Configuration Management in a Ground Station Network

Peter Müller[1] and Yves Doat[2]
ESA - Directorate of Human Spaceflight and Operations, 64293 Darmstadt, Germany

The paper focuses on the Configuration Management principles applied during the utilization phase in ESA's worldwide network of TT&C Ground Stations (ESTRACK) and the associated Control Centre facilities. Apart from the principles it describes the supporting Configuration Management tools and the benefits for ground operations and maintenance teams.

The Product Tree, a functional breakdown of ESTRACK Facilities, is the starting point of the Configuration Control Activities. A comprehensive inventory list contains the installed hardware and software and all the necessary documentation to describe it. Cross references into the Document Management System application ensure consistency and facilitate document retrieval. Configuration Status Accounting is supported by built-in configuration reports.

A workflow implementation for Configuration Changes ensures traceability of configuration change requests (CCRs), their approval or rejection from the responsible configuration control board (CCB) and their proper implementation into the ESTRACK network.

I. Introduction

ESA's worldwide network of TT&C Ground Stations (ESTRACK) comprises 11 antennae spread over 10 different locations around the globe. ESTRACK is remotely operated from ESA's European Space Operation Centre (ESOC), located in Darmstadt (Germany). Maintenance activities are carried out by dedicated teams in each individual ESTRACK location. ESTRACK is currently utilized by 11 flying ESA missions representing 14 spacecraft and also provides TT&C support to 3rd party organizations.

Configuration Management principles are applied to the entire ESTRACK network and the associated Control Centre throughout its whole lifecycle. ESTRACK is in the utilization phase (E), consequently this paper focuses on configuration control and configuration status accounting principles of configuration management.

In ESTRACK, the Ground Systems Engineering Department is responsible for the design, the production and the requirements verification during the definition and qualification phases A to D. During these phases, configuration items are identified and described in a breakdown structure, the so called Product Tree.

At the end of phase D an agreed baseline configuration is formally handed over from Engineering to Operations, this triggers the start of the Configuration Control process. Along with this handover, a 'consistent record of a product's functional and physical characteristics' (see 1) is entered into a Configuration Management DataBase (CMDB) to document the agreed baseline. This information is an input for the handover and is provided by Engineering

In the CMDB, the 'product's functional and physical characteristics' (see 1) are described in a Product Tree and in a detailed physical inventory list. The Product Tree is composed of different element types. In ESTRACK, the highest level element is called Terminal and forms the root element of a Product Tree. The Terminal is broken down in several functional elements called System, a System is broken down into physical elements called Equipment. Finally Equipment may be broken down into assemblies, the so called Sub-Equipment.

A physical inventory list describes all ESTRACK inventories, distinguishing between hardware, software and documents. Controlled documents and their source files are managed in a dedicated Document Management System

[1] Maintenance Engineer, Ground Facilities Infrastructure Section, ESOC, Robert-Bosch-Str. 5, 64293 Darmstadt, Germany.
[2] Head of Section, Ground Facilities Infrastructure Section, ESOC, Robert-Bosch-Str. 5, 64293 Darmstadt, Germany.

(DMS). Product Tree elements are linked to inventory items. Inventory Items of the type documentation are linked into the DMS. Product Tree, Inventory Lists and their relationships all together document the agreed baseline.

II. Documentation of the agreed Baseline

The agreed baseline configuration of the entire ESTRACK system is maintained during its utilization phase. Any deviations or evolutions from this baseline undergo a formal change procedure.

The documentation of the agreed baseline is described in this chapter.

A. Product Tree

The Product Tree in ESTRACK is a combination of a functional along with a physical breakdown. It is implemented according to the following assumptions:

- Each antenna or Control Centre in ESTRACK is described by an individual Product Tree.
- The root element of such a Product Tree is called Terminal .
- Every single Terminal is further broken down into functional elements. Such elements are called System. A System can be composed out of several lower-level Systems, the so called Subsystems.
- Every System / Subsystem is composed of physical element(s). These physical elements are called Equipment and are all together forming the function of the System / Subsystem.
- Every Equipment can be further broken down into assemblies, the so called Sub-Equipment .
- Every element in the Product Tree is uniquely identified by a so called Hierarchical Counter (HCNT).

