Standardization training program
E-40 discipline: Software Engineering

29/03/2023

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Your speaker

Standardization training program
E40 discipline: SW Engineering

Christophe Honvault

christophe.honvault@esa.int

- Software engineer
  - 20 years in industry:
    - 5 years experience in Ground Software
    - 13 years experience in Space Embedded Software
  - 12 years at ESA, ESTEC (Noordwijk)
    - 5 years as Software engineer (Flight Software)
    - 3 years as head of Software System Engineering section
    - 4 years as head of Software Technology section
- Responsible for the Technology Domain 2 and On-Board Software Harmonisation Dossier.
- Lead of the Avionics Competence Domain
- Coordinator of ECSS-E-ST-40C standard, chair of ECSS-E-ST-40C Rev1 Working group, co-chair of BSSC.
- Main research topics at ESA/ESTEC:
  - Avionics, FDIR, Artificial Intelligence, Big Data, Cybersecurity, Formal Methods, Quantum computing, Requirement Engineering, System software co-engineering, Model-Based Software Engineering, Software Architecture, Avionics product lines

Why a Software Standard?

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1. To support the business agreement between Customer and Supplier
   - Get a complete view of the software from management standpoint
   - Clarify developments activities
   - Focus the effort
   - Verify the completeness of the Statement of Work
2. The standard is completed with a Statement of Work that adds:
   - Delivery modalities
   - Software Development Environment (SDE)
   - Warranty
   - Intellectual Property Rights (IPR)
   - Customer Furnished Items (CFI)
   - etc.
3. For maturity reason
   - We want successful developments to be reproducible, not successful by coincidence (Spice level 2 of maturity ➔ standards)

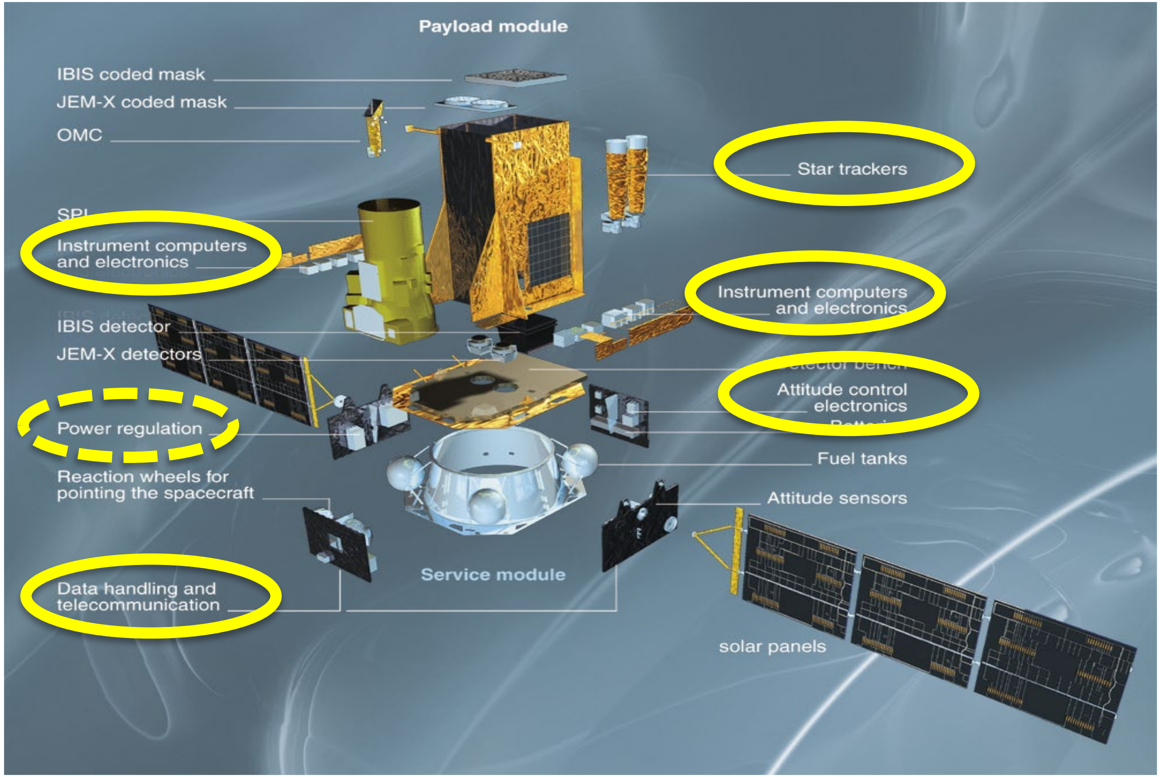
PART 1:
Role of Software in the System

Abstract

Just as software is one element in the overall engineering system, the ECSS-E-ST-40C standard for space software is one standard within the overall engineering branch of standards.

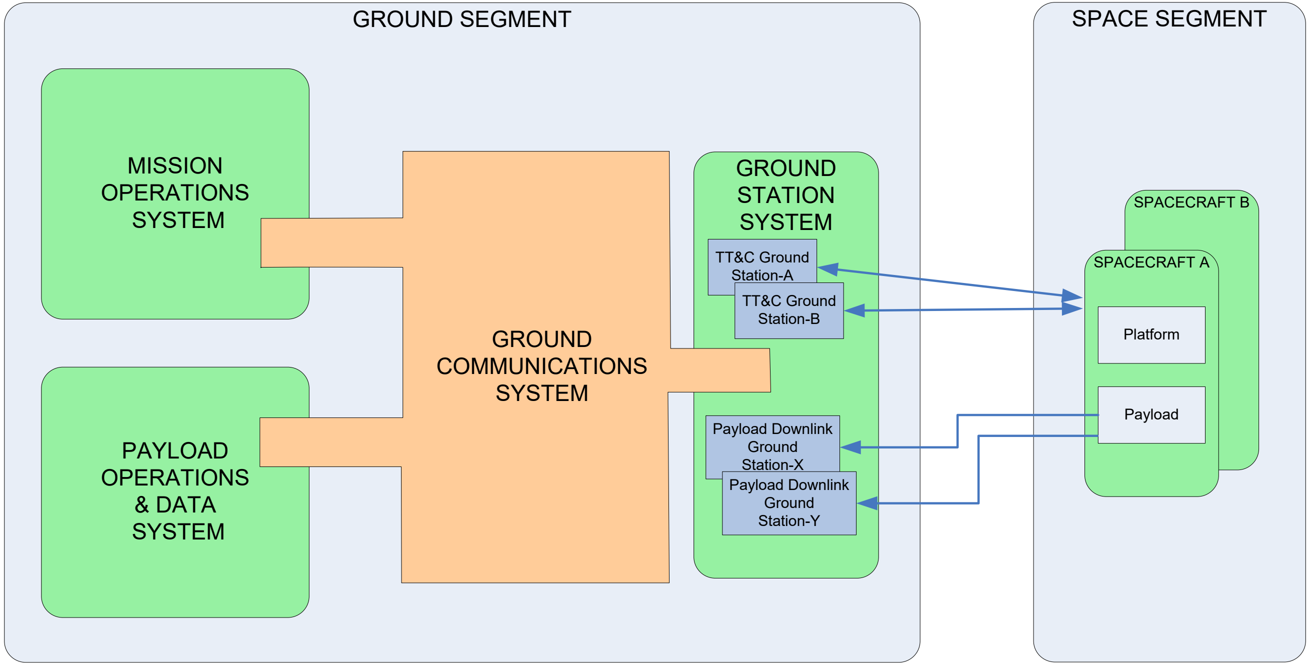
This module explains the relationship between ECSS-E-ST-40 and other ECSS standards.

Space software environments (I)


Payload module
IBIS coded mask
JEM-X coded mask
OMC
SPI
Instrument computers and electronics
IBIS detector
JEM-X detectors
Power regulation
Reaction wheels for pointing the spacecraft
Data handling and telecommunication
Service module
Star trackers
Instrument computers and electronics
Attitude control electronics
Fuel tanks
Attitude sensors
solar panels

Space software environments (II)

Ground and space segment


GROUND SEGMENT
MISSION OPERATIONS SYSTEM
PAYLOAD OPERATIONS & DATA SYSTEM
GROUND COMMUNICATIONS SYSTEM
GROUND STATION SYSTEM
TT&C Ground Station-A
TT&C Ground Station-B
Payload Downlink Ground Station-X
Payload Downlink Ground Station-Y
SPACE SEGMENT
SPACECRAFT B
SPACECRAFT A
Platform
Payload

Importance of software in the system

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1. Software implements (more and more of) the **system behaviour**
2. System **complexity** increases ➔ software size increases
3. **Software schedule** is squeezed within the system schedule
4. Software is the last **flexibility** of the system at the end of the life cycle *(but reconfigurable FPGAs are coming)*
5. Software is a candidate for **subcontracting** policies
6. Software touches many parts of the system. It has **interface** everywhere (ground – hardware – avionics – payloads – sensors – actuators – EGSE – security)
7. Software uses a **lot of data** from various system functional chains (centre of gravity, temperature, health status, voltage)
8. Software has several **users** (system – AIT – operation)

IMPORTANCE OF:

specifying **requirements** (and **interface**)

validating software

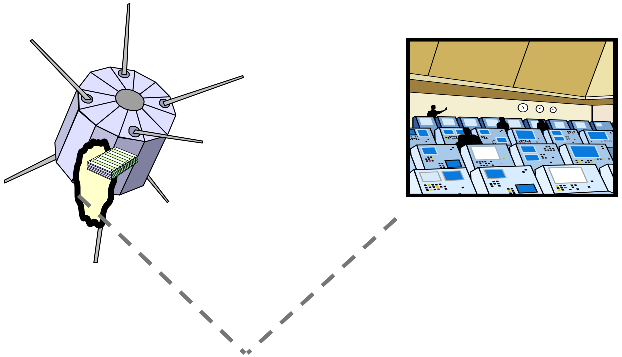
agreeing on a **development approach**

managing the **configuration**

Software and Space System Engineering

1. The software components of a space system play a role alongside the other engineering components such as mechanical and electrical

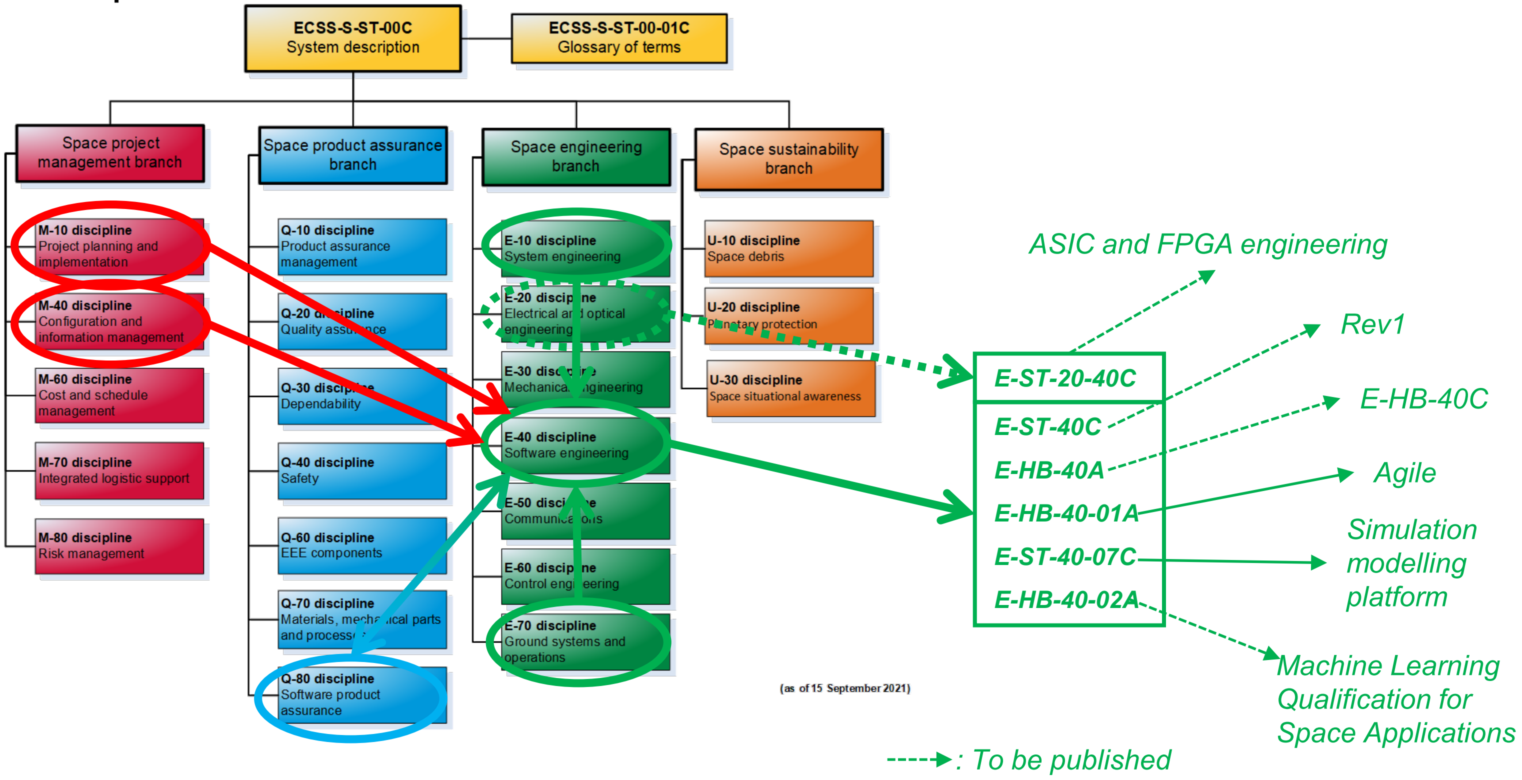
2. All of these various engineering components (including software) are governed by the overall discipline known as **space system engineering**



Software components are part of the overall mission system, together with other engineering components

Software in the ECSS System

ECSS Disciplines



Software and system, E40 and E10

The E-10 Standard for System Engineering

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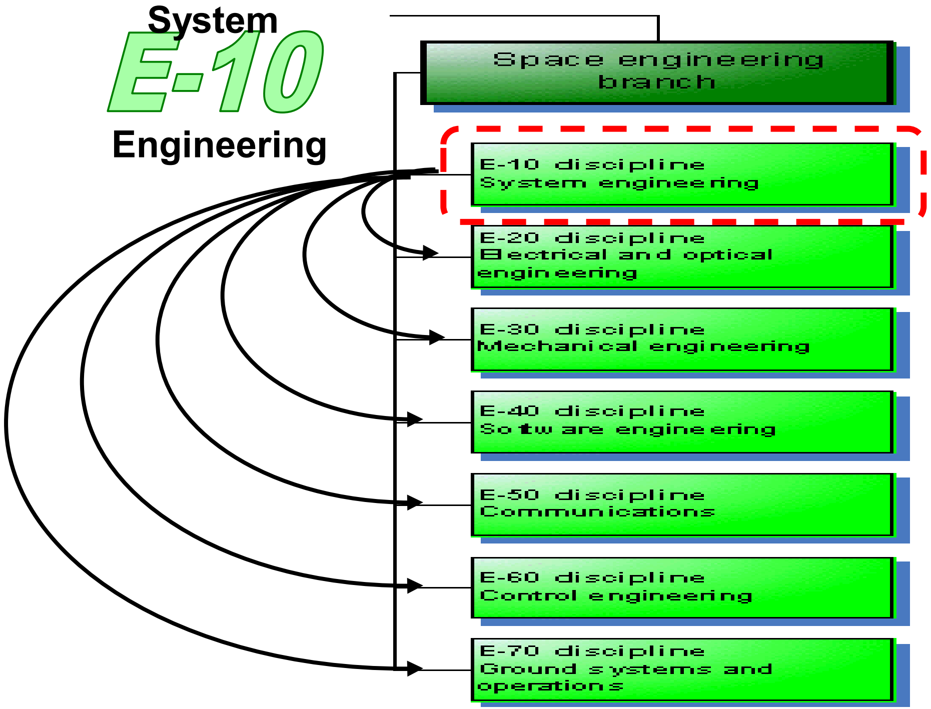
1. The **ECSS-E-10** standard is special in that it is relevant to **all** the engineering disciplines, **including software**
   a. It is intended to guide the development of systems including H/W, S/W, man-in-the-loop, facilities & services for space applications
2. It specifies implementation requirements for the responsible **system engineering organization**



The Five System Engineering Functions

1. **Requirement engineering**
   - Translates customer needs to input for design
2. **Analysis**
   - Supports all other activities with various modeling, simulation, test activities
3. **Design and configuration**
   - creates the physical architecture
4. **Verification**
   - Checks compliance with requirements
5. **Integration and control**
   - Overall management of the activities

It is important to be aware how the overall system engineering process is organized

Although the E-40 standard defines its own processes, they "echo" this overall organisation and terminology

E-10
4.1

Overview of the System Engineering

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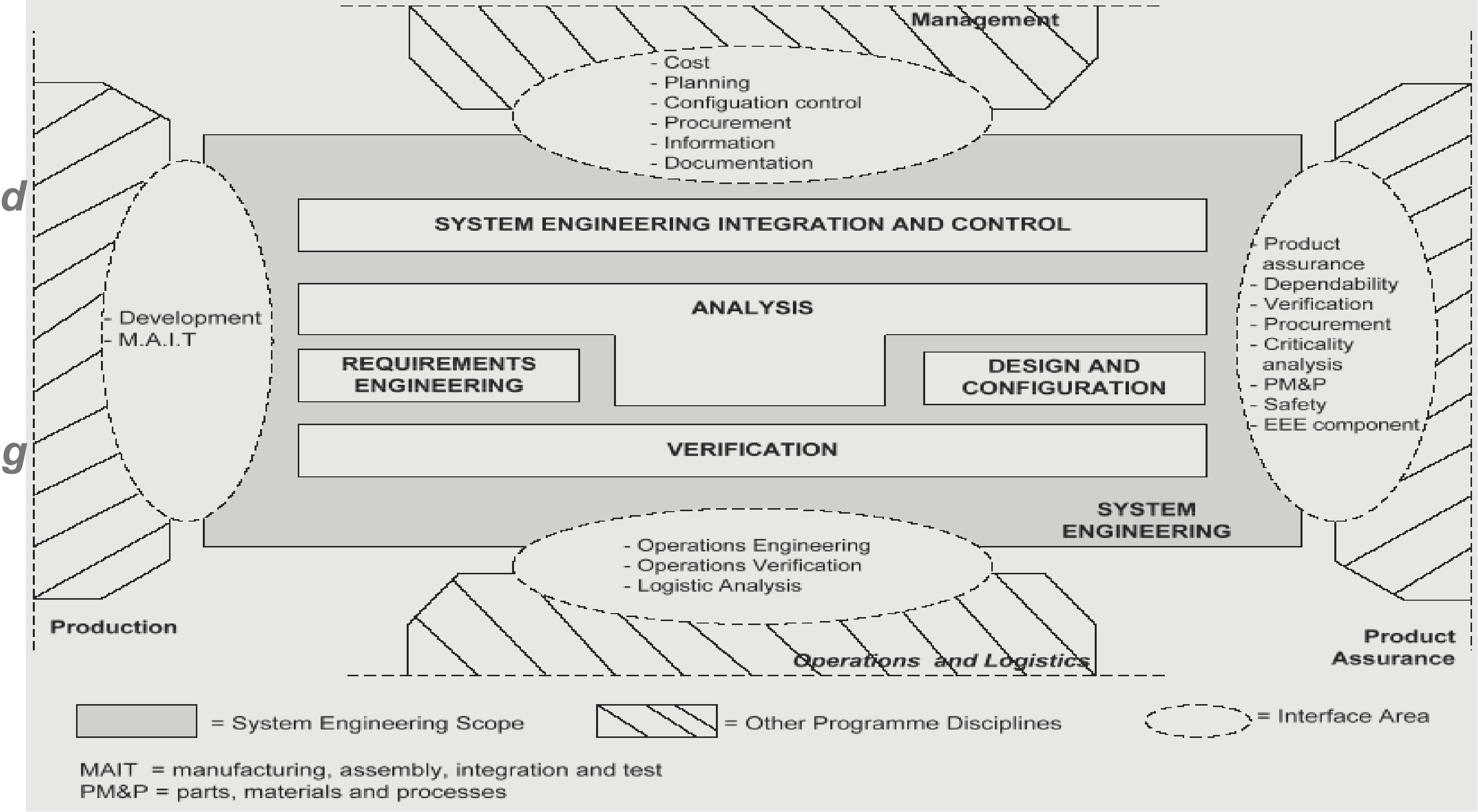
A simplified view in which the five main system engineering functions are identified



