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

BASELINE ARCHITECTURE REPORT - VOLUME 2

TRW-SCS-90-XT2

21 December, 1990

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TRW System Development Division
Systems Integration Group

213 Wynn Drive
Huntsville, AL 35805
205.837.2400

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George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

Attn: Mr. M. Watson/E035

Subject: Contract No. NAS8-37745
Baseline Architecture Report
Simulation Computer System for Space
Station Program

In accordance with the requirements of the subject contract, the technical report titled Baseline Architecture Report is herewith submitted and distributed as shown.

TRW Inc.
Systems Integration Group

for V. O'L. Bain
Contracts Administrator
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SPACE STATION SIMULATION COMPUTER SYSTEM (SCS) STUDY

BASELINE ARCHITECTURE REPORT

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CDRL: TRW-SCS-90-XT2

21 Decmber, 1990

Approved By:

J H Jensen

J. H. Jensen, Manager
SCS

Released By:

P. G. Dombrowski, Manager
Huntsville Systems Laboratory

SCS SCS

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NASA
MSFC EO-35
Huntsville, Alabama 35812

Prepared by:

TRW System Development Division
213 Wynn Drive
Huntsville, Alabama 35805

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Part 2

4.0 CONCLUSIONS AND RECOMMENDATIONS

The cost drivers (CDs) were combined into baselines as a way of summarizing the results of the study of the cost drivers. The resulting baselines are shown in Table 4.0-1. This table (combined with the details in section 3.2) provides answers to the ongoing PTC/SCS cost tradeoff efforts. The four baselines are:

- Cost Effective - This is the recommended, most cost effective baseline. Where there is a reasonable pay back, higher development costs are traded for lower operations costs (CD #s 6, 10, 16, & 24) Training capabilities that cost some more, but would enhance training in a significant way are added in (CD #s 17, 18, 27, & 28). This baseline also reflects recommendations for use in the PTC/SCS that are technically possible and would lower operations cost for a reasonable increase in development cost (CD #s 7, 23, & 33), but have not been followed by SSFP (ITVE or SSTF). It also differs by changing some of the impractical assumptions made to reduce costs to the CBR baseline, and then makes a cost effective (again trading development cost for operations cost) provision to cover these (CD #s 11 & 15).

- CBR - The CBR baseline includes three DMS Kits, non-DMS Kit PTTs, IP PTTs, (JEM and ESA, only one of which runs at a time), and an IT&V facility, and a development facility. ITVE and SSE will be used.

- Low Cost - This is a variation of the CBR baseline. The CBR baseline is already as low a cost high fidelity trainer that can support the estimated flow of payloads and trainees. For the Low Cost baseline, choices have been made that trade a slightly higher development cost for lower operations cost (CD #s 10 & 24). This baseline also reflects recommendations for use in the PTC/SCS that are technically possible and would lower operations cost for a reasonable increase in development cost (CD #s 7, 23 & 33), but have not been followed by SSFP (ITVE or SSTF). It also differs by changing some of the impractical assumptions made to reduce costs to the CBR baseline, and then makes a low cost provision to cover these (CD #s 11 & 15).

- Low Fidelity, Low Cost - This is designated as the absolute lowest cost PTC/SCS. It is also, at best, a medium fidelity simulator. It will not support flight equivalent payloads or payload flight software. All Spacelab PCTC experience indicates a trend toward more flight equivalent hardware and software, not less. Also, there is some risk in this approach that the payload training would be inadequate with potentially botched experiments and wasted valuable on-orbit time. It achieves some of its savings by trading lower development cost for higher operations cost. With this design, there is little possibility of realistic on-orbit payload problem solving assistance from the PTC/SCS.

The ground rules used in arriving at all four of the baseline solutions are the same as those stated in Appendix 1 and 2 of the SCS Overview and Summary Report from October 1989, with the following exceptions:

A. POIC training is assumed to be a POIC function. To reduce PTC/SCS cost, the separate PTC POIC training host and software were removed. This is in line with CBR, and operational experience that indicates a significant portion of the POIC training will be on the job training (OJT) due to the 24 hours per day 365 days per year POIC SSF operations at AC.

B. The extensive training analysis done by the SCS team was utilized to develop the proposed PTC/SCS baseline architectures. For the baselines, the number of concurrent sessions are as follows:

- 2 US Lab Modules
- 1 Development Unit Test
- 1 IT&V
- 1 International Partner's PTT Individual Training
- 3 PTT Individual Payload Training

C. No real-time training interface capability to the SSTF is provided. (Study Issue Assumption # 20)

D. OMGA and MPS will not run on the SCS, but will supply the needed information to support payload training. (Study Analysis Assumption # 3)

E. Crew and payload rotation will be no more often than every 90 days.

Each of these baselines will be discussed in following sections.

Table 4.0-1 OPTION COMPARISONS FOR COST DRIVERS

COST DRIVER	LOW Fi LOW COST	LOW COST	CBR BASELINE	COST EFFECTIVE
1-C&D Panel	b-virtual	a-custom	a-custom	a-custom
2-MPAC	b-sim.	a-F/E	a-F/E	a-F/E
3-P/L Fidelity	b-blk. box	a- full	a-full	a-full
4-Core Model Fidelity	b-simple	a-F/E	b-simple	a-F/E
5-Environment Fidelity	b-simple	a-full	b-simple	a-full
6-DMS Kit Use	d-sim.	a-all trnrs	b-mod. trnr	a-all trnrs
7-SIB/Host I/F	None	b-LAN	a-pt. to pt.	a-pt. to pt.
8-MDM Use	None	a-DMS	a-DMS	a-DMS
9-OMGA Use	None	a-F/E	a-F/E	a-F/E
10-Concurrent Sessions	all non-DMS	a-2+3Lo+1	b-2+3non+1	c-2+3+1+1
11-Flight Equivalent Payloads	c-0%	b-10%	40%+0%	a-40%
12-Trainees & P/Ls per Qutr.	a-90 & 90*	a-90 & 90*	a-90 & 90*	a-90 & 90*
13-P/L Changeout / Increment	d-5%*	d-5%*	c-10%*	d-5%*
14-DIF Representation	c-none	b-static	b-static	b-static
15-P/L Models built at PTC	c-0%	b-25%	c-0%	a-50%
16-P/L Remote Development	c-none	c-none	c-none	b-50%
17-Consolidated Inc.Training	c-none	c-none	c-none	b-limited
18-POIC Interface	b-limited	b-limited	b-limited	a-full
19-Train UOFs/ROCs/DOCs	c-none	a-via POIC	a-via POIC	a-via POIC
20-MODB/RODB Use	c-not used	a-all	a-all	a-all
21-Use of Ada	c-none**	a-all	a-all	a-all
22-Use of SSE/ITVE	c-none	a-all	a-all	a-all
23-P/L Model Trans. to SSTF	b-convert	a-turnkey	a-turnkey	a-turnkey
24-Model Trans.- PTT<->Mod.	c-comp. h/w	a-same h/w	d-none	a-same h/w
25-Attached P/L Rep.	b-in mod trnr	b-in mod trnr	b-in mod trnr	b-in mod trnr
26-P/L Video Representation	b-canned	a-dynamic	a-dynamic	a-dynamic
27-F/E P/L GSE	b-limited	b-limited	b-limited	a-full
28-P/L Stimulation	c-none	b-limited	b-limited	a-full
29-Instructors per Trainer	a-1	b-4	b-2	b-4
30-US P/Ls in IP Modules	b-sim IP Kits	a-IP Kits	a-IP Kits	a-IP Kits
31-Host Reconfigurability	c-none	b-reconfig	b-reconfig	b-reconfig
32-Malfunction Insertion	a-all major	a-all major	a-all major	a-all major
33-Simulator Modes	b-med/5	b-med/5	c-low/2	a-high/7
34-Session Data Handling	b-limited	a-full	a-full	a-full

* = Same for all baselines. These cost drivers have a large affect on cost and were explored for this reason. The current manifests were used for comparison for the four baselines.

** = Choice of language would be dictated by host machine and which language the programmers knew best to cut the development cost. Operations cost would be higher and synergism between centers is lost.

4.1 COST EFFECTIVE SOLUTION

In this section the best, most cost effective solution for supporting SSF payload training at assembly complete (AC) in the PTC is described and discussed. Several other related design alternatives are shown in section 4.5 "Other Designs" to illustrate other ideas resulting from the process of developing the various baselines.

Figures 4.1-1 and 4.1-2 illustrate the best, most cost effective solution for meeting the baseline PTC training requirements.

The advantages of the Cost Effective baseline design are:

- High fidelity training and support of the PDRD training requirements.
- Low cost. No non-DMS trainers, which eliminates the cost of the hardware and software needed to simulate the DMS functions.
- No problems or extra cost in migrating payload models from the PTTs to the Module Trainers.
- No problems transporting payload models from the PTC to the SSTF if the SSTF P/L session host is the same as the SCS hosts.
- Excellent failure recovery. If required, the detailed design could easily make short recovery times for all functions (training, development, and IT&V) possible. Dual ported disks, shared memory, and computer controlled switches can be added to provide the capability to reconfigure, utilizing other available SCS resources.
- Functions are totally separable. Training, development, and IT&V can be completely separated for scheduling and operating purposes. Trainees will not arrive to find a trainer down for some development problem.
- Low design risk. The SCS Study Team has high confidence that this design can support the baseline amount of required training, and that the design can be implemented, i.e. no loading, cable length, or network problems will necessitate a major design rework.
- JEM & ESA PTTs can be operated independently of each other.
- Online CBT.

