

**THE COLUMBUS LOGISTICS SUPPORT AT THE APMC:
REQUIREMENTS AND IMPLEMENTATION ASPECTS**

N 94 - 23935

C. Canu
Agenzia Spaziale Italiana (ASI)
Roma (Italy)

L. Battocchio
ALENIA SPAZIO S.p.A.
Torino (Italy)

S. Masullo
CISSET S.p.A. - Space Division
Roma (Italy)

ABSTRACT

This paper focuses the logistics support to be provided by the APM Centre (APMC).

Among the Columbus ground infrastructures, this centre is tasked to provide logistics, sustaining engineering and P/L integration support to the ongoing missions of the APM, i.e. the Columbus Laboratory attached to the Freedom Space Station.

The following is illustrated:

- an analysis of the requirements that are levied on the logistics support of the APM;
- how such requirements are reflected in the corresponding support to be available on-ground and at APMC;
- the functional components of the APMC logistics support and how such components interact each other;
- how the logistics support function interfaces with the other functions of the ground support;
- how the logistics support is being designed in terms of resources (such as hardware, dataware, etc...).

Emphasis is given to the data handling aspects and to the related data bases that will constitute for the logistics activities the fundamental source of information during the APM planned lifetime.

Functional and physical architectures, together with trades for possible implementation are addressed. Commonalities with other centres are taken into account and recommendations are made for possible reuse of tools already developed in the C/D phase.

Finally programmatic considerations are discussed for the actual implementation of the centre.

Keywords : APM Centre, Columbus, Ground Segment, IOI, Logistics.

1. INTRODUCTION

Columbus will be undoubtedly a demanding challenge for Europe in the next decades.

For the first time Europe will deal with crew permanently in orbit and with space elements to be serviced and maintained operational for many years.

As a matter of fact thirty years of uninterrupted operations of orbital elements are a challenge not only for the mission operational aspects but also for the whole of the ground infrastructures entrusted to support the space elements.

All the on-ground functionalities requested by the Columbus missions are implemented by the facilities of the IOI (In-Orbit Infrastructure) Ground Segment. Such functions can be grouped basically as follows:

- Mission coordination & planning;
- Monitoring & control of the space elements;
- Communication capability;
- Crew training;
- Integration & Logistics Support.

These functions are all essential for a safe and cost effective mission objective achievement.

A critical aspect, both technical and organisational, will be constituted by the effort to maintain both the space and ground segment during all their planned life cycle.

Consequently logistics will play a fundamental role in the Columbus era.

For the accomplishment of most of the Columbus APM logistics tasks, a new centre has been introduced inside the IOI ground infrastructures, that implements basically new operational concepts w.r.t. the previous space experiences.

It is the APMC, tasked to provide logistics, sustaining engineering and P/L integration support to the APM missions.

2. NOMENCLATURE

APM	= Attached Pressurised Module, called also Columbus Attached Laboratory
APMC	= Attached Pressurised Module Centre
ASI	= Agenzia Spaziale Italiana
CMCC	= Central Mission Control Centre
DB	= Data Base
DP	= Data Processing
EAC	= European Astronaut Centre
EGSE	= Electrical Support Ground Equipment
ILS	= Integrated Logistics Support
IOI	= In Orbit Infrastructure
MSSC	= Manned Space Lab. Control Centre

- ORU = Orbit Replaceable Unit
- PHS&T = Packaging, Handling, Store & Transport
- P/L = Payload
- POIC = P/L Operation & Integration Centre
- SSCC = Space Station Control Centre
- UHB = User Home Base
- USOC = User Support & Operation Centre

3. REQUIREMENTS OF THE APMC

The aims of the APMC are:

- To provide a repository of knowledge and expertise concerning the APM in order....
-to support the Space Station Freedom Control Centre and the Columbus Control Centres in operating the APM in orbit and maintaining it safe and operational as required...
- ...and to support users of the APM in designing, preparing and operating payloads.

In order to reach its aims, the APMC has the following main roles:

- as a referral centre for all other centres involved in the management and operation of the APM;
- as a support centre for potential and actual payload users;
- as a resource which may be used by the SSCC and/or the crew to help resolve contingency situations.

The centre will be responsible for many facets of the support to be provided both to those operating the APM and to its users, i.e. those who wish to fly payloads on it. The result of such a broad remit is the broad range of activities the centre must undertake.

These range from writing software for the APM to arranging intercontinental transport for equipment and spares.