E-10
5

System - Software relationship

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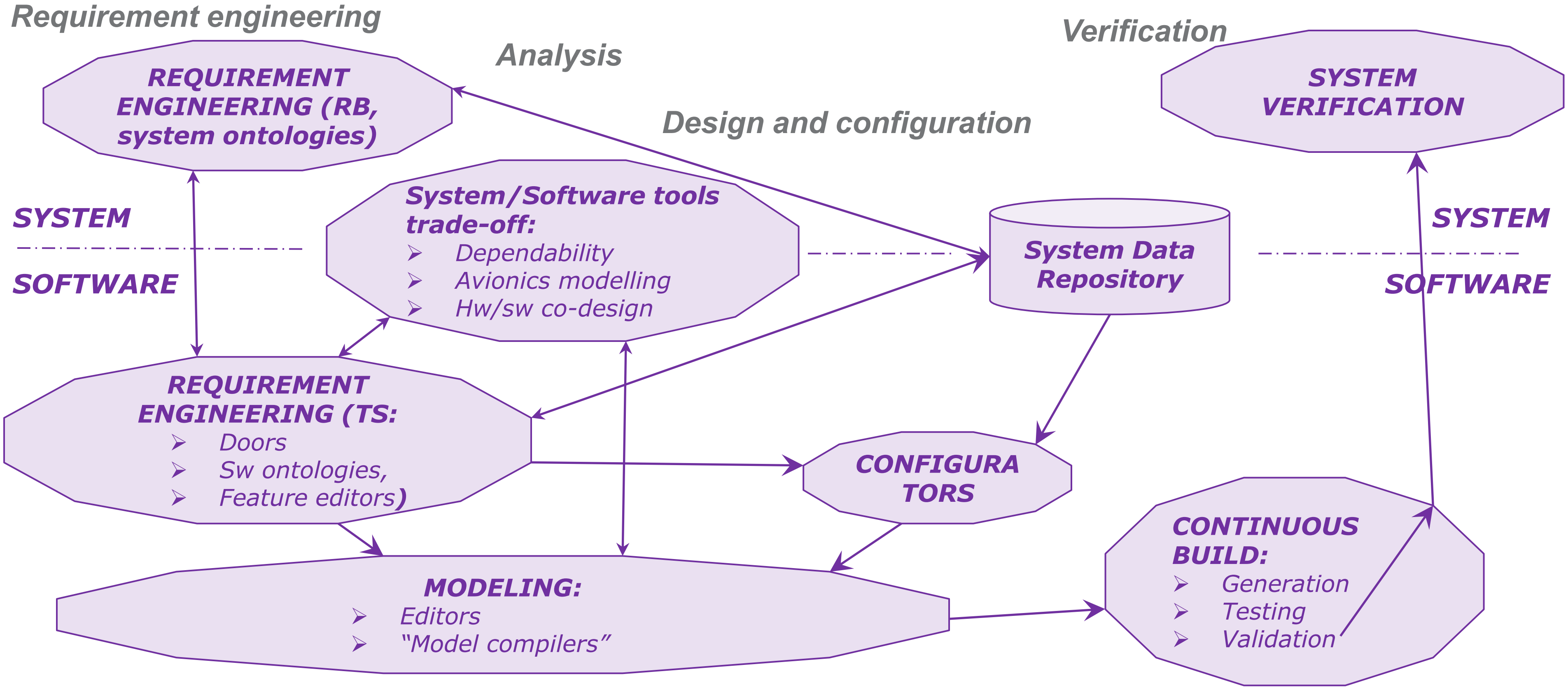
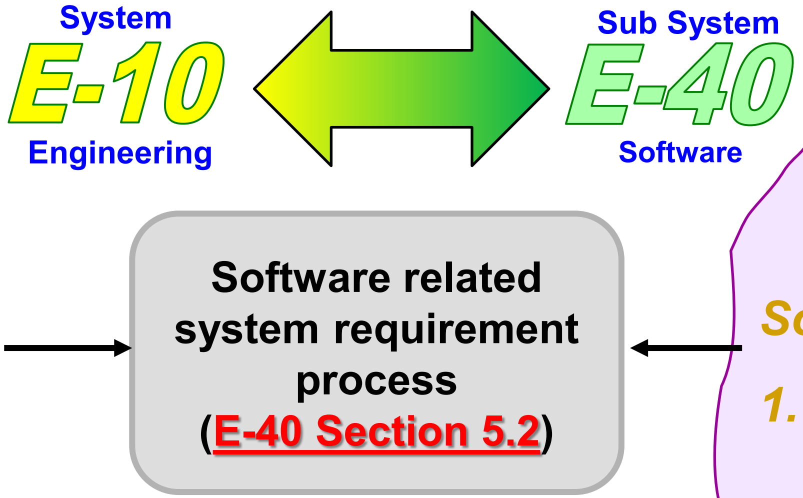


The Link Between E-10 and E-40

Space System Engineering

1. ***Requirements engineering***
2. ***Analysis***
3. ***Design and configuration***
4. ***Verification***
5. ***Integration and control***



Software related system requirement process
(E-40 Section 5.2)

This clause (5.2) of E-40 complements ECSS-E-10 for the specific software activities to be performed at system level by the customer

Space Software Engineering

Software related:

1. ***Requirements analysis***
2. ***Verification***
3. ***Integration and control***

Importance of good requirements

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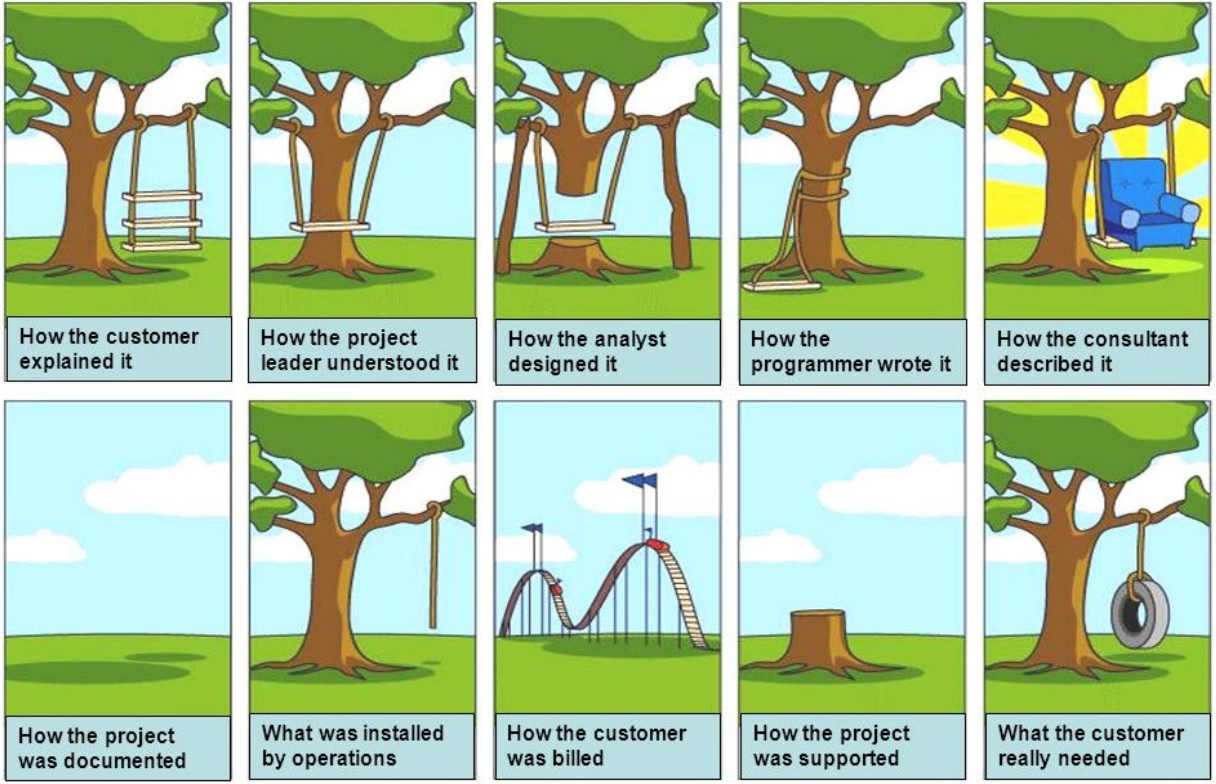

How the customer explained it
How the project leader understood it
How the analyst designed it
How the programmer wrote it
How the consultant described it
How the project was documented
What was installed by operations
How the customer was billed
How the project was supported
What the customer really needed

System software :
THE projects' critical issue…

1. System requirements related to software are normally done by the system entity (customer)
2. Software requirements are normally done by the software entity (supplier)
3. However, system requirements related to software may be:
   a. Delegated by the customer to the supplier.

      The customer may have initiated a software RB and ask for consolidation.

      The system requirements may be distributed in many (hardware) subsystem requirements.

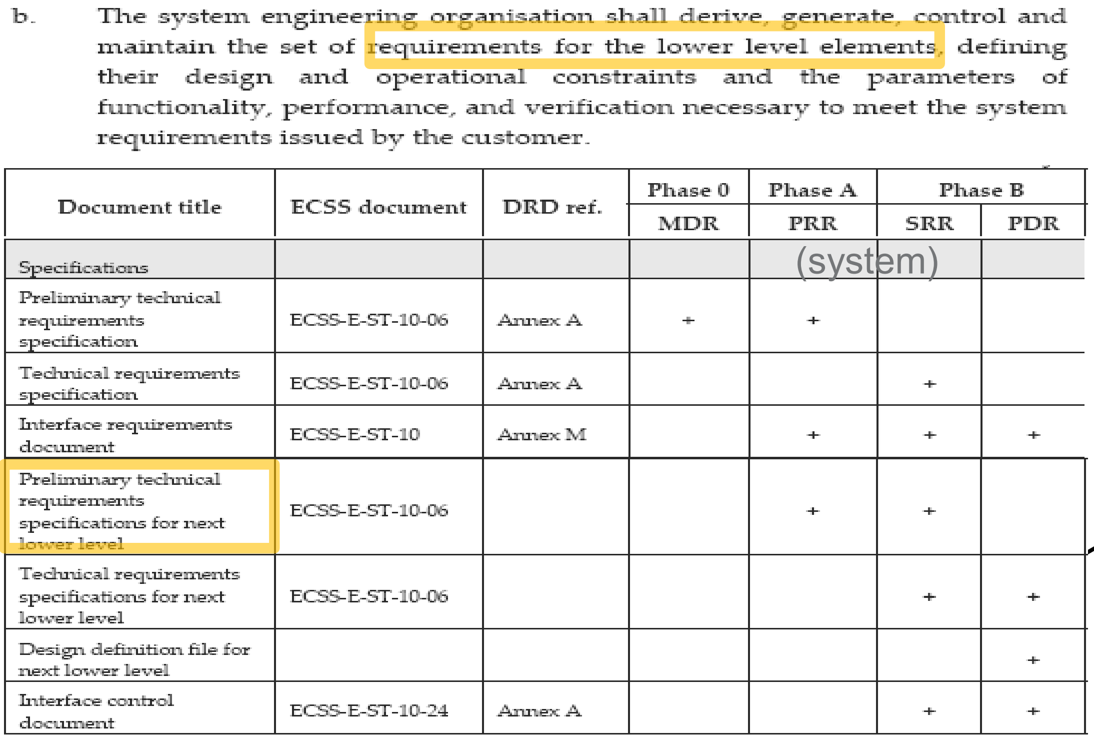
   b. Merged with the software requirements

      When the system is “software intensive”, there is no added value in having two documents but an incremental approach is recommended.

System software requirements weaknesses are the root of a lot of project troubles: integration issues, late change, delays, …

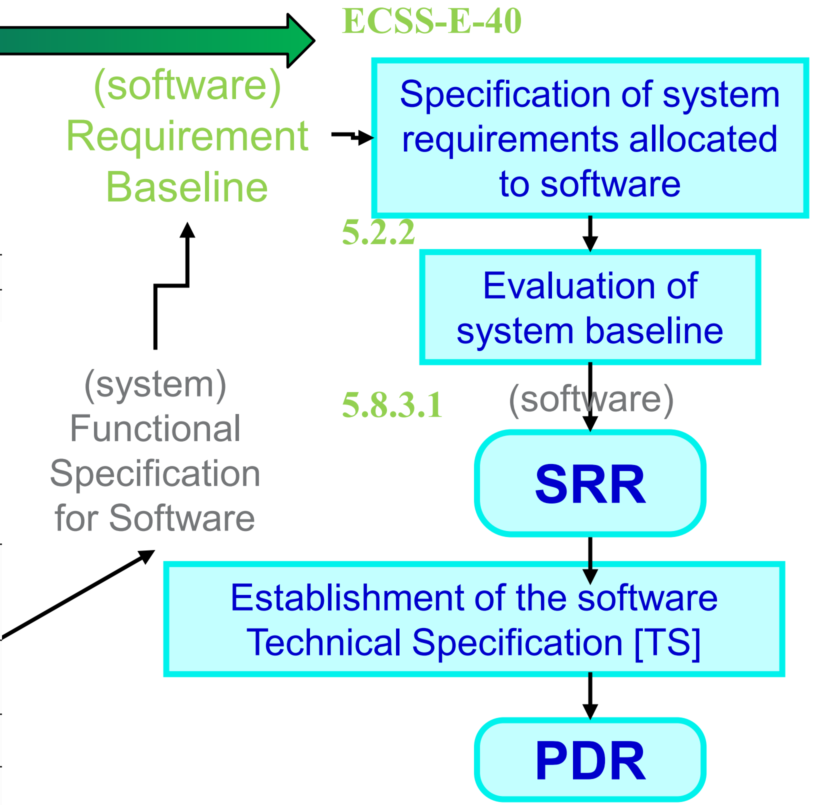
E10 and E40 Relationship

ECSS-E-10



b. The system engineering organisation shall derive, generate, control and maintain the set of requirements for the lower level elements, defining their design and operational constraints and the parameters of functionality, performance, and verification necessary to meet the system requirements issued by the customer.

Document title	ECSS document	DRD ref.	Phase 0	Phase A	Phase B	
			MDR	PRR	SRR	PDR
Specifications				(system)		
Preliminary technical requirements specification	ECSS-E-ST-10-06	Annex A	+	+		
Technical requirements specification	ECSS-E-ST-10-06	Annex A			+	
Interface requirements document	ECSS-E-ST-10	Annex M		+	+	+
Preliminary technical requirements specifications for next lower level	ECSS-E-ST-10-06			+	+	
Technical requirements specifications for next lower level	ECSS-E-ST-10-06				+	+
Design definition file for next lower level						+
Interface control document	ECSS-E-ST-10-24	Annex A			+	+



ECSS-E-40

(software) Requirement Baseline

Specification of system requirements allocated to software

5.2.2

Evaluation of system baseline

5.8.3.1

(software)

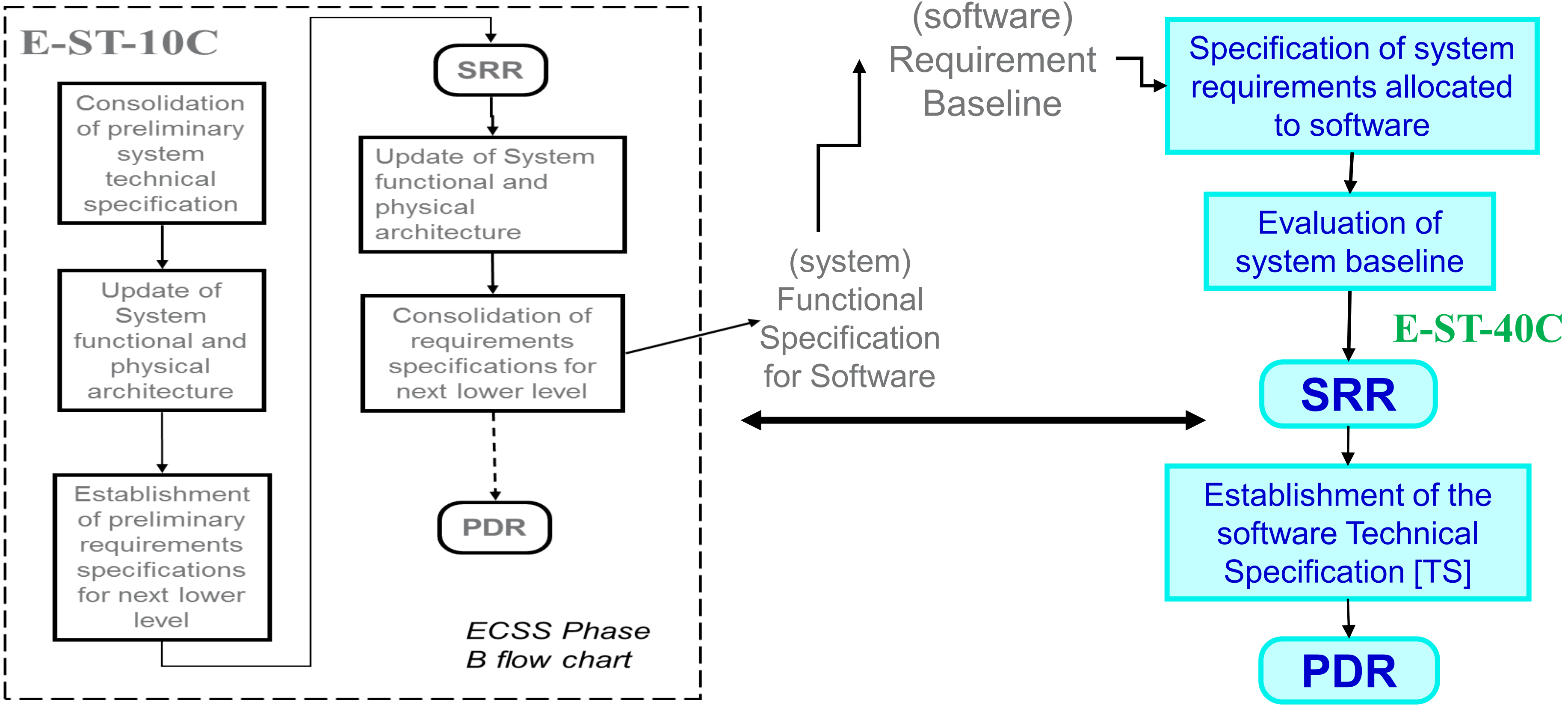
SRR

(system) Functional Specification for Software

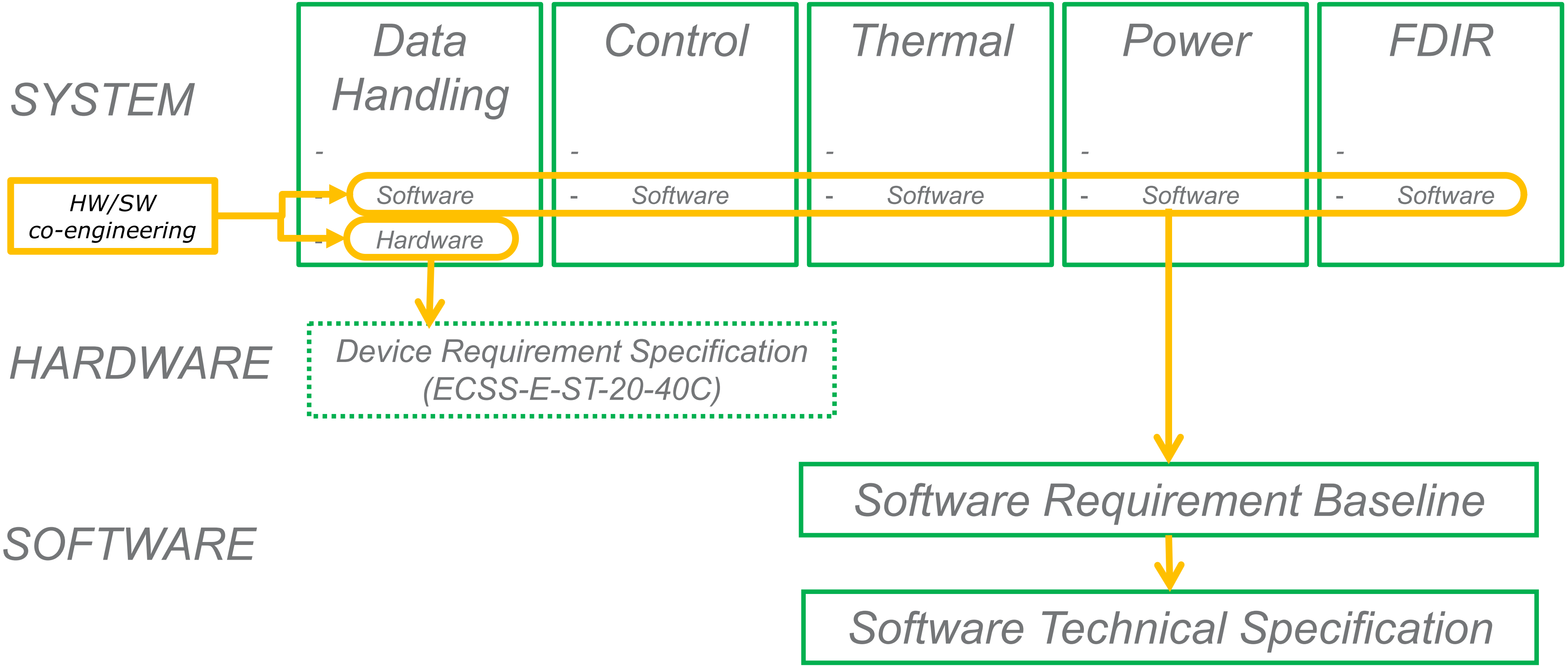
Establishment of the software Technical Specification [TS]

PDR

E-10 and E-40 Relationship


E-ST-10C
Consolidation of preliminary system technical specification
Update of System functional and physical architecture
Establishment of preliminary requirements specifications for next lower level
SRR
Update of System functional and physical architecture
Consolidation of requirements specifications for next lower level
PDR
ECSS Phase B flow chart
(system) Functional Specification for Software
(software) Requirement Baseline
Specification of system requirements allocated to software
Evaluation of system baseline
E-ST-40C
SRR
Establishment of the software Technical Specification [TS]
PDR

Software Requirements



What is Verification for System and Software?

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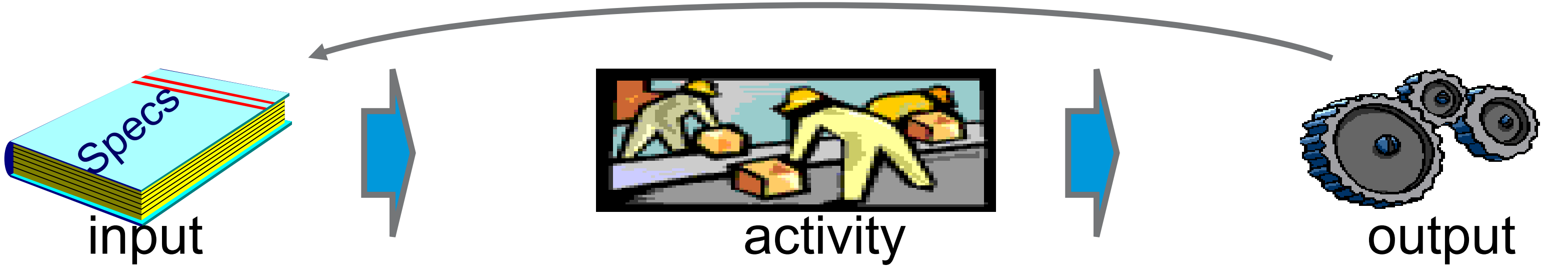
1. The **software verification** activities confirm that adequate specifications and inputs exist for any activity and that the outputs of the activities are correct and consistent with the specifications and inputs
   a. “Are we doing the thing right?”

correct & consistent?

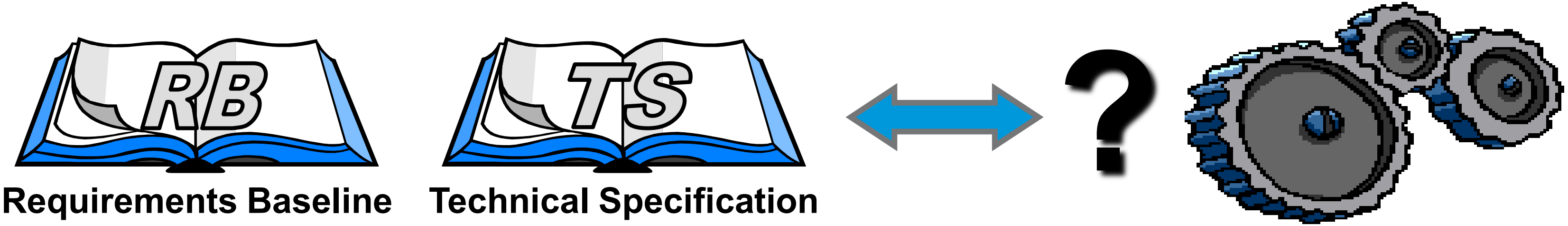


- *The system verification activities are more concerned with ensuring that the requested functionality has been implemented*

E-40
5.8

What is Validation for System and Software?

