



Space engineering

Logistics engineering

Foreword

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Change log

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Introduction

ILS, within the System Engineering process, is a disciplined, unified and iterative approach to the management and technical activities to:

- integrate support considerations into system and equipment design;
- develop support requirements that are related to supportability and readiness objectives;
- design; to acquire the required support.

Implementation of integrated logistics support (ILS), as an engineering discipline at all levels of the programme design phases, provides the framework to develop a total economical operational logistics support system based upon system performance and operation characteristics, system availability readiness objectives, realistic maintenance goals, related reliability and maintainability estimates, and alternative support element cost trades.

A logistics support analysis (LSA) is performed to define the logistics resource requirements for a system to be supported and a related support system to perform these tasks.

The process of logistics resource requirements definition comprises a series of planned, pre-structured tasks to be performed concurrently to the design process. This process is performed in continuous interaction with the disciplines engineering, product assurance, and configuration management.

The LSA is performed iteratively supporting in the early programme design development phase the refinement of logistics requirements, concepts and scenarios and as the system design matures eventually provides a consolidated data base for operational support requirements, definition of logistics support products and the generation of the required logistics documentation.

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Scope

This document defines the logistics engineering requirements in terms of approaches, methods and analyses to be performed for ensuring that development of space systems (manned and unmanned) properly takes into account and integrates the supportability and support aspects for the whole life cycle. It is intended to deal with both ground and on-orbit support system, and ensure that they are properly harmonized, reciprocally, optimized and phased together since the very early design and development phases leading to integrated solutions that have the lowest possible life cycle cost within the operational and safety limitations and constraints imposed by the operational environment.

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Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Technical Memorandum. For dated references, subsequent amendments to, or revision of any of these publications do not apply. However, parties to agreements based on this ECSS Technical Memorandum are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

ECSS-S-ST-00-01 ECSS -Glossary of terms

3

Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purpose of this Technical Memorandum, the terms and definitions from ECSS-S-ST-00-01 and the following apply.

3.1.1 line replaceable unit

item removable at ground organizational maintenance level

3.1.2 orbital replaceable unit

item removable at on-orbit organizational maintenance level

3.1.3 shop replaceable unit

line replaceable unit's internal components removable at ground intermediate maintenance level (shop)

3.2 Abbreviated terms

The following abbreviations are defined and used within this Technical memorandum.

Abbreviation	Meaning
AIT	assembly, integration and test
EVA	extra-vehicular activity
FMECA	failure mode, effects, and criticality analysis
ILS	integrated logistics support
LCC	life-cycle cost
LORA	level of repair analysis
LRU	line replaceable unit
ORU	orbital replaceable unit
PHS&T	packaging, handling, storage and transportation
RCMA	reliability-centered maintenance analysis
SRU	shop replaceable unit

4

Logistics support concept

4.1 ILS technical issues

The subclauses that follows identify and shortly describe the major areas of interest of the ILS. Dedicated subclause of the Technical Memorandum is presented to cover each issue herewith described with the applicable details.

The issues herewith listed covers tasks and analyses that are primarily under the responsibility of ILS (as for example maintenance procedures generation and spares determination) but includes also design issues that impacts on ILS and are impacted by ILS considering that the end item under development (e.g. the satellite) and the system designated for the end item support (e.g. the manuals and ground support equipment) are strictly correlated each other and are considered as a unique product named the space system similarly to the weapon system that is the terminology adopted in the military field.

As the weapon system is a complex of hardware, procedures, materials, skilled human resources that all together are capable to reach a predetermined objective (e.g. be able to bomb for 6 months with an operational availability of 0.95 %), so the space system becomes a complex of flight and ground hardware, procedures, materials, skilled human resources that together are capable to meet a similar composite objective described in the relevant specifications.

4.2 Definition of support scenarios and criteria

The definition of support criteria is a task performed in the initial phase of the development of a new product, and consists of the identification, assessment and agreement with the intended end user of the product under development of the parameters that enables to identify the operational support scenario and the criteria to be applied when support issues are analysed.

The major tasks are finalized to define the type and the conditions of the activities to be considered for the end product.

The definition of support scenarios and criteria is a task intended to establish the boundary conditions within the logistics is going to operate once in operations. These conditions are assumed as limitations in the design and development phase in order to influence accordingly the design of the end item and the associated support resources.

As results of this task documents shall describe the boundary conditions identified, a logistics concept and scenario or inputs to the definition of the system technical specification and statement of work for the development phase.

4.3 Development of the maintenance and logistics support concept

4.3.1 General

The development of a maintenance and a logistics support concept is the logical prosecution of the definition of the support scenario (see 4.2).

If, in fact, the establishment of a support scenario is used to define which support activities and requirements can be considered it does not help to define what is convenient to do in practical terms.

If the support scenario includes the availability of a human crew in a pressurized environment and the possibility to launch periodically support materials (e.g. tools and spares), this does not imply the knowledge of the maintenance tasks to be done or are conveniently done. This second information derives from a series of considerations involving an assessment of the tasks complexity, the criticality of the items to be maintained and the associated costs. These considerations lead to identify a typology of tasks and a technical approach to the development of the end item and the associated support system.

