TECHNISCHE UNIVERSITÄT MÜNCHEN
FACHGEBIET RAUMFAHRTTECHNIK
PROF. DR.-ING. HARRY O. RUPPE

Richard-Wagner-Str.18
80333 München
Tel.: 089 / 289-16003
Fax: 089 / 289-16004

Forum der Luft- und Raumfahrttechnik München

Seminare der Universitäten, der DGLR, des VDI u.a.

Flugwesen und Weltraumforschung

Wintersemester 1996/1997

Hörsaal N1095*, 14.30 Uhr

Do, 21. November '96	**Kostengünstige Erde/LEO-Transportsysteme der nächsten zwei Jahrzehnte** *Prof. Dr. Peter Kramer* Daimler-Benz Aerospace, Ottobrunn
Do, 28. November '96	**Markt und Entwicklung bei Kommunikationssatelliten** *Dr. Heinz Hermann* DASA / Dornier Satellitensysteme GmbH, Ottobrunn
Do, 19. Dezember '96	**ESA Aktivitäten zu zukünftigen Raumfahrttransportsystemen (FESTIP)** *Dr.-Ing. Heribert Kuczera* Daimler-Benz Aerospace, Ottobrunn
Do, 9. Januar '97	**Entwicklung und Produktion des Oberstufentriebwerks der Ariane 5** *Dipl.-Ing. Günter Langel, Dipl.-Ing. Helmut Zewen* Daimler-Benz Aerospace, Ottobrunn
Do, 16. Januar '97	**Columbus: Der europäische Beitrag zur internationalen Raumstation** *Dipl.-Ing. Hans-Jörg Pospieszcyk* Daimler-Benz Aerospace, Bremen
Do, 23. Januar '97	**Kryotechnik in der Raumfahrt unter besonderer Berücksichtigung der Beispiele ISO und IBSS** *Dipl.-Ing. Albert Seidel* Daimler-Benz Aerospace, Ottobrunn
Do, 30. Januar '97	**IRIDIUM: Die weltweite totale Mobilkommunikation** *Dipl.-Phys. Reiner Szepan* München
Do, 6. Februar '97	**Entwicklungsprogramm eines Gleitschirm-Nutzlastsystems innnerhalb des „Manned Space Program" (MSP)** *Dr. Günther Petry* Daimler-Benz Aerospace, Ottobrunn
Do, 13. Februar '97	**Sergej Korolev: Leben und Werk des großen sowjetischen Raketenbauers** *Dr. Tanja Jelnina* Russische Akademie der Wissenschaften und Hermann-Oberth Raumfahrt Museum e.V.
Do, 20. Februar '97	**Mondbasis-Entwurf: Fakten, Probleme, Möglichkeiten** *Dipl.-Ing. Peter Eckart* Fachgebiet Raumfahrttechnik, TU München

*(im Nordgelände an der Theresienstraße, zwischen Arcis- und Luisenstr.)

Achtung: Die Konfiguration wurde später leicht modifiziert. Der Name APM (Attached Pressurized Module) wurde in COLUMBUS geändert

COLUMBUS:
Der europäische Beitrag zur internationalen Raumstation
- **Technische Beschreibung**
- **Implementierung**

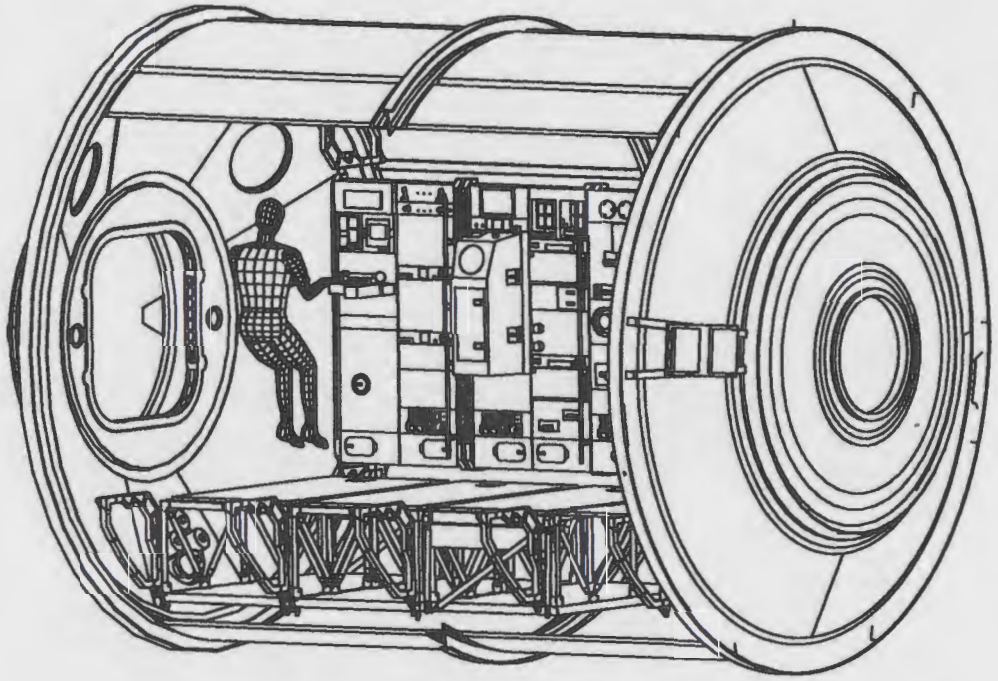
16.Januar 1997

H.-J.Pospieszczyk
COLUMBUS System Engineering Manager

COLUMBUS

Daimler–Benz Aerospace

Raumfahrt–Infrastruktur



COLUMBUS Attached Pressurized Module (APM)
– Reference Configuration Description –

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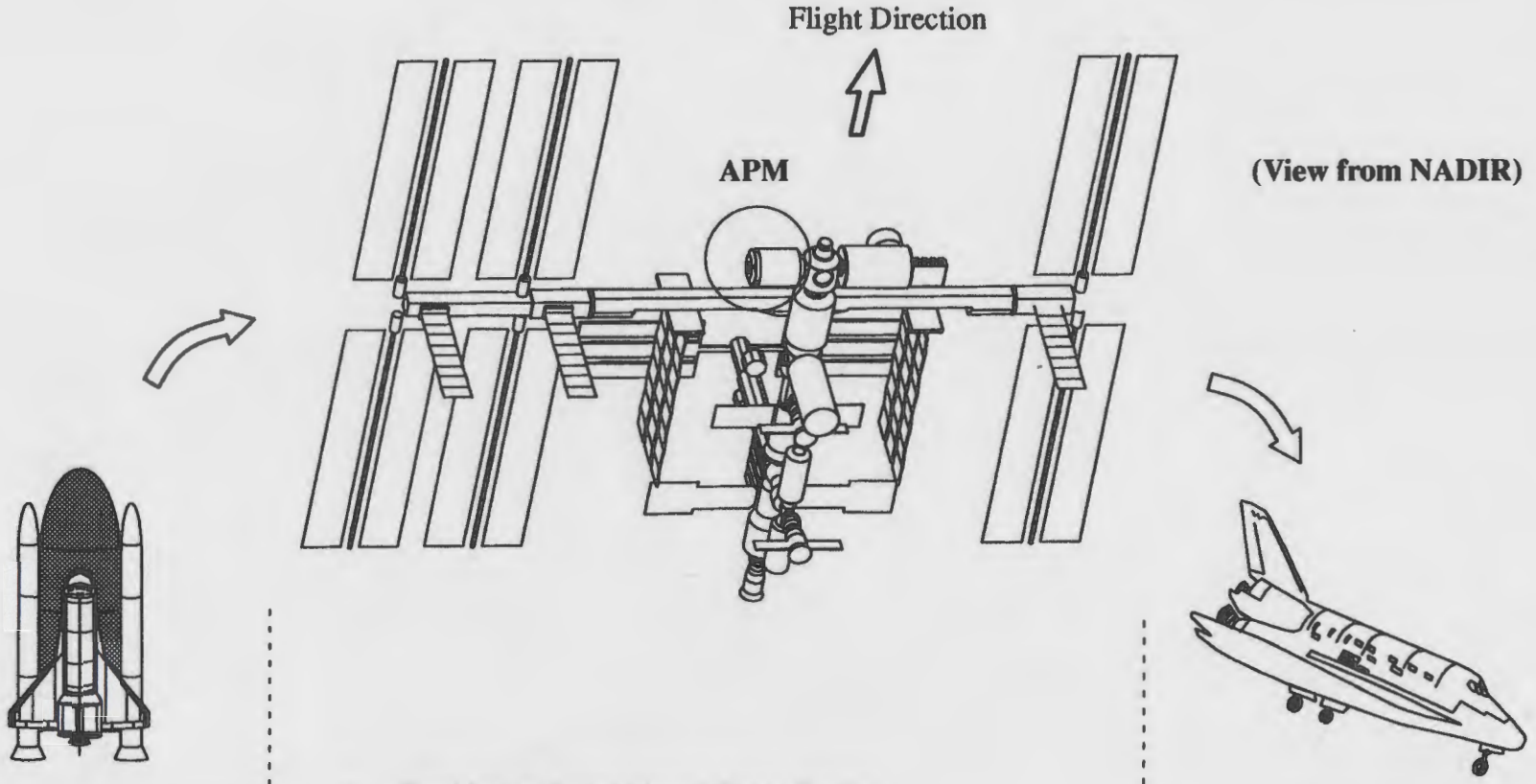
MISSION SCENARIO

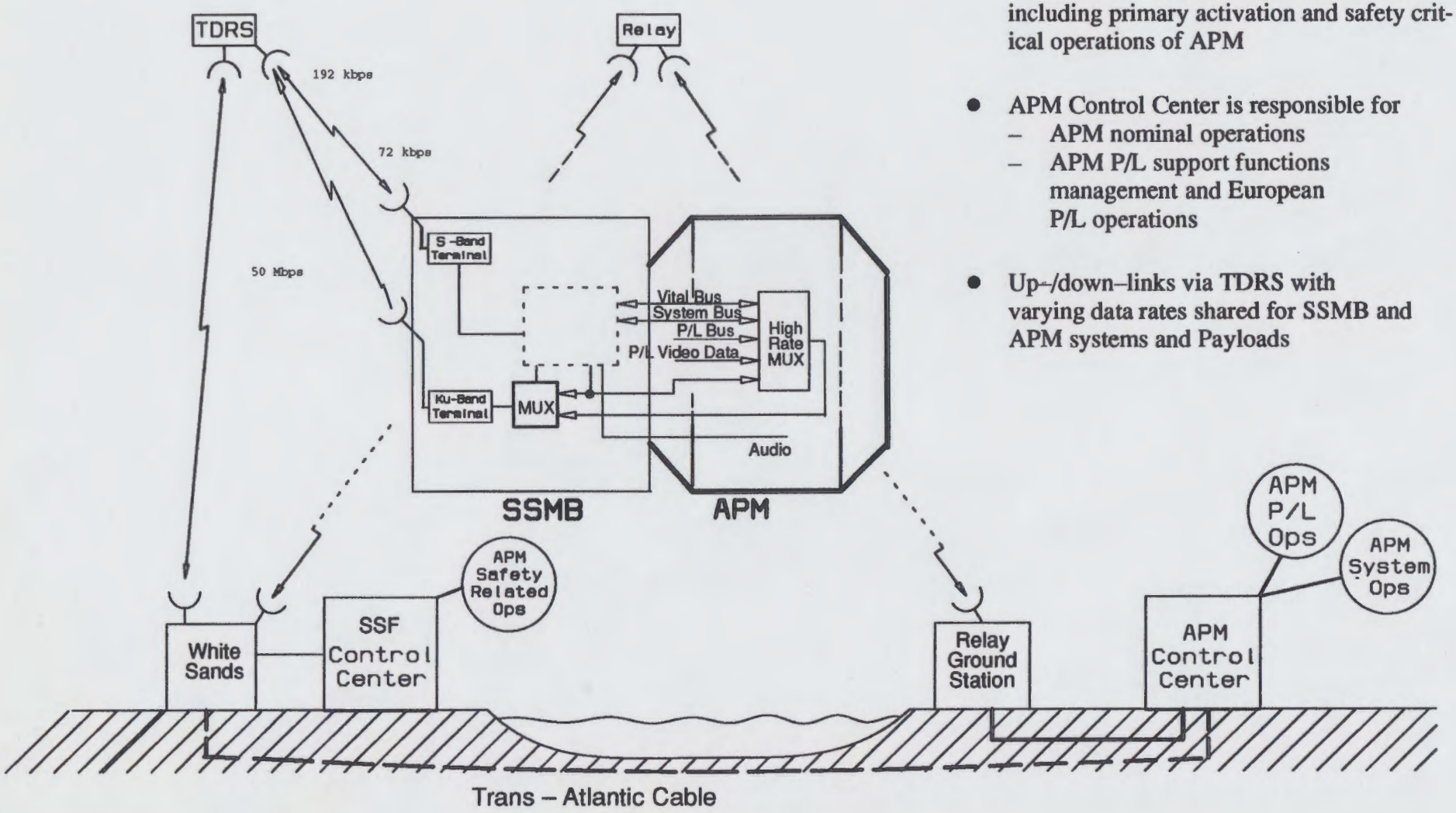


- APM launch with NSTS
- Full European Payload Complement at launch

- Berthing to International Space Station (ISS) by Remote Manipulator
- Permanently attached to ISS during its Life
- Distributed Autonomous Operations Concept incl. P/L Operations from Europe
- Resupply and P/L completion/reconfiguration via ISS logistics scenario

- APM Retrieval by NSTS at end of mission

MISSION SCENARIO (CONT'D)



- Intern. Space Station Control Center responsible for overall Station Management including primary activation and safety critical operations of APM
- APM Control Center is responsible for
  - APM nominal operations
  - APM P/L support functions management and European P/L operations
- Up-/down–links via TDRS with varying data rates shared for SSMB and APM systems and Payloads

PAYLOAD RESOURCES

Payload Accommodation:

- 10 active ISPRs in pressurized environment
- 3 stowage racks in pressurized environment
- Mounting and resources provisions for payloads to be mounted in the APM center aisle

Electrical Power:

- 120 VDC, up to 13.5 kW average for payload operation; actual power availability depending on ISS timeline

Thermal/Environmental Control(up to 14.5 kW):

- active P/L cooling by water loop
- heat removal by radiation/cabin air for P/L items external to racks
- vacuum and venting provision
- N_2 – supply

Data/Communications:

- up to 32 Mbps downlink to be shared with all SSMB P/L
- up to 10 kbps uplink

PAYLOAD RESOURCES (CONT'D)

Data Management/Processing:

- 1 P/L dedicated computer (SPARC)
- 100 Mbytes for P/L files on mass memory
- Dedicated MIL–STD–1553 Payload Bus
- Crew interface via Laptops
- LAN 802.3 (ETHERNET) interface for efficient down–link
- US Payload bus for direct connection to P/L MDM

Mass:

- Initial/Launch Payload 2500 kg
- On–Orbit: up to 9000 kg

Video/Digital Data:

- NTSC video standard interface
- Two cameras and monitors
- Cold redundant analog video recorder
- Video compressing capability
- Video and digital data multiplexing for transmission to ground

APM MISSION AND CHARACTERISTICS SURVEY

Mission Scenario

- Objectives:
  Multidisciplinary Missions, including Material Science, Fluid Physics, compatible Life Science Disciplines, Space Science and Technology Disciplines.

