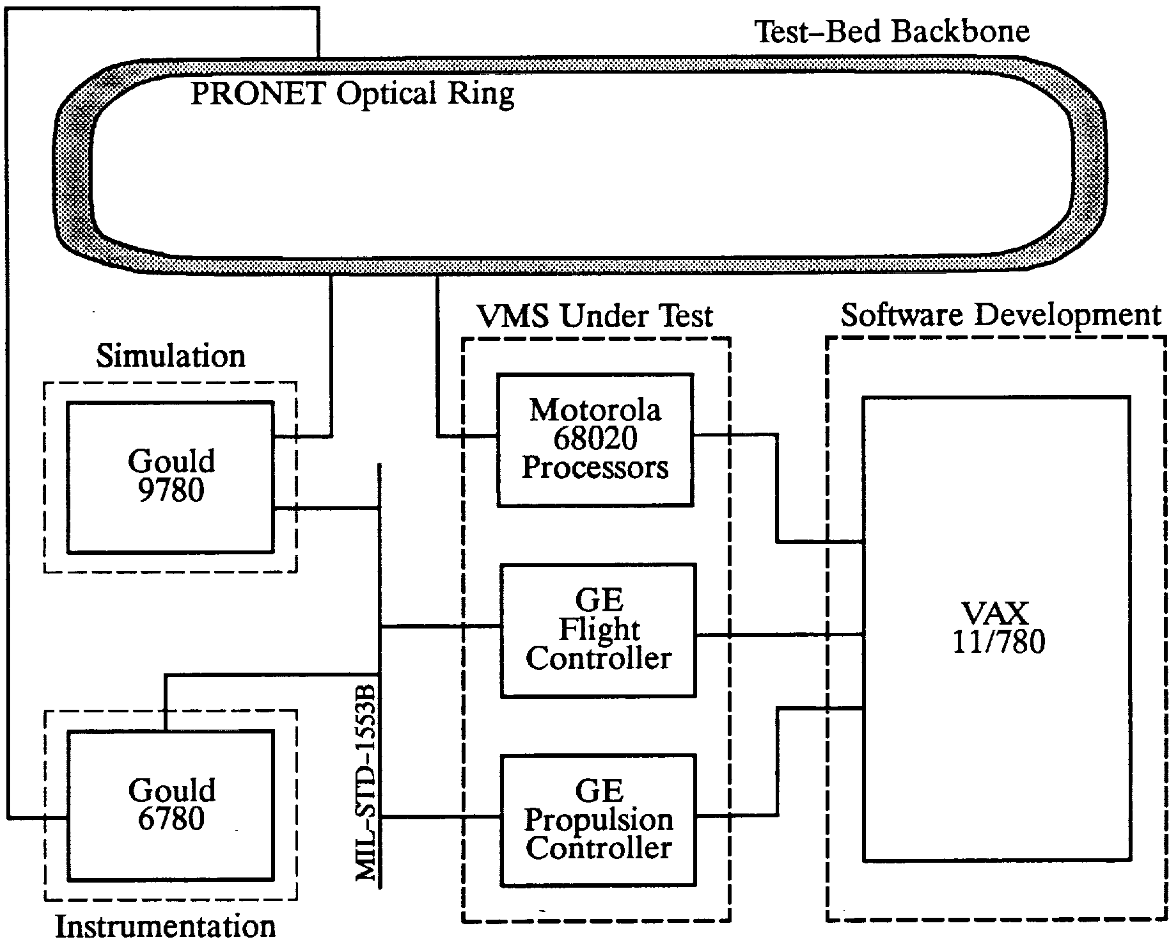


Figure 6 VMS Laboratory

ground support of the launch vehicle up to launch. In the future they hope to extend the capabilities of these labs to allow application to all phases of flight. The labs lack a common local area network tying the computers, control center, and hardware together. This addition is planned for near term improvement.

The labs basic configuration is an avionics hot bench with connections to several supporting computers. Emphasis is placed on real harnesses and hardware. The lab's support equipment includes raised floors, large doors, heavy duty hoist and a workshop area for maintenance and construction. Also, a central data display center with large screen displays is combined with the labs for data analysis and presentation.

Discussions with Ed Jones on the future of the GD labs and their work on the Heavy Lift Cargo Vehicle (HLCV) study were beneficial to this study. The future direction of the GD testbeds is to add local area network technology and computing resources to enhance their present facilities. These additions will make the labs more versatile. Their fourth quarterly report for the HLCV study was used as a source for Figures 7 thru 13.[GD89] Figure 7 presents the basic configuration of the proposed lab. It is important to note the use of local area networks to tie together distributed processing systems. The use of microprocessor based test equipment allows ease of control and modification of the facility. The communication interfaces for the testbed are shown in Figure 8. The testbed should have direct connections to both the main and the control processors. Figure 9 depicts the main simulation processor. In order to allow for expansion this unit should be a system of microprocessors or several small computer systems such as workstations. Figure 10 shows an experiment control processor. This processor would be used to control testbed hardware and apply stimuli to the system under test. Figure 11 is of the guidance and navigation testing facility. This facility includes a three axis table and several 80386 microprocessor for stimulus generation and system control. A system to model engine controllers is presented in Figure 12. One of the more difficult tasks for this system is to provide emulation of valve action in software. Figure 13 presents an approximate vehicle computer processing timeline that may be used in the determination of required computing resources for the lab.

5.0 General Dynamics Fort Worth Facility

A visit to the Fort Worth General Dynamics facility was made in April. The principle personnel from GD Fort Worth were Don Brown (817-763-2628) and Phil Barry.

