ECSS-E-ST-70C Space Engineering
Ground Systems and Operations
- training for user organisations

5 April 2023

EUROPEAN COOPERATION

ECSS

FOR SPACE STANDARDIZATION

Contents of this training presentation

- Introduction to ECSS, the position of the E branch and the E-ST-70C ("E-70") Level 2 standard and it's supporting Level 3 documents within the ECSS system
- Introduction to the Ground and Operations domains including the position of Space segment with Operations
- Operation engineering – approach and operation processes
- Operation engineering – an explanation of the ECSS processes
- Ground segment engineering – approach and ground segment processes
- Ground segment engineering - explanation of the ECSS processes
- Introduction to Ground and Operations lifecycles
- Introduction to ECSS-E-ST-70C DRD's and how to use them
- Where to go for more information

Note: A Glossary is available in ECSS-S-ST-00-01

What is ECSS?

- ECSS = European Cooperation for Space Standardization
- Started in 1993/1994 with the aim to develop a **single coherent set of space standards** for use by the entire European space community
- Cooperative effort between **ESA**, national space agencies (**ASI, UKSA, CNES, CSA, DLR, DSO, and NSC**) and European industry (represented by **Eurospace**)

What are the ECSS standards?

- For use on any space project by any party involved in the definition, design, production, verification or operation of any system (or part of it) or service
- Covering the complete project life cycle
- Identifying **what** is required rather than **how** to implement it
- A system of standards i.e. made of documents that are complementary and interconnected. They are **not intended to be used independently**.
- **Tailorable** to match specific projects needs

Tailoring is a process by which individual requirements are evaluated and de-selected where not applicable.

With justifications, existing requirements can be modified or new requirements added.

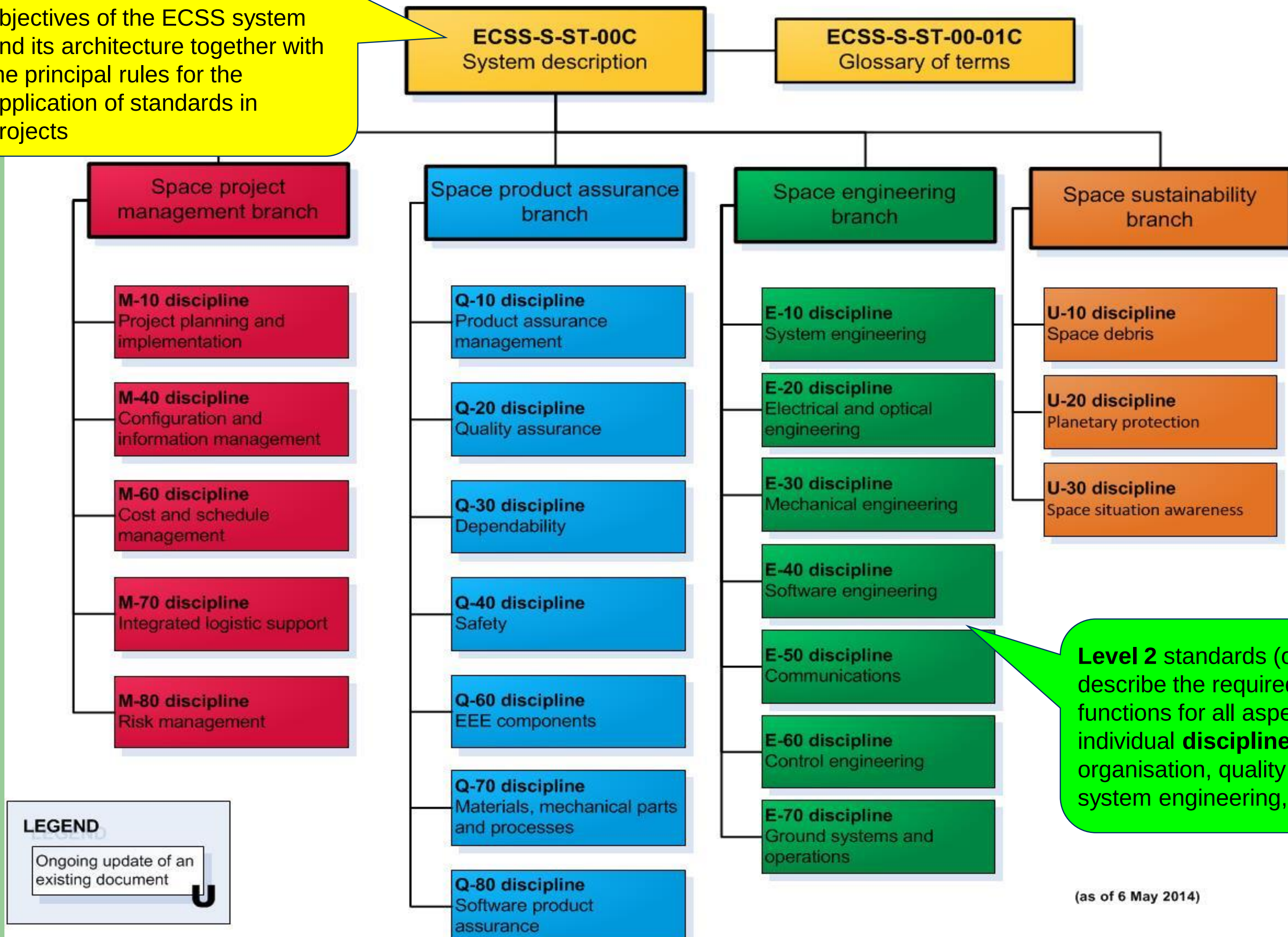
Benefits of the Standards?

- Standards make the development, manufacturing and supply of products and services more efficient, safer and cheaper
- Standards facilitate smooth and fair business between organizations
- Standards aid in the transfer of knowledge and enhance the engineering capabilities of smaller or developing organizations
- Standards assist in the education of today's and future engineers conformance to standards avoids "reinventing the wheel"
- Standards play an important role in enabling European industry to remain competitive in the marketplace and to conquer new markets

➢ An upfront investment is needed to use standards - but doing without leads to much larger cost and schedule risks.

Architecture of the ECSS Standards

Level 1 standards describe the objectives of the ECSS system and its architecture together with the principal rules for the application of standards in projects



Level 2 standards (one per discipline) describe the required objectives and functions for all aspects in the individual **discipline** (project organisation, quality assurance, system engineering, etc.)

Level 3 Standards

- Level 3 standards give requirements for methods and procedures to achieve many common functions required for the majority of missions.
- In addition they define the constraints and requirements for interfaces and performance of the specified function, product or activity.
- Use of the Level 3 standards also leads to improved interoperability within and between missions.
- Level 3 standards may be adapted to the needs of individual projects through tailoring.
- The following are the main Level 3 standards which apply to the E-70 Branch
  - **E-70-01 Spacecraft On-board Control Procedures**
  - **E-70-11 Space segment Operability**
  - **E-70-31 Monitoring and Control Data Definition**
  - **E-70-32 Test and Operations Procedure Language**
  - **E-70-41 Packet Utilisation Standard**
- Level 3 standards also apply to Space Segment element design in many cases.

ECSS-E-ST-70C: Ground Systems and Operations

SCOPE

Defines the basic rules, principles and requirements to be applied to the engineering of the ground segment and mission operations, which form an integral part of the overall system implementing a space mission

Covers development of the ground segment, operations preparation activities, mission planning activities, mission evaluation activities, the conduct of operations and all post-operational activities

