

**GALILEO GALILEI (GG)**

**TECHNOLOGY MATRIX AND  
CRITICAL TECHNOLOGIES REPORT**

**DRL/DRD: DEL-42/43**

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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.

As part of the above WP, the following tasks were included:

1. A technology assessment of the candidate satellite designs. The corresponding output was required to be a matrix summarizing the candidate technologies and status per individual function (DEL-42).
2. An in-depth assessment of technologies identified as critical. The corresponding output was required to be a Critical Technologies Report (DEL-43).

This document provides the output of Task 1 in the form of an assessment of the Technology Readiness Level (TRL) of the candidate technologies. The TRL is defined in Table 3-1 and the assessment is provided in Table 3-2.

Critical technologies for GG, already identified in the previous studies [RD 1], include the micro-thrusters (FEED, Cold Gas) and the Spin Rate Sensor. Because of the criticality, they were made the subject of dedicated WPs, with specific reports. Table 4-1 lists these documents making up the Design Definition File (DDF) and Design Justification File (DJF) of these technologies. Together, these documents make up the contents of DEL-43.

## **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 Standards**

- [SD 1] ECSS-M-00-02A, Space Project Management – Tailoring of Space Standards, 25 April 2000
- [SD 2] ECSS-E-ST-10C, Space Engineering - System Engineering General Requirements, 6 March 2009
- [SD 3] ECSS-E-10-02A, Space Engineering – Verification
- [SD 4] ECSS-Q-00A, Space Product Assurance - Policy and Principles, and related Level 2 standards.

### **2.3 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](http://eotvos.dm.unipi.it/nobili/documents/generalpapers/GG_PLA2003.pdf)
- [RD 3] A. Nobili, DEL001: GG Science Requirements, Pisa, September 2008

### **2.4 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

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- [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] GG.ALT.TN.2003, FEEP Microthruster System Technical Report, Issue 1
  - [RD 20] TASI-FI-44/09, Cold Gas Micro Thruster System for Galileo Galilei (GG) Spacecraft - Technical Report, Issue 1, May 2009
  - [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

### 3. GG TECHNOLOGY READINESS LEVELS

**Table 3-1: NASA Definition of Technology Readiness Levels**

TRL Level	Definition
TRL1	Basic principles observed and reported
TRL2	Technology concept and/or application formulated
TRL3	Analytical and experimental critical function and/or characteristic proof of concept
TRL4	Component and/or breadboard validation in laboratory environment
TRL5	Component and/or breadboard validation in relevant environment
TRL6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)
TRL7	System prototype demonstration in a space environment
TRL8	Actual system completed and "flight qualified" through test and demonstration (ground or space)
TRL9	Actual system "flight proven" through successful mission operations

**Table 3-2: GG Equipment Technology Readiness Levels**

PRODUCT TREE ELEMENT	TRL	HERITAGE / REMARKS
PGB mechanical assembly	4	GGG
Experiment Control Electronics (ECE)	4	GGG
PGB Control Electronics (PCE)	6-8	Boards - Various satellite projects
Payload Launch Lock mechanisms	4-5	LISA
Test Mass Assemblies	4	GGG
CDMU	7-8	GOCE
OBSW (Application SW)	4-8	GOCE & many other projects
Sun Sensors	8	Selex Galileo Avionica Smart Sun Sensor
Magnetometer	8	IAI TAMAM
Gyroscope	8	Honeywell MIMU/Northrop Grumman LN200/ Northrop Grumman microFors
Spin Rate Sensor Optical Head	4	Breadboard designed, manufactured and tested as part of this study
Spin Rate Sensor EU	4	
Solar Panels	7-8	GOCE
Battery	7-8	GOCE
PCDU	7-8	SICRAL, Atlantic Bird 1 and SICRAL 1B and Gaia
Transponder	9	GOCE if the unit integrated on PRIMA is no longer available
S-band LGAs	9	ATV
RFDN	9	GOCE
FEEP Cluster Assembly (FCA)	6	LISA PF qualification ongoing
FEEP Neutralizer Assembly	6	LISA PF qualification ongoing
FEEP PCU	6	LISA PF qualification ongoing
Cold Gas Propulsion System	4-6	GAIA, Small-GEO, Proba-3. Flight model to be supplied for GAIA by mid 2010. Delta development and qualification may be necessary to meet the GG requirements starting from GAIA equipment.

PRODUCT TREE ELEMENT	TRL	HERITAGE / REMARKS
Pressure Regulator Stage (PRS)	4	For GAIA this module is called MPFM and is procured from Astrium UK and is a mechanical pressure regulator. The PRS here considered (and for which the TRL is identified) is an Electronic Pressure Regulator based on TAS-I High Pressure Piezo Valve. Key components of the Electronic PRS are being developed and pre-qualified within an ARTES 8 contract with ESA. For the PRS based on the EPR concept, evolution from to TRL 4 to TRL 6 is foreseen by 2010 (development & technology consolidation by internal R&D funding and ARTES contract expected by autumn 2009).
Micro Propulsion Electronics (MPE)	6	By begin of 2009 an MPE EQM for GAIA will be ready for submission to the Qualification Test campaign at Unit level. Expected to evolve to TRL 8 within 2010.
Micro Thrust Actuation Stage (MTAS)	6	By begin of 2009 2 MT EQM's for GAIA program will be ready for being submitted to the Qualification Test campaign at Unit level
Cold gas spinup thrusters	7-8	
GCT tanks	8	
Harness	7-8	Various satellite projects
Thermal Control	7-8	Standard technology, dedicated application
Structure	7-8	Standard technology, dedicated application



#### 4. GG CRITICAL TECHNOLOGIES DEFINITION AND JUSTIFICATION FILE

The following table lists the documents and parts thereof that constitute the GG Critical Technologies DDF/DJF.

**Table 4-1: Critical Technologies Design Definition File (DDF) and Design Justification File (DJF)**

[RD n]	Doc ID	Title	Issue	Critical Technologies File Applicable Parts
8	SD-TN-AI-1167	GG Mission Requirements Document	2	DDF : Highest level mission requirements specification
6	SD-TN-AI-1163	GG Experiment Concept and Requirements Document	3	DDF : Experiment requirements specification
10	SD-SY-AI-0014	GG System Functional Specification and Preliminary System Technical Specification	1	DDF : Highest level satellite system technical specification
16	SD-RP-AI-0621	Technical Report on Drag and Attitude Control	2	DDF / DJF: Definition and justification of satellite attitude and drag-free control design, including critical technologies
19	GG.ALT.TN.20 03	FEEP Microthruster System Technical Report	1	DDF / DJF: Definition and justification of FEEP drag-free control actuator design (baseline)
20	TASI-FI-44/09	Cold Gas Micro Thruster System for Galileo Galilei (GG) Spacecraft - Technical Report	1	DDF / DJF: Definition and justification of CGPS drag-free control actuator design (alternative option)
21	SD-RP-AI-0630	Spin Sensor Design, Development and Test Report	1	DDF / DJF: Definition and justification of spin sensor design

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