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P A P E R

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Alenia Spazio

THE COLUMBUS ATTACHED LABORATORY

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ABSTRACT

As an integral part of the manned core of the Space Station Freedom, the European Columbus Attached Laboratory is one of the three Laboratory Modules to provide an environment and facility for laboratory work, including operational support to the crew.

Following the Preparatory Phase and major interfaces agreement reached between NASA and the International Partners, the Columbus Attached Laboratory has reached a level of definition which will allow proceeding with the full development phase.

This paper describes the main architectural and technical features of the current Columbus Attached Laboratory, as they have been derived from external and internal system requirements, in order to achieve overall performance capability and compatibility with the Space Station Freedom. Relevant aspects and design solutions are presented in the field of required resources, Payload and Crew accommodation.

The interoperability domain which regulates Columbus Attached Laboratory on-orbit life in its integrated role within the Space Station Freedom is also addressed in some of its main features.

Concluding remarks cover the major steps of the design, development and qualification plan.

1. INTRODUCTION

The **Columbus Attached Laboratory** is an integral part of the manned core of the **Space Station Freedom** (see Fig. 1, page 2) and is one of the three Laboratory Modules (with the NASA Lab and the Japanese Experiment Module) to provide an environment and facility for laboratory work, including operational support to the crew.

It will be launched from the Kennedy Space Center by the US National Space Transportation System and berthed to the Space Station Freedom by the Space Station Robotic Manipulator. Attached Laboratory operations and servicing is part of the nominal Space Station Freedom operations and resupply cycles (90 days). Operations do include end to end communications to the NASA Space Station Mission Control Center and to European experimenters via the Space Station communication system and TDRSS (Tracking and Data Relay Satellite System).

From this overall mission and operational scenario, the major requirements behind the Attached Laboratory design can be summarised as follows:

- Compatibility with the NASA Space Shuttle for launch and deployment
- Provision of a laboratory environment for experimenters
- Functional and physical compatibility with the Space Station Freedom and provided resources
- Operational support to the Crew (life and working environment)
- Compatibility with space environment
- 30 year life time

In order to meet these requirements, and taking into account basic agreements reached with NASA on major technical issues, the original Spacelab concept has been completely modified during the Preparatory Phase and the Attached Laboratory current architecture is now considered mature enough to start the full development phase.

This paper describes how the main architectural and concept choices have been derived from the System requirements above, specific design details are given as well as the selected development and qualification processes.

(*) ALENIA is the new Company resulting from the merger of Aeritalia and Selenia, taking over full responsibility for their functions, responsibilities and activities.

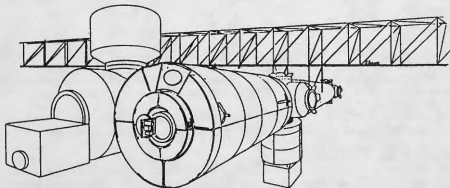


Fig. 1 - Columbus Attached Laboratory

2. MAJOR REQUIREMENTS AND ASSOCIATED CONCEPTS

• **Compatibility with the US National Space Transportation System (NSTS)**

All Space Station Manned Base Elements are brought on orbit by the NSTS and have therefore to comply with the NSTS requirements and capabilities:

- **Volume available in the cargo-bay** - It limits the external diameter (including Meteoroid and Debris Protection System) and the overall length of the ESA Module, taking into account other cargo items like the NSTS docking adaptor
- **Attachment stations available in the cargo-bay and constraints on the overall cargo Center of Gravity location** - C.o.G. constraints have been modified in order to improve safety for abort landing (Challenger impact), such that for long Modules like the ESA one, the center of gravity has to be significantly offset from the middle attachment (keel fitting). Possible solution has been found using a hyperstatic suspension and a specific configuration at launch.
- **NSTS Load Carrying Capability** - Due to the launch loads constraints, the Attached Laboratory cannot be launched fully outfitted and Payload complement shall be uploaded by separate NSTS flights.

• **Functional and physical compatibility with the Space Station Freedom**

As an integral part of the Space Station Manned Core, the Attached Laboratory has to be functionally and physically compatible with the Core Space Station architecture and provided resources through a clear definition of the major interfaces safeguarding the ESA responsibilities on the European Element.

