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STUDY REPORT - VOLUME 3

SPACE STATION COMPUTER SYSTEM (SCS) STUDY
for
NASA/MSFC

CONCEPTUAL DESIGN REPORT

TRW-SCS-89-T5

31 October, 1989

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Simulation Computer System for Space Station Program

In accordance with the requirements of the subject contract, the final technical report titled SCS Study Report, consisting of six volumes is herewith submitted and distributed as shown.

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SPACE STATION SIMULATION COMPUTER SYSTEM (SCS)
STUDY

REFINED CONCEPTUAL DESIGN REPORT

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SCS SCS

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TABLE OF CONTENTS ..... PAGE

INTRODUCTION 1
1.0 Conceptual Design Findings 2
1.1 Top Level Designs 2
1.2 Six Selected Designs 3
2.0 PTC/SCS Common Design Elements 7
2.1 PTC Facilities Supported By SCS 7
2.1.1 Consolidated Trainer 7
2.1.2 Combined Trainer 7
2.1.3 Part Task Trainer 9
2.1.4 Training Session Manager 9
2.1.5 POIC Trainer 9
2.1.6 Development Facility 9
2.1.7 Integration, Test and Verification (IT&V) Facility 9
2.1.8 CBT Stations 9
2.1.9 Instructor Stations 10
2.1.10 External PTC Interfaces 10
2.2 SSF Program - Architectural Concepts and Requirements 10
2.2.1 DMS Architecture 10
2.2.1.1 DMS Kits 11
2.2.1.2 SIB 13
2.2.2 Space Station Freedom Program Tools and Facilities 14
3.0 SCS Designs 14
3.1 Selection of Three Designs 14
3.2 Common Design Features 15
3.2.1 Payload Representation 19
3.2.2 Core Systems Representation 19
3.2.3 Crew Interface Representation 20
3.2.3.1 C & D Panels 21
3.2.3.2 Crew Console - Multipurpose Application Consoles (MPACs) 21
3.2.4 Audio/Video Systems Representation 21
3.2.5 Common Facility Architectures 21
3.2.5.1 Development Facility 24
3.2.5.2 External Interfaces 24
3.2.5.3 POIC Trainers 24
3.2.5.4 IT&V Facility 26
3.2.5.5 CBT Stations and Facility 26
3.2.6 Simulation Control and Monitoring 26
3.2.6.1 Training Session Manager (TSM) 26
3.2.6.2 Instructor Stations 27
3.2.7 Common Design Options 27
3.2.7.1 Payload Representation Options 27
3.2.7.1.1 Flight Equivalent Payload 27
3.2.7.1.2 Software Simulated Payload 32
3.2.7.2 Core System Options 32
3.2.7.3 C&D Panel Options 34
3.2.7.4 Audio/Video System Options 37

3.3 SCS Local Host Design....37
3.3.1 System Design....37
3.3.1.1 Network Architecture....37
3.3.2 Trainer Design....40
3.3.2.1 Host Architecture....40
3.3.2.2 DMS Components....45
3.3.2.3 Trainer Connectivity....47
3.3.2.3.1 Consolidated Trainer....47
3.3.2.3.2 Other Trainers....47
3.3.3 Host Loading....48
3.4 Shared Host Design....48
3.4.1 System Design....48
3.4.1.1 Network Architecture....50
3.4.2 Trainer Design....50
3.4.2.1 Host Architecture....54
3.4.2.2 DMS Components....58
3.4.2.3 Trainer Connectivity....58
3.4.2.3.1 Consolidated Trainer....59
3.4.2.3.2 Other Trainers....59
3.3.2.3.3 IT&V Facility....59
3.4.3 Host Loading....60
3.5 DMS Equivalent Design....60
3.5.1 System Design....60
3.5.1.1 Network Architecture....64
3.5.2 Trainer Design....66
3.5.2.1 Host Architecture....66
3.5.2.2 "DMS" Components....70
3.5.2.3 Trainer Connectivity....70
3.5.2.3.1 Consolidated Trainer....71
3.5.2.3.2 Combined Trainer....71
3.5.2.3.3 Part Task Trainer....71
3.5.3 Host Loading....71
4.0 SCS Design Comparison....73
4.1 Reliability and Maintainability....73
4.2 Expandability and Scalability....75
4.3 Cost....76
4.4 Computer Headroom....79
4.5 Hardware/Software Compatibility and Standards....80
4.6 Reconfiguration/Modularity....80
4.7 Ease of Operation....80
4.8 Performance/Functionality Versus Cost....80
4.9 Summary of Design Features....81
5.0 Conclusion....82
APPENDIX I. SYSTEM SIZING ANALYSIS....83

LIST OF FIGURES PAGE

Figure 1.1-1 SCS Top Level Conceptual Designs....2
Figure 1.1-2. Six Selected Designs....4
Figure 2.1-1 PTC/SCS Components....8
Figure 2.2-1 Basic DMS Component I/O Architecture....12
Figure 3.1-1 SCS Local Host Design....16
Figure 3.1-2 SCS Shared Host Design....17
Figure 3.1-3 SCS DMS Equivalent Design....18
Figure 3.2-1 Virtual Control & Display Panel Design....22
Figure 3.2-2 Audio & Video System Design....23
Figure 3.2-3 Overview Architectures of Common Facilities....25
Figure 3.2-4 Instructor Station....28
Figure 3.2-5 Payload Representation Options....29
Figure 3.2-6 SCS Payload Connection Options....31
Figure 3.2-7 Payload Simulation Options....33
Figure 3.2-8 Core System Model Options....35
Figure 3.2-9 SCS C&D Connection Options....36
Figure 3.3-1 Top Level View of Local Host Design....38
Figure 3.3-2 Allocation of SCS Functions to Local Host Design....39
Figure 3.3-3 Local Host Network Loading....41
Figure 3.3-4 Local Host Consolidated Trainer Design....42
Figure 3.3-5 Local Host Combined Trainer Design....43
Figure 3.3-6 Local Host Part Task Trainer Design....44
Figure 3.3-7 Local Host Loading....49
Figure 3.4-1 Top Level View of Shared Host Design....51
Figure 3.4-2 Allocation of SCS Functions to Shared Host Design....52
Figure 3.4-3 Shared Host Network Loading....53
Figure 3.4-4 Shared Host Consolidated Trainer Design....55
Figure 3.4-5 Shared Host Combined Trainer Design....56
Figure 3.4-6 Shared Host Part Task Trainer Design....57
Figure 3.4-7 Shared Host Loading....61
Figure 3.5-1 Top Level View of DMS Equivalent Design....62
Figure 3.5-2 Allocation of SCS Functions to DMS Equivalent Design....63
Figure 3.5-3 DMS Equivalent Network Loading....65
Figure 3.5-4 DMS Equivalent Consolidated Trainer Design....67
Figure 3.5-5 DMS Equivalent Combined Trainer Design....68
Figure 3.5-6 DMS Equivalent Part Task Trainer Design....69
Figure 3.5-7 DMS Equivalent Loading....72
Figure 4.0-1 Summary of Design Differences....74
Figure 4.3-1 Computer Platforms....76
Figure 4.9-1 Summary Results from a Comparison of SCS Designs....81

INTRODUCTION

The results of the refined conceptual design phase (Task 5) of the Simulation Computer System (SCS) Study are reported in this document. The SCS is the computational portion of the Payload Training Complex (PTC) providing simulation based training on payload operations of the Space Station Freedom (SSF).

In Task 4 of the SCS Study, the range of architectures suitable for the SCS was explored. Identified system architectures, along with their relative advantages and disadvantages for SCS, were presented in the Conceptual Design Report. Six integrated designs -- combining the most promising features from the architectural formulations -- were additionally identified in the report. The six integrated designs were evaluated further to distinguish the more viable designs to be refined as conceptual designs. The three designs that were selected represent distinct approaches to achieving a capable and cost effective SCS configuration for the PTC.

In this report, the results of Task 4 (input to this task) are briefly reviewed. Then, prior to describing individual conceptual designs, the PTC facility configuration and the SSF systems architecture that must be supported by the SCS are reviewed. Next, basic features of SCS implementation that have been incorporated into all selected SCS designs are considered. The details of the individual SCS designs are then presented before making a final comparison of the three designs.

1.0 Conceptual Design Findings

1.1 Top Level Designs

The range of SCS conceptual designs considered in Task 4 was the product of several system architectures combined with several trainer architectures. The top level designs numbered 1 - 6 are the different system architectures, and the letters A - D indicate the different trainer architectures. The system designs 1-6 represent the entire SCS architecture. The trainer designs A-D are alternative trainer subsets within these architectures.

#	NAME	DESCRIPTION
1.	Monolithic Host	A single host for all SCS functions.
2.	Programmable Switch	A programmable switch connects hosts to trainers.
3.	Local Host Network	Local hosts connected via a network.
4.	Network Combined	Trainer hosts combined plus a network.
5.	Shared Host Network	Distributed network with shared hosts.
6.	Autonomous Trainers	One host per trainer, no network.
A.	DMS Kit	GFE DMS Kits are used.
B.	DMS Compatible	DMS components or DMS like components.
C.	PCTC based	DMS simulated in software on a host CPU.
D.	Distributed non-DMS	No DMS Kits, processors on a network.

Figure 1.1-1 SCS Top Level Conceptual Designs

The following paragraphs discuss each of these top level designs.

The Monolithic Host (System Design 1) means that all SCS functions would be performed on one single host computer. All trainers and facilities would be connected to the single host computer via point to point connection methods. This design is simple, using a single CPU type and single operating system, and provides straight forward centralized control. Many successful computer systems have been built in the past using this architecture.

The Programmable Switch (System Design 2) provides multiple host computers that can be switched to support any trainer or any facility. This provides a high degree of fault tolerance and reconfigurability. Point to point connections are used.

The Distributed Network with Local Hosts (System Design 3) means that the trainers and facilities are connected via a network, but that each trainer and facility has one or more dedicated host computers directly connected to it. The network facilitates quick convenient communication between computers, aids in configuration management, and provides a means for centralized control. This design represents the current thinking in computer system design.

The Distributed Network with Combined Subsystems (System Design 4) is a variant of Design 3. The basic idea is that some of the trainers may be able to use the same local host computer, thus reducing the number of computers required.

The Distributed Network with Shared Hosts (System Design 5) means that none of the trainers have dedicated local hosts. The host computers are connected to a network and are only dedicated to a trainer for a particular training session. All data passed between the host and trainer for that session must now pass over the network. This design provides good fault tolerance and reconfigurability. The problem is the potentially high traffic load on the network might make this design impractical.

The Autonomous Trainers (System Design 6) means each trainer and facility has a dedicated host directly connected, and the computers are not connected. This design is simple, and would have a lower cost than ones that include a network. Many successful systems have been built in the past using this design.

The DMS Kit trainer design (Trainer Design A) uses DMS hardware to support core system simulations and payload flight software if available. This would promote easy interfacing of SCS payload simulations to the SSTF, since the SSTF will use DMS Kits. It also means that SCS hardware would not have to support all of the core and payload flight simulations.

The DMS Compatible trainer design (Trainer Design B) uses partial DMS Kits or DMS Kits without a SIB to support the core simulations needed for training. The lack of a SIB would make it more difficult to interface SCS simulations.

The PCTC Based trainer design (Trainer Design C) means that the core systems would be all simulated in software on a host computer. No DMS or compatible hardware would be used. This would cut hardware costs, but increase software costs. Transportability to the SSTF would be adversely affected.

The Distributed Non-DMS trainer design (Trainer Design D) also means that core systems would be simulated in software, but that distributed processors would be used instead of a host computer. If COTS 80386 processors or personal Computers (PCs) could be used, some modified DMS software might be usable.

1.2 Six Selected Designs

By considering the six system level designs (1-6) in combination with the four trainer designs (A-D), 24 possible designs emerged. Using the evaluation criteria and

viable candidates for refinement in SCS Study Task 5. The six selected designs are identified in Figure 1.1-2 using the top level designators introduced in Figure 1.1-1.

#	Top Level Designation	Name
I	3-A	Network Local Host - DMS Kit Trainers
II	3/5-A	Network Local Host and Shared Host - DMS Kit Trainers
III	4-B	Network Local Host with Combined Components - DMS Compatible Trainers
IV	3-C/D	Network Local Host - PCTC Based/Non-DMS Trainers
V	2-A	Programmable Switch - DMS Kit Trainers
VI	3-A/D	Network Local Host - DMS Kit/Non-DMS Trainers

Figure 1.1-2. Six Selected Designs

The six SCS designs are described in the following paragraphs.

I. SCS Integrated Conceptual Design 3-A

Integrates the Distributed Network Local Host architecture with the DMS Kit trainer design. The local hosts in each of the trainers perform all real-time simulation activities required to support payload training.

The distributed network allows maximum flexibility for high speed communications between the SCS facilities or subsystems. Any facility can exchange data with any other facility using a single interface. The implementation of a single local trainer host for payload simulation executive functions is less complex from a system software viewpoint than implementing shared hosts at the SCS level.

The use of the DMS Kits, including the SIB, is the SSE recommended approach to Space Station system development, integration, testing, and training. It is also the approach favored by the SSTF development effort at JSC. The use of the DMS Kit helps guarantee a high level of fidelity for payload training. Flight equivalent Space Station systems and payloads are easily integrated into the trainer with the DMS Kit. Also, Core system functional simulations, software developed for the SSTF, and SSE developed software would be directly transportable to the SCS. Likewise, PTC developed experiment models would be more easily transportable to the SSTF if developed in a DMS Kit environment. The SIB offers a great deal of functionality useful for simulations.

The SIB simplifies the implementation of some training requirements, like fault insertion.

II. SCS Integrated Conceptual Design 3/5-A

This design integrates a combination of the Distributed Network Local Hosts and Distributed Network Shared Hosts architecture with the DMS Kit trainer design. Individual shared hosts are allocated to perform real-time or non real-time functions, but not both. The real-time shared hosts support a different training scenario for each trainer. The local hosts support real-time training functions specific to a particular trainer.

This design is somewhat similar to 3-A (# I) above and shares many of the advantages discussed. The use of shared hosts for non real-time functions offers additional flexibility, increased fault tolerance, and allows more powerful, more cost effective hosts to be utilized than a design with only dedicated hosts.

III. SCS Integrated Conceptual Design 4-B

Integrates the Distributed Network with Local Hosts and Combined Training Components architecture with the DMS Compatible trainer design. The Combined trainer is integrated with the Attached Payload trainer, and other trainers might be combined.

This design utilizes a distributed network, like 3-A (# I) above. By combining trainers, a savings in equipment cost and possibly facility space can be obtained. The Part Task Trainers could also be combined such that a single host could support multiple Part Task Trainers.

IV. SCS Integrated Conceptual Design 3-C/D

Integrates the Distributed Network Local Host architecture with the synthesis of the PCTC-based trainer and the Distributed Non-DMS trainer. This architecture does not have a DMS Kit or DMS components. Some trainer functions are implemented on the trainer host and some functions are implemented on dedicated processors.

This design also utilizes a distributed network. The trainer design, with no DMS hardware components, offers flexibility of hardware configuration, and reduces risk resulting from uncertainties in the DMS Kit development schedule. In addition, COTS non-DMS hardware can be readily purchased from a vendor and is certain to be less expensive than DMS hardware. The use of non-DMS hardware does not necessarily preclude the use of DMS software. It is likely, however, that DMS software would require some degree of modification to run in a non-DMS hardware environment.

The use of PCTC-based trainers would give the economic advantage of starting from an existing facility which could evolve into the finally required trainers. The advantage of using both the PCTC-based trainers and non-DMS trainers is that neither of these trainer designs contains DMS components, and the opportunity for synthesis between these two types of trainers thus seems good. The non-DMS design is a distributed, microcomputer based design that should

compliment and perhaps off set some of the disadvantages of the somewhat monolithic PCTC-based design.

V. SCS Integrated Conceptual Design 2-A

Integrates the Programmable Switch with multiple host architecture with the DMS Kit trainer design. In this design, multiple trainers may be interfaced to the same host. The trainers may be switched and reconfigured quickly in the event of a host failure.

The use of shared hosts makes maximum use of system resources. Any trainer can be quickly configured with any host, providing increased flexibility and fault tolerance. The use of dedicated point to point interfaces between the trainers and the hosts ensures that communication bandwidth problems are minimized.

This design has a lot of promise. However, investigations conducted at the beginning of the Refined Design Task revealed that a switch capable of switching the required wideband high rate Direct Memory Access (DMA) channels currently does not exist. Existing switches can only handle 8 bit wide low rate channels.

VI. SCS Integrated Conceptual Design 3-A/D

Integrates the Distributed Network Local Host architecture with a combination of the DMS Kit trainer and the Distributed Non-DMS trainer. In this design, Non-DMS trainer elements are integrated with DMS trainer elements. Non-DMS trainer elements such as generic processors and peripheral devices are directly connected to the DMS LAN, instead of being directly connected to the SIB. In addition, elements of the Combined system approach are implemented in that the trainer host and SIB are shared across multiple trainers.

This design is similar to 3-A (# I) above. The use of some non-DMS components in the trainer provides additional flexibility, and allows increased trainer functionality. Functional areas where non-DMS components could be desirable are instructor control and monitoring, audio/video systems, Core systems interface, and payload simulation control. These areas are envisioned to be implemented on the trainer host in other designs, but there could be advantages to implementing these functions in a processor directly attached to the payload LAN.

2.0 PTC/SCS Common Design Elements

2.1 PTC Facilities Supported By SCS

The basic SCS is comprised of a number of relatively independent computer based facilities combined to implement the breadth of SCS requirements outlined in the SCS Concept Document. Figure 2.1-1 illustrates all of the PTC/SCS components required to accomplish the level and amount of payload training required for successful SSF payload operations. Support for all of the facilities identified in Figure 2.1-1 are included in each SCS design. The facilities consist of various trainer types capable of different levels of simulation fidelity and scope, and ancillary facilities providing training system support to the PTC. Many of the support facilities, as well as some of the trainer facilities, are implemented similarly across the three detailed designs. The major facilities comprising the SCS designs are discussed briefly in the following paragraphs.

2.1.1 Consolidated Trainer

The Consolidated Trainer is used for full fidelity, integrated training combining operations across the US Lab and attached payloads, Columbus Lab, and JEM Lab. The trainer represents the labs' payload systems, as well as all SSF core, communications, and space environment factors necessary for payload operations. In order to satisfy training requirements, the three labs are operated concurrently under a single integrated simulation session. Each of the constituent labs is a full scale, high fidelity laboratory module and experiment payload simulation system. The individual lab systems each support concurrent operation and representation of up to 24 payload experiments.

The Columbus Lab and JEM Lab, which have currently undefined architectures that may not be comparable to the DMS, are interfaced to the DMS in the US Lab through network gateways. For present design purposes, the individual Columbus and JEM Labs are represented with a basic architecture of similar functionality to the US Lab.

The Consolidated Trainer, and the other trainer types described below, provide for connection to flight equivalent payload instruments and to general purpose input/output devices used, in conjunction with software models, to simulate payloads.

2.1.2 Combined Trainer/Attached Payload Trainer

The Combined Trainers are used for full fidelity single-lab training on the individual US, Columbus, and JEM Labs. Each Combined Trainer provides simulation of all lab payload and related SSF functions and supports a full complement of experiments. The three lab trainers operate independently. The attached payload trainer is used for full fidelity training on payloads attached externally. It operates independently, and it's design is exactly like the combined trainer. Thus, no separate drawings were made for it.

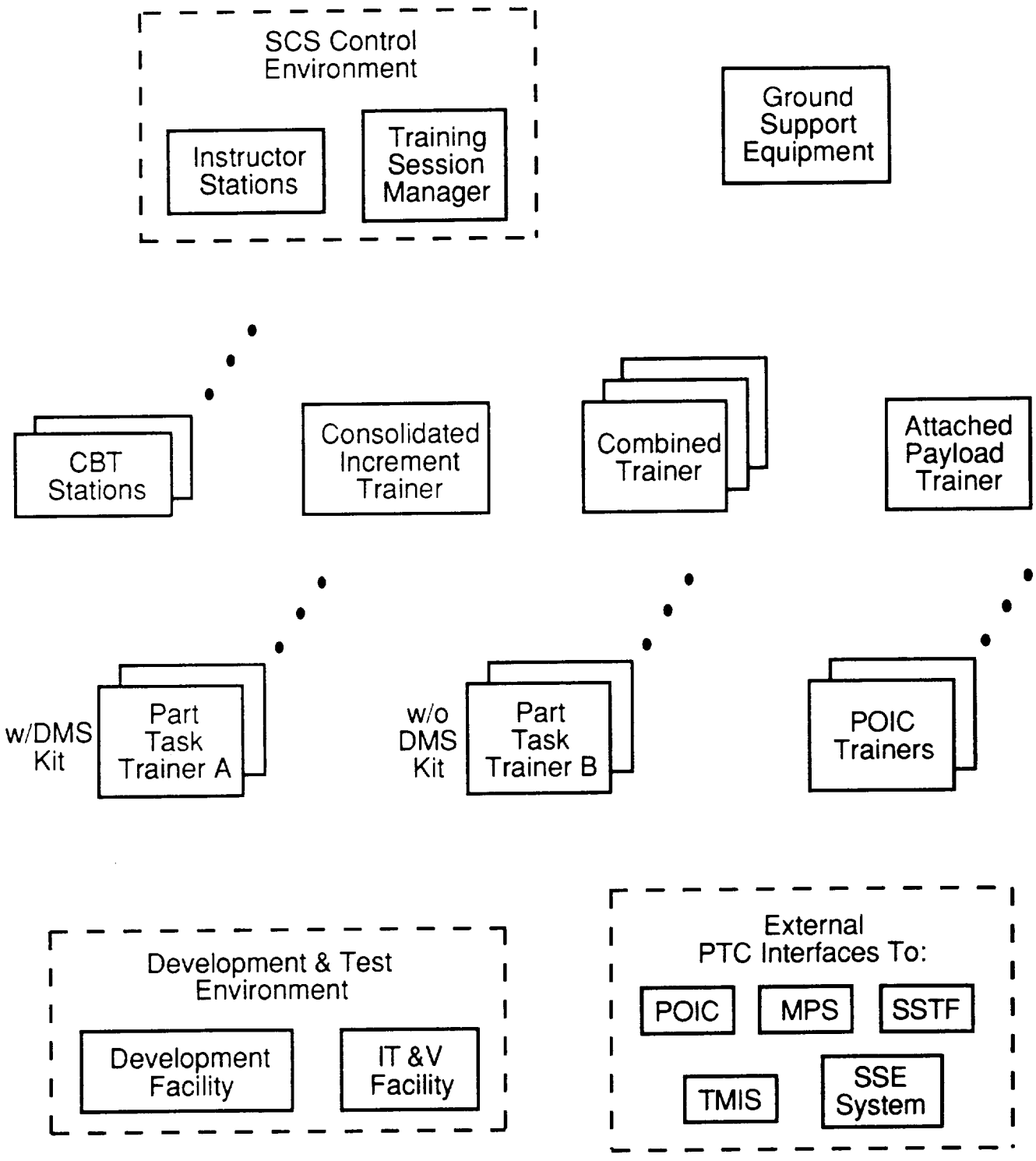


Figure 2.1-1 PTC/SCS Components

2.1.3 Part Task Trainer

The Part Task Trainers are used, on a standalone basis, for fundamental payload training on a limited number of experiment payloads operating concurrently. Only the more important SSF and environment factors are represented in the simulations for typical training sessions. The Part Task Trainers are of two types: 1) a DMS Part Task Trainer, and 2) a Non-DMS Part Task Trainer. The DMS Part Task Trainer incorporates flight equivalent hardware and software interfaced to a host processor, while the Non-DMS Trainer consists of a workstation and instrument interfaces. The Non-DMS Part Task Trainer is intended to use payload models yielding SSF simulations at a level of fidelity below that of flight equivalent representations.

2.1.4 Training Session Manager

The Training Session Manager controls trainer configuration, setup, training management, and other non-real time PTC functions. The Training Session Manager resides on a central host connected to individual trainers over a common network.

2.1.5 POIC Trainer

The POIC Trainer provides payload-specific training for ground operations in the POIC. The trainer consists of several workstations connected to a central host.

2.1.6 Development Facility

The Development Facility provides the software development environment for PTC staff and principal investigators involved in developing, maintaining, and documenting the recurrent applications software for PTC operations. This software includes: simulation scenarios, payload models, other space station and environment models, environment data bases, stimulator programming, training evaluation and management software, IT&V software, computer based training (CBT) courseware, and programming and simulation utilities.

2.1.7 Integration, Test and Verification (IT&V) Facility

The Integration, Test and Verification Facility is used to test payload equipment and payload model operation within the PTC trainer environment. The facility architecture is modeled after the Combined Trainer because investigation showed that a successful IT&V facility needed more capability than a Part Task Trainer, but did not need to be a full up Consolidated Trainer.

2.1.8 CBT Stations

The CBT Stations are used for preliminary training and refresher training. These computer based trainers integrate audio, video, and computer graphics to provide a realistic introduction to lab and payload operations using abstract models and low fidelity physical representations of the SSF payload environment. CBT training is designed for self-paced, standalone sessions.

2.1.9 Instructor Stations

The Instructor Stations afford monitoring and control of simulation training sessions on one or more trainers. The console and associated software permit flexible supervision of training sessions with capabilities to: 1) duplicate the views appearing on crew consoles and lab panels; 2) introduce device and data anomalies; 3) detect student actions; 4) communicate and route audio/video/digital information; and 5) track events/status of a simulation scenario.

2.1.10 External PTC Interfaces

The External PTC Interfaces enable communication links for data exchange with other centers including the POIC, Mission Planning System (MPS), and SSTF. The interfaces to POIC support the transfer of real time simulation data including table driven High Rate Link data, as well as programming files and management data.

2.2 SSF Program - Architectural Concepts and Requirements

The SSF program relies on several centers to provide mission support for system development, integration and test, and training. The architecture of the emerging SSF computing and communications systems has an immediate impact on the PTC and other center requirements to simulate or incorporate these standardized systems. To satisfy these requirements, the program is defining and developing the Data Management System (DMS) Kit. The DMS Kit includes flight equivalent processors, DMS software, consoles, mass storage devices, and I/O devices. The kit also includes the Simulation Interface Buffer (SIB) designed to provide control of the DMS components and connect them to a simulation host.

The use of the DMS Kit eases the job of the training system developer by avoiding the duplication of the DMS architecture and functional capabilities which are fully implemented within the kit. Adopting the kit also avoids redevelopment in response to program modification of SSF flight hardware/software which should be reflected automatically in kit upgrades. The use of kits, however, may be economically limited to SCS implementations of those training systems required, by rigorous training objectives, to achieve flight-like fidelity.

2.2.1 DMS Architecture

The DMS architecture incorporates the Payload and Core systems and their bridge to the Communications and Tracking (C&T) system. The SSF specified implementation of the DMS invokes modular double and triple redundancy of the system components and their interconnections. For purposes of PTC simulation, the SCS must fully represent the payload segment of the DMS. One approach to achieving this representation is to employ SSF DMS Kits available for simulation applications. While the approach insures functional fidelity, aspects such as flight level redundancy may not be replicated in the kits.

2.2.1.1 DMS Kits

The DMS Kit is comprised of equivalents of the DMS components and software used on the Space Station with the companion SIB provided as the link to the user's simulation hosts. The SIB is not part of the SSF hardware complement. The DMS Kit includes direct connections from the SIB to all DMS components, enabling the SIB to control and, in some cases, emulate the DMS components. Additional information on the DMS Kit is given below. For more detailed information see the latest issue of the "Prime Item Development Specification, Data Management System Kit", # SP-M-015, March 16, 1989.

The DMS components are a set of processors, peripherals, and terminals that are flight equivalent hardware and software developed for the SSF. The DMS components include operations and data management software and the Payload LAN. The principal DMS component types are listed below:

-Standard Data Processor (SDP)
-Mass Storage Unit (MSU)
-Time Generation Unit (TGU)
-Multiplexer/Demultiplexer (MDM)
-Multipurpose Application Consoles (MPACs)
-Bus Interface Adapter/Network Interface Unit (BNIU)
-Core LAN (FDDI based)
-Payload LAN (FDDI based)
-Local Bus (MIL-STD-1553B or IEEE 802.4 based)
-Network Bridge
-Ring Concentrator
-Star Coupler

The DMS components are designed with a great deal of commonality. This commonality extends to the enclosures, backplanes, processors, peripherals, interfaces, and operating system software. The SDP, MSU, fixed MPAC (F-MPAC), and MDM are all based on a backplane architecture such as Multibus II. These components derive their unique functionality from the specific configuration of boards and software installed on the backplane.

Figure 2.2-1. illustrates the important input/output features of the basic DMS component architecture. These channels represent the primary means of interfacing DMS components and other computing equipment to integrate a complement of trainers within the SCS.

The Core and Payload LAN are the network backbone of the DMS. These LANs are currently based on the Fiber Distributed Data Interface (FDDI) network (ANSI X3T9.5). This is a dual token ring, fiber optic LAN with a nominal bandwidth of 100 Mbps. The Payload LAN is the same type of LAN as the Core and is connected to the core LAN via a network bridge. The DMS components residing on the Payload LAN are attached to the FDDI through ring concentrators. Connection to the Columbus module and JEM module networks is accomplished through network gateways.

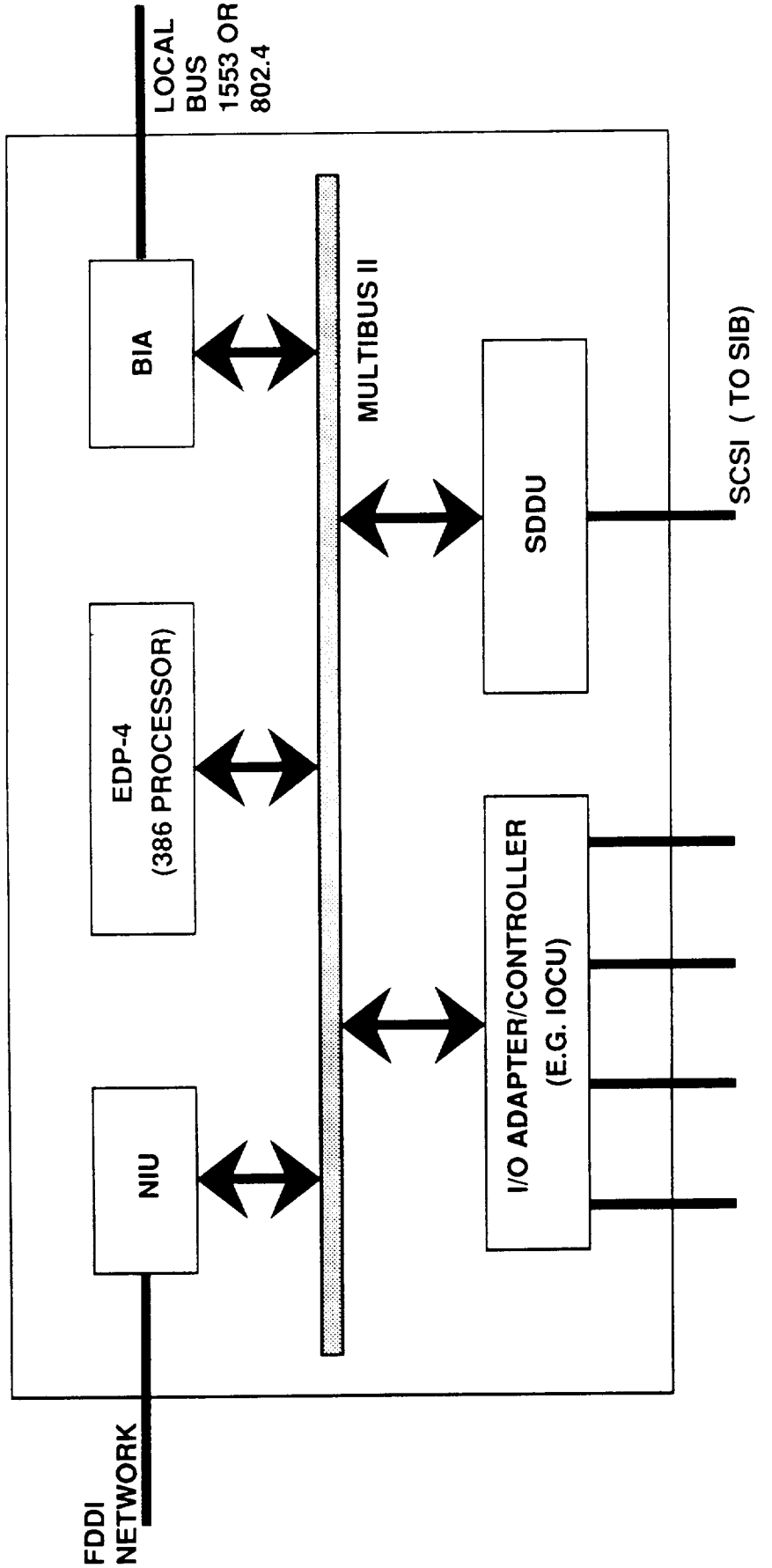


Figure 2.2-1 Basic DMS Component I/O Architecture

A Network Interface Unit (NIU) is used to interface the DMS components supporting the Payload LAN. The NIU card set provides all the services required by the Network Operating System (NOS). The NOS facilitates interprocess communication by providing a standard means for data exchange between applications.

