GALILEO GALILEI (GG)

SYSTEM VERIFICATION AND VALIDATION PLAN

DRL/DRD: DEL-51/52/53

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1. SCOPE AND PURPOSE

1.1 SCOPE

This document is submitted in partial fulfillment of Work Package 1A-ADC of the GG Phase A2 Study (DRL item DEL-51/52/53). It defines the AIV program for the Galileo Galilei Satellite verification and validation.

1.2 PURPOSE

This System Validation and Verification Plan provide a basis for review and evaluation of the effectiveness of the AIV program and its proposed elements. In addition it is an input to the lower level verification.

In this document it is proposed a scenario for the full requirements traceability throughout a sequence of verification events shared by different verification levels, ranging from unit, subsystem element and system level.

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2. REFERENCES

2.1 Applicable Documents

[AD 1] ASI, "Progetto Galileo Galilei-GG Fase A-2, Capitolato Tecnico", DC-IPC-2007-082, Rev. B, 10-10-2007 and applicable documents defined therein

2.2 ASI Reference Documents

[RD 1] GG Phase A Study Report, Nov. 1998, revised Jan. 2000, available at: http://eotvos.dm.unipi.it/nobili/ggweb/phaseA/index.html

[RD 2] Supplement to GG Phase A Study (GG in sun-synchronous Orbit) "Galileo Galilei-GG": design, requirements, error budget and significance of the ground prototype", A.M. Nobili et al., Physics Letters A 318 (2003) 172–183, available at: http://eotvos.dm.unipi.it/nobili/documents/generalpapers/GG_PLA2003.pdf

[RD 3] A. Nobili, DEL001: GG Science Requirements, Pisa, September 2008

2.3 GG Phase A2 Study Notes

[RD 4] SD-RP-AI-0625, GG Final Report / Satellite Detailed Architecture Report, Issue 1

[RD 5] SD-RP-AI-0626, GG Phase A2 Study Executive Summary, Issue 1

[RD 6] SD-TN-AI-1163, GG Experiment Concept and Requirements Document, Issue 3

[RD 7] SD-RP-AI-0620, GG System Performance Report, Issue 2

[RD 8] SD-TN-AI-1167, GG Mission Requirements Document, Issue 2

[RD 9] SD-RP-AI-0590, GG System Concept Report (Mission Description Document), Issue 3

[RD 10] SD-SY-AI-0014, GG System Functional Specification and Preliminary System Technical Specification, Issue 1

[RD 11] SD-RP-AI-0631, GG Consolidated Mission Description Document, Issue 1

[RD 12] SD-TN-AI-1168, GG Mission Analysis Report, Issue 2

[RD 13] DTM, GG Structure Design and Analysis Report , Issue 1

[RD 14] SD-RP-AI-0627, GG Thermal Design and Analysis Report, Issue 1

[RD 15] SD-RP-AI-0268, GG System Budgets Report, Issue 1

[RD 16] SD-RP-AI-0621, Technical Report on Drag and Attitude Control, Issue 2

[RD 17] TL25033, Payload Architectures and Trade-Off Report, Issue 3

[RD 18] SD-RP-AI-0629, Technical Report on Simulators, Issue 1

[RD 19] ALTA, FEEP Thruster Design and Accommodation Report, Issue 1

[RD 20] TAS-I, Cold-Gas Thruster Design and Accommodation Report, Issue 1

[RD 21] SD-RP-AI-0630, Spin Sensor Design, Development and Test Report, Issue 1

[RD 22] SD-TN-AI-1169, GG Launcher Identification and Compatibility Analysis Report, Issue 1

[RD 23] ALTEC-AD-001, GG Ground Segment Architecture and Design Report, Issue 1

[RD 24] SD-TN-AI-1218, GG Preliminary Product Tree, Issue 1

[RD 25] SD-PL-AI-0227, GG System Engineering Plan (SEP), Issue 2

[RD 26] TAS-I, Payload Development and Verification Plan, Issue 1

[RD 27] SD-PL-AI-0228, GG System Verification and Validation Plan, Issue 1

[RD 28] SD-TN-AI-1219, Report on Frequency Management Issues, Issue 1

[RD 29] SD-RP-AI-0632, GG Mission Risk Assessment And Mitigation Strategies Report, Issue 1

[RD 30] SD-RP-AI-0633, Report on Mission Costs Estimates, Issue 1

2.4 External Reference Documents

In the text the following documents are the ECSS normative documents and referred to as [ND xx].

[ND 1] ECSS-E-ST-10C ECSS System Engineering General Requirements

[ND 2] ECSS-E-10-02A ECSS Space Engineering “Verification”

[ND 3] ECSS-E-10-03A ECSS Space Engineering “Testing”

[ND 4] ECSS-E-30, Space Engineering - Mechanical - Part 1: Thermal

[ND 5] ECSS-E-30, Space Engineering - Mechanical - Part 2: Structural

[ND 6] ECSS-E-30, Space Engineering - Mechanical - Part 3: Mechanism

[ND 7] ECSS-E-30, Space Engineering - Mechanical - Part 5: Propulsion

[ND 8] ECSS-E-30, Space Engineering - Mechanical - Part 6: Pyrotechnics

[ND 9] ECSS-E-30, Space Engineering - Mechanical - Part 7: Mechanical Parts

[ND 10] ECSS-E-30, Space Engineering - Mechanical - Part 8: Materials

[ND 11] ECSS-E-40 Part 1, Software Engineering Standards

[ND 12] ECSS-E-ST-60-10C, Control Performance

[ND 13] ECSS-Q-00A, Space Product Assurance

[ND 14] ECSS-Q-ST-70-01C, Cleanliness and contamination control, 15 November 2008

3. DEFINITIONS AND ABBREVIATIONS

AD	Applicable Document
ACS	Attitude and Control Subsystem
ASI	Agenzia Spaziale Italiana
CCSDS	Consultative Committee for Space Data Systems
CNES	Centre National d'Etudes Spatiales
CPE	Control and Processing Electronics
DFACS	Drag Free Attitude and Control Subsystem
DoD	Depth of Discharge
E2E	End To End Simulator
ECE	Experiment Control Electronics
ECSS	European Cooperation for Space Standardisation
EP	Equivalence Principle
EPS	Electrical Power Subsystem
ESA	European Space Agency
FEEP	Field Emission Electric Propulsion
FEM	Finite Element Model
FOS	Factor of Safety
G/S	Ground Station
GG	Galileo Galilei Satellite
GGG	Galileo Galilei Ground experiment
HK	Housekeeping
INFN	Istituto Nazionale di Fisica Nucleare
IORF	Inertial Orbit Reference Frame
ISV	Independent Software Validation
LEOP	Launch and Early Orbit Phase
LL	Limit Loads
MLI	Multi Layer Insulation
MRD	Mission Requirement Document
OBCP	Onboard Control Procedure
OBDH	On Board Data Handling
P/L	Payload
PA	Product Assurance
PCB	Pico Gravity Box
PPRF	Payload Physical Reference Frame
QL	Qualification Loads
RD	Reference Document
RFDN	Radio Frequency Distribution Network
SD	Standard Document
SPRF	Satellite Physical Reference Frame
STS	System Technical Specification
S/C	Spacecraft
S/S	Subsystem
SEL	Single Event Latch-Up

SEU	Single Event Upset
SPoF	Single Point of Failures
STB	Software Test Bed
SVF	Software Validation Facility
TBC	To Be Controlled
TBD	To Be Defined
TC	Telecommand
TCS	Thermal Control Subsystem
TM	Telemetry
TRL	Technological Readiness Level
TT&C	Telemetry, Tracking & Command

4. VERIFICATION SUBJECT

The subject of the verification process is the Galileo Galilei Satellite and the relevant interfaces.

In the next sub-paragraphs are shortely described the GG mission, its design and its operations.

4.1 Mission objectives

The main objectives of the GG program are as follows:

- To carry out a test of the Equivalence Principle with sensitivity of a least 1 part in 10^{17}, in low, near-equatorial, near-circular Earth orbit, for a duration of at least 2 years;
- To design, develop, and test a small satellite, devoted to the above objectives, over a time span (Implementation Phase) not exceeding 3 years (TBC), within a level of resources commensurate with that of a small satellite program of ASI;
- To launch and operate the satellite using as much as possible the infrastructure and resources at the disposal of ASI;
- To use this opportunity to advance the implementation and use of Italian technology and know-how in the service of an outstanding scientific project.

4.2 Scientific objectives

The goal of GG is to test the "Equivalence Principle" (EP) to 1 part in 1017, more than 4 orders of magnitude better than today's laboratory experiments. As a consequence of this "Principle" all bodies in the gravitational field of a source mass should fall the same, in vacuum, regardless of their mass and composition. This phenomenon goes under the name of "Universality of Free Fall" (UFF) and is one of the foundations of General Relativity (GR). The need for testing the foundations of GR, hence the Equivalence Principle, is dictated by major current issues such as "dark" matter and "dark" energy, which together account for almost 95% of the Universe and, as the word "dark" indicates, are not understood.

The main reasons for testing the EP in space are:

- As compared to test masses in "free-fall towers", the experiment can last as long as the satellite keeps orbiting the Earth (in the conditions required by the experiment..), certainly much longer than 1 s or less available on ground;
- As compared to test masses suspended on torsion balances in the lab, the driving signal in space is about 3 orders of magnitude stronger;
- In space, absence of weight allows the test masses to be suspended from the spacecraft much more gently than on ground, where the suspension must withstand the local acceleration of gravity. In space, they are close to free test masses, and therefore they can be proportionally more sensitive to external effects;

- Finally, the orbiting spacecraft enclosing the instrument is an isolated system. Hence the perturbing effects of a laboratory experiment are utterly absent.

4.3 Mission Description

The satellite will be launched directly into near-circular, near-equatorial orbit by a small/medium launcher such as Vega (baseline) or PSLV (backup). Both launchers have capability much in excess of a small spacecraft such as GG, and a dual launch might be taken into consideration.
The design launch altitude will be between 520 km and 600 km. No orbit maintenance is planned, and the spacecraft altitude will be allowed to decay gently in time, with negligible impact on the satellite mission and operations.
Once set up and initialized, the experiment will run in a regular way without any changes to either orbit or attitude. Given the near-equatorial orbit, the satellite will experience a regular once-per-orbit sequence of eclipses (35 minutes) and passes above the equatorial ground station of San Marco near Malindi, Kenya (about 10 minutes, with small variations depending on the selected altitude).
The science mission is devoted to a single experiment that, once initialized, runs to the end of the scientific data collection. In the Launch and Early Orbit Phase, operators control the correct spacecraft activation and perform attitude and spin-up maneuvers. Experiment set-up and first calibration operations follow. Thereafter the Science Phase starts and the experiment is run in 7-day (TBC) long data collection intervals. Spacecraft health checks will be cadenced at regular intervals to monitor the correct data acquisition and spacecraft status.