1. The **software validation** activities ensure that the functionality of the developed system really corresponds to what was specified in the Requirements Baseline and further detailed in the Technical Specification
    a. "Are we doing the right thing?"
    b. "Does the running system actually implement the promised functionality?"



Requirements Baseline **Technical Specification**

□ *The system validation activities are more concerned with the way the system is used.*

Software and [ground] system, E40 and E70

Organisation of E70

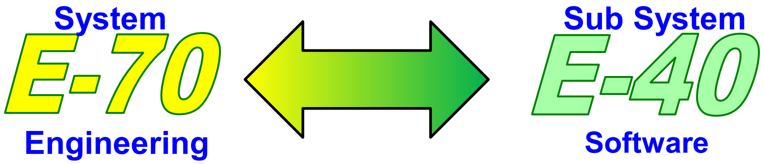
*5 **Operations engineering***
5.1 General
5.2 Requirements analysis and concept development
5.3 Mission operations data preparation
5.4 Mission operations data validation
5.5 Operations teams build–up and training
5.6 Operational validation
5.7 Operations execution
5.8 Space segment disposal

*6 **Ground segment engineering***
6.1 General
6.2 Ground segment definition
6.3 Ground segment production
6.4 Ground segment AIT and verification
6.5 Ground segment maintenance
6.6 Ground segment disposal

*7 **Ground segment and operations lifecycle***
7.1 General
7.2 Phase A: Mission and operational analysis, feasibility studies and conceptual design
7.3 Phase B: Preliminary design
7.4 Phase C: Detailed design
7.5 Phase D: Production, AIT and verification
7.6 Phase E: Mission operations
7.7 Phase F: Disposal
7.8 Summary of key documents and reviews

The Link Between E-70 and E-40

Ground Segment Engineering



Space Software Engineering

1. ***Requirements engineering (GSRD/SURD)***
2. ***Analysis + Design ~~and configuration~~***
3. ***Verification***
4. ***Integration and control** (production)*

Software related system requirement process (E-40 Section 5.2)

This clause (5.2) of E-40 complements ECSS-E-70 for the specific software activities to be performed at system level by the customer

Software related:

1. ***Requirements analysis***
2. ***Verification***
3. ***Integration and control***

Software Requirements

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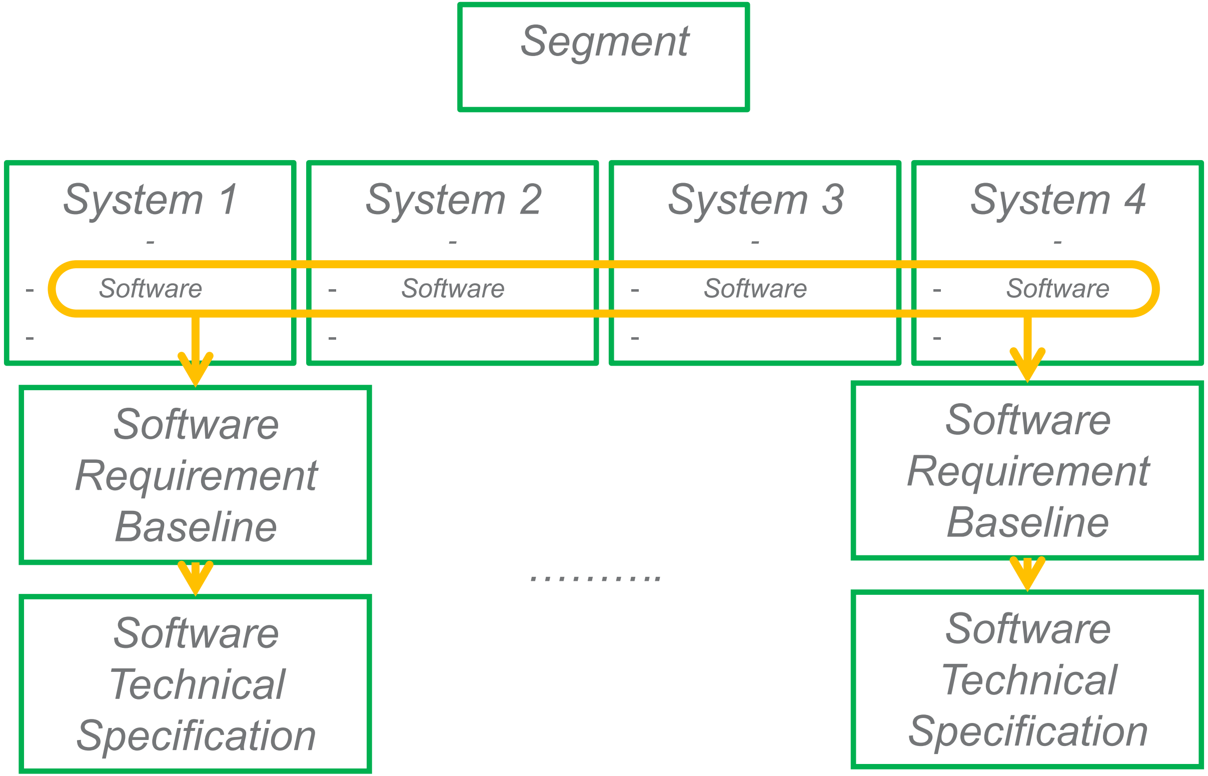
SYSTEM

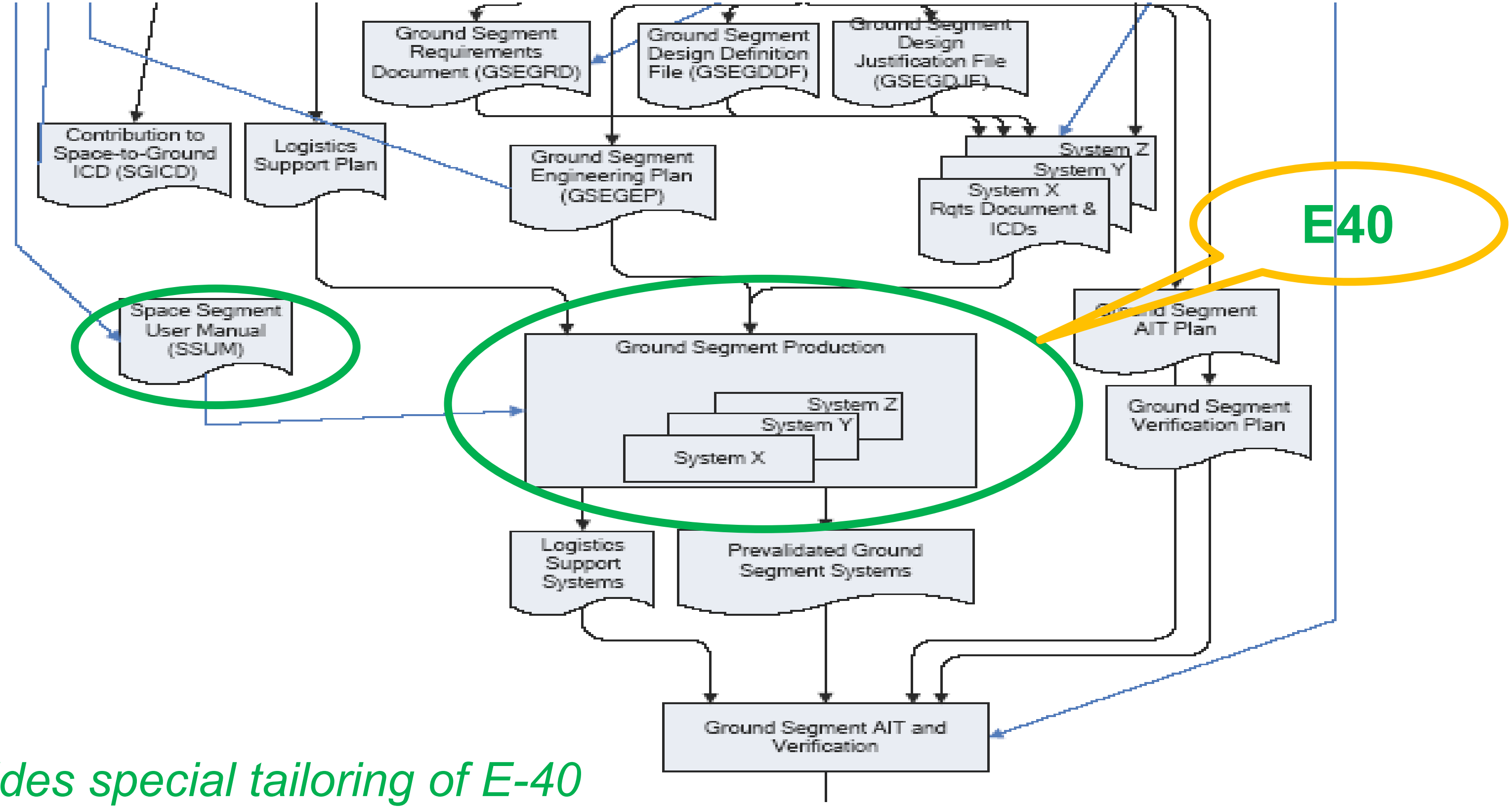
(SUB-)SYSTEM

Here E70 calls E10

SOFTWARE

Here E70 calls E40/Q80


Segment
System 1
-
- Software
-
System 2
-
- Software
-
System 3
-
- Software
-
System 4
-
- Software
-
Software Requirement Baseline
Software Technical Specification
……….
Software Requirement Baseline
Software Technical Specification



Ground Segment Requirements Document (GSEGRD)

Ground Segment Design Definition File (GSEGDDF)

Ground Segment Design Justification File (GSEGDJF)

Contribution to Space-to-Ground ICD (SGICD)

Logistics Support Plan

Ground Segment Engineering Plan (GSEGEP)

System Z

System Y

System X Rqts Document & ICDs

E40

Space Segment User Manual (SSUM)

Ground Segment Production

System Z

System Y

System X

Ground Segment AIT Plan

Ground Segment Verification Plan

Logistics Support Systems

Prevalidated Ground Segment Systems

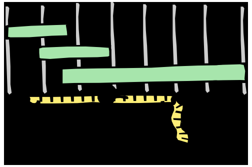
Ground Segment AIT and Verification

ESOC provides special tailoring of E-40

Project Planning and Implementation, E40 and M10

Project Planning and Implementation

1. Project planning and implementation is the project function, encompassing a coherent set of processes for all aspects of project management and control.
2. The E-40 software management process tailors M-10 for software to:



   a. define phases and formal milestones enabling the progress of the software project to be controlled

   b. define the software project breakdown structures to:
      - identify the tasks and responsibilities of each actor;
      - facilitate the coherence between all activities of the whole project;
      - perform scheduling and costing activities.

   c. set up the software project organization to perform all necessary activities on the project

M-10

Software Development Plan

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Annex O of ECSS-E-ST-40C: SDP DRD

- Management Approach (can be also in the project's SDP)
    - Objectives, priorities, master schedule, assumptions, dependencies, constraints, WBS, risk management, monitoring & control mechanisms, staffing plan, software procurement process, supplier management
- Software development approach (strategy, **development life cycle** [identification, relation with system life cycle, reviews and milestones and their documentation])
- Standards and Techniques (requirement analysis, design method, autocode, HMI standard, delivery format)
- **Development environment, testing environment** (requirement tool, design tool, compiler/linker, conf management, static analysis, test scripting language, testing tools)
- Documentation plan

Software Validation Plan

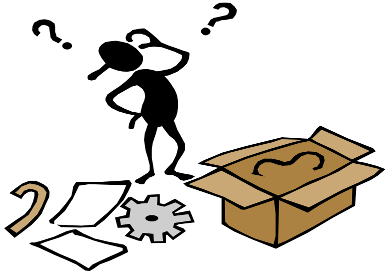
Annex J of ECSS-E-ST-40C: SValP DRD

- Management Approach (can be also in the project's SDP)
  - Approach, effort, independence, organisation, schedule, resource, responsibilities, tool, techniques, methods, [independent]] personnel, risks
- Validation tasks identification (description, item under tests, success criteria, resuming after interrupt, input, output, resources)
- **Validation approach** (requirements on testing activities, kind of tests to be executed; inspection/analysis/review of design approach; regression testing)
- **Validation testing facilities** (test environment, configuration [software, hardware, test equipments, comms, testing data, simulators, etc]
- Control procedures (problem reporting, problem resolution, deviation, waiver, configuration management)

Software configuration management, E40 and M40

Software Configuration Management

1. The **product tree** is the breakdown of the project into successive levels of hardware and software products or elements called Configuration Items (CI) [M-10]
2. For each software product CI, a software configuration file (SCF) is prepared to provide the configuration status of the software CI
   a. It controls its evolution during the programme or project life cycle
3. The SCF is a constituent of the design definition file and is called from M-40, requirement 5.3.3.2b and from E-40 and Q-80



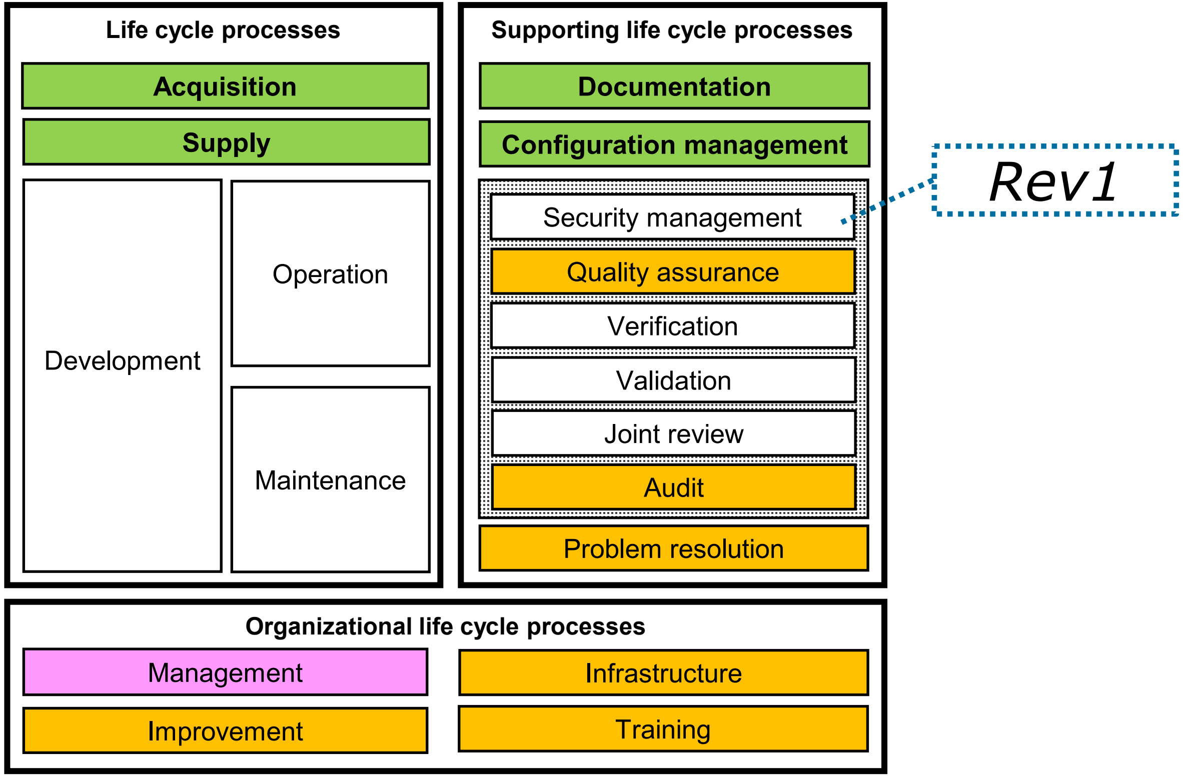
☞ **5.3.3.2 As designed data list** ☜

b. For each deliverable software CI, the supplier shall provide a software configuration file (SCF) in conformance with Annex E, software configuration file DRD.

M-40

Software product assurance, E-40 and Q-80

Software related processes in ECSS standards



Life cycle processes

Acquisition

Supply

Development

Operation

Maintenance

Supporting life cycle processes

Documentation

Configuration management

Security management

Quality assurance

Verification

Validation

Joint review

Audit

Problem resolution

Rev1

Organizational life cycle processes

Management

Infrastructure

Improvement

Training

🟩 Other ECSS

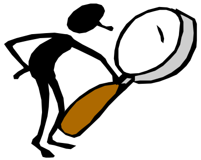
□ ECSS-E-ST-40

🟧 ECSS-Q-ST-80

🟪 Details for SPA and/or SWE

The Objectives of Software Product Assurance

1. The objectives of software product assurance are to provide adequate confidence to the **customer** and to the **suppliers** that developed or procured/reused software satisfies its requirements throughout the system lifetime
    a. In particular, that the software is developed to perform **properly** and **safely** in its operational environment, meeting the quality objectives agreed for the project
2. SPA consists of both:
    a. The assurance of the **process** (software process assurance)
    b. The assurance of the quality of the **product** (software product quality assurance)

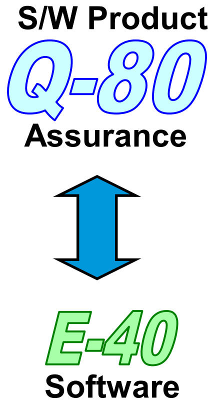


Q-80

4.1-2

The Relationship between E- 40 and Q-80

1. E-40 covers all aspects of space software engineering from requirements definition to retirement
2. Q-80 complements E-40 with product assurance aspects, integrated in the space system software engineering processes as defined in E-40
3. Q-80 is the entry point for E-40 into the Q-series of standards
4. Equally, the interface of Q-80 to the E-series of standards is via E-40
5. Together the two standards specify all processes for space software development



S/W Product

Q-80

Assurance

E-40

Software

4.1

References from E- 40 to Q-80

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1. Q-80 requirements are directly referenced and made applicable through E-40 requirements

☞ 5.2.4.8 Software safety and dependability requirements☜

a. The customer shall specify the software safety and dependability requirements in accordance with ECSS-Q-ST-80 clauses 5.4.4, 6.2.2 and 6.2.3, based on the results of the safety and dependability analysis performed at system level.

🗁 Expected Output 🗁

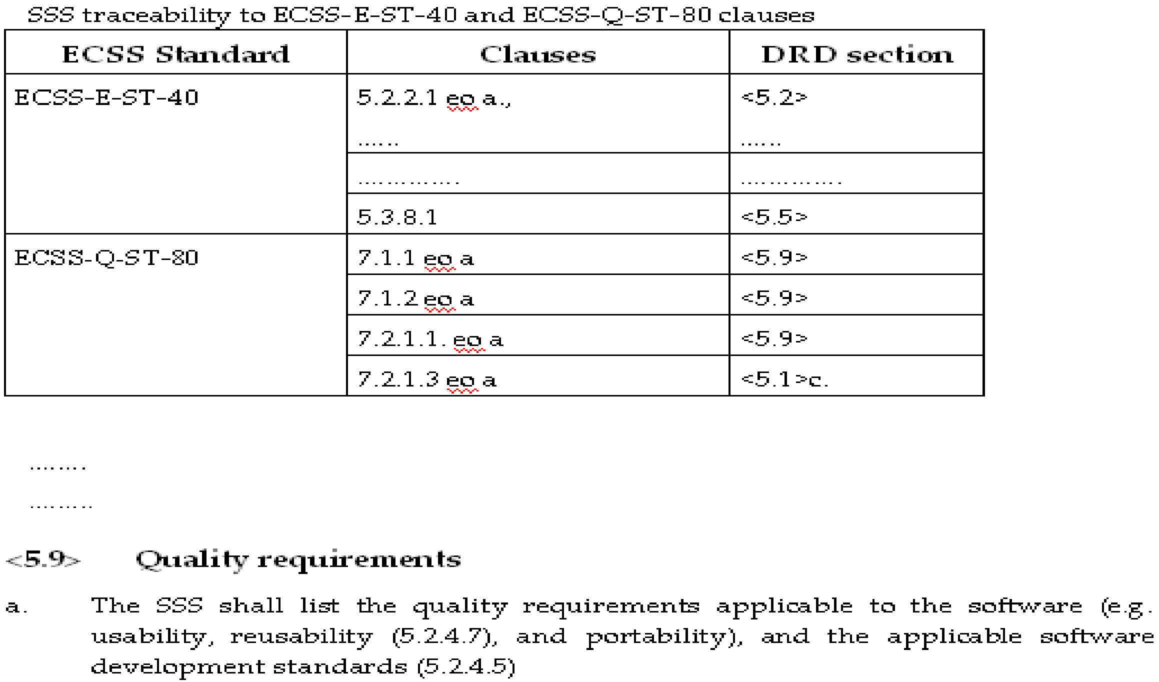
Software safety and dependability requirements [RB, SSS; SRR]

S/W Product
Q-80
Assurance
E-40
Software

E-40
5.2

References from E- 40 to Q-80

1. Q-80 requirements are referenced and made applicable through the DRDs defined in E-40 (normative)



SSS traceability to ECSS-E-ST-40 and ECSS-Q-ST-80 clauses

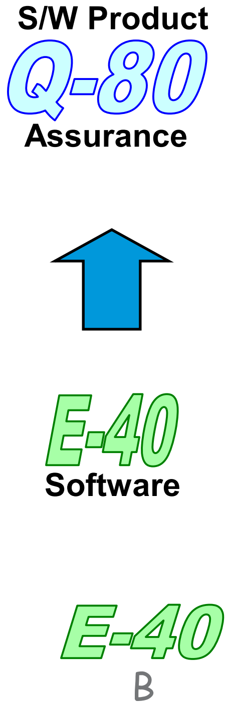
ECSS Standard	Clauses	DRD section
ECSS-E-ST-40	5.2.2.1 eo a., ……	<5.2> ……
	………….	………….
	5.3.8.1	<5.5>
ECSS-Q-ST-80	7.1.1 eo a	<5.9>
	7.1.2 eo a	<5.9>
	7.2.1.1. eo a	<5.9>
	7.2.1.3 eo a	<5.1>c.

……..