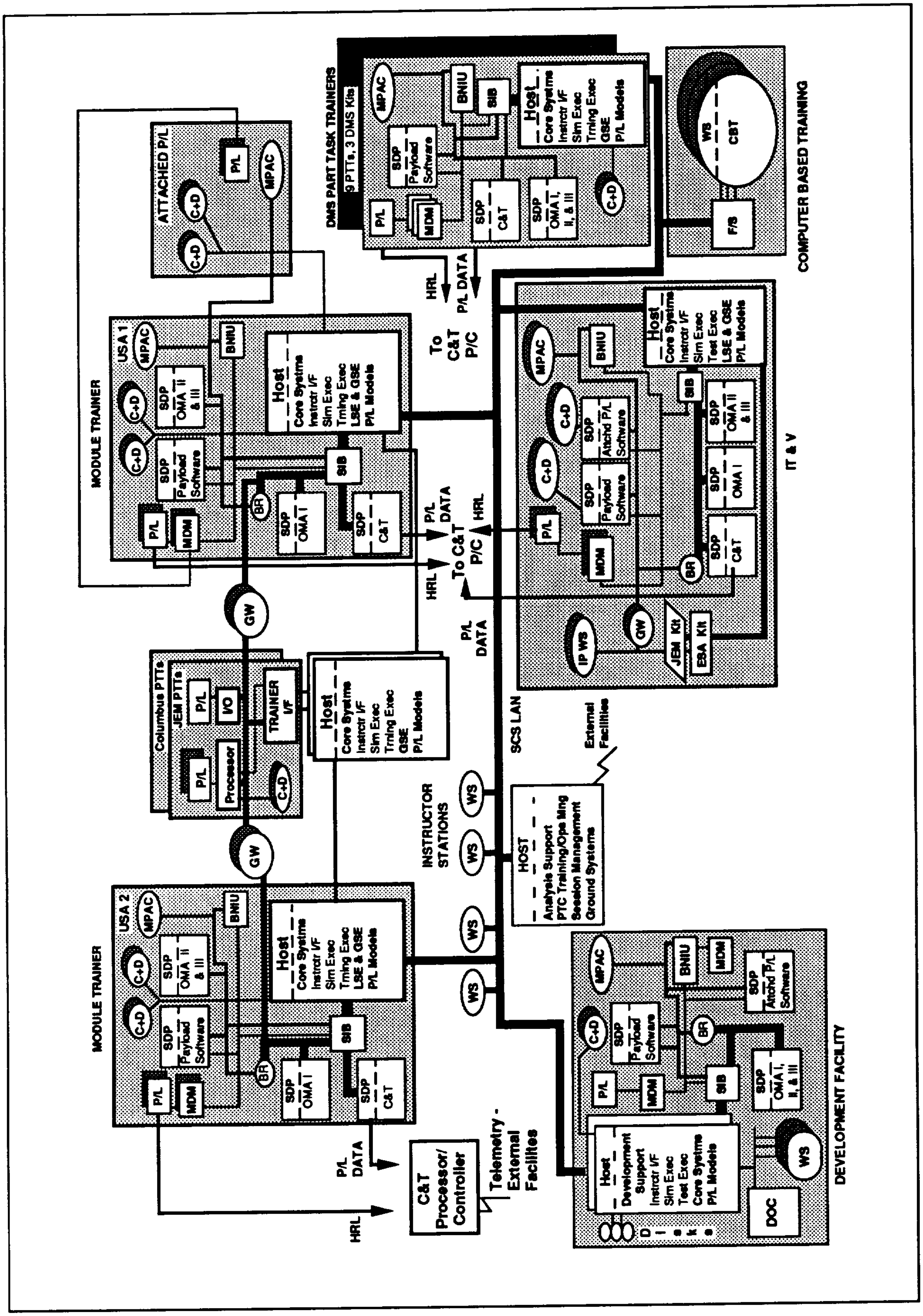

Figure 4.1-1. Seven Kit Local Host Design

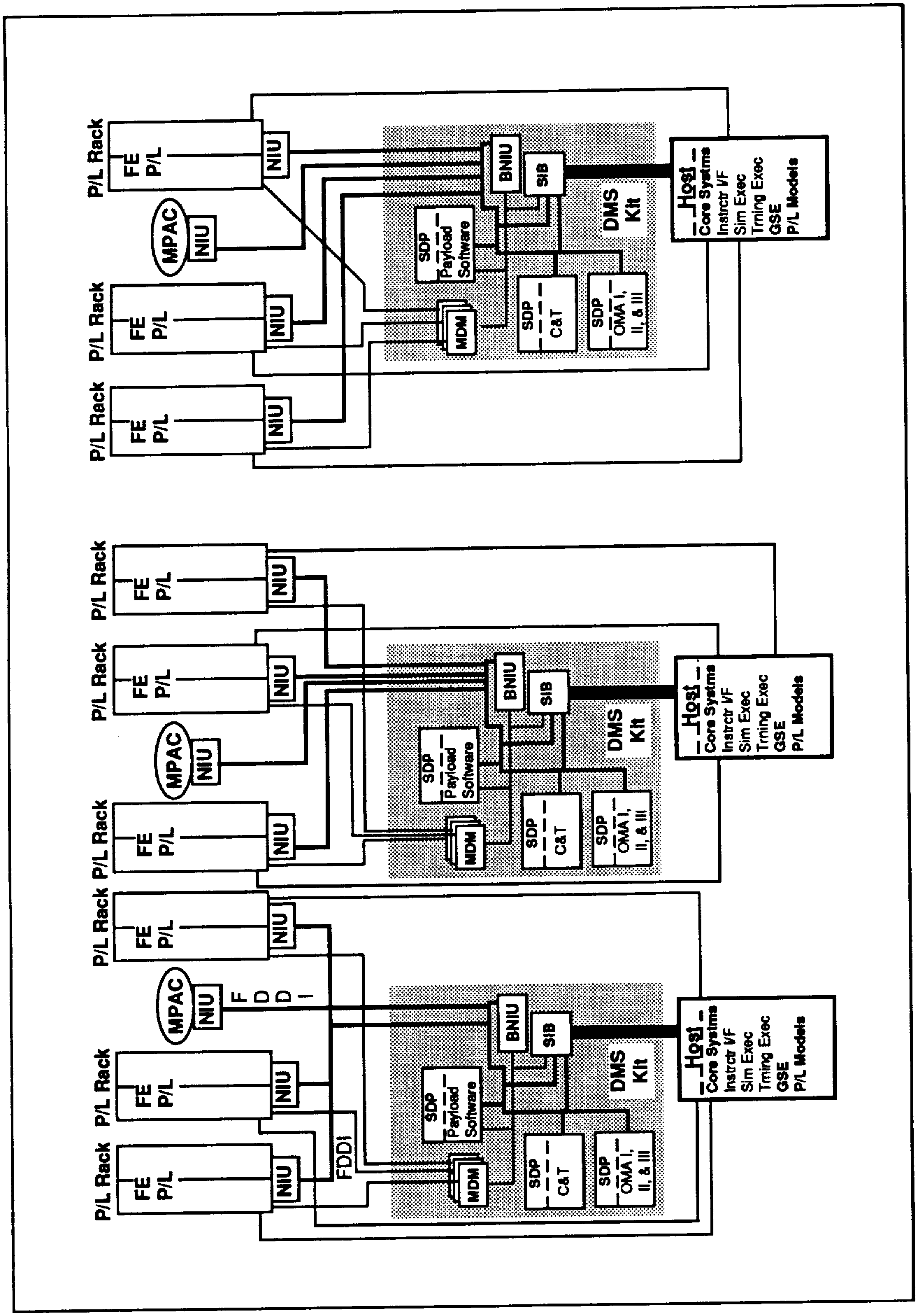

Figure 4.1-2. PTT Racks Driven by Three DMS Kits

4.2 CBR BASELINE

The ground rules used in arriving at the CBR baseline solution are the same as those used for the other baselines (see section 4.0), with the following exceptions:

A. Per CBR, Consolidated Increment Training was removed as a requirement on the PTC.

B. Per CBR, International Partner Lab Module training has been removed as a requirement on the PTC. Only US payloads in the International Partner Labs will be trained at the PTC.

Since the current Level II DMS Kit database shows three DMS Kits allocated for the PTC, this was used to derive the CBR baseline. Several other different designs are shown in Section 4.5 to provide a picture of the tradeoffs made to meet CBR. The current design in place as a result of CBR is shown in Figure 4.2-1.

The number of concurrent sessions that could be supported by three kit designs varies with the design, but a typical snapshot yields:

- 1 US Lab Module
- 1 Attached Payload Training Session (non independent)
- 0 Development Unit Test (Unit test is done in spare Module Trainer time)
- 1 IT&V
- 1 International Partner's PTT Individual Training
- 2 PTT Individual Payload Training

A non-DMS design for all PTTs was utilized as shown in Figure 4.2-1, the current CBR design. This cuts the design risk, but generates the problem of moving payload models from a simulated DMS environment to a real DMS Kit environment. It also raises the cost if a high fidelity non-DMS trainer is built, since a high fidelity DMS simulator will not be cheap to develop. The current baseline has a low to medium fidelity DMS simulator meaning that it does not support flight equivalent payloads nor payload flight software.

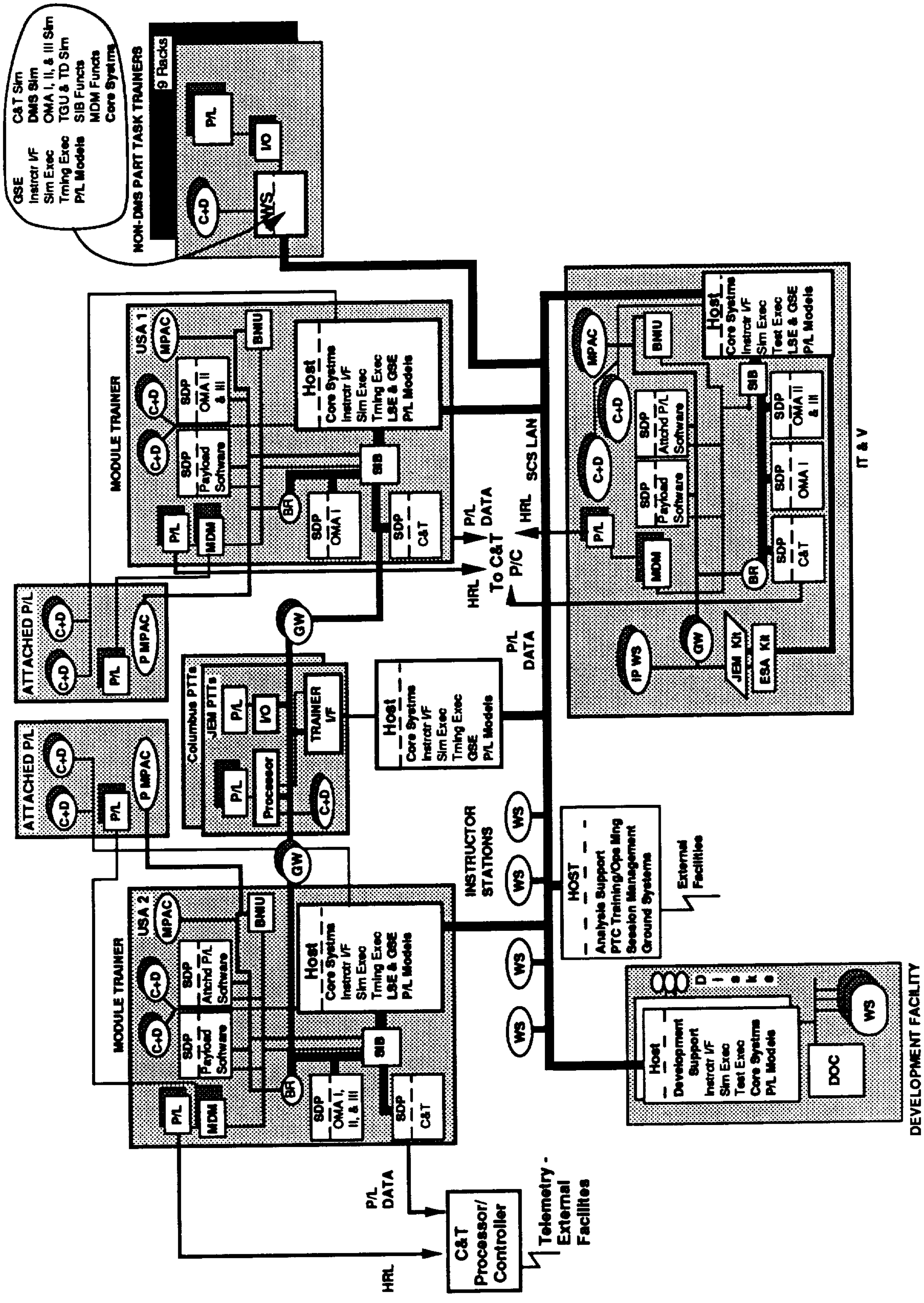

Figure 4.2-1 CBR Three Kit Local Host Non-DMS Kit PTTs Layout

4.3 LOW COST BASELINE

The ground rules used to arrived at the Low Cost solution are the same as those for the CBR baseline except:

A. For the low cost solution, the number of concurrent sessions are as follows:

- 2 US Lab Modules
- 1 Attached Payload Trainer (non independent, attached to module trainer)
- 0 Development Unit Test (Unit test is done in spare Module Trainer time)
- 1 IT&V
- 2 International Partner's PTT Individual Training
- 2 PTT Individual Payload Training

B. The rate of payload change out, based on the May 1990 OSSA Payload Traffic Model is estimated to be 5% or less per increment.

C. Significantly less crew hours per experiment will be needed, per conversations with the SpaceLab J training manager and WP01 training personnel.

Figures 4.3-1 and 4.3-2 illustrate the Low Cost baseline design. Note that non-DMS Kit PTTs are shown on the design. These would only be needed if more than two concurrent PTT training sessions are required. The hardware and software needed to obtain the same high fidelity simulation capability is extensive - see section 4.4 "Low Fidelity, Low Cost". Also note the appearance of a development LAN (DEV LAN), illustrating the need for unit test to share time on the module trainers, since a DMS Kit is not devoted to development.

The advantages of the Low Cost design are:

- High fidelity training and support of the PDRD training requirements.
- Low cost. No non-DMS trainers, which eliminates the cost of hardware and software needed to simulate the DMS functions. Also, two less DMS Kits required than the Cost Effective design (5 total).
- No problems in migrating payload models from the PTTs to the Module Trainers.
- No problems in transporting payload models from the PTC to the SSTF.
- Good failure recovery. If required, the detailed design could potentially make fairly short recovery times for all functions (training, development, and IT&V) possible.