The following general conditions contribute to define the development of the maintenance and logistics support concept, to be known and considered in order to start the design of the end item and its support system, In particular for a manned space system:

- human crew is available with a certain number of hours per year for performance of maintenance;
- a set of known tools is available on orbit to cover simple tasks or also more complex tasks at known maintenance workstation (after removal of the equipment under going maintenance);
- it is feasible to re-supply spares;
- There are activities not feasible on board for safety reasons;
- The working conditions are standard but with no gravity (0-g), however, for critical tasks (that preliminary require a station de-pressurization) it is feasible to work using the extra vehicular activity (EVA) suit.

In fact, in accordance with and without violating the scenario's constraints, various concepts for support are feasible. An equipment can have been designed based on corrective maintenance performed extensively at intermediate level minimizing the needs for resupply materials but spending a large amount of crew hours. A different approach can be to perform extensively preventive maintenance at organizational level trying to avoid the operational impacts of the failures, but with a large spending of resupply of spares.

Both the concepts are compliant with the scenario but they imply quite different approaches and costs.

4.3.2 Maintenance and logistics support concept

The definition of the maintenance concept is the definition of which type of activities are intended to be performed at the various levels of maintenance that the scenario provides.

The logistics concept is the complement to the maintenance concepts

considering that spares for organizational level maintenance support generally are equipment that are repairable and restorable to service while spares for intermediate maintenance support are sub-equipment or components hardly to be conveniently repaired. Consequently, the supply support and PHS&T chain to feed the resupply line in the two cases are very different.

The definition of the support concepts paired with the definition of the support scenario are generally established in a logistics concepts and scenario documents.

4.4 Evaluation and selection of design and support alternatives

In the initial definition phases until a preliminary design review is completed, various design alternatives can be injected into the engineering in order to define the most appropriate solutions. For example:

- The ILS specialists contribute to the assessment of those alternatives considering which impact they have on the support system. In case ILS specialists identify design features that constitute a problem for the support system, they can also ask for or propose design modifications that allow reaching a better compromise between the end item and the support system features.
- Furthermore, in parallel to the design definition, various support alternatives can be evaluated for a specific design to determine the most cost effective one. The selection is done based on the life cycle cost of each alternative as the most comprehensive parameter.

Figure 1 shows the logical process leading to the selection of a design and a support system optimized each other.

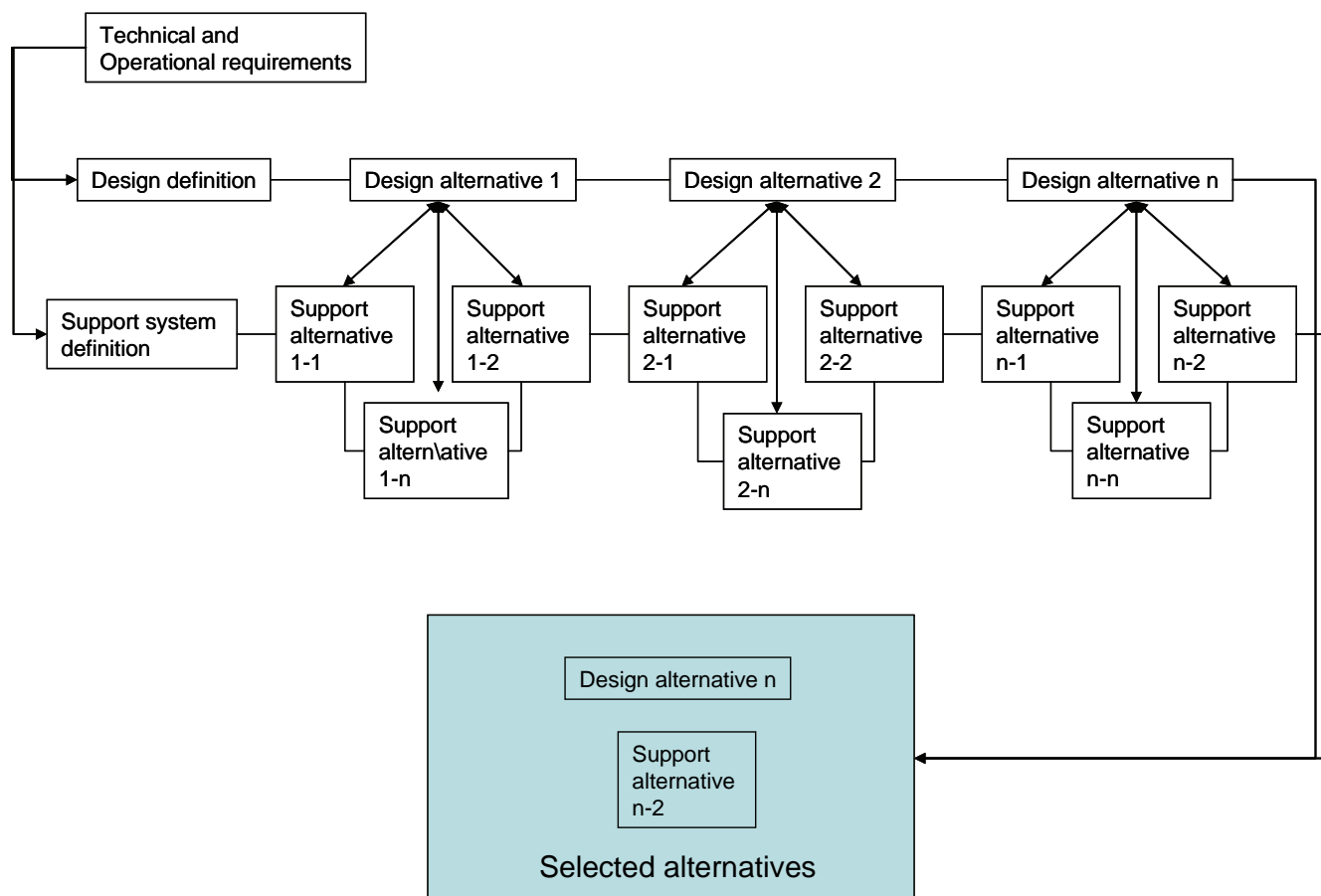


Figure 1: Design selection process

4.5 Support to system physical configuration and layout definition

4.5.1 General

The physical configuration of the end item plays an important influence on the attitude of an end item to be supported at a convenient cost.