In order to fulfil the demanded tasks, the APMC must have many external interfaces, that, as regards the ground infrastructures, are summarised in figure 1.

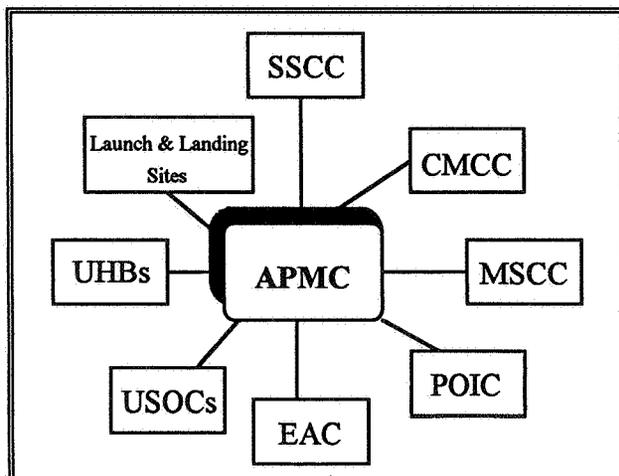


Fig. 1 APMC major interfaces with ground centres

All the activities that are required to be performed in the centre can be grouped in the following major functions:

- Engineering support
- Payload Integration Support.
- Integrated Logistics Support

The *Engineering Support* encompasses all the activities necessary to support the system engineering mission operations throughout the APM lifetime, i.e.

- Flight increment preparation support;
- Mission control support during operations execution;
- Acquisition, processing and distribution of telemetry data;
- High fidelity crew training;
- Configuration control;
- Strategic and tactical planning support;
- Operations assessment;
- Maintenance of flight configuration on board software and data bases;
- Maintenance of the board flight data files;
- Data archiving;
- Engineering assessment of design change proposals;
- Maintenance of the Engineering Data Library and Data Bases.

The *Payload Integration Support* activities envisioned in both the pre-operational and operational phases of the program include the establishment and maintenance of a capability that supports the decentralised user payload development and integration concept. It will be responsive to the User community requirements throughout the lifetime of the program. This function will provide for:

- Payload development and integration planning;
- Payload verification;
- Launch site payload processing and carrier integration;
- On-orbit operations monitoring;
- Landing site carrier de-integration and payload processing;
- Payload integration support function management and coordination.

The *ILS* includes the establishment and maintenance of an integrated support system that will be responsive to the flight element and program requirements for logistics processing.

The related functions are detailed in the subsequent section, devoted to the description of the logistics activities the APMC has to deal with.

Such major functions do not operate as stand-alone activities, but need a mutual and continuous exchange of data, plans and information with a frequent use of same equipment in order to best accomplish their assigned tasks.

4. LOGISTICS AT APMC

The logistics expected to be performed at APMC can be basically split into two groups of activities, i.e. :

- logistics in support of the APM, that is the system in orbit, to be supported effectively during its planned life;
- logistics supporting the centre itself.

Such a splitting is only functional and does not prevent that same operational equipment and personnel implement functions belonging to both of the a.m. groups.

As a matter of fact the basic functions that compose the APMC ILS capabilities can be applied to both APM and APMC as shown in the figure 2.

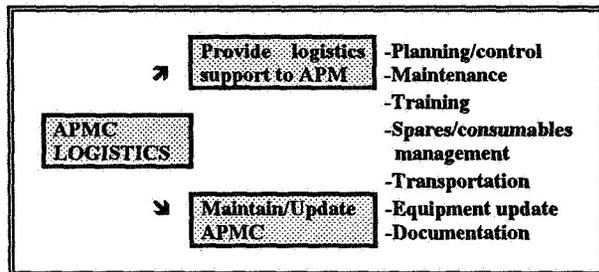


Fig. 2 APMC Logistics functionalities

These functions are detailed in the next following lines.

As a matter of fact the totality of the logistics tasks at the APMC can be well described as follows:

- Maintenance of all the ground support, airborne support and flight hardware at the organisational, intermediate and depot levels, including performance of internal and overhaul activities and verification and control of the outside contracted ones.
- Technical support of in orbit maintenance and servicing via situational analysis, simulation and interdisciplinary coordination with other centre functions. This is to aid in anomaly resolution during both nominal and contingency maintenance and servicing.
- Supply support for the maintenance function in terms of providing spares and repair parts, warehousing, inventory management and control, re-procurement, supplier and vendor retention, repair and overhaul process support and control.
- Transportation services for the maintenance and supply support items to and from their respective sources and user locations.
- Training for those personnel required to carry out the maintenance and supply support functions of logistics and support to crew training for the in situ repair procedures.
- Ground processing for the resupply and return hardware and those items of operational ground support equipment that are required to support the flight segment of the program.

