Product and Quality Assurance ECSS-Q-ST-10 and Q-ST-20

Heli Greus

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The presenter

Heli Greus, Senior Product Assurance Engineer, ESA ESTEC

- Nearly 20 years of experience in space domain
- First at industry in Finland as PA engineer and RF designer
- Joint ESA ESTEC in 2007 as PA and Safety Engineer
- Current position: Senior PA and Safety Engineer
    - Experience on Telecom, Earth Observation and Science satellites

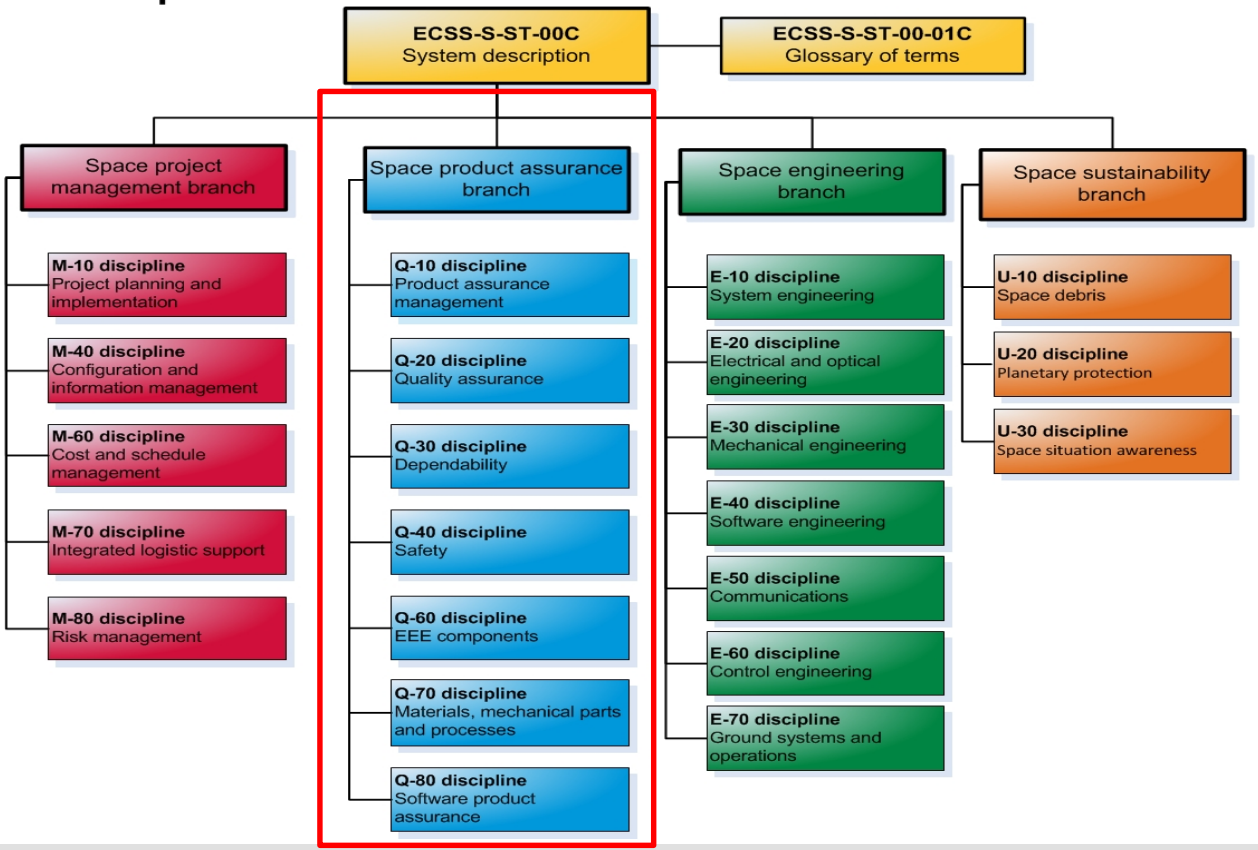
ECSS training session 3

Week		Days	Time	Speakers	Discipline
14-16 October 2019	1	14 October pm - Monday	13:30 - 17:00	Heli Greus	Q-10 Q-20 PA/QA
	2	15 October am - Tuesday	9:00 - 12:30	Fabio Restagno	Q-40 Safety
	3	15 October pm - Tuesday	13:30 - 17:00	Ralf de Marino	Q-60 EEE Components
	4	16 October am - Wed	9:00 - 12:30	Ton de Rooj + Graham Adrian	Q-70 Material, Mechanical parts and processes
	5	16 October pm - Wed	13:30 -17:00	Ton de Rooj + Graham Adrian	Q-70 Material, Mechanical parts and processes

ECSS website: **www.ecss.nl**

ECSS branches/disciplines

ECSS Disciplines



Outline of the presentation

Part 1 - Quality management system vs Product/Quality Assurance

Quality management system vs Product/Quality Assurance

Scope of Product Assurance

Part 2- Product Assurance Management requirements (ECSS-Q-ST-10)

PA/QA Plan

Critical Item Control

Nonconformance Control

Part 3 – Q-20 Quality Assurance (ECSS-Q-ST-20C)

Quality Assurance

Quality and safety assurance of space test centers

Storage, handling and transportation of spacecraft hardware

Off-The-Shelf items

Part 3 Implementation in project phases

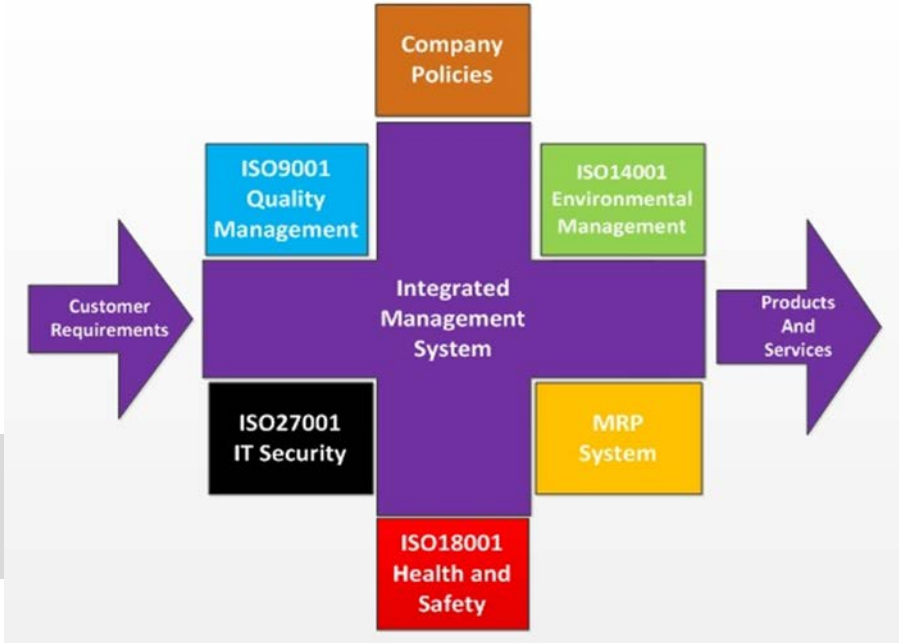
PA activities from project planning to launch

Scope of QA vs Quality Management

ISO 9000:2015 Quality management systems — Fundamentals and vocabulary

- ***Management*** *- coordinated activities to direct and control an organization*
- ***Quality management -*** *management with regard to quality*

Quality management is one of the systems to manage the organization



Quality Management is broader than Product / Quality Assurance and encompasses the entire organization

What is Quality Assurance?