- Mission Duration:
  Variable as a function of APM launch date and ISS life–time.

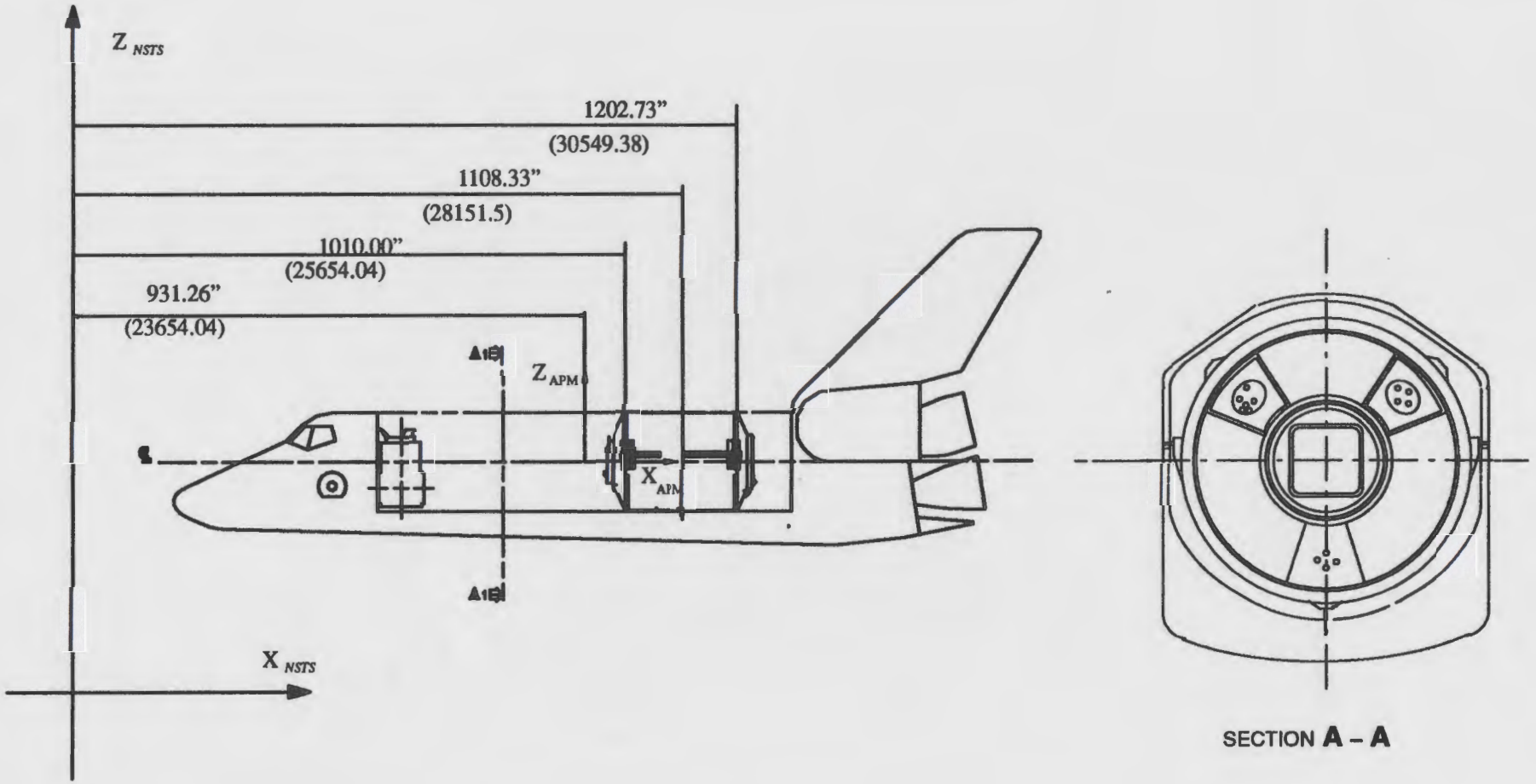
- Orbit:
  Nominal Range between 335 km and 460 km at 51.6 Degree Inclination.

- Payload Accommodation Capability for:
  - 10 Active International Standard Payload Racks (ISPR) in pressurized Environment.
  - 3 Stowage Racks in pressurized Environment.
  - Mounting and Resources Provisions for Payloads to be mounted in the APM Center Aisle.

Design and Performance

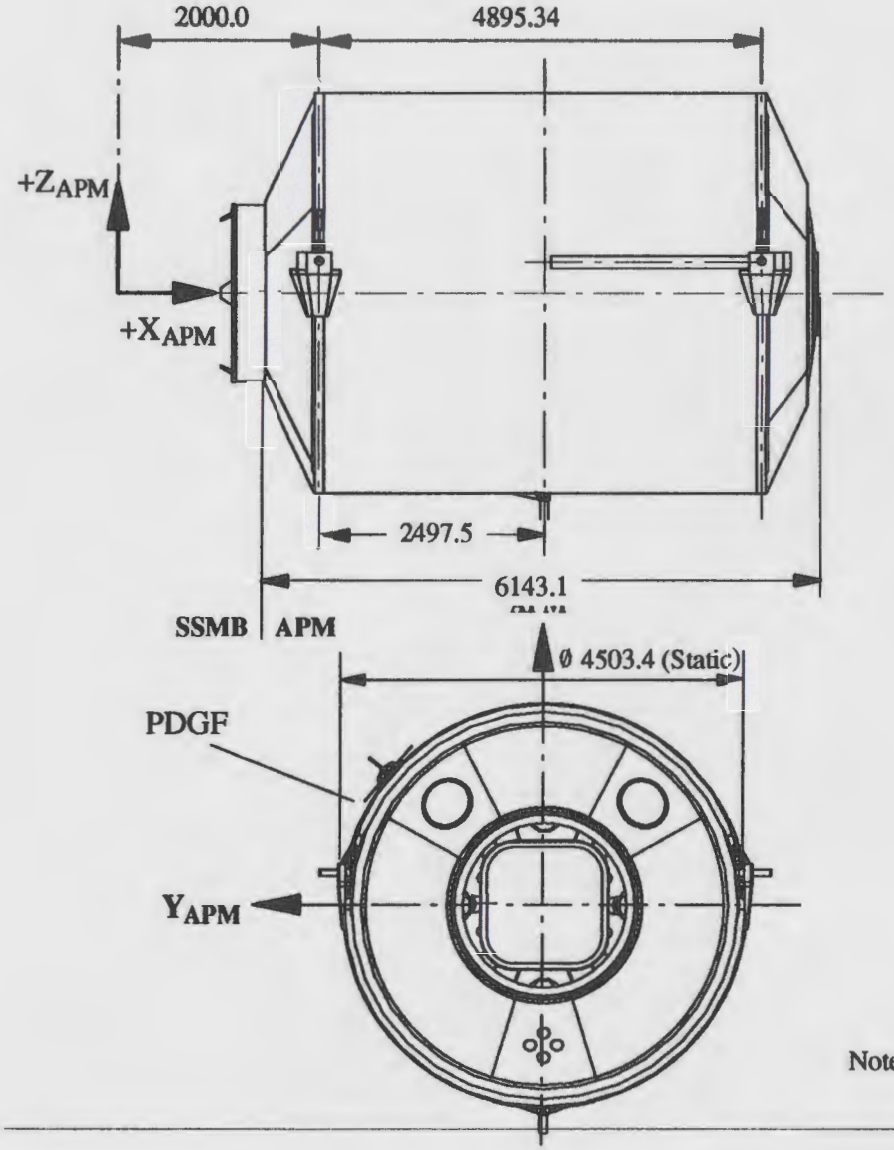
- Design Life:
  15 years via on–orbit maintenance.
- Overall Dimensions:
  6.4 m Length; 4.5 m Diameter.
- Launch Mass:
  12,500kg (incl. 2,500kg P/L).
- On–Orbit P/L Mass:
  9,000kg max.
- Electrical Power:
  120 VDC, sized for max 20kW.
- Data / Communication:
  Up to 32 Mbps down/up to 10 kbps up via ISS.
- Environmental Control:
  Sized for 3 crew members, total heat rejection up to 22kW.
- Resources:
  All Resources except Data Processing by ISS.
- Launch/Retrieval Vehicle:
  NSTS (Shuttle/Orbiter).
- Servicing:
  In Situ via IVA and EVA using NSTS
  90 days resupply cycle.

