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ACOP

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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

1. INTRODUCTION

1.1 PURPOSE

The scope of this document is to provide the results coming from Failure Modes, Effects and Criticality Analysis (FMECA), carried out on the ACOP.

The FMECA identifies all failures and modes of failure that can occur at ACOP and investigates the resulting performance and effects on system and mission success as well as the possible failure prevention and compensation methods. The Consequence Severity Categories has been assigned to each failure mode according to the severity of the potential observed failure effect on ACOP. The FMECA has been performed according to GPQ-010-PSA-102 [RD 8].
The analysis has been performed on the design at its current status, in the frame of CDR.

2. DOCUMENTS

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	Nov. 1997		Payload Accommodation Handbook for EXPRESS Rack
9	SSP 50184	D / Feb. 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

2.2 REFERENCE DOCUMENTS

RD	Doc. Number	Issue / Date	Rev.	Title
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 / Dec. 98		Documentation Standard for ESA Microgravity Projects
4	MS-ESA-RQ-108	1 / 28-Sep-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.

RD	Doc. Number	Issue / Date	Rev.	Title
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	ACP-TN-CGS-002	March 2005	2	ACOP Flight Safety Data Package Phase 0/1
12	ACP-PL-CGS-008	1/ October 2005		ACOP Maintenance Plan

3. ACOP SYSTEM DESCRIPTION

3.1 INTRODUCTION

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 the AMS-02 experiment by recording the 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.

The ACOP system shall be installed in the U.S. Laboratory Module, on the ISS, in one EXPRESS rack (see, for reference, Figure 3-1).

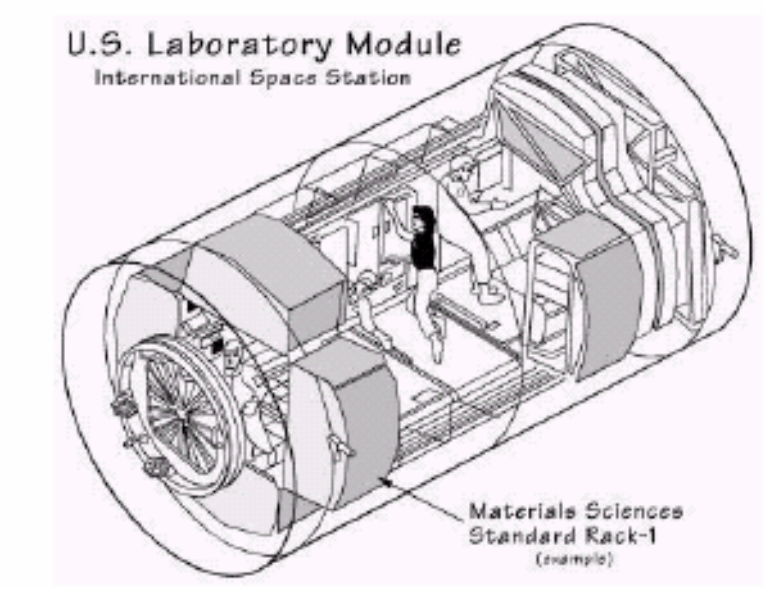

Figure 3-1 US Lab

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 3-2 and Figure 3-3. Figure 3-4 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 .

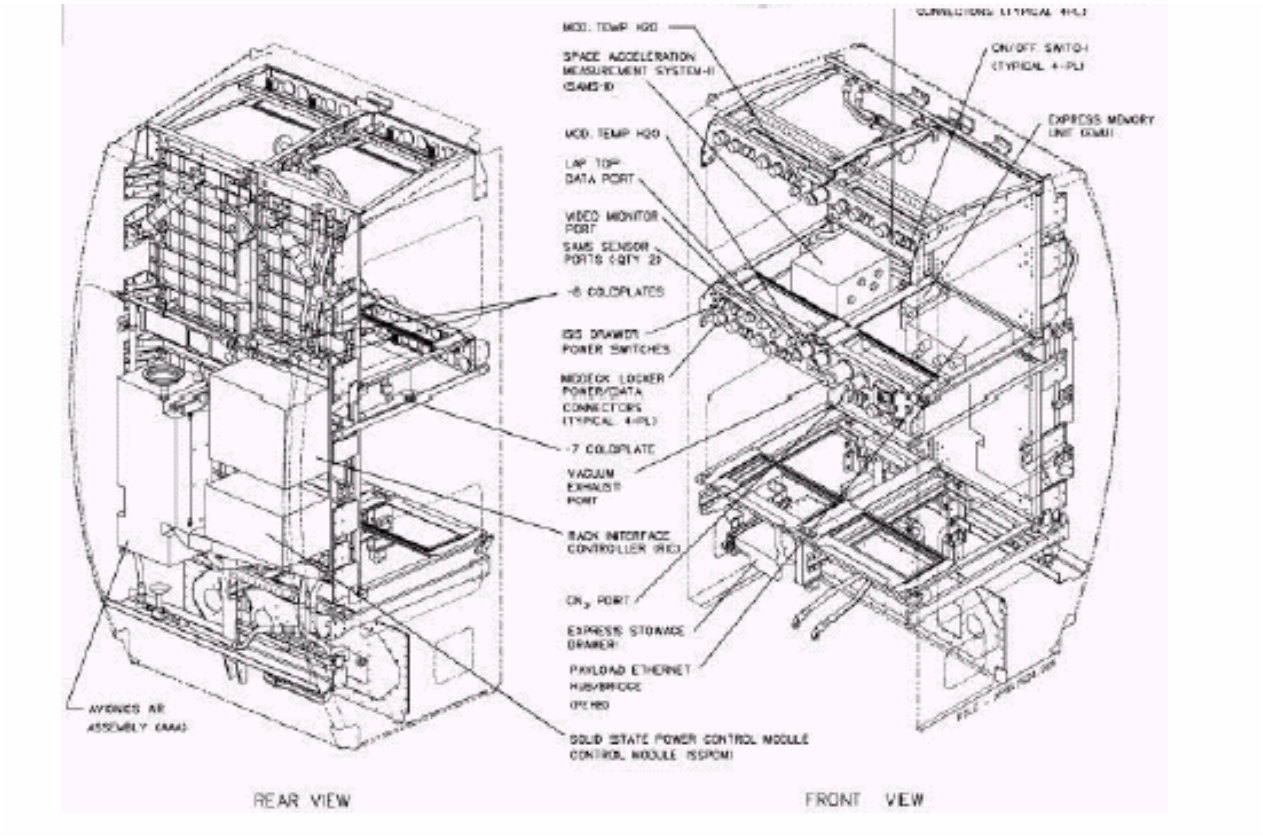

Figure 3-2 Example of an EXPRESS Rack (3D view)

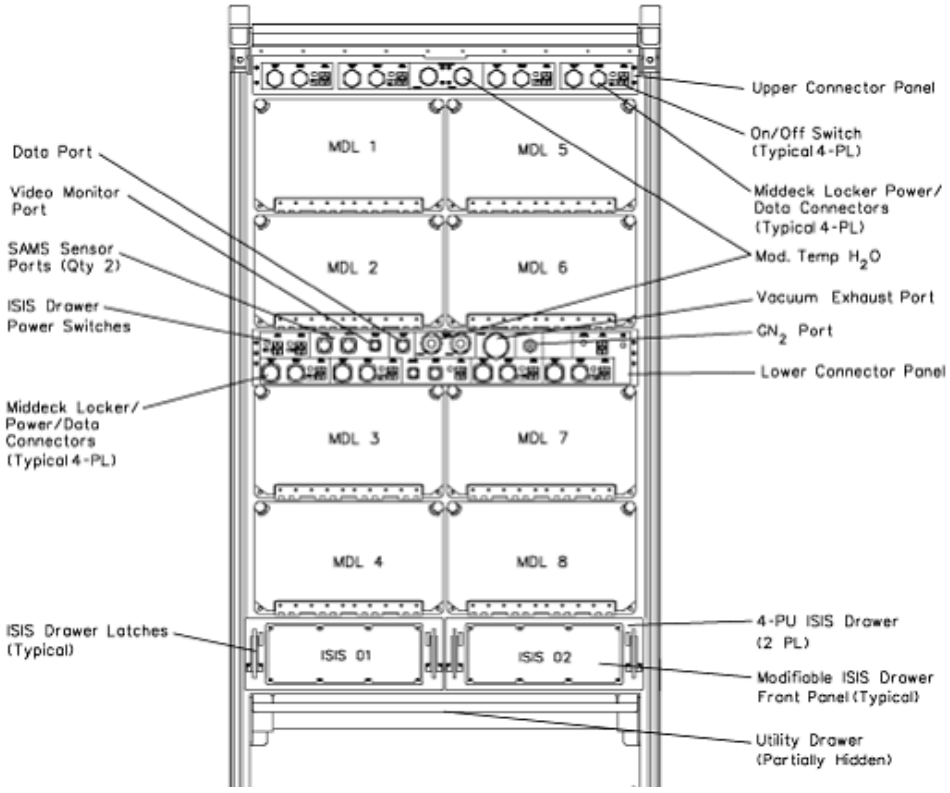

Figure 3-3 Example of an EXPRESS Rack (front view)

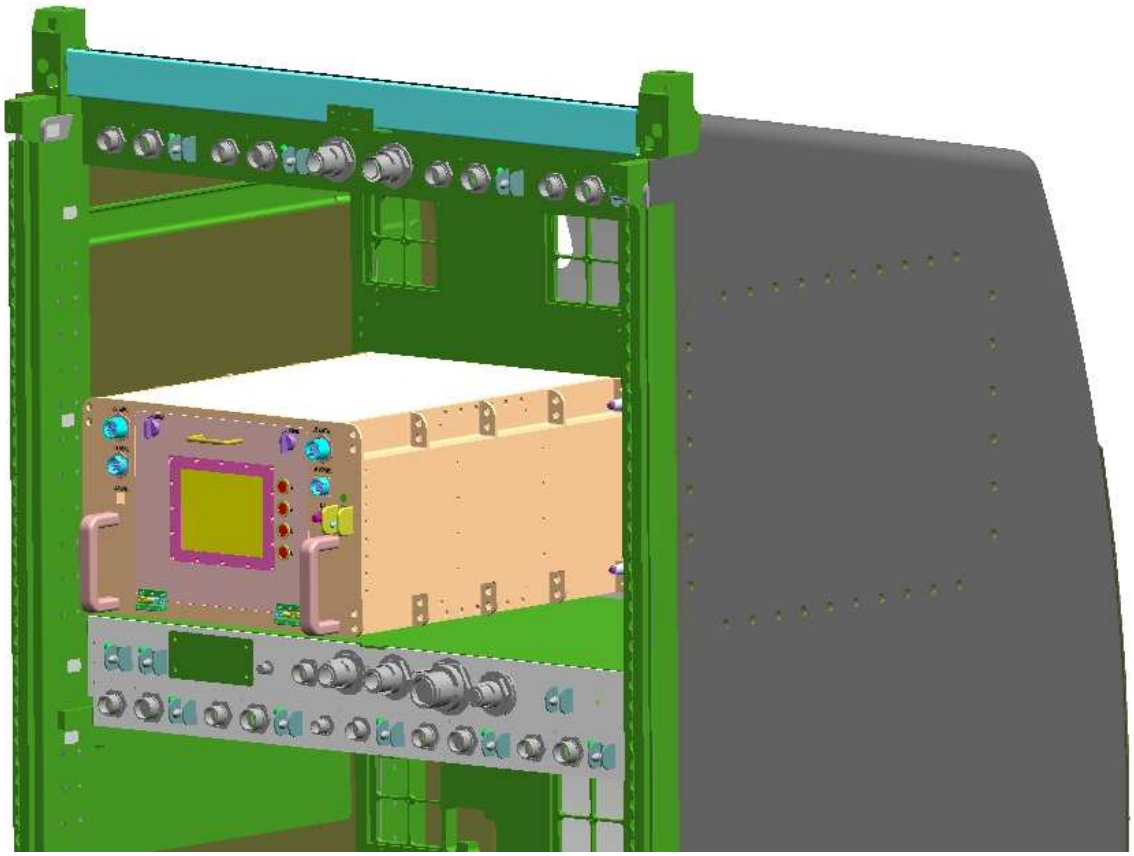

Figure 3-4 ACOP installed in an EXPRESS Rack (example of possible location)

3.2 ACOP SYSTEM OVERVIEW

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 3-5 and Figure 3-6, 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.

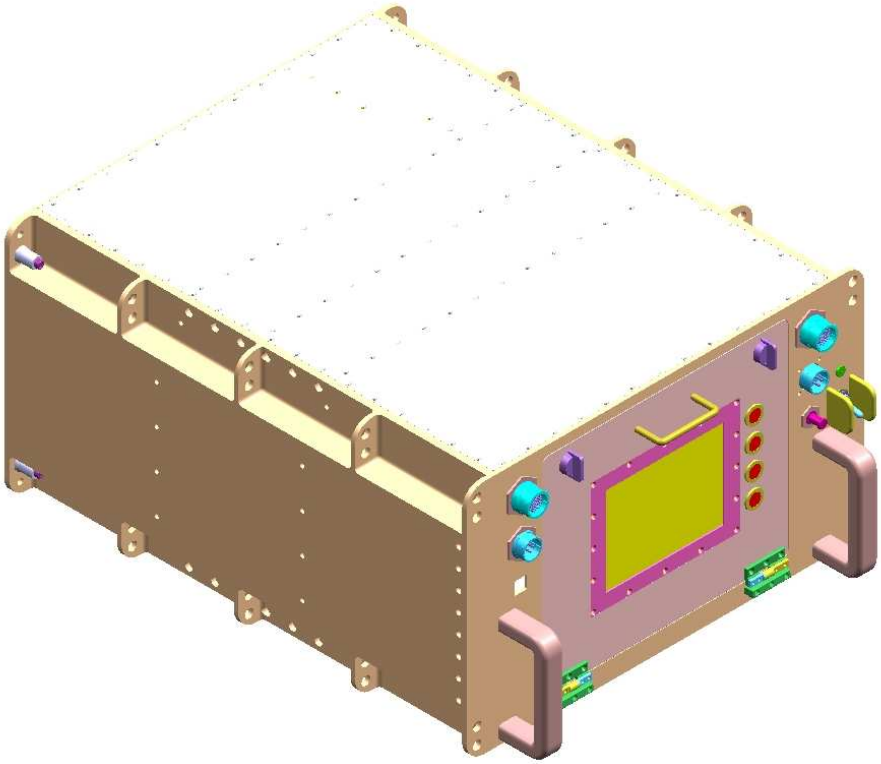

Figure 3-5 ACOP General Front View

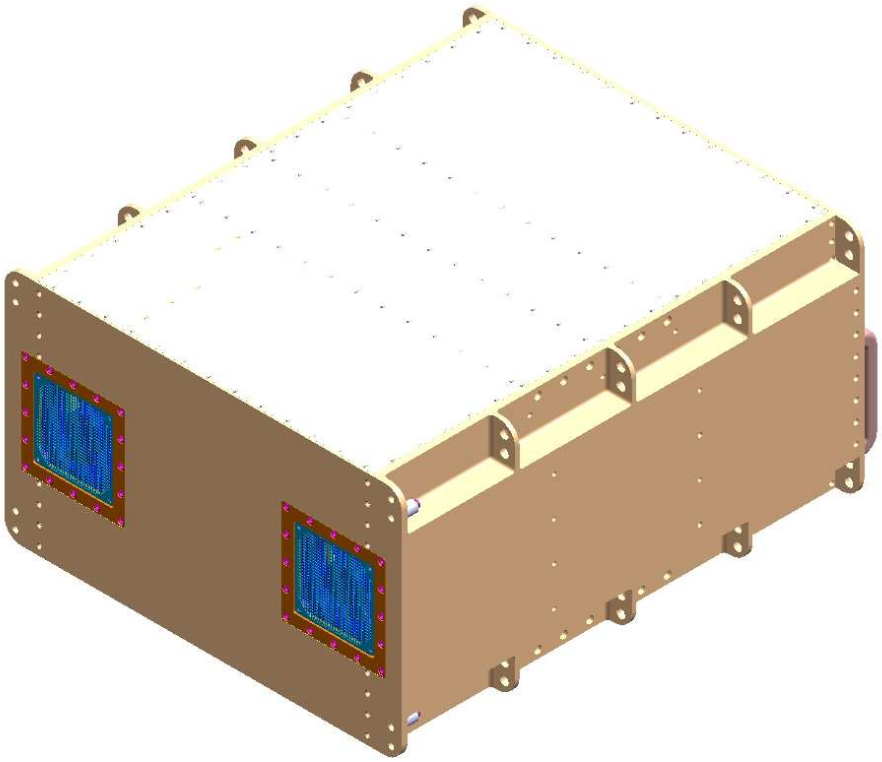

Figure 3-6 ACOP General Rear View

3.2.1 FUNCTION AND PURPOSE OF ACOP

ACOP has been designed to fulfill 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.
16. Upgradeable and expandable using COTS subsystems.
17. Provides support of ISS system upgrades (e.g. 100bt MRDL follow on systems).

---

[1] Durations indicated are 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 located 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.

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.

3.2.2 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 within 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 exchange 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.