For the functional compatibility, the main technical issues on which principle agreements have been reached with NASA are dealing with:

- Provision of power with an installed rating of 25 kW
- Provision of heat rejection capability compatible with the power resources
- Use of Space Station centralised Environmental Control and Life Support System
- Data transmission to ground via TDRSS (including Audio and Video data)
- Interoperability of computer systems and crew workstations for data exchange and standardised operations across the Space Station Freedom.

Physical compatibility is ensured by use of Common Berthing Mechanism for which the possibility of joint development is under elaboration between ESA and NASA.

• **Accommodation flexibility of Payload facilities and experiments**

The Attached Laboratory offers a set of standard resources for payloads:

- Volume with accommodation in replaceable single and double Racks
- Power from 1.5 to 6 kW per double racks
- Appropriate heat rejection via water and air cooling
- Data communication and video transmission through centralised equipment
- Separate vacuum and venting facility
- Supply of fluids (Nitrogen) from centralised storage
- CO₂ Fire Suppression System

Payload resources are standardised to a large extent between all three Laboratories to allow Payload Facilities and experiments to operate in any of the three Modules without major modifications in order to improve Payloads manifesting flexibility. In addition to standard racks, the Attached Laboratory provides a scientific Airlock for medium size Payloads requiring exposure to the outside Space environment.

● Support to the Crew

For a permanently manned Station, support to the Crew means:

- Life compatible environment which is ensured by use of the Space Station centralised Environmental Control and Life Support System
- Efficient working environment for which in addition to proper implementation of Human Factor requirements in the design, a concept of advanced Crew Work Station and associated facilities is being developed
- Safe environment through
 - Emergency Warning and Caution System (EWACS) associated with a CO₂ Fire Suppression capability
 - Fault tolerance requirements implying the concept of Failure Detection Isolation and Recovery.

● Compatibility with the space environment

Taking into account for a permanently manned Station the 30 years life time requirements, the most critical environment is coming from Meteoroids and Debris. In particular, the trend for Debris is showing a significant increase in the future, should a space debris policy not be agreed worldwide soon enough.

From the current knowledge, using available analytical tools and results from test campaigns undertaken both by NASA and by ESA as part of the Columbus Preparatory Programme, a Meteoroid and Debris Protection System (MDPS) has been designed, trying to optimise the protection efficiency against the launch capability.

● 30 years life time

Requirement for 30 years life time is imposing severe and new constraints (with respect to Spacelab) on the design, in particular:

- Hardware and Software maintainability for which concept have been developed for Orbital Replaceable Units (ORUs) and Software Replaceable Units (SWRU's)
- Protection against the Space environment by a "Meteoroids and Debris Protection System" (shielding) maintainable in orbit
- Access, inspection and on-orbit repair capability of the Primary Structure
- Design flexibility for reconfiguration
- Standardisation of hardware and software designs to minimise maintenance costs during the operational phase.

3. ATTACHED LABORATORY ARCHITECTURE AND DESIGN

3.1 Overall Layout

APM external configuration (Fig. 2, page 4) consists of a pressurized cylindrical main body with end cones at each side. The pressurized environment is assured by a 4.2 m inner dia cylindrical shell consisting of 3.2 mm thick aluminium panels, with waffle-pattern design externally oriented ribs, stiffened by T-shaped rings.

The forward cone is designed to accommodate the docking/berthing mechanism for permanent connection to one of the SSF resource nodes. A closure hatch is also provided at this egress route complying with all operational and functional requirements of SSF, including all necessary commonality with other hatches for crew safety.

The aft cone accommodates the installation of the scientific airlock designed for exposure of payloads to the space environment. A view-port is installed in the upper part of the APM aft cone for earth and space viewing.

The APM module is equipped with hyperstatic scheme fittings for transportation in the NSTS cargo-bay and is deployed for berthing to the appropriate node, by the SPDS system. A double wall system consisting of the basic APM shell combined with on-orbit replaceable sandwich panels used as shielding elements having a "bumper" effect, assures protection against micrometeoroids and space debris. Thermal insulation blankets are mounted between shell and bumper.

The internal layout is the result of various trades in volume efficiency from a physical and operational point of view and in ergonomic design criteria. The adopted design (Fig. 3, page 4) is based on a four stand-offs configuration providing double symmetry in the typical APM cross section and giving the possibility of installation of identical racks in all four directions. Ceiling, floor, left and right indicate the four sides for orientation purposes to provide local "1-g" vertical reference for the crew.

