Herschel/Planck Project

System AIV

Requirements Specification

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CHANGE LOG

date	issue	revision	pages	reason for change
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01/Jul/2002	2 (PDR issue)	0		Introduction of "Herschel" as formal Project name replacing "FIRST"
			19	Deletion of requirement on bench test (SRR RID AIV-47 on AIAI-55). New requirement on optical environment for Herschel testing (AIAI-52)
			36	Replace "goal" with "objective"
			45	Replace "goal" with "objective"
			46	Replace "goal" with "objective"
20/May/2003	2	1	22	New relative dates for SVT-1 and SVT-2

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1 PURPOSE OF THE DOCUMENT

This document is part of the Herschel/Planck System and Programme Requirements and constitutes the baseline requirements from ESA for the Herschel/Planck Project System AIV and covers Phases B, C/D and E_1 (the commissioning phase).

1.1 Definitions

- The Herschel/Planck composite is the name given to the assembly of Herschel satellite and Planck satellite in the configuration that will be integrated inside the Ariane V fairing.
- The Herschel satellite is the name given to Herschel in the configuration found after separation (the space segment in ESOC terminology). It therefore includes the Scientific Instruments.
- The Planck satellite is the name given to Planck in the configuration found after separation. As for Herschel, it includes the Scientific Instruments.
- The term spacecraft is used to describe the satellite without its Scientific Instruments (all flight hardware items not provided by the PI's)

1.2 Abbreviation List for Requirements

The requirements in this specification have been systematically numbered. The code applied consists of four letters and three digits. The four letters stand for AIV with AI, continued with an abbreviation of the area concerned. the systematic applied is illustrated in the table below:

Objective of the AIV programme	AIVR-xxx
Commonality Requirements	AICO-xxx
Verification Concept	AIVC-xxx
Verification Approach	AIAP-xxx
Types of Verification	AITY-xxx
Method of Verification	AIME-xxx
Level of Verification	AILE-xxx
Model Philosophy	AIMO-xxx
Spare Philosophy	AISP-xxx
AIT Sequence	AIAI-xxx
AIV Programme Flow	AIPF-xxx
Support Plans	AISP-xxx
MGSE	AIVM-xxx
EGSE	AIVE-xxx

2 APPLICABLE AND REFERENCE DOCUMENTS

The following documents of the latest issue or as defined herein form part of this specification.

In the event of a conflict between this document and other applicable documents, the conflict shall be brought to the attention of the ESA Project Manager.

In the case of a conflict between this specification and reference documents, this specification shall have precedence.

2.1 Applicable Documents

The latest issue as given in the Statement of Work of the following documents is applicable.

2.1.1 System Support Specifications

AD1-1 Herschel/Planck Product Assurance Requirements Specification, Document no. SCI-PT-RS-04683

AD1-2 Void

AD1-3 Planck Telescope Design specification,

Document SCI-PT-RS-07024

2.1.2 ESA Undertakings

AD2-1 Herschel Telescope Specification, SCI-PT-RS-04671

AD2-2 Planck telescope primary/secondary reflectors and inner baffle specification Document no. SCI-PT-RS-07422

2.1.3 Satellite System Interface Specifications

AD3-1 Herschel/Planck Space to Ground Interface Document (RF link), Document no. SCI-PT-ICD-07418

AD3-2 Herschel/Planck Operations Interface Requirements

Document SCI-PT-RS-07360

2.1.4 Instrument Interface Specifications

AD4-1 Instrument Interface Document, Part A (IID-A),
Document no. SCI-PT-IID-A-04624

AD4-2 Instrument Interface Document, Part B (IID-B):
Heterodyne Instrument,
Document no. SCI-PT-IIDB/HIFI-02125

AD4-3 Instrument Interface Document, Part B (IID-B):
Photoconductor Instrument,
Document no. SCI-PT-IIDB/PACS-02126

AD4-4 Instrument Interface Document, Part B (IID-B):
Bolometer Instrument,
Document no. SCI-PT-IIDB/SPIRE-02124

AD4-5 Instrument Interface Document, Part B (IID-B):
High Frequency Instrument,
Document no. SCI-PT-IIDB/HFI-04141

AD4-6 Instrument Interface Document, Part B (IID-B):
Low Frequency Instrument,
Document no. SCI-PT-IIDB/LFI-04142

2.1.5 Mission Support Documents

AD5-1 Herschel L2 Radiation Environment
ESA/Estec/wma/he/Herschel/3 dated March 4, 1997

AD5-2 Herschel/Planck Carrier Consolidated Report on Mission
Analysis FP-MA-RP-0010-TOS/GMA

2.1.6 Applicable Standard Documents

2.1.6.1 ARIANE Standards

AD6-1 ARIANE 5 User's Manual
Issue 3 / Rev 0 Mar 2000

AD6-2/1 CSG Safety regulations
Volume 1 - General rules CSG-RS-10A-CN
Issue/Rev/Date 5/1/03.03.99
(Volume 1 taken precedence)

AD6-2/2 CSG safety regulations,
CSG-RS-22A-CN issue 5/0 (Vol. 1) and
CSG-RS-22A (Vol. 2) Edition 4, August 1991

AD6-20 CSG Volume 2 Part 1. Ground Installations
GSG-RS-21A-CN Issue 5 / Rev 0 Dec 1997

AD6-24 Ariane Specification SG-0-01 Issue 3

2.1.6.2ESA Standards

AD6-3 Telemetry Channel Coding Standard,
ESA PSS-04-103, Issue 1, Sept 1989

AD6-4 Ranging Standard,
ESA PSS-04-104 Issue 2, March 1991

AD6-5 Radio Frequency and Modulation Standard,
ESA-PSS-04-105 Issue 2.4, Nov 1996

AD6-6 Packet Telemetry Standard,
ESA-PSS-04-106, Issue 1, Jan 1988

AD6-7 Packet Telecommand Standard,
ESA-PSS-04-107, Issue 2, Apr 1992

AD6-8/1 Generic Specification for Silicon Solar Cells,
ESA-PSS-01-604, Jan 1988

AD6-8/2 Generic Specification for Ga/AS cells,
SPA/TS-0006

AD6-9 ESA Power Subsystem Standard Specification,
ESA-PSS-02-10, Nov 1992

AD6-12 Data for Selection of Space Materials,
ESA-PSS-01-701

2.1.6.3ECSS Standards

AD6-10 Space Mechanisms Standard Requirements Specification,
ECSS-E-30-00 Part 2-3

AD6-11 ESA Fracture Control Requirements,
ECSS-E30-01A

AD6-13 A thermal Vacuum Test for the Screening of Space Materials,
ECSS-Q-70-02 Draft

AD6-14 A Thermal Cycling Test for the Screening of Space Materials and Processes,
ECSS-Q-70-04

AD6-15 Material Selection for Controlling Stress Corrosion Cracking,
ECSS-Q70-36A

AD6-16 Determination of Susceptibility of Metals to Stress Corrosion Cracking,
ECSS-Q-70-37

AD6-17 ESA Software Engineering Standards,
ESA-ECSS-E-40

AD6-19 Time Code format
CCSDS 301.0-B-2, issue 2

AD6-25 Software Product Assurance
ESA-ECSS-Q-80

AD6-26 Lossless data Compression,
CCSDS 121.0-B-1, May 1997

2.1.6.4Other Standards

AD6-18 MIL-HDBK-5

2.2 REFERENCE DOCUMENTS

RD-1 High Level Requirement Specifications Common Checkout and Flight Control Systems for Science Projects,

Document no RO-ESC-TN-5008

RD-2 An Approach to Common Checkout and Control Systems (CCCS) for Rosetta and FIRST/Planck

Document no RO-ESC-TN-5007

3 OBJECTIVE OF THE AIV PROGRAMME

AIVR-10 *The objective of the spacecraft Assembly, Integration and Verification (AIV) programme shall be to ascertain and to demonstrate to the Agency, that the spacecraft design is fully compliant with the spacecraft performance and operational requirements as required by the Agency, that it is correctly described by, and can be operated according to the operational documentation provided and hence is capable of fulfilling the scientific mission objectives.*

The Contractor has full responsibility for all AIV activities at unit, subsystem and satellite level including at satellite level the scientific payload. All activities will have to be performed in accordance with the AIV requirements and the documentation issued by the Contractor and approved/reviewed by the Agency.

The verification programme shall include all aspects of flight hardware and software, mechanical and electrical ground support equipment and any associated equipment, required to fulfil the programme objectives.

The verification programme shall be determined from the results of an analysis considering design risk, analytical tool availability, facility availability, test methods, implementation costs, schedule and confidence in the verification method proposed.