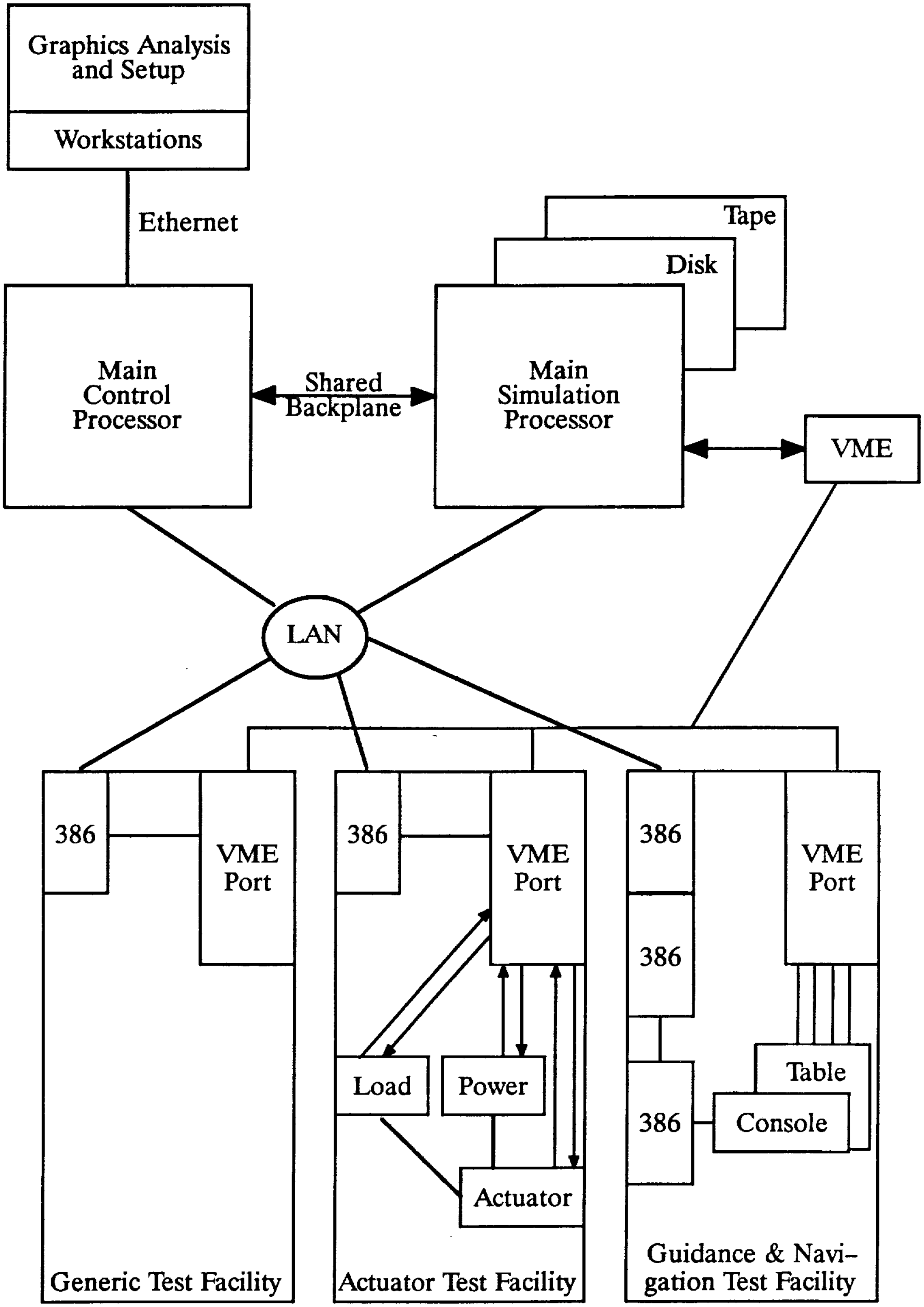


Figure 7 Basic Lab Configuration and Communications

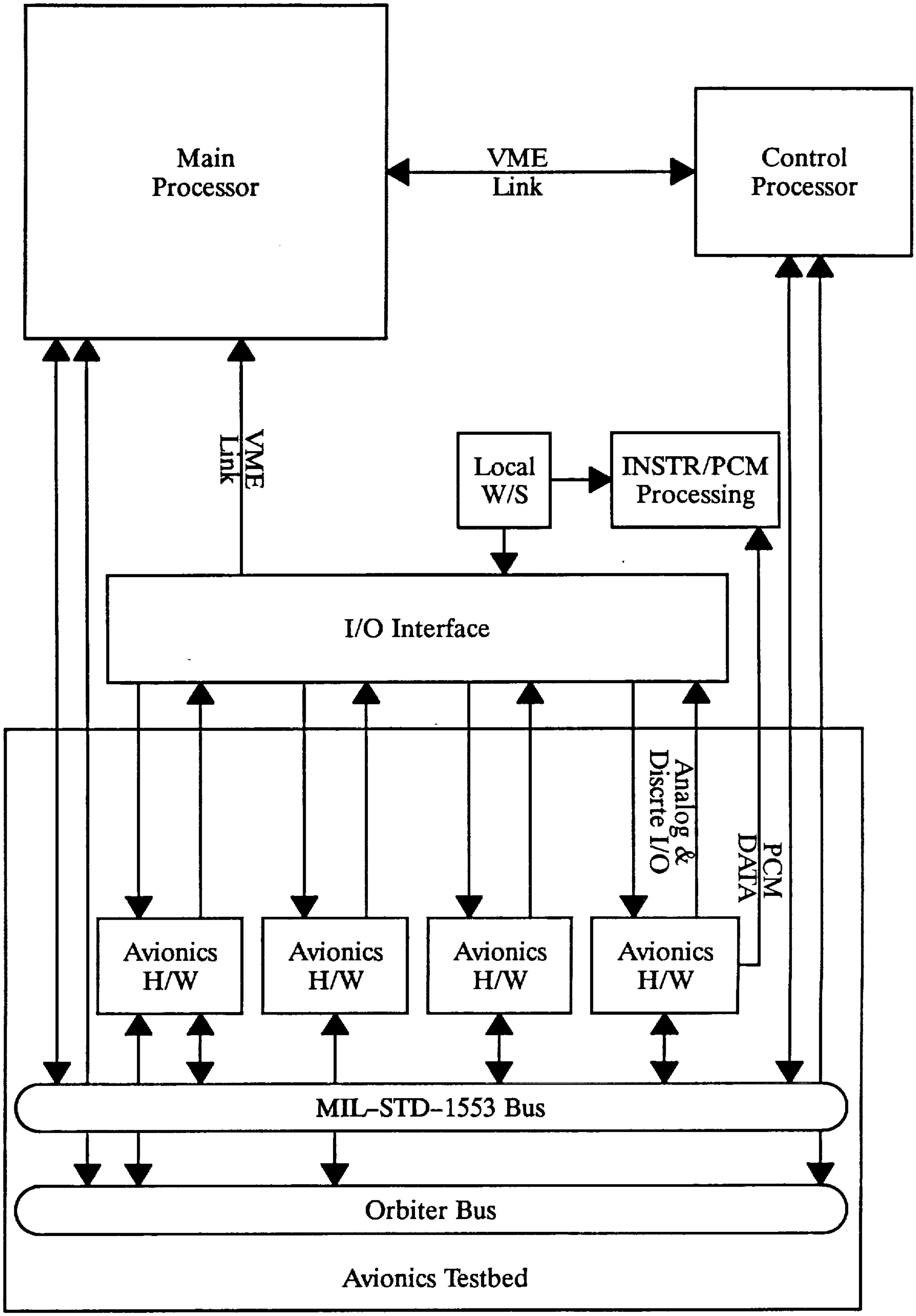


Figure 8 Avionics Testbed Interfaces

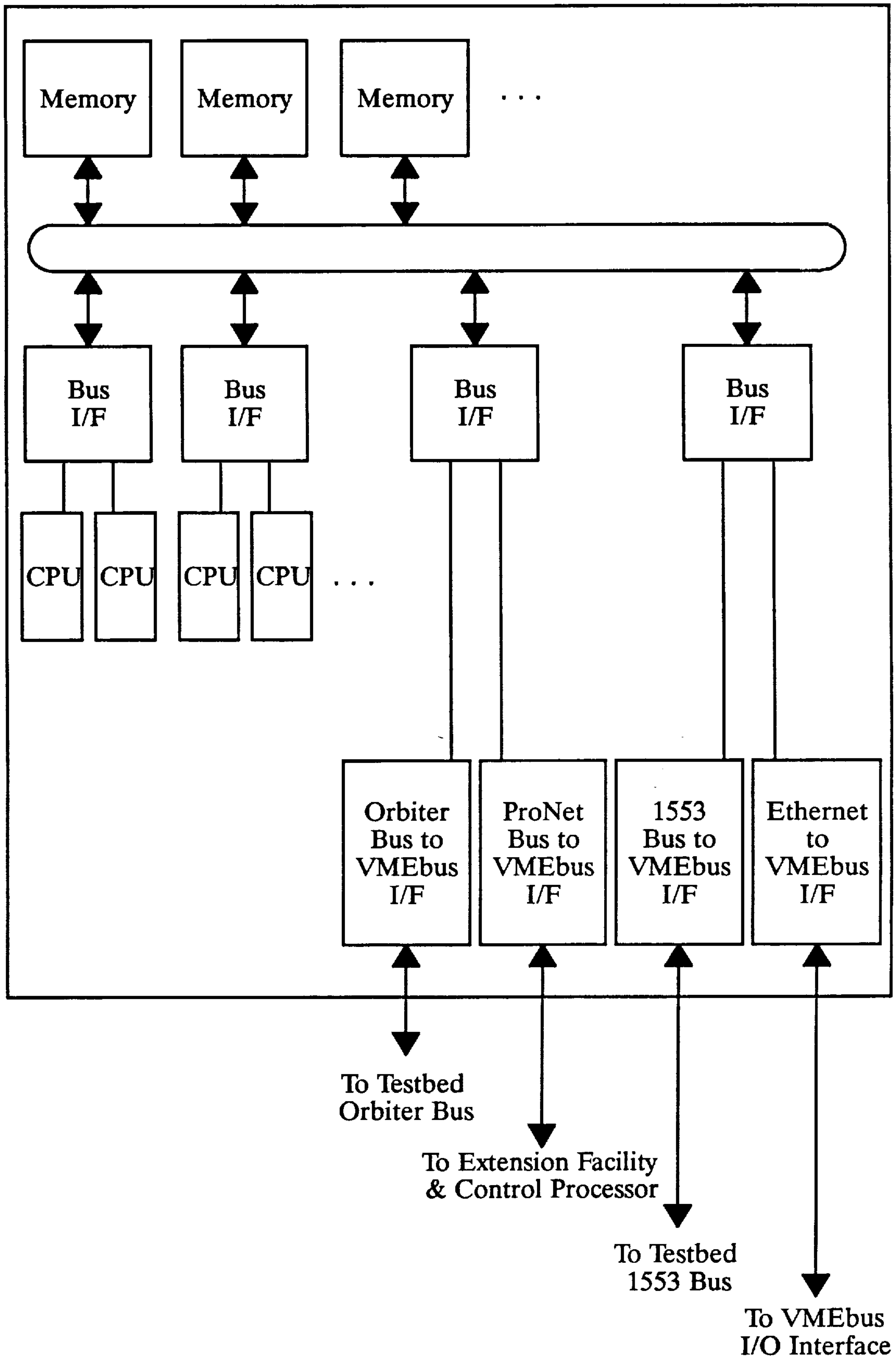


Figure 9 Main Simulation Processor

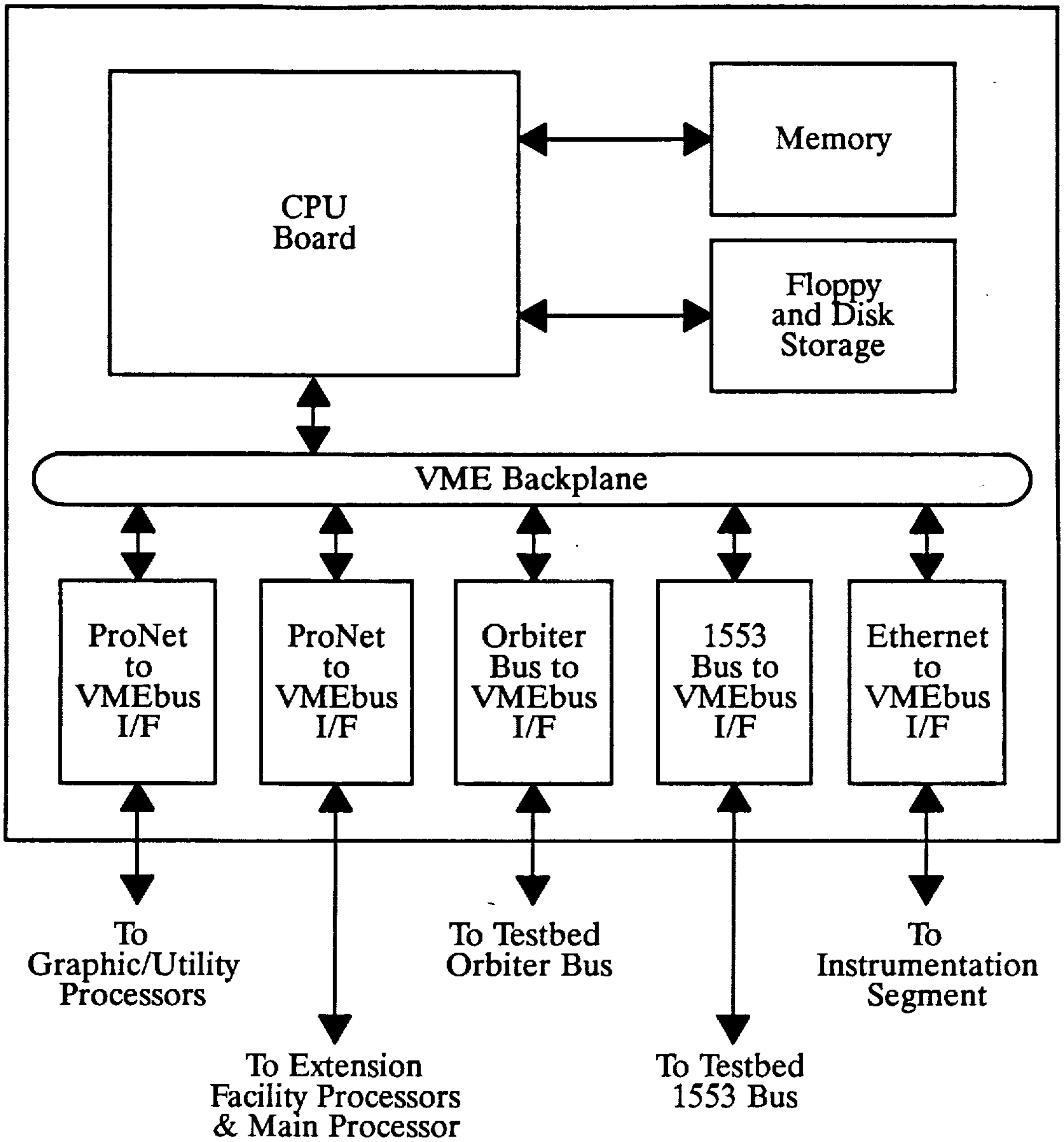


Figure 10 Experiment Control Processor

The GD Address is

General Dynamics
MZ 1771
PO Box 748
Ft. Worth, TX 76101

The avionics test facility there is mainly interested in the test of manufactured products to insure that they meet specs and to check that interfaces between sub–system operate properly.