The stand-offs are a mechanical support for utility lines and power/data distribution equipments. They also include hinge provision such that each rack has in fact the capability to be hinged, for rack access from the rear, for inspection of utility lines and utility interfaces and for inspection of the pressure shell internal surface. Each stand-off can also be removed and replaced for on-orbit maintenance, servicing and reconfiguration purposes.

The floor panels lying on the subfloor racks provide vertical reference to the crew and separate the crew compartment from the subfloor area dedicated mainly to the accommodation of thermal control and life support equipment.

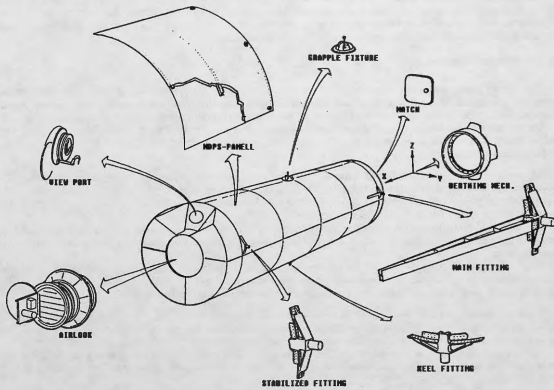


Fig. 2 - APM External Configuration

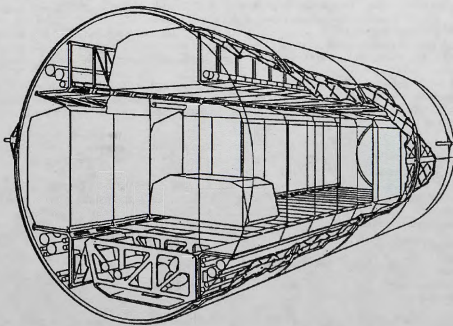


Fig. 3 - APM Internal Layout

The subfloor area is equipped with the same mechanical interfaces used for the side racks to permit installation of racks dedicated to storage or rack skeleton structures used as support structures for installation of subsystem equipment and components. The overhead area provides volume for accommodation of payload racks requiring limited power and heat dissipation and of storage racks/compartments.

3.2 Functional Architecture

The APM System, according to its definition as an integral part of SSF, has a full on-orbit autonomy for payload nominal operations, with crew and ground control override capability. It relies on the core Space Station for consumables supply, power supply, heat rejection, up/down link communication, habitation provisions.

During nominal conditions, the APM can be operated with "open and closed hatch" while, in a contingency case, the APM system is operated in a "closed hatch mode" maintaining utility interfaces with the ISS such as power, data, consumables.

All utility resources are transferred between the SSF Interconnecting Node and APM via dedicated utility lines routed in the forward cone at docking/berthing mechanism or feed-through level. Two crew members will nominally operate the APM system and payloads after the initial APM assembly and activation mission and the P/L integration mission. Design allows for up to six crew during shifts.

The APM is designed to be automatically operated during nominal operations with crew and ground control override capability. Its functional concept is based on four functional buses: power and data buses, thermal and air cooling loops.

Four information management levels perform and control on-board functions according to a hierarchical organization built up to reduce dependency from ground control and to minimize crew involvement, whilst still allowing at the same time crew overriding capability and intervention at all functional levels.

Electrical power generation and main distribution to the elements composing the Space Station is centralized at Space Station level. The APM receives electrical power conditioned at 123 ($\pm 3\%$) VDC through four power feeders each sized for 12.5 kw, and takes care of the internal distribution to subsystem equipments and payload.

Each couple of feeders is connected together within the APM power distribution system so as to form a double redundant bus power distribution system with a star distribution for P/L powering and bus distribution for APM system.

12.5 kw average is provided to the payload when 20 kw are made available from SSF. The voltage level at P/L rack interface is 123 V DC +3/-8V.

Acquisition and distribution of data necessary to manage and control the overall system and payload activities, is supported by means of distributed Standard Acquisition and Distribution Units and Subsystem or payload dedicated Local Area Networks. Data Management is performed by dedicated software (initialization, system and mission management, subsystem management) running on standard processors.

A Data Base System is used for all data and software storage. Data exchange with SSF is achieved by means of dedicated gateways, while communication with the ground is implemented through a multiplexing function and interfacing with the Space Station radio frequency section. This communication to the ground is also used for audio and video links.