ISO 9000:2015 Quality management systems — Fundamentals and vocabulary

Quality *- degree to which a set of inherent characteristics of an object fulfils requirements*

Quality assurance (QA) *- part of quality management focused on* ***providing confidence*** *that quality requirements will be fulfilled*

Quality control (QC) *- part of quality management focused on fulfilling quality requirements*

QA is about providing confidence that quality is achieved

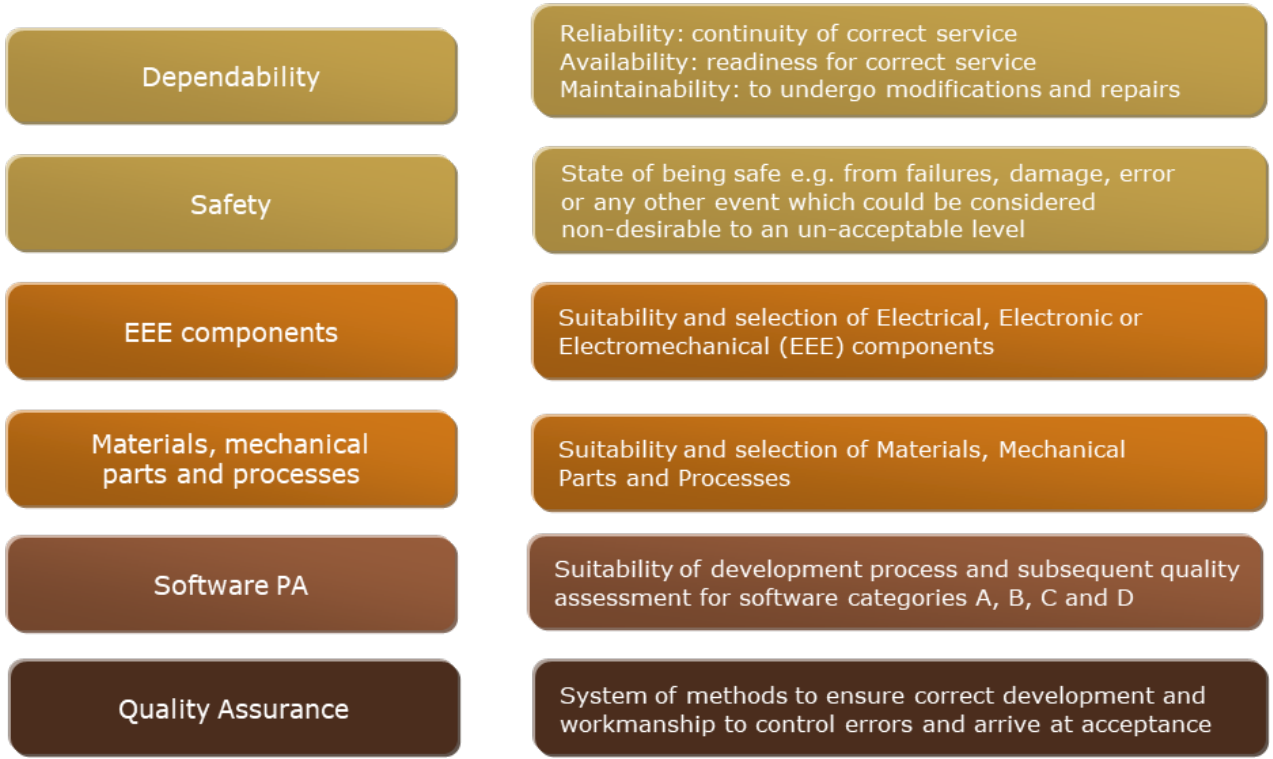
Scope of QA vs Product Assurance (1/2)

ECSS Glossary - ECSS-S-ST-00-01C

1. ***Product Assurance (PA)*** *- Discipline devoted to the study, planning and implementation of activities intended to assure that the design, controls, methods and techniques in a* ***project*** *result in a satisfactory degree of quality in a* ***product.***
2. In practice, PA pursues a **safe & successful mission, looking at all components of the system** (Hardware, Software, Human) **and their interfaces**
3. For this reason, in NASA and JAXA is named as **Safety and Mission Assurance**

Scope of QA vs Product Assurance (2/2)

QA is a discipline of Product Assurance



Who Are Product Assurance Engineers?

Cost of quality (1/2)

Internal failure costs: those incurred to remove defects from the products before shipping them to customers. Examples:

- Cost of scrap
- Rework labor and overhead
- Re-inspection of reworked products
- Disposal of defective products
- Down time caused by quality problems

External failure costs: those derived from shipping defective products to customers. Examples:

- Warranties
- Replacements
- Liabilities arising from the use of defective products
- Lost sales

Cost of quality (2/2)

Prevention costs: the costs incurred to avoid or minimize the number of defects at first place.

Examples:

- Improvement of processes
- Training
- Statistical process control
- Quality data reporting and analysis

Appraisal costs (also named **inspection costs**): those incurred to identify defective products before they are shipped to customers.

Examples:

- Control of incoming materials
- Final product testing and inspection
- Supervision of testing and inspecting activities
- Inspection and test equipment

You recognize the lack of quality at once…..

The Cost of Quality after launch

Product Assurance adds costs but this is weighed against risks:

- Loss of life, astronauts and general population
- Programmatic losses since replacement time can be long and costly
- Loss of national capabilities and prestige
- Environmental impacts
- Sustainability (space debris)

SCOPE OF PRODUCT ASSURANCE

Scope of PA for different types of projects (1/2)

Manned Space Projects

- Driven by safety: For instance hazardous materials elimination, avoid accumulation of energy
- Independent safety review
- Human factors to be considered

Unmanned Space Projects

- Driven by reliability: maintainability is limited, and most of times are public or commercial services

Scope of PA for different types of projects (2/2)

Ground based Projects

- Lower reliability requirements – availability achieved by maintenance
- Significant use of off-the-shelf components

Technology development Projects

- The PA involvement is tailored to the nature of the final product
- TRL: Technology Readiness Level is the key metric

Technology Readiness Level (1/3)

Technology Readiness Level	Milestone achieved for the element	Work achievement (documented)
TRL 1: Basic principles observed and reported	Potential applications are identified following basic observations but element concept not yet formulated.	• Expression of the basic principles intended for use. • Identification of potential applications.
TRL 2: Technology concept and/or application formulated	Formulation of potential applications and preliminary element concept. No proof of concept yet.	• Formulation of potential applications. • Preliminary conceptual design of the element, providing understanding of how the basic principles would be used.
TRL 3: Analytical and experimental critical function and/or characteristic proof-of-concept	Element concept is elaborated and expected performance is demonstrated through analytical models supported by experimental data and characteristics.	• Preliminary performance requirements (can target several missions) including definition of functional performance requirements. • Conceptual design of the element. • Experimental data inputs, laboratory-based experiment definition and results. • Element analytical models for the proof-of-concept.
TRL 4: Component and/or breadboard functional verification in laboratory environment	Element functional performance is demonstrated by breadboard testing in laboratory environment.	• Preliminary performance requirements (can target several missions) with definition of functional performance requirements. • Conceptual design of the element. • Functional performance test plan. • Breadboard definition for the functional performance verification. • Breadboard test reports.

Technology Readiness Level (2/3)

Technology Readiness Level	Milestone achieved for the element	Work achievement (documented)
TRL 5: Component and/or breadboard critical function verification in a relevant environment	Critical functions of the element are identified and the associated relevant environment is defined. Breadboards not full-scale are built for verifying the performance through testing in the relevant environment, subject to scaling effects.	• Preliminary definition of performance requirements and of the relevant environment. • Identification and analysis of the element critical functions. • Preliminary design of the element, supported by appropriate models for the critical functions verification. • Critical function test plan. Analysis of scaling effects. • Breadboard definition for the critical function verification. • Breadboard test reports.
TRL 6: Model demonstrating the critical functions of the element in a relevant environment	Critical functions of the element are verified, performance is demonstrated in the relevant environment and representative model(s) in form, fit and function.	• Definition of performance requirements and of the relevant environment. • Identification and analysis of the element critical functions. • Design of the element, supported by appropriate models for the critical functions verification. • Critical function test plan. • Model definition for the critical function verifications. • Model test reports.
TRL 7: Model demonstrating the element performance for the operational environment	Performance is demonstrated for the operational environment, on the ground or if necessary in space. A representative model, fully reflecting all aspects of the flight model design, is build and tested with adequate margins for demonstrating the performance in the operational environment.	• Definition of performance requirements, including definition of the operational environment. • Model definition and realisation. • Model test plan. • Model test results.

