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ACOP

Doc.Type: Design		*DRD N°:* E05	
Doc. N°: **ACP-TN-CGS-003**	*Issue:* **1**	*Date:* **Oct. 2005**	*Page* **1** *Of* **32**

Title : **Software Architectural Design Document**

	Name & Function	*Signature*	*Date*
Prepared by:	ACOP Team		
Approved by:	M.Grilli Laplena D Cinquepalmi C.		
Application authorized by:	Pini C.		
Customer / Higher Level Contractor			
Accepted by:			
Approved by:			

DISTRIBUTION LIST	N	A	I
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S. Pignataro (ASI)	1		X

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File: ACP-TN-CGS-003 Is1.doc

CHANGE RECORD			
ISSUE	*DATE*	*CHANGE AUTHORITY*	*REASON FOR CHANGE AND AFFECTED SECTIONS*
1	October 2005	---	First Issue

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1. SCOPE AND INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

The purpose of this document is to describe the software architecture for the AMS-02 Crew Operations Post (ACOP). The overall name for this software is ACOP-SW. It consists of three main parts ACOP-SYS-SW (the operating system and support libraries) ACOP-ERL-SW (the payload developed software on the EXPRESS Laptop Computer), and ACOP-APP-SW (the applications software). ACOP-SYS-SW provides support services and hardware interfaces to the payload developed mission explicit ACOP-APP-SW and ACOP-ERL-SW.

ACOP is developed as an embedded system in which the software is an integral part. Thus ACOP-SW is not a stand-alone product and is only expected to operate within the ACOP system.

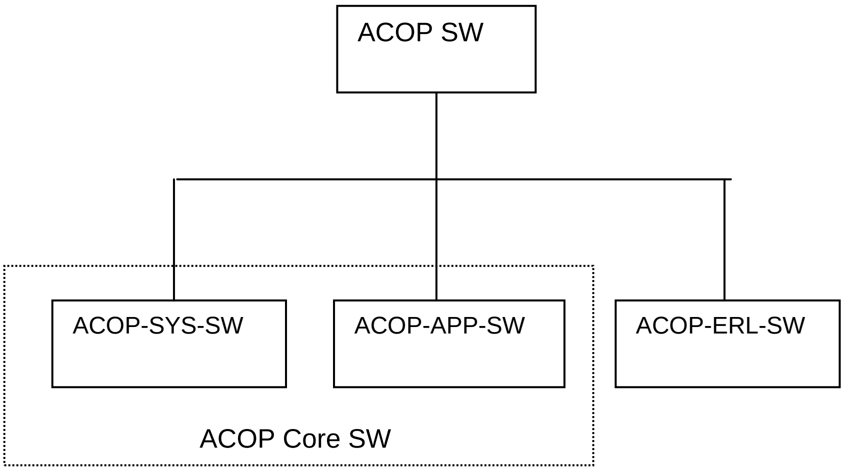

Figure 1-1 SW main parts

1.2 SCOPE OF THE SOFTWARE

ACOP-SW is the entire body of embedded software running on the ACOP hardware. ACOP-SW consists of three components:
(1) ACOP-SYS-SW providing low level functionality
(2) ACOP-APP-SW providing the mission explicit application software functions on the ACOP hardware
(3) ACOP-ERL-SW software developed by the ACOP project but which executes on the EXPRESS Rack Laptop.

The ACOP-SYS-SW and ACOP-APP-SW are two software part that will run on ACOP core Hardware, while ACOP-ERL-SW is the software running on Express Rack Laptop Computer. The ACOP SW software is shared in two parts in order to remark that the ACOP-APP-SW will be developed by AMS and it is considered as AFE (Agency Furnished Equipment) component.

1.3 DEFINITIONS AND ACRONYMS

A

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

B

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

C

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

D

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

E

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

F

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

FPGA	Field Programmable Gate Array
FSM	Flight Spare Model
G	
GIDEP	Government Industry Data Exchange Program
GSE	Ground Support Equipment
H	
HCOR	HRDL Communications Outage Recorder
HD	Hard Drive
HDD	Hard Disk Drive
HRDL	High Rate Data Link
HRFM	High Rate Frame Multiplexer
HW	Hardware
I	
ICD	Interface Control Document
I/F	Interface
IRD	Interface Requirements Document
ISPR	International Space-station Payload Rack
ISS	International Space Station
J	
JSC	Johnson Space Center
K	
KIP	Key Inspection Point
KSC	Kennedy Space Center
KU-Band	High rate space to ground radio link
L	
LAN	Local Area Network
LCD	Liquid Crystal Display
LFM	Low Fidelity Model
LRDL	Low Rate Data Link
M	
MDL	Mid-Deck Locker
MGSE	Mechanical Ground Support Equipment
MIP	Mandatory Inspection Point
MMI	Man Machine Interface
MPLM	Multi-Purpose Logistic Module
MRDL	Medium Rate Data Link
N	
NA	Not Applicable
NASA	National Aeronautics and Space Administration
NCR	Non Conformance Report
NDI	Non Destructive Inspection
NRB	Non-conformance Review Board
NSTS	National Space Transportation System (Shuttle)
O	
OLED	Organic Light-Emitting Diode
ORU	Orbital Replacement Unit
P	
PA	Product Assurance
PCB	Printed Circuit Board
PCI	Peripheral Component Interconnect (personal computer bus)
PCS	Personal Computer System
PDR	Preliminary Design Review
PEHB	Payload Ethernet Hub Bridge

PEHG	Payload Ethernet Hub Gateway
PFMAR	Preliminary Flight Model Acceptance Review
PLMDM	Payload Multiplexer De-Multiplexer
PMC	PCI (Peripheral Component Interconnect) Mezzanine Card
PMP	Parts, Materials & Processes
PROM	Programmable Read Only Memory
PS	Power Supply
Q	
QM	Qualification Model
R	
RFA	Request For Approval
RFD	Request For Deviation
RFW	Request For Waiver
RIC	Rack Interface Controller
ROD	Review Of Design
ROM	Read Only Memory
RX	Reception
S	
SATA	Serial Advanced Transfer Architecture (disk interface)
S-Band	Space to ground radio link
SBC	Single Board Computer
SC MDM	Station Control Multiplexer De-Multiplexer
ScS	Suitcase Simulator
SDD	Solid-state Disk Drive
SIM	Similarity Assessment
SIO	Serial Input Output
SOW	Statement Of Work
SPF	Single Point Failure
SRD	Software Requirements Document
STS	Space Transportation System (Shuttle)
SW	Software
T	
TBC	To Be Confirmed
TBD	To Be Defined
TBDCM	Training & Baseline Data Collection Model
TBDCMAR	TBDCM Acceptance Review
TBP	To Be Provided
TCP/IP	Transmission Control Protocol / Internet Protocol
TFT	Thin Film Transistor
TM	Telemetry
TRB	Test Review Board
TRR	Test Readiness Review
TRM	Training Model
TX	Transmission
U	
UIP	Utility Interface Panel
UMA	Universal Mating Assembly
USB	Universal Serial Bus
#	
100bt	Ethernet 100Mbit Specification
1553	Reliable serial communications bus

Table 1-1 Definitions and Acronyms

1.4 DOCUMENTS

1.4.1 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	August 2003		Standard Payload Integration Agrement 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
22	ACP-SY-CGS-001	3 / March 2005		ACOP System Specification

Table 1-2 Applicable Documents

1.4.2 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.
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
10	ACD-Requirements-Rev-BL	September 2005	Base Line	ACOP Common Design Requirements Document

Table 1-3 Reference Documents

2. GENERAL DESCRIPTION

2.1 DESCRIPTION OF ACOP

The ACOP System is a reliable special purpose computer intended to fly on the International Space Station (ISS) as a payload installed into an EXPRESS ISPR in the NASA US laboratory module. The main objective of ACOP is to provide an ISS Internal Facility capable of supporting 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 2-1).