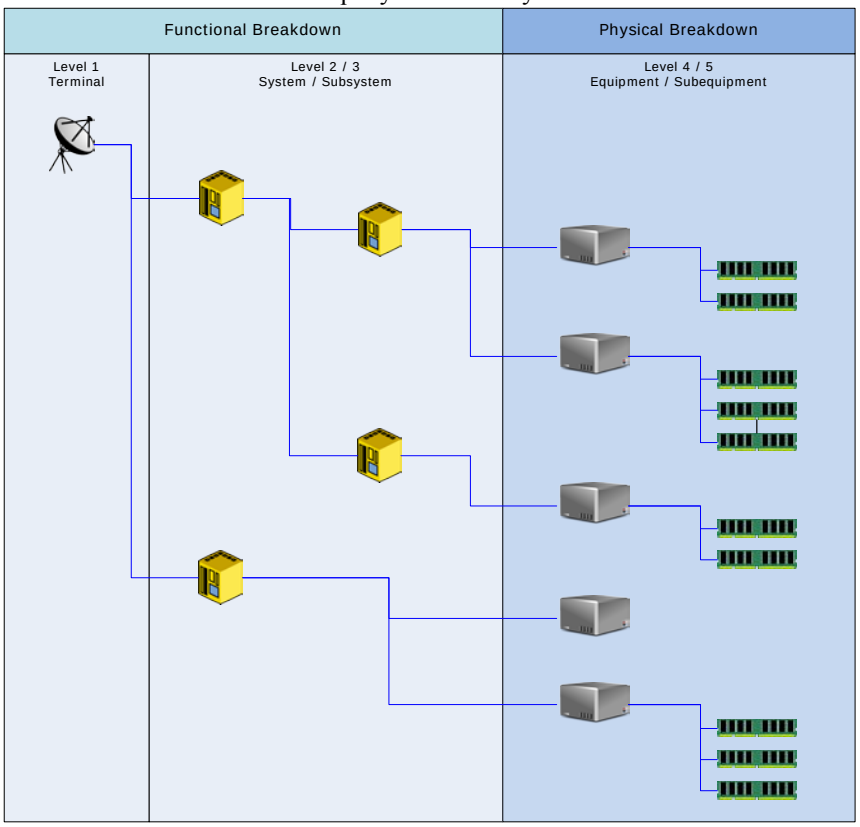


Figure 1 Product Tree Levels - Functional and Physical Breakdown

The Product Tree element identifiers (HCNT) follow a numbering scheme, that easily allows to determine the position and the level in the Product Tree.

TERM.L1.L2.L3.L4 …..

where TERM is the unique Terminal identifier, e.g. KIR1 for Kiruna 1 Antenna, L1 is an unique number for the level 1 element, L2 is an unique number for the level 2 element and so forth.

The combination of a functional and physical breakdown bears some advantages: additional attributes for each Product Tree element could facilitate operations, maintenance and Integrated Logistic Support (ILS) activities in the project.

1. Support to Ground Operations

In the ESTRACK Product Tree an operational status flag exists for every single Product Tree element. The operational status distinguishes between green, yellow (loss of redundancy or reduced performance) and red (out of order). Any status change is recorded along with a timestamp. This allows Ground Operations to assess the operational availability of a particular element at a given time and its consequences for Ground Operations. A report of non-green elements can be presented to Ground Operators in real time, supporting the right operational decisions.

2. Support to Maintenance and ILS Activities

Apart from the real time support to Ground Operations, the history of the operational status flags can be used to calculate the operational availability and the measured reliability (MTBF) of a system or one of its elements over a certain period of time.

The physical breakdown elements Equipment and Sub-Equipment can carry a logistics flag. This logistics flag distinguishes between Line Replaceable Units and Shop Repairable Units, facilitating the identification of the first line maintenance tasks and supporting the right-sizing of spare part stocks. Equipment and Sub-Equipment classified as Line Replaceable Unit are supposed to be exchanged by the local maintenance team at the Ground Station or Control Centre in case of a failure. Equipment and Sub-Equipment classified as Shop Repairable Units always require second and third line maintenance intervention and are not supposed to be exchanged by the first line maintenance team. An example would be a PC and its mainboard, where the PC (Line Replaceable Unit) could easily be exchanged by the local maintenance team, while the exchange of a mainboard has to be done at the manufacturer's or supplier's premises.