3.3 MECHANICAL STRUCTURE

The mechanical structure of ACOP consists of an outer structure (Locker) and an inner structure (Chassis). The ACOP dimension is 460x535x273mm meeting the Mid Deck Locker (MDL) form factor as modified for the EXPRESS Rack Payloads.. The chassis provides a 6U Compact PCI card cage for electronic boards, the four slots for hard disk driver (HDD) and a lot of fins in two sides as heat sinks. The LCD is mounted to the front door of the locker for system monitoring and control. The cooling air blows in and sucks out by two fans in the backplate; and there is a thin baffle between two fans to separate the cold and hot air flow. At corners of locker backplate, four captive bolts are used to fasten ACOP structure and EXPRESS rack backplate together

In the Figure 3-7 the ACOP with the front door open is presented:

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

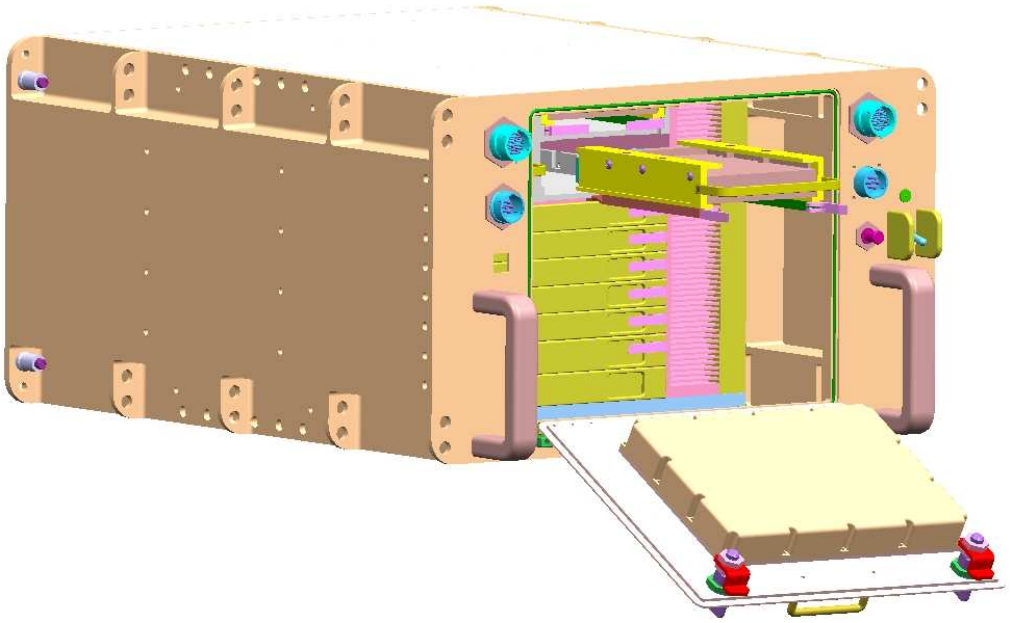

Figure 3-7: View of ACOP with the front door open

The main mechanical parts of ACOP are shown in the Figure 3-8:

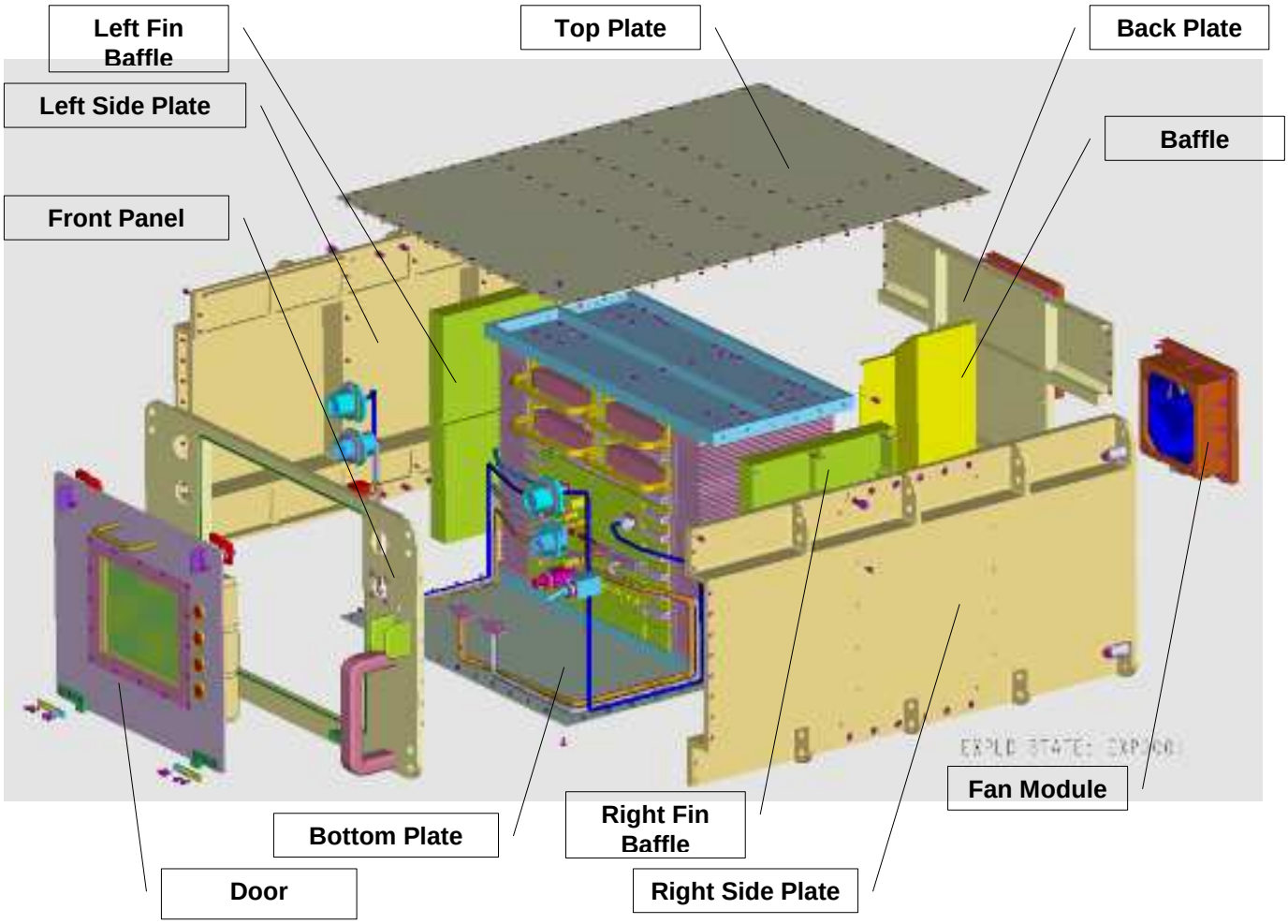

Figure 3-8 ACOP Main Component Exploded View

3.3.1 PRINCIPAL AVIONICS COMPONENTS

Figure 3-9shows the following principal avionics components:

- 5 Compact PCI cards
- 1 Power supply
- 4 Hard Drives
- 1 LCD
- Connectors

There are four Drive Caddies installed in the upper part of the Chassis and five CompactPCI and with 6U power supply installed in the lower part of the Chassis.

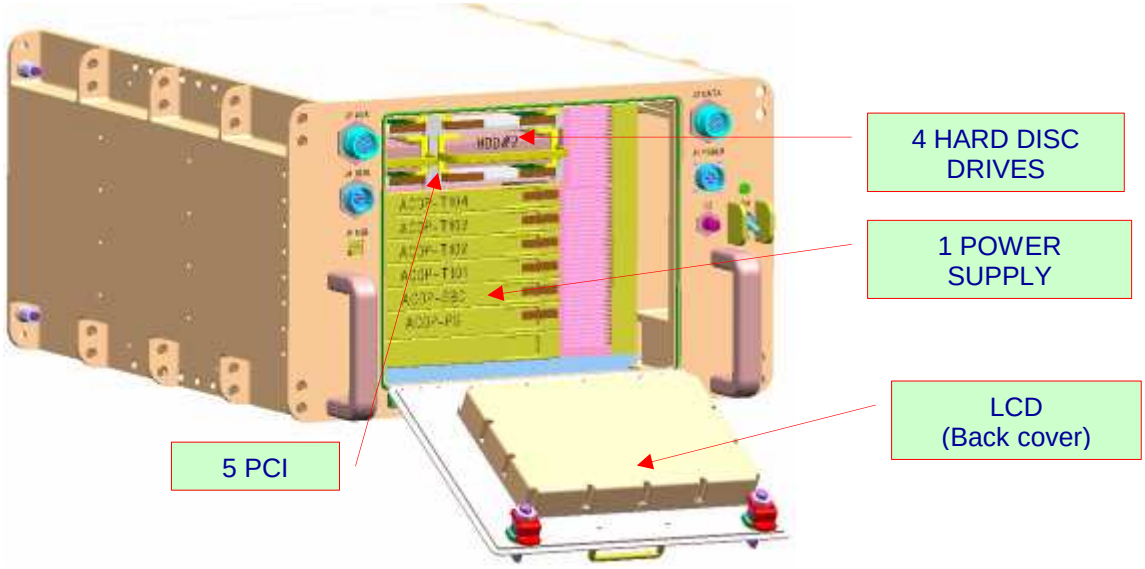

Figure 3-9 Principal Avionics Components

3.3.1.1 AVIONICS ON FRONT PANEL AND DOOR

All external connectors (Power, Data, HRDL, USB, and AUX), circuit breaker, power switch, and LED are mounted on the Front Panel. The LCD and push buttons are mounted on the Front Door.

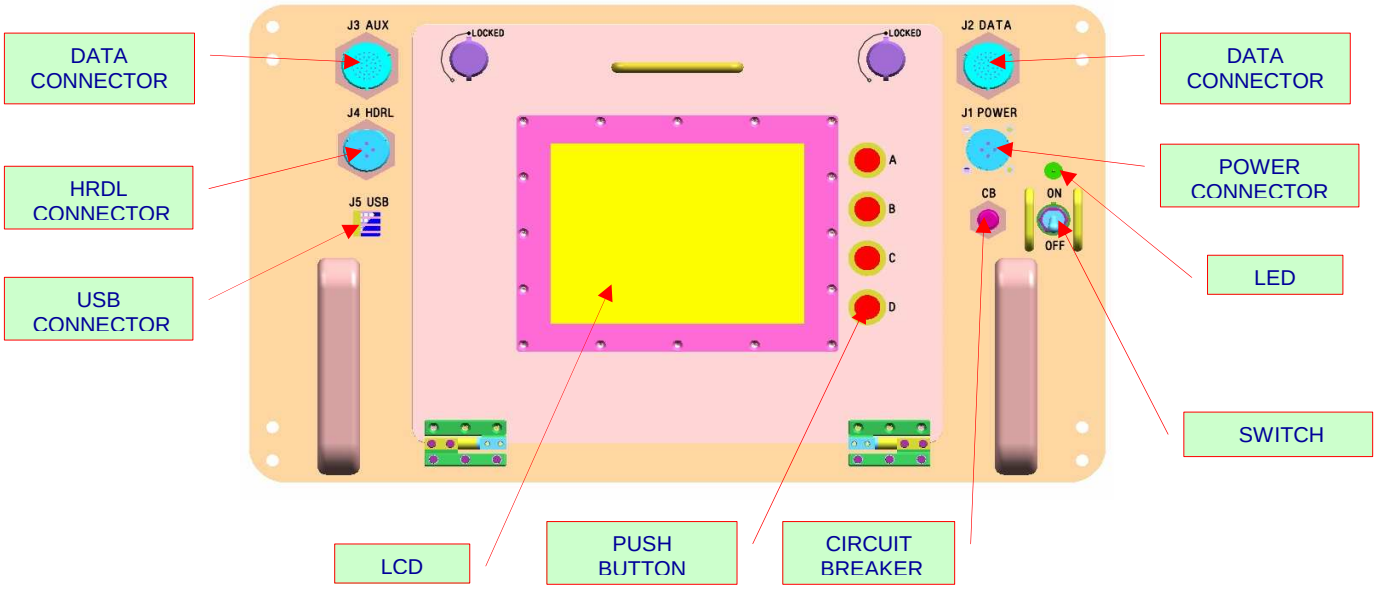

Figure 3-10 Layout on Front Panel and Front Door

3.3.2 THERMAL DESIGN

Heat dissipation of the hard disk drives, CompactPCI boards, and the power supply will be conducted to the heat sink fin walls by conduction. The rear access cooling airflow (via Avionics Air Assembly) will be drawn in by the inlet fan and through 1) the fins and 2) gap between Drive Caddy and the Caddy Plates to remove the heat by forced convection. Warm air will enter the outlet side of the rear of ACOP and will be exhausted by the outlet fan.[6]

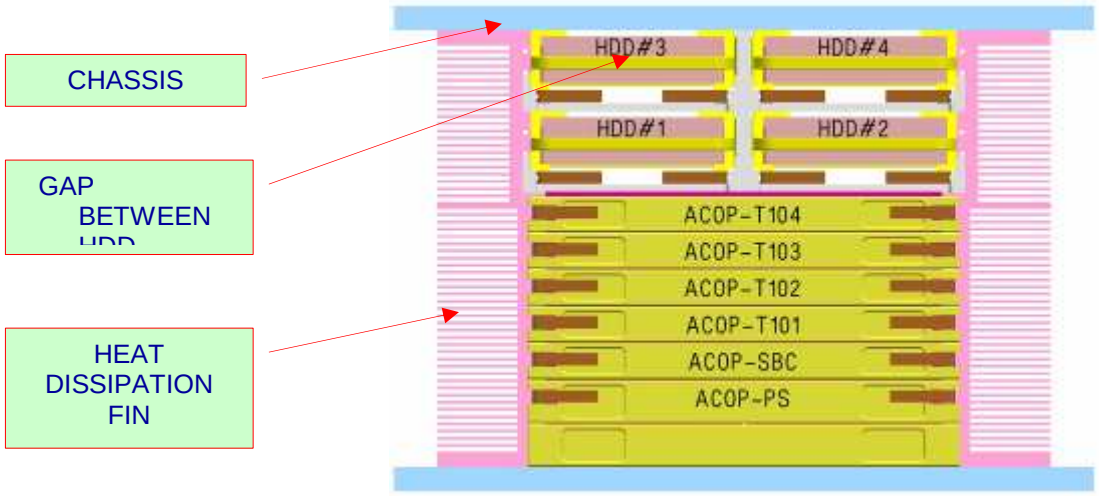

Figure 3-11 Thermal design (front view)

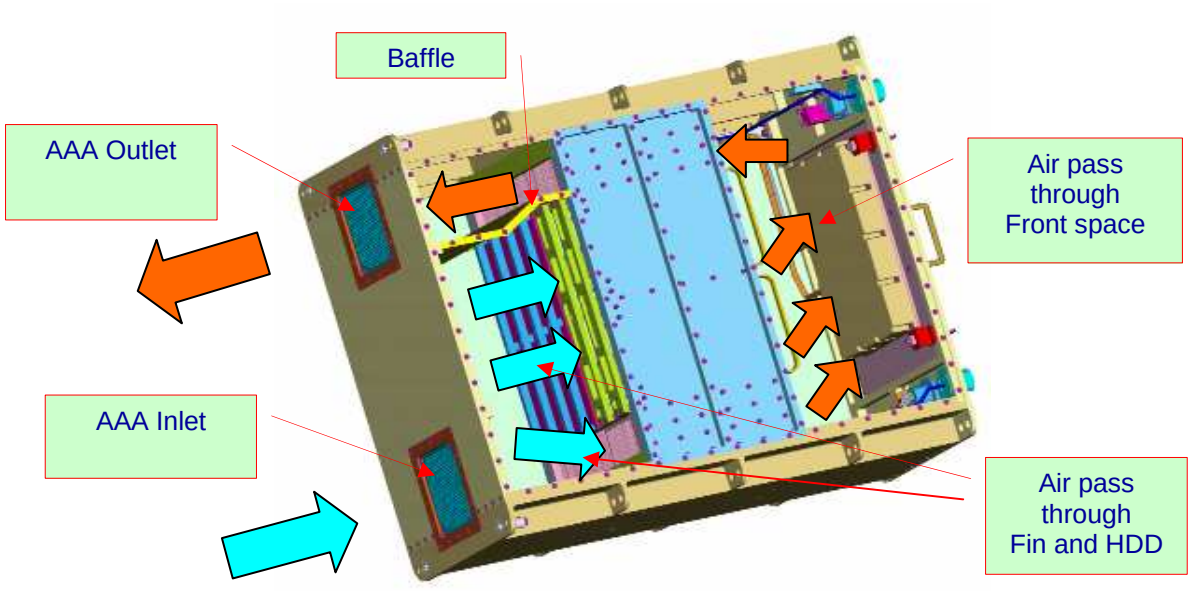

Figure 3-12 Cooling airflow (top view)

The main reason to implement two fans in ACOP is redundancy. Each fan can provide enough airflow rate, the other is for redundancy.

The size of ACOP inlet and outlet ports is 110 mm by 110 mm. Both are fitted with screens, with an open area ratio of 60%, in order to filter the cooling air. The size of the fans is be 92 mm by 92 mm.

[6] The inlet and outlet fans are independently managed by the software. Ether fan moves enough cooling air to provide nominal operations.

3.4 ELECTRICAL

3.4.1 ISS AVIONICS ARCHITECTURE

The ISS Command & Data Handling (C&DH) of the ACOP and AMS-02 system is shown as Figure 3-13.

