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A Resupply Scenario For The Columbus Mantended Freeflyer (MTFF)

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1. INTRODUCTION

Within the long-term framework of establishing a coherent system that supports permanent and autonomous European presence in space, the MTFF as an integrated flight configuration assumes a major role among the other COLUMBUS elements and joins Ariane V, HERMES, EDRS and Ground Segment facilities as an important building block, leading to a coherent European space capability.

The MTFF is designed for an operational on-orbit period of 30 years, which will be made possible by periodic in-orbit servicing activities.

The in-orbit servicing activities are to be made possible by a resupply system, which will have to provide and prepare all items needed for the in-orbit servicing. This will include exchange units for in-orbit maintenance and repair of system and payloads, consumables, new payload sets, etc.

This paper describes the involved processes on ground and in-orbit and identifies the required resupply infrastructure, covering the range from provision or off-line repair of units at a manufacturers site via ground/orbit transport to on-orbit storage, until utilization in a servicing activity.

The MTFF resupply scenario is more complex than those of the other COLUMBUS Elements due to various servicing locations/vehicles and resupply launch sites.

It has to be noted, that the concepts and facilities mentioned or described, present the Phase B state of the COLUMBUS program. In areas, where results of detailed analyses are not yet available, assumptions based on program philosophy and intent have been made.

2. MTFF DESIGN CHARACTERISTICS

The MTFF (Fig. 2-1) consists of a Pressurized Laboratory Module (PM) and a Resource Module (RM).

a) Pressurized Module

The configuration of the 7.5 m long Pressurized Module is characterized by a 2-segment 4 m diameter cylindrical pressure shell with identical cones on both ends. The primary structure is based on the Spacelab structure design.

The pressure shell is covered by thermal insulation, a micrometeorid and space debris protection shield and body mounted radiators.

Docking/berthing mechanism, hatch and a viewport are located at the forward end cone of the module.

The internal architecture (Figure 2-2) is a 1 g configuration (floor/ceiling arrangement), similar to that employed for Spacelab and also compatible with the Space Station internal configuration.

Four principal areas determine the internal layout of the module:

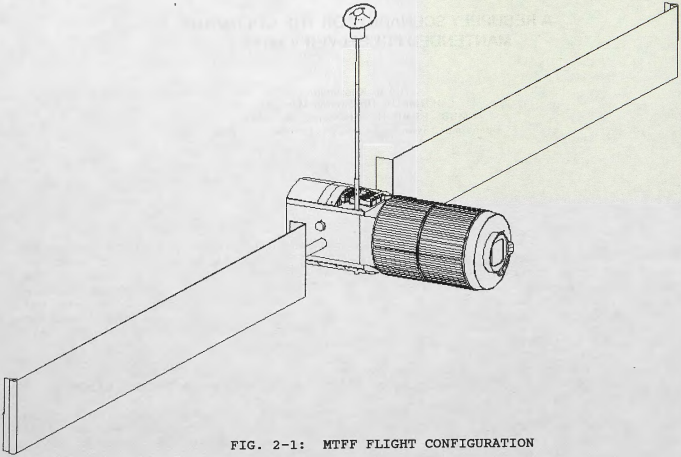


FIG. 2-1: MTFF FLIGHT CONFIGURATION

- o the lateral racks
- o the floor/subfloor area
- o the overhead area, and
- o the cone areas.

For reasons of good accessibility and easy exchange, the instruments are installed in racks only. The referenced lateral rack arrangement consists of five single racks per segment and side.

The maximum P/L accommodation capability in nominal operational conditions is 5000 kg and a volume equivalent to 22 single racks.

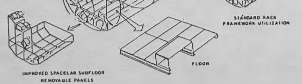


FIG. 2-2: PM INTERNAL ARCHITECTURE

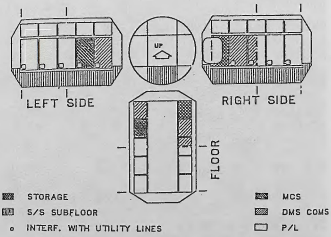


FIG. 2-3: PM S/S-P/L ACCOMMODATION

The subsystems required to sustain the module and to provide the necessary payload services and crew life support are accommodated under the floor, in standard side-mounted single racks and on the inside of the aft endcone. All under-floor subsystem equipment and the standard single or double racks can be exchanged on orbit.

Fig. 2-3 shows the rack partitioning between subsystems and payloads.