Technology Readiness Level (3/3)

Technology Readiness Level	Milestone achieved for the element	Work achievement (documented)
TRL 8: Actual system completed and accepted for flight ("flight qualified")	Flight model is qualified and integrated in the final system ready for flight.	• Flight model is built and integrated into the final system. • Flight acceptance of the final system.
TRL 9: Actual system "flight proven" through successful mission operations	Technology is mature. The element is successfully in service for the assigned mission in the actual operational environment.	• Commissioning in early operation phase. • In-orbit operation report.
NOTE: The present Table, taken from ISO 16290, is reproduced with the permission of the International Organization for Standardization, ISO. This standard can be obtained from any ISO member and from the Web site of the ISO Central Secretariat at the following address: www.iso.org. Copyright remains with ISO. The standard can be obtained from ISO or its members, see www.iso.org		

Further information on TRL: ECSS-E-AS-11C & ECSS-E-HB-11A

ECSS-Q-ST-10

Product Assurance Management

ECSS-Q-ST-10

Product assurance management

ECSS-Q-ST-10C Rev.1	Product assurance management
ECSS-Q-ST-10-04C	Critical-item control
ECSS-Q-ST-10-09C Rev.1	Nonconformance control system

ECSS-Q-ST-10C pre-tailoring matrix in chapter 6

Table 6-1: Pre-Tailoring matrix for ECSS-Q-ST-10C Rev.1

ECSS req. number	Space product types									
	Space system	Space segment element and sub-system	Space segment equipment	Launch segment element and sub-system	Launch segment equipment	Ground segment element and sub-system	Ground segment equipment	Ground support equipment	Software	Comments
5.1.1.1a	A	A	A	A	A	A	A	NA	NA	For Software, covered by clause 5.1.4 of ECSS-Q-ST-80
5.1.1.1b	A	A	A	A	A	A	A	NA	NA	For Software, covered by clause 5.1.4 of ECSS-Q-ST-80
5.1.1.1c	A	A	A	A	A	A	A	NA	NA	For Software, covered by clause 5.1.4 of ECSS-Q-ST-80
5.1.1.1d	A	A	A	A	A	A	A	NA	A	

ECSS-Q-ST-10C Rev1

Product Assurance Management

Product/Quality Assurance plans contents (1/3)

PA PLAN (ECSS-Q-ST-10 Annex A):

- PA organization, responsibilities and authority, resources, PA interfaces & processes
- PA implementation procedures, including:
  - PA & risk management and reporting
  - PA audits
  - **Critical items**
  - Document & data control
  - **Quality records**
  - PA contribution to CC
  - **NCRs & Alerts management**
- **QA processes & procedures**

QA PLAN (ECSS-Q-ST-20 Annex A):

- **QA processes and procedures** including training and certification
- Design and verification QA activities and processes Procurement QA activities and processes
- Manufacturing, assembly, integration (MAI) and testing QA activities,
- QA specific activities, including:
  - **Critical items, NCRs & Alerts**
  - Authority media, Traceability, **Records**
  - Metrology and calibration
  - Handling and storage
  - Statistical quality control

PA/QA plans contents (2/3)

PA/QA Plan shows how the quality will be managed/fulfilled, some examples:

- Lines of responsibilities, reporting, decision processes
- Procurement control, critical items control, quality records, audits
- Training of personnel, calibrated tools and machines
- Workmanship requirements and checks
- Traceability of work and parts (in both directions), storage
- Handling of non-conforming parts (containment, traceability, corrective actions, preventive actions), alerts management
- Overall compliance status and lists of exclusions

PA/QA plans contents (3/3)

-To the maximum possible extent, it should be based in existing company manuals and procedures, provided they are compliant to project requirements

-It has to be an operational document, that should be endorsed and applied by the organization

-Should identify all these aspects that are unique to the product: for instance, optics should address cleanliness and contamination prevention, electronics should address ESD protection, mechanism should address humidity effects to lubricants, SW should address coding standards & language etc…

Project PA Audits ECSS-Q-ST-10C rev1

- Establish and maintain audit plan for both internal and external audits
- Audit plan include current status and schedule for auditing
- General contents of project audits are detailed in ECSS-M-ST-10, clause 5.2.3
- In case of consistent poor quality or other problems extra audits can be planned

PA Audits (both external and internal)

- Preparation, questionnaire
- Execution
- Follow-up actions closure

ECSS-Q-ST-10-04C

Critical Item Control

Critical Item Control ECSS-Q-ST-10-04C

Critical items are potential threats to the performance, quality, dependability or safety of a system. These items require special attention.

Annex C of ECSS-Q-ST-10-04 provide for a checklist; examples include:

- Single point failures with major loss of function
- Unqualified technology or units whose performance cannot be tested
- Items with life-limited parts, contamination sensitive parts etc.

The method of assessing and tracking critical items, in a critical items list (CIL) is fully described in a dedicated standard ECSS-Q-ST-10-04.

Critical Item Control

The items shall be kept in the CIL which lists the mitigation actions and criticality of the item. Refer to ECSS-Q-ST-10-04 §5.1

The identification of critical items is done by the supplier as soon as a preliminary design emerges, first issue of CIL at Preliminary Design Review.

The CIL shall be reviewed during the design reviews and all listed critical items shall be closed by the acceptance review

ECSS-Q-ST-10-09C Rev1

Nonconformance control system

Nonconformance (1/2)

Major NCR has an impact on the **customer's requirements** on:

- safety of people or equipment,
- operational, functional or any technical requirements imposed by the business agreement (BA),
- reliability, maintainability, availability, lifetime,
- functional or dimensional interchangeability,
- interfaces with hardware or software regulated by different BA,
- changes to or deviations from approved qualification/acceptance test procedures,
- project specific items which are proposed to be scrapped.

Nonconformance (2/2)

Minor NCRs

- Nonconformances which by definition cannot be classified as major.
- If in doubt raise major NCR

Project PA Activities – NCR Process

When non-conformance is identified, a Non Conformance Report (NCR) is raised. An example report in Annex C in ECSS-Q-ST-10-09C Rev1.

Assessment of NCR is performed in a Non Conformance Review Board (NRB), mandatory participants PA and representative engineering.

Key aspects to cover:

- Which item/model is affected
- Criticality identification (Major/Minor)
- Root cause evaluation, Corrective/preventive actions
- Determine whether to return to supplier/use-as-is/rework/repair/scrap

Nonconformance review board (NRB) (1/2)

Internal NRB tasks

- Investigate the causes and consequences of the NCR and classifies the nonconformance either as minor or major
- For minor NCR disposes as follows:

➢ Return to supplier: This disposition only applies to nonconforming procured items.

➢ Use “as is”: The item is found to be usable without eliminating the nonconformance.

➢ Rework: The item is recoverable to conform completely to all specified requirements. Additional work is performed to prepare the item for the rework (e.g. removal of faulty work and cleaning). In no case should the result of earlier applied processes or the precondition for other processes to be applied later on, be affected.

➢ Scrap: The item is not recoverable by rework or repair, for technical or economic reasons.

➢ Repair: The item is recoverable such that it fulfils the intended usage requirements although it does not conform to the originally specified requirements.

Note: The repair procedure is either a. Qualified or standard repair procedure or b. Specific repair procedure.

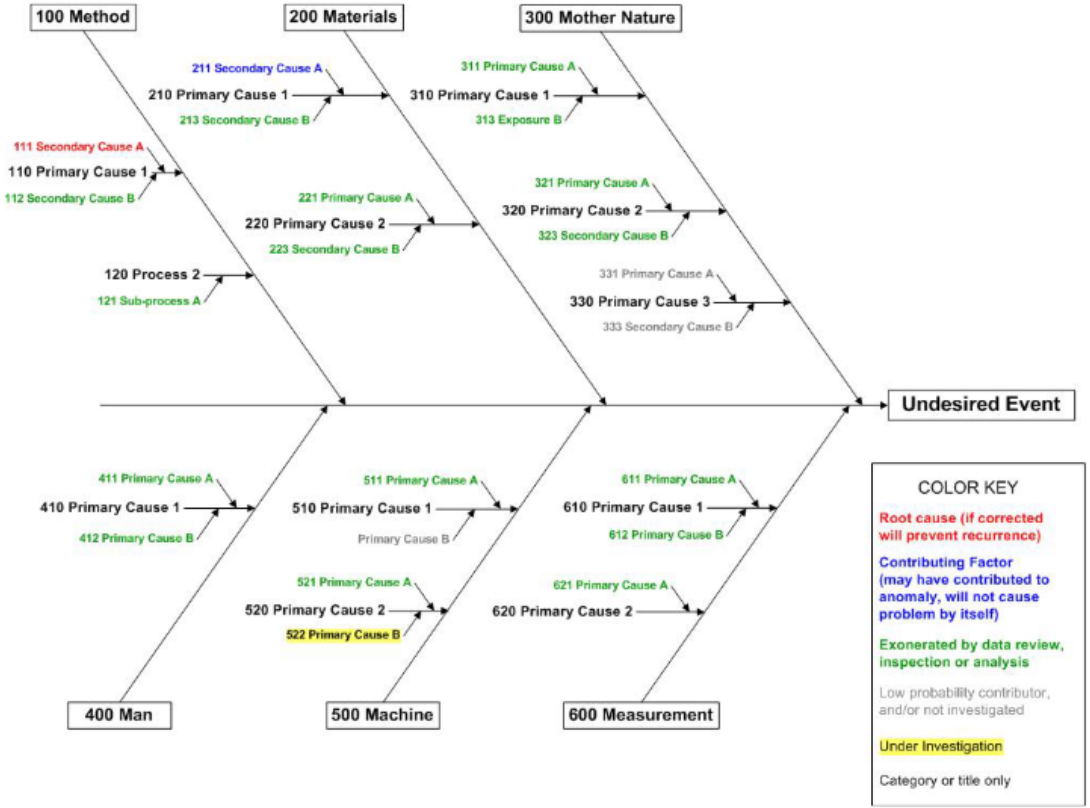
Nonconformance review board (NRB) (2/2)

Customer NRB – Major NCR

The customer NRB follows the same process as the internal NRB.

