

***AMS Note xxx december 2001***

***“Technical specification for the ACOP (AMS-02 Crew  
Operation Post) facility for the AMS-02 first mission”***

***Version 1.0***

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## 1. INTRODUCTION

### 1.1 DEFINITIONS OF TERMS & ABBREVIATIONS

External Interfaces All interfaces that are not internal.

Internal Interfaces Interfaces between subsystems being part of the ACOP system.

Similarity Verification data for hardware components previously qualified or flown shall be reviewed to verify that these component's prior verification requirements meet or exceed the current mission requirements. The review shall cover structures, materials, environmental, and operational requirements.

Analysis Hardware not previously qualified or flown will be analysed when analysis is the most efficient way to demonstrate capability to meet or exceed expected environmental conditions. The selected analysis techniques may typically include system engineering analyses, calculations, statistics, qualitative analyses, and computer simulation.

Inspection The hardware shall be thoroughly inspected or reviewed to validate that it has been built to the individual assembly drawings. Inspection or review shall also be used when it is more efficient or applicable to demonstrate compliance to requirements rather than perform calculable testing or analysis.

Demonstration The hardware shall be verified by observation that the design characteristics such as human factors, maintenance, operation, and access features are fulfilled. The pass/fail criterion of a Demonstration is qualitative. Considering the design requirement, the operation or assessment shall be acceptable based upon the judgment of those approved individuals (i.e. quality assurance, human factors, astronaut, etc.) who witness the demonstration.

Test The hardware shall be tested to verify that the design can withstand the environmental conditions and operate within the specified functional tolerances. Functional tests shall be performed before, during (if applicable), and after each environmental test. When testing is the chosen method, the tests shall be performed on appropriate hardware.

Review of Design The hardware shall verified by review of relevant design documents (drawings, specifications, lists, etc.) at the time of the Critical Design Review.

## ABBREVIATIONS

ABCL.....	As-Built Configuration data List
ACOP.....	Acquisition Crew Operation Post
ADP.....	Acceptance Data Package
AR.....	Acceptance Review
ASI.....	Agenzia Spaziale Italiana
ATP.....	Authorization To Proceed
BDC.....	Baseline Data Collection
BDCM.....	Baseline Data Collection Model
CCB.....	Configuration Control Board
CDR.....	Critical Design Review
CI.....	Configuration Item
CIDL.....	Configuration Item Data List
CM.....	Configuration Management
CSCI.....	Computer Software Configuration Item
DCL.....	Declared Component List
DIL.....	Deliverable Items List
DML.....	Declared Materials List
DMPL.....	Declared Mechanical Parts List
DPL.....	Declared Processes List
DRB.....	Delivery Review Board
DRD.....	Document Requirement Description
EEE.....	Electrical, Electronic & Electromechanical
EGSE.....	Electrical Ground Support Equipment
ER.....	Express Rack
ERLC.....	Express Rack laptop Computer
ERLS.....	Express Rack Laptop Software
EMC.....	Electro-Magnetic Compatibility
ESA.....	European Space Agency
FEM.....	Finite Element Model
FFMAR.....	Final Flight Model Acceptance Review
FM.....	Flight Model
FMECA.....	Failure Mode Effect & Criticality Analysis
FSM.....	Flight Spare Model
GIDEP.....	Government Industry Data Exchange Program
GSE.....	Ground Support Equipment
HRDL.....	High Rate Data Link
ICD.....	Interface Control Document
IRD.....	Interface Requirement Document
ISS.....	International Space Station
JSC.....	Johnson Space Centre
LFM.....	Low Fidelity Model
KIP.....	Key Inspection Point
MGSE.....	Mechanical Ground Support Equipment
MDL.....	Middeck Locker
MIP.....	Mandatory Inspection Point

MMI.....	Man Machine Interface
NRB .....	Non-Conformance Review Board
MPLM.....	Multi Purpose Logistic Module; Mini Pressurized Logistic Module
NA .....	Not Applicable
NASA .....	National Aeronautics and Space Administration
NCR .....	Non-Conformance Report
NDI.....	Non-Destructive Inspection
NSTS.....	National Space Transportation System
ORU.....	Orbital Replacement Unit
PA .....	Product Assurance
PCB.....	Printed Circuit Board
PDR .....	Preliminary Design Review
PFMAR .....	Preliminary Flight Model Acceptance Review
PMP .....	Parts, Materials & Processes
PSA .....	Project Specific Annex
QM .....	Qualification Model
RFA.....	Request For Approval
RFD.....	Request for Deviation
RFW.....	Request For Waiver
RIC.....	Rack Interface Controller
ROD .....	Review of Design
SIM.....	Similarity Assessment
ScS.....	Suitcase Simulator
SOW .....	Statement of Work.
SPF .....	Single Point Failure
SRD .....	Software Requirements Document.
TBC/tbc.....	To be confirmed
TBD/tbd.....	To be defined
TBDCM .....	Training & Baseline Data Collection Model
TBDCMAR .....	TBDCM Acceptance Review
TRB .....	Test Review Board
TRR.....	Test Readiness Review
TRM .....	Training Model
WBS.....	Work Breakdown Structure
WP .....	Work Package
WPD.....	Work Package Description

## 1.2 AIMS AND SCOPE

The aim of this technical document is to define :

- 1) the end products to be delivered by the Contractor during the phases B, C, D and E1 of the ACOP mission,
- 2) the tasks to be performed and the methods to be used to develop the products above
- 3) the related schedule.

The phase B shall consist of a system specification and preliminary design phase, culminating in a Preliminary Design Review.

The phase C shall consist of a detailed system and subsystem design phase, culminating in a Critical Design Review.

The phase D foresees the manufacture, integration and verification of the main ACOP System models, up to the final FM ACOP integration.

The phase E1 is the support phase to the flight mission up to the in orbit commissioning.

The major deliverables of this contract shall consist of:

- ACOP system models required to support the overall program, including
  - a Low Fidelity Model;
  - a Training Model (refurbishment of LFM plus an additional mock up providing Mechanical I/F's), defined in section 8.1 point b);
  - a Qualification Model (becoming Flight Spare Model when refurbished), defined in section 8.1 points c) and e);
  - a Flight Model, defined in section 8.1 point d);
- Spare parts, defined in section 8.1 point f);
- Ground Support Equipment (GSE);
- Software (as part of the ACOP system);
- Documentation.

The contractual activities shall include also the integration of ACOP into ISS, including the preparatory activities during phase B, C and D and the final integration.

The Contractor shall provide support services during phase E1, up to the in orbit commissioning, as specified in this document.

### 1.3 APPLICABLE DOCUMENTS

In the following table a number of AD are listed.

<b>A D</b>	<b>Doc. Number</b>	<b>Issue / Date</b>	<b>Rev.</b>	<b>Title / Applicability</b>
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 52000-EIA-ERP	Feb. 2001	A	Express Rack Integration Agreement blank book for Express Rack payload
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 <sup>1</sup>	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

<sup>1</sup> The ECSS-e\_40 shall be tailored to the need of the program. The Contractor shall provide a Tailoring Matrix defining the ECSS applicable requirements.

## 1.4 REFERENCE DOCUMENTS

In the following table a number of RD are listed.

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

## 2. MISSION OVERVIEW

The ACOP System is intended to fly on the International Space Station (ISS) as an Italian payload on the NASA laboratory. The main objective of ACOP is to provide an ISS Internal Facility capable of supporting AMS-02 experiment, performing the recording of Science data. In particular, ACOP shall allow a more flexible and efficient use of ISS TM downlink, providing a temporary backup of data generated by AMS-02 and preventing, in this way, possible losses of valuable data. In addition, ACOP is the operational interface to on board crew in order to control and monitor AMS-02 inside from ISS and to permit files and SW upload into the supported payloads.

Considering that ACOP exploits the ISS standard Interfaces, it could provide a flexible and common platform for the data recording coming from other ISS Internal/External experiment or payload with small customization.

The Alpha Magnetic Spectrometer (AMS-02) is a scientific instrument whose main functionality is to search for and detect different types of matter (dark matter, anti-matter). AMS-02 is mounted on the ISS external Truss (S3 position) as shown in Figure 2-1.