The major MTFF system functions performed by subsystems/components located in the PM are:

- o major part of the data management
- o GNC processing
- o thermal control of PM, incl. external radiators
- o internal PM environmental control and life support
- o power distribution
- o video/audio processing and high data rate multiplexing
- o caution and warning
- o fire detection and suppression

b) Resource Module

The Resource Module consists of three sections, RM/PM Adapter, Main Body and Super ORU.

The RM/PM Adapter attaches the RM to the PM via PM bulkhead connectors and PM attachment flange. Integral parts of the RM/PM Adapter are connecting structure, harness and pipework, and mechanisms for mechanical and utility connection. The RM/PM Adapter/Main Body interfaces may require 2 EVA men plus remote manipulation for contingency operation. The Adapter does not have any active components.

The Main Body integral parts are primary structure, support structure, mechanisms, harness, pipework, heat pipes, short boom antennas, magnetic torquers, and ORU mechanism interfaces.

Attached to the Main Body are two solar arrays including SAD/ERM, COMS package including ERM, a number of thermal radiators, and 33 standard

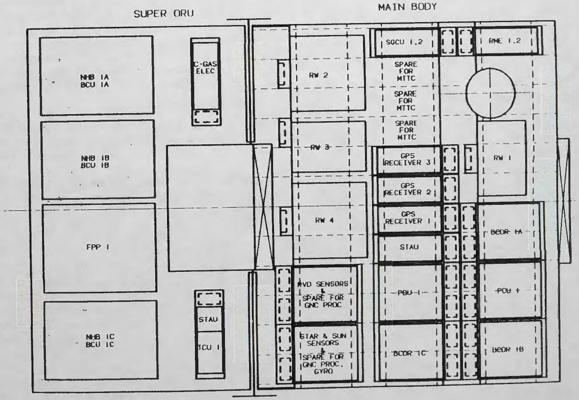


FIG. 2-4: RM SUBSYSTEM ACCOMMODATION

ORU's housing the RM subsystem components, which are not part of the Super ORU.

The Super ORU contains propulsion tanks (for 2 tons of bi-propellant), cold gas and ECLS tank, batteries, freon pump package and 4 standard ORU's for drive electronics.

Fig 2-4 shows the Subsystem/component accommodation on the RM.

The major MTFF system functions performed by subsystems/components located on the RM are:

- o RM portion of the DMS LAN and STAU's
- o actuators and propulsion with drive electronics, sun/star sensors, RVD sensors
- o passive thermal control of RM Main Body Equipment, active thermal control of Super ORU equipment
- o O2/N2 storage
- o power generation, conditioning and energy storage, power distribution
- o communications RF equipment, including transponders.

3. MTFF OPERATIONS CONCEPT

a) Launch and Initial Activation

The MTFF will be launched fully integrated by an Ariane V, carrying an initial payload of up to 2000 kg. The MTFF will be placed into an initial orbit of 450 km altitude and 28.5^{o} inclination.

b) Mission Orbit Profile

The mission orbit profile of the MTFF is arranged such that the free-flyer remains on average co-planar with the ISS, allowing rendezvous with the ISS for payload servicing at regular intervals of 180 days. After each servicing event, the MTFF performs a "boost-up" maneuver with a subsequent free drifting flight, requiring no further orbit corrections which could disturb the micro-gravity environment. In the HERMES servicing scenario, the MTFF will also fly co-planar with the ISS in order to allow servicing at the ISS in a contingency and/or mixed mode situation.

c) Routine Operations

Routine system operations are a continuous activity, punctuated by servicing, troubleshooting and the handling of contingencies. The EMCC will support these functions on a continuous basis.

The proposed servicing scenarios will involve synchronized operations of two space systems and their individual control centers, which will require thorough integrated planning. Overall operations responsibility will always reside with the manned vehicle's control center (SS or HERMES) to assure optimum safety for the crew.

During unmanned periods, MTFF systems must be controlled by on-board automation and the ground. Similarly, payloads in the untended, freeflying mode are subjected to automatic operation or control by a ground control center. The EMCC, or in manned periods the crew, shall always retain the capability to override automatic onboard actions or an autonomous system.

All ground initiated commands are normally required to pass through the EMCC. In those cases where ground commands have been authorized to bypass the EMCC, such commands, as well as those initiated by the crew, will be checked by MTFF on-board systems.

The System and Mission Management (SMM) software will monitor resources used by systems and payloads, detect and automatically resolve - or support the manual resolution of - resource conflicts or resource excesses.

d) Servicing

The servicing tasks have been grouped in a fashion that will accommodate the proposed 180 days HERMES visitation cycle, and recognize the special tasks reserved for the MTFF's return to the ISS.

