GALILEO GALILEI (GG)

Compliance matrix wrt Mission and Project Requirements and System Functional Specification and System Requirements Traceability Matrix

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The validations evidence are kept through the documentation management system.

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1. SCOPE AND PURPOSE

This document is submitted in partial fulfilment of Work Package 1A-ADA of the GG Phase A2 Study (DRL item DEL-28 and DEL-25).

The purpose of the document is to present the compliance of GG mission design to mission and project requirements, illustrating the traceability of functional and technical requirements to high level requirements issued in Mission Requirements Document and in Experiment Requirements and Concept Document, although the latter has been defined starting from mission requirements themselves. In the study functional and technical specifications have been derived from mission requirements and experiment requirements, according to the relation schematised in Figure 2.1-1. Therefore compliance between the high level requirements and the specifications that shall drive their implementation in system functional and technical definition will be checked and illustrated.

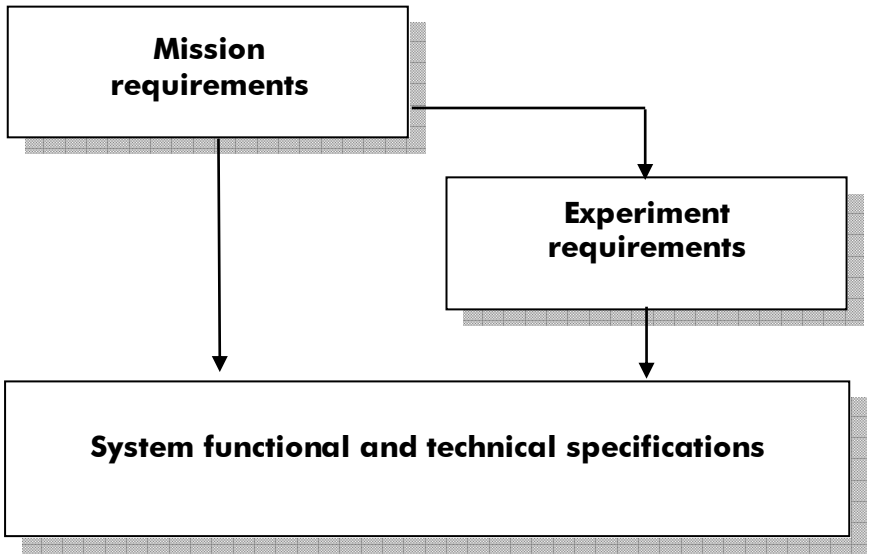

Figure 2.1-1: Derivation of system functional and technical specification and requirements compliance concept

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-2 Study Report, April 2009

[RD 2] GG Phase A Study Report, Nov. 1998, revised Jan. 2000, available at: http://eotvos.dm.unipi.it/nobili/ggweb/phaseA/index.html

[RD 3] 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 4] A. Nobili, DEL001: GG Science Requirements, Pisa, September 2008

2.3 GG Phase A2 Study Notes

[RD 5] SD-RP-AI-0625, GG Final Report / Satellite Detailed Architecture Report, Issue 1

[RD 6] SD-RP-AI-0626, GG Phase A2 Study Executive Summary, Issue 1

[RD 7] SD-TN-AI-1163, GG Experiment Concept and Requirements Document, Issue 3

[RD 8] SD-RP-AI-0620, GG System Performance Report, Issue 2

[RD 9] SD-TN-AI-1167, GG Mission Requirements Document, Issue 2

[RD 10] SD-RP-AI-0590, GG System Concept Report (Mission Description Document), Issue 3

[RD 11] SD-SY-AI-0014, GG System Functional Specification and Preliminary System Technical Specification, Issue 1