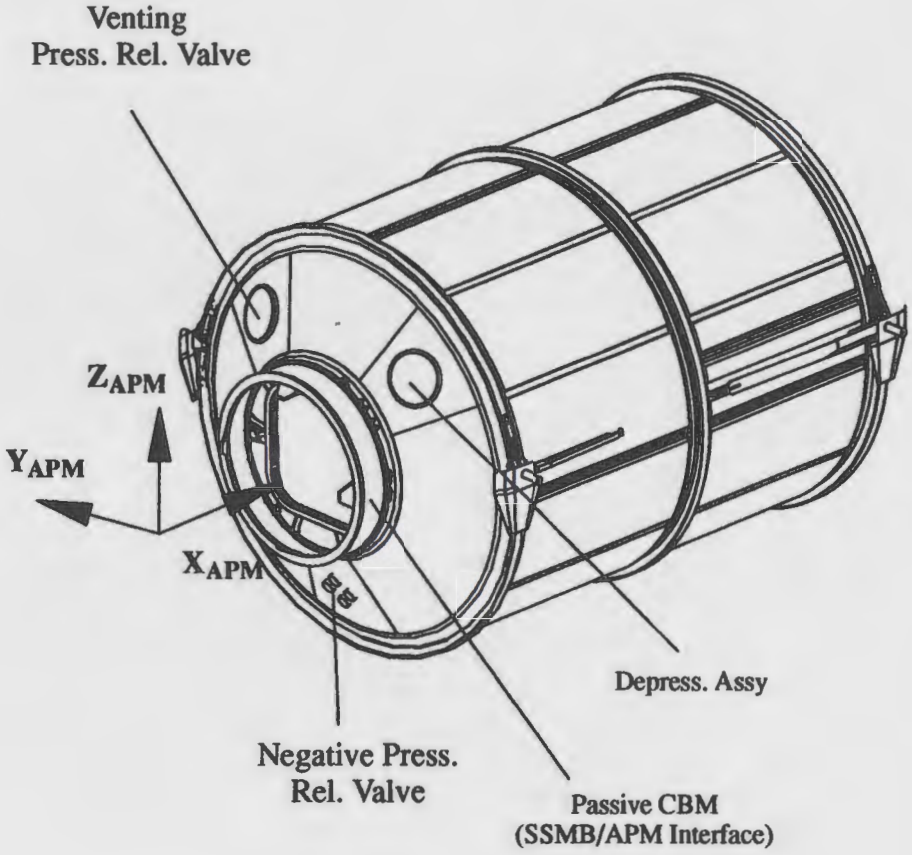
LAUNCH/RETRIEVAL CONFIGURATION



SECTION **A – A**

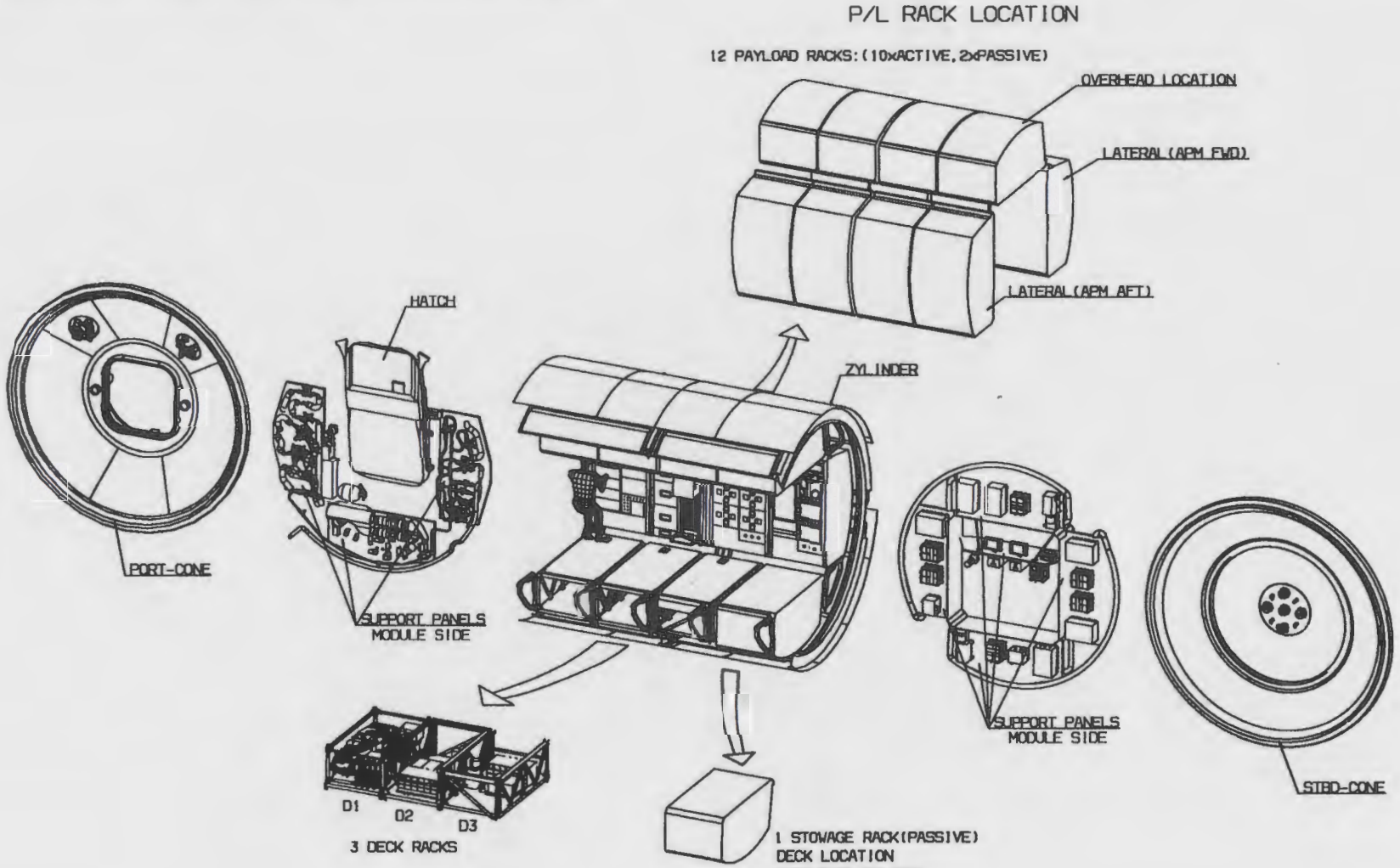
EXTERNAL CONFIGURATION



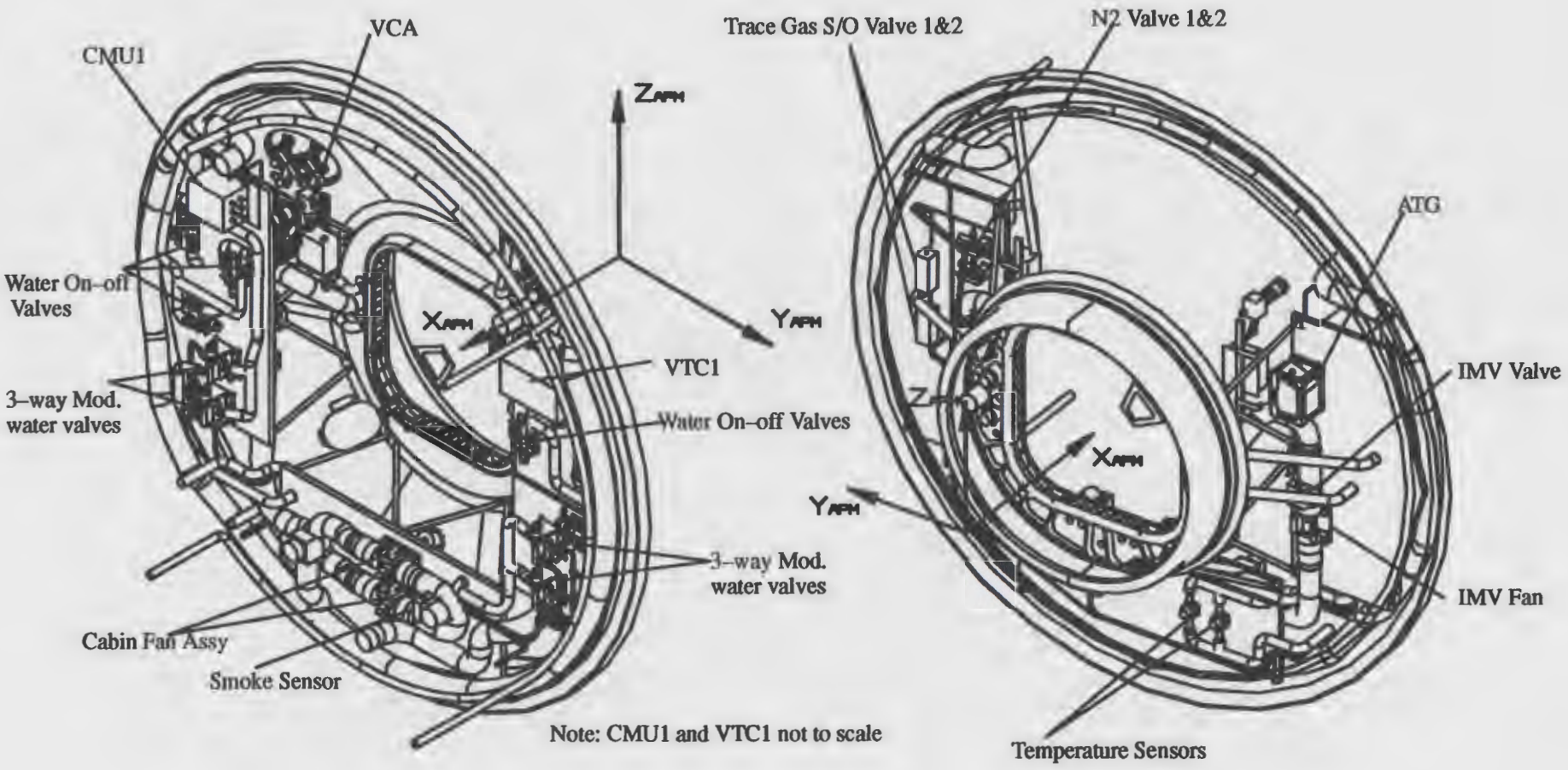


Note: MDPS not shown

INTERNAL CONFIGURATION

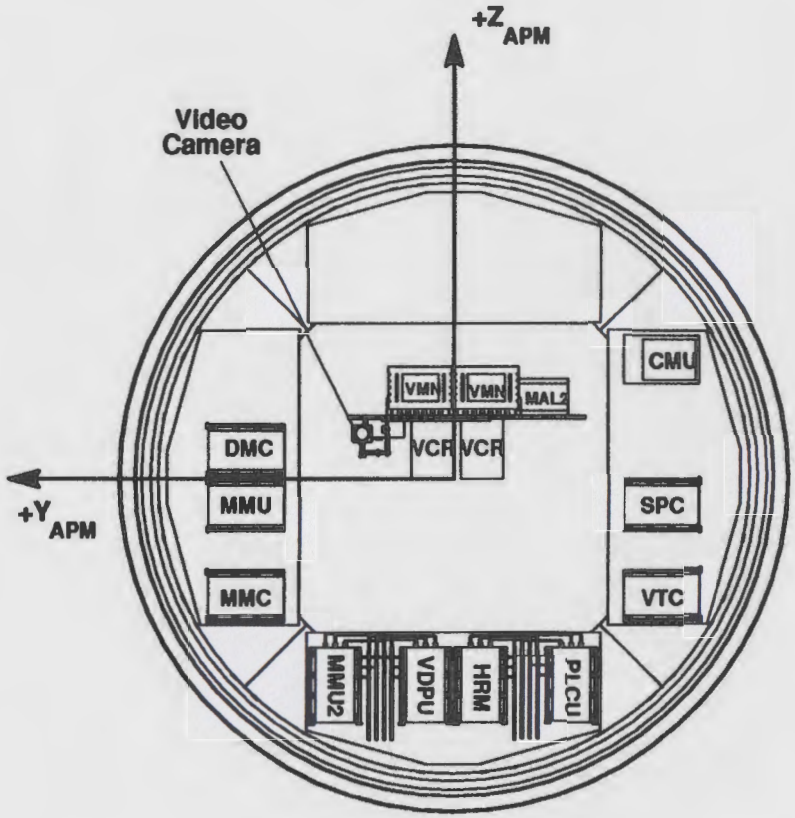


PORT CONE

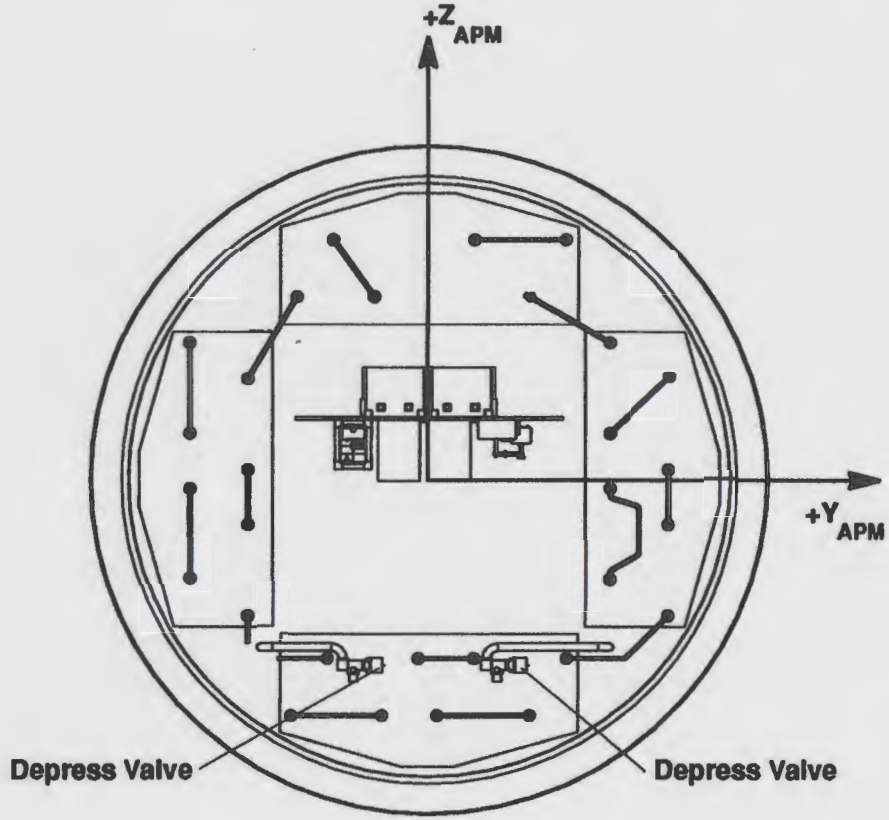


Note: Principle only, not all items shown

STARBOARD CONE

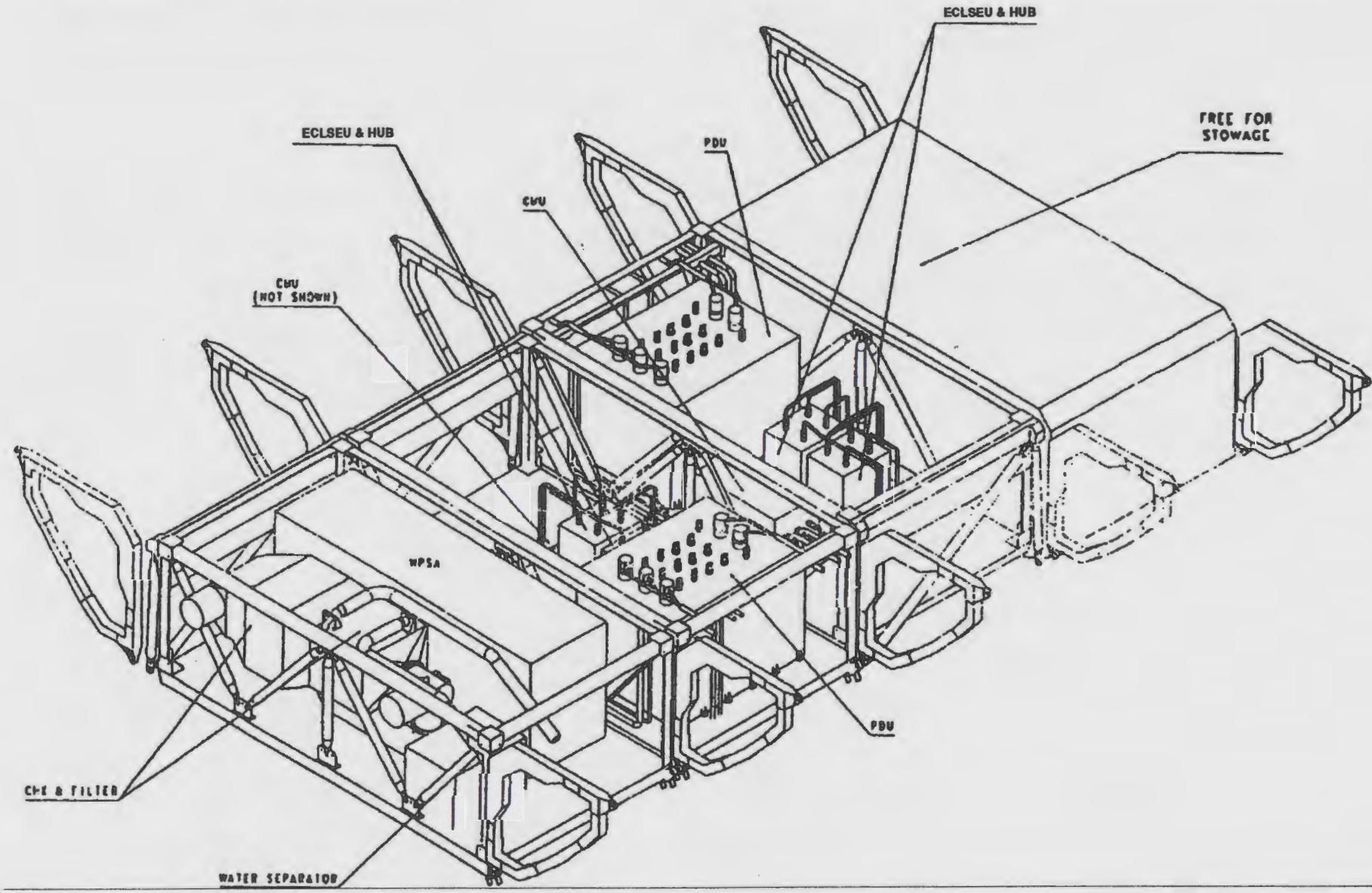


Module Side



Cone Side

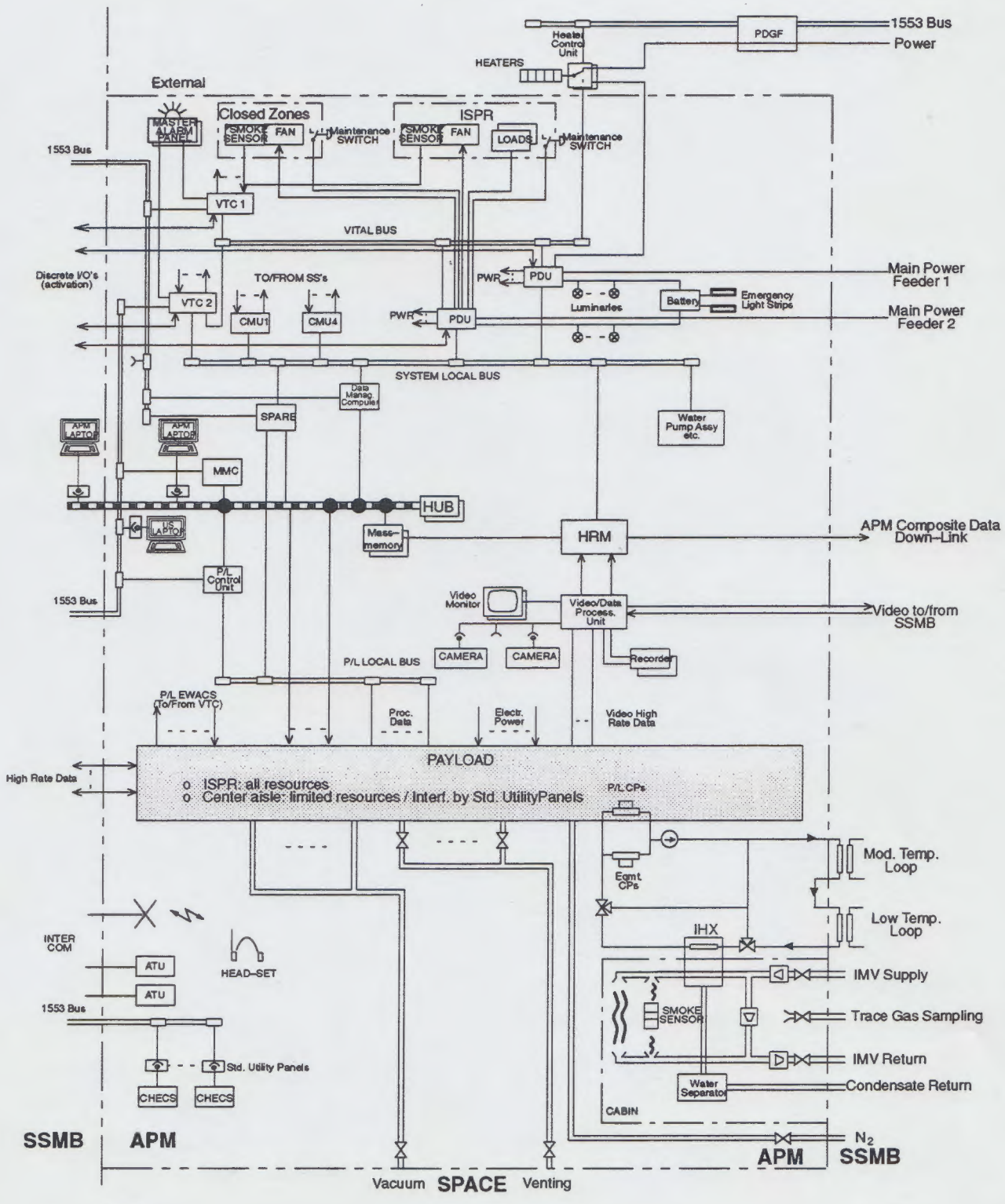
SUBFLOOR ARRANGEMENT



FUNCTIONAL ARCHITECTURE
MAIN FUNCTIONS/FAILURE TOLERANCE

APM Function	Failure Tolerance
Thermal Conditioning	1
N_2 Supply for P/L	0
Module Ventilation	1
Atmosphere/Temperature and Humidity Control	1
Prevention of Loss of Atmosphere	1
Fire Detection	1
Vacuum and Venting Services to P/L	0
Module Illumination	1 degraded after 1 Failure
System Level Monitoring/Control	1
Power Distribution	1
Up/downlink Communication for System/Payload Data	1
Voice Communication	0
Video/Data Distribution and Processing for System/Payload	1