On-board audio distribution is based on an analog technique and is implemented through a point to point connection concept. The video distribution is based on an analog colour system and a star distribution concept with digital modulation. A caution and warning system detects, announces and makes available the parameters of hazardous and critical events.

In addition to the make-up of breathable and earthlike atmosphere, the Environmental Control System takes care of APM Subsystem and payload cooling by providing the required radiation sink temperature, air and water cooling capability and thermal insulation.

Cabin air circulation is assured by two cabin loops with air flow controlled by a by-pass valve in parallel to the constant speed fans. Local air diffusion is guaranteed by recirculation fans located at the upper stand-off. Each loop is sized for 2-3 kw.

Intermodule ventilation with core SSF node assures:

- CO₂ removal
 - O₂ supply
 - N₂ supply
 - trace gas monitoring
 - pressure control
- } for repressurisation only

Revitalized air from core-SSF is fed into APM cabin loops while air returned to core-SSF is driven by the fan assy.

Samples of cabin air are provided to core-SSF for contamination monitoring and control. Humidity control is performed by APM and condensate water given to core-SSF for central processing. A typical cross section of APM with main functional line location layout is as per Fig. 4, page 6.

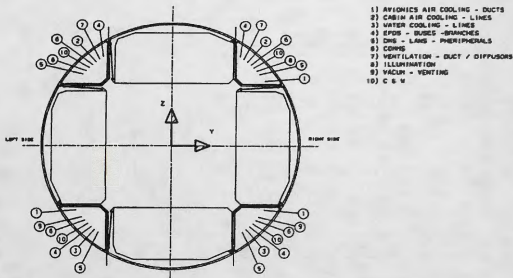


Fig. 4 - APM Typical Cross Section

3.3 APM Fault Management System

As a relevant application within the APM information management system and its hierarchical organization, this section provides a summary description of the APM Fault Management architecture from an operations perspective.

The APM performance at System, Subsystem or Payload level is monitored in order to verify that it is in the prescribed performance domain.

Events may anyway occur which put the APM performance out of the allowed domain; this is normally due to failures occurring at APM system, Subsystem or Payload functions. These events may signal permanent changes in the system behaviour or be intermittent. In addition, the mechanisms which allow the APM to detect events may be faulty or signal spurious events.

The APM fault management has a hierarchical architecture consistent with the overall APM information management system. This means that every Subsystem provides only for management of faults within their own fault management visibility and decision domain, whilst the System Level Fault Management (as implemented in the APM-SMM) provides for System Level co-ordination of Subsystem level fault management and for identification and isolation/recovery of failures whose symptoms are handled by APM-SMM processing.

Fault management is performed at the lowest level possible in the APM hierarchy. Only if fault conditions do not allow for local handling, local fault management processing conclusions are passed to upper level(s). The upper level undertakes the role of fault management co-ordination.

When FDIR (Fault Detection, Isolation and Recovery) actions are performed locally, the upper level is notified of the results taken. Such notification may trigger the system level to perform (command) co-ordinated recovery activities in other subsystems (or payloads) as the initial recovery may have side effects.

The upper level (s) may also request lower levels to initiate locally provided actions. An FDI function is provided at every hierarchical level. The exceptions at level $n+1$ trigger the FDI process at the same level (i.e. $n+1$ level) and constitute the input of the process itself. The output of such processing consists of the identified candidate failures. If no failure can be identified unambiguously at level $n+1$ then feedback to level n occurs.

4. COLUMBUS APM - SPACE STATION FREEDOM MCS INTER-OPERABILITY OVERVIEW

All relevant functions of the APM laboratory system are performed in a fully coherent and transparent mode with the overall station system, payload and crew operations. The inter-operability domain is meant to cover any physical/functional/operational interface which regulates APM on-orbit life in its integrated role within the SSF.

This section addresses some of the many fields which fall within this domain and provides a summary of their current implementation in the APM design.

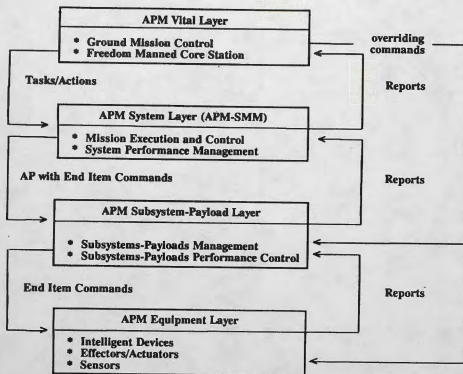


Fig. 5 - Hierarchical Operations Management Layers

4.1 Information Management System

The architecture of the APM information management system is defined considering its integrated function as a component of SSF. Besides its dependency on the Manned Core Station (MCS) in terms of resource generation, APM uses communication services supplied by the Space Station Freedom in support of the flight operations.