The Embedded Data Processor (EDP) is included in all DMS devices that require processing capability. This includes the SDP, MSU, MPAC, and versions of the MDM. In operation, the EDPs support DMS standard services as well as the software unique to their local applications.

The Bus Interface Adapter (BIA) provides the interface of EDP/SDP components to the Local Bus. The Local Bus is a network based on MIL-STD-1553B or IEEE 802.4. A Small Computer System Interface (SCSI) interface provides connections to the mass storage devices required by the MSU and the MPAC. The analog and digital I/O adapters of the MDM connect to the Local Bus. In the SSF DMS configuration, the Timing Generation System (TGS) connects the TGU to each DMS component over a separate Timing Distribution Bus (TDB). The TGU is connected to an SDP attached to the Core LAN. In conjunction with the currently specified SIB, however, the TGU is attached only to the SIB and the Local Bus through a star coupler.

The user interface within the DMS is the MPAC. This console provides a windows environment supporting concurrent access to systems status data, video data, user communications, C&W messages, et cetera. When appropriate, the MPAC may serve as a repeater for payload C&D panels affording direct monitoring and control of multiple payloads from a single station. The console also provides capabilities to perform payload related control actions and to store data. The fixed MPAC (F-MPAC) is attached to the Payload LAN, while the portable MPAC (P-MPAC) connects to the DMS Local Bus.

2.2.1.2 SIB

The SIB is the mechanism for connecting external computer equipment to the DMS. The SIB is not part of the Space Station hardware, but is being developed by the Software Support Environment (SSE) contractor to facilitate the connection of host computer systems to the DMS. In the latest baseline, the SIB provides a dedicated high speed link to a host computer, and allows the host to interface with the payload FDDI LAN and other busses which interconnect DMS components. The SIB can directly control DMS components in order to govern and recreate the course of simulated events. It may also substitute for the function of DMS components such as the TDB. Like the DMS components, the SIB design is modular and based on a common backplane.

The SIB supports connections to the: 1) FDDI network through a ring concentrator; 2) 802.4 Local Bus through a star coupler; 3) 1553 Local Bus; and 4) Time Distribution Bus. The SIB provides a SCSI interface to SDPs, MSUs, MDMs, and F-MPACs. While the SIB can access SDPs and MDMs through the FDDI connection, the SCSI interface through embedded SDDUs affords the SIB greater control. With this scheme, the SIB can start, stop, insert breakpoints, and otherwise control low level

functions of an SDP or MDM based on internal events. It also is capable of logging and replaying bus traffic sufficient to recreate the DMS aspects of a simulation session.

2.2.2 Space Station Freedom Program Tools and Facilities

The SSF program has provided certain tools and facilities for use in system development. These software tools are designed to ease system development, integration, and testing. The Software Support Environment (SSE) provides the analysis, design, and production tools to be used in common across the SSF development efforts. Systems integration of the SCS will be expected to rely on the accepted SSE set of development tools.

3.0 SCS Designs

3.1 Selection of Three Designs

The three SCS designs detailed in this report illustrate implementations offering varying degrees of resource sharing and utilization of the SSF DMS architecture. The designs attempt to satisfy the SCS requirements specified in the SCS Concept Document, however omission of capabilities in the designs does not waive these requirements. Each design offers a somewhat different profile of performance, cost, and schedule.

The selection of the designs for refinement was based on several considerations including the following:

-Networks are preferable to point to point connections due to their inherent flexibility.

- Incorporation of DMS kits minimizes the difficulties of managing different DMS configurations on the Space Station. In the PTC, it reduces the risk of software development, and simplifies software portability.

-Use of modular hardware and software, and the distribution of processing capabilities, where feasible, increases the reconfigurability and expandability of the system.

-Real time functions, processing, and communications should always be segregated from non-real time functions.

The three selected designs map to the six recommended in the Task 4 effort, but are not simply three of the six recommended. Due to the uncertainties in DMS Kit and SIB design uncovered in the first part of the Task 5 effort, it became clear that the three Task 5 designs selected to be refined needed to be broader than originally envisioned. Discussions with all members of the SCS team, including NASA, yielded the fact that the Task 5 investigation must address three possibilities:

1) The DMS Kits and the SIB will be available when needed by SCS, and the SIB will only connect to a host computer through a point to point parallel connection (like a Digital Equipment Corporation VAXBI 32 bit wide parallel interface).

2) The DMS Kits and the SIB will be available when needed by SCS, and the SIB will connect to a network through a high speed fiber optic connection.

3) The DMS Kits and the SIB will not be available when needed by SCS, or if available, are designed to meet flight system development and not training functions.

The designs selected to help address the above three possibilities and be refined were given names in order to avoid any indication at the outset of Task 5 that one design was favored over the others. The three selected are:

LOCAL HOST - This is the Network Local with DMS Kit Trainers (top level designation 3-A) and Task 4 recommended Design I (3-A : Network Local Host - DMS Kit). It addresses possibility number 1 above.

SHARED HOST - This is the Shared Host with DMS Kit Trainers (top level designation 5-A) and a variant of Task 4 recommended Design II (3/5-A : Network Local Host/Shared Host - DMS Kit). It addresses possibility number 2 above.

DMS EQUIVALENT - This is the Network Local Hosts with Non-DMS Trainers (top level designation 3-D) and a variant of Task 4 recommended Design IV (3-C/D : Network Local Host - PCTC Based/Non-DMS). It addresses possibility number 3 above. The PCTC Based option, although completely viable, was not included for further study because there is little need to explore through a "what if" design study a facility and design that currently exists. Also, this approach represents design methods reflecting state-of-the-art design from when the PCTC was developed, not current system design thinking.

A top level view of each selected SCS design is shown in Figure 3.1-1 through Figure 3.1-3.

The next section describes the SCS design features that are shared by all three designs. Variation in the implementation of these features is noted when appropriate. Subsequently, the unique configurations and distinguishing features of each SCS design are addressed in separate sections.

3.2 Common Design Features

In earlier phases of the study, a broad spectrum of architectural concepts was explored for possible application to the SCS. Several design guidelines for SCS emerged from these examinations. Following these guidelines, the selected SCS designs exploit variations along key architectural dimensions while other aspects of

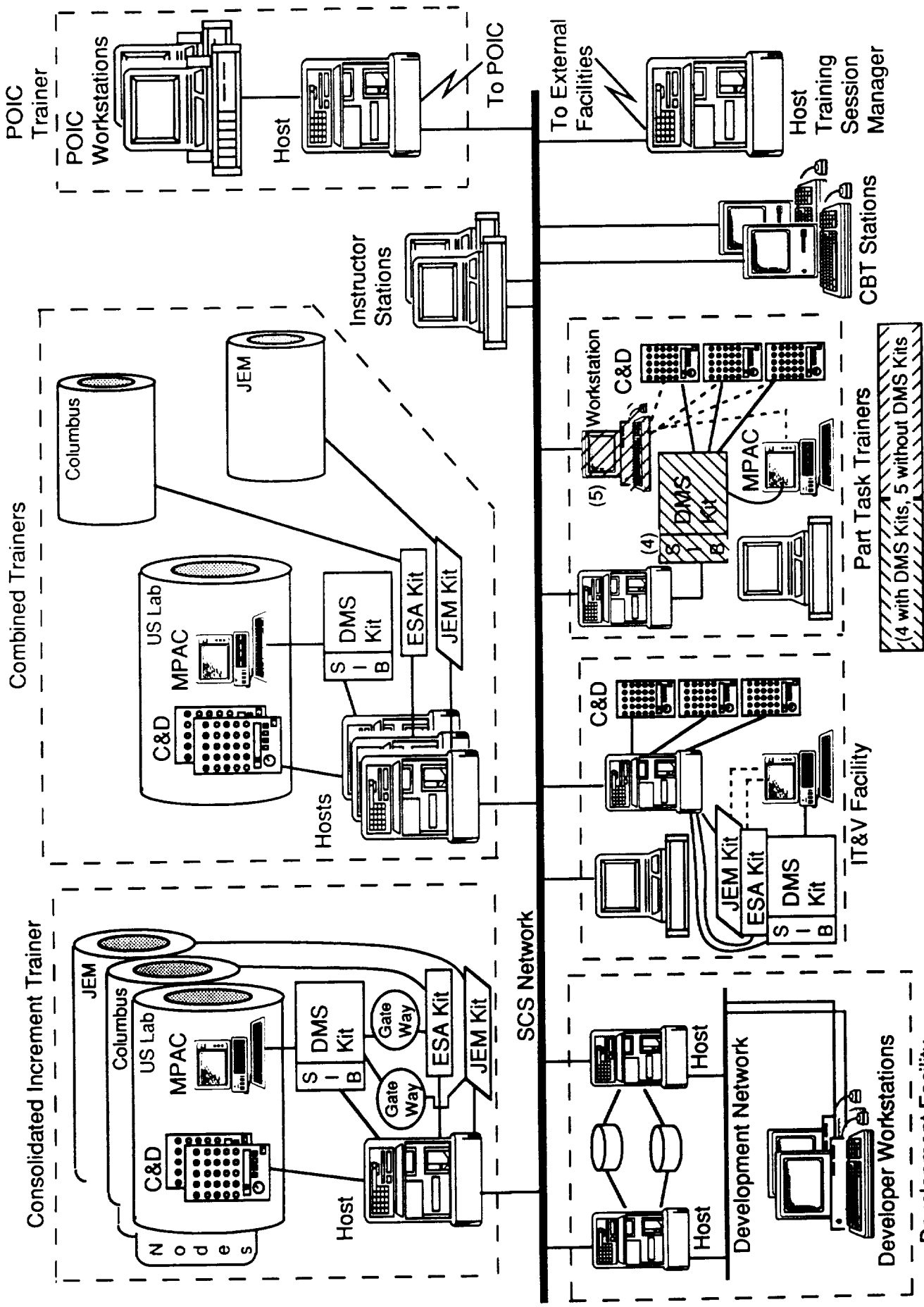


Figure 3.1-1 SCS Local Host Design

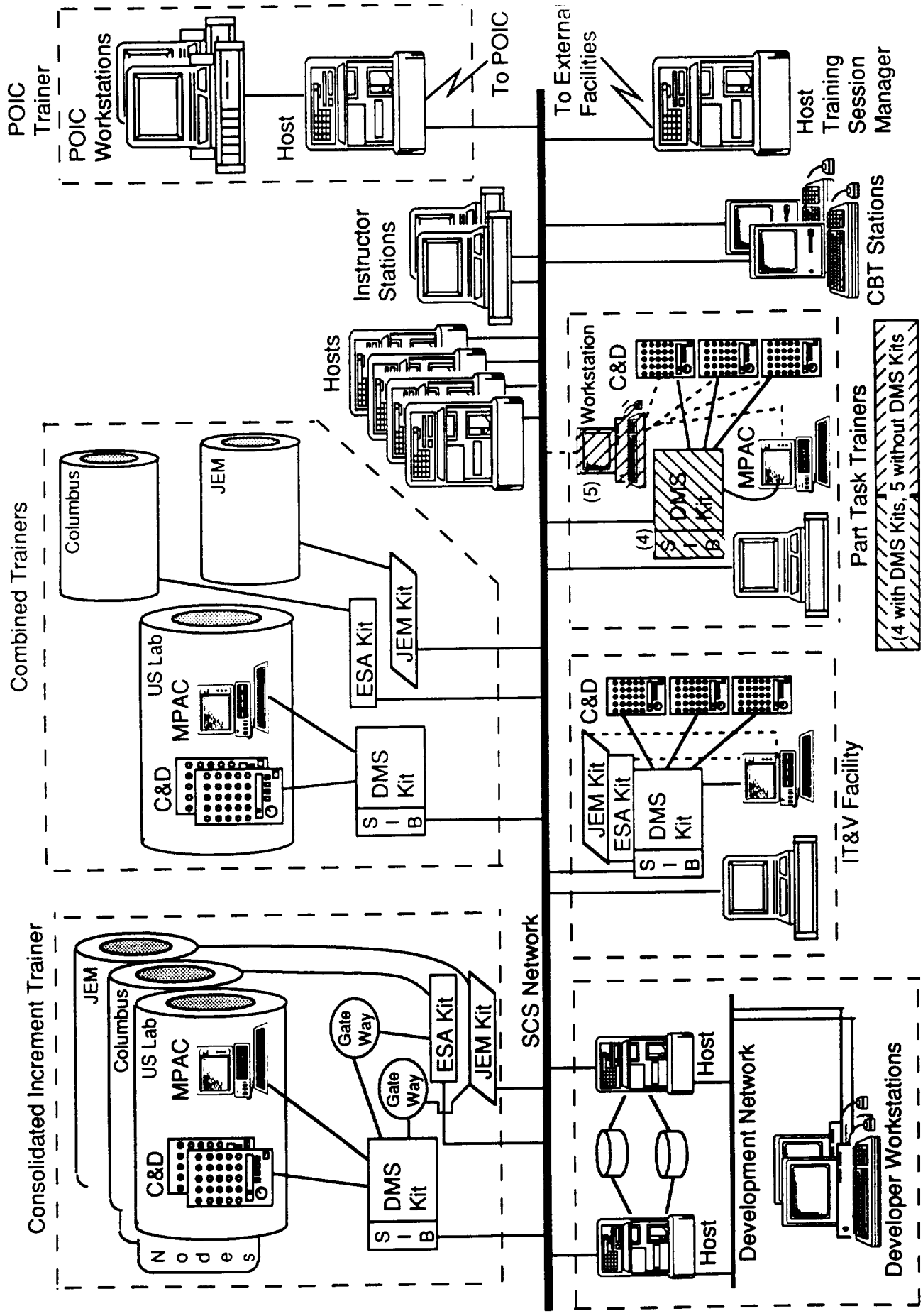


Figure 3.1-2 SCS Shared Host Design

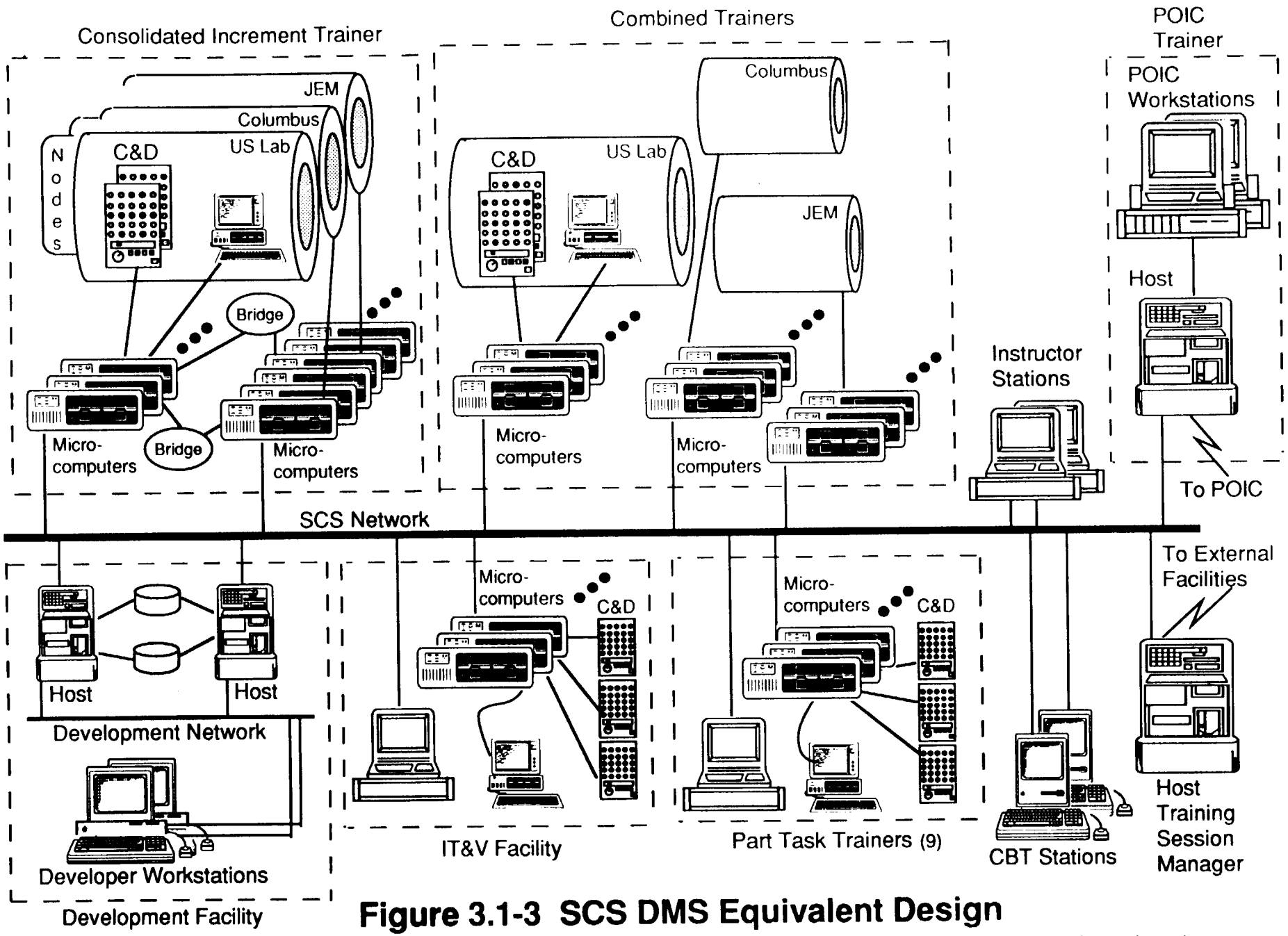


Figure 3.1-3 SCS DMS Equivalent Design

(Multiple microcomputers replace both host computers and DMS/ESA/JEM Kits within the trainers)

the architecture remain constant. The common features shared across designs occur in the following areas:

- Payload Representation
- Core Systems Representation
- Crew Interface Representation
- Audio/Video Systems Representation
- Facility Architectures
- Simulation Control and Monitoring

3.2.1 Payload Representation

The payload representations consist of either the flight equivalent payload hardware and software or a software payload model and associated control and display hardware. The flight equivalent article includes the DMS compatible instrument, a flight equivalent Control and Display panel, and associated flight equivalent software The software payload models consist of software that runs, under the simulation executive, either on the trainer's simulation host or in a DMS component processor.

Because flight equivalent payloads are expected to be available for payload training only 10 percent of the time, the majority of payload training will rely on the execution of software payload models. Further, the software payload models must achieve sufficient fidelity and robustness to drive simulation training sessions within both the PTC and, ultimately, the SSTF. Consequently, each SCS design must provide substantial computing capability within the real time simulation environment.

Flight equivalent payloads need to be appropriately stimulated to replicate the effects experienced in orbit. This stimulation includes direct sensor activation, effector feedback, and the ambient effects on the experiment of the space station's environment. The payload stimulator is an intelligent controller receiving data from the Core and environment models. The stimulator connects to a host I/O port and to the flight equivalent hardware directly and/or through the Local Bus. Within each trainer, the payload stimulators may also be responsible for controlling or emulating the necessary GSE services to sustain the payload.

The payload C&D panels associated with individual experiments are high fidelity functional equivalents of flight hardware positioned realistically in a trainer's lab mockup. Two panel types exist: 1) a generic reconfigurable terminal system i.e. a "virtual panel"; and 2) a hardware replication of the flight payload panel. In addition to the panels, activation of other experiment devices and associated lab support equipment furnished within the physical lab mockup will be implemented by SCS as required by training objectives.

3.2.2 Core Systems Representation

A representation of the Space Station Core systems is required to support any payload simulation using flight equivalent or software model implementations, e.g. power systems or GN&C must be simulated. For purposes of SCS conceptual design,

Core systems are treated as representing all space station systems that affect payload operations or performance, other than those encompassed by the DMS Payload LAN which is represented by hardware in all DMS designs. Core systems representations that interface with payload simulation include: Communications and Tracking (C&T); Guidance, Navigation, and Control (GN&C); Electrical Power; Thermal Control; Fluid Management System (FMS); and various lab support systems such as the Process Materials Management System (PMMS).

Environment models and data bases to represent the dynamic space and space station environments are also included in the Core systems category for convenience. Environment models may represent several ephemeral and other factors including gravity, celestial positioning, station dynamics, solar effects, mass properties, ambient conditions, and atmospherics. The Global Positioning System (GPS) model necessary to drive the TGS within the DMS may also be considered an environmental model. In this case, however, an actual electronic signal must be generated to stimulate the TGU. This capability is explained as part of the Payload Stimulator for the Local Host design described in Section 3.3.

The scope and fidelity with which Core system events and data need to be represented vary from one payload to another. For example, some payloads will require precise positioning data from the GN&C system, while these data will be entirely irrelevant to other payloads. It is assumed that software models of the Core systems, station environment, and flight equivalent DMS core software will be available from other SSF development programs.

Although the Communications and Tracking (C&T) system is included in this broad grouping, its relationship to telemetry presents unique requirements that are often handled separately in the SCS designs. The associated C&T model provides formatted uplink/downlink communications containing SSF data from the: 1) Payload LAN; 2) Core systems LAN; 3) payload High Rate Link; and 4) other audio/video sources. Payload LAN data and High Rate Link data may be obtained from both actual flight equivalent payloads and payload simulation models. The C&T model requires dedicated hardware to generate the telemetry data stream necessary to feed the POIC Trainers and the POIC.

All SCS designs incorporate a C&T telemetry system processor/controller to satisfy the C&T requirement. The processor/controller is shared among the design's lab trainers through a patch panel which routes one trainer's C&T-bound output to the processor/controller. In the DMS Equivalent design, C&T is implemented utilizing a distributed microcomputer. The output of the C&T is an SSF compatible telemetry data stream that can can be received by the POIC. The simulator inputs to the C&T include HRL, payload LAN, Core LAN, and host I/O feeds of science and command/status data. The C&T implementation also supports bi-directional SSF voice communication streams.

3.2.3 Crew Interface Representation

The accurate functional and, in some cases physical, representation of the various features of a payload that a crew member may interact with is, of course,

critical to simulator training. The two primary interfaces for monitoring and control are the rack mounted experiment's attached C&D panel and the lab's multipurpose application console (MPAC). Additional payload features such as mechanical controls are considered part of the lab-payload physical mockup and involve minimal interfacing to the SCS.

3.2.3.1 C & D Panels

The C&D panel consists of switches and indicators that provide payload control and display of information. When flight equivalent payloads are used, the associated C&D panel is integral to the hardware. Alternatively, when payloads are simulated with software models, the associated C&D panel may appear in two versions. One is a close replication of the actual panel hardware used on the flight payload. This is a custom designed piece of hardware dedicated to a particular payload experiment.

The other option uses a "virtual C&D panel" incorporating a high resolution touch sensitive graphic display and appropriate I/O interfaces to achieve a functionally accurate representation of the actual flight panel. The virtual panel, as depicted in Figure 3.2-1, can quickly be reconfigured to represent the control and display elements making up any flight payload experiment panel, including ones from different increments.

3.2.3.2 Crew Console - Multipurpose Application Consoles (MPACs)

The basic MPAC currently planned for the SSF is implemented within the DMS based SCS trainer designs using the DMS Kit supplied flight equivalent MPACs attached to the Payload LAN. Representation of the portable MPAC (P-MPAC) will be provided as needed and will implement a DMS Local Bus connection. In non-DMS trainer designs, the MPACs are implemented using appropriately outfitted graphics workstations and graphics terminals connected to an SCS Trainer LAN. In all SCS designs, the Combined Trainers have been configured with two crew consoles; the Consolidated Trainer with two consoles in the US Lab and one each in the JEM Lab and Columbus Lab; and one console in each Part Task Trainer.

3.2.4 Audio/Video Systems Representation

The Audio and Video Systems' capabilities accommodate onboard space station and lab internal communications and CCTV, audio communications with the ground, payload generated video, and computer generated imagery to simulate visual scenes and events associated with flight payload operations (such as viewing a star field). Speech synthesis and recognition permit automated simulation of verbal communications during a training session. A basic audio/video system is diagrammed in Figure 3.2-2. Internal PTC facility intercom and CCTV for instructor communications and training monitoring are not specified as part of the SCS in this document.

3.2.5 Common Facility Architectures

Many of the support facilities are common across the SCS designs. These facilities include the Development Facility, External PTC Interfaces, POIC Trainers,

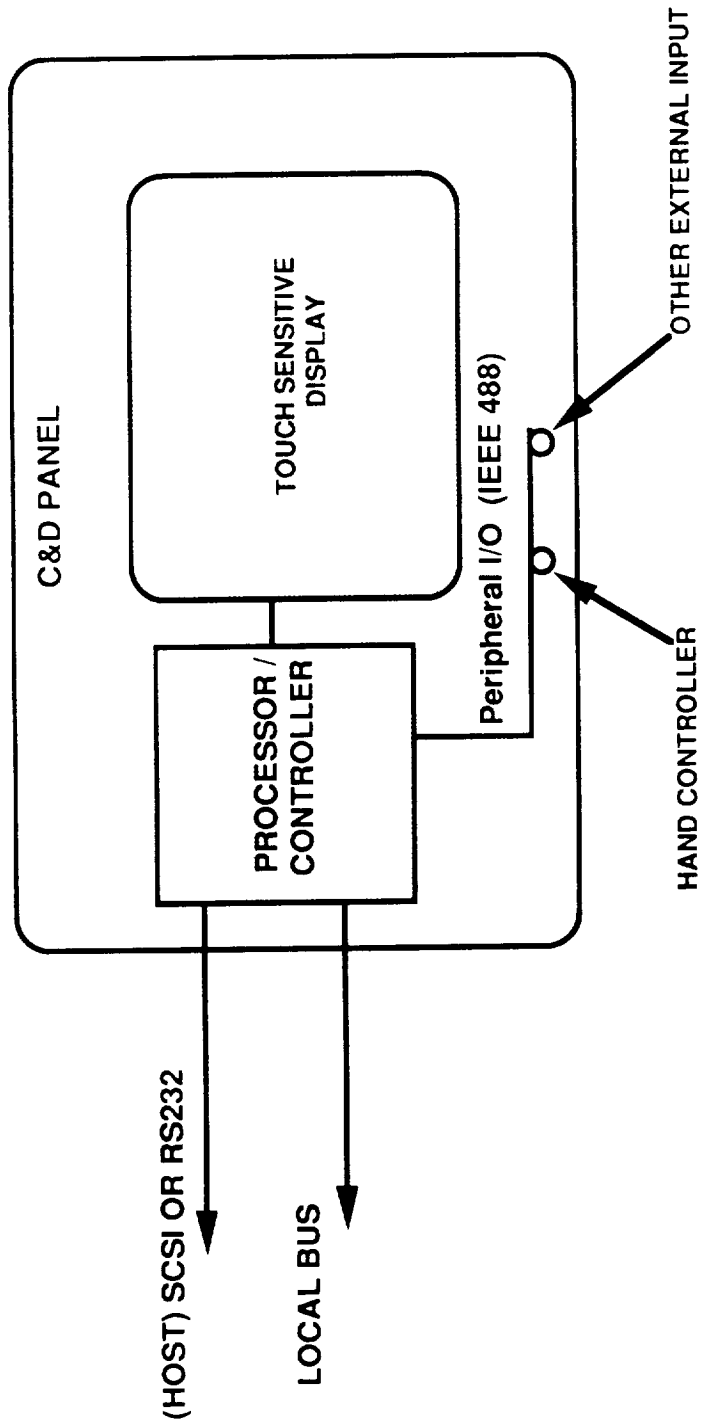


Figure 3.2-1 Virtual Control & Display Panel Design

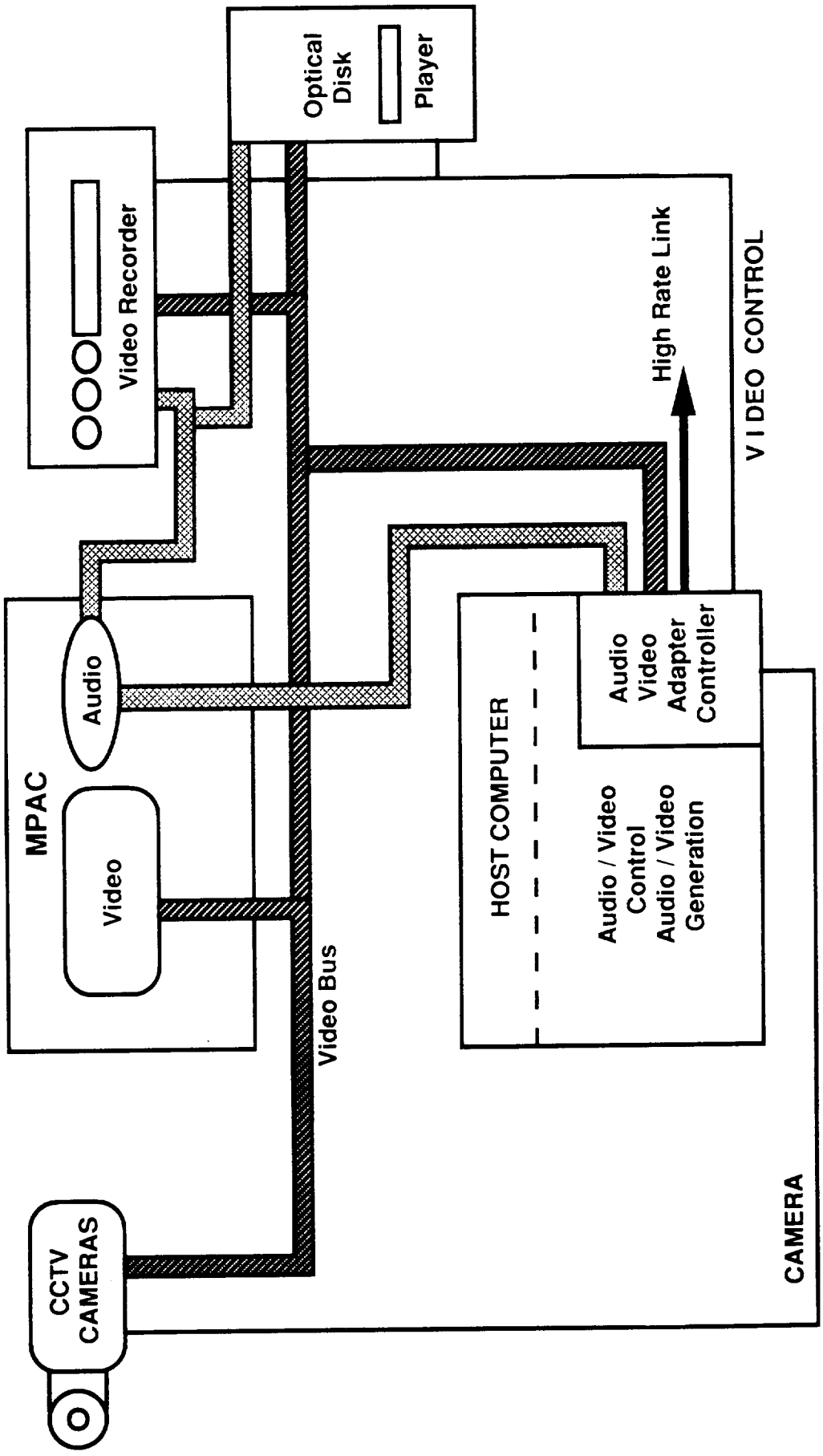


Figure 3.2-2 Audio & Video System Design

IT&V Facility, CBT Stations, Training Session Manager, and central Instructor Stations. A top level view of the facilities architecture is presented in Figure 3.2-3.

3.2.5.1 Development Facility

Because it is expected that 90 percent of the payload experiments installed in a trainer will be software simulation models, rather than flight equivalent payload hardware and software, a substantial SCS Development Facility is required. The facility has been designed to support on the order of 100 concurrent users performing a mix of software development tasks without impinging on the SCS LAN.