Payload set-up and servicing will be conducted by astronauts in a shirt sleeve environment, when the MTFF is berthed to the International Space Station (Fig. 3-1).

MTFF DOCKED TO ISS NODE

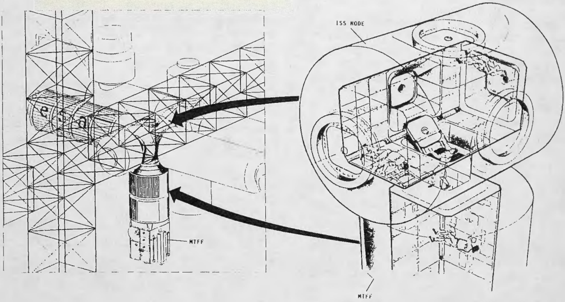


FIG. 3-1: MTFF SERVICING AT ISS

For external servicing at the ISS the MTFF may be moved to the station's servicing bay, where externally mounted ORU's can be replaced by the remote manipulator of the ISS. Refueling of the MTFF propellant will be by exchange of the Super ORU, also using the station's manipulator.

EVA back-up capability is provided by the ISS crew.

For the servicing scenario with HERMES, resupply and return materials for MTFF payloads and subsystems will be stored in the HERMES pressurized cargo bay.

For internal servicing, HERMES will be docked to the MTFF pressurized module as shown in Fig. 3-2. In this configuration, both HERMES airlock hatches (inner and outer) will be open to provide a passage for servicing of the internal equipment at shirt sleeve environment.

For external servicing the MTFF is berthed to HERMES at the Resource Module (Fig. 3-3), providing good HERA (HERMES Manipulator) access to the RM for servicing but requiring a flyaround.

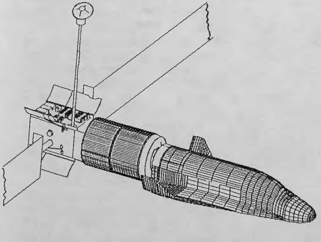


FIG. 3-2: MTFF INTERNAL SERVICING WITH HERMES

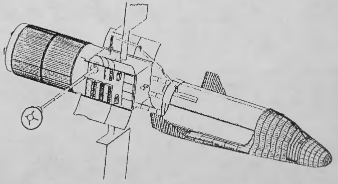


FIG. 3-3: MTFF EXTERNAL SERVICING WITH HERMES

e) Rendezvous and Proximity Operations

MTFF rendezvous and berthing operations with the ISS basically consist of automatically maneuvering the vehicle into the vicinity of the ISS to allow the Station Manipulator System to grapple the vehicle and berth it. The ISS crew will have initiation and ultimate decision authority during all activities within the ISS control zone.

The MTFF will be berthed at the free one of the two heavy duty docking ports for the Space Station Logistics Module.

For MTFF docking to HERMES, the MTFF will be configured as the passive vehicle after it has maneuvered into a "control box", remaining under EMCC control. The manned vehicle will take the active role to complete the berthing.

4. MTFF IN-ORBIT SERVICING TASKS

Servicing tasks for the MTFF can be grouped into servicing tasks for the Pressurized Module and into servicing tasks for the Resource Module. The main distinguisher for these tasks is that RM servicing tasks are without exception external servicing activities, which require extra vehicular activities or remote manipulation or a combination of both, whereas the vast majority of PM servicing tasks are internal servicing tasks, which can be performed by IVA in a shirt sleeve environment. Fig. 4-1 depicts the general servicing task categories.

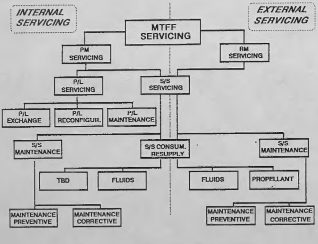


FIG. 4-1: MTFF SERVICING

The allocation of these servicing task categories to ISS and HERMES servicing scenarios is driven by MTFF requirements and servicing support provisions/capabilities of the servicing vehicles. (see Fig. 4-2).