In addition, it is controlled by the Space Station Control Center (SSCC) and supported in Europe via the MSCC and ground infrastructure which includes an APM Engineering Support Center. Payload Operations on board the APM are directed by the SSF Payload Operations and Integration Center.

These and other constraints mean that the APM information management system is functionally connected to the SSF information system, and its management hierarchy designed to be consistent with the overall SSF management hierarchy. The APM on-board hierarchical operations management is structured as per Fig. 5.

The so called **Vital Layer** includes the operational interfaces between the APM and the external control entities which are the Space Station Control Center and the Manned Core Station.

During routine operations, actions as well as commands/messages to APM are processed by the **APM System Layer** (Tier 2) which is based on the APM and Mission Management Software (APM-SMM).

APM-SMM provides, in particular, for control of the execution of incoming actions and for control of the APM overall System and Payload performance (i.e. System monitoring, Fault management, Configuration management, Checkout, Resource management).

The **APM Subsystem and Payload Layer** (Tier 3) is commanded and controlled, in routine operations, by the APM-SMM. Incoming actions are expanded by APM-SMM in Automated Procedures with commands which are executed by this layer.

Subsystems (and Payloads), directly control and actuate the APM end-items (i.e. Sensors, Actuators, Effectors) as well as intelligent devices of the avionics architecture.

Overriding commands may be sent by a given level to the lower levels, by-passing intermediate lower levels to provide for safe control of the Attached Laboratory during unplanned situations as well as contingencies.

The APM/MCS Inter-operability issues related to system management, information/data exchange and P/L operations can be summarized in the following main aspects:

- a System Command & Control
- b Crew Work Station Operations
- c P/L Management and Operations
- d On-Board Data Bases Objects Sharing
- e Ground Data Bases Objects Exchange
- f On-Board Audio/Video Systems
- g On-Board Power Distribution

a System Command and Control

As mentioned above, the system Command & Control concept of APM (Tier II manager) is based on predefined actions and operational tasks implemented via automated procedures and application software which generate the correct sequence of direct commands for all active parts of the system.

On the other hand, the SSF/MCS concept is based on a system manager (Tier I manager) which is able to handle 'objects' providing services to each other and interacting through 'status changes'.

These two different approaches are harmonized by providing an object model of the APM and the relevant set of services which can be understood by the SSF/MCS Tier I and can be accessed via a Command & Control protocol, allowing the Space Station Control Center to generate an integrated mission planning.

b Crew Work Station Operations

The Inter-operability concept applied to the on-board work stations implies that all work stations provide for a consistent and SSF standardized control over all space station systems/subsystems applications. This task has to be performed in a fully transparent way both for human factors and for operations.

The SSF work stations' Inter-operability is implemented through the "Virtual Terminal" mechanism, which allows all the on-board work stations to access each other, i.e. each work station is able to run software applications remotely.

In other words, the virtual terminal mechanism allows the use of, for example, the APM work station as if it were the MCS one and vice versa, in a fully transparent manner, without requiring any software transportation and/or compatibility, and regardless of the software objects' whereabouts. In addition, all the SSF work stations, including the APM one, provides the same human computer interface.

c P/L Management and Operations

Payloads can be located in any SSF laboratory, regardless of the payload provider (European, American, etc.). This means that each SSF module is able to present to a user the data management interface of any other module through a mechanism similar to the "Virtual Terminal" one, as described above: any P/L can assess locally and/or remotely any SSF service.

In other words, if an American P/L, designed for interfacing the SSF/MCS software services, is located in the MCS, it accesses all needed services locally; if the same P/L is located in the APM, it accesses the same resources, but remotely and in a totally transparent way, thanks also to the standardization of the data network protocols. This is valid, reversing the conditions, for an European P/L as well. In addition, a set of standard avionics H/W interfaces is provided by all SSF laboratories.