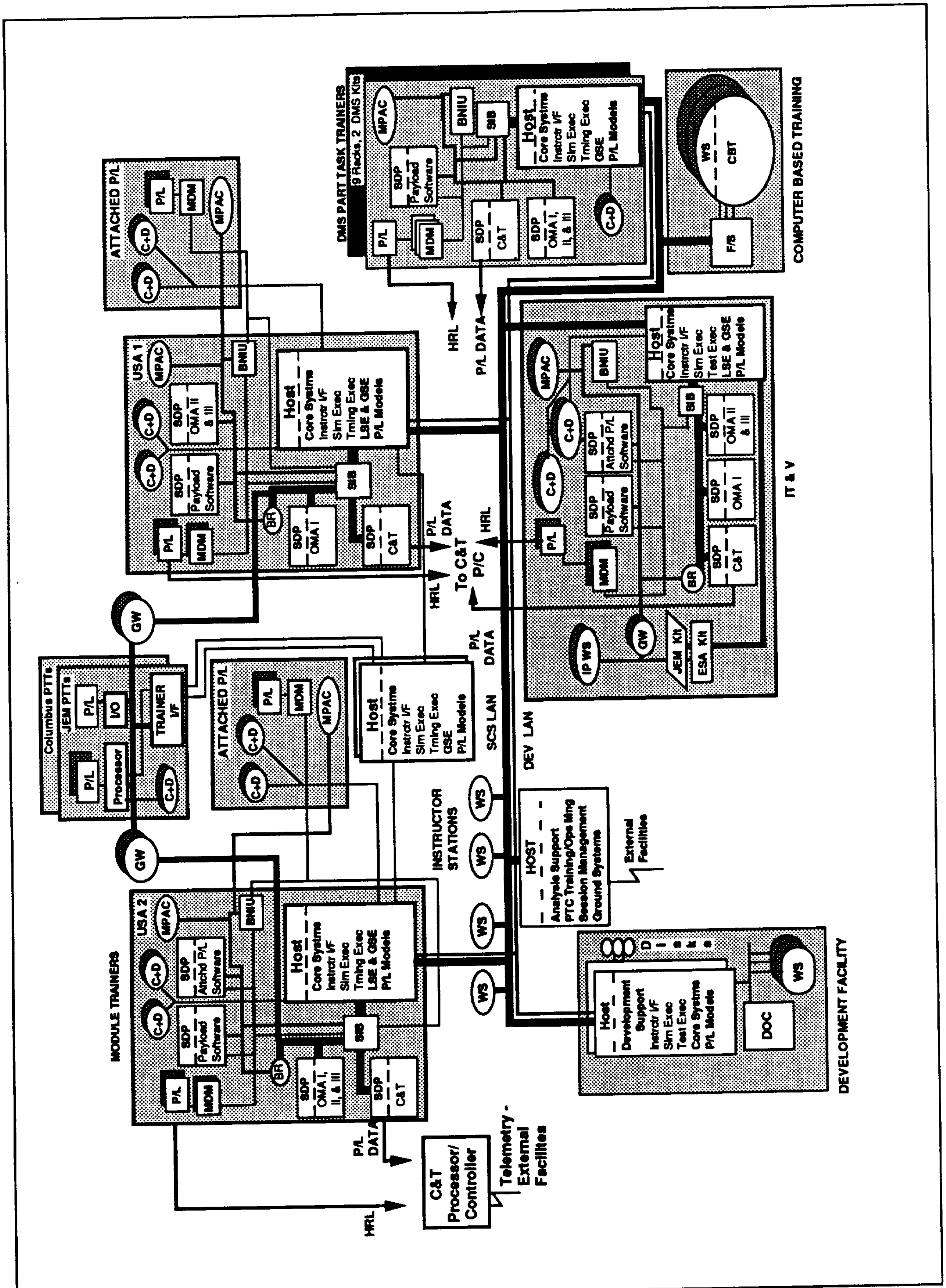

Figure 4.3-1 Five Kit Local Host Design

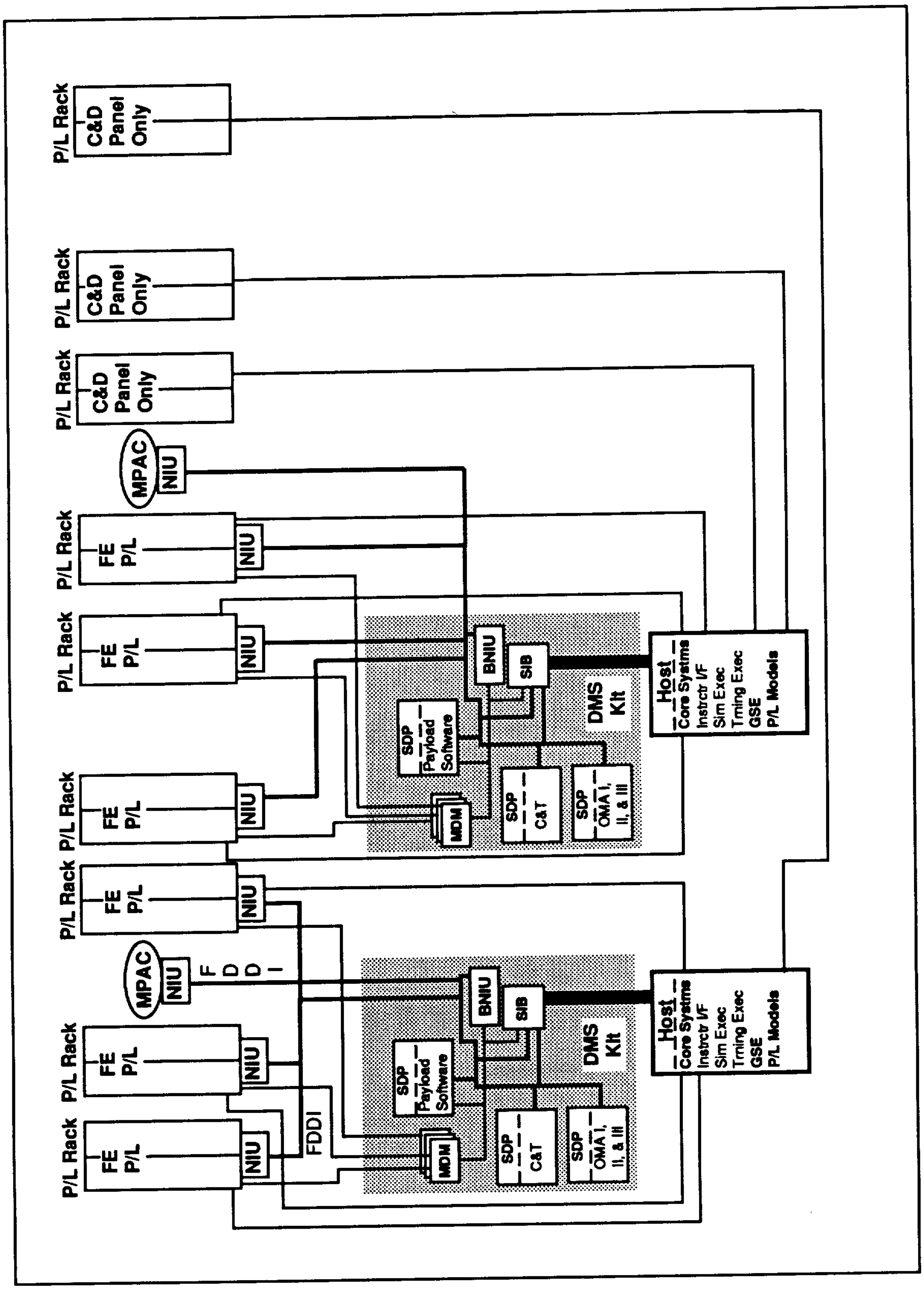

Figure 4.3-2 PTT Racks Drvien by Two DMS Kits

- Functions are mostly separable. Training, development, and IT&V can be mostly separated for scheduling and operating purposes. Probability is low that trainees will arrive to find a trainer down for some development problem.

- Moderate design risk. The SCS Study Team has good confidence, given the assumed loading constraints, that this design can support the reduced amount of required training, and that the design can be implemented, i.e. no loading, cable length, or network problems will necessitate a design rework.

4.4 LOW FIDELITY, LOW COST BASELINE

As discused extensively in the SCS Study Report Volume 3, the "Refined Conceptual Design Report", a DMS Equivalent design is consistent with the architecture of the Local Host design. This DMS Equivalent design will provide the low fidelity, low cost baseline.

Low fidelity here means that the design will not support flight equivalent payloads or payload flight software. Also, the MPAC would be different and virtual panels are used. Virtual panels would not have the look or feel of flight C&D panels. Their use would permit quick (in minutes) reconfiguration of a Lab Module trainer. This might, given a low enough flow of trainees, permit one (1) quick reconfiguration Lab Module to replace two (2) high fidelity Module trainers. However, training flow analysis done thus far shows that this is not possible. The development cost of one virtual panel Lab trainer might equal that of two high fidelity Lab trainers since virtual panels are not cheap. However, operations cost would be much less. The PTC Operations personnel would most likely have to build the virtual panel C&D displays, since this is specialized to the type of virtual panel employed.

This design replaces the flight equivalent DMS Kit components with commercial general purpose microcomputers and custom software. ITVE and SSE functionality would have to be purchased in COTS software and hardware. There are potentially some cost savings to be had here since the necessary COTS hardware is relatively inexpensive compared to DMS Kit hardware. But based on the SCS Study Extension Task 5 experience, no DMS or DMS Kit software would be used. Porting this software to COTS hardware has proven to be difficult and expensive. Some modifications to the COTS hardware would be needed to permit flight equivalent software to be used. Figure 4.4-1 illustrates the updated DMS Equivalent design.

There is the risk that the COTS hardware utilized will become obsolete and unavailable before the DMS Kit hardware does simply because NASA owns and controls the DMS Kit hardware. The Spacelab Computer Interface Devices (CIDs) are still operating today because they are a specialty item, much like the SIB part of the DMS Kits. If the CIDs had been COTS hardware, they would have become unavailable and non-maintainable years ago.

If a DMS Equivalent design is utilized, there will also be additional operating cost required to update the simulation to follow the changes in the flight system. This will require design work, reviews, code, unit test, and I&T. If DMS Kits are utilized, updates will consist of installing an testing the new DMS Kit flight equivalent software. Also, a DMS Equivalent design includes schedule risk since the DMS CDR is currently scheduled for 1993. Needed detailed technical data would not be available when needed. For the Low Fidelity, Low Cost baseline, less software is needed to replace DMS than is shown in Section 3.2-6 "Use of DMS Kits". This is because flight equivalent payloads and payload flight software are not supported.

Figure 4.4-2 illustrates the complexity of producing a high fidelity crew station MPAC utilizing COTS hardware. The 15" flat panel displays will run not only RGB displays, but display normal NTSC video in windows. These panels are not yet commercially available, and will only be available from IBM or Toshiba, who are jointly developing this technology. Simply put, you can buy the DMS Kits from IBM, or you can by the parts from IBM, and build your own kits. It is not clear yet that the latter will be cheaper.

An additional potential problem with the DMS Equivalent design is that of credibility with the astronaut trainees. If DMS Kits and fight software modified slightly to be flight equivalent are used for training, there will be little questioning by the crew of the results. If non-DMS hardware and non-flight software is utilized, the crew will challenge the training if something unplanned occurs. This happens now in Spacelab since the PCTC uses non-flight equivalent hardware and software. Even though the vast majority of the time the training is valid, the questions arise, and time is consumed verifying the training. This type of activity will be much less if flight equivalent hardware and software (DMS Kits) are used in training.

However, if training can be done on a very different form, fit and look MPAC, cost savings in hardware may be achieved by using personal computers or workstations for MPACs. Three windows on a single screen would represent the three MPAC screens. A COTS joystick and trackball would be used instead of flight equivalent hardware. A COTS keyboard would be used, which might not match exactly the flight keyboard. Software to drive the simulated MPAC screen would have to be developed as opposed to using flight DMS MPAC software. These personal computers or workstations will be maintainable for a long time. The cost of following the flight designs and modifying and maintaining this software over the life of the SSF might add considerably to the operations costs. While the DMS Equivalent design has appeal in giving less dependency on elements beyond PTC control and potential cost savings, currently it is difficult to justify choosing it due to training fidelity issues.

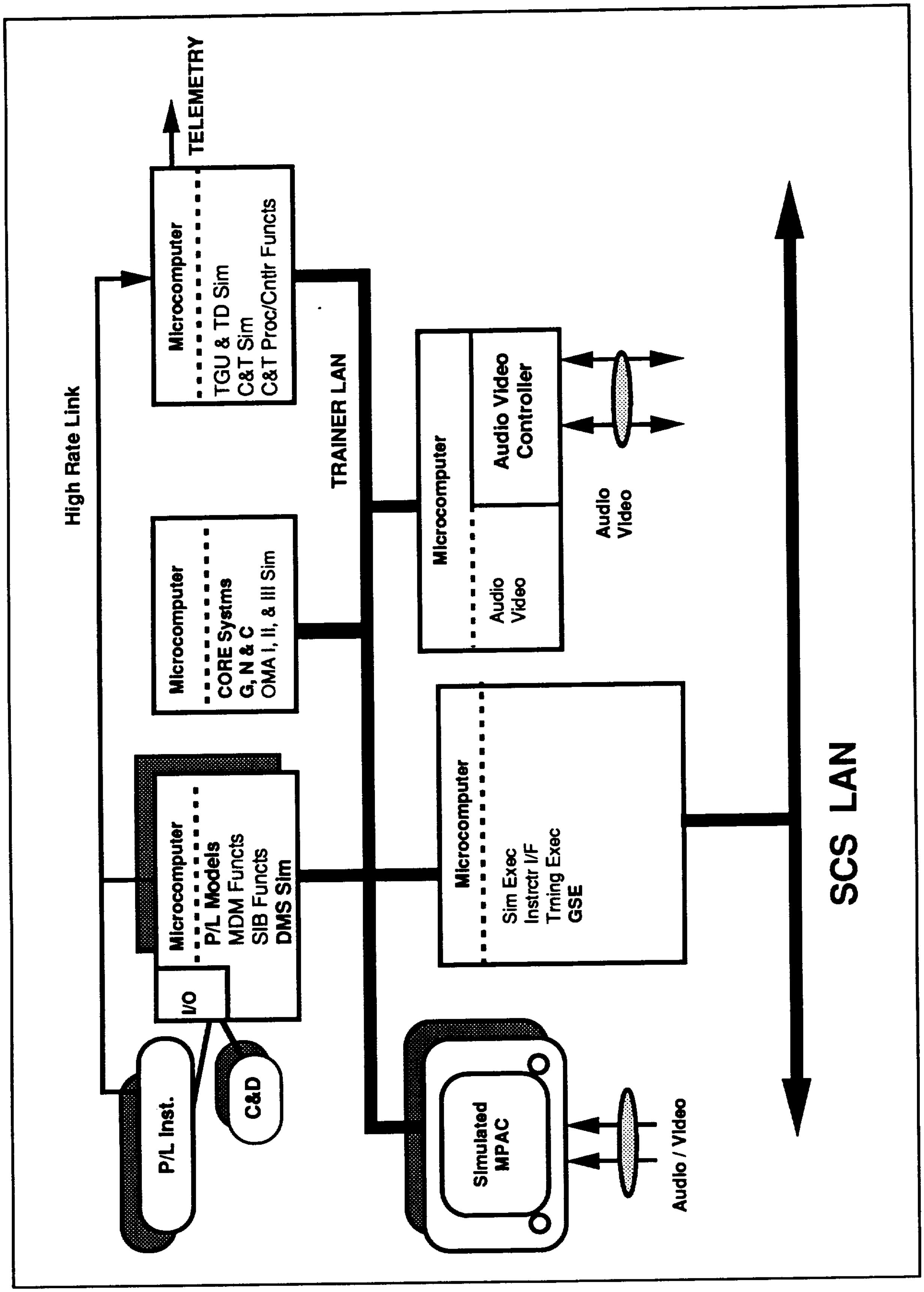

Figure 4.4-1 DMS Equivalent Module & PTT Trainer Design

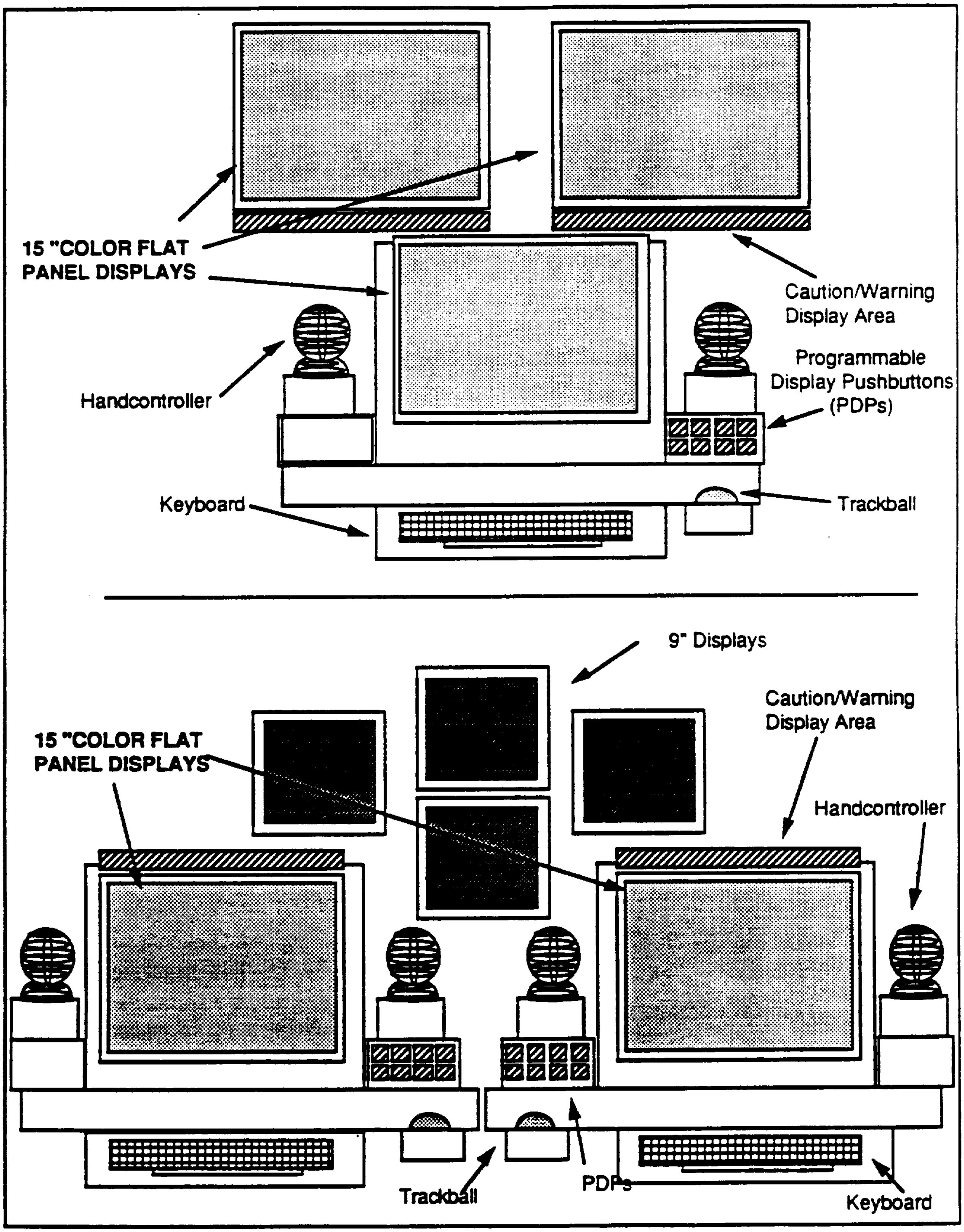

Figure 4.4-2 MPAC Layouts from March '90 PDR

4.5 OTHER DESIGNS

A number of other designs and options were considered during this very extensive baseline architecture effort. These pictures are printed here to aid future design discussions. The first, Figure 4.5-1, illustrates the use of an eighth DMS Kit to support an independent Attached Payload trainer. This design has all the features and advantages of the seven kit design, plus the additional advantage of independent training of attached payloads.

