ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS
OSSERVATORIO ASTRONOMICO DI TORINO

RAPPORTO TECNICO - TECHNICAL REPORT

METIS INSTRUMENT PROPOSAL
for the Solar Orbiter Mission
Part 4: Product Assurance Plan

Ester Antonucci (P.I.), S. Fineschi, G. Naletto, M. Romoli, D. Spadaro, S. Solanski, P. Lami and the Co-I's Team

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METIS INSTRUMENT PROPOSAL
for the
Solar Orbiter Mission

Part IV
Product Assurance Plan

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1 Introduction

METIS instrument will be design, developed and tested in close collaboration with industry. For this reason we will adopt for the development of METIS the standard PA plan of Thales Alenia Space Italia that with Galileo Avionica Space will carry out most of the activities indicated in the METIS WBS (ref [RD-1]).
Consequently, the applicable TAS standard [AD-3] “Space Segment Product Assurance Plan” is attached to this document in **ANNEX A – TAS Standard: Space Segment PA Plan**.

Tasks or elements designed, manufactured or tested by TAS subcontractors and scientific institutes or laboratories shall follow the same rules specified in the Standard TAS PA Plan.

2 Document References

2.1 Applicable Documents

AD-1 Solar Orbiter Experiment Interface Document – Part A Issue 1.0 – ref. SOL-EST-IF-0050 – October 2007

AD-2 Solar Orbiter Payload - Announcement of Opportunity ref. D/SCI – 23482 18 October 07

AD-3 TAS Standard - Space Segment Product Assurance Plan - 100141545F-EN Issue 3 of 4/9/07

2.2 Reference Documents

RD-1 METIS Proposal Management Plan Issue 01 ref: INAF/OATO nr. 97 of 15/01/2008

3 Acronyms

ADC	Analog to Digital Converter
AFT	Abbreviated Functional Test
AIT	Assembly, Integration and Test
AOCS	Attitude and Orbit Control System
APS	Active Pixel Sensor
BB	Breadboard
BBM	Bread-Board Model
CCD	Charge Couple Device
CFRP	Carbon Fiber Reinforced Plastic
CME	Coronal Mass Ejections
CNR	Consiglio Nazionale delle Ricerche
CNRS	Centre National de la Recherche Scientifique
CoI	Co-Investigator
CoM	Center of Mass
CoPI	Co-Principal Investigator
COR	METIS Visible and EUV Coronagraphic imager
CTE	Coefficient of Thermal Expansion
DMS	Data Management System
ECSS	European Cooperation for Space Standardization
EEO	Extended External Occulter
EEOM	EEO Mechanism
EM	Electrical Model
EM	Experiment Manager
EO	External occulter
EOM	External occulter Mechanism
EQM	Electrical Qualification Model
ESA	European Space Agency
EUI	EUV Imager
EUS	METIS EUV disk Spectrometer
EUV	Extreme UltraViolet
EUVC	EUV Channel
FEE	Front End Electronics
FEM	Filter Exchange Mechanism
FFT	Full Functional Test
FM	Flight Model
FOV	Field Of View
FS	Flight Spare
FWHM	Full Width at Half Maximum
GSE	Ground Support Equipment
H/W	Hardware
HeF	Aluminum low-pass filter of the coronagraph
HELEX	Heliophysical Explorers
HERSCHEL	Helium Resonance Scattering in the Corona and Heliosphere
HF	Narrow-band multilayer filter of the coronagraph
HGA	High Gain Antenna

HVPS	High Voltage Power Supply
HWRP	Half Wave Retarder Plate
IAC	Instituto de Astrofísica de Canarias
IAPS	Itensified APS
IAS	Institut d'Astrophysique Spatiale
IASF	Istituto di Astrofisica Spaziale e Fisica cosmica
IDP	Instrument Development Plan
IFE	Instrument Front End
IFSI	Istituto di Fisica dello Spazio Interplanetario
ILS	Instrument Line of Sight
INAF	Istituto Nazionale di AstroFisica
INFM	Istituto Nazionale Fisica della Materia
IO	Internal Occulter
IOM	Internal Occulter Mechanism
IR	Infrared
LAM	Laboratoire d'Astrophysique de Marseille
LCL	Latching Current Limiters
LCVR	Liquid Crystal Variable Retarder
M0	Sun-disk rejection mirror of the coronagraph
M1	Primary mirror of the coronagraph
M2	Secondary mirror of the coronagraph
MCP	Micro Channel Plate
METIS	Multi Element Telescope for Imaging and Spectroscopy
MGSE	Mechanical Ground Support Equipment
ML	Multilayer
MOC	Mission Operation Center
MoI	Moment of Inertia
MPPU	METIS Processing & Power Unit
MPS	Max-Planck-Institut fuer Sonnensystemforschung
MSSL	Mullard Space Science Laboratory
N/A	Not Applicable
NASA	National Areonautics and Space Administration
NOM	Nominal Observing Mode
NRL	Naval Research Laboratory
OAA	Osservatorio Astronomico di Arcetri
OACN	Osservatorio Astronomico di Capodimonte Napoli
OACt	Osservatorio Astronomico di Catania
OAPa	Osservatorio Astronomico di Palermo
OAR	Osservatorio Astronomico di Roma
OATo	Osservatorio Astronomico di Torino
OATs	Osservatorio Astronomico di Trieste
OGSE	Optical Ground Support Equipment
OP	Off Pointing
PA	Product Assurance
PI	Principal Investigator
PoliTo	Politecnico di Torino
QE	Quantum Efficiency
RD-n	Reference Document n

S/C	Spacecraft
S/W	Software
SC	Sun Center
SCORE	Sounding-rocket Coronagraphic Experiment
SEP	Solar Energetic Particles
SMM	Structural Mathematical Model
SO	Solar Orbiter
SOCS	METIS Solar Orbiter Coronal Spectrometer
SOHO	Solar and Heliospheric Observatory
STOM	Structural Thermal Optical Model
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
TEC	Thermo Electric Coooler
TM	Telemetry
TSOM	Time Share Observing Mode
TVLS	Toroidal Variable Line Space
UFOV	Unobstructed Field Of View
UniAq	Università di Aquila
UniCal	Università della Calabria
UniFi	Università di Firenze
UniPD	Università di Padova
UniPd	Università di Padova
UniPg	Università di Perugia
UniPv	Università di Pavia
UniRm	Università di Roma
UORF	Unit Optical Reference Frame
URF	Unit Reference Frame
UV	Ultraviolet
UVC	UV channel
UVD	Ultraviolet Detector
VD	Visible Detector
VIM	Visible Imager & Magnetograph
VLC	Visible Light Channel
VUV	Vacuum ultraviolet

ANNEX A – TAS Standard: Space Segment PA Plan

ThalesAlenia Space

QMS	QM
Standard :	100141545F-EN
Date :	4/09/07
Issue : 3	Page : 1/1

STANDARD

SPACE SEGMENT

PRODUCT ASSURANCE PLAN

Written by	*Responsibility*
PA Team	Quality and Process department
Verified by	
L. RAMADIER-GAYRAUD	Standard responsible
Approved by	
J. DESPAROIR	Quality & Process Vice president
M. COYER	QMS documentation manager

Approval evidence is kept within the documentation management system.

100181547K-EN

STANDARD

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ENREGISTREMENT DES EVOLUTIONS/*CHANGE RECORDS*

ISSUE	DATE	§: DESCRIPTION DES EVOLUTIONS *§: CHANGE RECORD*	REDACTEUR *AUTHOR*
1	13/02/07	First issue. **This document has been established in the frame of the WP4 PA/QA convergence with M.Auzas , E.Baruffi, L.Biffi, G.Bria-Berter, G.Canepa, E.Cassart, D.Dandurand, D.Demarquilly, Y.Folco, D.Foltran, M.Ferrante, ,R.Ruffato, M.Sarno, MJ.Vairon.**	L.Ramadier-Gayraud
2	13/04/07	Paragph 2.1 – Precision for reuse products Paragraph 10.4 – “Derating Requirements” : removal of the exception related to current in bundles.	L.Ramadier-Gayraud
3	4/09/07	Modifications according to the POS ASPI RO A00081 Paragraph 2.1 – Precision on the applicability of Space Radiation environment for geostationary mission only or dedicated document for other mission (consistensy with Radiation section) Correction of EEE Parts requirements reference	L.Ramadier-Gayraud

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1. introduction

1.1. Scope

This plan presents the Product Assurance (PA) programme which will be implemented by The Company and its Suppliers to satisfy programme requirements expressed by the Customer and declined to the Suppliers through (100141811S-EN).

This plan defines the PA policies, objectives, methods and activities related to design, development, manufacturing, assembly, test, delivery and launch site activities.
It is entirely applicable to Space Segment (Spacecraft, Ground Control Segment (SCC, TCR & simulator)) including the Influential means (Influential production, test or operation facilities mean all devices (tools, machines, software, processes) whose configuration has a direct impact on the ability of the user items to meet the functional and operational constraints and operation support (LEOP and IOT).

Dispositions in this document will be implemented and maintained throughout all phases of the contract. After approval by the Customer, this document will be accepted as a contractually binding document.

This plan shall be considered with associated Customer PA requirements Compliance Matrix.

1.2. Quality system

This plan is based on The Company Quality System compliant with AS/EN/JISQ 9100, ISO 9001 v2000, AQAP 2110 and recognised by certification.

The programme takes large profits from the most recent improvements achieved in Quality Systems, as well as from the 30 years experience achieved on previous space programmes with different Customers: Space Agencies (ESA, CNES, ASI, NASA) international organisations (INTELSAT, EUTELSAT, EUMETSAT), private organisations.

This plan takes benefits from European and US standards (ECSS, Mil, …).

A continuous effort is implemented to improve the quality and competitiveness of our products and Customer satisfaction. In this frame, upstream activities with regard to contract are performed such as Product lines and Proposal activities.

1.2.1. Product lines activity

In the objective to prepare project activities, The Company implement a common methodology defining the phases and reviews used to launch new products on the market.

For each product line a Product Manager is responsible for product marketing from market research to withdrawal from the market. He is the in-house owner of the product. He co-ordinates the product team. He is responsible for and guarantees product compliance with market expectations. He defines successive versions of the product.

A Product Steering Committee composed of company Directors decides on a product's commercial launch, financing and deployment. This committee manages and supervises product launch tasks or product evolution via the Decision Reviews (DR) which are the Management decision reviews.

Product Assurance activities are organised and managed as in the frame of a project.

The PDR and CDR reviews are conducted according to the same methodology as in the frame of a project.

1.2.2. Proposal phase

For Proposal a dedicated team is organised to propose the best response to Customer requests.

During this phase, specific internal reviews are conducted by senior management in order to control and approve the quality of the proposal.

During these reviews, particular attention is paid to:

- the understanding of Customer requirements
- discrepancies to standards (products and quality system) and consideration of lessons learnt
- industrial organisation
- proposed plans (management, product Assurance, development).

2. RELATED DOCUMENTS

2.1. Applicable documents

The following documents are applicable to the extent specified herein. In case of conflict between the applicable documents listed below and the requirements of this document, this document shall prevail. Unless explicitly specified otherwise, document issue date for each product shall be defined at the time of contract signature. For reuse products, the applicable standards are those applied during the qualification of the related product.

These requirements are transferred to the Suppliers through (100141811S-EN) as tailored version of ECSS-Q-20

Activities performed by The Company, are defined through the Company Quality Manual document (REF-ASP-MQ-1-E.)

- ECSS-Q-00: Product Assurance - Policy and principles (except for document applicable).
- ECSS-Q-20: Product Assurance - Quality Assurance (except for document applicable).
- 100141983G-EN : Standard Product Assurance requirements for ground product.
- 100141932B-EN : Standard Safety Product Assurance requirements for unmanned missions - Part 1: Safety assurance programme Safety requirements as tailored version of ECSS-Q-40
- 100141938H-EN : Standard Safety requirements for unmanned missions - Part 2: Detailed technical safety requirements for flight hardware and ground support equipment
  The applicability of all the documents as identified in the Chapter § 9.
    - US-MIL-STD-1576 Notice 01 dated 04/09/92 Electro explosive Subsystem Safety Requirements and Test Methods for Space Systems.
    - US-MIL-STD-1522-A Notice 3 dated 04/09/92 Standard General Requirements for Safe Design and Operation of Pressurised Missile and Space Systems.
    - ECSS-Q-70-36 or MSFC-STD-3029: requirements for controlling stress corrosion cracking (applicability according to § 9.6.7.).
  - Launch agency documentation: Launcher User's Manual and Range Safety Regulations (as applicable for the specific launch authority, issue/revision as valid at the date of the contract).
- 100141812T-EN : Standard Dependability Product Assurance Requirements as tailored version of ECSS-Q-30.
    - 100141982F-EN : Standard Instruction and data base for dependability analysis -
- 100141944N-EN : Standard Software Engineering and PA requirements as tailored version of ECSS-Q-80.
- 100141911C-EN : EEE Parts Product Assurance Requirements for High Reliability Parts. This document defined the applicability of normative references.
- 100141943M-EN : Standard Radiation Product Assurance requirements. This document defined the applicability of normative references.
- 100143671P-EN : Space Radiation environment for geostationary missions, TBD for other missions
- 100141941K-EN : Standard Materials and Processes Product Assurance requirements as tailored version of ECSS-Q-70

The applicability of all the documents identified in the Chapter § 14. are as defined in the 100141941K-EN

2.2. Reference Documents

- ECSS-P-00-Glossary.
- ECSS-Q-20-09B: Space Product Assurance - Non Conformance Control System.
- ECSS-Q-20-04A Critical Item Control
- ECSS-Q-20-07A : Quality assurance for test centres
- JSC 11123 : STS payload safety guidelines handbook.
- NSTS 13830C - Payload Safety Review and Data Submittal Requirements For Payloads Using the Space Shuttle or the International Space Station
- NSTS 1700.7B - Safety Policy and Requirements For Payloads Using the Space Transportation System
- KHB 1700.7C - Space Shuttle Payload Ground Safety Handbook
- JSC 542B form - Payload hazard report form
- MIL-STD-883C, METHOD 1019.3
- MIL-STD-883D, METHOD 1019.5 & 1019.6
- « Total Dose Steady State Irradiation Test Method ESA/SCC Basic Specification N° 22900, issue 3, November 1993
- «Single Event Effects Test Method and Guidelines ESA/SCC Basic Specification N°25100, Draft A, February 1995.
- JEDEC Test Standard # 57, « Procedures for the Measurement of Single Event Effects in Semiconductor Devices from Heavy Ion Irradiation », May 1996.

3. PRODUCT ASSURANCE programme management

3.1. Project kick off

Project kick off is conducted with the Customer in order to launch the project in line with the contract.
Since this review, project activities are managed by dedicated plans.
This present plan defines all Product Assurance activities implemented all along the project life.

3.2. scope

Programme management is responsible for ensuring effective Product Assurance in compliance with the contractual requirements.

A specific individual from The Company PA department will be appointed as Project Product Assurance manager and will be responsible to the Project Manager for management and status of the PA disciplines in the implementation of the approved PA Plan. His responsibilities include all aspects of the PA Plan, and he will act as the focal point of contact within the project for the Customer concerning Product Assurance matters, having direct access to the Customer PA manager, Project manager and Quality and Process management for regular PA reporting.

PA Manager is responsible for the following main activities:

- management of PA team
- implementation and maintenance of the programme PA tasks defined in the PA plan
- identification of needs of the necessary resources and organisation of the PA group and PA tasks planning
- verification that required PA activities are covered
- survey of audits of personnel, audits of certification procedures, and operations implemented in the frame of project
- reporting and documentation of the PA activities as defined in SOW
- implementation of non-conformance processing system
- identification and resolution of inconsistencies between Product Assurance applicable documents
- verification of identification and resolution of inconsistencies between others applicable documents
- control of PA schedule and cost
- control of Supplier PA activities (included The Company products).

3.3. PA ORGANIZATION

General requirements for organisation and responsibilities are defined in ECSS-Q-00.

The PA Manager has direct and unimpeded access to the top management of The Company through the hierarchical Quality line.

The PA Manager will be supported by project PA engineers and by a staff of specialists from each PA discipline (including Product and AIT QA engineers), drawn from the PA line organisations. Members

of the PA project staff report to him for project activities.

A project PA organisation will be implemented in accordance with the organisation chart on Figure 3.2-1.

The PA team uses the resources of The Company to cover the following activities:

- organisation and management of PA activities
- Quality Assurance Control (§ 4.)
- design and development control (§ 5.)
- Supplier and Procurement Control (§ 6.)
- manufacturing and AIT quality assurance (§ 7.)
- ground control segment product assurance (§ 8.)
- safety (§ 9.)
- dependability (§ 10.)
- software product assurance (§ 11.)
- EEE parts (§ 12.)
- radiation/Hardness (§ 13.)
- materials and processes (§ 14.)

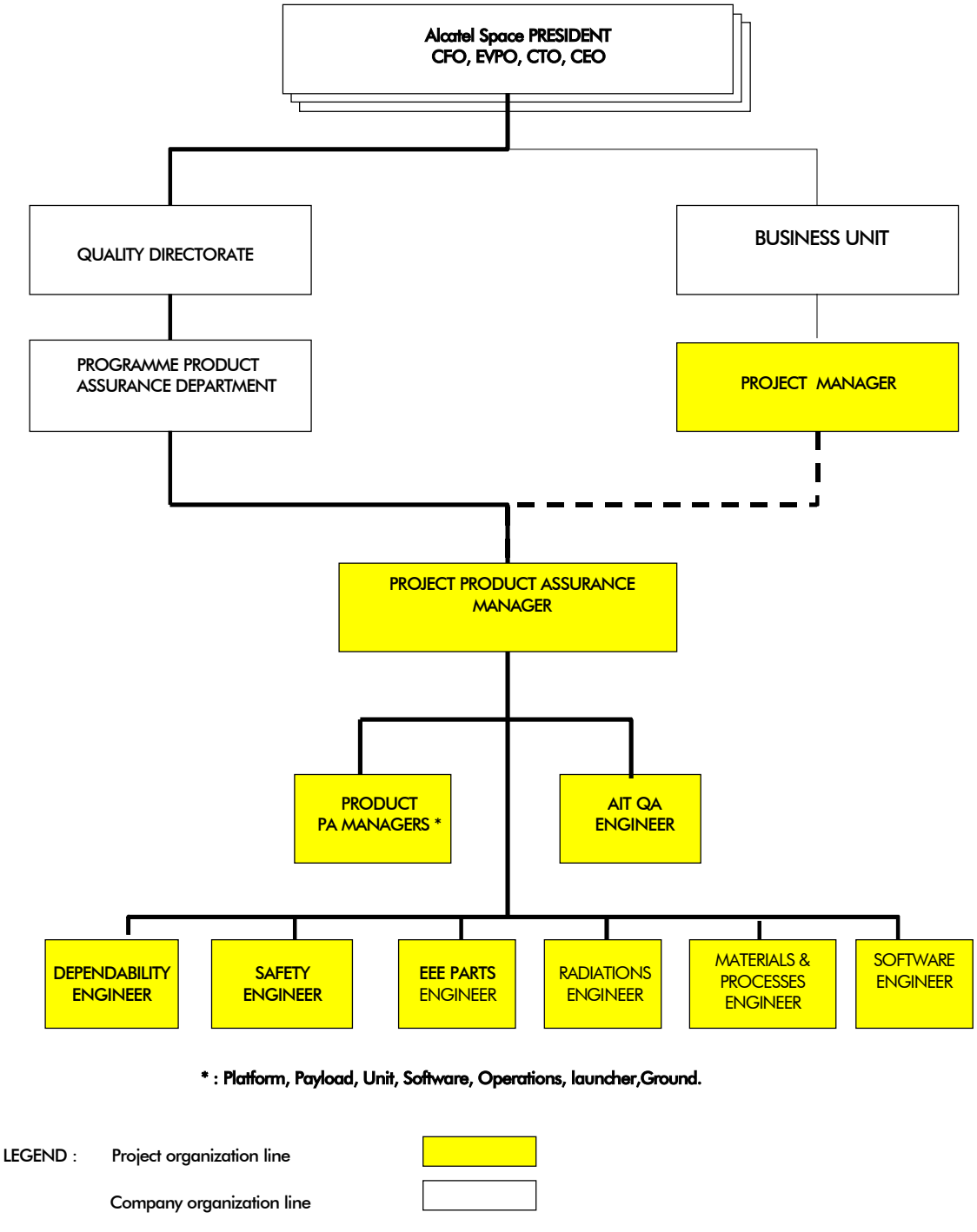


FIGURE 3.3-1 PROJECT PRODUCT ASSURANCE ORGANIZATION

3.4. PA Planning & review boards

3.4.1. PA planning

PA tasks will be planned consistent with the overall project schedules.
The PA programme will be implemented by the establishment of a PA team which will be responsible to accomplish all PA tasks described in the relevant Work Package Description (WPD's).
Dispositions will be implemented and maintained throughout all phases of the contract.
The PA tasks are divided according the different phases in a project, the division may also evaluate according to the contracts in particular for phase A and B. There are mainly :

- Phase A : analyse the Preliminary Customer requirements and ensure that the PA plan as well as the flow down of PA requirements satisfy the agreed Customer requirements .
- Phase B: Consolidation and maintenance of the Phase A activities on the basis of consolidated Customer requirements and preliminary definition. The respect and implementation of the Supplier PA requirements will be verified.
- Phase C/D : Respect and implementation of the PA plan at The Company and its suppliers related to design, development, manufacturing, assembly, test, delivery and launch site activities (if any) The respect and implementation of the Supplier PA requirements will be also verified accordingly
- Phase E : The tasks will be mainly devoted to control that activities are performed in accordance with the applicable requirements and the PA plan.

3.4.2. PA Review Boards

The following PA Review Boards (level N) will be held throughout the project:

- Non-conformance Review Board (NRB) as defined in § 4.6.2, with PA as chairman.
- Equipment Qualification Status Review (EQSR) if applicable as defined in § 5.4.1, with PA as chairman
- Manufacturing Readiness Review (MRR) Board as defined in § 7.3.2, with PA as participant
- Test Readiness Review (TRR) Board as defined in § 7.4.3, with PA participant
- Test Review Board (TRB) as defined in § 7.4.5, with PA as participant
- Delivery Review Board (DRB) as defined in § 7.4.9, with PA as member or chairman .
- Part Control Board (PCB) as defined in § 12.1.1, with PA as chairman
- Material and Process review as defined in § 14.3.3 with PA as chairman.
- The PA manager will attend as a member the Change Control Board (CCB).

3.5. PA status reporting

3.5.1. PA programme status review

In line with the SOW, PA programme status reviews will be conducted as part of progress meeting held on the project at equipment, subsystem and system level.

Participants in those reviews shall be:

- the PA manager, or the product PA manager (at subsystem or equipment level)
- PA engineers (reliability, parts, materials...) if necessary depending on the subjects under

concern
- the technical responsible, and the project manager representative (taking opportunity that such review takes place as part of the project progress meeting).

