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ACOP

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1. SCOPE AND INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

The purpose of this document is to provide documentation and data for flight operation and maintenance of the AMS-02 Crew Operations Post (ACOP).

The ACOP System is intended to fly on the International Space Station (ISS) as a payload installed into an EXPRESS ISPR in the NASA US laboratory module. The main objective of ACOP is to provide an ISS Internal Facility capable of supporting the AMS-02 experiment, performing the recording of Science data. In particular, ACOP shall allow a more flexible and efficient use of the ISS telemetry downlink, providing a backup of data generated by AMS-02 and preventing, in this way, possible losses of valuable data. In addition, ACOP provides a control and monitoring interface for the on-board crew to the external AMS payload. It also permits large software uploads into AMS.

1.2 DOCUMENTS

1.2.1 APPLICABLE DOCUMENTS

AD	Doc. Number	Issue / Date	Rev.	Title / Applicability
1	SSP 52000-IDD-ERP	D / 6.08.03		EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack Payloads Interface Definition Document
2	NSTS/ISS 13830	C / 01.12.1996		Implementation Procedures for Payloads System Safety Requirements – For Payloads Using the STS & ISS.
3	JSC 26493	17.02.1995		Guidelines for the preparation of payload flight safety data packages and hazard reports.
4	SSP 50004	April 1994		Ground Support Equipment Design requirements
5	SSP-52000-PDS	March 1999	B	Payload Data Set Blank Book
6	SSP 57066	October 28, 2003		Standard Payload Integration Agreement for EXPRESS/WORF Rack Payloads
7	GD-PL-CGS-001	3 / 17.03.99		Product Assurance & Rams Plan
8	SSP 52000 PAH ERP	November 1997		Payload Accommodation Handbook for EXPRESS Rack
9	SSP 50184	D / February 1996		Physical Media, Physical Signaling & link-level Protocol Specification for ensuring Interoperability of High Rate Data Link Stations on the International Space Program
10	SSP 52050	D / 08.06.01		S/W Interface Control Document for ISPR ***ONLY FOR HRDL, SECTION 3.4 ***
11	ECSS-E-40	A / April 1999	13	Software Engineering Standard
12	AMS02-CAT-ICD-R04	29.08.2003	04	AMS02 Command and Telemetry Interface Control document. Section AMS-ACOP Interfaces
13	SSP 52000-PVP-ERP	Sept. 18, 2002	D	Generic Payload Verification Plan EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack Payloads
14	NSTS 1700.7B	Rev. B Change Packet 8 / 22.08.00		Safety Policy and Requirements for Payloads using the STS
15	NSTS 1700.7B Addendum	Rev. B Change Packet 1 / 01.09.00		Safety Policy and Requirements for Payloads using the International Space Station
16	SSP 52005	Dec. 10, 1998		Payload Flight equipment requirements and guidelines for safety critical structures
17	NSTS 18798B	Change Packet 7 10.00		Interpretation of NSTS Payload Safety Requirements
18	MSFC-HDBK-527	15.11.86	E	Materials selection list for space hardware systems Materials selection list data
19	GD-PL-CGS-002	1 / 12.02.99		CADM Plan
20	GD-PL-CGS-004	2 / 07.04.03		SW Product Assurance Plan
21	GD-PL-CGS-005	2 / 09.05.03		SW CADM Plan

Table 1-1 Applicable Documents

1.2.2 REFERENCE DOCUMENTS

AD	Doc. Number	Issue / Date	Rev.	Title / Applicability
1	GPQ-MAN-02	1		Commercial, Aviation and Military (CAM) Equipment Evaluation Guidelines for ISS Payloads Use
2	BSSC (96)2	1 / May 96		Guide to applying the ESA software engineering standards to small software projects
3	GPQ-MAN-01	2 / December 98		Documentation Standard for ESA Microgravity Projects
4	MS-ESA-RQ-108	1 / 28 Sept. 2000		Documentation Requirements For Small And Medium Sized MSM Projects
5	PSS-05			Software Engineering Standards
6	GPQ-010	1 / May 95	A	Product Assurance Requirements for ESA Microgravity Payload. Including CN 01.
7	GPQ-010-PSA-101	1		Safety and Material Requirements for ESA Microgravity Payloads
8	GPQ-010-PSA-102	1		Reliability and Maintainability for ESA Microgravity Facilities (ISSA). Including CN 01
9	SSP 52000-IDD-ERP	E / 09/09/03		EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack Payloads Interface Definition Document
10	ACD-Requirements-Rev-BL	September 2005	Base Line	ACOP Common Design Requirements Document
11	ECSS-Q-60-11A	1 / 7 Sept. 2004		De-rating and End-of-life Parameter Drifts – EEE Components
12	ACP-PL-CGS-002	1 / 28 July 2004		ACOP PA Plan
13	ACP-RP-CGS-002	2 / October 2005		ACOP Operational Analysis Report
14	ACP-RP-CGS-003	2 / October 2005		ACOP Design Report
15	ACP-RP-CGS-004	2 / October 2005		ACOP Electrical Analysis and Design Report
16	ACP-RP-CGS-005	2 / October 2005		ACOP Structural Analysis and Design Report
17	ACP-RP-CGS-006	2 / October 2005		ACOP Thermal Analysis and Design Report
18	ACP-RP-CGS-007	1 / October 2005		ACOP Fracture Control Report
19	ACP-TN-CGS-001	2 / October 2005		ACOP FMECA and SPF List

Table 1-2 Reference Documents

1.3 DEFINITIONS AND ACRONYMS

A

AAA	Avionics Air Assembly
ABCL	As-Built Configuration data List
ACOP	AMS-02 Crew Operation Post
ACOP-SW	ACOP Flight Software
ADP	Acceptance Data Package
AMS-02	Alpha Magnetic Spectrometer 02
APS	Automatic Payload Switch
AR	Acceptance Review
ASI	Agenzia Spaziale Italiana *(Italian Space Agency)*
ATP	Authorization To Proceed

B

BC	Bus Coupler
BDC	Baseline Data Collection
BDCM	Baseline Data Collection Model

C

CAD	Computer Aided Design
CCB	Configuration Control Board
CCSDS	Consultative Committee on Space Data Standards (standard format for data transmission)
C&DH	Command & Data Handling
CDR	Critical Design Review
CGS	Carlo Gavazzi Space
CI	Configuration Item
CIDL	Configuration Item data List
CM	Configuration Management
COTS	Commercial Off The Shelf
cPCI	CompactPCI (Euro Card sized standard interface to the PCI)
CSCI	Computer Software Configuration Item
CSIST	Chung Shan Institute of Science and Technology

D

DCL	Declared Components List
DIL	Deliverable Items List
DIO	Digital Input / Output
DML	Declared Materials List
DMPL	Declared Mechanical Parts List
DPL	Declared Processes List
DRB	Delivery Review Board
DRD	Document Requirements Description

E

EEE	Electrical, Electronic & Electromechanical
EGSE	Electrical Ground Support Equipment
EM	Engineering Model
ER	EXPRESS Rack
ERL	EXPRESS Rack Laptop
ERLC	EXPRESS Rack Laptop Computer
ERLS	EXPRESS Rack Laptop Software
EMC	Electro-Magnetic Compatibility
ESA	European Space Agency
EXPRESS	EXpedite the PRocessing of Experiments to Space Station

F

FEM	Finite Element Model
FFMAR	Final Flight Model Acceptance Review
FLASH	Rewriteable persistent computer memory
FM	Flight Model
FMECA	Failure Modes, Effects & Criticalities Analysis

FPGA	Field Programmable Gate Array
FSM	Flight Spare Model

G

GIDEP	Government Industry Data Exchange Program
GSE	Ground Support Equipment

H

HCOR	HRDL Communications Outage Recorder
HD	Hard Drive
HDD	Hard Disk Drive
HRDL	High Rate Data Link
HRFM	High Rate Frame Multiplexer
HW	Hardware

I

ICD	Interface Control Document
I/F	Interface
IRD	Interface Requirements Document
ISPR	International Space-station Payload Rack
ISS	International Space Station

J

JSC	Johnson Space Center

K

KIP	Key Inspection Point
KSC	Kennedy Space Center
KU-Band	High rate space to ground radio link

L

LAN	Local Area Network
LCD	Liquid Crystal Display
LFM	Low Fidelity Model
LRDL	Low Rate Data Link

M

MDL	Mid-Deck Locker
MGSE	Mechanical Ground Support Equipment
MIP	Mandatory Inspection Point
MMI	Man Machine Interface
MPLM	Multi-Purpose Logistic Module
MRDL	Medium Rate Data Link

N

NA	Not Applicable
NASA	National Aeronautics and Space Administration
NCR	Non Conformance Report
NDI	Non Destructive Inspection
NRB	Non-conformance Review Board
NSTS	National Space Transportation System (Shuttle)

O

OLED	Organic Light-Emitting Diode
ORU	Orbital Replacement Unit

P

PA	Product Assurance
PCB	Printed Circuit Board
PCI	Peripheral Component Interconnect (personal computer bus)
PCS	Personal Computer System
PDR	Preliminary Design Review
PEHB	Payload Ethernet Hub Bridge

PEHG	Payload Ethernet Hub Gateway
PFMAR	Preliminary Flight Model Acceptance Review
PLMDM	Payload Multiplexer De-Multiplexer
PMC	PCI (Peripheral Component Interconnect) Mezzanine Card
PMP	Parts, Materials & Processes
PROM	Programmable Read Only Memory
PS	Power Supply

Q

QM	Qualification Model

R

RFA	Request For Approval
RFD	Request For Deviation
RFW	Request For Waiver
RIC	Rack Interface Controller
ROD	Review Of Design
ROM	Read Only Memory
RX	Reception

S

SATA	Serial Advanced Transfer Architecture (disk interface)
S-Band	Space to ground radio link
SBC	Single Board Computer
SC MDM	Station Control Multiplexer De-Multiplexer
ScS	Suitcase Simulator
SDD	Solid-state Disk Drive
SIM	Similarity Assessment
SIO	Serial Input Output
SOW	Statement Of Work
SPF	Single Point Failure
SRD	Software Requirements Document
STS	Space Transportation System (Shuttle)
SW	Software

T

TBC	To Be Confirmed
TBD	To Be Defined
TBDCM	Training & Baseline Data Collection Model
TBDCMAR	TBDCM Acceptance Review
TBP	To Be Provided
TCP/IP	Transmission Control Protocol / Internet Protocol
TFT	Thin Film Transistor
TM	Telemetry
TRB	Test Review Board
TRR	Test Readiness Review
TRM	Training Model
TX	Transmission

U

UIP	Utility Interface Panel
UMA	Universal Mating Assembly
USB	Universal Serial Bus

#

100bt	Ethernet 100Mbit Specification
1553	Reliable serial communications bus

2. DESCRIPTION OF ACOP

The ACOP System is a reliable special purpose computer intended to fly on the International Space Station (ISS) as a payload installed into an EXPRESS ISPR in the NASA US laboratory module. The main objective of ACOP is to provide an ISS Internal Facility capable of supporting AMS-02 experiment, performing the recording of Science data.

In particular, ACOP shall allow a more flexible and efficient use of ISS telemetry downlink, providing a backup of data generated by AMS-02 and preventing, in this way, possible losses of valuable data. In addition, ACOP provides a control and monitoring interface for the on-board crew to the external AMS payload. It also permits large software uploads into AMS.

ACOP is not designed to provide safety critical commands to AMS-02.

ACOP system shall be installed in the U.S. Laboratory Module, on the ISS, in one EXPRESS rack (see, for reference, Figure 2-1).

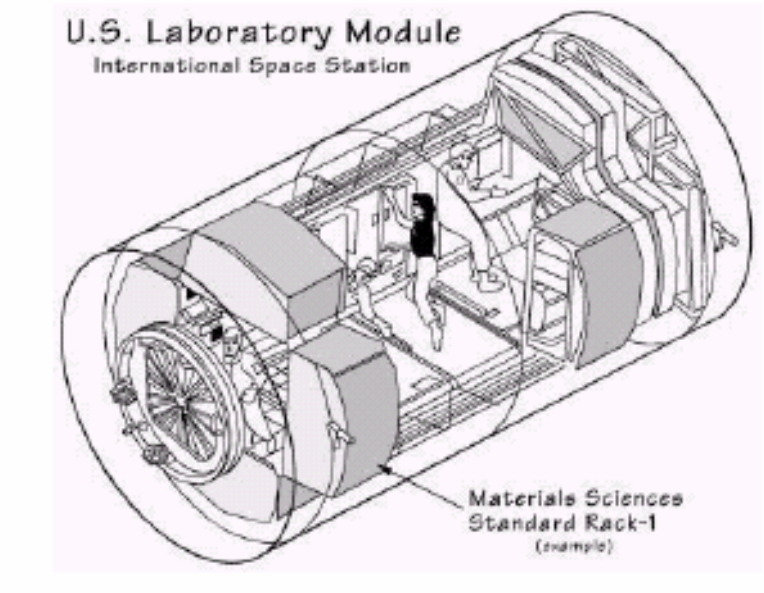

Figure 2-1 US-LAB

The standard configuration of an EXPRESS Rack is commonly known as 8/2. This means the rack can accommodate eight ISS Locker / Middeck Locker (MDL) units and two International Subrack Interface Standard (ISIS) units, as shown in Figure 2-2 and Figure 2-3. Figure 2-4 shows ACOP installed in such a rack (the location within the rack is just an example, the actual location will be determined by the ISS program).

On-board spare parts, including hard drives shall be accommodated in a standard soft bag.