Figure 4.5-2 illustrates the nine PTT racks being driven by a current PTT sized DMS Kit (3 MDMs) and a non-DMS host. This would support about 30% flight equivalent payloads. It would only be needed if more than one independent PTT session is required. Otherwise, the design shown in Figure 4.5-8 "PTT Racks Driven by One DMS Kit" would suffice. If concern for failure of the single host indicates a second host, the second host could be added to the Figure 4.5-8 design with minimal extra cost for interfaces and switches, rather than go to the Figure 4.5-2 design.

A higher percentage of flight equivalent payloads could be supported by utilizing one large DMS Kit for all nine PTT racks. The design shown in Figure 4.5-3 has enough MDMs to support flight equivalent payloads in all payload racks. This design also has very poor failure tolerance. Also, note that by adding three SDPs and one SIB and some other DMS components, we have the equivalent of a second DMS Kit to support PTT training. Add a second host, and a much more fault tolerant design can be produced.

Since the current Level II DMS Kit database shows three DMS Kits allocated for the PTC, several other three DMS Kit designs were done to explore the possibilities. The best one was selected for the CBR baseline. The others are here for reference.

The features of the all DMS Kit design shown in Figure 4.5-4 are:

- High fidelity training and support of the PDRD training requirements.
- Medium cost. In designs with no non-DMS Kit trainers, which eliminates the cost of hardware and software needed to simulate the DMS functions, costs are somewhat offset by the special switches and cables required to produce these design. Also, four less DMS Kits required than the baseline design. However, if the reduced load is to be supported, non-DMS PTTs must be developed.
- With the addition of non-DMS PTTs, there is high potential for problems in migrating payload models from the PTTs to the Module Trainers.
- No problems in transporting payload models from the PTC to the SSTF.
- Poor failure recovery. If one module DMS Kit fails, one half of training capability is lost. If non-DMS PTTs are used, this one third number gets smaller.

- Functions are not separable. Unit test would be done on the module trainers, probably in non-day shift hours.

- High design risk. Unless non-DMS PTTs are used, cable lengths and the switches required present a high probability of design problems that could necessitate major design reworks midway through. If non-DMS PTTs are used, the technical problems of migrating payload models from simulated to real DMS Kits arises.

More independent sessions can be supported via non-DMS PTTs. Considering the various three kit designs against the training loading analysis in section 1.2, it is clear that non-DMS PTTs will be needed to support the anticipated training load.

The next three kit design in this section and the CBR design represent the end points of possible design options. The all DMS Kit design shown in Figure 4.5-4 illustrates one of the potentially possible end points as it is an all DMS Kit design. To make this design possible, significant design assumptions (and thus risks) must be accepted. Assumptions associated with this design are:

- Switches for all types of signals (analog, digital, video, audio) of varying rates can be produced.

- Switches for Host to SIB connections can be made.

- Cable lengths are assumed to be no problem. Seventy five feet is the current SIB to DMS Kit limit.

Figure 4.5-5 Three Kit Local Host Partial DMS Layout shows a design that is between the two end point designs, the all DMS Kit and CBR designs. This design solves the problem of migrating simulations from simulated DMS to the real DMS Kit environment in the module trainers with a minimum of switching and cable length design risk.

The final three kit design, shown in Figure 4.5-6 Three Kit Local Host PTT Kit is a look at spreading the three available kits among three functions (Module Training, PTT Training, and IT&V) rather than two (Module Training & IT&V) as was done in the previous designs. This design also mitigates the problem of migrating simulators from non-DMS PTTs to the DMS Kit environment. However, utilizing one DMS Kit between the two module trainers, due to the required switches, presents a high degree of design risk.

If the requirements for flight equivalent payloads and payload flight software support are reduced from 40% to 33%, a second 5 Kit design with one DMS Kit for nine PTT racks, and one Kit for development is possible. This design is illustrated in Figures 4.5-7 and 4.5-8. Serious disadvantages of this design are that:

- The two US payload PTT sessions would be non independent.

- If the one US PTT kit failed, 100% of the PTC facility US PTTs would be down.

