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Paper Session III-A - Rack Level Test Facility- The Columbus APM Payload Verification Tool

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Rack Level Test Facility - The COLUMBUS APM Payload Verification Tool

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Abstract:

The COLUMBUS laboratory APM (Attached Pressurized Module) provides for the partial and complete exchange of payload facilities on-orbit. This laboratory is planned to be launched with initial payload installed and will remain in orbit until the end of its operational life. The initial payload will be upgraded in resupply missions until the full on-orbit payload capability is reached. Periodically servicing will be performed as well as on-orbit exchange of complete or partial payload facilities in resupply missions.

This scenario differs from the previous mission scenarios (e.g. Spacelab, EURECA), where both laboratory and payload are available on ground for verification of compatibility between payload and system and payload and payload facilities respectively in an integrated system test. With the exception of the initial launch payload, all subsequent COLUMBUS payloads must be verified with the laboratories on-orbit.

In order to gain the same level of confidence for successful on-orbit operation of COLUMBUS payloads, the approach is to have a test facility that provides all laboratory system resources, and emulates the complementary on-orbit payload.

The Rack Level Test Facility (RLTF) will be the primary tool to support the COLUMBUS users' acceptance process of payloads and their verification for compatibility with the on-orbit configuration.

According to the current COLUMBUS scenario two RLTFs will be implemented, one installed in the technical support center for the APM (APM-C) and one located at KSC to support both, European and International users adequately.

This paper addresses the RLTF role in the COLUMBUS utilization scenario, its design concept and architecture.

1. Introduction

The APM will form an integral part of the Space Station Freedom (SSF). On orbit the APM will rely completely on SSF resources and is embedded in the overall SSF operations scenario.

The APM will be capable to accommodate 10 000 kg of payload mass on orbit. The payload accommodation will be in accordance with the ISPR (International Standard Payload Rack) agreement. This agreement defines the system to payload interfaces and applies commonly to the US Lab, JEM, and APM. Due to launch mass constraints only 3800 kg initial payload can be installed at launch and the remaining payload needs to be delivered by NSTS resupply flights.

Compatibility of the initial payload and the APM will be verified in an integrated system test in the APM C/D phase.

In order to gain the same level of confidence for compatibility of subsequent payloads with the on orbit configuration a capability has to be provided on ground which simulates the APM system and emulates the complementary on orbit payload.

In the Columbus program this capability will be implemented by the Rack Level Test Facility (RLTF) which is considered the primary tool to support payload acceptance and eventually the verification of ISPRs to APM system interfaces.

This paper briefly describes the intended use of the RLTF in the COLUMBUS utilization scenario and the concept for implementation.

2.   COLUMBUS Utilization Scenario

The COLUMBUS laboratory will be utilized by European and International users.

Operation of the APM and its installed payload will be integrated in the overall SSF operation w.r.t. crew activities and high level command and control, communications and servicing.

The APM will be launched 1999 with its initial payload from which up to now only the European contribution has been (preliminary) defined. Current planning does not consider US payloads for the initial launch. According to that planning the initial launch payload will be composed of the Central Processing Visualization and the Microgravity Measurement System, and the three microgravity payload laboratories; High Temperature Materials Processing Laboratory, Biolab, and Fluidlab.

With the addressed initial launch payload about four ISPRs of the APM will be occupied. In subsequent resupply missions the initial payload will be up-graded until the full capability of 21 ISPRs including one storage rack of the laboratory is reached and the exchange of payload facilities will be required to perform new type of experiments.

For utilization with the APM payloads have been classified in class 1 and class 2 payloads (Figure 1). Class 1 payloads interface directly to the APM system whereas class 2 payloads interface to class 1 payloads and to other class 2 payloads. All before addressed microgravity payloads are so-called class 1 payloads, which are per definition self-standing facilities providing a general purpose technical infrastructure for different users. Major characteristics of class 1 payloads are their low exchange frequency and usefulness for various scientific experiments. Class 2 payloads are dedicated to certain scientific objectives and define the specific experiment to be performed. Both, class 1 and class 2 payloads are foreseen for exchange on-orbit during the periodically servicing.

" System "
⇨ DEFINES INTERFACE TO CLASS 1 PAYLOAD

Class 1 Payload
⇨ DEFINES INTERFACE TO CLASS 2 PAYLOAD
⇨ Low frequency (fewer)
⇨ Includes : ■ Single - USER Facility (SUF)
　　　　　　　■ Multi - USER Facility (MUF)
　(Facilities)　● Science Facility (SF)
　　　　　　　　 ● Drawer Rack (DWR)
　　　　　　　　 ● General Purpose (GP)
　　　　　　　　 ● Stowage Racks (STR)