The nominal duration of the mission is 1 year.

4.4 Experiment Concept

Two test masses of different composition form the GG **differential accelerometer**. The test masses are heavy (10 kg each) concentric, co-axial, hollow cylinders. The two masses are mechanically coupled by attaching them at their top and bottom to two ends of a coupling arm.
The coupling arm is made of two concentric tubes similarly attached at their midpoints to a single shaft. This assembly preserves the **overall symmetry** of the apparatus, when the two parts of the arm are taken together.
The masses are mechanically coupled through the balance arm such that they are free to move in the transverse (XY) plane. Differential acceleration acting on the masses gives rise to a displacement of the equilibrium position in the XY plane. The displacement of the test masses is sensed by two sets of capacitance plates located between the test cylinders, one set for each orthogonal direction (X and Y). Each set forms an **AC-bridge** so that a displacement of the masses causes an unbalance of the bridge and is converted into a voltage signal. When the physical system is mechanically well balanced, it is insensitive to `common-mode' accelerations. Moreover, the capacitance bridges are inherently sensitive to differential displacements. Thus, the differential nature of the accelerometer is ensured both by the dynamics of the physical system, and by the displacement transducer.

4.5 System Definition

Functionally the GG Satellite is defined as a modular product. The whole Satellite is composed of two modules: Platform (or Service Module) and Payload (Pico Gravity Box).
At lower level each module is composed of subsystems, each subsystem can be composed of one of more units plus auxiliary parts.
In the next sections are briefly described the two modules.

4.5.1 Payload Description

The GG payload is constituted by the PGB (Pico Gravity Box) laboratory, enclosing:

- The two cylindrical test masses
- Capacitance plates for “science-level” sensing of test mass relative displacements
- Small capacitance sensors/actuators for sensing relative displacements and damping the whirl motions
- Suspension springs and coupling elements
- Inchworms and piezo-ceramics for fine mechanical balancing and calibration
- Launch-lock mechanisms, associated to all suspended bodies.

The PGB also carries a small mirror, in correspondence of a photo-detector mounted on the inner surface of the spacecraft, for measuring small residual phase lags with respect to the spacecraft.

The payload electronics include:
The PGB Control and Processing Electronics (CPE), located on the spacecraft platform, managing PGB motion control (whirl sensing, whirl damping and drag-free control) and processing of all signals coming from the test masses (motion control and EP sensing).
The Experiment Control Electronics (ECE), housed inside the PGB, and communicating with the CPE via an optical link. The ECE locally manages whirl sensing and damper activation, under control by the CPE processor, and readout of the EP chain.

The payload apparatus further includes the necessary electrical harness and connectors and the thermal insulation.

4.5.2 Platform Description

The cylindrical symmetry of the test masses and their PGB enclosure, and the spin required to provide high frequency signal modulation, lead to a spacecraft of cylindrical symmetry, stabilized by rotation about the symmetry axis. The system configuration requirements are:

- The GG experiment implies an ad-hoc configuration; reuse of an existing platform cannot be proposed.

- The spacecraft shall fit the Vega fairing envelope, and the standard Vega 937 B adapter shall be used for launcher separation.
- The configuration shall allow easy integration of the PGB.
- Low area-to-mass ratio is required
- The spacecraft shape and its mass distribution must have a high degree of cylindrical symmetry. The spin axis must be a principal axis of inertia.

The proposed solution is a dedicated “spinning-top” structure supporting the PGB and equipment, plus two cylindrical solar panels. Sensors and electric thrusters are mounted to a central belt, while two S-band antennas are placed on booms aligned with the spin axis.

The spacecraft body is about 1.45 m in outer diameter and about 1.42 m high. The experiment apparatus is accommodated in a nested arrangement inside the body.
Equipment items are mounted internally to the central belt; thrusters and sensors are mounted externally. The solar array is made of two cylinders separated by a central belt for mounting equipment, including thrusters and sensors; this solution also allows a convenient distribution of thermal covers and radiators to achieve an efficient thermal control.

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5. VERIFICATION APPROACH

5.1 Verification Methods

Each verification process shall be accomplished by one or more of the following verification methods:

- Inspection
- Analysis
- Review of Design
- Test

5.1.1 Inspection (I)

Inspection is a method of verification that determines conformance to requirements without the use of special laboratory equipment, procedures, test support items or services. Inspection uses standard quality control methods to verify compliance with requirements of construction features, document and drawing compliance, workmanship standards, and physical condition. Emphasis is on observation of physical characteristics rather than performance.

5.1.2 Analysis (A)

Verification by analysis is a process used in lieu of, or in addition to, other verification methods to verify compliance to specification requirements. The selected techniques may include, but not be limited to, engineering analysis, statistics and qualitative analysis, computer and hardware simulations, and analog modeling.

Analysis may be used when it can be determined that:

a) rigorous and accurate analysis is possible
b) test is not cost effective,
c) verification by inspection is not adequate.

5.1.2.1 Similarity

Verification by similarity is the process of analyzing the specification criteria for hardware configuration and application for an article to determine if it is similar or identical in design, manufacturing process, and quality control to an existing article that has previously been qualified to equivalent or more stringent specification criteria. Special effort will be made to avoid duplication of previous tests from this or similar programs. If the previous application is considered to be similar, but not equal to or greater in severity, additional qualification tests shall concentrate on the areas of new or increased requirements.

5.1.3 Review-of-Design (RoD)

Review-of-design is verification method in which verification is achieved by validation of records or by evidence of validated design documents or when approved design reports, technical descriptions, engineering drawings unambiguously show the requirement is met.

5.1.4 Test (T)

Test is a method of verification in which technical means, such as the use of special equipment, instrumentation, simulation techniques, and the application of established principles and procedures, are used for the evaluation of components or equipment to determine compliance with requirements.
Testing is selected as the prime method of requirements verification and shall be used when analytical techniques do not produce adequate results; failure modes exist which could compromise personnel safety, adversely affect flight systems or payload operation, or result in a loss of mission objectives.
The analysis of data derived from tests is an integral part of the test program, and should not be confused with analysis as defined above.

5.2 Verification Levels

The requirement verification shall be performed incrementally at different verification levels.
Each requirement can be verified at one or more level.
The levels for GG project are:

- System level: complete Satellite
- Module level: Service module and Payload (PGB)
- Subsystem level: for what concern the GG service module the subsystems are:
  - On Board Data Handling (OBDH)
  - Attitude Control Subsystem (ACS)
  - Electrical Power Subsystem (EPS)
  - Telemetry, Tracking & Command (TT&C)
  - Propulsion
  - On Board Software (OBSW)
  - Structure
  - Harness
  - Thermal Control Subsystem (TCS)

  For what concern the Payload subsystems and components, detailed verification approach and description will be provided by P/L subcontractor in a dedicated document
- Equipment level: single unit/component level

5.3 Verification Stages

The GG verification process shall be implemented in subsequent verification stages all along the program life cycle.

The verification stages will be:

- Qualification (Q)
- Acceptance (A)
- Pre-launch (P)

5.3.1 Qualification

In this stage the verification objective shall be to demonstrate that, at all levels, the design meets all applicable requirements and includes proper margins.

5.3.2 Acceptance

In this stage the verification objective shall be to demonstrate that the GG components are free of workmanship defects and integration errors and is ready for subsequent operational use.
This stage is applicable at all levels.

5.3.3 Pre-launch

In this stage the verification objective is to verify that GG is properly configured for launch and it is able to work as planned in the mission phases
This stage is applicable only at system level (complete Satellite configuration).

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6. MODEL PHILOSOPHY

The model philosophy will support the following objectives:

- Verification of full compliance of the deliverable satellite
- Availability of development models to support verification of compliance with operational requirements and launcher compatibility requirements
- Early verification of critical and new design solutions and selected technologies
- Reduction of risk
- Minimize the number of models to accomplish schedule and cost constrains

Different model philosophy approach will be defined for different project levels: system, module (Platform & PGB), subsystem and unit.

6.1 Units and Subsystems Model Philosophy

Different model philosophies will be applied for units and subsystems according to whether they are recurring items or not. As general rule, a proto-flight approach will be defined for the recurring items. At equipment and subsystem levels, the verification approach will be defined in function of the individual unit/subsystem Technology Readiness Level (TRL). The general approach is to have a complete qualification test campaign and consequently a qualification approach on the new items, and to perform a reduced acceptance campaign on the recurring units.
The following non-recurring or (partially) new development items have been identified.

<u>Microthrusters</u>
At least one micro- thruster development model will be foreseen as part of the qualification process, before the flight model.

<u>Spin Sensor</u>
At least two models will be foreseen as part of the qualification process:
1) Engineering Qualification Model (EQM), this shall be submitted to a complete qualification test campaign to assess the design and the technological solutions;
2) Flight Model (FM), which shall be submitted to a test campaign at flight conditions before being installed on the satellite.

6.2 Platform Model Philosophy

As stand alone system the platform can be classified as recurrent system, since the avionics and the other subsystem has been already qualified from previous projects, anyway some GG

peculiarity have to be verified in detail, mainly for what concern the drug free control during the mission scientific phase, since the needs to ensure correct compensation of external disturbances to avoid errors in the measurements.
Also the peculiarity of GG mission profile need to be simulate on ground in the more representative possible way.