APM FUNCTIONAL ARCHITECTURE



LEGEND:

MIL–STD–1553 BUS (red.) — Std. Utility Panels

LAN 802.3 (red.)

OPERATION MODES

Mission		Start Event *	Qualitative Description
Phases	APM Modes		
Initialization	Unberthed Survival (APM grappled by SSMRS)	Grapple by SSMRS and switch–on of SSMRS power to APM	Minimum survival mode of APM by provision of power via SSMRS to APM for thermal conditioning only
	Berthed Survival	Connect utilities, availability of power for essential Command & Control functions	Survival mode of APM based on external resources from ISSA
	Support	Preparation for nominal APM operations	Initial activation from survival to full system performance including crew support but excluding P/L operations
Ops under reduced Performance	Support (manned)	(Re–)preparation for nominal APM ops excluding P/L	Re–activation to full system performance excluding P/L operations
	Support (unmanned)	(Re–)preparation for nominal APM ops excluding crew & P/L	Re–activation to full system performance excluding crew and P/L operations
	Housekeeping	Setting of APM to a reduced but active mode including min. crew support, excluding P/L ops	Survival conditions for crew (max. 2 persons w/o activity) and equipment
	Stand–by (unmanned) (1)	Setting of APM to a reduced but active mode excluding crew support and P/L ops	Survival conditions equipment (incl. P/L); allows quick re–activation
	Berthed Survival (2)	Switch to exclusively power to heater and essential Command & Control function	Degraded survival of APM and P/L based on external resources; EVA suit necessary
Roufine Ops	Nominal (manned)	Start of P/L and crew ops	In orbit nominal operations with crew including maintenance and servicing
	Nominal (unmanned)	Start of P/L ops	In orbit nominal autonomous operations

Legend:

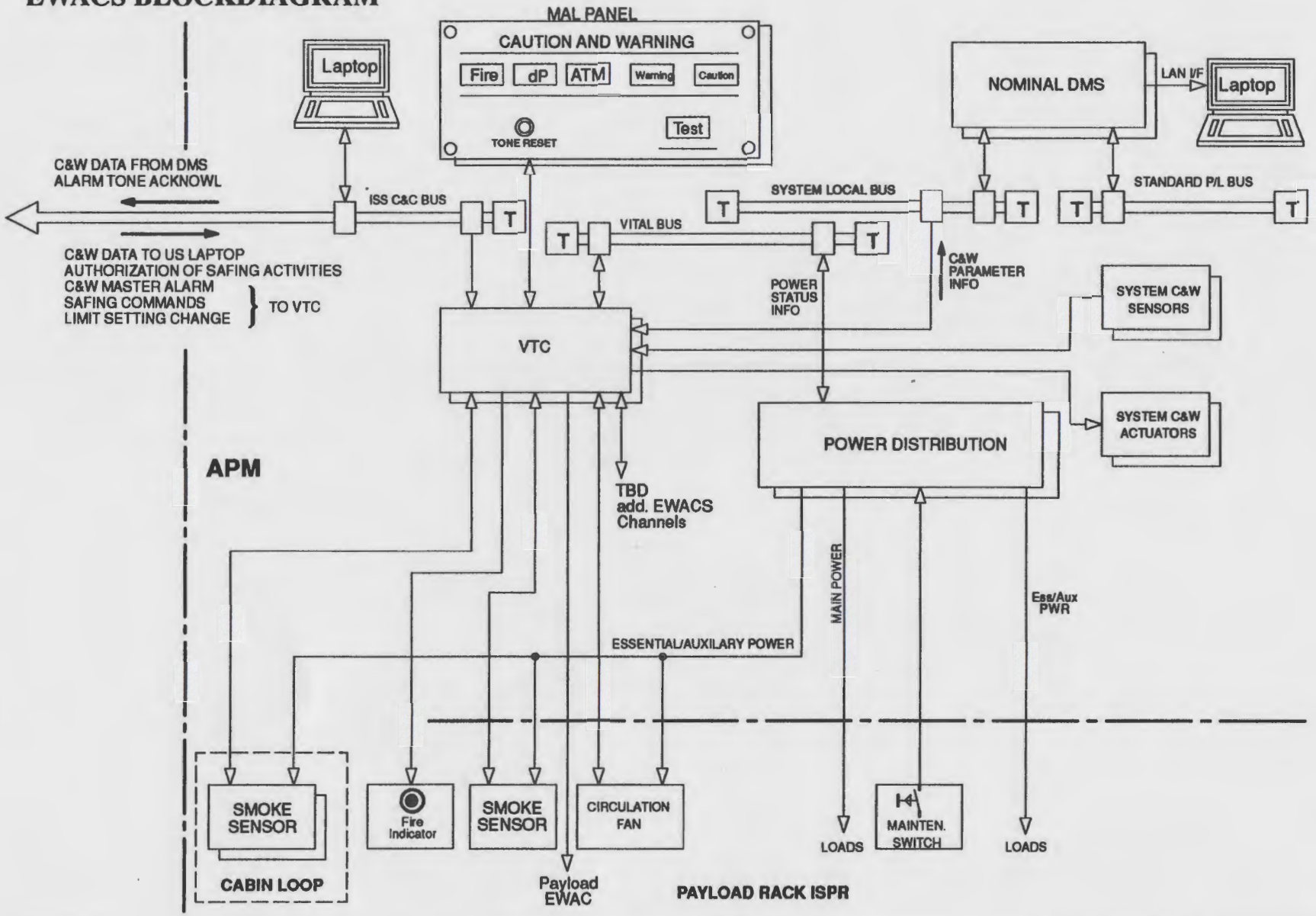
* End event identical with start event of phase that follows
1) Objective: Contingency repair
2) Objective: Power saving

EMERGENCY, WARNING, CAUTION AND SAFING (EWACS)

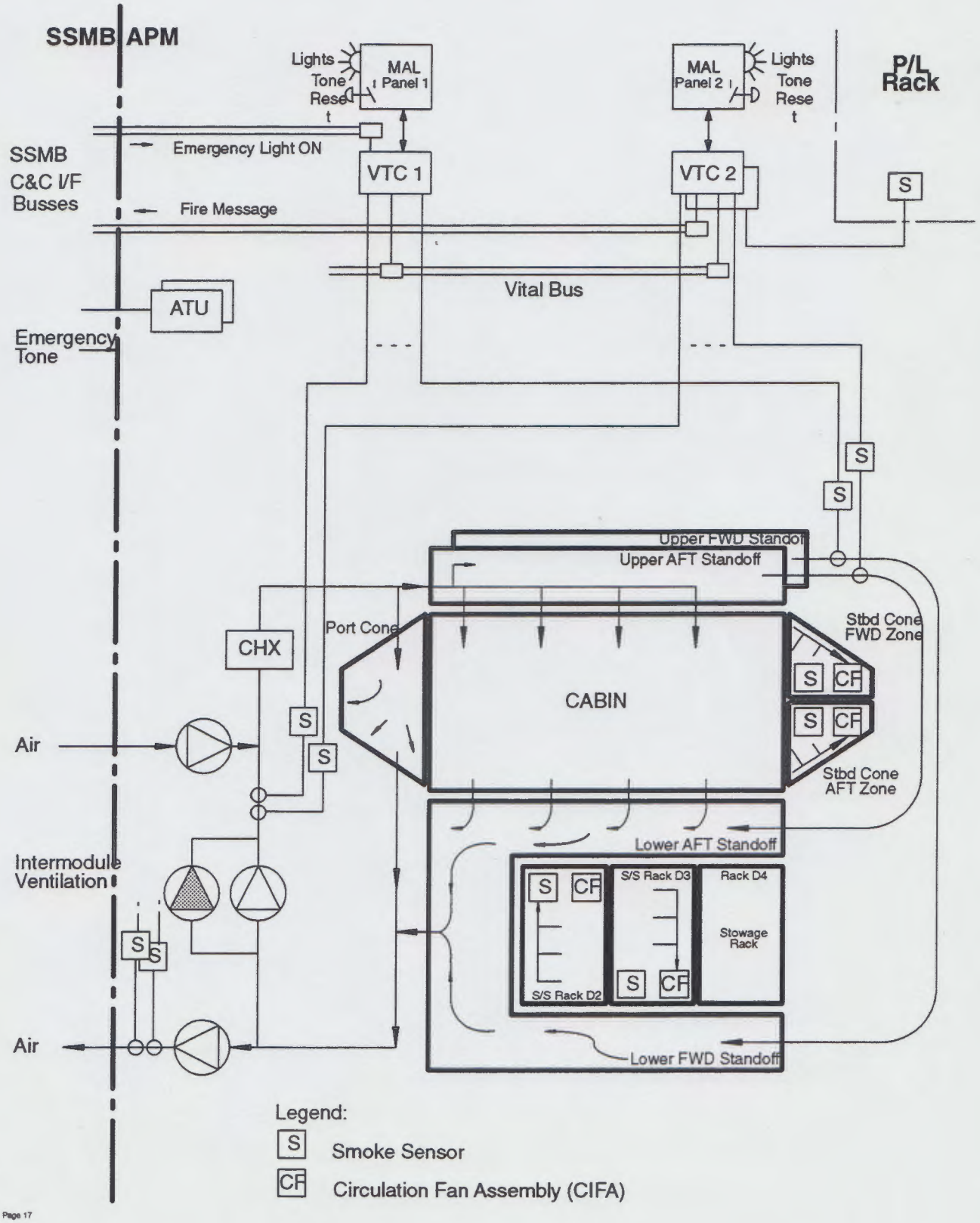
- The crew shall be alerted for:
  - EMERGENCY: life threatening condition requiring immediate safing action
  - WARNING: potential effect on safety, which may require safing action
  - CAUTION: no direct effect on crew safety but requiring corrective action

- APM EWACS relies partly on SSMB EWACS providing the following functions:
  - Out–of–limit status transmitted to SSMB
  - Data acquisition and monitoring/limit checking
  - Execution of safing commands
  - SSMB activates visible and audible annunciation in APM