SERVICING TASKS		SERVICING SCENARIO: IN SITU BY HERMES (180 D INTERVAL)	SERVICING SCENARIO: AT ISS (EVERY 3..4 YEARS)
P/L	SAMPLE EXCHANGE EXCHANGE / RECONF. MAINTENANCE	ROUTINE EVERY 180 DAYS	AT EACH VISIT TO ISS
S/S INT.	PREVENTIVE MAINTEN. CORRECTIVE MAINTEN.	ROUTINE EVERY 180 DAYS	AT EACH VISIT TO ISS
S/S EXT.	PREVENTIVE MAINTEN. CORRECTIVE MAINTEN. PROPELLANT CONSUMABLES	- LIMITED FOR SURVIVAL - -	TIMED FOR VISITS TO ISS

FIG. 4-2: MTFF SERVICING TASK ALLOCATION

Considered most important, especially in the early concept and design phases of a program of this magnitude are the maintenance processes, because of their direct design influence. The two servicing cases, by HERMES and at the ISS, are described to show the involved tasks in performing scheduled and unscheduled maintenance.

a) Servicing by HERMES

The scheduled and unscheduled maintenance events have to be timelined with the servicing missions.
Prior to the servicing mission, spare requirements have to be identified for the maintenance activities as well as requirements for maintenance support (tools/test equipment, ASE, maintenance data, i.e. manuals, check lists, etc.).The on orbit maintenance operations (repair in place vs. remove/replace) required at each mission determine EVA/IVA/RMA support requirements. In case of an unscheduled event (malfunction of an ORU), the on board systems (FDIR) shall isolate the faulty ORU; corrective maintenance action has to be timelined. Failed ORU's will be removed from the system (organizational level, on line), and replacement ORU's will be provided from a spares store at the servicing vehicle or at the flight element (only very limited storage capability on the MTFF).

After repair, system reverification will be performed by the onboard system as well as post maintenance activities (tools back to store etc.). Finally an update of the logistics/maintenance data and of the inventory list will be performed. Faulty ORU's will be returned to the ground maintenance facilities (download). H/W failures which are not allocated to ORU's, e.g. harness, piping etc. are to be handled on contingency basis (on line decision to be made, whether to repair in place, continue operations with reduced capability, or other workaround solutions).

b) Servicing at the ISS

The scheduled and unscheduled maintenance activities on the MTFF have to be timelined with the servicing visits to the ISS. Spares requirements information have to be identified and their supply to be timelined with the ISS logistics resupply flights of the NSTS, if not in stock on orbit. The maintenance operations to be performed (repair in place, vs. remove/replace vs. repair in ISS workshop) will determine the maintenance support requirements. The ORU repair shall consist in replacement of units (orbit shop replaceable units, OSRU's level) within the ORU. H/W failures, which are not allocated to ORU's will be handled on a contingency basis. Interface verification after replacement shall be performed on system level after the ORU is reinstalled in the Columbus Element. This will reduce the requirements for special test equipment and manpower in orbit. Post maintenance activities and update of data base will then be performed. The faulty ORU will be stored in the pressurized logistics module or unpressurized carriers of the ISS and will be returned to ground via the NSTS resupply flights.

c) MTFF Servicing Requirements

The specific servicing needs and intended/required methods and locations of the servicing tasks, which are mainly exchange/repair activities are briefly identified.

Subsystem and payload servicing in the PM is by exchange of ORU's or payload samples, and by replenishment of payload consumables. These activities can take place at each servicing opportunity at the ISS or during HERMES visits.

External equipment like body mounted radiators, protection covers, freon/water heat exchanger and pipework require EVA at the ISS.

For the RM/PM Adapter structure no repair capability is deemed necessary. Mechanical and utility connection mechanisms for the Adapter/Main Body Interface allow a contingency disconnection requiring 2 EVA men plus remote manipulation support and could be performed at the ISS.

The harness/pipework of the Main Body is routed inside the primary structure, allowing a limited repair capability by "jumper connections" or local harness replacement, requiring EVA.

ORU mechanisms and connectors are located to allow on orbit inspection, local repair capability is with connector savers by EVA. All mechanisms provide for EVA back-up for fail open/fail close conditions.

Short boom antennas and magnetic torquers have an EVA repair/exchange capability.

Solar arrays including SAD/ERM exchange is possible at the ISS by remote manipulation, single drum exchange is possible with EVA.

The COMS outboard package including ERM can be exchanged at the ISS by remote manipulation.

Thermal radiators can be exchanged by EVA at HERMES or ISS.

The standard ORU's on the Main Body and on the Super ORU can be exchanged by remote manipulation or EVA at HERMES or ISS.

Exchange of the Super ORU requires remote manipulation at the ISS, and in addition may require EVA in case of fail open/fail close conditions of the interface mechanisms.