- ILS-used documentation for the support of the maintenance, supply support, training and transportation including design and programmatic changes that effect those functions.
- Facilities management for the operation and maintenance required to house and support the maintenance, supply support, training and transportation functions.
- Limited logistic engineering capability for:
 - Monitoring and participation to design requirements modification;
 - Participation to the generation of new requirements and related specification;
 - Logistics issues monitoring and control for new APM and/or APMC items/equipment design and development contracted outside the APMC.
- Operational management, control and integration of:
 - ILS functions;
 - Their interfaces and coordination with the engineering support and payload integration support functions;
 - Strategic and tactical planning for flight increment manifest planning, including nominal and rescheduled flights with ILS impacts.

At the beginning of APM and APMC operations, the logistics activities shall be mainly based on suppliers inputs, related to MTBF, reliability parameters, costs etc. and on simulations.

As more information becomes available on system and subsystems due to the analysis of live data coming from APM and APMC operations, the logistics programs shall be upgraded in order to improve the logistics support in terms of minimising costs and maximising efficiency of all the system (i.e. space and ground).

5. LOGISTICS FACILITIES

The analysis conducted in the previous sections addressed only the functional aspects of the centre and in particular of those functions affecting the logistics to be performed in the centre.

All the identified functions must be translated into a set of facilities able to implement the needed functions. As regards the APMC logistics facilities, these can be grouped essentially in:

- Data Bases;
- DP-based facilities;
- Training materials and tools;
- PHS&T tools, materials and facilities;
- Workshops.

The figure 3 shows in a pictorial way the components of such facilities and simultaneously aims at providing the reader with the importance of their mutual

interactions for an effective conduction of the APMC operations.

It is also worthwhile mentioning the fundamental role the data bases have to play in the APM and APMC life, in support of most of the logistics facilities of the centre as intentionally pointed out in the figure.

It is beyond the scope of the paper to detail these facilities; only an overview is provided in order to show how the a.m. requirements can be satisfied by such facilities.

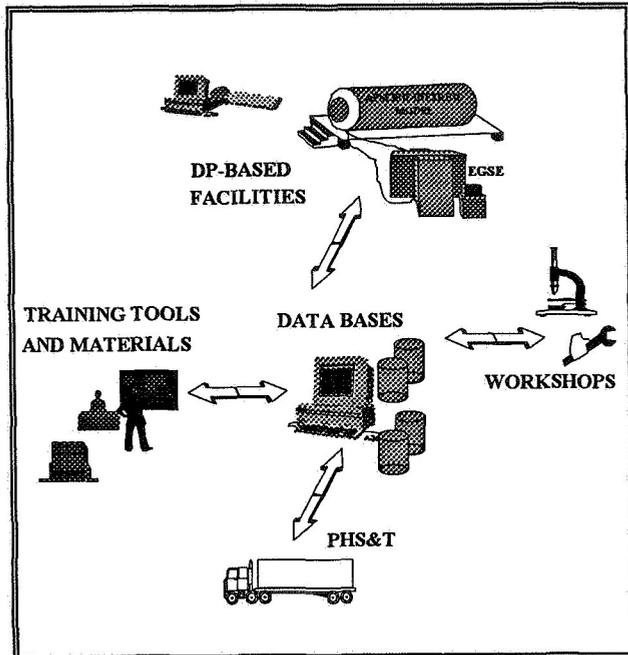


Fig. 3 Major APMC logistics facilities

5.1 Data Bases

The APMC will use several kinds of databases necessary during the performance of APM operations. Taking into account the ones that have major impact on the logistics activities, they can be summarised as follows :

- Mission data bases;
- Engineering D/B;
- Logistics D/B;
- Other Preparation Support D/B;
- APMC archives.

The figure 4 shows these groups of major data bases planned to be used at the APMC and the role of the logistics DB (it is not an architecture but only a picture aiming at summarising the APMC DBs and their interactions).

The Mission data bases encompass all the data related to the APM increments.

The data are organised per increment in order to allow the preparation of more than one increment at the same time during the preparation phase.