B. Inventory Lists

In order to maintain an as-built data list, it is essential to know, which inventories (product items in the sense of ECSS-M-ST-40C Rev.1) are performing which part of a function. In the context of ESTRACK we distinguish between different inventory types. All inventory items are identified by a unique ID, which is generated by the database engine of the CMDB. In addition, a human readable code identifies the inventory type.

ESTK.TYP.xxxxxxxxxx

where ESTK identifies an ESTRACK item, TYP specifies the inventory type (hardware, software, documents, consumable, digital media) and xxxxxxxxxx is an ID automatically assigned by the database engine in the moment a record is created in the database.

Each inventory type is described by different information.

1. Hardware

Hardware items are described by a product name, manufacturer, part number, model, serial number, etc. Each individual serial number is traced in an individual record.

2. Software

Software items are described by a product name, manufacturer, release date, installation date, version and revision number. Each individual ***instance*** of a software product is traced in an individual record.

3. Documents

Document items are described by their title, author, reference no., issue / revision and the issue date. A hyperlink field allows to retrieve the related document directly from the Document Management System (DMS), the repository for all ESTRACK documentation.

Document *items*, although not explicitly required by ECSS-M-ST-40C rev. 1, help to complete the description of a system, a sub-system or its entire components.

4. Consumables

Consumable items are described by their name, manufacturer/supplier, part no., their quantity and a Unit of Measure (UOM), e.g. pieces. Consumables normally do not have a serial no. and are not traced individually. Consumables are not under configuration control.

5. Digital Media

Digital Media items are described by their name, manufacturer, part no. or other identifier. Digital Media items may not only contain the digital media to install a software, but also the license document. A particular software may consist of a license, e.g. for 50 users, 3 CD/DVD sets and up to 50 instances (software items), where they are installed.

A history card is maintained for every single inventory item allowing the traceability of all kind of configuration changes, e.g. relationships between inventory items and product tree elements.

6. Benefits for Maintenance and ILS Activities

Apart from configuration changes, a history card allows the traceability of all kind of changes such as location changes, owner changes, etc. In addition, applied maintenance activities such as repairs or preventive maintenance can be traced back to an individual inventory item.

C. Inventory Libraries

Inventory Libraries are to be understood as templates for inventory items of different types. These templates carry all the common information of inventory items and may hold further information which is useful in other areas.

For hardware items a library record comprises at least product name, manufacturer, part number and model. Further physical and financial information supports the work in maintenance, logistics and engineering teams: price, supplier, dimensions, weight, MTBF, environmental conditions for operating and storing equipment, special shipment conditions, material safety datasheets (MSDS) for hazardous goods, etc. The serial no. distinguishes between individual hardware inventory items of the same model and part no.

For software items a library record comprises product name, manufacturer, release date, version and revision number. Each installation instance information is derived from a library record.

D. Documentation Management

While the CMDB records of document inventory items contain only a subset of the document's metadata such as title, author and revision, the ESTRACK documents are controlled in a Document Management System (DMS), a separate application apart from the CMDB. In the DMS, each individual document or data package is described by its so called index card. The index card contains the document's metadata and each individual document issue / revision is accessible from its index card and via a hyperlink interface. In the CMDB a particular field of document inventory items is able to handle hyperlinks. This allows the user to directly access the linked document from its original repository. The access rights to a particular document are controlled by the Document Management System and may differ from the access rights in the CMDB.

E. Relationships

Various relationships between inventory items of different types and Product Tree elements as well as between inventory items of different types allow to build the configuration of a system or the entire product.

The configuration history is derived from the history of establishing or removing individual relationships. Example: when a new software version is installed on a particular hardware, the relationship to the software item covering the old version is deleted and a relationship with the software item of the new version is established. Each case is traced in the history log.