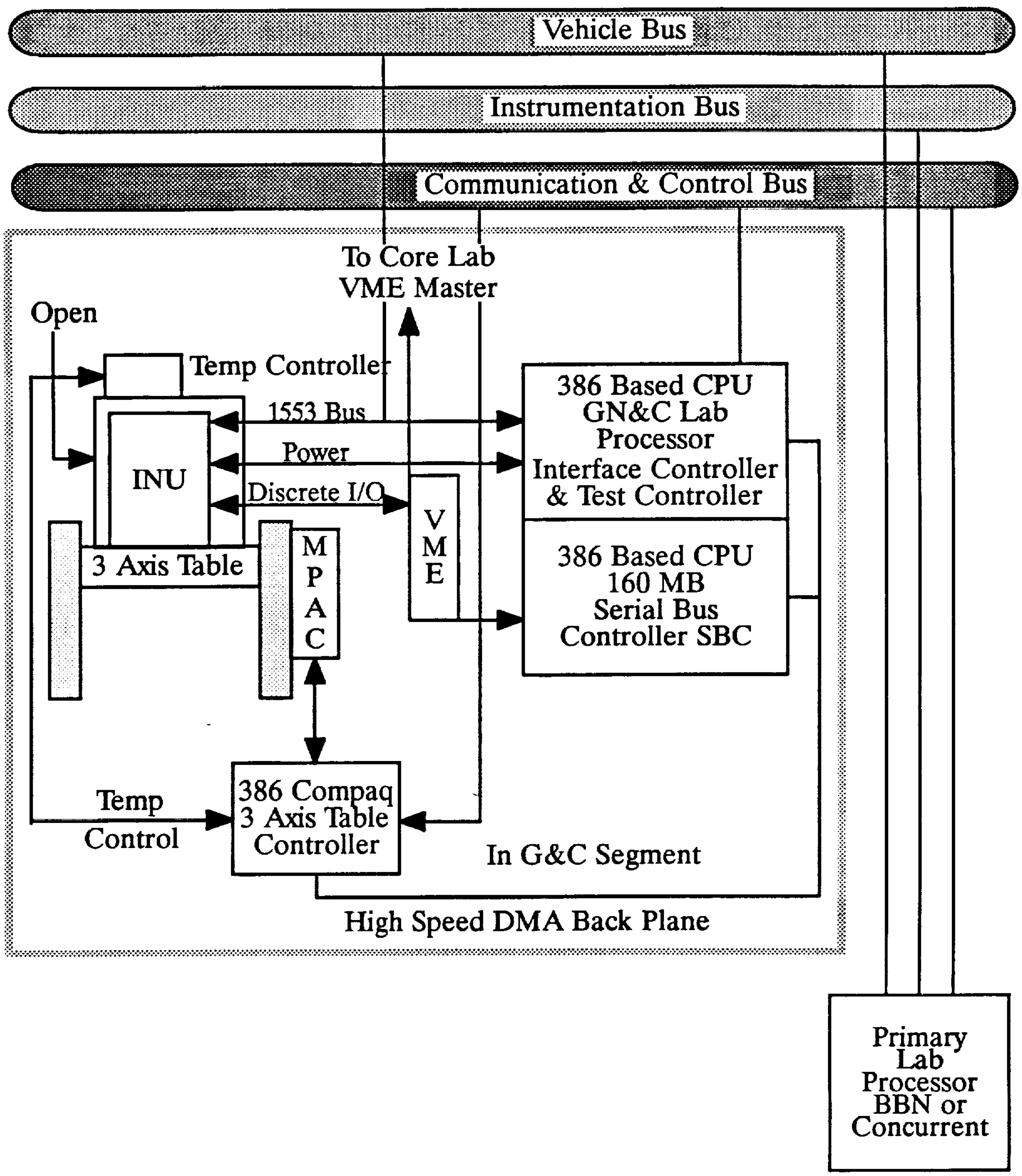


Figure 11 Guidance and Navigation Testing Facility

The computer system used by GD on most projects is the Harris H series. The computer communicates with the system under test through shared memory. If the system under test has a MIL–STD–1553B bus then a MBI unit is added as shown in Figure 14. The MBI unit is responsible for moving information from the shared memory to the communications bus and placing data from the bus