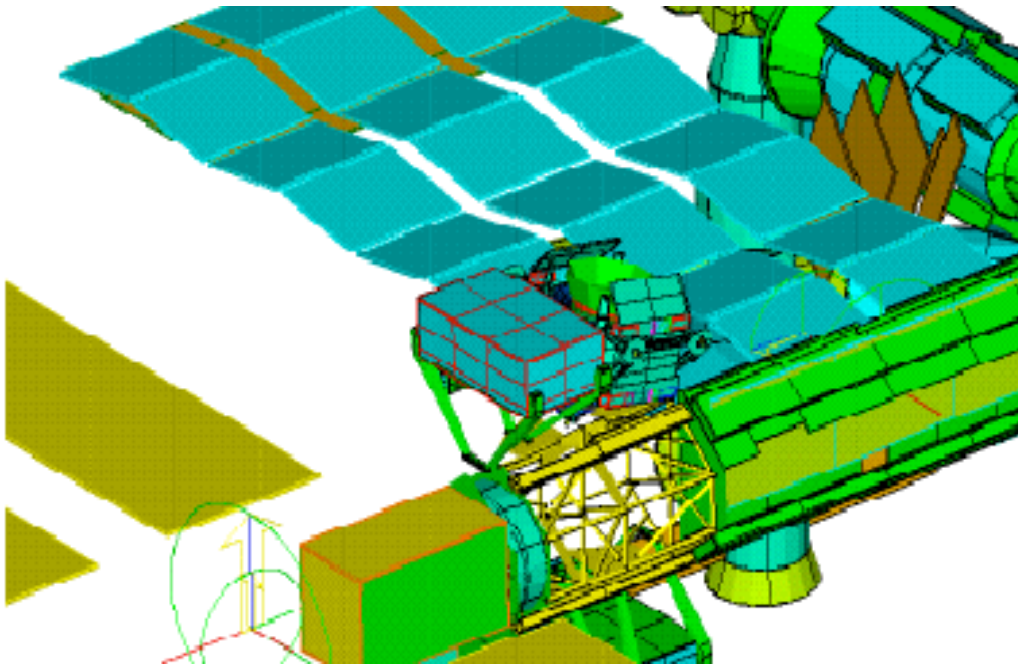


Figure 2-1 AMS-02

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

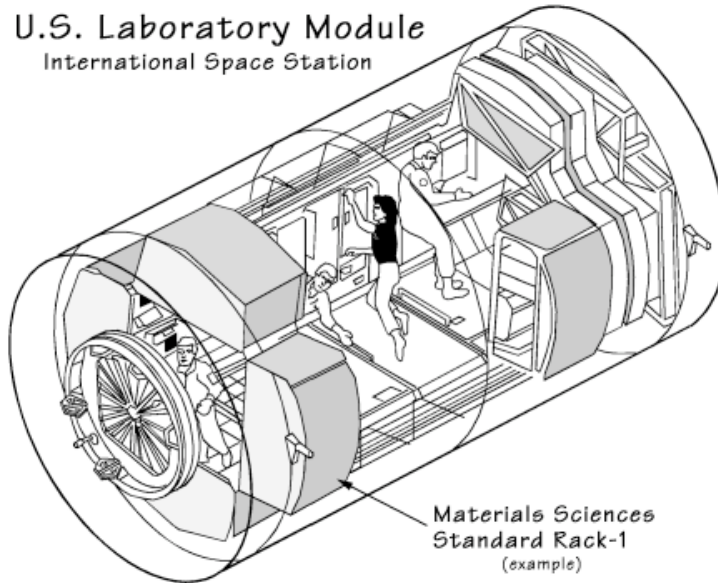


Figure 2-2 US-LAB

The standard configuration of an EXPRESS Rack is commonly known as 8/2. This means that it can accommodate eight ISS locker/Middeck Locker (MDL) and two International Subrack Interface Standard (ISIS), as shown in Figure 2-3.

On-Board Spare parts shall be accommodated in a standard soft bag.

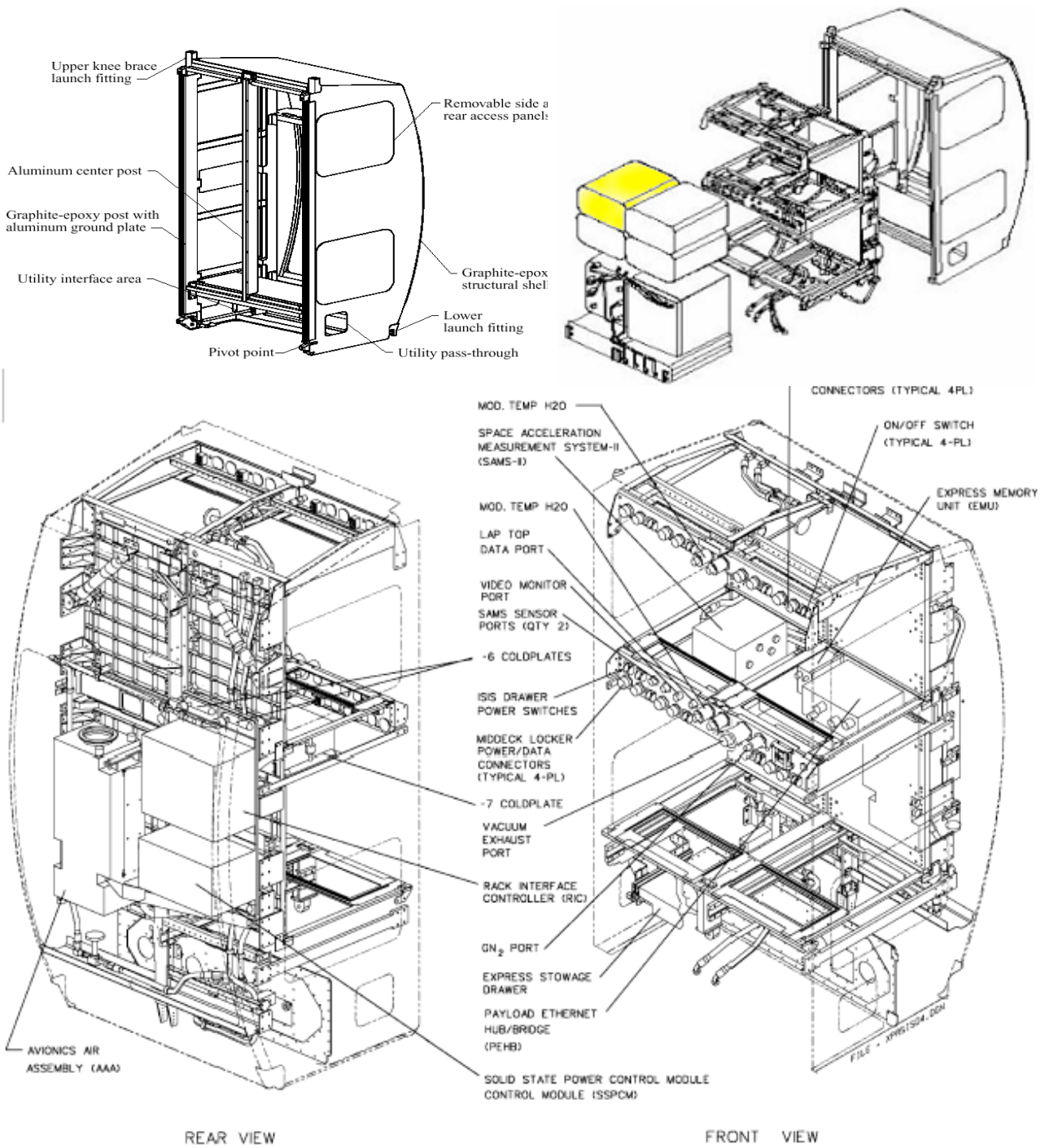


Figure 2-3 International Standard Payload Rack & EXPRESS Rack

ACOP occupies one MDL located in the ER. One possible accommodation is marked in yellow in Figure 2-3.

### 3. ACOP SYSTEM REQUIREMENTS

#### 3.1 ACCEPTANCE CRITERIA

The deliverable items in the frame of this contract will be accepted on the base of the compliance with the requirement listed in this contract. .

#### 3.2 TOP LEVEL BLOCK DIAGRAM

The ACOP System is composed by ACOP Flight Segment and the GSE. The ACOP Flight Segment Functional and Connections Block Diagram is depicted in Figure 3-1.