With the above implementation, activity on any P/L presents two aspects:

- P/L resource envelope allocation and management, e.g. power outlets and thermal cooling valves set, etc. This task is always performed by the local system manager of the laboratory which accommodates the P/L, using local services.
- P/L experiment conduction and relevant data exchange. This task is performed by the P/L and the relevant P/L manager/operator, interfacing either local or remote services; therefore the P/L can be independent from the physical position in the different SSF Laboratories.

d On-Board Data Base Object Sharing

The sharing with the SSF/MCS of the APM data base objects is obtained providing the SSF/MCS with the models of the limited set of APM objects impacted by Inter-operability operations (inter-operable objects).

This object knowledge sharing is statically implemented on-ground as described in the following section.

e Ground Data Base Objects Exchange

The APM ground data base has to exchange information with more than one data base on the NASA site. In particular:

- the information exchange from the NASA mission data base to the APM one can be considered limited to graphic objects (e.g. icons), therefore compatibility is attained adopting the same software development tool for implementing those objects. Nevertheless, even though the same tool is chosen, there could be a necessity of slight conversion of the object definition, according to the possible modifications made on the tool by the parties.
- the information exchange from the APM mission data base to the NASA one requires a dedicated conversion for all objects which have to be known by the SSF/MCS on-board data base.
- the information exchange from the APM mission data base to the Space Station control center requires a dedicated translation only for the object definitions (and not for the internal structure/content of the objects themselves), in order to allow the control center to be aware of the overall SSF on-board configuration.

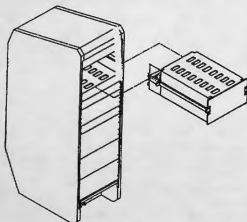


Fig. 6 - Typical Rack Subunit Installation

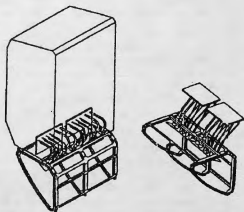


Fig. 7 - Routing of Rack Utility Lines

f On-Board Audio/Video Systems

Inter-operability in the area of Audio and Video services is obtained through a high level of standardization within the SSF/MCS. In particular, the APM Audio system is based on the same principles and devices adopted in the SSF/MCS, including the portable crew headsets, while the APM Video system provides the same baseband standard and the same interface for the on-board video portable cameras.

This implementation allows crew operations needing Audio/Video support to be location independent.

g On-Board Power Distribution

The APM power distribution is fully compatible with the SSF/MCS one at user level.

4.2 Laboratory Facilities and Payload Accommodation

Besides its essential role as accommodation for subsystem equipment in the APM architecture, the rack's primary task is the transportation and accommodation of payloads. Provisions for mechanical fixation and housing, as well as the appropriate environmental enclosure and interfaces to the utility resources and command lines are part of rack functions.

The rack is designed with the structural capability to withstand all the On-Orbit loads and the transport environment in the APM and in the Pressurized Logistic Carrier. It is conceived as a multi-use device made up of a basic common part that can be outfitted with different degrees of integration to satisfy rack application requirements like:

- accommodation of payloads
- installation of subsystem equipment
- use as storage compartments
- accommodation of workstation equipment and crew interface items.

Payload facilities/subunits and subsystem equipment are installed in the rack by sliding devices, which render them withdrawable and replaceable (Fig. 6).

The fully integrated rack is considered an Orbital Replaceable Unit, therefore its interfaces are standardized in all APM payload locations and are compatible with the Pressurized Logistic Carrier. In all lateral and ceiling racks requiring utility resources, the interfaces are connected frontally in the bottom-front area of the rack and connectors are accessible for easy manual mating/demating.

Utility resources are supplied to the rack in its nominal position and are maintained, by adoption of flexible lines, also in the rack tilted position (Fig. 7). For flexibility of equipment/facility installation and interchangeability, the rack's width and mechanical interfaces are designed according to unification standard EIA-125-310-C-77. Therefore a single rack can accommodate equipment designed according to the above "19-inch" standard.

The double size rack adopted in the Attached Laboratory layout accommodates two "19-inch" facilities placed side by side for larger facilities. Each side wall of the laboratory and the ceiling have the capacity to be equipped with 10 double racks for a total of 30 double rack stations, 26 of them available for payload accommodation or storage utilisation.

Within the side racks, the Attached Laboratory houses the primary work stations which are principally the Module Control Station and the Payload Work Bench. The primary tasks requiring human intervention are performed at these stations.