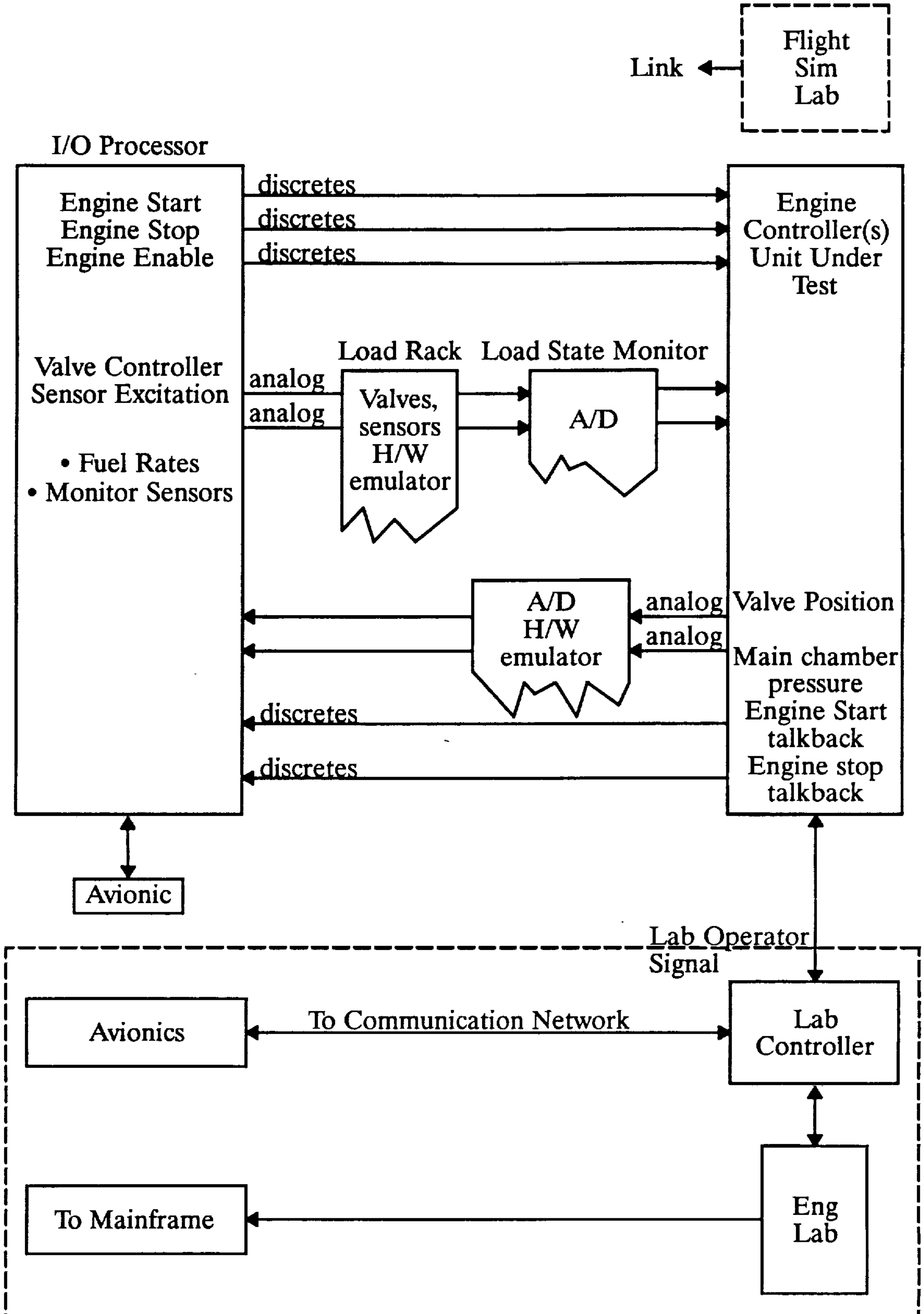


Figure 12 Propulsion Subsystem Testbed for MAST

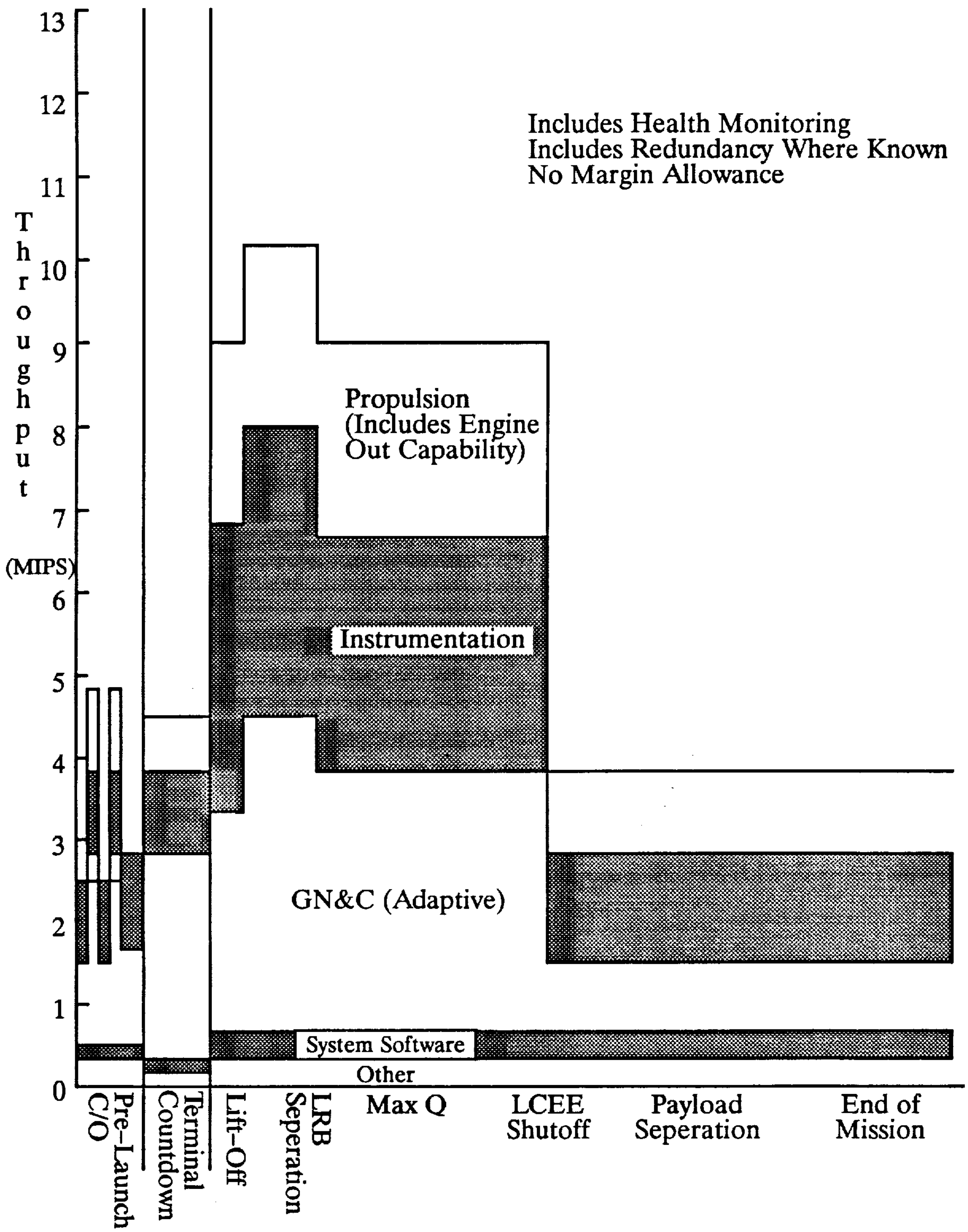


Figure 13 Approximate Vehicle Processing Timeline

into the memory. GD also occasionally adds an additional connection to sub–system buses and microprocessor buses to allow the main computer direct access to this level of the system under test.

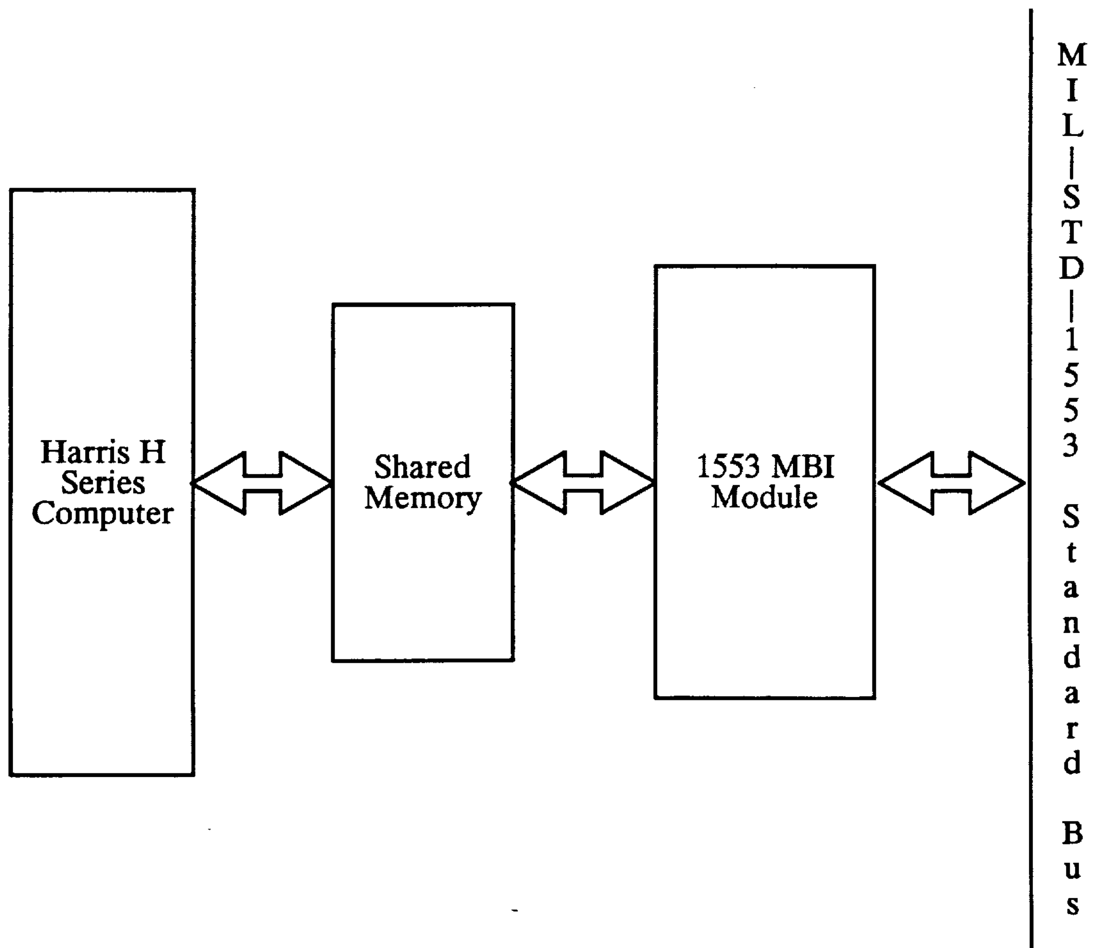


Figure 14 Standard Test Configuration (MIL-STD-1553 Bus under Test)

The philosophy at GD is that any facility that is used by a project typically becomes owned by that project for the duration of the project. Mr Brown was interested in the concept of developing a system that could be used from the design phase through the development of tests for the end product. However, he stated that when this has been attempted in the past a project came along that dominated and then took exclusive access of the facility. The plant at Fort Worth was very similar to the plant at San Diego in that the main concern seems to be the testing of sub-systems as opposed to design and test of new and developmental products. It was stated that past experience has shown that a meaningful test facility usually cannot be built until the prototype has been manufactured. Both GD facilities indicated that test stands for small sub-systems could be built at an early stage but that technology and project requirements change too rapidly for a systems development lab to keep pace.

6.0 NASA JSC Facility

In March 1989 Russ Nelson of Ford Aerospace and Glenn LeBlanc of the Johnson Space Center (JSC) were visited. They are involved with the Space Station DMS development testbed at JSC.

Russ Nelson
713–335–6157 at Ford Aerospace
713–483–7579 at JSC

Glenn LeBlanc
713–483–7015 at JSC

Their address at JSC is

National Aeronautics and Space Administration
Lyndon B. Jhonson Space Center
MZ FS53
Houston, TX 77058

They are studying the application of FDDI to the space station. They are presently studying the performance of the Fiberonics implementation of the FDDI protocol. Performance issues such as backbone delay, throughput, efficiency, and effects related to packet size are being studied. The FDDI network shown in Figure 15 is composed of four nodes. Three of the nodes have HP 4972A Lanalyzers and a Sun workstation. These nodes generate traffic and measure performance. The fourth node is a gateway to other systems. The system will support Apollo and Sun workstations and IBM PS/2 computers. One of the features of the testbed is the use of Isolan Fan-out units from BICC Data Networks. These units are used as wire centers and support up to 8 or 16 connections to a single FDDI node depending on the model used.

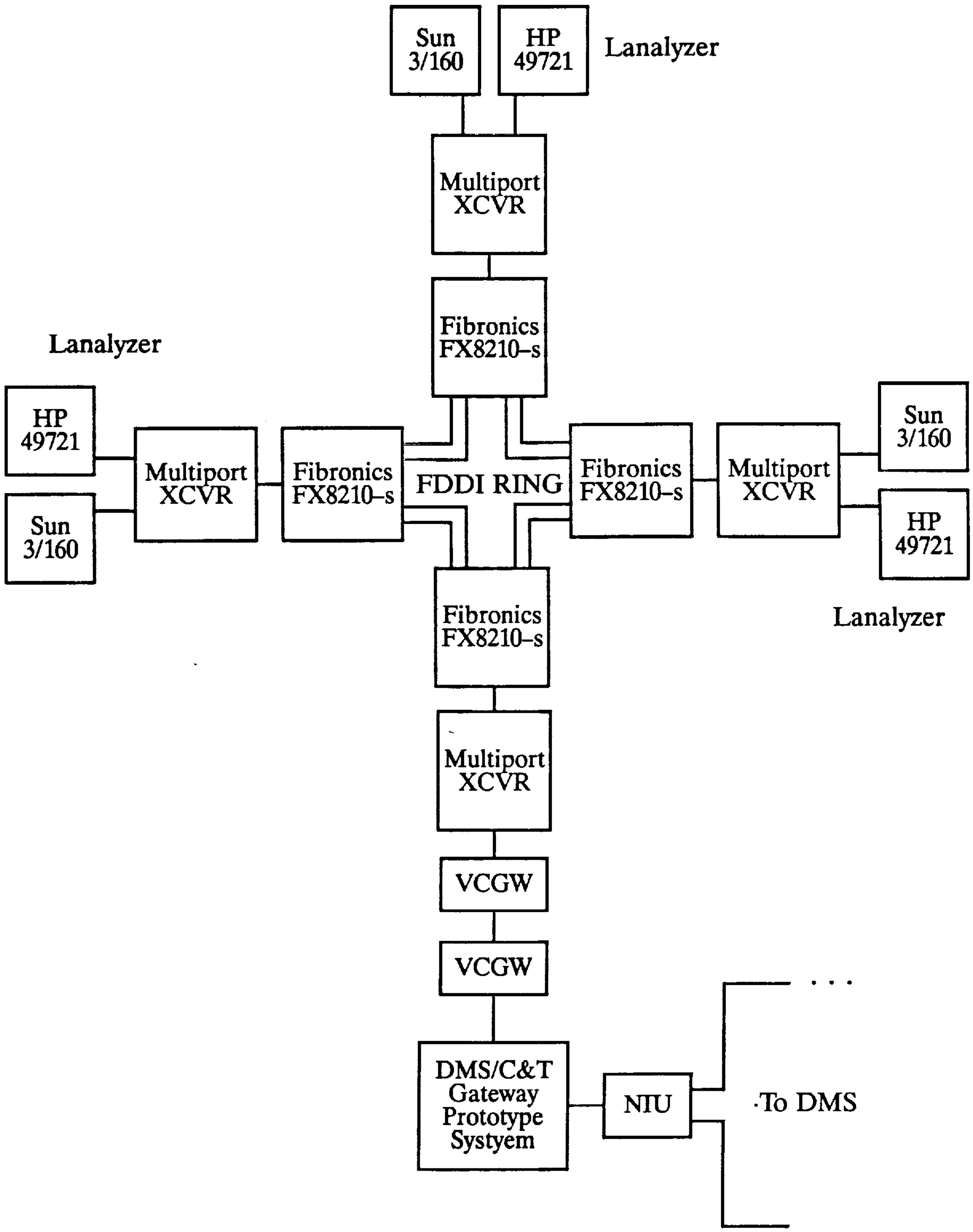


Figure 15 Space Station Control Center End-to-End Test Configuration

The performance studies do not include radiation resistance, triple redundancy or single nodes generating more than 10 megabits/second. These items should be covered for this application. It is thought that any node that generates more than 10 megabits/second will be given a dedicated link.