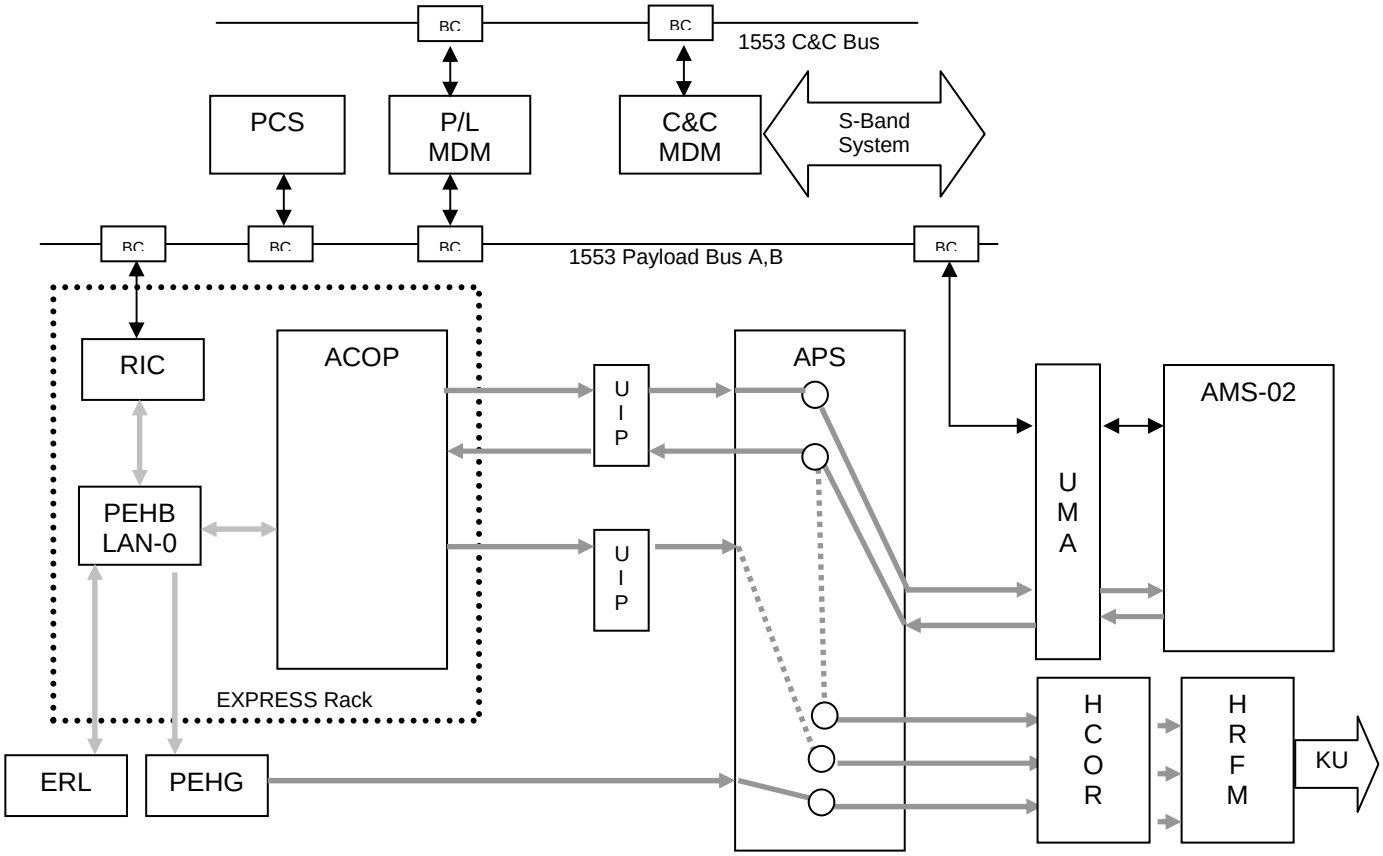

Figure 3-13 AMS-02 Avionic Architecture

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.

.

3.4.2 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 3-14.

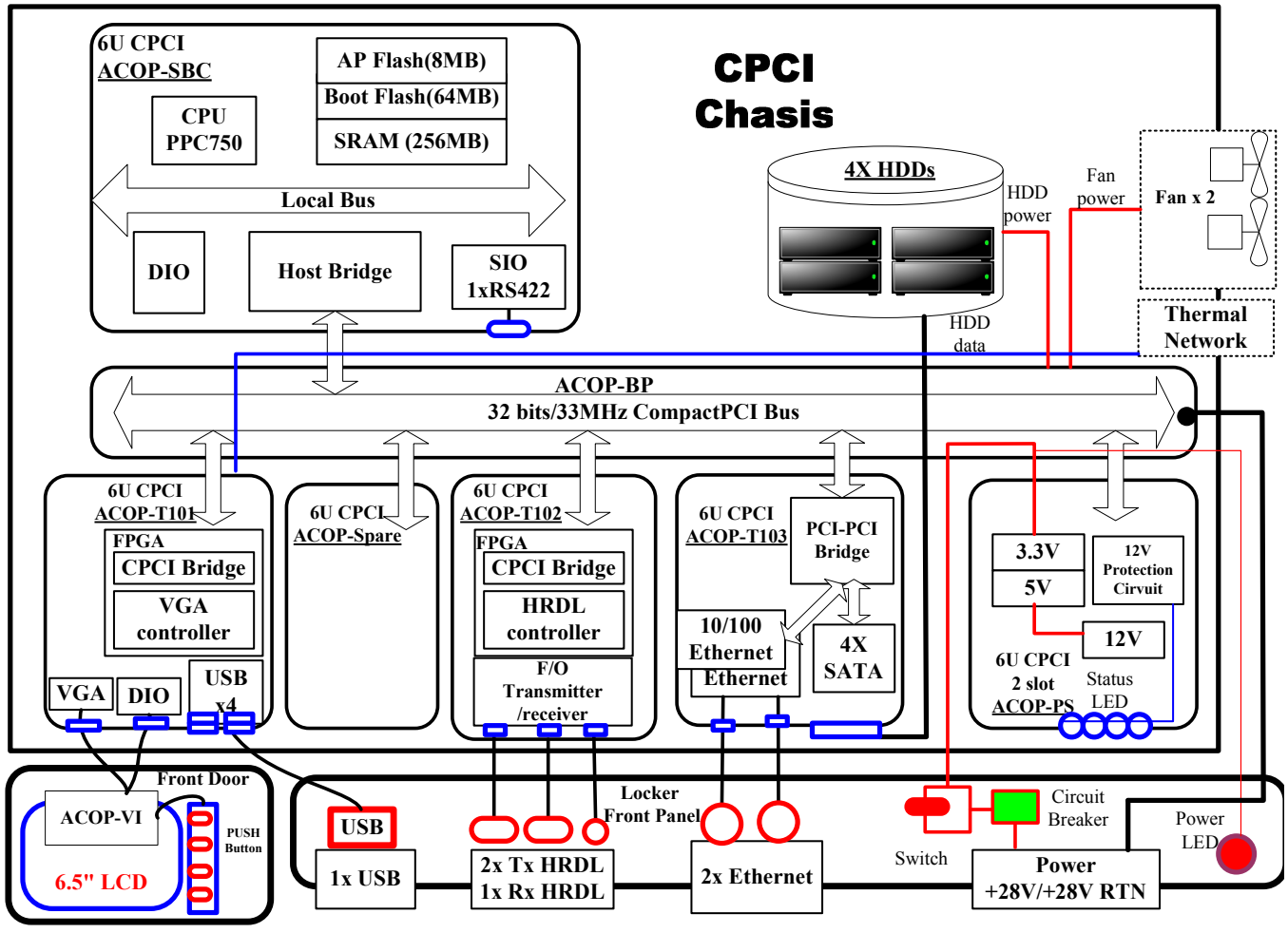

Figure 3-14 ACOP Electrical Block Diagram

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

.

3.4.2.1 POWER DISTRIBUTION AND POWER FEEDERS PROTECTIONS

The ACOP power distribution system includes the power input control on the locker front panel, the power distribution in ACOP backplane (ACOP-BP) and the power supply (ACOP-PS) module, as shown in Figure 3-15.

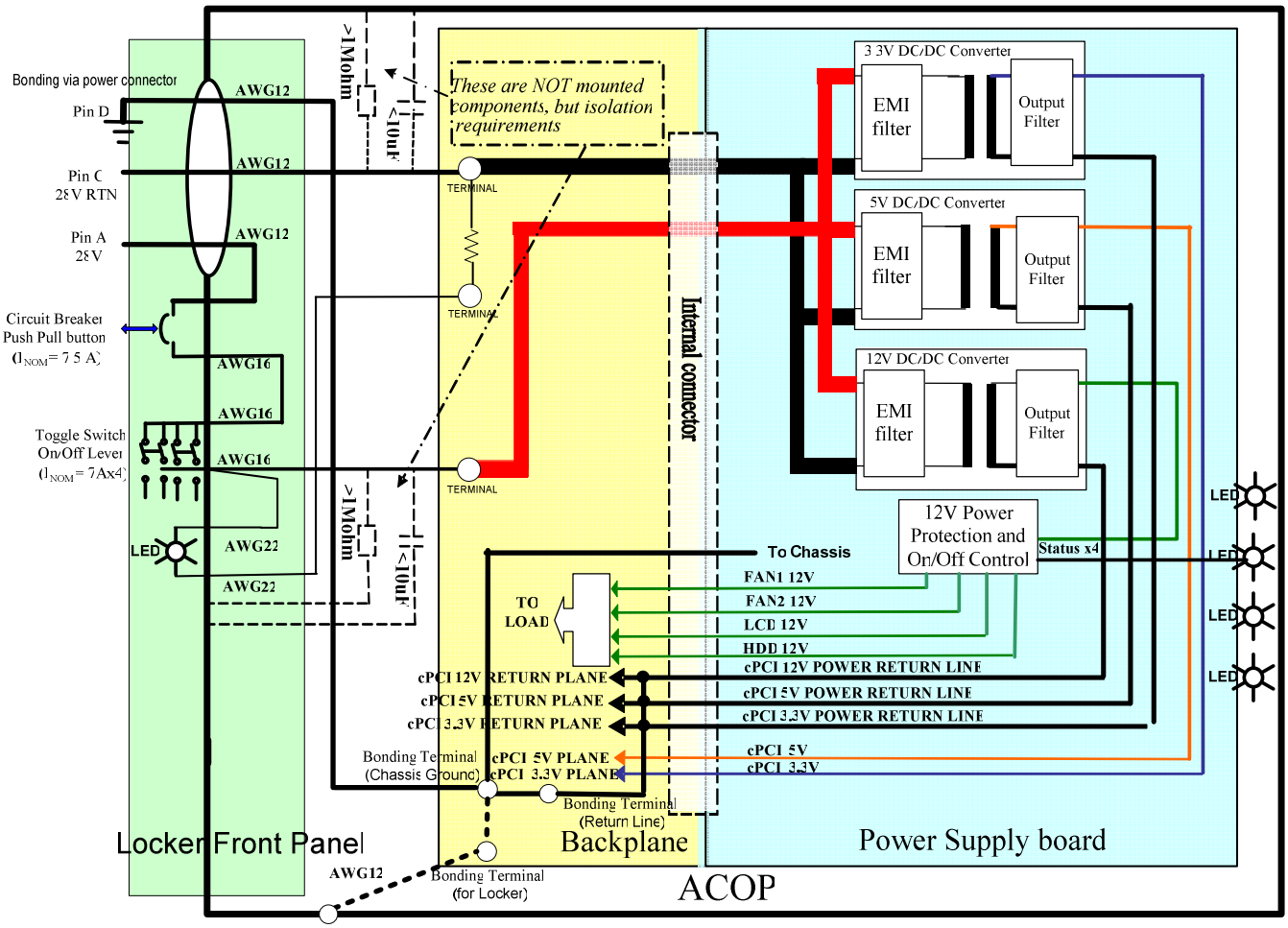

Figure 3-15 ACOP Power Distribution Diagram

The input voltage range for the ACOP-PS is 24 to 32Vdc, compliant with the +28Vdc power feeder voltage range provided by the EXPRESS Rack. The input voltage is first supplied to a circuit breaker which is used to protect wirings and downstream circuits from thermal damage that occurs during an over-current situation and as the first step of defense against electrical hazards. The circuit breaker's features include fail-safe operation, ambient temperature compensation and load protection function.

When not tripped the circuit breaker provides power to the front panel power switch. When the switch is moved to the ON position, power is provided to the system and a LED is turned on to indicate presence of 28V input voltage.

The switch output supplies the ACOP Power Supply (ACOP-PS), which is based on modular DC/DC converters implemented with hybrid integrated circuits. Each one incorporates two filters designed with output common mode filter chokes and low ESR capacitors. Three outputs provide 3.3Vdc, 5Vdc and 12Vdc power supplies with independent output regulation.
There are power terminals on ACOP-BP for distribution of regulated power to other ACOP devices. The DC-DC converters in ACOP-PS include a complete self contained EMI filter, allowing these units to meet MIL-STD-461 levels. Additional features include output common mode filtering, programmable soft start, open loop OVP protection, external synchronization inputs and an inhibit input.

The three different voltages, 3.3V, 5V and 12V, are distributed from ACOP–PS to CompactPCI backplane and other stand-alone devices (LCD, fans, etc.). There are protection circuits for each 12V power distribution, and the status is indicated by board mounted LEDs.

The ACOP Locker front panel power input control includes the following functions:

- 4 pole On/Off Toggle Switch

  This part (M8805/93-012) has been selected to meet the maximum input current requirement, including the condition of HDD startup with all 4 HDDs on simultaneously. Four poles of the switch are used, and connected in parallel. The current rating is 7A X 4 for 4 poles.

- A LED to indicate Power ON/OFF status.

  A green LED (JANTXM19500/521) is mounted on the Locker front panel to indicate Power ON/OFF status. A resistor (mounted on ACOP-BP) is connected in series to this LED to limit its current.

- An aircraft style push button Circuit Breaker for input over current protection:

The estimated maximum input power of ACOP is 113.45W (not including circuit breaker and wire losses). The estimated minimum input voltage of DC/DC Converters is:

24V (Vin lower bound) – 0.3V (CB voltage drop) – 0.2V (Wire loss drop) = 23.5V.

Therefore, the maximum input current is Pin(max) / Vin(min) = 113.45 / 23.5V = 4.83A. A 7.5A Circuit Breaker (MS 3320-7 1/2) has been selected to meet the requirements.

The ACOP-PS module is CompactPCI form factor and installed in the backplane, and provides the power source for ACOP electronics parts. The ACOP-PS includes the following functions:

- Convert input power (DC 28V) to meet the power requirements of all ACOP electronics parts.
- Isolation between 28V input from ISS and output load.
- Protection of each power output. (3.3V, 5.0V, 12V)
- 3.3V and 5.0V power source with a function of remote sensing.
- Provide on/off control of each 12V power distribution to Fan1, Fan2, and LCD.
- Provide protection status of each 12V power distribution to system, and indicate by board mounted LEDs.
- Provide two Dallas thermal sensors for each DC/DC Converter.

The ACOP-SBC board will provide a power monitor circuit for both the 3.3V and 5V supplies: during power up, the 3.3V power monitor circuit will hold the ACOP-SBC in reset until the power is stable. The 5V power monitor signal will be latched when faulted and the latched results will be provided as input to the CPU for software read then clear operation.

3.4.3 AVIONICS INTERNAL LAYOUT

Figure 3-16 below shows the internal layout of boards and components inside ACOP as it will be seen by the crew when the front panel is open.

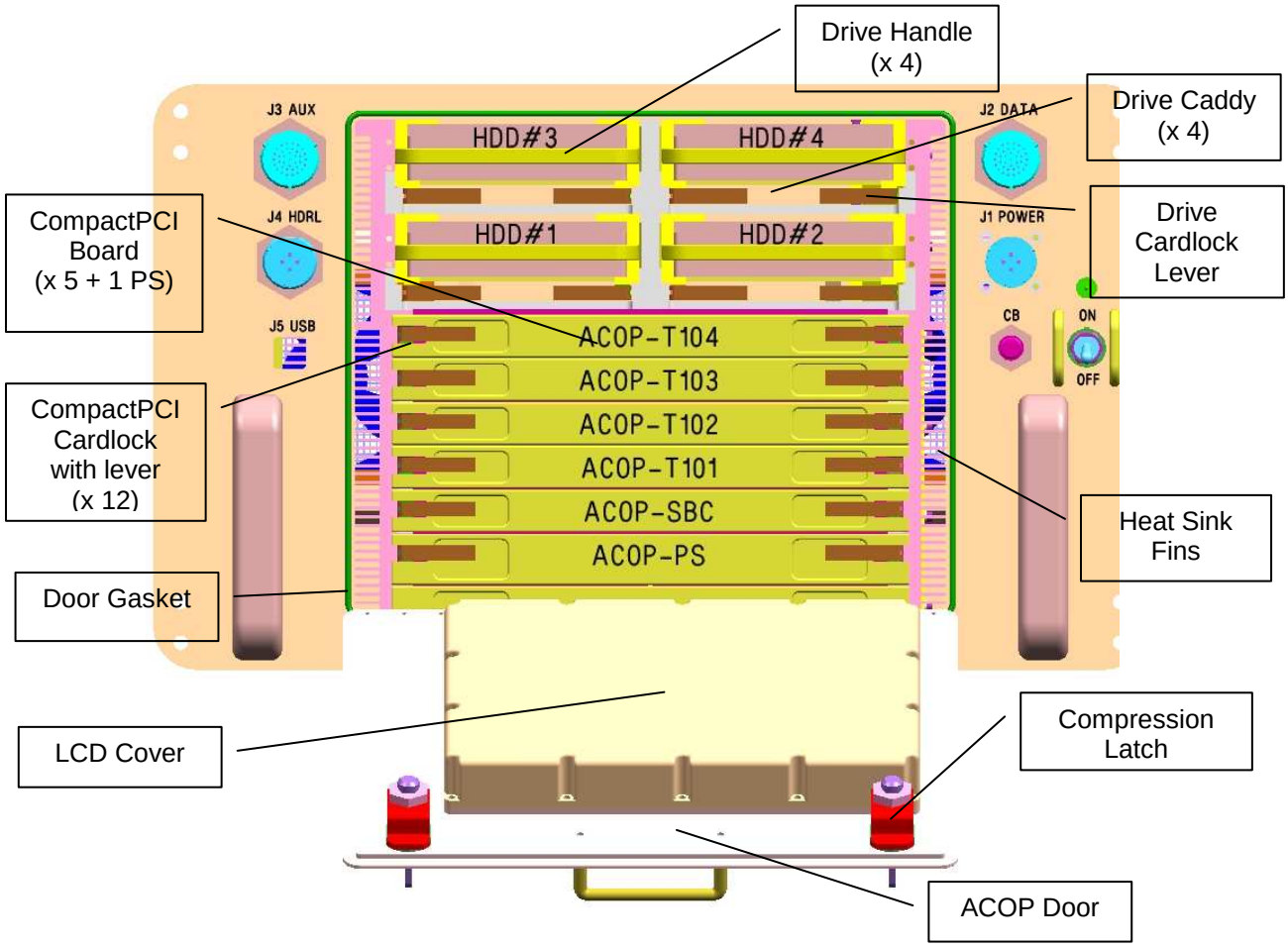

Figure 3-16 ACOP Main Components

The upper part of the chassis will be occupied by 4 Drive Caddies holding Serial ATA hard drives. The Drive Caddies will be fixed to the chassis by means of cardlock retainers provisioned with lever arms to minimize the crew effort to replace them. Power and data interface to each Drive Caddy is provided by means of a blind mate connector placed on the rear side.