For example, the implementation of an automatic failure detection and isolation capability, the easy accessibility to the items planned for removal or maintenance, the proper modularity developed in accordance with the foreseen failure modes, the standardization of the interfaces (mechanical, fluid, power and data as applicable) and components are all elements that enable for a reduction of the total support cost by reducing the needs for crew operations, for tools, for spares and upload mass (no good element is replaced only because attached to a faulty component).

4.5.2 ILS role

The role of the ILS is to participate to the design and layout definition in order to inject those concepts and principles in the system design since the beginning and to monitor and control that they are correctly and extensively applied.

Deviations from those general criteria are identified and justified in view of the total LCC or in view of violation of other more important operational and

performance criteria

All the ILS areas are impacted by the configuration and layout of the end item considering that not only maintenance but also the associated support equipment and tools, supply support and PHS&T efforts are driven by the selected solutions.

The main area of impact is on the maintenance that is the discipline that is at direct contact with the physical solution implemented in the design with all associated drawbacks.

All the proposed configurations are analysed from a maintenance perspective point of view in order to assess as early as possible the potential consequences, positive and negative, of each proposal.

4.6 Maintenance analysis

4.6.1 General

The support activities performed after entry into service of the end item have as final objective to keep in service the end item at the minimum cost and with the maximum of availability. As indicated in 4.5, the ILS activities are driven by the maintenance that is the primary source of resources' requirements.

The maintenance is, in fact, the ILS operational task that directly interfaces with the end item while it is in service. All other ILS operational tasks (e.g. reprocurring spares, updating manuals, and performing training, ship and store hardware) are consequences of the requirements for maintenance.

Identification and definition of maintenance needs is one of the primary tasks during the design and development phase. Completion of this activity enables for the correct and timely development of the support resources is necessary for the end item utilization.

Maintenance needs basically derives from two sources:

- the item degrades the performances in the time reaching soon or later a level no more acceptable;
- the item fails without a previously detectable degradation.

The first bullet above is the starting point for all the preventive maintenance, servicing or condition monitoring activities that lead to the identification of a restoral task that can be scheduled before the occurrence of the failure.

The second bullet identifies the source for all other maintenance that can be defined as corrective because it correct an actual situation where the items has lost one or all its functions.

4.6.2 FMECA

The FMECA identifies the potential modes of failure, quantify the associated level of probability and identify the consequences.

Starting from FMECA, the failure probability associated to an item can be identified and the set of corrective maintenance tasks to be prepared with all the associated resources can be established. Also, RCMA can be performed identifying and defining which can be the preventive activities that enable to reduce the failure probability.

4.6.3 LORA

The set of maintenance tasks defined and complemented with the set of all the resources deemed necessary for their correct performance can be fed to the LORA.

LORA establishes, using the logistics and maintenance scenario and concept parameters, based on technical complexity and costs which is the most correct level of maintenance for each task.

4.6.4 Maintenance plan

Conclusion of the task described in 4.6 is a maintenance plan. In this plan a set of resources is assigned for each maintenance task, a frequency and a location for performance. This implies that logistics and maintenance resources are developed and distributed in the various locations based on that plan.