[RD 12] SD-RP-AI-0631, GG Consolidated Mission Description Document, Issue 1

[RD 13] SD-TN-AI-1168, GG Mission Analysis Report, Issue 2

[RD 14] DTM, GG Structure Design and Analysis Report, Issue 1

[RD 15] SD-RP-AI-0627, GG Thermal Design and Analysis Report, Issue 1

[RD 16] SD-RP-AI-0268, GG System Budgets Report, Issue 1

[RD 17] SD-RP-AI-0621, Technical Report on Drag and Attitude Control, Issue 2

[RD 18] TL25033, Payload Architectures and Trade-Off Report, Issue 3

[RD 19] SD-RP-AI-0629, Technical Report on Simulators, Issue 1

[RD 20] ALTA, FEEP Thruster Design and Accommodation Report, Issue 1
[RD 21] TAS-I, Cold-Gas Thruster Design and Accommodation Report, Issue 1
[RD 22] SD-RP-AI-0630, Spin Sensor Design, Development and Test Report, Issue 1
[RD 23] SD-TN-AI-1169, GG Launcher Identification and Compatibility Analysis Report, Issue 1
[RD 24] ALTEC-AD-001, GG Ground Segment Architecture and Design Report, Issue 1
[RD 25] SD-TN-AI-1218, GG Preliminary Product Tree, Issue 1
[RD 26] SD-PL-AI-0227, GG System Engineering Plan (SEP), Issue 2
[RD 27] TAS-I, Payload Development and Verification Plan, Issue 1
[RD 28] SD-PL-AI-0228, GG System Verification and Validation Plan, Issue 1
[RD 29] SD-TN-AI-1219, Report on Frequency Management Issues, Issue 1
[RD 30] SD-RP-AI-0632, GG Mission Risk Assessment And Mitigation Strategies Report, Issue 1
[RD 31] SD-RP-AI-0633, Report on Mission Costs Estimates, Issue 1

3. COMPLIANCE TO MISSION REQUIREMENTS

3.1 Overview

In the following paragraphs the GG Phase A-2 requirements issued in MRD ([RD 9]) are reported together with the corresponding or related requirements issued in [RD 11]. A table representation has been chosen, for better evidencing the relations. Where correspondence occurs through a requirement from Experiment Concept and Requirements document ([RD 7]), it will be mentioned.

The following categories have been considered, corresponding to [RD 11] sections:

- ❑ Programmatic Requirements
- ❑ Mission Requirements
- ❑ System Functional Requirements
- ❑ Scientific Performance and Payload Requirements
- ❑ Satellite Physical Requirements
- ❑ Payload and System Functional Requirements
- ❑ Data Product Requirements
- ❑ Operational Requirements
- ❑ Verification Requirements
- ❑ Product Assurance Requirements

Comparison between MRD and [RD 11] items will be done as follows:

Mission requirements		**System functional and technical requirements Ref. document: SD-SY-AI-0014**		**Compliance**
...	...	...	...	...
MRD item	Item description	[RD 11] item	Item description	Y
...	...	...	...	...

If two or more MRD items are met by a single functional or technical specification, notation will be the following:

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance
...	...	...	...	..
MRD item 1	Item description	[RD 11] item	Item description	Y
MRD item 2	*Item description*			Y
...	...	...	...	...

and vice versa:

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance
...	...	...	...	..
MRD item 1	Item description	[RD 11] item 1	Item description	Y
		[RD 11] item 2	Item description	
...	...	...	...	...

In the tables compliance label is always referred to MRD items.
Note that if in the requirements include references to applicable or reference documents, these will be explicitly mentioned, without reporting the reference number used in original definition.

3.2 Programmatic Requirements

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-1	The GG satellite shall be compatible with launch in the time frame 2013-2020	ST.MIR-4	The mission and spacecraft design shall be compatible with a launch period duration as defined in GG MRD.	Y
MRD-2	The GG satellite shall be compatible with the cost policy of a small scientific satellite project of ASI.	ST.SCR-2	As general concept the spacecraft design shall be compliant to the ASI cost policy of a small satellite.	Y
MRD-3	The GG satellite shall be compatible with launch by VEGA.	ST.LIR-1	The spacecraft design shall be fully compatible with: i. all performances, requirements, interfaces and operations of VEGA launcher specified in the launcher interface control document; ii. all performances, requirements, interfaces and operations of at least another low cost launcher, as specified in the its interface control document; iii. the operations and safety requirements applicable at the selected ground segment/launch site.	Y
MRD-4	Besides VEGA, the GG satellite shall be compatible with launch by at least one low-cost launch vehicle.			Y
MRD-5	At launch, the total mass of the GG satellite, including the launch vehicle adapter, shall be less than 500 kg.	ST.SCR-3	Launch mass of GG satellite, including launcher adapter, shall not exceed 500 kg.	Y