The CompactPCI boards and the power board will be hosted in the lower section of the chassis. These boards are also will be fixed to the chassis by means of cardlock retainers.

The main characteristics of the ACOP card cage assembly are:

- 6U card cage for 5 double Eurocard CompactPCI boards in a CompactPCI chassis.
- Conduction cooling and wedge-locks for CompactPCI boards and power supply board.
- Double height power supply slot.
- Mounting provisions for CompactPCI backplane.

- 4 hard drives with caddies that can be removed from the chassis

The CompactPCI bus combines the performance advantages of the PCI desktop architecture with the ruggedness of the Eurocard form factor, a widely used standard within the industry for over 20 years. The Eurocard board provides more secure connectors and more available space for professional embedded platforms than the PCI cards in desktop computers. The CompactPCI standard has widely been accepted for a large spectrum of applications.
The CCA design in the ACOP case is based on the "IEEE 1101.2 - Mechanical Core Specification for Conduction Cooled Eurocards" specification and the board layout is shown
in Figure 3-17:

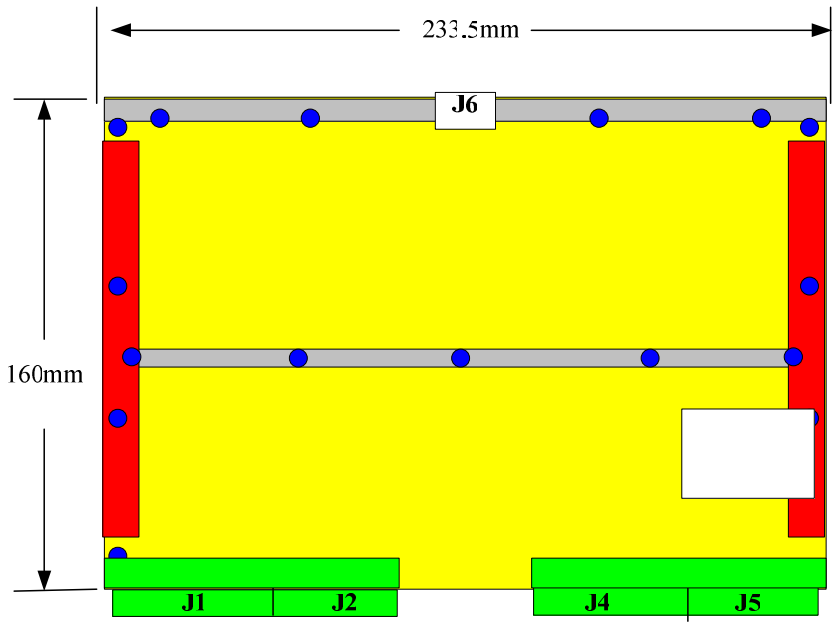

Figure 3-17 IEEE 1101.2- Mechanical Core Specification for Conduction Cooled Euro cards

To allow ACOP to operate in the ISS, the boards design incorporates the following techniques:

- Buried thermal layers within the PCB and provide a good thermal conductivity from components to the board edge.
- Heat sink for high power components
- Stiffening ribs cross the board
- Expandable wedge lock on both sides
- Components location based on thermal analysis

3.4.3.1 ACOP-SBC

The ACOP-SBC is a single slot 6U CompactPCI form-factor board that fits into a system slot of a standard CompactPCI backplane. It consists of an IBM PowerPC750 CPU with system memory, several peripherals and the CompactPCI interface.

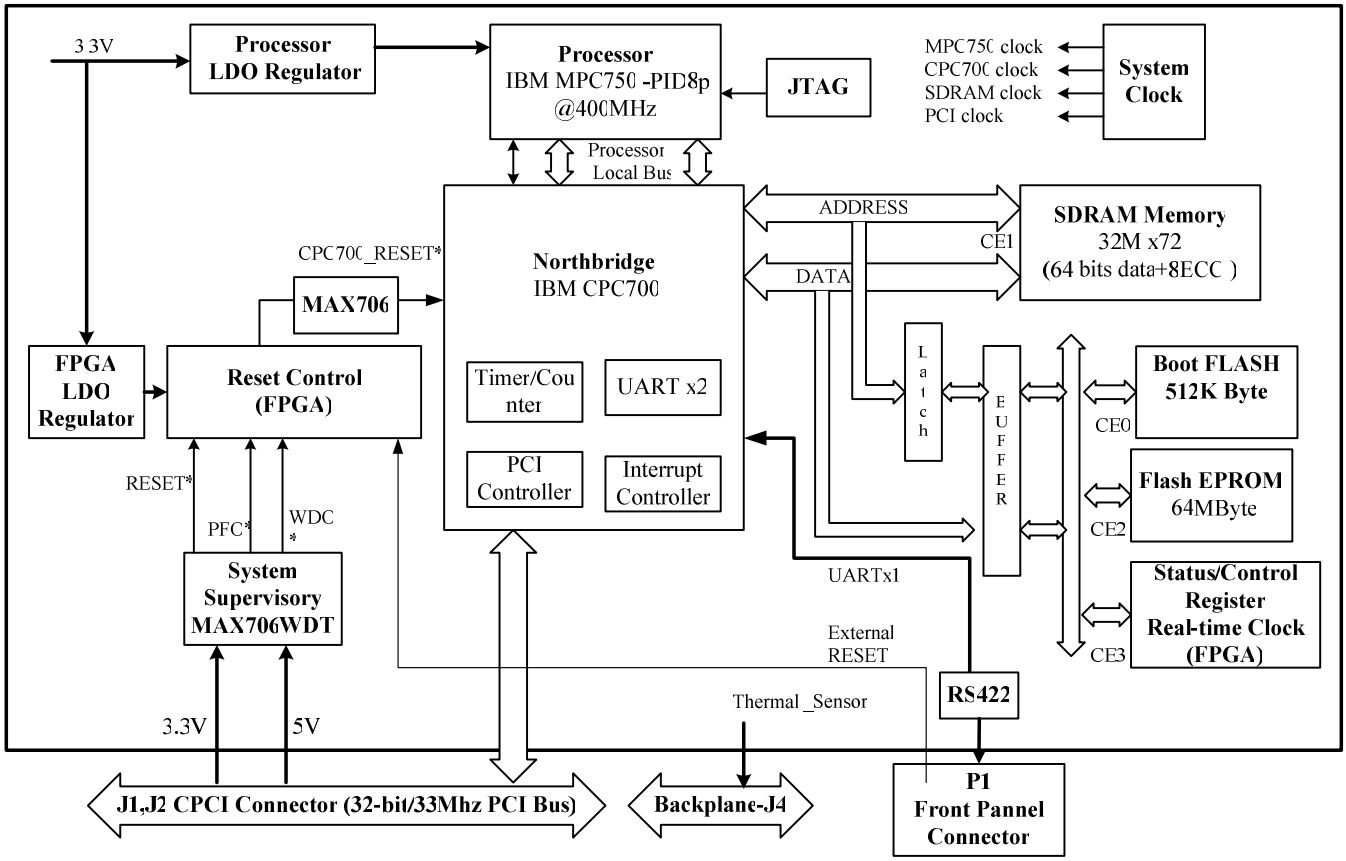

Figure 3-18 shows the main functional blocks that make up the ACOP-SBC board. There are two bus sections in the ACOP-SBC board design: the CPU bus provides connections to the North PCI Bus Bridge chip, which provides the connections to the processor memory.

The processor memory includes read only boot PROM, FLASH memory and SDRAM. The system allows the operational memory configuration to be customized to the specific application.

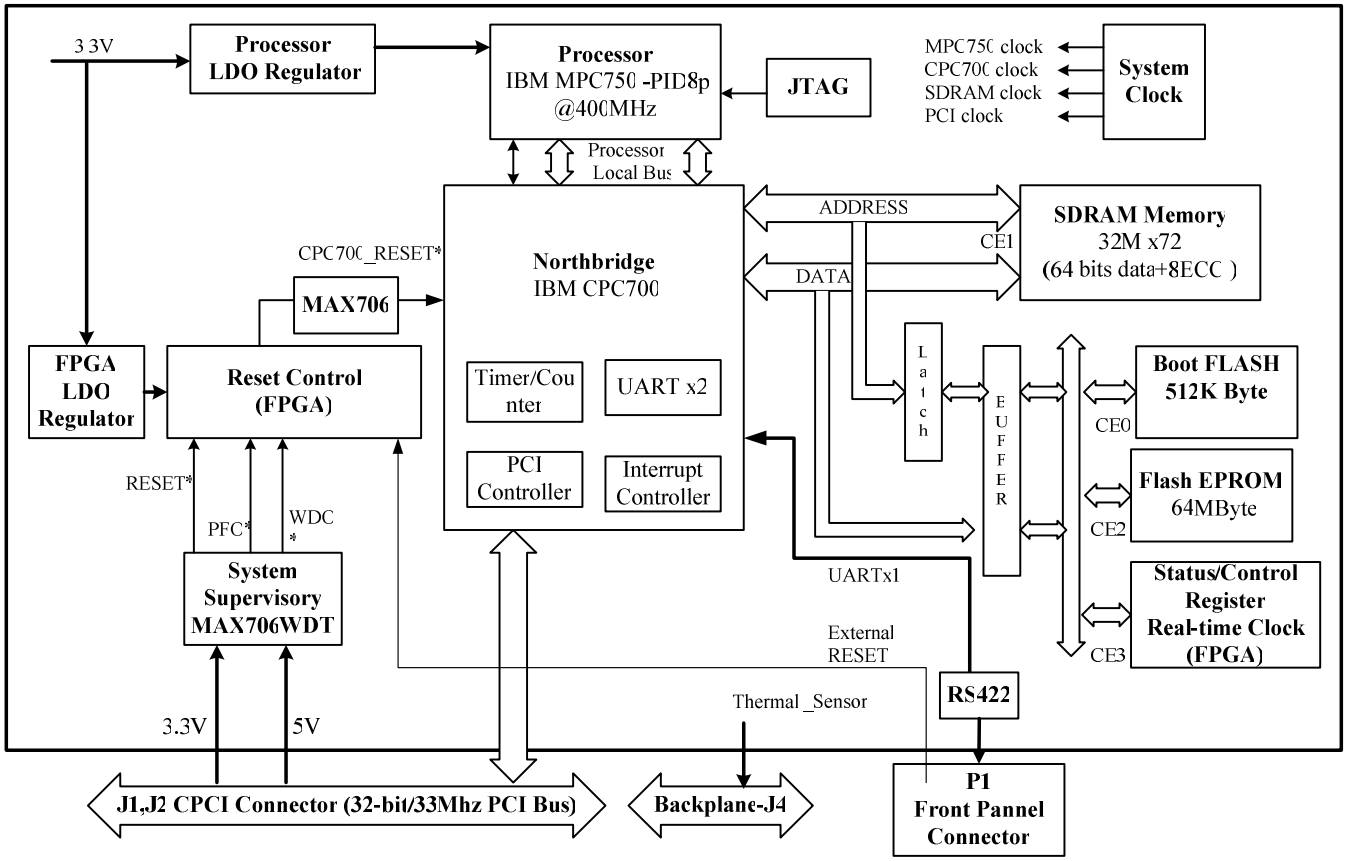

Figure 3-18 ACOP-SBC Functional Block Diagram

The following is a list of the hardware features for the ACOP-SBC:

- Microprocessor
  IBM PowerPC750 microprocessor running at 400 MHz
  On-chip Cache (Instruction/Data): 32K/32K

- CPU to PCI Bridge
  IBM CPC700 memory controller and PCI bridge
  CPU to SDRAM/ROM/Peripheral controller
  CPU to PCI bridge
  PCI to SDRAM bridge
  Provides Backplane CompactPCI signal

- Memory
  Boot PROM: 512K bytes Flash EEPROM
  Flash EPROM: 8M bytes, 32-bits wide
  SDRAM: 256M bytes, data bus width 72-bits with 64 bits data and 8 bits ECC

- 12 external interrupts, individually maskable
- Watchdog timer and supervisory circuit
  Power-on-reset, external reset
  Timer to monitor the CPU operation
  Power supply monitor for +3V and +5V
- On-board Peripheral
  Serial I/O: 16552D (16550A compatible), RS422 Interface
  General purpose timer: 32-bits time base, 5 capture event timers and 5 compare timers

Control register: Control/status registers, Watchdog restart/read, enable/disable register
Real-time clock count to mini-second

- Two set vias (three wires x 2) for thermal meters input
- PCI 2.1, 32-bits, 33Mhz, with 5 bus arbiter (REQ/GNT signal)
- CompactPCI system slot, PICMG 2.0 compliant

3.4.3.2 ACOP-T101

The block diagram in Figure 3-19 shows the main functional blocks of the ACOP-T101 board. An ACTEL A54SX72A FPGA is used to implement the PCI agent and VGA controller function. It is compliant with the PCI 2.2 specification and provides 33MHz performance. Two SRAM chips are used as video memory and buffer between system slot and the FPGA chip.

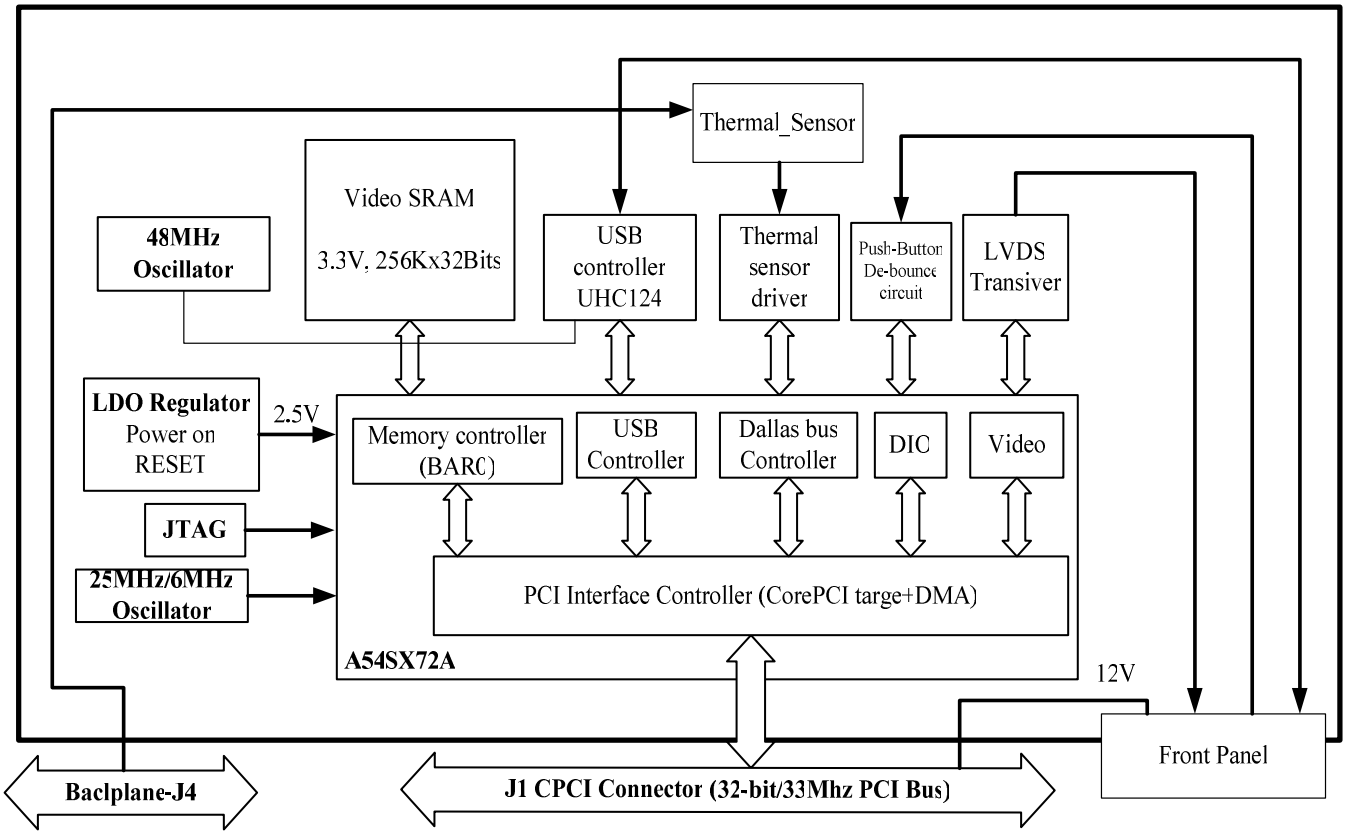

Figure 3-19: ACOP-T101 Functional Block Diagram

The following is a list of the hardware features for the ACOP-T101:

- LCD Graphic Function :
  - Only graphic mode supported.
  - Resolutions: 640x480 and 320x240
  - Color: 5 bits (bit1 to bit 5) for R, G, B. The value of bit 0 of each color is fixed to zero.
  - Clock frequency: 25MHz
  - Vertical frequency: ~ 60Hz
  - Video SRAM: 256K x 32bit

- Discrete I/O function
  - De-bounce circuit for push-button input
  - Two 1-wire buses for Dallas temperature sensor input

  - Output to adjust the brightness of the LCD backlight

- USB interface:
  - Supports USB Specification 2.0 (up to 1.5Mb/s) devices
  - Allow one PCI transaction to access both UHC124 controllers.
  - Support burst R/W by using backend throttling

- 32bits /33Mhz CompactPCI peripheral slot, PICMG 2.0 compliant

3.4.3.3 ACOP-T102

The ACOP-T102 board provides two transmit and one receive fiber optic interfaces meeting the ISS HRDL CCSDS packet mode standards. The interface provides intelligent reception and transmission of variable length CCSDS packets referred to in this document as frames. Frame data is received into and transmitted out of a buffer memory of 1MB contained on board. The configuration of FIFOs to manage the data is done by software allowing support for varying operational modes.

Support is provided for transmit data rate control within the interface. The software can configure a sync-symbol insertion parsing in terms of a data-symbol to sync-symbol ratio as well as specifying the number of sync-symbols between frames.