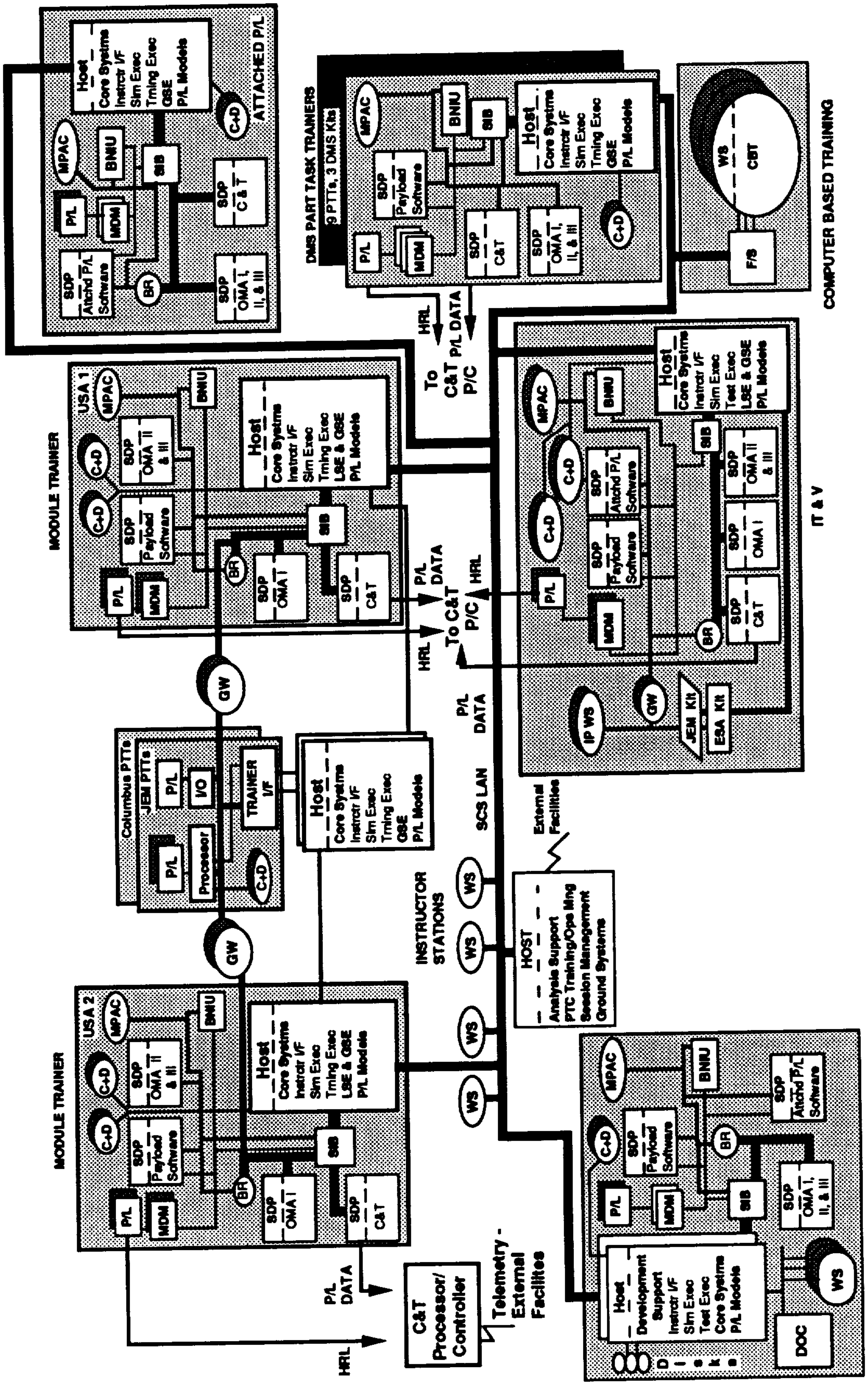

Figure 4.5-1 Eight Kit Local Host Design

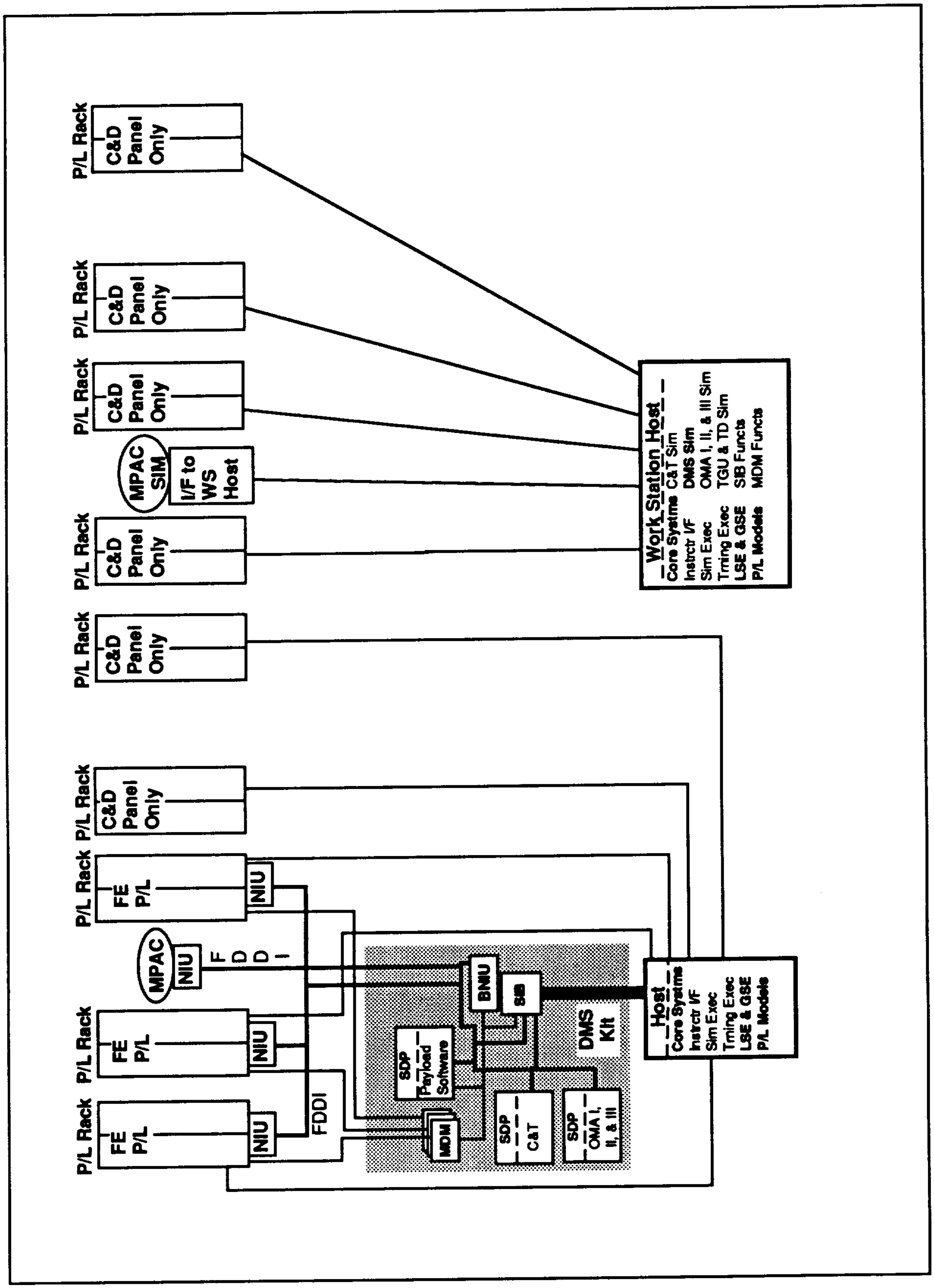

Figure 4.5-2 PTT Racks Driven by One DMS Kit & Non-DMS Hosts

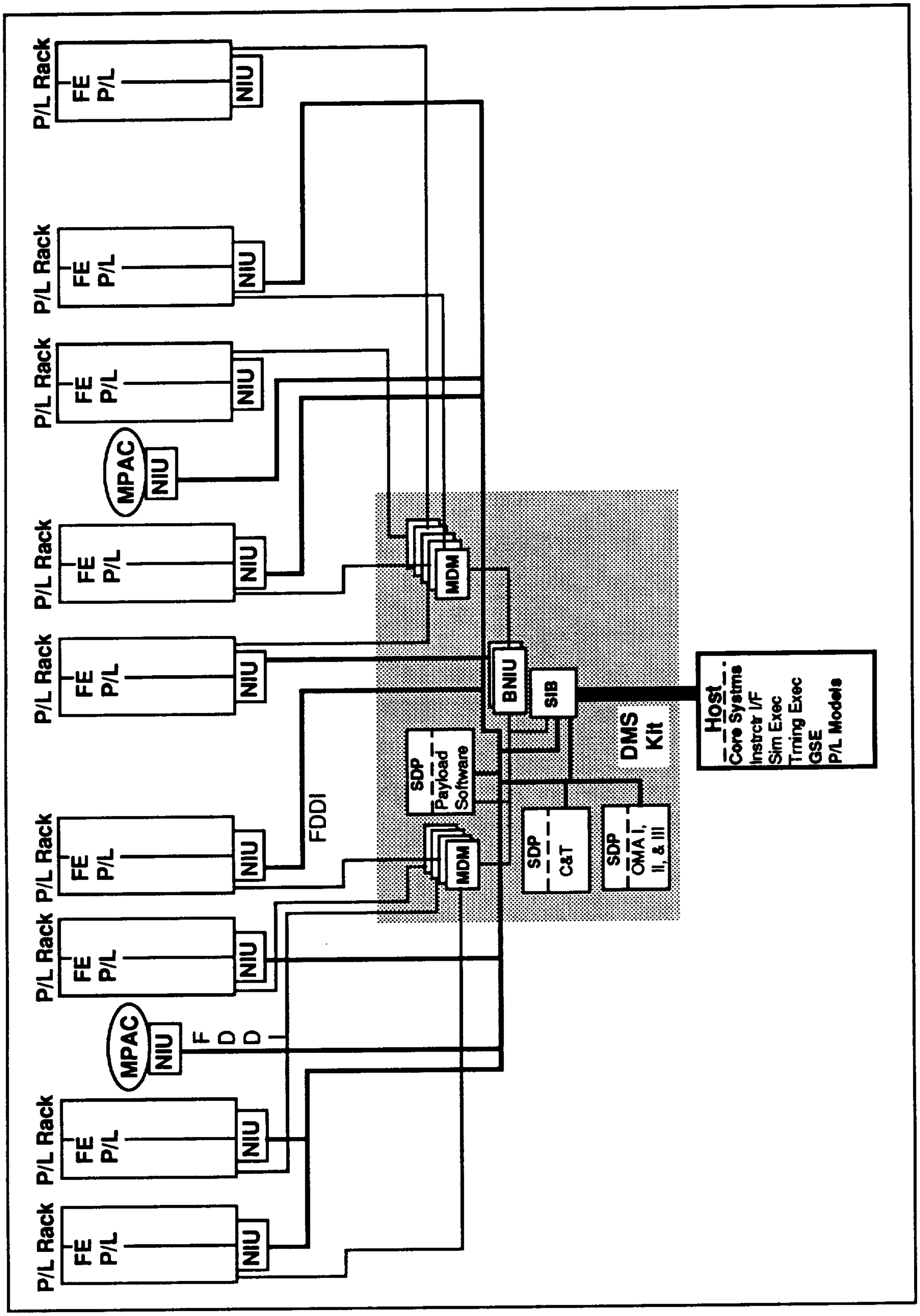

Figure 4.5-3 PTT Racks Driven by One Large DMS Kit

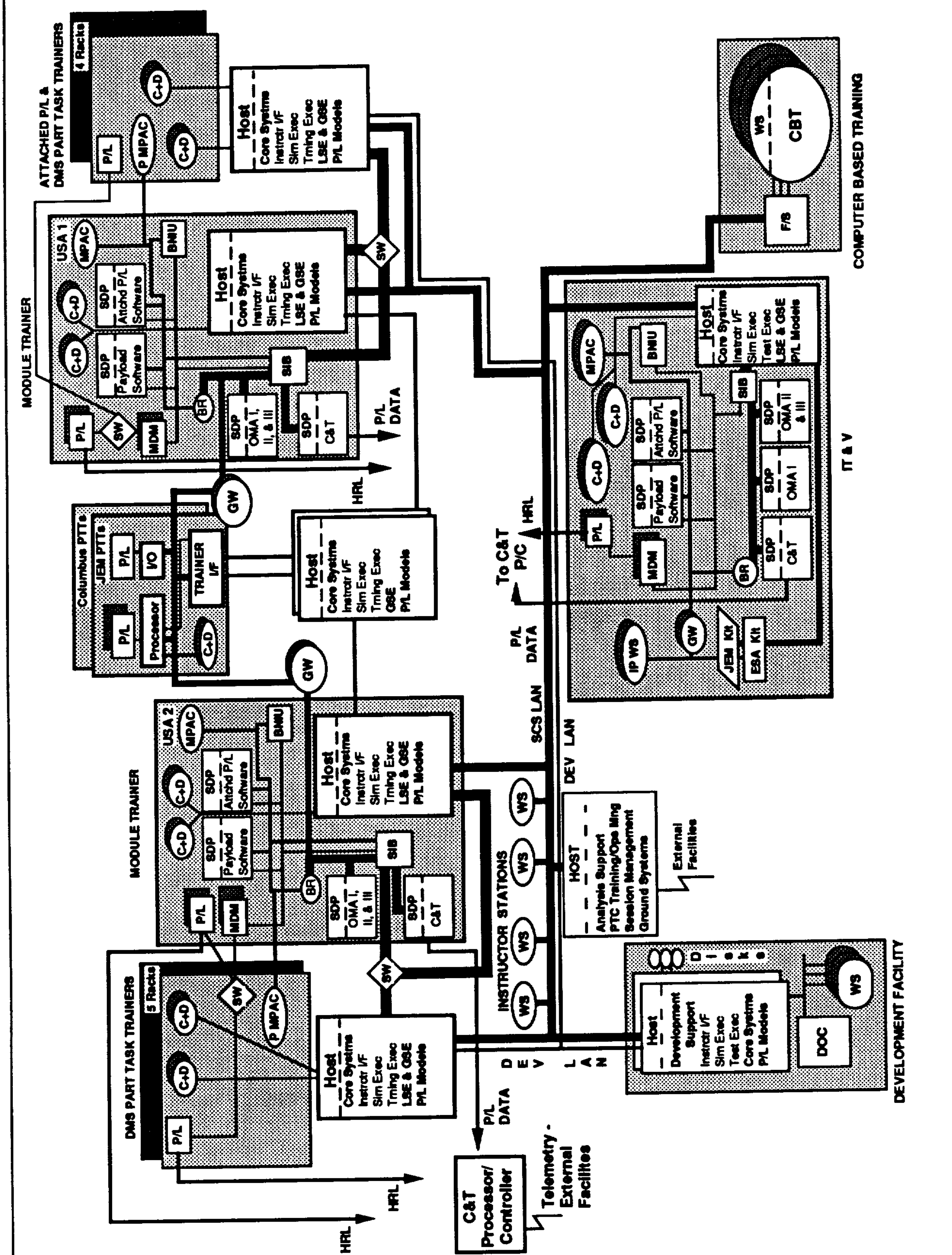

Figure 4.5-4 Three Kit Local Host All DMS Kit Layout

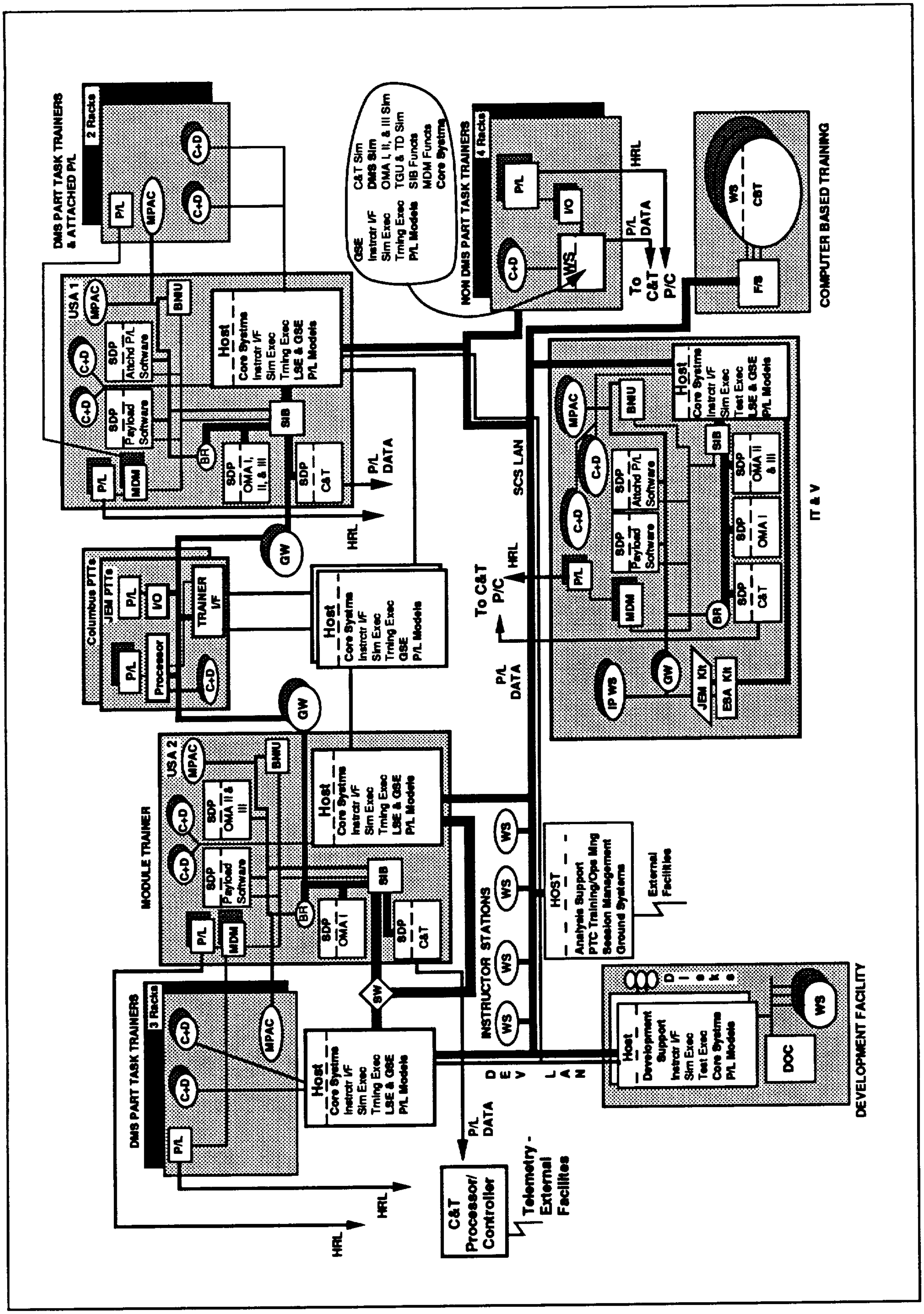

Figure 4.5-5 Three Kit Local Host Partial DMS Layout

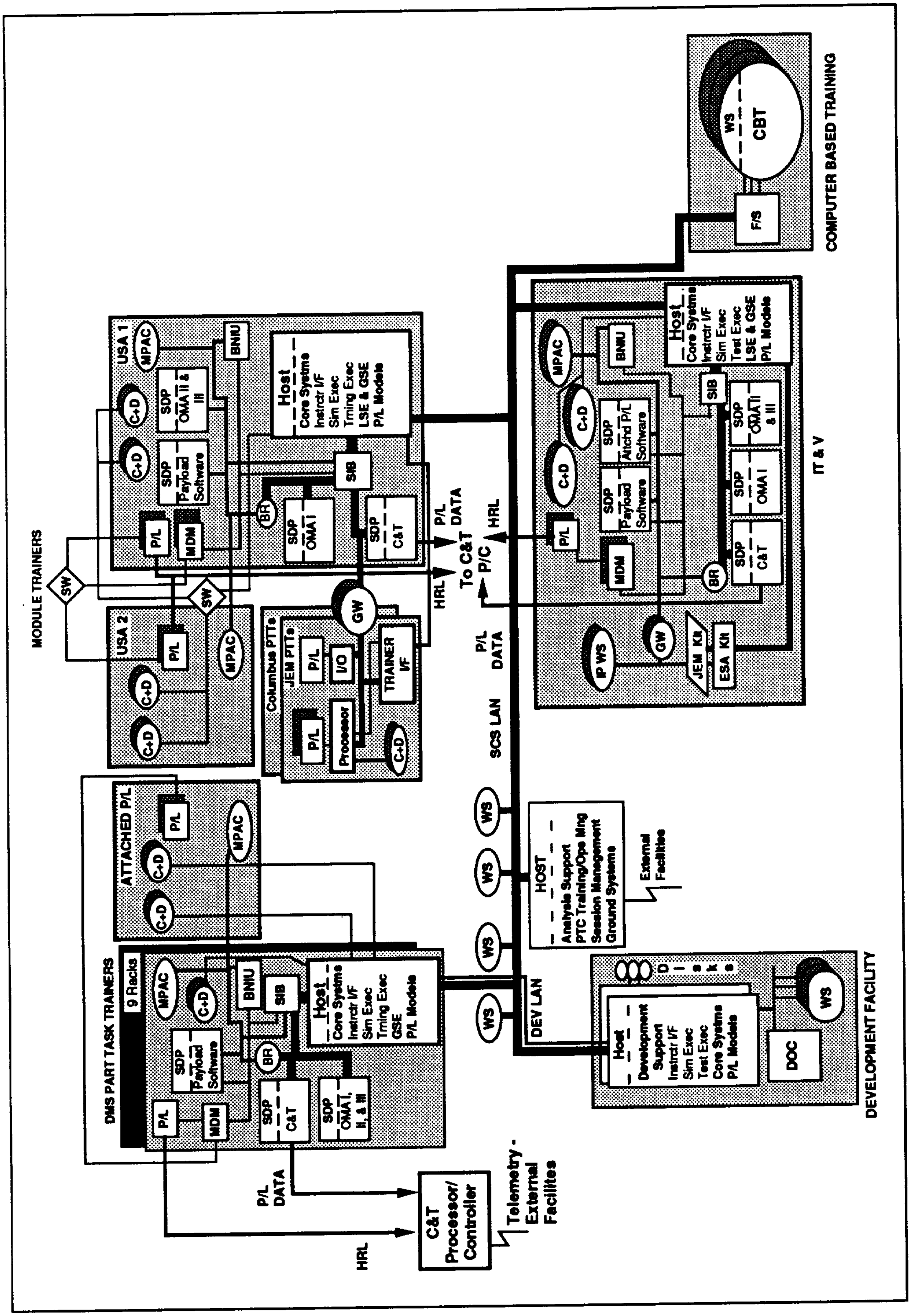

Figure 4.5-6 Three Kit Local Host PTT Kit Layout

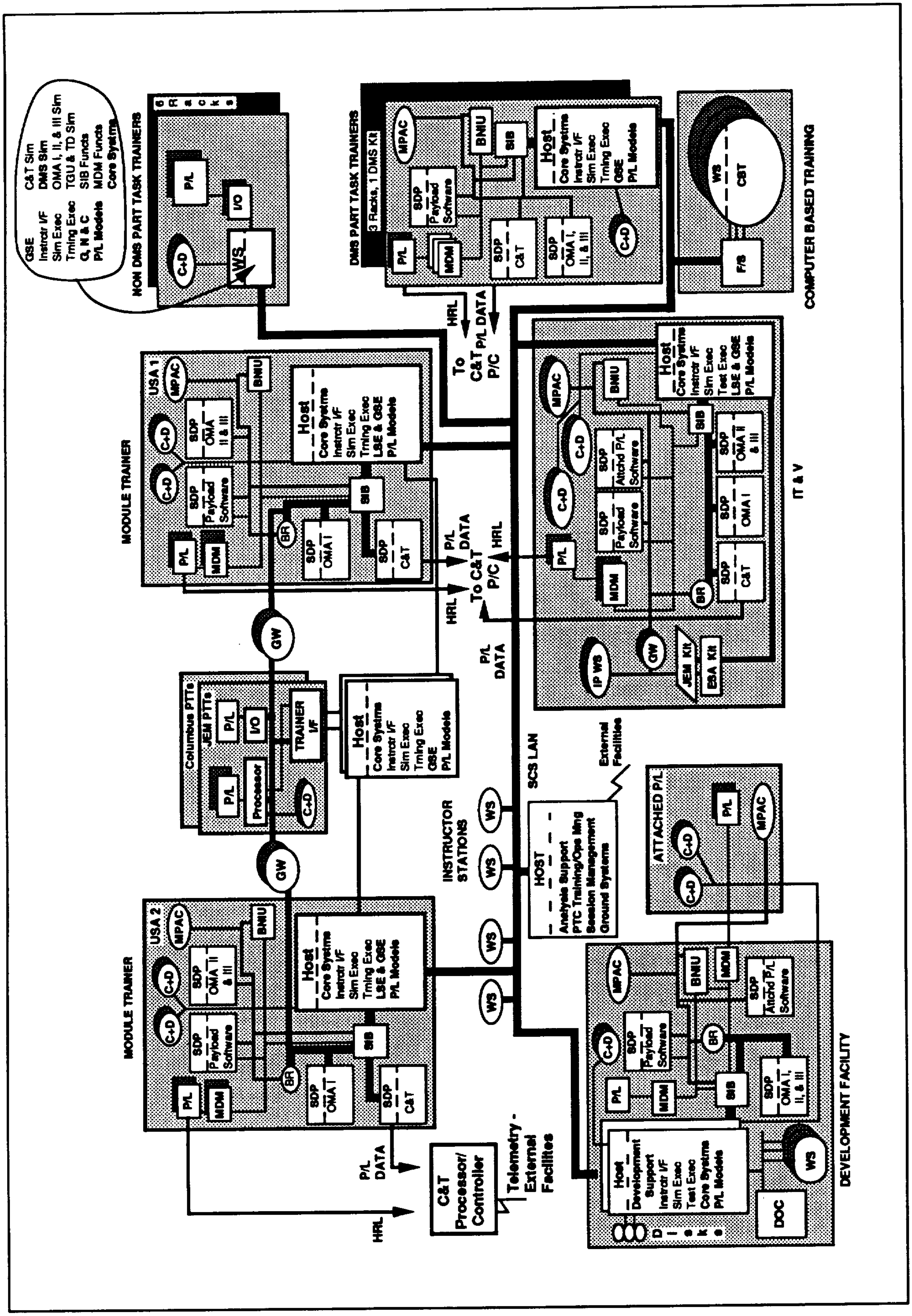

Figure 4.5-7 Five Kit Local Host Design with Development Kit

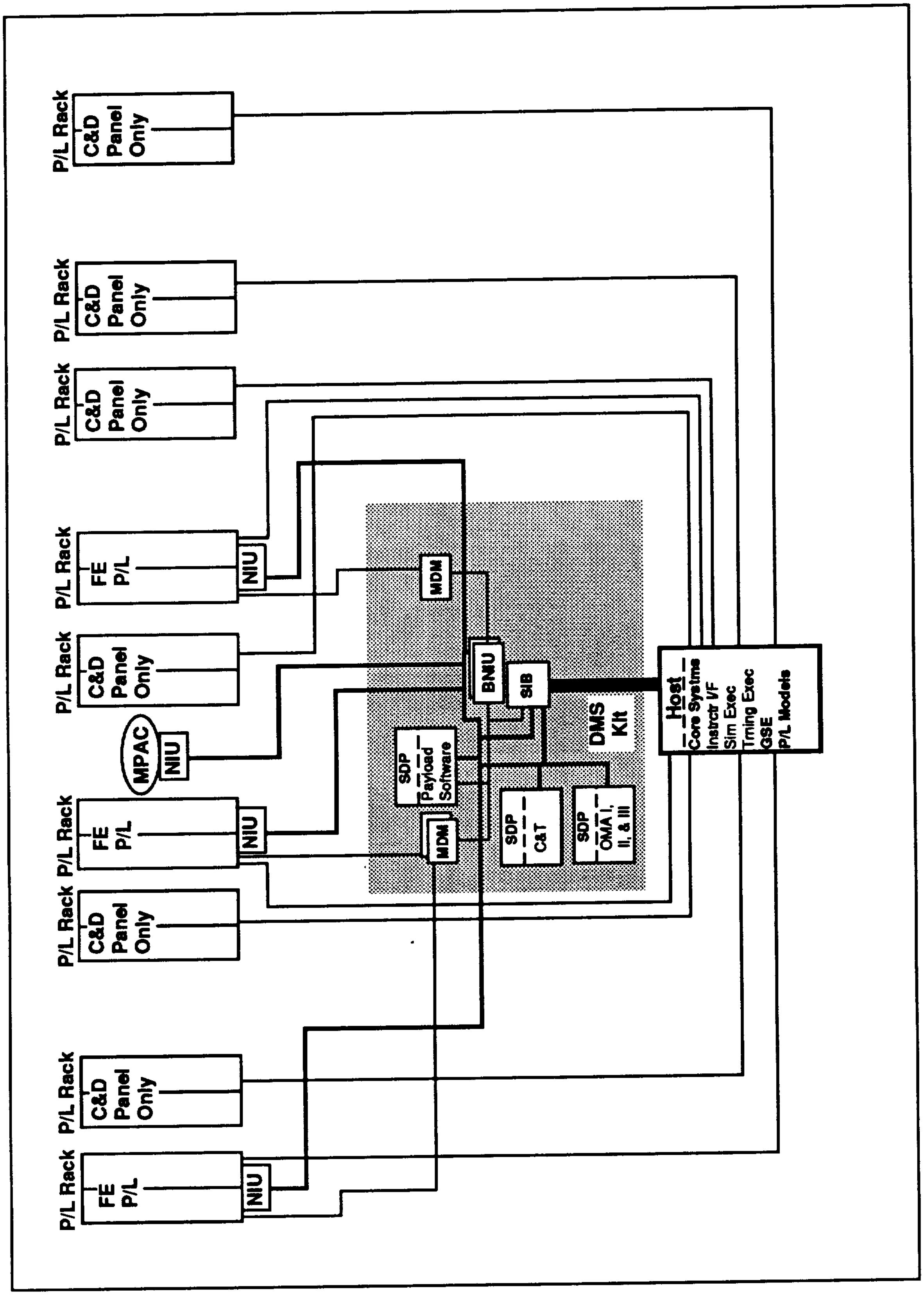

Figure 4.5-8 PTT Racks Driven by One DMS Kit

GLOSSARY

ACD - Architecture Control Document
APAE - Attached Payload Accommodation Equipment
BIA - Bus Interface Adapter
BNIU - Bus Network Interface Unit
CAMAC - Computer Automated Measurement And Control
CBR - Configuration Budget Review
CBT - Computer Based Training
CD - Cost Driver
CEI - Contract End Item
CGI - Computer Generated Imagery
CM - Configuration Management
COTS - Commercial Off The Shelf
CSCI - Computer Software Configuration Item
CUI - Common User Interface
DEMI - Deliverable Executable Machine Instruction
DMS - Data Management System
DOC - Discipline Operation Center
DOD - Department of Defense
DPM - Display Memory
EBCDIC - Extended Binary-Coded Decimal Interchange Code
ECAS - Experiment Computer Application Software
ECLSS Environmental Control Life Support System
ECOS - Experiment Computer Operating System
ECWS - Element Control Workstation
EDP - Embedded Data Processor
ESA - European Space Agency
ESC - Engineering Support Center
EVA - Extravehicular Activity
FCD - Functional Control Document
FEL - First Element Launch
FEU - Flight Equivalent Unit
FMPAC - Fixed Multi-Purpose Applications Console
FMS - Fluid Management System
FSIM - Functional Simulation
G,N&C - Guidance, Navigation, and Control
GFE - Government Furnished Equipment
GP - General Purpose
GSE - Ground Support Equipment
GSFC - Goddard Space Flight Center
GW - Gateway
HRL - High Rate Link
HWCI - Hardware Configuration Item
Hz - Hertz
IAV - Internal Audio Video
ICD - Interface Control Document
ICE - In-Circuit Emulator
IOS - Instructor Operator Station

IPS - Instrument Pointing System
IRD - Interface Requirement Document
IT&V - Integration, Test, and Verification
ITVE - Integration, Test, and Verification Environment
JEM - Japanese Experiment Module
JSC - Johnson Space Center
LAN - Local Area Network
LSG - Life Science Glovebox
LSW - Lab Science Workbench
MB - Megabytes
MDM - Multiplexor/Demultiplexor
MIPS - Millions of Instructions per second
MMU - Mass Memory Unit
MPAC - Multi-Purpose Application Console
MPS - Mission Planning System
MSFC - Marshall Space Flight Center
MSU - Mass Storage Unit
MWS - Materials Science Workbench
NASA - National Aeronautics and Space Administration
NDT - Non-scheduled Downtime
OMA - Operation Management Application
OMGA - Operation Management Ground Application
OMS - Operation Management System
OOD - Object Oriented Design
ORU - Orbital Replaceable Unit
OSI - Open Systems Interconnection
PC - Personal Computer
PCTC - Payload Crew Training Complex
PD - Payload Developers
PDR - Preliminary Design Review
PDRD - Program Definition & Requirements Document
PFE - PTC Facility Equipment
PI - Principal Investigator
PM Preventive Maintenance
PMMS - Process Materials Management Subsystem
PMPAC - Portable Multi-Purpose Applications Console
POGA - Payload Operations Ground Application
POIC - Payload Operations Integration Center
PSS - Payload Support System
PTC - Payload Training Complex
PTD - PTC Training Devices
PTT - Part Task Trainer
RAU - Remote Acquisition Unit
RC - Ring Concentrator
ROC - Regional Operation Center
RODB - Runtime Object Data Base
RTC - Real Time Clock
SA - Structured Analysis
SCS - Simulation Computer System

SCSI - Small Computer System Interconnection Standard
SDDU - System Development & Diagnostic Unit
SDF - Spacelab Software Development Facility
SDP - Standard Data Processor