Cold gas and ECLS tanks are sized for direct gas transfer by HERMES or ISS. Batteries and Freon Pump Package are EVA exchangeable at the ISS.

d) In-Orbit Storage and Handling of Resupplies

For the HERMES servicing scenario, where resupply and servicing events take place at the same time on-orbit storage will generally be restricted to short term intermediate stowage of exchange items. A very limited MTFF on-board storage of selected critical items will be investigated and may be possible.

For the Space Station servicing scenario, where the resupply and servicing events will not coincide, in-orbit storage, handling and movement of consumables and ORU's will be required.

For external equipment, the storage location will be the space station unpressurized logistic carriers located at the servicing bay.

For internal equipment, the storage location may be either the space station logistics module (typically for "normal" exchange candidates which are supplied on request due to preventive or corrective maintenance needs), or the APM or another TBD storage site on board the ISS.

The onboard inventory management system, has to provide adequate capability for control of handling & movement of

- consumables & piece parts
- spare parts
- exchange payloads
- tools and support equipment

5. UPLOAD DEFINITION/ESTIMATES

Two sections shall identify the resupply categories based on the servicing tasks described before. It will further briefly address the specific problem of quantifications/ predictions for upload assessments.

Results of the present state of upload assessments for HERMES and ISS servicing are shown.

a) Resupply Categories for HERMES Uploads

Based on the defined MTFF servicing needs, HERMES upload and servicing support capabilities, and the 180 days servicing cycle, the following resupply categories are relevant for the HERMES servicing scenario:

- o MTFF Payload
  - consumables
  - samples
  - exchange or add-on payloads for payload reconfiguration
  - exchange ORU's for preventive and corrective maintenance
- o PM Subsystems
  - consumables
  - exchange ORU's for preventive maintenance
  - exchange ORU's for corrective maintenance
- o RM Subsystems
  - exchange ORUs for selected corrective maintenance cases ("small" ORU's)
- o Airborne Support Equipment (ASE)
  - logistics racks for MTFF resupply storage in HERMES
  - utility I/F's as required
  - IVA tools (first mission only)
  - foot restraints (first mission only)
  - ORU exchange tools
  - P/L dedicated equipment
  - on-line repair kit

For the ISS servicing scenario the MTFF payload and PM related categories apply also. But in addition, based on the better servicing infrastructure of the ISS and the larger upload capabilities (mass and especially volume) to the ISS, RM servicing related uploads will have to be considered:

- o RM Subsystems
  - consumables (as part of Super ORU-exchange for preventive maintenance purposes, including bi-propellant, He, N_2, O_2)
  - exchange ORU's for preventive maintenance (Super ORU,(every 3-4 years), radiators (every 12 years), solar arrays(every 9 years), etc.)
  - exchange ORU's for corrective maintenance
- o ASE
  - IVA tools (first mission only)

- foot restraints
  (first mission only)
- ORU exchange tools
- P/L dedicated equipment
- on-line repair kit

(some ASE items may be on-board the European Attached Pressurized Module (APM), which could be shared for MTFF servicing).

(The remark "first mission only" applies to those ASE items, which remain on-board the MTFF for application in further servicing missions. They are only applicable for the location of the first servicing after MTFF launch.)

b) Resupply Quantification Considerations

Due to the restricted upload capabilities, limitations of HERMES launch mass and need to share ISS upload with the elements of the Core Station, the question of up-/download requirements and their quantification/prediction for feasibility assessment and programmatic considerations is of special importance.

Based on the available design data, mission concepts and operational concepts, the majority of resupply requirements can be quantified and deterministically predicted, and correlated to the advertised transport capability.

The only resupply needs, which cannot be determined in this way, are those related to corrective maintenance, since they result from equipment random failures.

The hardware items which have been identified as ORU's employ internal redundancies where needed to meet the Columbus system availability/safety requirements.

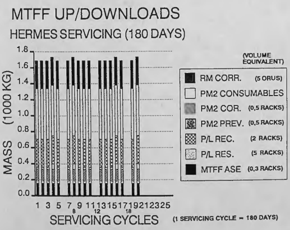
Still the probability of having an ORU failed during operational life exists. It is expressed by the ORU's "Mean Time Between Failure" (MTBF), which is a statistical term defining the average time between two failures.

Like any statistical prediction it is true only for a large number of "identical processes", but cannot predict the occurrence of an individual failure.

Hence the ORU's MTBF may be acceptable to estimate the overall upload/download yield over the 30 years mission life as a programmatic prediction, because the intervals between servicing (180 days for the MTBF) may be seen as a number of n "identical processes".