The interface removes all sync-symbols on reception.

The interface provides a means to transmit test patterns of symbols, including both valid and invalid symbols.

PCI DeviceID: 0x5309 (TBC)
PCI VendorID: 0x414D

The transmitter is capable to transmit frames from 1 to 4096 bytes length[7]. Data symbols can be interleaved with sync symbols d:s where d=0:20 s=0:20 where d is the number of consecutive data symbols and s is the number of consecutive sync symbols. Either s or d being zero means no syncs are inserted. The number of sync symbols in the gap between frames can be specified between 1 and 2 ** 23 –1 inclusively.

Receiver can receive frames from 0 to 4096 symbols with all sync symbols removed.

The hardware structure of ACOP-T102 board is shown in Figure 3-20. The PCI agent chip (Actel A54SX72A) includes the functions:

- translator between the PCI bus and interface back-end bus
- handling of the read/write operations (PCI memory space access) on the SRAM buffer
- Processing and metering data among the SRAM and TAXI physical devices

[7] The HRDL CCSDS packet size requirement is that packets will be from 100 to 4096 bytes length

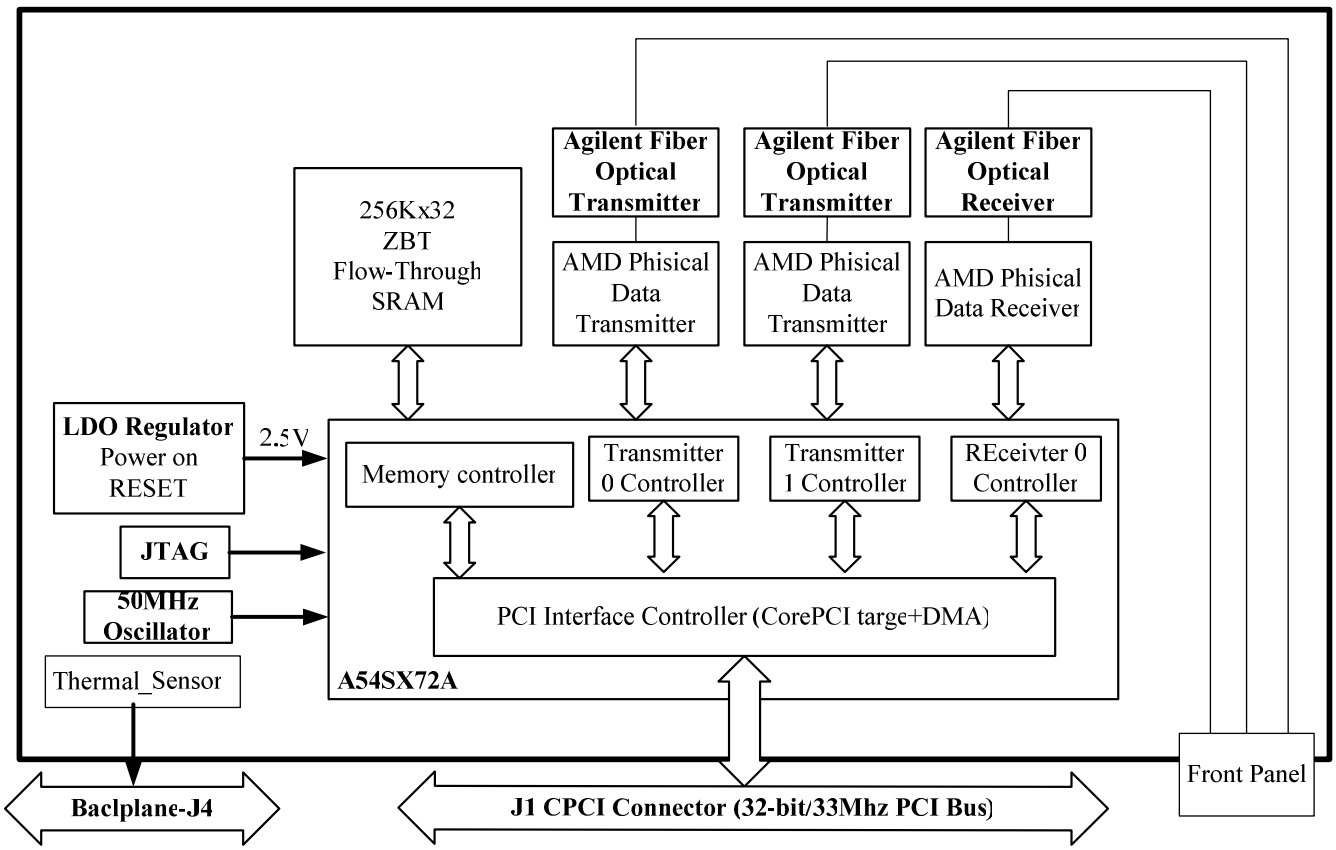

Figure 3-20: ACOP-T102 Functional Block Diagram

The following is a list of the hardware features for the ACOP-T102:

- Provides bi-directional buffering (queuing) of character data and conversion to/from TAXI serial signaling.
- Two transmit and one receive fiber optic interfaces meeting the ISS HRDL CCSDS packet mode standards
- UP to 100 Mbits/s (signaling rate is fixed to 125 Mbps) Asynchronous operation on each channel
- Provides intelligent reception and transmission of variable length CCSDS packets referred to as frames
- On board 1M bytes SRAM memory configured as FIFO like buffer for storing raw data from interface. The configuration of FIFOs to manage the data is done by software allowing support for varying operational modes.
- Software configurable sync-symbol insertion parsing in terms of a data-symbol to sync-symbol ratio as well as specifying the number of sync-symbols between frames.
- 32bits /33Mhz CompactPCI peripheral slot, PICMG 2.0 compliant

3.4.3.4 ACOP-T103

The ACOP-T103 provides four (4) separate SATA channels to access storage media such as hard disk drive. It uses a PCI-to-Quad-SATA Controller that supports a 32-bit, 66 or 33MHz PCI bus. It accepts host commands through the PCI bus, processes them and transfers data between the host and Serial ATA devices.

It can be used to control four independent Serial ATA channels: each channel has its own Serial ATA bus and will support one Serial ATA device with a transfer rate of 1.5 Gbits/sec (150 MBytes/sec). An industry standard PCI-to-PCI Bridge is used to support a 32bits internal PCI path at 33 MHz, for 132 MB/s operation.

The ACOP-T103 also provides two independent high-performance Fast Ethernet interface controller ports.

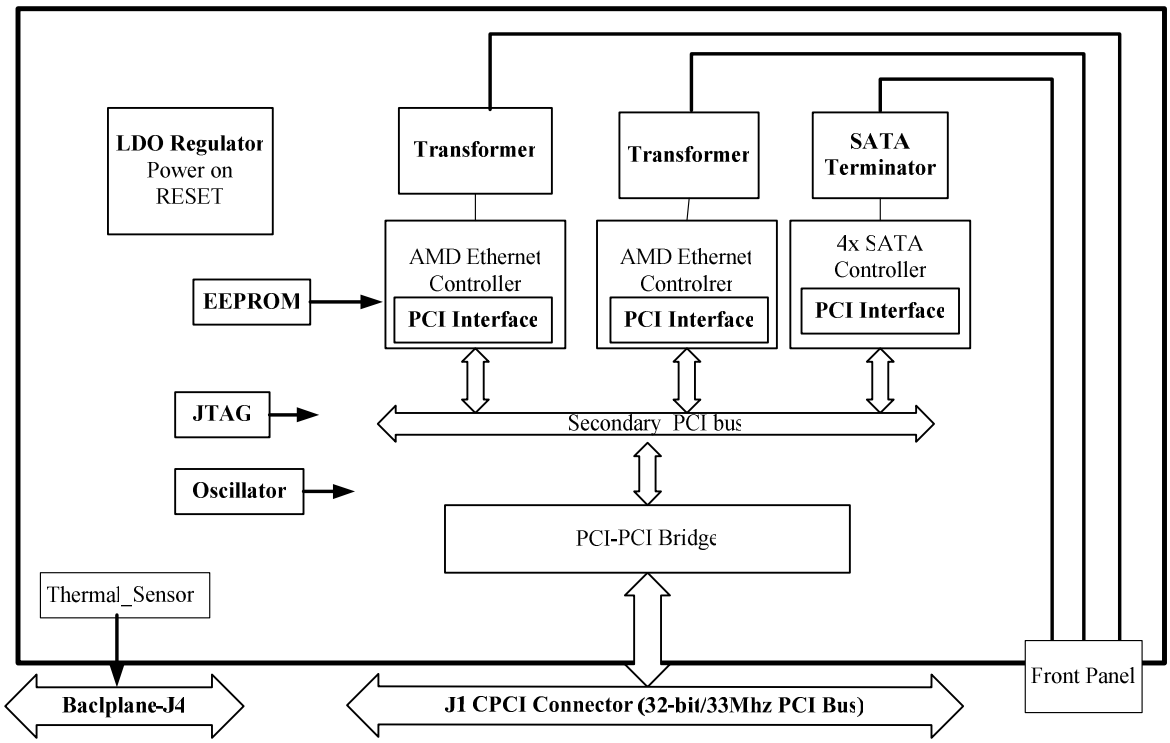

Figure 3-21: ACOP-T103 Functional Block Diagram

The following is a list of the hardware features for the ACOP-T103:

- PCI to 4-port Serial ATA (SATA) host controller
- Serial ATA transfer rate of 1.5Gbit/second
- Spread spectrum receiver and single PLL for all channels
- Independent 256 byte (32-bit by 64) FIFO per channel
- Integrated Serial ATA Link and PHY logic
- Compliant with Serial ATA 1.0 specifications
- Two IEEE802.3 10/100Base Ethernet ports, Both TX and RX supported
- 32bits /33Mhz CompactPCI peripheral slot, PICMG 2.0 compliant

3.4.3.5 ACOP-BP

The ACOP backplane is compliant to the PICMG 2.0 R3.0 standard for backplane, module connectors, mechanical and power interfaces. CompactPCI signals are routed on P1 connector row only. P2 connectors are installed only on the system slot positions. P3 connector row is not used at all.

Each of the CompactPCI segment provides +3.3Vdc signal environment only. All V(I/O) pins of each slot are connected to the corresponding +3.3V power planes. The peripheral interface signals for ACOP specific applications are routed on P4.

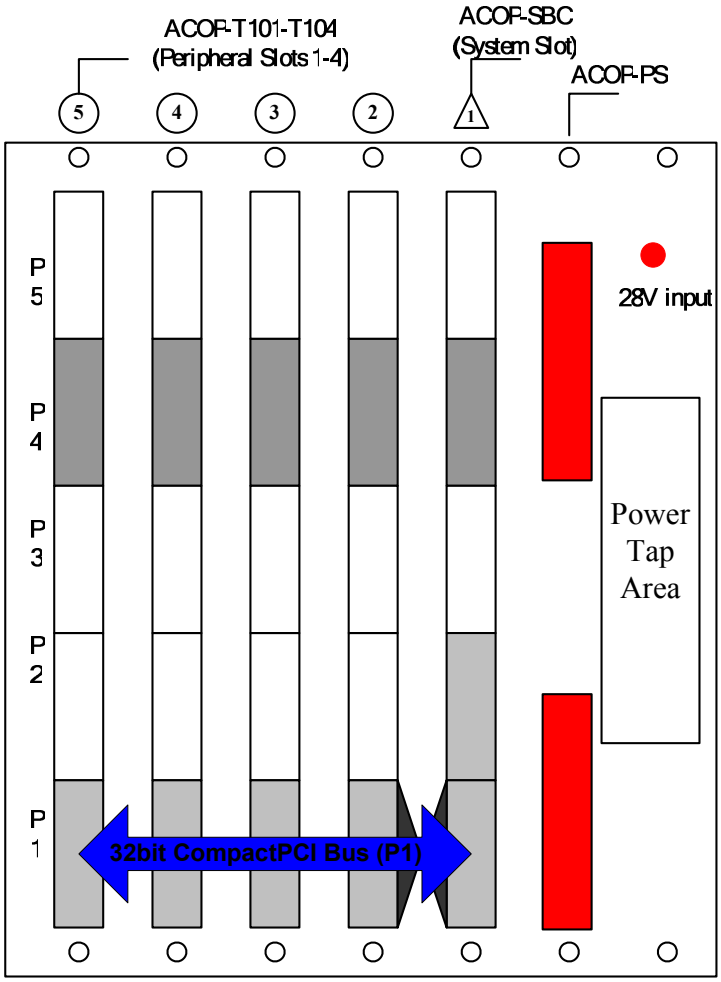

Figure 3-22 ACOP-BP Functional Block Diagram

The following is a list of the hardware features for the ACOP-BP:

- Compliant with the CompactPCI core specification (PICMG 2.0 R3.0), exclude the power for +12V and -12V power lines
- Support 32-bit, 33 MHz PCI bus operation
- 28V input to ACOP-PS
- Separate 12V distribution
- 3.3V V(I/O) signaling voltage only
- no Hot Swap capability, no Rear I/O capability
- 5-slot wide, one system and four I/O slots
- Standard 47 pins power supply slot
- Power terminals on ACOP-BP for distribution of regulated power to other ACOP devices..

3.4.3.6 ACOP-PS

The ACOP-PS module is CompactPCI form factor and installed in the backplane. The input voltage range is 24 to 32Vdc, compliant with the +28Vdc power feeder voltage range provided by the EXPRESS Rack.

Three outputs (generated by power DC/DC converter implemented with hybrid integrated circuits) provide 3.3Vdc, 5Vdc and 12Vdc power supplies with independent output regulation. The outputs of the ACOP-PS adopted the power interface requirements of PICMG specification for CompactPCI systems.

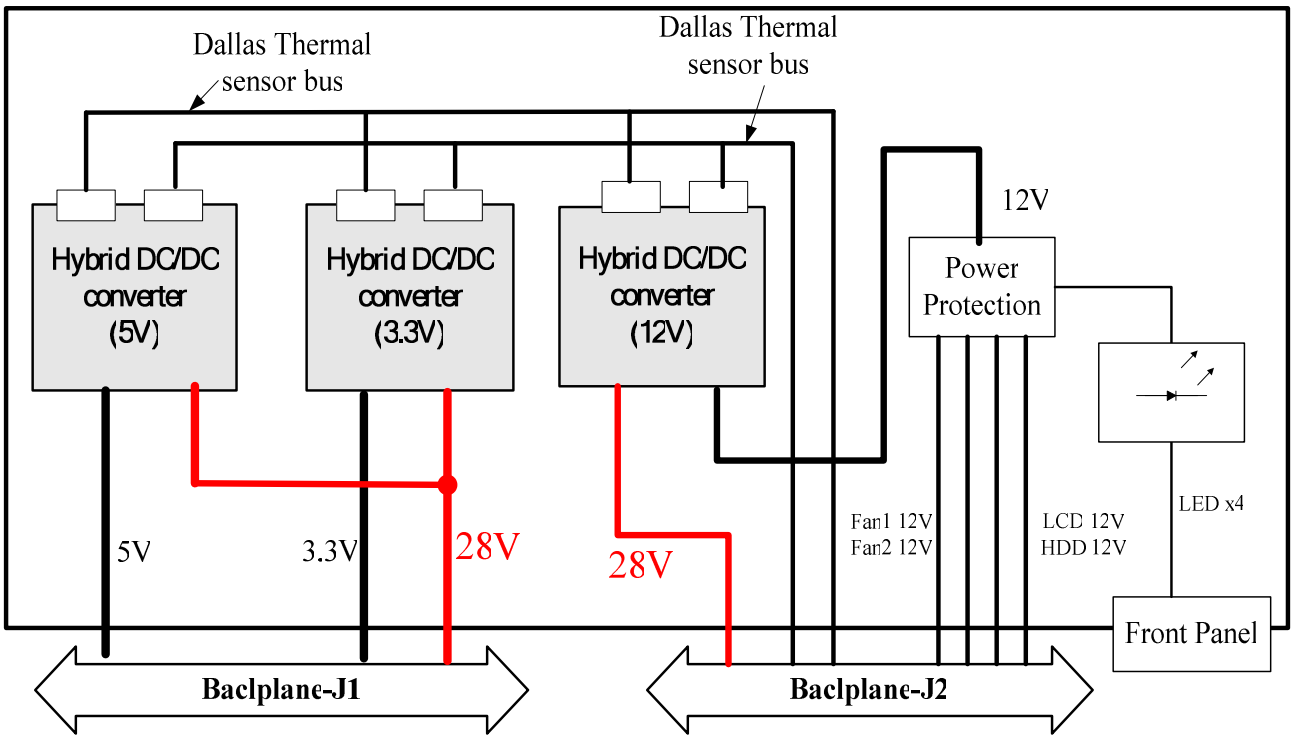

Figure 3-23 ACOP-PS Functional Block Diagram

The following is a list of the hardware features for the ACOP-PS:

- Input voltage range: 28Vdc ± 4Vdc
  (compliant with the EXPRESS Rack power specification 28Vdc +1.5Vdc / -2.5Vdc)
- Output voltages: +5.06V +/-3% ,+3.36V +/-3%,+12.1V +/-5%
- Efficiency: > 75% @ full load, nominal line
- DC/DC converters built-in protections: over-voltage, over-current, over temperature
- DC/DC converters isolation:
  Input to case: 500Vdc
  Input to output: 500Vdc
  Output to case: 100Vdc.
- DC/DC converters built-in EMI filters, meet MIL-STD-461C requirements CE01, CE03, CS01, CS02 and CS06.
- Over-current monitor and protection on 12V output lines for HDDs, LCD, Fan 1 and Fan2.
- Front panel LEDs to indicate the protection status of each 12V output line
- Backplane power connection via PICMG 2.11 compliant 47-pin power connectors.
- Environment: for Grade E MDI DC/DC converters, full output power at +125℃ (case temperature), linear derating to zero at +135℃ (case temperature).