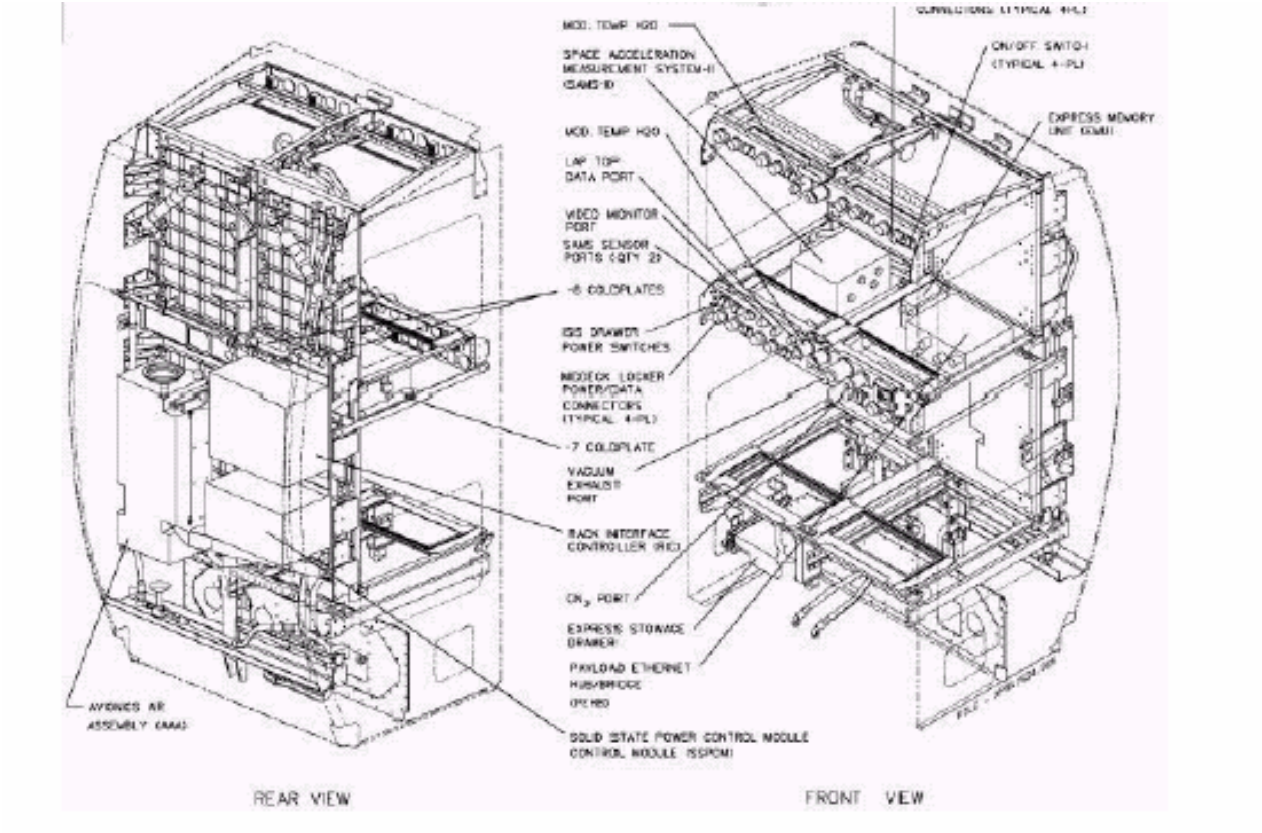

Figure 2-2 Example of an EXPRESS Rack (3D view)

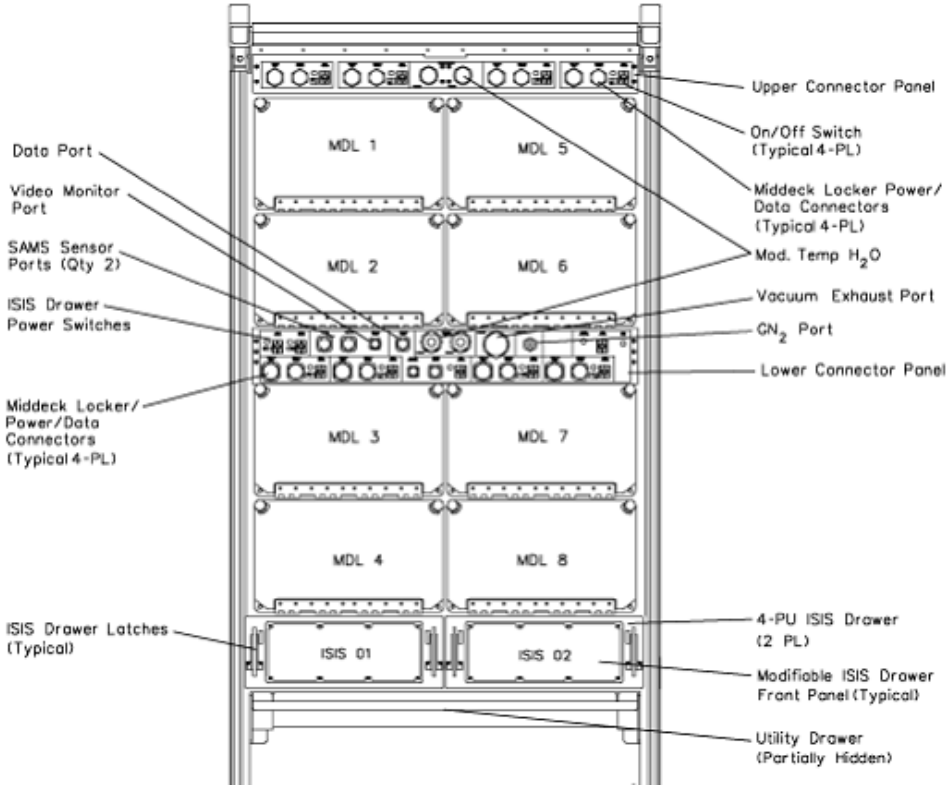

Figure 2-3 Example of an EXPRESS Rack (front view)

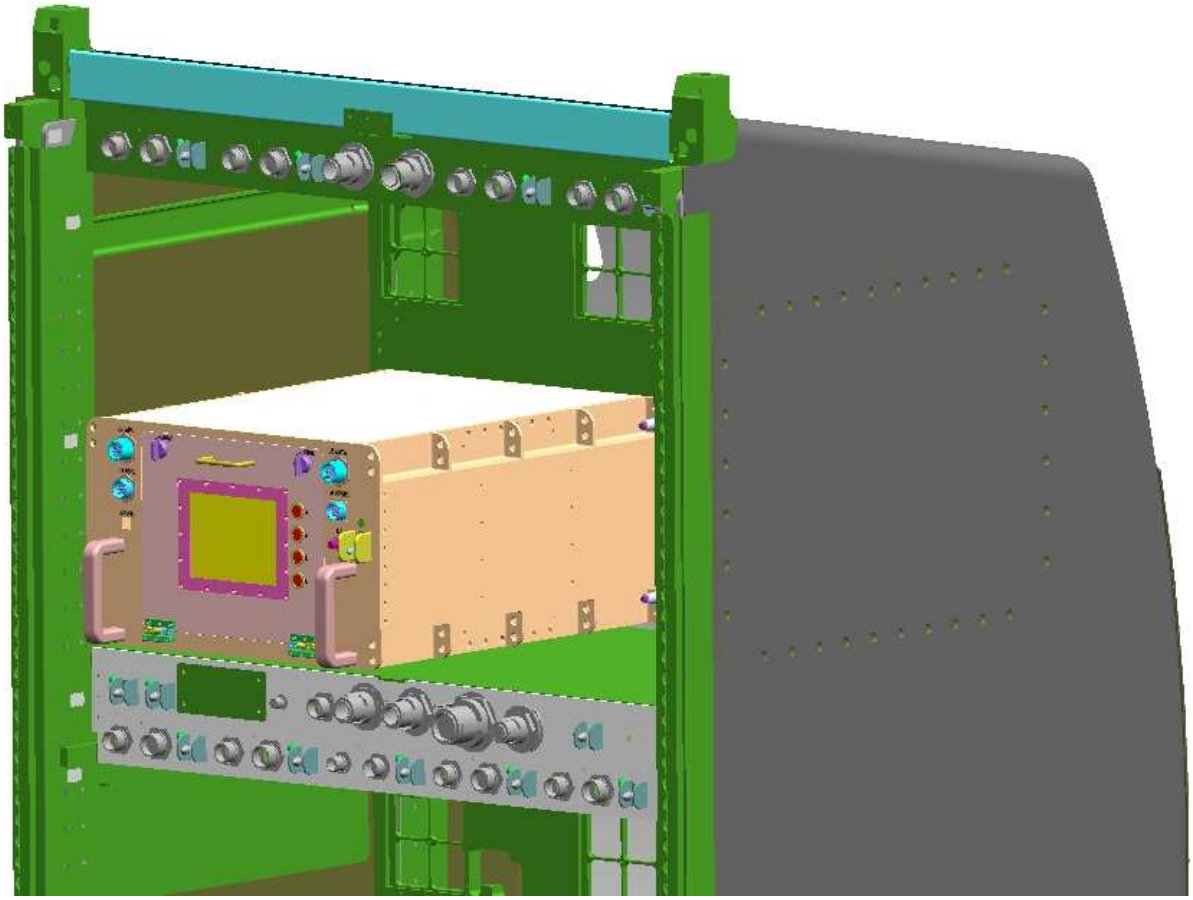

Figure 2-4 ACOP installed in an EXPRESS Rack (example of possible location)

ACOP provides these services:

1. On-orbit recording mechanism for large volumes of data at high rates
2. Play back for downlink of the recorded data at high rates
3. A crew interface for complex experiments
4. General computing facilities
5. Alternate bi-directional commanding path via the HRDL interface

ACOP will initially support a state-of-the-art particle physics detector, the Alpha Magnetic Spectrometer (AMS-02) experiment. AMS-02 uses the unique environment of space to study the properties and origin of cosmic particles and nuclei including antimatter and dark matter, to study the actual origin of the universe and potentially to discover antimatter stars and galaxies.

After the AMS-02 experiment, ACOP will remain in the US Lab as a general use computer for recording and managing large data volumes on the ISS. It will also allow a flexible and extensible control and monitoring interface for future payloads and, by using the large buffering capacity (> 1 TB), it will improve the data communication between Earth and the Space Station.

In addition to the ACOP system itself, shown in Figure 2-5 and Figure 2-6, a stowage bag will be sent to ISS with additional hard drives that can be exchanged with the hard drives in ACOP. From time to time the astronauts will perform this exchange enabling ACOP to record all of the AMS-02 data onto fresh hard drives. Once recorded, data will not be overwritten; rather the hard drives will be transported to ground as a permanent archive. The stowage bag will also contain spare parts for ACOP.

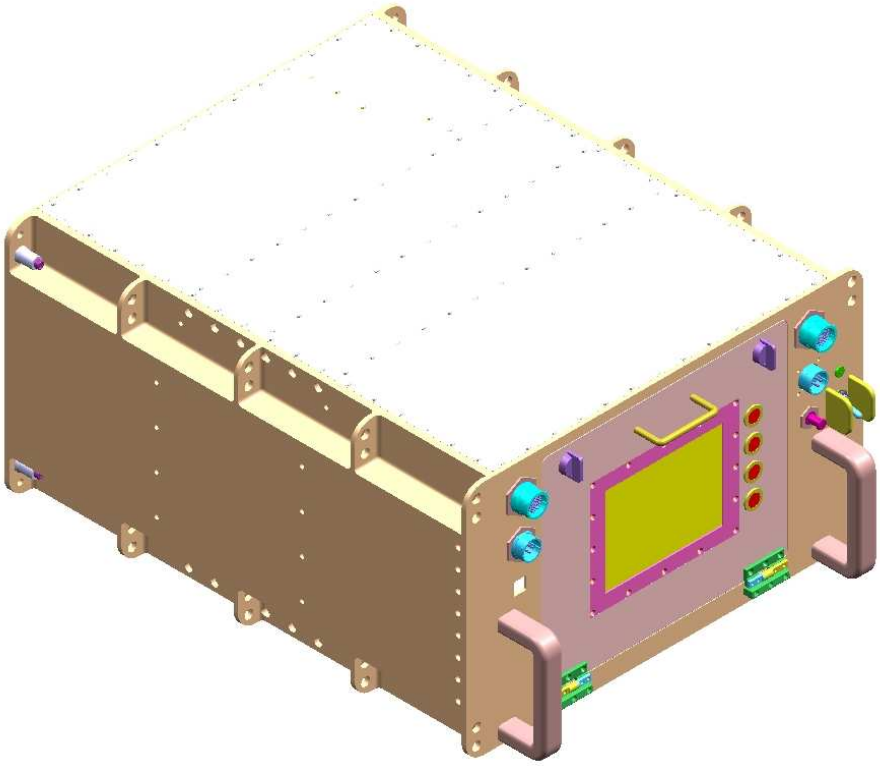

Figure 2-5 ACOP General Front View

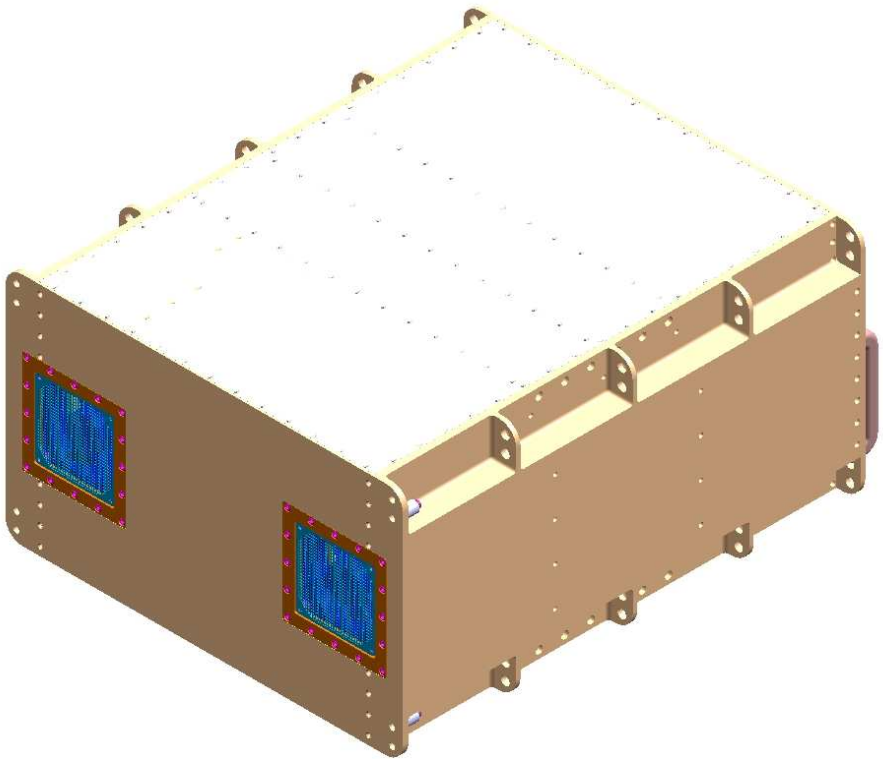

Figure 2-6 ACOP General Rear View

2.1 FUNCTION AND PURPOSE OF ACOP

ACOP has been designed to fulfil the requirements generated by the AMS-02 Collaboration. See the ACOP Common Design Requirements Document (document number: ACD-Requirements-Rev-BL, revision: baseline, date: September 2005) and the ACOP System Specification (document number: ACP-SY-CGS-001, issue: 3, date: March 2005) for a detailed description of the requirements.