AIVR-15 *The verification programme determines the amount of analytical work necessary and the type and sequence of testing required to deliver the final product at minimum cost and within baseline schedule. It shall also determine the model philosophy and the corresponding test equipment to be procured, together with an explanation of the logical sequence of verification and the control and iteration processes proposed for the different analytical and test models.*

4 COMMONALITY REQUIREMENTS

It is a fundamental design feature of the Herschel/Planck mission that commonality will be pursued, to the maximum extent reasonable throughout the Herschel/Planck Programme. This commonality encompasses 3 major aspects.

Commonality between Instruments

This concerns hardware elements (e.g. identical instrument on-board micro-processors, common chopper designs for PACS and SPIRE, common EGSEs designs, etc.) as well as common software elements (e.g. joint implementation of the on-board software -for Herschel -, common Real Time Assessment software, common instrument commanding scheme, common on-board memory management scheme, etc.)

Commonality/compatibility between Flight Control System and Check-Out System

These Commonality/Compatibility objectives are the outcome of a Department-wide policy which is currently applied (and evaluated) in the Rosetta and Mars Express missions.

RD-1 and RD-2 explain the rationale for the selected SCI-P approach. The major goals are to:

- reduce duplication of effort
- reduce risk
- reduce overall costs
- maximise synergy between AIV and Flight Operations

RD-1 and RD-2 identify the elements for which commonality is considered feasible and cost-effective and the elements for which compatibility is required. The following areas are currently identified:

- Mission Information Base (spacecraft and instrument data bases)
- Man Machine Interfaces
- Data Archiving and Distribution
- On-board Software Management
- On-board Software Maintenance (e.g. Software Development Environment, Software Validation Facility)
- User Language (for Test Procedures and in-orbit operations)

RD-1 contains a preliminary list of high level “requirements” covering these areas. These “requirements” are indicative of the issues to be considered. They do **not** constitute firm, final requirements imposed on the Contractor.

RD-2 proposes a phased implementation approach which is compatible with ESA's overall policy (EGSE procured by Industry) and which should allow to achieve the objectives listed above.

Commonality/Compatibility between Mission phases

It is a top level requirement that the transition between the various Integration and Test activities and between Test and Operations be as smooth as possible. In particular the Instrument Teams are working according to the following baseline:

- The same H/W -or compatible H/W- (e.g. the Instrument Stations for RTA/QLA) can be used throughout all phases of the Programme from the Instrument Level Tests (ILTs) to the in-orbit operations.
- To the maximum extent possible a standard set of interfaces will be implemented between the elements of the EGSE and the elements of the Flight Control System in such a way that the Instrument Station S/W can be moved from one test level to the next, up to the operations with no or minimal modifications.
- The Test Procedures developed for the Instrument Level Tests (ILTs) can be re-used during the System Tests in the Central Checkout System (CCS) environment and later on during operations (in particular during the Commissioning phase) with no or minimal modifications.
- The Instrument On-board Control Procedures (OBCPs) -if any- developed for the Instrument Level Tests (ILTs), can be re-used during the System Tests in the Central Checkout System (CCS) environment and later on during operations (in particular during the Commissioning phase) with no or minimal modifications.
- The Instrument EGSEs will be based upon ESOC's SCOS-2000 system
- The Flight Control System (to be provided by ESOC) will be based upon SCOS-2000

AICO-10 *The Contractor shall propose an AIV Programme and the supporting facilities required (e.g. EGSE) which to the maximum extent possible fulfil the Commonality/Compatibility Requirements listed above.*

5 VERIFICATION CONCEPT

AIVC-5 *The spacecraft design and build standard shall be verified against the Agency's spacecraft performance requirement and shall be governed by the Verification Programme Plan (VPP) (see Section 13.3)*

The VPP shall define all the activities from composite level down through satellites, modules, and subsystem to unit level.

The design verification shall be achieved by test, analysis, similarity, assessment or a combination thereof.

AIVC-10 *The verification programme proposed by the Contractor shall achieve for the full complement of the satellites flight hardware and software:*

- *Demonstration of design qualification*
- *Demonstration of flight acceptance*
- *Demonstration of flight requalification in case the flight build standard is invalidated*
- *Demonstration that the satellite performance, including the S/C autonomy for the mission duration are met by all flight and ground hardware, software and associated support equipment*
- *Demonstration that the satellite design, performance and behaviour is compliant with the operational documentation, procedures and data base.*

The verification programme should also meet the following objectives:

- ensure a consistent approach to development, qualification and acceptance tests at unit, subsystem and satellite level in order to launch a reliable end product which meets the system design and performance requirements.

- provide full visibility with regard to compliance of delivered hardware/software with the specified requirements

- Introduce the concept of verification at the design stage

- maximises the use of existing expertise

- optimise the use of existing facilities

- select, at an early stage of the programme, the most cost effective approach, which is compliant with the mission objectives

- optimise the design and use of the ground support equipment including the possibility for use during the flight operation phase.

6 VERIFICATION APPROACH

AIAP-05 *The spacecraft design and performance verification requirements shall be derived from the system performance requirements and design specification.*

AIAP-10 *The verification requirements shall be specified in terms of:*

- *The types of verification, i.e. the confirmation of design (qualification), the certification of manufacture and performance (qualification), the validation of workmanship and performance (acceptance and recertification).*
- *The levels of verification which are applicable at component, unit, subsystem, module and satellite levels.*
- *The methods of verification, which are unique or complementary: i.e. verification by similarity, by analysis, or by test.*

When this is completed, the Assembly, Integration and Verification Programme can be established and proposed to the Agency for approval prior to its implementation.

7 TYPES OF VERIFICATION

Confirmation Design

AITY-05 *The confirmation of the design shall be established by simulation, breadboard or other analytical tools, at an early phase in the development in order to verify the design feasibility and evaluate the system options satisfying the functional performance criteria. Design verification should commence at unit or component level and be completed at satellite level.*

Certification of Performance

AITY-10 *Performance for both hardware and software shall be validated on the flight model or a flight representative model. Performance tests, the functional tests and the environmental tests levels shall be above the maximum levels most likely to be seen during the life of the spacecraft i.e. on ground, during launch and during the mission.*

For Protoflight testing, an evaluation and analysis of the safety margins and of the test levels should be undertaken to ensure that a safe and coherent approach has been adopted and that excessive fatigue of the materials and equipment is avoided.

Validation of Performance

AITY-15	*The validation of performance shall take place on the flight spacecraft in accordance with the VPP requirements.*
AITY-20	*It shall be demonstrated that the flight model under test and the model for which the confirmation of performance has been validated are similar.*
AITY-25	*The validation of compliance to satellite operational documentation and data bases shall take place at subsystem and system level by a combination of test, simulation and analysis.*

8 METHODS OF VERIFICATION

Verification shall be performed by at least one of the following methods:

8.1 Verification by Test

AIME-05	*Two different types of tests shall be implemented to verify the qualification or the acceptance of a unit, subsystem, module or satellite. These are functional tests under ambient conditions and environmental tests where external constraints are applied.*

The functional tests consist of compatibility tests, interface tests and performance tests verifying that the electrical, mechanical or radio-electrical criteria are met. In general they are performed under ambient conditions, but for certain units are possible only in thermal vacuum.
The environmental tests consist in a selection of tests to be carried out in an environment similar to that found during launch and/or during the mission phases.

8.2 Verification by Analysis

Verification by analysis may be performed and may replace tests at all levels in particular if it can be shown that analysis provides a better method of verification of requirements.

AIME-10 *If verification is accomplished by analysis, the analytical method shall be established in terms of technical, cost and schedule advantages.*

8.3 Verification by Similarity

Verification by similarity may be applied to equipment or subsystems coming from another programme when reuse "as is" or minor modifications are proposed and the environmental conditions are common or scoped by existing qualification.

AIME-15 *For units coming from another programme and reused with none or minor modifications, an analysis of the qualification and acceptance test results of the other programme shall be carried out against the requirements of the current programme. Acceptance by the Agency of a proposal for Verification by Similarity will be done on a case by case basis.*

8.4 Design Verification Assessment

Verification by Assessment may be achieved by Inspection or by Design Review. In each case, the Contractor will have to provide a full technical assessment, detailing the conformity of the part to the applicable requirements for the intended application.

9 LEVELS OF VERIFICATION

The Contractor shall use the following levels of verification:

Equipment Level

AILE-05 *Generally equipment level verification shall be applied to units or sets of subunits for qualification/acceptance and the following equipment categories identified for qualification and acceptance purposes:*

Category A:

Off-the-shelf equipment requiring no modifications and shown to have already successfully passed a qualification test programme at least as severe as that imposed by the programme environmental test specification: no further qualification needed.