More…

STATUS

First published (Issue A) in April 2000

Updated and re-issued (Issue C) July 2008

ECSS-E-ST-70C: Scope

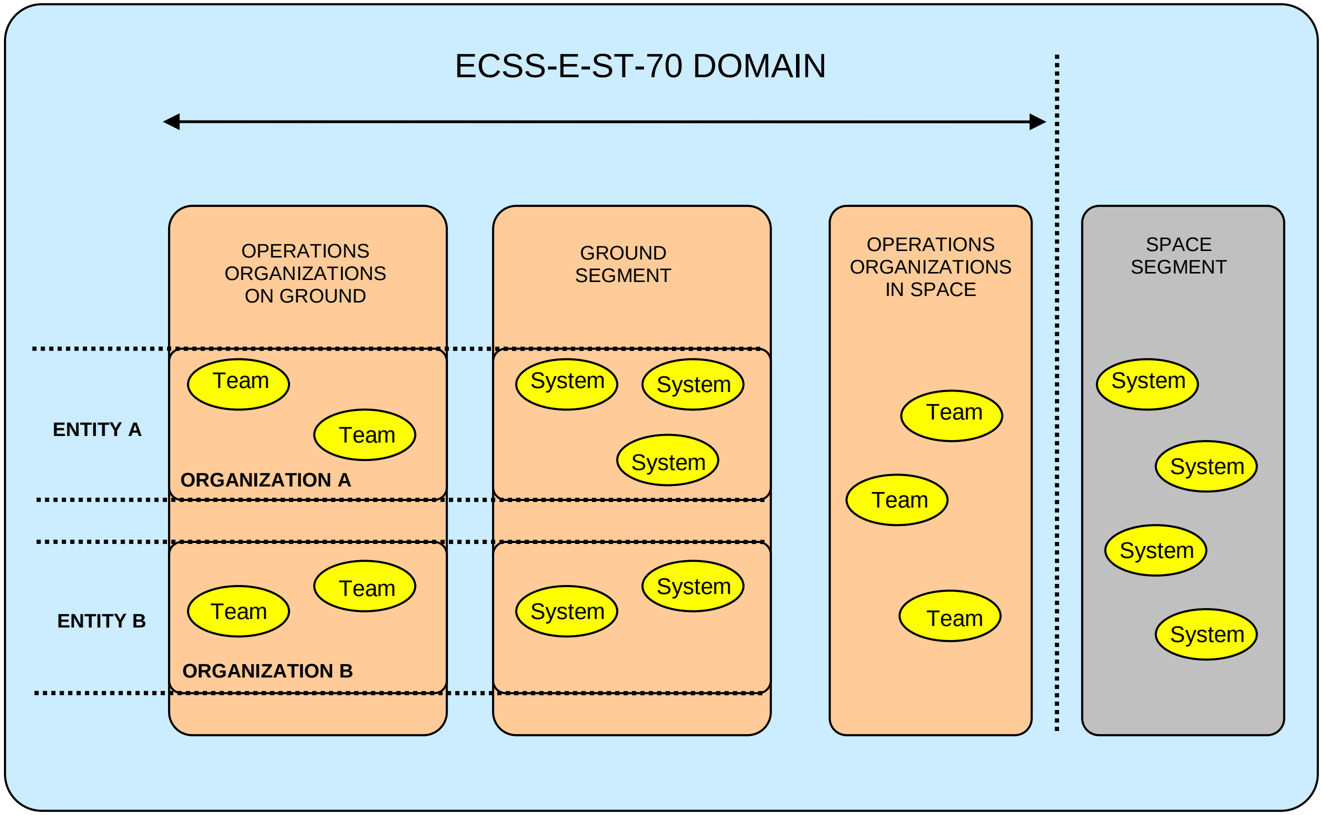
- The standard makes a clear separation between Ground segment Engineering and Operations Engineering, reflecting the fact that these skills may be provided by different suppliers
- A process-oriented approach is adopted for these engineering disciplines:
  - firstly, inputs, tasks and outputs are identified
  - then the processes are mapped onto the classical development and operation phases (A,B,C,D,E,F)
  - wherever possible, the process names (and associated documentation and reviews) are aligned with ECSS-E-ST-10C “System Engineering”.
- Document Requirement Definitions (DRDs) are provided for all the major ground segment and operations documents

Ground segment and Operations

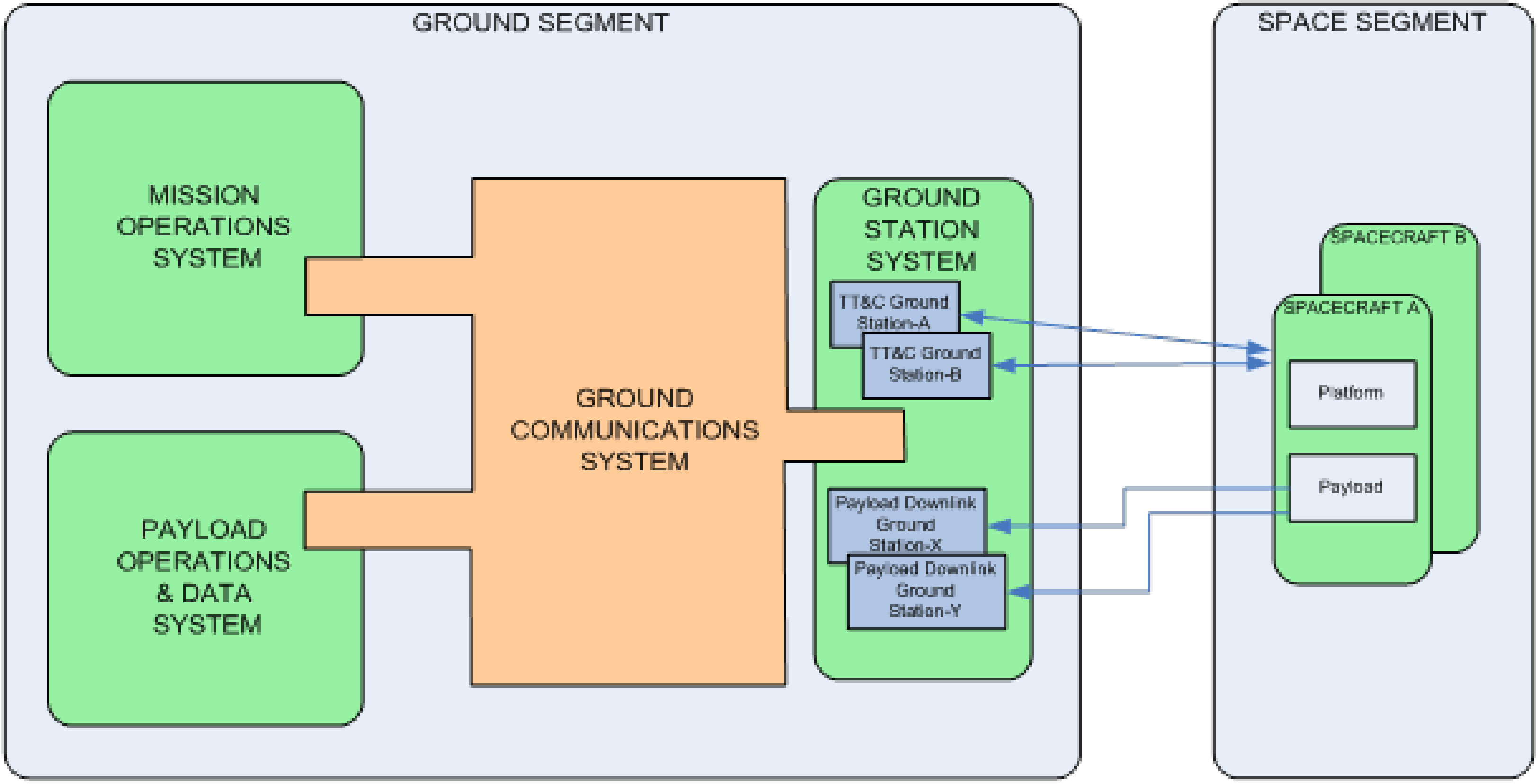
- ECSS-E-ST-70C is applicable to two main domains
  - **The ground segment** comprising all systems developed to support the operations preparation activities, the conduct of operations themselves and all post–operational activities.
  - **Operations organizations** comprising the human resources undertaking the mission preparation and mission operations tasks.

- One key point: ECSS considers ‘Operations’ to cover not just the mission preparation and operations for the ground segment but also for the space segment assets. In practical terms this means the Operations organisation often has to:
  - Prepare for both ground and space operations at the same time
  - Manage test configurations to support both space/ground system integration and flight operations.

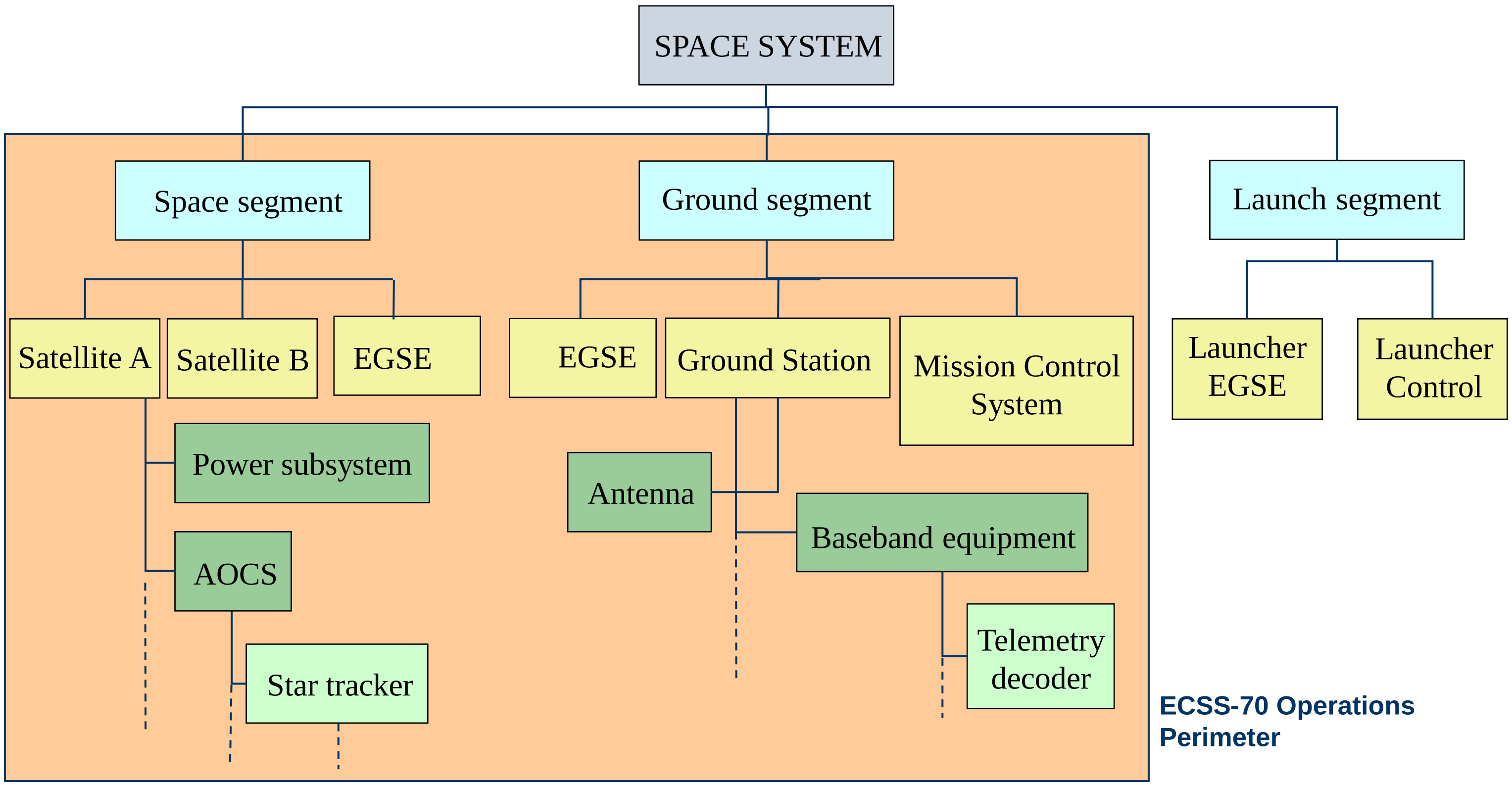
The ECSS-E-ST-70 domain



A typical Ground System layout



ECSS-E-ST-70 mission architecture



This is the architecture of a traditional ESA mission. Boundaries do vary e.g. In some cases EGSE is shared, in some Ground Station are 3rd party and effectively external. Mission control is also sometime separate for Space and Ground