An assessment whether requirements of higher level customers are impacted is performed. If so, these higher level customers are involved in ensuing NRBs. The need for a request for waiver is also identified and recommended by this NRB.

Project PA Activities –NCR root cause



Request for Deviation/Waiver ECSS-M-ST-40C rev1

Request for Deviation

Planned departures from requirements or design, describing why the product concerned cannot meet requirements of the baselined configuration documentation.

Request for Waiver

Unplanned departures from requirements or design.

Example form and requested content in ECSS-M-ST-40C Rev1.

ECSS-Q-ST-20

Quality Assurance

ECSS-Q-ST-20

Quality assurance	
ECSS-Q-ST-20C Rev.2	Quality assurance
ECSS-Q-ST-20-07C	Quality and safety assurance for space test centres
ECSS-Q-ST-20-08C	Storage, handling and transportation of spacecraft hardware
ECSS-Q-ST-20-10C	Off-the-shelf items utilization in space systems

ECSS-Q-ST-20C pre-tailoring matrix in chapter 6

Table 6-2: Pre-tailoring matrix per "Space product types"

	Space product									
ECSS req. number	Space system	Space segment element and sub-system	Space segment equipment	Launch segment element and sub-system	Launch segment equipment	Ground segment element and sub-system	Ground segment equipment	Ground support equipment	Software	Comments
5.1.1a	X	X	X	//	//	X[1]	X[1]	-	-	[1] except for suppliers of catalogue OFF-THE-SHELF items such as standard laboratory equipment, work stations,.. , from whom a dedicated QA plan is not required.
5.1.1b	X	X	X	//	//	X	X	-	-	

ECSS-Q-ST-20C rev2

Quality Assurance

Quality Assurance general requirements

Quality Assurance plan can be combined with Product Assurance Plan

The previous slides already introduced Critical Items Control and NCR management

In addition the QA general requirements (chapter 5.2) include:

- Management of Alerts
- Traceability
- Acceptance authority media
- Statistical quality control and analysis
- Metrology and calibration
- Handling, storage, transportation and analysis

Pre tailoring matrix can be found on chapter 6 of the standard.

Alert Management

Alerts are formal notification from a supplier or agency of a problem that can affect more than one user. Some sources

- GIDEP (US **G**overnment **I**ndustry **D**ata **E**xchange **P**rogram)
- NASA Parts advisory
- ESA Alerts (https://alerts.esa.int/)
- CNES Alerts
- JAXA Alerts

Industry also issue alerts, sometimes under different names

- Letter or notice
- Warning Notice (e.g. Airbus Defence and Space)

Alert Management

Alerts need to be assessed to determine whether a particular risk exists in the project (i.e. if item is within perimeter of the alert)

If product is affected then alerts usually provide recommendations that depend on the state of development.

Alerts can have major cost and schedule impacts. An example is to replace a EEE component after a unit has been completed.

Contractors are to maintain a listing of all alerts and the responses – this is reviewed periodically and is recommended to be part of the project progress reporting

ESA Alert System

It covers failures in:

- EEE parts, mechanical parts
- pyrotechnic devices
- materials
- software
- equipment

Problems regarding to:

- safety
- manufacturing processes
- handling procedures
- standard test methods
- standard operational procedures
- software development & test methods and tools
- continuity of production of an item

Criteria to issue an Alert

The observed problem may apply to **more than one project** or organisation

The problem was observed while the item was applied **within its specified limits**

A preliminary investigation has provided **sufficient evidence of the cause of the problem**

The problem is confirmed **not to be of a random nature**

The **complete traceability** of parts is not quarantined

ESA Alert EA-2012-PYR-4-A

- **Missed firing of one initiator (S/N48),** during Acceptance Test of Pyro-Initiators 1TAPWH40S batch 29 (delivered for Ariane 5 Vulcain Igniter applications)
- Pyro-Initiators are **used in almost all ESA Projects** also in Safety critical applications (solid motors igniters, fairing separation, solar array release)

ESA Alert EA-2012-PYR-4-A

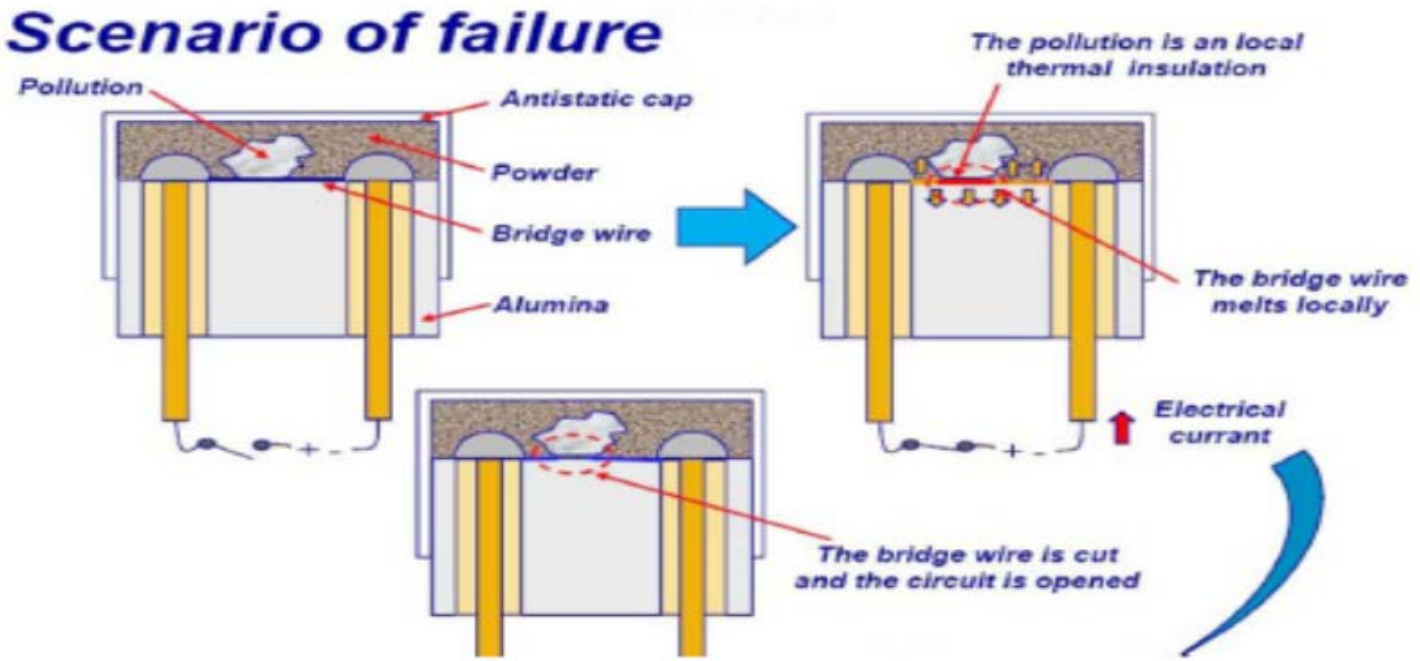
- The failure investigation performed identified the presence of a **polyamide particle** from the **antistatic cap**, in contact with the **bridge wire** inside the powder (AW1)

- The particle modified the thermal exchange between bridge wire and AW1 (thermal barrier) leading to the **local melting of the bridge wire** itself **without the ignition** of the AW1 powder.