………

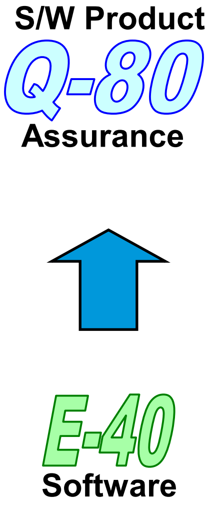
<5.9> **Quality requirements**

a. The SSS shall list the quality requirements applicable to the software (e.g. usability, reusability (5.2.4.7), and portability), and the applicable software development standards (5.2.4.5)



Main SPA Issues Referenced from E- 40

1. Software safety and dependability
    a. including criticality classification and E-40 tailoring
2. Product Quality requirements
    a. and their quantitative definition
3. Software reuse and procurement
    a. including identification and assessment/inspection
4. Software configuration management
5. (Independent) Validation and verification
    a. and testing
6. Software problems and nonconformances



E-40
5.2

Main Q-80 Requirements on Engineering activities

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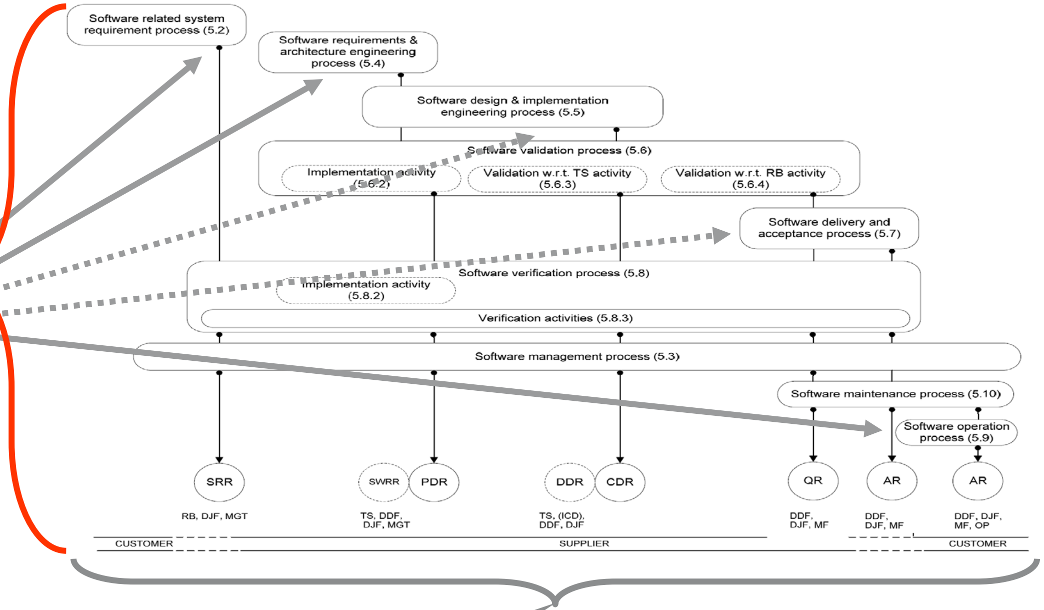
applicable to all software engineering processes [Q-80 6.2]

applicable to individual software engineering processes or activities [Q-80 6.3]


Software related system requirement process (5.2)
Software requirements & architecture engineering process (5.4)
Software design & implementation engineering process (5.5)
Software validation process (5.6)
Implementation activity (5.6.2)
Validation w.r.t. TS activity (5.6.3)
Validation w.r.t. RB activity (5.6.4)
Software delivery and acceptance process (5.7)
Software verification process (5.8)
Implementation activity (5.8.2)
Verification activities (5.8.3)
Software management process (5.3)
Software maintenance process (5.10)
Software operation process (5.9)
SRR
SWRR
PDR
DDR
CDR
QR
AR
AR
RB, DJF, MGT
TS, DDF, DJF, MGT
TS, (ICD), DDF, DJF
DDF, DJF, MF
DDF, DJF, MF
DDF, DJF, MF, OP
CUSTOMER
SUPPLIER
CUSTOMER

on the software development life cycle [Q-80 6.1]

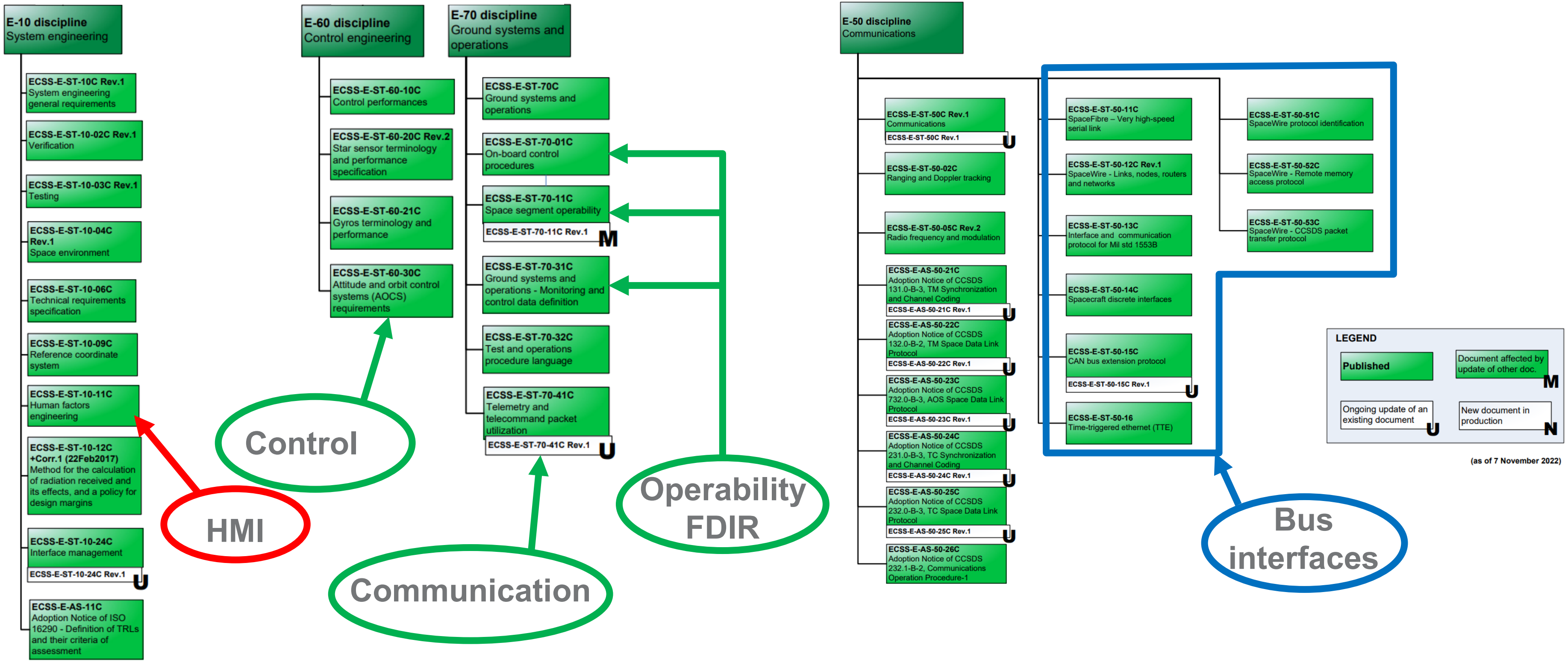
S/W Product
Q-80
Assurance

E-40
Software

Q-80

The Engineering standards generating software functional requirements

The Engineering standards generating software functional requirements



E-10 discipline
System engineering

- **ECSS-E-ST-10C Rev.1** System engineering general requirements
- **ECSS-E-ST-10-02C Rev.1** Verification
- **ECSS-E-ST-10-03C Rev.1** Testing
- **ECSS-E-ST-10-04C Rev.1** Space environment
- **ECSS-E-ST-10-06C** Technical requirements specification
- **ECSS-E-ST-10-09C** Reference coordinate system
- **ECSS-E-ST-10-11C** Human factors engineering
- **ECSS-E-ST-10-12C +Corr.1 (22Feb2017)** Method for the calculation of radiation received and its effects, and a policy for design margins
- **ECSS-E-ST-10-24C** Interface management
  - ECSS-E-ST-10-24C Rev.1 U
- **ECSS-E-AS-11C** Adoption Notice of ISO 16290 - Definition of TRLs and their criteria of assessment

E-60 discipline
Control engineering

- **ECSS-E-ST-60-10C** Control performances
- **ECSS-E-ST-60-20C Rev.2** Star sensor terminology and performance specification
- **ECSS-E-ST-60-21C** Gyros terminology and performance
- **ECSS-E-ST-60-30C** Attitude and orbit control systems (AOCS) requirements

E-70 discipline
Ground systems and operations

- **ECSS-E-ST-70C** Ground systems and operations
- **ECSS-E-ST-70-01C** On-board control procedures
- **ECSS-E-ST-70-11C** Space segment operability
  - ECSS-E-ST-70-11C Rev.1 M
- **ECSS-E-ST-70-31C** Ground systems and operations - Monitoring and control data definition
- **ECSS-E-ST-70-32C** Test and operations procedure language
- **ECSS-E-ST-70-41C** Telemetry and telecommand packet utilization
  - ECSS-E-ST-70-41C Rev.1 U

E-50 discipline
Communications

- **ECSS-E-ST-50C Rev.1** Communications
  - ECSS-E-ST-50C Rev.1 U
- **ECSS-E-ST-50-02C** Ranging and Doppler tracking
- **ECSS-E-ST-50-05C Rev.2** Radio frequency and modulation
- **ECSS-E-AS-50-21C** Adoption Notice of CCSDS 131.0-B-3, TM Synchronization and Channel Coding
  - ECSS-E-AS-50-21C Rev.1 U
- **ECSS-E-AS-50-22C** Adoption Notice of CCSDS 132.0-B-2, TM Space Data Link Protocol
  - ECSS-E-AS-50-22C Rev.1 U
- **ECSS-E-AS-50-23C** Adoption Notice of CCSDS 732.0-B-3, AOS Space Data Link Protocol
  - ECSS-E-AS-50-23C Rev.1 U
- **ECSS-E-AS-50-24C** Adoption Notice of CCSDS 231.0-B-3, TC Synchronization and Channel Coding
  - ECSS-E-AS-50-24C Rev.1 U
- **ECSS-E-AS-50-25C** Adoption Notice of CCSDS 232.0-B-3, TC Space Data Link Protocol
  - ECSS-E-AS-50-25C Rev.1 U
- **ECSS-E-AS-50-26C** Adoption Notice of CCSDS 232.1-B-2, Communications Operation Procedure-1
- **ECSS-E-ST-50-11C** SpaceFibre – Very high-speed serial link
- **ECSS-E-ST-50-12C Rev.1** SpaceWire - Links, nodes, routers and networks
- **ECSS-E-ST-50-13C** Interface and communication protocol for Mil std 1553B
- **ECSS-E-ST-50-14C** Spacecraft discrete interfaces
- **ECSS-E-ST-50-15C** CAN bus extension protocol
  - ECSS-E-ST-50-15C Rev.1 U
- **ECSS-E-ST-50-16** Time-triggered ethernet (TTE)
- **ECSS-E-ST-50-51C** SpaceWire protocol identification
- **ECSS-E-ST-50-52C** SpaceWire - Remote memory access protocol
- **ECSS-E-ST-50-53C** SpaceWire - CCSDS packet transfer protocol

LEGEND

🟩 **Published**	🟩 Document affected by update of other doc. M
□ Ongoing update of an existing document U	□ New document in production N

(as of 7 November 2022)

Summary of Part 1

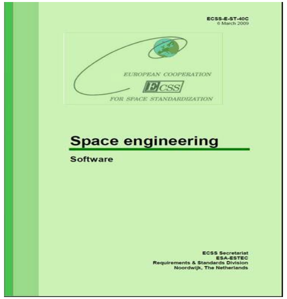
Summary of Part 1

1. Space software engineering is part of the engineering branch of the ECSS standards

2. The **E-10** standard specifies implementation requirements for the responsible system engineering organization. E-40 complements E-10 for the specific software activities to be performed at system level
   a. The link is reflected in E-40 **Clause 5.2, Software related system requirement process**
   b. These specific activities are performed in the project **phase B**
   c. They can be delegated by the customer to the supplier
3. **Software related system requirements are important**

4. E70 is the ground segment and operability standard.
5. M10 and M40 relate to project and configuration management
6. Q80 complements E-40 with respect to Software quality assurance
7. Several technical standards (not process models) generate software functional requirements.

PART 2:
A Roadmap to the Standard



ECSS-E-ST-40C
6 March 2009

EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

Space engineering

Software

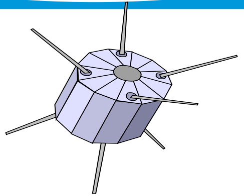
ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

Abstract

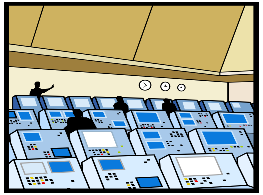
ECSS-E-40 is the standard for space software engineering. This module provides a road map to the standard, introducing the participant to its key concepts, and processes.

A Standard for All Space Software

Standardization training program
E40 discipline: SW Engineering



1. The E-40 standard is intended for application to **all software** developed as part of a space project
   a. flight software
   b. ground software
2. For ASIC and FPGA:
   NEW
   a. ECSS-E-ST-20-40C ASIC and FPGA engineering (<=> E40 for SW)
   b. ECSS-Q-ST-60-02D ASIC and FPGA product assurance (<=> Q80 for SW)
3. ECSS only address hardware and software, firmware is not defined. It is recommended to not use that term ot to clearly define it.

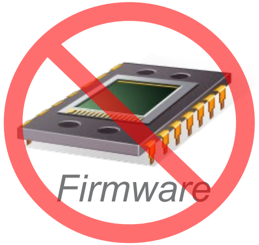


software
set of instructions and data executed on a processing unit

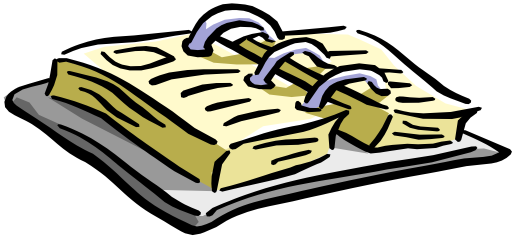
NOTE 1: See 3.2.20 for the definition of processing unit.

NOTE 2: Some processing units only require data, e.g. configuration of state machines or configuration data of a neural network.

NOTE 3 Files using Hardware Description Languages (e.g. VHDL, Verilog, System-C) used to model ASICs or bit stream files used to programme FPGAs are not software.



ECSS-E-40 Status



ECSS-E-40A 13 April 1999

First approved issue

ECSS-E-40B Draft July 2000

Not a formal version but applied to several projects

Public Review Version

ECSS-E-40 Part 1B November 2003,

ECSS-E-40 Part 2B 31 March 2005

Previous published version

ECSS-E-ST-40C 6 March 2009

Published Version

It is the reference for this course

Available from www.ecss.nl

ECSS-E-ST-40C Rev1 Public review ended January 2023

Publication planned in Q2 2023

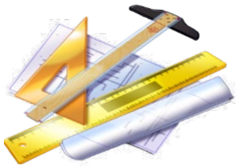
Some important aspects are already included in this course

E-HB-40: The E-40 Handbook

1. The main objective of the handbook is to collect software engineering best practices for the implementation of E-40 requirements
   a. It covers both flight and ground software
   b. It comes from project lessons learned
2. "*Getting started*" and "*Getting compliant*" introduction
3. Guidelines for each software process in E-40
4. Focus on specific issues (automatic code generation, reuse, on-board control procedure, etc.)
5. Technology supplements (use cases & scenarios, model driven engineering, real-time, testing for dependability), and addresses some generic engineering techniques.

Publication 11/12/2013, a revision has been initiated to align with ECSS-E-ST-40C Rev1, the public review is planned end 2023.

Life cycles



Methods, MDE

V&V

Real-Time

E-HB-40: Software Life Cycle

Life cycles

- Waterfall (not iterative) : RB frozen
- Incremental : RB frozen
- Evolutionary, RB evolve
- Spiral, Agile: RB evolve, risk related to final product → *ECSS-E-HB-40-01A (07/04/2020)*

Reviews and iterative life cycles

- SRR all versions
- PDR early version
- DDR middle version
- CDR, QR on last versions
- AR on the last version (including all corrections)

	V1		V2		V3		V4	
	Project	Technical	Project	Technical	Project	Technical	Project	Technical
SRR	X		X		X			
PDR	X		X			X		
DDR		X	X			X		
TRR				X		X		
TRB/DRB		X		X				
CDR					X			
QR					X			
AR							X	

E-HB-40: Logical Model

- Support the Technical Specification
- Representation of the requirements
- Independent from the implementation
- Used to check completeness and consistency
- Possibly executable

- Often not fully understood by suppliers: see section 5.4.2.3 of the handbook and Annex B. Update information will be provided in next release of the handbook.

E-HB-40: Unit tests and code coverage

UT objectives: check correctness of unit source code against design

No other way of testing than UT for :

- low level sw, hw i/f, drivers
- complex units, error management code
- boundary testing

Code coverage:

- contribute to UT objectives (cover all software)
- contribute to all sw reliability
- can be achieved by other mean that UT (e.g. functional tests)

Tailoring drivers:

- criticality of unit
- combine with functional tests , check coverage and complete
- level or size of the units

E-HB-40: Autocode

Standardization training program
E40 discipline: SW Engineering

Basic need:

a modelling style standard

to make sure the model is autocodable

Traditional way:

Model -> autocode

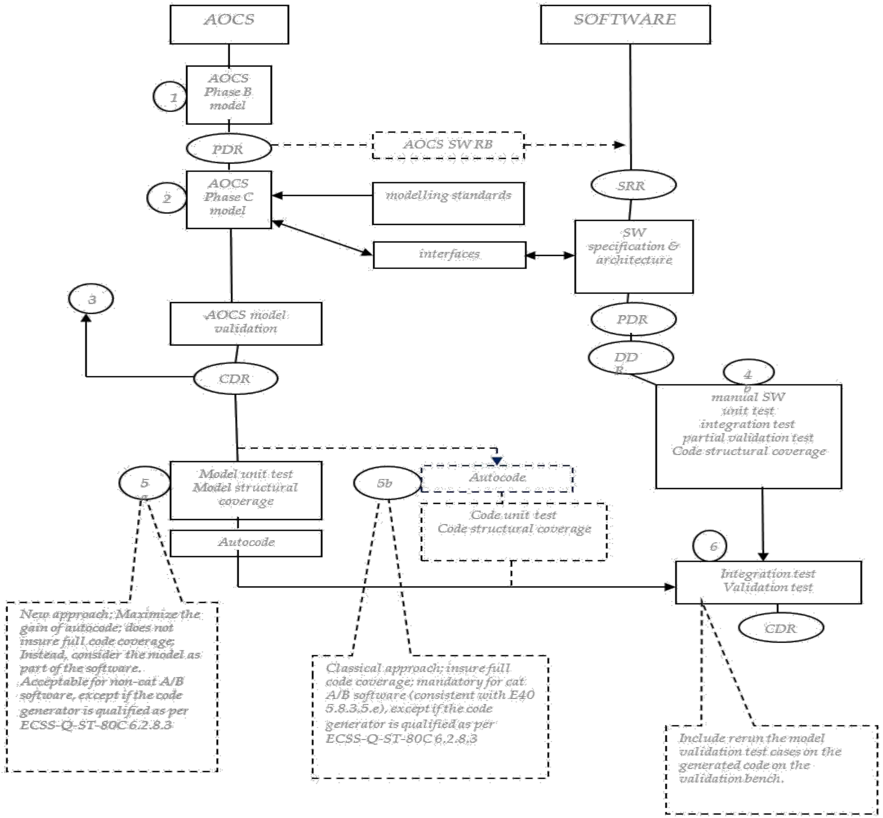
-> UT, IT, structural coverage

Envisaged way:

Model -> model UT & structural coverage

-> autocode

►SAVOIR-HB-005


AOCS
SOFTWARE
1
AOCS Phase B model
PDR
AOCS SW RB
SRR
2
AOCS Phase C model
modelling standards
interfaces
SW specification & architecture
3
AOCS model validation
PDR
DD R
CDR
4 b
manual SW unit test integration test partial validation test Code structural coverage
5 a
Model unit test Model structural coverage
Autocode
5b
Autocode
Code unit test Code structural coverage
6
Integration test Validation test
CDR

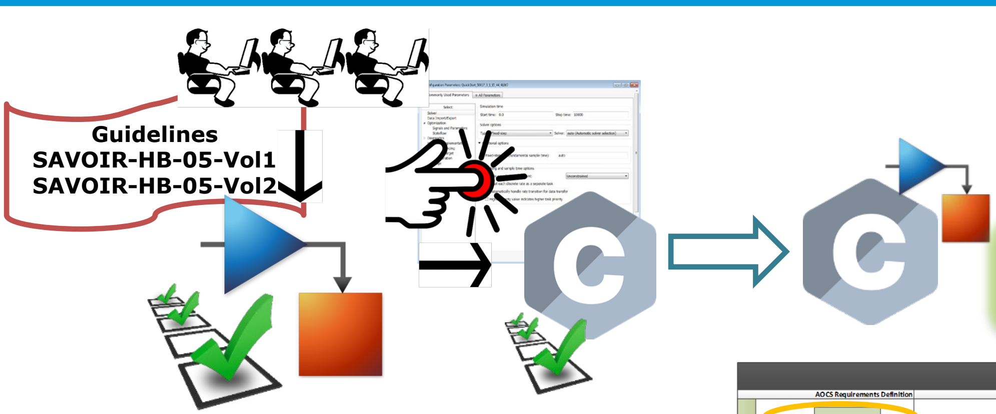
New approach; Maximize the gain of autocode; does not insure full code coverage; Instead, consider the model as part of the software. Acceptable for non-cat A/B software, except if the code generator is qualified as per ECSS-Q-ST-80C 6.2.8.3

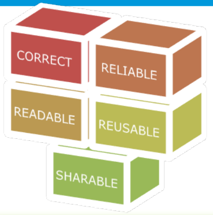
Classical approach; insure full code coverage; mandatory for cat A/B software (consistent with E40 5.8.3.5.e), except if the code generator is qualified as per ECSS-Q-ST-80C 6.2.8.3

Include rerun the model validation test cases on the generated code on the validation bench.