The Operations Organisation

- Operations organizations are comprised of teams. The composition, responsibilities and management of these teams varies between organizations and over time. The following personnel are typically involved in the teams:
  - Operations managers;
  - Spacecraft operators (astronauts, operations engineers, spacecraft analysts, spacecraft controllers);
  - Payload operators (e.g. payload specialists, Principal Investigators);
  - Mission planners;
  - Flight dynamics engineers;
  - Ground systems operators;
  - Mission exploitation engineers (e.g. scientific/algorithm experts, end-user community liaison staff, product generation support staff);
  - Ground systems maintenance engineers.
- A key initial task in establishing a Operations Organization is to establish a clear internal organisation and within this a single points of contact between each team and external entities.

Breakdown of a Ground System

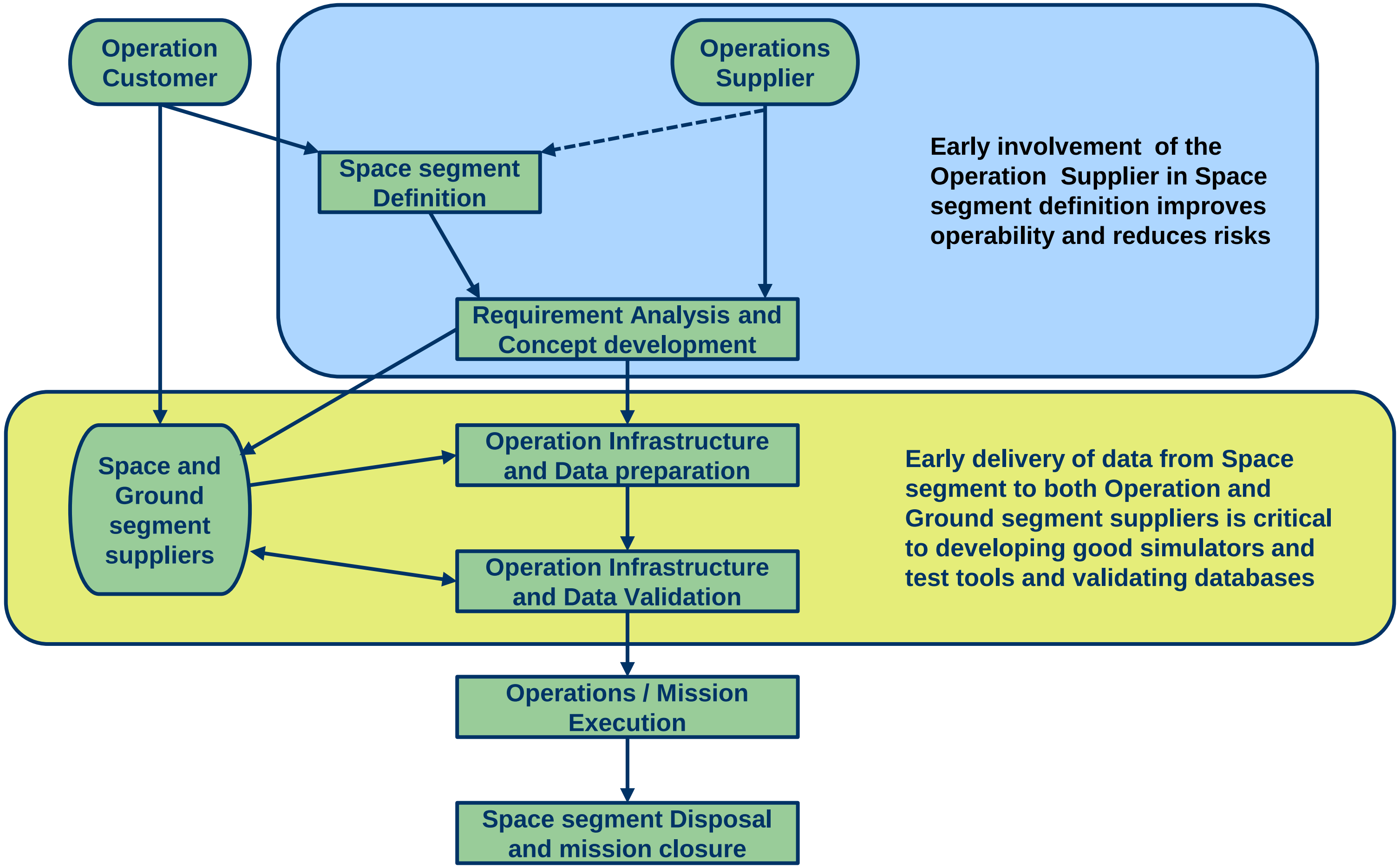
- The ground segment typically consists of the following top-level systems which can be distributed across various centres depending on the chosen ground segment architecture:
  - Mission operations system;
  - Payload operations and data system;
  - Ground station system;
  - Ground communications system.
- These top-level systems are further broken down during the design process.
- One area of importance is to consider the optimum split between Platform and Payload operations, and where within these Flight (or trajectory control) is located. In some missions the orbit is fixed and once established is not impacted by mission activities, in other cases the position of the Space asset is critical and is an integral part of the mission operations.

Operation Engineering overview

- A mission starts with an analysis of requirements and the development of an operations concept
- From the requirements generated both the systems and operations data required are defined, with a detail of how they will be validated
- From the operations concept teams are built-up and trained
- These teams perform the final operations validation
- Operational configuration management for both formal validation and operations phases then needs to be implemented
- Operations execution (LEOP, commissioning, routine phase operations) can then proceed
- The final mission phase covers the disposal operations of the Space segment at End of Life.

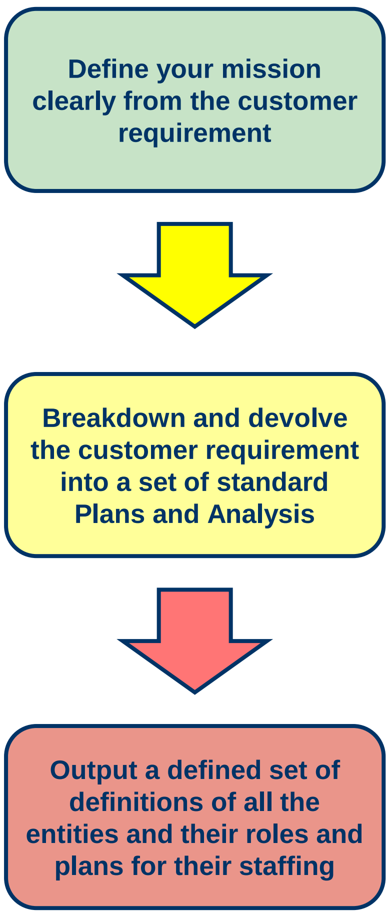
- The complete process is shown in the flow chart in the following 2 slides

Operation Engineering overview



Requirements analysis & concept development

Ref E-70 : Section 5.2



Needs from the customer:

- Mission description document (MDD)
- Operations customer requirements document (OCRD)

Process Description:

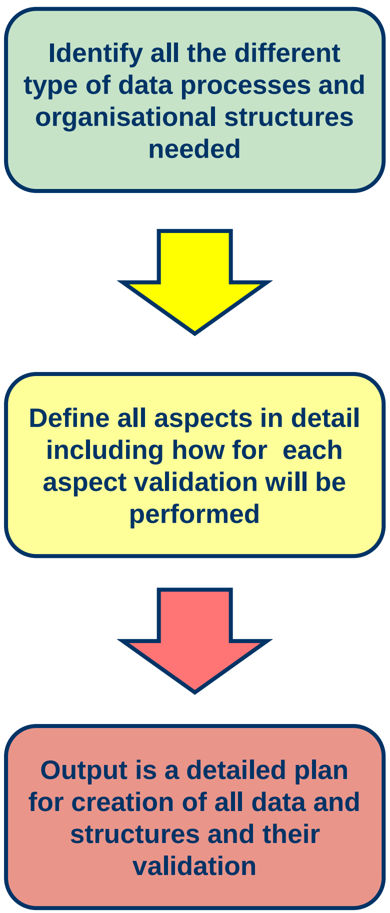
- Mission Analysis – identification of constraints and characteristics (MAR)
- Operational analysis – development of the operations concept (MOCD)
- Operational Interface Definition – Internal and External and CFI's
- Operations Engineering Plan – Staffing, Team Organisation, Schedule
- Contributions to Ground segment – Functionality, Performance, Tools
- Operational Validation Plan – Tests, Resources, Pass/Fail Criteria