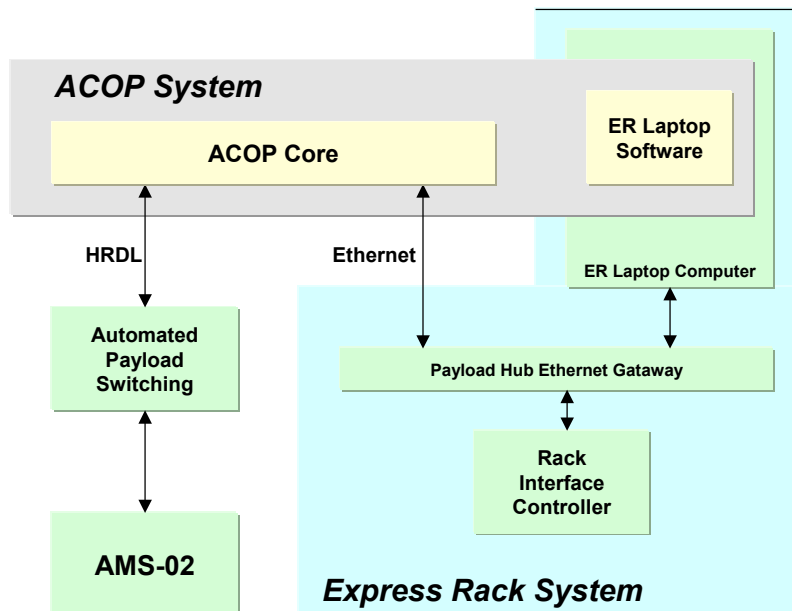


Figure 3-1 ACOP Functional and Connections Block Diagram

#### 3.3 CONTEST REQUIREMENTS

The ACOP facility shall be installed inside the US-Laboratory pressurized volume of ISS in order to be operated by the ISS onboard crew. Hereafter “External Payload” shall be understood as AMS-02.

#### 3.4 FUNCTIONAL AND PERFORMANCES REQUIREMENTS

##### 3.4.1 ACOP SYSTEM MAJOR TASKS

The ACOP facility shall provide the following main functionalities:

- **Data storage capability.** This allows the system to acquire and store the data coming from AMS-02 (TM; Science data and House-Keeping).
- **Logging capability:** this allows to report in a file the received ACOP Tele-and the command to AMS-02.
- **Stored Data Playback capability.** This feature can be exploited during the time periods of TM downlink availability. The data can be transferred over the downlink.
- **On ground command management capability.** This allows to receive the following telecommands from ground station
  - On-ground Tele-command for ACOP;
  - Routing of telecommand to AMS-02.
- **MMI functionalities.**
  - Capability to issue Commands for controlling AMS-02 or ACOP internal functions;
  - ACOP and AMS-02 Telemetry Data Visualisation and monitoring.
- **SW upload.** ACOP shall provide storage support for files and programs (SW patches, etc.) to be uploaded into AMS-02 control equipments.

### 3.4.2 ACOP SYSTEM MAIN PERFORMANCES

ACOP facility data storage capability (i.e. number of Mbyte) and of the autonomy period (i.e. number of Hours) shall be compliant to the following tables:

<b>Hard Drives</b>	<b>GB/unit</b>	<b>Units</b>	<b>Gbyte</b>
Nominal, Installed	200	4	<b>800</b>
Nominal, Stowed on orbit	200	10	<b>2000</b>
<b>Total Capability</b>			<b>2800</b>

*Table 3-1 ACOP STORAGE CAPABILITY*

In addition to the nominal hard drives, spare hard drives will be stored on orbit (see section 8.1 point f).

<b>Description</b>	<b>Mbits/sec</b>	<b>Gbyte/day</b>	<b>Gbyte</b>	<b>Days</b>
ACOP Autonomy without crew intervention	2	21,6	800	<b>37</b>
ACOP Autonomy without shuttle refurbishment	2	21,6	2800	<b>129</b>

*Table 3-2 ACOP Crew Autonomy Capability*

Full time and Full duplex connectivity between AMS-02 and ACOP is required.

### 3.4.3 DATA HANDLING

ACOP Data Handling shall be composed by the following sections:

- Express Rack Interface Section
- High Rate Data Link interface Section

The Express Rack Interface section shall be in charge of managing data with the Express Rack Interface Controller as define in the SSP-52000-IDD-ERP section 9 . The section includes a Table with the type of command packets and telemetry data packets available on the Rack Interface Controller. The ACOP shall only exploit some of this data packets, and based on the ACOP requirements (see section 3.5.3).

The High Rate Data Link section shall manage the data exchanged with AMS-02. In this case the contract shall be compliant with the AMS data as defined in the AMS Interface Control Document [AD 12] (data exchanged on the HRDL with AMS shall be a custom packet with on top the CCSDS format).

The following types of data shall be managed by ACOP System:

- On ground Tele-commands for ACOP via S-Band-Payload Multiplexer Demultiplexer-RIC
- On-ground AMS-02 Tele-commands via S-Band-Payload Multiplexer Demultiplexer-RIC and routed to AMS02 via HRDL
- ACOP Telemetry data
- AMS Telemetry data to be stored and downloaded and displayed by the ER laptop computer (ERLC)
- ERLC Commands for ACOP
- ERLC Commands to be routed to AMS
- Telemetry data to be sent to ER laptop computer

#### **3.4.4 MMI**

ACOP Man Machine Interface shall be implemented using two types of interface Control Panel:

1. Input Buttons and LEDs on the ISS Locker Front Panel. The LEDs shall show to the crew the essential data of ACOP (i.e. Health and Status flags indication). In the Health and status flags indication shall be included the Power supply status, Internal Temperatures, Fans status, available space on the Hard Drives.
2. The other MMI shall be provided by means the Express Rack Laptop Computer that is available in-orbit as a standard provision of the Express Rack Using this computer, it shall be possible to display all the types of data, such as ACOP TM data and AMS TM data. Moreover, the crew shall be able to send commands to ACOP or to AMS-02, by means of this MMI.

The Displayed data will be the following:

- ACOP House Keeping & Health Status data
- AMS House Keeping & Health and Status data
- Display of AMS Science Data packet content

### 3.5 INTERFACES AND BUDGETS

#### 3.5.1 MECHANICAL INTERFACES

##### 3.5.1.1 EXTERNAL INTERFACES

ACOP payload shall be accommodated in a MDL/ISS locker inside a Standard 8/2 Express Rack. The Physical & Mechanical I/F's shall be compliant to the SSP52000-IDD-ERP section 3.3 concerning the standard modular MDL/ISS locker sections.

The front panel configuration shall be designed in response to the ACOP requirement and AD and deviation from the standard concerns are foreseen . A custom front panel shall be manufactured. ORU parts shall be stowed in one soft bag.

The following images are for information only and aim to give an idea of characteristics of MDL's and soft bag for ORU parts.