To accomplish the above points, it is foreseen to use a GG Avionics Test Bench, composed of Off the Shelf breadboards electrically and functionally representative of the flight units (engineering models).
In addition to the above specific points the Avionics Test Bench will have in charge also:

- The testing on the GG on board SW in advance respect to flight model availability
- To perform specific test not possible with the flight items, like malfunctions simulation, FDIR intervention
- To verify the GG mission procedure
- To debug the AIT test SW and the test procedure to avoid mismatch and reduce the test durations on flight model
- Verify functionally the interfaces with the payload electronics: a PGB electronic simulator or a EM can be used to support this verification

6.3 Payload Development Plan

At payload (PGB) level, a two-model approach is envisaged. The PGB-STM (Structural Thermal Model) will be used to qualify the mechanical and thermal design, including the thermo-structural deformation aspects. The STM has therefore to be representative in terms of mechanics and thermal design. The PBG-PFM (Proto Flight Model) will be used to complete the acceptance from the mechanical, thermal and functional point of view, and will be the flight unit.
From the equipment point of view, the following units are new developments, and will be subjected to a complete qualification test campaign, including environmental testing (TV/TB, mechanical test):

- ECE and (partially) CPE
- Accelerometer
- Lock/unlock mechanisms.

The ECE and CPE will have Engineering Models, mechanically, thermally and functionally representative of the flight units. The Accelerometer is functionally covered by the GGG laboratory experiment; however an STM is needed anyway and will be provided as part of the complete PGB assembly. The mechanisms shall be completely flight representative, and shall be included in the PGB-STM.

6.4 System Development Plan

For what concern the platform and the system level (i.e. the complete Satellite) it is proposed a single Proto Flight approach at system level, with the following considerations:

- The functional Satellite performances will be validated using a dedicated End to End simulator (purely SW) plus an Avionics Test Bench where representative HW will be included in the loop. This HW will be composed of breadboards and 'Off the Shelf' component functionally representative of flight HW (as described in section 6.2)
- The Satellite thermo-structural performances and the compliance with the relevant requirements will be evaluated by analysis.

The Proto Flight Model will be the final product after integration and it is the model that will be launched. Since a single complete Satellite model is foreseen, It will be subject to a complete proto-flight test campaign in order to confirm the functional validation performed on Simulators and the thermo-structural performances evaluated by analysis

6.4.1 RF Suitcase

The interface compatibility with the Ground Station will be performed with the RF suitcase. This equipment will be composed of a Transponder model functionally representative of flight model and a CDMU breadboard, able to receive telecommands and generate telemetry.
The transponder temporary used in this application should be the EQM one or the flight spare, depending from the availability in the different project phases.

6.5 Spare Philosophy

The objective of the spare philosophy is to ensure adequate redundancies during the activities on ground, minimizing cost and schedule impact in case of failures. At the same time spares not needed shall be avoided, to limit as much as possible the cost increasing.
In the Hardware Matrix presented in the next paragraph is presented the minimum configuration of units spare suggested for GG.
At lower level for each unit a 'Spare Kit' will be defined with the subcontractors in order to have adequate redundancies on the products (components, cards, etc) that are not Off-the-Shelf.
To optimize the resources, the spare units here defined can be used for test benches like Avionic Test Bench or RF suitcase.

6.6 Hardware Matrix

On the basis of the selected model philosophy and of the qualification status of each equipment is defined the GG hardware matrix.

The equipment qualification status is classified according to the following categories:

- *Category A*: Off-the-shelf equipment requiring no modification which has been subjected to a qualification test program for space applications at least as severe as that imposed by the actual project specifications. Further qualification testing is not required.
- *Category B*: Off-the-shelf equipment requiring no modifications that have already been tested and qualified but subjected to a different qualification program or to a different environment. A delta qualification test program shall be decided and performed case by case.
- *Category C*: Off-the-shelf equipment requiring minor design modifications. A delta or full qualification test program shall be decided on a case-by-case basis depending on the impact of the required modification.
- *Category D*: Newly designed and developed equipment or existing equipment requiring major redesign. A full qualification test program shall be imposed.

The actual GG Hardware matrix is presented in **Error! Reference source not found.**.

Equipment	Dev Status	DM	EM/ EQM	STM	PFM/ FM	Spare	Heritage	Notes
Payload								
PGB assembly	D			1	1	parts	GGG	
Launch lock mechanisms	D	1		12	12	1	LISA	
Inner Test Mass Assembly	D			dummy	1	none		
Outer Test Mass Assembly	D			dummy	1	none		
ECE	D		1 EQM	dummy	1	kit		
CPE	D		1 EQM	dummy	1	kit		
OBDH								
CDMU	A		1 EQM		1	kit	GOCE	based on standard PRIMA equipment
OBSW	D		1		1			
ACS								
Sun Sensors	A				2 FM		SELEX Galileo	Smart Sun Sensor by SELEX GA
Spin Rate Sensor Optical Head	D	1 [*]	1 QM		2	1 (refurbished QM)		[*] Existing Phase A2 breadboard
Spin Rate Sensor EU	D		1 QM		2	1 (refurbished QM)		
Magnetometer	A				3 FM		IAI TAMAM	standard PRIMA equipment
Gyroscope	A				2 FM		MIMU	standard PRIMA equipment
EPS								
Solar Panels	B				2	parts		standard Solar Cells RWE 3G-ID2L/150-8040
Battery	A				1	kit		standard Battery Cells Sony 18650HC Li-Ion cell
PCDU	C		1 EQM		1	kit		based on standard PRIMA components
TT&C								
Transponder	A				2	1 kit	GOCE	
S-band LGAs	A				2	1 kit	ATV	
RFDN	A				1	parts	PRIMA	standard PRIMA equipment
Propulsion								
FEEP Thrusters	C				12	1	LISA PF	3 clusters of 4 thrusters each
FEEP Electronics	C				2	kit	LISA PF	
Cold gas microthrusters (option)	C				12	1	GAIA	3 clusters of 4 thrusters each
Cold gas spinup thrusters	C				12	1		2 branches of 6 thrusters
GCT tanks	C				2			
Harness	D				1 set	parts		
Thermal Control	D				1 set	parts		
Structure	D				1 set			

Figure 6-1

7. VERIFICATION STRATEGY

The verification strategy is defined combining in the more efficient way the different verification stages, verification levels and verification methods, in order to reach the following objectives:

- Satisfy the mission requirements
- Maintain the cost targets
- Respect the schedule constrains

The initial step of the verification process is the identification of the requirements to be verified. The general requirements are analysed to originate system and lower level specifications containing a consistent tree of performance, design, interface, environmental, operational and support requirements, which form the basis of the verification activities at the different levels. In order to facilitate the verification implementation in terms of planning, execution, control and reporting, the requirement generation and allocation activity will ensure specific requirement characteristics; each requirement shall be:

• **Traceable** with respect to one or higher level requirements;
• **Unique** and associate to a proper identifier (document and paragraph number);
• **Single** and not containing more than one requirement;
• **Verifiable** with one or more approved verification method;
• **Unambiguous** and containing a precise statement;
• **Properly referenced** to other requirements (with applicable document and paragraph identification); and should be associated with a specific **title**.

7.1 Preliminary Verification Matrix

Considering the GG mission requirements and its model philosophy, it is here defined a preliminary list of category requirements applicable to the mission.
Proper verification criteria are selected for each identified category as showed in Table 7-1.
The verification strategy will be reflected in a specific detailed verification matrix, prepared in the next project phase on the basis of the already defined verification methods and levels; it will contain the list of all requirements of the system specification with the proposed verification methods at equipment/assembly and system level. The verification matrix is the starting point for the Verification Control Document (VCD).

Requirement Category	System	Module		Subsystem	Unit
		Platform	Payload		
Configuration					
External Interfaces	T, R, I	T, R, I	T, R, I	T, I	T, R, I
Internal Interfaces	T, I	T, R, I	T, R, I	T, I	T, R
Physical Properties	A, T, R,I	A, R, I	A, R, I	R,I	A, T, R,I
Functional Performance					
SW performance	A, T	A, T	A,T	A, T	A, T, R
OBDH performance	A, T	A, T	N/A	A, T	A, T, R
ACS performance	A, T	A, T	N/A	A, T	A, T, R
TT&C performance	A, T	A, T	N/A	A, R	A, T, R
Propulsion	A, R	T	N/A	A, T, R	A, T, R
Mechanical Testing					
Random Vibration	A, T	N/A	A, T	N/A	A, T
Sine Vibration	A, T	N/A	A, T	N/A	A, T
Modal Survey Vibration	A, T	N/A	A, T	N/A	N/A
Quasi-Static	A, T	N/A	A, T	N/A	N/A
Acoustic	A, T	N/A	A, T	N/A	N/A
Separation Shock Test	A, T	N/A	N/A	N/A	N/A
Mechanism Check (antenna)	A, T	N/A	N/A	N/A	A, T, R, I
Thermal Testing					
TV/TB	A, T	N/A	A, T	N/A	A, T
EMC					
Conducted Em/Susc	A, T	N/A	N/A	N/A	A, T, R
Radiated Em/Susc	A, T	N/A	N/A	N/A	A, T, R
ESD	A	A	A	A	A,T
Quality Aspect					
Material Control & Process	A, R	N/A	N/A	N/A	A, R, I
Reliability & Maintainability	A, R, I	N/A	A, R, I	A, R, I	A, R, I
Cleanliness	A, R, I	I	I	I	A, R, I
Logistic					
Transportability	R	R	R	R	R
Handling on Ground	R	R	R	R	R

Table 7-1 Preliminary Verification Matrix

To accomplish the above verification matrix at the request stage level all the available models will be used, following the AIV program described in chapter 8.

8. VERIFICATION PROGRAM

The different verification method will be combined together in the verification program in order to ensure complete requirements closure.
Generally the test is the preferred verification methods, anyway for several requirements test is impracticable, too expensive or dangerous for the flight HW. In these cases alternative method is adopted.

8.1 Analysis, Review of Design, Inspection Program

Analysis

Analysis will be used to verify those requirements where testing is not applicable and where the experience gained in other space programs is applicable.
In establishing an analysis, the following main criteria must be met:

- The physical system is modeling in mathematical mode;
- The model used can be described and the use of that model justified;
- The boundary conditions are known and can be imposed to the model;
- The assumptions can be imposed to the model;
- The range of validity can be specified;
- The specified performance is verifiable without dubs due to analysis uncertainty.