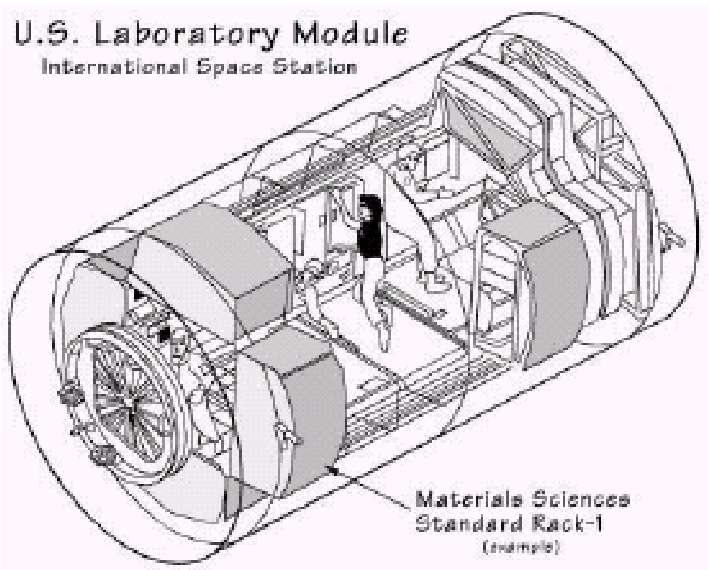

Figure 2-1 US Lab

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

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

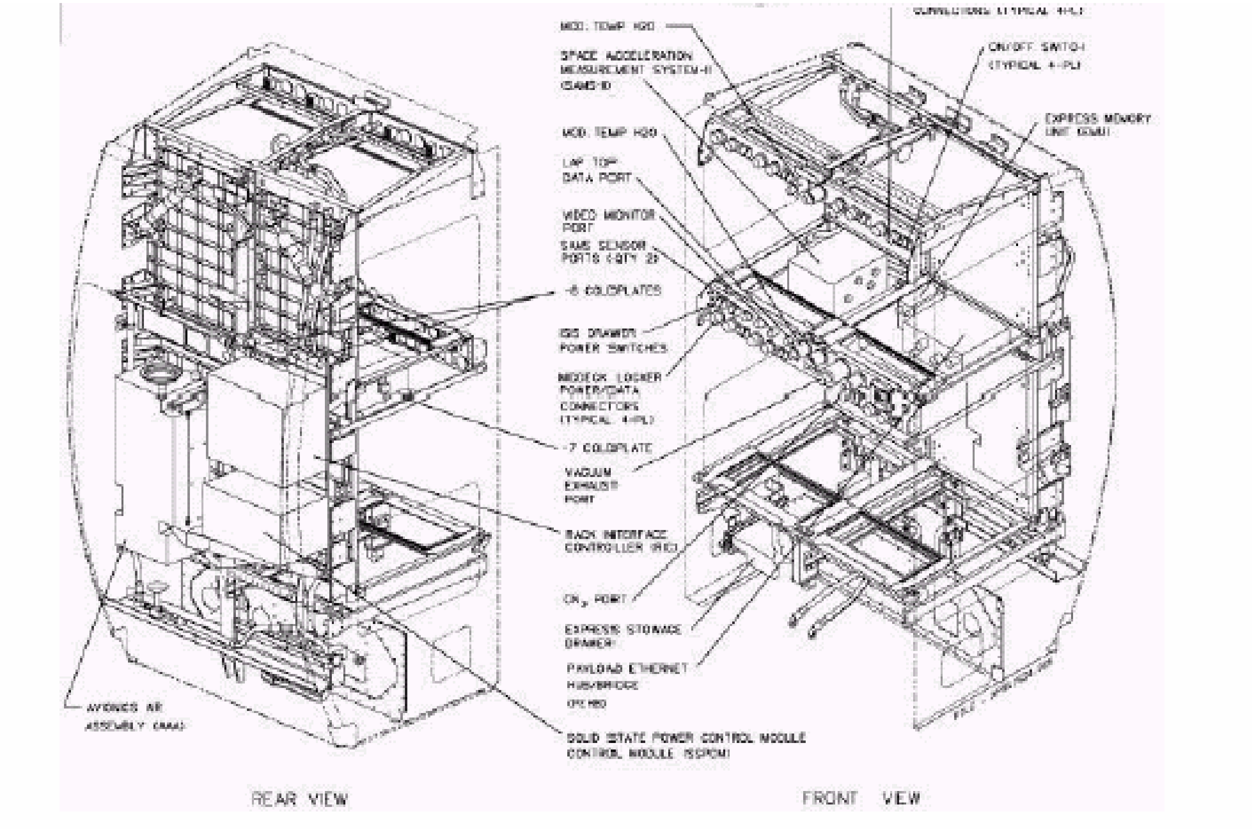

Figure 2-2 Example of an EXPRESS Rack (3D view)

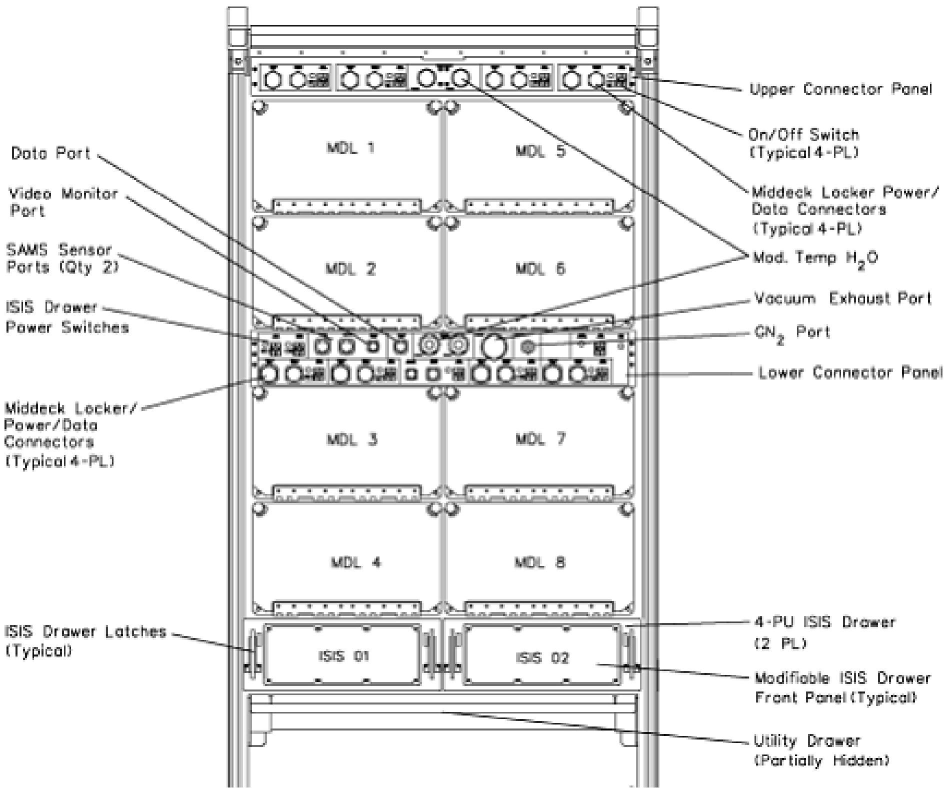

Figure 2-3 Example of an EXPRESS Rack (front view)