SAVOIR-HB-005

Standardization training program
E40 discipline: SW Engineering





ECSS E-40 Q-80 compliant

I. Vol I: General concepts

a) Development and verification process

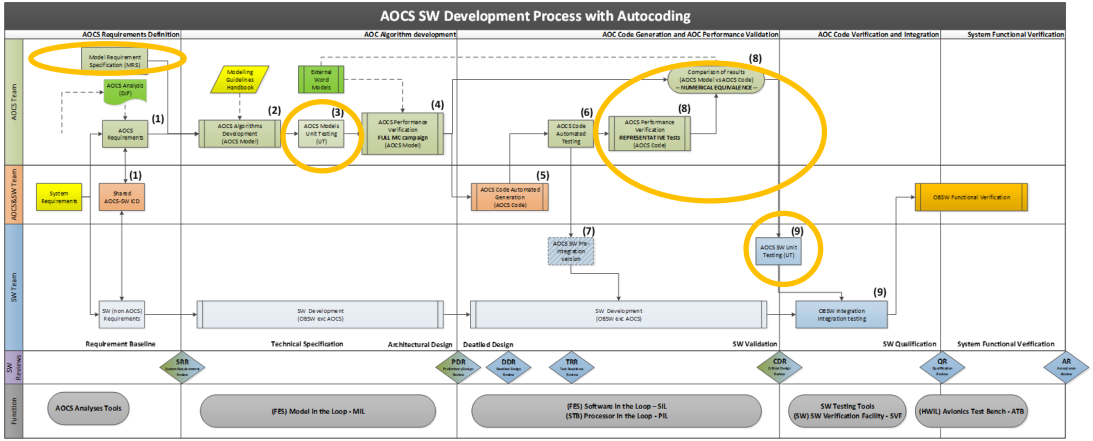
b) Compliance with existing standards

II. Vol II Modelling guidelines (AOCS modelling)

a) Define modelling guidelines

b) Configuration of code generation toolboxes

c) Classification of guidelines


AOCS SW Development Process with Autocoding
AOCS Requirements Definition
AOC Algorithm development
AOC Code Generation and AOC Performance Validation
AOC Code Verification and Integration
System Functional Verification
AOCS Team
AOCS&SW Team
SW Team
SW Reviews
Function
Model Requirement Specification (MRS)
AOCS Analysis (DJF)
(1)
AOCS Requirements
Modelling Guidelines Handbook
External Word Models
(2)
AOCS Algorithms Development (AOCS Model)
(3)
AOCS Models Unit Testing (UT)
(4)
AOCS Performance Verification FULL MC campaign (AOCS Model)
(8)
Comparison of results (AOCS Model vs AOCS Code) -- NUMERICAL EQUIVALENCE --
(6)
AOCS Code Automated Testing
(8)
AOCS Performance Verification REPRESENTATIVE Tests (AOCS Code)
System Requirements
(1)
Shared AOCS-SW ICD
(5)
AOCS Code Automated Generation (AOCS Code)
OBSW Functional Verification
(7)
AOCS SW Pre-integration version
(9)
AOCS SW Unit Testing (UT)
(9)
OBSW Integration Integration testing
SW (non AOCS) Requirements
SW Development (OBSW exc AOCS)
SW Development (OBSW exc AOCS)
Requirement Baseline
Technical Specification
Architectural Design
Deatiled Design
SW Validation
SW Qualification
System Functional Verification
SRR System Requirements Review
PDR Preliminary Design Review
DDR Deatiled Design Review
TRR Test Readiness Review
CDR Critical Design Review
QR Qualification Review
AR Acceptance Review
AOCS Analyses Tools
(FES) Model In the Loop - MIL
(FES) Software In the Loop – SIL
(STB) Processor In the Loop - PIL
SW Testing Tools
(SW) SW Verification Facility - SVF
(HWIL) Avionics Test Bench - ATB

The E-ST-40-07: Simulation Model Portability

Standardization training program
E40 discipline: SW Engineering

1. To enable simulation **model** reuse between project phases as well as between projects thus reducing cost of overall **simulator** developments as well as contributing to knowledge capturing.
2. The project activities requiring simulation support are described in E-TM-10-21.
3. The scope of the standard addresses the definition of simulation model interfaces and the associated development process in order to enable:
   a. Simulation Model Portability
   b. Simulation Model Reuse
   c. Model Development Productivity
   d. Simulation Model Integration
   e. Support for a model driven engineering process
   f. Support for simulation model meta data
   g. Support for dynamic simulations
   h. Handbook containing guidelines how to apply the ECSS-E-40-07 standard.
   i. Data integration

The E-40-07:
Simulation Model Portability

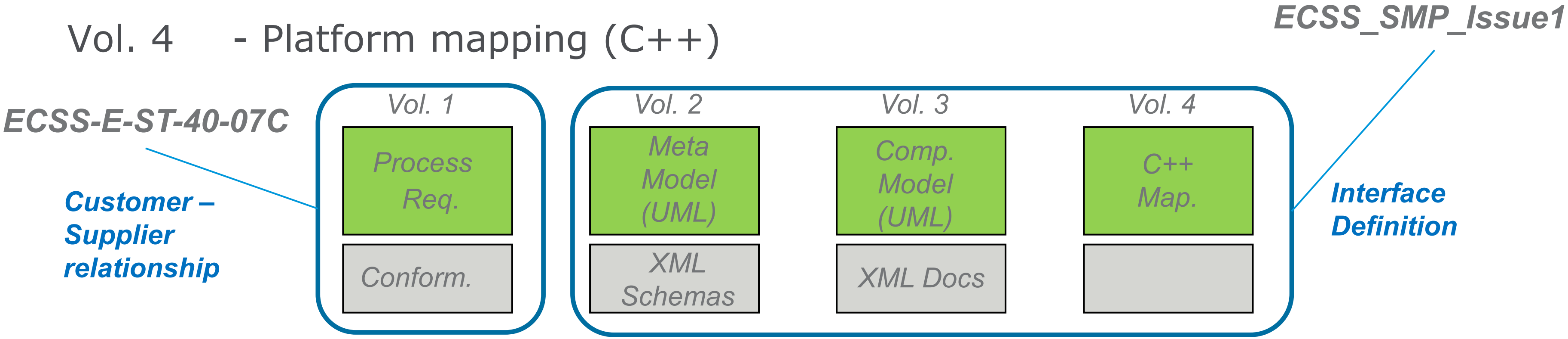
Vol. 1 - Process extending the E-40 Software Development Standard

- Requirements between Customer and Supplier – mainly defines the deliverables

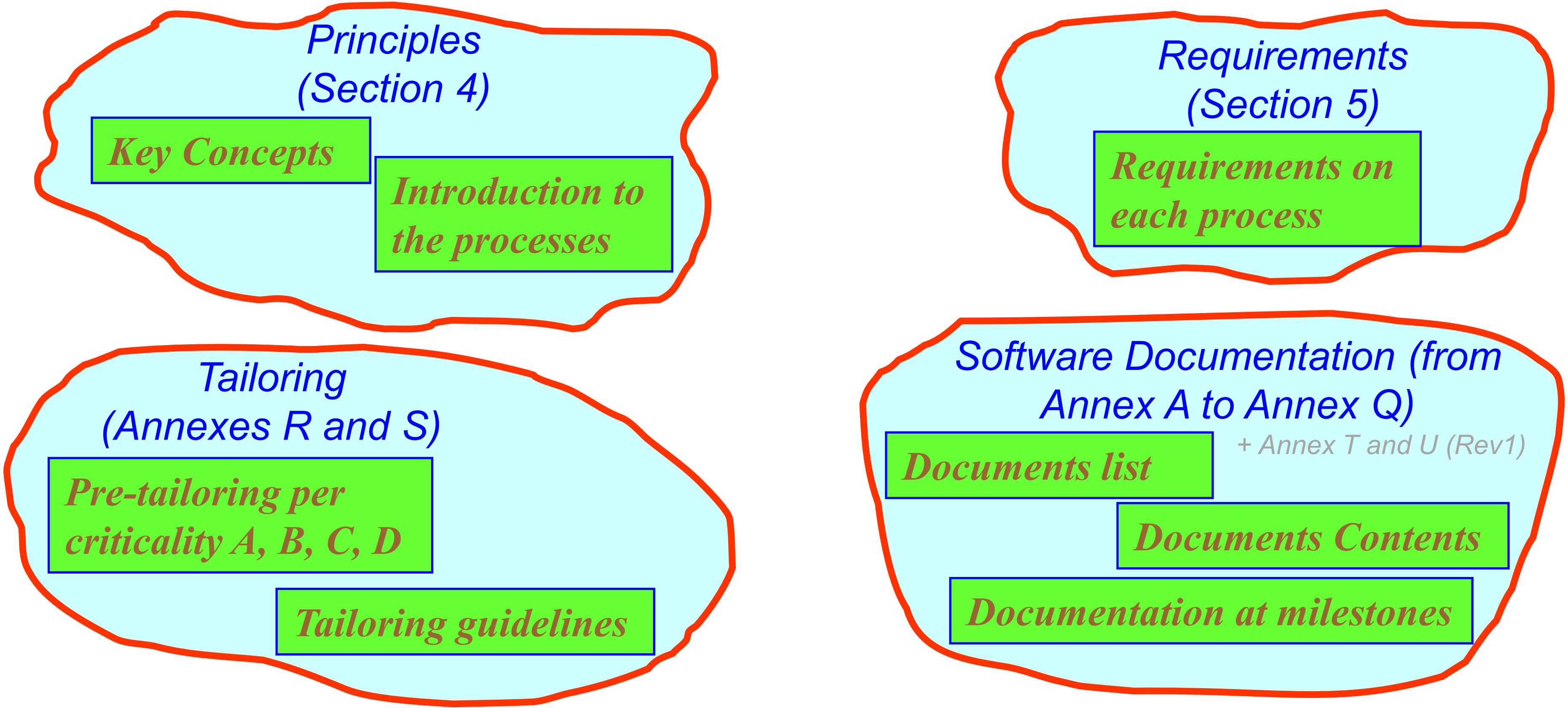
Vol. 2 - Platform independent language defining the simulation models (UML, XML Schemas)

Vol. 3 - Software component model (XML, IDL)

Vol. 4 - Platform mapping (C++)



Overview of the E-40 Standard



Principles
(Section 4)

Key Concepts

Introduction to the processes

Requirements
(Section 5)

Requirements on each process

Tailoring
(Annexes R and S)

Pre-tailoring per criticality A, B, C, D

Tailoring guidelines

Software Documentation (from Annex A to Annex Q)

+ Annex T and U (Rev1)

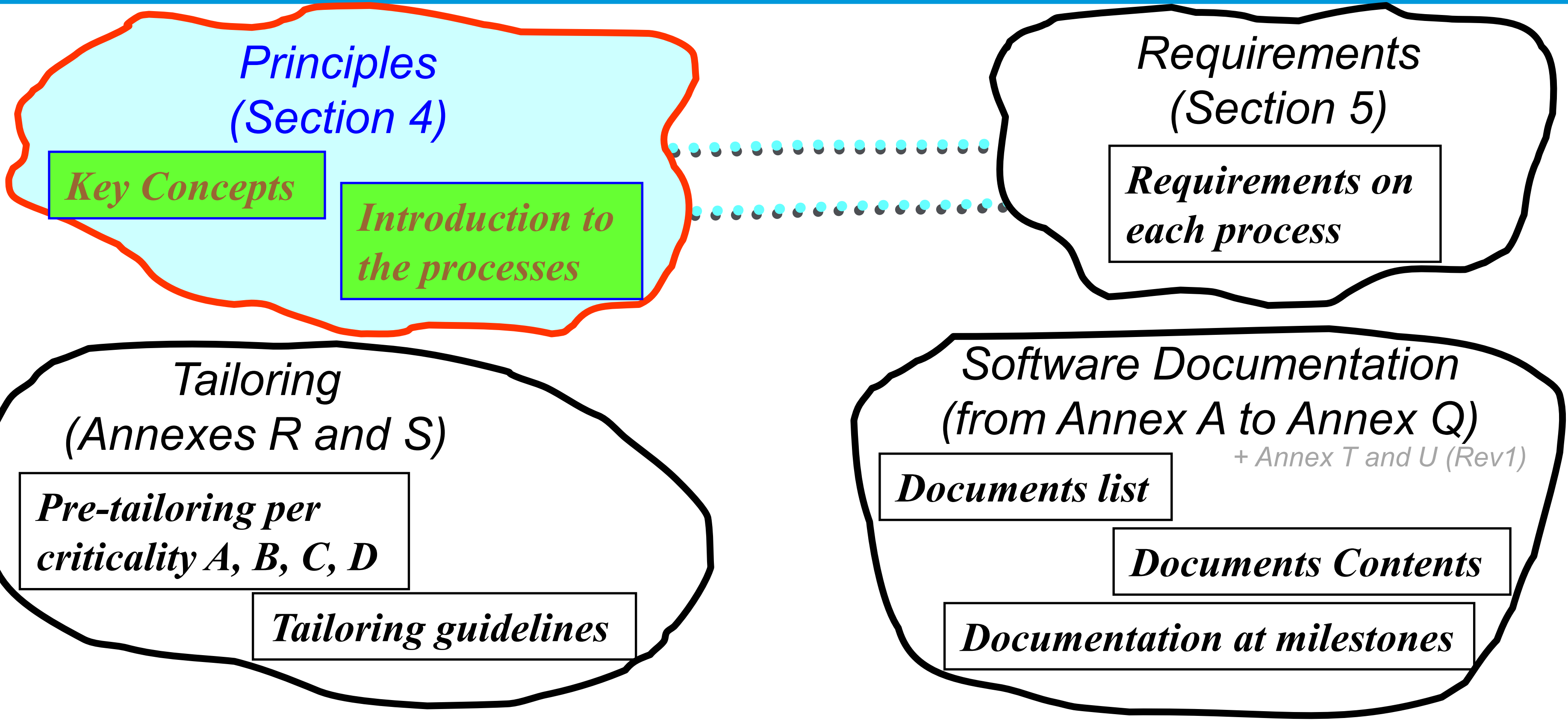
Documents list

Documents Contents

Documentation at milestones

Principles (Section 4)

Space System Processes – Section 4



Principles (Section 4)

Key Concepts

Introduction to the processes

Requirements (Section 5)

Requirements on each process

Tailoring (Annexes R and S)

Pre-tailoring per criticality A, B, C, D

Tailoring guidelines

Software Documentation (from Annex A to Annex Q)

+ Annex T and U (Rev1)

Documents list

Documents Contents

Documentation at milestones

Key Concepts in the E-40 Standard

Software in space systems

1. **Software is different from other engineering disciplines**
   a. Software has no mass, nor produces heat
   b. Software has no other physical property
2. **Software is highly flexible**
   a. Ideal for highly complex functions
   b. Increasingly used in space systems, from system level functions to the basic functions of a specific device
   c. Related effort (requirements, design, test) often underestimated
3. **Software engineering is a *pure* intellectual activity**
   a. Principal output is *documentation* (comprising code)
   b. Focus of the E-40 standard is on requirements for *contents* and *structure* of documentation

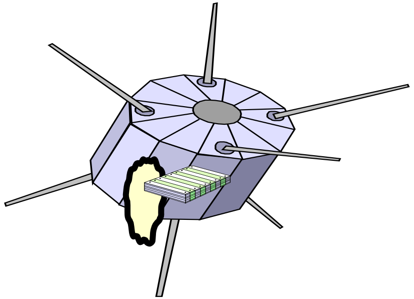
Summary of Key Concepts in E-40

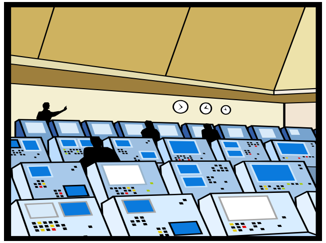
1. **Software is part of the overall System**
   a. Software is not to be treated in isolation
2. **Customer-supplier relationship**
   a. The relationship is made explicit
3. **Reviews as synchronization points**
   a. Reviews are a point of synchronization for the lifecycle processes
4. **Process orientation**
   a. Logical orientation (processes) rather than time-based (phases)

1- Software is Part of the Overall System

Standardization training program
E40 discipline: SW Engineering

1. E-40 makes explicit the fact that Space Projects generally involve many engineering disciplines, of which software is only one
2. This is reflected in the inclusion of requirements on system engineering processes related to software in the Standard

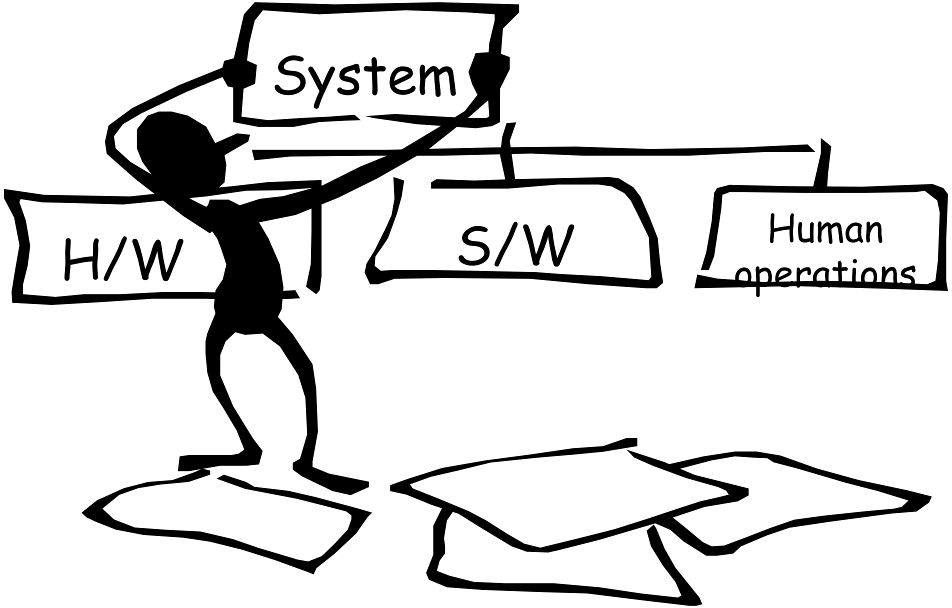




Software components are part of the overall mission system, together with other engineering components

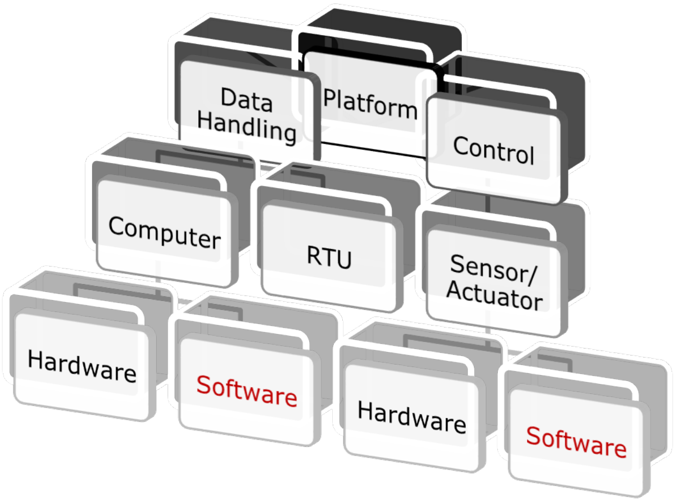
1- Software is Part of the Overall System

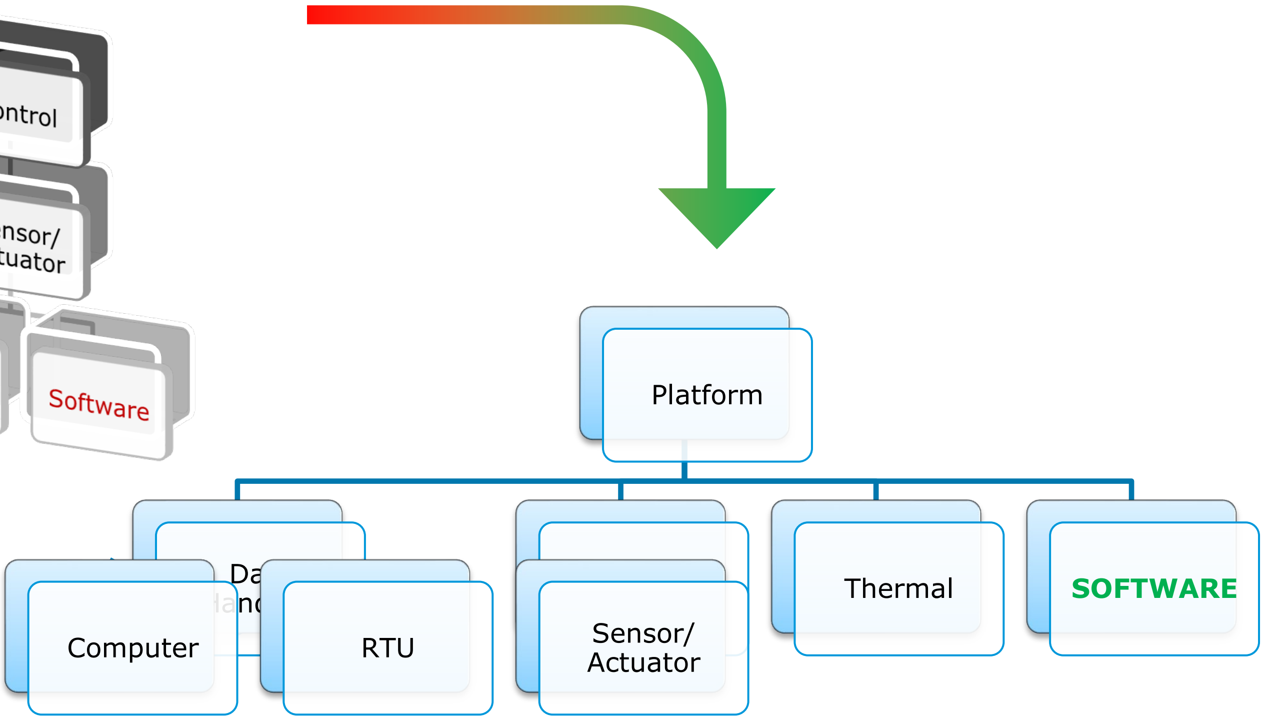
1. As part of the **system design** process, a physical architecture and design at system level is created
2. This physical architecture includes *everything*: hardware, software, and human operations
3. The driving force is the system level requirements
    a. The requirements are allocated to the different subsystems



1- Software in the WBS

Standardization training program
E40 discipline: SW Engineering

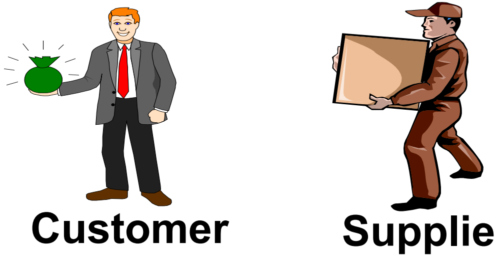




2- The Customer-Supplier Relationship

1. A fundamental principle in the E-40 Standard is the **customer-supplier relationship**
   a. it is assumed for all software development
   b. the organisational aspects are defined in M-10