The main characteristics of ACOP are summarized here below:

Capacities

1. Operates effectively in the ISS space environment.
2. Creates, on-orbit, an archive of all AMS-02 science data on removable and transportable media, using high capacity (200 GB or more) SATA hard drives.
3. Provides (based on an average data rate of 2Mbit/s) at least 20 days of recording capacity without crew intervention[1].
4. Provides (based on an average data rate of 2Mbit/s) at least 120 days of on board recording media capacity within an additional single mid-deck locker equivalent soft sided storage unit[2].
5. Recorded data is an irreplaceable archive of science data. Once recorded, data will not be overwritten; rather the hard drives will be transported to ground as a permanent archive.

Rates

6. For recording ACOP supports an orbital average data rate of at least 4Mbit/s with bursts of up to 20Mbit/s[3].
7. Supports the playback of recorded data to ground systems at selectable data rates up to at least 20Mbit/s sustained while simultaneously recording at prescribed rates (per 6.).
8. Supports an alternate AMS-02 ground commanding and housekeeping report path via the HRDL interface.
9. Supports ACOP to AMS-02 commanding at selectable data rates up to at least 20Mbit/s sustained. No requirement for simultaneous recording or playback operations at higher rates.

Interfaces

10. Provides a continuous operations display of ad hoc AMS-02 data and ACOP status for the ISS crew to monitor, via a LCD on the front panel.
11. Provides a continuous means for the ISS crew to issue ad hoc commands immediately to ACOP and to AMS-02 (without the need to un-stow or attach external equipment), by using accessible push-buttons on the front panel.
12. Provides an exhaustive diagnostic, monitoring and operations environment via the EXPRESS laptop computer.

Form

13. Housed within an EXPRESS rack locker and based on a CompactPCI 6U form factor.
14. Crew serviceable for hardware upgrades and repairs.
15. Crew serviceable for software upgrades and repairs.

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[1] Data capacity is completely dependent on application implementation.
[2] See note 1.
[3] The AMS-02 experiment has been designed to meet its physics goals when producing data at an average rate of 2MBit/s. Data is produced continuously. However, the physics that will be measured is unknown, and so are the peak and average data rates − 2Mbit/s average is the best estimate. Within AMS-02 a four-fold redundant 1GByte buffer (JBU) is provide to smooth the data flow and to allow for short term (less than an hour) interruptions in the data output from AMS, for example when the hard disk drives are being swapped within ACOP. After any such interruption, the data rate capability in ACOP must be able to make up for the lost time while not falling behind on the fresh data. Therefore ACOP is able to process data at a rate of at least twice the average data rate from AMS, namely 4Mbit/s.

16. Upgradeable and expandable using COTS subsystems.
17. Provides support of ISS system upgrades (e.g. 100bt MRDL follow on systems).
18. ACOP is to weigh less than 35.5 kg without disks (launch weight)[4].
19. ACOP to consume less than 200 W (at 28Vdc)[5]
20. Launch compatible with MLPM mounting and dynamics.

2.2 UTILIZATION CONCEPT

The following are the key points of the ACOP operational concept as it pertains to the AMS-02 mission:

- ACOP is principally a ground operated payload
- ACOP provides the mechanism for the crew to monitor and control AMS-02. Both front panel and EXPRESS Rack laptop based interfaces are supported.
- ACOP is powered and active whenever AMS-02 is active. Only short (< 8 hours) outages.
- ACOP has continuous direct access to two physical HRDL connections (1 Tx/Rx pair plus an additional Tx, via UIP J7 connectors in other racks). By means of these interfaces:
  a. maintains a continuous Tx/Rx connection via APS to AMS
  b. provides intermittent, schedulable Tx connection for downlink.

  The additional Tx connection may be replaced by connection to the upgraded 100BaseT MRDL, when available.
- The AMS-02 TX connection may be tee'd by the APS to the HRFM/KU for direct downlink.
- As KU access is available, ACOP will be commanded to use its additional TX connection to down link data. ACOP will have the ability to burst this transmission (~20Mbits/sec).
- All data transmitted by AMS-02 is recorded onto ACOP hard drives as a master copy of the AMS-02 science data.
- When ACOP has acknowledged that the data is recorded, AMS-02 can release that data from its buffers.
- The four installed hard drives will require periodic replacement by the ISS crew from the onboard stock of empty drives (30 minute operation about every 20 days)
- A batch of 20 hard drives provides at least 120 days of recording capacity.
- New batches of hard drives will be delivered to ISS and the original master copies of the AMS-02 data will be returned to earth.

2.3 MECHANICAL DESIGN

ACOP can be installed in any one of the 8 locations for Lockers of an EXPRESS Rack. Figure 2-4 shows one of the possible locations.

The mechanical structure of ACOP is mainly constructed by an outer structure (Locker) and an inner structure Chassis). All the parts will be made of aluminum alloy. See the ACOP Design Report for details.

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[4] See ACOP Design Report for the actual mass budget

[5] See ACOP Design Report for the actual power budget

2.3.1 FRONT PANEL LAYOUT

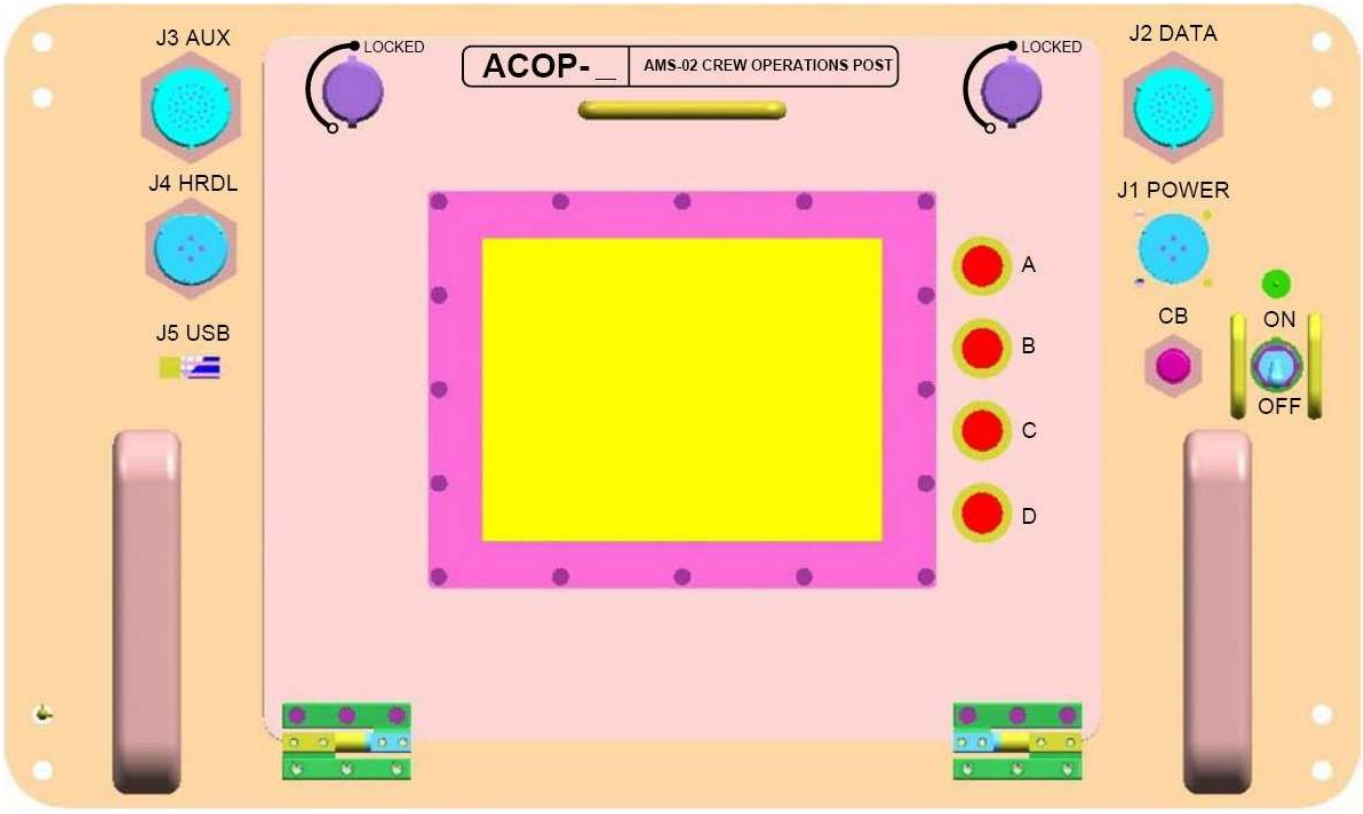

Figure 2-7 Front Panel Layout

Figure 2-7 shows the ACOP front panel. On the fixed part of the front panel four connectors are located for power (28 Vdc), data (Ethernet), High Rate Data Link (HRDL), and auxiliary data (a second Ethernet connection). A switch and circuit breaker control the power into ACOP and an LED indicates the current power status. Two hand holds are permanently installed on ACOP as both ACOP handling and crew mobility aids.

In the center of the ACOP front panel is a door mounted on friction hinges. The door is normally in the closed position and is held by two partial turn compression latches at the top. A handle facilitates the opening of the door. Labels indicate the closed and open positions.

Mounted on the door is an LCD panel for graphical displays. Four push buttons are provided to allow control of ACOP by the crew. The push buttons will allow the crew to navigate into the menus displayed on the LCD.

2.3.2 LOCKER NOMENCLATURE AND LAYOUT

This section introduces the nomenclature of the ACOP locker[6].

[6] This data will be the basis for the Operations Nomenclature (OpNom) submittal. Use of this nomenclature within flight procedures is subject to final approval.