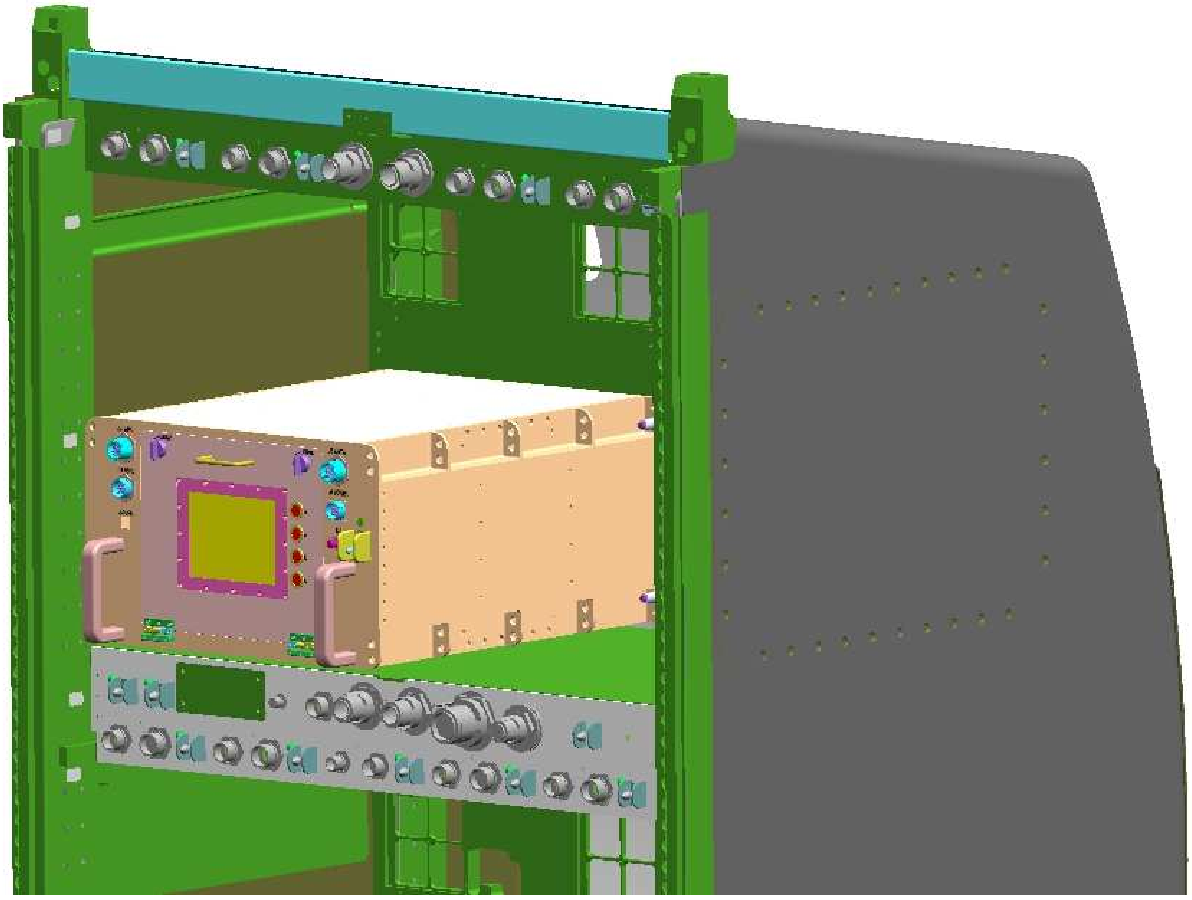

Figure 2-4 ACOP installed in an EXPRESS Rack (example of possible location)

ACOP provides these services:

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

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

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

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

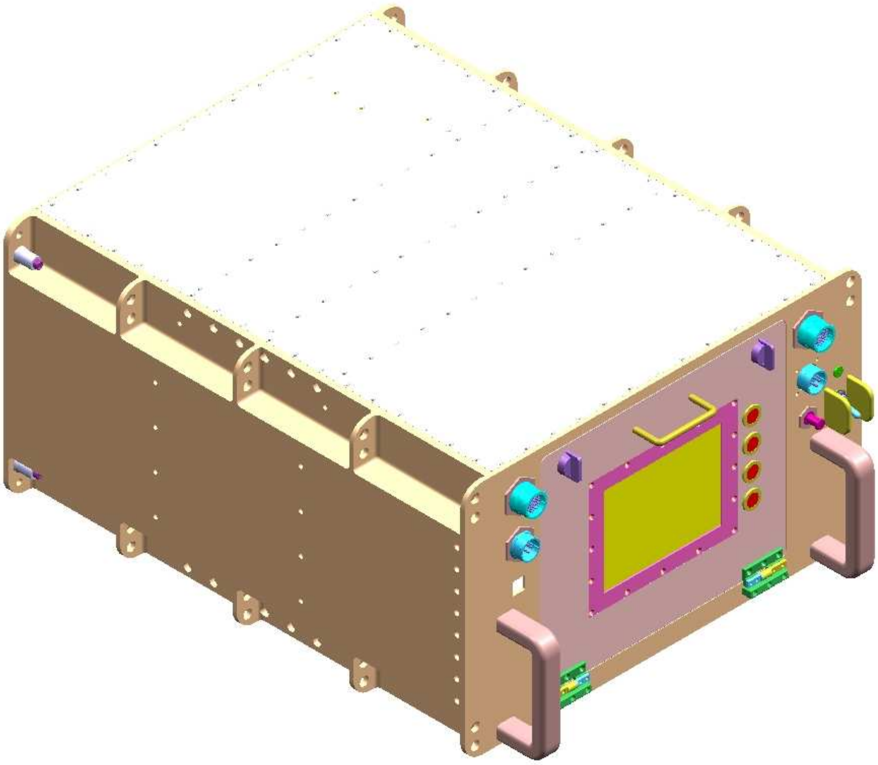

Figure 2-5 ACOP General Front View

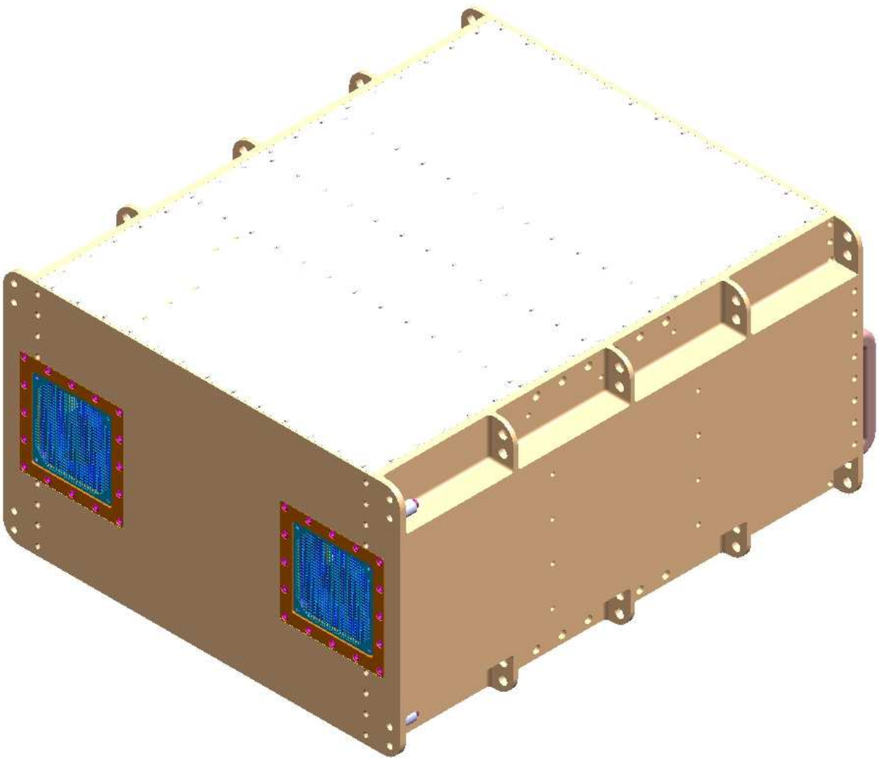

Figure 2-6 ACOP General Rear View

2.2 FUNCTION AND PURPOSE OF ACOP

ACOP has been designed to fulfil the requirements generated by the AMS-02 Collaboration. See the ACOP Common Design Requirements Document (RD10) and the ACOP System Specification (AD22) for a detailed description of the requirements.