1. Product Tree - Inventory Relations

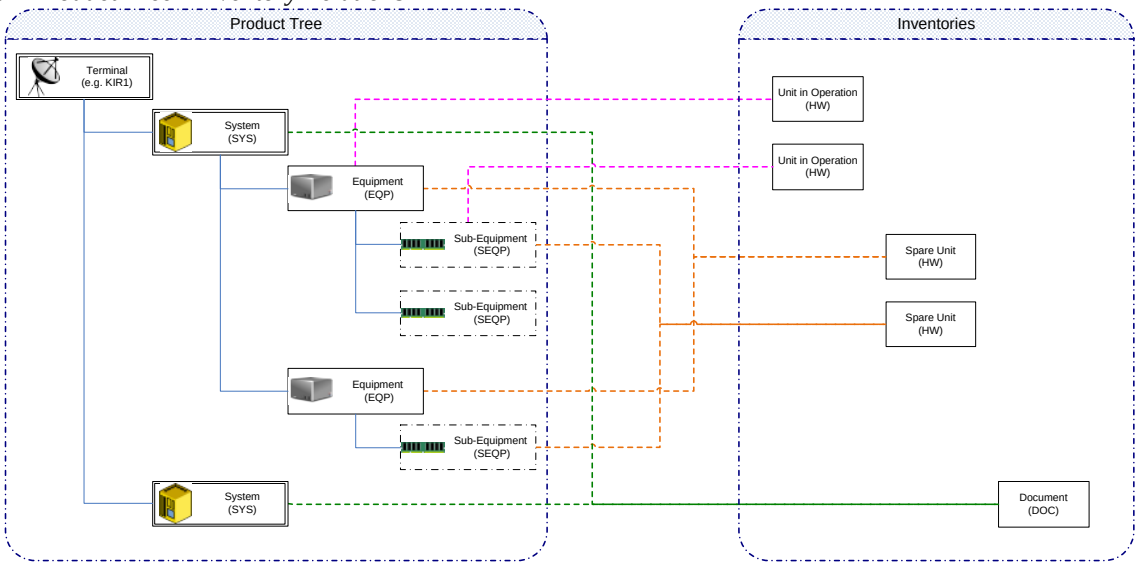


Figure 2 Relationship between Product Tree and Inventories

Relationships between Product Elements and inventory items describe a system and its physical breakdown.

- A document can be linked to multiple Systems: a document might describe the function of a system, a subsystem or more than one subsystem. It also might describe only a part of such a system.
- A hardware item *in operation* can be linked to only one equipment or sub-equipment in the product tree.
- A *spare* hardware item can be linked to many equipment or sub-equipment in the product tree, when it is able to replace such hardware or a sub-assembly of it.

2. Inventory - Inventory Relations

Relationships between inventory items of different types form a configured item in the sense of ECSS-M-ST-40C rev. 1. They create a bundle, which travels around with an inventory item of the type hardware.

- A software item is to be understood as a single instance of a software product. Hence it can only be related to one inventory item of the type hardware .
- A document might be related to one particular hardware item, e.g. a functional test report or a calibration certificate for that specific hardware item. Such documents can only be related to one inventory item of the type hardware and cannot be related to any Product Tree elements at the same time.

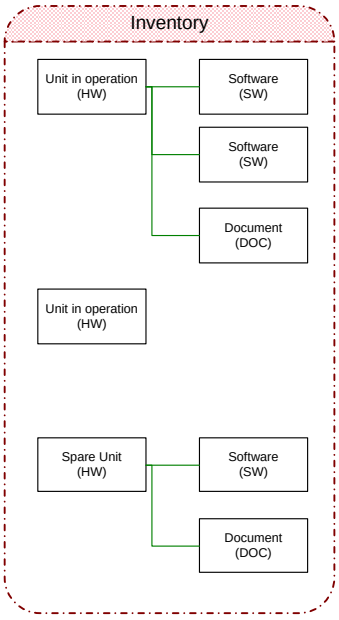


Figure 3 Relationship between different Inventories

F. Configuration Status Accounting on agreed Baseline Configuration

The CMDB application provides support for 2 different Configuration Status Reports. Both reports reflect the latest recorded configuration of configuration items.

1. Device oriented Configuration Report

A device oriented configuration report provides configuration information for a list of preselected hardware inventories, e.g. devices with an identical part no. This configuration report is split into different levels:

1st level: Device information like Product Name, Part-No., serial no., manufacturer as per ECSS-M-ST-40C rev. 1 identification marking requirements.