- The particle was suspected to have been generated by polyamide chip-outs coming from **manufacturing line** of the supplier

- The line was used also for other products

ESA Alert EA-2012-PYR-4-A



ESA Alert EA-2012-PYR-4-A

Perimeter of the Alert

Number of initiators with antistatic caps batch #543255 involved in the observed failure: **5000 units since 2009**

Since the supplier stated that there had not been any changes in the manufacturing process for the antistatic caps, also earlier batches were considered suspect ➔ **total of 45000 units**

ESA Alert EA-2012-PYR-4-A

Actions on / by manufacturer

- **Audit** with several recommendations to ensure defects free manufacturing
- Certification of a **CT-Scan inspection** to detect any defect on existing caps

Actions by users

- Preferred: **replace** suspect initiators, or perform **CT-Scan**
- **If not possible: use-as-is**, based on reliability evaluation performed by ESA

Traceability (1/3)

Traceability covers many type of activities

- Requirements/verification traceability
- Materials and parts traceability (procurement)
- Machine/operator/metrology traceability

Traceability (2/3)

Focusing on the production aspects

- Decision early in the design to determine what mechanical parts, assemblies or units to serialize
- Proper storage management, handling during AIT (bag/tag control)
- EEE and certain materials traced through date-codes or lot identification
- Shop travellers to contain information on machines, operators
- Quality records must be able to provide ***traceability in both directions*** – the source of a material/part and where it is eventually used/installed.

Traceability (3/3)

Traceability is vital information

- Assessing whether a system is within the perimeter of an alert
- Investigating a non-compliance
- Data collection for routine monitoring of quality (correlation)
- Containment and segregation of unsuitable materials or parts

Traceability documentation is found throughout

- As-built configuration list (ABCL) → in EIDP
- As-built declared component lists (DCL)
- Shop travellers or as-run procedures
- Inventory lists

Acceptance Authority

Acceptance Authority (formerly stamp control) is used to trace completion of operations and QA approval or inspections.

- Source or incoming inspection
- Process inspection, tests and final inspections, e.g KIP/MIP
- Storage and shipment preparations

This traceability also improves integrity and commitments to quality since the responsibility is documented and link to individuals

Statistical Data Analysis (1/2)

Effective quality management requires objective data to be collected and analysed to support decisions, for example:

- Inspection, sampling, screening of parts → accept/reject parts
- Material properties → accept into production chain
- Process repeatability and accuracy → are processes stable
- Performance (accuracy, resolution, and repeatability)→ accept/reject
- Failures → correlation, reasons, containment, correct and improve

General requirements for statistical methods are detailed in ECSS-Q-ST-20C Rev2, 5.2.8.

Statistical Data Analysis (2/2)

For companies producing many parts, statistical quality checks by sampling is permitted (e.g. EEE components)

- Requirements in §5.2.8 of Q-20
- Lot definition, lot sampling approach and allowable failures to be justified
- Statistical methods must be approved by customer

Metrology and calibration

The emphasis in the ECSS-ST-Q-20C is the completeness of the calibration of any items used for metrology.

- Calibration is up-to-date and traceable to calibration standards
- Traceability of machine/operator and training
- Validation, especially for use of software
- ensure that the means are adequate for the purpose of measurements (accuracy, resolution and precision)

→ Do not forget the national safety requirements for equipment involved with testing

ECSS-Q-ST-20-07C

Quality and safety assurance for space test centers

Test Facilities (1/2)

- All technical and programmatic risks associated with testing must be identified and managed
- Subject to ECSS-Q-ST-20-07C Quality and safety assurance for space test center's
    - QMS compliant with EN9100
    - Description of facilities, configuration control
    - Risk assessment, planning and documentation of test process
    - Personnel competence, awareness and training
    - Environmental control: temperature, RH, differential pressure, cleanliness
    - Safety programme for personnel, including the customer and visitors, the test specimen, the test facilities and its associated infrastructure
    - Site security and access control

Test Facilities (2/2)

The questionnaire on the use of hazardous items and operations can be found on Annex A of the ECSS-Q-ST-20-07.

The questionnaire is in three parts:

- Part 1: knowledge on safety hazards coming from the test specimen

(i.e. radioactive sources and generations, explosive devices, mechanical energy…)

- Part 2: sensitivity of test specimen

(i.e. sound levels with spectral distribution, humidity, chemicals, contamination…)

- Part 3: detailed description

(i.e. hazards to which personnel are exposed during the operation…)

Annex B: Typical test process sequence (EN 9100:2009 + ECSS-Q-ST-20-07)

ECSS-Q-ST-20-08C

Storage, handling and transportation of spacecraft hardware

Handling and Storage (1/2)

- Despite the obvious need for safe handling, accidents do occur during handling and transportation. The QA approach is to assess the risks, ensure personnel are trained and procedures are complete

- Storage in clean room or not?

Handling and Storage (2/2)

- Some of the handling risks to guard against
  - Unwanted contact, scratches to sensitive surfaces – consider handling devices, tooling protections, tethers, covers, captive screws
  - Cleanliness – training of personnel, facilities, monitoring
  - Access constraints – to be tackled during design phase
  - ESD – personnel training, grounding
  - GSE design – ensure complete validation before acceptance
  - Untested procedures – to be tackled during development using BB, EQM

Lesson learned from several handling accidents: most common causes (1/2)

Physical

- Interfaces handling tools – item non error-proof
- Improper tools
- Inadequate barriers
- Insufficient or misleading marking

Procedures

- Insufficient detail
- Ambiguity, interpretation

Lesson learned from several handling accidents: most common causes (2/2)

Human factors

- Training
- Lack of communication
- Stress
- Schedule pressure, improvisation

Error-proof design, reduce likelihood and impacts of human error!

Delivery: shipping, transportation

Shipping control

Items to be shipped must be inspected before release, for

- Completeness
- Adequate preservation and packaging
- Correct marking
- Presence of all required documents

Documentation shall include

- EIDP
- Handling and packing or unpacking procedure
- Any relevant safety procedures

Unloading the second Swarm satellite in Plesetsk (ESA/M. Shafiq)

Transportation - All necessary measures shall be taken to prevent damage to items during transportation

An example of transportation accident

http://www.bournemouthecho.co.uk/news/1633688.**investigation_into_space_cargo_chaos/**

21 August 2007

"It is designed to survive the rigours of terrestrial travel, but the multi-million pound satellite that became wedged in to the frame of Poole lifting bridge, may have been nobbled at its first hurdle.

The company, …, **has launched an investigation** in to how the lorry transporting several million pounds worth of satellite components to Poole ferry terminal, failed to make the 4.6 meter clearance height. …"

ECSS-Q-ST-20-10C

Off-the-shelf items utilization in space systems

Scope of OTS items

Off-the-Shelf (OTS) Items are those that, even if not necessarily developed for space applications, can be procured from the market and utilized in a space system.

This Standard considers complex OTS items, as for example: motherboards, cards, data storage units/items, optical equipment, photo cameras and video units, LANs, mechanical/electrical and electromechanical devices, batteries, sensors, monitoring support units, medical equipment and items, laptops

This Standard does not cover

SW OTS, re-use of OTS items already qualified for space applications, pieces, parts and materials e.g. EEE parts, thermocouples, rivets, fasteners, connectors, fittings, adhesives, insulation, wiring and plumbing.

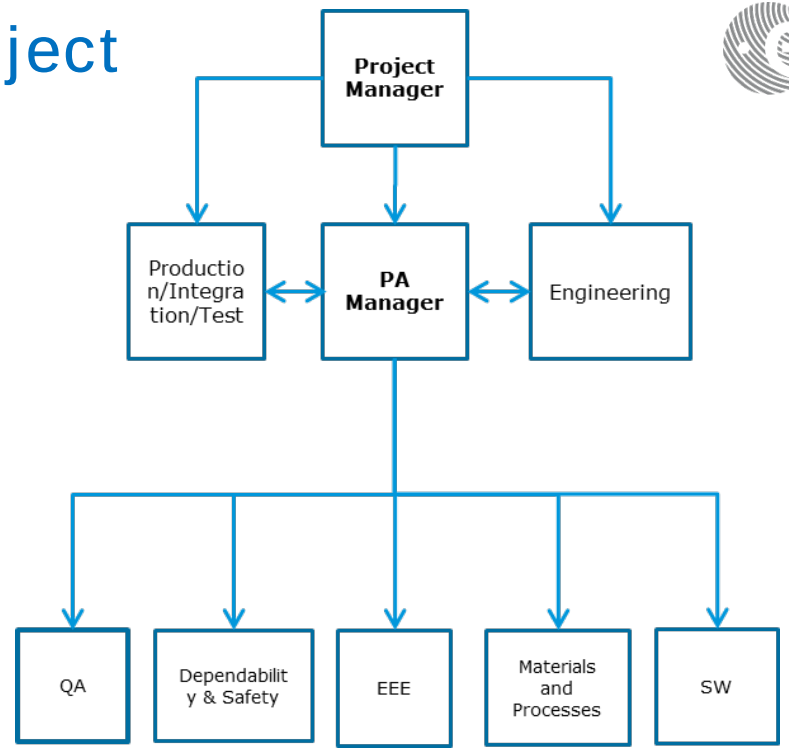
Documentation Requirements for OTS

- A dedicated OTS Plan (Annex A of ECSS-Q-ST-20-10C)
- Equipment specification
- OTS item evaluation dossier (Annex B of ECSS-Q-ST-20-10C)
- OTS item criticality
- Data collection (designed for aerospace or military application preferred)
- PA evaluation (dependability, safety, EEE parts, MMP)
- Engineering evaluation (structural, thermal, electrical
- Procurement and qualification