PA Project status review will systematically address the following subjects:
- progress of PA activities: qualification status, critical items, safety and reliability analyses,, software if applicable, parts materials and processes
- main problem areas
- status of Non conformances, processing of open new conformances
- status of request for waivers, processing as necessary.

3.5.2. Progress report

PA project status will be reported regularly to the Customer through reports as required in the Statement of Work. The reports will include descriptions of product assurance status, the major product assurance activities, and all notable accomplishments.

The PA section of progress reports will include:

- general statement of PA activities,
- PA Status on critical/items ,qualification, dependability, safety, EEE parts, Radiations, materials, process, software,
- PA Status List : NCR 's, RFW's, External Alerts (if applicable)
- summary of program audit held
- main problem areas, major non-conformances summary and open points
- Quality assessment on suppliers PA Activities
- planning of PA project reviews.

3.6. Personnel training and certification

Training programme for QA personnel whose performance determines or affects product quality and Certification of personnel will be performed under proposal of management. Formal certification for special processes or operations will be reached by dedicated courses. Verification of aptitude to perform the work is performed by the Quality Assurance department through consideration of capability and experience.

3.7. AUDITS

The aim of audits is to evaluate operations, activities, facilities, equipment, personnel and procedures to assess performance effectiveness, identify potential deficiencies, provide feed-back to management, and ensure implementation of timely corrective action.

Audits will be scheduled at Suppliers facilities based upon past experience of Suppliers:
- for new Suppliers if not certified ISO 9001 Standard version 2000 and/or assessed upon EN/AS/JISQ/9100 requirements
- in case of change of manufacturing location
- in case of serious problems.

Audits may take place at the Company facilities :

- in case of change of manufacturing location
- in case of serious problems
- in case of new management process or organisation implementation
- to verify management process stability (examples: manufacturing inspections, non-conformance, configuration management).

Audits reports performed in the frame of the contract will be available for consultation only.

The Customer will have the right to be represented in the audits in the frame of the project and will be notified according to the contract.

The Customer may perform audits in accordance with the contract.

3.8. Configuration management

The main objectives of Configuration Management and control are :

- to ensure that adequate definition and control of design and equipment configuration are maintained during all phases of the project
- to manage and control the design throughout the project, including management and control of the changes (design and contract)
- to control the as-designed assignment of equipment if applicable
- to verify that the manufactured as-built configuration of hardware and software corresponds to the configuration described in the released documentation and latest approved.

These objectives will also be followed by Suppliers.

Detailed dispositions are defined in the Configuration and Data Management Plan.

PA manager will verify the application of the configuration and management plan through all phases of the project.
In particular, Product assurance will verify that the configuration items and documents are identified And that the Applicable Contractual configuration is constituted.
The PA will verify all along the project life that at each step the applied configuration is in line with the applicable one .
Furthermore, it will be a Product Assurance task to certify that the hardware and software have been manufactured and tested according to the last issue of the contractual documentation.

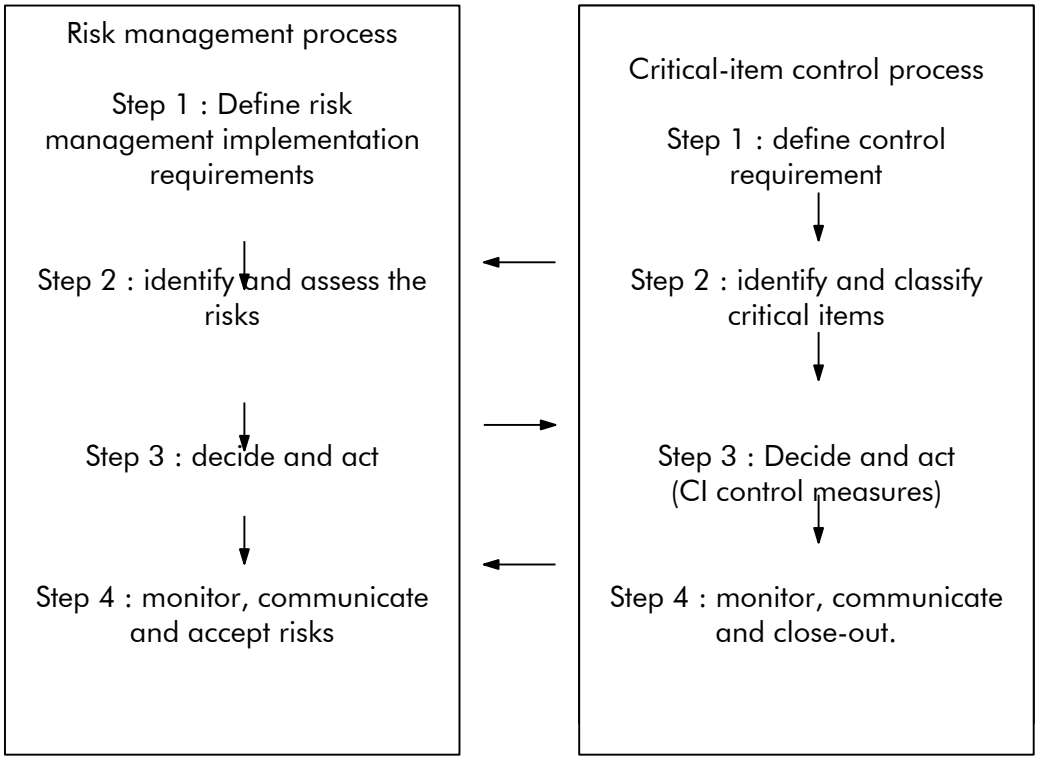
3.9. Risk management

Risk management is an iterative process through the different project phases in order to identify, assess, reduce and control all risks which could jeopardise the success of the project.

A risk analysis is conducted since the beginning of the project, following a Risk Management Plan in compliance with The Company procedures.

The Goal of Risk analysis is to identify items that may present particular problem to the project. This list includes the Critical Items.

The interface between the risk management and critical-item control processes is as follow (see details in ECSS-Q-20-04A as guideline) :



The risk analysis covers the following domains:

- technical documents
- architecture/design and development (including SPF, Elements with limited life characteristics, critical parts, qualification of new product, processes and technologies …)
- manufacturing assembly, testing(including heritage, handling, specific constraints, test benches, software…)
- development plan/schedule management
- contract/financial/cost.

PA manager will participate to the risk analysis and verify that the output is taken into account in the development plan.

3.10. Critical items management

The goal of Critical Item management is to list items that may present particular problems to the project, to define steps to reduce the probability of those problems occurring, and to implement effective controls. Critical Item Management will be performed using ECSS-Q-20-04A as a guideline.

The PA Manager is responsible for controlling the status of any required criticality reduction actions. Criticality reduction is performed through Mandatory Inspection Point (MIPs), audits, reviews, evaluation and qualification tests, and surveillance activities as described in the Critical Items List (CIL).

3.10.1. Definition

The Critical Item List will contain items classified as critical with consideration to the following criteria:

- items not qualified
- items which are difficult to test on ground
- items containing limited life parts (i.e., wear-out modes) in the frame of the project
- items which are highly radiation sensitive (i.e., not meeting the minimum allowable radiation level as defined in radiation requirements)
- items using non qualified, new or modified technologies
- items causing critical or catastrophically hazards
- single point failures and failures with risk of propagation (at upper level or to internal redundancy), as identified in paragraph 10.2.3.

3.10.2. Critical Item Control

The method to control the critical aspects of the designated item will be defined in the CIL.

Provisions for Critical Items Control may include one or more of the following, depending upon concerned classification criteria and qualification status/maturity of design (existing or new) of the critical items:

- design approach and applications
- life testing of prototypes or production samples, and extension or normal test or burn-in
- special handling procedures for hazardous items such as grounding of containers, operators, and work stations, for items sensitive to static electricity
- special quality provisions, inspections at intermediate steps in processing and test, specialised inspection and measuring equipment
- destructive testing samples of materials lots and production batches, non-destructive testing of flight hardware materials as applicable
- methods of controlling or improving degradation behaviour
- increase of intensity and/or frequency of quality inspection
- specific trend analysis for critical parameters. These parameters will be recorded and analysed throughout the life of each critical items.

3.10.3. Critical Item List

Each company having design responsibility will be required to submit a CIL according to the SOW.

Identification of critical items and the special provisions for each item will be subject to the Company approval. These CILs are reviewed by each Supplier, and are provided to the Customer for establishment of the CIL.

3.10.4. Critical Item Tests

Critical item tests (e.g., life tests) will be performed as indicated on the CIL. All testing will be in accordance with formally documented and controlled procedures. Failures during critical item testing will be reported in accordance with the non-conformance reporting system.

Critical parts/materials/subassemblies testing, except long-term life tests, will be completed before the first satellite acceptance testing.

3.11. CUSTOMER RIGHT OF ACCESS

The access to relevant quality documentation and records in The Company and in its Suppliers will be offered according to contract dispositions.
For confidential technologies, documentation review could be delegated to agencies or government organisations during validation or revalidation activities.

4. quality assurance control

4.1. DOCUMENTATION & data CONTROL

Documentation shall be released and controlled in accordance with the Configuration and Data Management Plan.

Particular attention will be paid to reviews of drawings, specifications and other technical data of the new design areas to ensure that the quality requirements of the project will be met in a timely and economical manner.

The adequacy and scope of design and development documentation, including that covering document from Suppliers, will be verified through review.

Product Assurance reviews and approves Qualification and Acceptance Test procedures, verifying that they list tests and measuring equipment and include step-by-step methods, making sure that acceptance and rejection criteria, test equipment set-ups, preliminary checkout instructions and environmental conditions are clearly stated.

Proper data and documentation exchange procedures and formats are set up throughout the project organisation.

Any obsolete documents and data retained for legal or knowledge preservation purposes are suitably identified.

4.2. product assurance documentation

Product Assurance documentation will include in line with SOW :

- product assurance plan
- product assurance requirements to Suppliers
- qualification status list (QSL)
- critical items lists (CIL)
- dependability and safety analyses
- parts (EEE and mechanical), materials and processes lists and documentation
- software quality assurance documentation
- inspection reports
- End Item Data Package (related to PA documentation)
- major non-conformance/failure reports
- RFW's
- quality records.

Quality records will provide objective evidence of complete performance of QA tasks and will demonstrate achievement of the required quality. They will be stored in safe conditions which prevent alterations, loss or deterioration and will be retained for the period specified in the SOW. They will be readily accessible and retrievable whenever they are needed.

Submission to the Customer for approval, review or information, will be as defined in the Contractual

Documentation Requirements List of SOW.

4.3. Stamp control

Stamps control will be used to signify the completion of manufacturing or test steps. The use of the stamps will be restricted to authorised personnel. Stamps will be traceable to individuals responsible for their use. The use of electronic signatures or bar codes in place of stamps is acceptable provided that similar traceability and responsibility records are maintained and available.

4.4. Traceability

A system is implemented to ensure the full traceability for all parts, raw materials and manufactured assemblies and also for operators involved in the manufacturing process.

Flight EEE parts traceability is maintained from incoming to installation on hardware and will be only related to manufacturing lot or date code or batch number.

4.5. Metrology and Calibration

Metrology control is implemented to ensure calibrated status of equipment used for measurements during inspection and formal test like qualification and acceptance testing.

Calibration control will include:

- verification of periodic calibration of measurement equipment by calibration laboratories
- checking of calibration chain status of inspection and test measurement devices before use for formal testing (for usual measurements, use of international and national standards)
- identification and separation of non calibrated equipment
- participation for non conformance review when measurement results indicate potential calibration error.

Metrology control will be implemented by calibration laboratory with QA verification of appropriate calibration status.

4.5.1. Calibration and Maintenance Programme

Records of each test equipment, tool, gauge model, manufacturer and performance will be maintained.
These records will be used to determine need for corrective actions. These corrective actions may include calibration period changes, preventive maintenance or removal of measurement equipment from use.
Each calibrated equipment will be provided with a tag or decal indicating:

- validity of calibration
- designation of calibration department.

4.5.2. Traceability

Reference standards used for calibration must be traceable to National Standards. When state-of-the-art requirements cannot be satisfied by these standards, specific internal reference standards will be developed.

4.6. anomalies & Non conformances control system

Anomalies (any deviation from the expected situation) are internally processed with PA control for implementation of corrective actions . In the frame of the project, the PA will ensure that each anomaly does not fall under the non conformance definition of § 4.6.1. If the anomaly is a non conformance, it will be processed as defined in § 4.6.1.3.

Methodology will be implemented to identify, document, manage, investigate and resolve non conformances that may occur during the manufacture or test of qualification/flight hardware and software and associated validated EGSE equipment in line with ECSS-Q-20-09.

Non conformance reporting and control are under the responsibility of PA. Non conformances are submitted to an NRB for disposition. Design engineering, reliability, safety, parts, materials, and other disciplines will participate when requested by the Manager NRB Quality Engineer. Non conformances will be documented on an non conformance Report.
NCR formal closure is done by PA manager (in particular the following points will be verified : Dispositions issued and approved by NRB members, justification files provided, dispositions implemented and certified)

4.6.1. Definition of Major and Minor Non conformances

A non Conformance is defined as non-fulfilment of a **requirement** [ISO 9000:2000]
Non conformances shall be classified as, either Major or Minor on the basis of their consequence as specified in ECSS-Q-20-09.

4.6.1.1. Major Non conformances

A Major non conformance is one that departs from contract requirements involving safety, performance, lifetime, reliability, availability and maintainability, physical or functional interchangeability.

4.6.1.2. Minor Non conformances

Any non conformances which do not impact any areas specified here above.

4.6.1.3. Processing Level

All major non conformances are notified in accordance with the Statement of Work to the next higher level of the product breakdown structure with proposed activities to be done.

This level will evaluate the potential impact.

a. If there is no impact at its level the non conformance processing will be performed together with the lower level.

b. In case of impact at its level the non conformance will be notified to the next upper level.

Upper levels will perform with the same policy according to the chart in Figure 4.6.2.3-1.

Upper levels will have the right to review the non conformance classification and status during PA progress meetings, audits, MIP's ...

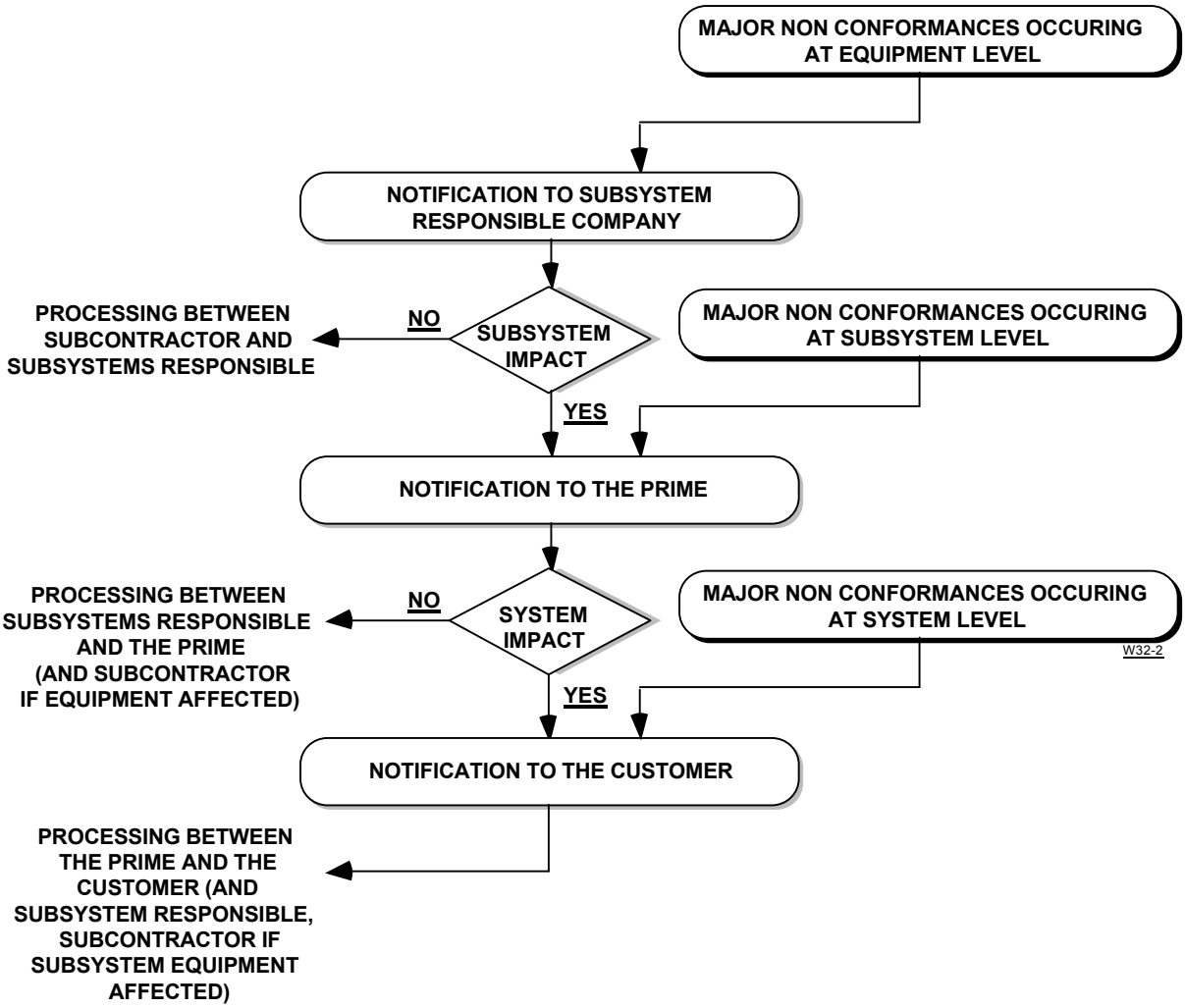


FIGURE 4.6.2.3-1 NCR/NRB FLOW DIAGRAM

4.6.2. Non conformance Review Board (NRB)

An NRB will be organized for the purpose of dispositioning non conformances and failures. The NRBs will be responsible for the investigation of causes and corrective actions including retest programmes. The NRB will:

- review and evaluate the non conformance to determine the cause of non conformance (special attention will be paid on any non conformance with unidentified root cause)
- recheck classification for non conformance
- check the impacts on the qualification status
- review records of previous similar or identical non conformance, if applicable
- determine a disposition and decision for corrective actions including actions to preclude recurrence
- decide upon necessity to perform failure analysis
- approve recurrence method and procedure for repair or rework, if applicable
- ensure accurate records of NRB actions
- define retest requirements, if applicable
- determine if a Request for Waiver is to be issued to formalize deviations from the required baseline in case of "use as is" or "repair" disposition
- verify if the hardware is flight worthy (overload, thermal stress ...).

Unanimous agreement of NRB members is required. Immediate disposition by the NRB is required to avoid impact on project schedule and cost.

Non conformances that do not adversely affect end-item safety, reliability, durability, performance, interchangeability, or other basic contract objectives, may be dispositioned, "use as is". When this disposition is used, a statement of the reasons considered appropriate will be documented on the NCR.

NRB voting memberships are System or subsystem engineering Manager, PA Manager or deputy.

On request Design, manufacturing and test engineers and other experts may participate as consultants.

The chart 4.6.2.3.1 defines the NRB level of participation depending on the level of occurrence and processing.

The Customer will be invited to participate as NRB member in the processing of potential Major Non Conformances at Customer level

4.6.3. Non Conformance Dispositions

Non conforming articles or materials are withheld from further operations awaiting disposition by authorised personnel under the foregoing conditions:

- if the non conformance is such that completion of operations or rework to established drawings, specifications, standards, or procedures will provide correction, this disposition is recorded and normal inspection and test operations are carried out during and after this rework
- if the article or material is obviously unfit for use, it will be dispositioned as scrap and procedures followed in identifying, controlling and disposing of it

- if an article or material is found to be non conforming on receipt, it may be dispositioned as return to Supplier. Copies of all information describing the non conformance will be returned with the articles so that adequate remedial and preventive action can be taken
- if articles or material can be repaired in accordance with manufacturing standards, shop order, or precedent NCR
- if further investigation is required to locate and define the non conformance
- if, before beginning satellite acceptance or qualification testing, non conformances exist that do not adversely affect safety, reliability, durability, performance, interchangeability, or other basic contract objectives of the end-item, the item may be dispositioned "use as is", or repaired.

4.6.4. Non conformance Reporting

The non conformance control system will include written procedures for the reporting and complete documentation of non conformance and activities.

Major non conformances with respect to contract requirements will be reported by The Company to the Customer.

The Company and Suppliers will prepare periodic status summaries of major non conformances and the progress of their disposition, corrective action and close-out. This status will be transmitted to the Next higher level Customer on a periodic basis as defined in the SOW.

4.6.5. Non conformance Status List

Minor and Major Non conformances status list will identify the non conformance report number, problem, problem cause, and close out status. This non conformance status list will be submitted periodically to the Next higher level Customer and will be included in the Acceptance Data Package. The minor NCR list will be in native language.

4.6.6. Trend Analysis

Each company will use its system of non conformance trend analysis to review and analyse non conformances for trends and to determine and implement corrective action. The trend analysis will include a periodic review of open problems across the project and those from other in-house projects for potential impact.

4.7. Alerts

The alert system allows the prompt interchange of information on failures or problems which can affect more than one user or can recur in other projects or circumstances if no preventive actions are taken.

It processes the external alerts and the internal major non conformances involving a generic risk on other products.

The processing is systematic and involves the Chief Technical Officer (CTO) for major decisions.

When the standard organization is not suited to the complexity or the gravity of the alert, the CTO can appoint an independent inquiry board involving external experts as necessary .

The alert processing aims at :

- identifying the root causes
- identifying the alert perimeter,
- identifying the alert fielded projects,
- specifying the protocol of actions for dealing with the alert on each alert fielded projects.

The Company involves the suppliers whose products delivered to The Company are in the alert field.

On receipt of the protocol, the project notifies the alert to the customer. When a non conformance is proven, a non conformance is issued at project level and a NRB is notified to the customer.

Customer information is maintained through the project organization.

4.8. Handling, storage and preservation

4.8.1. Handling

Quality Assurance personnel will verify that manufacturing, assembly integration and test documents contain relevant handling instructions where necessary.

During all phase of incoming inspection, manufacturing, assembly, integration and testing, QA personnel will monitor the handling of hardware items.

Inspections at predetermined points will ensure that all items are adequately protected against deterioration of quality characteristics by handling.

Special boxes, containers and transportation vehicles will be utilised for items which are susceptible to handling damage. Special handling equipment and controlled areas will be provided for proper handling of critical items.

4.8.2. Storage Control

Stored items will be protected against contamination deterioration, damage, or possible confusion of the items. Adequate safety and cleanliness, preventive maintenance and age control will be provided. Limited life items will be specially identified and controlled with respect to shelf life time.

All hardware items will be stored in environmental controlled areas with limited access for authorised personnel only. Special storage environment will be provided, if necessary.

4.8.3. Preservation

Preservation will be accomplished to protect hardware against deterioration, contamination and damage or degradation during transport and storage.