Outputs:

- A definition of all Operations internal and external operational entities
- Plans for all operational activities, staffing and resources

Mission operations data production

Ref E-70 : Section 5.3



Inputs:

- Operation customer design documents, manuals and databases
- Ground segment manuals and databases

Process Description:

- Definition of the detailed operations structure including responsibilities and operation roles and rules for decision making.
- Definition of timelines, schedules and constraints for major activities
- Definition of the procedures and rules for interactions with external parties
- Development of operation procedures for Space and Ground activities
- Population of Space and Ground segment operations databases

Outputs:

- The Mission Operation Plan (Organisation, Plans, Procedures, Timelines)
- Ground and Space segment control databases

Mission Operation Data Validation

Using the output of the production phase initiate the validation process

↓

Validate both data and systems maintaining strict configuration control thereafter

↓

Output is validate set of data and systems

Inputs:

- The Mission Operation Plan (Organisation, Plans, Procedures, Timelines)
- Populated Ground and Space segment control databases (inc. Simulator)

Process Description:

- The databases and the MOP are validated in two stages:
  1. Against a simulator emulating the spacecraft and ground system behaviour and/or tools provided by the spacecraft supplier
  2. Against the real spacecraft equipment in a flight realistic ground based system validation tests

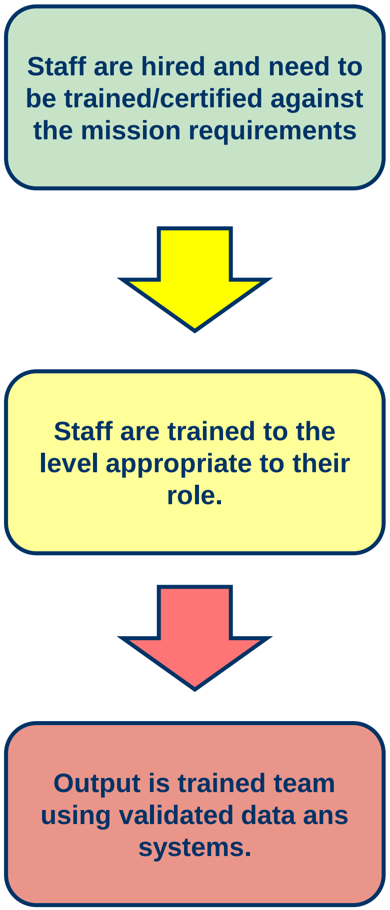
  Note: Due to limitations on Ground test operations some parameters might need to be validation by inspection or analysis

Outputs:

- Validated MOP and control databases for Space and Ground segments.

Operation Team Build-up & Training

Ref E-70 : Section 5.5



Inputs:

- Mission Operations Concept Document (MOCD) with the detailed planning supported with the context of the Mission Analysis Report

Process Description:

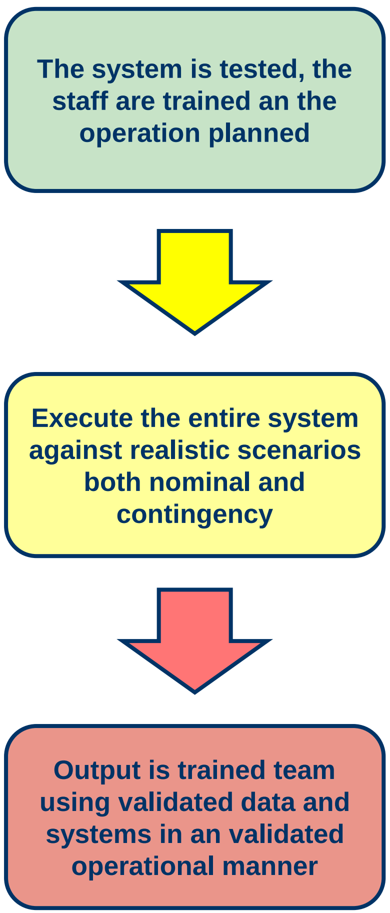
- The team build up is highly dependant on the nature of the mission however the system specialists of the Mission Control Team are normally required first and frequently benefit from a close involvement in the Space segment development including major reviews.
- The console controllers (SPACONS and their Ground segment equivalents) are usually recruited last but need the most formal training/certification
- The need for involvement of experts from the spacecraft supplier in important phases is critical and often underestimated

Outputs:

- Fully staffed and appropriately trained team.

Operational Validation

Ref E-70 : Section 5.6



Inputs:

- Verified ground system, Trained Team, Operation Validation Plan

Process Description:

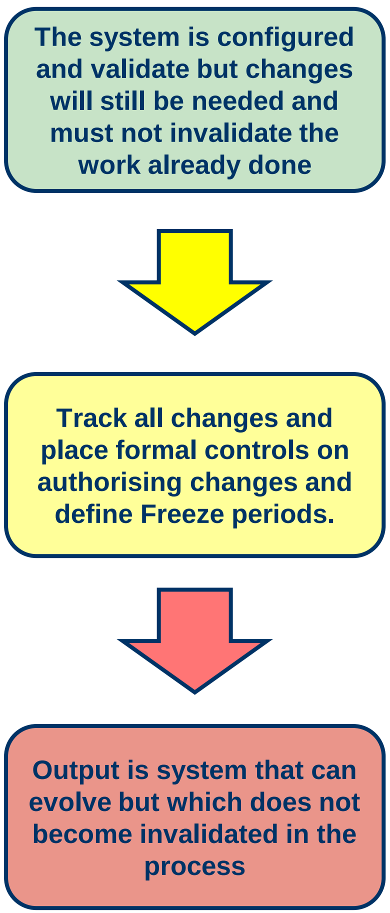
- This activity validates both the human and technical aspects of the “Operational System” within a realistic scenarios/context.
- This includes simulations and rehearsals with the Team exercising critical activities and contingencies where the scenarios validate the team structure, the FOP and the Ground segment control equipment.
- Also includes test targeted at testing ground infrastructure in operational scenarios such as Dataflow and Mission Readiness Tests involving items such as Ground Station and Network staff and assets

Outputs:

- Fully validated Ground segment including teams, procedures and equipment ready for in-orbit operations

Operation Configuration Management

Ref E-70 : Section 5.7



Inputs:

- According to ESCC-E-70 this phase is formally defined as starting once a Validated Ground segment exists and the Space segment is in it's final configuration.
- However… this process (perhaps in a lighter form) needs to start in the Operation Data Validation phase, especially when, as with most complex Ground segment, new software deliveries will continue in parallel to Operation Preparation.

Process Description:

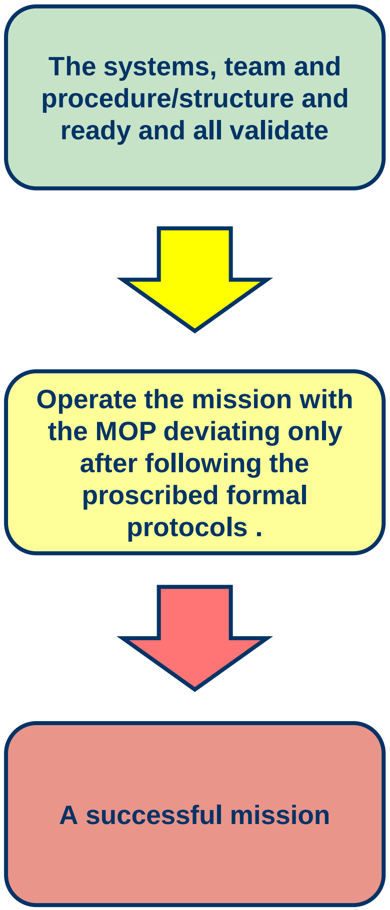
- All configurable parameters must be placed under configuration control (see ECSS-M-ST-40)

Outputs:

- A Configuration Management system with appropriate records and training

Operation Execution

Ref E-70 : Section 5.8



Inputs:

- Fully validated system, MOP, SSUM, GSUM and a trained team

Description:

- There are usually two distinct types of operations
  1. Critical Operations: Activities such as LEOP, Major Manoeuvres, Dockings or Landings. These require the team to be primarily composed of experts and management staff in case or mssion level decision making. Operators (e.g. SPACONs) work under the direct instruction of a team leader (e.g. SOM) advised by the experts operating primarily within the MOP.
  2. Routine Operations: The Operator (e.g. SPACONs) execute the mission directly using the process and procedures in the MOP.

Outputs:

- A safely and successfully executed mission with appropriate reporting and mission analysis.

Space segment Disposal

Inputs:

- All space and ground segment functions to be used for carrying out the space system disposal operations
- MOCD, Space segment User Manual.