For each increment this D/B encompasses:

- Data related to APMC configuration;
- Data related to APM configuration;
- Payload data references;

- Fault management data;
- Crew reference documentation.

The Engineering D/B embraces all the needed engineering data for APM, APMC and P/Ls, i.e. :

- graphical data, such as drawings, schemes, etc.;
- text data (such as requirements, crew procedures, flight data files, etc.);
- references to video and audio recordings;
- reference to paper documentation.

These engineering data are in many different forms, created by many diverse applications, not all of them necessary computer resident.

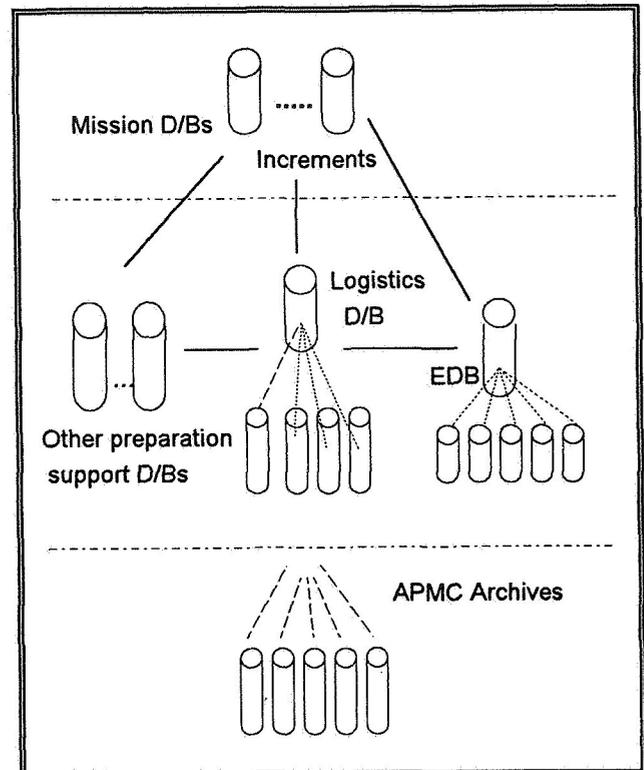


Fig. 4 DBs role at APMC

The Logistics D/B contain all relevant logistics data, classified as follows:

- Engineering data, encompassing
 - RAM data;
 - MTTR and MTBF data;
 - FMECA data
 - Others
- PHS&T data, related to
 - Packaging/Unpacking data and instructions;
 - Spares relevant data (size, weight, storage conditions);
 - Commercial data;
 - Others
- Training data, concerning
 - Skills;
 - Training results;
 - Etc...
- Documentation data;
- Historical data, mainly related to the results of maintenance interventions. Such data will be also

useful to analyse effectiveness of logistics organisations of the centre and to correct possible unfulfilment of imposed requirements of Availability and Reliability.

Other preparation support data bases are constituted by planning , P/L and on-board D/B.

The APMC Archives are made up by all data used during the execution of all the APM increments, encompassing the current increment and the data related to the past increments.

The complexity of such tools among APMC facilities will be adequately reflected in the H/W and S/W architectures with the related interfaces to both internal and external networks in order to get an efficient transferring of all the needed data during the execution of the logistics operations among the facilities (as shown in fig. 3) concerned.

5.2 DP-based facilities

The logistics activities at the APMC will exploit facilities, that heavily rely on data processing systems. An important set of tools that will be used in support of activities of the APM will be surely constituted by the APM Engineering Model and the related EGSE. It will be used to provide the capability to verify functions and measure performances for the purpose of acceptance, trouble-shooting and repair.

A more flexible tool is the APM Simulation Facility, that will be taken over from the C/D phase of the APM flight segment. Unless the breadboard of the on-board Data Management System (DMS) it is completely S/W-based and will allow prompt simulated configuration of the APM to help assess specific logistics operations, when needed.

Other DP-based tools are constituted by S/W programs running on workstations and/or PCs for specific purposes (such as logistics planning, reliability analysis tools and others).

5.3 Training materials

The training here addressed is only related to the personnel in charge to perform the logistics tasks as described in the previous section 4.

Anyhow commonalities of tools and facilities is expected among the diverse training tasks to be performed in order to optimise schedules and costs.

The planned materials can be summarised as follows:

- classrooms
- workbooks
- computer aided instructors (CAI)
- presentation materials
- mock-ups
- simulators
- instructor training materials
- tools to support training verification process

It is to point out that other training materials are constituted by the actual APMC operational

equipment, since on the job training is expected to be conducted as much as possible in the centre.