Figure 2 shows the process related to the definition of the maintenance analysis

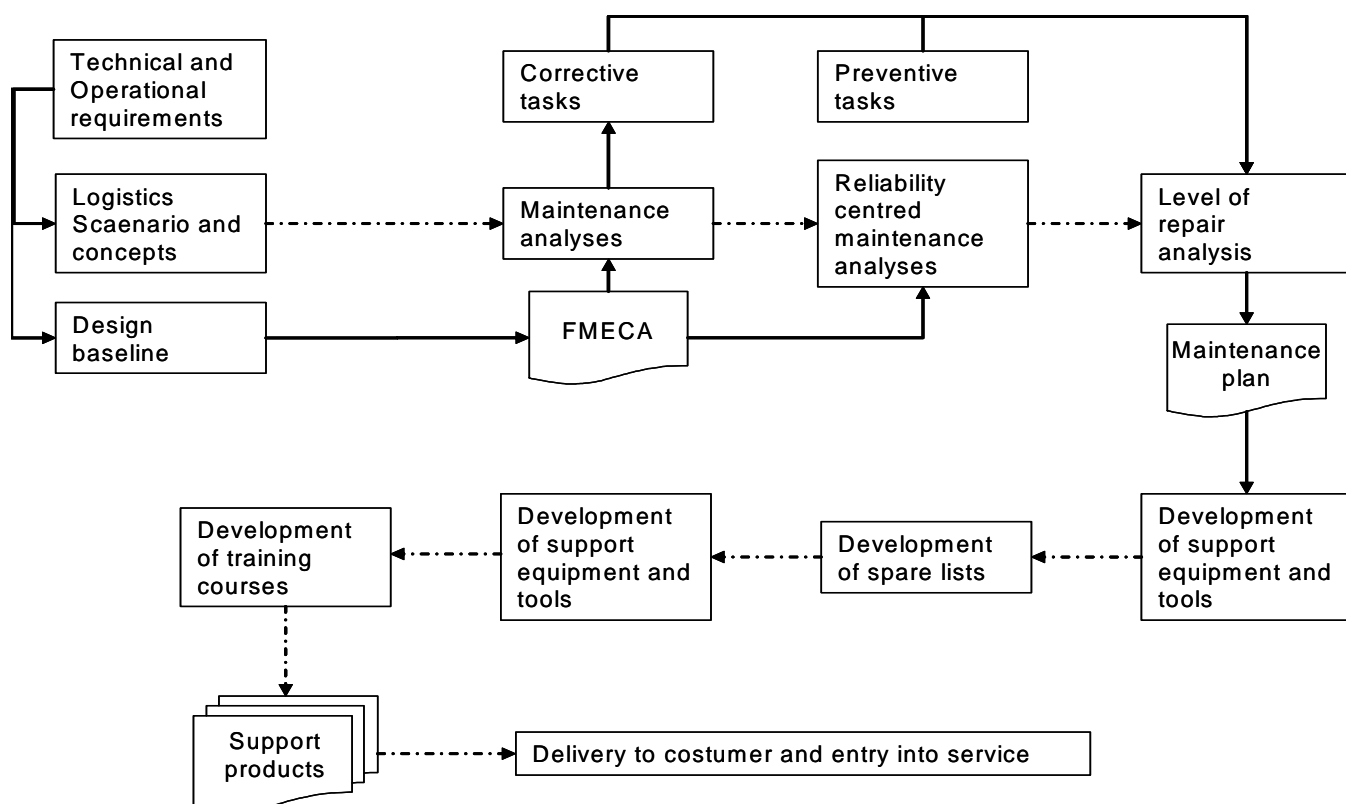


Figure 2: Maintenance analysis process definition

4.7 Software and hardware modularity (orbital and terrestrial replaceable units)

As a detailed part of the support provided to configuration and layout definition, the definition of the modularity level to be applied to software and hardware is one of the primary responsibilities within the ILS design and development effort.

This aspect is one of the key elements driving or driven by the maintenance and the levels of maintenance. Modularity and maintenance to be done at the various levels are strictly linked each other because modularity is done for maintenance and maintenance allows exploitation of modularity.

As a general rule, the hardware or software elements designated for being replaced at a certain level of maintenance is designed in such a way that they can be removed at that level avoiding or minimizing the requirement for dedicated equipment and tools and with the minimum cost.

For hardware the following can be defined:

For software, similar concept is applied, based on the possibility to upgrade or replace software elements at a designated operational level.

4.8 Resupply, stowage and return analyses

Resupply and return and stowage analysis applies only to the support scenario for manned modules where on orbit maintenance is feasible supported by logistics support materials (spares) launched when needed, stowed on orbit before usage and faulty items are returned.

Detailed analyses is done to ensure compatibility of requirements with available resources (resupply return or stowage mass and volume) to avoid incompatibilities.

Feedback of the resupply, return or stowage analyses is provided to the operational planning branches and to the design when the requirements cannot be met without introducing modifications.

Resupply and Return analysis begins with evaluating hardware items and classifying them as ORUs (see 4.6). This analysis leads to defining and examining the significant hardware physical attributes, such as weight, volume and in particular cases also shape, and determining the impacts on the available resupply/stowage/return capabilities.

4.9 Logistics Modelling & Simulations

Modelling and simulations are support elements during the design & development phase and also in the operational period to help anticipated planning of resources.

Models and simulations are simplified methods for evaluating the impacts of design solutions on the expected support requirements. They are mathematical representations of the expected operational and support scenario (models are considered more complete and detailed than simulations but in general and conceptual terms there are no difference) that includes:

- expected failures (normally based on Montecarlo method),
- planned maintenance (based on available maintenance plans) and other events as necessary, and feasible, and associate to each event specific support resources.

By running multiple times the models, statistical analyse results identify the most probable or most critical integrated scenarios.

By modifying the design parameters (e.g. by changing the modularity level of the end item increasing or decreasing the number of ORUs) the optimized solution versus the expected requirements are identified.

Modelling and simulations can be used at different level of complexity based on the effort required by the programme. In general terms, simple calculations based on known failure rates and maintenance frequencies are considered as very simple models. Dedicated ad-hoc models can be developed for strategic programmes (e.g. the International Space Station).

4.10 Maintainability, Testability and Accessibility for Maintenance

Maintainability, testability and accessibility constitute together with Reliability that do not normally pertains to ILS but to Design or Product Assurance, the most important terms of the “supportability” concept.

- Supportability is the attitude of an item to be supported effectively and at low cost within the given operational constraints. Others, contributors to supportability are identified with the:
 - Flexibility (capability to be adapted to uses different by the original ones),
 - Portability (applicable in particular for software element and measuring the capability to be adapted to different software operational environment or platforms)
 - Affordability (capability to stay within the intended cost envelopes),
 - Modularity (capability to be easily split in separate elements that can be interpreted as a particular aspect of the maintainability).