2nd level: Inventory to Product Tree relationship

3rd level: Inventory to Inventory relationship: hardware to software, hardware to document. Software items show information like ID, Product Name, manufacturer, version/revision and document items show information like ID, title, issue/revision, author as per ECSS-M-ST-40C rev. 1 identification marking requirements.

2. Product Tree oriented Configuration Report

A product tree oriented configuration report provides configuration information for a preselected product tree element and all its children. Consequently this configuration report recursively lists the selected Product Tree element and all of its children split into different levels per element:

1st level: HCNT and Description of the Product Tree element

2nd level: Relationship to hardware unit in operation including Product Name, Part-No., serial no., manufacturer as per ECSS-M-ST-40C rev. 1 identification marking requirements.

3rd level: Inventory to Inventory relationship of unit in operation: hardware to software, hardware to document. Software items show information like ID, Product Name, manufacturer, version/revision and document items show information like ID, title, issue/revision, author as per ECSS-M-ST-40C rev. 1 identification marking requirements.

4th level: available spares including Product Name, Part-No., serial no., manufacturer as per ECSS-M-ST-40C rev. 1 identification marking requirements.

III. Configuration Changes to the agreed Baseline

A. ESTRACK Configuration Change Process

Configuration Changes on ESTRACK Configuration Items are controlled in a dedicated process. As required by ECSS-M-ST-40C Rev. 1, this process comprises the change request, its approval or rejection by the responsible Configuration Control Board, its implementation, validation and documentation. The whole process is implemented as a workflow into the CMDB application. This does not only allow to document each individual request, but also to build a configuration history and trace the applied changes back to their original request.

Changes to the existing configuration can be requested by Engineering, Operations or Maintenance Team members. A formal CCR is created by the application. Dependent on their area of responsibility, the CCR is addressed to members of different CCB's (one for the control centre, one for ground station related equipment).

During the CCR lifecycle the application creates a record for each workflow step in the Configuration Change process. Such a record contains information to identify

- the CCR and its current status
- who performed a workflow step
- when it was performed
- what was the decision or information provided
- what is the next workflow step

Email notifications inform the next contributor about his task in the process; major milestones in the CCR workflow, e.g. CCB approval or rejection, are communicated to all involved contributors.

Changes to, departure of or introduction of new CI's are traced by the application by updating or introducing the corresponding CI's, i.e. the Product Tree structure, associated hardware and software inventory as well as documentation.

The current status of a particular CCR can be exported into a PDF file as a snapshot and printed at any time. Like for the inventory items, hyperlinks directly point into the Document Management System to access documents related to a particular CCR.