2. Customer – Supplier
   or
   System - Software

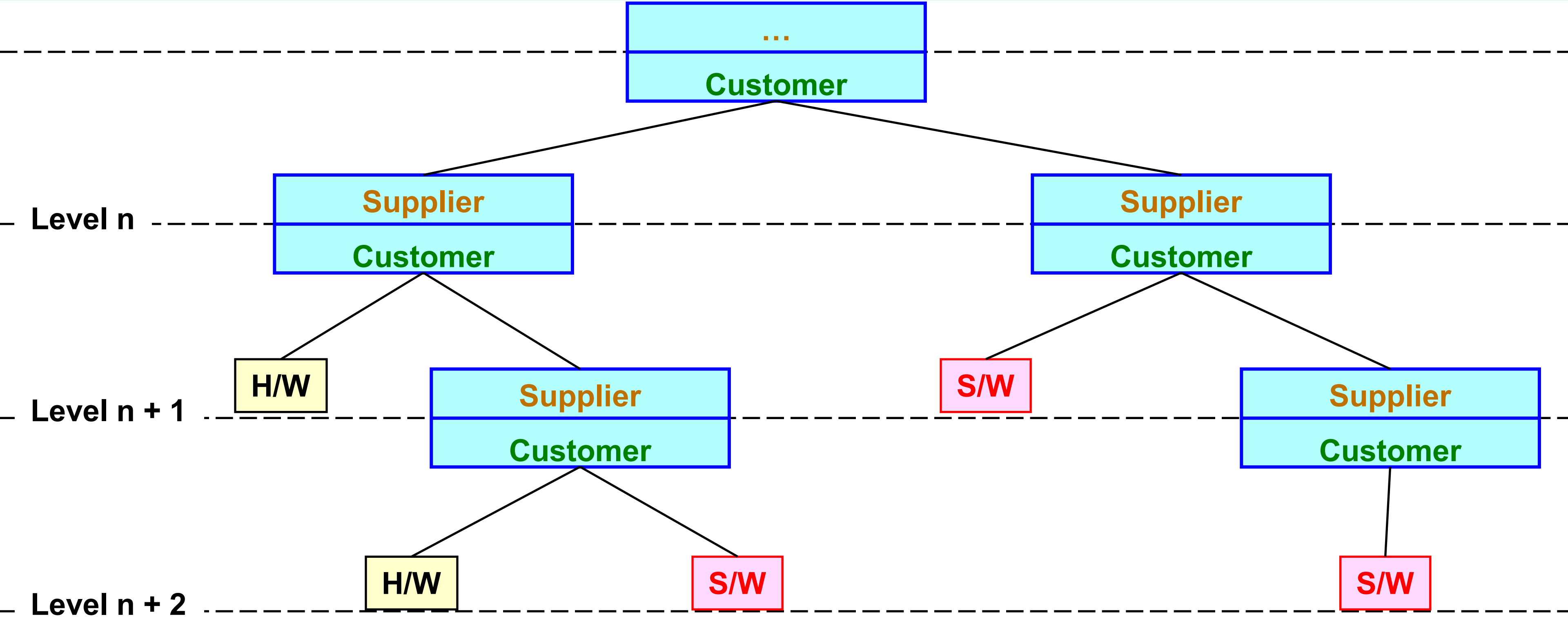


organisational aspects

Project
M-10
Organisation

E-40
4.2.1

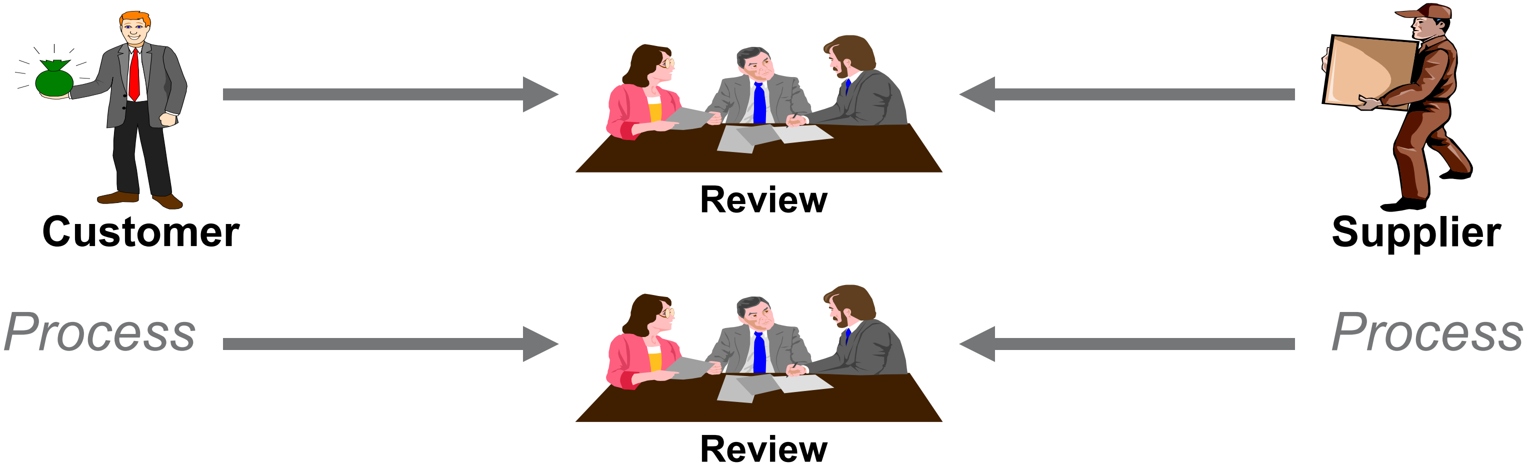
2- The Recursive Customer-Supplier Model



Note: This recursive model applies to all ECSS, see ECSS-E-ST-00C Rev1

3- Reviews are the Main Synchronisation Points

1. The reviews are the main interaction points between the customer and the supplier
    a. All reviews are applicable to software
    b. They are sequenced according to the overall system-level planning
2. The reviews are the main synchronisation points between processes



Customer

Review

Supplier

Process

Review

Process

E-40
4.2.1

4- Origins of E-40 in ISO/IEC 12207

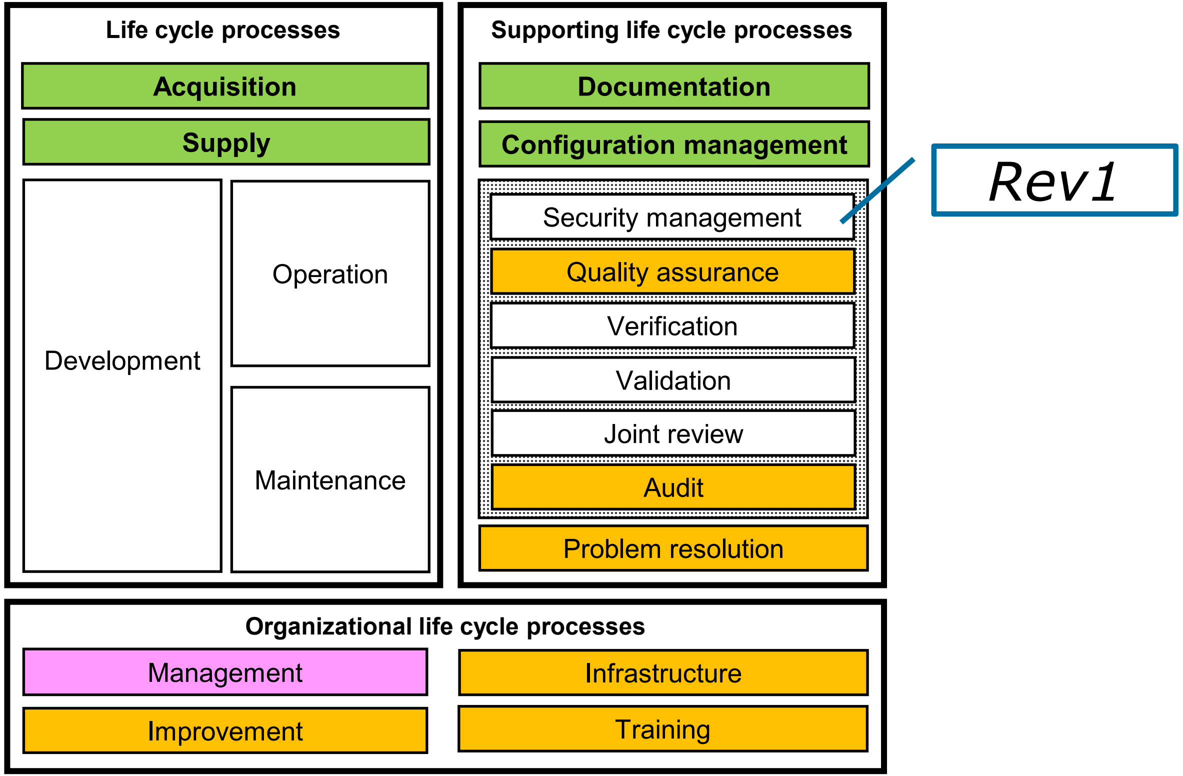
1. The structure and approach of the E-40 standard has its origins in the ISO/IEC standard 12207 (however not updated of the last release)
   a. Title: **Information Technology – Software Life Cycle Processes**
2. The ISO standard has a clear set of goals:
   a. "This International Standard establishes a **common framework for software life cycle processes**, with **well-defined terminology**, that can be referenced by the software industry."
   b. "It contains **processes**, **activities**, and **tasks** that are to be applied during the acquisition of a system that contains software, a stand-alone software product, and software service and during the supply, development, operation, and maintenance of software products."
   c. "This International Standard also provides a process that can be employed for **defining**, **controlling**, and **improving** software life cycle processes."

4- A Process-Oriented Approach

1. The major heritage from the ISO standard is the **process-oriented approach** to the life cycle
   a. More **freedom** this way!
2. Many previous approaches to engineering standards prescribed exactly *when* activities were to be carried out
   a. In contrast, the E-40 approach prescribes only *what* needs to be done, allowing the organisation considerable freedom in deciding when to do it, but respecting the constraints identified by the Reviews
3. For example, different life cycle models can be chosen by the organisation
   a. Waterfall, incremental, evolutionary, etc.
4. However… spacecraft waterfall model influences all subsystems…

Freedom to choose an appropriate lifecycle model is one advantage of the process-oriented approach

4-ECSS covers the ISO/IEC 12207 Standard



Life cycle processes

Acquisition

Supply

Development

Operation

Maintenance

Supporting life cycle processes

Documentation

Configuration management

Security management

Quality assurance

Verification

Validation

Joint review

Audit

Problem resolution

Rev1

Organizational life cycle processes

Management

Infrastructure

Improvement

Training

🟩 Other ECSS

⬜ ECSS-E-ST-40

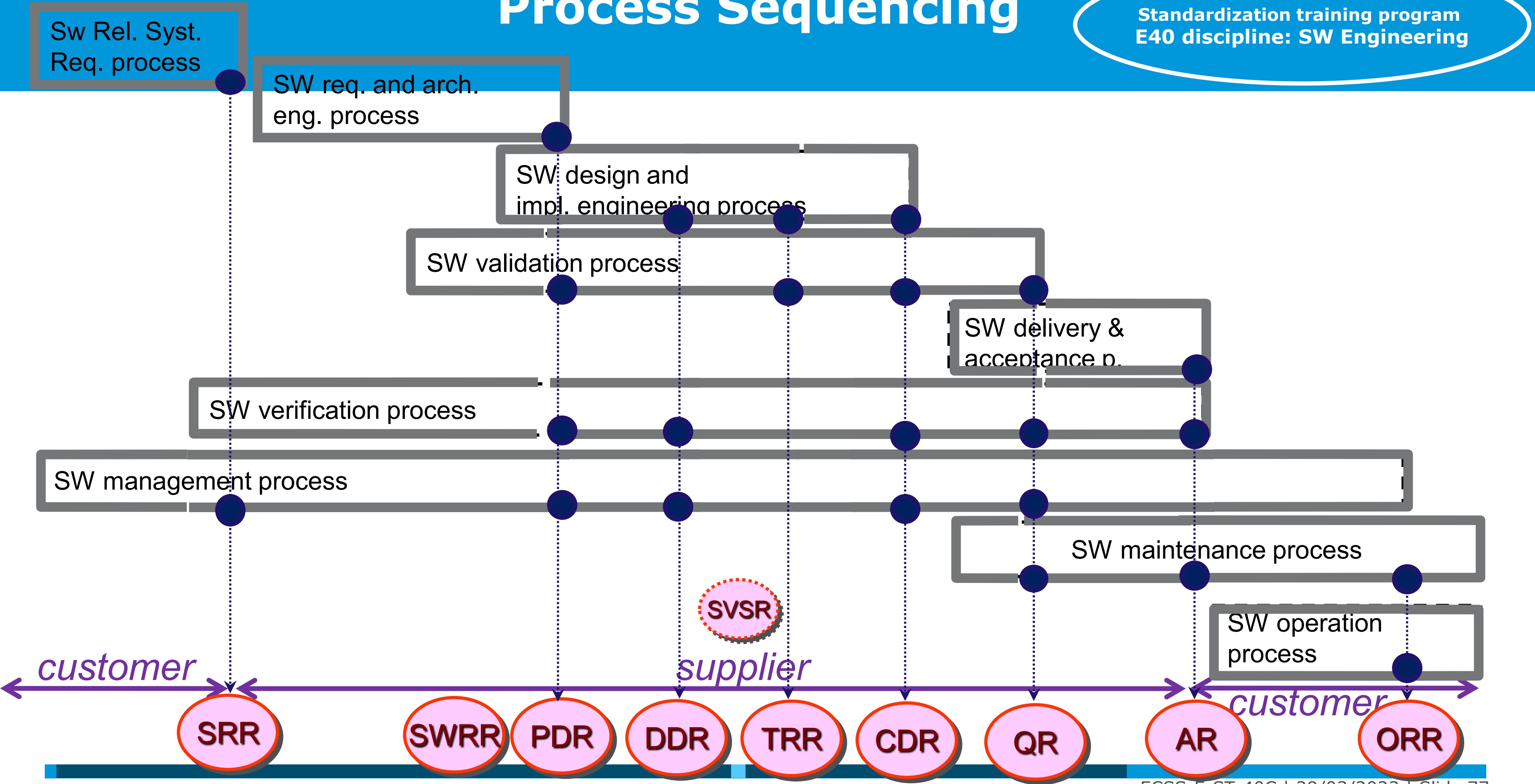
🟧 ECSS-Q-ST-80

🟪 Details for SPA and/or SWE

Introduction to the Processes

Process Sequencing

Standardization training program
E40 discipline: SW Engineering



Memo

Three levels of software validation

	First	Second	
Review	CDR	QR	AR
Against	TS	RB	RB
On (depend on model philosophy)	SVF	SVF/ATB/EM	Final environment (ATB/PFM)

E40 Roles

- Customer
- Supplier
- User: use functions of the software (i.e. reset)
- Software Operation Support Entity (SOS Entity): Help desk, hotline of the software
- Maintainer: correct the issues reported to SOS Entity, improve the software
- Operator: operate the software

Overview of E-40 Processes

5.2 Software related system requirements

- 5.2.2 Sw. rel. Syst. req. analysis
- 5.2.3 Sw. rel. system verification
- 5.2.4 Sw. rel. system integration & ctrl
- 5.2.5 System Requirement Review

5.4 SW req. & arch. engineering process

- 5.4.2 Software requirements analysis
- 5.4.3 Software architectural design
- 5.4.4 Preliminary Design Review

5.5 SW des. & impl. engineering process

- 5.5.2 Design of software items
- 5.5.3 Coding and testing
- 5.5.4 Integration

5.6 Software validation process

- 5.6.2 Validation process implementation
- 5.6.3 Validation w.r.t. the technical spec.
- 5.6.4 Validation w.r.t. the req. baseline

5.7 Software delivery and acceptance process

- 5.7.2 Software delivery and installation
- 5.7.3 Software acceptance

5.8 Software verification process

- 5.8.2 Verification process implementation
- 5.8.2 Verification activities

5.9 Software operations process

- 5.9.2 Process implementation
- 5.9.3 Operational testing
- 5.9.4 Software operation support
- 5.9.5 User support

5.10 Software maintenance process

- 5.10.2 Process implementation
- 5.10.3 Problem & modific. analysis
- 5.10.4 Modification implementation
- 5.10.5 Conducting mainten. reviews
- 5.10.6 Software migration
- 5.10.7 Software retirement

5.11 Software security process

- 5.11.2 Process implementation
- 5.11.3 Software Security analysis
- 5.11.4 Security risk treatment
- 5.11.5 Security activities in Sw lifecycle

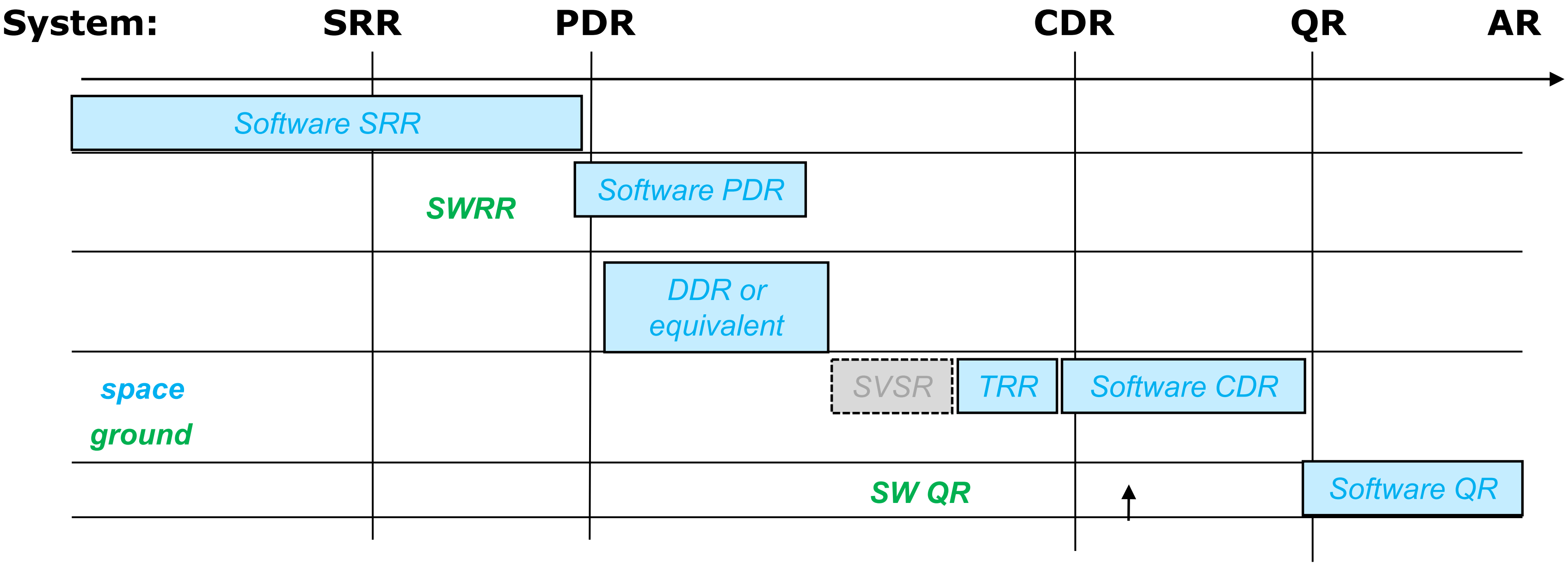
5.3 Software management process

- 5.3.2 Sw life cycle managmt.
- 5.3.3 Joint review process
- 5.3.4 Sw. Proj. Rev. Descr.
- 5.3.5 Sw Tech. Rev. Descr.
- 5.3.6 Review Phasing
- 5.3.7 Interface management
- 5.3.8 Tech. bdg & margin mngt
- 5.3.9 Compliance to Standard

Synchronisation Software – System reviews

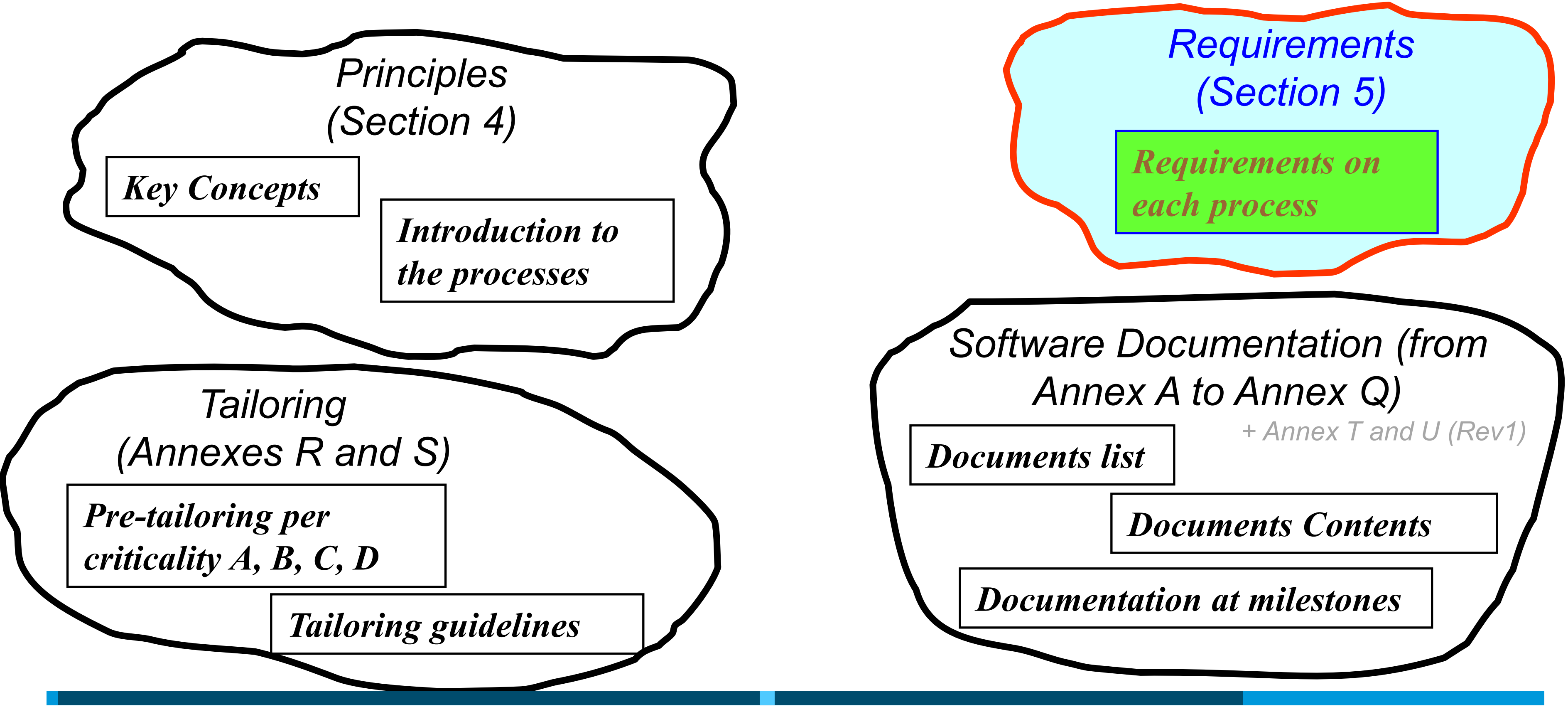
Standardization training program
E40 discipline: SW Engineering

NOTE: this diagram is just there to give a flavour of the review synchronisation; green boxes show when reviews may take place. It is not logically equivalent to the E-40 requirements.