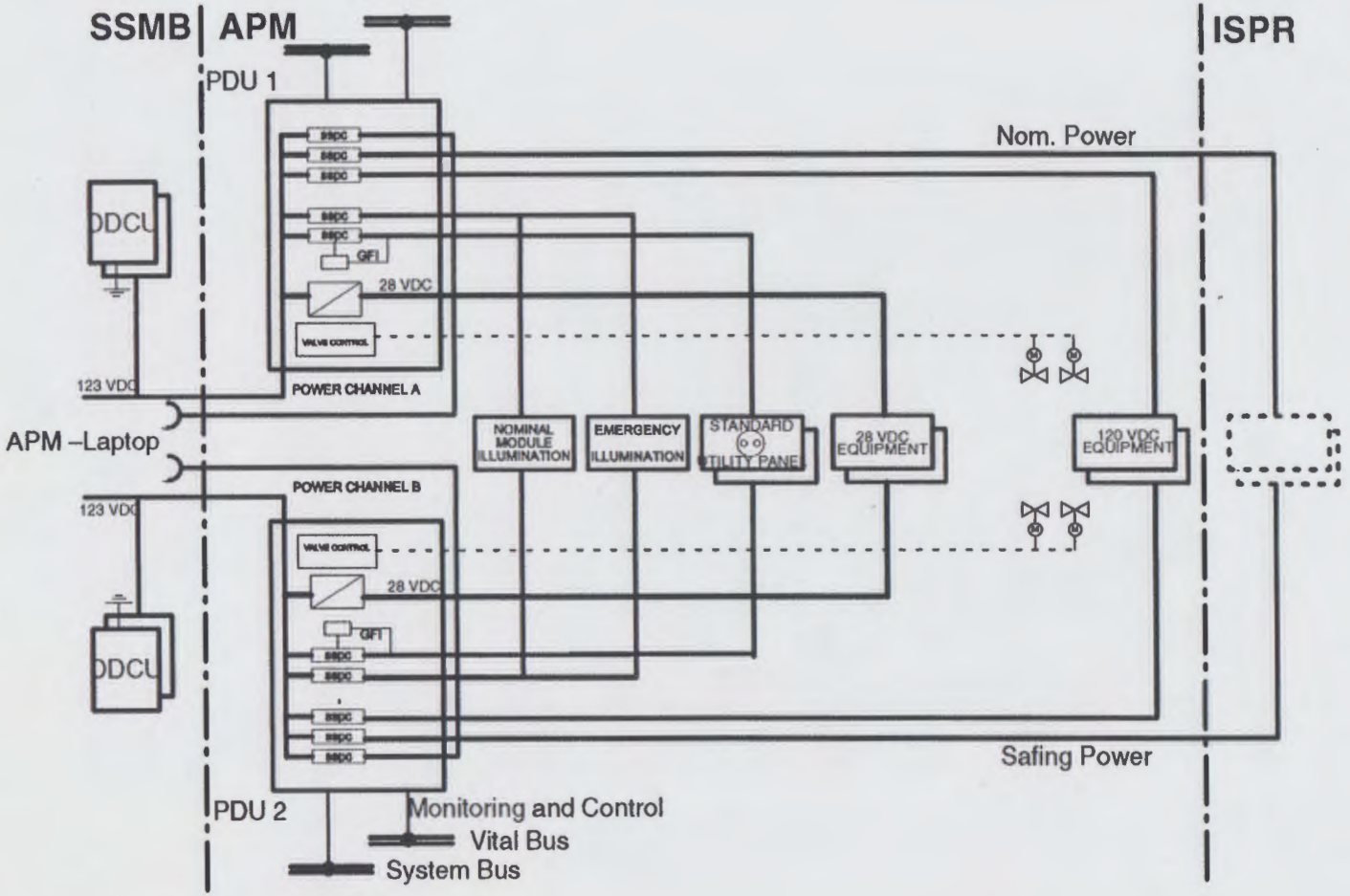
EWACS BLOCKDIAGRAM



FIRE DETECTION AND SUPPRESSION

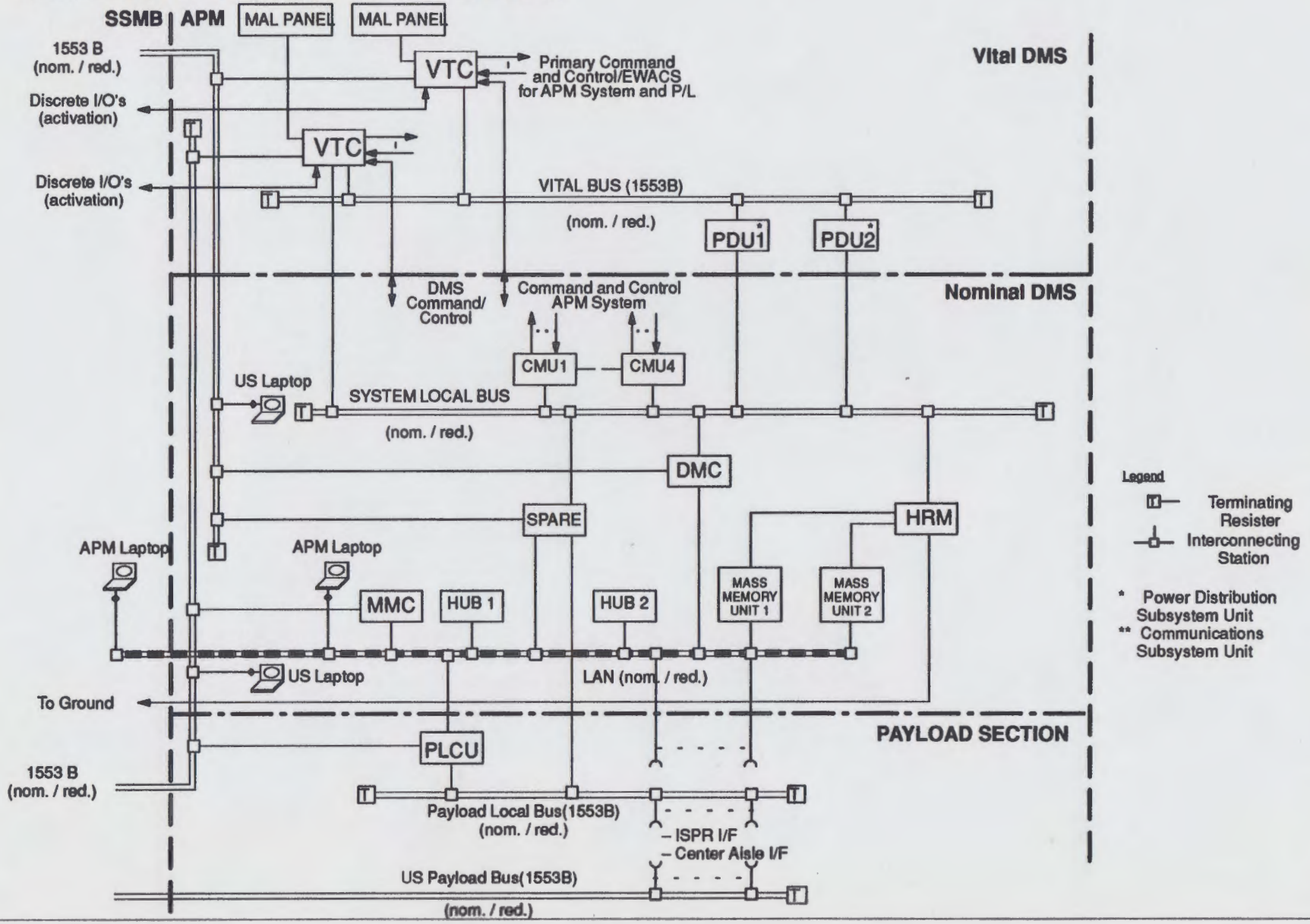


ELECTRICAL POWER DISTRIBUTION

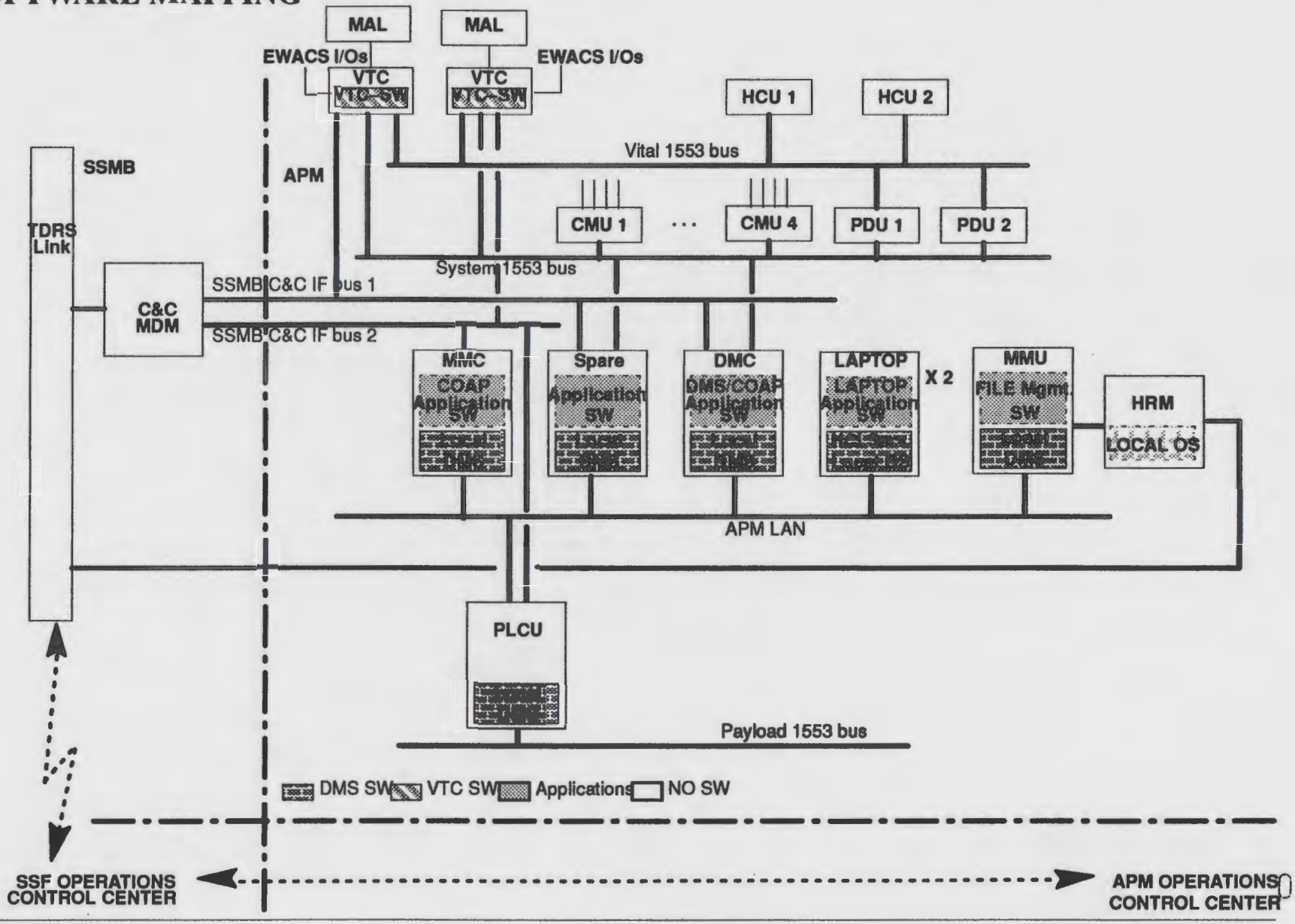


- Designed for up to 20 kW to S/Ss and P/L in total, max. 13.5 kW to P/L at 120 VDC
- Utility Power Outlets protected with Ground Fault Interuptor (GFI) to ensure crew safety even with grounding failure in portable equipment
- 120 VDC and 28 VDC for APM Equipment
- All 120 VDC Outputs protected/switched by Solid State Power Circuits (SSPC's)

DATA MANAGEMENT SYSTEM



SOFTWARE MAPPING



COMMUNICATIONS

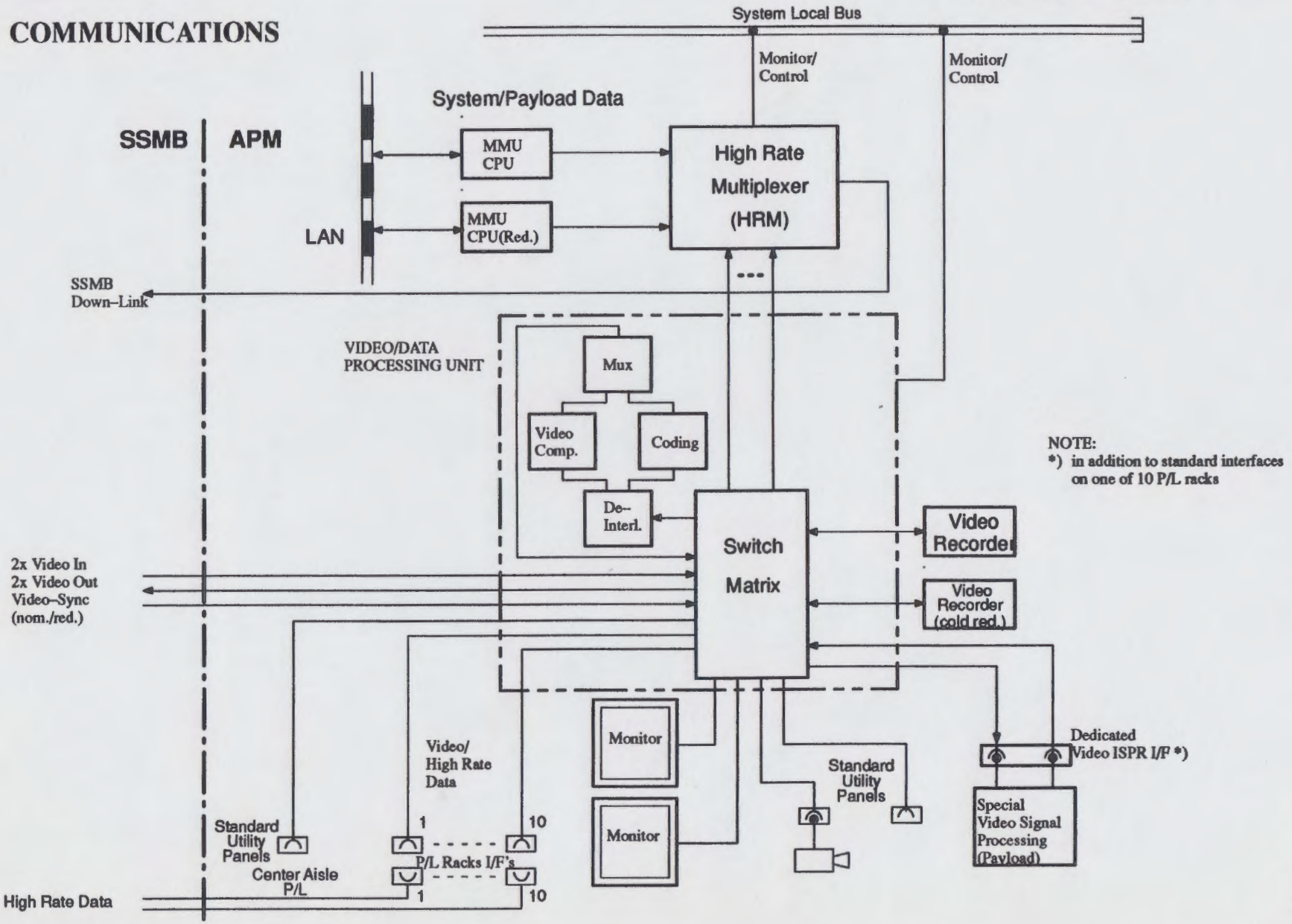
- Up–/Down–links for APM operations provided by ISS communication system (see para 1.2)
- Capabilities

Link	via TDRS
o Down	32 Mbps *
o Up	10 kbps **

* APM interface design capabilities/actual availability and date rates to be agreed with ISSA
** Limited by SSMB/APM interface

- Data Management System routes all system down–link data via LAN to MMU and HRM
- Other inputs to HRM:
  - Compressed video data
  - High Rate Digital data from Payload
- The telecommand up–link data stream is routed from the ISSA communication system to CCSDS–Packet receiver and finally and effectors