Table 3.2-1: MRD programmatic requirements traceability

3.3 Mission Requirements

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-6	The GG orbit shall be near circular, at a mean altitude such that [MRD-7] is met all through the mission lifetime.	-	*Orbit characteristics and altitude range described at par. 2.4.1. of [RD 11]..*	Y
		ST.EXR-1	GG Experiment requirements shall be as defined in Experiment Concept and Requirements Document (*EDR-3 and EDR-32 requirements refer to orbit choice between 500 km and 600 km*).	
MRD-7	The GG orbit shall be such that the maximum disturbing acceleration experienced by the satellite at any point of its orbit does not exceed 2×10^{-7} m/s^2.	ST.EXR-1	GG Experiment requirements shall be as defined in Experiment Concept and Requirements Document (*EDR-32 refers to 2×10^{-7} m/s^2 as the allowed value for overall non-gravitational acceleration contributions*).	Y
MRD-8	The GG orbit shall be near-equatorial, with inclination at launcher release not exceeding 5.5°.	ST.EXR-1	GG Experiment requirements shall be as defined in Experiment Concept and Requirements Document (*EDR-3 refers to 5° as maximum orbit inclination*).	Y
MRD-9	The GG mission phases shall comprise: ▪ Launch and Early Orbit phase (LEOP) ▪ Commissioning phase ▪ Normal Operation phase ▪ Disposal phase.	-	*Mission phases' description in par. 2.4 of the document is compliant to MRD-9.*	Y
MRD-10	The in-orbit lifetime of the GG spacecraft shall be at least 2 years after the end of the initial commissioning.	ST.SCR-6	The spacecraft shall have a nominal lifetime of 2 years in flight, from end of commissioning phase to end of nominal operational life	Y

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-11	The in-orbit lifetime of the GG spacecraft shall be at least 3 years after the end of the initial commissioning (*goal requirement*).	ST.SCR-7	The spacecraft shall have an extended lifetime of 3 years in flight, from end of commissioning phase to end of nominal operational life (*goal requirement*).	Y
MRD-12	After commissioning, the GG satellite shall be spin-stabilized.	ST.MIR-5	At separation from launcher the spacecraft shall be released in a spin-stabilised attitude with a spin rate of TBD Hz.	Y
		ST.MIR-6	The nominal spin rate shall be achieved during the Commissioning Phase by means of the spacecraft's own propulsion.	
MRD-13	The nominal spin rate of the GG satellite shall be 1 Hz.	ST.MIR-12	In nominal attitude the spacecraft shall maintain the nominal spin rate of 1 Hz.	Y
MRD-14	The nominal attitude of the spin axis of the GG satellite shall be orthogonal to the mean orbit plane at beginning of life.	ST.SCR-16	After in-orbit attitude acquisition, the spin axis of the GG spacecraft shall always be pointed within the angle specified in para. 5.4.3 of Experiment Concept and Requirements Document to the normal to the orbit plane. *Note that the EDR-59 requirement of [RD 7] states that the spin axis may be pointed within 1° angle from normal to nominal orbit plane. Considering that MRD-14 refers to mean orbit plane, EDR-59 and therefore ST.SCR-13 compliance to MRD-14 may be accepted.*	Y
		ST.EXR-1	GG Experiment requirements shall be as defined in Experiment Concept and Requirements Document.	