The reason that drives selection of maintainability, testability and accessibility (MTA) as major elements is their relevance to maintenance.

- Maintainability is the capability to be easily/economically maintained and shall be implemented for all items selected as maintenance items (subject to maintenance) with an increasing effort when the frequency of the maintenance increase (make more maintainable things requiring the more maintenance).
- Testability is the capability to be easily/economically tested to identify and locate failures and shall be directed to the feasible maintenance. It is required to be able to fault isolate the items that can or should be removed or repaired. To fault isolate non removable or non repairable hardware in not useful.
- Accessibility is one of the elements of the maintainability but it is also a pre-requisite (normally access for maintenance involves also physical elements not directly interested by the maintenance) and implies also

the capability to be accessed for operations, not only for maintenance. Also in this case, accessibility is a characteristics that shall be implemented where necessary, hence on the interfaces requiring to be operated for normal work or for maintenance.

Therefore a careful control shall be applied to coordinate/contribute to the design efforts in order that accessibility, maintainability and testability characteristics are properly introduced where and as needed.

The presence of ORUs not testable (fault locatable) or not accessible on orbit is a design inefficiency (why having an items removable at organisational level when it is not possible to know that it is the faulty item or can no be properly accessed).

The presence of accessible and testable items that are not repairable or removable is the same.

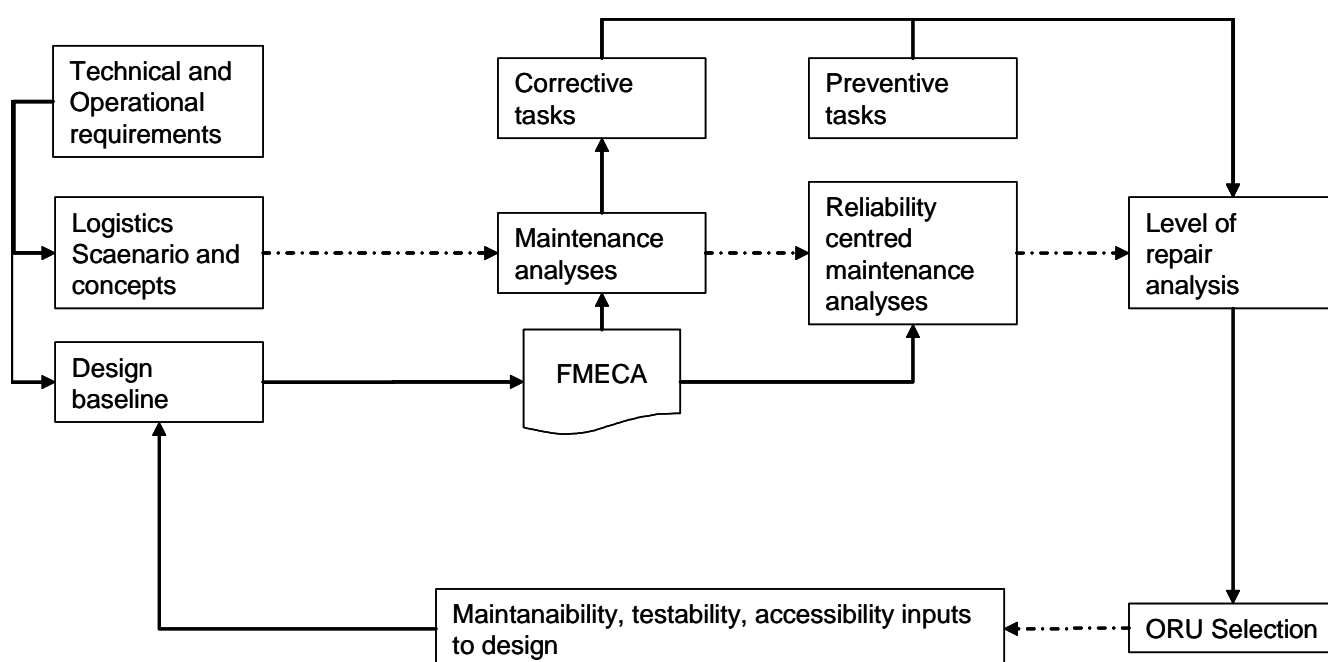


Figure 3: MTA process definition

4.11 Maintenance procedures development and associated safety aspects

The identification and definition of the type of maintenance tasks and the level of maintenance assigned to each of them is followed by the generation of a procedure.

- a. A high level procedure is developed to make possible the assessment of the maintenance level and the feasibility.
- b. As soon as the design evolves and becomes more detailed, the step-by-step procedure becomes more precise and detailed up to the identification of all single elementary activity, all part required and all tool including also an evaluation of the skill suggested for accomplishment.

The phased development of the procedures allows also identifying possible design problems or needs for additional tools providing an early solution to these problems.

The safety of the operations is one of the aspects that are kept into account in all phases in particular for on orbit operations.

The maintenance procedures are fed after the design completion to the Maintenance Manuals production phase where the procedures are complemented with all the data necessary to make their interpretation easy and complete and are transferred in the format required by the end Customer.

4.12 Maintenance tools identification and selection

Part of the maintenance procedures generation is the maintenance task analysis leading to the identification of the logistics resources necessary for the accomplishment of the procedure.