Category B:

Off-the-shelf equipment, requiring no modifications, already tested but not fully qualified to the correct levels: in this case completion of qualification is required via a complementary qualification test programme.

Category C:

Off-the-shelf equipment requiring minor modifications: complementary or full functional and qualification testing decided on a case-by-case basis depending on the previous test results and the extent of the modifications.

Category D:

Completely new equipment or equipment requiring major redesign: in this case, full functional tests and qualification is required.

Subsystem or Module Level

AILE-10 *Subsystem level verification shall be applied to an assembly of equipment or to a group of items which form an integrated part of the spacecraft.*

Providing that the interfaces are well defined and decoupled, and that a modular concept can be realised for functional and environmental tests then it may be possible to perform qualification and acceptance testing at subsystem or module level.

Satellite Level

AILE-15 *Satellite level verification shall be applied to models of the spacecraft (hardware and software) to demonstrate the full compliance of the satellite with its requirements. The satellite shall undergo qualification or acceptance testing or a combination of both (protoflight).*

Composite Level

AILE-20 *The composite level verification shall be applied to both satellites. (Herschel and Planck) to demonstrate full compliance of the composite with its requirements.*

10 MODEL PHILOSOPHY

The Prime Contractor is responsible for defining the Model philosophy to be applied to the Herschel/Planck program, while ensuring and demonstrating that the delivered products are fully verified (i.e. qualified and accepted) and fully compatible with the mission requirements. The Prime Contractor shall define, and propose for ESA approval, the Herschel/Planck Model philosophy taking into account:

- Reduction of risk, cost and optimisation of the planning within the schedule boundaries
- The already planned ESA Furnished Equipment models which will be made available - via ESA - to the Prime Contractor from the Equipment suppliers.
- The Flight Spare Model Philosophy as defined below

For Herschel/Planck a protoflight philosophy is proposed. However, to support this approach without introducing major risks, partial development models are considered:

- Avionic Models (AVM)
- Cryoqualification Models (CQM)
- Planck Radio-Frequency Model (RFM)

10.1 Avionic Models

The AVM should be used to verify the electrical and functional interfaces of the satellite. This model should also provide a test bed for on-board software testing as well as for testing the Electrical Ground Support Equipment including its software. The AVM should be also used for operation procedures development and testing.

10.2 Cryoqualification Models (CQM)

10.2.1 HERSCHEL INSTRUMENT CQM

This model has been introduced for the Herschel scientific instruments to demonstrate mechanical, thermal and electrical compatibility between the three Scientific Instruments. The instruments will be integrated in an existing cryostat possibly modified to improve the test representability i.e. the ISO QM cryostat. Seen from an instrument point of view, the test setup represents electrically the full Herschel configuration.
The test setup should also be used to perform initial EMC tests. (See AD4-1 paragraph 7.3)

10.2.2 PLANCK PAYLOAD MODULE CQM

The Planck PLM CQM should be used to qualify by tests the mechanical and thermal design of the Planck Payload Module as well as Instruments compatibility (see AD4-1 paragraph 7.3). For this purpose the following tests have been identified:

- Vibration sine test
- Acoustic test
- Thermal Vacuum/Thermal Balance test
- Functional test.

AIMO-01 *In order to carry out the above defined thermal vacuum/thermal balance test a Test Facility has to be adapted to accommodate the Planck Payload Module. These adaptations of the Facility shall be carried out considering compatibility with the use of the facility for the optical tests of the Planck Telescope Reflectors at operational conditions.*

10.3 Planck RFM

Given the criticality for the scientific success of the mission of the optical (radio frequency) properties (e.g. beam shape, polarisation, etc.) of the Planck system, and the fact that the radio frequency properties of the Planck telescope models will only be measured indirectly (using measures such as the WFE), a representative RF model is requested to ensure that the system is performing adequately from the optical/RF point of view.

AIMO-05 *The Planck RF Model shall be used to: (1) validate by measurement the optical and straylight mathematical models used in the design phases, (2) determine by test the radio frequency properties (beam shape and polarisation properties) of the Planck optical system (including detector feed horn, telescope, baffles, shields etc.), (3) establish and verify the relationship between the properties to be measured on the telescope QM and FM (e.g. WFE) and their radio frequency properties.*

10.4 Protoflight Models

The PFMs shall be flown. They shall, however, be fully qualified and fully accepted before shipment to the launch facilities.

For this purpose the following test have been identified:
Sine Vibration Test
Acoustic Test

Thermal Vacuum, Thermal Balance Test
EMC Test
Electrical and Performance Test
Ground Segment compatibility Test

AIMO-10 *The environment tests shall be performed to proto-flight levels (Qualification test levels, acceptance duration)*

11 SPARE PHILOSOPHY

AISP-05 *The contractor shall provide flight spares of all units of the Herschel and Planck SVM.*
These units shall available at the integration site for possibility of exchange. This philosophy shall also apply to Phase E_1 *(launch campaign).*

12 AIT SEQUENCE

Sequence

AIAI-05 *The verification sequence shall have four distinct phases:*
a) Mechanical/electrical integration of the equipment and/or subsystems to constitute the spacecraft system.

All interconnections are made, functionally verified by test sequences.

b) Full satellite test under ambient conditions. All functional performances and operational modes are verified by automated test sequences.

c) Full satellite test under different environmental conditions. All functional performances and operational modes are verified by automated test sequences under predicted environmental conditions.

d) Full ground segment compatibility test under flight operational conditions. The spacecraft and ground segment compatibility performances are verified in a flight representative environment.

AIAI-10 *The sequence shall be optimised in duration and logically defined. It shall be planned such to avoid re-testing, overlapping and timeout.*

AIAI-15 *The sequence shall optimise transport, manpower, ground support equipment, checkout equipment and facilities utilisation.*

AIAI-20 *A check of the satellite performance shall be made at the end of the integration sequence and shall be taken as reference. The* *same check shall be repeated at defined points in the programme to confirm by comparison satisfactory completion of specific test phases. Between environmental tests, a short functional test shall be made as a minimum to verify the integrity of the satellite.*

12.1 Integration

The following interfaces shall be carefully considered during the integration phase.

Mechanical Interfaces.
Equipment and components in the S/C requirements e.g. accommodation, accessibility, inspectability I/F loads, mounting dimension tolerances, volume, dimensions, tolerances, alignment and field of view constraints.

Thermal Interfaces
Thermal environment, surface treatment, thermal attachment and protections.

Electrical Interfaces
Wiring attachment, electrical connectors, shielding, grounding distribution and connection, input/output circuit characteristics and input/output functional checks.

Environmental Interfaces
Interface of the electrical ground support equipment connections and mechanical ground support equipment with the proposed facilities. The control of the cleanliness conditions during preparation and running of the test

Optical Interfaces
Protection of optical surfaces with covers during AIV, absence of objects (MLI, harness, etc) that could provoke obscuration or diffraction, alignment.

AIAI-25 *The integration programme shall baseline 5 days per instrument integration.*

AIAI-30 *With the exception of the focal plane units, telescopes and other units part of the payload modules. All S/C incoming inspection, assembly, integration and verification activities shall be performed in a clean environment in accordance with the following conditions:*

Temperature: 22 degrees C +/- 3 degrees C
Relative Humidity: 40-55%
Clean Conditions: Class 100000 of US Federal Std No. 209. B minimum.

AIAI-35 *Continuous dry nitrogen purging shall be provided to some hardware units upon their delivery to the integration site through and following their integration to the S/C. The standard dry nitrogen to be used during ground operations has the following specification.*

Oxygen less than 5 parts per million (PPM)
Water less than 5 ppm
Hydrogen less then 5 ppm
Argon less than 1000 ppm
CnHm less than 1 ppm

12.2 Functional and Performance Tests

AIAI-40 *The functional and performance verification activities shall commence with the sequential energisation of the subsystems and instruments. The instruments and the subsystems shall finally be completely activated in the satellite, and their performance verified against the performance specification. The interaction of instruments and subsystems between themselves shall also be checked during this process.*

The functional tests shall be run via automated test sequences except for specific cryogenic tests.

AIAI-45 *Correlation of functional/performance tests at subsystem level under specific environmental conditions to satellite functional/performance tests under similar conditions shall be performed.*

AIAI-50 *Where practicable implicit testing may be performed, meaning that a number of spacecraft functions are tested by using other spacecraft functions, and therefore do not need to be tested specifically. Spacecraft functions which are tested in this way should be clearly identified in test matrices and in test descriptions and procedures*

All tests shall be defined beforehand and described in test descriptions, plans and procedures.

The following functional verification shall be baselined in the development of the AIV programme.