Table 3.3-1: MRD mission requirements traceability

3.4 System Functional Requirements

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-15	To prepare the measurements the GG system shall perform the following functions: ▪ scientific and operational management of the measurements being part of the scientific mission, ▪ preparation of the measurement sequences according to the scientific operations plan (parameter optimisation, calibration).	ST.SFR-10	To prepare the measurements the GG system shall perform the following functions: i. scientific and operational management of the measurements being part of the scientific mission, ii. preparation of the measurement sequences according to the scientific operations plan (parameter optimisation, calibration).	Y
MRD-16	To prepare and upload the work plan the GG system shall perform the following functions: ▪ generation of payload work plan, ▪ generation of the satellite guidance, ▪ generation and validation of the platform and payload TCs, ▪ transmission of the TC sequences to the ground station.	ST.SFR-11	To prepare and upload the work plan the GG system shall perform the following functions: i. generation of payload work plan, ii. generation of the satellite guidance, iii. generation and validation of the platform and payload TCs, iv. transmission of the TC sequences to the ground station.	Y
MRD-17	The payload telemetry data shall be recorded on-board by the on-board mass memory in a continuous way. The mass memory capacity shall be sized to record 7 days (TBC) of mission before rollover.	ST.SFR-12	The payload telemetry data shall be recorded on-board by the on-board mass memory in a continuous way. The mass memory capacity shall be sized to record 7 days (TBC) of mission before rollover.	Y
MRD-18	The system design shall be compatible with a science daily telemetry volume of 2.5 Gbit/day.	ST.SFR-13	The system design shall be compatible with a science daily telemetry volume of 2.5 Gbit/day (TBC).	Y

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-19	The command and control uplink and downlink communications shall be performed in S-band, with a data rate able to handle all necessary TM/TC for housekeeping operations	ST.SFR-14	The command and control uplink and downlink communications shall be performed in S-band, with a data rate able to handle all necessary TM/TC for housekeeping operations	Y
MRD-20	Payload data downlink shall be done in S-Band	ST.SFR-15	Payload data downlink shall be done in S-Band	Y
MRD-21	Link shall be established for an elevation angle equal or higher than 10° (TBC).	ST.SFR-16	Link shall be established for an elevation angle equal or higher than 10° (TBC).	Y
MRD-22	The availability of the link shall be greater than 95%.	ST.SFR-17	The availability of the link shall be greater than 95%.	Y
MRD-23	TM and TC shall be compliant to the CCSDS standards for data coding in space-ground communications.	ST.SFR-18	TM and TC shall be compliant to the CCSDS standards for data coding in space-ground communications.	Y
MRD-24	P/L and HK telemetry data shall be separated through virtual channels in such a way that the ground station can immediately separate the telemetry flow into science data and functional housekeeping telemetry.	ST.SFR-19	P/L and HK telemetry data shall be separated through virtual channels in such a way that the ground station can immediately separate the telemetry flow into science data and functional housekeeping telemetry.	Y
MRD-25	During the scientific mission phase, a ground station availability of 90% (TBC) maximum shall be assumed.	ST.SFR-20	During the scientific mission phase, a ground station availability of 90% (TBC) maximum shall be assumed.	Y
MRD-26	The transmission of the HK data to the Mission Operations Centre shall be completed in less than 1 day after the end of a communication slot with the satellite.	ST.SFR-21	The transmission of the HK data to the Mission Operations Centre shall be completed in less than 1 day after the end of a communication slot with the satellite.	Y
MRD-27	The transmission of the P/L data to the Science Operations Centre shall be completed in less than 1 week after the end of a communication slot with the satellite.	ST.SFR-22	The transmission of the P/L data to the Science Operations Centre shall be completed in less than 1 week after the end of a communication slot with the satellite.	Y

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-28	The GG system shall perform the following functions: ▪ acquisition of the scientific data in P/L telemetry and pre-processing, ▪ systematic checks on the data validity and quality, ▪ instrument performances follow-up, ▪ instrument calibration and optimisation, ▪ processing of the scientific telemetry up to level 1, ▪ archiving and cataloguing of the data delivered to final users. These functions shall be performed by the Science Operations Centre.	ST.SFR-23	The GG system shall perform the following functions: i. acquisition of the scientific data in P/L telemetry and pre-processing, ii. systematic checks on the data validity and quality, iii. instrument performances follow-up, iv. instrument calibration and optimisation, v. processing of the scientific telemetry up to level 1, vi. archiving and cataloguing of the data delivered to final users. These functions shall be performed by the Science Operations Centre.	Y

Table 3.4-1: MRD system functional requirements traceability

3.5 Scientific Performance and Payload Requirements

In MRD scientific performance and payload requirements are issued in Section 8. Their detailed characterisation is illustrated in [RD 7] that is wholly recalled by [RD 11] with the ST.EXR-1 requirement ("Experiment requirements shall be as defined in Experiment Concept and Requirements Document").

Therefore it can be assumed that, as for [RD 11], there is full compliance to scientific performance and payload requirements issued in MRD (from MRD-29 to MRD-40).