The main characteristics of ACOP are summarized here below:

<u>Capacities</u>

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.

<u>Rates</u>

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.

<u>Interfaces</u>

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.

<u>Form</u>

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.

---

[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.

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

2.3 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:
  - maintains a continuous Tx/Rx connection via APS to AMS
  - 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.

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

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

2.4 FUNCTION AND PURPOSE OF THE ACOP-SW

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

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

2.4.1 ACOP-SYS-SW

ACOP-SYS-SW implements the following main functions:

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

2.4.2 ACOP-ERL-SW

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

2.4.3 ACOP-APP-SW

ACOP-APP-SW implements the following main functions:

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

2.5 ACOP HARDWARE PLATFORM

2.5.1 RELATIONSHIP TO ISS AVIONICS

The following diagram represents the relationship of ACOP to the ISS avionics systems.

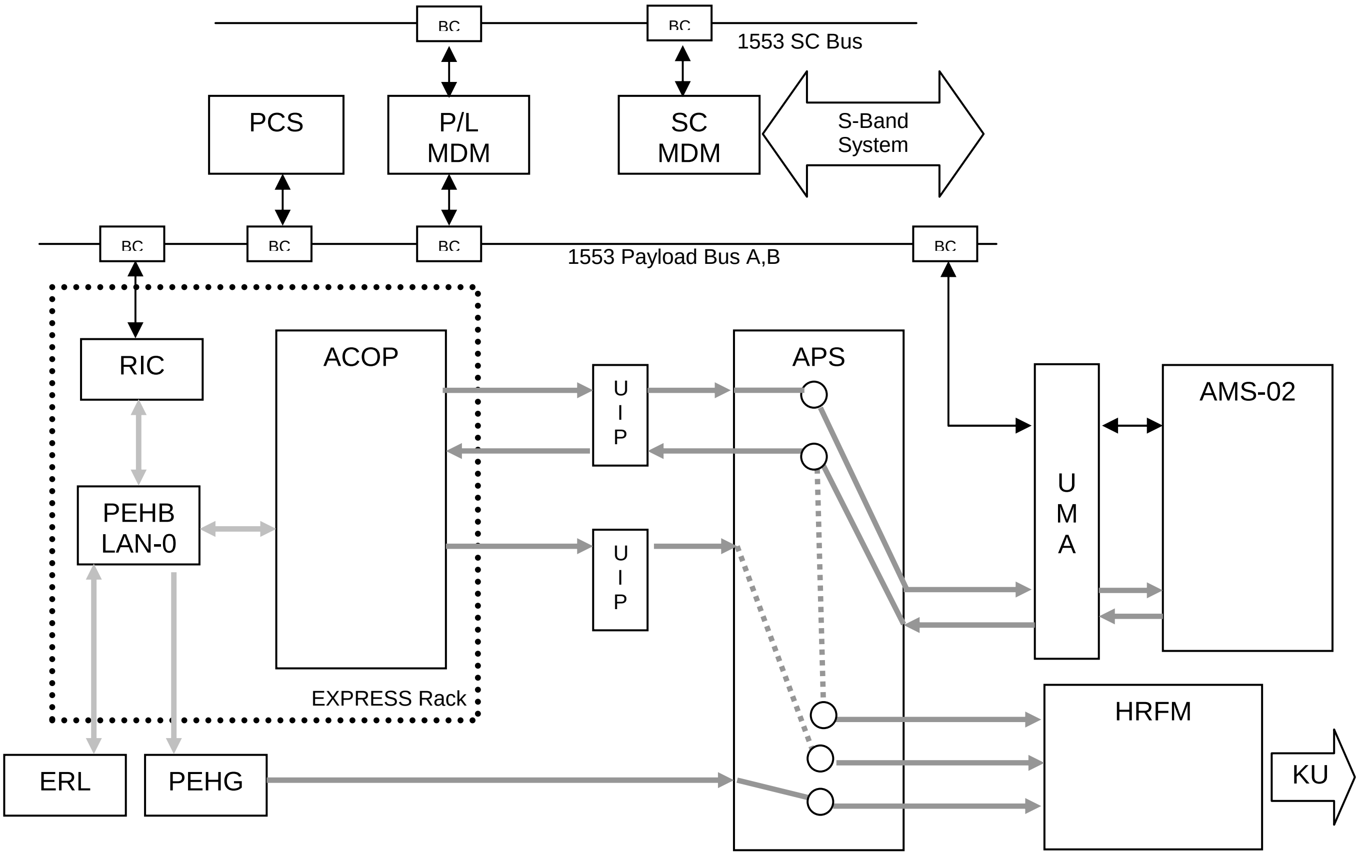


Figure 2-7 ACOP Relationship to ISS Avionics

2.5.2 HARDWARE PLATFORM

The following diagram represents the ACOP hardware platform (for more details see the ACOP Design Report).

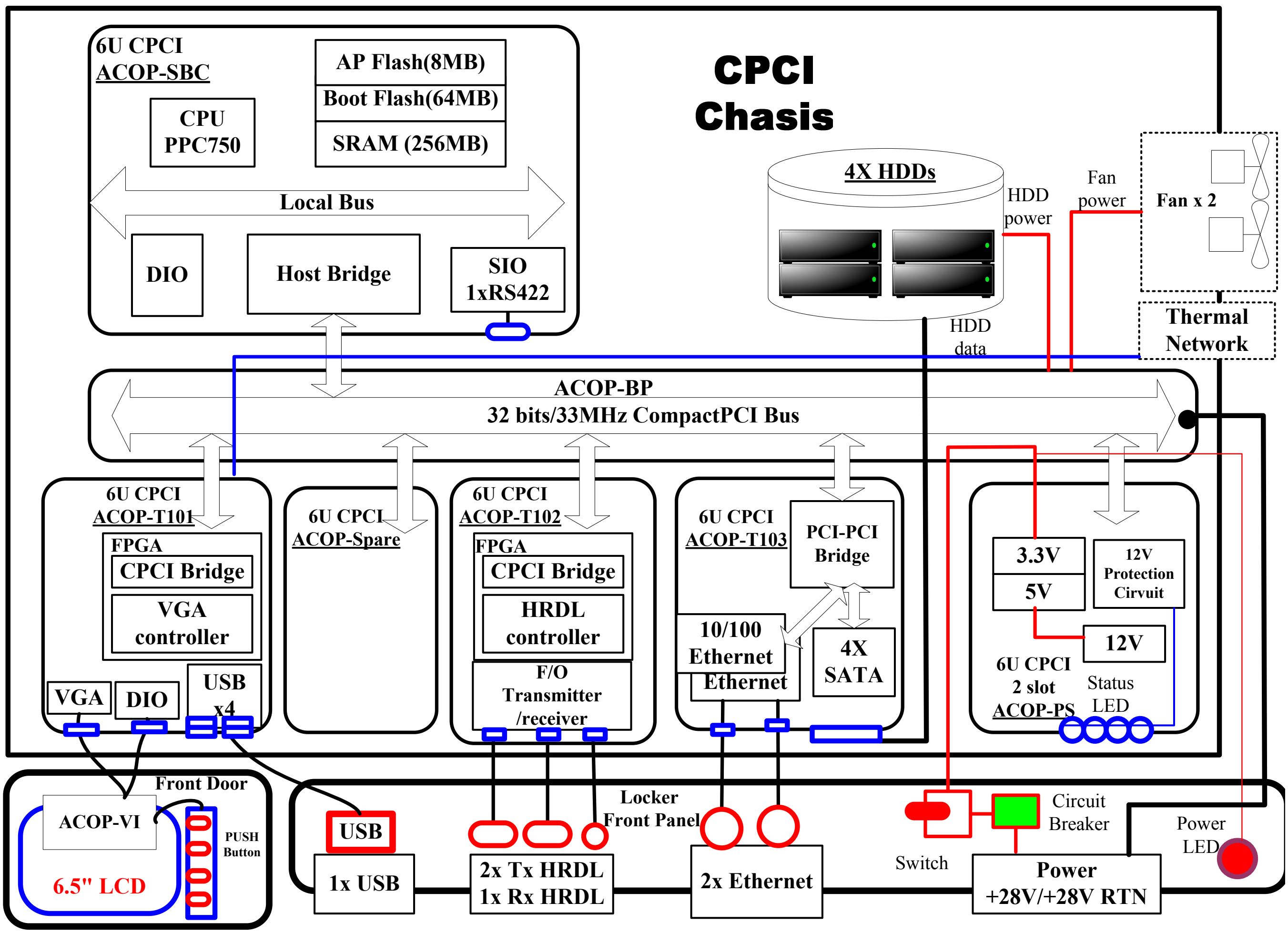


Figure 2-8 ACOP Hardware Architecture

2.5.3 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 2-9 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.