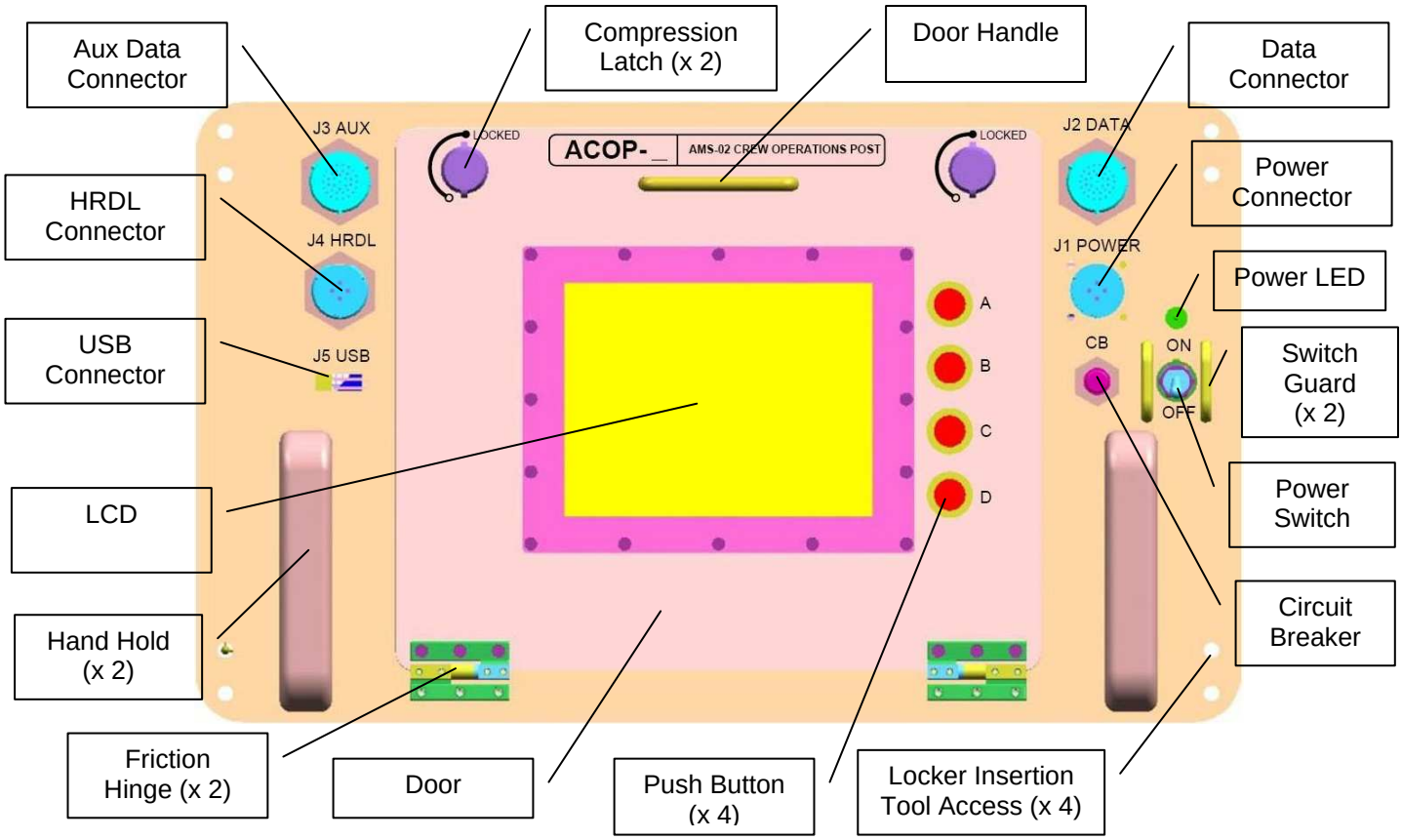

Figure 2-8 Locker Front Panel Nomenclature

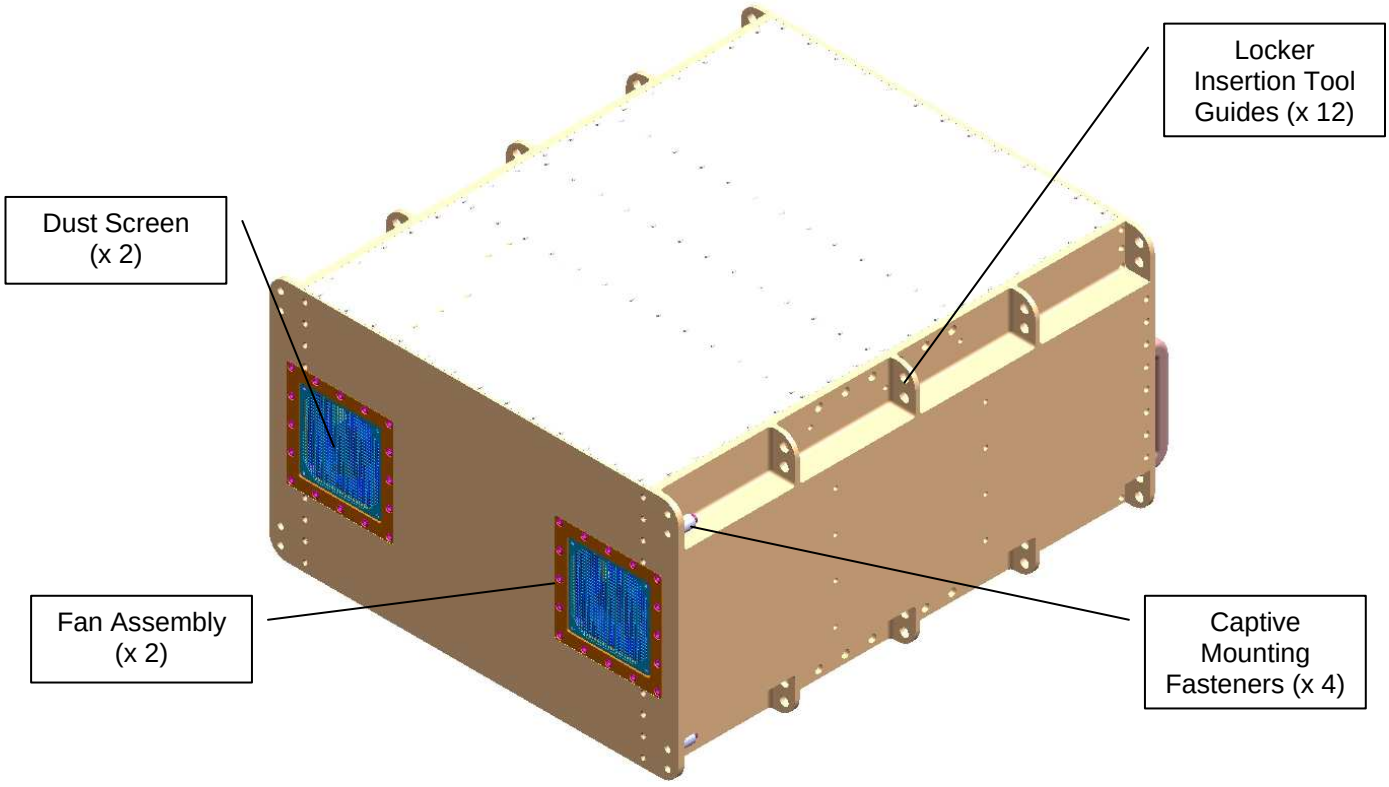

Figure 2-9 Rear View Nomenclature

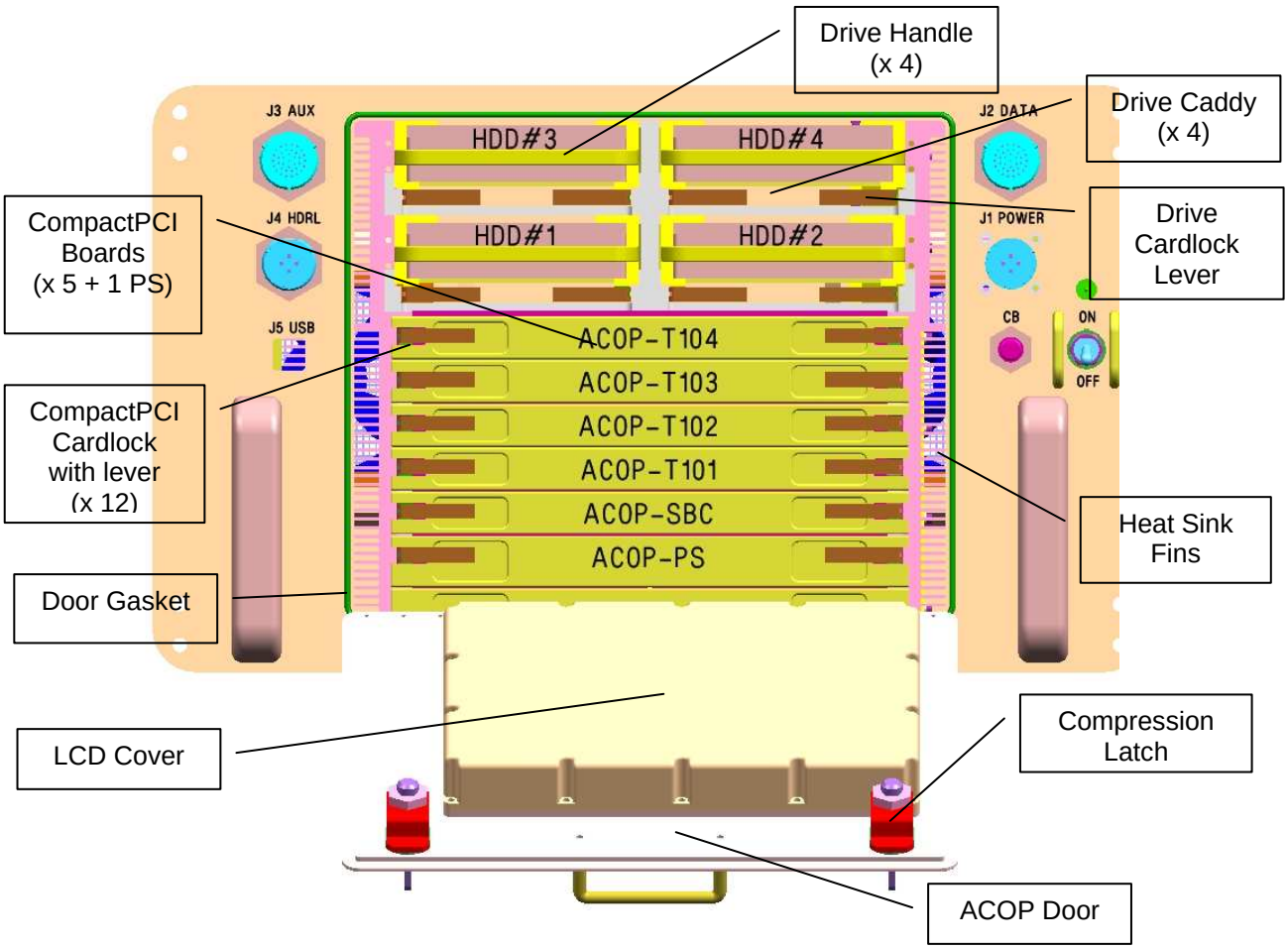

Figure 2-10 Front View Internal Nomenclature

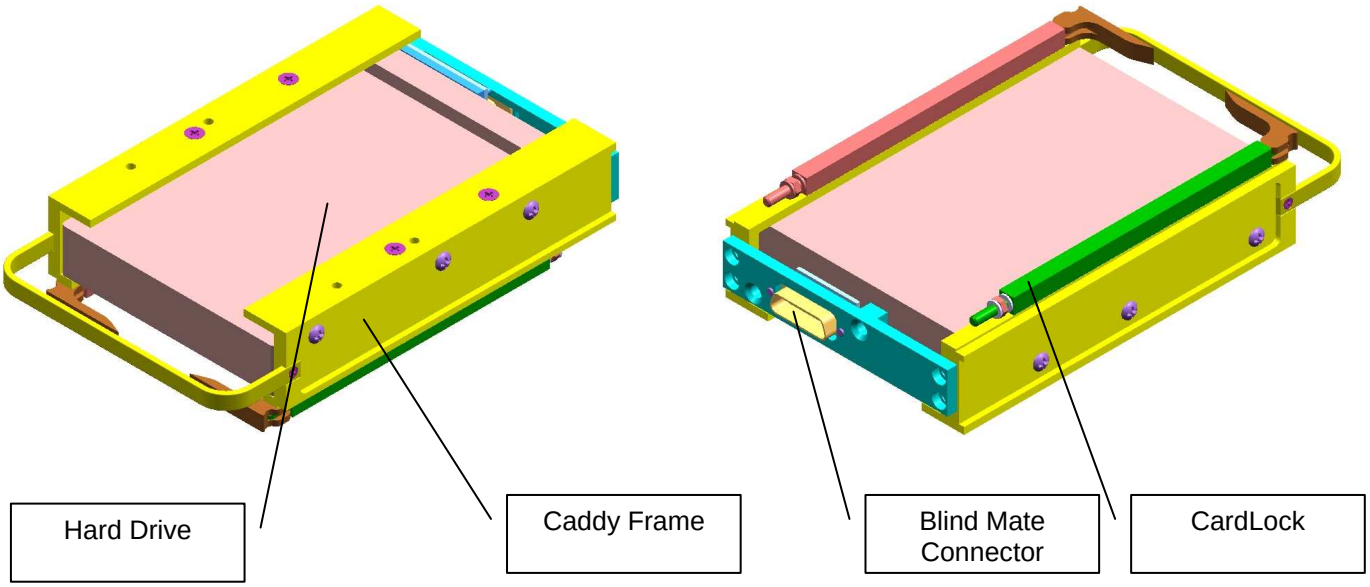

Figure 2-11 Hard Drive Caddies

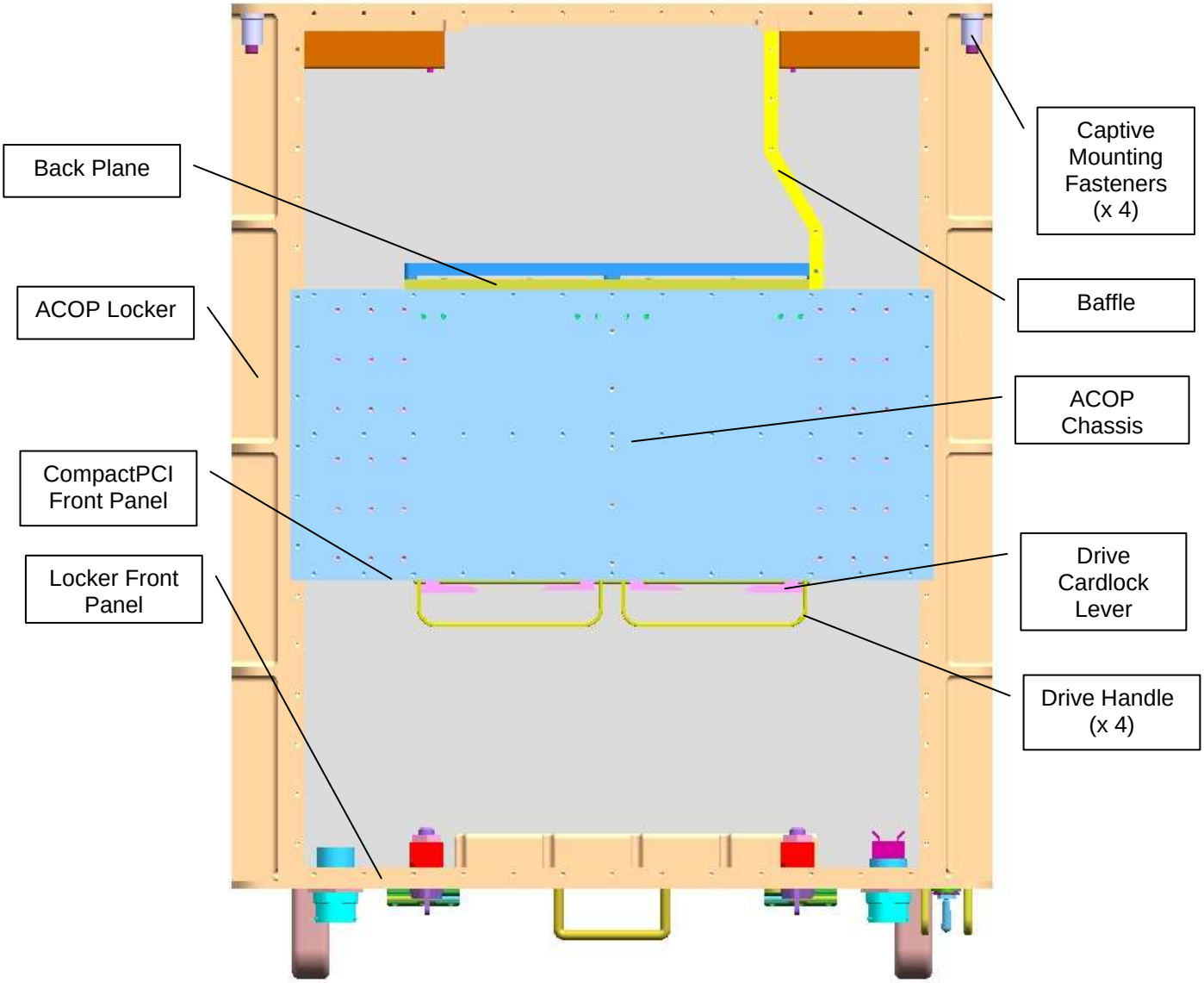

Figure 2-12 Top View Nomenclature

Figure 2-8 shows the major attractions on the locker front panel. The largest feature is a door providing access to the interior of ACOP. An LCD display and four push buttons that provide a simple operating interface to ACOP are mounted on this door.