Process Description:

- Disposal Operations Analysis
- Disposal detailed planning
- Development of products and processes for disposal
- Final de–orbiting, re–entry or retrieval operations

Outputs:

- Safely and environmentally optimised disposal of space segment
- Space segment disposal operations report

Break

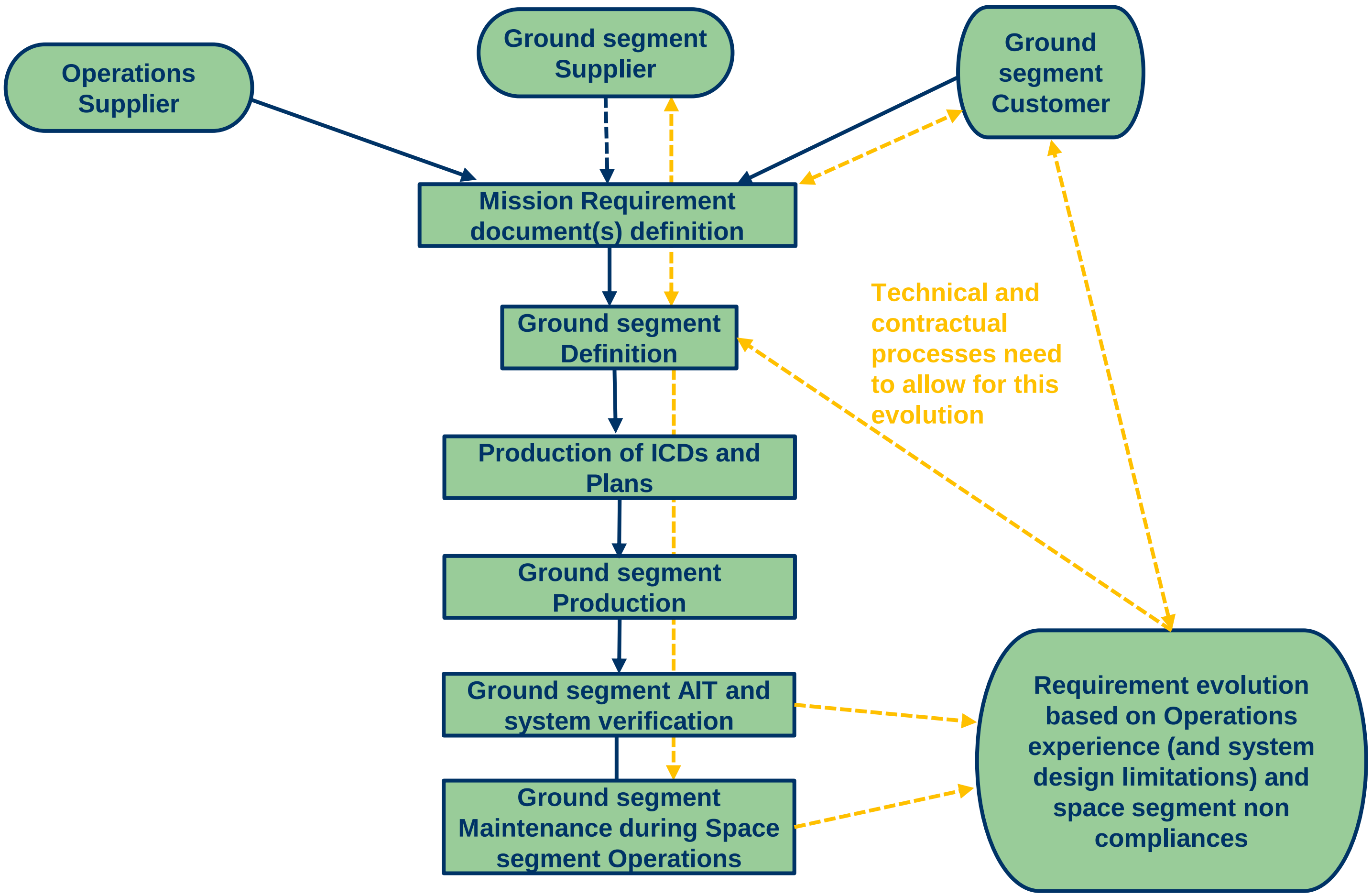
- Time for a coffee and informal discussion.

Ground segment Engineering

The main ground segment engineering processes are:

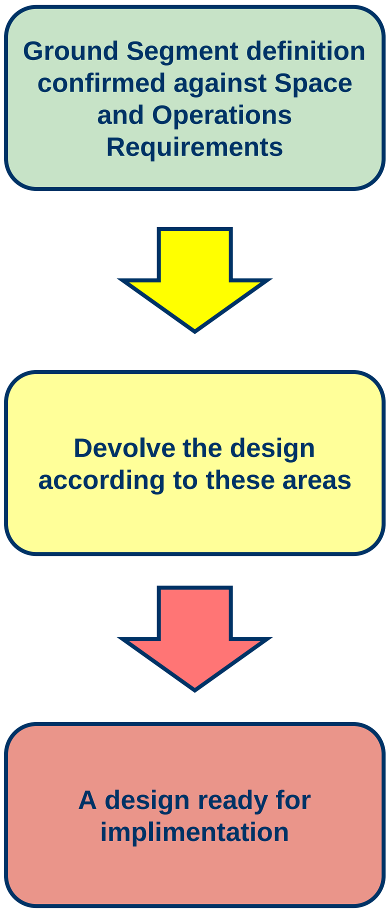
- Ground segment definition:
  - ground segment requirements engineering
  - analysis and design of the ground segment
  - technical interfaces definition (including space segment)
  - operational interfaces (including space segment)
- Ground segment production, including acceptance of each ground system
- Ground segment AIT and verification, covering the integration and testing of the individual ground systems, and progressively extending this to cover integration and verification of the whole ground segment
- Ground segment maintenance
- Ground segment disposal

Ground segment Engineering



Ground segment Definition

Ref E-70 : Section 6.2



Inputs:

- Ground segment Requirement, MRD, MOCD, Space Ground ICDs

Process Description:

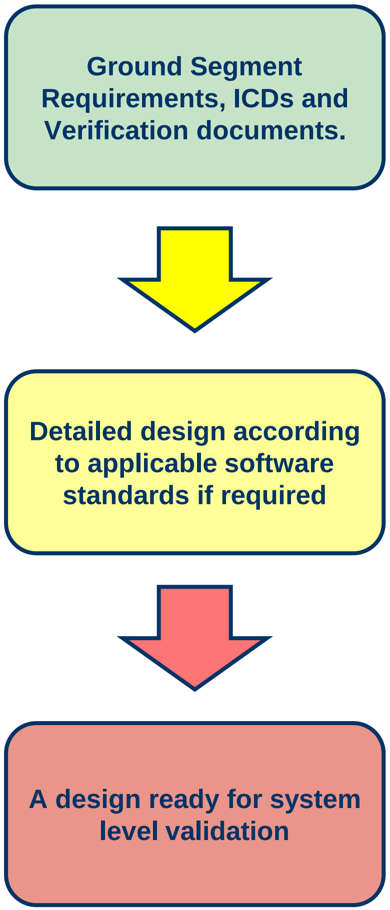
- Systems engineering to derive the complete Ground segment requirements, covering:
  - Functionality,
  - Performance,
  - Security,
  - Safety,
  - Interfaces,
  - Maintainability,
  - Operations,
  - Configuration Management.

Outputs:

- A fully functional devolve and consistent ground segment design

Ground segment Production

Ref E-70 : Section 6.3



Inputs:

- Ground segment design and verification documents, external ICDs
- Space segment Manuals and Databases

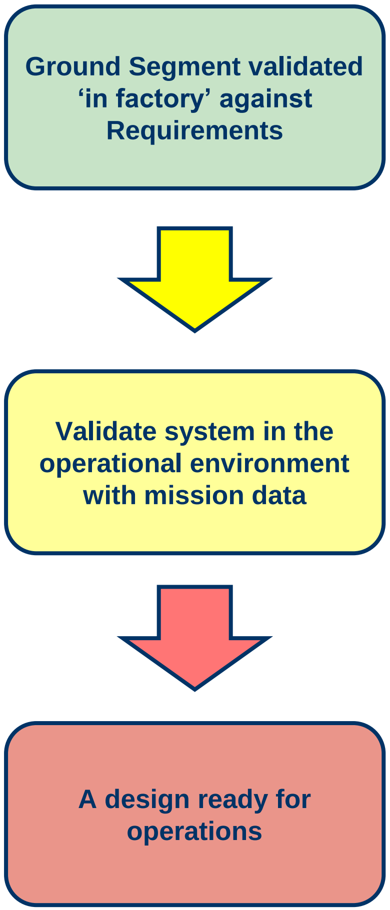
Process Description:

- System decomposition to facilitate efficient and practical design
- Analysis of the re-use of existing systems and considering future re-use
- Design with a view to assembly, verification, test and configuration control
- Verification at component and system level in factory
- Development of User Manuals and Early operations support planning

Outputs:

- A Ground System validated against design ready for System AIT

Ground Systems AIT



Inputs:

- A Ground System validated against requirements in factory
- Planning documents for integration into an Operational System
- Real or Simulated elements of the rest of the Operational System