The facility connects 40 workstations and diskless workstations to dual file servers via a local LAN. The diskless workstations are economical and will support the development function. The file servers provide common access to central code libraries, data dictionaries, batch job facilities, and configuration management tools. The workstations support the bulk of program design, code generation, compilation, and local configuration management. The dual file servers also provide the computational resource for 60 ASCII and graphics terminals (diskless workstations) attached to the local LAN through a terminal server. These terminals support source code editing, documentation authoring, and testing tasks, as well as batch job submission. The file servers connect to the SCS LAN to permit developed software to be downloaded to the SCS trainers and other facilities.

Figure 3.2-3 also depicts a documentation system and a portable test unit residing in the Development Facility. The documentation system is based on COTS publishing software running on a dedicated host. The portable test unit adapts the workstation to support payload interfacing/emulation for debugging payload models prior to IT&V testing. The test unit, shared by several developers, facilitates independent model development and should shorten the overall development cycle.

3.2.5.2 External Interfaces

The PTC/SCS will provide a real time interface to the POIC. This interface allows uplink/downlink data to be exchanged between the SCS and the POIC. Other facility interfaces will allow file transfers between the MPS, SSTF, and the PIs. The interfaces are implemented as gateways to appropriate wide area networks (WANs). The gateway host resides on the SCS LAN. Interfaces that must support full telemetry data streams are implemented with the host and an attached I/O processor.

3.2.5.3 POIC Trainers

The Payload Operations Integration Center (POIC) Trainers are provided for training POIC personnel in payload operations independently or in synchronization with lab trainers. Each POIC Trainer consist of a host processor and two workstations sharing the SCS LAN. The workstations serve as ground personnel stations. Instructor stations are located on the SCS LAN and are shared with other SCS trainers. The POIC trainer is connected to the SCS LAN and to an interface for the telemetry data stream. When this data stream is of moderate bandwidth, it may contain simulated or actual DMS Payload LAN data and High Rate Link data. Full capacity

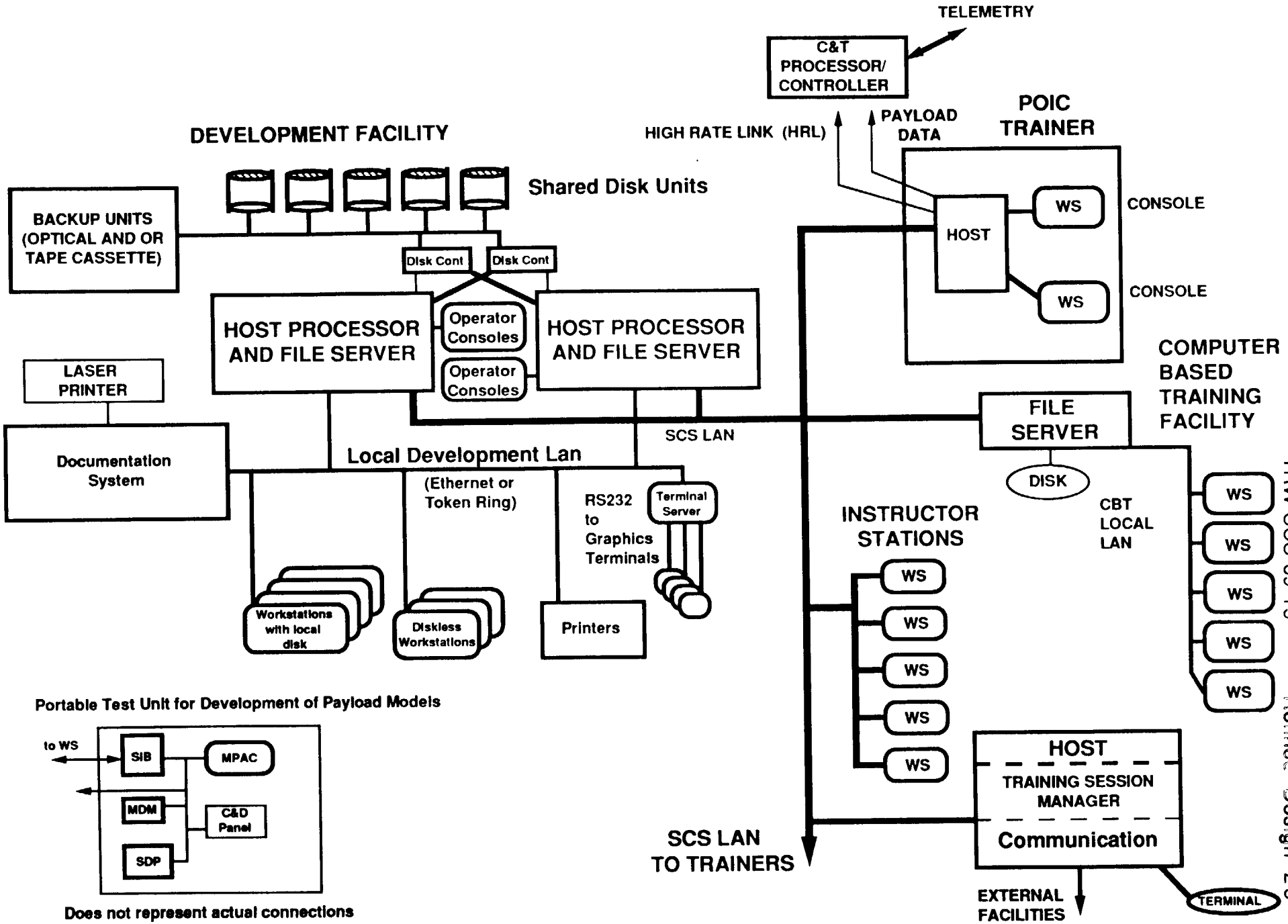


Figure 3.2-3 Overview Architectures of Common Facilities

dynamic downlink data streams, however, require a telemetry system processor/controller which is linked to a comparable C&T processor fed by one of the SCS lab trainers. Audio and video signals are represented realistically in the POIC trainers with appropriate video monitoring capabilities.

3.2.5.4 IT&V Facility

The IT&V Facility is used to integrate and validate, within the SCS lab trainer environment, the: 1) payload simulation models; 2) other SSF and environment models; 3) flight equivalent hardware and software units; and 4) physical and virtual payload C&D panels. These elements are operationally tested within the DMS, Core, C&T, and control aspects of the simulator configuration. LAN and bus monitoring capabilities and processor breakpoint capabilities are implemented within the facility using the SIB or comparable utilities. In all SCS designs, the architecture of the IT&V Facility is essentially identical to the Combined Trainer architecture. The facility connection to the SCS LAN permits software modules to be downloaded from the Development Facility.

3.2.5.5 CBT Stations and Facility

The CBT Stations consist of interactive graphic, video, and audio capabilities implemented on a workstation running customized courseware. The facility consists of several CBT Stations connected to a file server over a local LAN. The CBT file server is connected to the SCS LAN for downloading software and courseware from the Development Facility. Provision for local removable media such as optical, video, or magnetic disk is included.

3.2.6 Simulation Control and Monitoring

3.2.6.1 Training Session Manager (TSM)

The Training Session Manager (TSM) operates as a high level system executive residing on a single host attached to the SCS LAN. The TSM communicates directly with the simulation executive programs residing on the dedicated, shared, or distributed trainer hosts. The TSM controls access to the trainers on the SCS LAN and mediates all file transfers and message traffic. While most functions like setup and initialization precede simulation session running, near real time responsibilities do exist including supervision of Instructor Station requests. In all SCS designs, the Training Session Manager and its host are responsible for external interface communications with other facilities.

For purposes of SCS conceptual design, a common approach has been adopted for aspects of the simulation executive and its synchronization of real time simulation processing. The basic scheme is assumed to broadcast simulated space station systems/environment status information at a periodic rate to all DMS and payload representations simultaneously. This Core data and Core mediated environment data, output from the corresponding simulation models, are posted at least once every second for use by payload models and/or actual devices communicating with the DMS Payload LAN. Control and payload generated data

remain asynchronous and continue to be transmitted as they arise. The scheme accommodates the range of SCS designs considered here by ensuring an orderly means of communicating rapidly among the various simulation models and devices even when their host processors are distributed across the SCS.

3.2.6.2 Instructor Stations

The Instructor Stations are attached to the SCS LAN and communicate with the individual trainers through the simulation executives residing on the trainer hosts. The TSM monitors this communication to prevent inappropriate commands from disrupting real time simulation processing during a training session. Direct access to the simulation executives is granted to monitor status information and replicate the views appearing on the students' crew consoles and C&D panels. The stations are implemented as workstations with interfaces to the Audio and Video Systems and are represented in Figure 3.2-4.

3.2.7 Common Design Options

An additional feature shared by all SCS designs is the wide range of interface options supported. Within the SCS architectural context, capabilities are provided in each of the following areas:

- Payload Representation
- Core Systems
- C&D Panel
- Audio/Video System

3.2.7.1 Payload Representation Options

An attempt has been made across all SCS designs and their trainer types to integrate payload representations, of whatever kind, within the trainers in a consistent manner. Overall, the approach has been to accommodate as many interface schemes as are useful within a trainer design. Minimally, this has meant that each trainer provides a flight payload instrument interface, a C&D panel interface, and a payload model to DMS representation interface. DMS based trainers also provide a flight equivalent C&D panel interface and alternative methods of interfacing the flight equivalent payload instrument to DMS Kit components. The full mission trainers (Consolidated Trainer and Combined Trainers) in all three SCS designs could support all means of payload representation and C&D panel interfacing simultaneously.

Figure 3.2-5 illustrates the variety of payload representation options that will be discussed in detail in the following sections.

3.2.7.1.1 Flight Equivalent Payload

The flight equivalent payload consists of rack mounted or attached instrument chassis, an integral C&D panel, application software, and perhaps peripheral equipment. The payload may also utilize associated lab facility hardware provided to

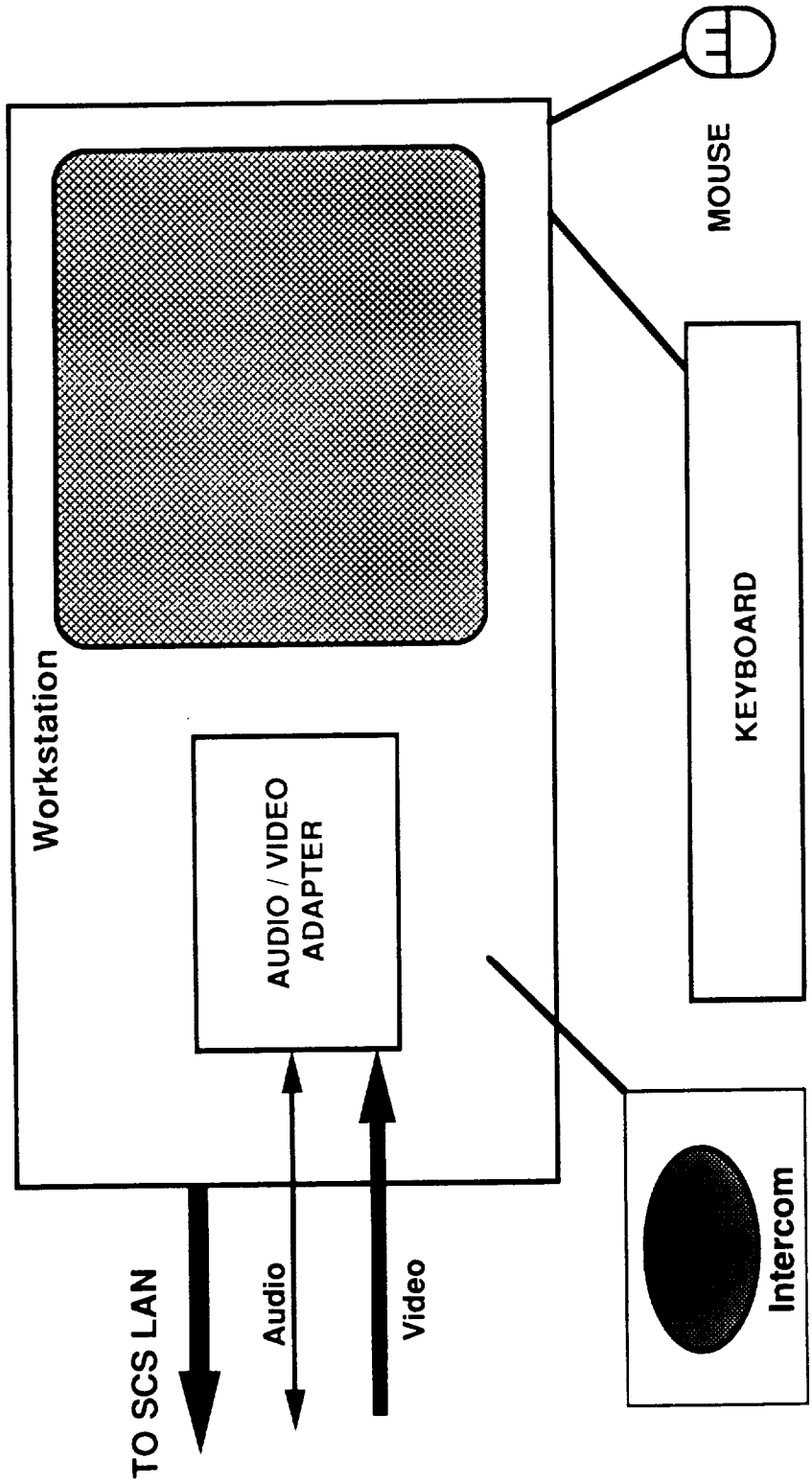


Figure 3.2-4 Instructor Station

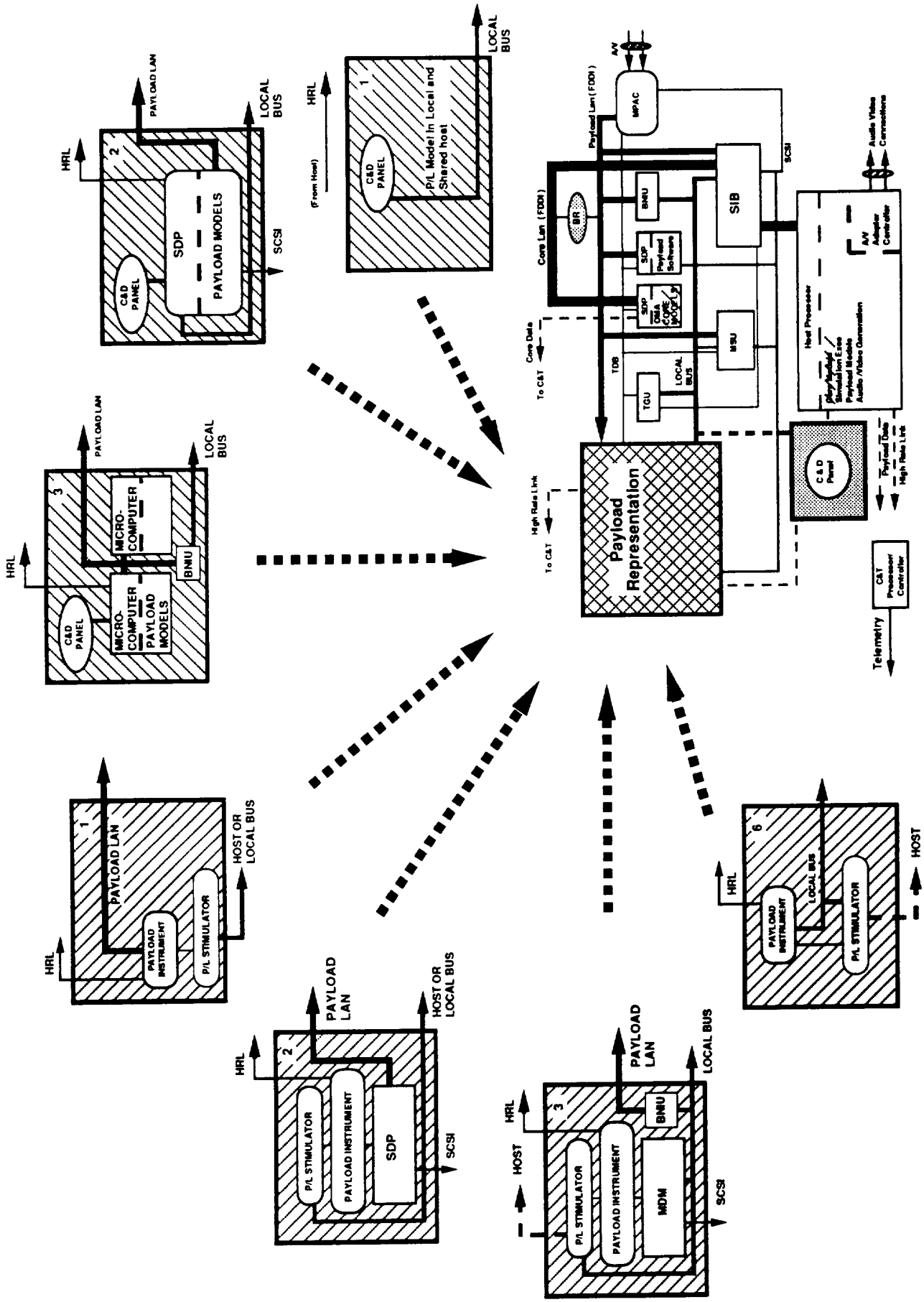


Figure 3.2-5 Payload Representation Options

support related experiments. The alternatives for integrating flight equivalent payload instruments into a trainer involve the following interfaces:

1. A flight equivalent payload, with its own NIU equivalent, connects directly to the Payload LAN.

2. A flight equivalent payload connects to an SDP through standard onboard I/O, or through an additional I/O adapter/controller attached to the processor bus.

3. A flight equivalent payload connects to an MDM.

4. A flight equivalent payload connects to a MDM or SDP as in (2) or (3), and has software executing on the component's EDP. (Not illustrated)

5. A flight equivalent payload, with its own standard I/O port, connects directly to a trainer's host computer. (Not illustrated)

6. A flight equivalent payload (with its own BIU) connects directly to the Local Bus.

These options are shown in Figure 3.2-6. The numbers in the upper right hand corner of each payload connection option correspond to the six listed above.

Where flight equivalent payloads are employed, a payload stimulator is required to provide sensor excitation and other ambient effects to the payload that would normally occur in flight. The stimulator is driven by Core and environment simulation models and data bases which represent the Space Station environment, and crew actions. A payload stimulator may furnish comprehensive real time stimulation to achieve the highest level of payload operation fidelity, or the stimulation may represent with some approximation only the more critical stimuli affecting payload operation and performance.

For control purposes, the payload stimulator can be integrated into a trainer using three different interfaces:

1. A payload stimulator connects to a trainer host directly using standard I/O port (RS232 or SCSI).

2. A payload stimulator attaches to the DMS Local Bus (and connects with the trainer host through the SIB).

3. A payload stimulator attaches directly to the trainer's network (Payload LAN or Trainer LAN), the latter being the case in a design without a DMS Kit.

The last connection requires that the stimulator incorporate a processor based controller and network interface. A dedicated processor could also allow the stimulator to operate autonomously, interfacing directly with the Core and environment

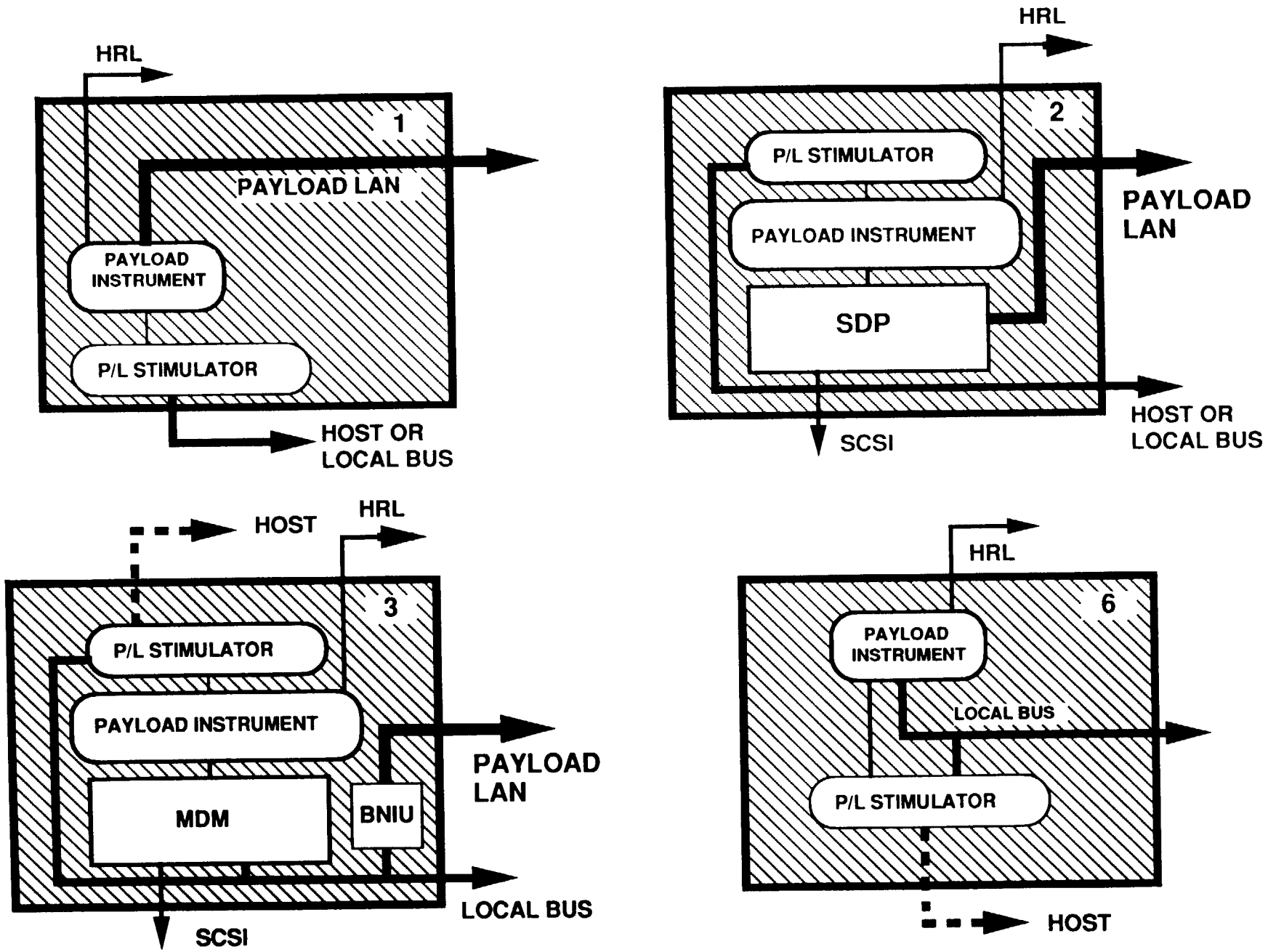


Figure 3.2-6 SCS Payload Connection Options

models over the Payload or Trainer LAN.

3.2.7.1.2 Software Simulated Payload

There are two aspects of integrating a software simulated payload into a trainer. First, the payload model must be hosted on a trainer host and interfaced with the trainer's DMS representation. Second, the associated hardware, providing a representation of the payload's control and display elements (e.g., C&D panel), must be interfaced within the trainer.

Alternative model interfaces can be implemented in the following ways:

1. A payload model executing in a local or shared host is interfaced to DMS or DMS compatible components through a SIB or other controlling device.

2. A payload model executing on an SDP, an EDP in another DMS component, a Dedicated Experiment Processor (DEP) or an SDP compatible processor, is connected to the Payload LAN, or to the Local Bus, or to both.

3. A payload model executing on a dedicated, distributed host is connected to the Payload LAN.

The options associated with a software simulated payload alternatives and DMS Kit based trainer are shown in Figure 3.2-7. The numbers in the upper right hand corner of each payload simulation option correspond to the list above.

3.2.7.2 Core System Options

The Core system can be represented with a suite of software models that interface with the DMS Kit or with the DMS Equivalent distributed host system. Other designs could incorporate flight equivalent components of the Core system as part of their DMS Kit trainer implementations. Such implementations could include the Core LAN and Core software available under the SSF program. Core software would be run on an existing SDP, or an additional SDP, in the DMS based trainers. This approach would make maximum use of flight equivalent software and available environmental models. These flight equivalent models will be built by other centers, and modifying and using these existing models as needed to support payload training could represent a significant cost savings in the building of the SCS. Using these models would also mean a more direct tracking of Core systems implemented within the SSFP by SCS through out the life cycle of the SCS. Any changes could be incorporated by transferring the new flight equivalent software rather than changing SCS software core models. The SCS Study has demonstrated that flight software and engineering models can be used, as well as training models. Use of SSFP Core system software would also help ensure easy integration of flight equivalent payload simulations. However, this approach, while reducing the amount of simulation software needed to represent Core functions, creates additional SCS requirements. The incorporation of Core components creates a more complex trainer configuration to

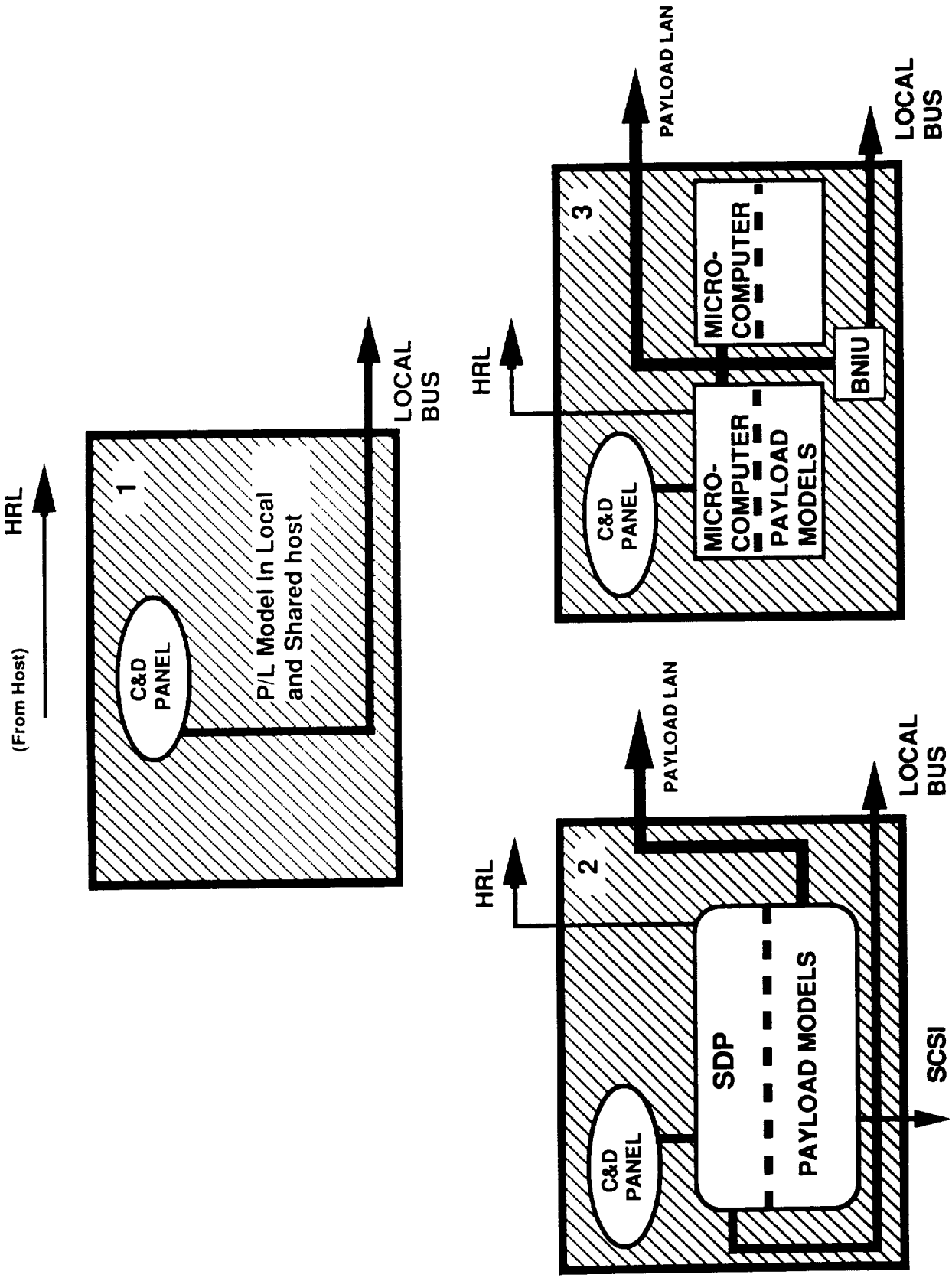


Figure 3.2-7 Payload Simulation Options

maintain. It also dictates more comprehensive high fidelity environment models and space station models to drive the actual Core systems realistically. The options for interfacing payloads, however, should not be affected by this choice in DMS representations, except that more comprehensive payload models may be required to accept actual Core systems data.

Depending on the particular SCS Study design, Core systems models execute in a central Trainer Host or in an SDP or dedicated processor in the DMS Kits. Flight equivalent DMS core software running in a DMS SDP may also be utilized. The choices of where to run core software models, and some of the other options for utilization of DMS Kits discussed are illustrated in Figure 3.2-8. In this figure, dashed lines or shaded ares represent the various options.

3.2.7.3 C&D Panel Options

C&D panels associated with the payload software model can be connected to a host I/O port or to the DMS Local Bus. C&D panels can also connect to CMDMs which reduces the amount of intelligence needed on the C&D panels themselves.

The C&D panel associated with a software payload model must be driven such that signals can get to the simulations from the panel, and indications can be sent from the simulation to the panel. Figure 3.2-9 illustrates C&D panel connection options. Panels can be processor based and support the following means of interface:

1. A C&D panel connects to a trainer host directly using standard I/O port (RS232 or SCSI). (Not illustrated)

2. A C&D panel attaches to the DMS Local Bus.

3. A C&D panel attaches directly to the Payload/Trainer LAN.

4. A C&D panel connects to an SDP via an I/O adapter attached to the processor bus.

5. A C&D panel connects to a MDM.

6. A C&D panel is part of a flight equivalent payload.

Both physical and virtual versions of the detached C&D panels are designed with sufficient onboard I/O processing to support direct connections to a host I/O port (SCSI or RS-232) or to the DMS Local Bus. Both panel types and all connection schemes can be supported simultaneously by the SCS designs. The arrangement allows the appropriate C&D panel to be connected directly to whatever processor is chosen to host the corresponding payload model and, in DMS based trainers, to maintain direct access to MDM signals.