Figure 2-9 shows the mounting interface and the interface to the EXPRESS AAA system.

Figure 2-10 shows the internal disposition of the ACOP boards as it will be seen by the crew when the door is opened. The upper part will be occupied by four hard drives mounted in caddies. The caddies will be fixed to the chassis by means of cardlock retainers (provided with levers to minimize the crew effort to replace them). The power and the data interface to the HDD are by means of a blind mate connector placed on the rear side of the HDD caddy. The system is designed to facilitate easy replacement of the boards and hard drives.

The CompactPCI boards plus the Power board will be hosted in the lower section of the chassis: these boards will also be fixed to the chassis by means of cardlock retainers.

Figure 2-11 Shows a top and bottom view of a hard drive caddy.

Figure 2-12 shows ACOP with the top surface removed exposing the layout and giving names of items difficult to see from the other views.

2.3.3 LABELS

ACOP will be labeled in accords to SSP 57000 Appendix C. For the front panel, silk screening will be used to apply the labels as shown in Figure 2-7. For the removable and replaceable parts the ISS Payload Label Approval Team (IPLAT) will assist with the development, creation, and application of the labels. Items that must be labeled for identification and stowage management include[7]:

- Drive Caddies (x 100+)
- CompactPCI Boards (x ~10)
- Cables (x ~10)
- USB FLASH keys (x 5)
- Fan Assemblies (x 3)

2.3.4 THERMAL DESIGN

ACOP is cooled using the Avionics Air Assembly (AAA) interface. The ACOP Back Plate has inlet and outlet ports for Avionics Air Assembly (AAA) cooling air. These ports are located to coordinate with the appropriate openings in the EXPRESS Rack back plate.

There is a fan in each of the inlet and outlet ports on the ACOP Back Plate. The two fans provide a surplus of air handling capacity and the operation of the fans will be managed to minimize acoustic noise. Screens protect the fans and ACOP internals from debris.

The system is designed to support the cleaning and replacement of the screens and fans.

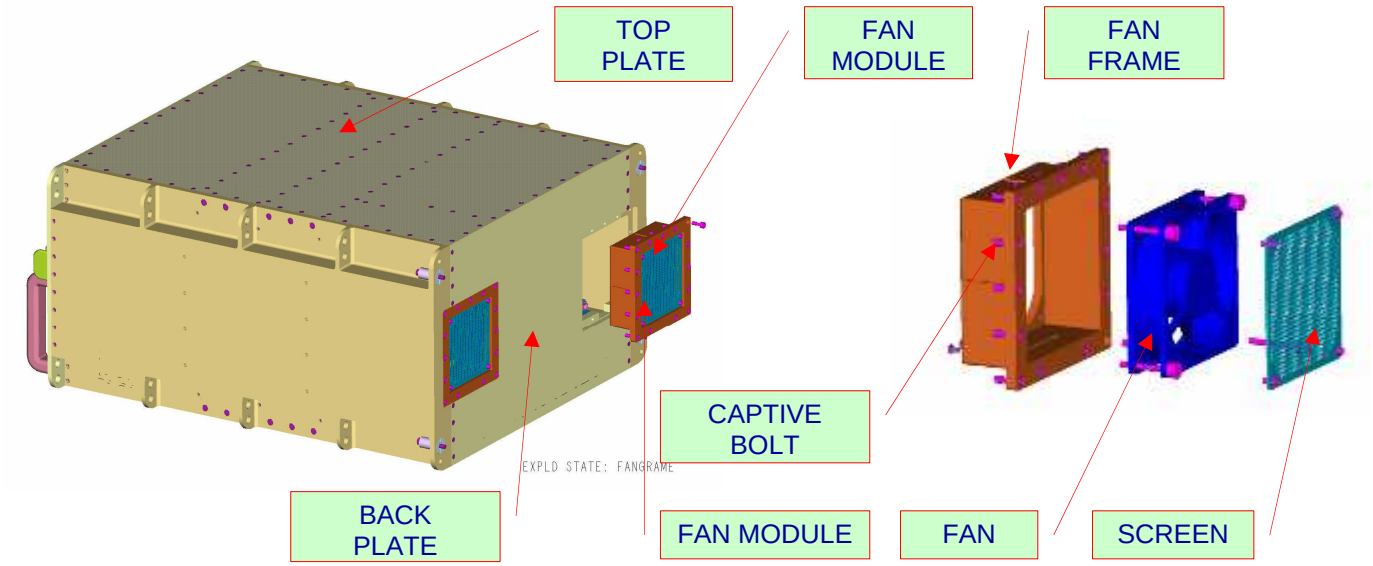

Figure 2-13 Fan Assembly External Details

[7] Counts of items to be labeled are estimates to be confirmed at a later date.

Figure 2-13 shows the exploded view of the Fan Assembly external components. The Fan is mounted in the Fan Frame and the debris Screen is attached to the Fan Frame using captive fasteners. The Fan Frame is attached to the Back Plate with captive fasteners to support on board maintenance and replacement.

Figure 2-14 illustrates the thermal management. Heat dissipated from the hard disk drives and CompactPCI boards will be conducted to the fin walls of the chassis by conduction transfer. The fans will draw air into ACOP from the AAA inlet port. Most of this airflow will blow through the fin channels, while a small flow will blow past the top and bottom of the hard drives. The airflow will enter the front chamber of ACOP and will continue by the back side of the Front Panel, thus removing the heat generated by the LCD electronics. The airflow will then flow through the opposite side chassis fin wall and exit via the outlet port into the AAA volume.

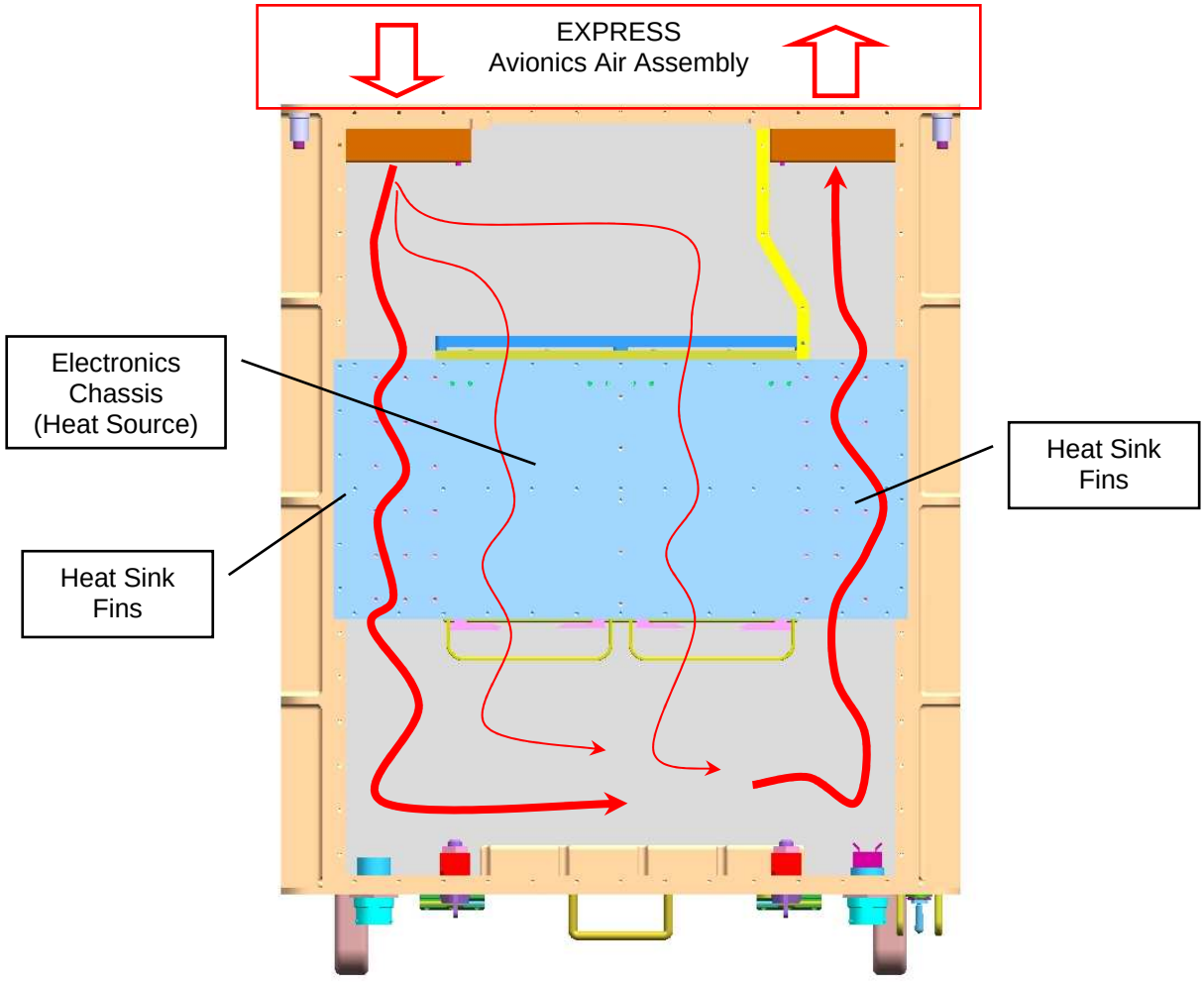

Figure 2-14 Thermal Design Top View

Figure 2-15 shows the heat sink fins. Through these fins the fans mounted in the back of ACOP can be seen.