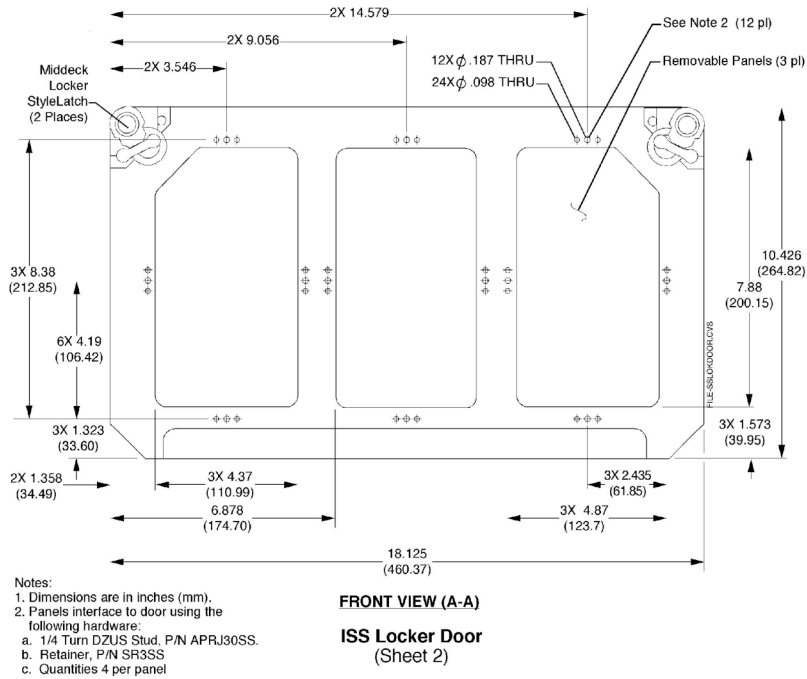


Figure 3-2: Standard Front Panel

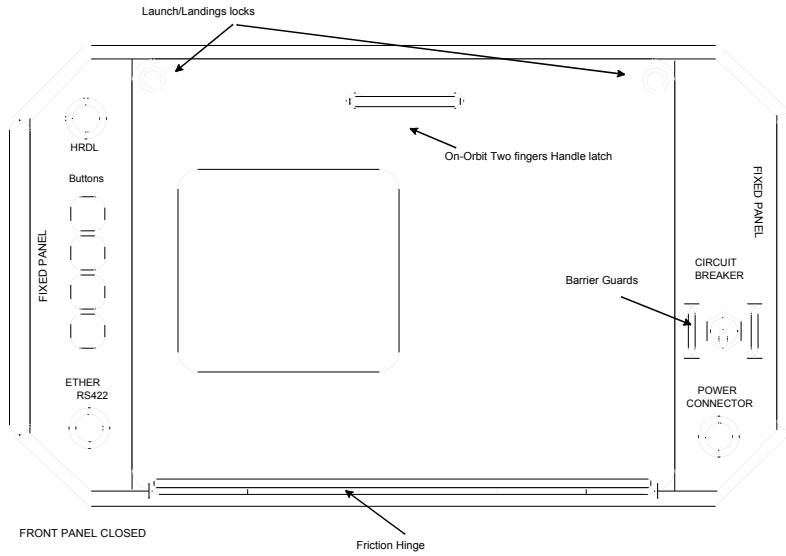
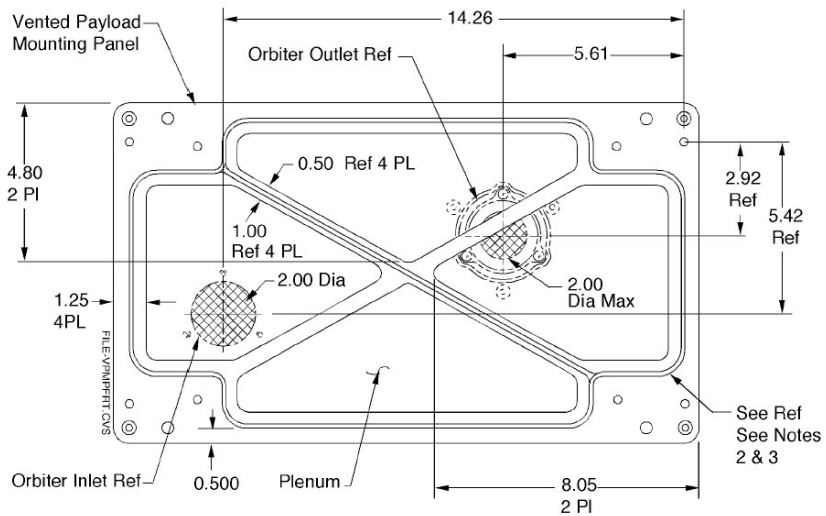


Figure 3-3: Custom Front Panel



- Notes:**
1. Dimensions are in inches.
  2. Seal is 0.062 inches thick above the surface of the panel and is 0.25 inches wide
  3. The seal is Silicon Sponge per AMS 3195.

Figure 3-4: Single Payload Inlet Outlet interface provision. MDL /ISS back interface

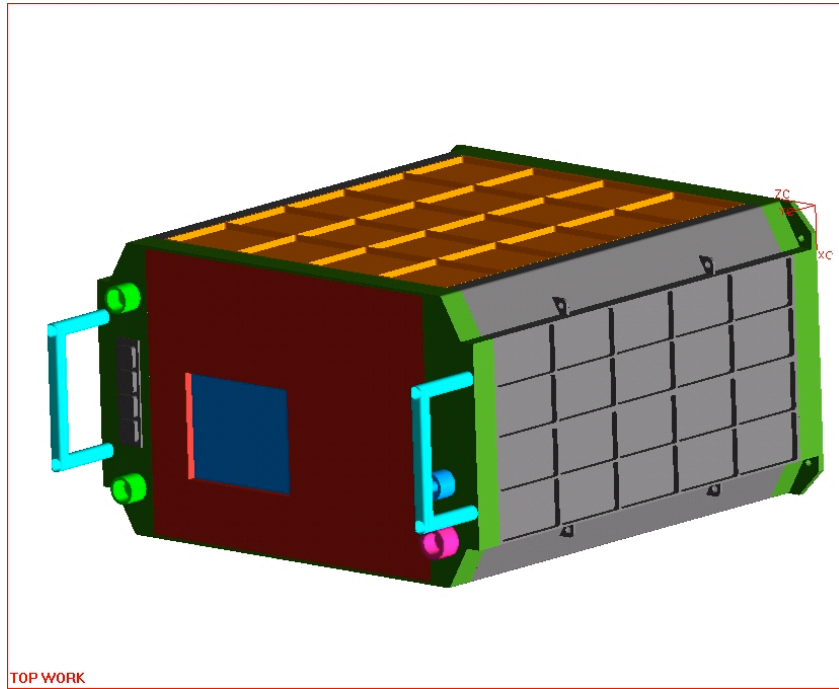


Figure 3-5: ACOP preliminary Mechanical design

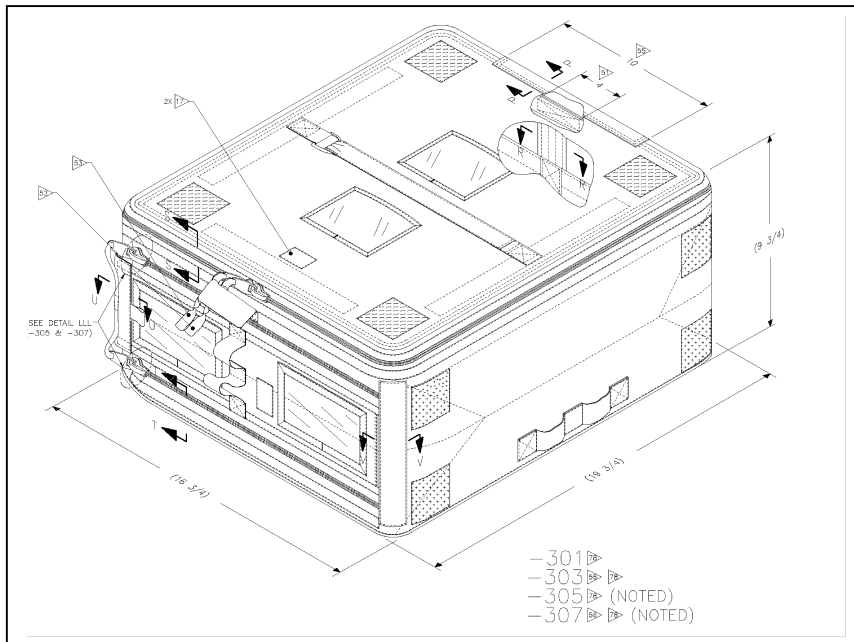


Figure 3-6; Soft Bag for ORU parts

### 3.5.1.2 INTERNAL INTERFACES

The Contractor is responsible for the definition, documentation, design, implementation and verification of the ACOP internal mechanical interfaces.

### 3.5.2 ELECTRICAL INTERFACES

#### 3.5.2.1 EXTERNAL INTERFACES

The external interface shall be divided in:

- Interfaces between ACOP and the Express Rack
- Interfaces between ACOP and ISPR, and AMS indirectly (only data I/F's)
- Interfaces with the crew

All the details related to the electrical interfaces of the ACOP facility within EXPRESS rack are defined in SSP52000-IDD-ERP, sections 8/9 (from pag.8-1 to pag 8-5; from pag.9-1 to pag 9-10).

The defined performances of the system require a special data link that is not usually available for a standard Express Rack payload: ACOP requires two transmit and one receive High Rate Data Link channels in order to receive the AMS-02 telemetry data and to download them on ground. For this reason, ACOP system shall use the two HRDL J7 connectors on ISPR UIP.