Requirements (Section 5)

Requirements – Section 5



Principles (Section 4)

- *Key Concepts*
- *Introduction to the processes*

Requirements (Section 5)

- *Requirements on each process*

Tailoring (Annexes R and S)

- *Pre-tailoring per criticality A, B, C, D*
- *Tailoring guidelines*

Software Documentation (from Annex A to Annex Q)

+ Annex T and U (Rev1)

- *Documents list*
- *Documents Contents*
- *Documentation at milestones*

How the Requirements are organised in E-40

1. Each requirement in the Requirements Clause 5 can be identified by a **unique hierarchical number**
2. Sometimes additional text is also provided to further explain the aims of the requirement
3. Requirements are associated with one or more **expected outputs**
4. In this course, there is a single, easily identifiable representation for both requirements and expected outputs

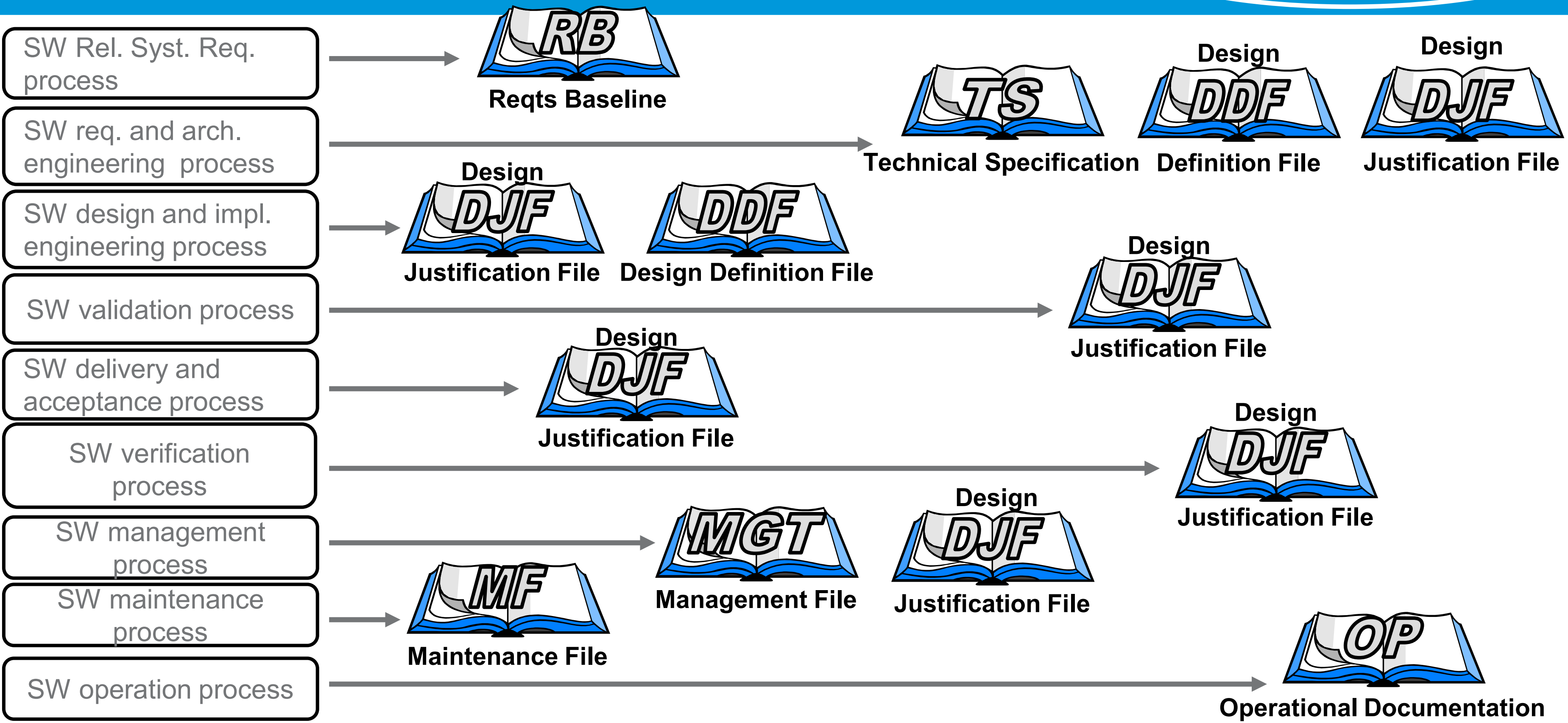
☞ Requirement ☜

Representation of a requirement in this course

🗁 Expected Output 🗁

Representation of an expected output in this course

Processes to Files



SW Rel. Syst. Req. process

Reqts Baseline

SW req. and arch. engineering process

Technical Specification

Design Definition File

Design Justification File

SW design and impl. engineering process

Design Justification File

Design Definition File

SW validation process

Design Justification File

SW delivery and acceptance process

Design Justification File

SW verification process

Design Justification File

SW management process

Management File

Design Justification File

SW maintenance process

Maintenance File

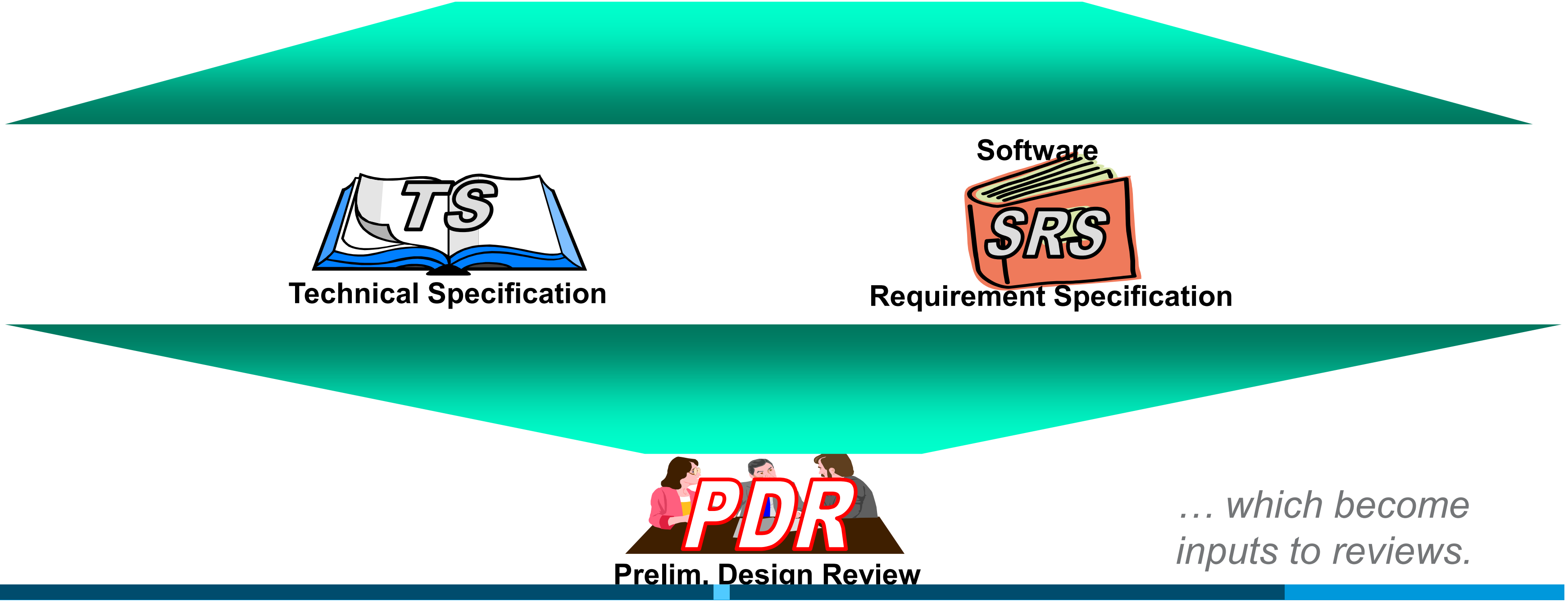
SW operation process

Operational Documentation

From Process to File/DRD to Review

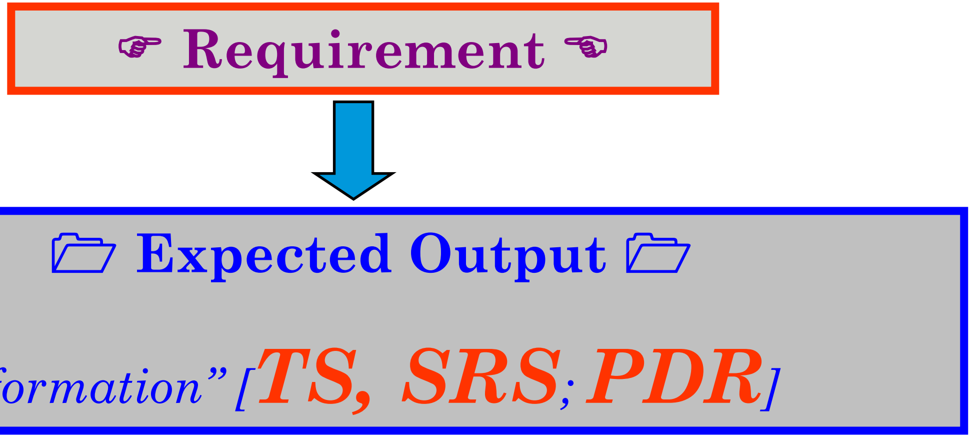
SW Req. & Arch. Engineering (5.4)

The process requirements cause information to be collected into files/DRD …



… which become inputs to reviews.

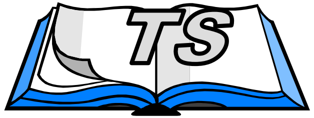
Expected Outputs specify: Files, DRDs and Reviews



☞ Requirement ☜

🗁 Expected Output 🗁

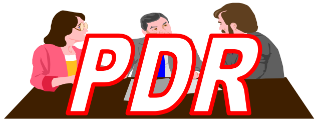
“some information” [TS, SRS; PDR]



Technical Specification

Software

Requirement Specification



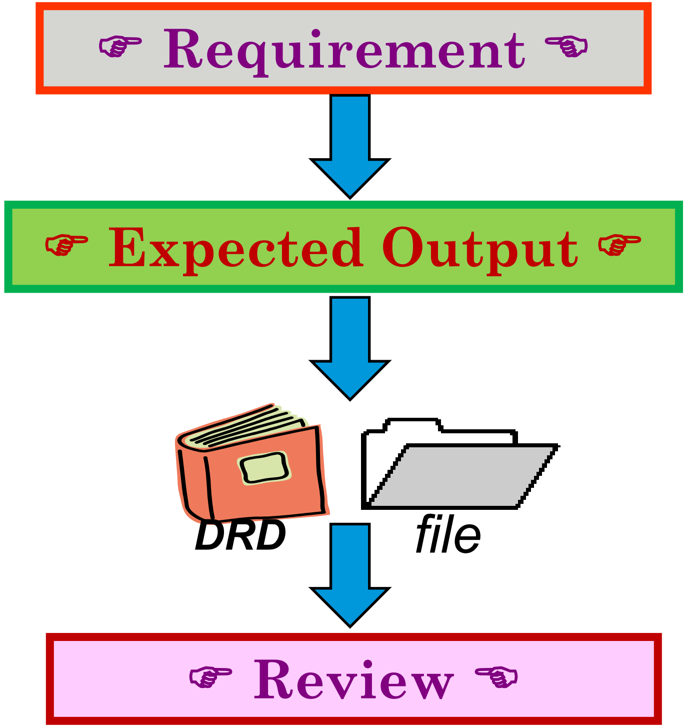
Prelim. Design Review

The associated file(s), DRD(s) and review(s) are indicated in square brackets

Expected Outputs and DRDs

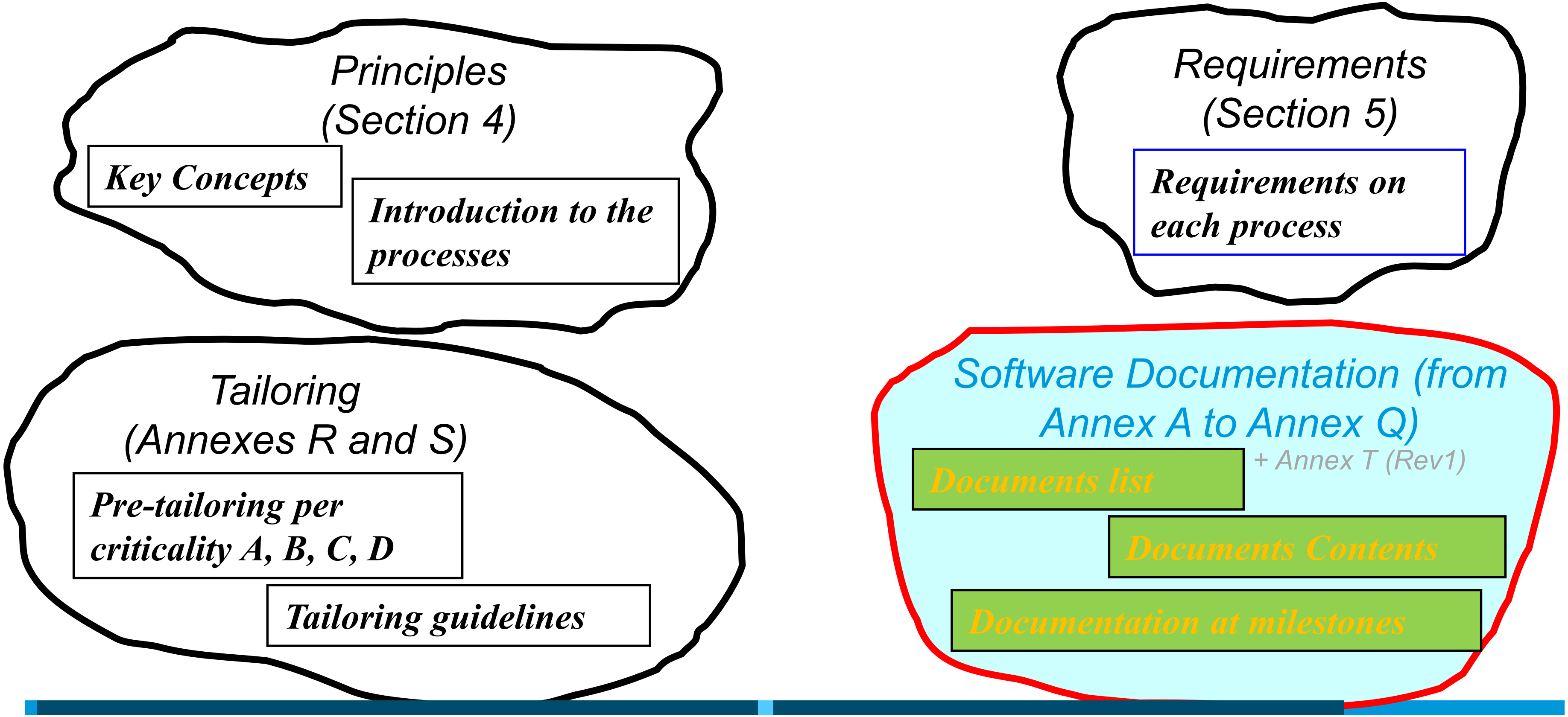
Standardization training program
E40 discipline: SW Engineering

1. The E-40 requirements cause **information** to be placed into **documents** .
2. This information is specified as the **expected output** of the requirement
3. Most documents are specified as **DRD**s [Document Requirement Description]
4. DRDs are made of **sections** and document requirements.
5. The documents are collected into **files** (in the sense of "collection of information") [old ECSS concept]
6. The expected output must be available at a **review**
7. **Annex A** gives the Document Requirement List (DRL), traced to the DRD and to the delivery reviews
8. **Annex Q** gives all the traces for the expected outputs



E-40
Annex Q

Software Documentation – from Annex A to Annex Q



Principles (Section 4)

Key Concepts

Introduction to the processes

Requirements (Section 5)

Requirements on each process

Tailoring (Annexes R and S)

Pre-tailoring per criticality A, B, C, D

Tailoring guidelines

Software Documentation (from Annex A to Annex Q)

+ Annex T (Rev1)

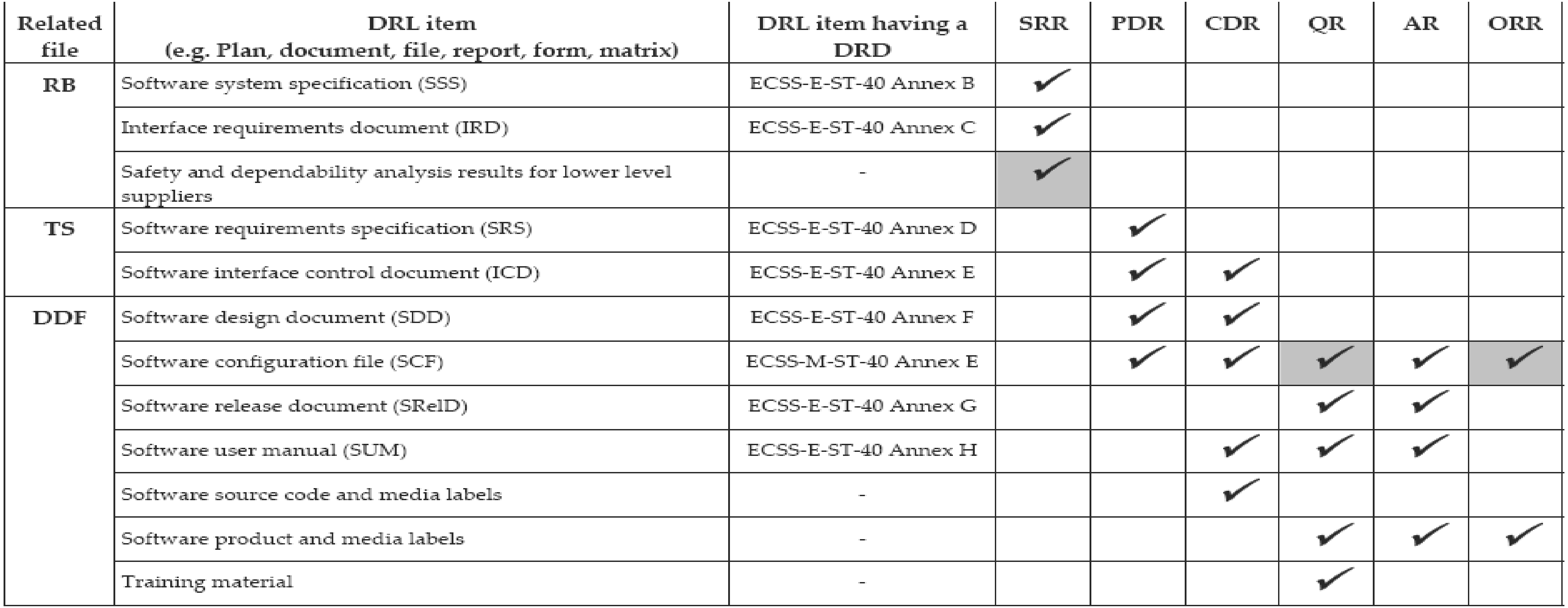
Documents list

Documents Contents

Documentation at milestones

The DRL

Annex A lists all the documents and their milestone



Related file	DRL item (e.g. Plan, document, file, report, form, matrix)	DRL item having a DRD	SRR	PDR	CDR	QR	AR	ORR
RB	Software system specification (SSS)	ECSS-E-ST-40 Annex B	✓					
	Interface requirements document (IRD)	ECSS-E-ST-40 Annex C	✓					
	Safety and dependability analysis results for lower level suppliers	-	✓					
TS	Software requirements specification (SRS)	ECSS-E-ST-40 Annex D		✓				
	Software interface control document (ICD)	ECSS-E-ST-40 Annex E		✓	✓			
DDF	Software design document (SDD)	ECSS-E-ST-40 Annex F		✓	✓			
	Software configuration file (SCF)	ECSS-M-ST-40 Annex E		✓	✓	✓	✓	✓
	Software release document (SRelD)	ECSS-E-ST-40 Annex G				✓	✓	
	Software user manual (SUM)	ECSS-E-ST-40 Annex H			✓	✓	✓	
	Software source code and media labels	-			✓			
	Software product and media labels	-				✓	✓	✓
	Training material	-				✓		

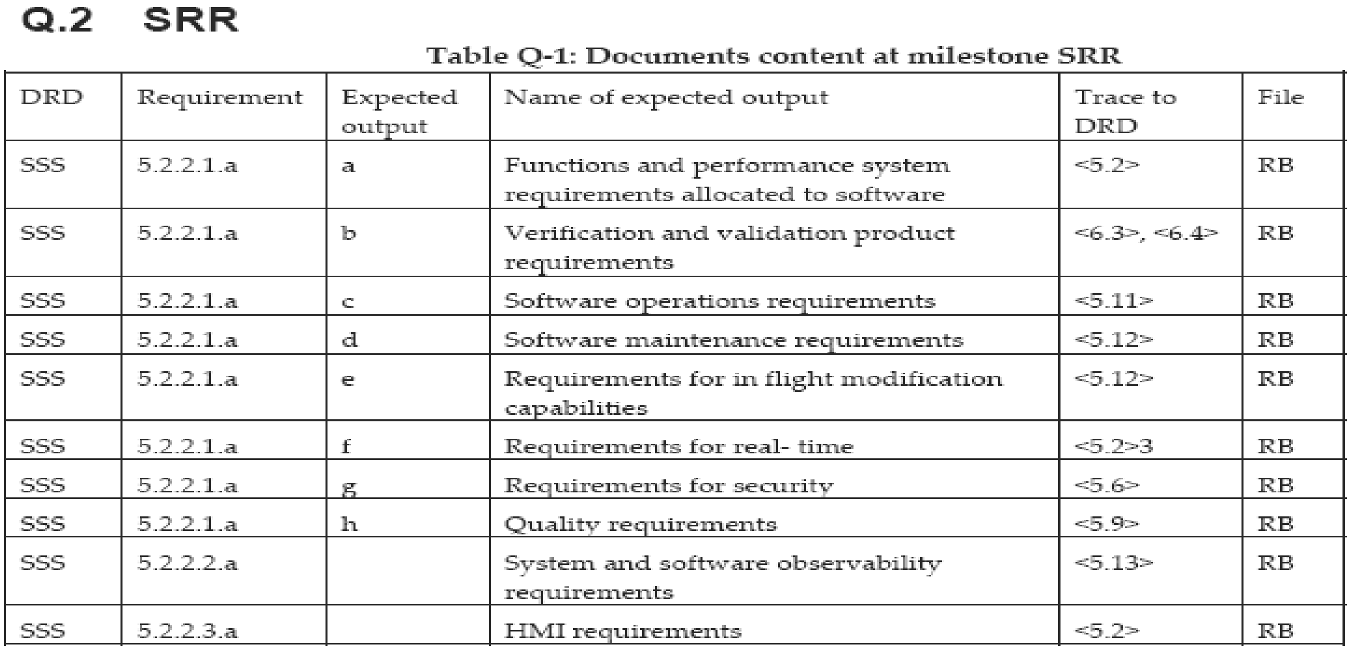
The DRDs

Annex B to P lists all the Document Requirements Definition

Annex B (normative) Software system specification (SSS) - DRD.................................... 84
Annex C (normative) Software interface requirements document (IRD) - DRD 92
Annex D (normative) Software requirements specification (SRS) - DRD 95
Annex E (normative) Interface Control Document (ICD) - DRD 102
Annex F (normative) Software design document (SDD) - DRD 106
Annex G (normative) Software release document (SRelD) - DRD 116
Annex H (normative) Software User Manual (SUM) - DRD.. 119
Annex I (normative) Software verification plan (SVerP) - DRD.. 124
Annex J (normative) Software validation plan (SValP) - DRD.. 129
Annex K (normative) Software [unit/integration] test plan (SUITP) - DRD......................... 134
Annex L (normative) Software validation specification (SVS) - DRD................................ 142
Annex M (normative) Software verification report (SVR) - DRD 149
Annex N (normative) Software reuse file (SRF) - DRD 156
Annex O (normative) Software development plan (SDP) - DRD 160
Annex P (normative) Software review plan (SRevP) - DRD... 166
Annex T (normative) Software maintenance plan (SMP) – DRD .... In ECSS-E-ST-40C Rev1
Annex U (informative) Software code verification .... In ECSS-E-ST-40C Rev1