For a credible prediction of individual up-/download requirements related with corrective maintenance, which is required in support of feasibility analyses, a different approach is needed.

A practical method of analyzing the random failure behaviour of a system, is by simulation (e.g. using the Monte Carlo model), when the design information on unit and part level is sufficiently detailed.



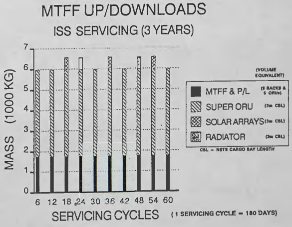


FIG. 5-1/5-2: MTFF RESUPPLY REQUIREMENTS

c) Upload Estimates

Figures 5-1 and 5-2 show the results of the MTFF uploads requirements estimates for HERMES and ISS servicing. For corrective maintenance events an upload mass margin for each servicing mission has been defined, depending on servicing interval and system reliability. Preventive maintenance estimates are based on the available data of life limitations of equipment.

The figures show masses, but give also the estimates of required volume, equivalent to NSTS cargo bay length, racks in the Space Station Logistics Carrier or HERMES, and standard ORU sizes (0.7 x 0.7 x 0.7 meters).

6. RESUPPLY SCENARIOS

Having discussed the required in-orbit servicing tasks and the identification of required uploads, we now will have a brief view of the overall system required. Fig. 6-1 shows a simplified picture of the complete MTFF resupply scenario.

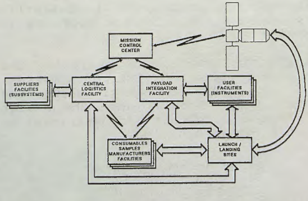


FIG. 6-1: MTFF RESUPPLY SCENARIO

Two major categories of resupplies and their different processing requirements shown:

- system related resupplies
- payload related resupplies

They can be characterized by their objectives:

- the system resupplies are required to sustain the system in orbit
- the payload related resupplies are intended to support payloads to utilize the system features, this being the one and only reason for the system's existence

and further by their different origins and processing ways before entering the flow of launch preparation activities:

- the system resupplies being procured from individual suppliers and processed through a logistics support system
- the payload related resupplies being provided by individual users and processed through a payload ground processing system.

More detailed logical flows of activities required to provide and process exchange ORU's and the related logistics processes are in Fig. 6-2.

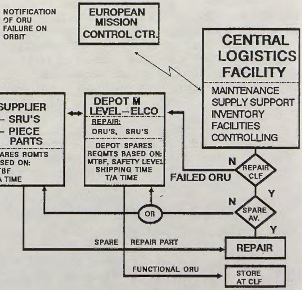


FIG. 6-2: ORU PROVISIONING LOGIC

The tasks to process an exchange payload until in-orbit integration, showing also the interfaces to mission preparation and mission control are shown in Fig. 6-3.

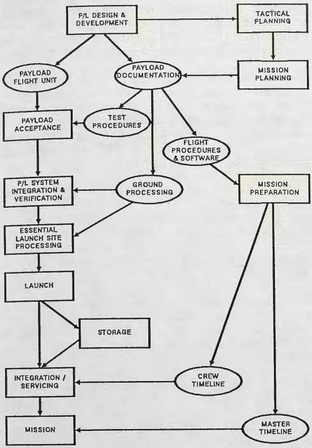


FIG. 6-3: PAYLOAD PROCESSING LOGIC

7. INVOLVED PROCESSES AND INFRASTRUCTURE

The tasks and scenarios identified and described in the preceding sections will have to be supported by effective logistics and ground operations systems, which general tasks and features are identified in this section.

a) Integrated Logistics Support System

Operational analysis and planning for an integrated logistics support system (ILSS) are currently an important part of the COLUMBUS Program preparation tasks. The primary objectives are to develop cost-effective support philosophies and logistics approaches to establish realistic logistics requirements and planning and to define associated facility and support equipment requirements. In addition the logistics resources will be estimated and requirements/recommendations developed to influence the design and development of COLUMBUS hardware and software to reduce the overall program costs.

All logistics requirements for the COLUMBUS system will be met by implementing a single and integrated logistics support system. This system fulfills the logistics requirements generated by the space system operations functions. The ILSS encompasses the ground and on-orbit supporting facilities, activities, tasks, and resources necessary to maintain COLUMBUS Program hardware and software in a fully operational condition. It also provides support to the up- and downloading of system and payload resupplies.

Principal sub-elements comprising the ILSS include servicing and maintenance planning and analysis, management of resupply, handling and transportation (including ground/orbit transport), training for equipment maintenance, technical data documentation, test and support equipment and facilities to support these sub-elements.