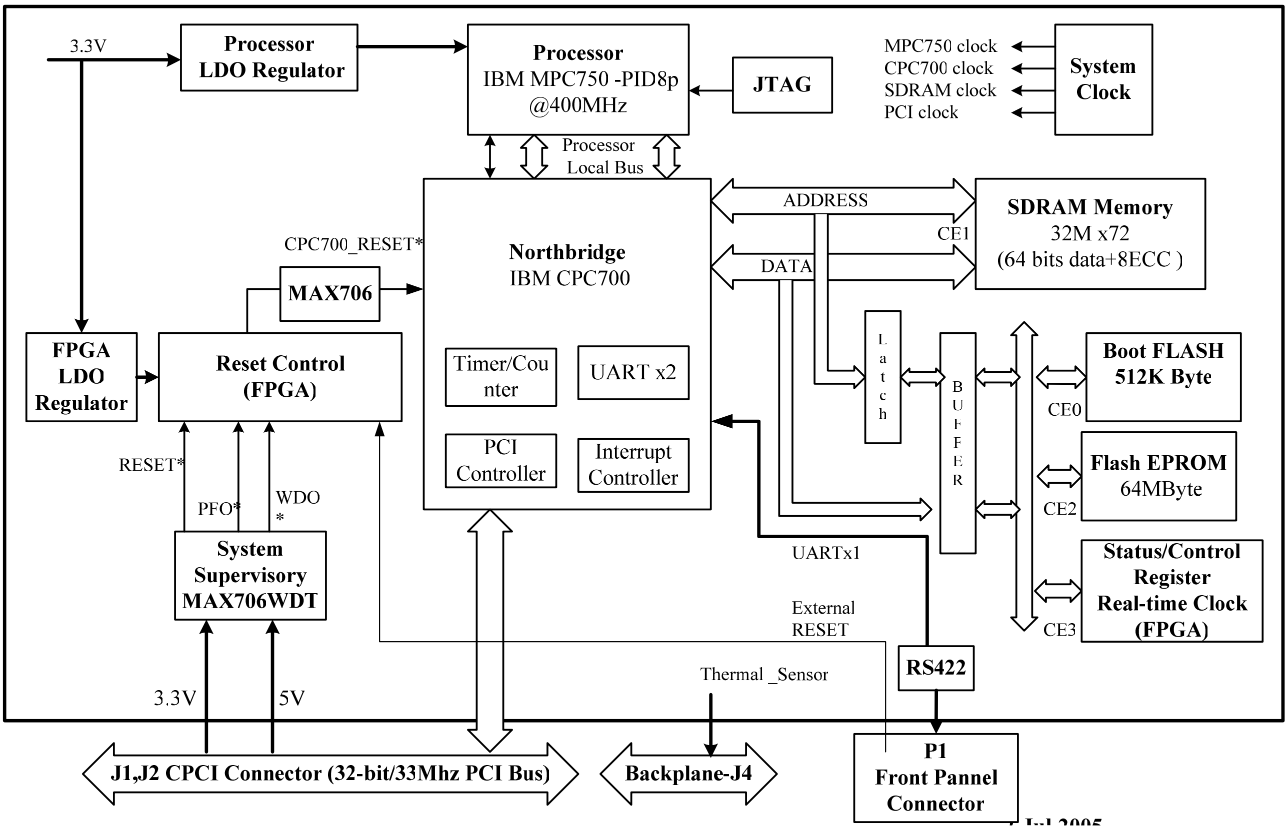


Figure 2-9 ACOP-SBC Functional Block Diagram

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

2.5.4 ACOP-T101

The block diagram in Figure 2-10 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.

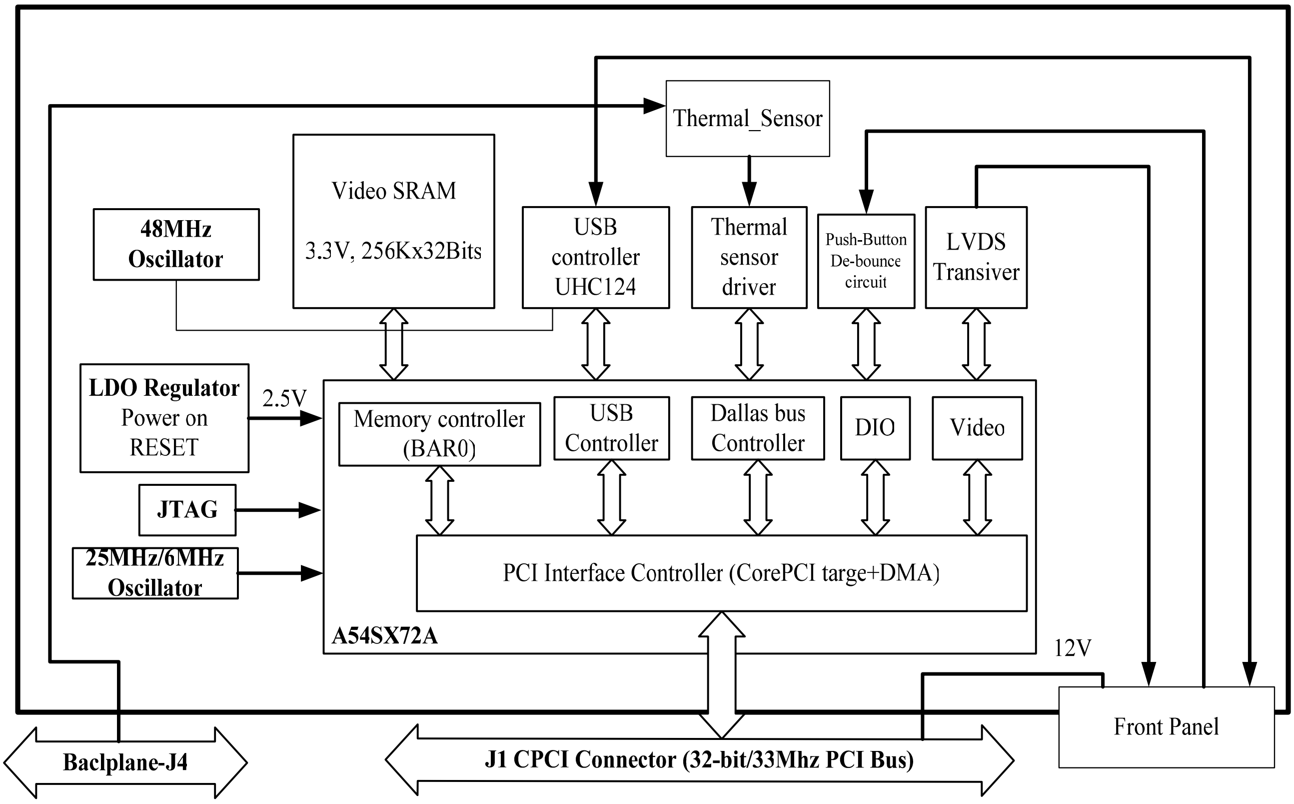


Figure 2-10 ACOP-T101 Functional Block Diagram

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

2.5.5 ACOP-T102

The ACOP-T102 module provides two transmit and one receive fiber optic interfaces meeting the ISS HRDL CCSDS packet mode standards. The hardware structure of ACOP-T102 board is shown in Figure 2-11. Two ZBT SRAM chips are used as buffers between System slot and the FPGA chip. The PCI agent chip (Actel A54SX72A) includes two main functions:

1) translator between the PCI bus and interface back-end bus
2) handling of the read/write operations (PCI memory space access) on the SRAM buffer

The FPGA chip accesses the DPM buffer though its right port. It also has a 5 bit parallel data interface with physical data transmitter (AM79865) and receiver (AM79866A) for HRDL.