3.6 Satellite Physical Requirements

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-41	The GG spacecraft total length and diameter shall fit within the fairing of the selected launcher.	ST.LIR-1	The spacecraft design shall be fully compatible with: i. all performances, requirements, interfaces and operations of VEGA launcher specified in the launcher interface control document; ii. all performances, requirements, interfaces and operations of at least another low cost launcher, as specified in the its interface control document; iii. the operations and safety requirements applicable at the selected ground segment/launch site. *Note that all the distinct MRD requirements should be met by stating that spacecraft design is compliant to all the prescriptions reported in the interface control document of selected launcher (VEGA or another low cost launcher). Therefore further detailed issue of specific requirements punctually corresponding to MRD ones is not needed.*	Y
MRD-42	The GG spacecraft shall fit with a standard launch adapter of the selected launcher.			Y
MRD-43	The GG spacecraft shall comply with fundamental lateral and longitudinal frequencies of the launch vehicle.			Y
MRD-44	Total mass budget in launch configuration shall be compliant with the launcher capability, referred to selected orbit.			Y
MRD-45	The GG spacecraft shall be compatible with a launch window of at least 30 consecutive days.			Y
MRD-46	During combined operations with the launcher, the GG spacecraft shall comply with the launcher operations and attitude.			Y
MRD-47	During all phases of the launcher mission, the GG spacecraft shall comply with the attitude profile of the launcher.			Y

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-48	The maximum level of particulate contamination shall be TBD.	ST.ENR-10	Maximum level of chemical and particulate contamination shall not exceed TBD.	Y
MRD-49	The maximum level of chemical contamination shall be TBD.			Y
MRD-50	The spacecraft shall be compatible with the radiation environment of the selected orbit.	ST.ENR-12	The spacecraft shall be able to withstand the effects of the varying flux of high energy particles encountered in its mission over the nominal operational life.	Y
MRD-51	The design margin philosophy shall comply with ECSS-E-10 Part 1, System engineering.	ST.SCR-1	The design margin philosophy shall comply with ECSS-E-10 Part 1, System engineering.	Y
MRD-52	All consumables (cold gas, propellant…) shall be sized from launch until the end of the nominal mission.	ST.SCR-8	All spacecraft consumables shall be sized to allow for the total operational life, from launch to end of nominal operational life.	Y
MRD-53	All consumables (cold gas, propellant…) shall be sized from launch until the end of the extended mission. Margins are not applied to the extended lifetime (*goal requirement*).	ST.SCR-9	All spacecraft consumables shall be sized to allow for the total operational life, from launch to end of extended operational life (*goal requirement*).	Y
MRD-54	All radiation sensitive units shall be selected and sized from launch until the end of the nominal mission.	ST.SCR-4	All radiation sensitive units shall be selected and sized from launch until the end of the nominal mission.	Y
MRD-55	All radiation sensitive units shall be selected and sized from launch until the end of the extended mission. Margins are not applied to the extended lifetime (*goal requirement*).	ST.SCR-5	All radiation sensitive units shall be selected and sized from launch until the end of the extended mission. Margins are not applied to the extended lifetime (*goal requirement*).	Y

Table 3.6-1: MRD satellite physical requirements traceability

3.7 Payload and System Functional Requirements

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-56	The spacecraft shall support and provide mechanical interface to the science instrument. Interface shall be compliant to experiment specific needs.	ST.SFR-2	GG space segment shall be designed taking the GG experiment requirements and needs as fundamental and driving references.	Y
		ST.SCR-19	The GG spacecraft design shall be done with reference to the scientific experiment specific needs.	
		ST.SCR-20	The spacecraft shall provide all necessary resources (volume, mass, power, data, pointing, alignment, location with respect to CoG, thermal control, heat rejection, etc.) to the payload in accordance with the requirements.	
MRD-57	The spacecraft electrical power S/S shall provide sufficient power to the payload during all mission phases.	ST.SFR-9	Required electrical power supply shall be available to the amount required by all on-board units in all mission phases	Y
		ST.SCR-20	The spacecraft shall provide all necessary resources (volume, mass, power, data, pointing, alignment, location with respect to CoG, thermal control, heat rejection, etc.) to the payload in accordance with the requirements	