The main requirements categories in which the verification by analysis will be carried out are:

- Physical Properties
- On Board SW Performances
- Mission Simulation
- Thermal Requirements
- Mechanical Requirements
- Reliability and Maintainability
- EMC

Review Of Design

Review of Design method will be used to verify some requirements where the review of the design concepts and, in general, the lower level documentation is involved. A typical case is when analysis, test at lower level (like on a single component), approved design reports, technical descriptions, engineering drawings unambiguously show that the requirement is met, without needs of additional analysis and test

The main requirements categories in which the verification by review of design will be carried out are:

- External & Internal Interfaces
- Physical Properties
- On Board SW Performances
- Mechanism behavior
- Reliability and Maintainability
- Material control and process
- Logistic requirements

Inspection

Inspection method will be used to verify those requirements where physical characteristics and interfaces are involved. The areas in which the verification by Inspection will be carried out are:

- Physical properties
- Interfaces
- Reliability and Maintainability
- Cleanliness

8.2 AIT Program

The assembly, integration and test program is part of the overall verification plan to ensure that GG including all support hardware, meets the requirements and is acceptable for operational use.
The purposed integration and test sequences are in principal based on the following rules:

- Before delivery for integration each equipment will be fully accepted for its intended usage;
- All items and their I/Fs shall be verified before integration by TAS-I onto the assembly;
- The test repetition for integrity validation will be optimized;
- The assembly test program will assure compliance of physical and functional interfaces relevant to GG and its GSE;
- Equipment/assembly final acceptance will be performed contextually to GG system acceptance.

8.2.1 Testing under SUBCO responsibility

The AIT activities performed by SUBCO on units and subsystems before the delivery at system level shall be devoted to accomplish the above rules, especially to ensure that the items will be delivered fully compliant versus the requirements.
The detailed content of the test campaign will be defined case by case starting from the category of the elements involved (as described in the HW matrix).
Typical approaches are:

- Full qualification test campaign: for new elements never used in space in the same configuration
- Delta qualification test campaign: for existing elements with specific changes respect to the existing qualified configuration
- Acceptance test campaign: for element already qualified for flight. In case of ‘Off the Shelf’ elements also a reduced acceptance test campaign can be agreed.

For each element Analysis and Review of Design can be used to optimize the test campaign respect to the requirements.

Anyway, for an electronic unit a typical test campaign flow will be:

- Testing on components, internal unit elements
- Unit Integration and Electrical Verification
- Unit Functional Testing
- Mechanisms verification (if applicable)
- Physical characteristics measurements (mass, CoG, MoI)
- Alignment measurements (if applicable)
- EMC (conducted, radiated, ESD)
- Mechanical testing at request levels and durations (qualification levels or acceptance level)
- Thermal Vacuum and Thermal Balance (qualification levels or acceptance level)
- Magnetic Testing (if applicable)
- Unit Functional re-testing after environmental test campaign
- Alignment check after environmental test campaign (if applicable)
- Mechanism check after environmental test campaign (if applicable)

8.2.2 Testing at system level

At system level the testing activities are foreseen on two models:

- Avionics Test Bench (ATB)
- Proto Flight Model (PFM)

For what concern the ATB the test campaign will be focused on:

- Functional I/F verification
- On Board SW testing
- Mission procedure validation
- Debug of test sequence that will be reuse on PFM
- PGB I/F verification in term of:
  - Physical compatibility (connectors dimension, pin allocation)
  - Electrical compatibility (signals characteristics)
  - TM/TC exchange
  - Science Data exchange

The PFM is the model for the flight; it will be subjected to a complete acceptance test campaign. The level and duration of various environmental tests will be typical acceptance level (see [ND 03]).
The preliminary flow of the PFM test campaign is reported in Figure 8-1.

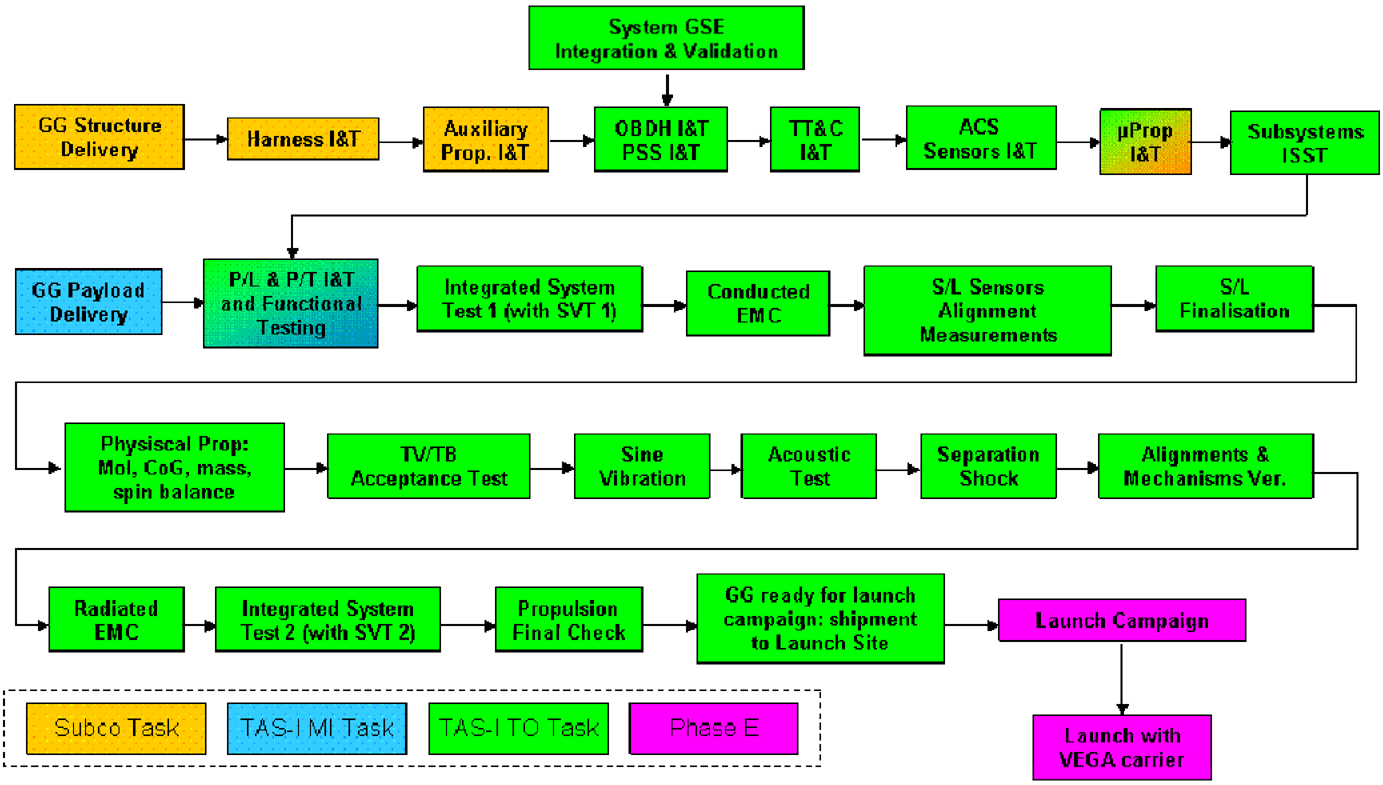

Figure 8-1 GG PFM AIT Flow

With different colors are identified the different industrial task responsibilities. Anyway this is a preliminary share of responsibility; it can be changed and/or refined in the next project phase. Mixed colours mean a jointed activity.

In the next sections is reported a brief tests descriptions.

8.2.2.1 Preparation Phase

Before to start with the I&T activities some preparation activities have to be done: Ground Support Equipment, tools, laboratory equipments, test sequences, support documentation shall be available and ready to use.
In particular for what concern the GSE to start the activities the following points have to be reached:

- The Mechanical Ground Support Equipments to handle the Satellite and its parts shall be qualified for the use on Satellite
- The Electrical Ground Support Equipment shall be qualified, integrated together and all the interfaces versus the Spacecraft shall be verified.
- The Test SW is debugged (as much as possible without the Satellite)
- The Satellite Database is available and loaded in the EGSE

8.2.2.2 Integration Tests

The following integration tests are performed on the equipments during the Satellite assembly process.

a) Mechanical Unit Integration including integration of additional HW like thermal filler (if any), thermocouples, heaters etc
b) Connection of unit bonding strap and measurement of grounding
c) Power input to unit measurements: first at all in unloaded condition (only input, unit electrically disconnected), after that in loaded condition
d) Unit switch on and measurements of inrush current and power consumption
e) Electrical integration of the Telemetry and Telecommand lines, with the following objectives:
   - Interface verification in accordance with the electrical design and interface standards.
   - Correct allocation of all relevant Telemetry and Command tags within the EGSE monitoring & control “housekeeping” data base
   - Verification that the system database is correctly filled with the Spacecraft commands and telemetry data: checking that the commands are addressed in the correct way and the telemetry is correctly decoded.
f) Verification that the waveforms on the on board data bus in input and output of the users are within the specified limits.

g) Verification of the electrical characteristics of special I/F not included in the previous cases (i.e. special I/F with the payloads)

8.2.2.2.1 PGB Mechanical and Electrical Integration

The PGB Integration is obviously more complex that the integration of the other components, mainly from a mechanical point of view.
In the actual configuration GG PGB will be a self-standing platform, equipped of all the units needed for its function, included the electronic unit to interface with the spacecraft.
The integration and the relevant verifications will be done in the following order:

- Mechanical I&T
- Power Lines Electrical I&T
- Data Lines Electrical I&T
- Functional check of correct exchange of data between PGB and Platform

These activities will be done under TAS-I Torino responsibilities but with support of PGB subcontractor.

8.2.2.3 Integrated Sub-System Test (ISST)

The objective of these tests is to verify the correct operation of the Satellite subsystems one by one. They are typically executed after that all the subsystem units have been completely integrated. In some cases missing units can be simulated to have a complete subsystem representation. In other cases part of ISST test cases can be planned later on in the test campaign, when the involved HW and SW will be available.
In any case it is standard policy to complete the ISST on all subsystems before start with the system testing and with the environmental test campaign (except special cases, like test involving use of real battery).

For the time being the ISST are foreseen on the following subsystems:

- On Board Data Handling
- Power
- ACS
- TT&C
- Propulsion
- Payload

Data Handling ISST

The Data Handling equipment is integrated at an early stage of the platform assembly sequence in order to built up as soon as possible the automatic telemetry and command control of the EGSE master computer. Furthermore, also the OBDH ISST will start as soon as possible in the system AIT flow and will be completed when also the other subsystems will be available.