ACOP shall utilize the Express Rack Laptop Computer to provide Man Machine I/F's to the Crew.

The Power requirement shall be compliant to the SSP52000-IDD-ERP document section 6 (from pag.6-1 to 6-17).The ACOP shall not be powered during the NSTS on-orbit transportation.

ACOP power budget shall be  $\leq 200$  Watt

The ACOP shall be powered by means the connectors on the ER upper or lower connector panel. Wire shall be provided to link ACOP front panel power connector to the ER connector panel. Electrical connector shall meet the SSP-52000-IDD-ERP section 6.6 (from page 6.15 to page 6-17).

ACOP shall provide overload protection devices for the power input line. (SSP-52000-IDD-ERP page 6-7)

ACOP input power line shall be isolated from the structure by at least  $1\text{ M}\Omega$  with a parallel capacitance of  $\leq 10\mu\text{F}$  measured at ACOP interface connector contact (SSP-52000-IDD-ERP from pag.7-21 to pag.7-23).

Table 3-3 summarizes ACOP external electrical interfaces.

	Type	Quantity	Remarks
DATA	Ethernet, 10Mbps	1	For the ER protocol to communicate to the RIC.
	Payload Developer Developed SW on ER Laptop Computer	1	
	TX HRDL	2	(Not ER Standard I/F)
	RX HRDL	1	(Not ER Standard I/F)
POWER	28V ( $\leq 200$ W)	1	
Cooling	EXPRESS Rack Avionics Air Assembly (AAA) Air Sys		

*Table 3-3 ACOP external electrical interfaces*

### 3.5.2.2 INTERNAL INTERFACES

The Contractor is responsible for the definition, documentation, design, implementation and verification of the ACOP internal electrical interfaces.

### 3.5.3 DATA INTERFACES

The Data interfaces shall be the following subset of the interface data element as defined in the SSP52000-IDD-ERP section 11 page 11-11, and from page 11-13 to page 11-46.

The subset of the data element shall be the following:

From ACOP to RIC (via Ethernet)

ACOP Health and Status data

Rack time request

ACOP Telemetry Data downlink

ACOP File Transfer Request

From RIC to ACOP (via Ethernet)

ACOP commands

ACOP file transfer Data Block

From ACOP to AMS

AMS commands

From AMS to ACOP

AMS Health & Status data

AMS Housekeeping data

AMS Science Data

### 3.5.4 MASS BUDGET

The ACOP Mass Budget shall be less than 50 Kg as defined in SSP-52000-IDD-ERP section 4.4.1 (pag4-5) excluding the ORU parts.

### 3.5.5 VOLUME ALLOCATION

ACOP facility uses a standard modular locker and it is provided approximately 2 ft<sup>3</sup> of volume. ACOP shall be compatible with Figure 3-7.

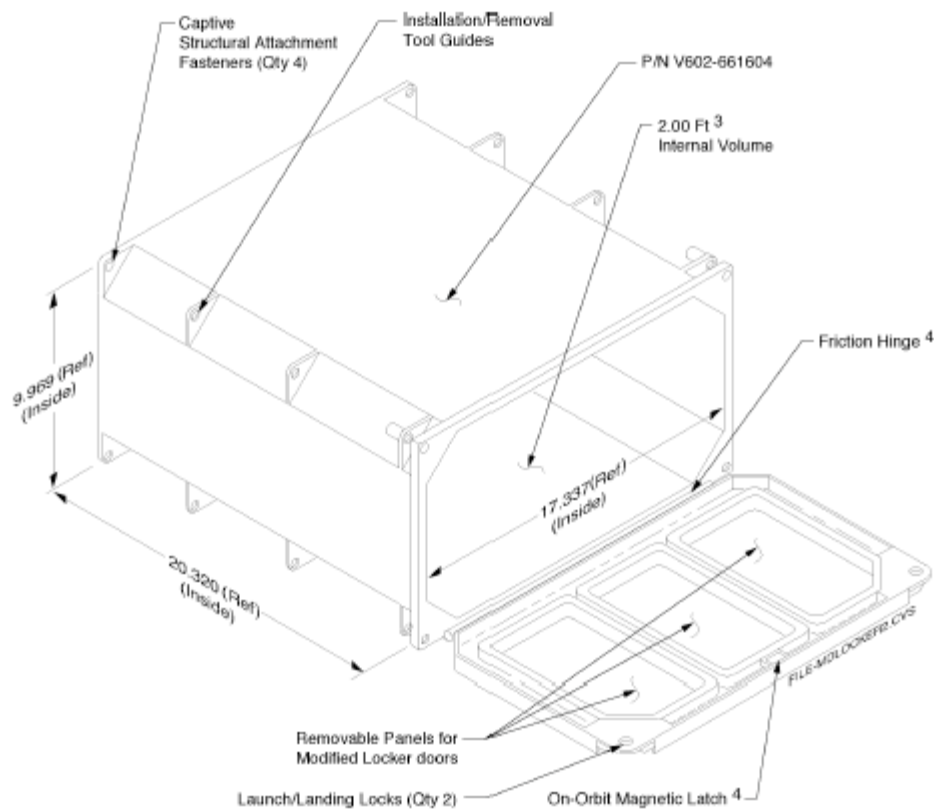


Figure 3-7 SML volume allocation

### 3.5.6 SOFTWARE

Any software developed for the ACOP shall be classified in one of the following types:

- Flight software
- Ground software

#### 3.5.6.1 FLIGHT SOFTWARE

**ACOP flight software** shall be composed by the following functional sections:

- Man-Machine Interface Software to control ACOP operations, to control AMS-02 and to display ACOP internal data or data coming from external payload.

The MMI SW shall provide the following functionalities

- Commands to ACOP management
- Commands to AMS management
- ACOP House Keeping and Health & Status display
- AMS House Keeping and Health & status display
- Data Display of AMS Science data content

- ACOP ISS Interface manager in charge of handling the Data acquired from the AMS-02 and download them on ground.

The ISS interface manager shall provide the following functionalities:

- It manages the Rack Interface Protocol with the Express Rack
- It manages communication protocol on the High Rate data Link
- It manages the communication with the ACOP internal peripheral

- ACOP System Manager software in charge of managing Payload data storage / playback to / from the ACOP.

The System Manager shall provide the following functionalities

- data storage of the Science data and HouseKeeping data coming from AMS-02.
- On-ground Downloading of the AMS-02 science data and House-Keeping data coming from AMS-02
- AMS-02 on-ground commands to AMS-02 routing
- Routing of AMS-02 commands, acquired by means of the Express Rack laptop computer.
- Logging of the delivered command packets
- Searching of the recorded AMS-02 science packet inside the data archive.
- monitoring and control of the ACOP system
- management of the Hard Drives during the data acquisition.

The ACOP Flight software shall be composed of the following Software Packages:

- ACOP core
  - ACOP Core Basic Software. This SW provides low layer for the data management;
  - ACOP Core Application Software, which provides the management of the all ACOP core system.
- Express Rack laptop Software (ERLS)
  - ERLS Basic Software
  - ERLS Application Software

The Contractor shall develop the ACOP Core Basic Software and the ERLS Basic Software in the frame of this contract and deliver it as part of the system (see section 8.2.3).

The ACOP Core Application Software and the ERLS Application Software and related EGSE shall be made available to the Contractor (see section **Error! Reference source not found.**). No development of this Application SW packages is in charge of the Contractor.