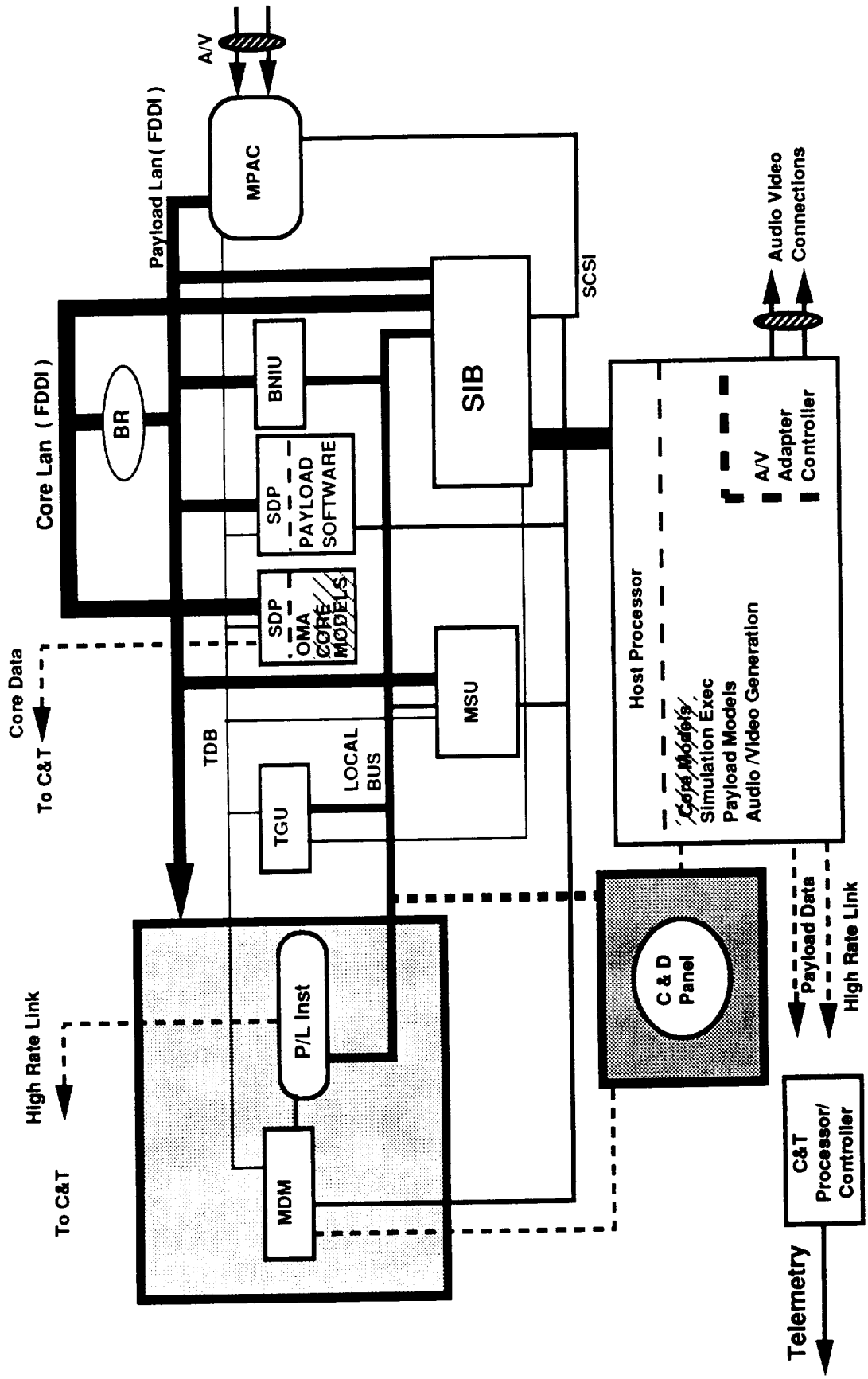


Figure 3.2-8 Core System Model Options

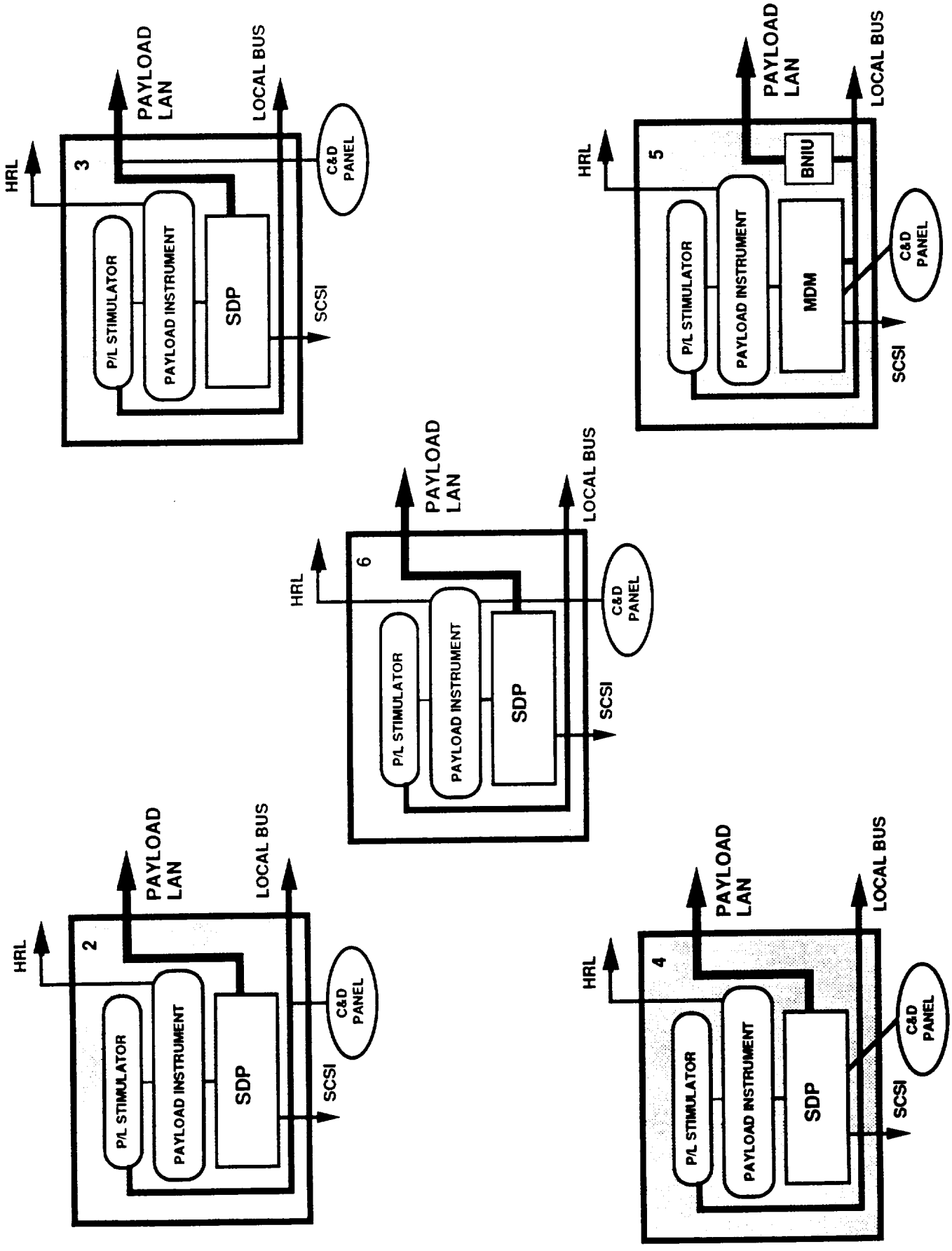


Figure 3.2-9 SCS C&D Connection Options

3.2.7.4 Audio/Video System Options

Where necessary, the audio and video systems are interfaced to the C&T portion of the Core systems representation to allow audio and video data to be formatted and merged into a trainer's telemetry data stream. High Rate Link data streams are assumed to be pre-formatted and to interface directly from the payload representation to the C&T processor/controller.

The audio and video systems in each SCS design are implemented using standard intercom stations, CCTV cameras, tape recorders, and optical disks under computer control. Additionally, computer generated speech synthesis, voice recognition, and graphic imagery are provided by coprocessors or peripheral processors connecting to the trainer host.

3.3 SCS Local Host Design

In the Local Host design, a separate host computer is dedicated to each major trainer and facility. The design was formulated to:

- use DMS kits and other SSF compatible components
- accept flight equivalent payload hardware and software without significant modification
- isolate and minimize the real time traffic loading on the SCS LAN
- interface directly with SSF support systems, development systems, and communications systems.

3.3.1 System Design

A top level view of the detailed Local Host design is shown in Figure 3.3-1. The distribution of SCS functions across the computer hosts and other system components of the design is summarized in the SCS functional allocation matrix presented in Figure 3.3-2. Details of this design are addressed in the following paragraphs.

3.3.1.1 Network Architecture

The Local Host design integrates the SCS using four types of LANs: 1) the SCS LAN which ties the separate facilities and trainers to central management and communications resources; 2) the Core LAN; 3) the Payload LAN within each DMS based trainer; and 4) the local LANs within each facility that connect workstations and terminals to their respective file servers. General specification of the network implementations is based on an initial analysis of the communications traffic and bandwidth requirements of the design. The results of this analysis are included in Appendix I.

In the Local Host design, the traffic on the SCS LAN consists predominantly of file transfers and message traffic between the Training Session Manger, Instructor Workstations, and Trainer Host computers. Based on a profile of infrequent large block transfers and orderly message traffic across a limited number of nodes, a Token

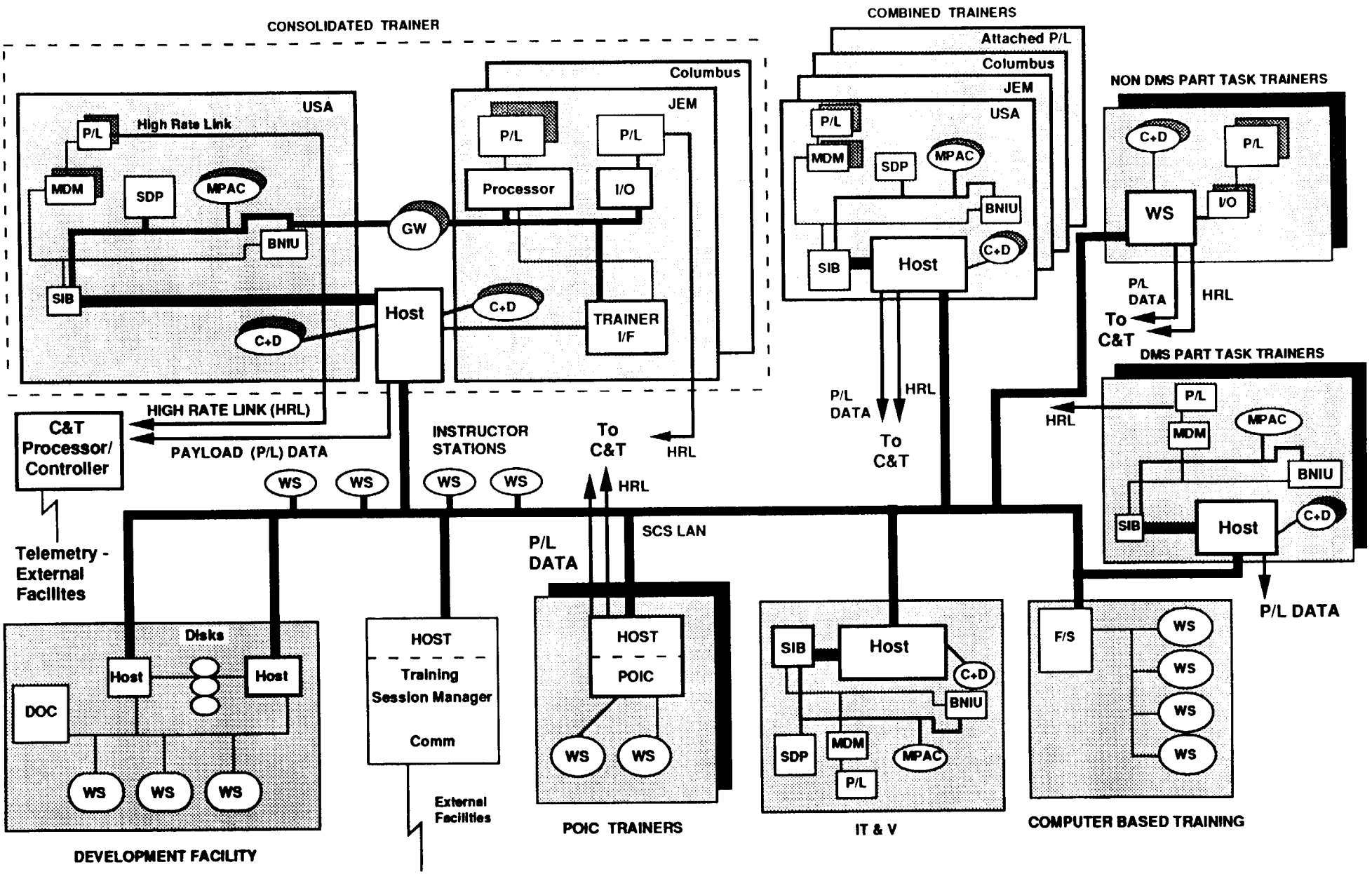


Figure 3.3-1 Top Level View of Local Host Design

LOCAL HOST DESIGN

Key:

- ● Totally Meets Requirement
- ◒ Partially Meets Requirement
- ○ Each Alternative Totally Meets Requirement

SCS FUNCTION	SYSTEM DESIGN COMPONENTS																		
	GP Host - Central	GP Host - Simulation	GP Host - Trainer	GP Host - Payload	Payload Instrument	C&D Emulator	DMS MDM w/EDP	DMS SDP	DMS MPAC	DMS P/L Network	Time Gen Subsys	SIB	Audio/Video System	P/L Stimulation H/W	GP Workstation	GP Terminal	File Server	SCS Network	Network Bridge/Gatewy
DMS Representation							◒	◒	◒	◒	◒	◒							◒
Core Systems Representation								●											
C&T System Representation								●											
Payload Representation			○		○														
Crew Interface Representation					○	○			○										
Simulation Executives			●																
POIC-DMS Interface			●																
PTC-POIC Link	◒																		◒
Payload Stimulator			◒											◒					
GSE Control			●																
Instructor Control and Monitoring	◒		◒												◒			◒	
Training Session Management	◒																	◒	
Operator Control & Monitoring	◒		◒													◒			
Configuration and Setup	◒																	◒	
Training Analysis	◒																	◒	
Training Information Management	◒		◒															◒	
POIC Personnel I/F Representation															●				
PTC External Interfaces	◒																		◒
Audio/Video System Representation			◒										◒						
Primary Instructional Delivery															◒		◒	◒	
Simulator, Scenario, & DB Dev.	◒														◒		◒	◒	
Developer Interface															○	○			
Crew Interface Prototyping	◒														◒				
Integrate & Test Simulators			◒			◒	◒	◒	◒	◒	◒	◒		◒	◒			◒	

Figure 3.3-2 Allocation of SCS Functions to Local Host Design

Ring implementation providing moderate throughput of 5-10 Mbps satisfies the anticipated communications loading. The contributing loads on this LAN are tabulated in Figure 3.3-3.

The Core LAN and Payload LAN consist of the FDDI LAN, concentrators, and NOS included as part of the DMS Kit and, minimally, are functionally equivalent to their SSF flight counterpart.

The use of local LANs within the CBT Facility and Development Facility support these workstation and file server configurations. The LANs support relatively low traffic loads accommodated within their 5-10 Mbps (CBT) and 10-20 Mbps (development) bandwidths, respectively. The advantage of a Token Ring implementation for these LANs is not implicit in the kind of large, and acceptably queued, file transfers that characterize much of their traffic. A Token Ring or Ethernet implementation achieving the necessary throughput can be used.

The SCS support facilities and POIC trainers also connect to the SCS Network. In the case of the POIC Trainers, it should be noted that the telemetry feed is handled by a separate communications system and does not enter onto the SCS LAN.

3.3.2 Trainer Design

The Consolidated, Combined, and DMS Based Part Task Trainers introduced in Section 2.2 share the same essential architecture in the SCS Local Host design. The trainer designs are diagrammed in Figure 3.3-4, Figure 3.3-5, and Figure 3.3-6, respectively. Differences in the designs are due solely to the trainer's configuration in respect to the number of labs and the number of payload experiments supported within a lab. One difference is that while the US Lab in the Consolidated or Combined Trainer is equipped with two crew consoles (MPACs), the remaining trainer labs have only one crew console.

Replication of the Space Station DMS architecture in these trainers with DMS Kits offers the benefits discussed in Section 3.2. The approach also ensures that: 1) flight equivalent payloads will operate within the trainer; 2) payload models developed by the PTC for training are transportable to the SSTF more easily; and 3) Core systems models developed for other Space Station requirements can be used with the trainers.

The Non-DMS Part Task Trainer design also shown in Figure 3.3-6 dedicates a workstation to serve as both the crew console and the primary computing platform. The workstation hosts the simulation executive, payload models, core models, and controls audio and video generated by an attached coprocessor. Payload instruments are interfaced using attached I/O adapters. The workstation connects to the SCS LAN and provides appropriate feeds (High Rate Link and Payload data) for a telemetry system.

3.3.2.1 Host Architecture

Each DMS based trainer relies on a dedicated local host -- connected to its SIB -- to support all real time simulation functions not provided within the DMS-SIB

LOCAL HOST DESIGN

* Values in K bits per second

			Host Platforms							
			SCS Maximum	Consolidated Trainer	Combined Trainers (3)	Part Task Trainers (9)	CDT F/S	Instructor Workstation	TSM Host	Development Facility
SCS NETWORK	REAL	DMS Representation	0	0	0	0		0	0	0
		Core Systems Representation	0	0	0	0		0	0	0
		C&T System Representation	0	0	0	0		0	0	0
		Payload Representation	0	0	0	0		0	0	0
		Environment Representation	0	0	0	0		0	0	0
		Crew Interface Representation	0	0	0	0		0	0	0
		Simulation Executives	0	0	0	0		0	0	0
		POIC - DMS Interface	0	0	0	0		0	0	0
		PTC-POIC Link	0	0	0	0		0	0	0
		GSE Control	0	0	0	0		0	0	0
		Instructor Control and Monitoring	5252.10	1050	1050	3150		0.14	1.96	0
		Audio/Video System Representation	0	0	0	0		0	0	0
		Real Time Totals	5252.10	1050	1050	3150	50	0.14	1.96	0
	NON-REAL	Training Analysis	550.0	200	200	100	50		0.14	
		Operator Control & Monitoring	10.0						10	
		Configuration and Setup	3000						1500	1500
		Non-Real Time Totals	3560.0						1510.14	1500

Figure 3.3-3 Local Host Network Loading

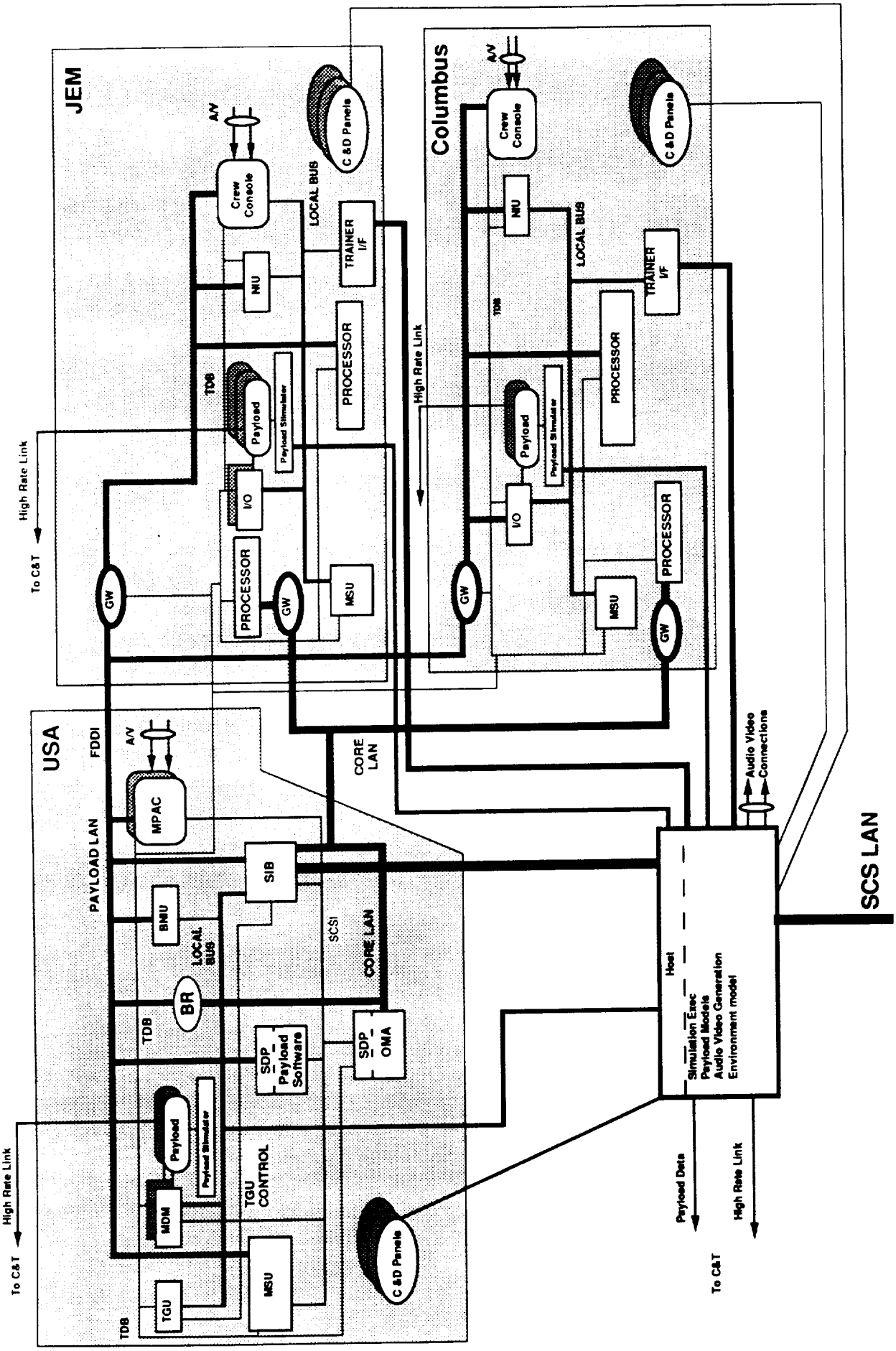


Figure 3.3-4 Local Host Consolidated Trainer Design

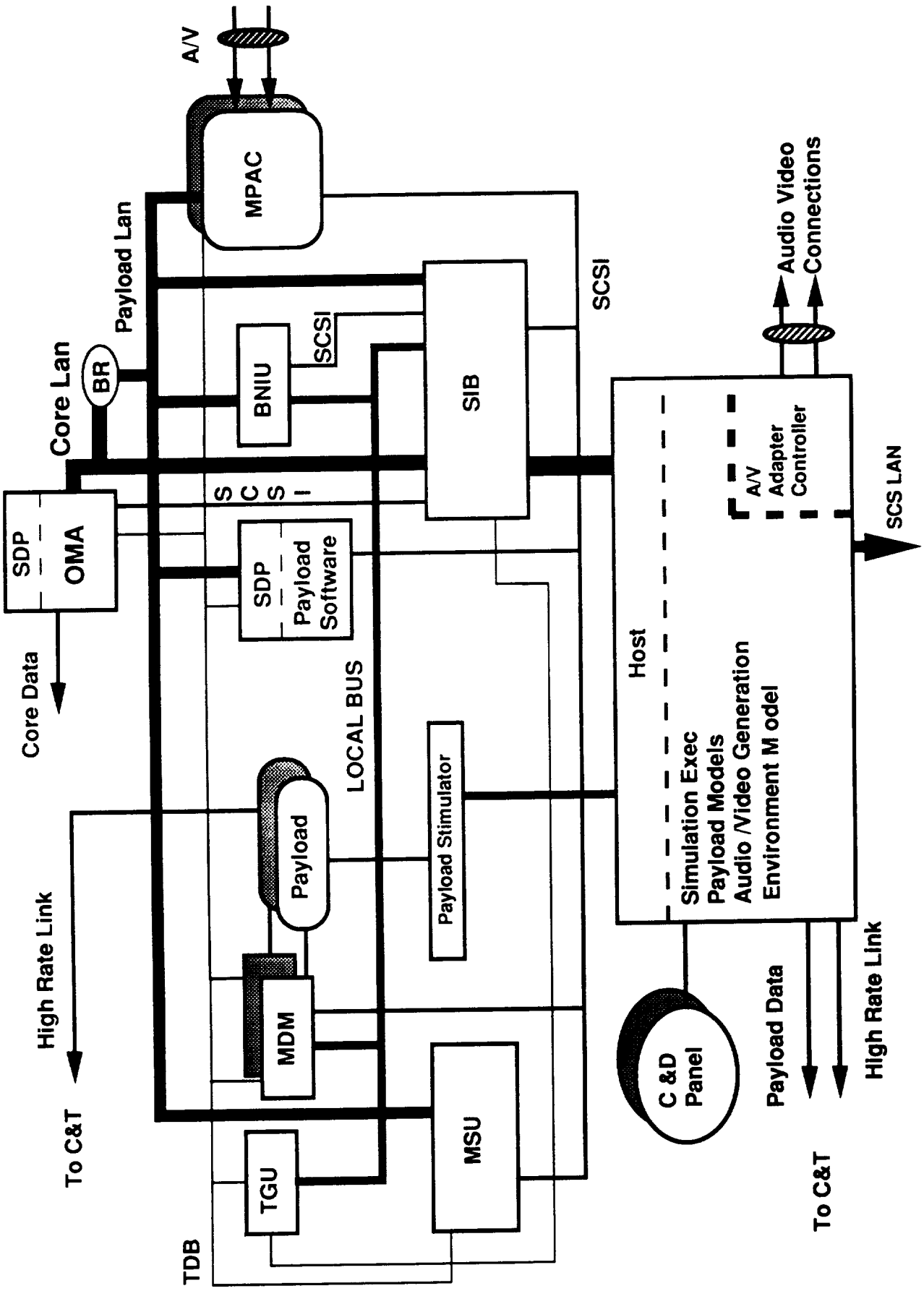


Figure 3.3-5 Local Host Combined Trainer Design

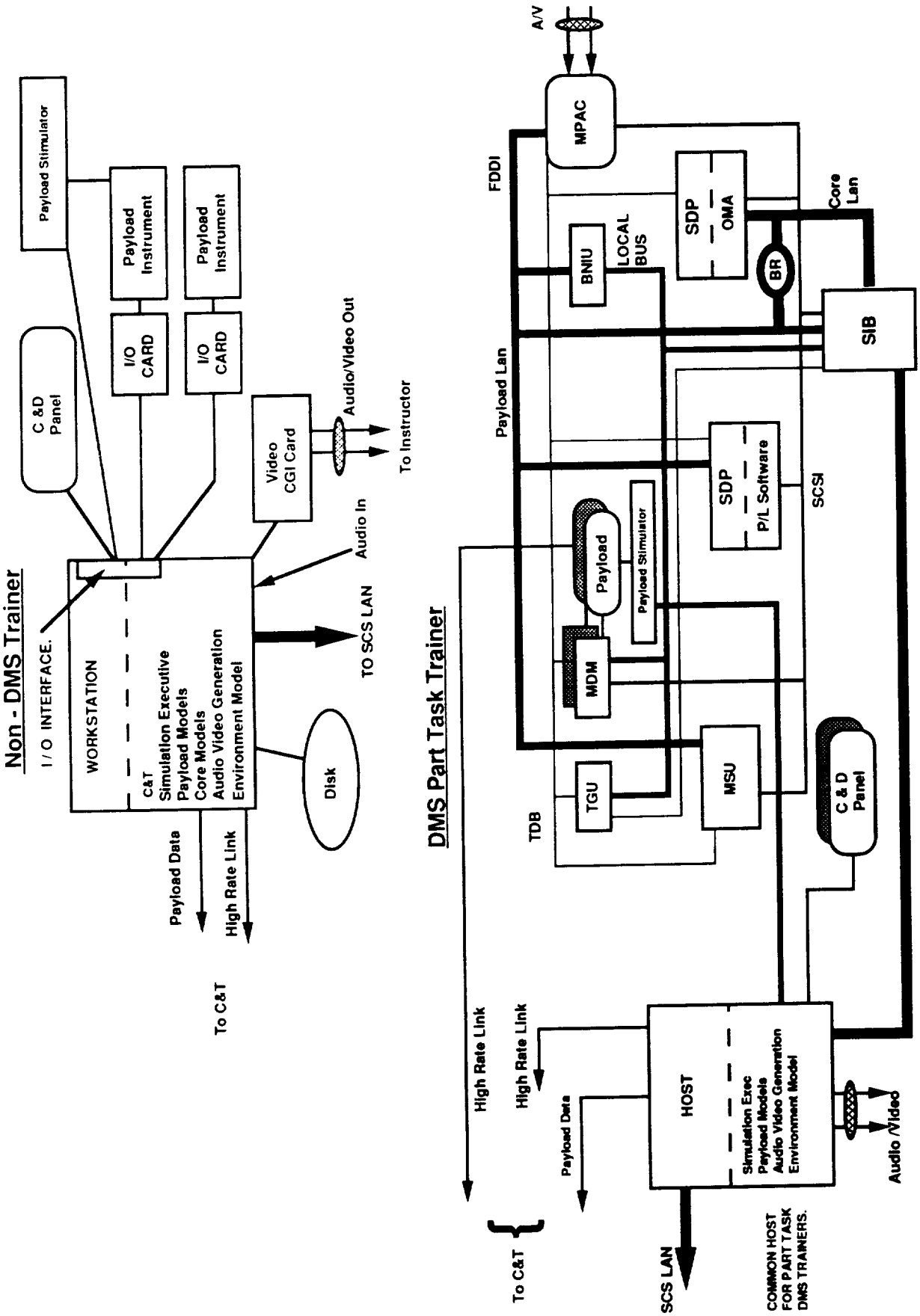


Figure 3.3-6 Local Host Part Task Trainer Design

complement. The Trainer Host provides the processing for: 1) the simulation executive governing real time functions; 2) configuration, setup, and initialization support to the Training Session Manager (TSM); 3) payload, core, and environment model execution; 4) audio/video control; 5) data base access 6) data/event recording; 7) device stimulation and GSE control; and 8) local diagnostics.

The Simulation Executive synchronizes scenario, payload model, core model, and data base execution in the host with DMS/OMA software execution in DMS Kit SDPs. Synchronization with, and control of, the DMS complement is mediated through the SIB. The Simulation Executive monitors system status, simulation session status, and student actions, and allows student console and panel views to be repeated on the Instructor Console. Through the SIB, the executive controls trainer operation including start, stop, step, freeze, sequence, and replay modes. It also synchronizes the interface between simulation execution and peripheral devices including the Audio and Video Systems and payload C&D panels. The Simulation Executive reports system configuration and simulation session status to the Training Session Manager.

The Trainer Host executes all payload simulations used in lieu of actual flight equivalent payloads. This simulation involves the simulation model software developed for that payload experiment and the C&D panel configured accordingly. The software is executed on the host to which the C&D panel is attached. If a payload normally generates video, the model based generation is controlled by the host using a processor attached video adapter. The host also controls other audio and video generated or replayed by the Audio and Video System diagrammed in Figure 3.2-2.

The Payload Simulation Host communicates with the SIB and its attached DMS components via a high speed bus channel link. It communicates with the Training Session Manager and other SCS training support facilities via the SCS Network.

The OMA and network operating system (NOS) software furnished with the DMS Kit is hosted on a DMS SDP. Flight equivalent payload software may also run in SDPs or EDP-4s within other DMS components. The SIB is assumed to provide the necessary platform and software to effect control and synchronization of the DMS configuration.

3.3.2.2 DMS Components

The DMS components comprising the DMS based trainers are described in Section 2.3.1. DMS software including the Operations Management Application (OMA), Network Operating System (NOS), and the DMS Standard Services are executed in the DMS SDP. Core systems are represented by simulation models running on the DMS The DMS components support the connection of flight equivalent payloads to the DMS. It is assumed and has been depicted in Figures 3.3-4 and 3.3-5, that flight equivalent payloads interface to the DMS through an MDM. Provided that the payload instrument is equipped with other interface capabilities such as a BIA or NIU, the trainer design will also accommodate these alternative modes of connection.

When payloads that normally generate video (or optical scenes) are simulated, the video signal is reproduced by the Audio and Video System depicted in Figure 3.2-2. The signal may be derived from a video source and/or computer generated imagery. Generated images are obtained from a video/graphics adapter attached to the Trainer Host. Similarly for audio signals replicating voice communications, the signal is reproduced from recorded media or generated by an attached audio adapter. When any computer generated audio and video presentations are required within the trainers, they are routed from the Trainer Host directly to crew consoles, instructor consoles, and other monitors. In the Local Host configuration, the trainer host serves as the host portion of the Audio and Video System depicted in the Figure 3.2-2.

The C&T system simulator accepts uplink data and downlink data and processes it before putting it on the Payload LAN or routing it to POIC Trainers or the POIC. High Rate Link data and concurrent Payload LAN data generated by flight equivalent payloads or by payload models are merged to form a telemetry stream. To encode dynamic video into such a downlink feed, the original signal is obtained from the Audio and Video System. Moderate rates of combined data may be processed by the C&T simulator to produce a realistic dynamic telemetry stream. High rates of dynamic data approaching SSF bandwidths require the processing of an external telemetry system (i.e. , the C&T processor/controller described in Section 3.2.2).

The C&T processing typically involved in a lab trainer simulation session is the model based representation of the flight-ground information exchange. The model need only insure that the logical content of relevant communications and telemetry, and transmission characteristics affecting data receipt, be preserved. This level of representation is assumed to be achieved by the rudimentary C&T model incorporated in the Core models. The production of full capacity dynamic telemetry streams, however, requires additional model fidelity and processing to derive controlling data that drives high speed data generation sources such as the video subsystem. Full telemetry representation sufficient to drive the POIC/POIC trainers also requires the real time merging, formatting, and transmission functions emulated by the C&T processor/controller. The additional processing requirements of the high fidelity C&T and driver functions are reflected in the host loading tables that appear later for the SCS designs.