The testbed has been used to determine failure recovery times for the system. Two values of interest are the 25 millisecond power loss recovery time and the 96 microsecond cable rehook recovery time. Documentation on the Fiberonics system is not complete at this time and this has led to difficulties. The station management software produces many diagnostics but their meaning is not documented.

Preliminary test of the system is scheduled to be concluded in late June. An internal report will be published and should be available in July. The system will eventually be used to model communications from JSC to the space station and back as shown in Figure 16. It is planned that the hardware at JSC and on board the station will be the actual hardware and only the radio link will be modeled.

7.0 The Proposed Local Area Network for the NASA/MSFC Testbed Backbone

Though ProNET is available and in use now, the future standard for high speed local area networks appears to be the Fiber Distributed Data Interface (FDDI). Therefore, FDDI is the recommended backbone LAN for the MAST facility. A typical avionics architecture using FDDI and MIL-STD-1553B is shown in Figure 17. The MIL-STD-1553B bus is used as a local distribution network for subsystems while FDDI is used as a backbone LAN for communications between subsystems. The relevant standards for FDDI are presented in Figure 18. Notice that Northrup is heavily supporting FDDI even though they presently use ProNET

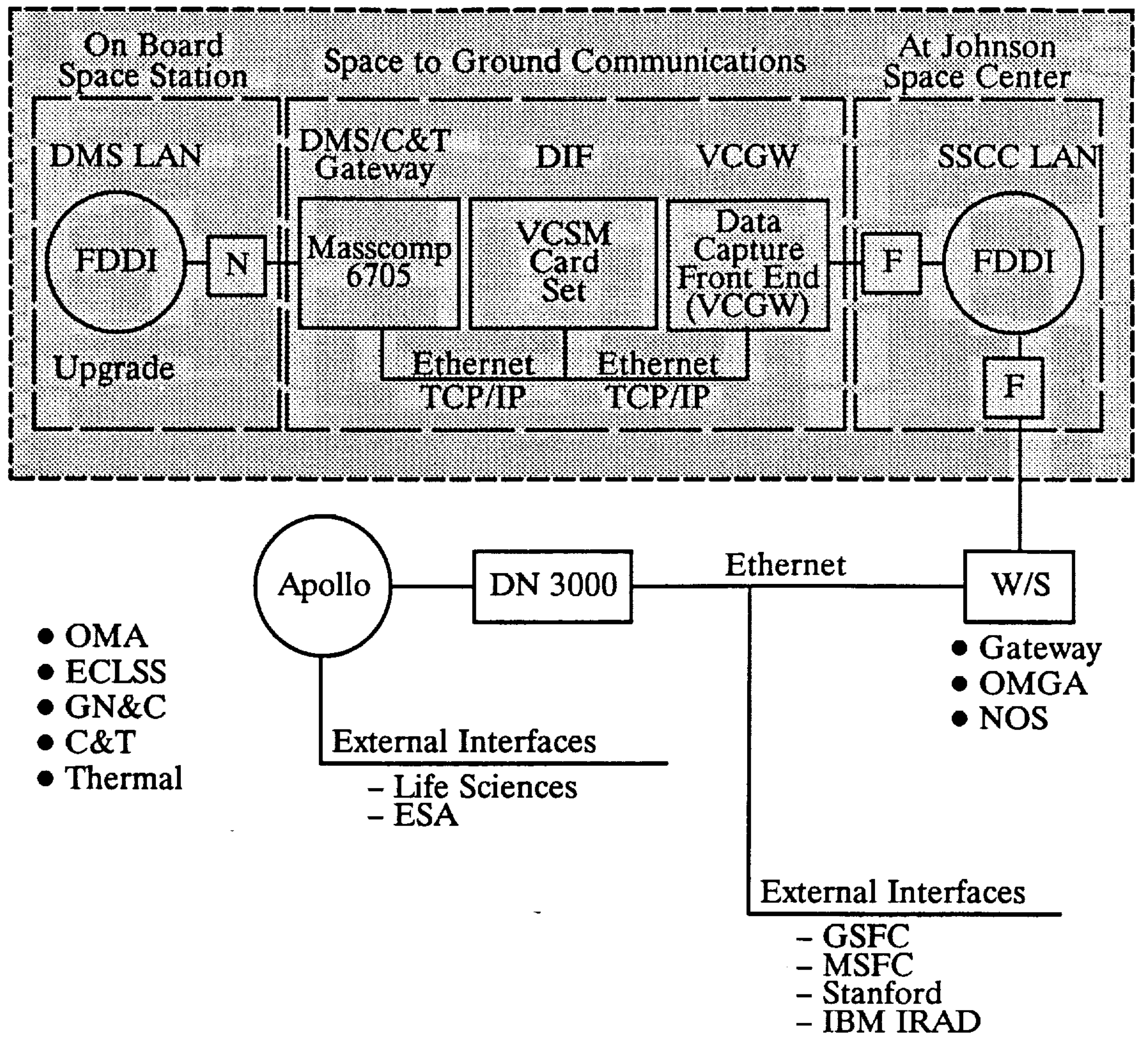


Figure 16 JSC ETC Interfaces

for their high speed LAN requirements. This would lead one to suspect that they will upgrade to FDDI as hardware becomes available. A functional block diagrams for FDDI is shown in Figures 19 and 20 and a communications model is shown in Figure 21. The important information in these figures is that FDDI is being developed with military requirements in mind. This should make components available that meet NASA's space qualification requirements. FDDI's use of counter rotating rings as shown in Figure 22 and optical bypass shown in Figure 23 should allow FDDI to meet NASA's requirements for redundancy and fault tolerance. For many FDDI systems up to three consecutive nodes may fail and go to .