SDT - Scheduled Downtime
SIB - Simulation Interface Buffer
SMF - Session Management Function
SPA - System Product Assurance
SRS - Software Requirements Specification
SRT - Scheduled Application Run Time
SS - Space Station
SSCC - Space Station Control Center
SSE - Software Support Environment
SSF - Space Station Freedom
SSFP - Space Station Freedom Program
SSIS - Space Station Information System
SSP - Space Station Program
SSTF - Space Station Training Facility
TBD - To Be Determined
TDB - Time Distribution Bus
TGU - Time Generation Unit
TMIS - Technical Management Information System
UIMS - User Interface Management System
UOF - User Operation Facility
UPW - Ultra Pure Water
USE - User Support Environment
WAN - Wide Area Network
WP01 - Work Package 1
WP02 - Work Package 2
ZOE - Zone of Exclusion

APPENDIX A - 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.

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).

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: <u>4-6</u>

Number of people simultaneously trained in each of the three Combined Trainers: <u>4</u>

Number of people simultaneously trained in each of the nine Part Task Trainers: <u>2</u>

Number of people simultaneously trained in the Attached Payload Trainer: <u>1</u>

Number of people simultaneously trained in each of the seven POIC Trainers: <u>2</u>

Number of people simultaneously trained in the CBT Trainers: <u>8</u>

Number of people simultaneously trained in the entire PTC: <u>40</u> 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: <u>15</u>

Number of simulation developers: <u>100</u>

Number of integration and test personnel: <u>10</u>
(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 Host MIPS 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)

0.5 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 A-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 A-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 A-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 A-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.

APPENDIX B - SOFTWARE SIMULATION FIDELITY LEVELS

Level 1 Fidelity Simulation: Level 1 fidelity simulations are simulations based on highly accurate mathematical representations that execute on a **cyclic basis.** They provide data values, command responses, timing, performance and user interface characteristics that are identical or nearly identical to those in the flight environment. This type of simulation uses **highly accurate dynamic equations with appropriate cross-coupling** between simulated elements. Requirements for these simulations are based on the characteristics of the hardware or software element to be simulated. These simulations provide a level of functional accuracy suitable for evaluating and estimating the expected performance of the flight system. Potential applications are performance evaluation, training, software testing, hardware integration/testing, problem investigation, on-orbit mission support and subsystem/system integration.

Level 2 Fidelity Simulations: Level 2 fidelity simulations are simulations based on highly accurate mathematical representations that execute on a **cyclic basis** They provide data values, command responses, timing, performance and user interface characteristics that are identical or nearly identical to those in the flight environment. This type of simulation makes use of **simplified dynamic equations with minimal cross-coupling** between simulated elements. These simplifications are based on engineering approximations and heuristics (i.e. a reduction in degrees of freedom). Requirements for these simulations are based on characteristics of the hardware or software elements to be simulated and the intended use of the simulation. These simulations do not allow the evaluation of the expected performance of the complete flight system but allow limited performance evaluation of some flight system elements. Potential applications are limited performance evaluation, training, software testing, hardware integration and testing and subsystem/system integration.