The ILSS may not directly control all of the implementing organizations and equipment involved in support of the logistics functions but it will coordinate all of them to accomplish the required logistics support tasks. For example the ILSS will maintain the logistics database for COLUMBUS transportation requirements. It will use this database to develop the COLUMBUS related input to the strategic level arrangements for use of the resupply launch vehicles HERMES and NSTS. The ILSS provides the function to ensure effective and economical logistics support to the program.

Out of the involved facilities the Central Logistics Facility (CLF) is the most important one. The CLF comprises the following functions:

The Centralized Logistics Facility (CLF) coordinates and controls all required logistics support activities. The CLF initiates procurement/repair requests and performs receiving inspection/control of ORU's, LRU's spares/repair parts & consumables for flight H/W and GSE. It provides for internal handling and

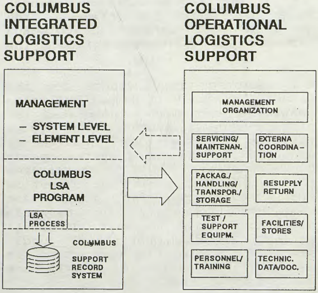


FIG. 7-1: COLUMBUS ILS SYSTEM

transportation as well as storage and appropriate facilities/equipment. The CLF performs inventory control and updates the logistics data base. H/W is provided for internal maintenance and/or to processing sites. The CLF serves for maintenance facilities/ support equipment etc. and executes required/scheduled maintenance tasks as well as maintenance training. The logistics data base is maintained and required logistics support activities initiated accordingly. Logistics data are processed and existing/future logistics needs for flight H/W and GSE determined.

b) Ground Operations System

Ground operations can have a significant impact on the overall COLUMBUS program costs. To be cost-effective, the ground operations must be minimized, yet they must provide a high level of confidence that on-orbit operations of the launched equipment will be trouble free.

In attempting to optimize the ground operations and eliminate unnecessary efforts, this ground processing planning includes activities that begin at the factory, continue through a central European processing (central at least on flight element level) and processing at the launch site, and culminate with on- orbit operations.

Previous experience and lessons learned from space vehicle and payload processing at European processing and launch site processing sites are being applied to ensure development of practical, efficient, and cost-effective planning.

This operational analysis and planning effort will be reflected in the hardware and software design and will ensure that facilities, systems, and support equipment are available to support the required prelaunch operations.

The required resupply ground processing for the different resupply categories (see Fig. 7-2) present a challenge for the ground processing planning.

The resupply components to be delivered to orbit vary in size, shape and function. The ground operations activities must therefore be tailored to satisfy the requirements of each piece of equipment and to ensure the functional integrity of the resupplies and their interfacing in-orbit systems/payloads after delivery to orbit.

High fidelity interface simulators will be used for the necessary physical and functional verification during ground processing.

Some of the resupply items will be processed through the launch site one time, while others will be launched into orbit and returned to be maintained, refurbished, and reconfigured for subsequent activities.

The ground processing flows must be structured to complement the on-orbit operation and servicing operations. The ground operations begin with final assembly and test of hardware/ software at the suppliers/users factories and Continue through the pre-integration in Europe, where applicable, and through the launch site processing. This approach shall accomplish commonality between the factory/pre-integration and launch site test requirements, test procedures, test equipment, and test results.