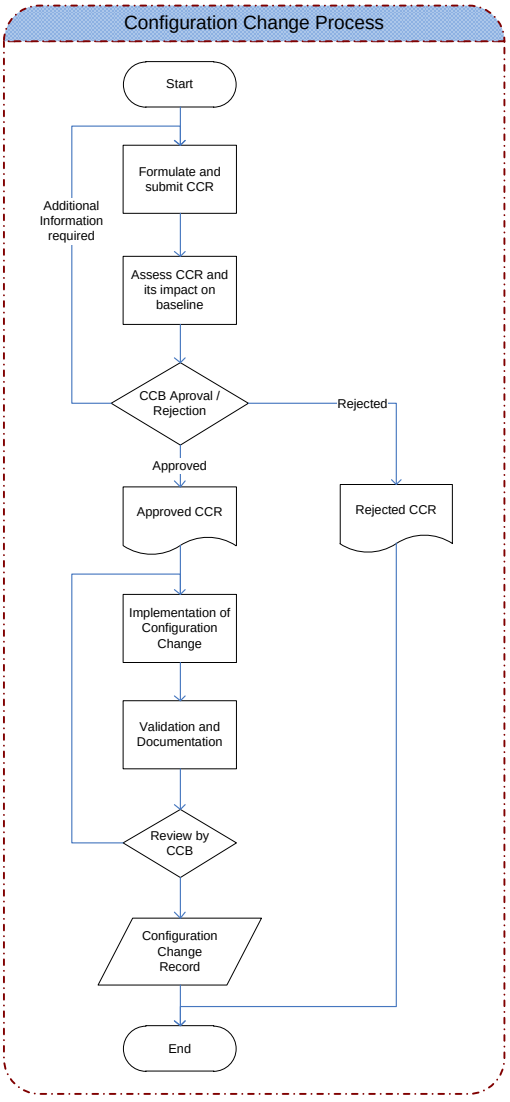
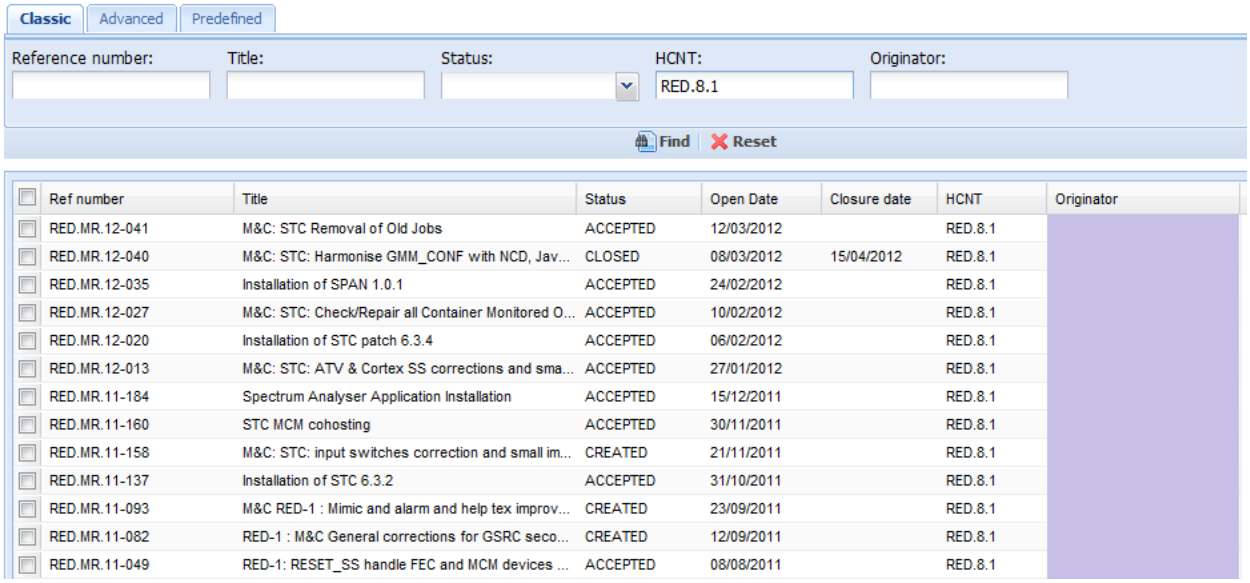


Figure 4: ESTRACK Configuration Change Process

B. Reporting on Configuration Changes

A filtering mechanism in the CMDB application allows to filter for configuration changes for either a particular product tree element or for a particular product tree element and all of its children. The resulting report shows all CCR related to the selected Product Tree element(s), their reference, title, requestor's name, opening date, eventually closing date and its status.



Ref number	Title	Status	Open Date	Closure date	HCNT	Originator
RED.MR.12-041	M&C: STC Removal of Old Jobs	ACCEPTED	12/03/2012		RED.8.1	
RED.MR.12-040	M&C: STC: Harmonise GMM_CONF with NCD, Jav...	CLOSED	08/03/2012	15/04/2012	RED.8.1	
RED.MR.12-035	Installation of SPAN 1.0.1	ACCEPTED	24/02/2012		RED.8.1	
RED.MR.12-027	M&C: STC: Check/Repair all Container Monitored O...	ACCEPTED	10/02/2012		RED.8.1	
RED.MR.12-020	Installation of STC patch 6.3.4	ACCEPTED	06/02/2012		RED.8.1	
RED.MR.12-013	M&C: STC: ATV & Cortex SS corrections and sma...	ACCEPTED	27/01/2012		RED.8.1	
RED.MR.11-184	Spectrum Analyser Application Installation	ACCEPTED	15/12/2011		RED.8.1	
RED.MR.11-160	STC MCM cohosting	ACCEPTED	30/11/2011		RED.8.1	
RED.MR.11-158	M&C: STC: input switches correction and small im...	CREATED	21/11/2011		RED.8.1	
RED.MR.11-137	Installation of STC 6.3.2	ACCEPTED	31/10/2011		RED.8.1	
RED.MR.11-093	M&C RED-1 : Mimic and alarm and help tex improv...	CREATED	23/09/2011		RED.8.1	
RED.MR.11-082	RED-1 : M&C General corrections for GSRC seco...	CREATED	12/09/2011		RED.8.1	
RED.MR.11-049	RED-1: RESET_SS handle FEC and MCM devices ...	ACCEPTED	08/08/2011		RED.8.1	