Product Assurance in ESA project

Product Assurance in a Project

- Management Support
  - Risk assessment
  - Configuration control
  - Procurement (requirements)
- Engineering
  - Design review process
  - Verification completeness
  - Qualification and Acceptance
- Production/AIT
  - Inspection
  - Training
  - Facilities/machines/testing



PA is 'independent' from engineering, cost control, schedule and production

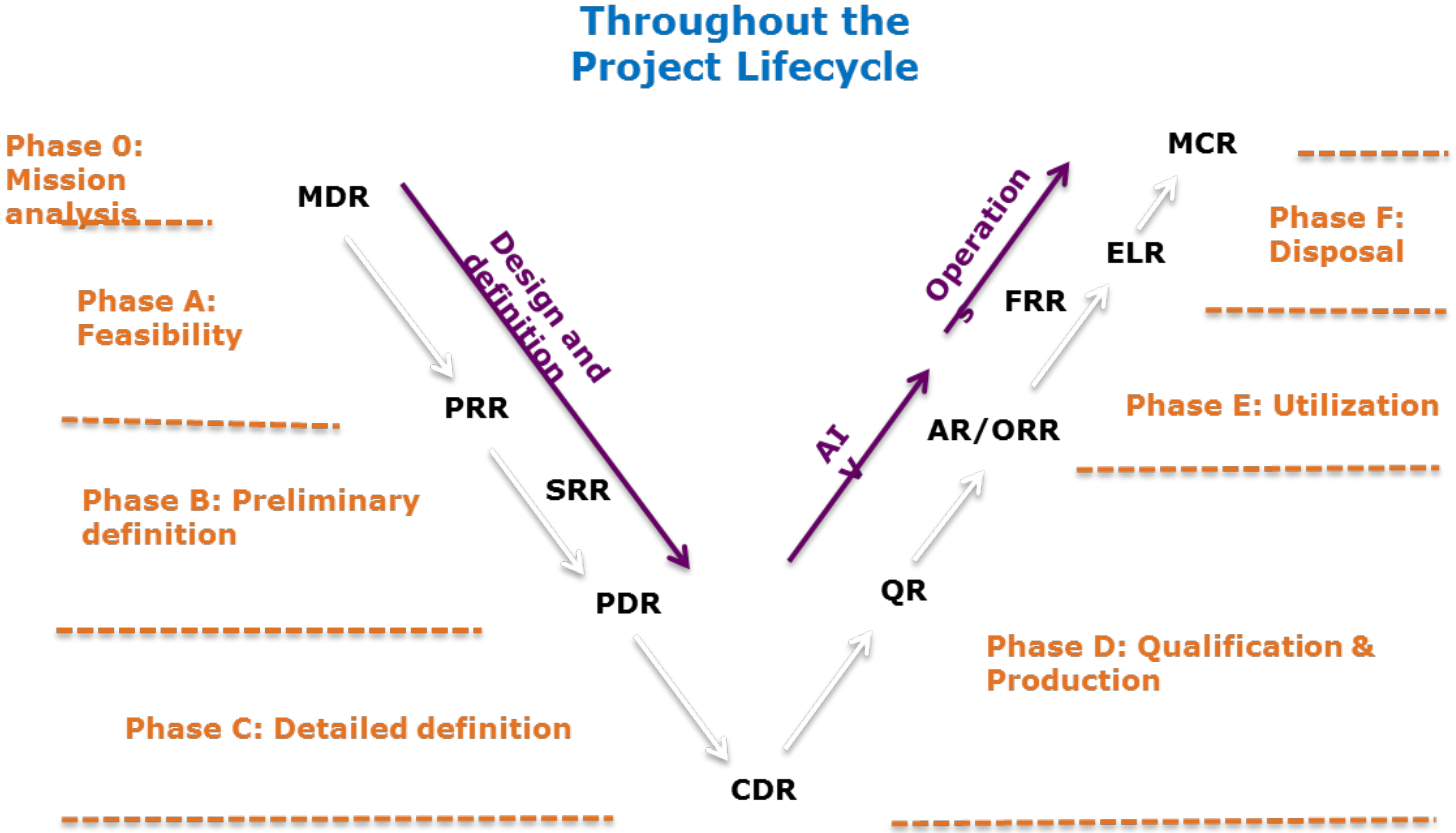
Roles of ESA PA

- Responsible for overall System PA activities
- Deal with inter segment issues
- Interface to Prime contractor(s)
- Monitoring is the main activity
- Responsible for generation of top level PA requirements for the project
- Reviewing the key review documentation for project milestones/reviews
- Providing expertise for PA activities to industry
- Participation to Anomaly meetings and project meetings

Roles of Industry PA

- Responsible for single element (Segment or Unit)
- Interface with ESA and lower tier contractors
- Definition of the PA Plan in response to the PA Requirements from the customer
- Definition, implementation and verification of the Quality processes in-house and at lower tier suppliers
- Day to day responsibility for project PA activities
- Direct compliance and configuration control activities
- Anomaly handling
- Control of MPCB process
- Control of PCB process
- Incoming inspection control of parts/materials

When is Product Assurance Needed?



PA Activities During Phase A/B

Identification of high level availability requirements and apportionment to subsystems

Identification of system Failure modes and mitigations

Ensure that failure mitigation requirements are in place

Concurrent Design Facility

PA Activities During Invitation To Tender

Preparation of Customer Product Assurance and Safety Requirements

Preparation of Customer EEE Requirements

Preparation of Customer Radiation Hardness Assurance Requirements

Identification of applicable Standards Baseline

PA Activities During Bid Preparation

Preparation of Statement of Compliance against the Tender documents

Tailoring of standards to the project (cubsesat vs satellite vs manned flight)

Preparation of a Product/Quality Assurance and Safety Plan

Identification of Requirements to flow down to sub contractors

PA Activities During Bid Evaluation (and SRR)

Verification of Statement of Compliance and evaluation of any non compliances

Evaluation of effectiveness of Product Assurance and Safety Plan

Evaluation of qualification efforts

Evaluation of requirements flow down to lower tier contractors

Qualification Status

The qualification status of the product, re-use file for SW, and its constituents should be stated and justified in qualification status list.

A qualification plan (could be part of the development plan) needs to be submitted

Category	Description	Qualification programme
A	Off-the-shelf product without modifications and • subjected to a qualification test programme at least as severe as that imposed by the actual project specifications including environment and • produced by the same manufacturer or supplier and using the same tools and manufacturing processes and procedures	None
B	Off-the-shelf product without modifications. However: It has been subjected to a qualification test programme less severe or different to that imposed by the actual project specifications (including environment).	Delta qualification programme, decided on a case by case basis.
C	Off-the-shelf product with modifications. Modification includes changes to design, parts, materials, tools, processes, procedures, supplier, or manufacturer.	Delta or full qualification programme (including testing), decided on a case by case basis depending on the impact of the modification.
D	Newly designed and developed product.	Full qualification programme.

PA Activities at Equipment Qualification Status Review

EQSR: Equipment Qualification Status Review (ESSB-M-ST-002)

- Determine Qualification Status (CAT A, B, C or D)
- Identify changes to unit functionality
- Identify flight Heritage
- Identify Obsolescence
- Identify changes in manufacturing processes
- Compliances to PA and development standards

Conduction of Design Reviews: ECSS-M-ST-10-01C

A dedicated procedure is established to define:

- Objectives and criteria for success of the review
- Contents of the documentation to be provided
- Assign responsibilities (reviewers, panels, board)
- Establish an schedule
- Normally handled by means of RIDs (Review Item Discrepancy), settled down at a collocation
- Action items are assigned if depart from normal work

Documentation integrity: technical & physical

- Documents must be released and modified through formal procedures (Configuration Control Plan ECSS-M-ST-40C rev1)
- A “Configured Item Document List” must be continually updated/maintained and made available to document users
- Obsolete documents must be promptly removed from all point of use, or clearly identified (e.g. “OBSOLETE” red ink stamp)
- Document users must be forbidden to alter or deface released documents (by adding personal notes, work instructions, etc.)