Level 3 Fidelity Simulations: Level 3 fidelity simulations are simulations containing **simple relationships between stimuli/commands and responses** that execute on an **event-driven basis.** They present the correct interface to the flight hardware/software and provide selected data values, command responses and user interface characteristics to an appropriate level of accuracy for the application of the simulation. No dynamic equations arc included in this type of simulation and simulated values are updated on a straight line or time delay basis. Requirements for these simulations are based on the appropriate interface description and the intended application of the simulation. Potential applications are low fidelity training, software testing, limited hardware integration and testing and subsystem/system integration.

Level 4 Fidelity Simulations: Level 4 fidelity simulations are simulations that provide the correct interface to the fight hardware/software and create a **static data flow load** to the associated network/bus that is the same loading that would be produced by the flight element. These simulations provide **little or no functional capability, no command responses and no dynamic data.** Requirements far these simulations are based on the appropriate interface description. Potential applications are build up and interface testing at integration/test facilities, early prototyping and network/bus loading studies. This type of simulation is usually the starting point for simulations that require higher levels of fidelity.

APPENDIX C - TRAINING LOADING ANALYSIS

Initial Estimates

The initial estimates performed on the original study contract were based on early space station data and only dealt with the crew training time periods. This estimation was only intended to provide very rough numbers to allow some sizing analysis for the SCS to support the requirements of the PTC. The estimates were based on the study team's past training experience and generated some percentages of training for the different functions. The percentages are as follows:

CBT, Payload Orientation, Class Room, & PI Site Visits	20%
PTT	40%
Module	20%
Consolidated	20%

These percentages were applied to the training flow and mapped to increments to show the concurrent training that must occur. The number of concurrent training sessions and their degree of independence drive the number of DMS kits, computers, and workstations required to accomplish payload training. The summary of this analysis is depicted in Figure A-1.

Spacelab Analysis

In order to determine more detailed estimates for SCS training, figures were utilized from past Spacelab experience. The Spacelab training hours could be correlated to Space Station for both crew training and POIC training. The estimates for the PI support and PTC development support were based on the current Space Station Program definition/schedule and our best engineering judgment. The following sections provide the details of this analysis.

Crew Training

Utilizing past Spacelab documentation (Astro-1 Integrated Training Plan) for Experiment/Instrument Training, the number of hours required for training per payload were estimated. Following are the types of training and approximate hours required for the Spacelab Astro mission.

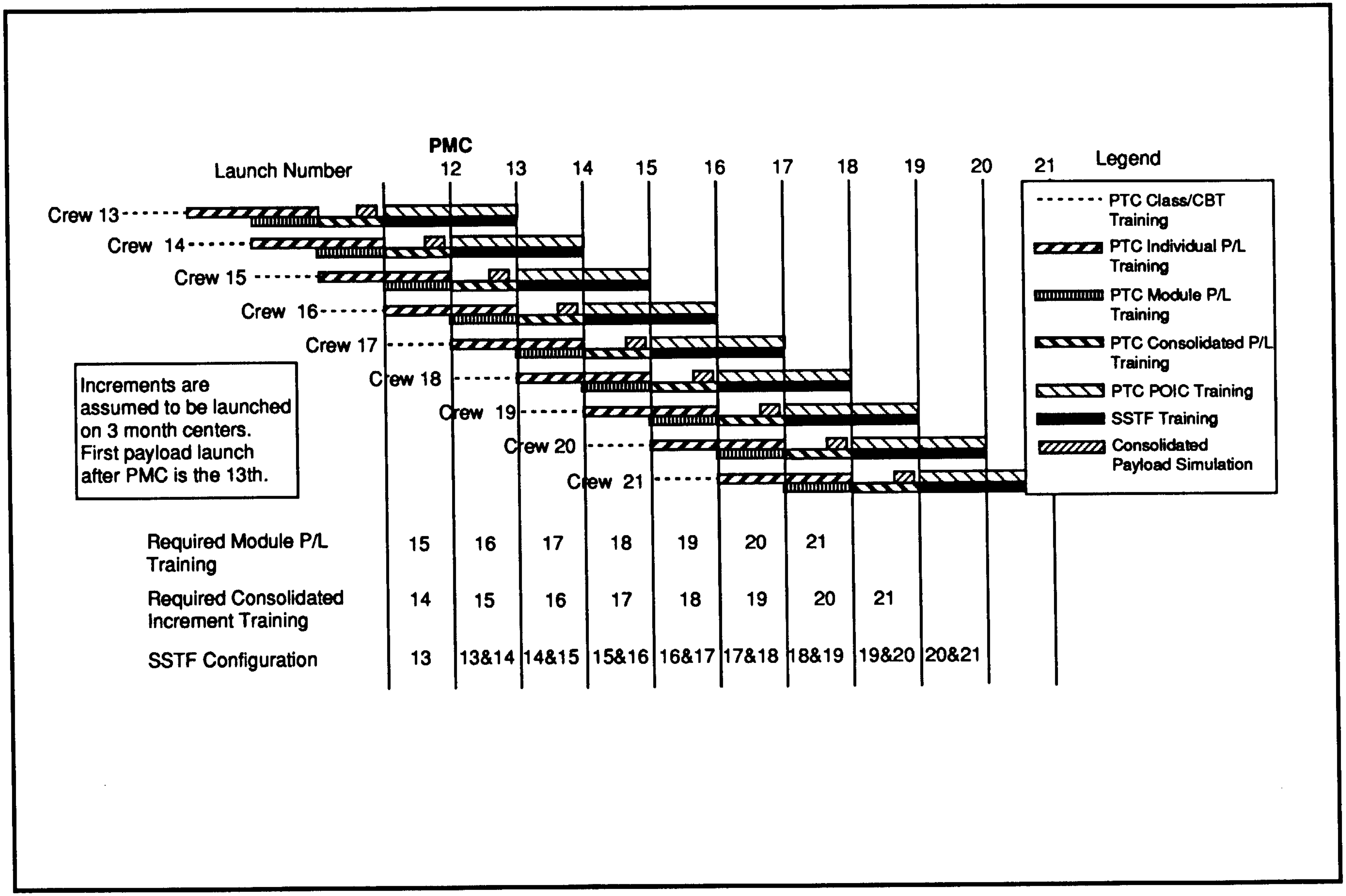

Figure A-1. Initial Training Increment Flow Analysis 90-Day Payload Increments/90-Day Crew Increments

Type of Training	CR	HO	Total Hours
Payload Orientation (PO)	16		16 hours
System/Experiment Interface Training	18		18 hours
Experiment/Instrument Training			
Image Motion Compensation System	11	4	15 hours
UIT	16	24	40 hours
HUT	9	51	60 hours
(+48 for new MS)	48		48 hours
WUPPE	4	56	60 hours
(+48 for new MS)	48		48 hours
Joint Operations (Combined Training for 4 experiments)	3	12	15 hours
(+24 for new MS)	24		24 hours
BBXRT	8	16	24 hours
Subtotal (Experiment/Instrument Training)	171	163	334 hours
Integrated Timeline Proficiency Training	8	24	32 hours
Simulations/Briefings	208		208 hours
Total	**592**	**350**	**942 hours**

CR = Classroom Training **HO = Hands-on Simulator Training**

Taking an average of the Experiment Training hours (IMCS[15] + UIT[40] + HUT[60] + WUPPE[60] + BBXRT[24]), excluding hours for new MS, yields 40 hours (199/5) as the average amount of training per payload. This data also shows the average 40 hours is broken into 10 hours of classroom training and 30 hours of hands-on training. As shown in the Reference Mission used in the SCS Study Analysis Report, there will be an estimated 43 U.S. Lab payloads per increment that require training. This complement is also made up of 17 complex/medium payloads and 26 simple payloads. The Astro mission is made up completely of complex and medium payloads. For the purposes of this analysis, the training hours for the simple payloads are estimated to be half of the required hours for complex and medium payloads in CBT/Classroom and part task training.

In our Study Analysis Report we determined that an equal number of experiments (43) will reside in the International Partner (IP) modules. Of that number we expect approximately 40% to be U.S. sponsored payloads. Therefore, we assume that there are 17 (43 X .4) U.S. payloads with the same ratio of complex/medium and simple experiments as in the U.S. Lab. This implies that the 17 is made up of 7 complex/medium experiments and 10 simple experiments.

CBT/Classroom Training

The CBT/classroom time for SSF training can be estimated as follows:

Payload Orientation	16
System/Experiment I/F	18
10 Hours per USL complex/medium payload(17)	170

5 Hours per USL simple payload(26)	130
10 Hours per IP complex/medium payload(7)	70
5 Hours per IP simple payload(10)	50
Integrated Timeline Proficiency	8
Simulations/Briefings	<u>208</u>
	670 Hours

Part Task Training

The calculations for estimating the PTT hours based on the Spacelab data are as follows:

30 Hours per USL complex/medium payload(17)	510
15 Hours per USL simple payload(26)	390
30 Hours per IP complex/medium payload(7)	210
15 Hours per IP simple payload(10)	<u>150</u>
	1260 Hours

Module Training

The estimation for module training hours is based on the Astro joint operations training and the integrated timeline training. However, we must take into account the complexity of payloads and the fact that the Astro experiments were tightly coupled since they were mounted on the IPS. Therefore, training hours for simple payloads are estimated at one hour for each of the two types of training. For this analysis, we have also assumed that the total hours necessary are approximately 15% less due to greater independence of the payloads. The total hours estimate is calculated as follows:

Astro hands-on joint operations training was 12 hours and involved 4 exp.
12/4 = 3 hours per experiment

Astro integrated timeline training included 5 experiments for 24 hours
24/5 = 4.8 hours per experiment

1 hour is utilized in each exercise for simple payloads

<u>**The total hours are:**</u>

Joint Operations:

3 Hours per complex/medium payload(17)	51
1 Hour per simple payload	26

Integrated Timeline:

4.8 Hours per complex/medium payload(17)	82

1 Hour per simple payload(26)	26
	185
Subtract 15% due to greater independence for the majority of SSF payloads	-28
	157 hours

Consolidated Training

The SSF consolidated training is expected to resemble the Spacelab integrated timeline training. Therefore, we can extrapolate the data from the integrated timeline activities to provide an estimate. Since the consolidated training includes about the same number of experiments in the two International Partner modules, we will assume that there are 86 payloads which include 34 complex/medium and 52 simple experiments. However, we must also assume that there is at least 25% less interactions between the total number of payloads in SSF considering that they are in different modules.

4.8 Hours per complex/medium payload(34)	163
1 Hour per simple payload(52)	52
	215
Subtract 25% due to greater independence	-54
	161 hours

Total Crew Training

The following table summarizes the estimated training hours and the percentages of the total training.

Training	Hours	% of Total
CBT/Classroom	670	30
Part Task Training	1260	56
Module Training	157	7
Consolidated Training	161	7
TOTAL	2248	100

Although these numbers can be supported by resources in the SCS, the real limiting factor is the crew availability. If the crew were available 100% of the time, there would be 2080 hours for training. Obviously, the 2244 hours estimated cannot be accomplished in the one year allotment for training. This estimation,except for consolidated, includes only U.S. payload training time. When considering total crew training activities, the training for the International Partner payloads must be considered. The same training assumptions for the SCS hour estimates can be applied to the remaining experiments in the IP modules. A quick estimate for the overall crew training hours can be calculated as follows:

SCS hours	2248
International CBT/Classroom	180
International part task training	540
International module training	157
Total Training Hours	3125
15% for travel, etc.	469
TOTAL HOURS	3594

This would indicate that a 21-month timeframe is necessary to train the crew members based on our training assumptions which includes a 40-hour week work schedule.

POIC Training

Estimates for POIC training are based on the Mission Independent Training Program Handbook for the Astro mission. Utilizing the list of courses for Mission Independent training, it was estimated that the Mission Dependent training was 30% of Mission Independent. In a similar fashion, upon calculating Line Organization Mission Independent training hours, it was estimated that Line Organization Mission Dependent training was 10% of Line Organization Mission Independent. Hours estimated for Self-Study are a general estimate arrived at by talking with NASA personnel. Approximate hours per POIC trainee for each designated type of training are identified below:

Mission Independent =>	307 hours
Mission Dependent =>	92 hours
Line Organization	
Mission Independent =>	16 hours
Mission Dependent =>	2 hours
Self-Study Training =>	18 hours
Total	435 hours

The CBT hours can be estimated as follows:

New Personnel

Assume 5 POIC crews of 25 personnel each
Assume a 10% yearly turnover rate
Assume that 75% of the above training can be accomplished with CBT

5 X 25 = 125 total personnel X 10% = 12.5 personnel to be trained each year

435 X .75 = 326 hours X 12.5 = 4075 CBT training hours/year

Incremental Training

Assume 4 hours CBT per experiment
Assume 7 experiments per 90-day increment (15% changeout)
Assume 5 crews of 25

125 X 7 X 4 = 3500 hours per 90-day increment

4 increments/year X 3500 = 14,000 hours/year

Any training which involves module or consolidated modes is expected to be accomplished in conjunction with the crew activities. Therefore, no additional SCS resources (other than the link to the POIC) are anticipated to support that type of POIC training.