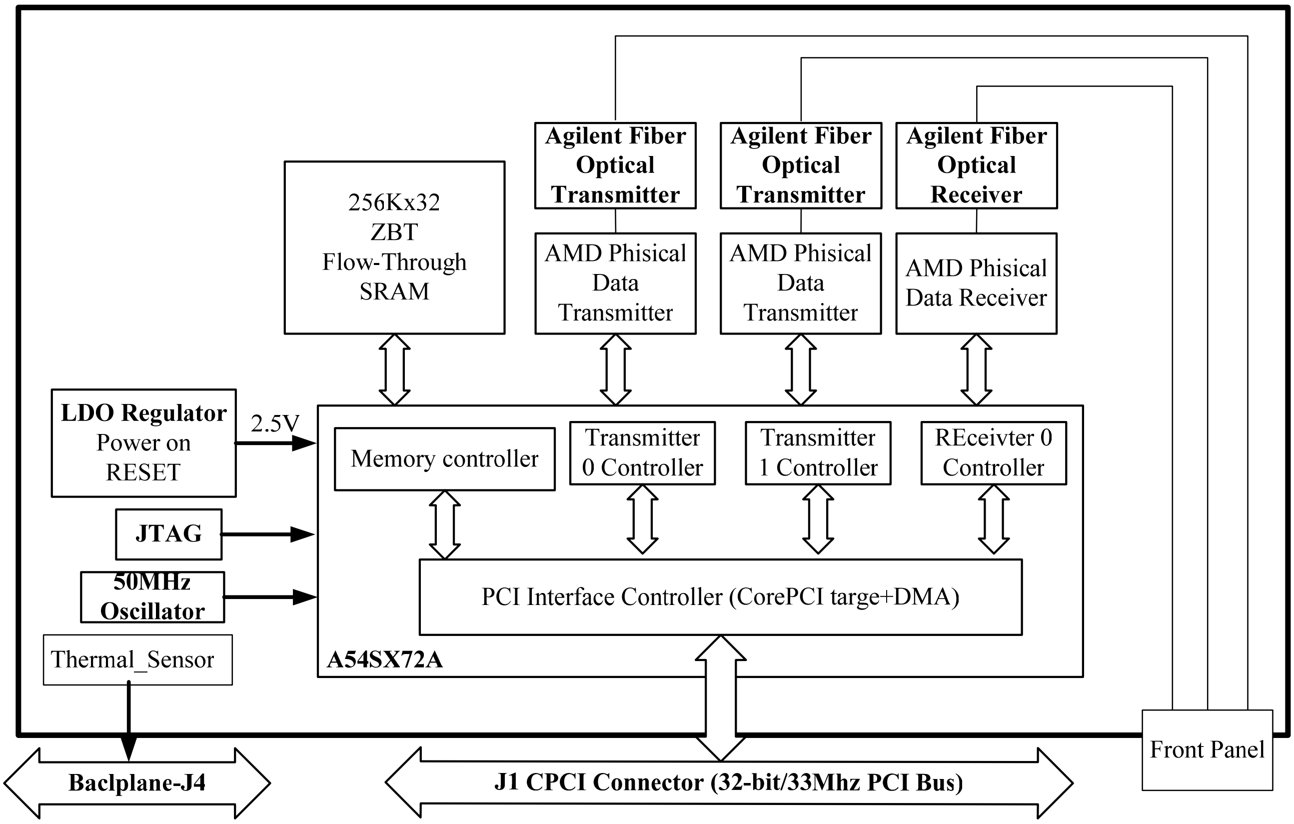


Figure 2-11 ACOP-T102 Functional Block Diagram

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

2.5.6 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.

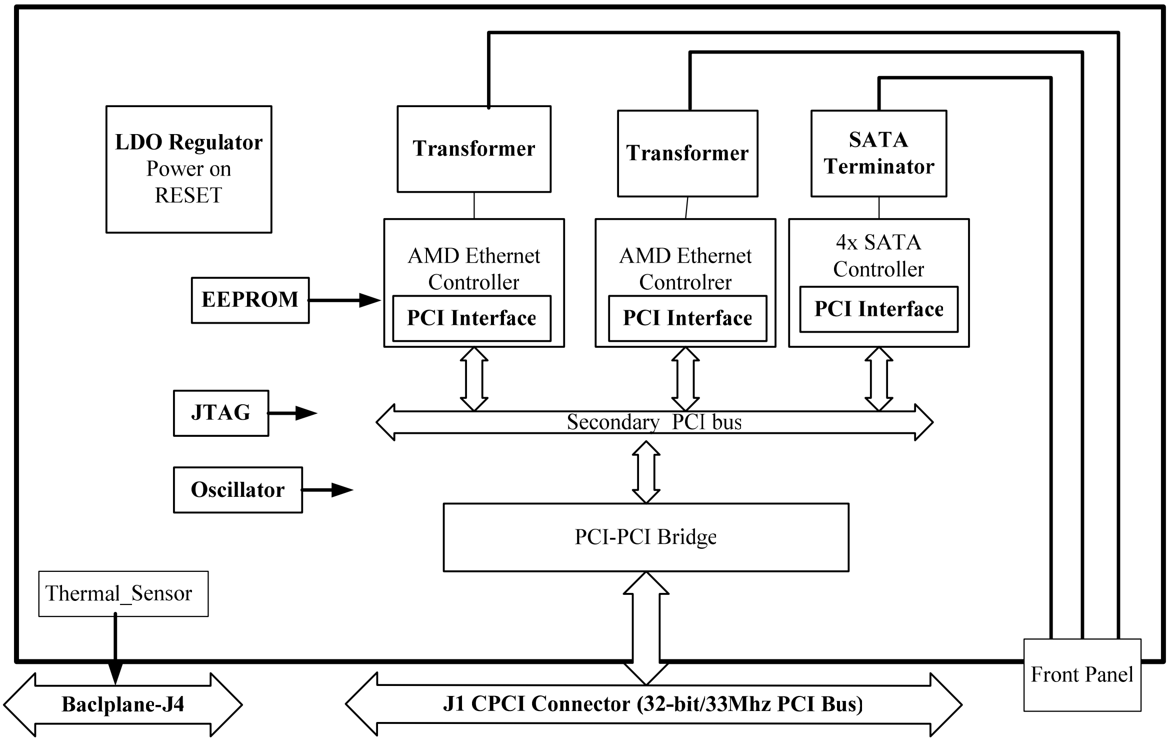


Figure 2-12 ACOP-T103 Functional Block Diagram

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

2.6 ACOP-SYS-SW - OPERATING SYSTEM PLATFORM

The diagram below shows the operational modes for the ACOP-SYS-SW.