Preliminary Design Review

PA Activities at Preliminary Design Review

Preliminary Design Review (PDR)

- Verification of the preliminary design of the selected concept and technical solutions against project and system requirements (including reliability/redundancy, FDIR concept, safety),
- Release of Declared Parts, Materials and Processes lists,
- Release of final management, engineering, product assurance and DDV plans, work breakdown structure and lower level specifications.
- Updated compliance matrixes.
- Release of CIDL and product tree.
- Identification of critical items and impact of alerts

PA after Preliminary Design Review

Follow up of activities, taking also into account that the procurement of lower items is going on

- Participation in the PDR of lower level items
- Part and Materials Evaluation (start of PCB, MPCB, ERCB, REACH)
- Critical Items and Alerts follow up
- Start of configuration control from the PDR baseline
- Possibly, growing pains: non-compliances produced along the manufacturing of EM's

PA Activities after Preliminary Design Review

Parts Control Board (PCB)

- Part Approval Document (PAD) ECSS-Q-ST-60C rev2 Annex D
- Radiation control board/radiation harness control board

Materials and Processes Control Board (MPCB)

RFA part 1

- Describes the materials/processes to be qualified
- Qualification Plan approval

RFA part 2

- Qualification reports
- NCRs/RFDs/RFWs

Registration, Evaluation, Authorisation and restriction of Chemicals (1/3)

REACH is a European Union regulation concerning the Registration, Evaluation, Authorization and restriction of chemicals. It came to force 1st June 2007.

REACH aim:

- to improve the protection of human health and the environment from the risks that can be posed by chemicals, while enhancing the competitiveness of the EU chemicals industry.
- It also promotes alternative methods for the hazard assessment of substances in order to reduce the number of tests on animals.

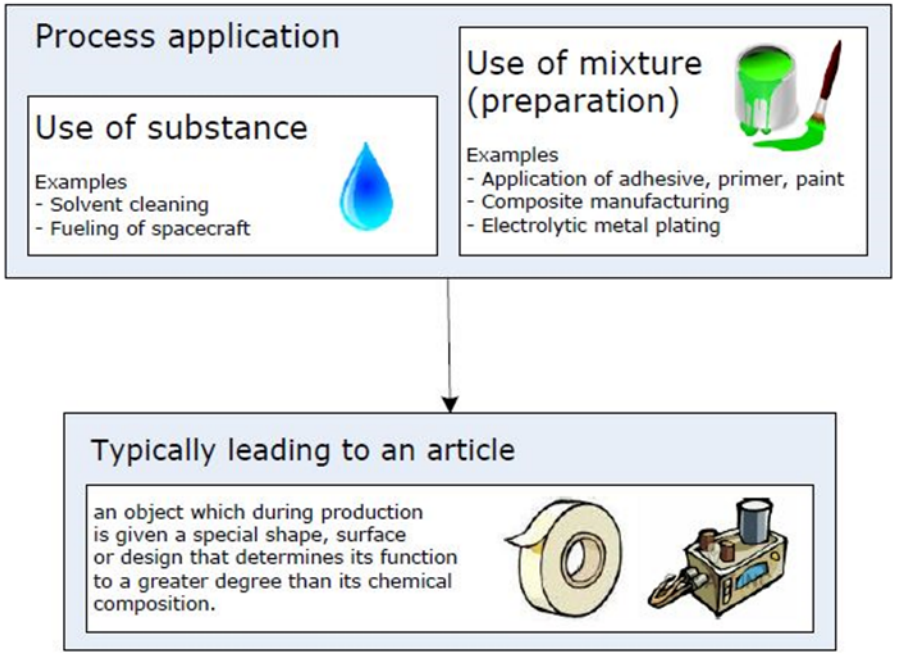
Registration, Evaluation, Authorisation and restriction of Chemicals (2/3)

REACH for space:

REACH is affecting European space industry as a whole (obsolescence).

The Materials & Process Technology Board (MPTB) is a European platform that includes industrial partners and national space agencies including members from Airbus DS, Airbus SafranLaunchers, ASI, Avio, CNES, DLR, ESA, MAP, OHB, REACHLaw, RUAG, TESAT, and TAS.

Registration, Evaluation, Authorization and restriction of Chemicals (3/3)



REACH obligations if a substance is classified a Substance of Very High Concern (SVHC) or mixture contains SVHC above threshold SVHC > 0.1%.

Trend of REACH:
Current estimates indicate ~ 8 % of our materials are probably affected in mid-term and 20% are possibly affected in long-term

Critical Design Review

PA Activities at Critical Design Review

Critical Design Review (CDR)

- Assess the qualification and validation status of the critical processes and their readiness for deployment for phase D.
- Confirm compatibility with external interfaces.
- Release the final design.
- Release assembly, integration and test planning.
- Release flight hardware/software manufacturing, assembly and testing.
- Release of user manual.

Critical Design Review

Expected outcome

- Final issue of reliability and safety analysis
- Final statement of compliance
- Parts, materials and processes approved
- All plans approved
- Supporting tests on Engineering models should be completed
- Actions from previous reviews completed as required

If everything regarding the design is approved, then it is time to start the production

Manufacturing Readiness Review

PA Activities at Manufacturing Readiness Review

Manufacturing Readiness Review

- Clean room check (entry, clothing, cleaning, environmental monitoring, ESD, training)
- Materials (Self life/dangerous items)
- Materials and processes qualification status
- Shop traveler, step-by-step instructions
- Training

Clean room rules –Example (1/2)

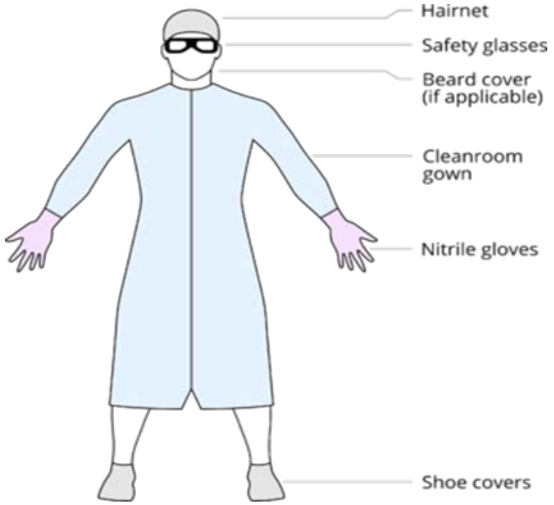
Pass clean room **training**

Undergo **controlled access**

Follow **entrance airlock** discipline

Wear **clean garments,** depending on class

Dress from head to toes, undress toes to head



PEOPLE ACTIVITY	PARTICLES/MINUTE (0.3 micr
Motionless (Standing or Seated)	100,000
Walking about 2 mph	5,000,000
Walking about 3.5 mph	7,000,000
Walking about 5 mph	10,000,000
Horseplay	100,000,000

Clean room rules –Example (2/2)

Personal actions typically **prohibited**

- Eating, drinking, smoking, wearing make up
- Fast motions
- Wearing torn or soiled garments
- Wearing clean room garments outside the clean room

Clean any items to be entered

Do not enter any substances, objects, materials or devices **that might compromise general cleanliness** (Flaking materials e.g. pencils)

Only approved tools and equipment

Clean room monitoring

Temperature control: 22° ± 3°C, to be monitored continuously

Relative Humidity control: 55 ± 10% , to be monitored continuously

Pressure control: A positive pressure differential shall be maintained between the cleanroom and the outside

Cleanroom and surrounding area: min 1,2 mm H2O (12 Pa)

Clean room and entrance lock: min 0,5 mm H2O (5 Pa)