Principal Investigator Support

Estimates for the support for the PIs include some training on SCS operations and hours to support to the integration and checkout of their experiment simulator. Based on the 15% changeout every 90 days, we can expect 7 new PIs with payloads for the U.S. Lab every increment and as many as 3 experiments for IP modules. Assume training for a 3 member PI team training concurrently. If we assume 4 hours of training on the SCS operations (CBT) and 2 weeks for integration and checkout of the payload simulator, we can estimate hours as follows:

CBT Training per increment (10 X 4) =	40 hours/increment
4 increments/year X 40 X 3 menloads in each PI team =	480 hours/year
U.S. Lab PTT Use per increment (7 X 80)	560 hours/increment
IP PTT Use per increment (3 X 80)	240 hours/increment

PTC Personnel

For this exercise, the estimates for the PTC software personnel will only incorporate the needs for CBTs. The software development needs for a consolidated, module, or part-task configuration to support testing activities will be provided in the software development facility identified in the SCS designs. The CBT hours estimate can be determined by:

Assume 140 PTC personnel
Assume a 10% yearly turnover rate
Assume a 20 hour course on PTC overview and detailed operations for each new person

140 X 10% X 20 = 280 CBT hours per year

Also, CBT hours must be available for course development
Assume 20 hours per experiment to support PIs and other activities
10 X 20 = 200 hours per 90-day increment

Training Resource Estimate

Based on the training hours estimated in the preceding sections, an estimate of the resources necessary to support those training hours can be determined. For example, 4075 CBT training hours must be available to support POIC training for new personnel. Given 2080 hours available per year yields a requirement for 2 CBT stations to support the training of new POIC personnel (4075 ÷ 2080) given ideal scheduling. Realistically, trainees will only be available 1/2 of their turn, so to fulfill the rest will require 4 CBT STHS. An analysis of the increment flow is also necessary to determine the number of crews to be trained in any particular time period assuming 45-day and 90-day crew increments. The crew flow for a 45-day increment has been depicted in Figure A-2 and incorporates a 12-month PTC training period split by the percentages of training time from our estimates on each training function. The flow clearly shows the number of crew that are simultaneously involved in each training function. The number of trainers operating concurrently are estimated for each of the training functions in the following sections.

The analysis effort did consider the fact that the station operator will not need the degree of training required by the other crew members. However, we determined that this made no impact on the need for PTTs since the PTTs support two personnel per session. Therefore, a crew would still require 2 PTTs to train simultaneously whether it was made up of 3 or 4 personnel. The total hours of CBT station time would be impacted, but the costs of CBTs are expected to be minimal. Since the degree of training for various members of the crew is still undefined and the apparent cost impacts appear to be very minimal, the final estimates did not incorporate any varying degree of training for specific crew members.

45-Day Crew Increments

CBT

2 crews of 4 training simultaneously	8
New POIC personnel	4
Incremental POIC personnel training	7
PI and PTC personnel support	3
Number of concurrent CBT sessions	22

PTT

4 crews training simultaneously (2 per PTT)	8
PI support	1
PTTs in concurrent use	9

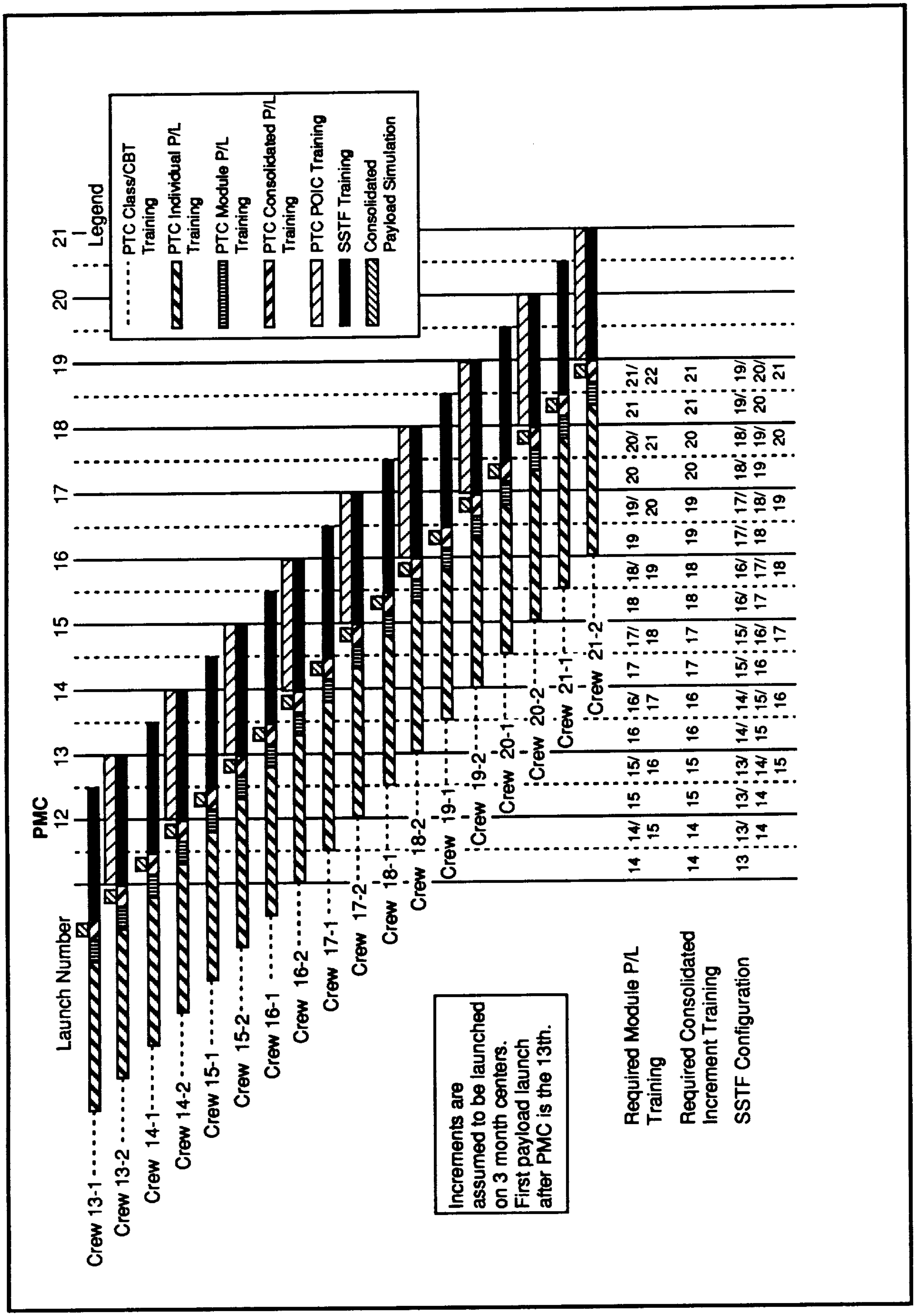

Figure A-2. PTC Training Increment Flow Requirements (Spacelab Data)

90-Day Payload Increments/45-Day Crew Increments

Based on the number of U.S. Lab experiments (43) and the number of U.S. sponsored experiments in the IP modules (17), the configuration of PTTs could include U.S. Lab (8 PTTs for U.S. Lab payloads) and IP (2 PTTs for JEM, and 2 PTTs for Columbus). Some time on the PTTs must be available to support the PI activity for payloads in the different IP modules, but the demand for U.S. Lab PTTs indicates the need for an additional PTT for the PI support. Since the PTTs will be different for each module, this implies that a total of 13 PTTs must be available to meet the possible training schedules and provide available time for PI support. The total number of configured PTT sessions that must be available at certain times in the training schedule are:

PTTs for U.S. payloads in the U.S. Lab (8 for crew and 1 for PI support)	9
PTTs for U.S. payloads in the JEM	2
PTTs for U.S. payloads in the Columbus	2
Concurrently available PTT sessions	13

Note -The U.S. Lab modules for module and consolidated training are expected to have available time to support any overflow of individual payload training.

Module

Only one crew at a time will need to be trained, so only a single U.S. Lab module and a single Attached Payload Trainer will be necessary to support training.

Consolidated

Only one crew at a time will need to be trained, so only a single Consolidated Trainer will be necessary to support training. The Consolidated Trainer must include a U.S. Lab module, a JEM module, an Attached Payload Trainer, and a Columbus Module. Since the 45-day increment flow shows simultaneous use of a module trainer and a consolidated trainer, a second U.S. Lab module will be necessary. It is expected that the Attached Payload Trainer can be the same one used to support U.S. Lab module training.

90-Day Crew Increments

If we evaluate the needs based on a 90-day crew increment, only those numbers involving the crew training must be modified. The following estimates are based on the 90-day flow shown in Figure A-3.

CBT

1 crew of 4 training simultaneously	4
New POIC personnel	4
Incremental POIC personnel training	7
PI and PTC personnel support	3
Number of concurrent CBT sessions	18

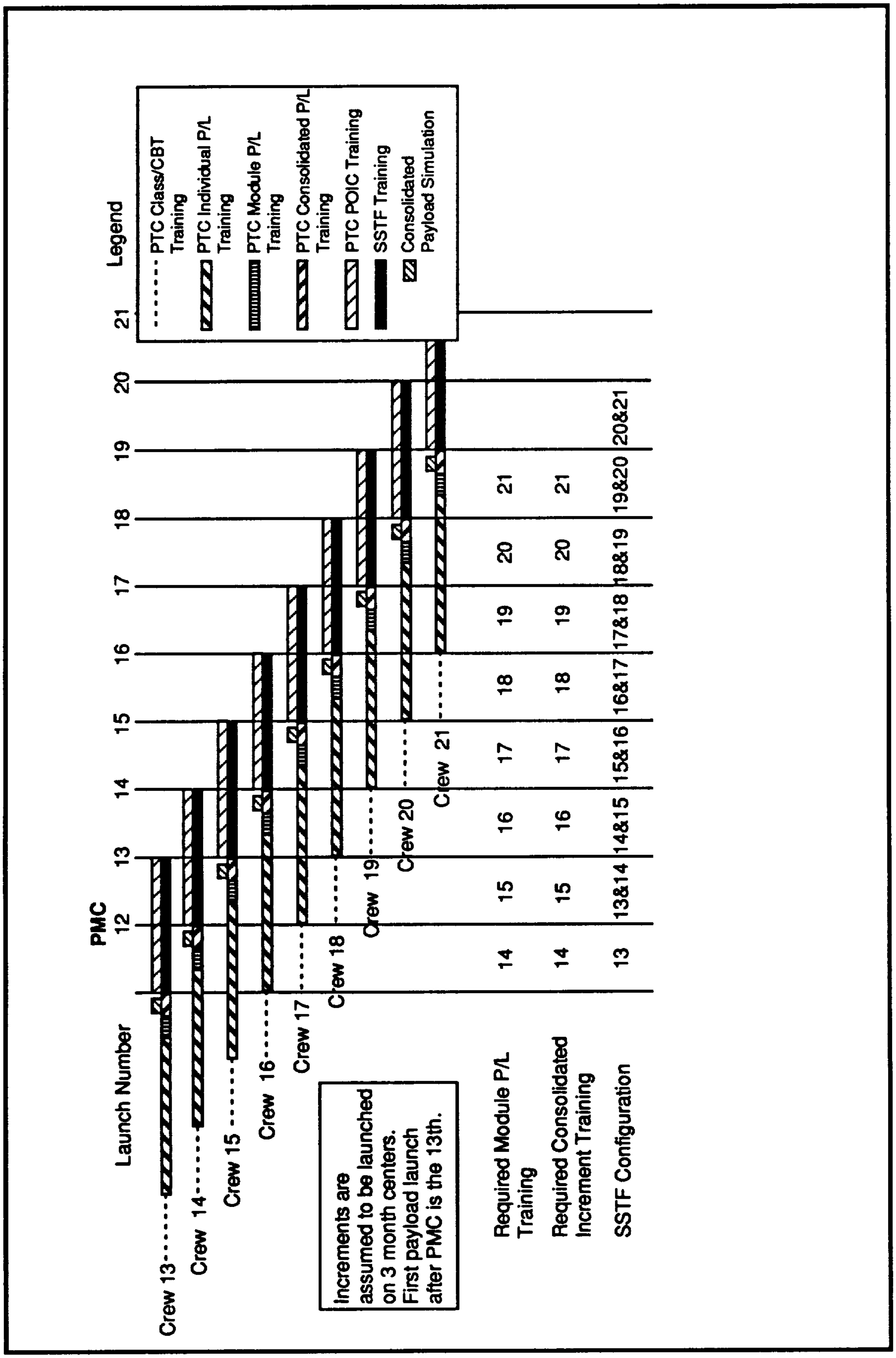

Figure A-3. PTC Training Increment Flow Requirements (Spacelab Data)
90-Day Payload Increments/90-Day Crew Increments

PTT

2 crews training simultaneously (2 per PTT)	4
PI support	1
PTTs in concurrent use	5

Based on the number of U.S. Lab experiments (43) and the number of U.S. sponsored experiments in the IP modules (17), the configuration of PTTs includes U.S. Lab (4 PTTs for U.S. Lab payloads) and IP (1 PTT for JEM, and 1 PTT for Columbus). Some time on the PTTs must be available to support the PI activity for payloads in the different IP modules, but the demand for U.S. Lab PTTs indicates the need for an additional PTT for the PI support. Since the PTTs will be different for each module, this implies that a total of 7 PTTs must be available to meet the possible training schedules and provide available time for PI support. The total number of configured PTT sessions that must be available at certain times in the training schedule are:

PTTs for U.S. payloads in the U.S. Lab (4 for crew and 1 for PI support)	5
PTTs for U.S. payloads in the JEM	1
PTTs for U.S. payloads in the Columbus	1
Concurrently available PTT sessions	7

Note -The U.S. Lab module is expected to have available time to support some overflow of individual payload training.

Module

Only one crew at a time will need to be trained, so only a single U.S. Lab module and a single Attached Payload Trainer will be necessary to support training. There will be available time in the module trainer to support needed time for individual payload training.

Consolidated

Only one crew at a time will need to be trained, so only a single Consolidated Trainer will be necessary to support training. The need for a second U.S. Lab module to support this will still be necessary even though there is no simultaneous operations expected for the module and consolidated trainers. This is due to the necessity for configuration time and some expected overflow of individual payload training into the U.S. Lab modules.

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NASA Contact - Michael Watson, MSFC, E035
TRW - Jeff Jensen, 213 Wynn Drive, Huntsville, AL 35805
Grumman - Michael Denny, 1000 Woodbury Road, Woodbury, NY 11797
Essex - Dan Dodson, 690 Discovery Drive, Huntsville, AL 35806

16. Abstract
NASA's Space Station Freedom program (SSFP) planning efforts have identified a need for a payload training simulator system to serve as both a training facility and as a demonstrator to validate operational concepts. The envisioned MSFC Payload Training Complex (PTC) required to meet this need will train the Space Station payload scientists, station scientists, and ground controllers to operate the wide variety of experiments that will be onboard the Space Station Freedom. The Simulation Computer System (SCS) is the computer hardware, software, and workstations that will support the Payload Training Complex at MSFC.

The purpose of this SCS Study is to investigate issues related to the SCS, alternative requirements, simulator approaches, and state-of-the-art technologies to develop candidate concepts and designs.

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