DC-DC converter

According to the power budget, the load required for each power source is as following:

Voltage	3.3V	5.0V	12V
Nominal current consumption (2 HDDs are ON; 2 HDDs are in stand-by)	5.41A	2.79A	2.26A
Maximum current consumption (4 HDDs are ON, only for a short period)	5.80A	3.79A	3.68A

Table 3-1 DC/DC converters loads

ACOP-PS will use DC-DC converter from MDI, the selection of DC-DC converter is according to the datasheet and ACOP power requirement.

Part No.	5193E-S03.3F	5680E-S05F	5031SE-S12	Remark
I/P Voltage Range	18 ~ 50Vdc at full power	18 ~ 50Vdc at full power	18 ~ 50Vdc at full power	At full power
Voltage Rating	3.3V	5.0V	12V	
Power Rating	26.4W	30W	75W	
Current Rating	8A	6A	6.25A	
Ripple(typ)	30 mVp-p	40 mVp-p	60 mVp-p	@2MHz B.W.
Ripple(max)	65 mVp-p	85 mVp-p	150 mVp-p	@2MHz B.W.
Regulation(typ)	10mV	10 mV	20mV	Line & Load Regulation
Regulation(max)	30 mV	50 mV	100 mV	Line & Load Regulation
Remote Sense	Yes	yes	yes	

Table 3-2 MDI DC/DC Converter Rating

DC/DC Converter (Voltage/Amperes)	5193E-S03.3F (3.3V/8A)	5680E-S05F (5.0V/6A)	5031SE-S12 (12V/TBDA)
O/P Power Rating	26.4W	30.0W	75W
Nominal Power Consumption / Derating	17.8W / 67.4%	13.9W / 46.3%	27.1W / 36.1%
Max. Power Consumption / Derating	19.1W / 72.3%	189W / 63.0%	44.2W / 58.9%

Table 3-3 MDI DC/DC Converter Power Derating

12V Load Protection

Three types of devices in ACOP consume 12V power (HDD, LCD, Fan), they are supplied by four independent lines (HDDs, LCD, Fan 1, Fan 2). Each line is provided on the ACOP-PS with an over-current protection managed by a

dedicated controller. This IC provides also the capability to shutdown each line by means of a control signal generated by the ACOP-T101 DIO interface.

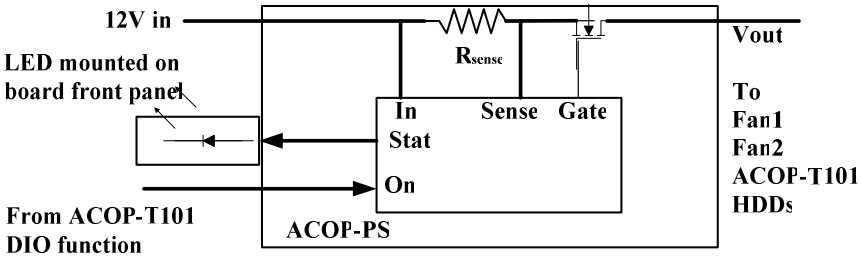

Figure 3-24 12v Load Protection Scheme

The controller provides startup current regulation, current glitch protection, over current protection and a status output to indicate a fault condition. Each status output drives a LED mounted on the ACOP-PS front panel.

The status output is an open-drain output which is high (LED is off) only if no fault is present. The status output goes low (LED is on) under the following conditions:

- During the UVLO (under voltage lock-out) delay period
- In startup
- When the output is forced off (On signal <0.6V)
- In an over-current condition, the threshold value is set by an external resistor
- In the retry timeout period (or latched off, for the latched parts)

Over-current protection

The over-current protection within the DC/DC converters is activated between 120% and 130% of the full load rated current. There is a combination of fast current limit function (provided through a current mode circuit with pulse by pulse protection) and slow current limit function. The typical delay to switch the converter off is 5ms, and the automatic restart is after 15 to 20ms approximately.

OVER-VOLTAGE protection

The trip point of the over-voltage protection within the DCDC converters is typically 133% of the nominal voltage. When a control loop malfunction causes an excessive over-voltage condition, the converter will be shut-off and then automatically restarted.
The over-voltage protection circuit does not monitor the output voltage, but the output voltage as reflected to the internal auxiliary transformer winding. So, if an externally applied voltage causes the output to exceed the voltage trip limit, the converter can neither sense this over-voltage nor limit it. However, this condition is unlikely to happen in ACOP (all the voltage distribution lines are isolated and separated from each other).

3.4.3.7 LCD MONITOR AND ACOP-VI

A Color Active Matrix Liquid Crystal Display (LCD) T-51750AA-V350 from Apollo Display with an integral LED backlight system will be mounted on the ACOP door. This TFT-LCD has a 6.5 inch diagonally measured active display area with VGA resolution (640 vertical by 480 horizontal pixel array). Each pixel is divided into Red, Green and Blue sub-pixels or dots which are arranged in vertical stripes.

ACOP-VI is an interface board between LCD panel and ACOP-T101, mounted on the LCD frame. It is a 4 layer PCB with the same size as the LCD frame (158mm x 120.36mm, TBC). It buffers all signals from ACOP-T101 and provides a switch circuit for the LED backlight power and dimming control. A simple switch circuit based on a power MosFET is used to switch on/off and dim the LED backlight. The PWM signal for dimming is generated from ACOP-T101. Backlight power is adjustable by means of push buttons and software.

The connections between ACOP-VI and ACOP-T101 are shown in Figure 3-25. Signal and power lines are connected through two MicroD connectors with twisted flying wires (< 18 inches):

- M83513/03-F11N (37pin) for LCD RGB signals.

M83513/03-D11N (25pin) for LCD control signals, 3.3V and 12V.
:

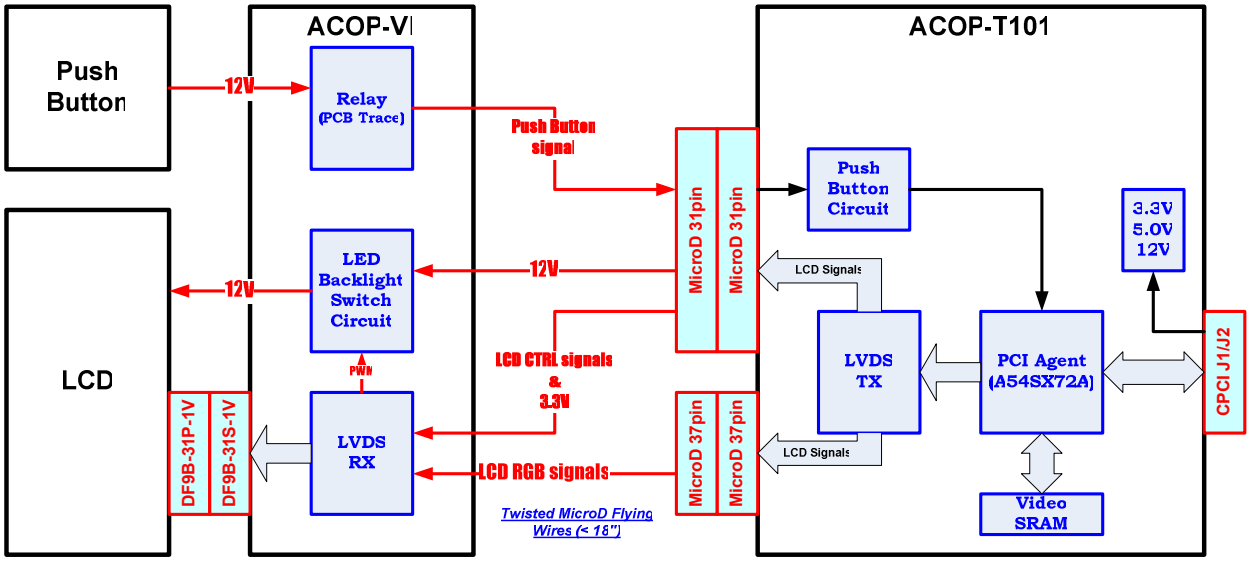

Figure 3-25 ACOP VI to ACOP-T101 Interface

The following is a list of the hardware features for the LCD module:

- Compatible with VGA-480, VGA-400, VGA-350 and free format.
- Screen size 6.5”
- Display format 640 x R,G,B x 480
- Display colors: 262,144 (6bits/per color)
- Active area/Outline area = 62.3%
- LED backlight (two rails)
- Backlight brightness adjustable
- Power requirements: 3.3V with 240mA (typ) and 12V with 450mA (max) for the LED backlight.

LCD (display will be covered with a protection plastic cover (LEXAN) to avoid potential shatterable material hazard.

3.4.3.8 HARD DRIVES

The four hard drives installed in ACOP will require periodic replacement by the ISS crew from the onboard stock of empty drives. A dedicated mechanical structure in the chassis backside provides blind mate connectors for the hard drives. Cables are provided to bring power and data connections to these connectors from ACOP-T103 and ACOP-BP.

The following is a list of the hardware features for the Hard Disk Drives:

- Serial ATA with 1.5Gb/sec interface speed
- Native Command Queuing
- Build-in 16MB cache buffer
- Capacity: 200 GB or more

3.4.3.9 THERMAL SENSOR NETWORK

Thermal monitoring of ACOP will be performed by means of two thermal sensors network. Each network consists of Dallas DS18S20 one-wire bus devices attached to a single bus. Each device has a unique 64-bit serial code stored in an on-chip ROM. which allows multiple DS18S20s to function on the same one-wire bus; thus, it is simple to use one CPU to control many DS18S20s distributed over a system. The digital I/O (DIO) interface in ACOP-T101 will allow ACOP-SBC CPU to access and control the thermal network.

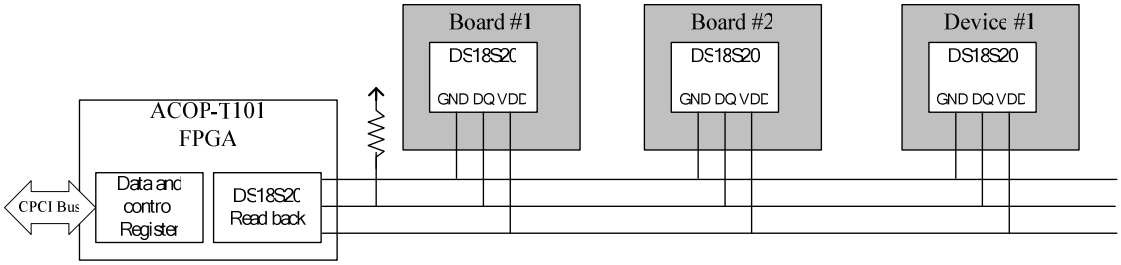

Figure 3-12 Thermal Sensor network Block Diagram

After system power up, the Dallas sensor network operation sequence is as following:

- CPU set search command in ACOP-T101 command register to scan network for new attached sensors and store newly found Device ID.
- Read and send out measured value for selected sensor. (see Figure 3-26)
- Read all available sensors in cycle with defined time interval; store all measured values in RAM.

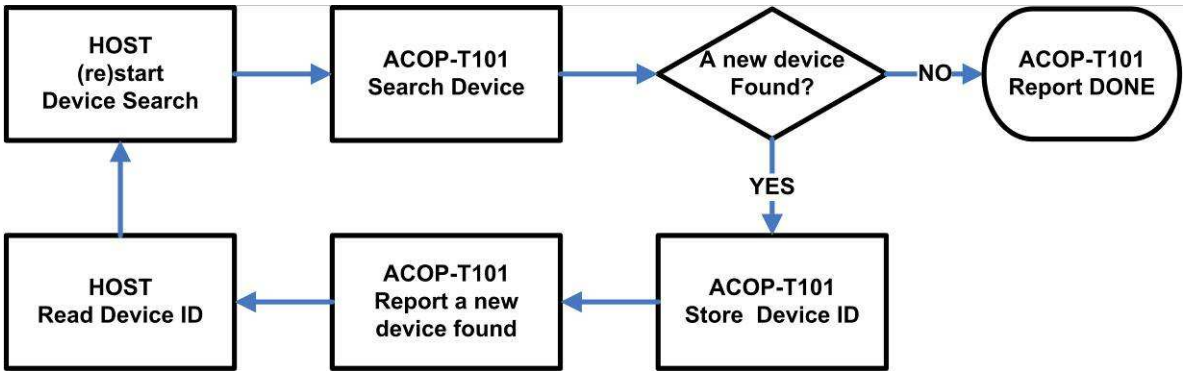

Figure 3-26 ACOP-T101 Thermal Sensors Handling

3.4.3.10 FAN CONTROL

ACOP is cooled using the Avionics Air Assembly (AAA) interface. Two fans near the inlet and outlet ports in the ACOP back plate provide the necessary airflow.
Fans are supplied by the ACOP-PS with two independent power lines provided with over-current protection and switching capability. The operations of the fans will be managed to reduce acoustic noise and avoid excessive air flow, thus avoiding air recirculation.

The baseline is to turn-on one fan at a time, thus reducing noise. Since the switching capability of the ACOP-PS is controlled by the ACOP-SBC CPU, it will be possible to turn-on/off the fans according to the operative needs of ACOPThe software will turn one or both fans ON and can monitor the current consumption of the active fans.

3.4.3.11 INTERNAL HARNESS

Table 3-4 provides a list of the internal harness of ACOP. The following figures show the wiring diagrams between the parts of ACOP.

Cable	Type /Size	From	To
Ethernet x 2	CAT5 22 AWG	ACOP-T103 Card Front Panel	ACOP Front Panel (MRDL connectors)
Fiber Tx1	ISS fiber	ACOP-T102 Card Front Panel	ACOP Front Panel (HRDL connector)
Fiber Tx2	ISS fiber	ACOP-T102 Card Front Panel	ACOP Front Panel (HRDL connector)
Fiber Rx	ISS fiber	ACOP-T102 Card Front Panel	ACOP Front Panel (HRDL connector)
External Power	12 AWG	ACOP Front Panel (Power connector)	ACOP Front Panel (Circuit Breaker)
External Power	16 AWG	ACOP Front Panel (Circuit Breaker)	ACOP Front Panel (On/OFF Switch)
External Power	16 AWG	ACOP Front Panel (On/OFF Switch)	ACOP-BP
External Power Return	12 AWG	ACOP Front Panel (Power connector)	ACOP-BP
Grounding	12 AWG	ACOP Front Panel (Power connector)	ACOP-BP
LED	22 AWG	ACOP Front Panel (On/OFF Switch)	ACOP Front Panel (LED)
LED	22 AWG	ACOP Front Panel (LED)	ACOP-BP
Push Buttons	26 AWG	ACOP Door	ACOP-VI Card
LCD Ribbon Cable x 2	26 AWG	ACOP-T101 Card Front Panel	ACOP-VI Card
LCD Backlight	26 AWG	ACOP-VI Card	ACOP-LCD
USB	USB 26-28 AWG	ACOP-T101 Card Front Panel	ACOP Front Panel (USB connector)
HDD Power	24 AWG	ACOP-BP	HDD Blind Mate Connector
HDD Data	SATA 26-28 AWG	ACOP-T103 Card Front Panel	HDD Blind Mate Connector
Fans Power	26 AWG	ACOP-BP	Fans

Table 3-4 ACOP Internal Harness

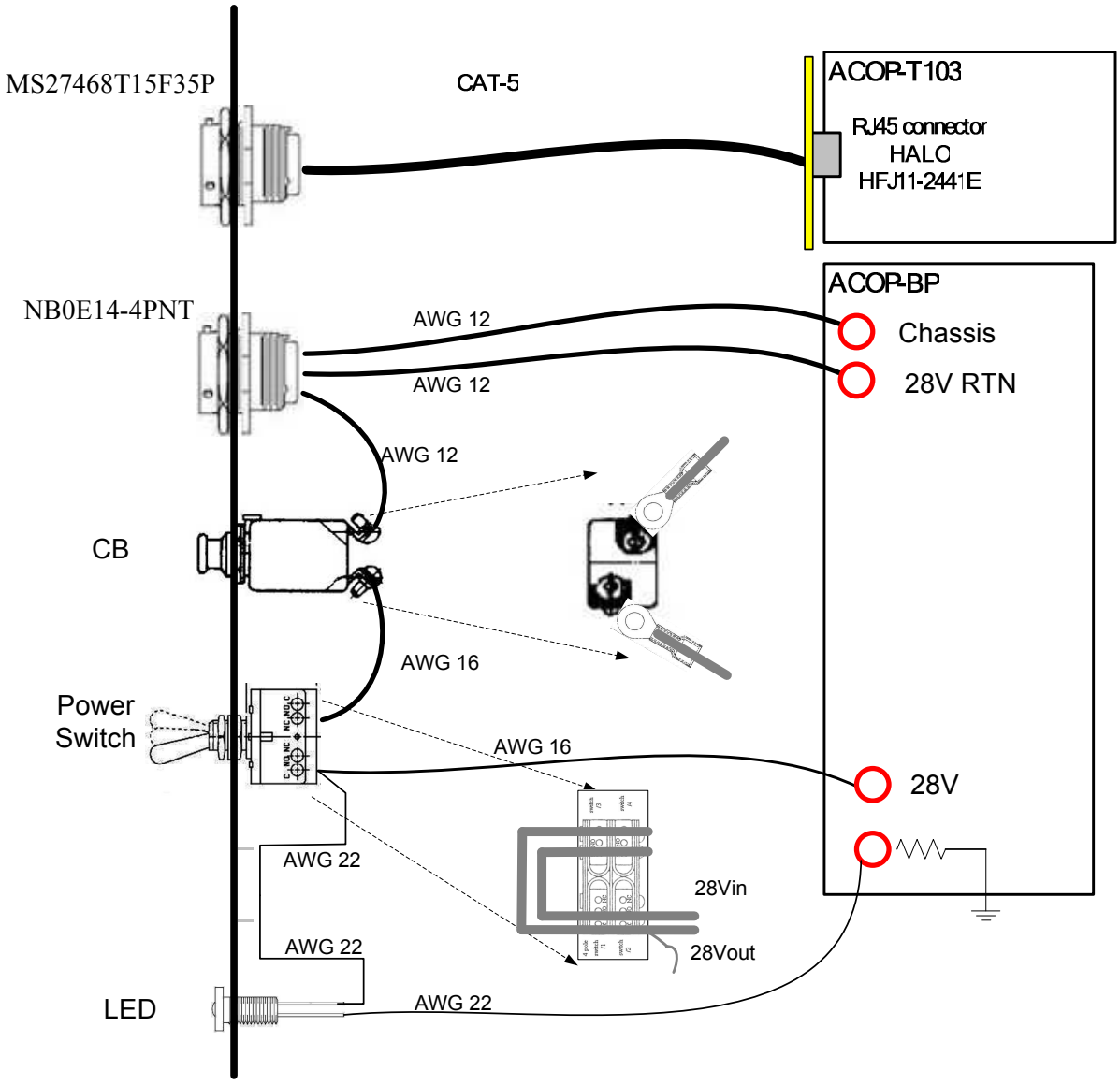

Figure 3-13 ACOP Front Panel Wiring Diagram (left-side)