COMMUNICATIONS

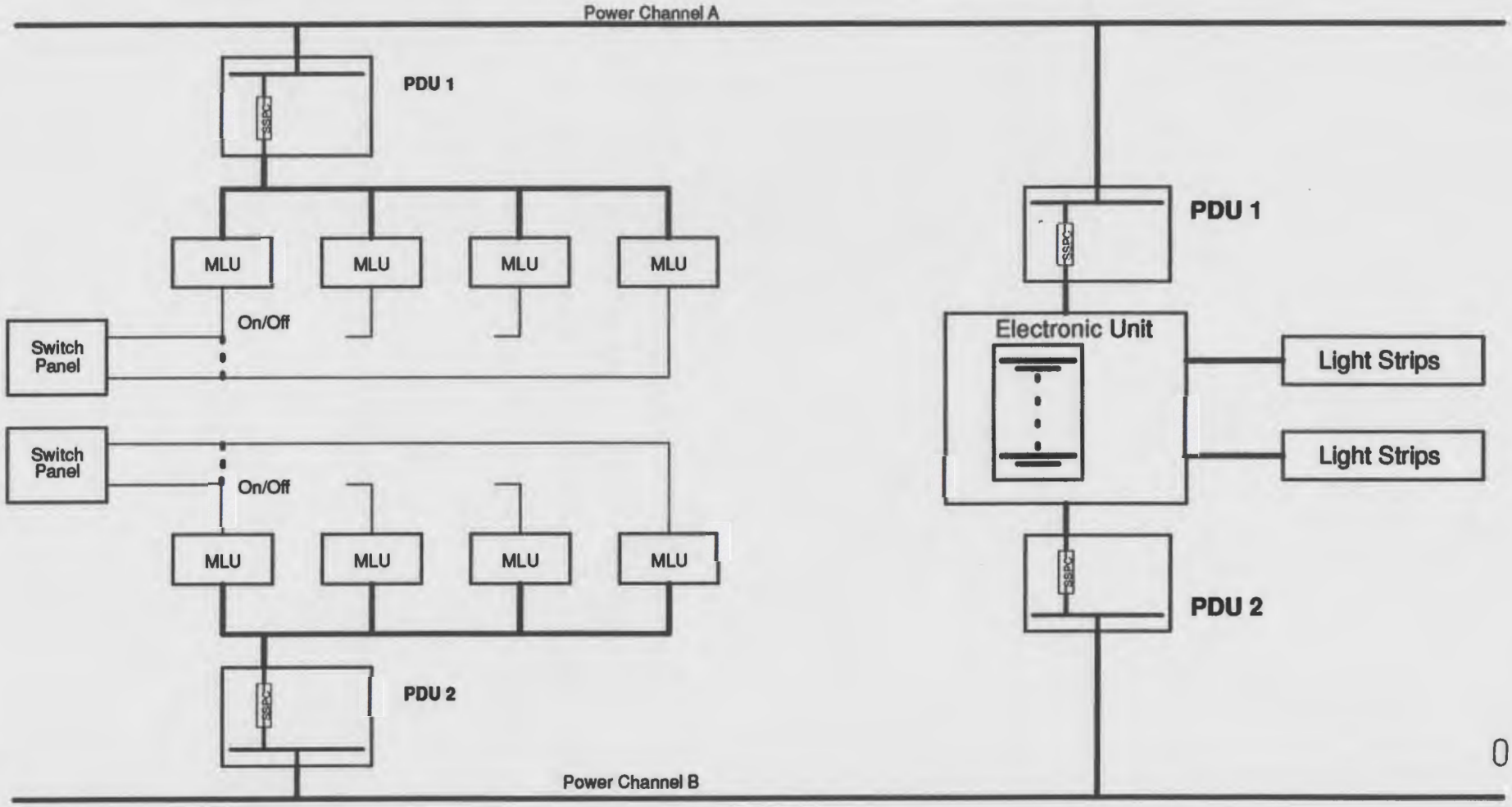


ILLUMINATION

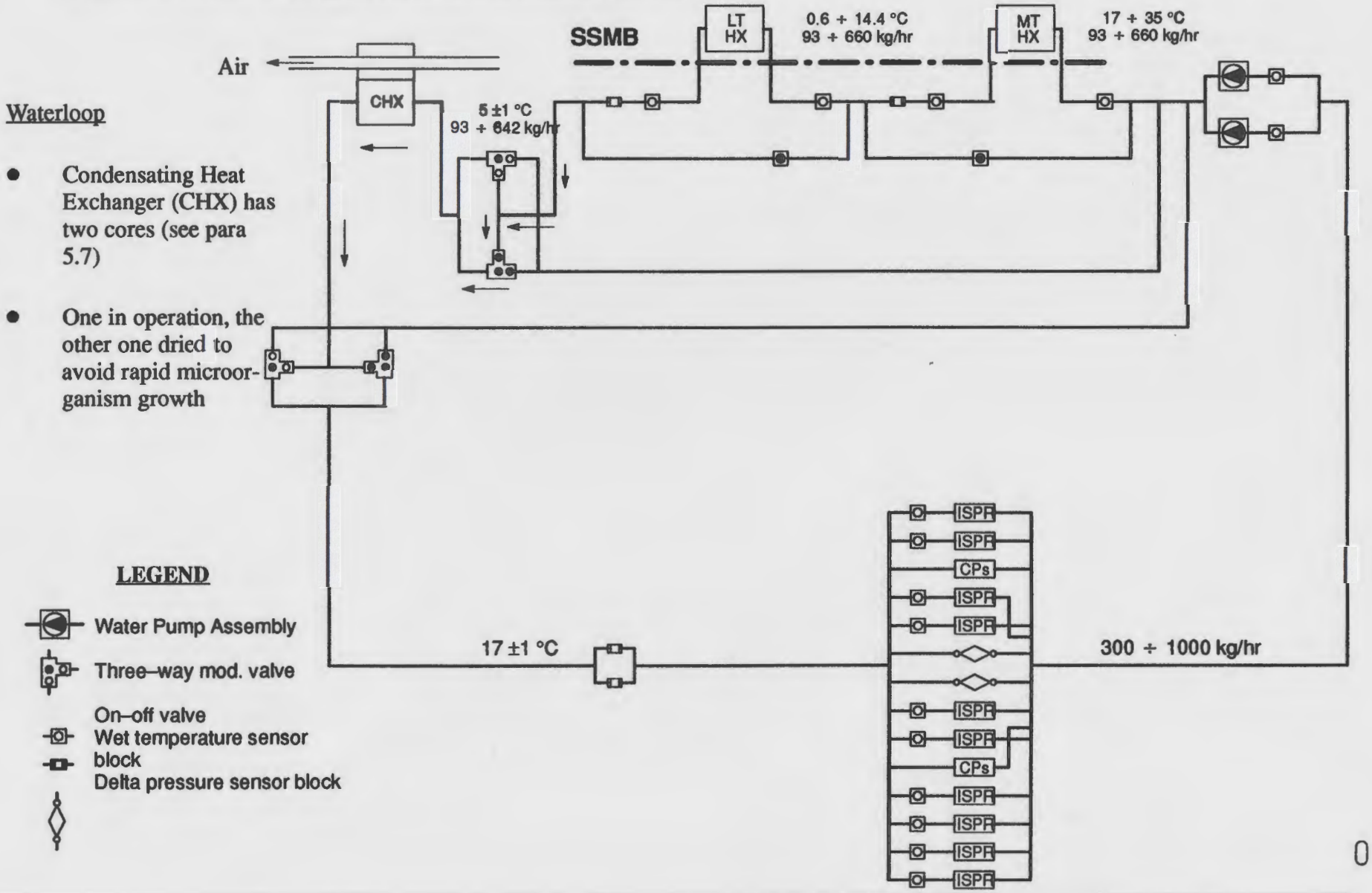
- APM provides internal illumination being fully based on station common items
- Emergency illumination automatically activated after complete power loss from SSMB allowing safe crew egress

Normal Illumination

Emergency Illumination



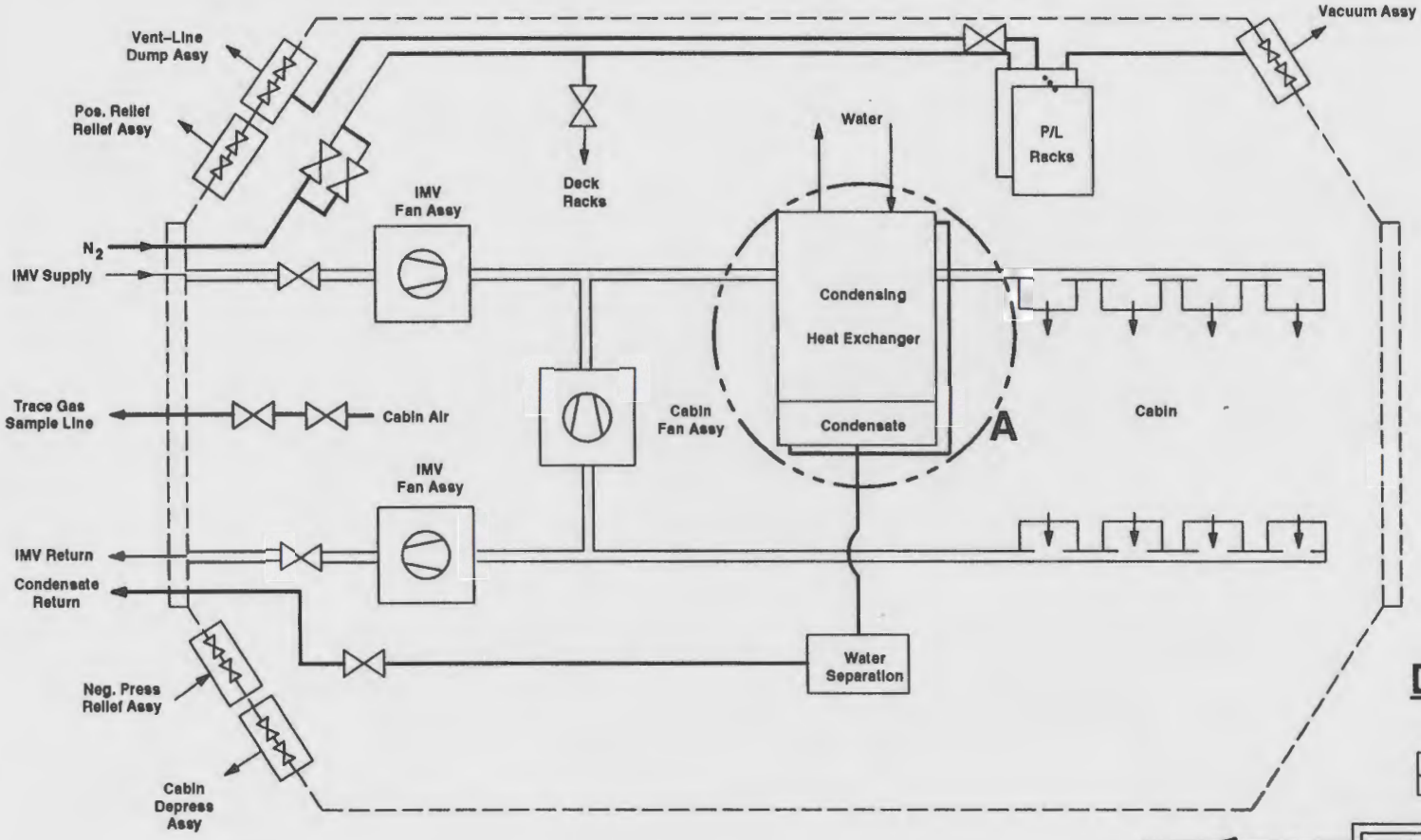
THERMAL CONTROL SYSTEM (TCS)



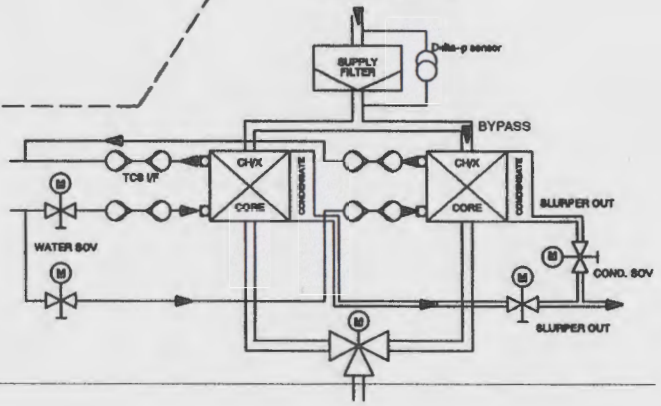
Waterloop

- Condensating Heat Exchanger (CHX) has two cores (see para 5.7)
- One in operation, the other one dried to avoid rapid microorganism growth

ENVIROMENTAL CONTROL AND LIFE SUPPORT

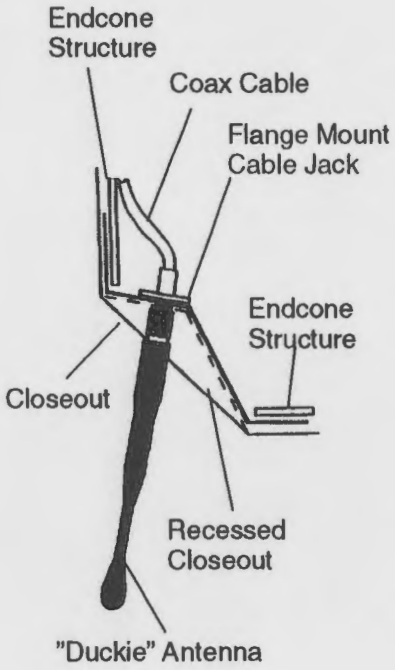


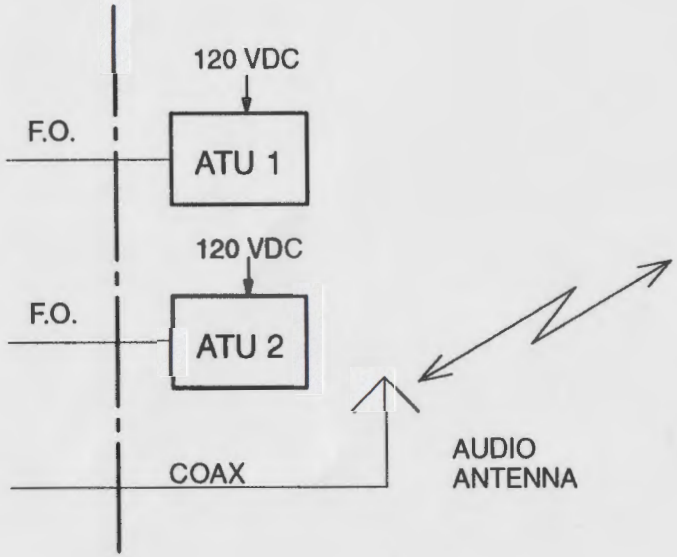
Detail A



- Size for 3 Crew Members working heavily
- IMU heat loads: 400/200 W (sensible/latent)