*The following tables provides a list of task and functionalities to be developed respectively by Basic SW and Application SW*

<b>Functionalities</b>	<b>Basic SW (to be developed by CGS in the frame of this contract)</b>	<b>Application SW (not part of this contract)</b>
<b>MMI SW (ERLS)</b>		
Commands to ACOP management	Provides transport layer ISO/OSI. (raw packet to be sent )	Provides the ISO/OSI Applicaton layer. TC management and Packet generation
Commands to AMS management	Provides transport layer ISO/OSI	Provides the ISO/OSI Applicaton layer
ACOP House Keeping and Health & Status display	Provides transport layer ISO/OSI	Provides the ISO/OSI Applicaton layer
AMS House Keeping and Health & status displa	Provides transport layer ISO/OSI	Provides the ISO/OSI Applicaton layer
AMS Science data display	Provides transport layer ISO/OSI	Provides the ISO/OSI Applicaton layer
<b>MMI SW (ACOP Core SW)</b>		
Buttons LED Management	Input Buttons	Buttons LED
<b>ACOP ISS Interface manager (ACOP Core SW)</b>		
It manages the Rack Interface Protocol with the Express Rack	Rack Interface Protocol Management	N/A
It manages communication protocol on the High Rate data Link	HRDL Driver (ISO/OSI) Link Layer	HRDL ISO/OSI network, Transport, Application layer
It manages the communication with the ACOP internal peripheral	Boards Driver (ISO/OSI link Layer) Digital IO Driver;	Peripheral communication application software

Functionalities	Basic SW (to be developed by CGS in the frame of this contract)	Application SW (not part of this contract)
	IDE controller Driver, Ethernet Driver	
The System Manager SW (ACOP Core Sw)		
data storage of the Science data and HouseKeeping data coming from AMS-02	N/A	All
On-ground Downloading of the AMS-02 science data and House-Keeping data coming from AMS-02	N/A	All
AMS-02 on-ground commands to AMS-02 routing	N/A	All
Routing of AMS-02 commands, acquired by means of the Express Rack laptop computer	N/A	All
Logging of the delivered command packets	N/A	All
Searching of the recorded AMS-02 science packet inside the data archive	N/A	All
monitoring and control of the ACOP system	N/A	All
Management of the Hard Drives during the data acquisition	N/A	All

Table 3-4 Basic SW and Application SW functionalities

### 3.5.6.2 GROUND SOFTWARE

The **ground software** is the software necessary for test, as well as for the training activities. It shall be specified in the design phase.

The ground software shall be composed of

- Electrical Ground support Equipment Software
- Training software

The EGSE software is the software for the ACOP test.

It shall run on a Standard PC with power PC or Intel CPU under Linux Operative System. The main tasks of the EGSE shall be the following:

- ACOP Tele-commands delivery
- ACOP-AMS House Keeping and Health status acquisition
- ACOP-AMS Science data packets acquisition
- AMS Commands delivery
- AMS format telemetry data packet simulator.

For the EGSE software is applied the same decomposition of the flight software. It shall provide two software packages:

EGSE Basic Software

EGSE Application Software

The EGSE basic software shall allow to test the Flight Software Basic software, while the EGSE application software shall provide all the functionalities for the Flight Application

Software. The Contractor shall develop the EGSE basic software while the Users will upgrade the EGSE providing the EGSE Application Software.

The training software is the software that shall be developed for the training of the Crew and the ACOP Ground personnel. It is the software that shall be installed on the Training Model.

The Contractor shall detail the system level software requirements, together with the associated hardware requirements (with reference to section 3.5.6.1). The Contractor shall identify how the overall software requirements are broken down into individual software (Computer Software Configuration Items - CSCIs). All software needs associated to the flight of ACOP System on ISS, covering both any flight software and the GSE software, shall be taken into account.

### **3.5.6.3 SOFTWARE IMPLEMENTATION**

In this phase, the Contractor shall produce, test, validate and integrate the software defined in the previous phase, together with the completion of the outstanding documentation.

The integrated software, as part of the QM, is accepted after successful completion of the QM Acceptance Review.

The integrated software, as part of the FM, is accepted after successful completion of the FM Acceptance Review.

The contractor shall document the user operational information in the ACOP System and related GSE Operations Manual. This information shall include a description of the Contractor's software maintenance concept.

### **3.5.6.4 PROTOCOL**

The Data Interface protocol shall be compliant to the SSP-52000-IDD-ERP section 9.2 Ethernet communication. This section of the applicable document shall manage the Interface communication protocol between ACOP and the Rack Interface controller.

The data interface protocol that controls the HRDL shall be compliant to related section of the Applicable document [12].

## **3.6 ENVIRONMENTAL REQUIREMENTS**

### **3.6.1 TEMPERATURE**

ACOP facility shall comply with SSP52000-IDD-ERP §5.1 page 5-1.

### **3.6.2 PRESSURE**

ACOP facility shall comply with SSP52000-IDD-ERP §5.1 page 5-2,5-3.

### **3.6.3 RADIATION**

Payloads on board the ISS are exposed to natural and induced radiation environments. The SSP 52000-PAH-ERP provides design guidelines and reference material addressing this subject including a radiation dose requirement of 30 rad (Si) per year.

## **3.7 PRODUCT ASSURANCE AND SAFETY REQUIREMENTS**

### **3.7.1 GENERAL**

The Contractor shall establish, implement and maintain a Product Assurance and Safety programme in accordance with this technical annex, with CGS PA Plan (Applicable document [7]) and related documentation Applicable Documents [19], [20] and [21]. The Contractor shall produce the relevant deliverable documents in accordance with the requirements and schedule established by this document.

The activities of the Contractor shall be planned to manage the necessary interactions with NASA for what concern: external interface design, safety, and the qualification and acceptance processes.

### **3.7.2 SAFETY**

In consideration of the importance of Safety for manned missions, both in terms of design compliance with the safety requirements and product conformity to the design, the Contractor shall take full responsibility for the following activities:

- a) Preparation of Flight and Ground Safety Data Packages as defined in Applicable document [7] and the submittal/presentation thereof to NASA. The Contractor shall submit the Safety Data Packages at the time of the ACOP system project reviews in a preliminary form compatible with the status of the design and the objectives of the review. These packages are subject of approval by NASA.
- b) Performance of the complete Safety Verification process including checking and approval of analyses carried-out by subcontractors, and verification of product conformity to the design and approved configuration. In particular the Contractor's PA & Safety organization shall witness and/or check the safety related tests and inspections performed either internally by other Company's organizations or by subcontractors, to ascertain adherence to requirements implementation of prescribed conditions and acceptability of results. These packages are subject of approval by NASA.

Participation in the ISS Safety Reviews relevant to the presentation of the ACOP Safety Data Package to the ISS Safety Authorities, as System Developer. As a consequence of the Safety reviews, the Contractor shall implement the corrective measures or action items identified as necessary by NASA, in terms of the implementation of both hardware and documentation corrections.

Summary of the planned Safety Review

1. Phase 0/I Flight Safety Review
2. Phase 0/I Ground Safety Review
3. Phase II Flight Safety Review
4. Phase II Ground Safety Review
5. Phase III Flight Safety review
6. Phase III Ground Safety Review

### 3.7.3 OFF-THE-SHELF EQUIPMENT MANAGEMENT

In order to comply to the technical requirements and in particular to allow the implementation of ACOP with up to date technologies able to provide the requested functionalities this programme shall consider the use of COTS electronic equipment and a specific COTS management program shall be drawn to allow a reliable usage of this commercial equipment in space environment.

This management programme shall be based on ESA and NASA documents. In particular the Reference Document [1] shall be considered as guide document. In this paragraph the philosophy of this management program is shown.

#### 3.7.3.1 RISK EVALUATION

A risk assessment shall be performed in order to verify the possible risk areas affected by the commercial COTS and identify the possible method to bring the electronic equipment at a level compatible with the space environment.

In the table below are identified the major risk area with the identified method to upgrade the COTS and or get confidence of suitability at space environment.

<b>Risk AREA</b>	<b>Assessment</b>	<b>Method</b>
Safety	Non safety critical function shall be performed by means COTS electronics	
Reliability	An analysis of the available reliability data shall be performed.	Screening test: Burn-in Vibration at ACOP system level Functional test Visual inspection
Environment	Analysis to be accomplished to verify the compatibility to the space environment.	Use of space qualified conformal coating Thermal test at ACOP system level Vibration test at ACOP system level Shield to the radiation environment

It shall be considered that in these last years the reliability of the commercial part is dramatically increased in coincidence of the improving of the control process method such as statistical method and so on. Although the reliability of Hi-Rel parts is still higher than the commercial parts the gap between the two processes is quite small. Nevertheless a 100% screening program shall be performed on the electronic COTS in order to increase the reliability of the equipment.

For this purpose the screening flow encompasses:

- Burn-in test will be performed at equipment level. Test temperature and duration shall be chosen on a case by case basis in order to avoid significant reduction of the equipment life time.
- Visual inspection (unit level)
- Vibration tests at ACOP system level
- Thermal test at ACOP system level
- Functional test at equipment / unit level

### **3.7.3.2 RADIATION**

For what concerns radiation environment, thanks to the equivalent thickness of aluminum around ACOP, the estimated absorbed dose is negligible during the overall mission time (see section 3.6.3).