Flight hardware will be packed in specially provided containers. These containers will be designed for the hardware and will take into consideration any requirement with respect to configuration, fragility and environment. Components, assemblies and parts shipped separately will be packed in accordance with the applicable specification.

4.9. Statistical quality control and analysis

The Company implement a statistical quality control and analysis control such as sample inspections plans, determination of quality levels, statistical process control and process capabilities studies may be used whenever such methods are suitable to maintain or improve the required control of quality.

4.10. WAIVERS AND DEVIATIONS

Waivers and deviations serve to identify the areas of non-compliance to project requirements and to obtain formal Customer agreement for not meeting these requirements.
Systems or Subsystems Engineering will justify and identify impact of each non conformance. Requests for waiver or deviation will be submitted to the Customer through the project control (for their cost/schedule impact) and the project manager.
Each waiver or deviation will include: a unique reference number; the title or subject; the name of the equipment, requirement, or performance parameter; the work breakdown structure number that is applicable; a description of the request; a justification of the request (including the reason); and the date of issue.

4.10.1. Definition of waiver and deviation

A deviation is a written authorisation to depart from the originally specified requirements for a product, prior to its production.

A waiver is a written authorisation to accept products which during production, or after having been submitted to, inspection or tests, are found to depart from specified requirements.

4.10.2. Waiver/Deviation Reporting and Approval

Requests deviations are issued for each non-compliance versus the applicable documents of the contract. The need of Request for waiver will be identified and recommended by NRB according to ECSS-Q-20-09B.
Waivers and deviations affecting requirements of the contract will be submitted to the Customer for approval.

5. DESIGN AND DEVELOPMENT CONTROL

5.1. GENERAL

Coordinated PA actions shall be planned throughout the design and development phases in order to assure that functional and technical requirements are consistent and that the design will fulfil the requirements.

QA personnel will ensure that the design rules and guidelines related to produceability, repeatability, inspectability, testability and operability are properly implemented in the design.

These actions will include:

- a close survey of the adequacy of design and development documentation
- the performance assessment of design reviews in line with SOW
- the critical items control plan as detailed in § 3.10.2
- the approval of design verification matrix as detailed in § 5.2
- the qualification testing witnessing
- the safety programme plan as detailed in § 9.
- the dependability programme plan as detailed in § 10.
- the software quality assurance programme plan as defined in § 11.
- the EEE parts plan as detailed in § 12.
- the radiation hardness plan as detailed in § 13.
- the materials and processes control plan as detailed in § 14.

5.2. VERIFICATION

Verification activities provide objective evidence that the designs meet their specified requirements and that any non-compliance is identified. This is the key to all demonstration documents such as technical notes, test reports, and qualification reports, and allows verification of the fulfilment of each requirement.

The Suppliers will be required to demonstrate compliance of equipment, subsystems, and spacecraft with specified requirements according to their relevant development and qualification tests.

Verification shall be accomplished by analysis, similarity, inspection or test. PA, Systems, or Test Engineering (depending on the level of integration) will verify that necessary development and qualification tests are conducted.

Verification activities will be implemented in the early phase of the project and will be provided through specific matrices (as compliance matrix, validation and verification matrix,..) according to the SOW reflecting the status of design at each design review

PA manager will verify regularly the progress of the different matrix completion

5.3. DESIGN REVIEWS

The Company will establish and conduct a programme of planned, scheduled and documented design reviews at the system and subsystem levels.

Each formal design review shall constitute a comprehensive critical audit of the design. The reviews aim to validate the design approach, achieve the required performances and provide recommendation for corrective action as necessary.

Each review shall be supported by a specific data package, including analyses and test data appropriate to the maturity level of the designs.

Design review meetings will be held at The Company or Supplier facilities as applicable.

Management of design review and submission of related data packages will be as defined in the Statement of Work. PA manager and/or Product PA manager will participate in design reviews at level N, with appropriate support from PA engineers (parts, materials and process, reliability, safety …).

5.4. Qualification

5.4.1. Equipment Qualification Status Review (EQSR)

In the early phase of the project, Equipment Qualification Status Review (EQSR) will be conducted to perform a comparison between the proposed unit and its qualified heritage

The review is led by the PA manager. The review board consists of the program manager, engineering manager and PA manager of each company (The Company , Subcontractor, Supplier). Other persons will participate as required or as delegated by the review board.

This review is an equipment development risk analysis and it will allow to agree on a development plan (development models to be manufactured, design reviews to be hold, schedule…)

The Subcontractor will justify a design/development/qualification category for each item of flight equipment as described below. This categorisation needs the approval of The Company and his Customer.

Each hardware will be assigned to one of the following "state of development" categories.

For Harness, Thermal control and structure (except primary structure), the review of qualification status will be held through the PCBs or the materials and processes reviews.

Remark: the detail of Qualification philosophy and model, based on justified Subcontractor proposal have to be agreed during EQSR.

Category

	Definition of category	Typical qualification philosophy
A	Hardware specifically designed and qualified for the project (no flight experience).	Qualification testing on EQM or QM. Note: early validation of design modification may need the use of BBM or EM.
B	Hardware derived from equipment developed and qualified in the frame of another project but with design, manufacturing and/or control procedures or with parts, materials and processes that must be changed for the present project.	Complementary qualification on PFM (or EQM/QM for major modifications). Note: design adjustment may need the use of BBM or EM.
C	Hardware developed and qualified in the frame of another project, and whose design, manufacturing and control procedures, as well as parts, materials and processes need no modification for the present project, but which are subject to more stringent specifications (e.g. Higher performance, longer operational life, environment specifications, etc...) For use in the present project.	Complementary qualification on PFM: - PFM sequence and associated justification documentation have to be established to cover all the effects of new more stringent environmental conditions.
D	Hardware developed and qualified in the frame of another project, whose design, manufacturing and control procedures, as well as parts, materials and processes can be used for the present project without modification and whose application in the present project exposes it to environments and requires performance, reliability and life consistent with those demonstrated in the previous qualification project and consistent with the qualification requirements of the present project.	Acceptance testing (no qualification necessary) - FM.

This review shall be held as far as a heritage is identified:

- in case of Category A, the design reviews shall be organised in line with the development plan
- for Equipment Category D (fully recurrent), the EQSR may be held without participation of the Supplier provided the EQSR forms are established and confirmed by the Supplier concerned. The EQSR will be organised if modifications are identified during the Company review.

5.4.2. Qualification Status List (QSL)

A Qualification Status List (QSL) will be issued at equipment, subsystem and system levels. This document summarises for each configured equipment, by reference to design definition, or build standard, the test requirements and results, and the manner by which a qualified status, compliant with the Customer's project requirements, is achieved.

The list will include the following information:

- Equipment designation : identification of hardware by name, Configuration Item number and model
- Next higher assembly level
- Manufacturer's name : Supplier

- Proposed category A, B, C, or D as defined hereabove
- Current qualification status/screening and applicability of qualification test versus requirements: with applicable qualification requirements (with reference documents) and relevant RFDs
- basis for qualification (qualification test results, heritage, and qualification on other projects) programme on which the qualification test was conducted issued from specific Equipment Qualification Status Review as far as a heritage is identified (Applicable documents which show the qualification achievement and relevant RFWs issued during the test campaign)
- Project on which the test was conducted
- test Report number.
- Identification of developments models (EM, EQM, QM, PFM) to be manufactured and tested for the project if necessary.
- the qualification status

The qualification model will be fully representative of the flight model and any differences have been analysed to evaluate their effects on the qualification status.

6. Supplier & Procurement control

6.1. general

The Company establish PA Specifications to be imposed upon Suppliers & Procurement sources through the QMS-QM 100141811S-EN.

These PA requirements are directly the application of the ECSS-Q-20B plus additional requirements or precision issued from The Company lesson learnt system.

The Supplier will submit a PA plan and a compliance matrix that will define all PA activities consistent with these PA requirements.

6.2. Supplier Selection & Procurement Sources

Suppliers and manufacturers having a quality assurance system adequately conforming with the Customer QA requirements will be selected.

Audits will be scheduled at Suppliers facilities based upon past experience of Suppliers (see § 3.7)

For Suppliers not yet selected before contract award The Company selection is conducted by assessment based on evaluation of the offered PA programme sustained by pre-awards survey as appropriate. Formal surveys of manufacturers' and Suppliers' facilities and quality assurance system will assure that they are capable of supplying items or services which meet all quality requirements.

6.3. Supplier & procurement Control

The purpose of Supplier survey is to ensure that PA Requirements are met by the Suppliers during design, procurement, manufacturing, assembly, and test phases.

The Company PA will be in charge of Supplier survey and will have direct contact with the Supplier's PA managers.

The degree of survey of the Suppliers by The Company will vary depending on the overall evaluation of the previous product quality, performance, facilities and organisation and the magnitude and complexity of the tasks to be performed. The level of surveillance may include:

- EQSR (except for Category A)
- parts, materials and processes reviews
- design reviews
- MRR
- MIP
- TRR/TRB/DRB
- NRB.

Requirements placed on Suppliers will include a systematic non conformance reporting providing a closed loop system to ensure effective analysis and corrective action. Reporting documents may be

those used in the Supplier's existing system but format and contents must be approved by The Company. A feedback system for reporting non conformances will be initiated and maintained in accordance with the requirements of the Statement of Work.
In case of any problems, The Company reserve the right to interfere in the lower tier suppliers activities in the frame of the project.

6.4. Incoming Inspection

Incoming inspections will be carried out in accordance with the procurement documents and the applicable engineering and QA requirements. Additional specific project requirements may be applied by QA instructions which are used to detail inspection procedures. Each received flight type item is identified on the incoming inspection report which also serves as record to provide traceability to the Supplier.

Items that have been source inspected are checked for identify, damage and evidence of accomplishment of the source inspection. Where required at the option of The Company (e.g. because of the complexity of source inspected items) further testing is accomplished.

Critical items and age-sensitive material will receive special attention during incoming inspection as defined by QA instructions. These instructions will provide the inspector with all necessary information with respect to detailed procedures, methods and techniques to be applied.

All material removed from its sealed container is identified with appropriate inspection stamp when released by incoming inspection.

7. MANUFACTURING AND AIT QUALITY ASSURANCE

7.1. GENERAL

Articles procured manufactured or assembled by The Company and its Suppliers shall be subjected to Quality Assurance controls including inspection and test programmes in order to ensure that the completed article is compliant with applicable drawings and specifications and to ensure that production activities do not degrade the quality designed into the product.

7.2. QA Management and Planning

QA activities will be planned, carried out and recorded in compliance with the project schedule.

The project QA documentation will be clearly identified and controlled.

The assigned QA personnel will report to the project PA Manager on the result and progress of QA activities. The QA task planning will be initiated by the PA Manager to be compliant with the overall PA task planning. This will include the availability of personnel, performance of QA tasks and preparation, review and acceptance of documentation.

7.3. Manufacturing and Stores Control

Items manufactured or assembled by The Company and its Suppliers will be subject to QA inspections and test programmes in order to ensure that applicable contract, drawing, specification and procedure requirements are fulfilled with the completed article.

Quality Assurance will ensure that the material inspected is compatible with the configuration indicated on the controlling shop order, that controlled documents are used, and that the inspection records reflect the as-built configuration of the item produced.

Age-sensitive materials and articles are clearly marked to show when the lifetime will be expended. Bonded stores located adjacent to fabrication and assembly areas maintain complete records and identification of age-sensitive parts, materials and supplies. QA surveillance is maintained and only conforming items are allowed to enter bonded stores.

7.3.1. Manufacturing Flow Charts and Shop Orders

Flow charts will be prepared to indicate all operations during manufacturing and equipment level assembly in sequence. These flow charts will also identify key and Mandatory Inspection Points.

Based on the flow chart, shop orders will be issued detailing the manufacturing flow serving as well for authorisation and control of manufacturing and assembly steps.

QA personnel will review the shop orders for:

- proper identification
- inclusion of adequate inspections
- consideration of relevant project requirements
- use of latest issued of documents referred to
- use of released parts and materials
- use of approved processes.

7.3.2. Manufacturing Readiness review (MRR)

For flight hardware subject to specific adaptations of design and/or manufacturing process with respect to the standard production, a dedicated internal review called Manufacturing Readiness Review (MRR) will be held prior to release the manufacturing

This review will:

- verify that the design is complete and tests results so far are satisfactory to provide high confidence that the item is ready for manufacturing
- verify that parts, materials and processes are qualified, documented and approved by The Company
- verify that the manufacturing flow chart has been prepared and approved by The Company, including his own MIPs
- verify adequacy of manufacturing equipment's and facilities used in implementation of critical processes.

The Review Board will include representatives of PA, design and manufacturing.

7.3.3. In-process Inspections

In-process inspections will be carried out in accordance with the applicable manufacturing documentation to:

- verify the use of controlled work instructions (drawing, manufacturing procedure, shop order, process documents, standards)
- verify that previous steps on the shop order are signed or stamped off
- assure that process verification samples are provided and tested/inspected as defined in the manufacturing specification
- review workmanship
- perform visual inspection
- to measure parameters as applicable
- prove logging of operating times during manufacturing or test for limited life items as required
- check if environmental conditions are observed if specifically specified.

7.3.4. Key and Mandatory Inspection Points

Key and Mandatory Inspection Points (KIP/MIP) will be performed with acceptable results before further manufacturing or test. KIPs and MIPs will be defined in the Manufacturing Flow Chart at equipment level and in the Assembly, Integration and Test Plan for system level. For critical items, in-process MIPs may be defined according to the criticality. Key Inspection Points will be performed in-house without participation of next higher contract level. Mandatory Inspection Points involves The Company and the Customer.

The Customer will be informed of the MIP planning and will be notified in advance of MIP performance and will be invited to participate at his discretion. The Customer will be requested to identify in advance those MIPs in which he would wish to participate.

If the Customer has not participated to the MIP, the minutes of meeting or MIP report will be provided to him.

7.3.5. Workmanship Standard

Manufacturing standards provide workmanship and inspection criteria for operations to be performed. Where necessary, new or revised standards meeting design requirements, will be developed to cover any special requirements of the project.

Manufacturing standards are called out on applicable drawings, plans or procedures and are readily available to manufacturing, assembly, test and inspection personnel.

7.4. Assembly, Integration & TEST Surveillance

Quality Assurance surveillance of assembly and integration activities will assure that all tasks are accomplished in line with applicable and released procedures and relevant QA regulations including documentation as required.

An AIT plan states the tests to be performed on each development model or flight model, in order to ensure that the requirements of the equipment specifications are met under applicable environmental conditions.

Test procedures describe the manner of performing each test listed in the AIT plan: purpose of the test, applicable documents, measurement principle with list of measurement equipment's used, input data, sequential procedure, success criteria, output data.

7.4.1. Inspections

Based on the AIT plan, inspections will be performed in line with established inspections procedures. Results will be recorded either by separate inspection reports or by entries in relevant AIT procedures as requested by the inspection procedure and depending on the complexity of inspection. Any non conformance detected during the inspection will be recorded on a non conformance report and processed according to the non conformance processing procedure.

The inspection status will be recorded in the Log documentation and will be maintained current.

Mandatory Inspection Points as defined in the AIT plan will be performed during the assembly and integration phase.

7.4.2. QA Witnessing during assembly and integration

Assembly and integration activities will be witnessed or monitored by QA personnel as defined in the

AIT plan.

- check of plans and procedures with respect to applicability
- regulation and observation of personnel access to assembly and integration areas
- control of critical items
- verification of implementation and maintenance of lists for hardware configuration status recordings leading to the final as-built register
- ensuring proper handling according to procedure
- ensuring adherence to safety provisions
- maintaining of ESD, cleanliness and contamination control
- control of specified environment
- maintaining of non conformance reporting system
- verification of correct control of limited life items
- recording of all activities for traceability (i.e. on Logsheets, identification labels, working copy of procedures, inspection reports)
- preparation of the acceptance data package
- control of the non flight item list up to the complete removal before launch.

7.4.3. Test Readiness Review TRR

A Test Readiness Review (TRR) is conducted to release the hardware prior to flight qualification and acceptance tests.

Following operations are conducted:

- verify that the documentation associated to the hardware is complete and available for the test release
- verify whether all NCR related to production are processed
- perform visual inspection and verification of hardware, test set-up, facilities and environment with regard to test configuration
- validate test bench configuration (both hardware and software) for the test
- validate test organisation and dispositions.

For sub-contracted test, a dedicated Facilities Readiness Review will be organised according to the Contract with ECSS-Q-20-07A as guideline.

7.4.4. Test Surveillance

During testing, Quality Assurance personnel will :

- ensure that the test procedures are followed and that all test equipment and facilities used are in accordance with relevant test documents
- ensure complete and accurate recording of data and test results
- ensure document non conformances and their dispositions are documented
- ensure that all planned/unplanned events during testing are recorded
- ensure that calibration status of test set-up and measurement devices are checked
- witness all critical test operations
- witness the environmental conditions and preventive provisions for ESD and cleanliness/contamination

7.4.5. Test Review Boards (TRB)

The TRB reviews are conducted during qualification or acceptance test of flight hardware to declare the tests results successful and authorize the release from the test facilities if applicable.

The main tasks are to examine the acceptability of the hardware through :

- review of documentation to confirm the completion of required operations
- review and analyse of test results to assure that they are within required limits, and that discrepancies are documented and dispositioned
- inspection of the hardware integrity.

7.4.6. Environmental control

7.4.6.1. Electrostatic Discharge Control

Electrostatic Discharge (ESD) Control is implemented for manufacturing, storage, inspection, assembly and test activities under the Company responsibility.

The ESD Control is supported by:

- the requirements and associated rules description
- the verification methods and periodicity
- periodic audits
- failed parts record and destructive physical analyses, as necessary
- personnel training.

7.4.6.2. Cleanliness and Contamination Control

Store, workshop, test, and inspection areas are equipped to meet controlled environmental conditions with respect to temperature, humidity and cleanliness in accordance with requirements.

When technical necessities require clean conditions for working operations related to manufacturing, assembly, integration and test of hardware, a clean area according to
ECSS-Q-70-01 will be available.

Additional provisions for contamination sensitive hardware will be provided in a Cleanliness and Contamination Control Plan, such as :

- preparation and application of special handling procedures
- definition of cleaning methods to be employed and specification of purity requirements of materials used for cleaning processes
- definition of methods to prevent contamination from clean items and assemblies
- definition of methods for measuring the cleanliness level of controlled areas.

7.4.7. Ground Support Equipment Control

GSE control is performed to ensure that MGSE and EGSE equipment will be accepted and released for use with qualification and flight hardware.

The GSE QA personnel will be available for progress meeting upon request.

7.4.7.1. GSE Hardware

The QA activities for GSE hardware will include:

- review of GSE interface drawings for compatibility with flight hardware
- performance of acceptance inspection
- survey of GSE acceptance tests
- review and approval of acceptance test results
- check of hardware release status before use on flight hardware
- assurance of adherence to applicable handling procedures.

7.4.7.2. EGSE Software

The QA activities for EGSE Software will include :
adherence to standards and procedures
review of test plans and procedures
survey of development life cycle with review at the end of each phase
participation in software validation
participation In hardware/software integration and validation
configuration Control of EGSE software and its documentation.

The software severity category for EGSE is “not significant” because in case of software anomaly , this has not impact on the mission, considering the following reasons :
The EGSE software is only used for non-operational ground activities: equipment test and during the integration phase on Communication Module or satellite.
Most of measurements and algorithms (software reuse) are validated through previous projects and for new projects, they are played with simulator, and consolidated with manual measures, as necessary.
Before EGSE connexion with a flight model, a validation of all the functions is performed with simulator (software or hardware) or with a DUT (representative model).

Refer to § 11.3 for software development quality

7.4.8. Log Documentation and Traceability

Each equipment or subsystem shall be delivered at system level with its own data package: verification of data package delivery is performed during incoming inspection.

During incoming inspection, Individual equipment or subsystem log sheet is fulfilled up to assembly on Spacecraft.

After this step, and all along AIT sequence, all events such inspections, assembly and/or tests performed on the hardware will be recorded step by step in AIT procedures. This documentation will be part of the Final End Item Data Package.
Basic contents of end item data package will be as follows:

- declaration of conformity
- as Built/as design configuration status
- non conformance status list

- reports of major non conformances
- requests for deviations/waivers
- top assembly drawing, Interface Control Drawing
- test reports
- logbook with the following content : general information, hardware configuration and traceability, hardware configuration change & status, Summary list of integration & test instructions, Non Conformances List, mate/demate of connectors recording, Operating time/cycle recording, Chronological order of events related to integration and test activities, reporting of all operations performed in procedure, Open works/open test list.
- user's or operating manuals, including handling, storage and transportation procedures
- MIP reports (including final inspection)
- log of actions
- suppliers EIDPs list
- loose item list (not installed items and spares)
- minutes of meeting of the Delivery Review Board.

PA manager will check completeness and consistency of the End Item Data Package as defined in the SOW and constituted by the configuration responsible
In case of equipment storage or return back to Supplier, the initial individual log sheet will be fulfilled with complete description of all events in the life of the hardware starting from incoming inspection.

7.4.9. Delivery Review (DRB)

Upon completion of the test sequence and final inspection, a formal acceptance of deliverable items will be performed. A Delivery Review Board (DRB), as contractually required, will be convened for I review of all relevant data to prove that all specified requirements have been satisfied, any deviations/waivers are properly documented and accepted and, finally, will authorise the item for delivery.

The board meeting will be chaired by the Contractor authority.

7.4.10. Marking, Labelling, Packing and Shipping Control

7.4.10.1. Marking and Labelling

It will be ensured by the PA personnel that marking and labelling for packaging, storage and shipping is in accordance with applicable specifications and procedures. In general, handling, storage and/or shipping procedures contain detailed marking and labelling instructions.

7.4.10.2. Packing

Packaging will be accomplished to protect hardware against deterioration, contamination and damage or degradation during transport and storage.

Flight hardware will be packed in specially provided containers. These containers will be designed for the hardware and will take into consideration any requirement with respect to configuration, fragility and environment. Components, assemblies and parts shipped separately will be packed in

accordance with the applicable specification.

7.4.10.3. Shipping Control

Shipping activities will be monitored by quality assurance to ensure that items to be shipped are properly preserved, packaged and identified to prevent degradation during transport. Documents and records accompanying each shipment will be verified to ensure conformance with established procedures and specifications.

Prior to shipping, inspections will be conducted to assure that all quality requirements are met.

7.5. QUALITY ASSURANCE AT THE LAUNCH SITE

Launch site operations will be performed according to detailed procedures which are approved by Quality Assurance Manager. Procedure will detail the operations required to prepare the spacecraft for launch and to verify its readiness for flight. The procedures will include quality assurance provisions integrated into the detail procedures for transportation, handling, assembly and test operational control, and will also include checklists for positive verification of complete accomplishment.