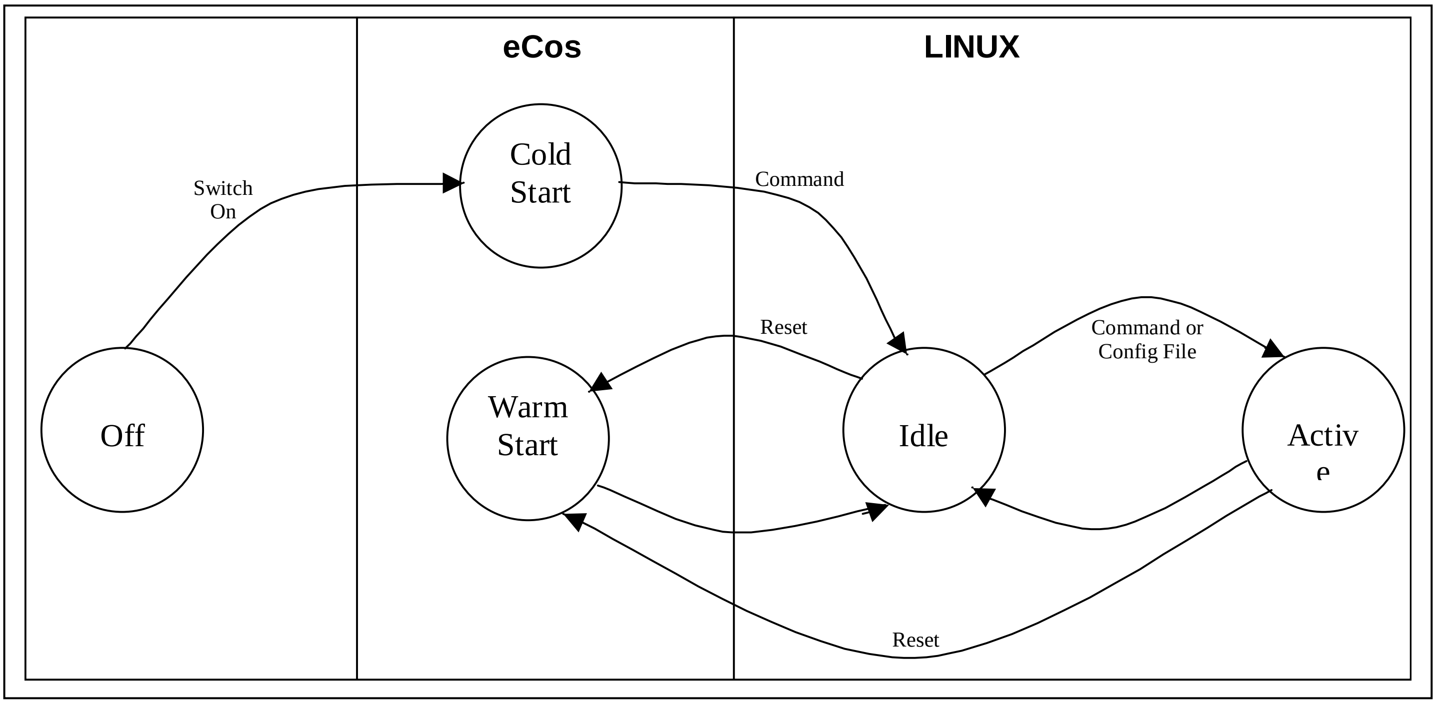


Figure 2-13 ACOP-SW Operational Modes

The following mode are identified

- ACOP has its power switch in the off position
- Cold Start: ACOP has just received power and is awaiting commands
- Wam Start: ACOP has just reset and is reloading the system
- Idle: ACOP has loaded LINUX but the application software is idle
- Active: ACOP application is actively recording data

2.6.1 BOOTROM MONITOR

Based on eCos, a open source embedded operating system. The BootRom monitor resides in the read only BootProm. This is brought to execution whenever the processor exits the reset state.

2.6.1.1 ECOS FEATURES

eCos has been designed to support applications with real-time requirements, providing features such as full preemptability, minimal interrupt latencies, and all the necessary synchronization primitives, scheduling policies and interrupt handling mechanisms. eCos also provides all the functionality required for general embedded application support including device drivers, memory management, exception handling, C, math libraries, etc. In addition to runtime support, the eCos system includes all the tools necessary to develop embedded applications, including eCos software configuration and build tools, and GNU-based compilers, assemblers, linkers, debuggers, and simulators.

eCos provides the following functionality:

- Hardware Abstraction Layer (HAL)

- Real-time kernel
    - Interrupt handling
    - Exception handling
    - Choice of schedulers
    - Thread support
    - Rich set of synchronization primitives
    - Timers, counters and alarms
    - Choice of memory allocators
    - Debug and instrumentation support
- µITRON 3.0 compatible API
- POSIX compatible API
- ISO C and math libraries
- libstdc++ library
- Serial, ethernet, wallclock and watchdog device drivers
- USB slave support
- TCP/IP networking stacks, including
    - Bootp/DHCP
    - DNS
    - TFTP/FTP
    - SNMP
    - IPv6
    - HTTPD
    - PPP
- File systems:
    - Journalling Flash File System (JFFS2)
    - RAM filing system
    - ROM filing system
- Graphics libraries, including
    - Portable Embedded GUI Library
    - Microwindows
    - VNC Server
- Power management
- GDB debug support

2.6.2 LINUX OPERATING SYSTEM KERNEL

Based on the LINUX 2.6 kernel providing applications services.

Note: What is called out here is just the LINUX kernel, not a full distribution of a whole LINUX system. As an embedded system ACOP will only utilize the LINUX kernel plus a command utility program.

2.6.2.1 LINUX KERNEL FEATURES

The ACOP-SYS-SW will provide the LINUX 2.6 kernel offer key performance enhancements for near-real-time systems.

- General new features
    - Pre-emptable Kernel
    - O(1) Scheduler
    - New Kernel Device Structure (kdev_t)
    - Improved Posix Threading Support (NGPT and NPTL)
    - New Driver Model & Unified Device Structure
    - Faster Internal Clock Frequency

  - Paring Down the BKL (Big Kernel Lock)
  - Better in Place Kernel Debugging
  - Smarter IRQ Balancing
  - ACPI Improvements
  - Software Suspend to Disk and RAM
  - Support for USB 2.0
  - ALSA (Advanced Linux Sound Architecture)
  - LSM (Linux Security Module)
  - Hardware Sensors Driver (lm-sensors)
- New features, Architectures
  - AMD 64-bit (x86-64)
  - PowerPC 64-bit (ppc64)
  - User Mode Linux (UML)
- New features, Filesystems
  - Ext3, ReiserFS (already in 2.4)
  - JFS (IBM)
  - XFS (SGI)
- New features, I/O Layer
  - Rewrite of Block I/O Layer (BIO)
  - Rewrite of Buffer Layer
  - Asynchronous I/O
  - IDE Layer Update
  - ACL Support (Access Control List)
  - New NTFS Driver
- New features, Networking
  - NFS v4
  - Zero-Copy NFS
  - TCP Segmentation Offload
  - SCTP Support (Stream Control Transmission Protocol)
  - Bluetooth Support (not experimental)
  - NAPI (Network Interrupt Mitigation)

2.6.2.2 HRDL DEVICE DRIVER

Kernel driver module for LINUX to support basic access to the ACOP_HRDL interface.

2.6.2.3 HARD DRIVE DEVICE DRIVER

Kernel driver module, plus file system support and S.M.A.R.T., for LINUX EXT3 access to hard drives.

2.6.2.4 USB HOST DEVICE DRIVER

Kernel driver, plus device support, for USB storage devices.

2.6.2.5 VIDEO DEVICE DRIVER

Kernel driver for basic frame buffer video device support.

2.6.3 BUSYBOX - COMMAND INTERFACE

This utility provides command line interface and support for various functions within the LINUX environment.

2.6.3.1 BUSYBOX FEATURES

BusyBox combines tiny versions of many common UNIX utilities into a single small executable. It provides minimalist replacements for most of the utilities you usually find in GNU coreutils, util-linux, etc. The utilities in BusyBox generally have fewer options than their full-featured GNU cousins; however, the options that are included provide the expected functionality and behave very much like their GNU counterparts.