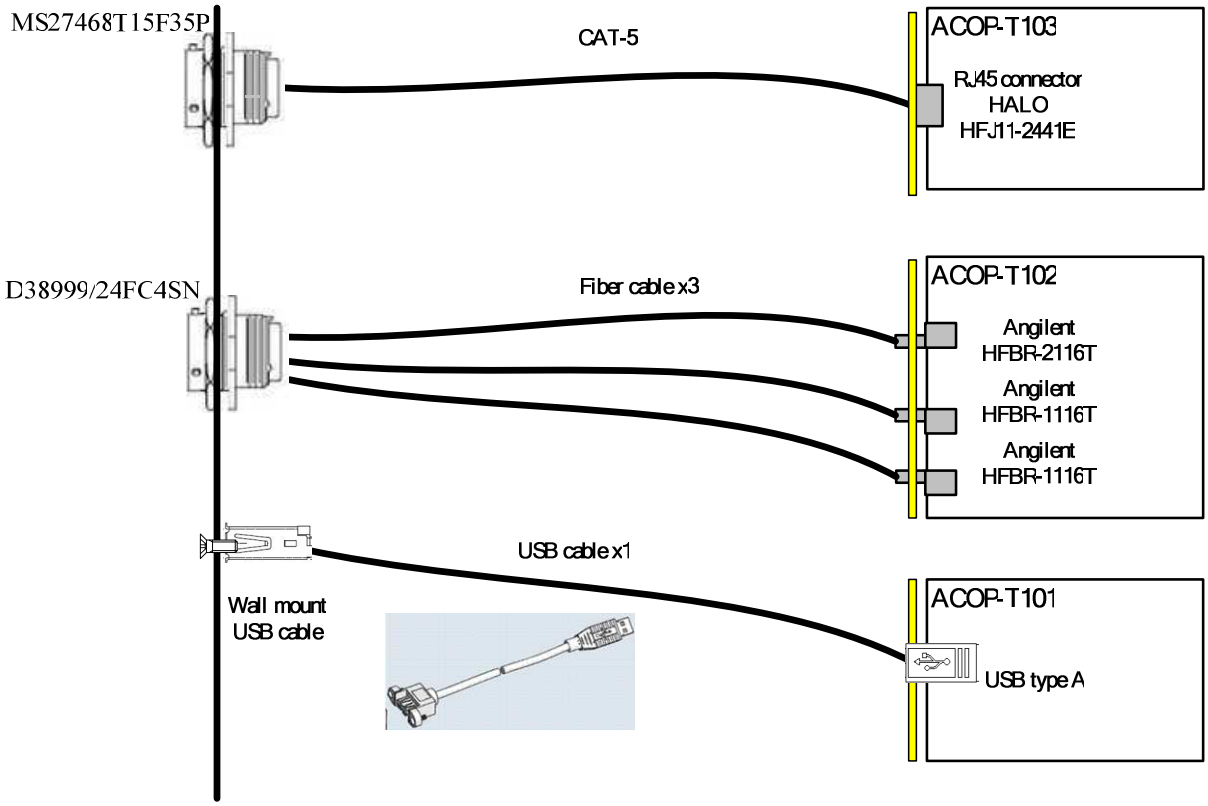

Figure 3-14 ACOP Front Panel Wiring Diagram (right side)

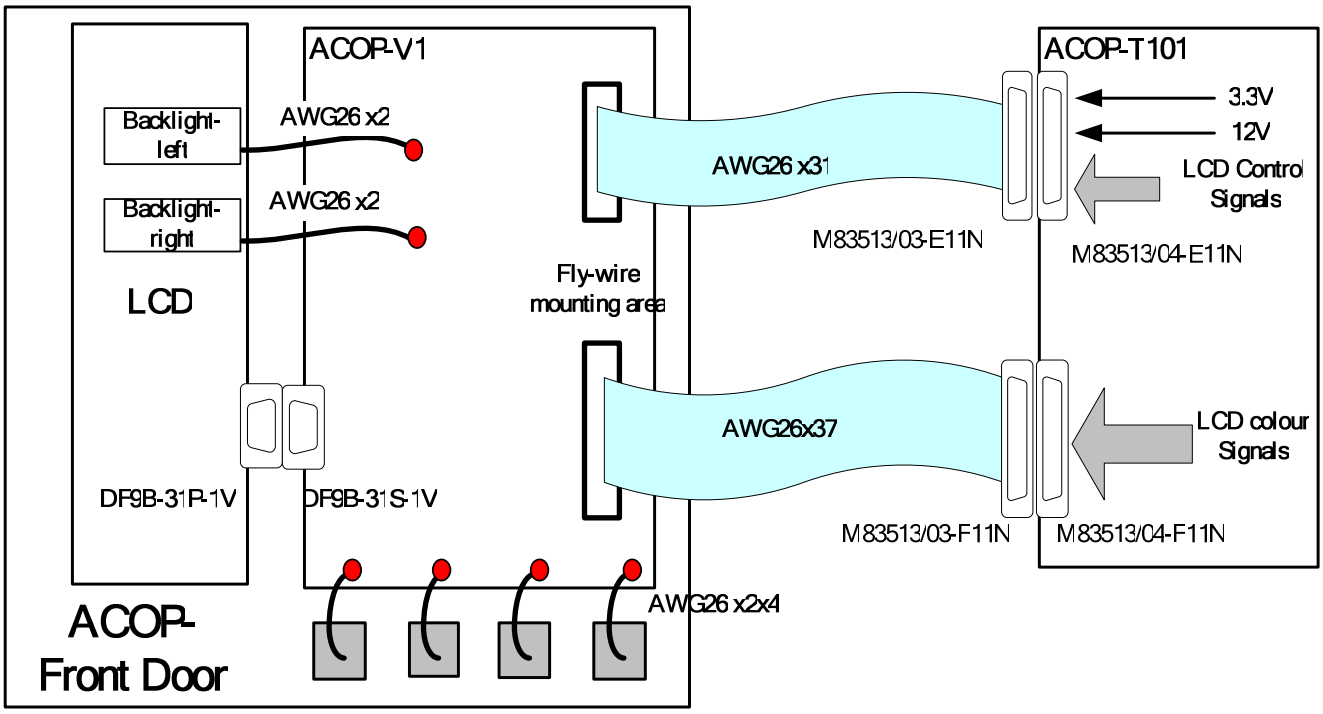

Figure 3-15 ACOP Front Panel Wiring Diagram (LCD panel)

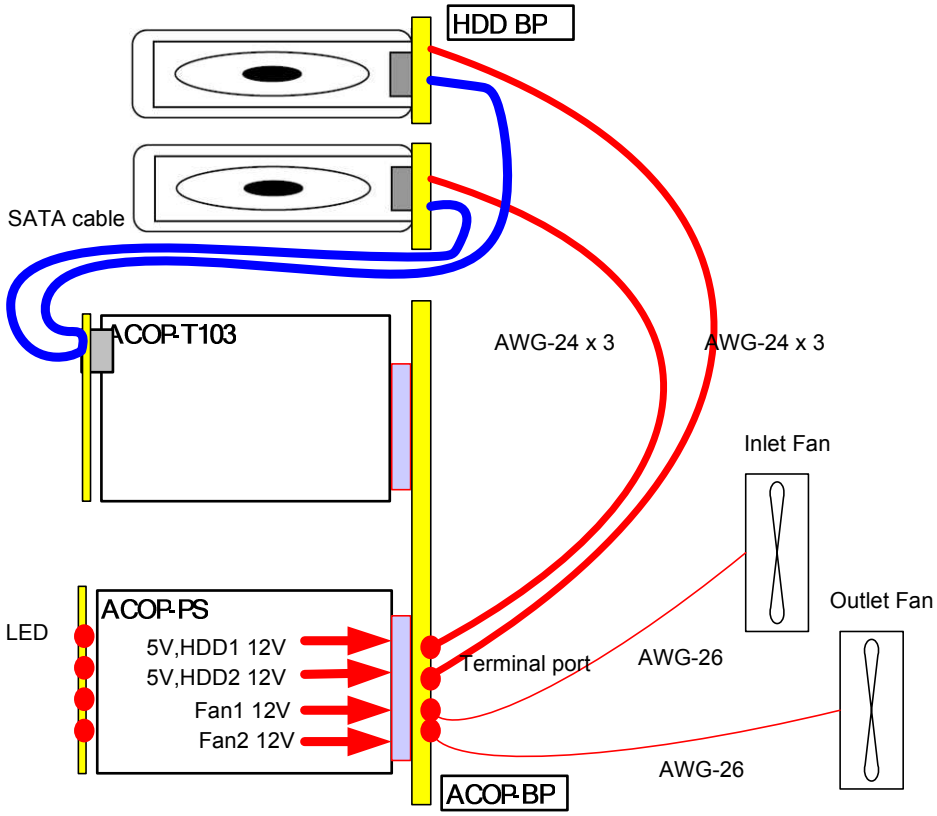

Figure 3-16 ACOP Backside Wiring Diagram (HDDs and FANs)

4. OPERATIONAL SCENARIO

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

4.1 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.

4.2 FLIGHT PHASE NOMINAL OPERATIONS

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.

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). Routing and securing of the external HRDL fibers along a to be determined path is part of this operation.

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.

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

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.

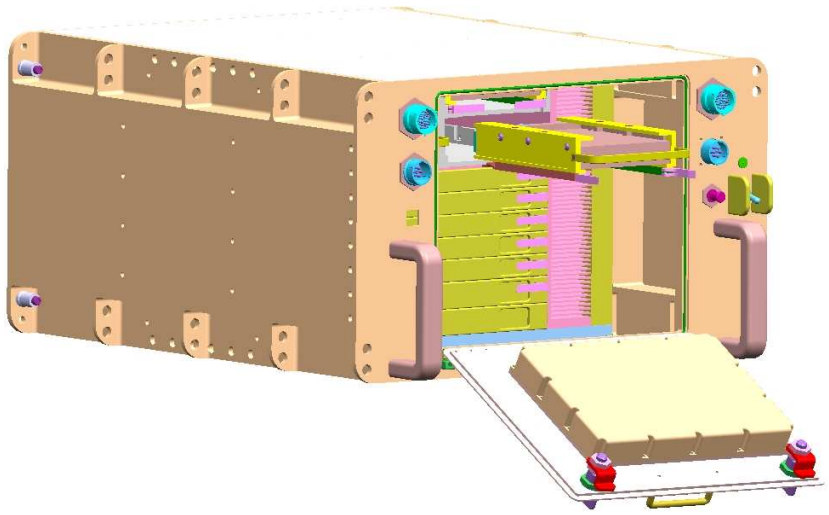

Figure 4-1 Hard Drive Insertion and Removal

To exchange hard drives the crew will:

1. Retrieve the appropriate ACOP storage bag (CTB).
2. Power off ACOP per 0above.
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 4-1) 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 0Power On.
8. Re-stow the ACOP stowage bag.

No tools are required for this activity.

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.

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.

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.

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, 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..

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.

4.3 RETURN TO GROUND

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

4.4 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.

5. FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS

5.1 GENERAL

The purpose of FMECA is to identify all failure modes of the system and rank them in accordance with the severity of the effects of their occurrence. Furthermore, it is to:

- identify possible failure modes and their possible effects
- determine the severity of each failure effect
- identify and possibly remove or control the Single Point Failures
- reduce failures causing outages or safety impacts
- identify requirements for controlling failure effects
- eliminate failure propagation
- validate and verify design redundancies.

5.2 RELIABILITY REQUIREMENTS

The ACOP reliability requirements are derived from [RD8].

5.2.1 CRITICALITY CATEGORIES

The following Reliability Categories, according to [RD8] and NSTS 1700.7B for safety categories [AD NASA 2], have been used:

Cat. 1a: *catastrophic*	(see applicable safety category)
Cat. 1b: *critical*	(see applicable safety category)
Cat. 2: *major*	The failure propagates across the interface and/or the facility cannot operate anymore.
Cat. 3: *significant*	The facility is partly operable (minor impact on the mission) or needs corrective on-orbit maintenance.

Items of criticality Category 1 failures which are not on-orbit maintainable, and all items with Category 2 failures shall be listed in a Single Point Failure (SPF) list.

5.3 ANALYSIS ASSUMPTION

The FMECA is based upon the design concept described in the section 3. The FMECA addresses the ACOP flight segment in all operation phases that are foreseen during the mission.
The analysis is performed at level to the major functions of the identified subsystems developed by CGS. Only single failures are considered. No double failure is taken in account.

The identified ACOP functional blocks are reported in the column 1-3 of the FMECA worksheets.

Unit /Assembly: ACOP-SBC						**Ref.:** Figure 3-18				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
1101	Main Memory SDRAM 256MB	1.1	Program data storage and execution	Loss of read/write capability	Impossible to manage SBC Loss of SBC functionality	Loss of ACOP functionalities	3	No data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1201	Flash EEPROM 64MB	1.2	To store main SW (RTOS code and the application code)	Loss of function	Loss of main SW Impossible to manage the SBC	Loss of ACOP functionalities	3	No data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1301	MicroProcessor IBM Power MPC750	1.3	Central processing	Loss of function	Impossible to manage SBC Loss of SBC functionality	Loss of ACOP functionalities	3	No data from SBC	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1401	Boot Flash ROM 512KB	1.4	To contain the primary bootloader	Loss of function	Impossibility to load on-board SW (booting the SBC board) Loss of SBC function	Loss of ACOP functionality	3	No data from SBC	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1501	North PCI Bus Bridge chip	1.5	To provide the connections to the process memory	Loss of function	Impossible to manage SBC Loss of SBC functionality	Loss of ACOP functionalities	3	No data from SBC	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1601	System Clock	1.6	To obtain synchronization between processor, bus and SDRAM.	Loss of function	Impossible to manage SBC. Loss of SBC functionality	Loss of ACOP functionalities	3	Anomalous or no data from SBC	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
	External Interfaces (Connectors)									
1701	J1, J2 (to ACOP-BP backplane)	1.7	To provide standard CPCI 32bits/32MHz J1 signals	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of SBC functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: ACOP-SBC						**Ref.:** Figure 3-18				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
1702				Degraded contact	Receiving/transmission capability degradation	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1801	J4 (to ACOP-BP backplane)	1.8	To provide Internal I/Fs for peripherals input/output signals	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of SBC functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1802				Degraded contact	Receiving/transmission capability degradation	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1901	P1 (Front Panel Connector) M83513/04-A09N	1.9	To provide External I/F for software development and troubling	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of SBC functionality	Inability to solve troubling or to load software upgrades	3	Anomalous data during trouble solving or software upload	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1902				Degraded contact	Receiving/transmission capability degradation	Inability to solve troubling or to load software upgrades	3	Anomalous data during trouble solving or software upload	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1701	ACOP SW (SYS, APP)	1.10	To provide low level functionality (SYS)	Loss of function due to SW internal failure or program/data memory failure	Impossibility to load APP SW and/or to support some function of APP SW Loss of SBC functionality	Loss of ACOP functionality	3	No data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
1702			To provide the mission explicit application SW functions (APP)	Loss of function due to SW internal failure or program/data memory failure	Impossibility to perform data handling Loss of SBC functionality	Loss of ACOP functionality	3	No data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12] Reload SW trough USB (TBC)	