Quality Assurance will closely control temporary installation of non flight items and temporary removal of flight items, which are needed to facilitate AIT and handling of the satellite. Records of temporary installations and removals will be maintained and documented as part of the Acceptance Data Package. Each installation/removal operation will be verified and assess by the operator and the Quality Assurance representative.

A physical "accommodability box" system will be used to make obvious the status of installations/removal of temporary items (flight/non flight).

Site receiving inspection will be performed by QA to verify that all equipment and materials described in the receiving documents have been received, are free from damage, are properly identified, and that records are complete.

Quality Assurance will interface with the Customer and provide support to launch readiness review and resolution of material review actions prior to launch.

8. ground CONTROL segment product assurance

Product Assurance programme is implemented on Ground Control Segment hardware/software and on support services for operations (LEOP and IOT), according to the same basic dispositions as defined for the spacecraft, with specific adaptations to the nature of these products.

8.1. ground Control segment hardware and software

Product Assurance programme covers the following activities:
review/approval of technical requirements, of applicable rules for design, maintainability, selection and use of parts and materials.
Design assurance including:

- availability analysis based on design configuration (including redundancy types and levels, and MTBF of each unit) MTT Replace and MTT Repair, spare and repair policy with the objectives to (Italy : only performed if required):
  - assess performances in term of average availability and state on compliance wrt requirements if any,
  - provide recommendation for the appropriate level of type of redundancy,
  - consolidate the maintenance strategy in term of spare and repair characteristics as policy (numbers and delays).
- Review of safety aspects, for compliance with applicable national and international standards. This activity is covered by the CE certification.
- Implementation of design review programme.

Supplier control: review/approval of procurement specifications, participation in TRR's at equipment level, acceptance reviews. Applicable product assurance requirements are based on ISO 9001 Standard version 2000.
Quality assurance in production of hardware in accordance with QMS-QM 100141983G-EN : “Standard Ground Products Product Assurance requirements”.
Software product assurance in accordance with dispositions defined in Chapter 11.
Non conformance control according to dispositions defined in paragraph 4.6.
On-site verification of installation and performance testing of the ground section including:

- incoming inspection of units and related documentation:
  - verification of recorded as built configuration status
  - non conformance control
  - witnessing of performance testing
  - participation in final acceptance review of the ground station, review/approval of the Acceptance Data Package.

8.2. support services for operations

Product Assurance programme is implemented to ensure that support services for operations are carried out according to the required process, and are covered by controlled procedures.

This programme covers the following activities:
review/approval of technical documentation: operations plan, procedures for in flight operations
control of validation tests performed on operational procedures (factory validation tests, on-site operational demonstration tests)

change control: review/approval of change notices applicable to operational procedures and related data base
non conformance control.

9. SAFETY

9.1. GENERAL

The spacecraft, its relevant Ground Support Equipment will be designed in compliance with the relevant applicable safety requirements.

The spacecraft background will be developed with the overall objective to be free of conditions, both in design and operations, that could produce uncontrolled hazards:
first for the ground personnel and the general public
then for the Launch Vehicle, other Launch Vehicle payloads if any, Ground Support Equipment, public and private property and the environment.
The policy is applied within Prime and Suppliers through QMS-QM 100141932B-EN and QMS-QM 100141938H-EN.

9.2. OBJECTIVES

The safety engineer, operating in the P.A. organization, will assure the implementation of the Safety program in close co-operation with design engineering and the other disciplines of the same organization (RAM, Parts Materials & Processes - PMP, Quality Assurance, etc.).

An effective safety related survey of the flight equipments/GSE through all project phases including design, development, manufacturing and testing will be yielded.

Plans, technical specifications, operation and test procedures to will be reviewed to ensure that:
adequate consideration is given to safety aspects
applicable safety requirements and provisions are incorporated into design, manufacturing and testing and are properly described in the relevant documentation
changes which may be necessary as a result of safety analyses and safety recommendations are adequately implemented
Depending upon specific local National rules and laws, those activities may be conducted by the safety engineer or the occupational safety manager or the PA personnel

All proposed design changes will be evaluated and considered against safety aspects. In particular no new potential hazards will be introduced by the implementation of a proposed design change.

Furthermore, the safety engineer will review all non-conformances and waivers which can affect the applicable project safety requirements or safety-critical functions and items.

The safety engineer will be present at those reviews/meetings concerned with safety-critical functions, procedures and items.

9.3. SAFETY REQUIREMENTS

Safety requirements will be in accordance with the relevant range applicable safety regulations. Compliance with specified requirements and criteria will be verified during the safety analytical process.

Those safety requirements are declined in the documents:
QMS-QM 100141932B-EN : Safety requirements for unmanned missions - Part 1: Safety assurance programme;
QMS-QM 100141938H-EN : Safety requirements for unmanned missions - Part 2: Detailed technical safety requirements for flight hardware and ground support equipment;
which are applicable to all parties involved in the design and operations of the satellite.

9.4. HAZARD ANALYSIS

Relevant Range Safety Regulations will be used during hazard analyses activities. ECSS-Q-40 and NASA document JSC 11123 STS Payload Safety Guidelines Handbook, NSTS 13830, NSTS 1700.7, KHB 1700.7 may be used as a tool.

They provide a description of potential hazards associated with spacecraft element operations or interfaces. They include guidelines for the elimination and/or control of hazards.

The Equipment/Assembly/Subsystem/System safety engineer will prepare and submit to the higher level of responsibility the safety analyses presented in this plan, in accordance with the Statement Of Work agreements. The primary objectives of the safety analysis process is to ensure that the applicable Safety Requirements are met and to obtain concurrence with the safety assurance process conducted by the Launch Site Agency. The safety analysis can use inputs from other analyses (FMECA, Fault Trees, Cause-Consequence Diagram, etc.).

The results of the analyses will be presented on hazard report forms (JSC 542 form may be used).

9.4.1. Hazard Reduction Precedence Sequence

The identified hazards will be eliminated or controlled to assure compliance with each applicable requirement specified in the relevant range safety regulation.

The order of precedence will be:

- Hazard elimination
- Hazard minimization
- Hazard control:
    - Design selection:
        - Failure tolerance design
        - design for minimum risk
    - use of automatic safety controls or devices
    - use of warning devices
    - use of special procedural controls.

9.4.2. Hazard Management

Hazard management will include the considerations and techniques used to accept or reject the ~~(~~hazards~~)~~. More precisely, hazard management for the satellite programme will include the hazard tracking, hazard resolution and resolution verification process (i.e., that efforts which occur after the hazards have been identified and evaluated).

During hazard analysis special emphasis will be placed on:

- prevention of structural failure
- selection of metallic materials (compliance with the stress corrosion requirements of ECSS-Q-70-36 or MSFC-STD-3029) for safety critical items
- compliance with MIL-STD-1522A for designing pressure vessels
- fracture control procedures to prevent propellant tanks structural failure
- compliance with MIL-STD-1576 for pyrotechnic systems except there will be no use of safe and arm device
- control of potential ignition sources
- non ionizing radiations hazards.

9.5. SAFETY ASSESSMENT

The satellite design will be reviewed in the light of compliance with the safety requirements. The following is a discussion of some technical aspects.

9.5.1. Failure Tolerance

No single failure or operation error will cause a critical hazard and no combination of two failures, operator errors, or radio frequency signals will cause a critical or a catastrophic hazard.
Critical and catastrophic hazard classification is provided in paragraph 10.2.5.

9.5.2. Control of Hazardous Functions

A function that may result in a critical hazard will be controlled by two independent inhibits. At least one inhibit will be monitored.

A function that may result in a catastrophic hazard will be controlled by a minimum of three independent inhibits. At least two inhibits will be monitored.

The liquid propellant system of the satellite will meet the applicable requirements with respect to mechanically independent flow control devices and electrical inhibits.

Monitoring and safing capability will be provided as required for controlling hazardous functions such as thruster firing.

9.5.3. Failure Propagation

All safety controls will be designed with the intent of precluding failure propagation from one to another control in series.

9.5.4. Redundancy Separation

All safety critical functions requiring redundancy will be designed with the intent of precluding failure propagation from main to redundant or vice versa.

9.5.5. Verification Requirements

A system of verification for all identified safety critical equipment or subsystems will be provided for the spacecraft.

9.5.6. Hazardous Procedures

Technical operating procedures are planned to be used on the spacecraft to control potentially hazardous operations on the ground:
at the Payload Processing Facility
at the Hazardous Processing Facility (Fuelling and encapsulation operations).

9.6. INTEGRATION AND TEST OPERATIONS SAFETY

The integration and test programme will be implemented for testing flight hardware prior to integration with the launcher. The spacecraft will be assembled and receive a complete system production acceptance test before shipment to the launch site. The GSE components will be acceptance tested and then will be used with the flight system at the launch site.

Launch site checkout operations include system testing of both the satellite and GSE individually and finally integrated system testing.

The Company will control integration and test operations extended up to that point when the spacecraft will commit for launch. During the assembly and test operations, the safety functions, consisting of system safety and occupational (Industrial) safety, maintain an active role in the manner described below. The two safety functions complement each other to provide safety in design and safety in operations.

9.6.1. Safety Reviews, Test Planning and Data

Product Assurance reviews test documentation to ensure that test procedures directing hazardous operations reflect conformance to safety requirements for the protection of personnel, facilities, and equipment, and to minimise the hazards associated with the test performance. System Safety reviews test results to determine any anomalous conditions that impact the safety of the design under consideration and to assure compliance with safety criteria.

9.6.2. Safety Monitoring of Tests/Operations

The safety functions, consisting of system safety and/or occupational safety monitor checkout operations that are designated as hazardous.
The following activities will reflect the safety effort:

- safety surveillance and inspections of activities, facilities and equipment will be maintained to ensure compliance with safety requirements
- safety surveillance and inspections of activities, facilities and equipment will be maintained to detect unsafe conditions or practices with follow-up corrective action where indicated
- personnel training and certification activities will receive active safety participation to assure competence in personnel assigned to hazardous operations.

9.6.3. Safety Review of Procedures

The safety functions, consisting of system safety and/or occupational safety work closely with operations personnel in the development of procedures which are used for the pre-launch integration and checkout of the systems. The procedures containing hazardous operations will be reviewed. In addition, those procedures will also be reviewed and approved by the Range Safety.

9.7. SAFETY APPROVAL PROCESS

The Company will perform safety analysis for the spacecraft, the ground support equipment and operations, and provide those analyses in a system safety data package.

Sufficient data will be provided to confirm compliance with the applicable safety requirements and concurrence with hazard analysis results.

This Safety Package will be provided by The Company to the Launch Services Customer which will provide it to the selected launch agency.

This Safety Package will be submitted in an incremental three phases approach.

The documentation content to be provided for safety submissions Phases 1 to 3 will be the same for all launch agency.

Note: In addition, for an ATLAS or DELTA Launch, the system safety package provided will support the development of the Missile System Pre-launch Safety Package (MSPSP) required for safety approval of the spacecraft design, tests and launch activities.

The MSPSP, written by the launch agency, is the data package which describes the launch vehicle, the payload (i.e. the Spacecraft) and its hazardous subsystems and operations.

The MSPSP is formally approved by the Eastern Range or the Western Range.

Each range safety organisation will review and comment each provided submission phase documentation.

A formal safety review may be planned by the range safety organisation to close each phase.

In addition, on request, The Company will support the Launch Services Customer during Safety Working Group and Technical Interchange Meetings that will be held to ensure exchange of the safety data necessary to verify compliance with range safety requirements.

9.7.1. Phase 1 Submission

A file will be prepared containing a description of the hazardous systems and items.

This document will also cover all safety related activities: component choice, safety and warning devices and in general all data concerning the evaluation of risk level.

The range safety organisation will classify the described hazardous systems and will declare if any special requirements are imposed by its safety department.

9.7.2. Phase 2 Submission

The hazardous system manufacturing qualification and acceptance documentation will be submitted. The range safety organisation will comment and approve the submission.

9.7.3. Phase 3 Submission

Acceptance data and operating procedures for systems classified as hazardous will be submitted.

The Company will also provide:
proof tests certificates for pressurised vessels (spacecraft items plus Ground Support Equipment)
proof tests certificates for handling devices including slings, shackles, etc.

- various required certificates (personnel qualification…).

10. dependability

10.1. SCOPE

The Reliability, Availability and Maintainability programme will ensure that the dependability analyses are performed with uniform contractual ground rules and standards. This plan establishes the criteria for analytical demonstration of specified quantitative and qualitative dependability requirements.

This programme will ensure fulfilment of the reliability mission and design life requirements of the spacecraft and its equipment.

This programme will be planned, implemented, and integrated in conjunction with other product assurance functions and with design, development, and production functions.

This programme activities will include the following activities:

- Failure Modes, Effects, and Criticality Analysis (FMECA) with identification of Single Point Failure (SPF)
- Hardware Software Interaction Analysis
- parts stress analysis (Parts Application Review)
- worst-case analysis
- reliability assessment
- availability/outage analysis
- maintainability activities.

All activities will be carried out in parallel to the design process in close co-operation with design engineers.

The policy is applied within Prime and Suppliers through 100141812T-EN and 100141982F-EN.

10.2. FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSES (FMECA)

10.2.1. General

To ensure that potential failures in the hardware are recognised early, FMECAs of system, subsystem and equipment will be performed. FMECAs will consider software implications to ensure that designs react acceptably to hardware failures and that the proper compensatory measures are implemented. The spacecraft mission phases, environmental constraints, and hardware operating modes will be considered in the analyses.

Failure effects will be analysed to determine the need for design change or other action.

The FMECAs will be performed to the circuit functional level or subassembly level (mechanical items) with emphasis on equipment interface failure effects (part level FMECA), propagation of failure effects to redundant, cross-strapped, or interfacing assemblies, and identification of single-point failure effects and fail-safe features. Failure modes or effects that require corrective actions will be followed up and documented in a formal way.
For EGSE, if considered needed on view of the outcome of risk analysis, a qualitative failure analysis

is conducted with the aim as identifying the risk of failure propagation to the flight HW. In such case the most appropriate tool will be selected for this purpose. It may be an FMECA (limited to I/F), or an analysis based on feared events or a Fault Tree Analysis.

10.2.2. FMECA Approach

The FMECAs will be generated from the start of design phase and updated throughout the design phases. All heritage hardware FMECAs will be reviewed to ensure that the failure modes and effects for spacecraft hardware items are addressed, updated as necessary, and criticality classifications assigned in accordance with programme usage and missions. Criticality classifications will be assigned to rank lower level effects and establish their resulting influence on spacecraft operation.

FMECA will be implemented to:

- document the interfacing failure modes of functional blocks of spacecraft hardware and the resulting failure effects on spacecraft assemblies, subsystems, and the spacecraft
- identify and eliminate single-point failure items whenever possible and minimise the probability of occurrence of the residual risks
- identify critical failure effects for concentration of efforts in the areas of quality, inspection, manufacturing controls, design review, configuration control, and traceability
- determine the need for more reliable designs; change in designs affecting parts, materials, or processes; adequacy for fail-safe design features; possibilities for design simplification; and/or sufficiency of redundancy and cross-strapping.

In order to fulfil the FMECA objectives and in particular to identify the possible risk of failure propagation due to physical interaction which could negate a redundancy and/or increase the criticality of the failure, a Product FMECA will be conducted in case of internal redundancy. Such analysis may be included in the FMECA.

10.2.3. FMECA Contents

The FMECA activity will be carried out in a systematic way to ensure that all spacecraft items and their interfaces are adequately addressed. Lower level FMECAs will be used as input in a build-up process to generate the subsystems and spacecraft higher level FMECAs. The FMECA sheets will include for each analysed item:

- identification
- short description of the function
- assumed failure mode
- possible failure causes (when available)
- effects on mission
- observable symptoms
- existing preventive or compensation measures
- criticality level and suffix according to Table 10.2-4-1
- recommendations and remarks
- the probability of failure for SPF's which are included in CIL.

In conclusion, list of SPFs and risk of failure propagation (criticality 1) will be provided. The results of the FMECA will be used as input to the design reviews and for implementing corrective actions.

10.2.4. Criticality Classification

A criticality level will be assigned to each assumed failure mode according to its effect. If not otherwise specified in the project the criticality levels will be in accordance with Table 10.2-4-1.

		DEFINITION	
NAME	LEVEL	DEPENDABILITY	SAFETY
Catastrophic	1	See note 1.	Loss of life, life-threatening or permanent disabling injury or occupational illness. Loss of system. loss of an interfacing manned flight system. Loss of launch site facilities. Severe detrimental environmental effects.
Critical	2	Complete loss of mission or functionality	Temporarily disabling but not life-threatening injury, or temporary occupational illness. Major damage to interfacing flight systems. Major damage to ground facilities. Major damage to public or private property. Major detrimental environmental effects.
Major	3	Major degradation of mission or functionality	
Minor or Negligible	4	Minor or negligible degradation of mission or functionality	

Note 1 (Dependability) : the severity of the possible propagation of failure to upper level shall be considered as catastrophic.

TABLE 10.2-4-1 CRITICALITY CATEGORIES

It has to be noted that these categories are established without considering the possible redundancy or back up (for Dependability and Safety purpose).

In addition to these criticality categories is added a suffix with the following rules :

- **a suffix "S"** (for Single point failure) is added in case no redundancy or back up is implemented in the design.

- **a suffix "R"** (for Redundancy) is added in case a redundancy or a back up is provided and made operational before propagation of failure or criticality increase;

- **a suffix "H"** (for Hazardous) is added in case of hazardous risk (safety).

The criticality category for a particular failure mode is determined by the most severe effect of the considered failure.

The criteria for mission success, as well as those associated to the definition of "major degradation" and "minor or negligible degradation" will be established by the upper level, and in a way to avoid confusion. In principle, "major degradation of the mission" is associated to situation where the mission is not completely fulfilled. Those situations where the degradation could be considered as "minor" have to be identified to be able to share without ambiguity the failure cases among criticalities 3 and 4.

In addition all SPFs identified at a given level will be submitted to the upper level approval.

10.2.5. FMECA Report

A FMECA report will be supplied and updated in accordance with the SOW. The FMECAs will include the following types of information:

a. A description of the mission, function and interfaces.

b. The functional Block Diagram of the item with a description of the functional elements of the hardware.

c. The functional block level FMECA.

d. A list of SPFs and risk of failure propagation (criticality 1).

10.2.6. Definition of Single Point Failure (SPF) and inputs for Critical Items List (CIL).

A Single Point Failure (SPF) is an item for which no redundancy or back up is implemented in the design. Such item is identified with a suffix "S" in the FMECA.
Those items identified in the system and subsystem Fmecas with criticalities 1(all suffixes), 2 (H and S) and 3 (S) will be considered as critical items and processed as such in the CIL.
Items identified in the unit Fmecas with criticalities 1 (all suffixes) and 2 (H) will be considered as critical items and processed as such in the CIL. Furthermore, for SPFs at unit level with criticality 2 and 3 , the decision to consider them as to be included in CIL or not will be taken in cooperation with the upper level, i.e with consideration of possible redundancy identified at this level.

10.3. hardware software interaction analysis

The aim of such analysis, which is developed by the SW PA and the Dependability engineers, is to

ensure that in case of failure management by SW from catastrophic or critical categories (refer to chapter 11 for definition), it reacts in an acceptable way to HW failure. Such analysis is conducted at spacecraft level with the necessary inputs from involved subsystems. It can be accomplished in a dedicated document or incorporated in the FMECA, providing the need as indicated in Q80-03 is covered.

10.4. PARTS APPLICATION REVIEW

Stress analysis will be performed for EEE parts. at electrical unit level only.

For electronic equipment, the Parts Derating Analysis will be performed to identify non-compliance's w.r.t ECSS derating requirements and to direct the necessary changes to the design to comply with ECSS derating requirements.

Internal process shall be used to report, track and to ensure that corrective action takes place and that all derating issues are resolved.

All flight equipment will be analysed to determine individual part stresses (voltage, current power, temperature, etc.) in transient as well as in steady state conditions and the reference equipment temperature to be used in the analyses will be the maximum acceptance temperature. The parts stresses will be compared to the project derating criteria. In cases where no data can be found in the project derating criteria or if data is considered as not applicable due to irrelevant conditions (e.g., low temperature) other sources can be used with justification to be submitted to The Company approval.

Request for Deviation to the Project derating requirements will only be prepared after all applicable design alternatives have been investigated and the risks associated with the electrical stress or part application discrepancies have been determined and found acceptable.

All applications exceeding these criteria will be approved by The Company before incorporation into the design by submission of a Request for Deviation.

A list of the parts exceeding the stress criteria will be presented in the stress analyses.

Stresses exceeding the derated value may be permissible for specific periods, such as burn-in and inadvertent overstress due to failure of related components during tests, provided these conditions do not exceed manufacturers approved ratings.

Part Derating Criteria

Electrical parts will be derated from maximum manufacturers ratings in accordance with: the ECSS Q 30 11 "Derating – EEE components" with the following exception :

- item 6.34 (RF passive components) in ECSS Q 30 11 : no derating on temperature.

In case of application of another source or standard, the compatibility with the ECSS document will be established by the unit supplier. For units developed before issuance of ECSS Q 30 11 the alternative rules will be subjected to upper level approval.

The maximum allowable stress ratios for parameters not specifically listed in these derating documents shall be expressed as in applicable international standards, and submitted to The Company approval.
Transient or surge conditions shall be taken into account where applicable, and derating determined as follows:
when the procurement specification includes parameter values for transient or surge conditions, then the same derating figures as for steady state equivalent parameters shall be used, unless otherwise specified
when transient or surge conditions are applicable, but no transient or surge values are specified, then it must be assured that the transient or surge values are below the steady values of the procurement specification.
All part temperatures are calculated at the maximum specified acceptance test temperature of the applicable assembly including any temperature rise from the component baseplate to the part location.

10.5. WORST CASE ANALYSIS (WCA)

10.5.1. General

The worst-case analysis ensures that item electrical performances comply with the applicable equipment specification under worst-case operating conditions. It will be performed on equipment critical elements, or elements subject to accuracy performance requirements or sensitive to environmental conditions.

Engineering organisations are usually responsible for the completion of worst-case analyses on flight hardware items for which they have design responsibility. They are required to ensure that the analyses are adequately prepared, that design margins are adequately demonstrated by analyses and/or tests, and that the documentation is complete and sufficient. All WCA shall be formally approved by engineering organisations. Worst-case analysis reports will be prepared and submitted to the Customer as required by the SOW.

Reliability personnel will be responsible for providing the aging effect data, for ensuring that worst-case analyses are appropriately completed (methodology) and that the results of the analyses ensure compliance with all applicable requirements. Applications exceeding these criteria where it is not feasible or possible to correct by means of redesign or other means must be approved by The Company before incorporation into the design by submission of a Request for deviation.
This activity is limited to equipment level.

10.5.2. Analysis Method

The analysis is required to demonstrate sufficient operating margins for all operating conditions of the individual circuits. The methodology guideline to be used when conducting such analysis is the ECSS Q 30 01 “Worst case circuit performance analysis”. The analyses will consider (as applicable) such factors as:

- part parameter variations
- normal operating modes and contingency operating modes
- full range of input voltage, current and frequencies variations
- acceptance temperature

- circuit loading
- circuit stimulus
- ageing, total dose and displacement damage effects.
- potential race conditions (i.e. mismatch in delay times).
- A combination of testing and analysis may be employed to obtain results through actual measurements.