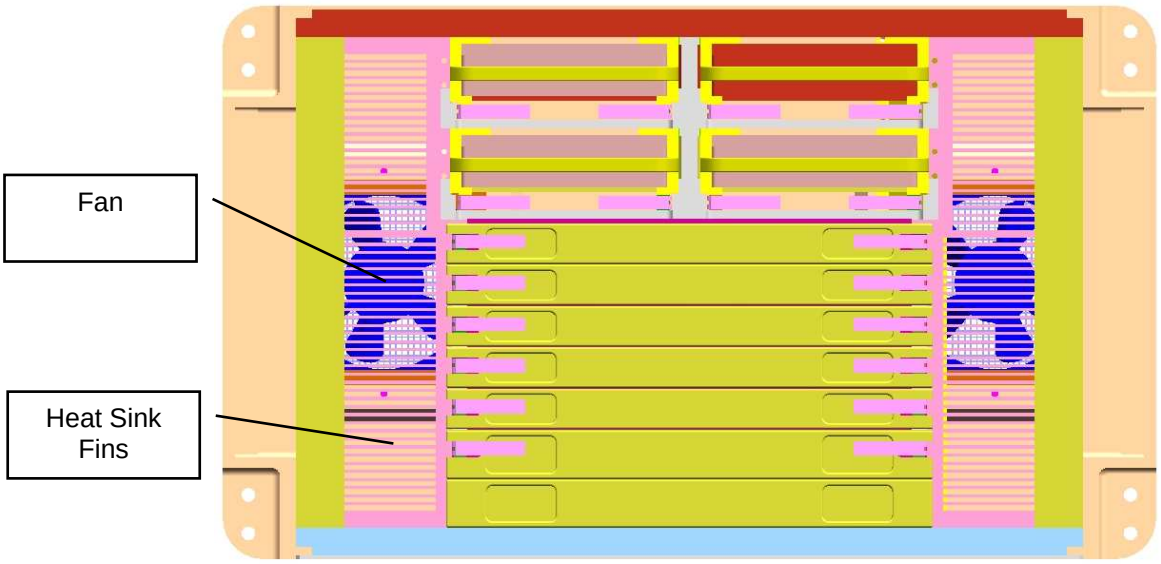

Figure 2-15 Thermal Design Front View

2.4 AVIONICS DESIGN

2.4.1 ELECTRICAL AND OPTICAL INTERFACES

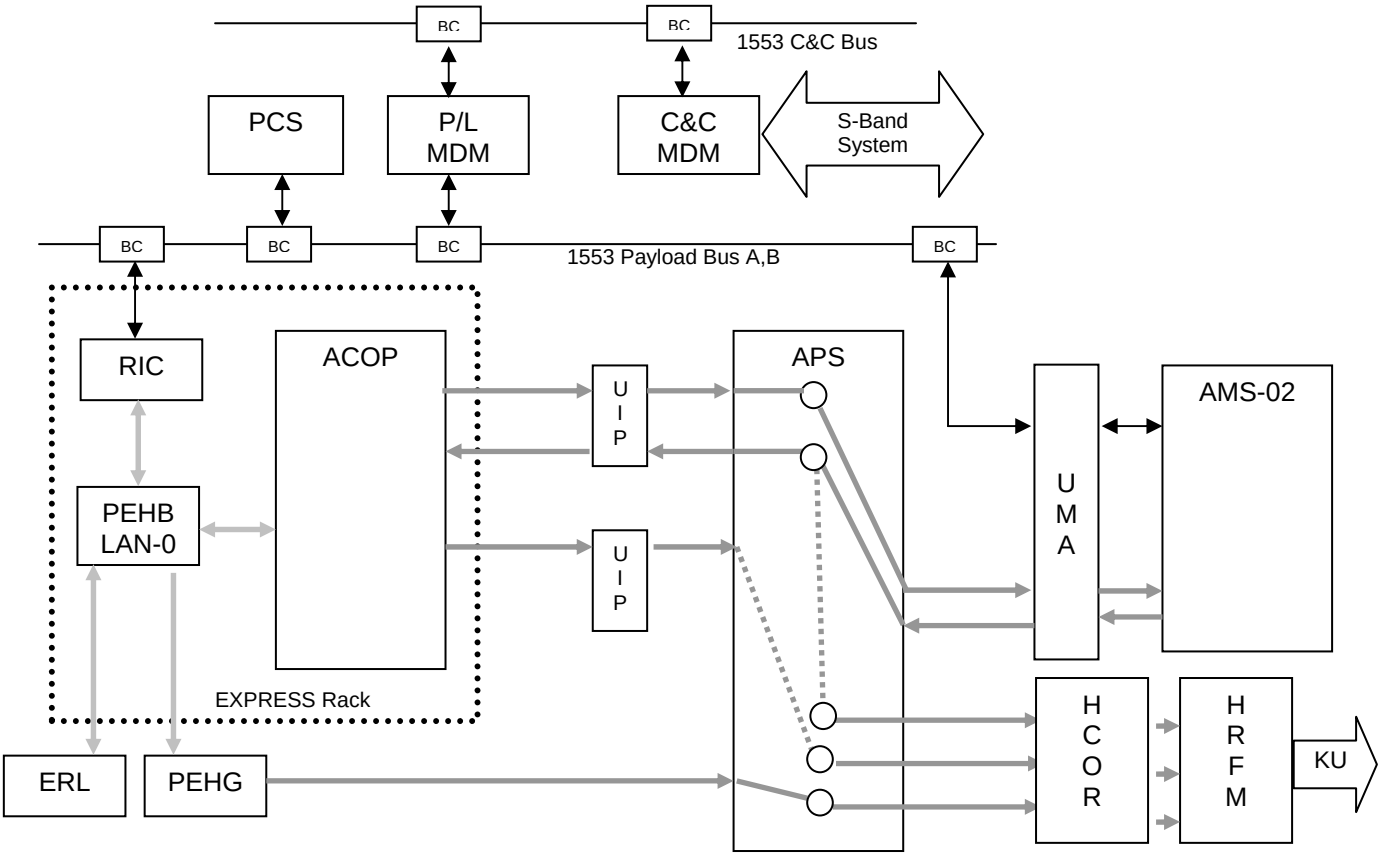

Figure 2-16 ACOP Relationship to ISS Avionics and AMS-02

Figure 2-16 shows the electrical interfaces of ACOP with the ISS and AMS-02. In this drawing the tiers of the 1553 busses are simplified to make the drawing more comprehensible.

Commanding and housekeeping data for ACOP is handled via the EXPRESS Rack Interface Controller (RIC). ACOP communicates with the RIC software on an Ethernet connection via the Payload Ethernet Hub Bridge (PEHB) using the Transmission Control Protocol/Internet Protocol (TCP/IP).

All ISS HRDL fibers are connected on one end to the Automated Payload Switch (APS). This device provides cross bar switching among the fiber systems of ISS. ACOP has two prime targets for HRDL transmission transfers. The first is the High Rate Frame Multiplexer (HRFM - via the High-Rate Communications Outage Recorder (HCOR). The HRFM interleaves data to the KU-Band transmission system for downlink. The second transmission target is the AMS-02 payload. The APS can be configured to tee data transmitted by AMS-02 to both the HRFM and ACOP. ACOP has a single receive source for HRDL which is the AMS-02 payload.

At all times ACOP maintains an active bi-directional connection via the HRDL interfaces to AMS-02. As KU access is made available, ACOP can be commanded to use its additional TX connection to down link data. ACOP will have the ability to burst this transmission (~20Mbits/sec). All data transmitted by AMS-02 is recorded onto ACOP's hard drives as a master copy of the AMS-02 science data. When ACOP has acknowledged that the data is recorded, AMS-02 can release that data from its buffers.

2.4.2 ACOP AVIONICS ARCHITECTURE

The ACOP system is based on CompactPCI systems. It contains a single board computer and several interface boards (including HRDL fiber interfaces, Ethernet interfaces, USB interfaces to upgrade the operating system and programs, digital input-output and video interfaces).

ACOP will also contain four exchangeable hard disks used to archive the data and the necessary interfaces. Other parts of ACOP are a LCD screen and a simple push button interface, present on the ACOP Front Panel as part of the man-machine interface.

Fans will guarantee the internal air flow necessary for cooling. A thermal sensor network will be mounted on the chassis and PCBs to monitor the operating temperatures.

In the main chassis and front panel there are the electrical parts which include a set of digital computer hardware and software. The functional block diagram of electrical parts is shown as Figure 2-17

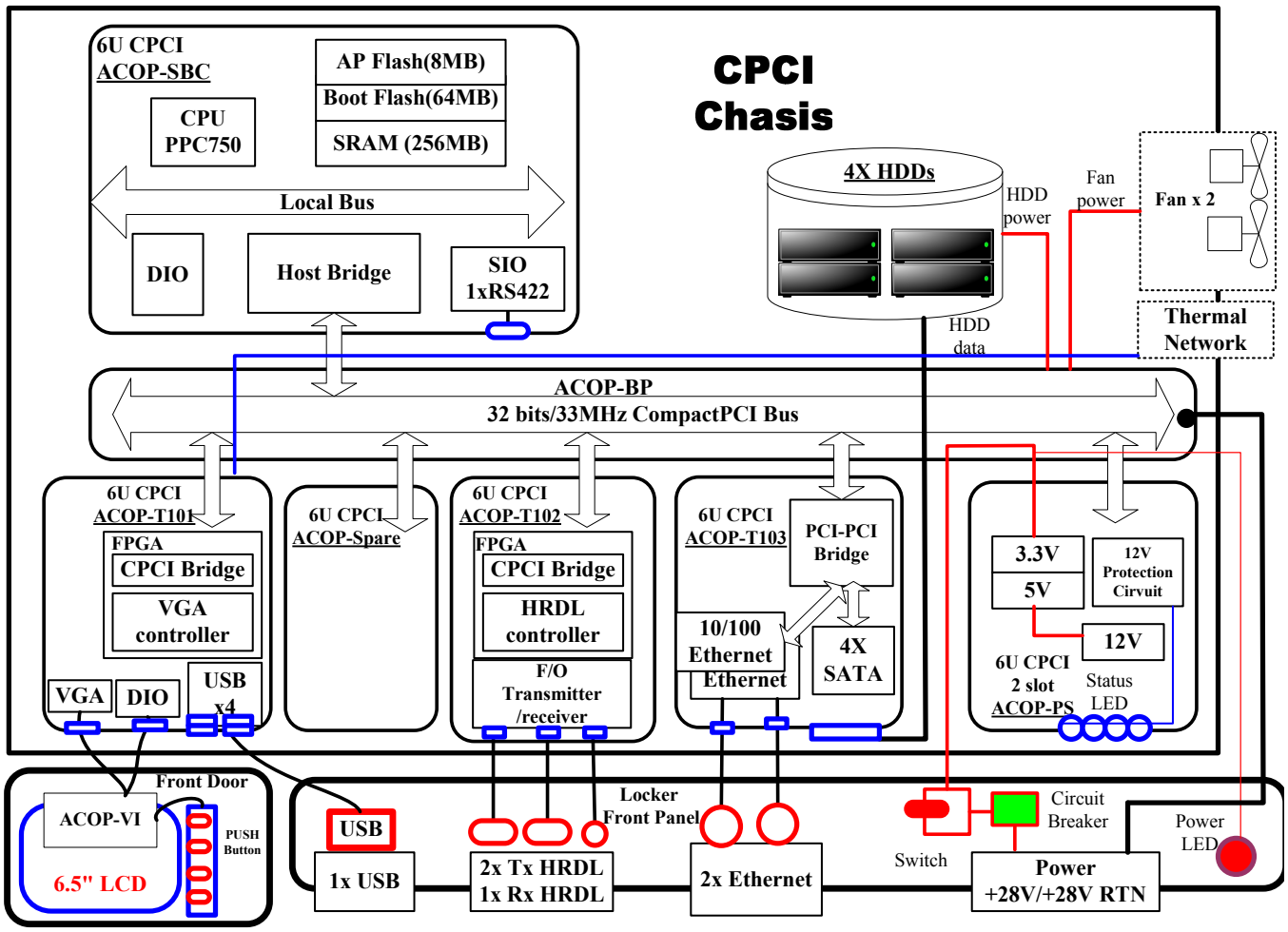

Figure 2-17 ACOP Electrical Block Diagram

The ACOP chassis includes the following modules:

- ACOP-SBC: single board computer, based on the IBM PPC 750, which provides 400Mhz speed as well as standard CompactPCI bus interfaces and acts as CompactPCI system slot.
- ACOP-T101: provides video output interface, 4 USB 2.0 interfaces, and a digital I/O (DIO) interface.
- ACOP-T102: provides 2 fiber optic transmit and 1 fiber optic receive interfaces.

- ACOP-T103: provides 2 Ethernet ports and 4 SATA ports.
- ACOP-Spare: spare slot for future expansion purpose
- ACOP-PS: double height power supply.
- 4 hard disk drives mounted in exchangeable caddies

The ACOP front panel will be equipped with:

- One aircraft style push button Circuit Breaker
- Four Momentary Push Buttons
- One On/Off Toggle Switch
- One LED monitoring power supply presence (Power Status LED)
- One HRDL Connector
- One Power Connector
- Two MRDL Connector with 10/100 base Ethernet
- One USB connector
- One LCD screen with LED backlight

2.5 ACOP SOFTWARE

ACOP-SW is the entire body of embedded software running on the ACOP hardware. ACOP-SW consists of three components:

- ACOP-SYS-SW providing low level functionality,
- ACOP-APP-SW providing the mission explicit application software functions on the ACOP hardware,
- ACOP-ERL-SW software developed by the ACOP project but which executes on the EXPRESS Rack Laptop.

The ACOP-SYS-SW consists of eCos, an open source embedded operating system and LINUX Operating System kernel (version 2.6). Drivers under LINUX OS for all the CompactPCI boards and the storage devices will be used.

The ACOP-APP-SW will be based on a cooperative multitasking system which moves messages among tasks. Tasks are used to provide: interfaces to external devices, functions (such as recording), data management (telemetry queue manager), and automation of functions (master control task).

2.5.1 ACOP-SYS-SW

ACOP-SYS-SW implements the following main functions:

- Boot ROM monitor providing boot strapping operations and low level file transfer functions.
- Initialization of the ACOP hardware.
- Operations of the ACOP hardware interfaces via device drivers.
- Exception handling.
- Diagnostic and system self-tests.
- Management of data storage devices and file systems.
- External command processing for system commands.
- Execution and control of ACOP-APP-SW.

2.5.2 ACOP-ERL-SW

ACOP-ERL-SW implements a complete ISS crew interface on the EXPRESS Rack Laptop for ACOP monitoring and commanding.

2.5.3 ACOP-APP-SW

ACOP-APP-SW implements the following main functions:

- Monitoring of resources and environment relevant to ACOP Health and Status.
- Functional interfaces to ISS avionics C&DH systems.
- Functional interfaces to the ISS HRDL interfaces.
- Data recording.
- Data playback.
- Detailed data management.
- Detailed management of data contents with regard to external systems.
- External command processing for applications commands.
- A menu driven Man-Machine Interface using the LCD and push buttons.

3. FLIGHT OPERATIONS PHASES

The flight operation phases are listed below. All the ACOP Flight Operations are safe in accordance with NSTS 182798B Interpretation Letter MA-00-038.

3.1 LAUNCH PHASE

Nominally ACOP will be launched installed in a transportation rack within the MPLM (compatibility with other transportation modes such as the aft flight deck and the ATV will be investigated if necessary). ACOP is not powered and no hard drives are installed during assent. Hard drives, and other spare parts, are carried in a soft side stowage bag.

3.2 FLIGHT PHASE NOMINAL OPERATIONS

3.2.1 INSTALLATION OF ACOP INSIDE A US LAB ISPR

Activity	Tool	Classification	Frequency	Duration
Locker insertion	Locker insertion tool	Nominal	Initial installation	60 minutes

The ACOP will be installed into a US Lab ISPR by the crew using the standard locker insertion tool to secure the four captive bolts in the rear of ACOP to the EXPRES rack back plate. Any launch locks on the front panel will be released and four hard drives installed.

3.2.2 EXTERNAL CABLE INSTALLATION

Activity	Tool	Classification	Frequency	Duration
External cabling	None	Nominal	Initial installation	60 minutes

The crew has to install the external cables that connect ACOP to the ISS: program provided power cable (J1), HRDL cable (J4) and program provided data cable (J2) (see Figure 2-7). Routing and securing of the external HRDL fibers along a to be determined path is part of this operation.

3.2.3 POWER ON

Activity	Tool	Classification	Frequency	Duration
Power on	None	Nominal	As required	2 minutes

Other then brief (less then 8 hours periods) of ISS low power modes and during hard drive exchange ACOP will be powered on. The Power On phase consists of:

- Enabling power from the EXPRESS rack
- Placing the ACOP Power Switch on the Locker Front Panel in the “ON” position
- Observing the Power LED is illuminated
- Verifying on the display that the booting phase of ACOP has finished successfully and ACOP is in the cold start mode (see below).

Once powered and booted, the ACOP operational mode can then be selected either by the crew with the command interface or by ground commanding.

3.2.4 POWER OFF

Activity	Tool	Classification	Frequency	Duration
Power off	None	Nominal	As required	2 minutes

Nominally ACOP is informed that it is being powered down ether by crew interaction or by ground commanding. When so instructed it enters the Active Idle mode. Once this condition has been verified ACOP can be switched off.

Off nominally ACOP can simply be powered off. In either case this consists of:

- Placing the ACOP Power Switch on the Locker Front Panel in the “OFF” position
- Disabling power from the EXPRESS rack
- Observing the Power LED is extinguished

3.2.5 HARD DRIVE DISKS INSTALLATION AND EXCHANGE

Activity	Tool	Classification	Frequency	Duration
Hard drive change	None	Nominal	Every 20 to 30 days	30 minutes

The ISS crew will be in charge of installation and exchange of hard drives. The operation will be made with ACOP powered down.