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-58	An adequate thermal environment shall be granted to all the subsystems, as well as to the scientific payload, so that it can operate nominally.	ST.SFR-5	Satellite thermal design shall provide the required thermal conditions to all satellite units for all the mission phases.	Y
		ST.SCR-20	The spacecraft shall provide all necessary resources (volume, mass, power, data, pointing, alignment, location with respect to CoG, thermal control, heat rejection, etc.) to the payload in accordance with the requirements	
		ST.SCR-320	Dimensioning of the Thermal Control shall cover worst-case scenarios derived from every mission phase up to the end of the operating lifetime, and worst combination of expected physical properties (BOL/EOL) and operative conditions and Safe Modes, as defined in Thermal Environment section.	
		ST.SCR-321	Structural parts shall be kept as a whole within temperature, temperature gradient and temperature stability ranges required to ensure the integrity and performance of the spacecraft during all nominal and non-nominal mission phases.	
		ST.SCR-322	DFACS equipment (in particular: FEEP thrusters, if present) and main engines valves temperatures shall be kept within their design ranges when in non-operative, pre-firing and soak-back conditions for all mission scenarios, and, in particular, for all envisaged Sun-illumination conditions.	
		ST.SCR-326	The spacecraft shall be able to withstand the foreseen thermal environment and the temperature levels and thermal cycling encountered during all mission phases, taking into account any possible environmentally induced degradation of materials and their properties.	

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-59	The spacecraft shall host the communication S/S for all uplink and downlink communications (science payload and housekeeping).	ST.SFR-6	Satellite communication subsystem shall allow downlink for telemetry/housekeeping and payload science data and uplink for telecommand data in all mission phases, with the foreseen modality	Y
		ST.SCR-165	A Communications Function shall be provided to perform the following tasks: ▪ to receive and demodulate telecommands, ▪ to modulate and transmit the telemetry, ▪ to transpond the ranging signal.	
		ST.SCR-313	Radio frequency (RF) systems have the goal of performing downlink communication of science and telemetry/housekeeping data and uplink communication of telecommand data. They include transmitters, receivers, antennas and their associated transmission lines including connectors. Transmitters and receivers require high mutual isolation.	
		ST.GSR-1	The spacecraft shall be able to interface with the ASI Ground Segment. The applicable requirements for this interface are defined in the space-to-ground interface control document.	
		ST.GSR-2	The spacecraft shall be able to fulfil the science data downlink requirements.	
MRD-60	The spacecraft shall have the capability to handle all the telecommands received from ground, transmit them to the payload instrument and send back all acknowledgments for ground control.	ST.SCR-165	A Communications Function shall be provided to perform the following tasks: ▪ to receive and demodulate telecommands, ▪ to modulate and transmit the telemetry, ▪ to transpond the ranging signal.	Y
		ST.SCR-167	The spacecraft shall be able to handle simultaneously: telecommand, telemetry and ranging.	

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-61	The spacecraft shall have the capability to enter and exit from all the functional modes and to emit in real time the current hardware and software status for diagnostic purposes.	ST.SCR-34	The telemetry shall provide unambiguous identification of the modes and mode transitions.	Y
		ST.SCR-35	The spacecraft shall be able to support the modes based on any compatible combination of onboard main and redundant units.	
MRD-62	The AOCS shall enable the spacecraft to perform all the orbital manoeuvres that may be necessary for the performance of the mission and the achievement of the science objectives.	ST.SFR-8	Attitude and orbit control subsystem shall perform all the following tasks: ▪ manage the satellite orbit and attitude with the required accuracy and stability; ▪ perform orbital manoeuvres; ▪ detect and deliver information about satellite attitude conditions with the required accuracy	Y
		ST.SCR-170	An Attitude & Orbit Control Function shall be provided to acquire, control and measure the required spacecraft attitude during all phases of the mission, and to produce, control and monitor all the necessary actions for the mission performance.	
MRD-63	The AOCS shall enable the spacecraft to perform attitude control in all the mission phases, compliant with the pointing requirements of the scientific payload	ST.SFR-8	Attitude and orbit control subsystem shall perform all the following tasks: ▪ manage the satellite orbit and attitude with the required accuracy and stability; ▪ perform orbital manoeuvres; ▪ detect and deliver information about satellite attitude conditions with the required accuracy	Y
		ST.SCR-170	An Attitude & Orbit Control Function shall be provided to acquire, control and measure the required spacecraft attitude during all phases of the mission, and to produce, control and monitor all the necessary actions for the mission performance.	