The analysis method will be tailored to the circuit function, and to the adequacy of the analytical models (true WCA, Root Mean Square Method, Monte-Carlo simulation may be used).

For parts submitted to Radiation Lot Acceptance Test, the parameter drift values will be derived from radiation test by comparing the post-test values with the pre-test value.

10.6. RELIABILITY ASSESSMENT

10.6.1. General

Reliability numerical evaluation will be performed for components, equipment, subsystems and for the spacecraft to demonstrate compliance with the contractual numerical reliability requirements. The reliability assessments will be updated during the project to include the impact of design changes and more detailed design information as the spacecraft hardware design matures. Reliability trades will be used during all phases of the project to identify the relative merits of alternative designs and to assist in problem resolution (i.e., to determine the possible numerical reliability impact resulting from a potential problem situation).

Reliability functional Block Diagrams will be developed and used to represent the system and subsystem design configurations as they operate over the specified mission phases. These functional Block Diagrams will in turn be the basis for the reliability Block Diagrams that indicate the redundancy, cross-strapping, and single thread items of the designs. The reliability Block Diagrams then become the basis for defining the quantitative reliability of hardware from the unit to the end item spacecraft level. Mathematical models (either discrete or dynamic) will then be used, along with the failure rates calculated for the hardware items, to determine numerical reliability. Reliability Block Diagram are provided as part of Reliability analysis.

The numerical reliability assessments will be governed by the requirements given hereafter.

Quantitative reliability requirements will be specified in the applicable equipment, subsystem, and system performance specifications.

Reliability predictions will be prepared with the necessary level of detail for all spacecraft hardware items, including operational duty cycles, dormancy factors, environmental factors, and functional descriptions. The results of quantitative reliability assessments will be reported and provided as part of design reviews.

10.6.2. Reliability assessment assumptions

Typical assumptions which affect the interpretation of quantitative reliability results are:

a. The design assessed is representative of the flight design.

b. Useful life of a component begins after the satisfactory acceptance test of the component.

c. Mission phases are independent. Stresses experienced in a phase do not affect the failure rate of succeeding phases.

d. Part failure rates are usually constant during the useful life period and wear out factors are not operative during the required mission life unless otherwise stated and appropriate models will be used in those cases.

e. Individual part failures are independent.

f. Parts and materials are qualified for their application and environment.

g. Circuit design performance margins are sufficient for the effects of production variance, radiation environment, thermal environment and ageing.

h. Production processes and testing do not introduce unknown latent damage or failure mechanisms and are approved for use for the mission.

i. Failures rates are estimated in accordance with the requirements of this plan.

j. For structural items and mechanisms, the most appropriate method among constant failure rates, stress strength method (reliability estimations taking into account structural and functional safety margins) or other will be selected by the unit supplier and submitted to upper level approval.

k. Possibility of part failure due to radiation will be considered when assessing the failure rate.

10.6.3. Mission and system definition

The mission and system definition required for reliability assessment consists of:

a. Definition of mission functions and modes of operation including descriptions of functional modes of operation, alternate modes of operation, equipment duty cycles and required operational periods.

b. Definition of the environmental profile during the required mission time including phases of operation during which a given environment is applicable.

10.6.4. Failure rates standards

10.6.4.1. Project failure rates

The guideline applied when selecting a failure rate source is the ECSS Q30 08 “Components reliability data sources and their use”. The selected standard is the MIL-HDBK-217 F + Notice 2 which will be used to determine EEE piece part failure rate, with the exception of hybrids for which MIL-HDBK-217 E + Notice 1 can be used but shall be explicitly referenced in the analysis.

The failure rates listed in Table of the Annex 2 (Fixed Failure Rate Items) can be used instead of MIL-HDBK-217 and are provided for use to assess system reliability at all levels of indenture. Other data

can only be used if justified and after The Company approval.

For the equipment Preliminary Design Review, the part count reliability prediction method of the MIL-HDBK-217 will be applied.

For the Critical Design Review, the reliability will be predicted using the part stress method, dependent upon electrical stresses and component temperatures derived from unit thermal analysis.

10.6.4.2. Failure rate and thermal and electrical stress derating

Thermal and electrical stress influences on part failure rate will be incorporated into the reliability assessments as soon as the necessary design data are available and stress analyses completed. The final assessment of each design will incorporate failure rates derived from the calculated stress ratios and the average operating temperature of the units or equipment.
The equipment average temperatures figures on baseplate will be considered in the analysis.
Reliability assessment at unit level is performed over the complete acceptance temperature range (with a minimum of four temperature values), with a reliability target fixed for a typical average baseplate temperature. When performing the reliability assessment at upper level (subsystem or system), the unit average temperature specific to the concerned application is considered. The way to assess the average baseplate temperature over the complete lifetime will be submitted to The Company approval.

10.6.4.3. Failure rate adjustment factors

The multiplying factors listed in Table 10.5.4.3-1 will be used for the purpose of assessing mission reliability. These factors are applicable only to the designated mission phase under evaluation and are to be applied to the base rate to adjust for mission phase environmental and equipment operating conditions.

a. Duty Cycle Factors

When applicable, duty cycle multiplying factors will be used.

b. Non Operating Factors

Standby or non operating multipliers shall be used to assess the reliability of non operational equipment in accordance with Table 10.5.4.3-1.

MISSION PHASE	DURATION FOR CALCULATIONS	MULTIPLIERS	
		ELECTRICAL	MECHANICAL
Launch/Boost Perigee Burn Apogee Burn Transfer Orbit and time prior to mission operation in GO (IOT)	0. 5 hours (1) 0.1 hours (1) 2.5 hours (1) as required for the particular mission	40 (on) 4 (off) 1 (on) 0.1 (off)	40 (on) 1 (off) 1 (on) 0.01 (off)
Orbit on Station (Operational lifetime)	(2)	1 (on) 0.1 (off)	1 (on) 0.01 (off)

TABLE 10.5.4.3-1 STRESS/OPERATING FAILURE RATE MULTIPLIERS

(1): Typical value, exact value for each mission to be determined by mission analysis.
(2): For the specified lifetime.

10.6.4.4. Quality factor equivalences

Table 10.5.4.4-1 provides a list of equivalence's between failure rate quality levels specified in MIL-HDBK-217 and those specified by European Space Agency documents.

PARTS MAIN TYPE	EUROPEAN LEVEL	MIL-HDBK-217 LEVEL
Passives	SCC B SCC C	MIL S MIL R
Relays	SCC B SSC C	0.5* MIL R MIL R
Discrete Semiconductors	SCC B SCC C	0.5* MIL JANTXV (JANS) MIL JANTXV
Integrated Circuits	SCC B SCC C	Class S categories Class B categories
Hybrids	ECSS-Q60-05 ~~(*)~~ Others	Class S categories Class B-1 categories

TABLE 10.5.4.4-1 QUALITY LEVEL EQUIVALENCE'S

10.6.5. Reliability assessment documentation

A reliability assessment report will be prepared and submitted in accordance with the Statement of Work. Each reliability assessment will include the following information:

a. A description of the item, types of redundancy, and the item operational modes.

b. A functional Block Diagram of the design.

c. A reliability model for each operating phase which is analysed including:

- reliability Block Diagrams
- failure Rates for each block of the Reliability Block Diagram
- mathematical models or applicable dynamic model data
- probability of success results
- a comparison of the results with the specified requirements.

10.7. AVAILABILITY/outage analyses

10.7.1. General

Such analysis is conducted in case quantitative availability requirement is assigned, and in case of need to consolidate the maintenance plan of ground control station. It concerns flight hardware , as

well as ground stations.

It aims at assessing the performances of the concerned design in term of availability, in order to verify the compliance w.r.t requirements and to consolidate the design (redundancy philosophy) and the maintainability plan if any (spare policy).

The basic considered guideline for such analysis is the ECSS Q 30 09 “Availability analysis”.
All sources of interruption are basically covered in the frame of the analysis, that says :

definitive mission interruption consecutive to single or multiple failures,
outages (i.e temporary non compliance with the technical requirements) caused by random events (reconfigurable failures , radiations or Single Event Phenomena) or deterministic events (like recalibration phases or un-operational periods)

10.7.2. Method

The inputs to be collected are the following (to be adapted to the context) :

the list of potential possibility of mission interruption with associated data and information (MTBF, probability of occurrence, number, effect on mission, down time, MTTRepair, MTTReplace,),
the proposed redundancy and spare policy (if applicable).

For the purpose of the calculation, a defined response time for remedy of the outage causing event is generally taken into account in the accrued downtime.

Then a mathematical model is built and all the data combined in order to determine the relevant availability of the system, this in a way which is compatible with the requirements terms.

10.7.3. Outputs

The outputs in term of availability will be expressed in order to be adapted with the requirements. It may be presented as follows (examples) :
average availability versus time.
Outage characteristics for certain time internals (month, year, lifetime period) including:

- mean number of outages
- mean duration of one outage
- mean cumulated outage duration
- unavailability versus time due to outages.
- Probability to have an interruption with a duration longer than a given value, and over a given period.

In addition, recommendation for design modification or maintenance plan adaptation may be proposed, in order to optimize the robustness of the design w.r.t the risk of mission interruption.

10.8. maintainability

10.8.1. Scope

The maintainability assurance programme will insure that maintainability requirements of products are

defined, implemented, co-ordinated and integrated throughout the product life cycle. Maintainability assurance programme applies to the activities associated with repair, rework and preventive and corrective maintenance. It therefore concerns cases where repair or replacement of unit is foreseen.

The maintainability assurance programme will include:

verification that maintainability requirements are taken into account in design construction
verification that preventive and corrective maintenance are implemented according to documented plan and procedures, and that results of implementation are property documented, reported and verified in accordance with quality assurance dispositions.

10.8.2. Design requirements

Design requirements for maintainability will consider the following objectives:

- **a.** Optimisation of testability, including verification of redundancy, and fault isolation capability.
- **b.** Minimisation of the need for special tools and special test equipment.
- **c.** Minimisation of requirements for special skills.
- **d.** Consideration of human-factor requirements.
- **e.** Minimisation of design complexity.
- **f.** Maximisation of commonality/interchangeability.
- **g.** Simplification of maintenance tasks.
- **h.** Standardisation of products.
- **i.** Maximum of accessibility.
- **j.** Maximisation of modularity.
- **k.** Minimisation of the need for preventive maintenance.

Related design requirements are introduced in applicable design standards (e.g. general equipment design and interfaces requirements) and technical specifications.

Verification of their implementation in design will be performed as part of design reviews.

10.8.3. Maintenance

Preventive and corrective maintenance including rework/repair operations will be implemented according to the following :
items subject to preventive maintenance will be identified. Their maintenance status will be systematically checked before product delivery to the next higher assembly level, during subsystem and system tests, before satellite delivery and before launch
preventive maintenance operations will be implemented according to controlled plans and procedures.

Verification and results will be reported and verified in compliance with applicable quality assurance dispositions. Implementation of maintenance operations will be documented in the logbook implementation of corrective maintenance will be performed within the Non conformance processing system (see § 5.6.). Dispositions for repair/rework will be decided and defined by the NRB. As a basic rule, re-testing after repair/rework will include functional tests and environmental tests according to the nominal acceptance test sequence. Specific amendments to the nominal test sequence can be decided by the NRB on a case by case basis, considering the nature of repair/rework operations and potential risks resulting from cumulating of test stresses on a same item.
Maintainability features which results will constitute an input for availability analysis.

10.9. Task applicability matrix

The present PA Plan applies to different types of products (spacecraft with telecom or scientific payload, GSE, Ground station), different levels (system, subsystem, functional channels, units) and different phases within the projects (preliminary up to operational).

Different activities are therefore selected or not , depending on the a.m criteria and also in order to consider specific requirements. To clarify what is basically performed in term of analysis vs type of products, level and phases, a “Task Applicability Matrix” is presented here after in Table 10.9.1.

	L E V E L					
Analysis	**spacecraft**	**payload / Functional channels / subsystems**	**units**	**EGSE**	**Ground control station**	**software**
reliability assessment	PDR : generally limited to a budget CDR : detailed and consolidated	PDR and CDR (1)	PDR and CDR	N/A	N/A	N/A
FMECA	PDR : generally limited to list of identified critical items and SPFs CDR : detailed and consolidated	PDR and CDR (1)	PDR and CDR Product Design Fmeca needs are to be covered in case of internal redundancy (5)	N/A	N/A	N/A
parts stress analysis	N/A	N/A	PDR and CDR	N/A	N/A	N/A
worst case analysis	N/A	N/A	PDR and CDR	N/A	N/A	N/A

qualitative failure analysis at I/F level (4)	N/A	N/A	N/A	the tool to be used (Fmeca, faired event analysis, FTA or others) is selected in order to be the more convenient w.r.t the context	N/A	N/A
availability analysis	PDR : generally limited to methodology CDR : detailed and consolidated (2)	N/A	N/A	N/A	PDR : generally limited to methodology CDR : detailed and consolidated (3)	N/A
HSIA	see SW column	N/A	N/A	N/A	N/A	(6)

(1) :for subsystems or functional channels, analysis may be included in spacecraft one, in accordance with the SOW.
(2) :in case it is performed, because of quantitative requirement, S/C availability analysis may be included in
reliability assessment report.
(3) :conducted in case of need to consolidate the maintenance plan.
(4) :decision to perform or not such analysis for a given EGSE is driven by the outcome of risk analysis. Analysis is generally made available for information but not deliverable.
(5) :this complementary exercice can be subject to a specific document or included in the Fmeca.
(6) :this analysis, which concerns SW with Catastrophic or Critical category, can be accomplished in a dedicated document or in the Fmeca, providing the need as indicated in ECSS Q80 is covered. It is conducted at spacecraft level with inputs from involved subsystems.

TABLE 10.9. 1 TASKS APPLICABILITY MATRIX FOR DEPENDABILITY ANALYSIS

11. SOFTWARE PRODUCT ASSURANCE

This section establishes the Software Product Assurance (SW PA) Programme based on ECSS-Q-80B and ECSS-E-40-Part1B.
It describes the specific SW PA provisions relevant to:

- the role of Prime contractor,
- the role of in-house software development
- the control of software suppliers

11.1. Software Product Assurance Responsibility and Reporting

According to the responsibility levels, the SW PA manager is responsible for the followings tasks:

Software PA Activities	Prime contractor level	in-house software development (Company)	control of software supplier
To plan, organise, control SW PA activities	X	X	
To verify that the foreseen SW PA activities are correctly developed	X	X	X
To establish and update the plan as necessary	X	X	
To participate to the system activities for the Software PA aspects (SW PA requirements, integration,/validation tests …)	X		
To manage SW dependability and safety issue	X	X	X
To approve suppliers' software product assurance plans			X
To establish the SW PA requirements for suppliers	X		
To verify the compliance matrix and the justifications	X		X
To participate in the negotiation and the assessment of the contractual changes for the software quality aspects	X	X	
To verify that the SW product assurance dispositions stated in the present plan are applied on all SW processes implemented on the software project	X	X	
To participate in software reviews as necessary	X	X	X

To assess the consistency of the produced documents with respect to the input documents (including applicable standards)	X	X	X
To manage the Software anomalies and non-conformances	X	X	
To support the system risk management process	X	X	
To review the Supplier and the Company activities relevant to COTS/ MOTS procurement and to re-use of existing in-house products		X	X
To implement the measurement program and to provide results in the SW PA Report	X	X	
To review the metrics provided by suppliers and the relevant assessment			X
To manage SW dependability and safety issue	X	X	X
To perform verification and validation activities follow-up	X	X	X
To ensure correct implementation of configuration control for SW products and documentation		X	X
To perform software products delivery and acceptance follow-up	X	X	X
For category “catastrophic” (see § Software categorisation) to follow-on ISVV activities (Independent Software Verification and Validation)	X		
To participate to the management of the software project alert	X	X	
To perform SW PA report (including metrics results)	X	X (via the Prime contractor PA manager).	
To perform audit, if necessary	X	X	X

The level SW PA Manager reports to the Project Manager via the Prime contractor PA manager.
The SW PA manager at software development level reports to the SW PA manager at Prime contractor level .
The SW PA organisation is independent in terms of authority, personnel and resources of the development department, in order to ensure an independent evaluation.

11.2. SW Dependability and Safety

11.2.1. Software Analysis

A functional analysis of the software (software severity analysis) is performed at *system* level to assign a severity to the software functions on the basis of the applicable software severity category definition (see chapter “software categorisation”), and of the dependability and safety severity classification of the system functions as defined by the RAMS analyses. A severity category is assigned to each software components on the basis of the relevant software function severity.
Review of lower level software severity allocation is performed at *customer* level to ensure correctness of assigned component severity.

The software analysis final objectives are:
- Ranking of the software products according to the effects the software failure can imply on the dependability and safety of the system functions involving software.
- Modulating the software development process on the basis of the software severity (e.g. requirements and standards applicability)
- Identifying possible methods to downgrade the software severity
- Ensuring the implementation of the identified software requirements

The Software Product Assurance manager identifies the software quality requirements and verifies that the quality requirements and the methods for preventing and controlling software failure effects are effectively implemented and documented, by verifying the Software Documentation and activities.

11.2.2. Software categorisation

Each Software Component (Configuration Item) identified in the Product Tree shall be categorised according to the following software severity definition.

SW Severity Category	SW Severity Definition
Catastrophic	Software component whose anomalous behaviour would cause a failure of system function resulting in: • **Catastrophic** consequences (safety or dependability)
Critical	Software component whose anomalous behaviour would cause a failure of system function resulting in: • **Critical** consequences (safety or dependability)
Major	Software component whose anomalous behaviour would cause a failure of system function resulting in: • **Major** consequences (dependability)
Minor	Software component whose anomalous behaviour would cause a failure of system function resulting in: • **Negligible** or **Minor** consequences (dependability)
Non significant	Software component whose anomalous behaviour has: • No Impact on mission

In case of :

a. *A safety barrier as watchdog, back-up or emergency procedure or hardware inhibiting function are available to prevent hazard development and/ or unacceptable consequences on dependability, and*

b. the time to effect is sufficient to implement the back-up/ emergency procedure

then the SW category can be downgraded to the immediately lower level. SW of Category"catastrophic" can be reduced to category"critical"; SW of category"critical" can be reduced to category"major", SW of category "major" can be reduced to category "minor".

11.2.3. Handling of High Severity Software

The high severity software is defined as software having a severity "catastrophic", "critical" and "major".

The high severity software is managed according to appropriate measures to ensure the software reliability.
The measures include :

- ISVV activities for category "catastrophic",
- Use of software design or methods that have performed successfully in a similar application
- Software components segregation, e.g. all software components on processor shall have the same severity category of the components with higher severity
- Prevention of sharing or overlaying of data including stacks and processor registers between software components with different criticalities
- Check of incoming commands, data and messages and rejection of illegal ones (defensive programming)
- Prevention of software component failure if it does not receive an expected message
- If identification of unreachable code, 2 cases :
  - Removal of this code and analysis of the need for re-verification and revalidation
  - Justification for maintaining this code provided
- Identification and removal of deactivated code, or demonstration through a combination of analysis and testing that the means by which such code could be inadvertently executed are prevented, isolated or eliminated
- Regression testing after any change of the underlying platform hardware, and any change of the tools that affect directly or indirectly the generation of the executable code
- Analysis of the need for additional verification after any change of functionality or performance of the underlying platform hardware and any change in the environment in which the software or the platform hardware operates
- Re-testing of previously tested instrumented code without instrumentation
- Integration and validation testing on non-instrumented code
- Test Coverage rate verification

11.3. Software development process

11.3.1. Life cycle model

The software development and maintenance life cycle is provided in project Development Plan.

The SW PA manager ensures that:

- the software life cycle is defined to meet the project software engineering and PA requirements

- the milestones are defined according to the applicable requirement
- the outputs for each phase are defined
- a milestone is scheduled before the software validation process to verify the software status
- Milestones are scheduled to ensure that the phases activities and products have been realized according PA provisions for the processes described below.

11.3.2. Software requirements analysis

Software technical specifications are established to fulfil the next higher requirements.

Software functional behaviour and performance capabilities are specified. This specification also include interface , data base requirements and budget analysis requirements.

Non customer needs are taken into account as: design constraints, software reuse,… For “critical” and “catastrophic” software’s, results from the HSIA (Hardware, Software Interface Analysis) have to be taken into account for the definition of the technical specification.

If relevant, safety requirements are defined, including those related to methods of operation and maintenance, environmental influence and personnel injury.

Mandatory software engineering practices are identified, taking into account software categorisation and risk analysis.

Specific objectives are defined to be considered for software requirements properties, as completeness, consistency, clarity, accuracy, verifiability.

Traceability from next higher requirements to software requirements is established.

11.3.3. Software design

Software requirements are analyzed according to a defined methodology in order to elaborate a logical and physical model of the software which will satisfy them.
Mandatory software engineering practices are identified, as design method and tools. Specific rules are defined for software in which numerical accuracy is relevant.
Specific objectives are defined to be considered for design properties, as completeness, consistency, modularity, robustness, adaptability.
Traceability from Software requirements to Software design is established.

11.3.4. Software coding

Coding standards are defined, consistent with the project requirements and quality requirements (programming language, naming conventions, coding rules, numerical accuracy in case of mission severity such as guidance algorithm) and applied.
Each unit is individually tested where required according to software category (no formalized unit test for categories “minor” and “no significant”). Specific objectives are defined to be considered for code properties, as complexity, maintainability.

11.3.5. Software test and validation

Before starting the testing activities, the SW PA reviews the Test Plans and Test Procedures to ensure that the test procedures are adequate, implementable and traceable.
Specifically :

- The test objectives identified in the plan are satisfied
- The test typology is defined (functional, performance, etc.)
- For each test input, foreseen results and test execution conditions are defined
- Each test procedure contains the step-by-step actions for performing the test.

The integration strategy is defined according to software design and constituent release strategy to identify :

- the aggregates of software units and their sequence of integration
- the tests specifications covering software design and static or dynamic internal interfaces to be tested and required testing environment
- the regression test strategy for integrated software units subject to change

Specific objectives for integration tests coverage are defined according to software category. The integrated software is tested in order to verify that it meets all functional, performance and external interface requirements defined during software requirement analysis.

The software validation test strategy is defined to identify:

- the tests specifications covering software requirements to be tested and required testing environment
- the analysis needed to verify the software requirements which are not testable
- the regression test strategy for system constituents subject to change

Software validation can be done in the development environment or/and in the target environment according to the SOW.