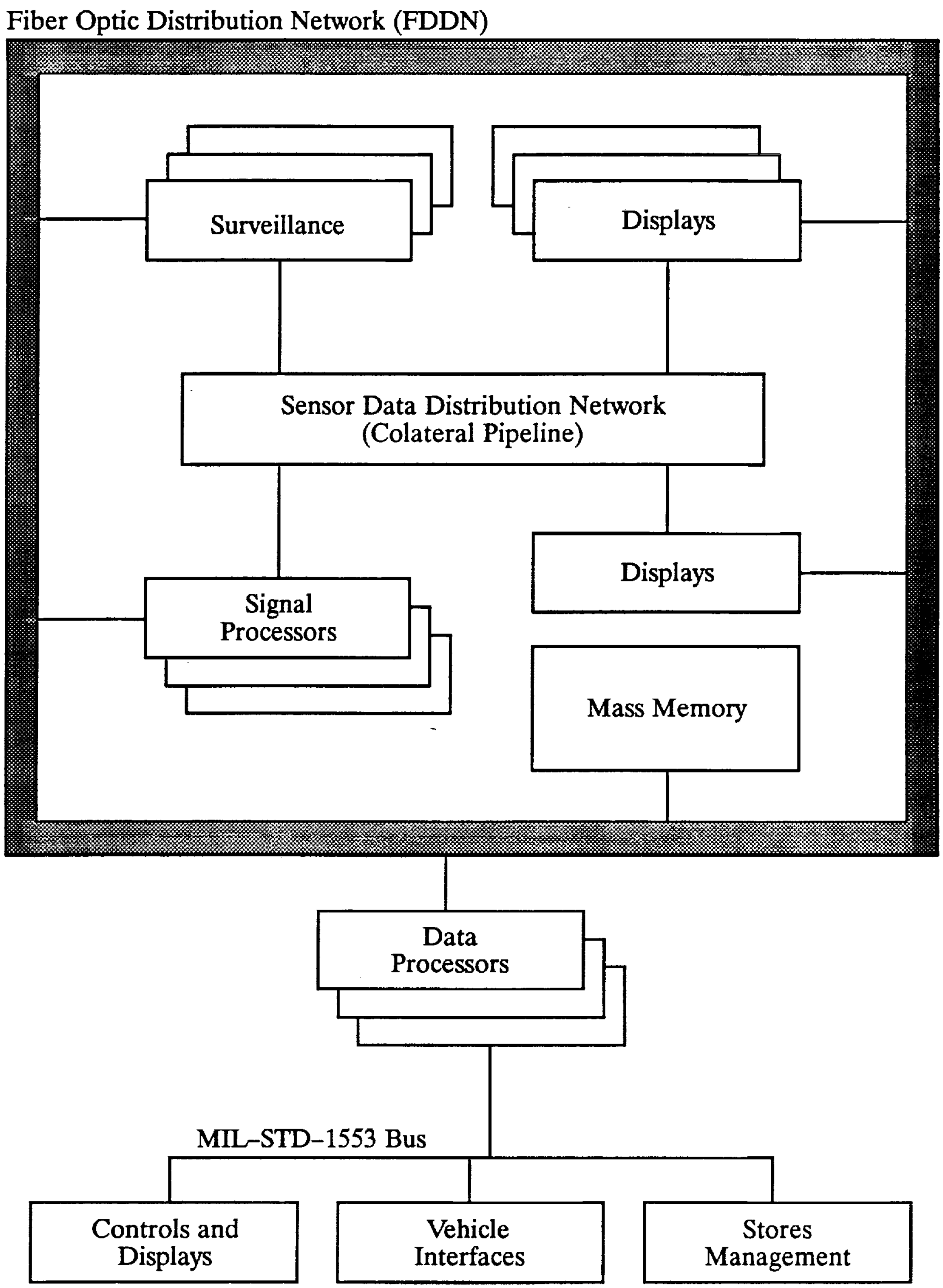


Figure 17 Proposed Distributed Avionics Architecture

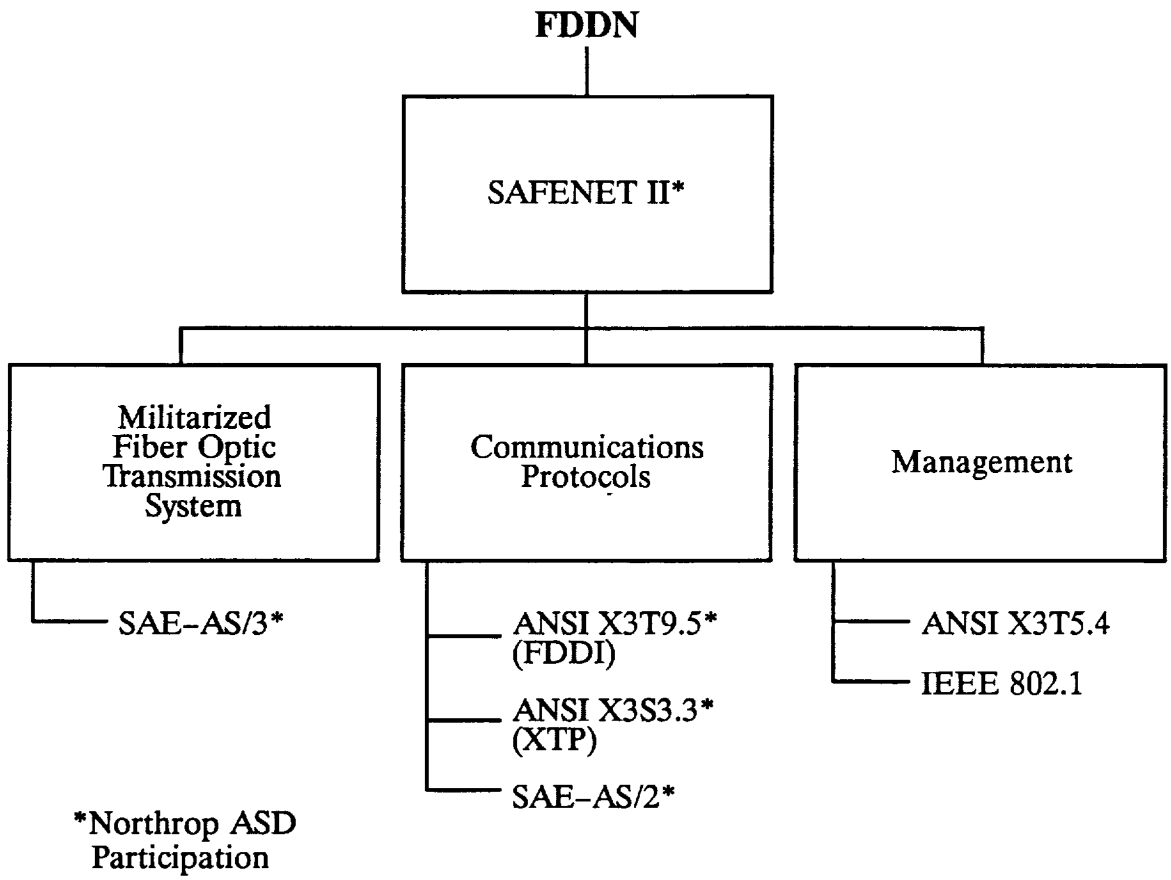


Figure 18 Standarization Efforts Relevant to FDDN

optical bypass before the ring is broken for the remaining stations. For these reasons it is proposed that FDDI be used as the MAST backbone.

7.1 The Proposed Architecture for the Testbed

The visits to various facilities were useful in developing and refining the proposed architecture for MAST. The Northrup facility and General Dynamics proposed expansions were major influences. The Northrup VMS philosophy is generally what is generally followed with the upgrade to a FDDI backbone LAN.[COHN88] The proposed system is shown in Figures 24 and 25. Figure 24 assumes that each stage has its own LAN and multiple stage vehicles have bridge nodes between stages. This introduces a point of failure and the problem of packets on the system addressed to dropped stages must be dealt with. This system

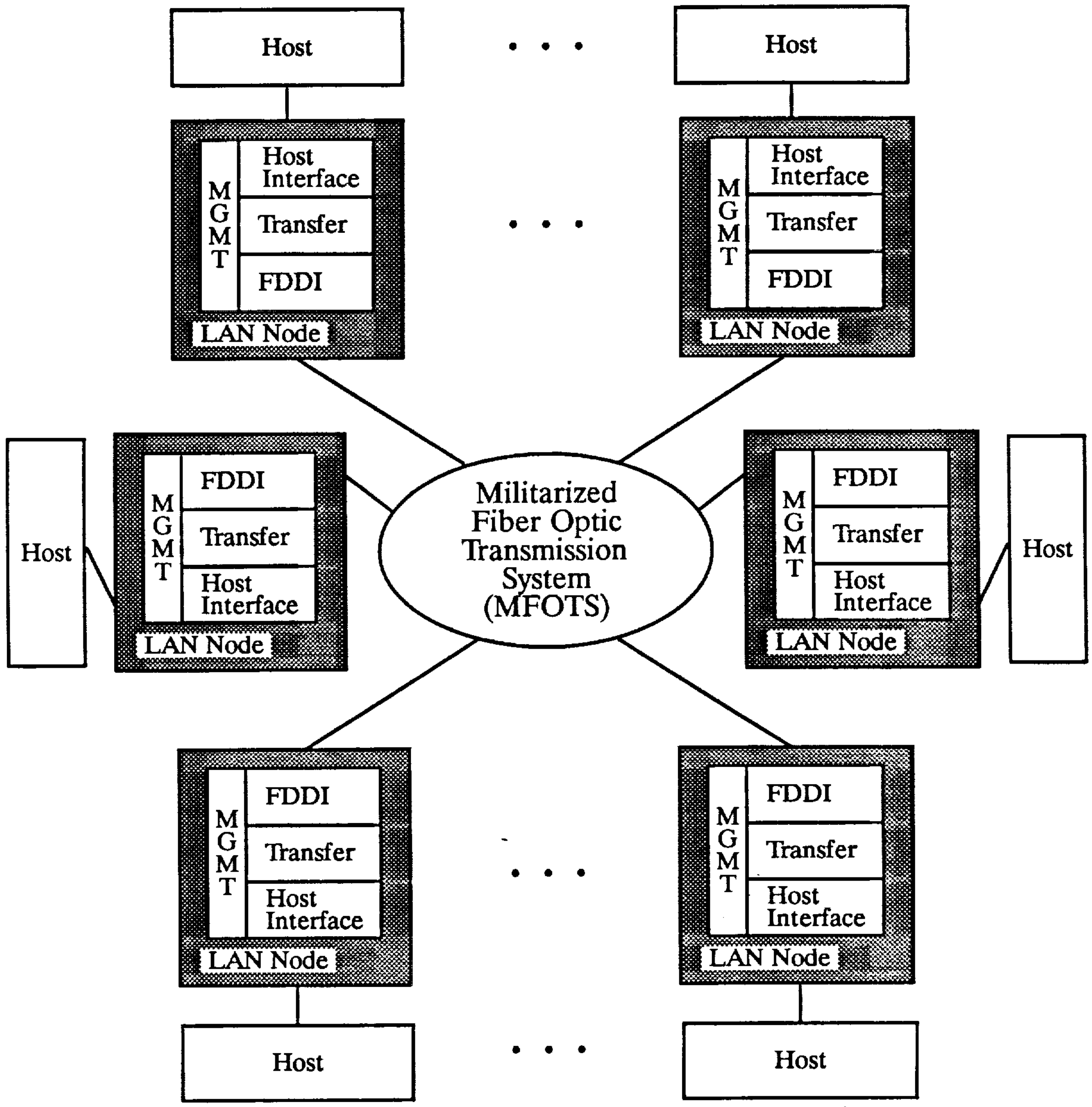


Figure 19 FDDN Functional Block Diagram

would be considered inferior to the system presented in Figure 25 because the Backbone network does not have access to each stage. These access points would be used to record bus traffic and to input stimuli to the system. They would also be used to input initial conditions and supply responses from nodes that are temporarily out of the system.