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-64	The spacecraft shall respond to on-board critical failures (endangering the mission) by switching to safe mode, independently from ground control.	ST.SCR-37	The spacecraft shall autonomously prevent execution of forbidden mode transitions. It shall be possible for Ground to overwrite the enable/disable status of any defined pair of autonomous mode transitions	Y
		ST.SCR-105	It shall be possible to enable/disable autonomous entry, and to force entry into Safe Mode by telecommand. Autonomous entry shall be enabled by default.	
MRD-65	The spacecraft shall remain in safe mode conditions for at least 7 days (TBC) without ground intervention.	ST.SCR-114	Essential onboard autonomous functions, compatible with the survival requirement of 14 days in cruise without Ground contact, shall be available in Safe Mode.	Y
		ST.SCR-118	Recovery from Safe Mode shall be undertaken under Ground control.	
MRD-66	In safe mode the system shall provide enough power to maintain the thermal conditions within the prescribed qualification limits for the on-board equipments.	ST.SCR-109	The Safe Mode final condition shall be defined such that: ▪ uninterrupted power supply, as required for spacecraft safety, is provided; ▪ a thermally safe attitude is maintained; ▪ communications with the Ground are guaranteed	Y
MRD-67	Safe mode shall be recovered from ground.	ST.SCR-118	Recovery from Safe Mode shall be undertaken under Ground control.	Y

Table 3.7-1: MRD payload and system functional requirements traceability

3.8 Data Product Requirements

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-68	The level-1 product shall contain: ▪ a header, with the context used to generate the product ▪ the following science extracted data (TBC): o Position of test masses relative to each other o Position of test masses relative to PGB o Spin reference signal o Temperature o Spin axis attitude o Phase difference between PGB and spacecraft o TBD ▪ the following quality data flag: TBD	ST.SFR-24	At least payload measurements shall deliver the following information: i. Position of test masses relative to each other ii. Position of test masses relative to PGB iii. Spin reference signal iv. Temperature v. Spin axis attitude vi. Phase difference between PGB and spacecraft.	Y
		ST.SFR-25	Payload output science data shall be delivered together with at least context information and data quality indication, in the appropriate format compliant to needs of on-ground data processing and elaboration (	

Table 3.8-1: MRD data product requirements traceability

3.9 Operational Requirements

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-69	All operations shall be autonomous, executed on the basis of time-tagged operation sequences that shall be loaded at least one day in advance.	ST.MIR-2	The control functions (telecommands) provided at each level of the design hierarchy shall be capable of achieving the mission objectives under all specified circumstances. *Note: This can include the use of redundant equipment.*	Y
MRD-70	The satellite shall autonomously detect its status, basing on automatic self-check procedures and programmable decision tables.	ST.MIR-1	The spacecraft shall provide visibility of its internal status and configuration to the Ground Segment in accordance with the level of detail and the time delays specified for all nominal and foreseeable contingency operations, including subsequent diagnostic activities. *Note: Foreseeable contingency operations are derived during the failure analysis performed in the mission development process (e.g. the Failure Modes, Effects and Criticality Analysis).*	Y
MRD-71	On detection of an anomaly, the satellite shall suspend the scientific operations.	ST.SCR-64	The management of anomalies within a unit, subsystem or instrument shall be handled in a hierarchical manner, such that resolution is sought on the lowest possible level. Scientific operations shall be suspended whenever an anomaly is detected.	Y
		ST.SCR-111	No mission products need to be generated in Safe Mode.	