Before the start of any formal test campaign a Test Readiness Review (TRR) is held. The SW PA manager participates in the TRR for ensuring that :

- The test configuration is as foreseen in the approved test documentation
- The tests procedures and data are approved
- Software verification matrix is established to demonstrate that each software requirement is covered by validation tests or verification.
- All tests are foreseen to be performed on the same software version without intermediate rebuild
- Expected results are defined
- Known Software Non-Conformance and Request for Waiver (RFW) are identified
- When requested, validation test are carried out by staff that has not taken part in the design or coding of the software being validated
- Collection of test metrics during test execution is foreseen to compare test coverage with stated goals

Following any formal test campaign, a Test Review Board (TRB) is held. The SW PA manager participates in the TRB for ensuring that :

- The test campaign is performed in accordance with the plan and procedures
- tests execution is documented and traced
- tests report is prepared and updated
- test findings are analysed and actions for managing the SW remaining open NCRs are

initiated
- test documentation updating is foreseen to facilitate the subsequent maintenance phase.

The TRR/TRB at software level can be grouped with the TRR/TRB at equipment level.

11.4. Software Product Procurement Process

The procurement of COTS/MOTS products and the re-use of existing products follow a series of activities performed at software engineering level that includes :
- identification of needs,
- possibilities and advantages of using COTS/ MOTS/ re-used software with regards to identified risks,
- definition of requirements and list of candidates,
- products assessment, evaluation of corrective actions at product or upper level,
- product selection,
- procurement and installation.

For the choice of reused software or COTS/MOTS to be used for or integrated into the system , the SW PA manager provides support to the COST/MOTS assessment performed by the engineering team e.g :
- Product evaluation versus applicable requirements and standards
- Severity of the provided function
- Operational behaviour or validation level
- Warranty
- Documentation availability
- Installation, training and use conditions
- Documentation and code configuration control
- Maintenance and future upgrading conditions
- Copyright constraints
- Licensing conditions
- Durability and validity of methods and tools used in the initial development, planned to be reused
- Product quality status (open non-conformances, waivers, etc.)
- Back up solutions

All these information's concerning product selection are prepared and finalized during the design process. The COTS/MOTS products procurement elements are submitted to an incoming inspection with adequate criteria.
In case the re-used product has been developed with standards different from the project ones, the SW PA manager ensures that evidence of suitability exists or methods for compliance with the quality requirements are implemented.

11.5. Methods, Tools and Supporting Environment

The Software Development Environment (SDE) and the Software Verification Facility (SVF) technical

assessment are under engineering responsibility. The choice of the development computer is described in the development plan. Suitability of methods and tools is justified (maintainability, experience or training of the team to apply them, compliance with the project standard).
The SW PA manager participates in the evaluation of methods and tools for the quality aspects and ensures that methods and tools are defined in the documentation, in case THE COMPANY is directly responsible for the procurement of SDE and/ or SVF.
The SW PA manager performs follow-up of the SDE and/ or SVF procurement process as part of the supplier control activity in case procurement is performed by a supplier.

11.6. Software Configuration Management Control

Software components are managed in order to ensure control of their release and change. Any version delivered to customer can be retrieved from configuration management system.

Configuration items and included configuration elements are identified in order to cover all delivered products (including documentation).

A configuration management plan is drawn up to define when and how configuration items will be managed.

Procedures for controlling the changes, delivering, marking, protecting and archiving the product are defined or referenced in the configuration management plan. As far as possible, company standard procedures are used.

This plan also defines security dispositions for files and media.
A protection mechanism is implemented to prevent unwanted modifications or damages to the released software product (source code, executable code, database, data, etc.).
In this frame it shall be assured that software products are provided with an identification key “checksum”. The checksum value shall be provided in the Software Configuration File.
SW PA manager ensures that the checksum value is associated to the product before the release, and that it is verified at the reception of provided products.
In case the protection mechanism is based on a supplier specific tool, the tool will be agreed with the customer.

A configuration baseline is established at least at each development milestone and for each software release. The configuration status of each configuration baseline is formalized in a Software Configuration Item Data List, which is verified by the SW PA manager against completeness and consistency.

Each COTS, MOTS or re-used component is put under configuration control after its incoming inspection.

For each contractual delivery, a Software Configuration Item Data List and a delivery notice are provided to the customer. The delivery notice includes the delivery description and the conditions and limitations of use; it also defines or references the known anomalies, the installation procedure, and additional information such as fixed non conformance, implemented evolutions and validation status.

Note : in case of patch, a software release note is drawn up in place of a Software Configuration Item Data List; it identifies configuration changes with regards to the origin configuration baseline.
The physical support containing the software product to be released is identified with :

- software product identifying name
- release version

- reference to the SCIDL

11.7. Verification Process

The SW PA manager verifies that the product assurance dispositions stated in the present plan are applied and participates in the verification process along the whole software life cycle. In this frame, the SW PA manager maintains cooperation with the engineering team. SW PA activities during the Verification process consist of :

- Review support
- Documentation review
- Inspection

a. Review Support

Reviews to be held are defined in the software project management plan according to contractual requirements
The SW PA manager participates in the foreseen reviews as necessary to ensure that:

- The verification activities foreseen for each phase are adequate to ensure software product conformance to requirements and standards applicable to the phase
- The verification activities have been performed as planned
- High severity software has been managed and verified as planned
- Software products are verified and comply with the phase requirements (technical requirements, standards, procedures)
- Verification results and relevant actions, SW NCRs to ensure compliance with requirements are recorded and checked

b. Documentation Review

The SW PA manager reviews the software project documentation prepared by the Company and verifies the documentation delivered from suppliers as necessary to ensure that the SW quality requirements are implemented. The SW documentation is formally reviewed by the supplier SW PA manager before release according to the project applicable requirements.

c. Inspections

The objective of the inspections is to identify software products defects and the compliance status versus applicable standards.
SW PA manager performs inspections both for in-house developed products and subcontracted ones as necessary.
Inspections is performed according to a written procedure defined as necessary at project level identifying :

- inspected items
- person in charge (not the author of the object to be inspected)
- participants
- means of inspection (tool, check list)

A report is prepared for each inspection specifying inspected item, author, inspectors, inspection criteria and findings.

11.8. SUPPLIER Selection and Control

The SW PA manager defines the SW PA requirements for suppliers, from higher level PA

requirements and standard SW PA requirements (taking into account precedence order)..
The supplier will provide as answer a SPAP including the compliance matrix to the SW PA requirements.
During the supplier selection, the SW PA reviews the tenders' proposals to verify compliance to the applicable requirements and provides the relevant conclusions..
During the project life cycle the SW PA manager is responsible for verifying and ensuring consistency and adequacy of the supplier software development and quality process versus the applicable requirements (see PA tasks §"Software Product Assurance Responsibility and Reporting")

11.9. Delivery, Installation and Acceptance of the Software Product

Any software delivery is performed on a frozen configuration baseline verified for compliance, completeness and consistency.
Delivery preparation includes :

- collecting the verified and approved acceptance data package documents
- generating the delivery support and marking it
- drawing up a delivery notice

The installation strategy and procedure, needed resources, constraints and customer support are described and previously approved by the customer..

The Delivery Review Board (DRB) is held to ensure that the products to be delivered :

- are compliant with the specification unless Requests For Waiver are accepted by the Customer
- source code and executable code are univocally linked
- the version of the software products is the one which was submitted to the successful test campaign
- all changes have been approved
- all products are identified, under configuration control, archived and the media for delivery is correctly marked..

The SW PA's witness the acceptance test as necessary to ensure that :

- the executable code is generated from the source code under configuration control
- the software product installation is performed according to the installation plan
- the agreed test procedures are performed (included regression tests if necessary)
- any problem is managed via SW NCR generation
- the user requirements are satisfied in the target environment
- the Software User Manual has been verified and accepted by the customer.
- At the end of the acceptance campaign, the Acceptance Report is prepared and verified.

11.10. Software Anomaly and Non-Conformance

See section Anomalies & Non conformances control system (§4.6)
The SW PA is involved as necessary in the Software Anomaly/Non-Conformances process to ensure that all the identified problems are analysed and that the corrective actions are identified, approved and implemented.

The SW Non-Conformances (NCR) are formally managed starting at the beginning of the software

product Validation versus the Technical Specification.

11.11. Maintenance Process

In order to maintain the software in operational conditions, modification, migration, and retirement of software components are managed according to dedicated dispositions.
Note: these dispositions are restricted to the maintenance activities addressed by the contract.

The maintenance strategy addresses all kind of maintenance activities : corrective (routine and emergency), evolutionary, improving, adaptive and preventive maintenance. It is defined and documented in a maintenance plan.

The maintenance plan describes the organization, the procedures, the human hardware and software resources foreseen to perform the maintenance activities. Active processes during development are carried on and adapted in order to preserve the integrity of the operational system, in accordance with applicable quality requirements.
All patches are duly documented and placed under configuration control before their application into the software; in case SW patches are applied only as a temporary solution and a subsequence SW release is foreseen to fix the problem, the patches shall be traced only until the new release is issued.

If a system or software product is migrated from an old to a new operational environment, it is ensured that all induced activities (including regression tests)are defined and documented.

A post-operation review, including all actors concerned by the migration, is performed to assess the impact of changing to the new environment.

11.12. Firmware

The SW PA manager provides support for the software quality aspects during the firmware (PROM, ASICS, FPGA) life cycle as necessary to meet the applicable quality requirements.
The procedure to ‘burn in’ the device is documented. The programming equipment is calibrated.
The firmware device marking identifies hardware and software components.

11.13. Software Quality Metrication Model (SQMM)

11.13.1. Quality objectives definition

Software Quality objectives are expressed in term of characteristics of the software product and software development processes. For each of these characteristics one or more quantifiable sub-characteristics are identified.

The quality sub-characteristics are evaluated and monitored thanks to metrics. Two categories of metrics are defined: product metrics related to measuring the products of the development, process metrics related to measuring the processes themselves.

For each metric a target is defined, correlated to the product software severity categories.

The quality characteristics are chosen according to software requirements. Quality characteristics are presented here after as reference (to be tailored according to requirements).

Functionality	Conformance of the software design and implementation to stated requirements
Efficiency	Software ability to minimise the used resources (processors, store, drivers, inputs-outputs)
Integrity	Software ability to protect its code and its data against wrong inputs or unauthorised access
Reliability	Software ability to insure its functions in specified environment conditions with the required accuracy during a specified duration
Maintainability	The capability of the software product to be modified. Modifications can include corrections, improvements or adaptation of the software to changes in environment, and in requirements and functional specifications.
Usability	Capability of the software to be understood, learned, used and liked by the user, when used under specified conditions.
Portability	The capability of the software product to be transferred from one environment to another.
Reusability	Degree to which a software module or other work product can be used in more than one computer program or software system.
Suitability for safety	The capability of the software product to achieve acceptable levels of risk of harm to people, business, software, property or the environment in a specified context of use.
SW Development Effectiveness	Extent to which planned activities are realized and planned results achieved

11.13.2. Assessment method description

This assessment is based on **verification activities** (based on PA rules check lists) which have to be performed during the development phases. Specific dispositions are taken to ensure the monitoring of the product quality and its evolution.
Metrics are defined and evaluated in order to help this monitoring in each development phase.

Two types of metric are considered :
quantitative metric: numeric value directly measured through its value (e.g "number of statements in a ADA procedure").
qualitative metric: no numeric value presented as a query (e.g "Adherence to coding standard) ").

When it is possible to define target values (boundaries) for quantitative metrics, these metrics are automatically transformed in qualitative metrics, for example: Qualitative metric is "Number of statements has to be < 100 for each ADA procedure" based on the quantitative metric “Number of statements”.

The objective is to verify that the target, applicable for each metric according to the software product severity category, is met.
Metrics are collected, stored, analyzed and reported on a regular basis. Corrective actions are decided when necessary to maintain them inside acceptable boundaries.

12. EEE Components CONTROL PLAN

This section describes the organization, approach, methods and procedures implemented internally by The Company to be applied in all project phases for selection, procurement and control of Electric, Electronic, and Electromechanical (EEE) parts, used in house flight (FM) hardware as well as for engineering (EM) and qualification (EQM) hardware, this section includes :

- EEE parts procurement responsibility organization
- Parts activities at prime contractor level
- Parts Selection, standardization and approval process
- Parts procurement
- Quality assurance system implemented on EEE parts

In addition, this section describes EEE parts quality assurances dispositions implemented on the project by The Company with respect to sub-contractors control.

The structure of this Components Control Plan is fully compliant with ECSS Q60 B requirements.

12.1. organizational structure, responsibility descriptions, management approach

12.1.1. Organizational structure

The Company EEE parts activities involves Parts Engineering, Parts Quality Assurance and Parts Purchasing organizations. The corresponding activities are described by QMS procedures.
These 3 organizations are participating to the periodic update of The Company Standard EEE parts requirements.
For purchased equipments, EEE parts aspects are managed by quality assurance organization and in relation with purchasing internal entities. When requested by contract a Programme Parts Control Board (PCB) will be implemented. PCBs are chaired by EEE Parts Quality Assurance responsible for the project and supported, as necessary, by Parts Engineering, Electrical designers, PA, Parts Purchasing organization, etc…

12.1.2. Main Responsibility description

The Company will be responsible to plan and enforce an effective EEE control program prior, during and after procurement, on which the selection philosophy, procurement provisions and all EEE applicable requirements are fully reflected, flown-down to subcontractors, implemented and verified.
The Company and its sub-contractors are responsible for parts used on the project even after customer PAD approval.

EEE parts Quality assurance organization main responsibilities are: monitoring the internal overall EEE parts processes, non conformances management, parts manufacturers inspections, surveillance and audits, Customer reviews preparation and management. Suppliers parts approval and PCBs processes management, Over-all project declared parts list publication and EEE database updating

EEE parts Engineering internal organization main responsibilities are: Equipment designers support, DAE/PRB process management (Board for new parts selection), Parts technology survey, Specification writing, In House equipments declared part lists /PAD sheet issuing and incoming

inspections.

EEE Parts purchasing internal organization main responsibilities are: RFQ management, schedule and cost negotiations with manufacturers, invoicing process monitoring.
EEE Parts purchasing is organized by Commodity leaders.

All EEE internal organizations have direct contacts with parts manufacturers on corresponding activities and Quality assurance EEE organization has direct contact with EEE parts experts from sub-contractors.

12.1.3. Management approach

In order to meet Projects schedule requirements, the Company policy is to procure EEE parts in anticipation and in compliance with the Internal Standard QMS-QM 100141911C-EN Requirements.

Suppliers are allowed to procure parts in anticipation and according to their Internal standard if the requirements of The Company Standard QMS-QM 100141911C-EN are met.

When customers additional requirements to the The Company Standard are imposed for the project, The Company and its Sub-contractors establishes a compliance matrix and proposals to achieve compliance.
On a case by case basis, when full compliance to additional requirements cannot be technically obtained, technical justifications and rationale are prepared and presented during Parts Control Board meetings.

12.1.4. Concurrent engineering.

The Company will support subco policy in concurrent engineering monitoring the effectiveness of their approach in front of the project requirements (Quality, performance, schedule and cost) since the earl phase B. In similar way, the management of co-ordinated procurement agency (whenever it is foreseen) will be conducted according to concurrent engineering principles. For internal manufactured H/W The Company EEE parts organization is based on concurrent engineering concept trough DAE/PRB process involving simultaneously Electrical Designers, Experts from parts engineering, Quality Assurance parts, processes and material Experts, Radiation experts, purchasing and manufacturing (when necessary).
In order to meet project requirements (Performances, Quality, Schedule and Cost optimization), activities such as Data analysis, Radiation tests, DPAs, User LATs, EBTs (Parts mounting validation etc…) are launched simultaneously.
Sub-contractors policy in concurrent engineering is evaluated during periodic Audits

12.2. CONTROL OF LOWER LEVEL SUPPLIERS, PROCUREMENT AGENTS (If any) AND MANUFACTURERS

12.2.1. Control of EEE Parts manufacturers

Based on parts technological criticality and manufacturer qualification status, The Company implement on an annual basis a manufacturer surveillance plan with scheduled on-site visits or audits

Metrics based on number of non conformances, alerts and field failures are established and are used to implement manufacturers surveillance reinforcement.
Precap inspections, orders follow-on and customer source inspections, participates to manufacturers surveillance action plan.
All audits and visit reports are recorded and kept under configuration control.

12.2.2. Control of Sub-Contractors

The Company perform sub-contractors control activities such as PCBs, Audits, EEE Parts procurement data reviews, evidence of EEE parts manufacturer control plan.
In Addition, all sub-contractors are requested to provide The Company with a Certificate of non Usage or elimination of Pure Tin components finishes.
PCBs with sub-Contractors are established at the early stage of the project in order to have all parts approved by The Company prior to manufacturing activities.

12.3. PROCUREMENT SYSTEM

The Company proceed to “Self Procurement “ of EEE Parts (Including Hybrids elements) for In-house built units.
Standard EEE parts are procured according to controlled specifications with maximum extend to ESA ESCC or US MIL specification system.
For specific EEE Parts (Asics, Procured Hybrids, transformers etc.) not covered by an existing Agency specification or for parts having specific requirements, an The Company configured procurement specification is used. These specifications are based on ESCC or MIL documents structure for High Reliability parts.
All encapsulated, High reliability parts, are procured directly from EEE parts manufacturers or Assembly and tests houses. Chips for Hybrids are procured either from Manufacturers or from Chip Specialized procurement agents.
Suppliers may use Internal EEE parts procurement organization or procurement agent services (CPPAs). In both cases, standard EEE parts are procured according to controlled specifications with maximum extend to ESA ESCC or US MIL specification system.

12.4. RADIATION CONTROL PROGRAM

See Radiation Section

12.5. COMPONENTS SELECTION AND STANDARDIZATION

The selection of high reliability EEE parts is based on the knowledge regarding technical performance, qualification status and history of previous usage in similar applications with maximum use of qualified parts and with established reliability history.
Preference is given to parts from sources that would necessitate the least evaluation/qualification effort.
EEE parts are selected in compliance with the requirements of the project (Mission life, operating stability, materials, safety, quality, reliability) and to withstand all environmental conditions including tolerance to radiation exposure (total dose, single events and displacement damage effects for active

parts).
Selection is performed taking into account:
- minimization and standardization of the number of different generic part types and families
- long term availability and parts from multiple sources are preferred.

The following items are not considered EEE parts and will be controlled at higher level by the relevant disciplines:

- Intermediate products containing discrete components on substrate – PCBs.
- solar cells.
- batteries cells.
- HF sub assemblies – coaxial cables assembly – waveguides elements.
- TWTs.
- RF switches, coaxial or waveguide.

12.5.1. Selection of standard components

Preference is given to High reliability EEE Standard Parts selected on the basis of proven qualification (ESCC, MIL,NASA, European National Agencies …etc.) from the following lists:

- ESCC QPL and QML
- EPPL part1 (European Preferred Parts List)
- NSPL (NASA Parts Selection list) level1(taking into account the associated application notes)
- MIL QPLs and QMLs, (Qualified Parts List and Qualified Manufacturer List)

Suppliers standard components selection is verified during EEE Lists and PADs Analysis/Approval.

12.5.2. Selection of non standard components

Preference is given to Non Standard EEE parts from manufacturers or sources employing effective product assurance program in manufacturing and tests or from parts used on other equivalent space projects with flight experience.
When ESCC or MIL High Reliability part does not allow to meet the project performances, parts being usually available commercially and having the capability to be used in space applications can be selected.
These parts categories are subject to evaluation, approval and qualifications requirements as described in QMS-QM 100141911C-EN standard.
Sub-contractors dispositions on non standard parts are verified during PAD analysis, PCB and procurement data review meetings.

12.5.3. In House Manufactured Parts

All EEE parts manufactured by the User (e.g. coils and transformers) in accordance with internal process procedures will be documented through specifications / source control drawings.
Minimum screening requirements will be those of the nearest applicable ESCC or space level MIL specification; for other in-house parts the screening sequence and the lot acceptance will be defined in relevant PAD.

12.5.4. Specific components

When a technology is not covered by an applicable generic specification, the procurement responsible will describe in the PAD the procurement strategy adopted.

- Magnetic Parts

The “in house” magnetic parts are requested to be designed an screened using the MIL-STD-981 as guideline.

- Hybrid Circuit

The hybrid circuits, either self manufactured or procured, are requested to in accordance with ECSS-Q60-05 or MIL-PRF-38534 class K.

- ASIC & FPGA

The ECSS-Q-60-02 is applicable or a specific document covering requirements for development, prototype manufacturing, testing, validation and quality assurance is requested to be issued.

- MMIC

The procurement of MMICs will be in accordance to ESCC 9010 and ECSS-Q-60-12. A specific document covering requirements for development, prototype manufacturing, testing, validation and quality assurance is requested to be issued if ECSS-Q-60-12 cannot be applied.

- One Time Programmable Device

One time programmable devices are requested to be submitted to a post-programming sequence, unless agreed equivalent sequence by PAD process.
When post-programming sequence is applied the procurement of virgin parts may be done to military quality level (class Q).

12.5.5. OTS Equipment EEE parts

Users are requested to review the components used in Off-the-Shelf equipment to verify the suitability of the equipment in front of the project requirements. The review has to consider the used components list, the derating applied rules, the environmental conditions inclusive radiation and the equipment design.
Users are requested to provide the results of such review with sufficient details to enable upper level contractors / The Company to establish the acceptability of OTS equipment for Programme mission. DCL, qualification reports, traceability records, space heritage demonstration, field return data, audit report are example of documents to be provided as agreed on case by case basis.

12.5.6. Standardization

In order to standardize and reduce the number of different generic part types and families, standardization is achieved trough the The Company DAE/PRB process.
In addition, Electrical designers refers to the PPL (Preferred Part list).
Sub-contractors EEE parts standardization policy is verified during audits, PAD sheet analysis and PCB meetings.

12.5.7. DAE/PRB Process

The selection and standardization of EEE parts is implemented through the Internal DAE/PRB process. The DAE/PRB process requires the successful completion of 2 phases before authorization of procurement.
This process requires DAE/PRB Committees with the participation of Electrical Designers, Experts from parts engineering, Quality Assurance parts, processes and material Experts, Radiation experts, purchasing and manufacturing (when necessary).
DAE/PRB status sorted by EEE parts Families, project, date, approval status, etc…can be obtained electronically. DAE/PRB committees reports are issued at each meeting.

Sub-contractors may have their internal processes for new parts selection. Such processes are covered by Audits agenda.

12.5.8. Parts for Engineering and Qualification Model (EM/EQM)

The EEE parts for EM and EQM may be selected from lower quality level. Commercial parts may be used with the provisions that the parts will be form, fit and function compatible to the flight parts. Preference will be given to manufacturers who will supply the parts in hi-rel quality level.
The components selected for EQM will be hermetic sealed (plastic packages will be generally avoided) and will meet the extended temperature range (- 20º C to + 85º C).
In the event that EM will be used inside vacuum chamber, the components must be capable to withstand the environmental conditions (i.e. surface finish will be compatible with vacuum testing).
The FPGA used in EM/EQM will be necessarily from the same manufacturer with the guarantee to be fit, form and function representative, possibly with the same chip as the parts intended for flight.