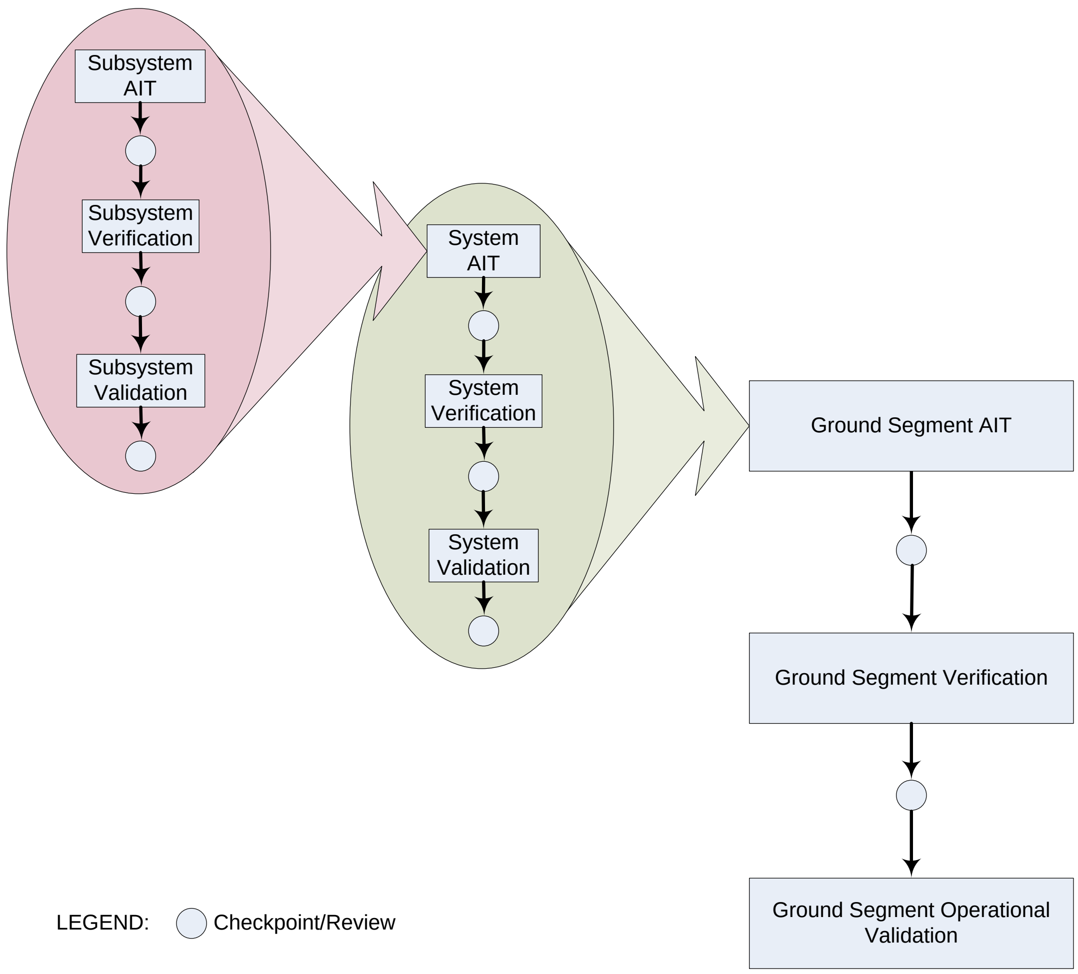
Process Description:

- Ground systems verification against its requirements using the best available mission data
- Verification of the Ground System against the other system elements internal and external
- Confirmation of functions of the Ground segment in a realistic operational environment
- Validation of configuration control and maintenance planning

Outputs:

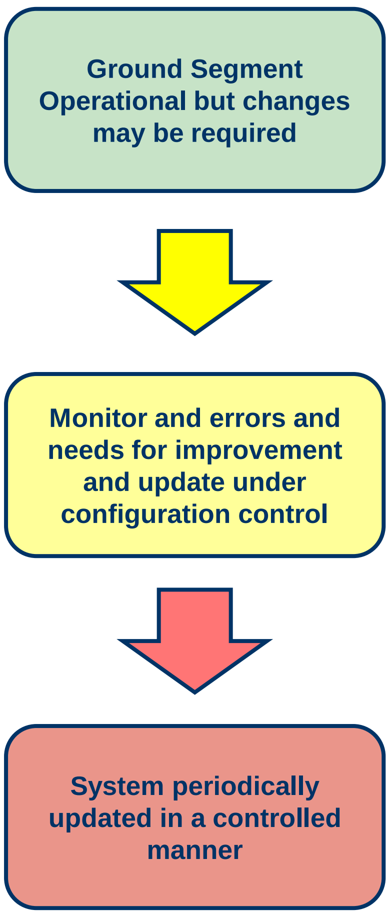
- A fully functional validated system with validated on-going maintenance

Ground System AIT flow



Ground System Maintenance

Ref E-70 : Section 6.5



Inputs:

- Ground System Designs, Plans, definition and justification files, User Manuals and Procedures

Process

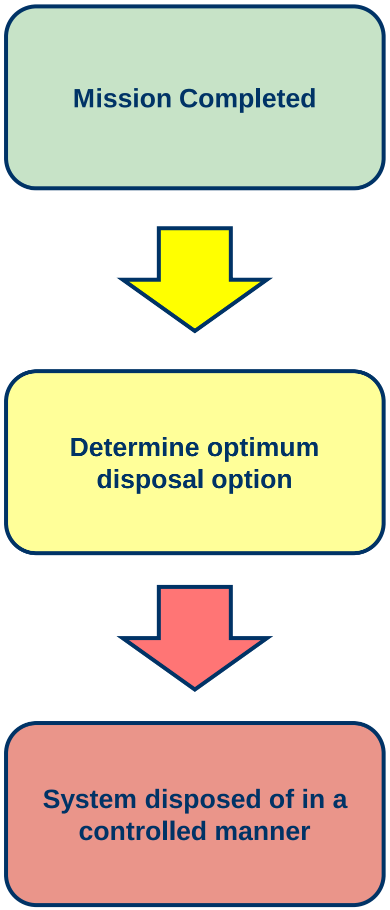
- Identify and initiate system monitoring, error reporting and performance processes
- Identify and initiate processes form system upgrades and enhancements taking care to:
  - Align technical and contractual processes
  - Align Space segment activities with Ground segment maintenance periods
- Ensure configuration control processes are established
- Identify and initiate obsolescence monitoring processes

Outputs:

- A well controlled, documented maintenance process

Ground System Disposal

Ref E-70 : Section 6.6



Inputs:

- Fully operational ground segment at the declared end of the mission

Process Description:

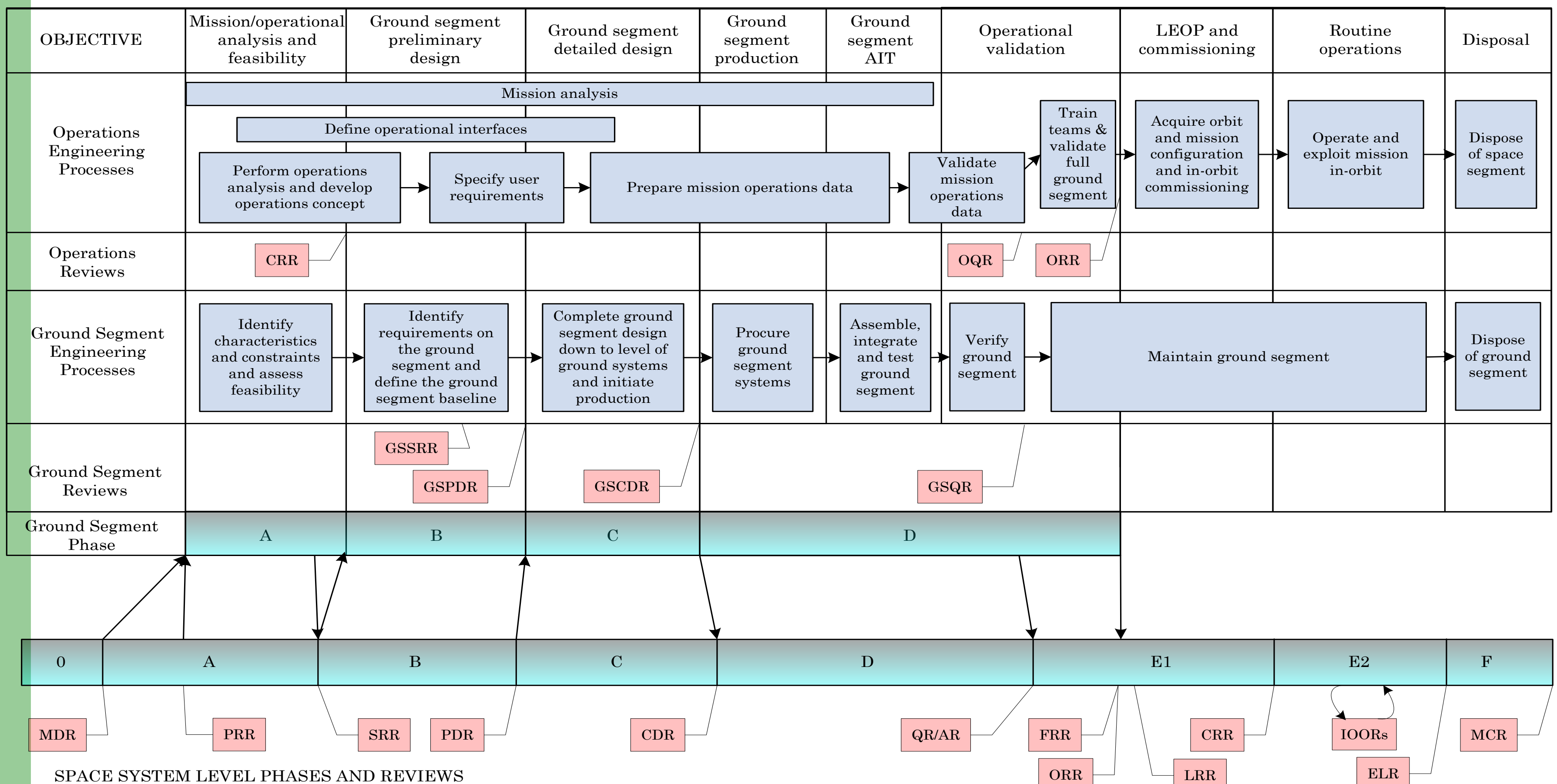
- Analysis of optimum disposal process
- Consideration of re-use opportunities
- Validation of disposal processes
- Execute disposal or recycling activities

Outputs:

- A ground segment disposed of in an economic and environmentally efficient manner
- Appropriate mission records and archives

Ground segment and operations lifecycle

Ref E-70 : Section 7



Note: Table 7-8 (page 79) of E-70 provides a full list the of the milestones for the delivery of each document at preliminary and final status.