When flight equivalent instruments are used as the payload device, the instrument is electronically and physically driven, or excited, by a Payload Stimulator. The stimulator is configured and programmed to provide the excitatory signals and other stimuli necessary for the payload to function approximately as it would in space, and respond realistically to environmental inputs and manipulations arising out of the simulation scenario during a training session. The stimulator also controls the supply of GSE services (from a non-SCS PTC facility) that are necessary for the device to function appropriately. The stimulator is a processor based I/O adapter/controller plus the required effectors/actuators that attach to the payload instrument. A Payload Stimulator also generates the electronic signals necessary to emulate the GPS input to the TGU in DMS based trainers.

The stimulator is connected (using an RS-232 or SCSI interface) directly to, and under the control of, the Trainer Host (or workstation in the Non-DMS Part Task

Trainer). The stimulator responds to lab systems and Core systems models, in conjunction with specifications in the payload model, which in turn are driven by scenario events, ad lib control events, and outputs of the environment model.

Finally, it should be noted that in all DMS based trainers in the Local Host design the TDB has been implemented explicitly in the trainer diagrams. This implementation, under the current DMS Kit specification, is not actually necessary. The TDB can be eliminated because the SIB, connected directly to the TGU, assumes the bus function of distributing TGU (or equivalent) timing signals to the individual DMS components. It was elected, however, to represent the bus separately in case SIB functionality changes and provides timing function backup.

3.3.2.3 Trainer Connectivity

Trainer connectivity is implemented in varying degrees throughout the Local Host Design. The greatest connectivity exists within the Consolidated Trainer. All trainers are interconnected only by the SCS LAN which, in this design, is intended to carry a minimal amount of real time simulation traffic.

3.3.2.3.1 Consolidated Trainer

The Consolidated Trainer has three means of connectivity across its three constituent labs: 1) Payload LANs; 2) common Timing Generation System and Distribution Bus (TDB); and 3) common Core models. At present, the nature of the LANs to be employed in the Columbus and JEM labs is not known. The DMS Kits incorporate gateways between the US lab and the other labs. If the Payload LANs of the Columbus and JEM labs are compatible with the OSI layers 1 and 2 adopted by the FDDI protocol, the gateways may be replaced with bridges.

The Consolidated trainer relies on a common Simulation Executive hosted on a single computer to supervise all three labs. The processor hosts all payload models. Generation of the trainer's audio and video for the labs is also under the control of this host. The Columbus and JEM labs are connected to the host through an undetermined interface identified in the figures as a Trainer I/F.

Core models run on DMS Kits. The C&T processor/controller performs the C&T processing required and is utilized via a patch panel to connect to the consolidated trainer, as well as all other trainers.

3.3.2.3.2 Other Trainers

The Combined Trainers and Part Task Trainers operate independently and are only interconnected through the SCS LAN. Each trainer, including the Non-DMS Part Task Trainers, relies on a dedicated LAN for primary connection. In addition to the component connectivity provided by the payload LAN for all trainers, except for the non-DMS PTTs, the SIB adds additional connection paths to the DMS based trainers.

3.3.3 Host Loading

Host loading for the Local Host Design is based on estimated maximum loadings of the SCS. It was assumed that all trainers were in operation concurrently with a full level of software development activity. The capacity in Mips of the general purpose hosts comprising the Local Host Design is tabulated in Figure 3.3-7. The figure summarizes the estimated computational resource in Mips required to execute each of the basic SCS functions identified in the function allocation matrix presented earlier in Figure 3.3-2. Appendix I has been included to provide more details on the assumptions and methods underlying these estimates.

The Trainer Hosts in this design have maximum computing capacities ranging from approximately 20 Mips for Part Task Trainers to 38 Mips for the US Lab Combined Trainer and 60 Mips for the Consolidated Trainer.

The host sizing to support the various SCS facilities common to all SCS designs are presented once in this table. The substantial Mips requirements to support the Development Facility stems from a heavy reliance on high fidelity payload models. The distributed modular design of this facility, however, yields a large number of relatively small platforms allowing easy incremental implementation of the full facility.

3.4 Shared Host Design

The Shared Host design is comparable to the Local Host Design in most design respects beyond the architectural difference in the basic deployment of, and access to, the Simulation Hosts that replace the previous design's Trainer Hosts. The objectives of the Shared Host design goals were to:

- achieve flexibility in application and usage of host computers
- use DMS Kits
- accept flight equivalent H/W
- interface directly with SSF support systems
- improved reconfigurability
- maximum use of SCS LAN.

3.4.1 System Design

The Shared Host design meets SCS requirements and achieves SCS objectives by using an architecture which permits the SCS processing load from all trainers to be shared among multiple hosts instead of allocating a fixed load to dedicated hosts. All SCS facilities, other than the actual lab trainers and the Training Session Manger, are implemented in the same manner as the Local Host design.

The distinguishing characteristic of the Shared Host Design is that the trainer hosts do not reside in the individual Combined, Consolidated, and DMS Part Task trainers, but rather on the SCS Network. A small number of general purpose hosts reside on this LAN and are shared by the eight DMS based trainers. Six hosts have been specified: five for simulation and one for the Training Session Manager and

LOCAL HOST DESIGN

SCS FUNCTION	Total SCS MIPS	MIPS Cosolidated Trainer			Combined Trainers			Four DMS-Part Task Trainers	Five NON-DMS Trainers	IT&V	Inst Stat	TSM Host	Development Facility		CBT		7 POIC Trainers		C&T Processor
		US	JEM	Colum	US	JEM	Colum						F/S	WS	F/S	WS	HOST	2WS	
DMS Representation	7.5							0	7.5										
Core Systems Representation	39	6			5	5	5	8	5	5									
C&T System Representation	31	2			2	2	2	6	5	2									10
Payload Representation	72	12	6	6	12	6	6	8	10	6									
Environment Representation	37	3			3	3	3	12	10	3									
Crew Interface Representation	25.9	0.1	0.05	0.05	0.1	0.05	0.05	0.2	25.25	0.05									
Simulation Executives	26	6			3	3	3	4	5	2									
POIC - DMS Interface	10.5	2			1	1	1	2	2.5	1									
PTC-POIC Link	10								0										10
GSE Control	1.4	0.1			0.1	0.1	0.1	0.4	0.5	0.1									
Instructor Control and Monitoring	254.5	1.1			1.1	1.1	1.1	4.4	5.5	0.1	240	0.1							
Training Session Manager	4.31	0.1			0.1	0.1	0.1	0.4	0.5	0.01		3							
Operator Control & Monitoring	0.14	0.01			0.01	0.01	0.01	0.04	0.05	0.01									
Configuration and Setup	1.5	0.1			0.1	0.1	0.1	0.4	0.5	0.1		0.1							
Training Analysis	4								0			4							
Training Information Management	4				0			0	0			4							
POIC Personnel I/F Representation	112				0			0	0			0					56	56	
PTC External Interfaces	5				0			0	0			5							
Audio/Video System Representation	85	15			10	5	5	20	25	5									
Primary Instructional Delivery	24				0			0	0						8	16			
Simulator, Scenario, & DB Dev.	310				0			0	0				70	240					
Developer Interface	66				0			0	0				16	50					
Crew Interface Prototyping	36				0			0	0				6	30					
Integrate & Test Simulators	18				0			0	0	18									
Lab Trainers Total	**318.1**	**47.5**	**6.05**	**6.05**	**37.5**	**26.4**	**26.4**	**65.84**	**102.3**										
Facilities Total	**866.6**									**42.3**	**240**	**16.2**	**92**	**320**	**8**	**16**	**56**	**56**	**20**
SCS Grand Total	**1184**																		

Figure 3.3-7 Local Host Loading

external communications. These hosts share the processing load between them, with no fixed allocation of a host to a specific trainer. In keeping with the SCS Conceptual Design Report, these hosts are referred to as Simulation Hosts.

A top level view of the Shared Host design is presented in Figure 3.4-1. The allocation of SCS functions to design components in the Shared Host design is tabulated in Figure 3.4-2.

3.4.1.1 Network Architecture

The Shared Host design employs four types of LANS: 1) the SCS LAN connecting trainers to hosts and interconnecting the SCS facilities; 2) the Core LAN, which interconnects the core SDP and the SIB; 3) the Payload LAN, which interconnects the DMS components and the SIB; and 4) the local LANS within each facility connecting workstations and terminals to their respective file servers.

In contrast to other designs, the traffic on the SCS LAN is predominantly real time data exchanged between the DMS based trainers and their simulation models executing on the shared Simulation Hosts. Based on initial estimates compiled in Appendix I, the expected maximum load on the LAN is 71 Mbps. The estimate is within the bounds of FDDI Token Ring networks which offer the added advantage of being compatible with the projected FDDI implementation of the SSF DMS Core and Payload LAN. Further, the short synchronous message character of simulation exchanges favors a Token Ring implementation. The contributing loads on this LAN are tabulated in Figure 3.4-3.

Except for the Non-DMS Part Task Trainer, trainer types connect to the SCS LAN through their respective SIBs. In the Non-DMS trainer, each trainer workstation connects directly to the SCS LAN.

The SCS support facilities and POIC trainers also connect to the SCS Network. In the case of the POIC Trainers, it should be noted that the telemetry feed is handled by a separate communications system and does not enter onto the SCS LAN. Similarly, the High Rate Link communications in other trainers is isolated from the Payload and SCS LANs on a separate communications system. The use of local LANs within the CBT and Development facilities support the related workstations configurations and their interconnection to the file servers. The estimated bandwidth for these LANs is the same as presented for the Local Host design in Section 3.3.1.1.

The Core and Payload LANs are both FDDI networks. The Core and Payload LAN will be modeled after the SSFP flight LANs to connect the various DMS components and, in some cases, payloads. It is assumed that both Core and Payload LANs are included in the DMS Kit.

3.4.2 Trainer Design

The Shared Host trainer configurations of DMS components (or workstations in the Non-DMS Part Task Trainer) are the same as in the Local Host trainers except that the video portion of the Audio and Video System is implemented differently. The

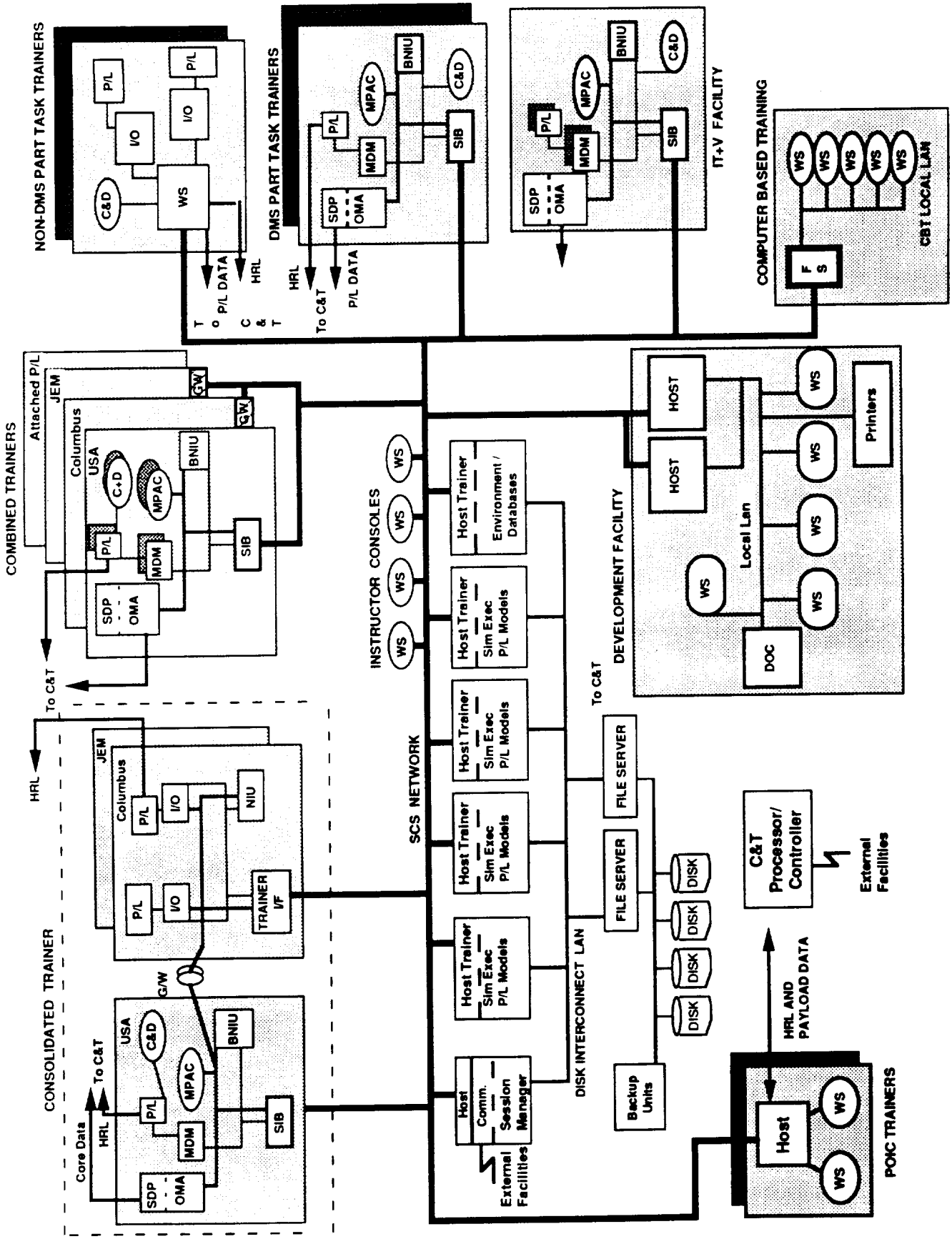


Figure 3.4-1 Top Level View of Shared Host Design

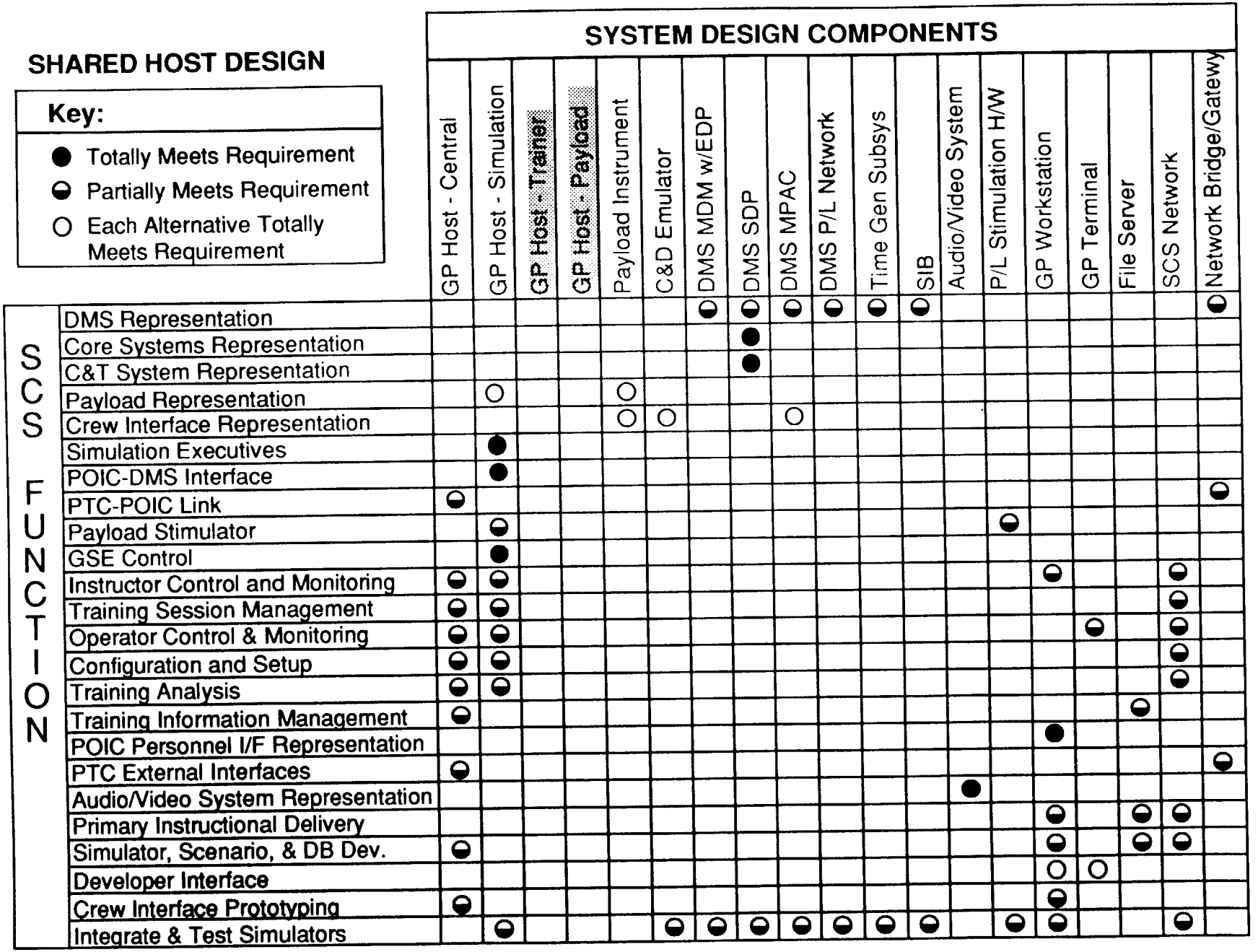


Figure 3.4-2 Allocation of SCS Functions to Shared Host Design

SHARED HOST DESIGN

* Values in K bits per second

			Host Platforms									
			SCS Maximum	Shared Host	Consolidated SIB	Combined SIB	Part Task SIB	Non-DMS Trainer	Instructor Workstation	TSM Host	CBT F/S	Development Facility
SCS NETWORK	REAL	DMS Representation	24	0	5	15	4		0	0		0
		Core Systems Representation	150	128	8	12	2		0	0		0
		C&T System Representation	900	0	250	450	200		0	0		0
		Payload Representation	36000	36000	0	0	0		0	0		0
		Environment Representation	715	650	15	30	20		0	0		0
		Crew Interface Representation	810	160	150	300	200		0	0		0
		Simulation Executives	72	72	0	0	0		0	0		0
		POIC - DMS Interface	135	0	50	75	10		0	0		0
		PTC-POIC Link	0	0	0	0	0		0	0		0
		GSE Control	29	29	0	0	0		0	0		0
		Instructor Control and Monitoring	28000	4000	4000	12000	8000	8000	0.14	1.96		0
		Audio/Video System Representation	4500.17	4500	0.1	0.03	0.04		0	0		0
		Real Time Totals	71335.17	45539	4478.1	12882.03	8436.04	8000	0.14	1.96		0
	NON-REAL	Training Analysis	50								50	
		Operator Control & Monitoring	10							10		
		Configuration and Setup	3000									3000
		Non-Real Time Totals	3060						0	10		3000

Figure 3.4-3 Shared Host Network Loading

difference -- necessary to detach this function from the remote host implementation -- is described below. A further difference arises in the interface between the Training Session Manager and individual Simulation Executives. The potential integration of these functions (TSM and Simulation Executives) on a common host reduces network traffic and increases overall efficiency. The DMS Core SDP runs the flight equivalent OMA and core models. The Shared Host trainer types are diagrammed in Figure 3.4-4 through Figure 3.4-6.

Each trainer is supported by two or more hosts accessed on the SCS LAN and shared with other trainers. This means that time sharing or parallel execution of TSM and simulation executives, as well as simulation models, is performed on a host. The allocation of hosts and functions indicated in Figure 3.4-2 is somewhat arbitrary and is easily reconfigured. Indeed, one of the advantages of the Shared Host design is the level of fault tolerance that can be gained by dynamically reallocating functions when a host is overloaded or failing.

In contrast to other designs, the Shared Host DMS Part Task Trainers share one SIB. This is an assumed possibility that would add flexibility to the SCS design, and is not the current SIB baseline. This option's availability thus depends on the final SIB design, and could also be implemented within the Local Host design. A trainer's DMS components and the Core systems models, however, remain exclusive to the individual trainer. The trainer connectivity is discussed further in a later section.

3.4.2.1 Host Architecture

The Shared Host design is depicted consisting of five hosts. While the number is preliminary, initial estimates of computing resource requirements and the distribution of simulation and training functions confirm the reasonableness of this selection. This bank of comparable hosts is used to support all real time simulation functions not provided within the DMS-SIB complement, and all TSM and other non-real time training facility functions. In order to support reassignment of trainers, reallocation of simulation functions, and load balancing, the hosts run the same operating system and share common disk storage.

In addition to their interconnection via the SCS LAN, the shared hosts are provided with a common high speed channel connected to a dual configuration of file servers. This sharing of disk storage keeps SCS LAN traffic from mushrooming with simulation data base activity. The disk storage is expected to maintain the virtual memory SCS global data base for all training sessions, as well as configuration, initialization, and environment data bases. Other benefits of this configuration include enhanced system backup and recovery capabilities, and a basic capacity for fault tolerant operation by taking advantage of the redundant file servers and disks.

The Simulation Executive synchronizes scenario, payload model, and data base execution in the host with DMS/OMA software execution in DMS Kit SDPs. One Simulation Executive for each active trainer is executed on one of the shared hosts. Besides coordinating DMS, SIB, and model driven activity in real time, a Simulation Executive provides access and logging capabilities to enable instructor control and status reporting to the Training Session Manager, residing on a shared

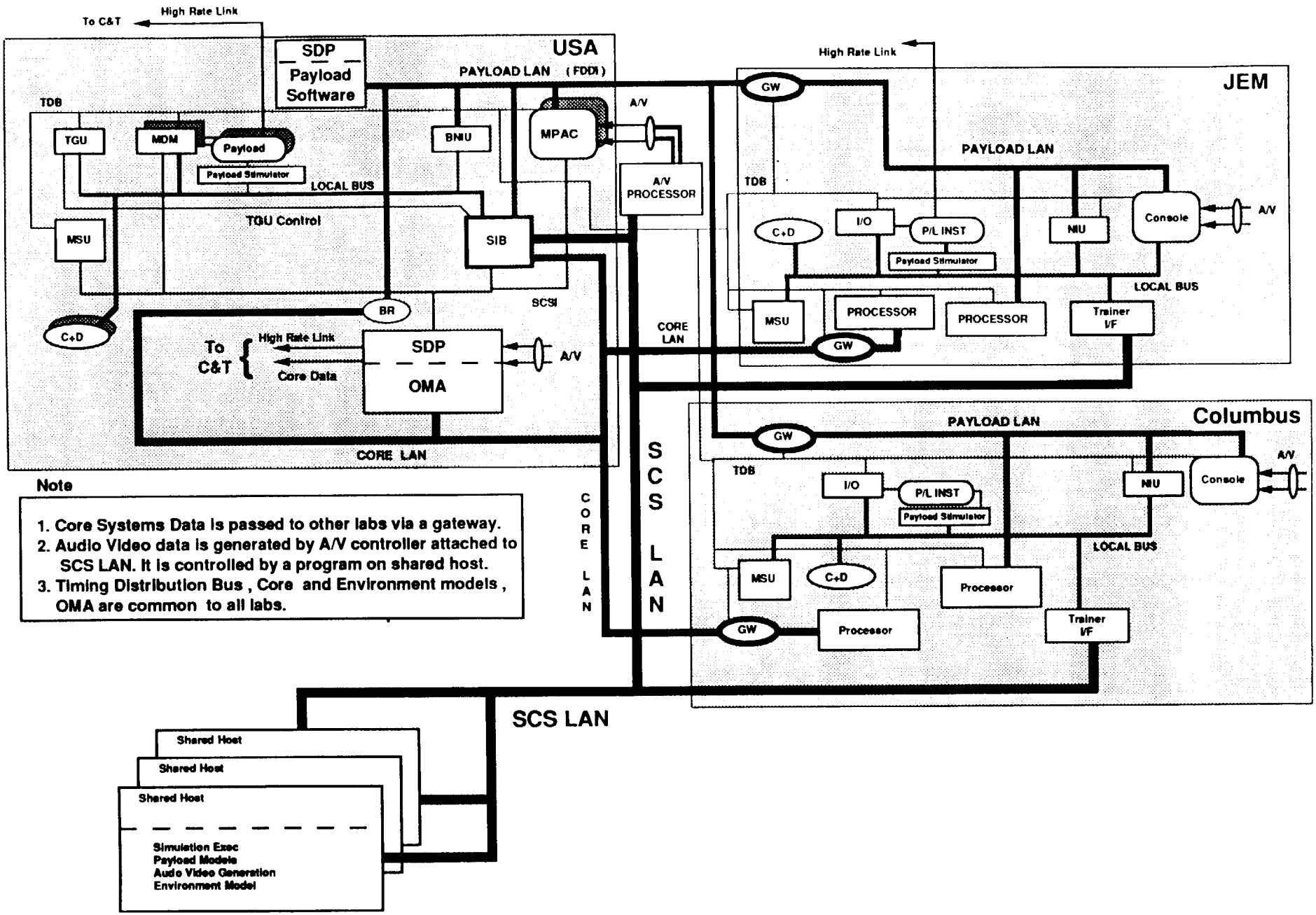


Figure 3.4-4 Shared Host Consolidated Trainer Design

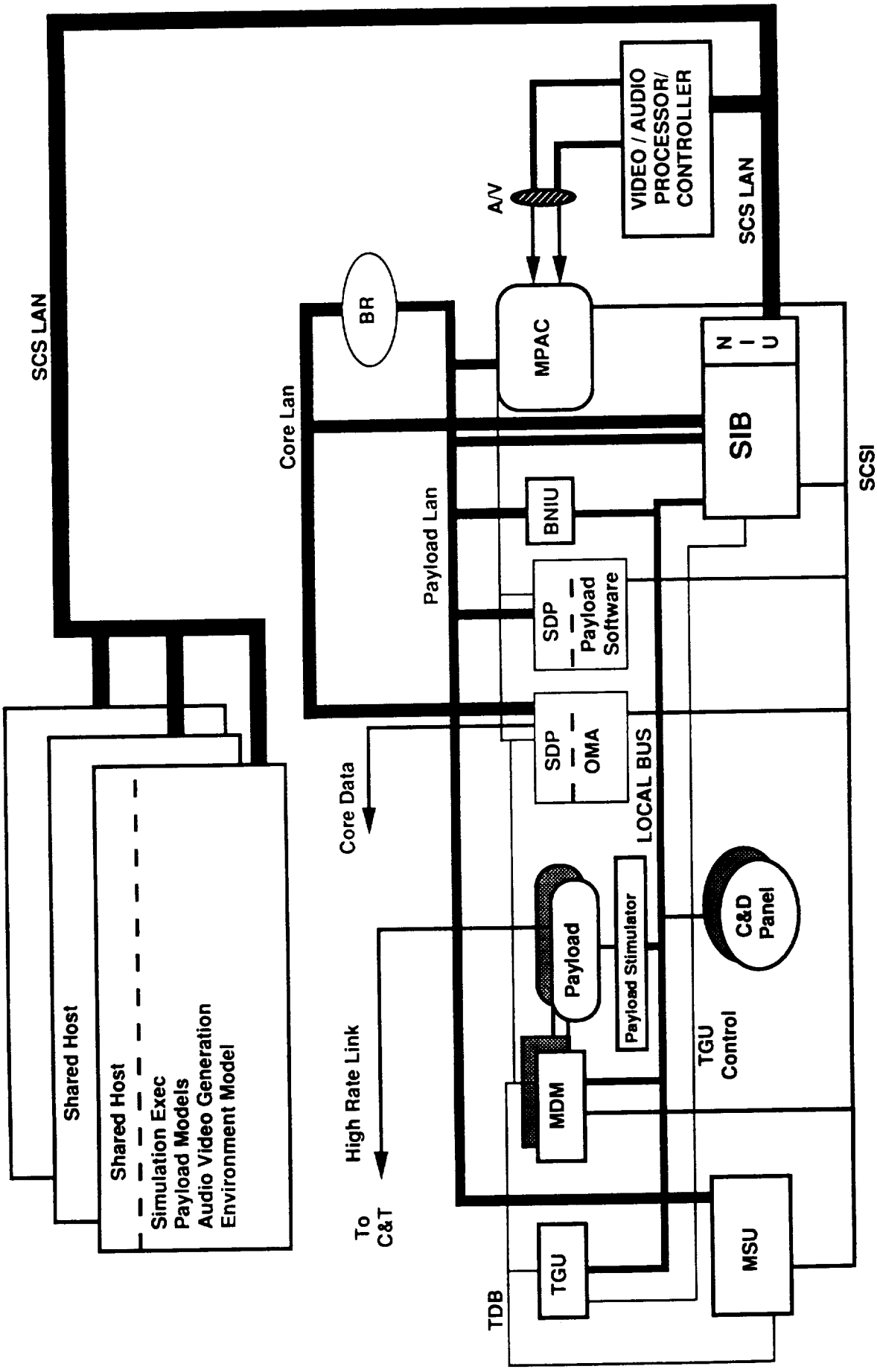


Figure 3.4-5 Shared Host Combined Trainer Design

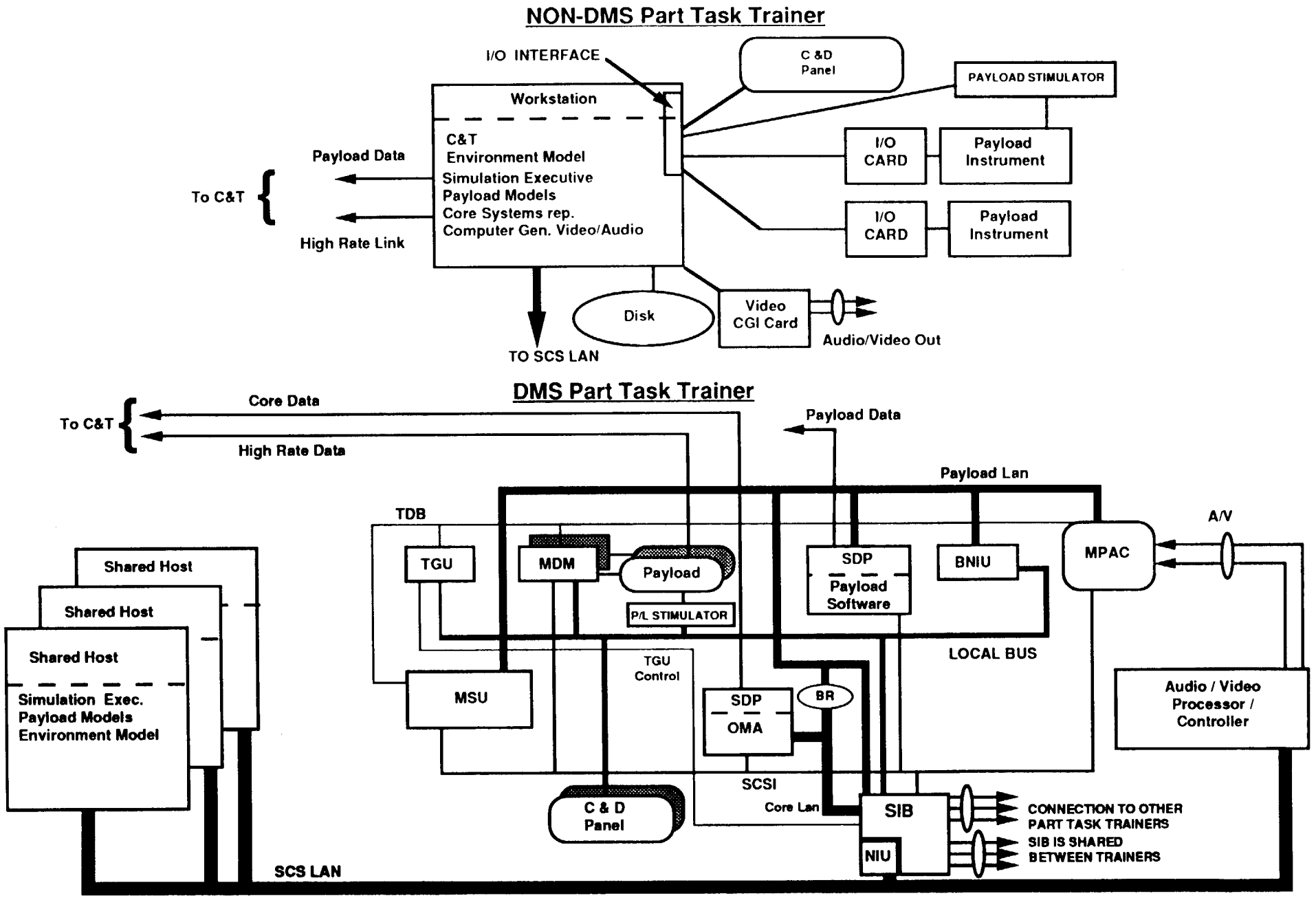


Figure 3.4-6 Shared Host Part Task Trainer Design

host localized for non-real time processing. The simulation synchronization scheme proposed for all SCS designs in Section 3.2.6.1 provides the means to sustain an efficient exchange of simulation data between the shared hosts and the trainers.