Functional tests during integration:

AIAI-52

(Applicable to Herschel)

It shall be possible to provide an optical representative environment for the instrument focal plane units within the cryostat in cold conditions on ground, such as to allow functional and performance verification of these units after system integration and test. This environment shall represent the optical power coming from the telescope in-orbit, i.e. 70 K @ 4% emissivity, to an accuracy of +/-25%, in the six wavelength bands of SPIRE and PACS over the 80 – 670 µm range while taking into account all system requirements such as straylight.

Bench Test (BT)

AIAI-55 *Deleted*

Unit Function Test (UFT)

AIAI-60 *To be performed directly following integration on to the S/C which is sufficiently equipped to perform the test. This will normally be a short low level electrical and functional test to verify the interfaces with the S/C and to ensure the successful integration of the unit on the S/C. This test is a subset of the IST.*

System Integration Test (SIT)

AIAI-65 *To be performed during the process of integration to verify the interaction of instruments and subsystems between themselves. The baseline adopted for the programme is however to minimise the number and complexity of SITs.*

Functional tests after completion of integration:

Integrated Satellite Test (IST)

AIAI-70 *The purpose of the Integrated Satellite Test (IST) shall be to verify correct operation of the fully integrated satellite in a series of representative mission modes including autonomous (Mission Timeline – MTL and On-Board Control Procedures – OBCPs) and backup modes.*

AIVR-80 *The IST shall be an automated test, run from the Central Checkout System using a combination of test procedures and control files developed from unit or subsystem level electrical test sequences. Results will be recorded electronically.*

AIAI-85 *A full IST shall be performed at major milestone during the overall AIV programme, i.e. following the successful completion of the satellite integration, during major points of the satellite environmental test programme, as completion of the full satellite level verification programme and during spacecraft checkout, at the launch site.*

The IST should be broken down into a number of mission phases as follows (provisional):

Launch and Transfer Phase
Eclipse Phase (if applicable)
Operational Phases

AIAI-90 *Functional testing of deployables and RCS shall be performed as part of the IST.*

AIAI-95 *The payload shall be operational within the constraints defined by the environmental conditions and the instruments operational modes exercised during the Operational Phases of the IST. The IST shall be run with the spacecraft fully flight configured except where test conditions dictate otherwise.*

AIAI-100 *The IST sequences shall be structured such that certain operational modes may be deleted or enhanced according to the test or the conditions under which it is run, the major options being:*

- *Integrated Satellite Test as described above*
- *Thermal vacuum IST to be run during the hot and cold soak phases of the satellite thermal vacuum test*
- *EMC IST to be used during system EMC tests, in which case the spacecraft and payload shall be run in its highest emission mode and most sensitive susceptibility mode to verify system compatibility*

AIAI-100 *During the thermal vacuum IST the payload shall have its operational time maximised to enable full functional checkout to be carried out.*

To the maximum extent functional procedures shall be developed and commissioned on the spacecraft and following updating reissued for the flight model programme.

<u>Short Functional Test (SFT)</u>

AIAI-110 *The Short Functional Test shall be a subset of the IST sequences and shall be run to verify system electrical integrity following local movement of the spacecraft or between axes during vibration or similar environmental tests. The payload part* *of this test should normally be limited to a switch on and a functional verification of interfaces.*

Specific Performance Test (SPT)

It is possible that verification of instrument performances or specific subsystem performance may require a spacecraft configuration or test set-up different from that required for a standard SFT. SPT may be performed at a particular time in the S/C integration & test process depending on the instrument set-up requirements.

AIAI-115 *The SPT shall preferably be a stand-alone test, and easily adaptable in such a way that it may form an add-on module to the main IST.*

12.3 Ground Segment Compatibility Tests (GSCT)

AIAI-120 *To demonstrate the compatibility between Herschel/Planck and the ground segment a series of system validation tests shall be performed. These can be defined as follows:*

Mission Operation Centre

The MOC mission control software should be validated as far as possible early in the programme, with the aid of a dedicated spacecraft software simulator, using the telemetry data generated during satellite check-out tests, and supplemented by System Validation Tests (SVT) with the satellite hardware itself.

AIAI-125 *Each satellite shall be capable to support the 3 SVTs and Listen-in Tests*

Nominally, three System Validation Tests (SVT-0, SVT-1, SVT-2) with the satellite are performed before launch by the operation team (ESOC) with the support of the prime contractor.

The objective of the various SVTs can be summarised as follows:

SVT-0 The objectives of SVT-0 as well as the activities carried out are similar to SVT-1 (see below).
SVT-0 will be performed with the S/C linked via a Network Data Interface Unit, or similar interface to the MOC via a communication network & TC & voice network connection. NDIU and links will be provided by the mission operations centre. These tests should be planned to take place around L-18 months and last for a maximum of 5 days per satellite.

SVT-1 is the principal full flight operational system test carried out with all the H/W & S/W elements required for the mission. The main objectives will be to verify the satellite - MOC interface for all Telemetry (TM) formats and Telecommand (TC), the validation of the MOC TM and TC processing systems, the validation of MOC TM & TC data bases, characterisation of satellite (spacecraft and payload) behaviour, e.g. power consumption, the confirmation of FOP data, and the validation of procedures.
This test should be planned to take place around L-11 months and last for a maximum duration of 15 working days per satellite (8 hr day-5 day week).

SVT-2 is the final verification of the integrated flight ground segment with the flight spacecraft interfaces and functional performances prior to launch. SVT-2 should be planned to take place around L-5 months (before shipment for the launch campaign) and last for a maximum duration of 10 working days per satellite.

- Listen-in Tests
During important tests at the AIV (e.g. TB-TV tests), ESOC will also perform, on a non-interference basis and without commanding Listen-in Tests. These shall be performed with the S/C linked to the MOC like for the SVT-0.

12.4 System Environmental Test Programme

AIAI-130 A system environment test programme shall be executed to demonstrate that the satellite can perform nominally and survive under environmental conditions equivalent or more severe than predicted for the mission.

The following environmental tests shall form a part of the spacecraft qualification and flight acceptance baseline programme:

AIAI-130 The thermal vacuum test shall fulfil two functions, the first being a full scientific payload test with all sensors operational and the second being a complete system level qualification/acceptance test.

- Solar Simulation Test (Thermal Balance)
To confirm adequacy of thermal analysis and temperature prediction models.
- Thermal Vacuum Test

To verify proper function and performance over the full temperature range and in vacuum.

- Electromagnetic Compatibility Test.
- Separation and Shock Test.

12.5 System Parameter Measurement Programme

AIAI-140 *During the AIV programme, the system parameters will need to be monitored and verified against the agreed requirements specification.*

13 AIV PROGRAMME FLOW

AIPF-05 *The AIV programme flow document associated with the AIV programme shall be defined using the following outline.*

13.1 Environmental Specification

The Environment Specification shall be derived from consideration and analysis of the Herschel/Planck System Requirements (AD1-1) plus payload and the Launch Vehicle Requirements as detailed in the Ariane 5 Users Manual.

The environmental Specification shall be utilised to produce the Environmental Test Specification as system, subsystem and unit levels. The two Specifications may be included in one document.

13.2 External Constraints

The external constraints applicable to the project will be identified separately. They cover areas in which the Agency imposes specific solutions on the Contractor, for example:

The use of Agency specified and provided facilities for flight operations phase. The use of Agency specified launch vehicles. The imposition by the Agency of major milestones in the programme such as launch date, spacecraft delivery etc.

13.3 Verification Programme Plan

The verification of the spacecraft design against the spacecraft requirements shall be governed by a single document at system level. The objectives of this document, the Verification Programme Plan (VPP) shall be to demonstrate how the Contractor intends to verify the System Level Performance imposed by the Agency. It shall provide a logical flow from unit level, through subsystem level to system level for verification.

13.3.1 VERIFICATION REQUIREMENTS

The Verification Requirements shall be derived directly from the FIRT/Planck System requirements and shall consist of the system level parameters requiring verification in order to demonstrate that the overall programme objectives are met. It shall be sub-divided into system module and subsystem sections and shall include all flight hardware and software.

13.3.2 FUNCTIONAL VERIFICATION

The functional verification approach shall be derived from the Verification Requirements established under 13.3.1 to determine the Verification methods and tools required to demonstrate that the spacecraft design and performance meets the spacecraft system requirements. Also the required design and development activities at unit, subsystem and system levels shall be identified.

This task is an iterative process until compatibility is achieved between constituents of the spacecraft system requirements.

Contractor past experience, status of technology proposed, availability of design aids and tools, availability of suitable test facilities and proposed design margins shall all be assessed during the iterative process.