Phase A

On most missions the Ground segment Phases are broadly aligned with the Space segment – but usually planned to lag behind somewhat as the design and operational needs of the Space segment are usually the primary driver the core mission specific Ground segment functionality.

In Phase A while the baseline functions and performance requirements of the Space segment are usually firmly established it is normal to only characterize the ground segment, in terms of operational feasibility and needs, expected performance and reliability, availability, maintainability and safety objectives.

However it is crucial that any operation or performance constraints that the Ground segment might place on the Space segment are identified and incorporated in the Space segment design.

Phase A for both finishes at a Customer Requirement Review when the requirements and operational concepts need to be aligned.

Phase B

The purpose of this phase is to achieve the ground segment baseline and to prepare the necessary procurements for the production of the ground segment. In parallel, the mission operations concept is further developed as the Space segment is in parallel refined.

In parallel to the refinement of the technical and operation design this phase must also identify the optimum decomposition of the ground segment in to lower level components either for the purpose of be procured or design separately.

A balance needs to be stuck between the design benefits of a certain decomposition and the complexities that will be introduced if this results in components being procured from different entities.

Phase B ends with a ground segment preliminary design review (GSPDR), which needs to follow the successful completion of the space system PDR.

Phase C

The purpose of the ground segment design phase is to complete the design of the ground segment to the level of individual systems and to start production.

Phase C includes the definition of the operations organization and the start of production of mission operations data (operational procedures, monitoring and control databases and detailed mission analysis).

It is important that working level communications between Ground and Space segment developers are established in this Phase. Care must be taken to respect contractual boundaries and to operate within parameters agreed with the Customer but significant fit in reducing mission risks can be achieved with the right collaboration.

Phase C concludes with the ground segment critical design review (GSCDR) which needs to be accepted by the Customer .

Phase D

All ground systems are procured and integrated into an operational ground segment ready to support the space segment.

This includes

- A qualified ground systems delivered to the Operations site
- Test and training tools in place and operational
- User and maintenance documentation for each ground system
- Validated operation databases and trained, certified teams.

Key issues often encountered in this phase are

- Insufficient test tools for both site and factory testing (common if additional system development is still required in parallel)
- Insufficient configuration control is implemented and user documentation is insufficiently detailed requiring unplanned Ground developer support.

The ORR constitutes the final acceptance of the ground segment.

Phase E

The space system is operated in accordance with the MOP and the Ground segment maintained in accordance with the logistics support plan

If changes in the space segment or ground segment during phase E result in the need to modify mission operations data or ground systems, these changes are developed, verified and validated as during the earlier phases

The phase is divided into two sub-phases (see ECSS-M-ST-10):

- Sub-phase E1 which is an overall test and commissioning phase of the space and ground segments.
- Sub-phase E2 which is the utilisation phase itself.

Configuration control becomes critical in this phase as does developing a strategy to managing the user configurable parameters of the Ground segment (often overwritten when new deliveries of Ground segment components are made).

Phase F

Phase F is normally initiated when the space segment reaches end of life and is withdrawn from service. After preparation and planning in liaison with the space segment customer this can include transferring the spacecraft to another orbit, with eventual landing or destructive re–entry.

The Ground segment can only be decommissioned and disposed of after completion of Space segment activities.

Re-use and/or recycling of the Ground segment need to be considered in advance of any scrapping process.

The Mission ends with the Mission Closure Review (MCR)

Document Requirement Definitions (DRDs)

DRDs contain only the requirements for document contents with no prescription for document structure, although a suggested structure is given. The following DRDs are included as annexes to ECSS-E-70

- Annex A Customer requirements document (CRD)
- Annex B Mission analysis report (MAR)
- Annex C Mission operations concept document (MOCD)
- Annex D Operations engineering plan (OEP)
- Annex E Space segment user manual (SSUM)
- Annex F Operational validation plan (OVP)
- Annex G Mission operations plan (MOP)
- Annex H Operations anomaly report (OAR)
- Annex I Operations procedures
- Annex J Customer furnished items and services requirements document (CFISRD)

ECSS-E-70 Level-3 Standards

The following level-3 supporting standards are directly referenced in ECSS-E-70:

- ECSS-E-ST-70-01 Space engineering – On-board control procedures
- ECSS-E-ST-70-11 Space engineering – Space segment operability
- ECSS-E-ST-70-31 Space engineering – Ground systems and operations – Monitoring and control data definition
- ECSS-E-ST-70-32 Space engineering – Test and operations procedure language
- ECSS-E-ST-70-41 Space engineering – Telemetry and telecommand packet utilization standard

Additional supporting standards

In addition to those specifically mentioned the following are also relevant in to the ECSS-E-70 area when developing a programme:

- ECSS-E-ST-70-01C Spacecraft On Board Control Procedures
- ECSS-E-ST-50-03c Space data links – Telemetry transfer frame protocol
- ECSS-E-ST-50-04c Space data links – Telecommand protocols, synchronization and channel coding
- The relevant mission areas are show in the following 2 slides

The Packet Utilisation standard

What is the Packet Utilisation standard (ECSS-E-ST-70-41) ?

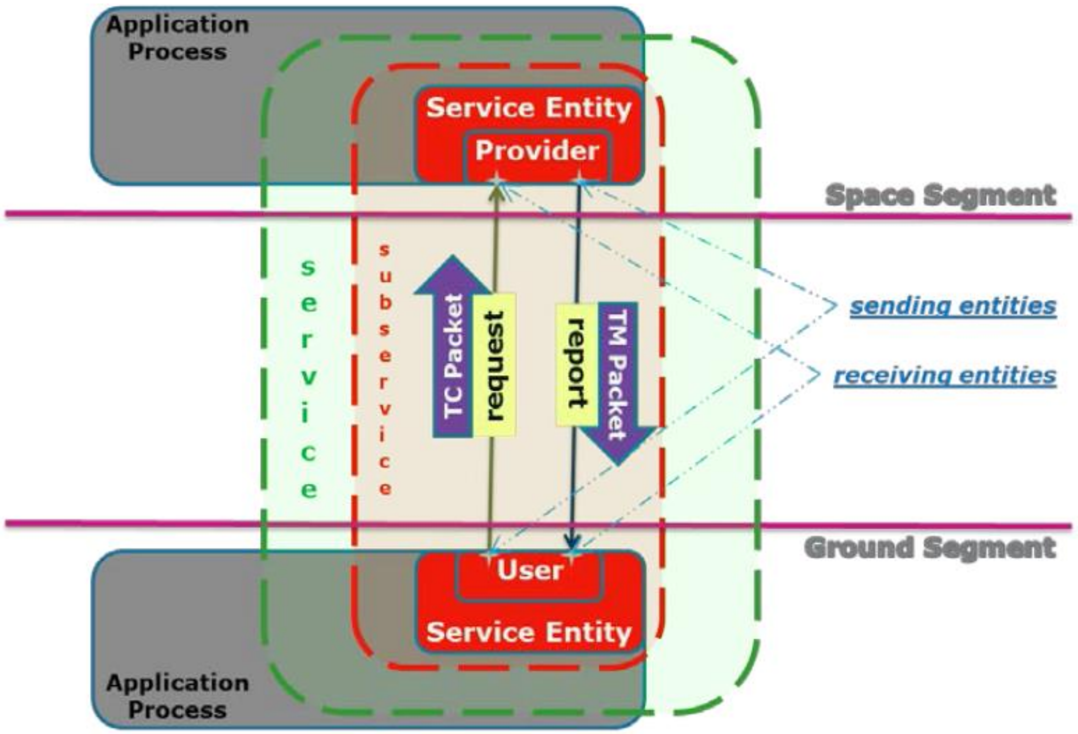
- The CCSDS Space Packet Protocol (CCSDS 133.0-B-1) and the ECSS-E-ST-50 series address the end-to-end transport of telemetry and telecommand data between user applications on the ground and application processes on-board the satellite, and the intermediate transfer of these data through the different elements of the ground and space segments.
- This packet utilization standard (PUS) complements those standards **by defining the application level interface between ground and space**, in order to satisfy the requirements of electrical integration and testing and flight operations.
- The PUS is currently at issue C / Document In Review 1 (DIR1)

How does the PUS work

- This Standard defines a set of services that satisfy all the fundamental operational requirements for spacecraft monitoring and control during satellite integration, testing and flight operations. It also specifies the structure and contents of the telecommand packets used to transport the requests and the telemetry packets used to transport the reports.
- This Standard can be used by any mission, no matter what its domain of application, orbit or ground station coverage characteristics. However, it is not the intention that the PUS should be applied in its entirety to a given mission.
- For each mission the **Space-to-Ground Interface Control Document** defines:
  - Which application processes are being implemented and their roles
  - which PUS services are supported by each application process.