AUDIO

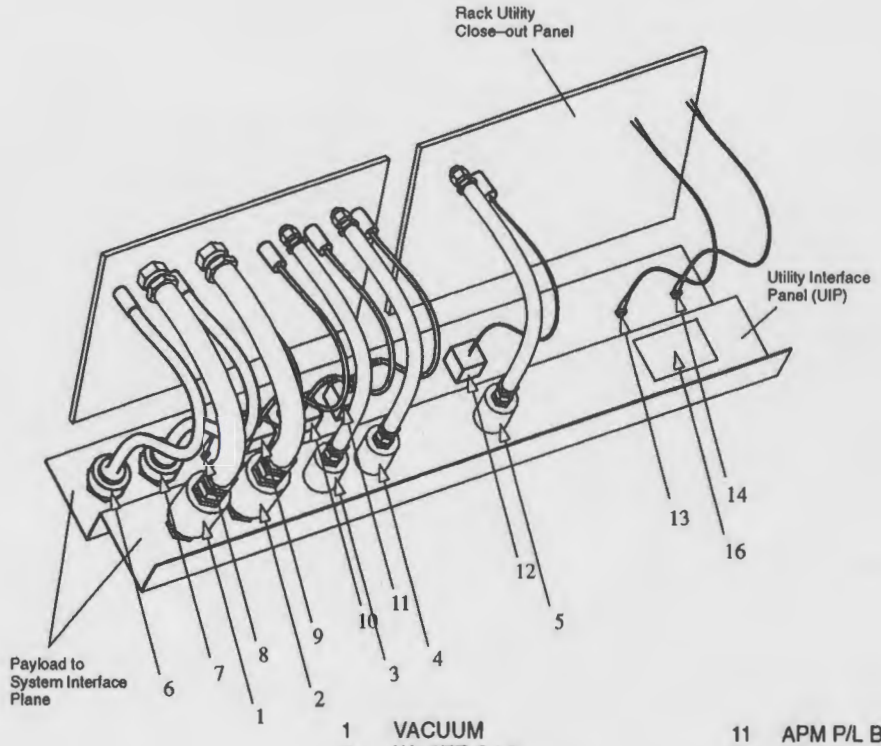




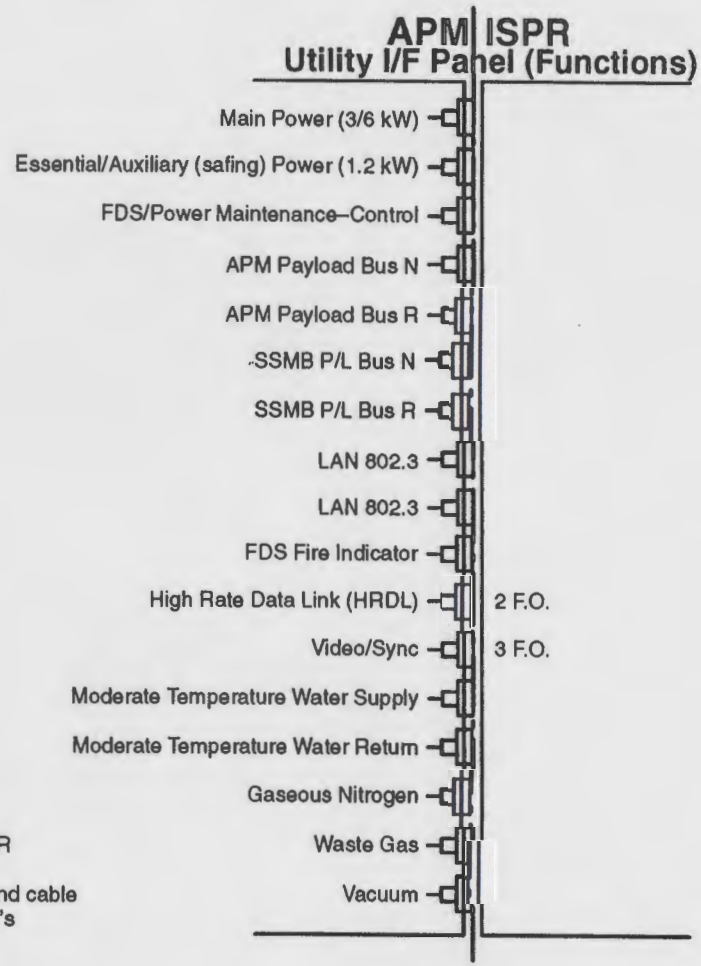
- Two Station Common Audio Terminal Units for local Audio Communication and EWACS audible annunciation
- One Station Common Audio Antenna for Audio Communication with wireless Head–Sets to allow Astronout movement without hinderance by cabling
- Wireless Head–Sets carried to APM from SSMB on–orbit (not part of APM deliveries)

PAYLOAD INTERFACES / ISPR

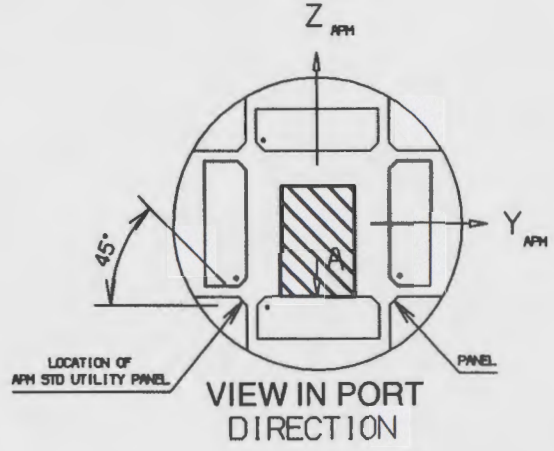
- 10 provisions for accommodation of active P/L racks, which are in accordance with the ISPR (International Standard Payload Rack) requirements (location see para 3.5)

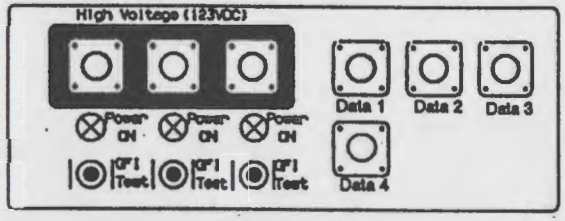


1	VACUUM
2	WASTE GAS
3	TCS MOD SUPPLY
4	TCS MOD RETURN
5	GN2
6	SAFING POWER
7	MAIN POWER
8	VIDEO/SYNC (FO)
9	HRD (FO)
10	FPS/POWER MAINTENANCE SWITCH
11	APM P/L BUS
12	APM P/L BUS
13	LAN 802.3 RED.
14	LAN 802.3 NOM.
15	FDS FIRE INDICATOR (to be implemented)
16	CUT–OUT for utility and cable routing between ISPR's
17	SSMB P/L BUS (to be implemented)
18	SSMB P/L BUS (to be implemented)



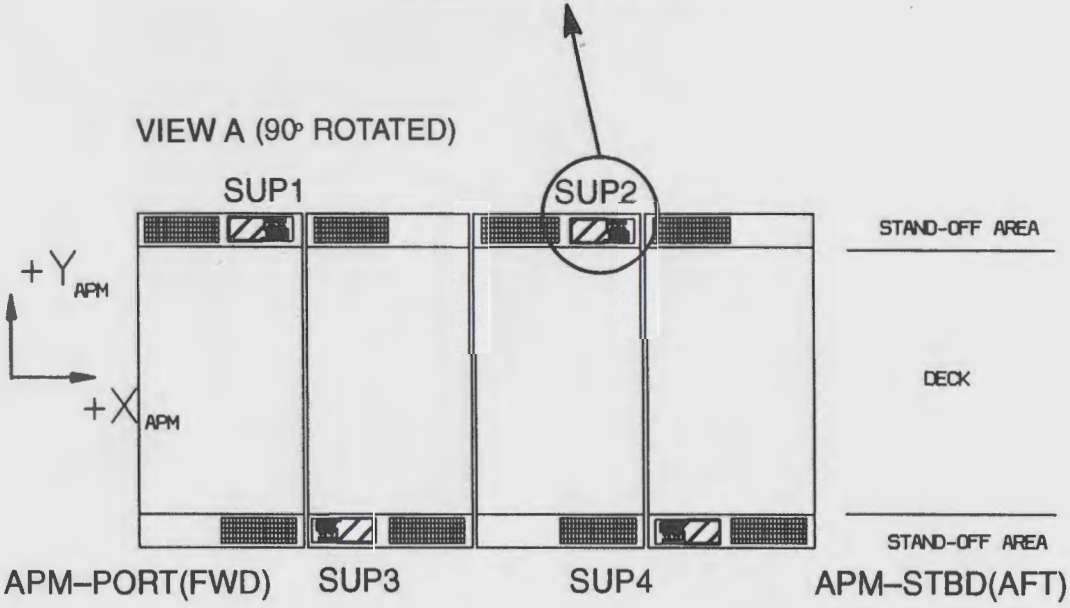
CENTER AISLE

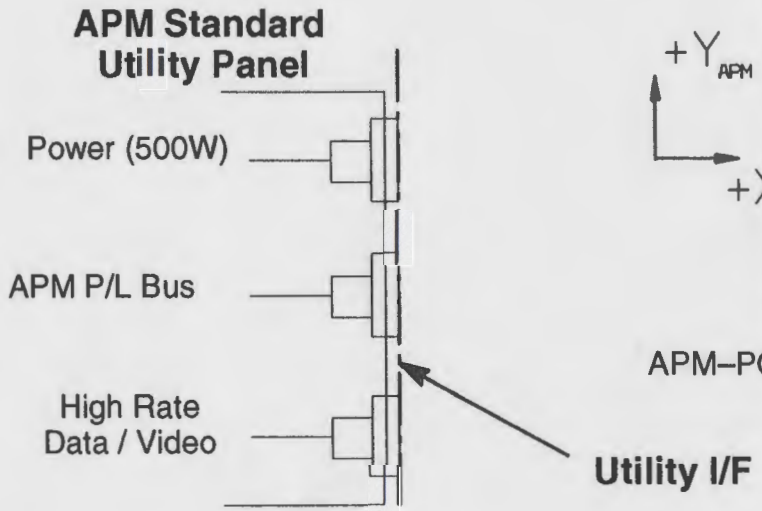




Standard Utility Panel Layout

Volume for
Center Aisle Payload





BUDGETS

MASS BUDGET

SUBSYST./ASSY	SPECIFIED MASS/KG PER MISSION PHASE			REMARKS
	Launch	On–Orbit	Safe Disposal	
Structure	6119	6119	6119	
Harness	548	548	548	
Illumination	32	32	32	
Thermal Control Items	735	735	735	
ECLSS incl. FDS	621	621	621	
Outfitting compl.	252	252	252	
Station Common Items				
– ATU & VCR Cold Plates	15	15	15	
– Passive CM	177	177	177	
– Hatch	109	109	109	
– PDGF	23	23	23	
EPDS Items	185	185	185	incl. VTC/CMU Support (24kg)
DMSS	238	238	238	
Video	103	103	103	
Station Common Items				
– PBA (1 x)	8	8	8	
– PFEX (2 x)	16	16	16	
– MAL (2 x)	5	5	5	
– Laptops (2 x)	10	10	10	transport outside APM
– ATU (2 x)	18	18	18	
– Audio Antenna (1 x)	1	1	1	
Air	92	92	92	
Water	109	109	109	
APM System Mass	9416	9416	9416	
Margin	484	484	484	System & PICA Margin
Payload	2500	9000	2500	On–orbit: 9000 kg internal
Total:	12400	18900	12400	
Launcher Capability/APM Interface	12400	18900	12400	On–orbit capability limited by I/F forces

ELECTRICAL POWER BUDGET

Subsystem Assembly	Power Budget [W]							Remarks
	Launch	Operation under Reduced Performance				Routine Operation		
		Unberthed Survival	Berthed Survival	Support (mannded)	House–keeping	Unmanned	Manned	
Lighting	0	0	5	245	245	5	245	Norm./Emerg. Lighting
Thermal Control	0	700	725	281	281	543	543	incl. Fire Detection Items
ECLSS	0	48	681	970	970	1050	1050	
Harness	0	17	19	47	38	328	339	load dependend losses
PDU	0	0	57	361	115	304	561	incl. load dependet losses
DMS	0	0	50	580	490	535	635	incl. 2 APM laptops/2 MAL Panels
Video	0	0	0	154	0	254	344	
Audio	0	0	0	69	69	0	69	
Div. Equipments	0	0	0	80	80	0	130	CHeCS equipment, US laptop
Total:	0	840	1677	2912	2413	3178	4073	
Margin	0	160	328	238	187	422	427	
APM System Power	0	1000	2005	3150	2600	3600	4500	
Payload	0	0	0	0	800	8000	13500	
Required Power	–	1000	2000	3150	3400	11600	18000	APM with Payload
Available Power		1800	20000	20000	20000	20000	20000	from SSRMS/SSMB

Implementierung

- o **Rahmenbedingungen**
- o **Spezifikationen**
- o **Zeitplan/Programmphasen**

Politische und finanzielle Rahmenbedingungen (1)

„International Govermental Agreement“ (IGA) und ESA/NASA „Memorandum of Understanding“ (MOU) bilden die politische Basis der europäischen Beteiligung an der ISS:

- **IGA regelt als Staatsvertrag zwischen USA, Japan, Kanada und den an der Raumstation beteiligten ESA Mitgliedstaaten**
  - **Beteiligungen sowie deren Finanzierung**
  - **Nutzungsbestimmungen,**
  - **rechtliche Rahmen der Zusammenarbeit und bestimmt die Raumfahrtbehörden als die Exekutivberechtigenten-/verplichteten**
  - **Beitritt Rußland**

- **MOU zwischen ESA/NASA beinhaltet im wesentlichen**
  - **detailiierte Programmbeschreibung**
  - **Programm-Management Aufgaben, Verantwortlichkeiten**
  - **Zugangs- und Nutzungsrechte**
  - **Aufteilung der Nutzungskosten**

Verhandlungen IGA & MOU sollen bis Mitte 1997 abgeschlossen sein.