Contamination monitoring and control

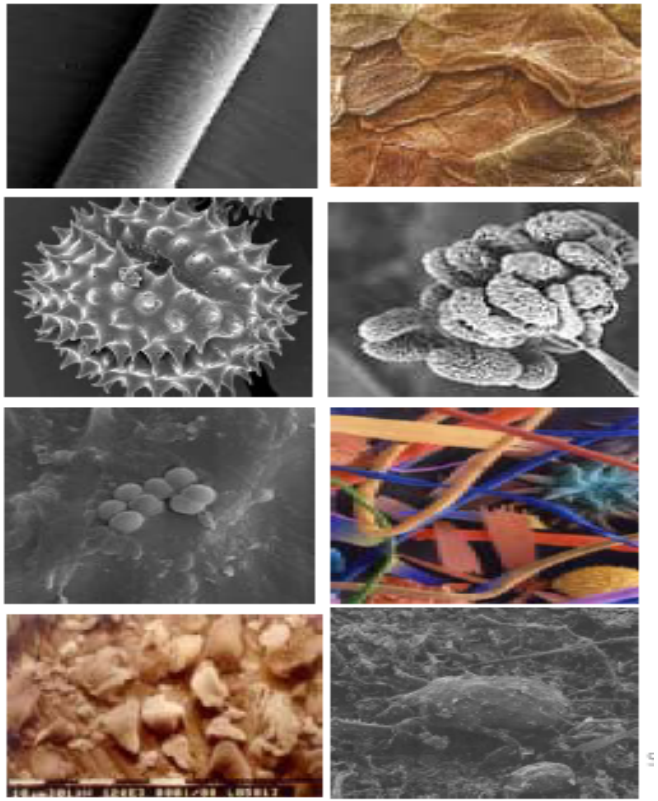
Common particulate cleanroom contaminants and their size

Contaminant Type	Size (∝m)
Human hair	70-100
Human skin flakes	0.4-10
Pollen	5-100
Mold	2-20
Smoke	0.01-1
House dust	0.05-100
Bacteria	0.25-10

Sizes of a number of common cleanroom contaminants

Activity	Rate (> 03∝m/min)
Motionless/Sitting/Standing	100,000
Head/Arm/Neck/Leg motion	500,000
All above with foot motion	1,000,000
Standing to Sitting Position	2,500,000
Walking (2 mph)	5,000,000
Walking (3.5 mph)	7,500,000
Walking (5 mph)	10,000,000

Particle generation rates for a number of human activities



Clean room monitoring

Particle Fall Out (PFO) Provides level of deposited particulate on a surface. Test methods:

- Particle Fall Out plates (Obscuration factor)
- Tape lift (Particle counting, mostly manual)
- Si-wafer (Particle counting, automated counting, optical microscopy or Scanning Electron Microscopes-Energy Dispersive X-ray)

Airborne particulate monitoring

- Portable, mobile & fixed counting systems, mostly based on laser scattering techniques

Molecular Contamination

- Collector Plate (MOC's), periodically analysed by FTIR or Chromatography for presence of organic and silicone based compounds

PA Activities during manufacturing

Inspections (Mandatory Inspection Point (**MIP**)/Key Inspection Point (KIP**)**

- MIP: Customer **must** be invited
- KIP: Customer participation is **optional**

Non conformance (NCR) handling

Criticality identification and **Root cause** Analysis

Waivers and Deviations

Coverage and Handling

PA Activities–Inspections (MIPs/KIPs)

Inspections that give maximum visibility and consist of

-Physical Item inspection

-Review of documentation related to the item

- Expected configuration (as-built vs as-designed)
- Log Books including Mate/Demate records
- Calibration documents
- Test reports
- Open Items and non conformances status
- Red/Green tag items lists

PA tasks at Tests

PA Activities at Test Readiness Review

Test Readiness Review (TRR)

- Does the test facilities meet the test requirements?
- Are test procedures ready and formally released?
- Is the unit under test configuration complete?
- Is all test equipment calibrated?
- Have all open anomalies been processed?
- Are all open work items in correct state?

PA Activities – Post Test Review

Post Test Review (PTR)

- Is the as-run complete?
- Have all variations been red-marked/recorded in process variation sheet?
- Are all NCRs formally tracked?
- Have test objectives been met?
- Can the test set-up be broken?
- Can next test start?

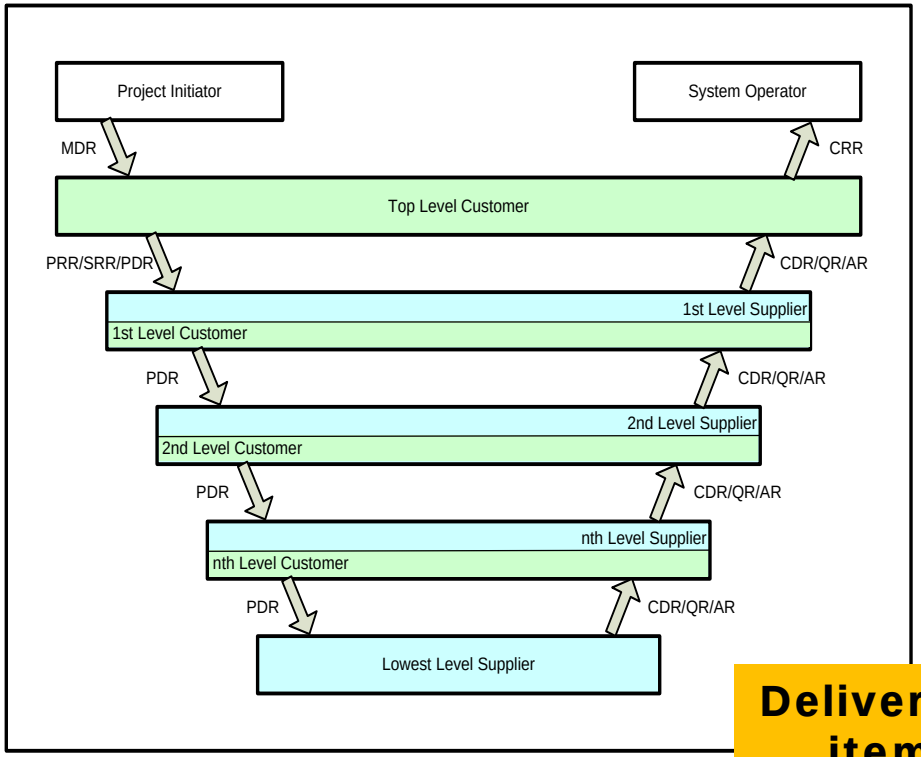
PA Activities at Qualification / Acceptance Review and Delivery

PA Activities at Qualification/Acceptance Review and Delivery

Qualification / Acceptance Review (QAR) / Delivery

- Have all qualification and acceptance tests been completed?
- Are all NCRs tracked and appropriate waivers/Deviations raised and approved?
- Is the End Item Data Package (EIDP) complete?

Acceptance and delivery process



- Complex customer-supplier chains are the norm for space projects
- Therefore, a **formal acceptance process for all deliverable items is required**
  - Acceptance Procedures, Acceptance Reviews …
  - At any contractual level
  - To ensure that conformity of the items to be delivered is fully assessed and documented

End Item Data Package (EIDP) (1/2)

- To be provided by the supplier for each deliverable item

- Basis for formal acceptance reviews

- To be maintained and integrated into higher level EIDPs during subsystem or system integration and testing

End Item Data Package (EIDP) (2/2)

EIDP Main contents

- Certificate of Conformity of the item (CoC)
- As Built Configuration List (ABCL)
- NCR list (and copies of major NCRs)
- Summary and status of RFDs and RFWs
- Logbook of the item
- Documents to be used for further integration, testing and operation in higher level assemblies
- Procedures to be used for the proper handling of the product after its final delivery
- Copies of the product test reports (or how to find them)
- List of the loose items and not installed items

Delivery Review Board (1/2)

The DRB **authorizes the shipment of the items under acceptance**, certifying that:

- the items **conform to contractual requirements** and approved configuration
- the items are **free from material and workmanship deficiencies**
- all **non-conformances are closed-out**, or corresponding plans are accepted
- the **EIDP** is complete and accurate

Delivery Review Board (2/2)

DRB includes **representatives** from

- the receiving organization (chairing)
- the submitting supplier
- higher level customer(s)

Delivery shall only be authorized by the **unanimous agreement** of the DRB members

Preparation for Delivery

- **Packaging** materials, methods, procedures and instructions to provide for protection of item
  - while at the supplier's plant
  - during transportation
  - after their arrival at destination
- Appropriate **marking and labelling** for packaging, storage, transportation and shipping of items must be implemented

PA Activities at Launch

PA activities preparation to launch

Each S/C launch requires specific precautions and trainings

Hazardous activities on the launcher (fueling)

Think and plan in advance how to prepare for critical functions and how to protect the sensitive instruments (i.e. contact launch site well in advance about contamination sensitive instruments and launch site preparation steps)

GREEN/RED tag operations preparation and inspections

Define GO/NOGO criteria

Agree ESA/Industry roles and responsibilities

Define launch success criteria

PA activities after launch

In case of anomaly be ready to start investigation

In case no anomaly, follow up the operations

Questions?