5.4 PHS&T tools

The APMC will have stores, highly equipped and automated to allow effective movement, handling and distribution of materials, supplies and equipment in the centre and outside.

Tools encompassed in such a category are constituted by lifting devices, cranes and facilities to help keep track of items under APMC control (such as bar code readers, optical devices, etc...) in order to get an optimum stocking of items.

5.5 Workshops

Equipped workshops will allow to perform all the intermediate maintenance of the centre and to carry out tasks in support of the flight element and the related payloads.

Workshops allowing to intervene in electrical and electronic, mechanical and fluidic works are consequently necessary in the APMC.

These workshops shall be equipped with off-the-shelf tools (such as multimeters, frequency generators, etc...) plus ad-hoc facilities (e.g. workbenches to execute peculiar maintenance on specific component of the centre).

5.6 Commonalities and trades

Most of the facilities needed inside the centre to support the logistics operations don't have to be developed ad-hoc.

These could be grouped in two main categories:

- already developed for the space segment and reused, after due modification and/or customisation in the centre (such as DBs developed during the C/D phase);
- common with other ground facilities (such as training materials).

The development and/or transfer of such facilities must be phased carefully with the actual needs of the diverse users in order to have on time the requested support.

Furthermore trades will be necessary to best assess options in the off-the-shelf equipment.

6. PROGRAMMATIC ASPECTS

The APMC, developed by ESA for the above mentioned functions, will be located in an ASI infrastructure, being designed by Alenia Spazio in the frame of a national contract covering all the buildings and the general support services definition.

Parallel and complementary ESA and ASI studies (both implemented by Alenia Spazio as Prime, with Ciset contributions) are running in order to complete the design of the entire facility in all its own features.

The Italian portion of the study will be over within the year 1993 and the planning is to start the building-up of the infrastructures at the beginning of 1994.

The physical facility should be completed two years later with all the internal general services equipment ready to support the ESA APM mission specific infrastructures and staff.

In addition to the above mentioned planning it is important to mention, for a clear general picture on APMC what are the programmatic aspects from ASI side on the Centre.

ASI is involved with NASA in the development of the Space Station Freedom Logistics Modules. At the moment the studies on the first module, the so called Mini-Pressurised Logistics Module (MPLM), are entering in phase C/D.

ASI is planning, and negotiating with NASA, to host facilities acting for different functions in support to the Logistics Modules.

Those functions (like sustaining engineering, logistics support, some integration tasks, etc.) shall be managed by an Italian Centre in strict coordination with the NASA facilities.

ASI plans to develop this Centre in the same location of the APMC (city of Torino area) using the same general support services already planned for the latter, in full synergy for all the common aspects and with the goal to improve the final total performance of the entire system versus each single program needs.

7. CONCLUSIONS

The importance of logistics activities in their multiple aspects for a long-duration space programs, such as Columbus, has been addressed, showing the importance of the APMC in the ground infrastructures in support of the APM operations.

The building of such a centre should prove again that ILS has to be performed not as a stand-alone and a post-development activity, but has to be conducted in parallel with the implementation phase of the centre, keeping continuous touch with the C/D phase running activities of the flight element.

More embedded is ILS in the overall APM program and more effective will result in the overall life of the entire system.

Due to the peculiarities of the Columbus program, APMC is expected to play a vital role in the operational phase of the APM with its available logistics infrastructures, for a cost effective accomplishment of the APM targets.

8. ACKNOWLEDGMENTS

The authors wish to thank Dr. G.F. De Luca for the technical advice provided in the preparation of the paper.

9. REFERENCES

1. Battocchio L., Harris D.R. and Sarlo L. **The Columbus APM Centre Flexible and Efficient Engineering Support.** ESA SP-308, October 1990.
2. De Luca G.F., Masullo S. and Randisi S. **The Requirements on Data Systems of Columbus Logistics and Engineering Support.** ESA SP-308, October 1990.
3. De Luca G.F., Grazi R. and Masullo S. **Integrated Logistics Support: Suggested Approach for Columbus.** 3rd Space Logistics Symposium, Colorado Springs, April 90.
4. Masullo S. and Berni R. **Real Time Simulation Approach in Columbus Pressurized Module.** International Symposium on Space S/W Engineering, Torino, December 1988.