3.4.2.2 DMS Components

The DMS components described in Section 2.3.1 are employed in this design similarly to the Local Host design as described in Section 3.3.2.2. A dedicated processor/controller is utilized to perform the C&T system simulation, just as was done in the Local Host design. This configuration stems from the requirement to provide downlink data streams from individual lab trainers as part of the telemetry data exchange with the POIC and POIC Trainers. The close interface with a specialized telemetry system (when full bandwidth emulations are necessary) and with the trainer's audio and video systems prevents a remote shared host implementation of the C&T capability. High Rate Link data generated by flight equivalent payloads or by payload models are merged with payload data to feed the external telemetry system.

To encode dynamic video into such a downlink feed, the original signal is obtained from the Audio and Video processor/controller connected to the Payload LAN. This specialized processor/controller includes processor attached audio/video adapters and frame buffers providing direct feeds to SCS systems. When any computer generated audio and video presentations are required within the SCS Shared Host trainers, it is routed from the process/controller directly to crew consoles, instructor consoles, and other monitors. It serves as the host portion of the Audio and Video System depicted in Figure 3.2-2.

As in all DMS based designs, flight equivalent payloads typically interface to the DMS through an MDM. When payload models are used in lieu of flight articles in the Shared Host design, the simulation software is executed on the shared hosts. The C&D panels associated with the payload, however, are connected to the DMS through the Local Bus, rather than to a trainer host in the Local Host design. The Payload Stimulator described previously in Section 3.3.2.2 for the Local Host design is also compatible with this design. In the Shared Host design, however, the stimulator attaches to the Local Bus instead of the trainer host.

3.4.2.3 Trainer Connectivity

Trainer connectivity is similar to that found in the Local Host SCS except that inter-trainer connectivity is facilitated by the fact that software functions for different trainers reside on the same host. Thus, connectivity is achieved in the form of interprocess communications among executive function and simulation function real time applications. These communications, although not needed to meet currently specified SCS requirements, could be used to meet future implementations affording reconfigurability across trainers. For example, this mode of communications is one way to drive all trainers with a common scenario and data base.

Another approach to increased reconfigurability, which is not shown in the figures, is to connect directly to each trainer's Payload LAN via gateways or bridges to the SCS LAN. This would connect independent trainers comparably to how the

Consolidated Trainer is implemented, allowing three Combined Trainers to be reconfigured and serve as the consolidated labs trainer. The connection also achieves a level of fault tolerance and additional flexibility by providing an alternative path between host and DMS which bypasses the SIB. The latter feature would apply equally well to an SCS Local Host implementation.

The SIB's connection directly to the SCS LAN, instead of to a host computer, adds the proper (FDDI) network interface as a requirement to the SIB furnished in the DMS Kit. This is not the current SIB baseline, however, Lockheed indicated a FDDI connection refinement was being considered. This is different from the high speed processor bus channel used to connect the SIB to the Trainer Host in the Local Host design.

3.4.2.3.1 Consolidated Trainer

As in the local host design, the Consolidated Trainer has four means of connectivity: 1) Payload LANs; 2) Core LAN; 3)common Timing Distribution System using the Timing Distribution Bus (TDB); and 4) common Core models running on a shared host. This trainer also uses a common processor/controller for C&T processing. The path for Core data and payload data to the Columbus and JEM labs is the Core and Payload LAN gateways to their respective lab trainer networks, as illustrated in Figure 3.4-4

3.4.2.3.2 Other Trainers

As with the Consolidated Trainer, the connectivity of the Shared Host Combined Trainer and the Non-DMS Part Task Trainer is essentially the same as that found in the Local Host design.

In contrast to other designs, the DMS Part Task Trainers take advantage of the SIB's assumed capability to directly support multiple units of each DMS component. Consequently, the hosts' SCS LAN connection to a single SIB fans out through the SIB's multiple DMS links to several Payload LANs, each integrating a suite of DMS components to represent a separate part task trainer. Independent Simulation Executive, Core model, and payload model processing are maintained on the shared hosts. The obvious advantage of this approach is the reduction to one the number of SIBs required to implement the four trainers.

While the workstation of the Non-DMS Part Task Trainer resides on the SCS network, these trainers do not use the shared hosts for real-time simulation processing, relying on them only for Training Session Management functions. Regardless, the option exists to use the shared hosts for real time processing if necessary. The same arrangement and option exist, with the addition of some software, for the POIC Trainers

3.3.2.3.3 IT&V Facility

The IT&V Facility, based on the design of the Combined Trainer, depends on the shared hosts for its Simulation Executive, some Core models, and payload model

executions. The connectivity with the Development Facility on the SCS LAN, permits software models to be uploaded directly to the facility's corresponding hosts.

3.4.3 Host Loading.

Host loading for the Shared Host Design is based on estimated maximum loadings of the SCS. It was assumed that all trainers were in operation concurrently with a full level of software development activity. The capacity in Mips of the general purpose hosts comprising the Shared Host Design is tabulated in Figure 3.4-7. The figure summarizes the estimated computational resource in Mips required to execute each of the basic SCS functions identified in the function allocation matrix presented earlier in Figure 3.4-2. Appendix I has been included to provide more details on the assumptions and methods underlying these estimates.

The five shared Simulation Hosts in this design each have maximum computing capacities of approximately 30 Mips. The Non-DMS Part Task Trainers are hosted by workstations with a maximum required capacity of 20 Mips.

3.5 DMS Equivalent Design

The basic architecture of the SCS DMS Equivalent design is consistent with the architecture of the Local Host design. The trainer implementations, however, are distinguished by not employing the DMS Kits. The design objectives of the DMS Equivalent design include the following:

- achieve sufficient DMS function without relying on SSF flight equivalent components
- distribute processing requirements across standard inexpensive computer platforms
- minimize centralized SCS LAN traffic loads
- maintain SSF DMS compatibility to interface DMS components and software
- maximize reconfigurability

3.5.1 System Design

The DMS Equivalent design addresses SCS objectives by adopting a distributed processing implementation in the trainers using standard commercial hardware. The design replaces the flight equivalent DMS components of the previous trainer designs with commercial general purpose microcomputers and custom software. The SIB and Trainer Host are also replaced by these general purpose microcomputers tied together on a trainer LAN. This network replaces the Payload LAN and other DMS/SIB busses. A top level view of the DMS Equivalent Design is shown in Figure 3.5-1. The allocation of SCS functions to the DMS Equivalent Design is shown in Figure 3.5-2.

The design, while straight-forward to implement, presents certain challenges. Although the necessary hardware should be inexpensive, the potential cost of custom software, if the commercial hardware cannot support SSF flight equivalent software

SHARED HOST DESIGN

SCS FUNCTION	Host Platforms														
	Total SCS Trainer MIPS	Five Shared Hosts	Five Host Non_DMS Trainers	Instructor Workstation (15)	TSM Host	Development Facility		CBT		POIC Trainers (7)		A/V Control Consolidated	A/V Control Combined	A/V Part Task	C&T Tele. Processor
						F/S	WS	F/S	WS	HOST	2WS				
DMS Representation	7.5	0	7.5									0		0	
Core Systems Representation	35.6	30.6	5									0		0	
C&T System Representation	17.0	2.0	5												10
Payload Representation	70.5	60.5	10												
Environment Representation	26.2	16.2	10												
Crew Interface Representation	25.9	0.7	25.3												
Simulation Executives	25.5	20.5	5												
POIC - DMS Interface	10.5	8.0	2.5												
PTC-POIC Link	10.0	0	0												10
GSE Control	1.4	0.9	0.5												
Instructor Control and Monitoring	254.4	8.9	5.5	240	0.1										
Training Session Manager	1.3	0.8	0.5		3										
Operator Control & Monitoring	0.1	0.1	0.1		0										
Configuration and Setup	1.4	0.9	0.5		0.1										
Training Analysis	4.0		0		4.0										
Training Information Management	4.0		0		4.0										
POIC Personnel I/F Representation	112.0		0		0					56.0	56.0				
PTC External Interfaces	5		0		5.0										
Audio/Video System Representation	83.0	3.0	25									15	20	20	
Primary Instructional Delivery	24.0		0					8.0	16.0						
Simulator, Scenario, & DB Dev.	310.0		0			70.0	240.0								
Developer Interface	66.0		0			16.0	50.0								
Crew Interface Prototyping	36.0		0			6.0	30.0								
Integrate & Test Simulators	18.0	18.0	0												
Lab Trainers Total	**310.3**	**153.0**	**102.3**									15	20	20	
Facilities Total	**874.6**			**240.0**	**16.2**	**92.0**	**320.0**	**8.0**	**16.0**	**56.0**	**56.0**				**20**
SCS Grand Total	**1184.8**														

Figure 3.4-7 Shared Host Loading

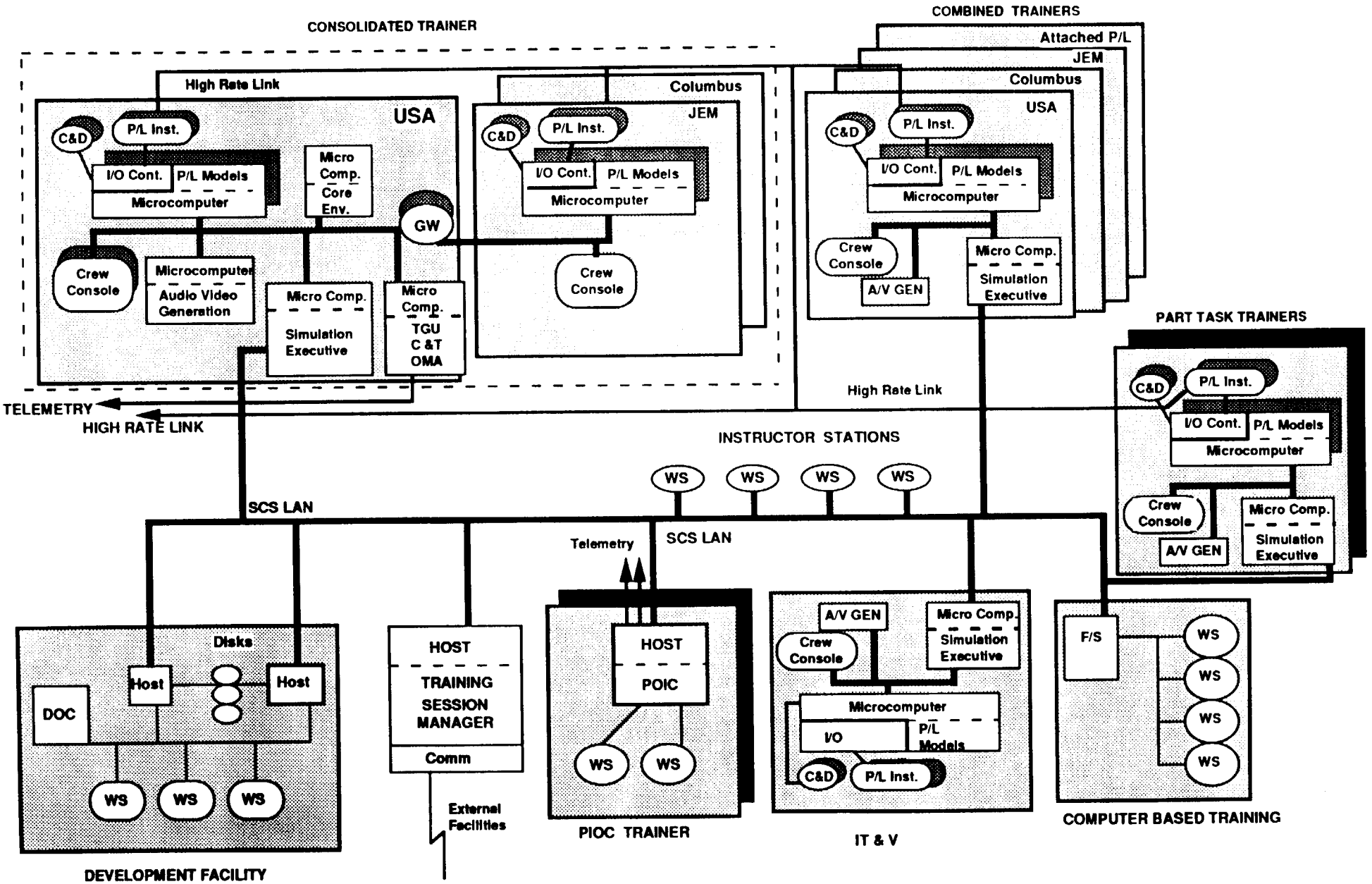


Figure 3.5-1 Top Level View of DMS Equivalent Design

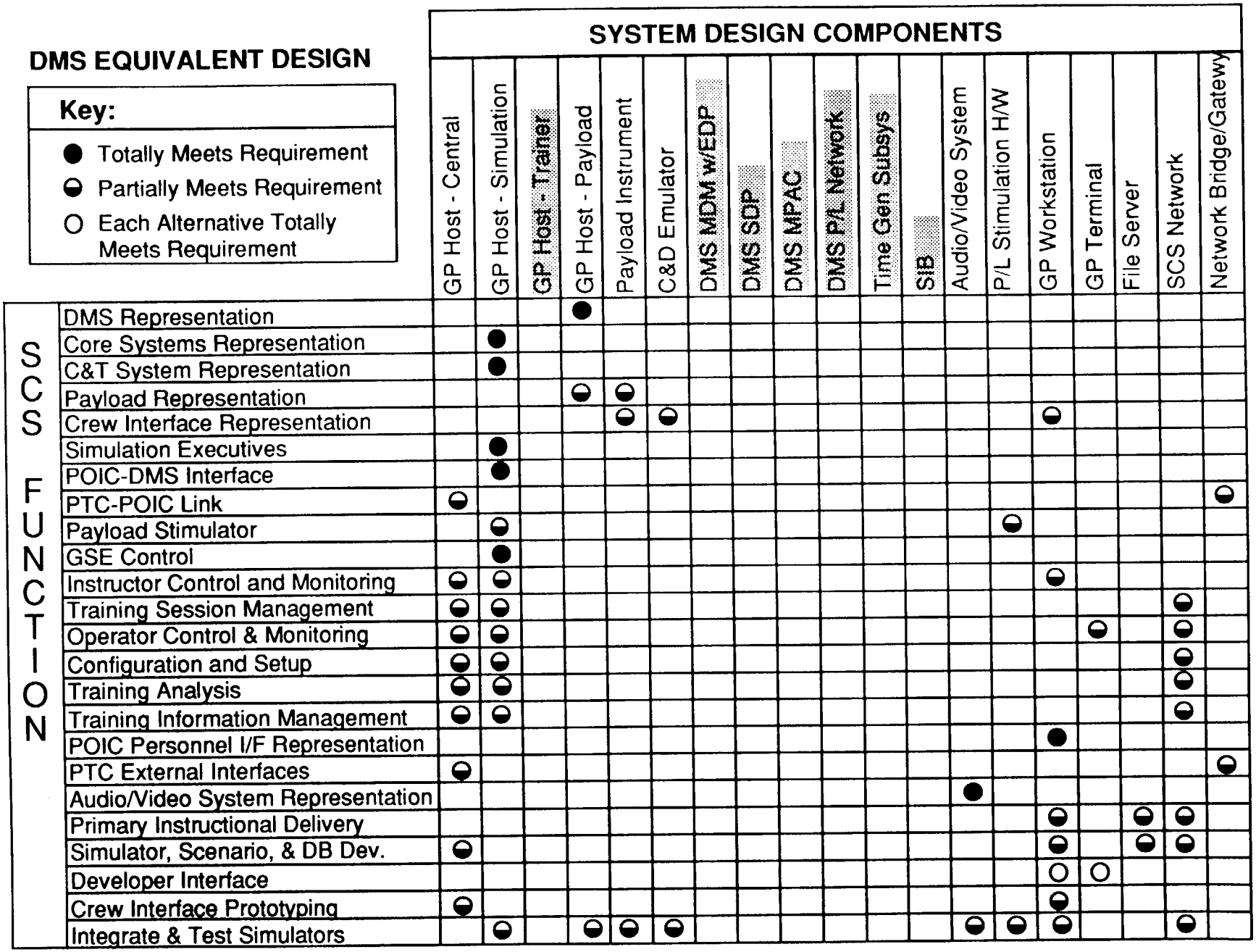


Figure 3.5-2 Allocation of SCS Functions to DMS Equivalent Design

without major modification, could be substantial. Also, changes in the SSF specification and design will necessitate close tracking of program upgrades to the SSF software and hardware.

3.5.1.1 Network Architecture

The DMS Equivalent design contains three types of networks: 1) the Trainer LAN which connects all the processing and I/O components comprising a trainer; 2) the SCS LAN which interconnects the trainers and other SCS facilities; and 3) the Local LANs of the Development Facility and CBT Facility.

The Trainer LAN is the backbone of each trainer. This network bears all real time simulation traffic among the attached microcomputers supporting payload models, environment models, Core models, and the Simulation Executive, as well as the payload instruments and I/O devices.

The average and maximum traffic loads on the Trainer LAN depend directly on the nature of the (actual or simulated) payload. The payload data acquisition/generation rates possible for a single payload experiment create a wide range of possible loads on the Payload LAN representation. Disregarding for the moment any substantial data output, the total simulation traffic on the Trainer LAN can be estimated to vary between 3 Mbps in the Part Task Trainer and 13 Mbps in the Consolidated Trainer, based on the number of payloads under active control. If the aggregate of the 48 actual onboard payloads modeled by the SCS were active onboard the in orbit SSF at the same time, and were all sending data even a moderate rate, the FDDI 100 Mbps would not be fast enough. If the aggregate of 48 active payloads in the Consolidated Trainer were active in the SCS, the same approach to the 100 Mbps limit of a FDDI network implementation would be made. Thus the SCS is limited in the number of active payloads, but this limitation mirrors the actual SSF design. The contributing real time loads on the Trainer LANs are tabulated in Figure 3.5-3.

The SCS LAN is similar in function to the Local Host design supporting the Training Session Manager (TSM) link to all trainers and the interconnection of the other SCS facilities. The traffic on the LAN is primarily file transfers during configuration and initialization, and instructors' interaction with the trainers through their respective Simulation Executives. The maximum required bandwidth to support bulk transfers (which can be queued) and TSM message exchange is estimated at approximately 4 Mbps. The undemanding character of these data communications suggests that any Ethernet or Token Ring network implementation will be satisfactory. The real time and non-real time contributions to the SCS LAN loading are also shown in the figure.

The Local LANs in the Development and CBT are identical to other SCS designs and have been described previously.

DMS EQUIVALENT DESIGN

* Values in K bits per second

			Host Platforms								
			SCS Maximum	Consolidated Trainer	Combined Trainers (3)	Part Task Trainers (9)	Crew Workstation	Instructor Workstation	TSM Host	Development Facility	CBT F/S
TRAINER NETWORK	REAL	DMS Representation	5	5	5	5					
		Core Systems Representation	32	32	32	16					
		C&T System Representation	250	250	150	50					
		Payload Representation	10000	10000	6000	2000					
		Environment Representation	32	32	32	16					
		Crew Interface Representation	150	150	100	50	50				
		Simulation Executives	48	48	16	2					
		POIC - DMS Interface	50	50	25	10					
		PTC-POIC Link									
		GSE Control									
		Instructor Control and Monitoring	40	10	5	1					
		Audio/Video System Representation	2500	2500	1500	500					
		Real Time Totals	13077	13077	7865	2650	50	0	0		
	NON-REAL	Configuration and Setup	3000								
		Non-Real Time Totals	3000								
SCS NETWORK	REAL	Instructor Station	3.5					0.14	1.96		
		Monitor	4000								
		Real Time Totals	4003.5			2650		0.14	1.96		
	NON-REAL	Training Analysis	550	200	200	100					50
		Operator Control & Monitoring	10						10		
		Configuration and Setup	3000						1500	1500	
		Non-Real Time Totals	3560						1510	1500	

Figure 3.5-3 DMS Equivalent Network Loading

3.5.2 Trainer Design

The Consolidated, Combined, and Part Task Trainers have essentially the same architecture in the DMS Equivalent design. Differences between the trainers arise in how they are used and the number of payload experiments they support. The DMS Equivalent trainer designs are shown in Figure 3.5-4 through Figure 3.5-6.

Trainers in the DMS Equivalent approach distribute DMS and payload functions across several microcomputers residing on their Trainer LAN. The functions are simulated or emulated using standard computer platforms, I/O devices, and LAN systems, and custom simulation software. Relying solely on the LAN for all DMS component communications, means that a greater portion of these communications are centralized in DMS simulation models. It also means that the low level control functions provided by the SIB are implemented at a higher level across the Trainer LAN whenever this control actually spans separate DMS Equivalent microcomputers.

The payload instruments, C&D panels, Audio and Video System, Payload Stimulator, and other devices and software remain the same as described previously for other SCS designs. In the case of the crew console, the workstation adopted for the non-DMS Part Task Trainers in previous designs is used through out the DMS Equivalent design instead of flight equivalent MPACs. The instructor stations are located on the SCS LAN and communicate with the Simulation Executives under the supervision of the TSM.

While the goal of the DMS Equivalent trainer design is to achieve the same level of useful SSF payload compatibility as do other SCS designs, its success depends on final DMS Kit capabilities. Regardless of the level, this design can achieve compatibility at a savings by eliminating the development and hosting of many high fidelity SSF representations. Environment representations necessary to enable the operation of a complete DMS in order to support payload models and flight equivalent instruments are large and costly to host. Most representations of Core systems, the environment models and data bases that drive them, and some DMS systems are not deemed necessary to support payload operations in a simulation environment. These representations are necessary only when the full complement of actual DMS components must be driven to perform accurately and in concert with one another.

It is expected that flight equivalent software will require modification to run in this environment. Also, payload models developed for this environment will require modification to run in DMS based trainers.

3.5.2.1 Host Architecture

The intent of the trainer design is to use general purpose microcomputers to recreate the essentials of the DMS that are necessary to operate payloads to meet training objectives. The viable host architectures are those that are compatible with the SSF DMS components. This compatibility can be achieved at a useful level, for example by selecting computer platforms using the same (or microcode compatible) CPU as SSF articles (e.g., Intel 80386). Further compatibility can be achieved by

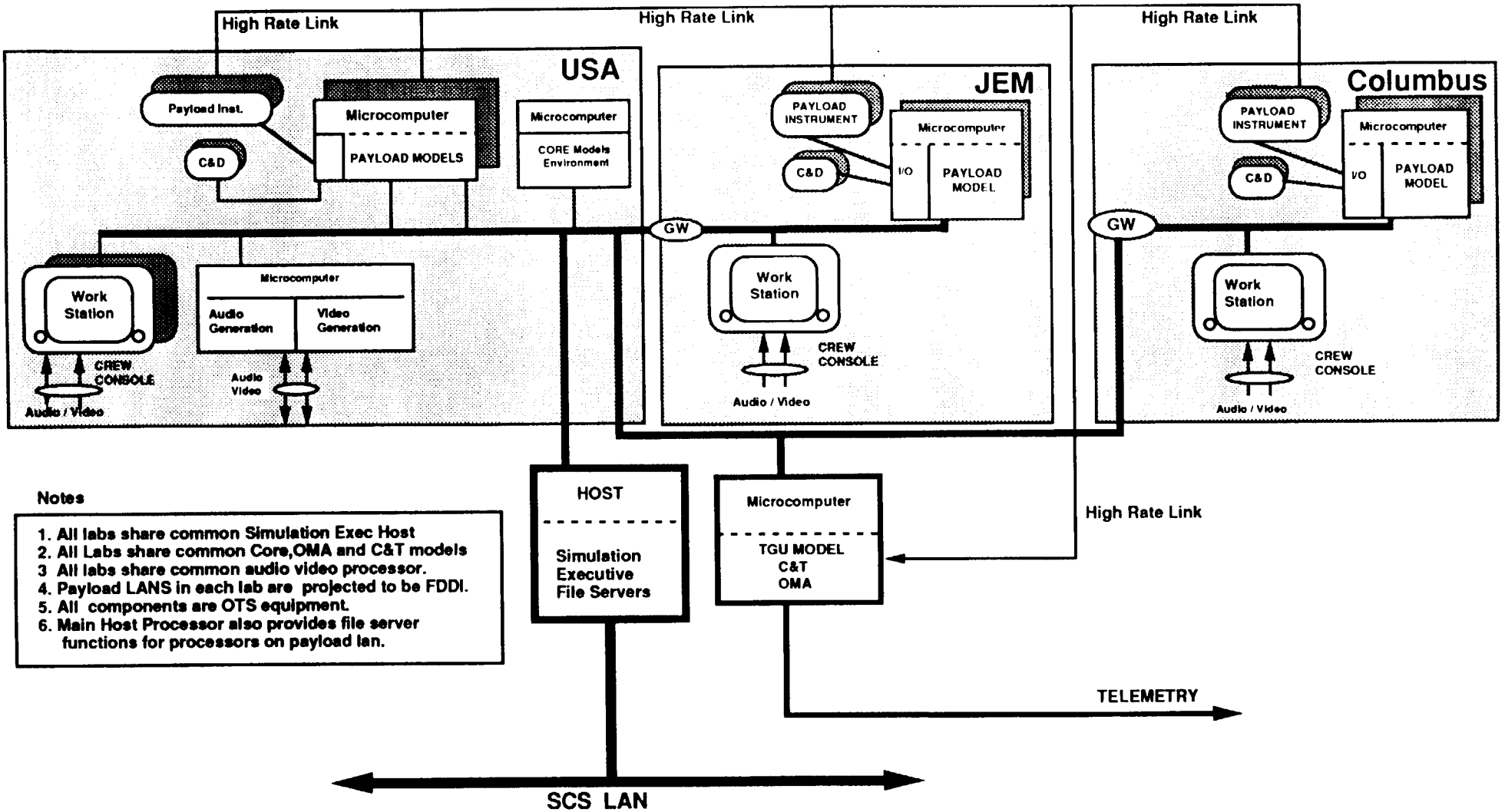


Figure 3.5-4 DMS Equivalent Consolidated Trainer Design

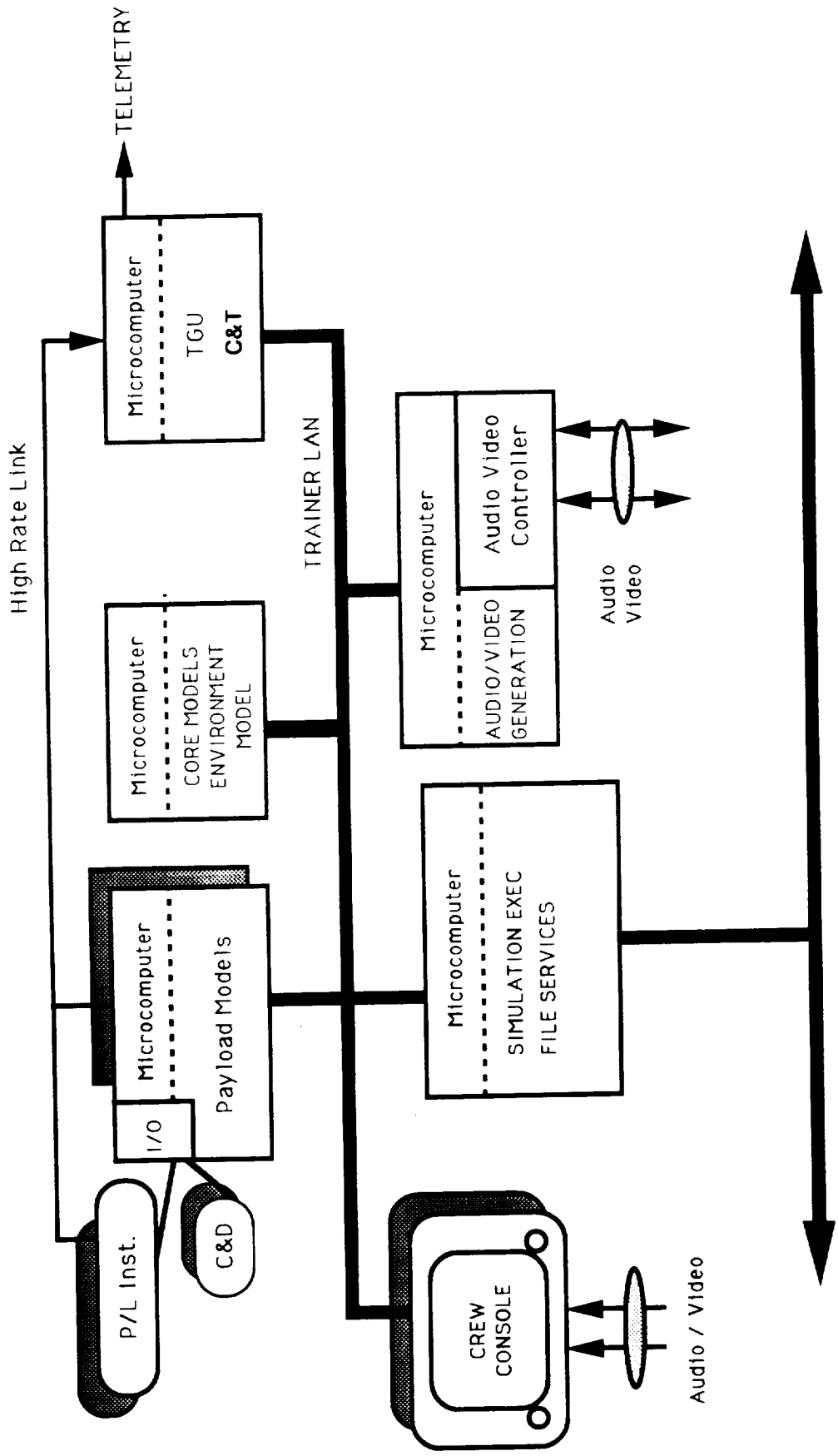


Figure 3.5-5 DMS Equivalent Combined Trainer Design

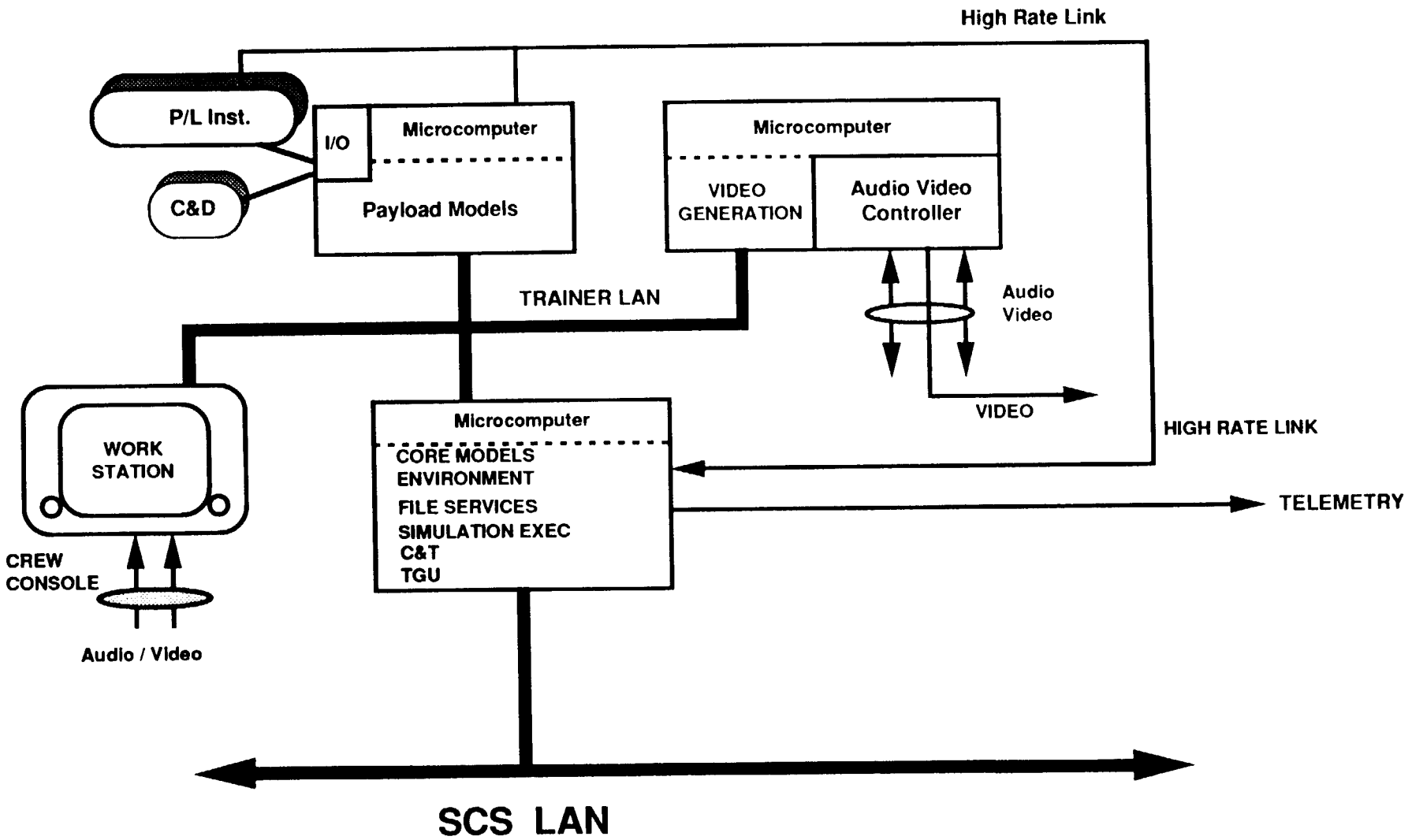


Figure 3.5-6 DMS Equivalent Part Task Trainer Design

selecting on the basis of the processor's backplane bus (e.g., Multibus II) and operating system support. Attaining these levels of compatibility will establish the ease of recreating SSF-like system applications, and the ease of actually porting SSF code modules to SCS trainer microcomputers.