Class 2 Payload
⇨ DEFINES EXPERIMENT
⇨ High frequency (many)　　　　　**INTERFACE TO**
⇨ Includes : ■ Samples　　　　　　　➡ MUF SF
　　　　　　　■ Instruments　　　　　➡ MUF SF
　　　　　　　■ Drawer Instrument　　➡ MUF DWR
　　　　　　　■ Stand-alone Instruments ➡ MUF GP or STR
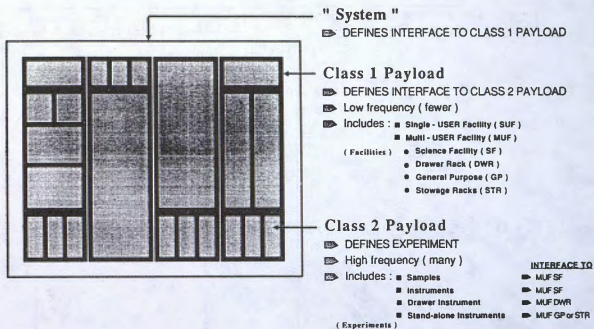　(Experiments)

Figure 1:　　Class 1 and Class 2 Payload Definition

The described APM mission scenario differs from previous mission scenarios as for example of Spacelab or EURECA, where laboratory and payload are available on ground for verification of the payload to system interface and inter-payload compatibility. Figure 2 sketches the major difference between the Spacelab and COLUMBUS scenarios: Due to the availability of all flight elements necessary for Spacelab missions physical integration and test can be performed subsequently at each level. COLUMBUS payloads have to be tested independently from the APM, transported to space and will not come into contact with the APM before their on-orbit integration in their operational environment.

With the exception of the initial launch payload all payloads will have to be verified with the APM on-orbit. This refers to the exchange payload as well as to the up-grade payload.

To overcome this difficulty of P/L verification the RLTF has been defined. The RLTF will represent the flight configuration for the payload under test and will provide relevant test features necessary to support verification of compatibility between the payload under test, the APM and the complementary payload. Both, European and International partners payloads verification will be performed on the RLTF.

For payload development an adequate number of DMS Interface Simulators will be provided to the APM users. These simulators will represent the APM DMS to payload interface physically and functionally to the extent sufficient for payload S/W development and adaptation to the APM system.
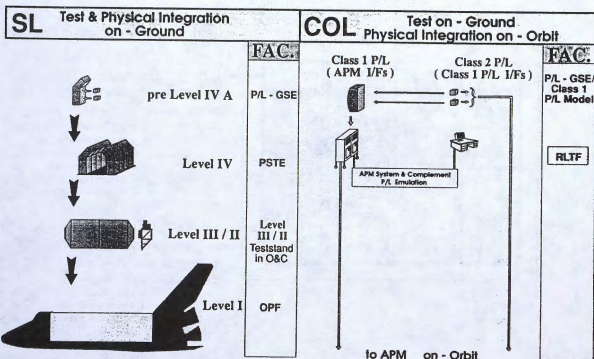
Figure 2: Spacelab versus COLUMBUS Payload Verification

3. Role of the RLTF in the Utilization Scenario

The RLTF will be the primary tool to support the COLUMBUS users acceptance of payloads and their verification. It will also be capable to support troubleshooting during payload on-orbit operation.

The RLTF will be physically and functionally capable to accommodate COLUMBUS class 1 payloads. The concept to verify class 2 payloads is to have a representative class 1 facility model available with the RLTF for accommodation (Figure 2). The RLTF will be primarily used for compatibility verification of subsequent payload with the APM on-orbit. This verification will ensure payload physical and functional compatibility including the acceptance of associated operational S/W. The RLTF is considered to be a self-standing facility which needs only basic facility resources and accommodation in a clean environment.

The RLTF can be configured to reflect the actual on-orbit configuration which enables in principle also to support off-line troubleshooting concerning the payload to system interfaces. The only functional interface to the operational environment of the RLTF will be a communication link for data import and export which can be established by the case. This enables to feed in payload downlink data, e.g. as required for troubleshooting.

Beside the envisaged role for payload acceptance and verification two other potential operational areas are currently under discussion, which are usage of the RLTF for payload related crew training and the

accommodation of payload breadboard models during their development. For both purposes it will provide basically all prerequisites by representing the flight configuration and its inherent monitoring and control functions.

4. RLTF Design Concept

The RLTF design approach was driven by three major considerations:

o   to represent the APM with high fidelity on-ground
o   design and operational commonality with the APM C/D products
o   versatility w.r.t. operational areas considering the envisaged life-time of 30 years

A high degree of fidelity will have to be implemented for

- Provision of on-orbit available physical resources as power, water cooling, N_2 and vacuum/venting (except of course μg-environment)
- Processing of low, medium rate and video data, and high rate data
- Simulation of payload facility related system operations monitoring and control capability
- Simulation of the on-orbit complement payload as far as system interfaces are affected
- Provision of the structural system to payload interfaces

This will be achieved by maximum use of APM C/D products. However, no redundancies of the APM will be implemented for cost reasons. Figure 3 presents all identified functional interfaces of the RLTF to the payload under test.