Figure 5: List of CCR's for a particular Product Tree element

A future enhancement foresees to produce such a report not only from the CCR view, but also directly from the Product Tree view. An intelligent reporting on approved and implemented and validated changes can facilitate management decisions and resource planning on the entire ESTRACK system.

IV. Outlook

The modular design of the CMDB application allows future enhancements. As reported in chapter II, A above, the Product Tree contains availability information. A synchronization of the availability information from the Product Tree with the monitoring & control system used in ESTRACK Remote Operations would provide real-time information to the ESTRACK operators.

The efficiency of the inventory management process can be improved by applying a barcode containing the inventory ID to each individual inventory item. Barcode labels, e.g. the 2D QR code, can be read by barcode readers each time an item is changing its location, its operational status or in the course of an inventory inspection. Furthermore reading the barcode can be used to view or edit inventory item details. This requires, apart from the necessary barcode infrastructure, support from the CMDB application.

Obsolescence information like manufacturer's obsolescence alerts, product support lifecycle, could be introduced into the inventory libraries. This would allow a systematic reporting on the obsolescence status on system, subsystem and device level.

V. Conclusion

The ESTRACK teams benefit from a well-managed and up-to-date CMDB combined with integration and logistics information by improving the reliability of ESTRACK and reducing the associated costs.

By continuously polling the operational status of the entire network, ground operations can be made aware of functional deficiencies at any time, e.g. with a color code masking of unavailable functions. This supports real time decisions on selecting only the available elements in redundant chains and helps to avoid human errors.

Engineering teams can monitor the installed inventory and the rolled out configuration of subsystems or equipment in their area of responsibility. This ensures, that even the configuration of spare parts not used operationally is kept up to date and that such spares are ready to be used operationally at any time.

Maintenance and Logistics teams finally are able to trace history, status and location of their equipment at any time. Real reliability measures can be derived from the history data and can be compared against the reliability figures provided from manufacturers. Results are helping to predict and hence avoid potential failures and to optimize the supply chain: have the right parts at the right place, minimize delays due to transportation and procurement.

Appendix A
Acronym List

CCB	Configuration Control Board
CCR	Configuration Change Request
CI	Configuration Item
CMDB	Configuration Management DataBase
DMS	Document Management System
ESA	European Space Agency
ESOC	European Space Operations Centre
ESTRACK	ESA Tracking Station Network
HCNT	Hierarchical Counter
ILS	Integrated Logistic Support
LRU	Line Replaceable Unit
MTBF	Mean Time between Failure
SRU	Shop Repairable Unit

Appendix B
Glossary

Configuration Management	Configuration management is the process for establishing and maintaining a consistent record of a product's functional and physical characteristics compared to its design and operational requirements. Configuration management is applied throughout the entire life cycle of the product …(1)
Configuration Control	Configuration control is the process for controlling the evolution of, or departures from agreed baselines. It includes the preparation, justification, evaluation, disposition and implementation of engineering and contractual changes, deviations and waivers. (2)
Information / Documentation Management	Information/documentation management is the process for ensuring timely and effective creation, collection, review, delivery, storage, and archiving of project information. (3)
Product Tree	The product tree is the breakdown of the project into successive levels of hardware and software products or elements, articulated to perform the functions identified in the function tree. (4)

References

[1] ECSS Space Project Management, "Configuration and information management", ECSS-M-ST-40C rev.1, 06-Mar-2009, p. 14

[2] ECSS Space Project Management, "Configuration and information management", ECSS-M-ST-40C rev.1, 06-Mar-2009, p. 24

[3] ECSS Space Project Management, "Configuration and information management", ECSS-M-ST-40C rev.1, 06-Mar-2009, p. 15

[4] ECSS Space Project Management, "Project planning and implementation", ECSS-M-ST-10C rev.1, 06-Mar-2009, p. 16