13.3.3 PERFORMANCE VERIFICATION ANALYSIS

Analysis of the Functional Verification Plan shall be carried out to determine or confirm the model philosophy required to demonstrate full verification. Definition of the level, unit subsystem, module or system at which various verification methods will be applied shall be given together with justification demonstration and flight acceptance shall be fully explained including all safety factors. Due account shall be taken of the errors inherent in all verification activities and their effect on the overall confidence of the verification process.

13.3.4 MEASUREMENT SPECIFICATION

The measurement Specification shall examine each of the system level requirements derived in the Verification Requirement Specification which specifies the individual parameters to be measured at system, module, subsystem or unit level together with the conditions of measurement, specified values, limits and measurement uncertainty.

The specification supports the Functional Verification Plan in which the condition of measurement, build level (system, module, subsystem or unit) and procedures are Identified to verify that the spacecraft design meets the system performance requirements.

Individual subsystem and unit level test procedures shall be produced defining the parameters which are required to be measured prior to delivery in order to verify that the requirement as defined in the relevant subsystem or unit specification had been fulfilled.

An essential part of the measurement specification is the definition of a trend analysis which lists the key parameters to be monitored during each test including the conditions of acceptability from unit level to in-orbit lifetime to evaluate the time dependent variation in each parameter.

14 SUPPORT PLANS

14.1 General

AISP-05 *Utilising the VPP together with other relevant inputs the following AIV support documents shall be produced*

14.2 AIT Plans

These documents shall describe the organisation and tasks associated with the assembly, integration and test of spacecraft models built under the programme. For each spacecraft model the associated AIT plan shall identify:

The objectives of the plan
The AIT team organisation and test organisation philosophy and policy, including the integration of the ESA resident AIV team (if applicable)

The test control and data assessment philosophy including verification of relevant mathematical models

The AIT sequence from unit to composite level, the relevant test programme including block diagrams of even flows giving due consideration to the technical requirements, test logistics and ground support equipment logistics
A detailed schedule and resource utilisation showing the timing and location of the AIT phases including identification of all slack and contingency planning built into the programme to ensure timely delivery of the spacecraft to the Agency.

For each test, a task description giving test objectives, test configuration, test support team, test data analysis, GSE and facility support requirements.

A listing of the documentation which will be required to support the AIT programme including configuration control procedures to be implemented during AIT and identification of the correlation with the AIT schedule.

A listing of all the support plans relevant to the system level AIT plan such as module and subsystem AIT plans.

14.3 Schedule and Resource Plan

This document shall be derived from the VPP and Spacecraft System Requirements and shall detail the overall resources required by the Contractor to complete the verification process and give schedules for the various phases of the programme. Programme milestones shall be identified in the plan together with reference to other detailed support plans such as the AIT plans. If the Contractor wishes, he may make the Schedule and Resource Plan part of the AIT plan.

14.4 Error Analysis Plan

This document shall be derived from the measurement specification and shall detail the errors which may occur in each type of measurement proposed together with the proposed method of assessing their contribution to a satellite level parameter identified in the Verification Requirements. The methods of error assessment and apportionment shall be agreed with the Agency by means of this plan prior to commencement of any AIV activities.

14.5 Facilities and Transport Plan

This document shall describe all the facilities to be used during the programme including the requirement dates and intended periods of occupancy, the specific interfaces required and the GSE intended to be used on the site together with the team to be allocated.

Each mode of transportation to be used shall be covered in a separate section listing all unusual or specific requirements and all safety related topics to be considered.

14.6 Hardware and Software Test Matrix

This document shall list all the equipment to be built or procured under the programme.
It shall indicate the category, the model type, the number per spacecraft system model and the type of unit level tests to be undertaken.

14.7 EGSE/MGSE Requirement Specifications

Analysis of the VPP shall be used to derive the requirements for both Electrical and Mechanical Ground Support Equipment. These requirements shall be listed in this document and shall be correlated with the applicable design requirements. In addition this document shall detail the overall EGSE/MGSE deployment requirements derived from analysis of the VPP. It shall take due account of the logistics and schedules for the AIT plans and shall justify the number of items of each required to support the programme. Full account shall be taken of the possible contingency and work-around solutions which are identified in the AIT plans.

14.8 Verification Control Plan

This document is essentially a compilation of all the applicable verification documentation derived for the programme.

It shall be arranged in order of each requirement derived from the Verification Programme Plan and list the applicable documents, the final reporting of assessments, tests and analyses, the authority for agreement, the relationship with the AIV Master Schedule and the Project Control Plan.

The document shall be structured to include spacecraft unit level. subsystem level, module, scientific payload and system level, the latter being the final binding document.

15 GROUND SUPPORT EQUIPMENT

AIVM-01 *All the ground support equipment shall be compliant with the CSG safety regulation.*

15.1 Mechanical Ground Support Equipment

15.1.1 GENERAL

AIVM-5 *The MGSE shall include all mechanical equipment which is necessary to support the unit, subsystem, module, satellite or composite level AIV activities as well as the launch operations.*

MGSE shall include the following categories of equipment:
- Handling and integration equipment
- Transportation and storage equipment
- Contamination protection and chemical cleanliness protection equipment
- Interface adapters
- Test adapters
- Clamp bands for test/handling/transportation and storage
- RCS filling and pressurisation equipment.

The MGSE shall also include the equipment necessary to service the Herschel cryostat, the Cryo-Vacuum Servicing Equipment (CVSE):
- Transfer lines for filling the cryostat with LHe
- Superfluid production and maintenance tools
- Cryostat emptying, warm-up and take-out equipment
- Dewars for LHe storage
- Leak detector.

The MGSE shall include equipment to perform tests of the Herschel Instruments:
- Tools permitting to open the cryo-cover to verify alignment without breaking vacuum
- Tools providing a cold plate simulating the emission of the telescope also without breaking the vacuum when opening the cryo-cover.

The specifications shall be derived for the MGSE from the VPP.

15.1.2 REQUIREMENTS

AIVM-10 *All MGSE shall be designed, manufactured and handled such that flight hardware, for which it is intended, never experiences* *any environmental conditions outside the defined envelope.*

- MGSE Interfaces Compatible with Spacecraft Hardware

AIVM-15 *All MGSE interfaces shall be compatible with the Spacecraft hardware.*
AIVM-20 *All MGSE interfaces shall be compatible with the facilities including launch site, as described in the Facilities Plan and shall be demonstrated prior to use and formally accepted.*
AIVM-25 *All MGSE shall be designed to avoid contamination (EMC or chemical) of either the spacecraft or facility.*

- Non-Magnetic Material

AIVM-30 *In particular any MGSE with direct spacecraft interface shall be non-magnetic.*
All adaptor designs are subject to approval by the Agency.

- Steering Wheels

AIVM-40 *MGSE required to be moved over short distances within a facility shall be mounted on large self-steering wheels subject to size and weight criteria.*
AIVM-45 *MGSE shall be designed, verified and certified to take into account the applicable national safety standards, in addition to any specific spacecraft related safety requirements.*

- Interfaces

AIVM-55 *Interfaces with flight hardware shall be subject to formal configuration control and shall be compatible with the EMC and chemical cleanliness requirements of both the spacecraft and facilities. Configuration, interfaces and mass properties shall be compatible with all facilities to be used during the programme. Electrical interfaces shall be designed to be compatible with all facilities proposed for the programme.*

- Reliability and Safety

AIVM-60 *The MGSE shall not cause failure or damage to the spacecraft.*

- Design Load Factor

AIVM-65 *All MGSE handling devices shall be designed to European or applicable national regulations with respect to working load and proof load testing.*

These factors may have to be increased if dictated by National Safety Standards.

- Lifting Device Protection

AIVM-70	*Any lifting device, which may pass over the spacecraft, shall be provided with particle and oil shield protection.*
AIVM-75	*MGSE shall be designed avoiding sharp corners and edges.*

- Interface Protection

AIVM-80	*Special protection adapters shall protect all spacecraft mounting interfaces.*

In general during ground handling, mating/demating shall be done by breaking MGSE interfaces (rather than flight hardware/MGSE interfaces).

- Launcher Safety Regulations

AIVM-85	*The MGSE shall meet the requirements of the safety regulations of the launcher authority (AD 6.20)*

- Locking of Movable Parts

AIVM-90	*All movable parts of MGSE equipment shall be fitted with locking and braking devices.*
AIVM-91	*GSE shall be resistant to corrosion or shall be suitably protected against corrosion in the anticipated environment.*

- Type and Quantity

AIVM-93	*Equipment shall be procured to support the AIV programme according to the ESA approved schedule.*
AIVM-94	*It shall be possible to supply additional GSE on the request of the Agency in case schedule slippages occur. The design of the MGSE shall be optimised to achieve the maximum utilisation of the same MGSE at the various levels of the AIV activities.*
AIVM-95	*Equipment shall be designed, where applicable, for multiple use. If two or more sets of equipment are required, they shall be interchangeable, i.e. the units shall be mechanically and electrically identical.*

- Cleanliness

AIVM-100	*The MGSE shall be designed, manufactured, tested, handled, packed and operated in such a manner as to avoid contamination and shall meet the spacecraft and facility*

cleanliness requirements. MGSE shall be compatible with the cleanliness control plan prepared by the Contractor.