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-72	Resumption of the scientific operations shall be commanded by the ground.	ST.SCR-118	Recovery from Safe Mode shall be undertaken under Ground control.	Y
MRD-73	In normal operations, the satellite shall receive commands and transmit telemetry from/to its dedicated Ground Station located at TBD.	ST.GSR-1	The spacecraft shall be able to interface with the ASI Ground Segment. The applicable requirements for this interface are defined in the space-to-ground interface control document.	Y
MRD-74	During LEOP, extended coverage of the spacecraft is required in order to: ▪ observe the on-board status after separation, ▪ guarantee the spacecraft command and control link during all critical operations, ▪ perform orbit determination (Doppler and ranging).	ST.GSR-3	In LEOP additional support ground stations shall be foreseen (in addition to nominal Ground Segment stations operating in nominal phase) to provide a TBD coverage of the spacecraft orbit and to perform the following tasks: i. observe the on-board status after separation, ii. guarantee the spacecraft command and control link during all critical operations, iii. perform orbit determination.	Y
MRD-75	During LEOP, additional ground stations shall be employed to achieve TBD% coverage of the orbit.			Y

Table 3.9-1: MRD operational requirements traceability

3.10 Verification Requirements

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-76	ECSS-E-10-02A (Space Engineering – Verification) shall apply.	ST.VER-1	Verification requirements provided by the GG Mission System Assembly, Integration and Verification (AIV) Requirements Document (to be issued in accordance to ECSS-E-10-02A (Space Engineering – Verification) shall apply	Y

Table 3.10-1: MRD verification requirements traceability

3.11 Product Assurance Requirements

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-77	Product Assurance (PA) requirements provided by ECSS-Q series and the detailed requirements provided by lower level standards defined in ECSS-Q-00A for each of the PA disciplines shall apply.	ST.PAR-1	Product assurance requirements provided by the GG Mission Product Assurance Requirements Document, to be issued in accordance to ECSS-Q-00A (Space Product Assurance - Policy and Principles, and related Level 2 standards) shall apply. Tailoring of PA requirements standards shall be performed according to ECSS-M-00-02A (Space Project Management – Tailoring of Space Standards).	Y
MRD-78	Detailed requirements from the applicable Level 2 and Level 3 ECSS standards shall be tailored according to the characteristics of the mission and the input required to perform an effective risk assessment process.			Y
MRD-79	Tailoring of PA requirements standards shall be performed according to ECSS-M-00-02A.			Y
MRD-80	Tailoring of detailed requirements with regard to risk assessment shall assure that all PA tasks necessary to provide the required qualitative and quantitative input for the risk assessment process are provided.			Y
MRD-81	Single Point Failures (SPF) with catastrophic and critical consequences as defined in ECSS-Q-40A and ECSS-Q-30A are a subset of critical items to be identified in the scope of the risk assessment process.			Y
MRD-82	Risk assessment and control shall be performed in compliance with ECSS-Q-00A, clause 3.3.5.			Y

Mission requirements		System functional and technical requirements Ref. document: SD-SY-AI-0014		Compliance (Y/N)
MRD-83	Risk assessment according to ECSS-Q-00A contributes to the overall project risk management process according to ECSS-M-00-03b. In particular safety and dependability critical items identification and control shall comply with: ▪ ECSS-Q-30B, clause 5.3 (dependability critical items) ▪ ECSS-Q-40B, clause 5.4 (functions) ▪ Launch site Safety Regulations	ST.PAR-1	Product assurance requirements provided by the GG Mission Product Assurance Requirements Document, to be issued in accordance to ECSS-Q-00A (Space Product Assurance - Policy and Principles, and related Level 2 standards) shall apply. Tailoring of PA requirements standards shall be performed according to ECSS-M-00-02A (Space Project Management – Tailoring of Space Standards).	Y
MRD-84	Identification and control of SPFs as defined above applies to: all interfaces between payload instruments and the spacecraft module, including mechanical, thermal, electrical (power, data, EMC/EMI, pyrotechnics), radiation, as far as applicable.			Y

Table 3.11-1: MRD product assurance requirements traceability

4. ACRONYMS

AD	Applicable Document
AOCS	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
ECE	Experiment Control Electronics
ECSS	European Cooperation for Space Standardisation
EP	Equivalence Principle
ESA	European Space Agency
FEM	Finite Element Model
FOS	Factor of Safety
G/S	Ground Station
GG	Galileo Galilei
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
P/L	Payload
PA	Product Assurance
PCB	Pico Gravity Box
PPRF	Payload Physical Reference Frame
QL	Qualification Loads
RD	Reference Document
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
TM	Telemetry

END OF DOCUMENT