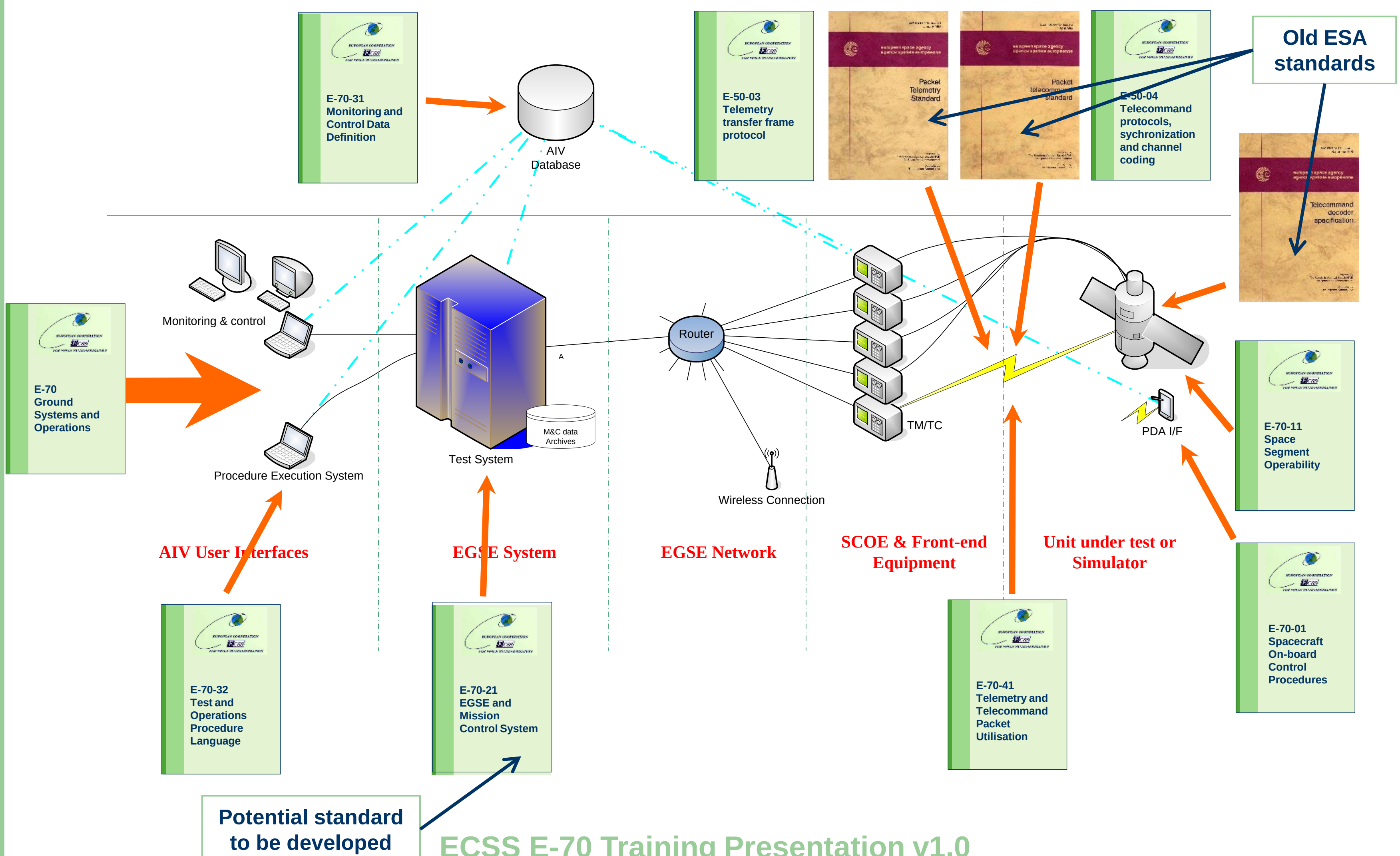
The PUS Space/Ground Model

As depicted to the right a PUS service is deployed both on-ground and on-board. Each PUS service is implemented within PUS service entities, each one having either the role of a service provider or the role of a service user.



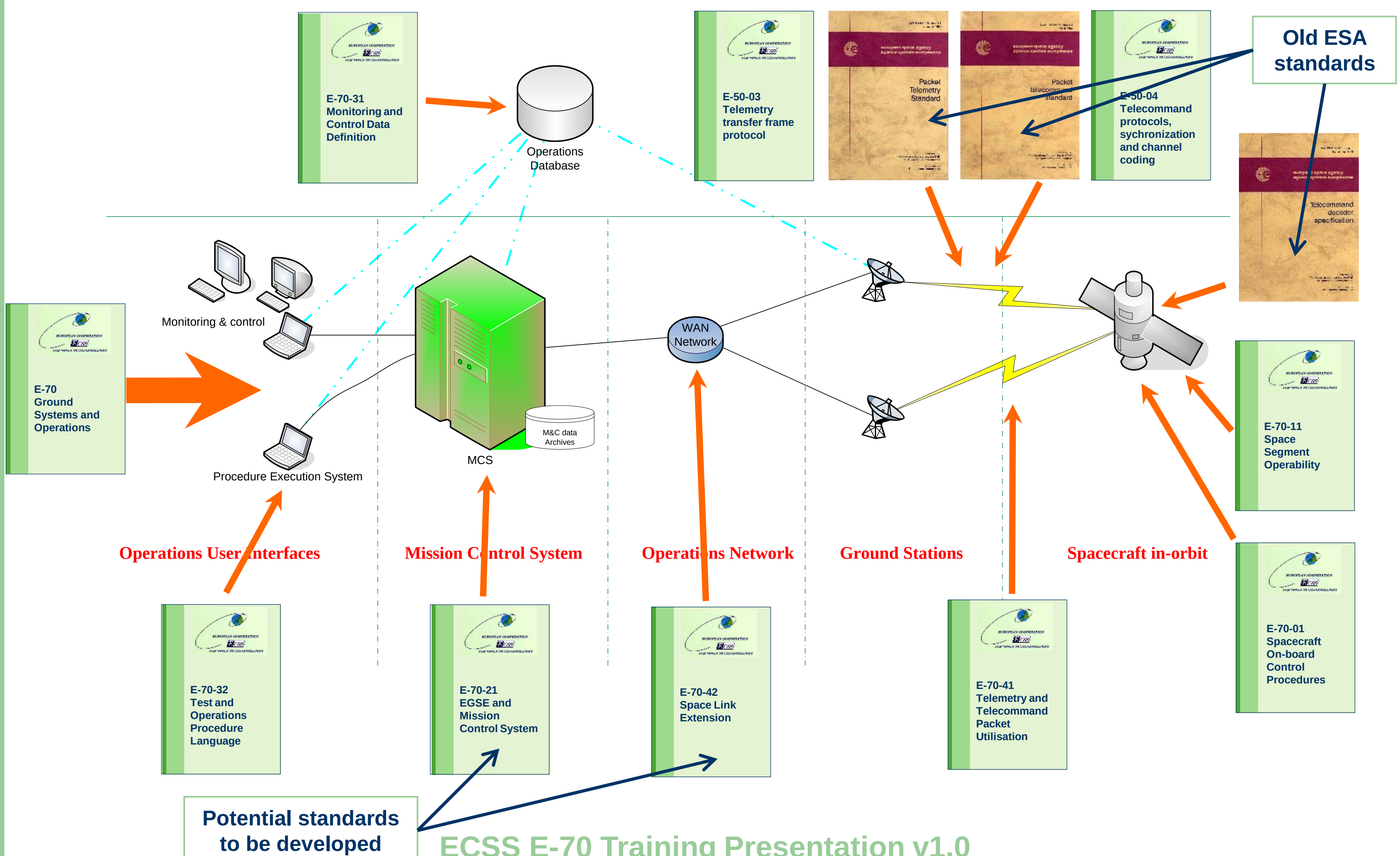
EGSE and Mission Control System Standards

Ref E-70 : Supporting Standards



EGSE and Mission Control System Standards

Ref E-70 : Supporting Standards



Critical areas

Standards need to be established early as they cover the coordination of all segments, many under different responsibilities. Critical areas include:

- Definition of overall mission concepts at system level with due consideration being given to ground segment and operations aspects;
- Spacecraft operability and maintainability;
- Adequacy of inputs delivered by the operations customer (OC) to the mission operations teams;
- End–to–end validation of the complete space system including space and ground (i.e. validation of the mission)
- Reuse, to the maximum extent, of space segment operations knowledge and data between space segment design, space segment AIT, EGSE and mission operations;
- Commonality between processes and services of the ground segment and also between space segment AIT and mission operations;
- Security and safety;
- Ground and space-to-ground communications design and cost.

Closing summary

ECSS brings you a complete, consistent and proven set of requirements for space programmes covering:

- Management – planning and processes
- Engineering – design, development, validation and operations
- Quality – process and approaches
- Sustainability

ECSS-E-ST-70 brings you a ready to use set of standards with all planning, design, development and operation processes, templates all ready to use.

The standards can be used ‘as is’ or tailored for a specific mission and is written in such a way that existing customer documents and templates can be re-used within the ECSS framework with the ECSS examples used to cross check contents rather than rewriting things from scratch.

➢ **Better mission quality, reduction of risk, and the long term benefits of interoperability .**

For more information and support

- The latest version of all ECSS documents can be accessed at the ECSS

  Website: www.ecss.nl

- Within ESA the first contact point for further assistance is:

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E-mail: ECSS-Secretariat@esa.int

- Trainer for this session: david.kenyon@mda.space

- The End