Scope of this ISST is to verify the capability of the CDMU and its SW, mainly in terms of:

- Correct managements of the applicable services of the ESA Packet Utilisation Standard that define the network protocol between the on board units and with ground
- Management of the analogic interfaces with the users
- Correct running of the SW routines
- Verification of the operative modes foreseen for the mission
- Management of the internal redundancies

Anyway, it is not scope of the ISST the complete on board SW verification: the SW will be developed in simulated environment and will be verified on the ATB. Only a reduced subset of these tests will be also executed at system level, this mainly for the following reasons:

a. Time: the schedule at system level is anyway compressed and a SW validation campaign is long and complex.
b. A use of the real HW for the full SW validation increases also the risk of stress and damages on the flight HW.
c. Impossibility to perform some verifications without special equipments available only at ATB level (like emulators, bus spy)
d. Impossibility to perform some verification with the real HW, for example when it is needed to simulate failures

Power ISST

This section of the ISST is mainly dedicated to the PPDU capabilities to regulate correctly the input power and to distribute it to the users.
The possible power source, that are Solar Panel and battery are simulated.
Cycles of sun/eclipse simulating what foreseen in orbit will be done to check that the units will be always correctly powered.
In a late stage of the test campaign also the real battery (normally integrated late in the AIT flow) can be used, with real charge/discharge cycles.
Finally, it’s also part of the power ISST the verification of the Thermal Control Subsystem, by check of the correct correspondence between heaters, thermistors, thermocouples physical position on the Satellite and the relevant telemetry & telecommand management.
Also the internal subsystem redundancies will be verified during the power ISST.

ACS ISST

Final scope of the verifications on the ACS is to ensure that the Attitude and Orbit Control Subsystem is able to fulfill the mission requirements in term of orbit and attitude control in the entire foreseen operative mode, include back-up and recovery modes.
The GG philosophy of ACS testing is to perform at low level (ATB) all the performance test.
A reduced subset of these test cases (closed loop) will be repeated in the ACS ISST to verify also after the real HW final integration the subsystem performance.
A dynamic simulation running on the Avionics SCOE gives the input data to the sensors to simulate the mission environmental.

Moreover, it will be part of the ACS ISST a campaign of end-to-end verification and polarity test to verify the ACS sensors and actuators.
Also the internal subsystem redundancies (sensors, actuators, relevant SW management) will be verified.

TT&C ISST

Main scope of the TT&C ISST is to verify that the subsystem is able to transmit correctly to ground the data coming from the OBDH and to receive and distribute to OBDH the ground commands. The complete subsystem functions will be verified and characterized using ground equipment (TT&C SCOE) linked via RF cables and waveguides to the subsystem. All the possible paths, main and redundant, will be verified.

Propulsion ISST

Main scope of the Propulsion ISST is to verify the propulsion subsystem capabilities after its integration on Satellite.

Two propulsion systems are implemented on board:
- A standard on/off cold-gas thruster system (auxiliary propulsion), used for the initial attitude stabilization and for the spinup operation;
- A system of proportional Microthrusters possessing high accuracy and high thrust resolution, for the purposes of the drag-free control.

Two options for the microthrusters are envisaged at this stage: FEEP and cold-gas proportional thrusters. The trade-off between the two types will be concluded in Phase B.

For what concern the auxiliary propulsion the ISST testing shall include:

- Testing of electrical I/F with Power Subsystem

- Testing of electrical I/F with ACS Subsystem
- Verification of Command & Monitor
- Thruster's Valves activation
- Thruster's Valves leak check
- Pressure Transducer reading and calibration
- Overall Leak Check

In same test cases a thruster simulator will be used instead of real ones, to avoid not needed valves activations.
The Overall Leak Check is repeated also at the completion of environmental test campaign, before authorization to ship the Satellite for the launch campaign.

For what concern the micro-thruster propulsion the content of ISST will be function of the choosen option. The general approach will be:

- Similar to auxiliary propulsion in the cold gas case
- Limited to electrical checks and functional simulations in case of FEEP, since it is not possible to switch on the flight FEEP thrusters during the ground activities.

PGB Functional Test

These tests will be performed after Payload mechanical and electrical integration on the platform. It is a functional verification of the P/L functionality directly managed by the On Board Data Handling. Main areas of verification will be:

- Correct managements of ESA PUS applicable to the P/L between P/L electronics and OBDH
- Management of the P/L analogical interfaces
- P/L operative mode verification
- Simulation of scientific data acquisition transmission to the On Board Data Handling
- Test on Storage Capabilities of scientific data
- Specific P/L performance test that have to be done at system level to satisfy the relevant specification (if any)

Obviously on ground the scientific data will be opportunely simulated as request by the test objectives.

8.2.2.4 Special Performance Test (SPT)

The SPT is run to check certain important electrical (or mechanical) parameters that cannot be verified during integration or ISST.
Reason is mainly that, during SPT, some special set-up has to be prepared with configuration of the internal connections different to the final configuration reached after integration.
For example, it possible that to verify some unit's performances it is needed to access some connectors nominally not accessible.

Specific case of SPT can be:

- AOCS sensors optical check
- Pyro and thermal devices end-to-end check (polarity)
- Fuses integrity verification
- Specific P/L test not possible during ISST
- Specific mechanisms activation

After completion of these tests the nominal system configuration has to be restored, verifying also that the nominal performances are unchanged

8.2.2.5 Integrated System Test (IST)

The Integrated System Test is the main test performed at system level, aimed to check the functional capabilities of the whole Satellite fully integrated and in final flight configuration.

Main objectives of IST will be:

- verify correct functionality of all the subsystems in the Satellite environment
- verify inter-function between different equipments and subsystems and correct exchange of data
- simulate the mission profile, verifying the Satellite performance in the different mission phases and with different operative mode of Satellite and Payload
- in case of not nominal event (opportunely simulated) verify the Satellite capabilities to recovery the mission, using also redundant configurations.

Nominally, the IST will be performed 2 times during the environmental test campaign. The first time after completion of the Satellite integration (payload included) and before the environmental test campaign. The second time at the end of the environmental test campaign; immediately before the launch campaign.

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A comparison of the test results of the IST's (as far as electrical and functional performances are concerned) will form part of the assessment of the successful achievement of the test campaign objectives.

A reduced version of IST, named Integrated System Check (ISC), can be used to verify the Satellite health status in some specific phase of the environmental test campaign. For example: before and after the mechanical test (vibration, acoustic).

8.2.2.6 System Validation Test (SVT)

During the SVT the Satellite, fully integrated and tested, is directly driven by the Mission Center.
The Mission Center will sent the telecommands and receive telemetry in remote way. It will be connected via dedicated line (ISDN) to the Central Checkout Equipment (managed by TAS – AIT) that is directly connected to the Satellite.
Scope of the test is to validate the Mission Center database and the flight procedures (at least for what is possible on ground) and to allow a familiarization of the Mission Control team with the Satellite.
Nominally, 2 sections of SVT are foreseen, one in the time frame of IST1, the second in the time frame of IST2.

8.2.2.7 Thermal Tests

8.2.2.7.1 Thermal Balance Test

The main purpose of thermal balance testing is to demonstrate the ability of the thermal control function to maintain temperatures inside the specified operational limits and to verify that the GG satellite performs correctly under vacuum and thermal conditions expected to be encountered during the mission. The test is also used to validate the analytical thermal model of the GG Satellite, including the Payload thermal control.

8.2.2.7.2 Thermal Vacuum/ Thermal Cycling Test

The purpose of Thermal Vacuum temperature cycling (TV/TC) tests is to demonstrate functionality of the GG Satellite under vacuum and thermal conditions exceeding the design temperatures by a margin, different in qualification or acceptance case.
The number of thermal cycles is normally 4 in acceptance case (PFM case).

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Anyway, the number of cycles (as the temperature values) can change for different mission profiles. For GG a detailed test requirement will be defined in the next project phases.

8.2.2.8 Mechanical Tests

8.2.2.8.1 Sinusoidal Vibration Test

The purpose of the Sinusoidal vibration test is to demonstrate that GG Satellite can withstand the vibration environment encountered during launch.
The objectives of the sinusoidal vibration test are:

- to achieve the qualification of the structure S/S (including secondary structures) versus the low frequency transient vibration environment specified by the launcher.
- to verify the alignment stability.

For GG this test is foreseen at acceptance level on the fully integrated flight Satellite to confirm the analysis predictions.

8.2.2.8.2 Static Load

The purpose of the static load tests is to demonstrate by application of acceleration loads, that GG Satellite is capable of sustaining the launcher induced static and dynamic loads without suffering permanent deformation or failure. The static load will be defined by analysis and verified in the frame of the Sinusoidal Vibration test.

8.2.2.8.3 Modal Survey

The modal survey is not a test in the sense of having any go/no-go criteria; its successful completion does not indicate compliance with design requirements, except for the case in which one of the design objectives is to keep certain frequency ranges free from natural frequencies of the space vehicle. The purpose of the modal survey is to determine experimentally the following modal parameters of the space vehicle in the dynamic range of interest, typically up to 100 Hz:

- natural frequencies,
- mode shapes,
- damping factors.

The results of a modal survey are used in two ways: first, as mentioned above, to check whether or not any natural frequencies fall into an undesirable range, secondly to run a correlation/updating activity of the FEM of the satellite, through comparison of analytical and experimental natural frequencies and modes shapes.
Dedicated Low Level run/s will be performed, on the shaker, in order to determine the full set of modal parameters for the validation of the dynamic mathematical model. The low level runs planned during the Sinusoidal Vibration sequence will be used for this purpose.

8.2.2.8.4 Shock

The purpose of shock testing is to demonstrate that the GG Satellite can withstand shock levels predicted for flight.

Furthermore, it will be necessary for the following aspects:

- To demonstrate the proper functioning of the Spacecrafts separation systems as far as the cutting and release of the Clamp Band and Separation bolts are concerned.
- To evaluate the shock levels propagation into the satellite elements when subjected to shock event.
- To recover shock levels at unit interface.

In this mission the major shock is expected when the GG satellite will be separated from Launch Vehicle. Consequently this test has to be performed during the system GG test campaign, using a flight representative model of the launcher interface ring.