- EMC

AIVM-105	*Electrical circuits shall not be a source of interference such that spacecraft on-board system performance can be degraded.*

- Transportability

AIVM-110	*The MGSE shall comply with regulations for ground, sea and air transportation covering all locations proposed for the programme.*
AIVM-115	*MGSE shall be designed for road, sea and air transportation by normal commercial facilities.*
AIVM-120	*Containers for units, subsystems and system equipment shall be reusable and permit ease of packing.*
AIVM-125	*Large containers shall be compatible with fork lift and crane equipment.*
AIVM-130	*Spacecraft container(s) shall be waterproof*
AIVM-131	*Transportation of GSE and spacecraft within Europe will be mainly by road. If the transport to the launch site is by air, the design and sizes of all equipment's shall be compatible with aircraft readily available in Europe*
AIVM-132	*Transport containers for units not on the S/C, e.g. during shipment to the launch site and transport containers for GSE shall be provided and they shall facilitate easy transport with the necessary protection against damage.*

- Container Flushing

AIVM-135	*S/C Container shall be flushed and over pressurised with dry nitrogen gas, specification as defined in paragraph 12.1.*

- Container Shock Recording

AIVM-140	*S/C container shall be equipped with mechanical shock recording equipment.*

- Container RCS Leak Test

AIVM-145	*S/C container shall be capable of being used for overall RCS leak tests.*
AIVM-146	*The spacecraft container shall be suitable for transport of the unfueled and the fully fueled spacecraft.*
AIVM-147	*The spacecraft container shall be suitable for transport of*

partially filled cryostat.

- Environment

AIVM-150 *The MGSE shall meet the following transportation environment conditions:*
Temperature: -40°to +60°C (this includes 15°C for the effect on solar radiation) for a time not exceeding 5 hours
Humidity: up to 100% RH
Shock: 10g for max. 20 ms
Pressure: equivalent to 15 km altitude

AIVM-155 *MGSE for transport and handling shall provide environmental conditions better than the flight acceptance levels of the equipment contained within them.*

- Design Life and Maintainability

- Maintainability

AIVM-160 *MGSE shall be designed for minimum scheduled maintenance. Components requiring scheduled maintenance shall be easily accessible. Those components shall be identified and maintenance material and manpower shall be available for their operational lifetime. Critical sub assemblies/components shall be designed for on-site replacement or repair.*

- Design Life

AIVM-165 *The design lifetime and warranty of all contractor supplied MGSE shall cover a period extending for 3 years after spacecraft delivery. In case the spacecraft is placed in storage this warranty shall be extended accordingly.*

- Test Requirements

Testing, other than proof loading or proof pressure tests, shall be kept to a minimum and where possible, be replaced by analytical methods. MGSE for pressurant or propellant usage shall always be proof tested prior to use.
Interface compatibility shall be proven before use on the flight or flight spare hardware.

AIVM-170 *All lifting equipment and pressurant and propellant equipment shall be certified in operational configuration at least annually or in accordance with National Safety regulations where these are more stringent.*

- Commercial equipment

All commercial equipment including tools which are not part of an integrated MGSE to be used during AIT and launch operations phases shall be provided as loan pool equipment, and not as dedicated project equipment.

- Grounding

AIVM-175	*MGSE shall provide a ground to the spacecraft compatible with EMC requirements (e.g. earth loop shall be avoided).*
AIVM-180	*MGSE shall provide a ground lug for grounding to facility ground.*

- MGSE Mating

AIVM-185	*MGSE which may be disassembled, and requires re-assembly prior to use shall carry clear marks and instructions for assembly.*

15.2 Electrical Ground Support Equipment (EGSE)

15.2.1 INTRODUCTION

The Contractor is required to supply all electrical ground support equipment, with the exception of instrument specific EGSE, to support all aspects of the spacecraft AIV programme and subsequent launch operations. This will include all electrical equipment required to support the activities defined by the VPP, plus launch operations, including:

- unit/subsystem development and testing, including “Bench Test”
- unit and subsystem integration activities
- module and system level functional end environmental testing
- ground segment compatibility tests
- launch operations

The EGSE requirements in the following sub-sections cover all equipments required to support the programme (as described above). The requirements are broken down into general requirements (including design, construction, reliability, maintainability etc.) which apply to all equipment, and then into specific sets, (each described later in section 1.2):

- CCS, Central Checkout System (for support of all system level test activities)
- SCOE, Specific Checkout Equipment (for unit/subsystem specific activities or interfaces)
- SIS, Spacecraft Interface Simulator (for interface verification prior to system

integration)

It should be noted that the following sections represent top-level system requirements, eventually the contractors VPP and AIT plans will dictate the detailed requirements on the EGSE.

15.2.1.1 EGSE Concepts

Although many conventional EGSE requirements apply to equipment envisaged to support the Herschel/Planck AIV programme a number of key points were identified:

1. Need for use of On-board Control Procedures during AIV. A need was identified to exercise on-board procedures during AIV programme to the greatest extent, such that the on-board software and autonomy functions are exercised to the greatest possible extent on the ground. To this end Ground-Test versions of On-board Control Procedures (OBCPs) should be incorporated into the Spacecraft database and used within the system-level AIV campaign. This will require the incorporation of appropriate tools for the management and analysis of these procedures during the AIV programme.

2. Need for early OB software validation
   The Herschel/Planck software validation facility will be used early in parallel to the AIV programme to independently exercise the on-board software. A need was identified for interaction of CCS with SVF, in terms of sharing of database information (including OBCPs).

3. Need for careful and early management of satellite database. The core criticality of satellite database (SDB) for AIV programme, software validation and preparation of procedures requires that management tools should be available early in the programme for high-level manipulation and configuration control of SDB. These tools may well need to be available in advance of core CCS. Portability between CCS, Instrument EGSE (tbc), SVF and MOC should be ensured.

15.2.2 General EGSE Requirements

The following section gives general requirements, which apply generally to all elements of the EGSE equipment.

AIVE-2 *All EGSE software shall comply with the software standard defined in AD6-17.*

AIVE-4 *Execution of all EGSE S/W functions shall not load the corresponding system above:*
60 % under normal conditions
80 % under peak conditions.

15.2.2.1 General Interface Requirements

AIVE-5	*The equipment shall be fully compatible with all spacecraft internal and external interface requirements.*
AIVE-10	*It shall be possible to directly power all equipment from the available mains supply at all sites where it is envisaged for the equipment to be used.*
AIVE-15	*An EGSE interface shall be provided compatible with the ESA provided NDIU for TM and TC interface between the satellites and the Mission Operation Center (MOC).*

Note: In recent projects ESOC have used an "NDIU lite", i.e. a ground segment simulator which interfaces with the CCS by TCP/IP and which issue Telecommands using the CCS protocol to the TM/TC interface. It is likely that a similar set-up will be used for Herschel/Planck.

15.2.2.2 Reliability and Safety

AIVE-20	*The equipment shall comply with applicable European and national safety regulations.*
AIVE-25	*EGSE shall include over-voltage protection, loss of external power or reverse polarity shall not cause damage to hardware or the loss of significant test data.*
AIVE-30	*All equipment shall incorporate failsafe design, such that safe electrical output levels are presented in the case of any failure.*
AIVE-35	*The equipment shall be designed for continuous operation for periods of utilisation required by the AIT plans, and for launch operations.*
AIVE-40	*The equipment shall be designed and constructed for ease of maintenance.* *Corrective and planned maintenance of any equipment shall not exceed 5% of the planned utilisation period in any one month.*
AIVE-45	*Where two or more units of a given type are required, each shall be electrically, functionally and mechanically compatible, so that they are fully interchangeable.*
AIVE-50	*As far as possible the equipment shall have the capability of being checked and calibrated using commercial test equipment. Where not possible, special test aids shall be provided.*
AIVE-55	*Sufficient spares shall be provided to cover the utilisation period of the equipment, bearing in mind contingency work around solutions proposed in the AIT Plan, and for launch operations.*
AIVE-60	*EGSE shall be calibrated with reference to a National Bureau of Standards.*
AIVE-65	*Maintenance contracts with service agencies or suppliers shall enable support to be obtained within the 5% utilisation per*

month maintenance requirement at any envisaged site.