The Consolidated Trainers and Combined Trainers incorporate five (or more) microcomputer platforms in place of a host for: 1) the Simulation Executive and file services; 2) the TGS model; 3) audio and video generation; 4) the Core and environment models; and 5) the payload models. When the number of payload models is high, such as in the US Lab Combined Trainer, two (or more) payload microcomputers are included. Also, the workstations support the processing necessary to emulate required MPAC functions. The microcomputer platform hosting the Simulation Executive provides a network interface to the SCS LAN and the TSM.

The Part Task Trainers are all implemented with the same non-DMS architecture. They differ from the other DMS Equivalent trainers only in the number of distributed microcomputers that are dedicated to run simulation models. This consolidation of computing resources is due to the significantly fewer payloads that are supported concurrently during part task training and the commensurate reduction in the scope of DMS component representation necessary to maintain appropriate lab fidelity. The Part Task Trainer also distributes Core model execution onto the workstation used to represent the MPAC, reducing the number of dedicated general purpose computers to three.

3.5.2.2 "DMS" Components

DMS component (hardware and software) functions are simulated or emulated using commercially available standard microcomputer systems and the necessary simulation software. The functional fidelity of the DMS simulation is comparable to DMS Kit capabilities within the strict domain of payload training objectives. This means that some functions supported by the Kit that relate to Core and other non-payload systems may not be implemented. This restriction shall not, however, diminish the capability to interface actual flight equivalent payloads and related DMS components within the trainer to support training objectives. Component interfacing will typically be supported with appropriate I/O devices attached to the processor bus of the microcomputers.

The Part Task Trainer type incorporated in the DMS Equivalent design only simulates the DMS payload environment. The trainer's computer platforms, including the workstations used to represent the MPACs, host a complement of DMS simulation models necessary to ensure sufficient lab fidelity for payload training. No direct emulation of individual DMS components is undertaken.

3.5.2.3 Trainer Connectivity

The computer platform which hosts the Simulation Executive for each trainer type includes a network interface to attach the trainer to the SCS LAN. This configuration serves to isolate each trainer on the SCS LAN, but is not a necessary feature of the design. Instead, network bridges could be used to link individual trainer

LANs to the SCS LAN. This alternative would reduce the protective level of isolation among trainers and the SCS while increasing the degree of reconfigurability across trainers.

3.5.2.3.1 Consolidated Trainer

The Consolidated Trainer uses the Trainer LAN to link the US lab, Columbus lab, and JEM lab. For current design purposes, the Columbus and JEM labs were implemented in a manner functionally like the US lab. The same architecture is used to support payloads while sharing all of the space station representations in common. Consequently, four of the five US lab microcomputers are shared to provide the Simulation Executive and file services, TGS and C&T models, audio and video generation, and Element Core, and environment models. The labs' Trainer LANs are connected with gateways as depicted in Figure 3.5-4. This configuration serves to isolate the Columbus and JEM labs from one another, but is not a necessary feature of the design. A single Trainer LAN could be employed to implement all three labs. This approach, however, would not achieve a representation of the actual SSF lab interconnectivity which is mediated with gateways.

3.5.2.3.2 Combined Trainer

Connectivity in the Combined Trainer is comparable to the connectivity implemented in one lab of the Consolidated Trainer. The replacement of the host attachment to the SCS LAN with a bridge to the trainer LAN would allow these trainers to share a single Core and environment representation under one Simulation Executive. The arrangement would allow the three trainers to serve temporarily as a Consolidated Trainer.

3.5.2.3.3 Part Task Trainer

Part Task Trainer connectivity is, aside from fewer distributed microcomputers, comparable to the Combined Trainer. The replacement of the host attachment to the SCS LAN with a bridge would allow these trainers to share their distributed microcomputers in order to, for example, temporarily expand the capacity of one Part Task Trainer to support an additional number of payloads.

3.5.3 Host Loading

Host loading for the DMS Equivalent design is based on estimated maximum loadings of the SCS. It was assumed that all trainers were in operation concurrently with a full level of software development activity. The capacity in Mips of the general purpose microcomputers comprising the SCS DMS Equivalent design is tabulated in Figure 3.5-7. The figure summarizes the estimated computational resource in Mips required to execute each of the basic SCS functions identified in the function allocation matrix presented earlier in Figure 3.5-2. Appendix I has been included to provide more details on the assumptions and methods underlying these estimates.

The SCS TSM host in this design has an estimated maximum required computing capacity of 16 Mips. The various types of trainers are comprised of several

DMS EQUIVALENT DESIGN

SCS FUNCTION	Total SCS MIPS	MIPS Cosolidated Trainer			Combined Trainers			Non-DM Trainers	IT&V	TSM Host	Instructor Workstation	Development Facility		CBT		7 POIC Trainers		C&T Tele. Processor
		US	JEM	Colum	US	JEM	Colum					F/S	WS	F/S	WS	HOST	2WS	
DMS Representation	24	1.5	1.5	1.5	1.5	1.5	1.5	13.5	1.5									
Core Systems Representation	35	6			5	5	5	9	5									
C&T System Representation	29	2			2	2	2	9	2									10
Payload Representation	72	12	6	6	12	6	6	18	6									
Environment Representation	33	3			3	3	3	18	3									
Crew Interface Representation	95.95	15.1	5.05	5.05	10.1	5.05	5.05	45.45	5.05									
Simulation Executives	26	6			3	3	3	9	2									
POIC - DMS Interface	10.5	2			1	1	1	4.5	1									
PTC-POIC Link	10																	10
GSE Control	1.4	0.1			0.1	0.1	01	0.9	0.1									
Instructor Control and Monitoring	254.5	1.1			1.1	1.1	1.1	9.9	0.1	0.1	240							
Training Session Manager	4.31	0.1			0.1	0.1	0.1	0.9	0.01	3								
Operator Control & Monitoring	0.14	0.01			0.01	0.01	0.01	0.09	0.01									
Configuration and Setup	1.5	0.1			0.1	0.1	0.1	0.9	0.1	0.1								
Training Analysis	4									4								
Training Information Management	4				0			0		4								
POIC Personnel I/F Representation	112				0			0		0						56	56	
PTC External Interfaces	5				0			0		5								
Audio/Video System Representation	95	15			10	10	10	45	5									
Primary Instructional Delivery	24				0			0						8	16			
Simulator, Scenario, & DB Dev.	310				0			0				70	240					
Developer Interface	66				0			0				16	50					
Crew Interface Prototyping	36				0			0				6	30					
Integrate & Test Simulators	18				0			0	18									
Lab Trainers Total	398.2	64.0	12.5	12.5	49.0	37.9	37.9	184.1										
Facilities Total	873.1								48.8	16	240	92	320	8	16	56	56	20
SCS Grand Total	1271.																	

Host Platforms

Figure 3.5-7 DMS Equivalent Loading

microcomputers each, ranging from approximately 3 Mips to 8 Mips each for the payload microcomputer(s) in a Part Task Trainer and the Consolidated Trainer, respectively, and 5 Mips to 12 Mips each for the other dedicated microcomputers in a trainer.

4.0 SCS Design Comparison

The SCS designs described in this document share many similarities in spite of their different architectures. The common and the unique features characterizing these designs have been detailed in previous sections. Design implementations have also been contrasted in terms of their efficiency and performance. In the present section, the relative advantages and disadvantages of the designs are summarized.

Contrasts in performance and value associated with the designs are a consequence of a limited set of differences among the SCS designs. Each design satisfies the SCS functional requirements tabulated in the Function Allocation Matrices of Sections 3.3, 3.4, and 3.5. The principal SCS design differences are identified in Figure 4.0-1.

The design process and the present comparison of designs can consider several factors indicative of system performance and value. The following factors, where applicable, have been considered in assessing the relative merits of each design.

* Reliability and maintainability
* Expandability and scalability
* Cost (cost to build, life cycle cost, and schedule risk)
* Computing headroom
* Hardware/software standards
* Reconfigurability and modularity
* Ease of operation
* Performance/functionality versus cost

In all SCS designs, cost, performance, modularity and reliability have been the predominant considerations. The design differences summarized in the figure reflect the attempt to formulate designs that maintain a favorable balance of these factors.

4.1 Reliability and Maintainability

The trainers in the Local Host and Shared Host designs rely on DMS Kits. Assuming the DMS Kits implement the fault tolerant redundancy features of preliminary SSF DMS specifications and adopt SSF quality assurance controls, DMS based trainers should enjoy high levels of reliability.

The DMS Equivalent design should have a reasonably high reliability since it will use off-the-shelf components. In addition, off-the-shelf components will potentially have better maintainability over DMS components since they are standardized commercial products which will have readily available maintenance services and

Design Aspects	SCS DESIGNS		
	Local Host	Shared Host	DMS Equivalent
Trainer Host	Single Dedicated Host	Multiple Hosts	Multiple Microcomputers Distributed On Dedicated Trainer Lan
Trainer Interface	SCS LAN to Host	Host SCS LAN to SIB	SCS LAN to Microcomputer
Flight Equivalent Payload Interface	DMS MDM	DMS MDM	I/O Adapter on Processor bus
C & D Panel Interface Chosen	Direct to Host	DMS Local Bus	Direct to Microcomputer
Payload Models	In Trainer Host	In Trainer Host	In Dedicated Microcomputer(s)
C & T Model	In Dedicated C&T Controller	In Dedicated C&T Controller	In Dedicated Microcomputers
High Rate Link	From Trainer Host to C&T Controller	From DMS SDP to C&T Controller	Dedicated Microcomputer on LAN
Audio /Video System	Adapter / Controller on Host bus	A/V Processor /Controller on SCS Lan	Adapter / Controller on Dedicated Microcomputer
Part Task Trainer	Two Types: DMS-Based with Dedicated Host Non DMS Workstation Based	Two Types: DMS-Based sharing SIB and Multiple Host on SCS Lan Non DMS Workstation Based	One Type: DMS Equivalent based with Multiple Microcomputers on a dedicated Trainer LAN
Type of Data on SCS Network	Mostly Non-realtime development data, except real-time instructor commands	Real-time model to DMS data + instructor commands + non-real time development data	Mostly Non-realtime development data, except real-time instructor commands

Figure 4.0-1. Summary of Design Differences

nearby inexpensive spares inventory. The maintainability of DMS Kit s and the SIB may be dependent on specialized resources.

The lower host platform count in the Shared Host design lends a certain advantage to the design in respect to system reliability. The aggregate system-wide incidence of failure, which is largely a function of equipment count and robustness of the equipment, should decrease with the Shared Host's dependence on fewer and larger platforms. Maintainability is often improved with large platforms because they incorporate more internal diagnostics. When many small platforms are used and are the same, maintainability is facilitated by the replaceability of any platform with another unit.

The Local Host design would have a reliability much like the PCTC. Maintainability would be good since, except for the DMS Kits, commercial equipment could be used.

Software reliability is greater in the designs where Space Station Freedom software can be used. It is assumed that DMS Kit software and SSE or equivalent simulation model software will reflect the reliability benefits of program test, validation and wide-spread use of SSF simulation software.

4.2 Expandability and Scalability

The DMS Equivalent design has an advantage over the other SCS designs in both the ease and cost of expanding its trainer configurations. The cost associated with designing the DMS Equivalent with DMS and other SCS functions distributed across numerous dedicated hosts is paid once in the original design effort. Expansion using this design via distribution and replication will only involve the cost of purchasing and installing hardware. The expansion of DMS based trainers may be hindered by the availability of multiple DMS Kit components and intrinsic limitations to expansion in the Kit hardware and software architectures.

Further, the Shared Host design is more easily expanded than the Local Host design. The common platforms in the former design are assumed to be similar, if not identical. Similar computers can be added to this bank to assume the same processing tasks, such as payload model execution, as other platforms. This augments the resources available to all trainers without altering the basic configuration or incurring additional overhead beyond that already in place to manage the sharing of resources.

Scalability is favored by the open architecture approach of the DMS Equivalent design which has the flexibility to accommodate computer platforms which can be scaled easily to provide specific levels of computing power. The same advantage can also apply to the custom simulation software of the DMS Equivalent design, if it is developed to support adjustable resolution, or detail, in a simulation. For example, modular structured simulation models can be incorporated to allow both abstract and detailed representations of DMS payload systems. Thus, the fidelity (and computing demands) of the model may be adjusted to match the fidelity of available data and the fidelity demanded by the desired training objectives.

4.3 Cost

The cost considerations of system designs are multifaceted, often with one cost being offset by another associated cost. Costs for SCS include the: 1) cost to build hardware and software; 2) life cycle cost; and 3) schedule risk. The costs summarized below should be accounted for in any comparison of the SCS designs.

Cost to Build

Hardware costs for the SCS designs involve the cost of their general purpose computers, their flight equivalent hardware, and their trainer peripherals and other facility peripherals. For the most part, the peripherals and the computers supporting the ancillary SCS facilities are common across the SCS designs and their costs will be comparable. The cost of the general purpose computers supporting the trainers, however, differ for each SCS design. These hardware costs depend on the total computing horsepower required by the design, in Mips (millions of instructions per second), and the number and size of platforms used to deliver that total. The relative cost of appropriately sized computers varies with size in the approximate fashion depicted in Figure 4.3-1. This table identifies several classes of computer platforms by size and their relative cost per Mips, where the cost of mainframe Mips is the reference (1.0). This data was generated originally as part of the Study Analysis Task (see A-6/A-8), and this table is an extrapolation of that data.

Computer Class	Mips Range	Relative Cost/Mips
Super	100 - 1000	0.30
Mainframe	20 - 120	1.00
Mini-Super	50 - 200	0.25
Super-Mini	30 - 80	0.35
Mini/Midi	10 - 40	0.50
Workstation	6 - 20	0.15
Micro	1 - 8	0.10

Figure 4.3-1 Computer Platforms

Hardware Cost

A review of the computing requirements of each SCS design (appearing previously in Figures 3.3-6, 3.4-6, and 3.5-6) revealed a total trainer requirement of 360 Mips for the Shared Host, 383 for the Local Host, and 429 Mips for the DMS Equivalent design. When these loads are distributed across the assigned computer platforms, the increased Mips of the DMS Equivalent design is more than offset by the lower per-Mips cost factor of the smaller Micro to Mini/Midi platforms (0.1 - 0.5).

The DMS Equivalent design advantage is increased by the additional cost of the DMS Kit hardware of the other designs. Flight equivalent DMS components are not included in the accounting of general purpose host requirements in the sizing

analyses in Appendix I. This is because it is assumed that the DMS Kits will be designed such that they will be fast enough and large enough to support the necessary DMS OMA and other core software.

The Local Host design relies on more platforms with an overall higher cost factor of Super-Mini to Mini/Midi (0.35 - 0.5). The resulting increase in cost reflects the concentration of functionality onto a dedicated trainer host. These hosts, for example, must accommodate a large number of I/O channels to support payload representation devices (i.e., C&D panels and payload stimulators).

The Shared Host design, while needing the fewest Mips, tends to concentrate those Mips into the fewest machines (Mini-Super to Mainframe). This yields a computer platform cost factor of 0.25 - 1.0. The concentration achieved in the Shared Host design also means that a significant overhead is borne to manage the multitasking/multiprocessing environment needed to service multiple trainers and achieve load balancing.

The unique consolidation of trainer communications on the SCS LAN yields traffic levels requiring a FDDI implementation of the network for all designs. The present cost per node of FDDI implementations is 6 -10 times that of Ethernet or other Token Ring network. While this premium is expected to drop significantly over the next few years, a significant cost differential will probably continue to exist.

Software Cost

The DMS Equivalent design entails the highest initial software development costs to cover custom DMS simulation models. The high cost reflects the assumption that flight equivalent software will not be used without significant modification, and the fact that SSF upgrades will have to be mirrored with new development. Conversely, these custom DMS models can be fashioned to integrate efficiently with payload models. Consequently, the DMS, Core, and payload models need only represent the variables and fidelity that are necessary for training objectives. There is no need, as with the DMS based designs, to accommodate full flight equivalent representations and associated space station simulation requirements.

If, in addition to the DMS/OMA software, it is assumed that SSE Core models are available for SCS use, much less software will be needed to develop the Shared Host and Local Host designs. However, if SSF software is not available at the outset, the high fidelity models necessary to support flight equivalent hardware will exceed DMS Equivalent software requirements.

Cost to Build SCS ROM

A ROM is a rough order of magnitude estimate, generally accurate to plus or minus fifty percent. This ROM was constructed by applying a consistent cost methodology across the three very different designs, to provide a congruent cost estimate solely for the purpose of comparing the three designs in an objective manner.

First, an average was taken of the range of Mips cost factors for each design. This yielded an average Mips cost factor for each design. Next, a cost per Mips amount of $100,000 per Mips was selected. This seems high, but it is intended to cover not just the computer costs, but associated costs like the networks needed, graphics workstations, instructor workstations, and required COTS software. Multiplying the mean Mips cost factor by the Mips required by each design yields an adjusted hardware cost. Multiplying this by the cost per Mips gives a standard hardware cost ROM for each design.

The costs to perform systems engineering, requirements analysis, design, code, test, and IT&v are estimated to be at an average base of approximately 2,500 man months (MM). Using a MM cost of $8,500 per MM, yields a base labor cost of $17M. For the Shared Host design, and additional factor of 10% is included to represent the increased complexity of a distributed design. For the DMS Equivalent design, it is necessary to add an estimated 100,000 lines of source code (SLOC) to cover the possibility that the core system models would need to be developed from scratch. At a production rate of 150 SLOC per MM, this translates into 666 MM, or $5.7M.

Note that the cost of DMS Kits are not included in the ROM, nor are the PTC trainer hardware costs estimated, since these are considered GFE for SCS purposes. The summary of the cost to build is shown in the following table.

	Local Host	Shared Host	DMS Equivalent
Mean MIPS CF	.425	.625	.3
H/W Cost Factor	162.7	225	128.7
H/W ROM Cost	$16.3M	$22.5M	$12.8M
Labor ROM	$17.0M	$18.7M	$17.0M
Core S/W ROM	0	0	$5.7M
TOTAL ROM	$33.3M + DMS Cost	$41.2 + DMS Cost	$35.5 + 0

Life Cycle Cost

Life cycle costs will be based on several factors including: 1) necessity and ease of hardware and software upgrades; 2) necessity and ease of hardware and software maintenance; 3) system reliability affecting training (production) time; and 4) ease of operation. Most of these factors are considered separately elsewhere. Aside from the quantity of components to be maintained, most life cycle cost factors are constant across the SCS designs. The exception is hardware related costs stemming from the different types of hosts and LANs comprising the designs.

In designs where DMS kits are used, higher life cycle costs are expected for hardware maintenance. The specialized equipment configuration in the DMS Kits is expected to limit the maintenance resource options and thereby keep maintenance costs high. Considering the single source for the kits, upgrade and replacement costs are also expected to be high. Use of standardized, commercial hardware in the DMS Equivalent design should minimize these costs. However, as discussed previously,

any modifications or upgrades to SSF DMS elements will necessitate corresponding changes in the custom DMS software of the DMS Equivalent design keeping the life cycle costs high. In contrast, it is assumed such updates would be provided automatically by the SSF program to facilities using DMS Kits.

Schedule Risk

The likelihood of an SCS implementation encountering delays that could jeopardize training schedules or otherwise increase development costs is difficult to project. All three designs have degrees of risk associated with software development overruns, availability of hardware, and design/integration problems preventing criterion system performance.

One apparent source of risk is the Local Host and Shared Host reliance on DMS Kits. Given a single supplier for these custom units, problems could arise in delivery of units, spares, diagnostics, and documentation. The design of the kits, and the SIB in particular, could also prove problematic in respect to efficient integration with other SCS components. The SIB's proprietary interface for connecting to a simulation host, for example, may represent an undue design constraint.

Although these concerns do not arise with the DMS Equivalent design, initial development of the design's DMS simulation software carries the risk of a longer than expected development cycle.

The Shared Host design also presents the risk that the multitasking/multiprocessing environment to manage simultaneous payload simulations across several lab trainers will prove difficult to implement. Such systems can experience drastic performance drops with small increases in the number of concurrent tasks.

4.4 Computer Headroom

All designs include base computing resources to sustain moderate increases in resource loading. (Assumptions made for the sizing analysis in Appendix I impose estimates of maximum load which will not practically occur). Appendix I and the sizing and loading tables show the basic analysis before the required 50% reserve factor is applied. This factor is attained easily by multiplying the Mips and network loading estimates provided by 1.5.

The provision of adequate computing headroom is least critical in the DMS Equivalent approach. This design has the advantage of small modular hosts that will, if any deficiency arises, simplify the incremental expansion of its computing power.

The Shared Host design enjoys the intrinsic benefit of load balancing across a bank of hosts. This yields substantial functional headroom by allowing computing demands to be reapportioned dynamically for most SCS functions. Because individual payload operations are more likely to be sporadic than continuous in a training scenario, the steady state computing load level is expected to fall substantially below the potential peak levels. This characteristic favors the efficiency of a load

sharing architecture, especially when slight process delays due to extreme peaks are tolerable.

4.5 Hardware/Software Compatibility and Standards

There are two overlapping sets of hardware and software standards applicable to SCS designs. First are the SSF program standards pertaining to the implementation of flight articles and those pertaining to simulation systems. The second set of standards are those applicable industry/society standards relating to computer systems, communications, and software. By-and-large, the SSF standards are drawn from the second set of standards -- the prevailing industry/society standards affecting commercial offerings at the national and international level.

While an attempt is being made to adopt commercial standards within the SSF, the DMS Equivalent design offers more opportunities to configure SCS systems that exploit the compatibility and expandability benefits of standardized hardware and software. The selection of system elements and components in this design can be based more on a consideration of immediate market offerings and trends, than on SSF DMS design decisions. Outside of trainer implementations, however, the choices for implementing SCS facilities are the same for all SCS designs.

4.6 Reconfiguration/Modularity

As discussed previously, the DMS Equivalent design has the greatest degree of modularity and affords the most freedom for reconfiguring trainers. The Shared Host design, on-the-other-hand, offers the most latitude for rapid redistribution of computing resources. Also, as discussed in Section 3.4.2.4, the Shared Host offers more options for interconnecting the individual lab and part task trainers. While not part of the PTC/SCS requirements, this capability affords useful flexibility in combining trainers into new configurations. Other aspects of reconfigurability are constant across the SCS designs. The Local host is most like many current systems, and has limited reconfiguration/modularity. New hosts would have to purchased for much of any type of growth or change. Since the hosts are dedicated to a particular trainer, if that host fails, no easy reconfiguration ability exists to recover.

4.7 Ease of Operation

The SCS designs all depend on the same Training Session Manager (TSM), network of Instructor Stations, and SCS support facilities (as well as operator consoles) to operate the trainers. Consequently, from a human machine interface perspective and a manning perspective, the SCS designs are comparable.

4.8 Performance/Functionality Versus Cost

All SCS designs satisfy functionality and performance requirements. Additional capabilities, where they exist, have been addressed. Overall, the designs vary in cost based on their inclusion of DMS Kits. Consequently, the DMS Equivalent approach

offers the best performance to cost ratio assuming the performance/functionality is the same for all three designs.

4.9 Summary of Design Features.

The table presented in Figure 4.9-1 summarizes the comparison of the three SCS designs. The preceding paragraphs have addressed the more salient features and criteria for a successful SCS design. Meaningful comparisons among the conceptual designs have been related in the text to various tradeoffs among these factors. The table indicates the relative position of the SCS designs in respect to each independent factor.

FACTOR	LOCAL HOST	SHARED HOST	DMS EQUIVALENT
Reliability/ Maintainability	Good	Good	Good
Expandability/ Scalability	Limited	Good	Good
Cost	High	Lower	Lowest
Computing Headroom	Limited	V. Good	Good
H/W & S/W Standards	Good	Good	Flexible
Reconfigurability/ Modularity	Limited	Good	V. Good
Ease of Operation	Good	Good	Good
Performance vs Cost	Fair	Better	Best

Figure 4.9-1 Summary Results from a Comparison of SCS Designs

5.0 Conclusion

The three SCS refined SCS conceptual designs each offers an effective solution for the PTC simulation system. Where warranted, these designs incorporate common design elements to insure that they completely and efficiently implement the SCS functions and features that have been underscored in this study as essential capabilities. Other potential SCS designs and hybrid combinations of the refined designs, may satisfy PTC requirements equally well. In this case, the refined designs will provide the baseline architectures and performance necessary for a comparative analysis of final SCS designs.

The ultimate design selection is principally contingent on SIB, DMS Kit, and SSE design decisions not yet made. The ultimate design selection is also contingent on schedule, both the schedule for the DMS Kits, SIB, and SSE, and the timing of the actual SCS design process. The cost of various computers and the power of various COTS hardware and software will be large factors. The release of a new CPU of twice the power of previously available CPUs is occurring at an ever quickening pace. The amount of compute power, network capability, and other hardware costs are changing rapidly.

Overall, the SCS Study has resulted in three viable refined design alternatives which can be used as the foundation for future SCS design work and analysis. Most importantly, the SCS Study has produced a thorough and well thought out set of SCS candidate designs satisfying detailed system requirements.

APPENDIX I. SYSTEM SIZING ANALYSIS

The basic method and assumptions used to derive estimates of SCS design computing resource requirements are outlined in this appendix. Computing resources were estimated for the computational processing and communications necessary to support the basic SCS functions as delineated in the Function Allocation Matrices. The estimates are presented for purposes of sizing each SCS design in separate tables in the Detailed SCS Design Report. The LAN Loading tables (Figures 3.3.1-3, 3.4.1-3, and 3.5.1-3 in the report) tabulate the network loadings in the Local Host, Shared Host, and DMS Equivalent designs, respectively. The Host Loading tables (Figures 3.3.3-1, 3.4.3-1, and 3.5.3-1 in the report) tabulate the host loadings in these designs, respectively.

Loadings on the SCS LAN and the trainer LANs are expressed as kilobits per second (Kbps) of input from the various hosts and processors. Process loadings on the hosts, themselves, are expressed as millions of instructions per second (Mips) for the SCS functions (application and operating system software).

The LAN Loading tables reflect:

- the communications requirements in Kbps placed on a design LAN by each SCS function (the predetermined Core and Payload LANS included in the DMS Kit are not considered).

- distinction between real time and non-real time functions and requirements. (Because, when active, individual trainers are either engaged in a simulation training session (real time) or a setup period (non-real time), the maximum of the two loadings is used in the sum for the total estimate.)

- the total LAN communications bandwidth requirement (Kbps) for each trainer and facility comprising the SCS design. (The maximum across lab trainer types is used as the "trainer LAN" total in the DMS Equivalent design.)

- the total SCS LAN loadings based on the aggregate of the maximum estimates of communications requirements of all simultaneous SCS functions.

The Host Loading tables reflect:

- distribution of SCS functions across trainers and facilities.

- the total host computer cpu requirements in Mips for SCS functions (listed on left side of chart).

- total host computer cpu requirements for each each trainer and facility.

- total SCS design host computer cpu requirement.

1.0 PTC Configuration and Use Assumptions

In order to determine rough order of magnitude (ROM) estimates for the SCS, several assumptions about PTC usage and configuration were made. These assumptions are based on analyses performed during the study, and documented in the Study Analysis Report, and a wide range of SSF information gathered over the course of the study. The report reflects the known SSF and PTC expectations held by NASA during this analysis phase.

1.1 User Load on Physical Facility

Number of people simultaneously trained in Consolidated Increment Trainer: 4-6

Number of people simultaneously trained in each of the three Combined Trainers: 4

Number of people simultaneously trained in each of the nine Part Task Trainers: 2

Number of people simultaneously trained in the Attached Payload Trainer: 1

Number of people simultaneously trained in each of the seven POIC Trainers: 2

Number of people simultaneously trained in the CBT Trainers: 8

Number of people simultaneously trained in the entire PTC: 40 Note: This sum does not equal the sum of all the Trainers since there would never be 100% utilization of all Trainers.

Number of instructors in the PTC: 15

Number of simulation developers: 100

Number of integration and test personnel: 10
(could also be the proportion, at any one time, of development personnel engaged in IT&V tasks)

Number of support personnel: 15

Total number of people who work or train in the PTC at one time: 180

1.2 Number of Payloads per Trainer

Total number of experiments in the Consolidated Increment Trainer: 72 (US Lab 36 + Columbus Lab 16 + JEM Lab 16)

No. of simultaneous experiments in the Consolidated Trainer: 48

It should be noted that while there will likely be more experiments in concurrent operation on the Space Station than this number, there will not be more than four crew

members on duty at any time. The other operating experiments do not require simultaneous operator intervention. In addition, while the other experiments do represent a load on Space Station resources, it is not necessary to model that load at a high fidelity in the PTC. (The load of the other experiments will be represented at a low fidelity). It should also be noted that the total number of experiments and the number of simultaneous experiments includes an appropriate proportion of attached payloads.

Total number of experiments in the Combined Trainers: US Lab 36, Columbus Lab 16, JEM Lab 16

No. of simultaneous experiments per lab: 24 USA
12 Columbus
12 JEM

Total number of experiments in each Part Task Trainer: 4

No. of simultaneous experiments in Part Task Trainer: 4

Total number of experiments in Attached Payload Trainer: 4

No. of simultaneous experiments in Attached Payload Trainer: 2

Number of concurrent tests in IT&V : 6

Number of experiments per processor (SDP, MDM): 1

Percentage of experiments trained on with flight equivalent hardware: 10%

Payload software models will be developed and used for training for 90% of the experiments.

2.0 General Assumptions about SCS Functions

The estimates included in this section are based, in part, on study analysis task T-1, Scope of Payload Crew Training in PTC, Report Volume 6. Where appropriate, the host computer loading results reflect the overhead Mips required by a multitasking/multiprocessing operating system.

LAN loading values were derived from estimates of the maximum average message/packet lengths and their frequencies. The message/data traffic is divided into real time and non-real time functions. Given that real time and non-real time functions occur at separate times in the PTC, the larger of the two estimates was selected as the bandwidth requirement.

The Mips shown in the Host loading tables reflect the estimated CPU power required to accomplish the associated SCS function. The US Combined Trainer was used as the based for all calculations.

Processing requirements for the SCS trainer and support facility functions have been estimated, in part, by comparison to known requirements for similar functions in real time and support systems previously developed and deployed by Grumman. Comparable real time systems include flight simulators, ship handling simulators, test stands, and command and control systems. Support systems include system and application programming environments for these real time facilities and for large MIS installations. Where possible, comparable program size in terms of lines of code and rate of repetition is used as the estimator. Otherwise, the size of the computing resources dedicated to the similar function is used as the estimator. Interpolation was used to scale the estimates when necessary.

2.1 DMS Representation

2.1.1 Assumptions

We assume the estimates included in study analysis task T-1, Scope of Payload Crew Training in PTC, Report Volume 6, reasonably portray the code sizes of payload models. These estimates are higher level language code such as Ada. For conversion to host loading Mips, one line of Ada code is assumed to generate approximately 10 cpu instructions.