The Module Control Station is a dedicated global working area to provide access to all data management, audio and video services, images, graphics and copy of texts. The system housekeeping and the payload operation control are performed from the Module Control Station.

The Payload Work Bench is the primary work station for the performance of specific payload operations, e.g. pre-and post-processing analysis, servicing and maintenance.

Other work stations are called secondary and are distributed locally to permit direct operations on the payloads with crew assistance and support for special processes.

A specific facility provided by the Attached Laboratory in support of the payloads is the Scientific Airlock. It is installed in the aft end of the Laboratory and its function is to allow payload exposure to the space environment.

The location of the Scientific Airlock in the aft cone also allows both deep space and earth viewing.

After opening of the outer hatch, the payloads are exposed to the external environment by means of a payload mount sliding device.

The APM is equipped with a Vacuum and Venting Facility that provides the payload with the following capabilities:

- "clean" vacuum conditions for any payload requiring such an environment during its processing
- venting capability for evacuation and removal of waste gases from the payload facilities and from the Scientific Airlock.

Vacuum and venting functions are both accomplished with the use of dedicated lines connecting the payload accommodated in the lateral racks to the Fluid Management System of the Space Station Freedom.

5. DEVELOPMENT APPROACH

In the Columbus programme Alenia is the Contractor responsible for the Attached Pressurised Module.

The development program is **phased with main milestones** of SSF development, and tailored to offer for launch the fully qualified and verified module.

The program review approach contains the following major events:

- Preliminary Design Review (PDR) - Occurs after completion of development activities, including testing, and serves to authorize manufacturing and testing of Engineering and Qualification Models
- Critical Design Review (CDR) - Occurs after qualification testing and serves to authorize Flight Model testing
- Two Flight Acceptance Reviews - One occurring at Alenia premises after Flight Model testing and before first launch payload integration, and a second one after APM shipment, with installed payload, to the launch site.

The APM development model philosophy follows a classical approach as a result of various trades performed.

Development models and breadboard for equipment and subsystem activities are planned for design finalization; development fixture and mock-ups are foreseen at flight configuration level.

One **Qualification Unit (QM)** at full flight design and flight standard (including hi-rel) is foreseen for each equipment type in order to conduct full formal functional and environmental qualification tests.

Engineering Model (EM) units, fully representative of the **Flight Model (FM)** in fit, form & function (no hi-rel components) are foreseen for subsystem and flight configuration functional qualification testing. FM units are fully acceptance tested at equipment/assy and F.C. levels.

6. CONCLUSION

After an extensive Preparatory Phase, and development of major interfaces agreements with the Space Station Programme, the Columbus Attached Laboratory has now reached a level of definition such that the full development phase can technically proceed. This phase has been already started as part of the Columbus Phase 1 activities and Phase 2 should be confirmed in June 1991.

The Columbus Attached Laboratory together with the various resources provided by the Space Station Freedom shall offer to the User community, both European and International, unique opportunities with:

- a wide range of applications (Life sciences, Material sciences, General Physics, Chemistry and Technology, Astronomy, Solar Physics, Plasma Physics, Atmospheric Physics) using both internal Racks facility in a zero gravity environment and the capability of a Scientific Airlock
- a large volume available for Payloads similar to that offered by four Spacelab segments
- interfaces compatibility with the other Space Station laboratories and therefore Payload manifesting flexibility
- operating facilities for Experimenters and the Crew using advanced techniques for data processing/transfer and sophisticated man-machine interfaces.

To comply with these basic mission requirements, advanced technical features have been implemented in the Attached Laboratory design which shall allow wide operational capabilities in automatic mode or with the Crew, including automatic reconfiguration in case of failure.

In addition, the basic design is compatible with the needs of a long duration permanently manned Space Station which requires protection against space environment (space debris, radiations...) and reconfiguration capabilities through in-orbit maintenance.

ABBREVIATIONS

APM	Attached Pressurised Module
EWACS	Emergency Warning and Caution System
FDI	Failure Detection and Identification
ISPR	International Standard Payload Racks
JEM	Japanese Experiment Module
MDPS	Meteoroid and Debris Protection System
MCS	Manned Core Station
NSTS	US National Space Transportation System
ORU	Orbital Replaceable Unit
SMM	Software Mission Management
SSCC	Space Station Control Center
SSF	Space Station Freedom
SWRU	Software Replaceable Unit