- The tools are one of the primary elements to be considered in particular for the on orbit environment.
- The number and type of tools required shall be minimized and the maintenance interfaces (bolts, fasteners, junctions) shall be standardized as much as possible with this objective in mind.
- New or special tools shall be selected only when any other possibility is forbidden or not convenient. The tool selection shall be done after a verification of their usability using physical or electronic mock-ups and considering the operational environment (e.g. in 0-g conditions it might be difficult to apply the standard torque levels).
- Selected tools, paired with the tasks they are used for, shall be fed to the maintenance plan for operational implementation of the resources in view of the operations phase.

4.13 Spares identification, definition and quantification

Besides the maintenance tools, another resource that can be identified by the task analysis are the spares based on the task frequency and on the needs (for replacement or repair parts or consumables).

- Identification of spares should take place as early as possible at least for the initial set.
 - For programmes with short “support life” (like satellites) the early identification is necessary in order to procure spares together with primary hardware in support to the assembly, integration and test (AIT) phase before launch.
 - For programmes with a post delivery support phase, the early identification allows for procurement integrated with production not only for the AIT phase but also for the initial operational life phase. This approach is named SAIP, Spares Acquisition Integrated with Production, is defined in MIL-STD-1561 and is normally the most convenient way for procurement of spares.

Early spares identification is important also for Long Lead Time Items that shall be ordered in advance in respect to the need (various months or years in some cases).

For major spare items, the identification is feasible before proceeding with a detailed task analysis considering the failure characteristics of the items and the intended usage.

Elements allowing for an early identification and quantification of spares are:

- Values of Mean Time between Failure,
- Wearout Life
- Identification of preventive maintenance needs requiring change-out of items

Beside the initial identification and quantification, based on the characteristics of the items, the final spares quantification shall be done considering not only the hardware to be supported but also the supply pipeline. Logistics lead times play a role at this regard because they increase the need for spares coverage.

4.14 Standardization (tools and support resources)

4.14.1 General

Standardization of support resources is day-by-day task that shall be accomplished through a careful monitoring of the design evolution.

The specification is responsible for the introduction of this criterion into the scenario. Anyway this type of requirement can not be imposed in an extremely rigid way because it might become a problem if imposed with low flexibility. Hence, the wording of such a requirement is usually open to interpretations and due to this characteristic, it is normally easy for designers to find good reasons for selecting in their design solution ad-hoc interfaces, fasteners.

4.14.2 ILS Role

The role of the Logistics and maintenance analysts consists in the monitoring of all solutions and verifies if the deviations from standards are really justified and which problems might generate in case special interfaces are used.

4.15 Development of logistics support elements and documentation

The development of logistics elements and documentation is a task that leads to the build-up of the support system. Once the primary system, the end item, is frozen in terms of design, the definition of the required support resources can be completed and the development of the support product can start with the objective to phase their availability with the deployment into service of the end items.

As an example, together with the end item a set of initial spares shall also be provided to cover initial requirements for corrective and preventive

maintenance. Only after an initial operational experience is available, the operational spares re-procurement line can be fine tuned for the real needs.

Availability of support resource shall also be phased with the possibly agreed Logistics Responsibility Transfer Plan. This applies in case the Customer intends to acquire the support capability transferring it from Industry. The Plan is intended to define what capability, when and how is transferred.

Manuals, catalogues and technical documentation in general shall be prepared as per the agreed standards. The definition of formats, standards and their applicability shall be early completed in the development phase with the Customer.

4.16 Packaging Handling Storage and Transportation of equipment and end items

PHS&T is a task that, similarly to maintenance, is split in various sequential phases from the beginning of the development phase to the completion of delivery:

- a. Identify and define needs (do I need to PHS&T something in the programme?)
- b. Define scenarios and concepts (what is to be PHS&T, which methods can be applied, when they occur, which frequency, which type of protection is required).
- c. Define technical requirements
- d. Develop support resources that are procedures, materials, equipment, planning, contracts, plans and other documentation.
 - o Procedures are necessary for packaging, storing, handling, transporting all items in proper way, avoiding damages.
 - o Materials (boxes, foams, insulation's, labels, silica gel) and equipment (containers, handles, purging carts, and lifting devices) are necessary for preparing, protecting and handling hardware during all phases in the logistics pipeline.
 - o Planning and contracts are necessary for executing when required and as required the PHS&T tasks.
 - o Plans are necessary for knowing what to do and when.
 - o Other documentation can be identified in the shipping list, custom documentation, invoices, requests for permissions and authorizations, certification of items, operations and personnel and activity reports.
- e. Execute PHS&T operations since development phase start (e.g. by preparing and executing shipment to test facilities).

4.17 Reparability Analysis

Repair is the task to restore a failed item in serviceable conditions.

When the failed item is the primary end item (Space Module, GSE or other) repair might simply be remove and replace of failed component. Failed

components at this level are ORUs or LRU.

When failed LRUs or ORUS are removed and replaced with good hardware, they can be subject to a repair task finalized to identify and replace which lower level component caused the ORU failure.

In case the ORU are designed to support this activity, the lower level components should be conceived as SRU that conceptually are intended as items designed to be easily replaceable facilitating in this way the maintenance.

The reason why an ORU is designed based on SRUs or not is because an analysis is done to identify if the ORU could be conveniently repaired or not.