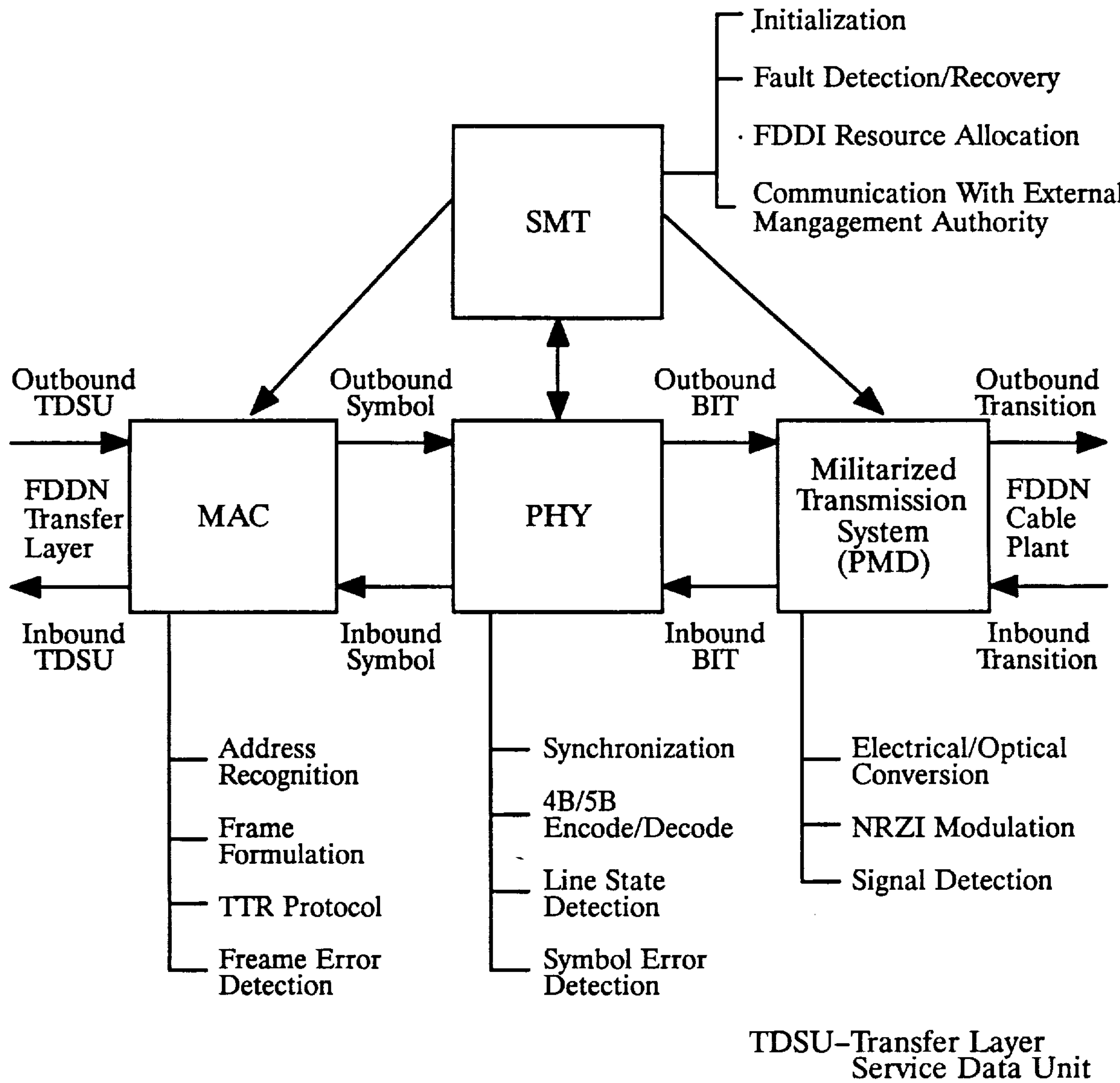


Figure 20 FDDI Functional Block Diagram

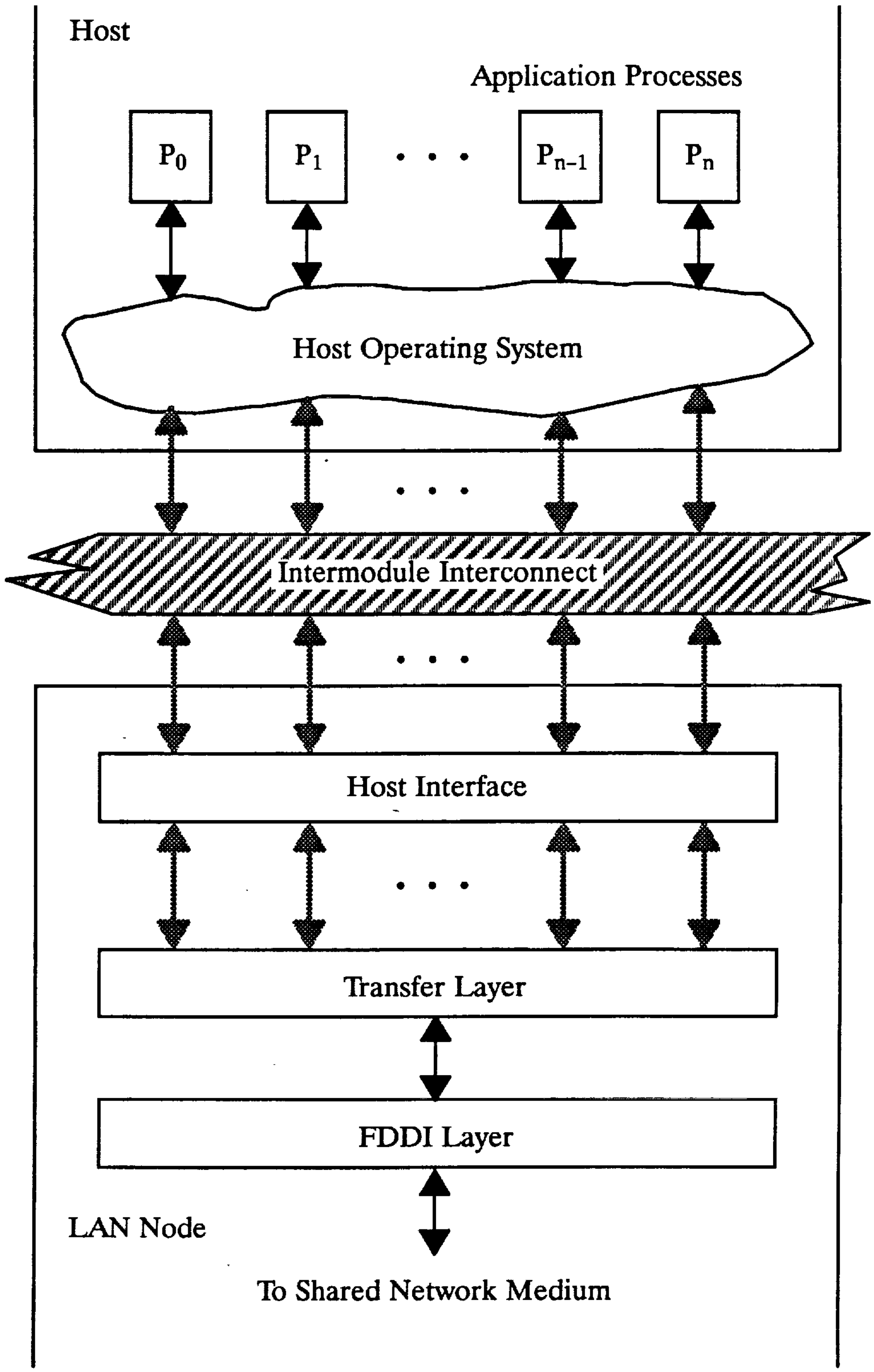


Figure 21 FDDI Communications Model

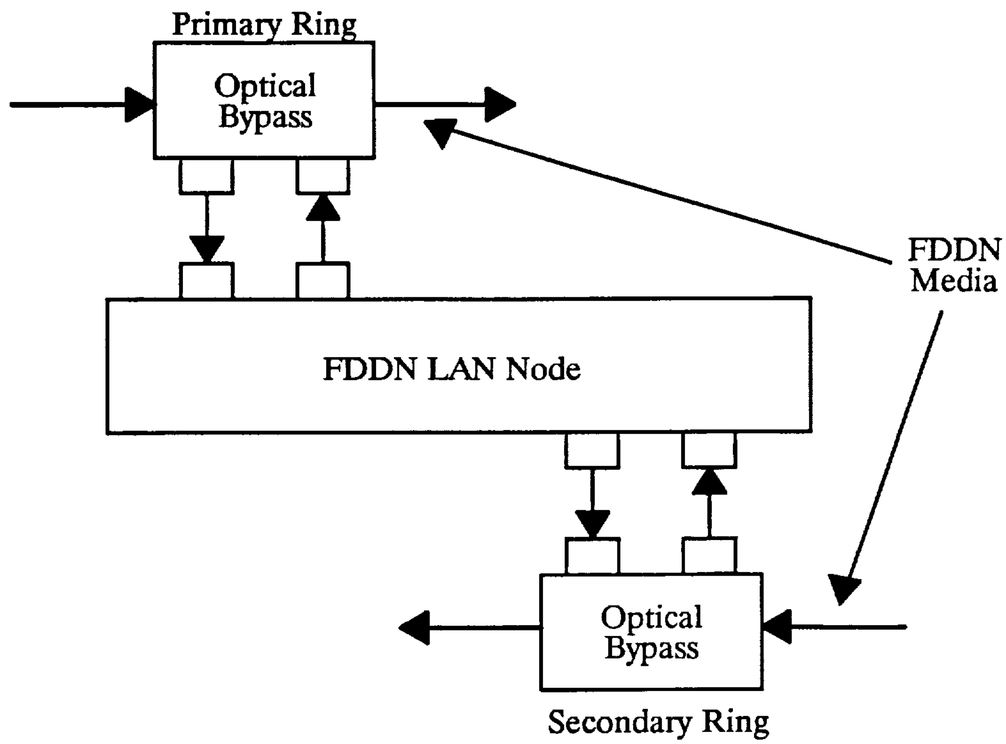


Figure 22 FDDN LAN Node Attachments

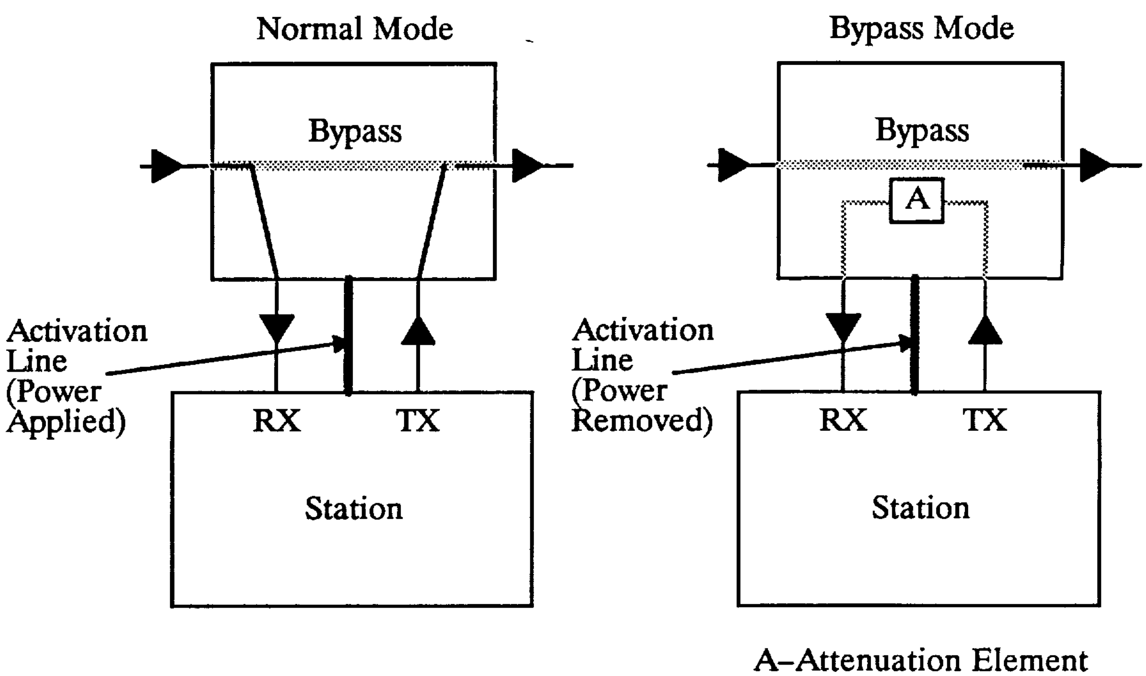


Figure 23 Optical Bypass Operation

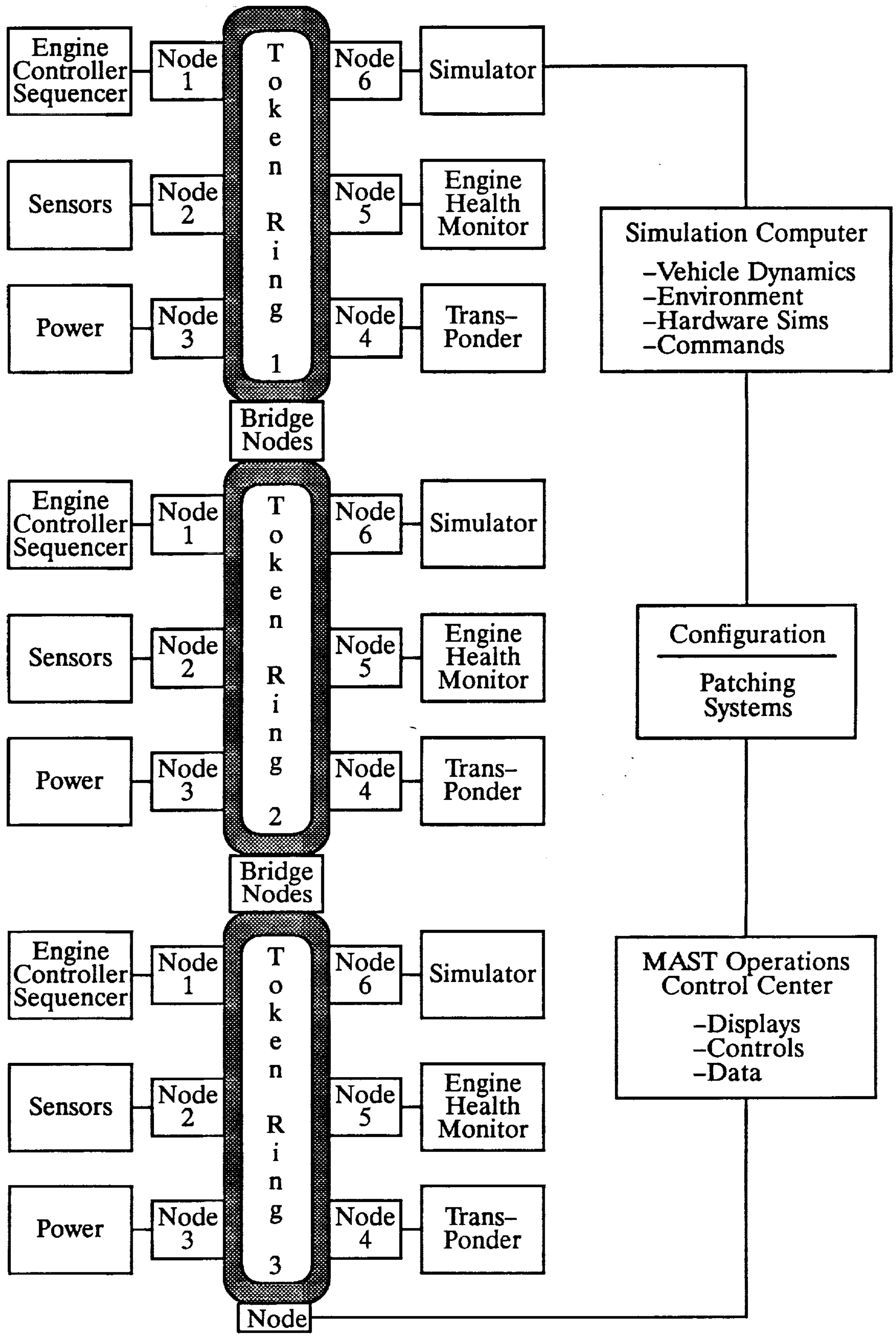
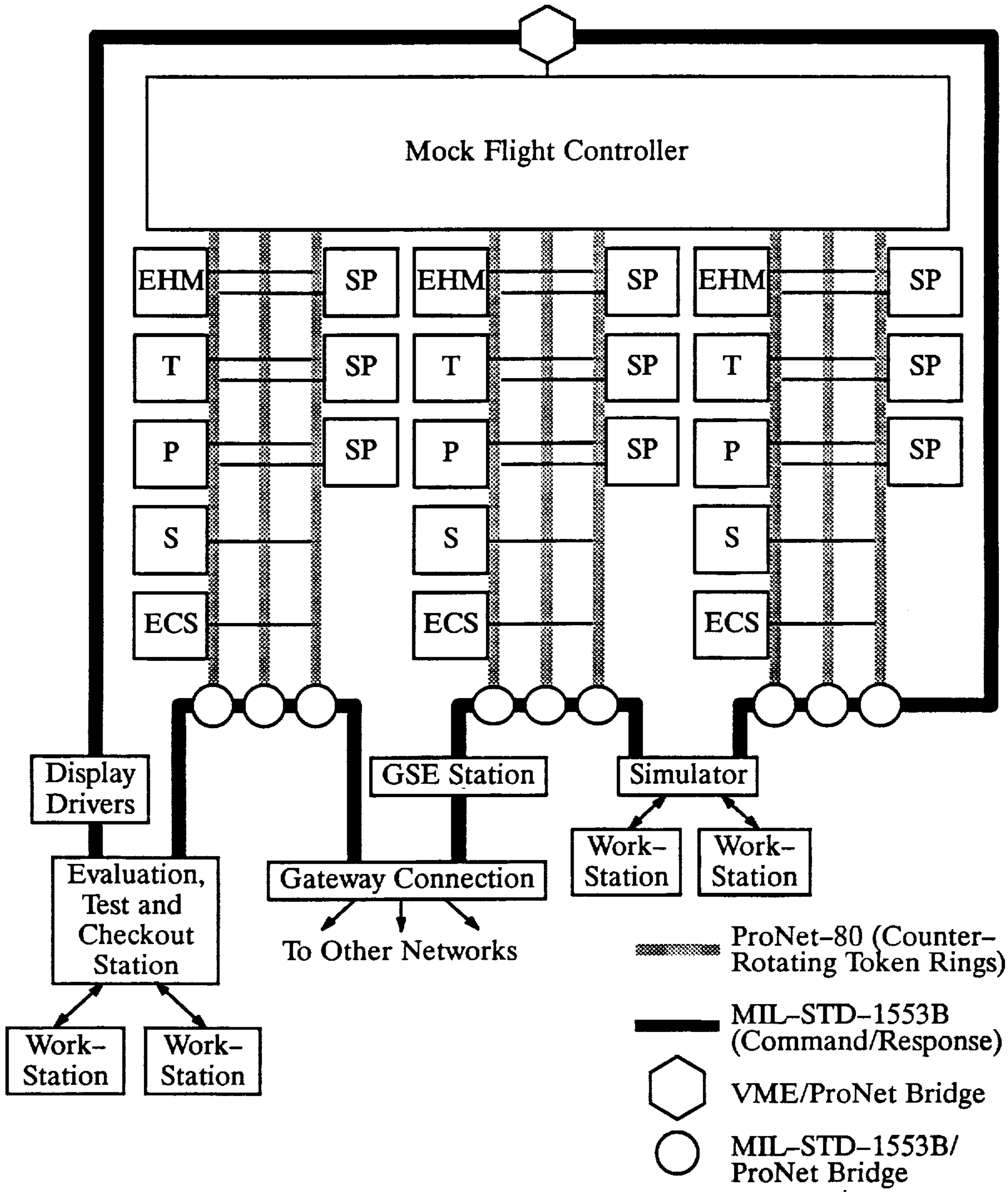


Figure 24 Possible MAST Topology



ECS = Engine Controller/Sequencer
S = Sensor
P = Power
T = Transponder
EHM = Engine Health Monitor
SP = Spare Plug

Figure 25 Proposed MAST Topology

Several points that should be made about the testbed are:

- The use of microprocessor based test equipment and communications is essential to the requirement of easy flexibility.
- The Local Area Network used must have bandwidth available for future expansions of the facility. The use of a fiber system will allow this even if the protocol is changed. However, FDDI is expected to be used well above 100 megabits/second as hardware becomes available.
- The computing systems for simulation and control should be composed of distributed microprocessing systems so that as requirements grow the system can expand easily.
- The technology used in the facility should be as up to date as possible to avoid obsolescence but standards should be used wherever possible.

Several points that should be made about the testbed facility are:

- Use raised floors throughout the facility. This allows for easy cable installation and modification
- Provide ramp access to all doors or to at least one large door.
- Plan for obsolescence and expansion. Over design power and air conditioner systems by at least fifty percent.
- Provide convenient access between labs. Equipment will often be moved between labs.
- A workbench area should be provided for all areas. Maintenance, construction and installation task will be required often for this facility.

- Assessable storage for manuals and computer media should be provided.

- Make cable lengths longer than required and up to the farthest corner when practical. Expansion will require the movement of equipment. Also route cable through trays and label cables every three feet when practical.

- Use incandescent lighting where possible to reduce noise. Provide separate dimmer controls for areas with video displays to reduce glare.

Display Area:

- Provide a presentation and display area that will accommodate approximately thirty people.

- Provide several large screen displays for presentation.

- Provide for the display of information from any workstation in the facility.

- Provide slide and viewgraph facilities for presentations.

- Provide workstation area with stations to control presentation.

Main Computer Room

- Provide separate computer room for noise control.

- Room should be central to facility to reduce communications route lengths and delays.

- Provide visibility to and from other areas.

Workstation Environment

- Use a minimum of a six foot table for each station. The footprint of most stations monitor and keyboard covers smaller tables and, therefore, does not leave room for documentation and scratchwork.
- Provide accessible storage for documentation and backup media.
- Provide small demonstration area for approximately ten people.

Systems Integration Area

- Provide separate area for the integration of facilities in other sections.
- Provide convenient access to other labs and main computer room.

7.0 References

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