The expected outputs

Annex Q gives the traces
Review – DRD – Requirement – DRD section - File

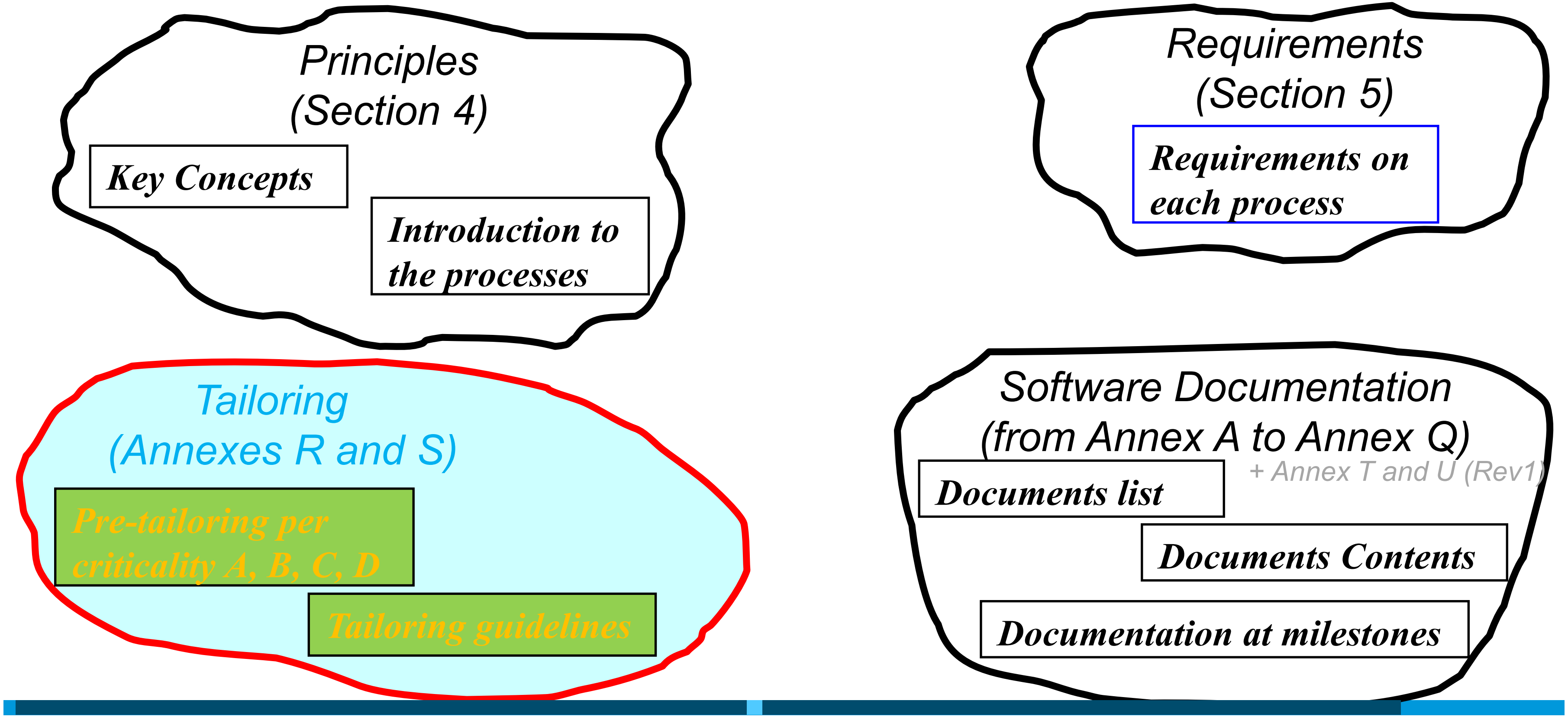


Q.2 SRR

Table Q-1: Documents content at milestone SRR

DRD	Requirement	Expected output	Name of expected output	Trace to DRD	File
SSS	5.2.2.1.a	a	Functions and performance system requirements allocated to software	<5.2>	RB
SSS	5.2.2.1.a	b	Verification and validation product requirements	<6.3>, <6.4>	RB
SSS	5.2.2.1.a	c	Software operations requirements	<5.11>	RB
SSS	5.2.2.1.a	d	Software maintenance requirements	<5.12>	RB
SSS	5.2.2.1.a	e	Requirements for in flight modification capabilities	<5.12>	RB
SSS	5.2.2.1.a	f	Requirements for real- time	<5.2>3	RB
SSS	5.2.2.1.a	g	Requirements for security	<5.6>	RB
SSS	5.2.2.1.a	h	Quality requirements	<5.9>	RB
SSS	5.2.2.2.a		System and software observability requirements	<5.13>	RB
SSS	5.2.2.3.a		HMI requirements	<5.2>	RB

Tailoring - Annexes R and S



Principles
(Section 4)

Key Concepts

Introduction to the processes

Requirements
(Section 5)

Requirements on each process

Tailoring
(Annexes R and S)

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Software Documentation
(from Annex A to Annex Q)

+ Annex T and U (Rev1)

Documents list

Documents Contents

Documentation at milestones

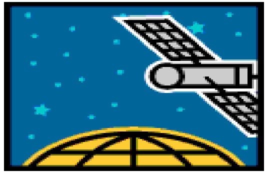
Tailoring

1. The ECSS family of standards has been designed to **minimize** the need for **tailoring** for each project.
    a. This is a fundamental underlying concept throughout the system
2. The ECSS-E-40 standard lists **exhaustively** the requirements for the **best practices** in space software engineering
    a. that is, it covers *all possible types* of space software engineering projects
3. But it is pre-tailored **according to the criticality levels** as defined in the ECSS-Q-ST-80 (see Annex R: normative).
    a. A way to apply the standard in the most efficient manner possible
4. Further tailoring guidelines are provided based on programmatic and technical factors (**Annex S: informative**).
5. Customer makes the tailoring, or delegate to Supplier (risk!)

E-40
Annex R, S

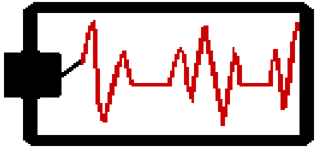
Some Requirements Concern Specific Types of SW

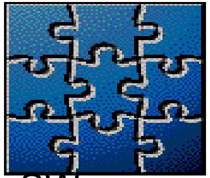
1. Clause 5 of E-40 is entitled simply **“Requirements”** because, as a rule, the requirements may be considered to be applicable to *any* space software
2. In practice, however, some requirements in Clause 5 depend on the **nature** of the software
3. Other requirements depends on a **particular** project **context** (e.g. if software needs to be migrated)
4. This is always **explicitly mentioned in the requirements**
5. Their list is summarized in **Annex S**


Flight software

HMI software

Annex S.2 indicates all the conditional requirements


Real-time SW


SW reuse

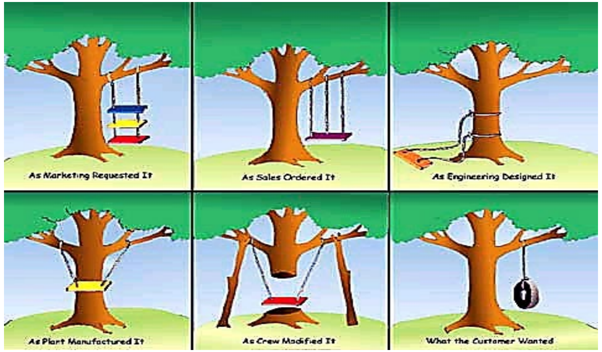
What are the E-40 Platinum Requirements?

They are all Platinum requirements

a. An army of reviewers has contributed to produce this third version of the E-40

b. There is a good reason why each of them is there!

Tailoring is further discussed in E-40 Handbook (4.2.5)



1. Non tailorable topics:
   a. specifying **requirements**
   b. **validating** software
   c. agreeing on a **development approach**
   d. managing the **configuration**

2. Tailoring build-in the Standard
   a. Per criticality A, B, C, D
   b. According to contract scope & context (Annex S.2 – S.3)

Further Tailoring is a RISK!

a. merging the requirement baseline and the technical specification increases the risk to loose the customer or supplier standpoint, i.e. to miss a use case or to miss an implementation requirement.

b. skipping joint reviews increases the risk to discover late disagreements between customer and supplier on the product capability or quality, causing substantial reengineering

c. non managing technical budgets and margins increases the risk to discover unfeasibility late in the project

d. not using design methods increases the risk to develop weak architectures and inconsistent designs

e. not defining interface increases the risk of integration issues

f. not documenting the detailed design increases the risk to loose control on the software development such as capability to anticipate implementation errors, to debug, to integrate, to maintain, to master safety and dependability, etc.

g. skipping unit tests increases the risk to discover bugs late in the process and to jeopardize the schedule.

h. not rerunning the full validation tests on the last version of the software increases the risk to leave bugs in the product

i. not performing full verification activities increases the risk to affect the quality of the product

j. non complying with DRDs content increases the risk of having non complete documentation, and of missing information for maintenance

k. non compliance with the DRDs structure increases the effort of the reviewers and can lead to identifying discrepancies because the information has not been found

➔ Risk Management = Project decision

Summary of Part 2

Summary of Part 2

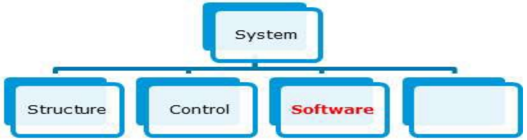
1. Software is a subsystem in the overall system
2. Explicit & recursive customer-supplier (or system-software) relationship
3. Process model with reviews
4. Requirements -> Expected outputs → files → documents -> reviews
   a. Annex A of E-40 lists the required information of each file at specific reviews
   b. For some documents, DRD is provided specifying their contents (most of them in E-40, but also in M-40 and Q-80)

5. Tailoring is a fundamental aspect of using the ECSS standards in an efficient way
   a. Help the Customer to prepare the project Invitation to Tender
   b. Help the Supplier to bid and execute the project
6. Annexes R and S are the primary source of information on the proper approach to tailoring the E-40 requirements:
   a. Characterize the project
   b. Evaluate each requirement

Conclusion of the E-40 training

E-40 Training Conclusion

1. Software is a subsystem in its own rights



1. Its activities start in Phase B
    a. E-40 Clause 5.2, Software related system requirement process

~~Software is a phase~~

BULLSHIT

C/D issue

2. **Requirements (in particular system/customer requirements) are important**

3. Understand the standard to better tailor it.

4. E-40 is applied together with Q-80

ECSS-E-ST-40C Rev1

- 68 Change Requests have been processed.
- Main updates:
  - Revisit of definitions, including new definition of “software”
  - Introduction of security aspects
  - Make the standard less waterfall
  - Reinforce the verification of code
  - Ensure consistency with ECSS-E-ST-20-40C standard to be published
  - Consider the outcomes of ISVV guidelines update
  - Introduce the Software Delivery Review Board and Software validation specification review
  - Introduce the Software Validation Control

Questions

ECSS-E-ST-40C
6 March 2009

EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

Space engineering

Software

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

Rev1 planned in Q2 2023

Credits:

- Jean-Loup Terraillon

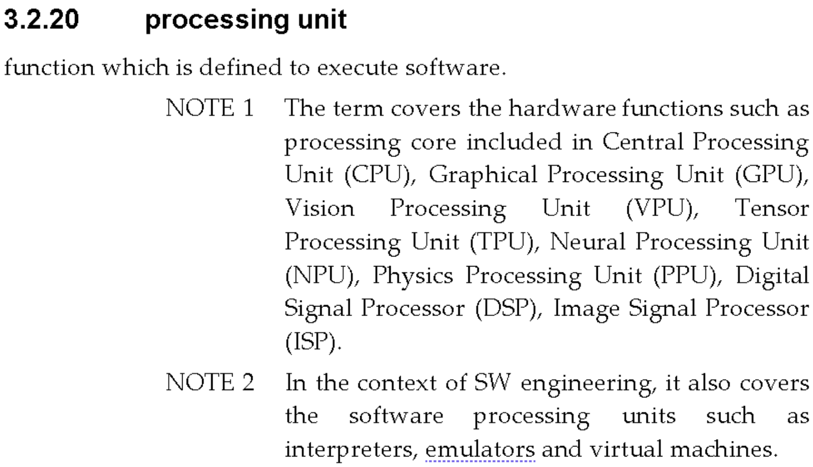
- Christophe.Honvault@esa.int

- http://www.intecs.it/

More on Rev1
(if time allows)

Definitions

1. Definitions agreed with ECSS-E-ST-20-40C (ASIC, FPGA and IP Core engineering standard)

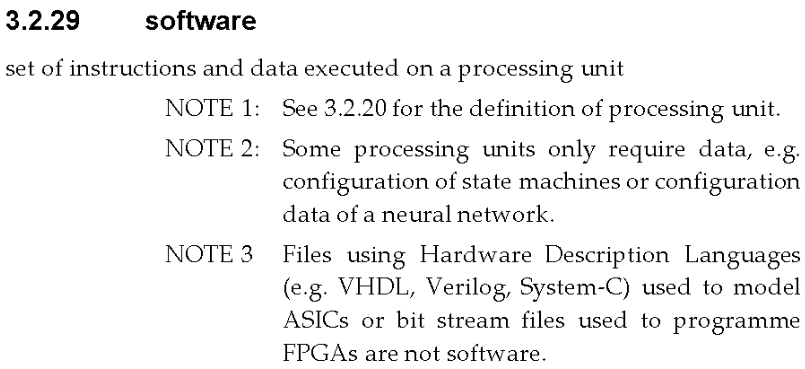


3.2.20 processing unit

function which is defined to execute software.

NOTE 1 The term covers the hardware functions such as processing core included in Central Processing Unit (CPU), Graphical Processing Unit (GPU), Vision Processing Unit (VPU), Tensor Processing Unit (TPU), Neural Processing Unit (NPU), Physics Processing Unit (PPU), Digital Signal Processor (DSP), Image Signal Processor (ISP).

NOTE 2 In the context of SW engineering, it also covers the software processing units such as interpreters, emulators and virtual machines.



3.2.29 software

set of instructions and data executed on a processing unit

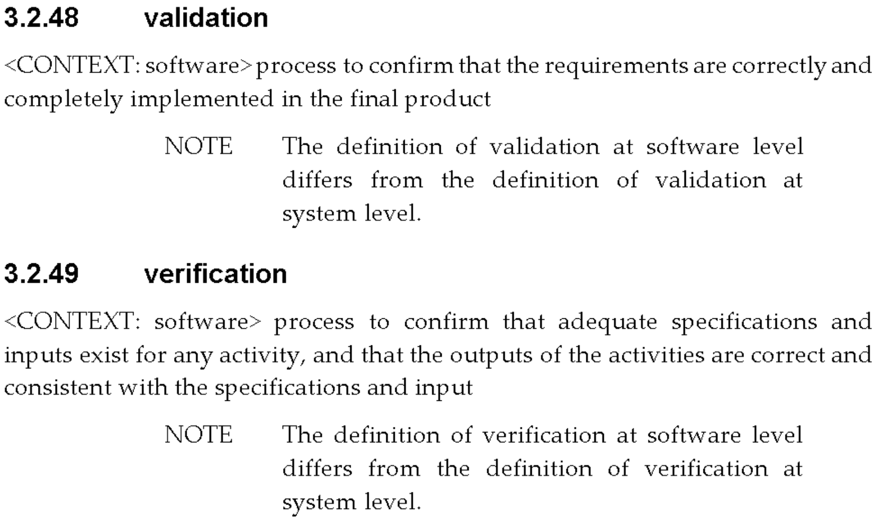
NOTE 1: See 3.2.20 for the definition of processing unit.

NOTE 2: Some processing units only require data, e.g. configuration of state machines or configuration data of a neural network.

NOTE 3 Files using Hardware Description Languages (e.g. VHDL, Verilog, System-C) used to model ASICs or bit stream files used to programme FPGAs are not software.

Definitions

2. Use of the <CONTEXT:software> for verification and validation to emphasis the difference with ECSS Glossary (ECSS-S-ST-00-01C – 1 October 2012)



3.2.48 validation

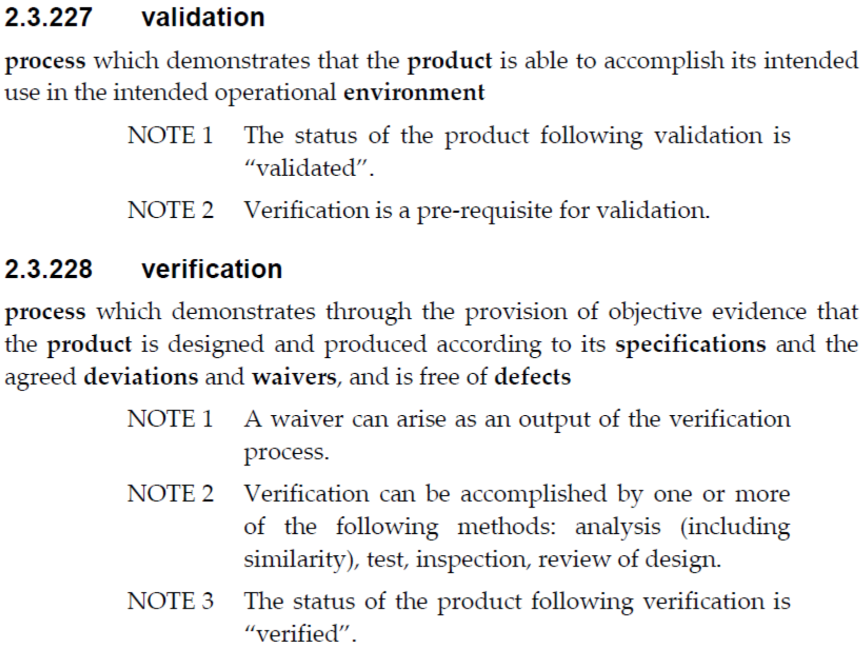
<CONTEXT: software> process to confirm that the requirements are correctly and completely implemented in the final product

NOTE The definition of validation at software level differs from the definition of validation at system level.

3.2.49 verification

<CONTEXT: software> process to confirm that adequate specifications and inputs exist for any activity, and that the outputs of the activities are correct and consistent with the specifications and input

NOTE The definition of verification at software level differs from the definition of verification at system level.



2.3.227 validation

process which demonstrates that the **product** is able to accomplish its intended use in the intended operational **environment**

NOTE 1 The status of the product following validation is "validated".

NOTE 2 Verification is a pre-requisite for validation.

2.3.228 verification

process which demonstrates through the provision of objective evidence that the **product** is designed and produced according to its **specifications** and the agreed **deviations** and **waivers**, and is free of **defects**

NOTE 1 A waiver can arise as an output of the verification process.

NOTE 2 Verification can be accomplished by one or more of the following methods: analysis (including similarity), test, inspection, review of design.

NOTE 3 The status of the product following verification is "verified".

Security

3. Many requirements and a new section (5.11) have been added to support the introduction of security aspects in the development process.
   - Only address the security process at Software engineering level
   - A new standard to address security aspects at System level is under preparation.
   - One new Security File with three items:
     - Software security management plan (SSMP)
     - Software security analysis report (SSAR)
     - Security risk treatment plan (SRTP)

Make the standard less waterfall

4. The standard shall be independent from any software life-cycle.
   - As per 5.3.2.1a, "The software supplier shall define and follow a software life cycle …"
   - The standard was still containing many references to the waterfall life-cycle: 16 updates have been implemented
   - Examples:
     - Although the spacecraft reviews suggest a waterfall model, the software development plan can implement any life cycle, as iterative model, spiral model, and Agile model …
     - Several iterations of software engineering processes can occur depending on the selected software life cycle.

Reinforce the verification of code

Standardization training program
E40 discipline: SW Engineering

5. Verification of code is of prime importance to minimize the errors during operations.
    - Clause 5.8.3.5 on Verification of code has been consolidated (simplified)
    - Annex U “Software code verification” has been added. It is informative but it is highly recommended to perform the identified verifications.
        - The proposed verifications are supported by tools (free and commercial)
        - It would be completed by guidelines provided in the next revision of the handbook

Consistency with ECSS-E-ST-20-40C

6. ECSS-E-ST-20-40C is the new standard on “ASIC, FPGA and IP Core engineering”
    - It defines the engineering process related to the development of …
    - A Hardware/Software co-engineering approach is of prime importance to develop on new systems including multi-core processing units and reprogrammable FPGAs (including SoCs)
    - Consistency is done at the level of the definitions and at the level of the process.
    - Hardware/Software co-engineering is a system activity that is flow down to software through SSS and IRD. Supplier has to define its development plan considering the constraints related to the development of the hardware.

New items

7. New reviews
    - Software Delivery Review Board: is usually performed in all projects, the standard formalize this review.
    - Software validation specification review: is not a new review but an anticipation to the TRR.
8. New (virtual) document
    - ECSS-E-ST-40C did not ask for a Verification Control Document (VCD) for Software
    - Revision introduces a Software VCD that is a list of standard outputs to be made available to the Customer. The outputs are not formalised in a document and can be provided in electronic format or access to the software development framework.