- Reparability shall be evaluated with respect to the technical feasibility of the task but also with the economical convenience. In fact, once an ORU is failed, the Customer can procure a new item or ship for repair the faulty one to the repair workshop. Only an economical benefit is more attractive the second solution and the economical benefit can be determined only by analysing all the involved parameters and making trade-offs.
- Reparability analysis shall start from the identification of possible type of failures (FMEA) associated to an assessment of the technical feasibility of the repair for each of them. An idea of the level of maintenance where repair can be accomplished can already be generated in this phase.
- An economical estimate shall be done to quantify the possible cost of the repair from trouble shooting to completion of post repair acceptance test.

As a consequence, a scenario assessment shall be completed trying to understand which frequency of occurrences can be estimated, if and which level of risk can be accepted for repaired units, which are the other cost elements that influence final selection (e.g. ground processing cost for the faulty unit and fixed cost occurring for maintenance of the repair lines).

Therefore, conclusion shall not be that a unit is generically “repairable” but “conveniently repairable within the scenario where it will operate”.

Units selected for being repaired in case of failure shall be designed in such a way to increase their maintainability level; hence a SRU design shall be extended to all internal components with a critical failure rate.

4.18 Qualification of maintenance procedures

This task shall be executed in order to validate the maintenance procedures.

The verification of requirements is performed using various means:

- a. Verification by test: this verification is executed using:
 - Physical Mock-up (in 0-g or 1-g)
 - Digital Mock-up
- b. Verification by Analysis: This type of qualification is based on the 0 or 1-g test results acquired by means of selected procedures. These data is used to prove the executability of the procedures not tested; the demonstration is based on the similarity of the tested procedures, or part of them, with the procedures not tested.

- c. **Verification by Review of Design:** This type of qualification is based on the fact that the provider already qualifies some of the components/items/tools at component and assembly level. The component/item/tool design is checked against the product design and configuration to qualify the relevant portion of the logistic requirements.

4.19 Personnel Training Support

Training shall be prepared and supported by suitable aids based on documentation, mock-ups, and simulators as necessary.

Training shall come out from the operations and logistics and is associated to specific tasks and equipment.

As far as logistics is concerned, while the support functions are identified, training requirements identification shall be also performed.

4.20 Verification and control of requirements

Each space program starts with a complete definition of the requirements that have to be met in order to deliver to the user (e.g.: space agency) a compliant product.

The verification and control of requirements shall start just after the issuing of these requirements.

A dedicated panel including the two parties – product developer and customer has to be set up in order to constantly verify the status of the requirements and to amend them if necessary.

Modification of a specific requirement has to be tracked in official documentation.

4.21 Logistics Activities in the Exploitation Phase

After the on-orbit commissioning, a space system has to be maintained in an operational status and used in accordance with the target of the mission by providing the necessary support resources in terms of spares, procedures, technical support

The Operational needs clearly identified and defined are related to:

- a. Providing the planning capability and the associated analytical functions in terms of being able to identify the technical, operational and programmatic objectives, to define the methods and needs to reach them and to implement the consequent operational tasks into the ILS activities' flow. This include the capabilities to perform simulations, resupply and return and on-orbit stowage analysis.
- b. Providing maintenance support in terms of preventive requirements, assessment of corrective maintenance priorities, provision of maintenance procedures, and management of ground maintenance cycle for returned hardware.
- c. Providing Supply Support in terms of re-procurement of spares and materials, procurement of new hardware if needed.

- d. Ensure coherence of the technical documentation in order to maintain up to date the space system technical documents and databases in accordance with the flight hardware configuration and operational procedures and policies.
- e. Providing Ground Processing / Launch Site Support that is the capability to support Launch Organizations in the ground processing and integration in the launcher of the space system dedicated resupply resources and in the de-integration and ground processing of the returned space system hardware
- f. Providing Training Support to the space system Team and other personnel involved in the processing of the space system hardware
- g. Providing a Logistics Support Analysis capability that maintain the space system logistics source data (LSAR) up-to-date as necessary and support new development of modifications of hardware.
- h. Provide the capability to manage and coordinate the whole spectrum of the above identified tasks and supports in accordance and in compliance with the space system support requirements. Manage means in particular to take decisions; hence this includes the capability to assess various scenarios with associated probabilities to become real and associate management risks.

4.22 Logistics Support Information System

The Logistics Support Information System is a set of information tools that support the logistics engineer during the entire life of the product starting from the development to the exploitation phase. The Logistics Support Information System is constituted as follow:

- LSAR Database
- Inventory Database
- Maintenance Management Database

4.22.1 LSAR Database

MIL-STD-1388-1 constitutes the basic standard for the Logistics Support analysis (LSA). In accordance with this standard, the LSA can be defined as the selective application of scientific and engineering efforts undertaken during the acquisition process, to assist in complying with supportability and other Integrated Logistics Support (ILS) objectives.

The logistic support analysis record is part of the requirements detailed in the MIL-STD-1388-1.

LSAR includes 14 individual data records pertaining to some of the technical characteristics of the system.

MIL-STD-1388-2 constitutes the basic standard for the LSAR.

The LSAR Database (Logistics Support Analysis Record) is based on the standard MIL-STD-1388-2. This database shall contain:

- Operations and maintenance requirements
- Item reliability and maintainability characteristics
- Failure mode and effect analysis

- Criticality and maintainability analysis
- Operation and maintenance task summary
- Operation and maintenance task analysis
- Personnel and support requirements
- Support equipment and training material description and justification
- Unit under test and automatic test
- Facility description and justification
- Skill evaluation and justification
- Support items identification
- Support items identification (application related)
- Transportability engineering characteristics

The LSAR DB outputs in phase C/D are the Summary Reports, which represent a condensed set of the LSA data.