12.5.9. Parts for GSE

Parts for GSE and other non-flight parts which interface with flight hardware during assembly and test will be selected and procured at a standard compatible with flight hardware, i.e. at the same level as those for EM, as minimum. Savers for connectors will be used to ensure that the flight hardware integrity is not degraded.

12.5.10. Declared Component List (DCL)

Suppliers are requested to issue a Declared Components List (DCL) in an editable electronic format identifying all components types needed. This list is requested to be kept under configuration control (Issue and identification of changes) .
The DCL contents is compliant with ECSS-Q-60 requirements.

The Company as prime contractor issue a DCL based on all suppliers DCLs . This DCL is issued in an editable electronic format .
This list is kept under configuration control (issue and identification of changes) The content of the Company DCL is compliant with ECSS-Q-60 requirements.

The DCL is issued at PDR and CDR.

12.6. COMPONENTS DATA ACQUISITION AND ASSESSMENT

EEE Parts delivered to The Company have the Manufacturer Certificate of conformance.
Screening data, LAT/Lot Validation Testing, QCI/TCI defined in the applicable procurement documents will be available at the manufacturer's facilities or delivered with the parts when required by the purchase order.
Assessment for parts acceptance is performed trough analysis of the manufacturer Data package (Screening, LAT results, etc.) during final CSI or during Incoming inspection.
Data packages are analyzed by EEE parts experts from Engineering and Quality organizations.

Assessment for parts flightworthiness is performed by additional data analysis such as DPA, Radiation tests results, Up screening test results (if any), NCRs dispositions etc…. This documentation is available In The Company or subcontractors premises for customer review.
EEE Parts procurement data review are scheduled between The Company and sub-contractors in order to verify the parts procurement quality compliance

12.7. COMPONENTS EVALUATION AND RELATED TESTING APPROACH

New parts technology not covered by a valid or acceptable qualification are subject to Evaluation programs as described in EEE standard (100141911C-EN)

The evaluation program covers the following activities:

- Constructional analysis (Design, Materials, Workmanship, Potential Hazard, Reliability Aspects).
- Component manufacturer assessment and Heritage.
- Evaluation testing (Electrical, Environmental, Endurance).
- Component mounting capability.
- Radiation Hardness (Total dose and single events sensitivity).

When several part types coming from the same part family, technology and processes are identified as flight candidates, the evaluation program may be performed on a single part type (generally the more complex electrical function).
Sub-contractors components evaluation reports and testing approach are reviewed during PAD approval process.

12.8. COMPONENTS APPROVAL

The PCB will have the task to review any equipment DCL and to approve the use of all components taking into account the suitability of the selected component to the project requirements (quality level, operative temperature range, lifetime, radiation tolerance, etc.) and standardization related issues.
Any component will be approved for FM use through Part Approval Document (PAD) prepared by the procurement authority.

PAD (Parts Approval Document) are issued internally and by sub-contractors for all EEE Parts, including qualified Military class level S parts, Class V parts, Class K parts, Jan S parts, QPL listed ER MIL passive parts, QPL listed Military specifications passive parts, ESA/ESCC qualified parts and all in-House manufactured parts.
PADs are requested to Sub-Contractors to be submitted to the upper level contractor chain up to The Company approval

When contractually required by the project, PADs are submitted to the customer for approval during PCB meetings.

Since the approval process call for other documents reviews, (Internal specifications, Evaluation reports, Procurement data, DPAs etc…, these reviews are held in sub-contractors facilities for purchased Equipments and in The Company facilities for In House manufactured Equipments..
The previous use or approval of a part (via PAD or DCL approval) for previous project will not be considered as an automatic approval. It will be considered and traced in any case in the section "APPROVAL STATUS" of the relevant PAD. Specific application and environmental constraints will e in any case taken into account on a case by case basis.
The Company will operate so that all PADs will be tentatively approved prior the equipment CDR close out.

12.9. COMPONENTS TESTING, INSPECTION AND STORAGE

12.9.1. Components testing

All parts to be incorporated into flight standard hardware are submitted to screening tests.
The minimum screening requirements are those defined in ESCC or MIL system standards and in compliance with Company EEE requirements (100143911C-EN)
All screening or up-screening tests will be performed by the parts manufacturer or at test houses approved by The Company.

In addition to parts screening tests and depending on Manufacturer or Parts Qualification status, Lot Acceptance Tests or QCI qualifications are performed using the following rules:

ESA ESCC Space Qualified parts: LAT/LVT on procured lot is not requested due to periodic lot validation tests performed by the manufacturer and monitored by Space Agencies.
MIL Space Qualified parts: QCI or TCI tests to be performed by the manufacturer are in accordance with the quality level of the MIL specification as defined in 100141911C-EN, table A1 and associated notes.
Non Space Qualified parts: For non space qualified parts, LAT or comparable QCI are performed in accordance with the closest applicable ESA ESCC or MIL Specification.

Based on past experience with the same part from the same manufacturer, LAT/QCI are decided on a case by case basis when supporting data for the part type under consideration are available. When no changes are demonstrated on part design, construction and manufacturing processes, The Company apply a 2 years LAT/QCI periodicity, similar to Space agencies parts qualification extension period.
In other cases, LAT/QCI rules apply on each lot basis.
The LAT/QCI sample size for expensive parts are identified in the corresponding PAD sheet.
All the above components testing approaches apply to sub-contractors

12.9.2. Inspections

Throughout the procurement special attention to the Manufacturer's interpretation and adherence to the requirements of the procurement. When applicable, this will include the performance of audits, specification integration and source inspection.

Prior to parts screening, Precap inspection and prior to parts shipment from manufacturers final source inspection are performed at manufacturer facilities to ensure conformance with requirements of the purchase orders, procurement specification(s) and data requirements.
Performance of these inspections is based on the requirements specified on QMS-QM 100141911C-EN Standard, table A1 (Screening and inspection matrix)and associated notes.
The final source inspection may be replaced by incoming inspection on non critical parts.

Depending on manufacturer location, Precap and Final Source Inspections may be sub-contracted to The Company approved tests houses experts.
For critical parts, surveillance visits may be extended by spot checks and LAT/QCI monitoring as appropriate to ensure conformance with process identification document and procurement specification(s).

Post manufacturer shipment, Incoming inspection activities are performed in The Company premises to verify conformance with the purchase order requirements.
Incoming report document is issued for each delivery.
Incoming inspection activities includes Marking control; Quantity verification; Packing checking; Review of the manufacturer delivered documentation.
If the parts have passed successfully a final CSI (or buy-off) or for parts received from a procurement Prime/Agent, providing that incoming inspection has been performed by the Agent, the incoming inspection may be limited to:
- Quantity and damage verification.
- Checking of packaging, conditioning, documentation.

When applicable, additional RVT and DPA tests are performed by The Company Approved tests houses in compliance with Company Standards QMS-QM 100141943M-EN and QMS-QM 100141911C-EN requirements. RVT, LAT and DPA tests results will be available before the installation of the components into flight hardware.
In order to comply with schedule constrains, occasionally, parts may be allowed to be assembled prior to additional DPA, LAT and RVT tests completion. In that case, a temporary Non Compliance is recorded and linked to the parts trace. This temporary non compliance appears also at equipment level until additional tests are completed an results approved.
RVT, LAT and DPA tests reports are configured documents and available for review in The Company premises.
All major inspection points are identified in the corresponding PAD.
All the above inspections points apply to sub-contractors

12.9.3. Storage

Parts are handled and stored in accordance with the requirements of ECSS-Q-20B, storage conditions are adequate to inhibit degradation of the surface finishes of the mounting areas of the components.

Procedures for handling and storage of components are implemented by The Company and are applicable for any facility dealing with components for flight application.
EEE parts are stored in cleanliness controlled environment (22°C +/- 5°C) and Relative Humidity = 55% +/- 10%) with appropriate measures to segregate and protect components during receiving inspection, storage, and delivery to manufacturing.
Control measures to ensure that electrostatic discharge susceptible components are identified and

handled only by properly trained personnel using anti static packaging and tools.
All the above storage requirements apply to suppliers

12.9.4. Relifing

The Company apply Relifing policy for parts being stored for more than 6 Years with a relifing Procedure addressing relevant tests for each part family. Sub-Contractors relifing procedures are allowed by The Company if they meet the same testing requirements.
Sub-Contractors relifing procedures. are reviewed and approved by The Company prior or during PCB meetings . In addition relifing tests reports are reviewed at sub-contractors premises on sample basis.

12.9.5. Traceability

Traceability during parts manufacturing and testing is maintained as required by the procurement specifications.
Traceability data are maintained from Parts Incoming to installation on hardware and post Equipment delivery. Traceability is related to Parts manufacturing lot or date code or batch number.
Traceability policy apply in full to sub-contractors

12.10. COMPONENTS QUALITY ASSURANCE ACTIVITIES

The components quality assurance main activities are:

- Monitoring of the internal EEE parts processes
- Participation in the Parts approval process
- EEE parts non conformances management
- Participation to the Alert process
- Inspections, surveillance and audits at parts manufacturers facilities
- Preparation and management of Customer reviews
- Quality committee management with industrial units
- Dash-Board data collection
- Participation to Company Standard EEE Parts requirements updating

12.11. ASSESSMENT OF PROBLEM NOTIFICATION AND ALERTS

12.11.1. Problem notification, Non Conformances or Failures

See section Anomalies & Non conformances control system (§4.6)
Any observed deviation of EEE Components from requirements as laid down in applicable specifications or field failure are controlled by the Non Conformance Control System.
Any non conformances occurring during Incoming inspections, Documentation review, DPAs, RVT, Relifing, Integration and tests of equipment, storage and handling are reported and subject to Non Conformances dispositions.
In addition, the MRP Application has all EEE non conformances recorded to allow traceability at equipment level

12.11.2. Alerts

See section Alert (§4.7)

12.12. PROGRAM PLANNING WITH SCHEDULE OF TASKS LINKED TO PROJECT MILESTONES

Internally to The Company parts needed for the project are declared in the Production Data Management (PDM) application.
This PDM is electronically linked to the Manufacturing Ressource Planning (MRP) application. The MRP application is used by the purchasing organization to schedule and to follow-up EEE parts orders.
The MRP application is used also to manage Scheduling, milestone, stock availability, obsolescence traceability, procurement data, Incoming tests ….etc.

12.13. SPECIFIC COMPONENTS CONTROL AND BACK-UP PLANS WHENEVER THERE IS EVIDENCE OF POSSIBLE SCHEDULE, QUALITY OR TECHNICAL PROBLEMS

Specific components control or back-up plans are implemented and progress is reported to the Equipment responsible Engineer in case of possible impact on the project.
Technical and Quality problems are managed under the Internal alert process leading to manufacturer surveillance reinforcement.
Schedule impact is minimized by internal manufacturing flow revision.

12.14. REPORTING AND DELIVERABLE DOCUMENTATION

12.14.1. Reporting

Reporting is in line with the section 3.5.2.When PCBs are contractually required by the project, action progress report will be issued between each PCB.

12.14.2. Deliverable documentation

The EEE parts documentation to be delivered for Customer review and approval is contractually defined by the SOW (see § 4.2)

radiation/hardness

12.15. INTRODUCTION

12.15.1. foreword

The hardware will be designed to survive the space radiation environment during the Radiation Design Lifetime. The purpose of this document is to provide a Space Radiation Hardness Assurance Plan that will be implemented during project in order to prove that the hardware will continue to perform its function throughout its Radiation Design Life.
The policy is applied within Prime and Suppliers through QMS-QM 100141943M-EN

12.15.2. SCOPE

General damage mechanisms to which the satellite will be subjected include :

Total dose damage of electronics and solar arrays due to electrons and protons.
Single event phenomena (upsets, latchups, burnouts, Transient, Hard Error, Functional Interrupt, ...) of electronics due to the cosmic ray, solar flare environments and trapped protons.
Displacement damage induced by protons

The radiation review Space Radiation Environment applicable for this mission is given in Applicable Document (QMS-QM 100143671P-EN for geostationary satellite, TBD for other missions).

12.16. total dose evaluation and hardness assurance

The harware unit will be designed to account for the Total Dose Effect, during the Radiation Design Lifetime (RDL), as specified in Applicable Document QMS-QM 100143671P-EN for geostationary satellite, TBD for other missions).

The Space Radiation Hardness activities will proceed through these non-chronological tasks :

- Parts selection, characterization and Radiation Lot Acceptance Testing
- Deposited doses calculations
- Equipment worst case analysis (WCA)
- Corrective actions.

12.16.1. parts selection

Parts will be selected in order to survive the on-orbit space radiation environment for the specified mission time as well as still permitting the units in which they are installed to meet all their performance specifications. The minimum allowable radiation level is the Total Dose Threshold (TDT) level defined behind 15 mm of Aluminum of a Solid Sphere shielding, according to applicable document (QMS-QM 100143671P-EN). All parts will meet the Total Dose Threshold (TDT), as specified in Applicable Document (QMS-QM 100143671P-EN for geostationary satellite, TBD for other missions).

12.16.2. TOTAL DOSE RADIATION LOT ACCEPTANCE TEST (RADLAT)

Due to the lot-to-lot variability in Total Dose effect, all active parts, will be submitted to Radiation Lot Acceptance Tests (RADLAT). As a general basis, the RADLAT testing matrix is given in table here below.

However, on a case by case basis, test criteria could be relaxed taking into account total dose data on previous lots. For example, for a given part/Manufacturer, if total dose behaviour is steady and if there is no technology modification, test frequency can be reduced. In any case, technical data will justify this relaxation.

The generic RADLAT testing matrix is as follow :

	MOS / BiCMOS			BIPOLAR			
Zener Diodes				10	RD-1	High or Low	5
Transistors	All	RD-1 or RD-3	High or Low	2	RD-1 or RD-3	Low	5
Analog Ics	All	RD-1 or RD-3	Low (1)	All	RD-3	Low	5
Logic Ics	1	RD2 or RD3	Low (1)	4	RD3	Low	5
ASICs, FPGA	All	RD2 or RD3	Low (1)	All	RD3	Low	2-3
RAM, PROM, Processors	2	RD2 or RD3	Low (1)	6	RD3	Low	2
Optoel., CCD,	All	RD2 or RD3	Low (1)	All	RD3	Low	5

(1) : For fully MOS technology devices High Dose Rate can be used

Table13-2-2-1 : Total Dose Screening Matrix

With

RD1 : MIL-STD-883C, METHOD 1019.3
RD2 : MIL-STD-883D, METHOD 1019.5 & 1019.6
RD3 : « Total Dose Steady State Irradiation Test Method ESA/ESCC Basic Specification N° 22900, issue 3, November 1993

All	All diffusion lot tested
1	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than 1 year.
2	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than 2 year.
4	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than 4 year.
6	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than 6 year.
10	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than 10 year.

Table 13-2-2-2 : RADLAT Test Criteria

Low Dose Rate is lower or equal to 360 rad/hour (0.1 rad/sec).

Silicon Nitride layer will be avoided unless RADLAT data demonstrates an acceptable total dose behaviour.

Some device technologies are inherently hard to total dose ionizing dose effects. The following classes of parts are considered as total dose insensitive :

Non Zener Diodes	Not sensisitive up to 300 Krad(si)
GaAs	Gallium Arsenide devices such as FETs and HEMTs show little parametric variation.
Std TTL Logic	Extensive testing on 54XX, 54L, 54S devices show these parts to be only marginally degraded
ECL	Emitter Coupled Logic devices exhibit little parametric shift out to several Mrad(si)
Microwave Devices	Step Recovery, Varactor, Schottky, Microwave Mixer and Multiplier Diodes exhibit negligible shifts
Quartz	No Total Dose testing required unless in Swept technology

For these parts, deposited dose levels will be lower than 300 krad(si).

For Radiation Hardened parts, data have to be provided by the part manufacturer.

12.16.3. Use of Teflon

Teflon can be used, under the following conditions :

- Evaluation experimental data are provided to demonstrate a sufficient hardness level

- It is shielded to meet the following total dose requirements

TOTAL DOSE Mrad	ALLOWABLE MATERIAL
> 500	Kapton only (no Teflon)
80 - 500	Kapton, ETFE (1)
20 - 80	Unconditionally : Kapton, ETFE : Conditionally (4) : PTFE (2) & FEP (3)
<= 20	Kapton, ETFE, PTFE & FEP

(1) : ETFE Ethylene Tetra Fluoro Ethylene (DuPont Tefzel, Raychem x-linked)
(2) : PTFE : Poly Tetra Fluoro Ethylene
(3) : FEP Fluorinated Ethylene Propylene
(4) : Use of PTFE and FEP Teflon above 20 Mrad is restricted to applications where are no mevements of the wire during trhe mission.

12.16.4. deposited dose calculations

The Company will perform an accurate deposited dose analysis of the hardware. Therefore, a detailed 3D radiation model of the equipment will be performed, with parts models included. The equipment will be located inside the 3D satellite radiation model. If not satellite radiation model is available, the following approximation will be used :

Inside	0 . 5	0 . 5
Outside	1 . 6	0 . 1

Table 13-2-4-1 : Preliminary Satellite Radiation model

Two Deposited Dose calculation methods will be used :

- **Preliminary analysis : Ray Tracing** : This calculation method is based on the straight ahead approximation. Solid Angle Sectoring Analysis are performed taking into account the angle of incidence between the ray and the shielding (Slant Path). The Dose Depth Curve for a Solid Sphere shielding will be applied. A minimum sectoring resolution of 1800 elementary solid angles is used.

Accurate analysis : 3D Monte Carlo : This accurate calculation method will be used on 'critical parts'

before to implement corrective actions. A minimum resolution of 2000 histories will be used.

12.16.5. worst case analysis

Circuit WCA will evaluate the equipment susceptibility to the radiation environment. WCA includes the effects of temperature, ageing, and radiation degradation. This equipment WCA is a valuable tool to identify clearly critical parts. Because there is a 'within one lot variability', it is necessary to use statitical tools in order to estimate the Post-Rad parameters values. This Post-Rad value, for each electrical parameter shift, will use the 3 sigma approach :

Delta XL = <delta x > + 3 . For increasing total dose shift

Delta XL = <delta x > - 3 . For decreasing total dose shift

12.17. single event phenomena hardness assurance

Cosmic rays, solar flares and high energy trapped protons can induce various effects, caused by the energy deposited by a high energy particle as it interacts with the sensitive portions of an electrical device. These effects are : Single Event Upset (SEU), Single Event Latch-Up (SEL) , Single Event Burnout (SEB) , Single Event Gate Rupture (SEGR) , Single Event Transient (SET) and Single Event Hard Error (SHE).

12.17.1. PART CARACTERISATION

Heavy ion testing will be performed in agreement with :

«Single Event Effects Test Method and Guidelines ESA/ESCC Basic Specification N°25100, Draft A, February 1995.
JEDEC Test Standard # 57, « Procedures for the Measurement of Single Event Effects in Semiconductor Devices from Heavy Ion Irradiation », May 1996.

Main characteristics are :

LET values will be calculated as follow :

- Identify the device N-EPI layer L_0 in µm
- calculate the deposited charge Q_{dep} , in pC, over this layer, then $LET_{equ.} = \frac{Q_d}{L_0}$ in pC/µm

Heavy ion species and energies (range) will be selected in order to make sure that :

- The ion range will be greater than the EPI layer thickness
- The saturated device cross section is obtained. If not, 50% of the die surface will be considered

A part will be Destructive Single Event Free if no event is observed, at $LET_{equ.} \geq 60$ MeV.cm²/mg, up to a fluence of 10^7 ions/cm².

12.17.2. PART SELECTION

12.17.2.1. Single Event Upset

The Company will analyse to effect and the criticity of SEU for the equipment. For digital technologies, the The Company will use parts with a well known SEU sensitivity in terms of LET threshold and cross section.

If the orbit is exposed to proton environment and if the Heavy Ions LET threshold is lower than 15 MeV.cm2/mg, then there prediction tools (PROFIT, SIMPA, …) will be used.

12.17.2.2. Single Event Transient

This includes such devices as Linear integrated circuits that do not suffer logic upset as such, but may produce a large output spike that can appear as a false command. Experimental data will be provided in order to justify the use of selected parts, and SET frequencies will be determined.

12.17.2.3. Single Event Latchup

As a preferred baseline approach, only Single Event Latchup Free parts will be used.

Single Event Latchup sensitive parts could be used upon a case by case basis .

12.17.2.4. Single Event Burnout

As a preferred baseline approach, only Single Event Burnout free parts will be used

In order to prevent permanent damage, bias requirement is as follow :

For N-Channel Power MOSFETs from International Rectifier, design requirements are as follow :
VDS $\leq$ 50 % BVDSS @ BVDSS $\leq$ 200 Volts

For VDS above 50% or BVDSS > 200 Volts or other manufacturers, Heavy Ions data will be provided in order to demonstrate SEB free behaviour

POWER MOSFET P-CHANNEL and BIPOLAR POWER transistors are SEB free.

12.17.2.5. Single Event Gate Rupture

As a preferred baseline approach, only Single Event Gate Rupture free parts will be used

For Power MOSFETs from International Rectifier, design requiremnts are as follow :

N Channel : VG $\geq$ 0 Volt & P Channel : VG $\leq$ 0 Volt

Single Event Gate Rupture sensitive parts could be used upon a case by case basis .

12.17.3. single event upset rate calculation

For a given phenomenon, the part cosmic rays response is a curve of Device Cross Section versus LET of incident ions. The Heavy Ions SEU rate hi will be calculated for each active part. The Proton SEU rate pr will be calculated for each active part having an Heavy Ion SEU LET threshold lower than 15 MeV.cm2/mg, and if the orbit is exposed to proton environment.

The Total SEU rate is seu = hi + pr

12.17.4. single event upset & transient effects analysis

The Company will perform a SEU effects analysis in order to identify the SEU effects and criticality.

The Company will perform a SET effects analysis in order to demonstrate to determine the effects of SET on equipment performance, taking into account the following effects on performance :

OP-amps	V_{max} =+/- V_{CC} & t_{max} =15 µs
Comparators	V_{max} =+/- V_{CC} & t_{max} =10 µs
Voltage Regul.	V_{max} =+/- Vcc & t_{max} =10 µs
Voltage Ref.	V_{max} =+/- V_{CC} & t_{max} =10 µs
PWMs	Double Pulses, two missing pulses, multiple missing pulses in a row, device shut off. Assess impact in specific application.

For those applications, THE COMPANY will demonstrate that a SET will not produce an out of specification.

12.17.5. Destructive Single Event Effects Acceptance Criteria

Parts sensitive to Destructive Single Event Effects (Latchup, Gate Rupture, Burnout, ...) will be used, after the following analysis process :

Step 1 :

- To perform an heavy ion testing in order to get the accurate device cross section vs $LET_{equ.}$ characterization curve.
- Tests will be performed at the application biais conditions (no interpolation)
- The LET_{th} is the last point for which no destructive event is observed.

Step 2 : Calculate Destructive Single Event equivalent Rate eq, taking into account experimental device cross section vs LET curve.