Single events effects shall not be considered critical for this type of application.

### **3.7.3.3 OUTGASSING/OFFGASSING ISSUE.**

No forbidden materials such as PVC (Polyvinylchloride), Beryllium shall be used in the electronic COTS. All the PCB shall be covered with space qualified conformal coating.

### **3.7.4 GIDEP ALERTS**

The Contractor shall provide for the assessment of relevance for incoming NASA alerts, and the definition, implementation and follow-up of necessary actions at any contractual level.

### **3.7.5 PA & SAFETY DOCUMENTATION**

In performing the PA and Safety tasks, the Contractor shall provide adequate documentation, as listed in 8.2.

## **3.8 GSE**

The Ground Support Equipment (GSE) of the ACOP shall consist of Mechanical Ground Support Equipment (MGSE) and Electrical Ground Equipment (EGSE).

It shall be developed to perform the following functions:

- To permit the functional, performance and environmental verification of ACOP system;
- To permit the ACOP system ground maintenance, including any necessary calibration and re-calibration, if applicable;
- To permit safe transportation of ACOP;

- To permit stand-alone operation of ACOP system at the post delivery integration site for nominal functional and performance check-out, for trouble shooting purposes and for the crew training;
- To provide an accurate simulation of the external interfaces that it replaces.

In particular, the GSE shall comprise equipment to provide a suitable environment for all the development support (a precise definition of all required features shall be given by the contractor):

- Commercial regulated power supply to provide ACOP with required power source;
- ACOP external interfaces simulator (external Payload, ISS TM downlink) to allow ACOP verification in the applicable external environment;
- Portable Printer;
- Harness and connector adapter, that provide the same external interface to power and data as found in the selected workspace aboard the ISS;
- EGSE Software to assess ACOP system performance and functionality;
- MGSE to assess the crew operability for ACOP and for ground training.

### **3.8.1 I/F SIMULATORS**

The Suitcase Simulator (ScS) simulates the ACOP to Rack Interface Controller (RIC) protocol and I/F's as defined in the SSP-52000-IDD-ERP document section 9. The ScS is the standard tool for the Express Rack Payload - RIC protocol and Interface validation.

The ScS is a standard provision that shall be made available to ACOP (see SSP-52000-PAH-ERP section 5.3 ).

Besides, ACOP shall be directly interfaced to the APS (Automated Payload Switching) and indirectly to AMS and the HCOR. The ScS has no High Rate Data Link output capability and in order to validate the HRDL I/F's an HRDL simulator is therefore required. The HRDL I/F's (TAXI scope) simulator shall be made available to ACOP to validate the interface.

The Scs and the TAXI scope are considered a standard provision equipment. .

## 4. VERIFICATION PROGRAMME

### 4.1 GENERAL

The ACOP System, including any software, shall be fully verified in order to ensure its flight worthiness and that it meets the applicable performance and design requirements. Full verification encompasses the verification of all system level requirements, whether performed at system or subsystem level.

The Contractor shall verify the requirements as specified in the verification method field of the requirements tables in the ACOP System Specification document once approved.

The verification shall be performed by one of the following methods or by a combination thereof:

- Analysis (A)
- Review of Design (ROD)
- Demonstration (D)
- Similarity Assessment (SIM)
- Inspection (INS)
- Test (T)

All physical and functional performance parameters, interfaces and safety controls shall be verified.

Relevant to the stated verification method, the Contractor shall perform the following tasks:

- a) Define the detailed verification conditions for each corresponding design requirement.
- b) Define per requirement the resulting analysis, test, product assurance control, type of closure document and close out schedule.
- c) Perform the corresponding verification activities and close out each verification requirement against the specification requirement.

The Contractor shall control the verification programme by means of the Verification Matrix.

A preliminary Verification Matrix, reported below. It defines the test to be done on the Models to be delivered. It shall be refined in the Verification Plan document.

<b>Tests</b>	<b>LFM</b>	<b>TrM</b>	<b>QM</b>	<b>FSM</b>	<b>FM</b>	<b>Spare Parts</b>
Functional Tests	X	X	X	X	X	X
Physical & Mechanical		X (Mechanical I/F)	X		X	
Vibration			X		X	
Thermal			X		X	
EMC/EMI			X			
Acoustic Noise			X		(X <sup>2</sup> )	

*Table 4-1 Preliminary verification matrix*

A complete Verification Matrix, shall be provided as part of the Verification Plan and include the identification of all system and subsystem requirements as well as the identification of all verifications by Analysis and Demonstration.

A final verification Matrix shall be provided, as part of both the System Specification and the Verification Plan.

*The verification shall be performed consistent with the programme milestones. The planning and recording of verification close-out shall be made in the Verification Plan.*

## **4.2 SOFTWARE VERIFICATION:**

The planned software verification program foresees the documented tests at the following levels

- SW/SW Integration Test vs the Architectural Top level Design Document:
  - Software Integration Test between the ACOP core Basic SW package and the ACOP core Application Software Package.
  - Software Integration between ACOP core SW and ERLS SW.
- Software System Test: software test of the ACOP system overall vs. the Software Requirement Documents
- Software Acceptance Test: software test of ACOP system overall vs the ACOP System Specification.

## **4.3 CLOSURE OF REVIEW OF DESIGN VERIFICATIONS**

It shall be a Contractor objective that requirements of an unquantifiable (e.g. subjective) nature (such as some human factor requirements) that are to be closed via Review Of Design, are closed at the time of completion of the CDR. The Contractor shall prepare, in time for the CDR, prototypes of the critical parts (if any) of ACOP System of sufficient fidelity to allow this objective to be realized.

## **4.4 ANALYSES**

The Contractor shall perform studies and trade-off in order to optimize his selection of design solutions from technical and programmatic points of view, considering also life-time

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<sup>2</sup> Acoustic Noise tests shall be performed on the QM. If the results are marginal, they will be performed also on the FM

support aspects. All verifications by analysis shall be documented in analysis reports. All verifications by analysis shall be closed prior to the release of the manufacturing drawings.

#### **4.4.1 FUNCTIONAL PERFORMANCE ANALYSIS**

The Contractor shall perform all the necessary functional and performance analyses to demonstrate that the design of the ACOP is compatible with its functional and performance requirements as given in the System Specification. The results of these analyses shall be considered in the design reports.

#### **4.4.2 ELECTRICAL ANALYSIS**

The Contractor shall perform all electrical analyses needed to demonstrate that the ACOP design is compatible with the requirements as defined in the System Specification Document. In case the same verifications can be performed by tests the Contractor shall propose a test based adequate approach.

The Contractor shall analyze the electrical architecture including internal and external interfaces, and derive design solutions to achieve the required performances within the overall budgets.

The Contractor shall perform electrical analyses covering the data and electrical power characteristics, shielding, bonding, and grounding. These analyses shall be performed in compliance with the applicable requirements. In addition, the Contractor shall evaluate the compatibility of the off-the-shelf equipment with respect to the applicable electrical design, identifying the required modifications.

The Contractor shall analyze the requirements related to the local management and control functions, failure detection, isolation, and recovery capabilities, safety compatibility, and sensor and actuator redundancy management.

The Contractor shall analyze the required electrical interface characteristics and performances, command and monitoring distribution, data rates, timing, delays, and synchronization, demonstrating a compatible electrical equipment interface design and layout.

The Contractor shall analyze the power resources needed by each ACOP sub-system in order to operate in nominal and non-nominal conditions.

The Contractor shall analyze connector and wiring design to provide a compatible equipment interface design and layout.

The Contractor shall perform the necessary analyses as inputs for establishing a ground and in-flight checkout concept.

The Contractor shall perform the necessary analyses which are required in case of actions following NCRs.

#### **4.4.3 LIFE CYCLE ANALYSIS**

The Contractor shall generate a life cycle analysis based on the expected orbital and ground duty cycle (for time-varying and life-influencing factors such as mechanical cycles, thermal cycles, and electrical cycles) that shall be taken into account in the design and verification activities.

The outcome of this analysis shall be reflected in the ACOP Design Report, the FMECA and Single Point Failure (SPF) List and the facility Maintenance Plan.

The ACOP system lifetime the Contractor shall consider is: 3 years.

The ACOP mission duration shall be: 45 months.

The ACOP operative life shall be: 3 years.