The LSA Summary Reports in phase C/D, and in Phase E when a whichever design modification occur, form a base to:

- determine the impact of design features on logistic support
- provide data for trade-off studies, life-cycle costing, and operational logistic support modelling
- maintenance and supply support planning
- repair parts and tools definition and provisioning
- identification, description and justification of:
 - a) Support and Test Equipment
 - b) Tools and Support Equipment
 - c) Facilities Information
 - d) Training Requirements

4.22.2 Inventory Database

The Inventory database is a tool dedicated to track information related to the inventory assets pertaining to the program. This tool supports the Logistics Engineer in the development phase and in the exploitation tracking all the inventory assets avoiding mistakes in the spares procurement.

This database shall permit to:

- identify the location, the availability and the applicability of the assets
- identify the Configuration-controlled asset, including versioning and applicability of assets on products
- Manage serial and lot numbered parts
- Manage kits
- Control of stocking requirements
- To have a central archive of suppliers and manufacturers
- Control the Inventory level and automatic replenishment processes
- Reserve assets

4.22.3 Maintenance Database

The Maintenance database is a tool dedicated to gather information related to the assets pertaining to the program in terms of maintenance activities performed on a specific item. This tool supports the Logistics Engineer in the tracking of the maintenance task performed and in the anomaly resolution process, when a failure is detected.

In order to collect the maintenance data the minimum following set of data elements has to be foreseen:

- Part number
- Serial number/lot number
- Version number
- LCN
- NHA Part Number
- NHA Serial Number
- NHA Version number
- NHA LCN
- Event Type
 - a. Anomaly detection Process
 - b. Maintenance Task execution
 - c. Troubleshooting activity
 - d. Failure Isolation results
- Event Description
- Maintenance Task Description
- Recommended Changes

The maintenance planning task consists in the day-by-day management of the ground maintenance activities and in the preparation of inputs to the on-orbit maintenance planning.

4.22.3.1 Ground Maintenance Planning

The relevant field of operations are:

Maintenance planning of flight hardware in the ground cycle

Maintenance planning for ground hardware (GSE).

This includes the following master functions:

- a. Generation of all required support documentation and or disposition (i.e. shipping orders for hardware to be sent to suppliers)

For maintenance activities to be performed internally to the Support System, with internal resources in terms of personnel and materials, the system shall generate work-orders used to activate the operational tasks. For lacking resources it shall activate the re-procurement system/function and for externally accomplished works requires the support of subcontractors, shipping orders shall be generated and consequent support requests issued to the procurement and purchasing

system/function. Work orders shall be accompanied by reference to the suitable technical documentation as necessary.

Generation of schedules for works accomplishment

The system shall be able to define and prepare schedules and work orders for tasks accomplishment.

Monitoring of works status (progress reporting)

The system shall be able to require and receive progress reports from the operational personnel or from the subcontractors management function. These data are used to update/fill the forecast tables for pending jobs.

Delays in respect to the original completion data overcoming pre-defined limits for each work shall be reported by issuing Maintenance Problem Reports to the management.

Generation of completion forecasts for all pending jobs

Scheduled jobs shall be provided with a completion estimated data that is kept updated considering the received progress reports.

Loading of closure reports for completed works

Completed jobs shall be loaded and recorded with associated closure reports containing all information related to the job itself, duration, cost, and deviations from nominal, suggestions/recommendations.

4.22.3.2 On-orbit Maintenance Planning

A complete Maintenance Management tool includes the following master functions for generation of planning inputs to the overall ISS on-orbit maintenance planning:

- a. Collection of all works to be completed with completion time constraints if any.
This implies the possibility to feed into the maintenance management tool for each manager piece of hardware the following information:
- b. Maintenance Plan data (which preventive maintenance in the next planning period)
- c. Operational updates to maintenance plan (corrections to preventive maintenance scheduling due, for example, to corrective interventions)
- d. Requests for corrective maintenance (actual failures to be restored)
- e. Requests/forecast for on-condition based maintenance (these are request, hence based on real requirements, for maintenance actions to be planned in the next planning period while are simply forecasts for the future next planning periods, if these have to be managed).
- f. Operational requirements for the repaired hardware (by when each items shall be ready) in order to support priorities allocation.
- g. Verification and planning of resources availability (time, personnel, materials, support items) and compatibility among the different works.

This implies the possibility to have and interface to the LSAR for getting resources requirements for each task and to the Inventory System for verification of physical availability of resources. The information about the maintenance personnel and Subcontractors availability are assumed to be part of the Maintenance Management System itself.

Each identified resource must be allocated in quantity and time to each scheduled maintenance task.

h. Generation of schedules for works accomplishment

The system shall be able to generate integrated schedules for the next planning period considering available resources versus requirements and allocated priorities as boundary conditions.

Bibliography

The publications listed below were used in the preparation of this Technical Memorandum, and contain background information relating to the subject addressed.

ECSS-E-ST-10	Space engineering – System engineering general requirements
ECSS-M-70	Space project management – Integrated logistics support
ECSS-Q-ST-30	Space product assurance – Dependability
MIL-STD-1388-1A	Logistics support analysis
MIL-STD-1388-2A/2B	DoD requirements for logistics support Analysis record