8.2.2.8.5 Acoustic

The purpose of acoustic tests is to demonstrate that the space vehicle can withstand the acoustically induced vibration environment encountered during relevant mission phases. Acoustic tests are to be conducted in a reverberant acoustic chamber, with the launch configuration mounted on a test fixture simulating dynamic flight mounting conditions, but being low frequency decoupled from chamber floor and wall structure-born vibration.

The acoustic test is also useful to validate the random vibration criteria specified for the on board units.

8.2.2.8.6 *Physical Properties*

The purpose of the physical properties measurements is to determine the space vehicle mass, centre of gravity location, and moments of inertia around its three coordinate axes. The principal configurations are the launch and orbit insertion configurations, but the mission profile may require determinations in other configurations as well.
The experimental results will be compared with the mathematical models: dummy masses can be mounted on board to reach the request Satellite physical configuration.
Since GG is a spin stabilized Satellite also a spin balance measurement will be performed.

8.2.2.8.7 *Alignments*

On GG the major objective that has to be reached by alignment measure is the positions of ACS sensors and actuators, which must be well know, within specified tolerances, since these are essential parameters for the orbit control law.

To accomplish the above objectives all the sensors and actuators shall be provided of optics markers (mirror cubes) to allow measurements with theodolites, visible also with the Satellite fully integrated.
To adjust the position of the item under test the system used will be by shimming under the mounting screws with thin aluminum layers.

The measurements, conducted in a suitable alignment facility, have to be performed prior and subsequent to all environmental tests that may affect the alignment, such as thermal vacuum and vibration tests, or after transports.

8.2.2.8.8 *EMC/ESD Tests*

The purpose of electromagnetic compatibility testing is to determine whether or not any space vehicle operations could be adversely affected by electromagnetic interference from external sources, and whether or not the space vehicle itself emits any electromagnetic signals that might adversely affect its own operations.

The EMC/ESD Tests can be subdivided in:

- Conducted Emission: verification that in some operative configurations the conducted emission (i.e. the electromagnetic noise spreading on a confined guide, like electrical conductor) of the item under test doesn't exceed the specified thresholds.
- Conducted Susceptibility: verification that in some operative configurations the conducted electromagnetic noise (opportunely generated during the test at the specified level) cannot disturb the performance of the item under test
- Radiated Emission: verification that in some operative configurations the radiated emission (i.e. the electromagnetic noise spreading in open space) of the item under test doesn't exceed the specified thresholds. One typical scope of this measurement is to ensure the compatibility with the launcher requirements in launch configuration
- Radiated Susceptibility: verification that in some operative configurations the radiated electromagnetic noise (opportunely generated during the test at the specified level) cannot disturb the performance of the item under test. One typical scope of this measurement is to ensure the Satellite compatibility with the launcher emission in launch configuration
- Electro-Static Discharge: verification of electro-static discharge effects on the unit under test performances

The proposed approach for GG is:

- To perform both at unit level and at system level the Conducted Emission and the Conducted Susceptibility.
- To perform by test at system level the verifications on Radiated Emission and Radiated Susceptibility
- To perform by test at equipment level and by analysis at system level the ESD verifications.

9. AIV TOOLS

In this section are briefly described all the necessary AIV tools needed to support the GG program under direct TAS-I responsibility, i.e. the AIV tools defined for the activities at system level. The AIV/AIT tools used during subcontractors' activities are not included.
Anyway, some tools and equipments used at SUBCO level can be deliverable to prime if useful at system level.

9.1 GSE

The Ground Support Equipments are all the test equipments needed to support the GG test campaign.
To optimize cost and schedule aspects these equipment will be refurbished or used 'as it is' from previous projects each time when this is possible. Case by case verification will be done in the next project phase.

9.1.1 MGSE

Mechanical Ground Support Equipment, to provide the mechanical supporting interface to the GG and its constituent parts during all its ground and testing operations. The MGSE allow the handling, the accessibility and the transportability of the Spacecraft, supporting all the set-ups foreseen during the test campaign, always in safe condition for the operators and for the Hardware.
The MGSE set includes also the GG transport container.

9.1.2 EGSE

Electrical Ground Support Equipment and Operational S/W will enable the practical demonstration of correct functioning of GG during its operations.
The EGSE shall be used to support GG test campaign and the various associated test configurations foreseen during all assembly and integration phases.
The EGSE shall be a complete simulation and test execution system and it shall provide supervisor control, test execution and simulation environments at the same time: so the EGSE

shall be able to operate as an integrated and a highly automated test bench, consequently it shall simulate and emulate internal GG missing items and the functional external interface.

The main components of the GG EGSE will be:

ATB Test Equipment:

This item will interfaces with the Avionics Test Bench and it's able to:

- Simulate the power subsystem, supplying the ATB units
- Simulate the missing avionics units / sensors, to allow the attitude data recostruction
- Receive, decode, calibrate and archive telemetry data
- Send telecommand
- Manage the Satellite Database
- Provide interfaces with the on board data bus
- Allow preparation, debugging and execution of automatic test sequences
- Allow archived data restoring and analysis

With this equipment it is possible to monitor in real time the ATB status.

The ATB TE is stand alone equipment, it is nominally not connect to the other EGSE equipment, anyway it is request a compatibility with the EGSE used on PFM, to ensure the test sequences and the archive data portability.

Central Check-Out System (CCS)

The CCS is the core of the EGSE, used to perform the entire electrical and functional test campaign on GG.

It interfaces with the GG On Board Data Handling by the TM/TC FEE and it is connected with the other SCOE (Special Check-Out Equipment) that allow the simulation of the Satellite external environment.

It is able to:

- Receive, decode, calibrate and archive telemetry data
- Send telecommand
- Manage the Satellite Database
- Provide interfaces with the on board data bus
- Allow preparation, debugging and execution of automatic test sequences
- Allow archived data restoring and analysis
- Send commands and receive data from the SCOEs
- Provide a direct spy link with OBDH bus (TBC)

With the CCS it is possible to monitor in real time the Satellite and the equipments (SCOE) connected to it.

Special Check-Out Equipment (SCOE)

The main SCOE are:

- Power SCOE: to simulate the Satellite power sources subdivided in :
    - Solar Arrays Simulator

- Batteries simulators: able to simulate the batteries charge and discharge (working also as dynamic load)
- Umbilical power: used on ground during the test campaign in case of low power request from the Satellite and also used (in different configuration) to supply the Satellite on launch pad
- Umbilical SCOE: I/F with the Spacecraft TM/TC lines thought the Umbilical lines and on the other side with the TM/TC FEE. This link is used to perform test where the presence of RF link is negligible, allowing a more simple set-up

- TT&C SCOE: to provide RF uplink and downlink between on board TT&C and ground
- Avionics SCOE: to provide environmental simulation during the closed loop test and HW simulation or electrical units stimulation during the overall test campaign

The SCOEs are linked to MTP via LAN and are commanded in remote way from the MTP consolle. For dedicated test purposes it is also possible to use the SCOEs in local mode
Nominally the SCOE's exchange data with the CCS, not directly with the Satellite

PGB EGSE

Furthermore there are some PGB GSE that will be delivered by PGB subco and used at system level, these are:

- PGB Simulator: it will be functionally representative of PGB interfaces versus the Service Module and it will be used to verify the data exchange between PGB and plaform on ATB.
- PGB SCOE: this SCOE shall be able to receive the Satellite scientific telemetry from CCS (or from TM/TC Front End) and decode it, to check the Payload status during the system testing. As all the other SCOE, it will be able to exchange data with the CCS. In special case shall be possible also enable a direct link between P/L SCOE and Satellite via TM/TC FEE (TBC).

In Figure 9-1 is presented the GG test configuration during system test in ambient condition.

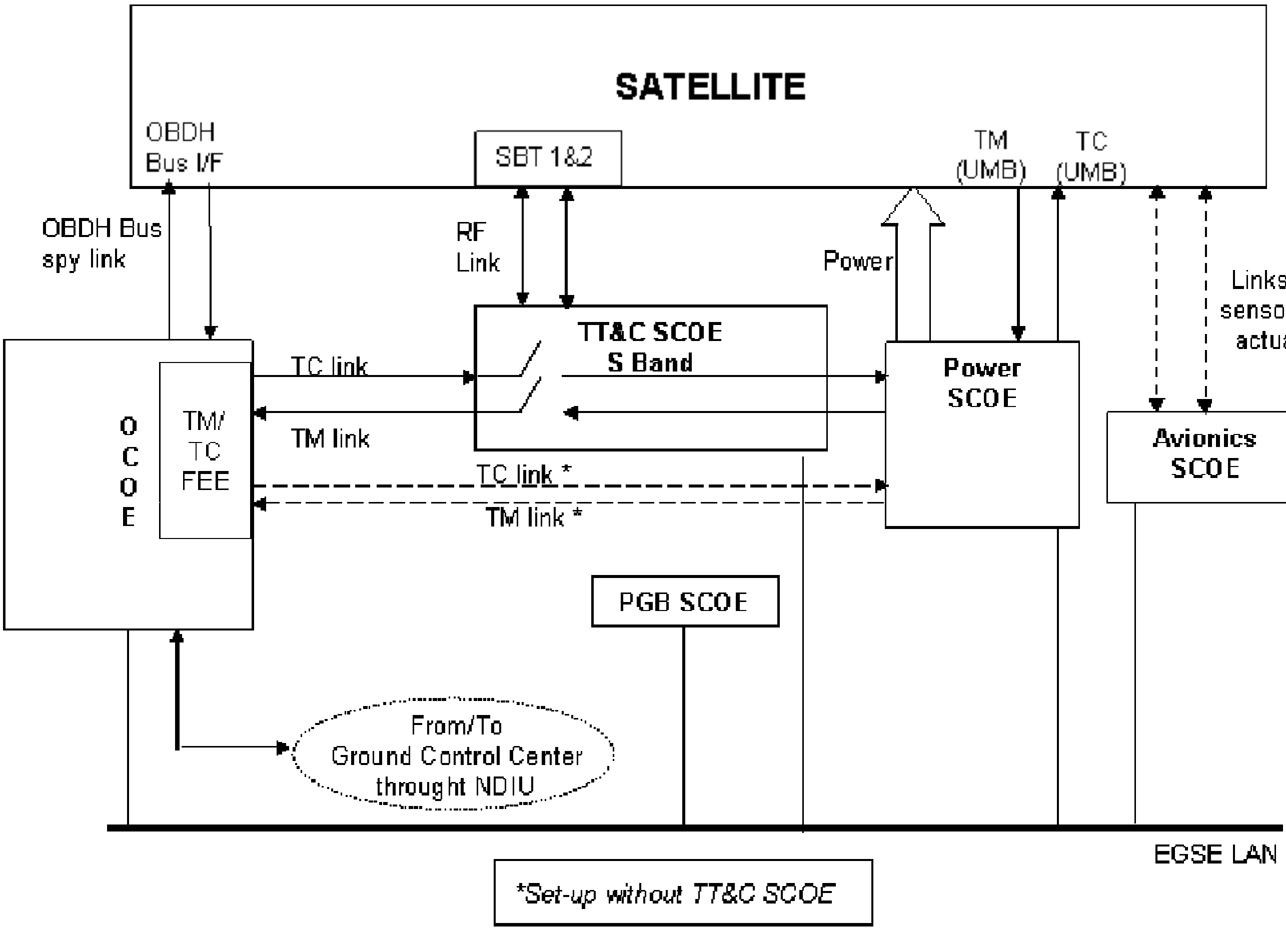

Figure 9-1 GG System Test Configuration

9.1.3 OGSE

At system level the Optical Ground Equipment foreseen for GG are the Stimulators needed to verify qualitatively the health status of ACS sensors during the different phases of test campaign.
These OGSE shall be very simple since no performance measurements are request at system level and are of two categories:

1. Optical Stimulator (like a focalized lamp) to check Coarse Sun Sensors and Spin Sensor
2. Infrared Stimulator (like a heater) to check the Earth Sensors

9.2 Standard Laboratory Equipment

Standard Laboratory Equipment will be made also available to support the AIV/AIT program. They will consist of standard mechanical tools, calibration and measurement equipment (ohmmeter, voltmeter, oscilloscope, etc.), power supplies, Interface Test Boxes.

9.3 AIT Facilities

AIT facilities breakdown at system level for all the models is as follows:

- For harness installation, mechanical and electrical integrations, Integrated Function Tests and EMC tests (conducted): at the TAS-I integration clean room facility.
- For Sine Vibration, Acoustic, TB/TV, Mass Properties a specific environmental test facility
- Launch campaign will be performed in the Launch Authority Facilities

9.3.1 Contamination control

An effective cleanliness and contamination control program will be implemented in order to prevent contaminant-induced degradation from exceeding permitted levels in all the test facility used.

All the assembly, integration, testing, storage and transportation activities will be performed in a clean environment in accordance FED- STD-209 D, table II.

Temperature	:	22° C +/- 2° C
Relative Humidity	:	40 % ÷ 55 %
ΔP	:	2 mm H_2O
Clean Conditions	:	Class 100,000

9.3.2 Definition of external AIT Facility

As described before the external AIT Facility shall be able to support the GG environmental test campaign.
The facility shall be defined together with the customer and shall satisfy:

- Compatibility with GG dimensions
- Enough space for GG EGSE, MGSE

- Availability of clean room 100000 for GG functional and mechanical test
- Possibility to perform at levels / accuracy request by GG:
    - TV/TB
    - Sine vibration
    - Acoustic Test
    - Shock Test
    - Physical Properties: Moment of Inertia, Center Of Gravity, mass, spin balance.
- Offices and logistic support
- Cost Aspects

Detailed facility requirements will be defined in the next project phase.

CONTROLLED DISTRIBUTION

10. VERIFICATION CONTROL METHODOLOGY

10.1 General

The correct implementation of the verification program is monitored following a day by day verification control concept oriented to prevent potential problems and to reduce risks of cost increasing and schedule slippage.
This concept is centered on the use of a computerized system to support the maintenance of the verification control document and all the associate data.
The computerized methodology allows:

- the real time control during the program life cycle, utilizing the tool capability to anticipate problems and monitor progresses in the verification activities
- identification of impacts in case of change of requirements
- immediate and flexible reporting of data in support to the preparation of the program verification documentation

The documentation that will be associated with the GG verification process is summarized in Figure 10-1

10.2 Verification Data Base

All the verification requirements are fed into the verification Data Base. This will be organized in order to be under configuration control and to avoid alteration without authorization.
For all verification activities the resulting reporting and execution documentation will be introduced in agreement with the flow shown below
The Verification Data Base system will include suitable application programs for requirement verification control and requirement traceability.

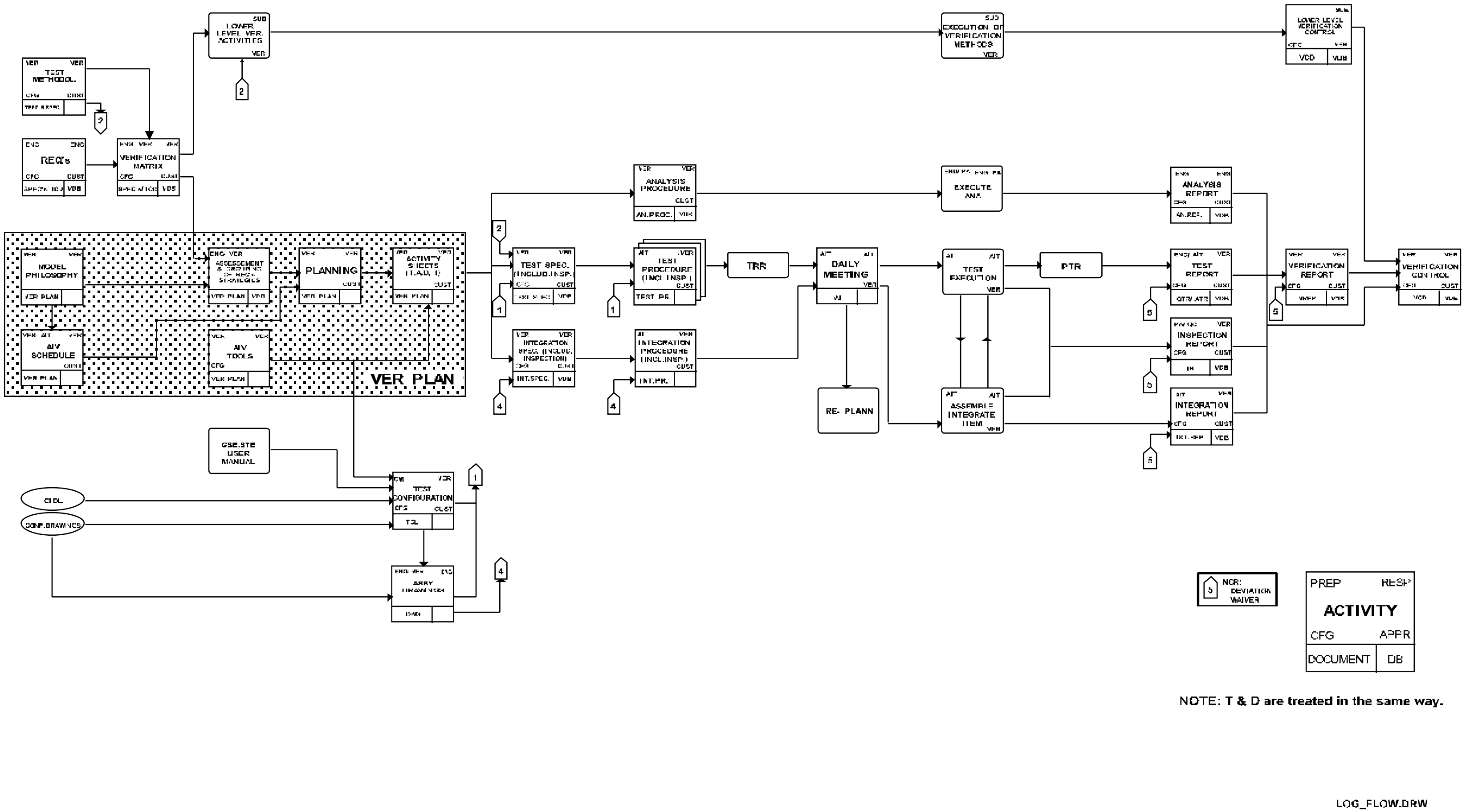

Figure 10-1 GG Verification Process

11. DOCUMENTATION

In this section is presented the GG documentation involved in the verification process, a scheme with the relationship between the different documents is presented in Figure 11-1