	MANUFACTURERS SITE PROCESSING	EUROPEAN INTEGRATION SITE PROCESSING	CENTRAL LOGISTICS SITE PROCESSING	LAUNCH SITE PROCESSING	POST FLIGHT PROCESSING
SUPER ORU	● UNITS ACCEPTANCE	● ASSEMBLY ● INTEGRATION ● VERIFICATION ● SHIPMENT TO LAUNCH SITE		● FINAL ASSEMBLY ● SERVICING ● CHECKOUT ● INSTALLATION IN STS	● ESSENTIAL LANDING SITE PROCESSING ● BACK TO EUROPEAN INTEGRATION SITE
SUBSYSTEM ORUs	● ACCEPTANCE		● VERIFICATION ● SHIPMENT TO LAUNCH SITE	● INSTALLATION IN LAUNCH VEHICLE	● ESSENTIAL LANDING SITE PROCESSING ● BACK TO CENTRAL LOGISTICS SITE
SUBSYSTEM CONSUMABLES	● CONTAINER ACCEPTANCE (IF APPLICABLE)		● CONTAINER VERIFICATION (IF APPLICABLE) ● SHIPMENT TO LAUNCH SITE (IF APPLICABLE)	● PURCHASE ● ACCEPTANCE ● SERVICING ● CHECKOUT ● INSTALLATION IN LAUNCH VEHICLE	● ESSENTIAL LANDING SITE PROCESSING ● CONTAINER BACK TO CENTRAL LOGISTICS SITE (IF APPLICABLE)
PAYLOAD ORUs	● UNIT ACCEPTANCE	● ASSEMBLY ● INTEGRATION ● VERIFICATION ● CONFIGURATION FOR LAUNCH ● SHIPMENT TO LAUNCH SITE		● RECEIVING COMPLEMENTARY PAYLOAD ● FINAL ASSEMBLY ● SERVICING ● CHECKOUT ● INSTALLATION IN LAUNCH VEHICLE	● ESSENTIAL LANDING SITE PROCESSING ● BACK TO EUROPEAN INTEGRATION SITE ● DISASSEMBLY ● BACK TO MANU–FACTURERS SITE
PAYLOAD ORUs SAMPLES CONSUMABLES	● ACCEPTANCE ● SHIPMENT TO LAUNCH SITE			● ASSEMBLY ● CONFIGURATION FOR LAUNCH ● SERVICING ● CHECKOUT ● INSTALLATION IN LAUNCH VEHICLE	● ESSENTIAL LANDING SITE PROCESSING ● BACK TO MANUFACTURERS SITE

FIG. 7-2: RESUPPLY GROUND PROCESSING REQUIREMENTS

Operations performed at the assembly factory or pre-integration site will, in many cases, not have to be repeated at the launch site. Some operations will, of necessity, be repeated to ensure that critical interfaces satisfy requirements, and that critical systems function properly and have not been degraded due to the passage of time or due to the transportation environment between Europe and the launch site.

Another variation for the resupply ground operations is presented by the necessity to cope with two entirely different launch vehicles at different launch sites.

Processing of resupplies, which go with the NSTS to the ISS, will be at KSC; processing for the resupplies with HERMES/ARIANE 5 will be at CSG.

The major difference, in addition to the different launch site infrastructure, will be the approaches to load the resupplies.

The NSTS employs a logistics element consisting of a pressurized and of unpressurized carriers, which will be processed in parallel to the NSTS and enter the NSTS flow at the latest possible time, on the launch pad.

The logistics carrier(s) will be removed after return from orbit in the OPF.

Resupply loading/unloading in/from the logistics carrier(s) will be in the Space Station Processing Facility (SSPF).

Post transport inspection/verification and preparation for logistics carrier integration/installation will either be in the SSPF too, or in an off-site facility, whatever the most economical process will be. Hazardous operations will be either in the Space Station Hazardous Processing Facility (SSHPF) or also off-site.

HERMES provides an integral pressurized compartment into which resup-

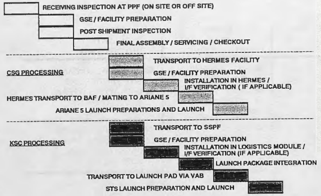


FIG. 7-3: PAYLOAD LAUNCH SITE PROCESSING FLOW

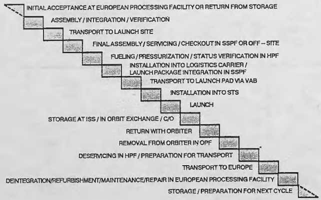


FIG. 7-4: SUPER-ORU GROUND TURNAROUND FLOW

plies will be directly installed/integrated, together with their individual support structures.

Post transport inspection/verification and preparation for HERMES installation/integration will be in one of the ARIANE 5 or HERMES payload processing facilities on-site CSG, which are presently being defined.

Figures 7-3 and 7-4 depict typical processing flows for payload launch site processing at KSC and CSG and for the RM-Super ORU ground processing cycle.

8. CLOSING NOTE

This paper could of course only give an overview of the problems involved in servicing on orbit elements and providing the necessary resupplies for this servicing.

But the magnitude of methods, procedures, facilities to be developed and implemented should have become obvious.

If one considers, that the MTFF is just one element of the COLUMBUS program scenario, and that in addition the ISS with its infrastructure and the other participating international elements will have to be supported in a few years from now, one gets an impression of the tremendous effort which lies ahead.

It is a serious challenge to our ingenuity if we are to accomplish the ambitious objectives of the tasks ahead, and it is also something, which we, the Operations and Logistics people of all involved programs, can only do together.