AIVE-70 *The design lifetime and warranty of all equipment shall cover a period extending for 3 years after spacecraft delivery. This warranty shall be extended by any period when the spacecraft is stored and unpowered.*

15.2.2.3 Cleanliness and Environmental Requirements

AIVE-75 *It shall be a design objective to minimise the number and physical size of any equipment requiring close proximity (<5m) to the spacecraft.*

AIVE-80 *The equipment shall be designed and constructed to meet the defined cleanliness classes in all areas in which it will be used.*

AIVE-85 *Any equipment presenting a direct mechanical interface with the spacecraft shall be non-magnetic, i.e., non-magnetic connectors.*

AIVE-90 *The equipment shall be designed to work under the following conditions:*

- Temperature $25°C \pm 15°C$

- Humidity up to 90% RH

AIVE-95 *The physical properties of the equipment (dimensions, mass, point loading) shall be compatible with all sites (and associated handling devices) where it is envisaged for the equipment to be used.*

15.2.2.4 Test and Verification

AIVE-100 *EGSE shall be connected to flight hardware only with flight quality connectors or corresponding connector savers , connector mating/de-mating cycles between GSE and flight equipment shall be minimised.*

AIVE-105 *Verification of the design, construction, interfaces and performance shall be carried out in accordance with well defined procedures approved by ESA, this shall include interface compatibility with the on-board and ground-based elements.*

15.2.2.5 Transport and Containers

AIVE-110 *The equipment shall be delivered with, and subsequently transported in, reusable containers of rigid design. Such containers shall be transportable by normal commercial facilities (road, rail, sea, air) and sufficiently durable for all transports identified by AIT plans and for launch operations.*

AIVE-115 *To ease transportability over short distances (e.g. within a test* *facility), all equipment subject to size and weight (tbd) shall be mounted on swivelling, lockable, wheels. Furthermore, minimal disassembly/assembly of the equipment for packing, shipment and re-installation, shall be required.*

15.2.2.6 Documentation

AIVE-120 *The equipment shall be supported by a set of documentation to a level and quality consistent with their intended use. This shall be maintained during the period of usage of the equipment.*

15.2.3 CENTRAL CHECKOUT SYSTEM

15.2.3.1 CCS Definition

The Central Checkout System (CCS) is conceptually the core of the System EGSE, from which all testing is prepared, controlled and results archived. It presents the primary operator interfaces, and single point of control, for the supporting of all aspects of the system-level AIV programme.

AIVE-125 *In compliance with AICO-10 the Contractor shall issue the specification for the Herschel/Planck EGSE for review and concurrence by the Agency.*

AIVE-130 *All items of the CCS that are jointly identified by ESA and the Contractor as having the potential for Commonality/Compatibility with the Flight Control system (FCS) shall be deliverable items. The Agency reserves the right to deliver the corresponding source code and supporting documentation to the FSC contractor.*

The use of industry standard interface and protocol (e.g. TCP/IP over Ethernet), is intended to simplify and standardise the SCOEs as much as possible, such that off-the-shelf equipment may be used.

AIVE-135 *The CCS shall provide a standard interface for on-line and off-line data distribution to instrument EGSE equipment. Note - this interface shall not support any real-time control or commanding from the instrument EGSE.*

AIVE-140 *The CCS shall provide a standard interface to Front End Equipment for low-level handling of both the TT&C chains from/to the spacecraft, and for high-rate TM output from spacecraft via a ground-test connector.*

AIVE-145 *The CCS shall provide a gateway connection for access via*

	public/private Internet, for data and information dissemination to the wider Herschel/Planck community.
AIVE-150	*Such standard interfaces as defined above shall be implemented in such a way as to ensure that data distribution and traffic due to off-line activities do not impact upon test critical and real-time traffic.*
AIVE-151	*The CCS shall allow recording of specific Herschel and Planck TM data (spacecraft and Instruments) – format to be agreed jointly between ESA and Contractor.*
AIVE-152	*The CCS shall provide and use configuration tool facilities for all items, e.g. software modules, calibration and monitor tables, test sequences, command sequences and displays.*

15.2.3.2 CCS Safety Requirements

AIVE-155	*Telecommands shall be subject to a pre-transmission check against the Satellite Database, to restrict and/or provide operator confirmation for the execution of hazardous commands.* *In addition during the SVTs where spacecraft commanding is done from the MOC a facility shall allow to block/veto specific commands from ESOC if considered dangerous.*
AIVE-160	*The prime function of the Central Checkout System shall be to provide reliable monitor and control facilities to allow the operators to ensure the integrity of the spacecraft and instruments during all electrical system level activities.*

15.2.3.3 CCS Primary Functions

AIVE-165	*The CCS shall provide all automated facilities and high-level tools for preparation, execution and results/failure analysis and reporting of all electrical tests of the spacecraft and payload required to meet the system level programme.*
AIVE-170	*Display of test progress, processed data error reports and test procedures shall be available on CCS in real time.*

15.2.3.4 Test sequence language

AIVE-175	*The CCS shall support a simple test sequence language made up of a number of statements that enables the unit/subsystem supplier or the instrumenter to specify the tests to be performed. Such defined test language shall be useable directly by the operators, and from pre-defined automated sequences.*
AIVE-180	*The system shall support the execution of parallel/nested test*

sequences, as required for a full satellite test/mission – simulation of the spacecraft.

AIVE-185 *The CCS shall support comprehensive tools for manipulation of the test sequences, including:*
- Preparation and inter-active de-bugging,
- Structured Test Sequence library
- Configuration Control of Test Sequences
- Full control over sequence execution
- Automatic logging of test sequence actions

15.2.3.5 Satellite Database

AIVE-190 *The CCS shall support a development environment for the population and configuration management of the satellite database. Selection of the Data Base Management System (DBMS) shall require ESA approval.*

The data base environment should provide, at least, the following key functions:
- data base administration (defining e.g. data base domains and access rights)
- automatic low-level validation of data
- tracking of database modifications
- import/export of database between platforms

It may be necessary to provide such an environment early in the programme to allow preliminary database population and test-sequence definition to be performed before the start of the AIV programme.

AIVE-195 *The selected database management system shall be supported by, and transferable between, a wide range of environments without modification.*

This is to re-enforce the compatibility of this database with the MOC and the instrumenter community.

15.2.3.6 Spacecraft TM and TC Monitoring

AIVE-200 *The CCS shall process all spacecraft housekeeping data, maintaining a comprehensive real-time status of all on-board units, for use by test sequences, for display to operators, and for the automatic monitoring of hazardous conditions.*

AIVE-205 *The CCS shall use information from the SDB to perform the automatic verification of TC reception and successful execution on-board.*

Such monitoring as defined in the previous two requirements shall be performed in accordance with command and parameter definitions held within the Satellite Database (SDB).

15.2.3.7 Onboard Control Procedures preparation, monitor and control

AIVE-210 *The CCS shall furnish an environment for the development of any On-Board Control Procedures (OBCPs) for execution during the AIV campaign.*

This environment shall include facilities for : compilation and validation of OBCPs against SDB, configuration control of OBCPs, uplink of OBCPs to spacecraft.

AIVE-212 *The CCS shall support the execution of off-line tasks (e.g. test preparation) in parallel with test execution.*

AIVE-215 *The CCS shall provide facilities for the monitor and control of OBCPs.*

The status of resident OBCPs should be available in spacecraft HK. Such OBCPs will be controllable by telecommand, and their status available in telemetry. The aim is to allow high level management of these procedures, by operators and from test

15.2.3.8 Test Result Database

AIVE-220 *The CCS shall maintain complete archives of all data used and generated during testing of the spacecraft, this being called a Test Result Database.*

AIVE-225 *This archive shall be available on-line, and also archived to non-volatile medium.*

AIVE-230 *All archived data shall be time correlated to an accuracy of 1 second (tbc).*

AIVE-235 *A high level access tool shall be provided for archive management, cataloguing and data retrieval.*

Data storage shall be structured and under user control to facilitate cataloguing of data and simplify retrieval. This should ensure that archived data could be precisely extracted and reported. A retrieval tool should allow all levels of data available in SDB to be used in retrieval criteria.

15.2.3.9 Real Time Data distribution

AIVE-240 *The CCS shall support the real-time distribution of instrument telemetry data, test status and SCOEs status (where applicable) to the instrument EGSE's.*

Essentially TM and SCOE status will be sent to the Exp. EGSE, however in addition test status information and events for synchronising Instrument EGSE data gathering should be distributed over the same interface.