Unit /Assembly: ACOP-T101						**Ref.: --**Figure 3-19				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
2101	Actel FPGA	2.1	To provide correct command and data exchange with SBC to manage T101 (Memory controller, USB Controller, Dallas bus controller, DIO, Video)	Loss of function	Impossible to provide commands and signals Loss of T101 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
2201	256kx32 Video SRAM (#2)	2..2	Video memory and Buffer between system slot and FPGA	Loss of read/write capability	Impossible to provide correct commands and signals Degradation of T101 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
2301	LVDS transiver	2.3	To provide LCD signals coding	Loss of function	Impossible to show data on display Degradation of T101 functionality	Degradation of ACOP functionality	3	No data displayed on LCD	Corrective maintenance: provide spare Board as for §3 of [RD #12] Use of laptop to show data	
2401	LCD controller	2.4	To adjust brightness of the LCD backlighting and to control RGB signals and LCD panel	Loss of backlighting	Low visibility data on display Degradation of T101 functionality	Degradation of ACOP functionality	3	No brightness change if requested / no light from the panel	Corrective maintenance: provide spare Board as for §3 of [RD #12] Use of laptop to show data	
2401				Loss of control of LCD panel	Impossible to show data on display Degradation of T101 functionality	Degradation of ACOP functionality	3	No data displayed on LCD	Corrective maintenance: provide spare Board as for §3 of [RD #12] Use of laptop to show data	
2501	Push Button de-bounce circuit	2.5	To provide Push Button input	Loss of function	Impossibility to use push buttons Degradation of T101 functionality	Degradation of ACOP functionality	3	Push Buttons Malfunctions	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: ACOP-T101						**Ref.: --**Figure 3-19				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
2601	Thermal sensor driver	2.6	To provide thermal sensor data to FPGA	Loss of function	No or incorrect data from the thermal sensor	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
2701	USB Controller UHC124	2.7	To provide USB 2.0 I/F (#2)	Loss of function	Impossibility to update SW if needed Degradation of T101 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
2801	Thermal sensor	2.8	To provide temperature indication of T101 board	Loss of function	No or incorrect data from the thermal sensor	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
	External Interface (Connectors)									
2901	J1	2.9	To provide standard CPCI 32bits/32MHz J1 signals	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of T101 functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
2902				Degraded contact	Receiving/transmission capability degradation	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
21001	J4	2.10	To provide peripheral input/output signals and 1 wire temperature buses	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of T101 functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
21002				Degraded contact	Receiving/transmission capability degradation	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: ACOP-T101						**Ref.: --**Figure 3-19				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
21101	P1	2.11	To provide LCD RGB signal	Short/open circuit	Some image data missing, incomplete image displayed	Degradation of ACOP Functionality	3	Incorrect image composition	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
21102				Degraded contact	Some image data missing, incomplete image displayed	Degradation of ACOP Functionality	3	Incorrect image composition	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
21201	P2	2.12	To provide LCD module control signal and power	Short/open circuit	Impossible to show data on display Degradation of T101 functionality	Degradation of ACOP functionality	3	No data displayed on LCD	Corrective maintenance: provide spare Board as for §3 of [RD #12] Use of laptop to show data	
21202				Degraded contact	Degradation of image composition Degradation of T101 functionality	Degradation of ACOP functionality	3	Incorrect image composition	Corrective maintenance: provide spare Board as for §3 of [RD #12] Use of laptop to show data	
21301	P3, P4, P5, P6	2.13	To provide USB 0, 1, 2, 3 signals	Short/open circuit	Impossibility to update SW if needed Degradation of T101 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
21302				Degraded contact	Receiving/transmission capability degradation	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: ACOP-T102						**Ref.: --**Figure 3-20				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
3101	Actel FPGA	3.1	To provide correct command and data exchange with SBC to manage T102 (memory & data TX/RX on optical fibres)	Loss of function	Impossible to provide commands and signals Loss of T102 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3201	256kx32 ZBT SRAM (#2)	3.2	Buffer between system slot and FPGA	Loss of read/write capability	Loss of raw data from interface Degradation of T102 functionality	Degradation of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3301	Agilent Fiber Optical Transmitter (data 0)	3.3	To provide interface between T102 electrical signal bus and optical signals (converts data to light)	Loss of function	No data transmission on optical fibres.	Degradation of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3401	Agilent Fiber Optical Transmitter (data 1)	3.4	To provide interface between T102 electrical signal bus and optical signals (converts data to light)	Loss of function	No data transmission on optical fibres.	Degradation of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3501	Agilent Fiber Optical Receiver	3.5	To provide interface between T102 electrical signal bus and optical signals (converts data from light)	Loss of function	No data receive on optical fibres.	Degradation of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
	External Interfaces (Connectors)									
3601	J1	3.6	To provide standard CPCI 32bits/32MHz J1 signals	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of T102 functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: ACOP-T102						**Ref.: --**Figure 3-20				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
3602				Degraded contact	Receiving/transmission capability degradation	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3701	J4	3.7	To provide peripheral input/output signals and 1 wire temperature buses	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of T102 functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3702				Degraded contact	Receiving/transmission capability degradation	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3801	P1	3.8	To provide optical data transmission from T102	No light transmission	Loss of I/Fs Impossible to transmit data/commands Loss of T102 functionality	Loss of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3802				Degraded light signal	Low data rate on TX 1 port	Degradation of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3901	P2	3.9	To provide optical data transmission from T102	No light transmission	Loss of I/Fs Impossible to transmit data/commands Loss of T102 functionality	Loss of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3902				Degraded light signal	Low data rate on TX 1 port	Degradation of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
3101	P3	3.10	To provide optical data receive to T102	No light transmission	Loss of I/Fs Impossible to receive data/commands Loss of T102 functionality	Loss of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: ACOP-T102						**Ref.: --**Figure 3-20				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
3102				Degraded light signal	Low data rate on TX 1 port	Degradation of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: ACOP-T103						**Ref.: --**Figure 3-21				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
4101	AMD Ethernet Controller (#2 channels)	4.1	To provide two Ethernet I/F controller ports	Loss of function	Impossible to transmit/receive data and/or to transmit commands Degradation of T103 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
4201	SATA Controller (#4 channels)	4.2	To provide access to ACOP HDD storage systems	Loss of function	Impossible to transfer data to HDD. Degradation of T103 functionality	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
4301	PCI Bridge	4.3	To provide T103 internal I/F between two PCI buses (external and internal)	Loss of function	Impossible to receive/transmit data or commands on ACOP PCI bus	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
	External Interface (Connectors)									
4401	J1	4.4	To provide standard CPCI 32bits/32MHz signals	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of T103 functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
4402				Degraded contact	Receiving/transmission capability degradation	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
4501	J4	4.5	To provide peripheral input/output signals and 1 wire temperature buses	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of T103 functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
4502				Degraded contact	Receiving/transmission capability degradation	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: ACOP-T103						**Ref.: --**Figure 3-21				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
4601	P1, P2, P3, P4	4.6	To provide SATA 1÷4 data port	Short/open circuit	No data to/from HDD	Degradation of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
4602				Degraded contact	Low data rate to/from HDD	Degradation of ACOP functionality	3	Anomalous or no data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
4701	P5, P6	4.7	To provide Ethernet 1 & 2 data port	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of T103 functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
4702				Degraded contact	Receiving/transmission capability degradation	Degradation of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: Unit: ACOP-PS						**Ref.:** Figure 3-23				
Operational Mode:						**Operational Phase:**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
5201	28 V Input EMI Filter (#3)	5.2	Filtering of primary power noise and disturbance	Filter has open circuit	No 28V power supply to PS PS not working	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	One filter for each DC/DC
5301	Hybrid DC/DC Converter 12V	5.3	To provide 12V voltage conversion	DC/DC converter off	No 12V power supply PS board shutdown	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
5401	Hybrid DC/DC Converter 3.3V	5.4	To provide 3.3V voltage conversion	DC/DC converter off	No 3.3V power supply PS board shutdown	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
5501	Hybrid DC/DC Converter 5V	5.5	To provide 5V voltage conversion	DC/DC converter off	No 5V power supply PS board shutdown	Loss of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
5601	Spike and EMI Filter (#3)	5.6	Filtering of secondary power noise and disturbance	Filter has open circuit	No outlet power supply Degradation of PS functionality	Degradation of ACOP functionality	3	Loss of data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	One filter for each DC/DC
5701	Overload protection	5.7	To detect the failure in case of overvoltage /overcurrent/short circuit/overtemperature condition	Loss of function protection	If failure occurs, the protection does not shutdown the PS board	Loss of PS functionality and failure propagation to other subsystems / assemblies/equipment as second failure	3	Loss of data from ACOP	None	Second failure required before failure has effect on performance (TBC)
5801	J1	5.8	To provide standard CPCI 32bits/32MHz signals, +28V, +5V, +3,3V, Sensing signals and grounding	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of PS functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: Unit: ACOP-PS						**Ref.:** Figure 3-23				
Operational Mode:						**Operational Phase:**				
5802				Degraded contact	Receiving/transmission capability degradation	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
5901	J2	5.9	To provide +12V and control signals	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands Loss of PS functionality	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
5902				Degraded contact	Receiving/transmission capability degradation	Loss of ACOP functionality	3	Anomalous data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	

Unit /Assembly: ACOP-BP						**Ref.: --**Figure 3-22				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
6101	ACOP Backplane	6.1	To provide mechanical and power I/Fs to PCI	Loss of function	Impossible to transmit/receive data and/or provide power Loss of PCI functionality	Loss of ACOP functionality	2	Loss of data from ACOP	None	
	Power Terminals									
6201	CON3, CON4, CON5, CON6, (HDDx) (#4 HDD)	6.2	To provide 12V and 5 V to HDD	Short/open circuit	Impossible to read/write on the concerned HDD HDD slot no more usable	Degraded ACOP functionality	3	HDD Not working,	Increased spare substitution rate	To be taken into account in HDD spare parts count
6202				Degraded contact	HDD malfunction	Degraded ACOP functionality	3	Anomalous data from ACOP	Increased spare substitution rate	To be taken into account in HDD spare parts count
6301	CON1, CON2 (#2 FAN)	6.3	To provide power to FANs	Short/open circuit	No power to one FAN	Reduced air flow	3	Temperature rise	One FAN flow generation is enough to provide ACOP sufficient heat dissipation	
6302				Degraded contact	Reduced power to one FAN	Reduced air flow	3	Temperature rise	One FAN flow generation is enough to provide ACOP sufficient heat dissipation	
6401	BT3, BT4	6.4	To provide ground reference	Short/open circuit	No effect	No effect	3	Non detectable	None	
6402				Degraded contact	No effect	No effect	3	Non detectable	None	
6501	BT1, BT2	6.5	To provide +28V power line	Short/open circuit	No 28V provided	Loss of ACOP functionality	2	No data from ACOP	None	
6502				Degraded contact	Increased power dissipation	Degradation of ACOP functionality	3	Anomalous data from ACOP	None	

Unit /Assembly: ACOP-BP						**Ref.: --**Figure 3-22				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
	Connectors									
6601	Harting 1701 154 2203 (Vertical male ,Type A, with upper shield)	6.6	to provide CompactPCI P1,P4 I/F	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands on PCI Bus	Loss of ACOP functionality	2	Anomalous or No data from ACOP	None	
6602				Degraded contact	Receiving/transmission capability degradation	Degradation of ACOP functionality	3	Anomalous or No data from ACOP	None	
6701	Harting 1741 154 2203 (Vertical male, Type B, with upper shield)	6.7	To provide CompactPCI P2 I/F	Short/open circuit	Loss of I/Fs Impossible to receive/transmit data/commands on PCI Bus	Loss of ACOP functionality	2	Anomalous or No data from ACOP	None	
6702				Degraded contact	Receiving/transmission capability degradation	Degradation of ACOP functionality	3	Anomalous or No data from ACOP	None	
6801	Positronic Industries PCIH47F9300A1	6.8	ACOP-PS 28V power supply	Short/open circuit	No 28V provided	Loss of ACOP functionality	2	No data from ACOP	None	
6802				Degraded contact	Increased power dissipation	Degradation of ACOP functionality	3	Anomalous data from ACOP	None	

Unit /Assembly: ACOP-LCD monitor and ACOP-IV						**Ref.: --**Figure 3-25				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
7101	LCD Display	7.1	To provide ACOP data and status visualization to crew							See FMECA N°9401
7201	Relay (PCB Trace)	7.2	To interface Push Button signal	Loss of function	Anomalous signal from Push Buttons	Degradation of ACOP functionality	3	Anomalous behaviour of Push Button I/F	None	
7301	LED Backlight Switch Circuit	7.3	To provide LCD backlight dimming	Loss of function	No LCD Backlight dimming possibility	Degradation of ACOP functionality	3	LCD backlight dimming impossible	None	
7401	LVDS RX	7.4	To receive 3,3V LCD RGB signals and LCD control signals	Loss of function	No data displayed on LCD	Degradation of ACOP functionality	3	No images displayed	None	
7501	Micro D 37 pin (#2) M83513/03-D11N	7.5	To provide I/F for LCD RGB signals	Short/open circuit	Some image data missing, incomplete image displayed	Degradation of ACOP Functionality	3	Incorrect image composition	None	
7502				Degraded contact	Some image data missing, incomplete image displayed	Degradation of ACOP Functionality	3	Incorrect image composition	None	
7601	Micro D 25 pin (#2) M83513/03-F11N	7.6	To provide I/F for LCD control signals, 3,3V, 12V	Short/open circuit	Impossible to show data on display	Degradation of ACOP functionality	3	No data displayed on LCD	None	
7602				Degraded contact	Degradation of image composition	Degradation of ACOP functionality	3	Incorrect image composition	None	

Unit /Assembly: ACOP-Hard Drive						**Ref.: --**Figure 3-16				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
8101	ACOP hard drive (#4)	8.1	To provide data experiment recording	Loss of function	Impossible to record data	Loss of ACOP functionality	3	No data from ACOP	Corrective maintenance: provide spare Board as for §3 of [RD #12]	
8102				Breakage or damage while disk in high rotational speed	Impossible to record data	Loss of ACOP functionality Generation of brittle materials	1b	Visible damage	The Potential Hazard has been tracked in the Hazard Report ACP-STD-001 in the [RD11]	

Unit /Assembly: ACOP-Front Panel						**Ref.: --**Figure 3-7				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
9101	HRDL Connector	9.1	To provide HRDL Interface	Open circuit	Impossibility to transmit and/or receive ISS HRDL CCSDS packet data	Loss of ACOP functionality	2	No data from ACOP	None	
9102				Degraded contact	Degraded transmit / receive capacity	Degradation of ACOP functionality	3	Anomalous data from ACOP	None	
9201	MRDL Connector (#2)	9.2	To provide data/command I/F	Short/open circuit	Impossibility to transmit/receive data and commands from/to ACOP	Degradation of ACOP functionality	3	Loss of ACOP data	LCD Push Buttons can provide a limited list of commands ; moreover two Ethernet lines can provide commands to ACOP	
9202				Degraded contact	Degraded transmit / receive capacity	Degradation of ACOP functionality	3	Anomalous data from ACOP	LCD Push Buttons can provide a limited list of commands ; moreover two Ethernet lines can provide commands to ACOP	
9301	LCD display	9.3	To provide ACOP data and status visualization to crew	Loss of function	Impossible to show data on display	Degradation of ACOP functionality	3	Anomalous data from ACOP	Data are shown trough laptop	
9302				Rupture	Impossible to show data on display	Degradation of ACOP functionality Generation of shutterables materials	1b	Visible damage	The Potential Hazard has been tracked in the Hazard Report ACP-STD-001 in the [RD11]	
9401	Circuit Breaker +28 V	9.4	To provide emergency electrical isolation of the ACOP system from ISS	Fails open	No 28V power supply to ACOP	Loss of ACOP functionality	2	LED on front panel OFF	None	
9402				Fails close	in case of failure downstream no overcurrent protection	Degradation of ACOP functionality	3	Intervention of express pallet overload protection	None	

Unit /Assembly: ACOP-Front Panel						**Ref.: --**Figure 3-7				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
9501	Momentary Push Buttons (#4)	9.5	To provide Crew interface with ACOP software	Loss of function	Anomalous signal from Push Buttons	Degradation of ACOP functionality	3	Anomalous behaviour of Push Button I/F	None	
9601	On/Off Toggle Switch	9.6	To provide ACOP main power	Fail open	Inability to turn on ACOP	Loss of ACOP functionality	2	LED on front panel OFF	None	
9602				Fail close	Inability to shut-down ACOP	Degradation of ACOP functionality	3	LED on front panel ON while Switch in ON position	Circuit Braker on front panel; Express rack switch upstream	
9701	LED monitoring power supply presence (Power Status LED)	9.7	To provide visual power-ON signal to the crew	Fail open/Fail close	LED on front panel OFF	Inability to see the status of ACOP power	3	ACOP still working while LED is OFF	None	
9801	USB connectors (#2)	9.8	To provide USB I/F connector on front panel	Short/open circuit	Impossibility to update SW if needed	Degradation of ACOP functionality	3	Anomalous data from ACOP	None	
9802				Degraded contact	Low data rate through USB channel	Degradation of ACOP functionality	3	Anomalous data from ACOP	None	
9901	Power connector	9.9	To provide 28V electrical power to ACOP	Short/open circuit	No power provided to ACOP	Loss of ACOP functionality	2	LED on front panel OFF No data from ACOP;	None	
9902				Degraded contact	Increased power dissipation	Degradation of ACOP functionality	3	Anomalous data from ACOP	None	

Unit /Assembly: ACOP- Thermal Hardware						**Ref.: --**Figure 3-12				
Operational Mode: --						**Operational Phase: Flight operations**				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
10101	Fans (#2)	10.1	To provide airflow for heat dissipation	Breakage while in high rotational speed	No airflow generation	Temperature increase Generation of brittle materials	1b	High noise coming from ACOP	The Potential Hazard has been tracked in the Hazard Report ACP-STD-001 in the [RD11]	
10102				Motor jamming	No airflow generation from the stopped Fan	Decreased heat dissipation airflow	3	Temperature increase	Second FAN flow is enough to provide ACOP heat dissipation	

Unit /Assembly: ACOP- Mechanical						Ref.: --				
Operational Mode: --						Operational Phase: Flight operations				
N°	**ITEM / BLOCK**	**ITEM**	**FUNCTIONAL BLOCK**	**ASSUMED FAILURE MODE**	**EFFECTS AT EQUIPMENT LEVEL**	**EFFECTS AT SYSTEM LEVEL**	**CR.**	**FAILURE DETECTION METHOD**	**PREVENTION OR COMPENSATION METHOD**	**REMARKS**
11101	Mechanical parts	11.1	To provide structural integrity	Rupture	Loosing of structural parts	Loss of ACOP functionality	1a	Visible damage	The Potential Hazard has been tracked in the Hazard Report ACP-HR11]	

6. SINGLE POINT FAILURE LIST

The most identified failure modes are Severity Categories 3 because all CompactPCI (ACOP-SBC, T101, T102, T103), Hard Drives, the Power Supply (PS) and Fan Modules are On orbit Maintenance Items.
For the failures no. 8102, 9302, 10101, 11101 having Severity Categories 1a the Safety Hazard Analysis has been performed in order to identify the associated hazard and the adequate controls (Refer to [RD11]).

The Single Point Failures with the rational for their acceptance are listed in the following table:

ACOP SPF List		
FMECA N°	ITEM	Rational
6101	ACOP Backplane	Material selection, Production processes, structural analysis assure a risk level acceptable in the frame of ACOP design constraints
6501	BT1, BT2	Standard Reliable Compact PCI connectors
6601	Harting 1701 154 2203 (Vertical male ,Type A, with upper shield)	
6701	Harting 1741 154 2203 (Vertical male, Type B, with upper shield)	
6801	Positronic Industries PCIH47F9300A1	
9101	HRDL Connector	Connector is provided by NASA
9401	Circuit Breaker +28 V	The MIL qualified components assure a risk level acceptable in the frame of ACOP design constraints
9601	On/Off Toggle Switch	
9901	Power connector	Connector is provided by NASA

Table 6-1: SPF List