Step 3 : The Destructive Single Event device application will be accepted only if : $\lambda_{eq} \leq \frac{\lambda}{10}$

where λ is the reliability failure rate of the part (@ 25°C).

Step 4 : if : $\lambda_{eq} > \frac{\lambda}{10}$, then the Destructive Single Event device application will be accepted only if there is no impact on the equipment and/or system reliability analysis.

12.18. displacement damages

If the orbit is exposed to a severe proton environment, then Displacement Damage effects is a serious problem to electronic devices.

The Company will consider Displacement Damage effects if required by the customer.

For Geostationary missions, Displacement Damage will be analyzed only on opto-electronic devices such as : opto-couplers, CCD, solar cells, ….

For MOS devices, this effect can be ignored because the sensitivity threshold is high enough.

The acceptance of the parts will be based on displacement damage test data. The data will be taken from neutron testing databases and proton test results. Equivalence between protons and neutrons can be deduced from environment specification. If no data are available, proton irradiation evaluation tests can be performed. RADLAT Testings will be performed with Protons @ energy ≥ 150 MeV or with neutrons @ 1 Mev

Displacement Damage Test Criteria :

Optronic (CCD, Optocouplers, ...)	All diffusion lot tested
Linear Ics	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than 4 years.

Transistors	Lot tested if flight diffusion lot number different of data diffusion lot number and data date code older than 10 year.

The electrical parameters drifts induced by displacement damage must be added to Total Dose drifts in the Worst Case Analysis.

13. MATERIALS AND PROCESSES

13.1. SCOPE

This plan establishes the policy applicable for materials, mechanical parts and processes used in flight equipment, subsystem and system.

The implemented plan ensures the adequacy for the application of all materials and processes and verifies that the materials and processes comply with project contractual, design, quality and performance requirements.

This plan provides detailed procedures relative to :

- control and approval of materials and processes
- selection policy and specific requirements for materials and processes.

The policy is applied within Prime and Suppliers through QMS-QM 100141941K-EN.

13.2. Definitions

13.2.1. Material

Raw or semi-finished product or compound (gaseous, liquid, or solid) of specific characteristics, which is processed to form a part or a finished product.

13.2.2. Mechanical part

Piece of hardware that is not electrical, electronic or electromechanical, and which performs a simple (elementary) function or part of a function in such a way that it can be evaluated as a whole against expected performance requirements and cannot be disassembled without destroying this capability.

13.2.3. Processes

Set of inter-related resources and activities which transforms a material or semi-finished product into a semi-finished product or final product. The definition of Process excludes mechanical operations such as standard milling, drilling, turning and mechanical assembly. The concept of Process also covers all the facilities required : personnel, environment, equipment, tooling and corresponding methods.

13.2.4. Critical material

Material that is new to an individual company or non-validated for the particular application and environment or has caused problems during previous use that remain unresolved.

13.2.5. Critical mechanical part

Mechanical part that requires specific attention or control due to fracture mechanics aspects and limited-life aspects, or with which the contractor has no previous experience of using the mechanical part in the specific application and environment or that are new or non-qualified or has caused problems during previous use that remain unresolved.

13.2.6. Critical process

Process is declared critical when it is new to an individual company or non-verified for the application in question or has caused problems during previous use that remain unresolved.

13.2.7. Request for approval (RFA)

Document with which the supplier or user asks the competent body for permission to use a critical material, mechanical part or process.

13.2.8. Special process

Process where quality cannot be completely ensured by inspection of the end article only.

13.3. POLICY FOR CONTROL AND APPROVAL OF MATERIALS AND PROCESSES

13.3.1. General

The basic elements for the management of the materials and processes are:

a. Materials and Processes control procedure and Customer reviews.

b. Materials and processes lists including approval status and previous use.

c. Request For Approval Material (RFAM) and Request For Approval Process (RFAP), qualification plan and reports, and waivers, when necessary.

The basic objectives are to control the selection, procurement, and qualification of materials and processes to fulfil the specific mission requirements consistent with the schedule of hardware manufacturing and tests.

A materials and processes PA representative reports functionally to the PA manager and supports the project team to implement these requirements.

An early task of this representative is to identify critical items related to materials and processes.

These items are included with necessary controls and/or qualification tests in the Critical Items List (CIL).

13.3.2. Materials and Processes control procedure

The review of material and process is carried out by the Materials and Processes representative assisted by other relevant experts as necessary (design, inspection, development, manufacturing, test).

This procedure begins early in the project during initial equipment design and selection of materials and processes.

The Materials and Processes representative :

- verifies that materials and processes lists are representative of the hardware design
- reviews and approves materials and processes lists and the revisions of these lists
- supports investigations into material and process non conformances
- supports project reviews as necessary
- reviews the additional items related to materials and processes in the CIL
- verifies and approves the materials and processes qualification activities and participates in the review and approval of request for approval (RFAM/RFAP).

13.3.3. Customer reviews

To obtain the validation status for materials, mechanical parts and processes, the materials and processes PA representative presents to the Customer those activities which have been performed in order to comply with this document together with results obtained.

To conduct the review effectively and to demonstrate acceptability, the materials and processes PA representative submits for review the following documents and data:

a. Materials, and processes lists.

b. Validation plans and reports for critical materials and processes.

c. Specifications, documentation supporting the selection and application of materials and processes as required.

Upon completion of this review, the materials and processes PA representative makes a formal statement of the approval status of the materials and processes and, if necessary, specifies the actions to be taken before approval.

The materials and processes PA representative organises technical review meetings with his Suppliers at all levels, as appropriate.

For confidential technologies, documentation review could be delegated to agencies or governmental organisations during validation or revalidation activity.

13.3.4. Materials and processes Lists

13.3.4.1. General

The materials and processes lists are the basic documents for the management of the materials and processes activity. They reflect the current design at the time of issue and include all the materials and processes employed in manufacture. Each material and process is identified, and its application is defined. Materials and processes lists are subject to review and approval before submission for approval to Customer.

At the system and subsystem levels, the materials and processes lists are composed from the collection of the materials and processes lists including all the materials and processes intended for use in the flight equipment.

13.3.4.2. Contents of the Lists

Materials and processes lists are broken down into clear categories to facilitate locating each item in the documentation.

The lists include the following detailed information for each material and process used.

For materials :

- item number (as the reference of the material in the material list); it is the same through the duration of the project
- precise identification at procurement level: designation of identification (type, nature, form, condition of the product) manufacturer, vendor or Supplier, and procurement specification or standard (or datasheet)
- information about implementation: processing parameters (finish, temper, condition, cure, mix ratio, etc.), location where used, environment and quantity codes (when relevant), outgassing data, corrosion and stress corrosion cracking codes
- approval status, comments and reference documents.

For processes :

- item number (as the reference of the process in the processes list); it is the same through the duration of the project
- clear description of the process
- manufacturing and inspection, specification reference(s), title and applicable issue
- use and location at equipment level
- approval status, comments, and reference documents.

13.3.5. Request For Approval/Material (RFAM) and Process (RFAP)

If it is foreseen to use a material or process :

- that is not space proven, or
- that has been used on previous space projects but not for the same application or environment and needing additional qualification tests.

A Request For Approval Material (RFAM) or Process (RFAP) is established.

Previous projects materials and processes lists are used to determine if RFAM/RFAP are necessary.

The following information is provided with the RFAM/RFAP :

- justification for use of the unqualified material /process (if necessary)
- qualification plans and schedule.

After approval of the qualification plans and schedule by the Customer, the qualification tests are implemented to demonstrate the conformance to the project requirements.

Upon completion of these tests, a qualification test report is submitted to the Customer for approval. The RFAM or RFAP is closed and the Critical Item List (CIL) and the materials and processes lists are updated.

13.4. SELECTION POLICY AND SPECIFIC REQUIREMENTS

It is the policy to use only those materials and processes that have been demonstrated to be suitable for use :

- by being qualified on ground within the framework of a formal qualification programme
- by demonstrating satisfactory use in space on previous space projects with similar applications and environmental conditions.

13.4.1. Materials

Materials are selected in accordance with design, quality, and performance criteria for their intended application.

Each material is controlled by a detailed procurement specification or a standard. Specifications define the material properties, requirements, test methods and acceptance criteria.

Where suppliers do not accept specifications and procurement is by means of a datasheet, internal, in-house receipt inspection is introduced to ensure that the validation status of the material is maintained during the subsequent procurements.

The following requirements are taken into account if the environmental conditions of the mission require their application.

13.4.1.1. Vacuum

Outgassing tests are carried out as per ECSS-Q-70-02A (A thermal vacuum test for the screening of space materials) or per ASTM E595-93 (Total mass loss and collected volatile condensable materials from outgassing in a vacuum environment) on materials whose conditions of use can lead to contamination.

The acceptance criteria for materials used in space applications are as follows (unless otherwise stated by specific project requirements):
recovered Mass Loss (RML) < 1.00%,
Collected Volatile Condensable Material (CVCM) < 0.10%.

Materials close to optical surfaces may require additional testing to be evaluated on a case-by-case

basis.

Pure tin (> 97 %) electroplated or electroless plated, mercury, cadmium, zinc and polyvinyl chloride (PVC) are not used

13.4.1.2. Thermal cycling

Materials subject to thermal cycling are assessed to ensure their capability to withstand the induced thermal stresses.

13.4.1.3. Radiations

Materials used on the spacecraft external surfaces are assessed to determine their resistance to the radiation dosage expected during the mission.

ESA PSS 01 706 Issue 1 (The particle and ultraviolet (UV) radiation testing of space materials) is applied in order to demonstrate resistance of materials to radiation (electromagnetic and particles).

13.4.1.4. Atomic oxygen

Materials used in the outer surfaces of space systems in low earth orbit are resistant to received atomic oxygen flux. Acceptance criteria are defined on a case-by-case basis.

13.4.1.5. Meteoritic environment

The influence of a meteoritic environment on the materials is examined on a case-by-case basis.

13.4.1.6. Electrochemical compatibility

When bimetallic contacts are used, the choice of the pair of metallic materials used takes into account specification ECSS-Q-70-71A rev 1 (Data for selection of space materials) or MIL STD 889 notice 3 dated 17/05/93 (Dissimilar metals) data.
Maximum allowed couple is 0.5 V in controlled environments and 0.25 V in other environments (no temperature or humidity controls).

13.4.1.7. Corrosion

Corrosion resistance is demonstrated for materials subject to corrosion throughout their life cycle (e.g.: storage, transportation, launch). ECSS-Q-70-71A rev 1 (Data for space materials) or MSFC-HDBK-527 Issue F (Materials selection list for space hardware systems) is used as a guideline.

13.4.1.8. Stress corrosion

Materials used for structural and load bearing applications (subject to tensile stress) are chosen in compliance with table 1 of ECSS-Q-70-36A (Material selection for controlling stress corrosion cracking) or MSFC-STD-3029 Rev A (Selection of metallic materials for stress corrosion cracking resistance in sodium chloride environments).

Any material not covered by these standards is tested according to ECSS-Q70-37A (Determination of

the susceptibility of metals to stress corrosion cracking) or MSFC-TD-3029 Rev A (Selection of metallic materials for stress corrosion cracking resistance in sodium chloride environments).

13.4.1.9. Flammability

The use of flammable materials is avoided whenever possible and/or potential propagation is controlled through separation barriers.

13.4.1.10. Biocontamination

The biocontamination aspect of materials is examined on a case-by-case basis.

13.4.1.11. Fluid compatibility

Materials in contact with an identified fluid is selected to be compatible with that fluid. If adequate compatibility data are not available, then testing is performed according to
NASA-STD-6001 dated 09/02/98 (Flammability, odor, offgassing and compatibility requirements and test procedures for materials in environments that support combustion), test number 15.

13.4.1.12. Limited life materials before implementation

Limited life materials are identified as such, their properties are controlled, and upon acceptance at incoming inspection, expiration dates are marked on the containers or on the materials. Expired material can be re-certified for one extended period of use (maximum half of initial life), subject to satisfactory evaluation of parameters sensitive to deterioration (mechanical, chemical, and physical properties).

13.4.1.13. Toxic materials

Equipment containing toxic materials (e.g. BeO,…) are suitably labelled. Radioactive materials, carcinogen materials, CFC are not used.

13.4.1.14. Optical, mechanical, or electrical GSE hardware

Materials used in optical, mechanical, electrical GSE are selected to withstand the applied environmental conditions (vacuum, mechanical stresses, thermal stresses…) without degradation and impact on the flight hardware (contamination, surface degradation, electro-mechanical and chemical effects).

13.4.2. Processes

Processes are selected on the basis of their compatibility with the materials to which they are applied, and their proven consistency in achieving the specified design, quality, and project performance requirements.

The materials used during the implementation of processes satisfies the requirements of this document.

Each process is controlled by a detailed specification. Specifications define the process implementation and associated acceptance criteria.

For the following specific processes, these requirements, except deviations duly accepted by the Qualifying Authority (agencies or governmental organisations), are applied.

13.4.2.1. High reliability connections

ECSS-Q-70-08A (The manual soldering of high-reliability connections), ECSS-Q-70-26A (The crimping of high-reliability connections) or CNES/QFT/SP.0050.6 Ed 2 (Spécification de réalisation de sertissages), ECSS-Q-70-18A (The preparation, assembly, and mounting of RF coax cables), ESA PSS 01 738 Issue 1 (High-reliability soldering for surface mount and mixed technology printed circuit boards) or NASA-STD-8739.3 Change 2 (Soldered electrical connections), NASA-STD-8739.4 Initial issue (Crimping, interconnecting cables, harnesses, and wiring), NAS 5300.4 (3M) Initial issue (Workmanship standard for surface mount technology) are applied for high reliability connections.

ECSS-Q-70-28A (The repair and modification of PCB and solder joints for space use) or MIL-PRF-55110 F (Printed wiring boards, rigid, general specification for) is applied for repair and modification of PCB assemblies.

13.4.2.2. Printed circuit boards

ECSS-Q-70-10A (The qualification of printed circuit boards), ECSS-Q-70-11A (The procurement of printed circuit boards) or MIL-PRF-55110 F (Printed wiring boards, rigid, general specification for), MIL-P-50884 C Amendment 4 (Printed-wiring, flexible and rigid-flex) are applied for qualification and procurement of printed circuit boards.

13.4.2.3. Conformal coating

Conformal coating is used on PCB assemblies according to NAS 5300.4 (3J-1) (Workmanship standard for stacking and conformal coating of printed wiring boards and electronic assemblies) used as guidelines or customer approved document for qualification and implementation. Duly justified deviation only for performances aspects is accepted.

13.4.2.4. In house manufactured hybrids

In house hybrids are manufactured in a validated hybrid line according to ESA PSS 01 605 Issue 1 (Capability approval programme for hermetic thin-film hybrid microcircuits), ESA PSS 01 606 Issue 1 (Capability approval programme for hermetic thick-film hybrid microcircuits), ESA PSS 01 612 Issue 1 (Capability approval programme for Microwave hybrid integrated circuits (MHICs)), or alternate document approved by the Customer or by the Qualifying Authority.

Lot acceptance test or element evaluation of active and passive dice are conducted according to ECSS-Q-60-05 (Generic procurement requirement for hybrid microcircuits) or alternate document approved by the Customer or by the Qualifying Authority.

Screening of hybrids on a 100% sampling basis are implemented according to level 1 of ECSS-Q-60-05 (Generic procurement requirement for hybrid microcircuits) or or class K of MIL-PRF-38534 E (Hybrid microcircuits, general specification for) or alternate screening approved by the Customer or by

the Qualifying Authority.

Lot acceptance test of hybrids are conducted according to ECSS-Q-60-05 (Generic procurement requirement for hybrid microcircuits) or MIL-PRF-38534 E (Hybrid microcircuits, general specification for) or alternate document approved by the Customer or by the Qualifying Authority.

13.4.2.5. In house manufactured magnetic parts (coils and transformers)

In house magnetic parts are designed and screened using MIL STD 981 B (Design, manufacturing and quality standards for custom electromagnetic devices for space applications) as a guideline.

Minimum screening on a 100% sampling basis is : visual inspection, electrical measurements before test, thermal cycling (minimum 25 cycles), high temperature storage (minimum 96 h) and final electrical measurements.

13.4.3. Control of Processes

General policy is to verify that:

- manufacturing and control means associated with the process are recognised as suitable and are used under appropriate conditions (environment and cleanliness)
- personnel certification requirements are clearly described where applicable
- the process specifications, manufacturing and inspection procedures including clear acceptance criteria, exist and have been approved
- materials associated with the processes are approved and appear on the material list.

Special processes are those which the quality cannot be completely ensured by inspection of the end article only. They are specifically identified and controlled.

By example, structural welding, crimping, soldering, gluing are special processes.

For special processes, process control is ensured by means of adequate procedures and personnel certification and/or machine certifications.

Annex 1 - ABBREVIATION

AIT	Assembly Integration and Test
CDR	Critical Design Review
CEO	Chief Executive Officer
CFO	Chief Financial Officer
CIL	Critical Items List
COTS	Commercial Off The Shelf
CTO	Chief Technical Officer
DCL	Declared Component List
DPA	Destructive Physical Analysis
DPL	Declared Parts List
DRB	Delivery Review Board
DVM	Design Verification Matrix
EEE	Electric Electronic Electromagnetic
EGSE	Electrical Ground Support Equipment
ESA	European Space Agency
EVPO	Executive Vice President Operation
FMECA	Failure Modes, Effects and Criticality Analysis
GSE	Ground Support Equipment
I/F	InterFace
IOT	In Orbit Test
JSC	Johnson Space Center
LAT	Lot Acceptance Test
LEOP	Launch and Early Operations
LET	Linear Energy Transfer
MGSE	Mechanical Ground Support Equipment
MIP	Mandatory Inspection Point
MRP	Manufacturing Ressource Planning
MSFC	Marschall Space Flight Center
MSPSP	Missile System Prelaunch Safety Package
MTBF	Mean Time Between Failure
MTT	Mean Time To
NCR	NonConformance Report
NRB	Nonconformance Review Board
NSPAR	Non Standard Part Approval Request
PA	Product Assurance
PAD	Parts Approval Document

PCB	Parts Control Board
PDM	Production Data Management
PDR	Preliminary Design Review
QA	Quality Assurance
QCI	Quality Conformance Inspection
QPL	Qualified Part List
QSL	Qualification Status List
RFAM	Request For Approval/Material
RFAP	Request For Approval/Process
RID	Review Item Discrepancy
RADHARD	Radiation HARDened
RADLAT	Radiation Lot Acceptance Test
SCC	Satellite Control Center
SEB	Single Event Burn-out
SEE	Single Event Effect
SEL	Single Event Latch-up
SEU	Single Event Upset
SOW	Statement Of Work
SPA	Software Product Assurance
SPAP	Software Product Assurance Plan
SPF	Single Point Failures
STS	Space Transportation System
TRB	Test Review Board
TRR	Test Readiness Review
WCA	Worst Case Analysis.

Annex 2 - FIXED FAILURE RATE ITEMS

RF ITEMS DESCRIPTION	FAILURE RATE (10-9.h-1)
Adapter	0.6
Attenuator, Coaxial/WG (fixed resistive type)*	0.6/0.15
Circulator, Coaxial/WG*	1.1/0.3
Coaxial Connector*	0.27
Coupler, Coaxial/WG*	0.8/0.3
Diplexer, Coaxial/WG*	2.1/1.3
Equaliser, Coaxial/WG*	1/0.5
Ferrite Bead	0.2
Ferrite Junction/Element	0.1
Filter, Coaxial/WG*	0.6/0.1
--(each additional section)	0.1
Hybrid (splitter/combiner) coaxial (3 way)*	1.0
--(each additional port)	0.27
Hybrid, Waveguide	0.2
Load Element	0.05
Isolator, Coaxial/WG*	1.1/0.3
RF Switch, coaxial (per port, standby)*	0.5
--and for switching	10/operation
RF Switch, waveguide (per port)	0.5
--and for waveguide, ferrite, for switching	10/operation
--and for waveguide, motor type, for switching	50/operation
Termination, coax/WG*	0.9/0.6
Waveguide Section (with flanges)	0.1
Waveguide Section, Flexible (with flanges)	1
Waveguide Tuning Screw (unstaked)	0.1
Waveguide Tuning Screw (epoxy staked)	0.01

(*): mated pair coaxial connection

ANNEX 2 - FIXED FAILURE RATE ITEMS (Cont'd)

MECHANICAL ITEMS DESCRIPTION	FAILURE RATE (10-9.h-1)
Accelerometer (MECH)	50
Bearing (1 set, with low load)	10
Boom Hinge Assembly	60/cycle
Cable Tension Device	5.0
Catalyst Bed Thruster	166/cycle
Compression Spring	10
Electrothermal/Arcjet/Ion Thruster	500/cycle
Fill/Drain Valve (or Cap)	56/seal
Gear	2
Gimbal	50
Gyro (use manufacturer's data when justified)	2.000 per axis
Hinge Joint	100
Hold Down Arm	100
Hold Down Latch	100
Momentum Wheels/Reaction Wheel Assemblies	100
Motor (low speed)	100
Nozzle, Hot Gas	510/cycle
Nozzle, Cold Gas	17/cycle
Pin Puller Device	4800/cycle
Pulley	5
Resolver	100
Separation Nut/Explosive	4800/cycle
Shaft (Rotating)	2
Shear Pin Puller	50/cycle
Solenoid Valve	160/cycle
Squib	900000/cycle
Tanks, Propellant	50
Tanks and Plumbing (per inch of weld)	0.6
Thruster, operate	50/cycle
Thruster, close	60/cycle
Torsion Wire	50
Torsional Spring	10

ANNEX 2 - FIXED FAILURE RATE ITEMS (Cont'd)

OTHER ITEMS DESCRIPTION	FAILURE RATE (10-9.h-1)
Antenna (Reflector)	1
Antenna (Horn)	1
Antenna (Reflector Absorber)	0.5
Antenna (Feed Horn)	0.1
Antenna (Polarizer)	0.1
Antenna (OMT)	1.0
Battery cell, NiH (use test/flight data when available, 2% open/98% short)	32 for Geo orbit (Note 3)
Bolometer	100
Crystal, General Purpose Quartz	20
Fuse	0.5
Fusistor	10
Heater (all types)	5
Interconnections (solder, crimped connection, surface mounted technology, connector active pin)	0.035 (Note 1)
Magnetic Amplifier	14
Positioner Transducer	10
Slip Rings and Brushes	10/brush/slip ring contact
Solar Cell (20% open, 80% short)	1
Strain Gauge (Resistance Type)	10
Thermostat	25/cycle
Travelling Wave Tubes (use manufacturer's data)	(Note 2)
GaAs FET	Use manufacturer data if available

Notes:

1. Plated through hole failure rate included in associated solders.

2. The use of any failure rate for TWT shall be justified by supporting analysis based on operational history of the specific TWT design (with 60% confidence level).

This failure rate is resulting from the application of a duty cycle equal to 90 days (eclipse periods)/year to an initial failure rate equal to 100 fit.

Failure rates in the tables are given for high-rel parts.

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