For purposes of the sizing analysis, it was assumed that SCS simulation functions do not cycle at greater than 10 times per second, and that some functions such as payload operations may cycle less frequently (e.g., two times per second). Correspondingly, iterative software modules were assumed to repeat 10 times per second, or less as noted. These rates afford a background temporal resolution of 10 hertz which is believed, for training objective purposes, to yield more than adequate fidelity.

2.1.2 Processing Requirement

DMS representations are accomplished in two ways: 1) by DMS Kits; and 2) by custom software on trainer hosts and other hardware. The DMS Kit components and their processing capacities are fixed by the SSF program and can not be treated as SCS design variables. Since the Local Host and Shared Host designs employ DMS Kits, these trainer computing resources are predetermined and are not included the the sizing analysis. However, where non-DMS solutions are used, such as NON-DMS Part Task trainers and the DMS Equivalent SCS design, the host processing loads are represented.

The estimates included in the analysis are based, in part, on study analysis task T-1, Scope of Payload Crew Training in PTC, Report Volume 6. Where appropriate, the host computer loading reflects the additional cpu processing required to support a multitasking/multiprocessing operating system.

The T1 study estimates that DMS software processing for Core systems functions, OMA, and DMS standard services requires 48,200 lines of code. This code,

assumed to execute at 4 hertz, was projected to require an additional 55 percent overhead for the operating system.

The portion of this estimate attributable to software model representation of OMA and DMS services was taken to be 25 percent, with the remaining 75 percent for Core systems representation. Thus, 25 percent of 48,200, or 12,050, lines of code was used to estimate the DMS and OMA function requirements. In contrast to the T-1 Study, the code was assumed to execute at the full background frequency of 10 hertz to insure a capability for high system fidelity. Further, the overhead for the operating system was assumed to make up only 20 percent of the total processing load.

Based on the above, the processing requirement for DMS representation is equivalent to:

12,000 lines of code for DMS and OMA functions
X 10 instructions per line of code
X 10 hertz (cycle rate)
X 1.25 overhead (20 percent of total)

1.5 Mips

This estimate of host loading applies to all trainers where DMS representations are modeled with custom software and hardware.

2.1.3 Communications Requirement

Communications requirements impacting the LAN loading stem from the TGU data stream is implemented without the dedicated DMS timing bus (TDB). The maximum LAN loading is estimated on a maximum timing message size of 60 bytes being broadcast once every 100 msec:

60 byte message
X 8 bits per byte
X 10 hertz resolution

4.8 Kbps of bandwidth = approx. 5 Kbps.

2.2 Core Systems Representation

2.2.1 Assumptions

Even though DMS designs may employ some flight equivalent Core software, substantial Core systems modeling will still be necessary.

2.2.2 Processing Requirement

Of the 48,200 lines of code estimated in the T-1 study, 75 percent is taken to represent Core system models. This is equivalent to approximately 36,150 lines of

code. The required processing resource to preserve a temporal resolution of 10 hertz is, thus:

36,150 lines of code for Core models
X 10 instructions per line
X 10 hertz
X 1.25 overhead (20% of total)

4.52 Mips = approx. 5 Mips

In the Consolidated trainer, 1 Mips was added to support the additional requirements of the JEM Lab and Columbus Lab.

2.2.3 Communications Requirement

The LAN loading that results from Core system representations was estimated to take the form of a broadcast message with an average length of 50 bytes transmitted at a frequency 10 hertz. This translates to 4 Kbps of bandwidth loading on the SCS (or Payload) LAN.

In the DMS Equivalent design, the bandwidth estimate was increased by a factor of 8 (to 32 Kbps) to accommodate message lengths up to 400 bytes that may be necessary for the total substitution of DMS components.

Both estimates are based on comparisons to similar real time simulation functions associated with flight and ship handling training simulators.

2.3 C & T Systems Representation

2.3.1 Assumptions

The aggregate science data downlink telemetry stream of all experiments is comprised of payload data borne by the Payload LAN and by the High Rate Link. When the aggregate stream must reflect a high bandwidth, it is typically modeled using a static, preformed data stream to augment the small dynamic data stream taken from the Payload (or Trainer) LAN. This latter stream may also include all uplink payload commands and downlink Core systems data and health and status responses generated by the models and flight equivalent instruments. It is assumed that, overall, High Rate Link data is generated by only five percent of the payload representations.

When a dynamic, full bandwidth downlink telemetry stream is required in order to feed the POIC and/or the POIC Trainers, a separate, dedicated C&T processor platform will be used in conjunction with an SCS lab trainer. It is assumed, however, that only one trainer interacts dynamically with the POIC or the POIC Trainers at the same time.

The Space Station science data component of the telemetry downlink is greater than 100 Mbps but will not typically be more than 150 Mbps. The PTC will not implement, simultaneously, more than one dynamic data stream of this magnitude.

2.3.2 Processing Requirement

The C&T function is implemented at two levels , producing: 1) a limited bandwidth dynamic telemetry stream (but with a preformed full bandwidth static stream); or 2) a full bandwidth dynamic telemetry stream suitable for driving the POIC or its equivalent.

Basic Model

The basic trainer C&T representation is a software model capable of: 1) simulating the general telemetry environment and communication system control; and 2) emulating, at a greatly reduced capacity, the fundamental C&T telemetry function of packet assembly and disassembly (PAD).

While the code required to perform conversion and PAD-like functions can be complex, only a small portion of the code is used in a repetitive fashion to sustain a transmission. This subset of code was taken as the basis for estimating the throughput processing requirement. To provide a moderate capacity real time dynamic link, a 1,000 hertz cycle frequency was used.

80 lines of repetitive code
X 10 instructions per line
X 1000 hertz
X 1.25 overhead
---
1 MIP required for 10 Mbps C&T processing

The PAD requirement of 1 Mip provides for a real time, dynamic C&T link of 10 Mbps.

The processing load for the communications control function was estimated on the basis of comparable existing code. The anticipated program size of 800 lines of repetitive code was used in the calculation.

800 lines of repetitive code.
X 10 instructions per line
X 10 hertz
X 1.25 overhead (20% of total)
---
1 Mips

The resulting total basic C&T model requirement is estimated to be:

1 Mips (PAD) + 1 Mips (control) = 2 Mips.

Dedicated C&T Processor

The C&T processor/adapter performs the necessary communication processing to output a high fidelity telemetry data stream with a high bandwidth of greater than 100 Mbps. Multiple processors can be combined to achieve even higher aggregate bandwidth telemetry data streams.

The computing resource estimate of the required cpu processing Mips is based on a program containing a small module for the bulk of the sustained PAD-like communications processing:

80 lines of repetitive code
X 10 instructions per line
X 10,000 hertz
X 1.25 overhead
---
10 Mips

2.3.3 Communications Requirement

C&T processing imposes no additional load on the existing LAN traffic in any of the SCS designs. Generation of High Rate Link data when the flight equivalent payload instrument is not used, however, does yield an additional load as described in Section 2.18.3 Audio and Video System.

2.4 Payload Representation

2.4.1 Assumptions

Payload sizing was based on the results of the T-1 Study which are assumed to reflect reasonable maximum payload models sizes.

The control of several concurrent payloads presents a significant load on the operating system. This extra processing requirement for real time concurrency control is reflected in the estimates provided for the Simulation Executive function.

2.4.2 Processing Requirement

The temporal resolution (cycle time) required for payload models varies widely depending on the nature of the payload experiment and the fidelity of the payload model necessary to meet training objectives. The maximum fidelity or resolution that can be supported, without loss of precision, is equal to the background (DMS, Core, and C&T) processing rate of 10 hertz. The minimum resolution suitable for a payload model could be as low as several seconds or minutes per iteration (cycle).

An average, high fidelity resolution of 2 hertz was used to determine the processing requirements.

Size of Payload Models - T-1 Study

The payloads have been classified as complex, medium, and simple. The lines of code required for each type were estimated for:

a complex model as 34,700 lines of code.
a medium model as 22,000 lines of code.
a simple model as 7,150 lines of code.

In the extended analysis for detailed SCS design, the distributions of the experiment models was biased toward the complex side in order to insure maximum capacity. The mix of model types was assumed to be:

Complex - 30% Medium - 30% Simple - 40%

Based on this mix, the average module of code executed repetitively is estimated at 20,000 lines of code.

The cpu processing requirement for the payload model of this size is:
20,000 lines of code
x 10 instructions per line
x 2 hertz update rate
x 1.25 overhead (20% of total)
---
5 Mips per payload model

2.4.3 Communications Requirement

The communications requirements for payloads vary based on the experiment's data acquisition and control profiles. The impact considered in this section is limited to the science and the health and status output which places a load on the Trainer or SCS LAN. Many of these data streams may be lower than 1 Kbps on the average. The base rate used in this analysis for active payloads was .5 Mbps which, when summed for the number of simultaneous payloads, represents the instantaneous maximum to be expected for a lab trainer.

For example, 12 simultaneous experiments in a Combined trainer times .5 Mbps equals a total maximum load on the Shared Host SCS LAN of 6 Mbps.

When payload science data is selected and routed for monitoring, such as during instructor monitoring in the Local Host design, the data stream from each selected payload is assumed not to exceed 2 Mbps. The corresponding impact on LAN loading is described in Section 2.11.3 Instructor Control and Monitoring.

2.5 Environment Representation

2.5.1 Assumptions

Environment models are necessary to sustain DMS, payload, and Core system functions, and to structure training session simulation scenarios.

The implemented fidelity of environment models varies with the type of SCS trainer.

2.5.2 Processing Requirement

It is estimated that full environment models providing adequate fidelity for the the Combined and Consolidated trainers will account for 24,000 lines of code. Since environment models are part of the matrix driving payload instruments and models, they must be able to execute at the background frequency of 10 hertz.

The resulting maximum cpu processing requirement is:

24,000 lines of code
x 10 instructions per line
x 10 hertz
X 1.25 overhead
---
3 Mips

2.5.3 Communications Requirement

The communications requirement associated with the environment models was estimated on the basis of a single LAN broadcast message at the maximum background rate of 10 hertz. These messages could represent space, space station, and ground environment variables and related systems data. The average message was assumed to contain 100 four byte variables.

The resulting load on the SCS or Trainer LAN is:

100 environmental variables
X 4 bytes long
X 8 bits per byte
X 10 hertz
---
32 Kbps

2.6 Crew Interface Representation

2.6.1 Assumptions

MPAC usage is distributed accordingly:

Consolidated Increment Trainer: 2 USA, 1 JEM, 1 Columbus
Combined Trainer: 2 USA , 2 JEM , 2 Columbus
Part Task Trainers: 1

Audio and video I/O is not considered in this analysis because these data streams are isolated from SCS design LANs. The streams are both internal to the

console and sourced from a separate Audio and Video System over dedicated communications links which are independent of the SCS and Trainer LANS.

Experiment displays available on the flight MPAC are simulated with high fidelity.

The switches and indicators on the Control and Display Panel may be simulated at a medium fidelity.

2.6.2 Processing Requirement

It is assumed that a windowing environment and local array processing will be required of the crew console to provide realistic interactive graphics. In conjunction with requirements for peripheral I/O including video, it is estimated that the function requires a workstation with a minimum of 5 Mips cpu power.

2.6.3 Communications Requirement

LAN loading estimates for the MPAC and its non-DMS equivalent are based on a maximum expected command stream output represented by the interaction of a position controller such as a joy stick. A data rate of 50 Kbps was used.

2.7 Simulation Executives

2.7.1 Assumptions

The Simulation Executive is responsible for essentially all real time simulation control and coordination within a trainer. This includes the orchestration of payload models, DMS, Core systems, SIB, instructor interfaces, performance recording, and interfaces with network control programs during a training session.

Each trainer has its own Simulation Executive.

2.7.2 Processing Requirement

The Simulation Executive's real time function is required to interact with the trainer systems at the background frequency of 10 hertz. The scope of the executive requires substantial software support. Based on similarity to other complex real time systems, the total program size is estimated to be approximately 20,000 lines of code. It is estimated that the repetitive code module necessary to support a single function, such as an active payload model or a monitoring/recording activity, is approximately 1,000 lines of code.

On the average, it can be expected that approximately 20 active payloads and other simulation functions can occur simultaneously in a full fidelity lab trainer. In order to span these concurrent events, the equivalent of one repetitive code module must be executed for each function.

Therefore, the repetitive, time sharing nature of a Simulation Executive is expected to require:

20 concurrent functions
X 1,000 lines of code
X 10 instructions per line
X 10 hertz
X 1.50 overhead (40% of the total)
---
3 Mips

The operating system overhead appears higher in these estimates because of the high sustained level of concurrency necessary to execute the simulation. The Simulation Executive code is also responsible for the interface and synchronization of models with the trainer and SCS system components. Much of this processing invokes operating system resources.

2.7.3 Communication Requirement

The communications requirement necessary to control payload operations has been estimated to range from 1 to 1.5 Kbps per payload model. This bandwidth provides for ten 12 byte command messages per second per payload.

2.8 POIC - DMS Interface

2.8.1 Assumptions

The POIC-DMS interface can be represented by both a real time interface to the POIC (or a POIC Trainer) and a ground control model running in the trainer host.

The POIC-DMS Interface is assumed to interact with the OMA or equivalent models on a real time basis. Uplink commands and responses are modeled fully.

A trainer's modeled telemetry stream includes Core systems data, Payload LAN data, High Rate Link science data, and audio communications. These data are, in turn, reacted to by the modeled POIC ground systems.

2.8.2 Processing Requirement

The size of the POIC-DMS interface model was estimated at 8,000 lines of code. This translates to 1 Mips of cpu processing power.

The 1 Mip computes as follows:

8,000 lines of code
x 10 instructions per line
x 10 hertz
x 1.25 overhead
---
1 Mips

An additional 1 Mips was added to the Consolidated trainer to support the requirements of the JEM Lab and Columbus Lab.

2.8.3 Communications Requirement

The communication requirements for the POIC - DMS interface are based on a maximum expected command stream output represented by the interaction of a position controller such as a joy stick. A data rate of 50 Kbps was used.

2.9 PTC - POIC Link

2.9.1 Assumptions

It is possible, with the aid of the C&T processor box, to connect the PTC directly to the POIC or a physical representation of it. In these cases, it is assumed that only one trainer interacts dynamically with the POIC or POIC Trainer.

The Space Station Science data components of the telemetry stream downlink is greater than 100 Mbps but will not be typically more than 150 Mbps. The PTC will not implement at any given time more than one dynamic data stream of this magnitude.

2.9.2 Processing Requirement

The processing requirements associated with PTC-POIC link parallel that of the C&T communications processor. The processor, under the control of the Training Session Manager host and coupled with a high speed LAN or telecommunications link, provides the computing resource for this function.

C&T Dedicated Processor

This processor and adapter supports a C&T telemetry link of greater than 100 Mbps. Multiple processors can be used to achieve still higher aggregate capacity communications link.

The cpu processing power required is estimated on the basis of a small, rapidly cycling module of code serving as the core of this function. Consequently:

80 Lines of repetitive code
X 10 instructions per line
X 10,000 hertz
X 1.25 overhead
---
10 Mips

2.9.3 Communications Requirements

The PTC - POIC represent no communications load on the SCS LAN.

2.10 GSE Control

2.10.1 Assumptions

Ground Support Equipment (GSE) is a simple model which supplies control signals to GSE control devices or payload stimulators, or simulates ground support equipment functions in order to furnish parameter values to payload models.

Ground Support Equipment is external to the SCS within the PTC.

2.10.2 Processing Requirement

The necessary GSE fidelity in terms of temporal resolution will vary with the nature of the payloads and the models implemented to meet training objectives. The resulting cpu processing requirement is expected to be quite modest. Based on a total repetitive code of 4,000 lines executing at an average cycle rate of 2 hertz, the estimated requirement is:

4000 lines of code
X 10 instructions per line
X 2 hertz
X 1.25 overhead

.1 Mips

2.10.3 Communications Requirement

The communications requirement per payload is based on the amount and frequency of control data used to drive the GSE device or the payload stimulator.

The estimated 0.5 Kbps is derived from an expected 30 bytes of command data per payload recurring at 2 hertz.

2.11 Instructor Control and Monitoring

2.11.1 Assumptions

Instructor Stations are located on the SCS LAN.

Trainer audio and video are feed to and from the Instructor Stations via the separate Audio and Video System.

An Instructor Station may be used to monitor more than one (and up to four) trainers, crew consoles, or separate payloads at the same time.

2.11.2 Processing Requirement

In each of the SCS designs, the instructor stations were implemented as individual workstations. The workstation needs to be capable of supporting the operating system and file transfers, the windowing environment, multiple active processes in separate windows, local administrative processing, and control of audio and video equipment. It was determined, from known performance with similar tasking, that a high end workstation of approximately 16 Mips is required.

2.11.3 Communications Requirements

The Instructor Station consoles are assumed to be a source of command streams into the trainers equivalent to the output of a position controller, or a parameter array for dynamic adjustment of simulation scenario events. A data rate of 50 Kbps was used.

Data traffic from the trainers to the consoles for monitoring functions differs among SCS designs. It has been assumed elsewhere that the maximum average data output of a payload onto the Payload LAN (not High Rate Link data) is 1.5 Mbps. To insure adequate monitoring capacity for payloads above this average, a 2 Mbps stream is assumed in this analysis. Further, this 2 Mbps may be the filtered result of an even larger payload data stream, when necessary.

In the Shared Host design, the full data stream is already on the SCS LAN when the payload source is a model (running on a shared host).

If, on-the-other-hand, the data originates from a flight equivalent instrument, the full payload data stream is routed through the SIB onto the SCS LAN. This presents an additional loading on the SCS LAN as shown in Figure 3.4.1-3. It is assumed that in these cases, the PTC/SCS-wide maximum number of payloads being viewed concurrently by instructors is 10 and that the data streams are filtered down to 2 Mbps, if necessary.

The presence of the trainer host(s) in the Local Host and DMS Equivalent designs, permits the payload data stream to be filtered to provide just what data can be displayed as a whole on an Instructor Station console. The resulting data stream used is 300 Kbps per concurrently viewed payload.

It should be noted that these loadings do not reflect audio and video signals which, in all SCS designs are routed directly to the consoles by a separate Audio and Video System which does not use the SCS or other LANs.

2.12 Training Session Manager

2.12.1 Assumptions

Trainer hosts have local disk which support virtual memory swapping, operating system requirements, training scripts, code management, and all required data bases.

In two of the three design, the TSM receives training results from the transfer in a non-real time mode. The exception is the Shared Host design where training result are transferred in real time.

The Training Session Manager coordinates and controls instructor interactions with the Simulation Executives.

The training Session Manager controls all external communications with the PTC.

Training analysis and data base functions reside on the Training Session Manager Host.

2.12.2 Processing Requirements

The TSM's function is comprised predominantly of non-real time tasks associated with the configuration and setup of the trainers and interfacing with the management of training data. (Actual training data analysis and management tasks are covered later as separate functions). The computing resource host loading for the TSM is estimated to be 3 Mips as indicated, for example, in Figures 3.3.3-1 and 3.5.3-1. The estimate is based on engineering judgement for an acceptable response time for complex tasks across several independent trainers and facilities.

2.12.3 Communications Requirements

The Training Session Manager produces some loading on the SCS LAN during both real time and non-real time operations. During real time operation, the TSM interacts with Instructor Stations to set up basic transaction sessions between the instructors and one or more Simulation Executives. The TSM also monitors the basic status of each Simulation Executive/Trainer.

The LAN loading estimated at .14 Kbps per instructor station represents the passage of infrequent commands to the Simulation Executives and includes status data flowing the other direction.

The maximum non-real time loading on the LAN during configuration and setup, assuming all trainers are prepared at the same time, is summarized in Figure I-1.

	Estimated Mbytes Per Trainer	Total Mbits Per Trainer	Transfer Rate Mbits/sec	Minutes to Transfer
Consolidated	27	216	3	1.2
Combined	27	216	3	1.2
Part Task	63	504	3	2.8
CBT	5	40	3	0.22
POIC	50	400	3	2.22
Totals	172	1376	3	7.64

Figure I-1. Configuration and Setup Analysis

1. Goal was to configure the PTC in under 10 minutes.
2. The Development Facility and TSM will load SCS LAN.
3. Trainer response to transfer is minimal.
4. Sizes of application from T-1 Study.

2.13 Operator Control and Monitoring

Operator Control and Monitoring functions are performed on system consoles that reside on the various SCS hosts. Operator functions consist primarily of non-real time functions and no not require additional processing power, or contribute to the network loading.

2.14 Configuration and Setup

The bulk of the processing associated with this function is performed as part of the TSM function and has already been included in those estimates.

2.15 Training Analysis

2.15.1 Assumptions

Training Analysis is supervised by the Training Session Manager in a non-real time mode.

2.15.2 Processing Requirements

In addition to Training Session Manager supervision, host support of training analysis includes processing for descriptive statistics, multivariant inferential statistics, and plots and graphs. These tasks can be implemented with COTS software packages. Custom software would support (but not concurrently) the analysis of scenario session recordings to abstract meaningful data for submission to the statistics packages. The cpu processing load estimated to perform these functions within a reasonable time frame is 4 Mips for application code and database operation.

2.15.3 Communications Requirements

There is no communications requirement beyond the transfer of training data achieved in the Training Data Management function, described in the next section, that would impact the SCS LAN loading.

2.16 Training Information Management

2.16.1 Assumptions

Training data are collected in real time via the Simulation Executives and transferred to the Training Session Manager for record keeping and administration. These data are also submitted to, and the results received from, the Training Analysis function described above.

2.16.2 Processing Requirements

In addition to Training Session Manager supervision, host support of training information management includes all data base functions and report generation. These tasks would be implemented with COTS software packages. Custom software would support (but not concurrently) the capture and storage of scenario session recordings. The cpu processing load estimated to perform these functions within a reasonable time frame is 4 Mips for application code and database operation.

2.16.3 Communications Requirements

SCS LAN loading is based on the following estimates:

3,000 records of 80 bytes per student in Consolidated and Combined trainers.

1,000 record of 80 bytes per student in the Part Task trainers and CBT trainers.

Average of two minutes allowed to transfer data from trainers.

When multiplied by the number of trainers and students, a total of 47,360 Kbits needs to be transferred. A composite transfer rate of 550 Kbps enables the data to be transferred from all trainers in approximately 2 minutes. The calculations are summarized in Figure I-2.

Trainer Type	Records Per Student	Bytes per Record	Kbits per Student	Number of Students	Number of Trainers	Total Kbits Required	Transfer Rate Kbits/sec	Minutes to Transfer
Consol.	3000	80	1,920	4	1	7,680	200	0.64
Combined	3000	80	1,920	4	3	23,040	200	1.92
Part Task	1000	80	640	2	9	11,520	100	1.92
CBT	1000	80	640	8	1	5,120	50	1.71
Totals	8000	80	5120	18	14	47,360	550	1.92

Figure I-2. Training Results Transfer Analysis

Goal was to keep transfer time for training results under two minutes.

2.17 POIC Personnel I/F

The PTC includes seven POIC trainers. Each trainer supports a host and two workstations. The host processes and controls all uplink and downlink exchanges and provides disk storage capacity to the workstations.

Each of the seven POIC trainers includes a host and two workstations. The workstations support a windows environments and connections to the Audio and Video System.

The processing requirements estimated for a POIC Trainer are:

POIC host .	8 Mips
Workstation... 4 Mips * 2 =	8 Mips
	16 Mips

The host requirements stem from:

C&T processing	5 Mips
File Server, OS, Sim Exec	3 Mips

4 MIPS is a small workstation capable of supporting graphics, windows, and operating systems.

2.18 PTC External Interfaces

The joint combined training mode with JSC is not specified. For this reason, there is no requirement for real time data interchange between the SSTF and the PTC. File transfers between the SSTF and the PTC are supported. File transfers between the PTC and the PIs are supported.

2.19 Audio and Video Systems Representation

An Audio/Video Processor/Controller is used to augment the Trainer Host.

Five percent of all payload models require A/V generation.

Additional communications processing is required to support High Rate Link data creation when the flight equivalent instrument is not used. The High Rate Link function of the corresponding payload model generates the command stream that drives the actual source device (of telemetry data stream), such as the Audio and Video System. This specialized device then generates the actual High Rate Link data stream for feed to the facility's dedicated C&T processor, and on to the POIC or POIC Trainer link.

The additional processing requirement was estimated as the maximum for a single payload model, recalling that only five percent of the payloads are expected to generate High Rate Link data. Basing the maximum estimate on a computer generated imagery requirement of one command statement (18 bytes) for every Kilobyte of video data, and a maximum High Rate Link output for a single payload of 40 Mbps, results in:

18 bytes (command)
X 8 bits per byte
X 5,000 kilobyte units of video data
(for an 80 Mbps stream)

0.72 Mbps = approx. 0.75 Mbps LAN loading

In the example of one full fidelity Combined lab trainer with two simultaneously active HRL payloads, the total LAN loading for that trainer is 1.5 Mbps.

2.20 Primary Instruction Delivery

The SCS facilities, including the CBT Facility, were designed, configured, and sized on the basis of general system architecture and engineering experience with similar general purpose MIS and development implementations. The basic allocation of cpu processing and communications resources to accommodate reasonable expectations for the specific functional loadings on the facility are provided in the following sections.

2.20.1 Assumptions

CBT models are of low fidelity.

CBT models may require prerecorded audio and video inputs.

Eight students will be training at one time.

2.20.2 Processing Requirement

The CBT is configured with host file server and eight disk or diskless workstations. The CBT file server provides data base and file services to the workstations as well as handle any SCS LAN request. Training results are kept on CBT file server and transferred to the training session manager in a non-real time mode.

Based on engineering experience with comparable configurations, the processing load on the CBT file server is estimated to be not more than 8 Mips.

The processing load on the workstations, with or without local disk storage, is estimated to be 4 Mips.

2.21 Simulation, Scenario, and DB Development

The SCS facilities, including the SCS Development Facility, were designed, configured, and sized on the basis of general system architecture and engineering experience with similar general purpose MIS and development implementations. The basic allocation of cpu processing and communications resources to accommodate reasonable expectations for the specific functional loadings on the facility are provided in the following sections.

2.21.1 Assumptions

The facility must support 100 concurrent users in the development of payload models, training scenarios, and other simulation models and databases.

A variety of workstations and graphics terminals can be used to support the development effort.

2.21.2 Processing Requirements

The SCS Development Facility has been configured to consist of 40 workstations in total, of which 30 workstations are allocated to support the development of simulation models, scenarios, and database software. Thus, the function relies on 30 workstations at 8 Mips per workstation for a total computing capacity of 240 Mips.

In addition, 70 Mips of the dual file servers is allocated to support databases, compilers, debuggers, and multiple batch jobs.

2.21.3 Communications Requirement

The separate facility LAN supports virtually all communications requirements for the development function, and has been sized at 10 Mbps which is considered more than adequate to support file services under the given configuration and number of stations. Average response time for queries would be expected to be on the order of 1 to 2 seconds.

2.22 Developers Interface

The Developer Interface function of the SCS is actually a subset of the SCS Development Facility described in the previous section. Additional requirements associated with this aspect of the facility are identified below.

Sixty terminals connect to the host file servers via terminal servers. The terminals rely on the cpu processing capacity of the host file servers. The allocated host cpu processing requirement per terminal/user is 1 Mips, where:

60 users * 1 Mips = 60 Mips allocation.

Similarly, the file server load for a diskless workstation is 1 Mips, where:

20 Workstation * 1 Mips = 20 Mips.

Twelve Mips are allocated for expansion and additional processing support to the higher capacity workstations.

2.23 Crew Interface Prototyping

The prototyping activity for crew interfaces including C&D panels and virtual C&D panels is a subset of the Development Facility function. Additional cpu processing allocated to support specific prototyping environments takes the form of six workstations. Five of these 6 Mips workstations are used as prototyping stations, with the sixth workstation used as a file server.

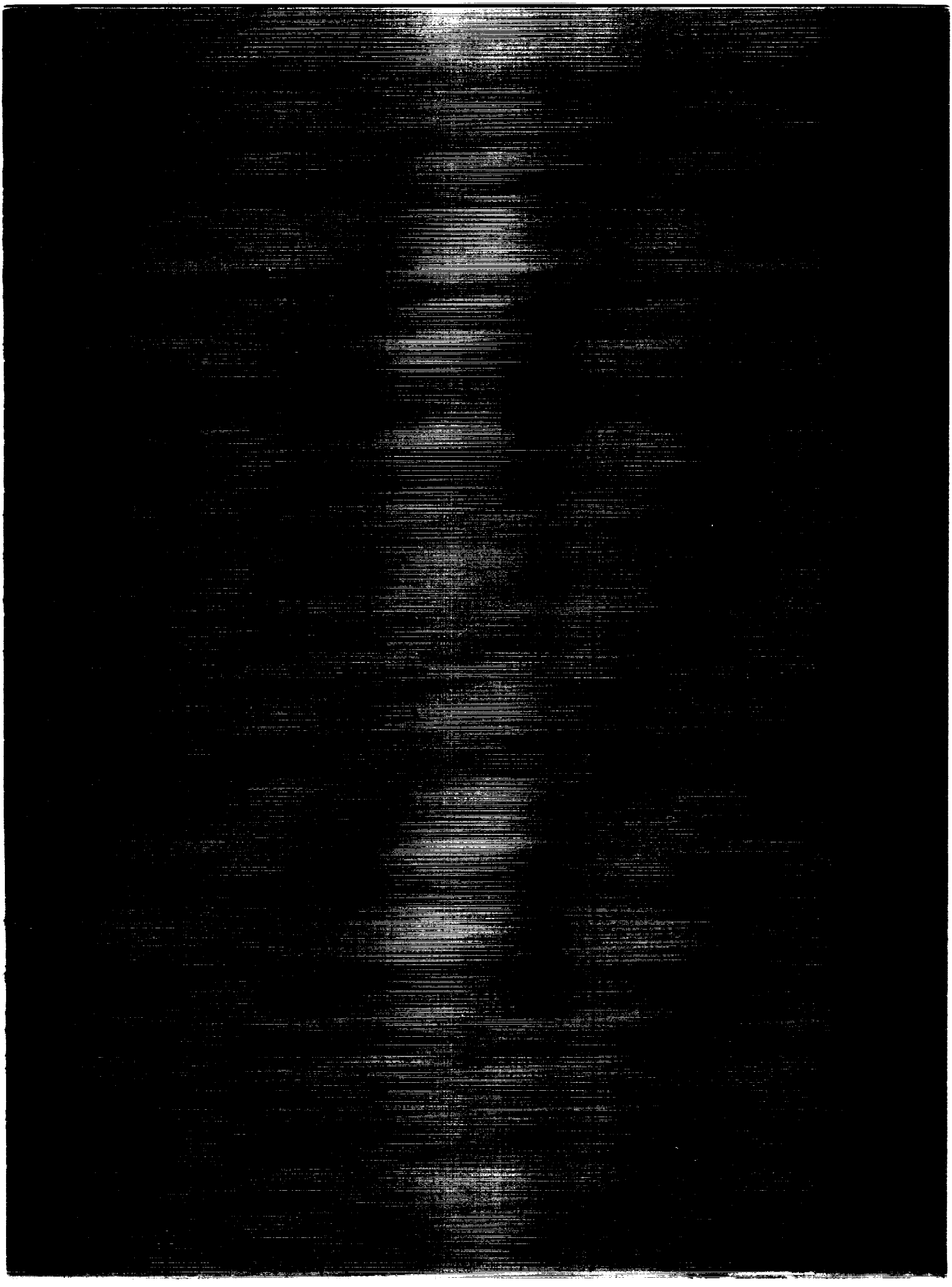
2.24 Integrate and Test Simulations

The SCS facilities, including the IT&V Facility, were designed, configured, and sized on the basis of general system architecture and engineering experience with similar general purpose MIS and development implementations. The basic allocation of cpu processing and communications resources to accommodate reasonable expectations for the specific functional loadings on the facility are provided in the following sections.

2.24.1 Assumptions

It is assumed that the larger, more complex payload models will require significantly more IT&V time, thus altering their proportion in the payload model mix used to set the average cpu loading. To accommodate this shift, the average requirement of a payload model was increased from .5 Mips to 1 Mips.

It is assumed that 6 of the developers will be testing payloads concurrently.

2.24.2 Processing Requirements

Based on an estimate of an additional 3 Mips to support debugging and other capabilities unique to IT&V tasks, 18 Mips was allocated to the IT&V host to support the testing of 6 payloads concurrently. This processing capacity is in addition to that resident in the IT&V lab configuration unit which is equivalent to a Combined Trainer.