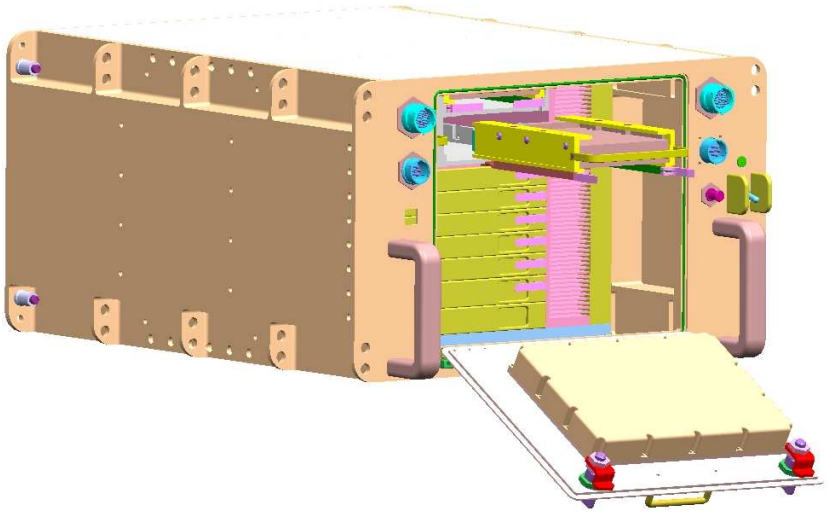

Figure 3-1 Hard Drive Insertion and Removal

To exchange hard drives the crew will:

1. Retrieve the appropriate ACOP storage bag (CTB).
2. Power off ACOP per 3.2.4 above.
3. Open the front panel door by:
   - Releasing the two compression door latches.
   - Open the door by pulling door handle

   The LCD font panel will remain in the open position thanks to a friction hinge.
4. Remove hard drive caddies (see Figure 2-11 and Figure 3-1) already installed, if any, by:
   - Unlocking the two cardlocks on the drive caddy
   - Using the caddy handle to pull out the hard drive.

- Logging the drive serial number on the provided worksheet
- Placing the removed drive into the stowage bag.

5. Hard drives will be inserted by:
   - Getting a fresh drive from the storage bag
   - Logging the drive serial number on the provided work sheet
   - Inserting the drive caddy into the desired location
   - Locking the two cardlocks
6. Close the door and lock with the compression latches.
7. Restore power and resume operation per section 3.2.3 Power On.
8. Re-stow the ACOP stowage bag.

No tools are required for this activity.

3.2.6 SOFTWARE UPGRADE

Activity	Tool	Classification	Frequency	Duration
Software upgrade	None	Nominal	Few times per year	5 minutes

Software upgrades will be performed by using a USB storage device inserted by the crew in the USB port on ACOP Locker Front Panel. This infrequent activity is considered nominal. The crew will power off ACOP, insert the USB key and power on ACOP. Activity will be monitored by the crew on the LCD display and the crew will be requested to verify that the upgrade occurred. Following a successful upgrade ACOP will be powered off, the USB key removed, and power restored.

3.2.7 CPCI BOARDS AND POWER BOARD SUBSTITUTION

Activity	Tool	Classification	Frequency	Duration
CompactPCI board exchange	None	Non-nominal	As required	20 minutes

This activity is considered as a non-nominal activity. It is to be performed in case a board fails or needs to be upgraded. The activity will be performed with the ACOP powered off and according a specific plan that clearly will define the procedure steps. This procedure will be very similar to the hard drive exchange.

3.2.8 INSPECTION AND CLEANING OF THE INLET AND OUTLET DUST SCREENS

Activity	Tool	Classification	Frequency	Duration
Clean air screens	Locker insertion tool	Nominal	60 days (TBC)	60 minutes

As determined necessary, ACOP shall be removed from the ISPR and the dust screens inspected and, if required, cleaned. The base line plan is:

- After 60 days of service ACOP will be removed from the EXPRESS rack for inspection and cleaning of the inlet and outlet dust screens located on the back of ACOP.

  The crew shall provide the ACOP team with an assessment of cleanliness of the screen and then remove as much residue as possible using sticky tape and or a vacuum cleaner.

- Subsequently repeat this inspection and cleaning twice annually, subject to the observed cleanliness of the AAA system.

- Operationally the ACOP POCC will be monitoring the ACOP thermal profile. Any screen blockage will result in a temperature rise. In the event of an unexplained thermal rise the ACOP POCC will request a prompt diagnostic inspection by the crew of both the screens and fans. After the diagnostics the screens will be cleaned.

Note: there is no specification available to date defining the cleanliness of the AAA airflow nor is there any operational experience with rear breathing EXPRESS rack experiments.

3.2.9 REPLACEMENT OF A FAILED FAN

Activity	Tool	Classification	Frequency	Duration
Fan replacement	Locker insertion tool	Non-nominal	Seldom if ever	60 minutes

Fan health will be monitored in the AMS POCC. In the unlikely event a fan fails in ACOP it will be possible to replace the fan on orbit. The operation involves the removal of the ACOP locker from the EXPRESS rack, unfastening the fan module (see Figure 2-13, disconnecting the fan power, then reversing these steps to install a replacement fan available in the soft stow spares kit contained in the ACOP stowage bag.

3.2.10 FAILURE AND FAULT DIAGNOSIS

Activity	Tool	Classification	Frequency	Duration
Diagnosis	None	Non-nominal	Seldom if ever	TBD

There are a number of protections present inside ACOP (over-current, over-voltage, over-temperature). Some of these protections have indicators on the front of the printed circuit boards inside the ACOP door. In the unlikely event of a fault or failure the crew will be asked to support diagnosis of the problem.

In all cases the fault recovery is a power cycle and the recovery of a failure is a board level replacement from the set of key spare parts kitted within the ACOP soft stowage bag.

3.3 RETURN TO GROUND

The current baseline is that ACOP will not be returned to the ground.

3.4 OPERATIVE MODES

ACOP is primarily a ground operated system but can be crew commanded.

ACOP will have the following principal operating modes:

- Powered off
- Cold start
  - Software upgrade (a special condition of cold start)
- Warm start
- Active Idle
- Active
  - Recording
  - Playback
  - Recording and Playback

During any of the active modes ACOP can serve as a crew interface for directing commands to AMS-02.

During any of the states other then powered off ACOP will accept ground commands.

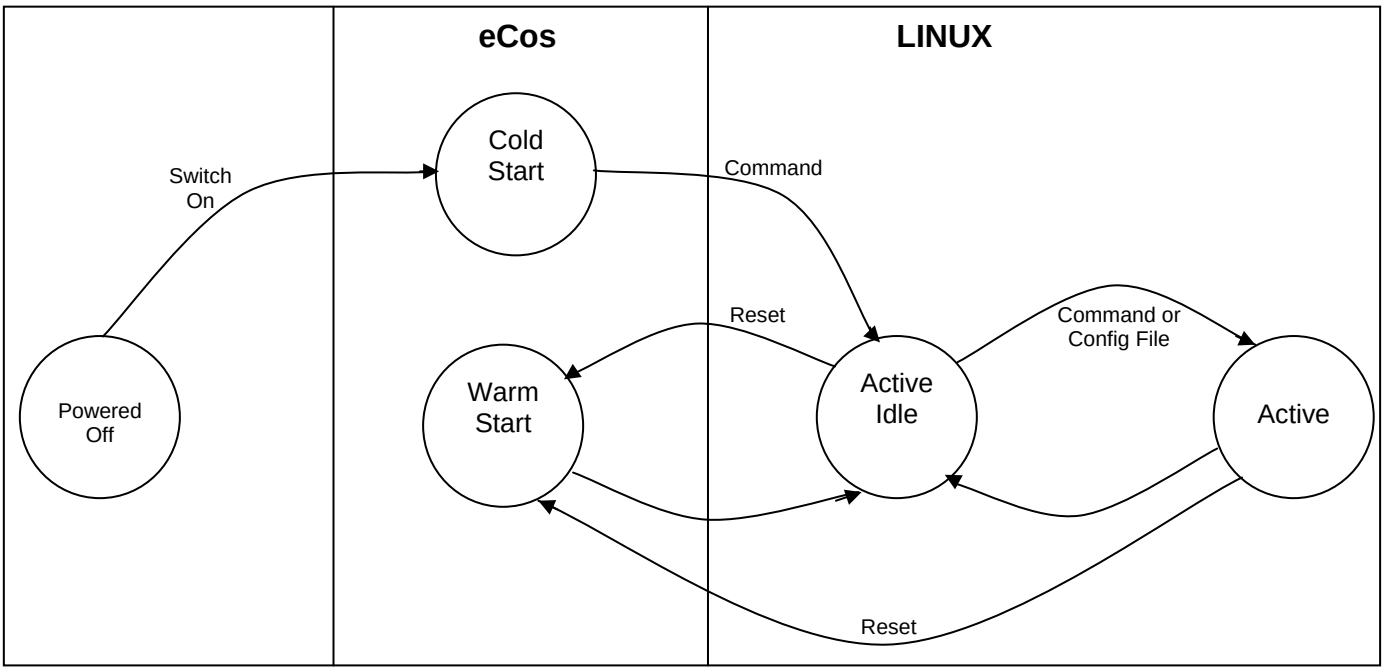

Figure 3-2 Operation Modes State Diagram

Figure 3-2 shows the state diagram of these modes.

When ACOP enters the Cold Start mode it can accept commands and requires a particular command to proceed to the active modes. This command can originate from either the crew interfaces or the ground interface. If during the Cold Start mode it is determined that a properly formatted USB key is inserted the crew is interrogated to see if a software upgrade should be performed. A software upgrade consists of copying software and configuration files from the USB key to the ACOP software storage media, namely flash memory located on the ACOP-SBC board.

3.5 GRAPHICAL CREW INTERFACES

The crew is provided two graphical interfaces to ACOP. A simple automatic teller machine (ATM) style of soft labeled buttons is provided via the front panel LCD. Support is provided for key monitoring and operations functions for both ACOP and AMS-02 via this interface. This interface includes ACOP front panel controls for the LCD for backlighting and contrast. This is discussed more in the following section.

A second, more extensive, interface is provided via the EXPRESS Rack Laptop (ERL) computer. It is anticipated that several graphical interfaces for both ACOP and AMS-02 will be developed for ERL.

4. ACOP FRONT PANEL INTERFACE

This section presents the current proposed front panel interface.

The ACOP front panel provides a standalone crew interface capable of displaying key conditions for both AMS-02 and ACOP itself. Using a simple "ATM" style of button presses the crew can issue commands to ether AMS-02 or ACOP as well as configure key operating parameters of ACOP.

This section provides a look and feel of the proposed interface but is by no means a complete design of the system.

Conceptually the interface is organized in "pages", where each page has a unique screen view and set of push button actions indicated by soft labeling. The following state diagram gives a top level representation of the menuing system. Nominally the LCD is displaying a status page that was last selected. This page has the top button soft labelled "Menu". When the Menu button is pressed the LCD displays the "Main Menu". These are the top two states in Figure 4-1.

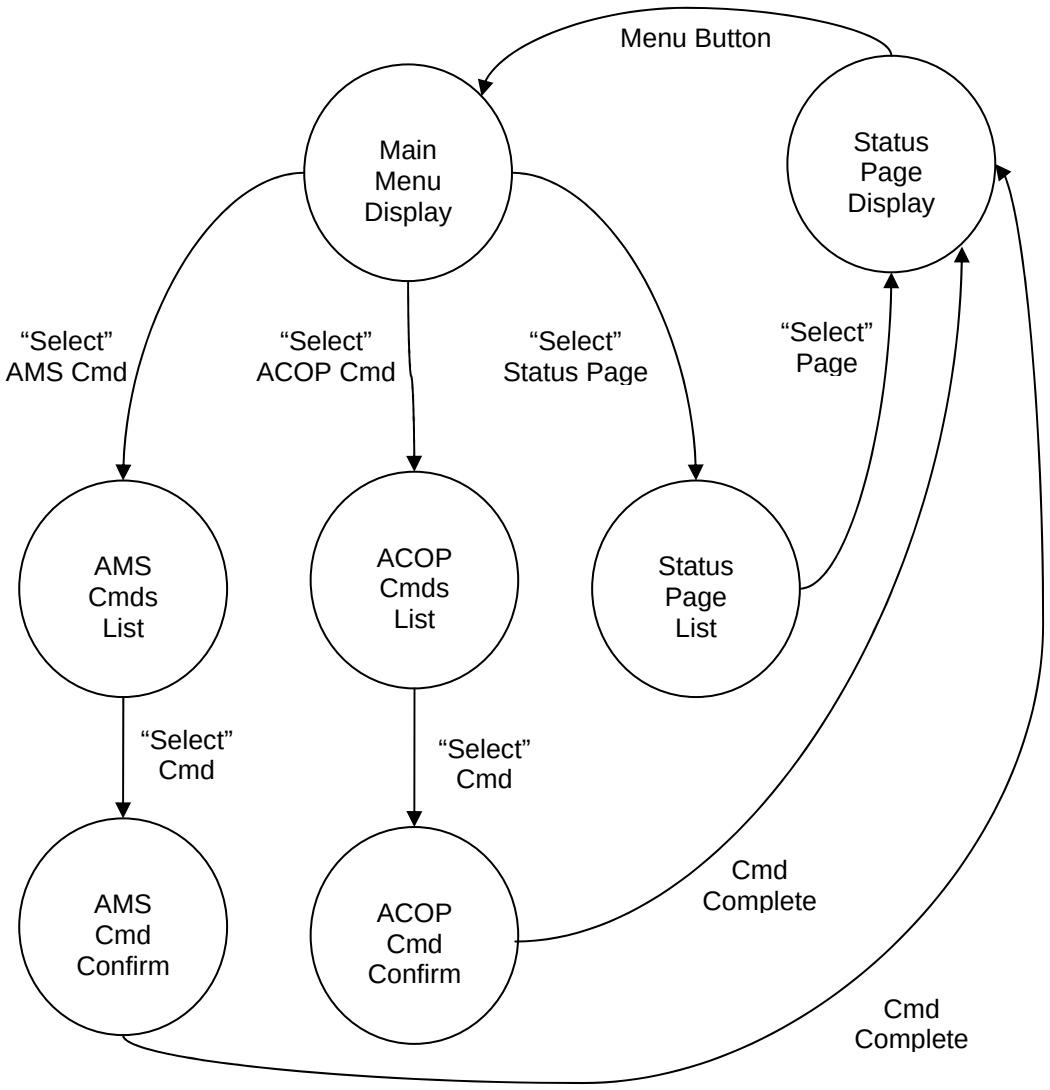

Figure 4-1 Front Panel User Interface

4.1 MAIN MENU

Figure 4-2 shows the ACOP Main Menu. The ACOP front panel buttons A, B, C and D have the labels: BACK, UP, DOWN, SELECT. Pressing BACK will return to the prior screen. Pressing UP moves the diamond arrow on the left (shown pointing to “AMS Operations & Commands”) up one line. Pressing DOWN moves this arrow down one line. Pressing SELECT makes the selection of the next menu level.