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Politische und finanzielle Rahmenbedingungen (2)

- **offene Punkte/Probleme bei IGA/MOU**

  - **„Common System Operations Cost“:**
    ESA Rat in Toulouse bestimmt als Zielvorgabe, daß die europäische Beteiligung das 0.6 fache eines AR/ATV launches pro Jahr nicht übersteigen soll;

  - **Nutzungsresourcen außerhalb APM;**

  - **Kompensation des APM-Transportes mit NSTS**

  - ***APM Start-Termin noch nicht engültig fixiert***

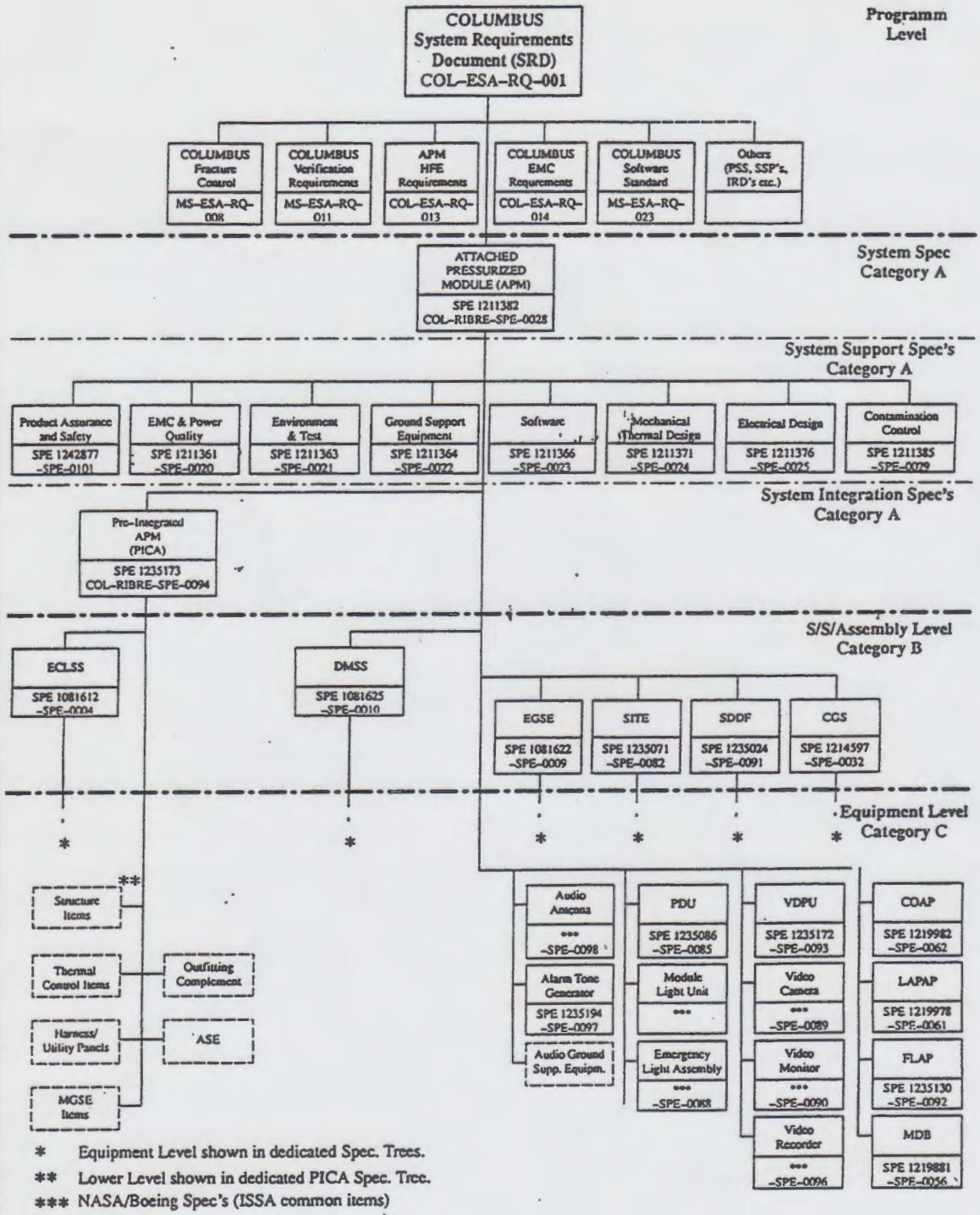
COLUMBUS Phase C/D - Geographical Return

Country	Amount (ECU)	%	Subscription %
Belgium	19.113.660	3,31	3,00
Switzerland	2.642.847	0,46	2,50
Germany	272.033.612	47,16	41,00
Denmark	3.794.123	0,66	1,17
France	118.087.604	20,47	27,60
Spain	6.503.000	1,13	2,00
Great Britain	1.077.000	0,19	0,00
Italy	147.510.521	25,57	18,90
Norway	2.081.500	0,36	0,46
Netherlands	2.234.605	0,39	0,94
Canada	1.002.269	0,17	0,00
Sweden	718.000	0,12	0,43
Total	576.798.741	100,00	98,00
50% MGSE/EEE-Agent	4.650.000		
USA/Sonstige	61.446.517		
Programme	642.895.258		

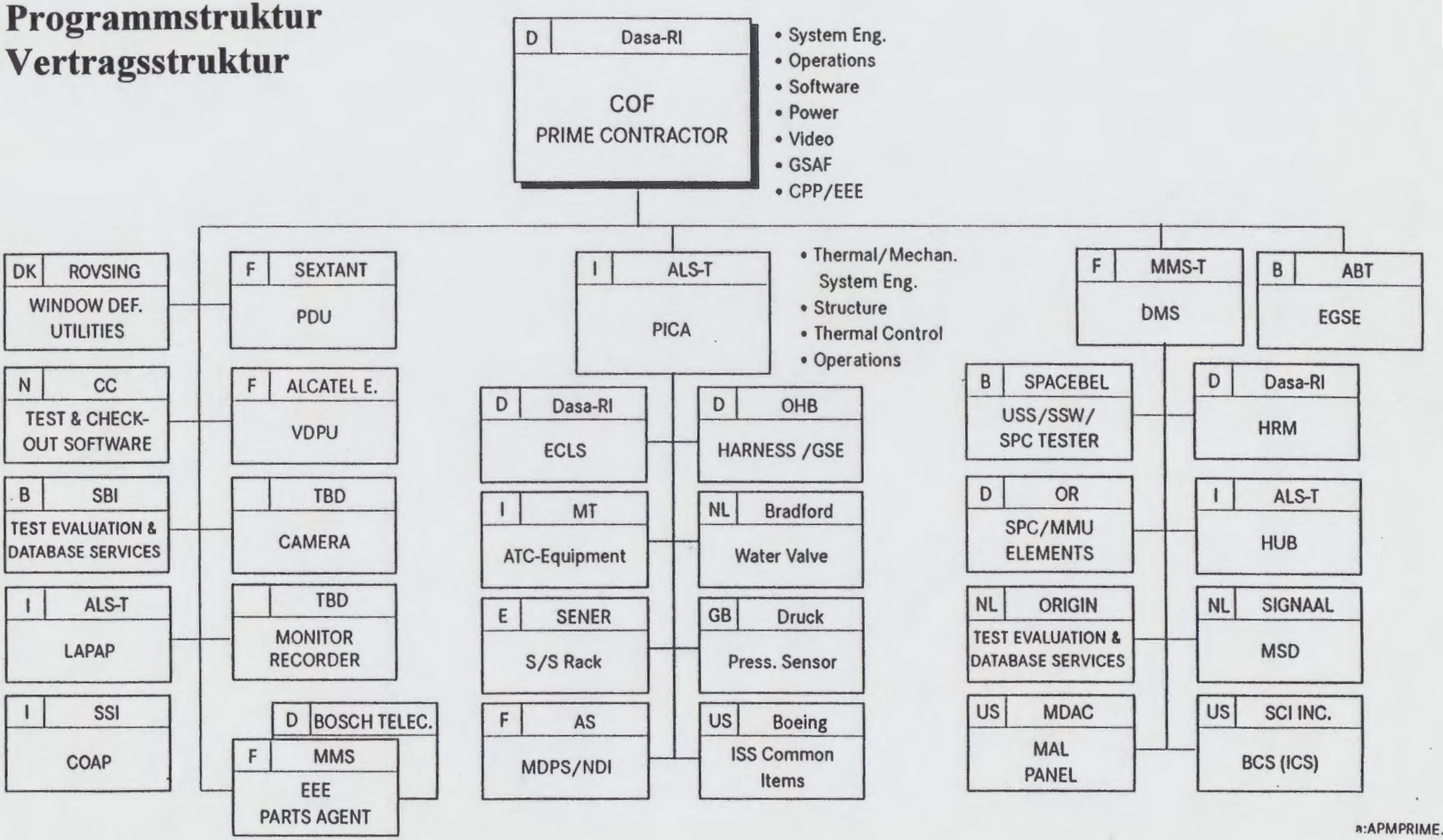
Beauftragung von Unterauftragnehmern

- **Jeder Auftrag ist definiert durch**
  - **Vertrag**
  - **Statement of Work mit:**
    - **--- Lieferumfangsliste (Produkte und Dokumente)**
    - **--- Anforderungen an Dokumentation**
  - **Spezifikation mit Anforderungen an Produkte**
  - **Festpreis mit Zahlungsmeilen**
- **Der Auftragsinhalt ist der ESA bekannt, Lieferumfang und geographische Verteilung der Aufgaben gelten als vereinbart und sind nur mit Zustimmung der ESA zu ändern.**

Spezifikationsbaum



Programmstruktur
Vertragsstruktur



a:APMPRIME.

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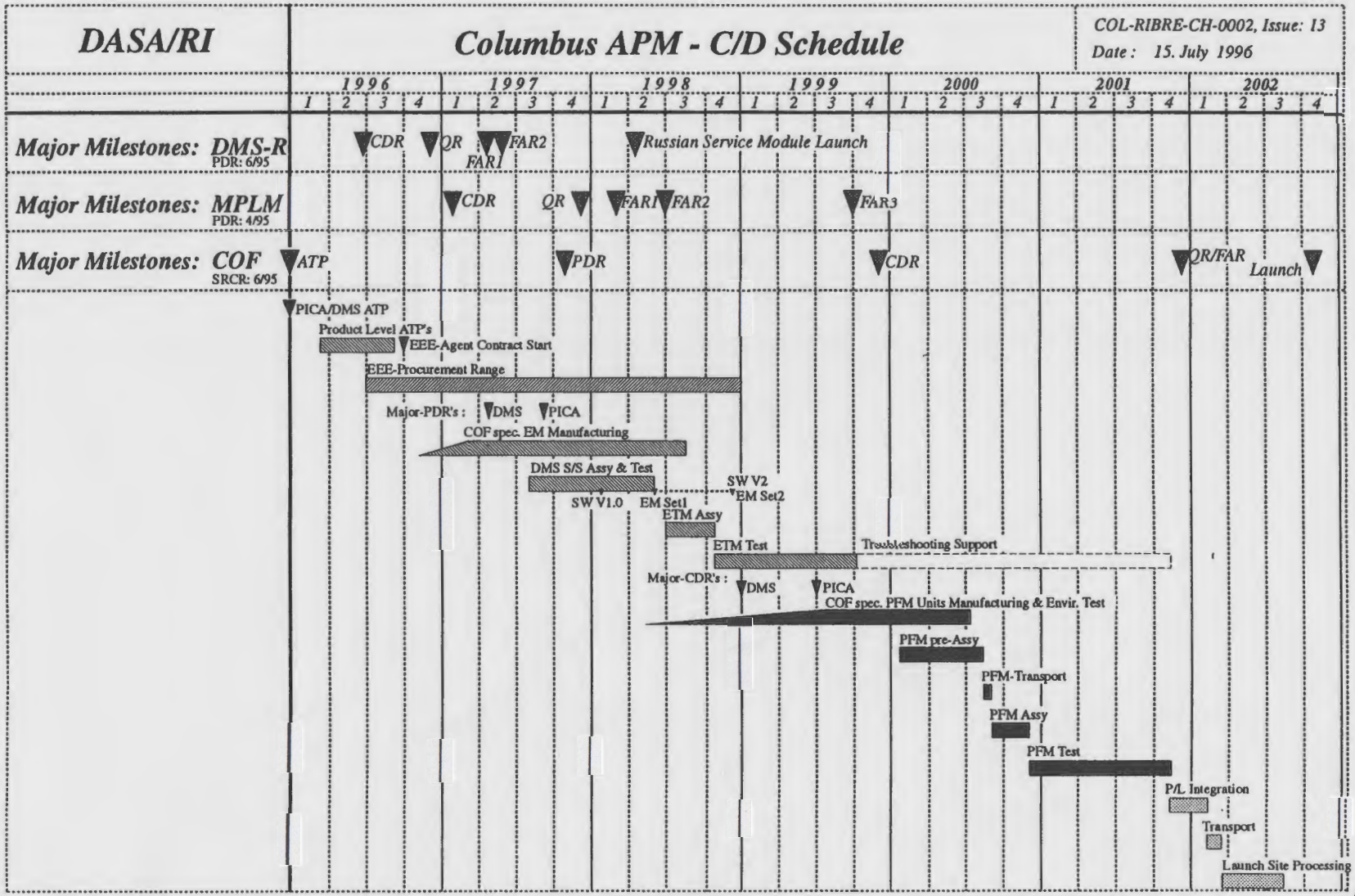
Programmphasen

- **Vorstudien: Machbarkeit**
- **Phase A: Konzept Studie**
- **Phase B: Projekt Definition**
  - **Detaillierte Definition/Spezifikation**
  - **Angebot für Phase C/D**
- **Phase C: Entwurfsdefinition**
  - **Detaillierter Entwurf**
  - **Breadboarding**
  - **Kompatibilität (Design integration/integrity)**
- **Phase D: Fertigung und Integration (Zusammenbau)**
  - **Verifikation (Certificate of Qualification)**
  - **Abnahme (Certificate of Acceptance)**

} **Mit gestuften formellen Überprüfungen**

- **Phase E: Betrieb**
  - **Nutzlasteinbau**
  - **Start**
  - **Inbetriebnahme**
  - **Operationeller Betrieb**
  - **Entsorgung**

Zeitplan


DASA/RI
Columbus APM - C/D Schedule
COL-RIBRE-CH-0002, Issue: 13
Date : 15. July 1996
1996
1997
1998
1999
2000
2001
2002
Major Milestones: DMS-R
PDR: 6/95
CDR
QR
FAR1
FAR2
Russian Service Module Launch
Major Milestones: MPLM
PDR: 4/95
CDR
QR
FAR1
FAR2
FAR3
Major Milestones: COF
SRCR: 6/95
ATP
PDR
CDR
QR/FAR
Launch
PICA/DMS ATP
Product Level ATP's
EEE-Agent Contract Start
EEE-Procurement Range
Major-PDR's :
DMS
PICA
COF spec. EM Manufacturing
DMS S/S Assy & Test
SW V1.0
EM Set1
SW V2
EM Set2
ETM Assy
ETM Test
Troubleshooting Support
Major-CDR's :
DMS
PICA
COF spec. PFM Units Manufacturing & Envir. Test
PFM pre-Assy
PFM-Transport
PFM Assy
PFM Test
P/L Integration
Transport
Launch Site Processing

Entwurfsüberprüfungen

Ereignis	Ziel
o PRR (Prelim. Reqmts. Review)	System Anforderungen für Phase C/D Angebot
o SRR (System Reqmts. Review)*	Teilsystemanforderungen, Festlegung Testmodelle
o PDR (Prelim. Design Review)*	Freigabe Fertigung Ingenieursmodelle
o Crew Station Reviews	Kommentierung durch Astronauten
o CDR (Critical Design Review)*	Freigabe Fertigung Flugmodelle
o QR (Qualification Review)*	Nachweis der Erfüllung aller Anforderungen
o FAR (Final Accept. Review)*	Abnahme des Produkts durch Auftraggeber

* mit komplementären Entwurfsüberprüfungen auf Teilsystem und Geräteebene

Entwurfüberprüfungen (Forts.)

- **Aufgabe:**
  - **Überprüfung des technischen Fortschritts**
  - **Formelle Freigabe der Ergebnisse als Basis für die nächste Phase**

- **Methodik:**
  - **Datenpaket wird vom Auftragnehmer erstellt**
  - **Kritik formulierten (RID's, DN's, etc.)**
  - **Boards (Entscheidungen zu jedem offenen Punkt)**
  - **Action Items zur Implementierungskontrolle der Entscheidungen**

- **Zur Beachtung:**
  - **Auftraggeber prüft Auftragnehmer (Chairman)**
  - **Logik dreht sich während der Entwicklung um:**
    - **Requirements: top-down (zuerst Systemanforderungen festschreiben)**
    - **Design: bottom-up (zuerst Entwurf auf Geräteebene prüfen)**

System Assembly, Integration and Test