#### **4.4.4 OPERATIONAL ANALYSIS**

The Contractor shall perform all operational analyses needed to demonstrate that the design of ACOP is compatible with the ISS operational requirements, as described in the ISS related documentation.

In particular, analyses shall be performed to demonstrate that the crew operations and crew time requirements, the stowage, the up- and down- load requirements are compatible with the requirements and resource allocations. Where applicable, operations test will be included in functional tests.

#### **4.4.5 TEST AND ACCEPTANCE REVIEWS**

##### **4.4.5.1 GENERAL TESTING APPROACH**

Verification methods shall be in accordance with Applicable Document [13]. In case of the document allows analysis or test, the contractor shall define in the ACOP Verification Plan the most appropriate approach.

Where tests are performed on actual flight hardware, the Contractor shall assess and implement any refurbishment prior to starting any acceptance related activity.

The testing shall be in accordance with the test requirements contained in the Applicable Documents..

The Contractor shall provide:

- a Test Procedure, at least two weeks in advance of the test, unless an alternative period is agreed. Testing shall not start before approval of the corresponding procedure
- the final Test Report, within three weeks after test completion
- on request, preliminary test results within two weeks after completion of the test.

##### **4.4.5.2 QUALIFICATION AND ACCEPTANCE**

The Contractor shall perform test reviews, involving the Test Review Board, after each ACOP qualification and acceptance test. The purpose of these reviews is to:

- Assess the test article configuration by comparing design standard and build standard
- Review the status of non conformances and to assess the impact on the validity of the test
- Review test data and logbooks and to verify the results from the initial test data evaluation
- Ensure completeness of the test data and the appropriateness of test decisions
- Authorise the next phase

The qualification and acceptance test programme shall take into account the previous history of the equipment, where it is an existing item. Where previous testing is not in conformity with the specified levels, complementary testing shall be performed.

The qualification and acceptance tests shall be performed in accordance with test procedures which are approved.

As close out evidence of the Contractor's verification program, the Contractor shall submit all documentation (analysis reports, test reports, etc.) required for the qualification/acceptance of the ACOP System, as part of the Acceptance Data Package. The Acceptance Data Package shall be available when all qualification and acceptance activities have been successfully performed and the related final test reports have been completely established.

Approval of this data package shall be the basis for closing out the verification activities.

With respect to the deliverable items acceptance review, the Contractor shall prepare and support, in terms of documentation, logistics, and technical resources, the Acceptance Reviews to carry out a detailed assessment of the compatibility of the technical development with the project requirements.

## 5. **RELIABILITY AND MAINTAINABILITY**

During the period of preliminary design prior to the PDR, the Contractor shall develop and document the approach and requirements for maintainability and for the maintenance of the ACOP System with respect to its use on the ISS. The resulting PA approach and requirements shall be appropriately documented during the subsequent phases of detail design, manufacture and verification.

## **6. Manufacture, Assembly And Integration**

### **6.1 MANUFACTURING**

The Contractor shall implement the manufacturing and refurbishment modes as described in the ACOP Project Plan.

Manufacturing and refurbishment of the ACOP System shall be in compliance with established refurbishment, manufacturing and assembly flows and approved processes and procedures. The fabrication of parts and the assembling of subassemblies shall be performed in accordance with released engineering documentation.

This control shall include timely availability of facilities and resources, usage of skilled personnel, and assurance of qualified workmanship and conformance with required methods, processes and handling instructions.

The Contractor shall ensure that the tools, test equipment, jigs used are inspected prior to use and verified to ensure that hardware is built to the approved drawings. All tooling shall be properly maintained, calibrated and stored throughout the contract duration along with relevant documentation. All electronic test equipment developed, including their computer software, as used for in process testing of the ACOP System and the associated subassemblies down to printed circuit board level, shall be identified, recorded, maintained, calibrated and stored throughout the contract period along with relevant documentation according to the applicable document.

### **6.2 ASSEMBLY AND INTEGRATION**

The Contractor shall provide all the necessary resources to ensure and verify that the sub-assemblies and assemblies of ACOP System can be correctly assembled.

## 7. PACKAGING, TRANSPORTATION AND STORAGE

In this section the transportation of the ACOP models is planned. The transportation involves the following ACOP models for the following activities :

**TrM** : Transportation of the Training model (TrM) to the Training Facility ( JSC)

**FSM** : Transportation of the FSM to the CERN for the ACOP-AMS test.

**FM** : Transportation of the FM to the KSC for launch processing.

The contractor shall be responsible for ACOP models transportation according to the above list.

### 7.1 PACKAGING

The Contractor is responsible for the provision of appropriate packaging for the hardware as necessary to prevent damage during transportation and storage. The packaging shall be such as to allow transport of the hardware via surface or air transport. The transport containers shall be reusable.

The Contractor shall make available transport containers for ACOP System items and GSE to permit the return of such items, in the event of their failure at e.g. the NASA JSC or KSC, to their developers for repair.

All packages shall be conspicuously marked with handling instructions and pictorial markings symbolizing

- the grounding receptacle (if required)
- the slinging/hoisting points
- the moving/tie down points
- the total weight and C/G position

The specifications for the symbols, their positions, colors and sizes shall be in accordance with international standard ISO 1950. The direction of transportation shall be indicated by labels on the outside of the package, corresponding to the required transportation orientation of the hardware. In addition, all critical items shall be labeled with "Critical Item" tags.

The Contractor's responsibility includes the updating of any packing procedures and the maintenance of materials.

### 7.2 TRANSPORTATION

The Contractor is responsible for transportation of the ACOP and support equipment to their final destination (JSC or KSC or other sites), including the associated expenditure (transportation, insurance). The transportation relevant information shall be documented in the Acceptance Data Packages.

### **7.3 STORAGE**

The hardware which is required to be stored shall be adequately protected against deterioration and damage. Life limited items and materials must be listed and controlled for identification and possible elimination of over-aged materials from storage sites.

Storage requirements shall be documented in the relevant Acceptance Data Packages.

## 8. DELIVERABLES

### 8.1 MODEL PHILOSOPHY

Contractor shall provide the following models (including related software) and spares:

#### a) Low Fidelity Model (LFM)

The purpose of the LFM is to allow early SW development and test of the AMS-02 that shall be supported by ACOP during the mission.

#### b) Training Model (TRM)

The purpose of the TRM is to support the following main activities:

- Crew training procedure and flight procedure development and validation;
- Training of crew trainers;
- Crew training

In order to support these activities, the build-standard of the TRM shall be as follows:

- Replicate all FM functions and performances
- Provide a MMI identical to that of the FM
- Implement the same or equivalent safety controls as implemented on the FM
- Use commercial of the shelf components.
- Provide data in a format that can readily be incorporated into a common database with that coming from the FM and TRM
- Support procedure preparation and validation, and training in connection with off-nominal trouble shooting and maintenance activities.

#### c) Qualification Model (QM)

The QM shall support all the qualification test as follow:

- Functional & Performance Tests
- Physical Characteristic check
- Acoustic noise
- Random Vibration and Resonance search
- Thermal test
- Electro-magnetic interference / Electro-magnetic compatibility

The purpose of the qualification model is also to allow the development and test of the unit without interfering with the integration of the FM.

d) Flight Model (FM)

The FM shall consist of all elements, hardware and software, that shall be carried and/or utilized on-board the Space Shuttle and ISS.

e) Flight Spare Model (FSM)

The FSM is an equivalent of the Flight Model and shall be obtained from the refurbishment of the QM. The QM parts that have been overstressed during qualification tests shall be replaced in the FSM. The QM mechanical and electrical parts that are not overstressed by the qualification test shall be exploited for the FSM.

f) Spare Parts and Assemblies

The Contractor shall provide spare components / parts in order to maintain and to permit the fast repair of all ACOP System models. The Contractor shall propose the most suitable model philosophy and shall evaluate the possibility to upgrade models .

The ORU Spare Parts list shall include the following:

- 2 Hard Drives
- 1 Cpu Board
- 3 Carrier Boards with PMC
- 1 PMC module for each peripheral type
- 1 Power Board
- 4 Fan Boards
- 6 Optical cable
- 2 Power Cable
- 2 Ethernet Cable

In addition to the ORU Hard Drives, the following shall be considered as on ground spare parts for development purposes:

- 2 Hard Drives