Payload under Test			
Resource Provisioning:	**Measuring:**	**Communications:**	**Mechanical Environment:**
• Power • Water Cooling • Vacuum • Venting • N_2	• Mass • CoG • Water Temperature • Power Consumption • Venting Pressure • Vacuum Pressure	• Low Rate Data Reception • Video/Medium Rate Data Reception • High Rate Data Reception • Time Provisioning • Monitoring & Control	• Mechanical Attachments • I/F Connection
RLTF			

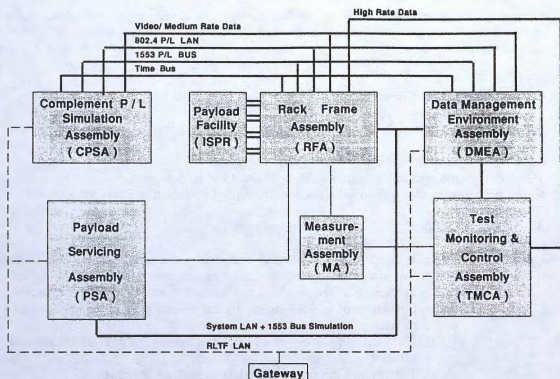Figure 3:   RLTF Functional Interfaces to Payload under Test

Figure 4:   RLTF Block Diagram

Beside the advantage of high fidelity the use of APM C/D products will also minimize development and operational costs. Implementation costs will be reduced by using e.g. breadboard level models of the DMS, refurbished equipment from APM C/D phase which has been used for development and qualification tests, and deriving new developments from C/D products design. In particular APM C/D S/W will be used like the Verification, Integration and Check-Out Software (VICOS).

Operations costs will be reduced by using to the maximum extent APM C/D procedures and manuals for operating the RLTF and use of flight application software necessary for payload verification. Logistics costs will be minimized because of identical spares for the implemented APM C/D equipment.

Versatility will be achieved by a physically and functionally modularity.

The RLTF will be composed of six functional assemblies

    o   the Test Monitoring and Control Assembly (TMCA)
    o   the Data Management Environment Assembly (DMEA)
    o   the Rack Frame Assembly (RFA)
    o   the Payload Servicing Assembly (PSA)
    o   the Complement Payload Simulation Assembly (CPSA)
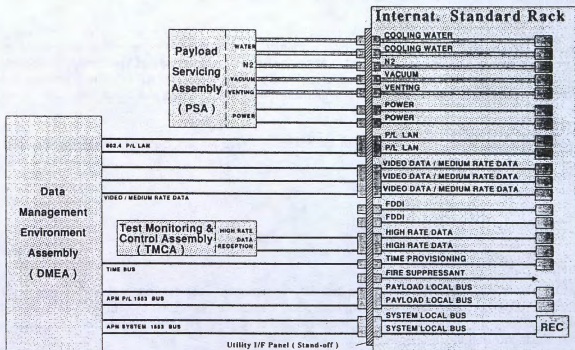   o   the Measurement Assembly (MA)

Figure 5:   RLTF Provisions

These assemblies will be accommodated on a working platform. The TMCA, DMEA, PSA and CPSA are connected by a LAN (Figure 4). These assemblies can be used individually or in configurations as required to cope with the intended operation and future applications.

In the following these assemblies are briefly described. Their interfaces to the ISPR are shown in figure 5.

TMCA

From a test point of view the TMCA represents the "heart" of the RLTF. It provides the functions of central RLTF control, test preparation and evaluation, test monitoring and control, and test item stimulation and payload high rate data reception. Furthermore the TMCA provides for establishing of reproducible test conditions. A direct connection to the DMEA enables TM data acquisition and telecommanding simulation.

DMEA

The DMEA represents the APM system related data processing and communications environment of the P/L. To ensure that all types of payload related data and commands can be verified properly all DMS and video processing functions are emulated by ground copies of the appropriate flight H/W. Beside the addressed advantages this approach has in addition a considerable cost benefit during the RLTF operational life, as the real flight S/W can be executed on the DMEA, compared to the

establishment of flight S/W simulations for each mission increment.

RFA
The RFA represents the mechanical on-orbit environment of a ISPR. It is capable to accommodate up to two integrated racks which is considered to be the maximum exchange payload per resupply mission. The RFA is the only assembly which interfaces directly to the test item. All interfaces between the laboratory system and the payload will be implemented in realistic design and dimensions.

PSA
The PSA provides all physical resources to the test item, which are available within the APM.

- power
- cooling
- vacuum
- venting
- nitrogen
- fire suppression

It will consist of individual servicers and a dedicated workstation. Each servicer will provide one of the addressed resources and is composed of a controller, a resource generation system and the front end equipment. The front end equipment will be ground copies of flight H/W and connected to the DMEA for commanding and monitoring purposes.

CPSA
The CPSA will represent the on-board complementary payload. Functionally it completes the DMEA, RFA and PSA in representing the on-orbit configuration and provide for bulk simulation of the on-orbit payload. In particular payload data traffic and consumed physical resources will be simulated.

MA
The MA will provide for determination of

     o   rack mass
     o   rack Center of Gravity (CoG)
     o   cooling water temperature at rack outlet

5. **Concluding Remarks**

The RLTF has been specified and defined within the framework of the Element Center studies contracted to COLUMBUS industry by ESA. The RLTF is currently in the design definition status. Its implementation is planned in time to be ready for APM initial launch payload processing.