BusyBox has been written with size-optimization and limited resources in mind. It is also extremely modular so you can easily include or exclude commands (or features) at compile time. This makes it easy to customize your embedded systems. To create a working system, just add /dev, /etc, and a Linux kernel. BusyBox provides a fairly complete POSIX environment for any small or embedded system.

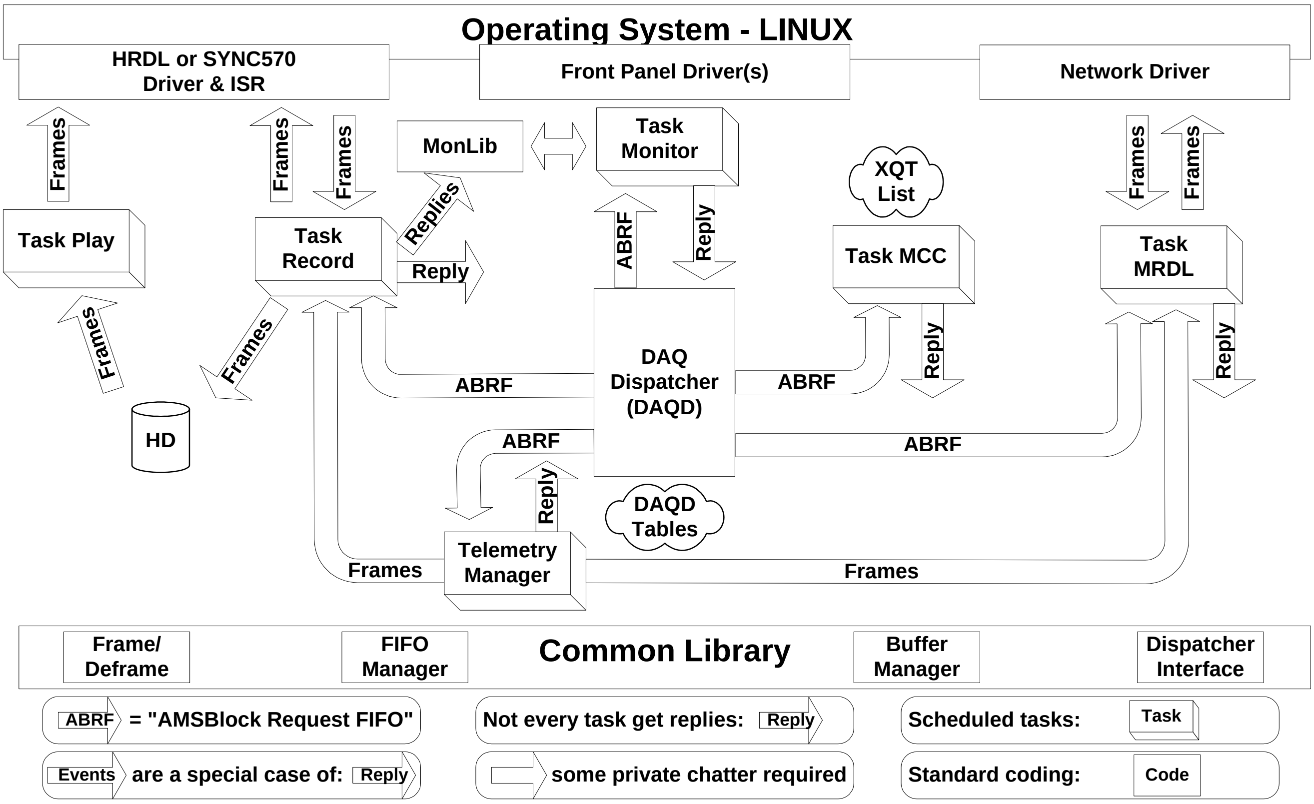
BusyBox is extremely configurable. This allows you to include only the components you need, thereby reducing binary size. Run 'make config' or 'make menuconfig' to select the functionality that you wish to enable. The run 'make' to compile BusyBox using your configuration.

Commands supported include:

addgroup, adduser, adjtimex, ar, arping, ash, awk, basename, bunzip2, busybox, bzcat, cal, cat, chgrp, chmod, chown, chroot, chvt, clear, cmp, cp, cpio, crond, crontab, cut, date, dc, dd, deallocvt, delgroup, deluser, devfsd, df, dirname, dmesg, dos2unix, dpkg, dpkg-deb, du, dumpkmap, dumpleases, echo, egrep, env, expr, false, fbset, fdflush, fdformat, fdisk, fgrep, find, fold, free, freeramdisk, fsck.minix, ftpget, ftpput, getopt, getty, grep, gunzip, gzip, halt, hdparm, head, hexdump, hostid, hostname, httpd, hush, hwclock, id, ifconfig, ifdown, ifup, inetd, init, insmod, install, ip, ipaddr, ipcalc, iplink, iproute, iptunnel, kill, killall, klogd, lash, last, length, linuxrc, ln, loadfont, loadkmap, logger, login, logname, logread, losetup, ls, lsmod, makedevs, md5sum, mesg, mkdir, mkfifo, mkfs.minix, mknod, mkswap, mktemp, modprobe, more, mount, msh, mt, mv, nameif, nc, netstat, nslookup, od, openvt, passwd, patch, pidof, ping, ping6, pipe_progress, pivot_root, poweroff, printf, ps, pwd, rdate, readlink, realpath, reboot, renice, reset, rm, rmdir, rmmod, route, rpm, rpm2cpio, run-parts, rx, sed, seq, setkeycodes, sha1sum, sleep, sort, start-stop-daemon, strings, stty, su, sulogin, swapoff, swapon, sync, sysctl, syslogd, tail, tar, tee, telnet, telnetd, test, tftp, time, top, touch, tr, traceroute, true, tty, udhcpc, udhcpd, umount, uname, uncompress, uniq, unix2dos, unzip, uptime, usleep, uudecode, uuencode, vconfig, vi, vlock, watch, watchdog, wc, wget, which, who, whoami, xargs, yes, zcat

2.7 ACOP-APP-SW - APPLICATION SOFTWARE PLATFORM

The following diagram shows the overall organization of the ACOP applications software for the AMS-02



mission.

Figure 2-14 Application Software Organization

2.7.1 COOPERATIVE MULTITASKING SYSTEM

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

The tasks for ACOP-SW for the initial AMS-02 mission are discussed below.

2.7.2 TASKRIC

This task (see Task MRDL) provides the interface between the Rack Interface Controller (RIC) and ACOP-SW. It receives commands and creates health and status data.

2.7.3 TASKRECORD

This task provides support for the three HRDL interfaces. If recording is active it records all data received on the HRDL interface to files on the active hard drive. CCSDS packets are examined to determine if their APID's are for payload to payload traffic. Payload commands to ACOP-SW are processed and Payload replies are returned via the HRDL interface.

2.7.4 TASKMCT

This task provides support for scheduled activities such as gather data for health and status.

2.7.5 TASKTQM

This task (see Telemetry Manager and Task record) provides consistent telemetry queue management for all external interfaces.

2.7.6 TASKXFER

This task provides for file transfer protocols within the ACOP telemetry streams.

2.7.7 TASKFEP

This task (see Network Driver) provides the generic network interface to support network attached requests such as from the ERL.

2.8 DEVELOPMENT ENVIRONMENT

2.8.1 DEVELOPMENT HARDWARE

Software testing is done on the ACOP/TRM (Training Model). The avionics hardware environment of this unit will be keep in reasonable harmony with the flight model developments.

2.8.2 DEVELOPMENT SOFTWARE

The ACOP-SW development directly occurs on standard laptop systems operating with the LINUX operating system. The ACOP-SW is developed using the standard cross development tools provided by GNU. Executables generated within this environment are transferred by the network to the ACOP/LFM for testing. Networked based graphical debug tools are available.