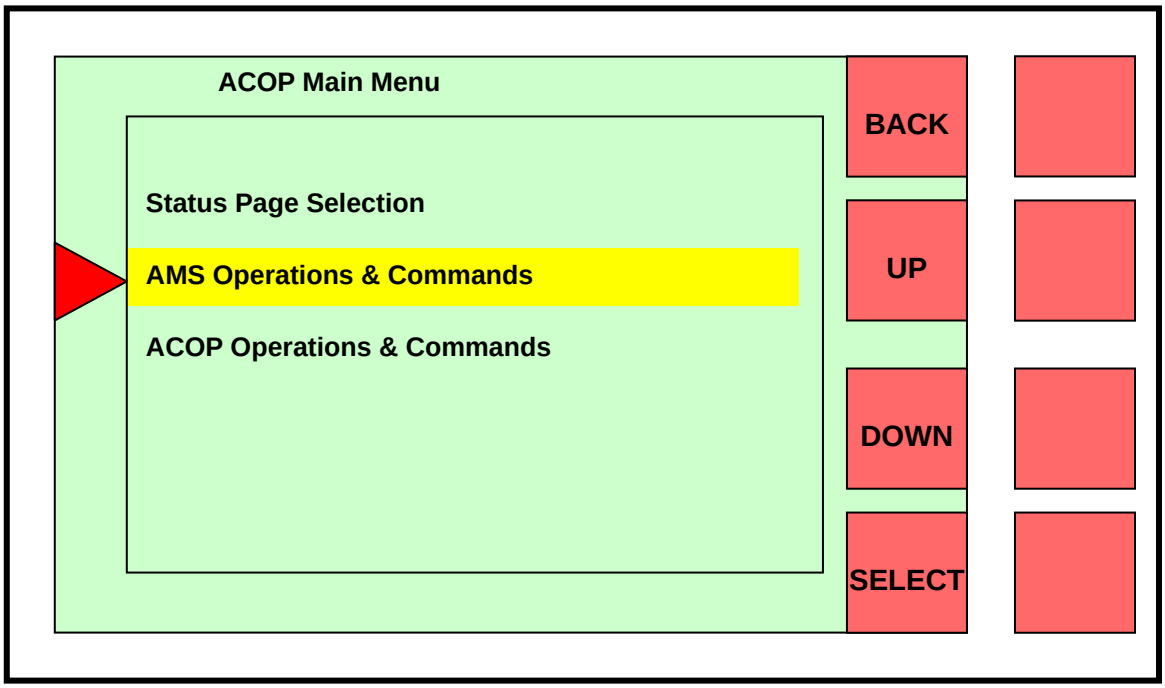

Figure 4-2 ACOP Main Menu

4.2 ACOP OPERATIONS & COMMANDS MENU

Operation of this menu (shown as Figure 4-3) is similar to the Main Menu. It has an additional scroll bar display to give feed back to the user.

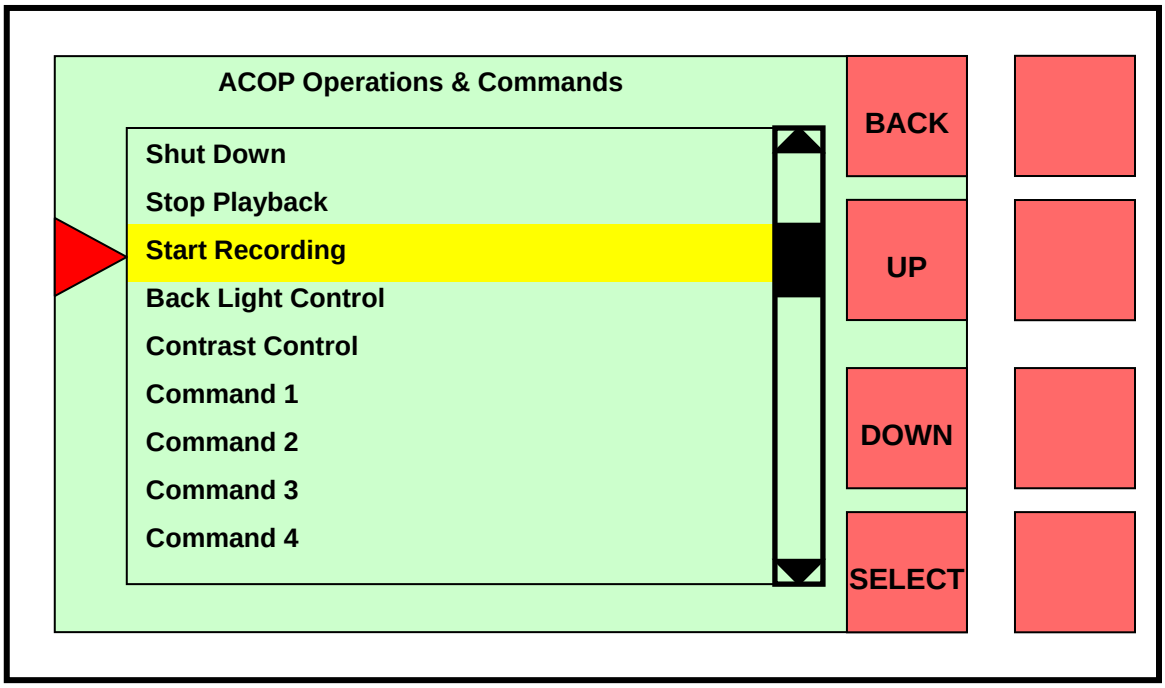

Figure 4-3 ACOP Operations and Commands Menu

4.3 CONFIRMATION DIALOG

Where appropriate, confirmations will be present as shown in Figure 4-4. After confirmation an acknowledgement message will be briefly displayed before displaying the current status page.

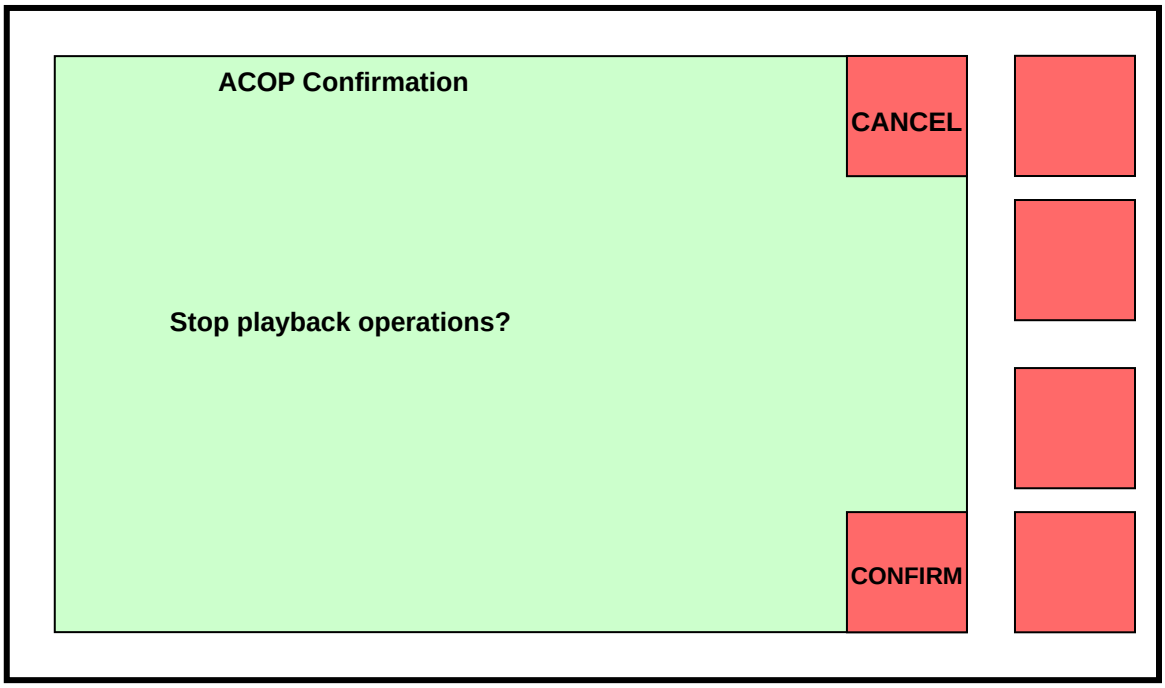

Figure 4-4 Confirmation Dialog

4.4 BACKLIGHT SLIDER MENU

This menu supports setting the backlight brightness. It will operate as a simple slider with UP for more light and DOWN for less light. This function is also available on all status pages.

4.5 COLD-START MENU

When the system boots up from a cold start (initial application of power switch) this menu will request how the ACOP user would like to proceed.

- Command Selection List
  - Software upgrade
  - Diagnostics
  - Set default configuration file
- Execute button w/confirmation
- Proceed with normal ACOP application

4.6 AMS OPERATIONS & COMMANDS MENU

This menu page will operate comparatively to the ACOP Operations & Commands menu.

- Command selection list
  - Func-1
  - Func-2
  - …
- Execute button w/confirmation dialog

4.7 STATUS DISPLAYS

Status display pages will vary considerably. All will have the top A button soft labelled MENU, the B button soft labelled BRIGHTER, the C button soft labelled DIMMER and will have a Page-n label and title. The data display may take more liberties with the graphics nature of the LCD then the menuing system.

4.7.1 AMS-02 AND ACOP COMBINED STATUS SUMMARY

Figure 4-5 is preliminary. The screen will show AMS-02 Critical Health Data (CHD) – a summary level of the AMS-02 state plus comparable data from the ACOP health and status data.

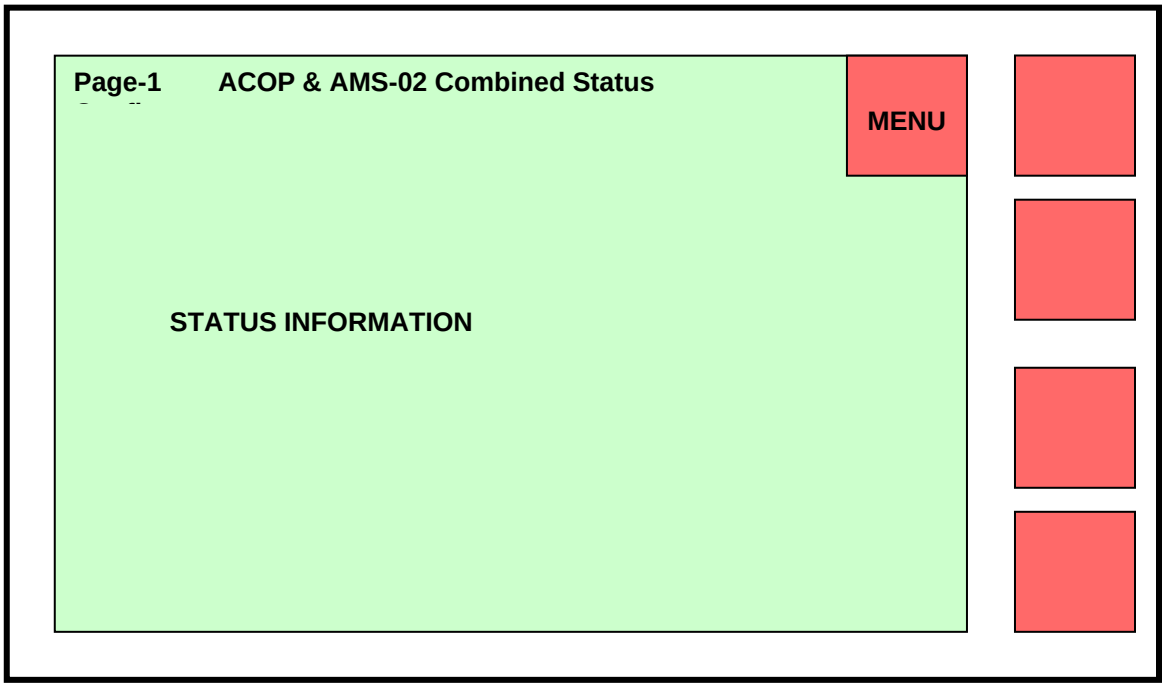

Figure 4-5 Typical Status Page Display

4.7.2 AMS-02 CHD SUMMARY

This screen displays a human readable interpretation of the AMS-02 CHD.

4.7.3 ACOP STATUS DISPLAYS

Some typical ACOP status displays are listed below.

- ACOP Status Summary
- ACOP Operational Detail
- ACOP Disk Utilization Detail
- ACOP Recorder Detail
- ACOP Playback Detail

4.7.4 AMS-02 STATUS DISPLAYS

Some typical AMS-02 status displays are listed below.

- AMS-02 Status Summary
- AMS-02 Operational Detail

4.8 FRONT PANEL BUTTON SPECIAL FUNCTIONS

In the event the LCD has become unreadable because the back light is too low or the contrast insufficient these special functions will bring these settings to well known values.

- Set Contrast at Midpoint - Press and hold top two buttons.
- Set Backlight at Midpoint - Press and hold top and bottom buttons.