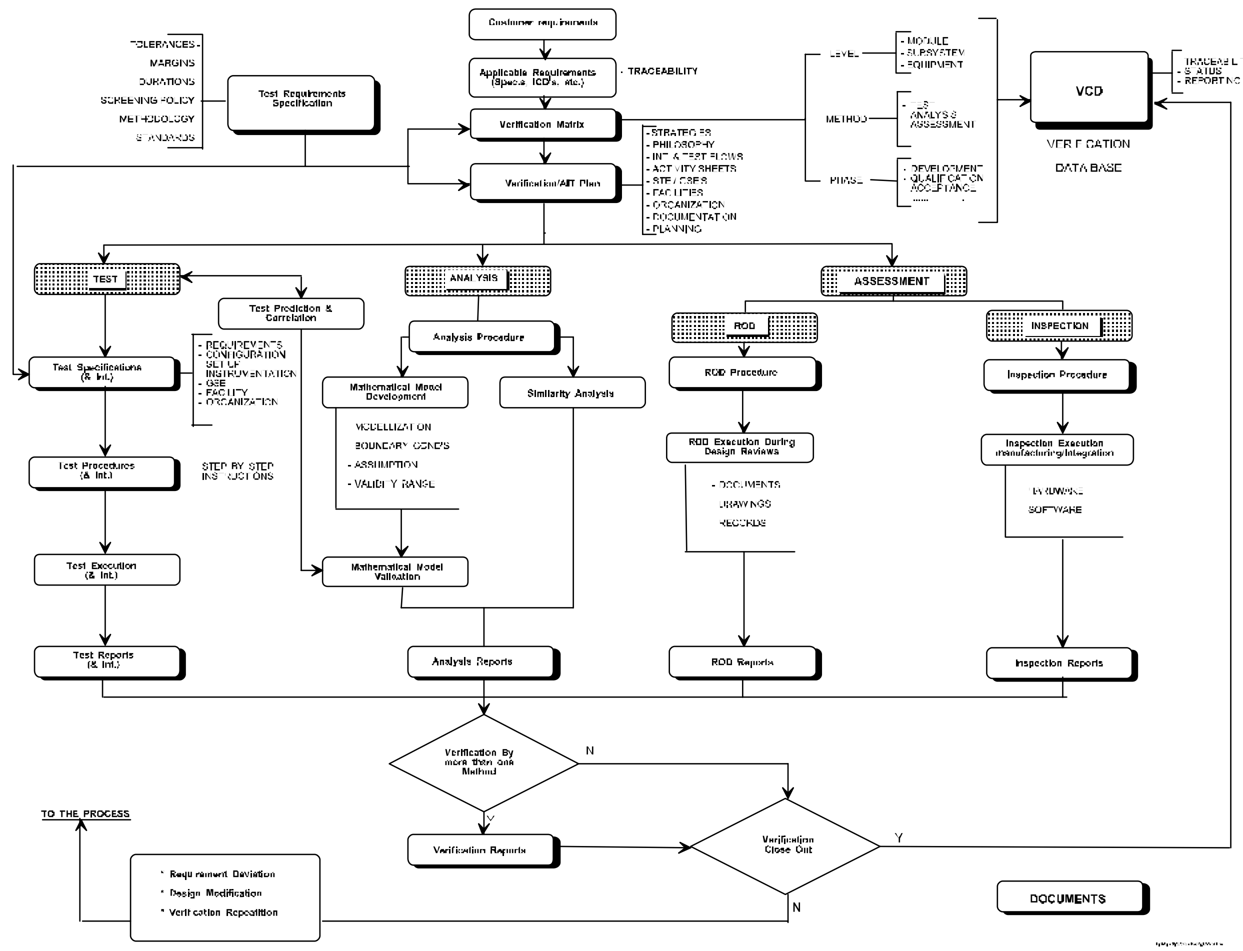

Figure 11-1 Verification Document Relationship

11.1 Environmental and Test Requirement Specification

This document is a system support document issued by the Prime applicable to all verification levels through proper reference within the relevant item specifications. It contains the general test requirements in terms of type of tests, sequences, margins, duration, tolerances, screening policy and methodology.

11.2 AIV Plan

This document is the master verification plan and demonstrates how the system requirements will be verified by a coherent implementation approach. It contains the overall verification approach, the model philosophy, the verification implementation program and the relevant planning. It describes the system activities and it outlines the equipment level activities.

11.3 AIT Plan

This document contains the integration and test program, the task sheets, the verification tools, the verification management and organization.

11.4 Test Specifications

These documents will be prepared for each major integration and test activity described in the AIV plan, with the objective to detail the integration and test requirements.

11.5 Test Procedures

These documents provide the detailed step-by-step instructions for conducting the integration/test activities in agreement with the test specification requirements.

11.6 Test Evaluation Reports

The test evaluation reports will describe the performed test activities illustrating results and conclusions in the light of the test requirements.

11.7 Analysis Reports

These documents will describe, for each analysis, assumptions, utilized methods, software and results. They contain proper evidence that the relevant requirements are satisfied and the indication of deviations, if any.

11.8 Inspection / ROD Reports

These documents will describe each verification activity performed, inspecting hardware during manufacturing/integration or reviewing documentation during design reviews. They contain proper evidence that the relevant requirements are satisfied and the indication of any deviation.

11.9 Verification Reports

These documents will be prepared in case that more than one of the defined verification methods are utilized to verify a requirement or a specific set of requirements. They explain the approach followed and how the verification methods were combined to achieve the verification objectives.

11.10 Verification Control document

The Verification Control Document centralizes all the information relevant to the verification status of the applicable requirements.
This document will be prepared at each verification level and maintained current by the responsible verification organization.
It contains the default data like requirement text, number, title, verification entries at the applicable level for all the GG requirements. These informations can be automatically acquired from the electronic file of GG specifications.
The final VCD purpose is to provides all the information relevant to all the GG requirements and the relevant closure reference.

11.11 Other Documents

NCR, RFW/D and etc. will be prepared and treated, if any, according to the PA rules as defined in the PA plan.

12. ORGANIZATION AND MANAGEMENT

12.1 General

This section describes the overall organization and management techniques for performing the Galileo Galilei assembly, integration and verification activities presented in this plan.
The main tasks to be performed are:

- Design and development plan preparation and control
- Verification Control Document preparation and control
- Test Equipment/Instrumentation requirements definition
- Facility Requirements definition
- Integration/Test Procedures preparation
- Integration/Test activity execution
- Integration documentation preparation
- Test and Verification Reports preparation
- Control of analysis reports for verification purposes
- Monitoring of subsystem activities for verification purposes

12.2 Organization

The overall organization of the AIV activities and its relationship with the company organization is presented in this paragraph.
The following groups are involved in the overall verification process:

AIV Team

These teams will provide a Program Verification Manager (AIV Manager) which is responsible, by means of dedicated personnel (AIV engineers), of the following tasks:
- Verification management and interface with the Customer
- Contribution to Project Design Review
- Interface with the AIT Teams involved in the testing activities
- Design and development plan preparation
- Verification Philosophy and AIV plan preparation
- Verification Matrix Definition
- VCD preparation
- Monitor of lower level verification documentation
- Test Specification Preparation (in collaboration with engineering team)
- Review and Approval of Test Procedure

- Participation to Test Readiness Review (TRR) and Post Test Review (PTR)
- Participation of Daily Meetings
- Monitor system integration and test execution in order to evaluate test results (in collaboration with engineering team)
- Participation to Non Conformance disposition
- In case of major Non Conformance, participation to Material Review Board (MRB)
- Preparation of Verification Reports
- Chairing of Verification Control Board (VCB)
- Chairing of Test Review Board (TRB)

AIT Team

These teams will provide a AIT Manager which is responsible, by means of dedicated personnel (AIT engineers), of the following tasks:

- Managements of all AIT activities
- Interface with the Teams involved in the verification activities
- Preparation of detailed Integration & test planning and schedules
- Preparation of Integration and Test Procedures
- Design, preparation and utilization of Ground Support Equipment and test tools (H/W & S/W)
- Procurement and maintenance of AIV tools
- Interface with Test Facilities
- Execution of Integration and Test activities
- Chairing of Test Readiness Review (TRR) and Post Test Review (PTR)
- Chairing of Daily Meetings
- Preparation of Test Reports
- Participation to Non Conformance disposition
- In case of major Non Conformance, participation to Material Review Board (MRB)

Quality Control / Quality Assurance Team

This team will provide a Program Quality Control Responsible which is in charge, by means of dedicated personnel and entities, of the following tasks:

- Participation to TRR and PTR
- Participation and QC monitoring of Integration and Test execution and attendance to Daily Meetings
- Chairing of MRB
- Execution of Quality Control Inspection and preparation of relevant reports
- Certification of H/W, S/W and documentation
- Non Conformances Report (NCR) preparation and management
- Review and approval of Integration/Test Procedures (including Procedures Variation Sheets (PVS) if any) and VCD Documents

12.3 Management Tools

The major management tools that are utilized for the control of the AIV activities are the follows.

12.3.1 Verification

The verification activities will be performed in the following main steps:

- establishing Verification Control Documents analyzing the requirements of applicable Specifications
- engineering approval of VCD and verification activity planning
- verification control, monitoring of the GG activities, documents and reviews on the light of the applicable specifications

12.3.1.1 Verification Control Board (VCB)

The objective of the VCB is to review VCD, check its completeness, and delete existing requirements duplication.
The VCB has also the purpose to evaluate the verification results on the basis of the information provided by the verification groups and the supporting functional department.
The Verification Control Board decides upon the acceptance of verification or on further actions necessary to close a verification requirement.
The Verification Control Board required members are:

- AIV Manager (chairman)
- Integration and Test Engineers
- Engineering disciplines representatives
- Quality Control Responsible
- Configuration Control Responsible

12.4 Integration and Testing

12.4.1 Incoming Inspection

Before starting the integration activities an incoming inspection shall be performed on each delivered item to check the quality of the H/W to be integrated. As a minimum the following checks are foreseen:

- completeness of H/W according to the shipping documentation visual inspection (no degradation has occurred)
- completeness of the data package
- conformity of identification markings and serial numbers
- cleanliness

12.4.2 Hardware Storage

All inspected H/W will be stored under controlled environment. Special storage conditions will be provided if necessary.

12.4.3 Mechanical /Electrical Integration

The integration will be performed according to fully signed and released Integration Procedure. The handling and integration activities of flight H/W in the various integration and testing facilities shall only be carried out by trained and briefed personnel having the necessary experience and using the dedicated GSE.

12.4.4 Integration and Testing control

The Integration and Test activities will be followed and monitored by QC inspectors which will control:

- documentation and hardware / software availability
- NCR / PVS status
- Performance of each step-by-step operation and its certification
- Filling of the Integration Log-book

- Work Items / Deviation Work Items completion

In particular will be adopted the following:

12.4.4.1 Test Readiness Review (TRR) and Post Test Review (PTR)

The objectives of these reviews are respectively to declare the readiness for the test authorizing the start of the test and to review the preliminary results declaring the test completion.
They are carried out during phase C/D, prior and after each main integration and test activities covered by a specific Integration and Test Procedures.
The TRR's and PTR's are held by the Test Review Board in which the following members are required:

- AIT manager or his representative (chairman)
- AIV Manager
- Integration and Test Engineers involved in the activities
- System Engineer
- Quality Control Responsible
- Configuration Control Responsible

12.4.4.2 Daily Meeting

The objective of this meeting is to plan and control daily the integration and test status. Dedicated Work Item written on the basis of the applicable requirements and procedures are authorised. The Daily Meeting also address decisions relating any changes to approved procedures and Work Items in order to authorise Procedure Variation Sheets (PVS) and Deviation Work Items (DWI); any deviation from nominal schedule is also analysed and actions are taken.
The Daily Meeting chairman is the AIT manager or his representative.

12.4.4.3 Material Review Board (MRB)

In case of major Non Conformances during verification activities, a Non Conformance Report is written and processed to assure correct actions and disposition through a MRB in line with PA project requirements.

12.4.5 Delivery Review Board (DRB)

At the end of the verification activities a DRB will be held to prove to the Customer that there is adequate documentary evidence to demonstrate that the product has satisfied all requirements. The DRB will be composed by System Engineer, AIV Manager, Quality Control Responsible and Customer representatives.

END OF DOCUMENT