15.2.3.10 Off-line data distribution

AIVE-245 *Data from the Test Results Database shall be available off line for both local and remote distribution and interrogation.*

AIVE-250 *Data pertaining to spacecraft, EGSE and test campaign status shall be made available to the wider Herschel/Planck community via off-the -shelf protocols (e.g.. WWW).*

15.2.3.11 Operator Interfaces

AIVE -255 *The operator interface shall be user-friendly with a consistent "look and feel" between applications.*

In principle the development of the MMI should consider the potential for 3 categories of user, each of differing levels of S/C and EGSE expertise:

- System administrator, with detailed knowledge of the EGSE internals and usage, but limited AIV and spacecraft knowledge.

- EGSE operator, expert user of EGSE with limited knowledge of internals, responsible for SDB population, test sequence production and test-environment configuration, some spacecraft knowledge.

- Test Conductor, subsystem/instrument engineer, ESA representative or AIV team member who has detailed spacecraft, test or subsystem knowledge, who will actually execute or witness a test, but should be able to do so without being an expert EGSE user.

AIVE-260 *Display of user information (pertaining to test status, EGSE status and spacecraft status) shall be available to the user in user-definable textual and graphical formats. Such information being available in a hierarchical manner to allow an overview, with increasing levels of detail to be provided.*

15.2.4 SPACECRAFT INTERFACE SIMULATOR (SIS)

15.2.4.1 SIS definition

The Spacecraft Interface Simulator (SIS) has the primary function of allowing early interface verification prior to delivery and integration of units at system level. It will exactly simulate mechanically, electrically and functionally all generic on-board interfaces (namely power and data handling). The unit will be developed by the contractor and furnished to subsystem developers. Such simulators may then be re-used during the system level test program for re-verification of interfaces, and should supply limited facilities for simulation of missing units.

15.2.4.2 SIS Architecture

AIVE-265 *The spacecraft Interface Simulator shall exactly simulate, for bench level testing of all units prior to integration on the spacecraft.*

AIVE-270 *All interfaces shall be simulated mechanically, electrically and functionally, according to contractor controlled interface documents. Also allowing failure simulation.*

15.2.4.3 SIS Interfaces

AIVE-275 *The SIS shall present the following external interfaces:*
- on-board interfaces (S/C as seen by unit)
- on-board interfaces (Unit as seen by S/C)
- Instrument EGSE interface
- Local operator interface
- Local printer interface

15.2.4.4 SIS Primary Functions

AIVE-280 *SIS shall exactly simulate spacecraft interfaces (power, data, special - tbd) and protocols. Functions shall be provided to allow full monitor and control of this interface, to allow all nominal interface functions to be exercised, and to allow response to failures to be verified.*

AIVE-285 *SIS shall provide for either a local operator or a remote computer system to monitor and control all SIS functions.*

AIVE-290 *SIS shall perform basic packet validation of telemetry received from a unit, and then forward such TM packets and status* *information over the Instrument EGSE interface.*

AIVE-295 *SIS shall accept telecommands and status information from the Instrument EGSE interface, perform final TC packetisation, and forward to the unit in real-time.*

AIVE-300 *SIS shall provide facilities for recording and filing control and status information, and additionally for recording and replaying TM/TC traffic, over either interface (OB-data handling, or instrument EGSE) as appropriate.*

Such recorded TM/TC information may then be replayed, allowing the SIS in a basic manner to simulate the unit level itself at system level.

AIVE-305 *SIS shall provide for local printing of on-line status information, and off-line archived data.*

15.2.5 SPECIAL CHECKOUT EQUIPMENT (SCOE)

15.2.5.1 SCOE definition

There is a need for Special Checkout Equipment (SCOEs) which will be necessary to interface directly with particular on-board units requiring non-generic, or specialised interfaces or test-equipment which will not be readily available within the CCS itself. Specifically these could be identified for interfacing between TM/TC Front End Equipment and the Spacecraft TT&C chains, for providing power to the spacecraft under test, for simulation and monitor of the AOCMS system. These will be conceptually designated as TT&C, AOCMS and Power SCOEs. The need for other SCOEs may be identified by the contractor.

15.2.5.2 SCOE Architecture

AIVE-310 *The SCOE shall as much as possible use “off-the-shelf” equipment, and avoid custom-made hardware and software developments.*

AIVE-315 *The SCOE functionality shall fulfil the prime requirement of providing an interface between CCS and on-board equipments, with internal SCOE functionality limited to facilities for interface verification.*

AIVE-320 *The SCOE shall allow all functions to be controlled and monitored remotely by the CCS. Monitor and control of all primary functions shall also be available to the local operator interface.*

AIVE-325 *Following power-on all necessary operations for SCOE set-up shall be possible via remote control. All such set-up functions shall also be remotely verifiable.*

15.2.5.3 SCOE Interface

AIVE-330 *The SCOE shall present the following external interfaces:*
- Appropriate monitor and control interface to CCS (as defined above),
- Specialised direct interfaces to specific subsystem,
- Standalone local operator interface

15.2.5.4 SCOE Primary Functions

Such requirements are dictated by individual sub-system requirements, VPP and AIV plans. Therefore they cannot be detailed at this level.

15.2.5.5 TM/TC Front End Equipment

15.2.5.6 TM/TC (FEE) Definition

The FEE shall provide the interface between the CCS and the Spacecraft (possibly via a TT&C SCOE - see earlier) for the real-time transfer of TM from the spacecraft and TC to the Spacecraft. In the case of TC, the FEE will perform final packetisation of the Telecommands. In the case of TM the FEE will accept TM transfer frames either from the Spacecraft TM chain (RF or video), or from an OBDH test connector for high-rate uncompressed data. Performing validation at the Frame and low-level packet level, all data will be subsequently forwarded to CCS along with associated status information.

15.2.5.7 FEE Architecture

AIVE-335 *The FEE functionality shall fulfil the prime requirement of providing an interface between CCS and the spacecraft TM/TC chain (possibly via TT&C SCOE), with internal FEE functionality limited to automatic protocol validation and facilities for interface verification.*

AIVE-340 *The FEE shall allow all functions to be controlled and monitored remotely by the CCS. Monitor and control of all primary functions shall also be available to the local operator interface.*

AIVE-345 *Following power-on all necessary operations for FEE set-up shall be possible via remote control. All such set-up functions shall also be remotely verifiable.*

15.2.5.8 FEE Interfaces

AIVE-350 *The FEE shall present the following external interfaces:*
- Appropriate monitor and control interface to CCS (as defined above)
- Interfaces to TT&C chain, and OBDH test connectors,
- Standalone local operator interface

15.2.6 THE HERSCHEL/PLANCK DATABASE (SDB)

The definition of the SDB is given in AD3-2.

15.2.6.1 SDB concept

The Herschel/Planck project intends to create a common database that serves engineering, on-board software, AIV and Flight Operations areas. Such database shall be used by:

- Engineering as a common and centralised repository for engineering data during phase C/D
- On-board software to generate the needed real-time environment for on-board software execution,
- AIT to generate the real-time environment of the CCS/avionics SCOE for system/avionics test activities,
- Flight operations to generate the real-time environment of the MCS for satellite flight operations

The database shall be administered by the Prime Contractor until it is headed over to ESA/ESOC for the flight operations phase. Access to the database will be provided to the distributed sites according to privilege and domain allowing secure control of this information throughout the satellite lifetime.
A core element of this database will therefore fully describe the configuration and behaviour of the satellite, this will be referred to as the Satellite Operational Database, and will be developed to be fully compatible for use within the Herschel/Planck MOC and Instrument EGSE. This will ensure that the ground-test environment of the satellite is as closely as possible, and as early as possible within the programme, representative of the final operational environment of the satellite.

In summary the design *objective* is to achieve a single standardised information set for use in all ground test activities, and finally in real operations. This database then becomes the central critical element for the reliable test and operations of the Herschel and Planck Spacecraft.

AIVE-355 *The Satellite Database (SDB) is the sole repository of all information relating to:*
- Satellite configuration
- System Test configuration information

- EGSE configuration
- Satellite Operational Database
- a definition and description of the satellite build status
- the on-board software tables definition
- the on-ground operation of the satellite
- the in-flight operation of the satellite flight model, covering both the spacecraft communication and flight dynamics needs

AIVE-360 *The contractor shall support this database such that compatibility of the Satellite Operational Database with MOC development is ensured. This compatibility will be the primary design objective of the SDB.*

AIVE-365 *The SDB shall be defined and controlled by the contractor, with direct involvement of project representatives for interfacing with PI teams and ESOC.*

AIVE-370 *All changes to the Satellite Database shall be formally controlled with the involvement of ESA..*

AIVE-375 *The Satellite Database will be the prime repository for information defining the detailed function of the spacecraft and all units on-board. The definition of this database shall therefore be the responsibility of the Contractor with support from ESA. Database population shall be from information produced by the Contractor, Subcontractors, Instrument groups and ESOC.*

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