# SPIRE

**SUBJECT:** **RAL Project Plan for SPIRE**

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# Glossary

| | |
|---|---|
| CQM | Cryogenic Qualification Model |
| ESA | European Space Agency |
| FIRST | Far Infrared and Submillimetre Telescope |
| FS | Flight Spare (Model) |
| FTB | FET Box |
| HCSS | Herschel Common Science System |
| Herschel | Herschel Space Observatory (formerly FIRST) |
| ICC | Instrument Control Centre |
| PFM | Proto-Flight Model |
| PI | Principle Investigator |
| PIMS | Project Information Management System |
| PPARC | Particle Physics and Astronomy Research Council |
| RAL | Rutherford Appleton Laboratory |
| RO | Responsible Organisation |
| S/C | Spacecraft |
| SPIRE | Spectral and Photometric Imaging REceiver |
| SSTD | Space Science and Technology Department (of RAL) |
| STM | Structural Thermal Model |

# 1. INTRODUCTION

The Herschel Space Observatory, the fourth of ESA's Cornerstone missions, is a space-borne observatory operating in the far infrared and sub-millimetre wavelength ranges. The responsibility for the design, implementation and operation of the scientific instruments on the Herschel spacecraft is given to consortia, made up from members of research institutions and universities, under the leadership of a Principle Investigator (PI). The Rutherford Appleton Laboratory (RAL) is one of the institutes responsible for providing and operating the Spectral and Photometric Imaging REceiver (SPIRE) instrument.

Current PPARC funding covers those activities leading to the delivery and commissioning of the Flight and Flight Spare instruments and to the implementation of the SPIRE Instrument Control Centre (ICC). It does not cover the Operations Phase or Post-Operations activities, which will be a subject of a further bid to PPARC at a later date.

## 1.1 Scope

This document describes the management and development of those areas of the Herschel SPIRE instrument for which the RAL, and in particular the Space Science and Technology Department (SSTD), has responsibility. It is intended to show how the project will be managed to meet the ISO9001 standard as implemented in the SSTD. It is the Project Management Plan identified in the SSTD Task Allocation and Project Monitoring Procedure (AD01) and contains that information required by the Project Manager's Requirements Procedure (AD02).

As RAL is responsible for the overall management of the SPIRE project, many of the project management activities are covered by the appropriate SPIRE documentation. Where applicable this document refers to material contained these existing SPIRE project documents, or contains extracts from them.

## 1.2 Documents

### 1.2.1 Applicable Documents

| | | |
|---|---|---|
| AD01 | ISO9: SPAP/007 | Task Allocation and Project Monitoring |
| AD02 | ISO9: SPAP/008 | Project Manager's Requirements |
| AD03 | SPIRE-RAL-PRJ-000029 | SPIRE Management Plan |
| AD04 | SPIRE-ESA-DOC-000178 | FIRST/Planck Instrument Interface Document (IID) Part A, (SCI-PT-IIDA-04624) |
| AD05 | SPIRE-RAL-PRJ-000031 | SPIRE Work Breakdown Structure |
| AD06 | SPIRE-RAL-PRJ-000030 | SPIRE Product Tree |
| AD07 | | SSTD Management Plan (Issue 7.1) |
| AD08 | SPIRE-ESA-DOC-000198 | FIRST Science Implementation Requirements Document |

### 1.2.2 Reference Documents

| | | |
|---|---|---|
| RD01 | SPIRE-RAL-DOC-000184 | SPIRE Project Office Requirements |
| RD02 | SPIRE-RAL-PRJ-000455 | SPIRE Major Milestone List |
| RD03 | SPIRE-RAL-PRJ-000626 | SPIRE Configuration Management Plan |

| | | |
|---|---|---|
| RD04 | SPIRE-RAL-PRJ-000032 | SPIRE Document Management Plan |
| RD05 | SPIRE-RAL-PRJ-000018 | SPIRE Science Implementation Plan |
| RD06 | SPIRE-ESA-DOC-000189 | Product Assurance Requirements for FIRST/PLANCK Scientific Instruments |
| RD07 | SPIRE-RAL-PRJ-000017 | SPIRE Product Assurance Plan |
| RD08 | SPIRE-RAL-PRJ-000033 | SPIRE Configurable Documents Tree |
| RD09 | SPIRE-UCF-PRJ-000064 | SPIRE Scientific Requirements Document |
| RD10 | SPIRE-RAL-PRJ-000034 | SPIRE Instrument Requirements Document |

# 2. PROJECT BREAKDOWN

## 2.1 Work Allocation

Table 3.1-1 (taken from AD03, but updated in the light of subsequent discussions) identifies the institutes that comprise the SPIRE consortium and the major areas of work for which they are responsible.

| Institute | | Role |
|---|---|---|
| ATC | Astronomy Technology Centre, Edinburgh | Provision of Beam Steering Mechanism (BSMm)<br>Systems Engineering effort<br>Provision of ICC Operations Staff (TBC) |
| DESPA | Obs. de Meudon, Paris | Provision of FTS expertise and design support |
| Grenoble | CEA, Grenoble | Provision of $^3$He cooler |
| IAC | Instituto de Astrofisica de Canarias, Tenerife | Provision of ICC operations staff |
| IAS | Institut d'Astrophysique Spatiale, Orsay | Support of ground calibration |
| ICSTM | Imperial College of Science, Technology and Medicine, London | Provision of ICC UK DAPSAS Centre<br>Provision of ICC operations staff (TBC) |
| IFSI | Instituto di Fisica dello Spazio Interplanetario, Rome | Provision of Digital Processing Unit (DPU)<br>Provision of DPU On-Board Software (OBS)<br>Provision of ICC operations staff |
| JPL | JPL/Caltech, Pasadena | Provision of Bolometer Detector Arrays<br>Provision of JFET Modules<br>Provision of RF Filter Modules |
| LAM | Laboratoire d'Astophysique de Marseille | Provision of Mirrors<br>Provision of FTS mechanism (SMECm)<br>Provision of FTS and BSM control and signal processing electronics |
| MSSL | Mullard Space Science Laboratory, Surrey | Provision of FPU structure<br>Provision of FTB enclosure<br>Provision of ICC operations staff (TBC) |
| Padova | Padova Observatory | Provision of ICC operations staff |
| Cardiff | Cardiff University, Cardiff<br>Wales | Provision of Test Cryostats and support for Detector Arrays testing<br>Provision of Calibrators<br>Provision of Filters, Dichroics, and Beam Dividers<br>Provision of ICC operations staff (TBC) |
| **RAL** | **Rutherford Appleton Laboratory, Oxfordshire** | **SPIRE Project Management.**<br>**Provision of SPIRE Project Office.**<br>**Provision of AIV and Ground Calibration Facilities.**<br>**Provision of EGSE**<br>**Provision of ICC Operations Centre.**<br>**Instrument Cold Vibration**<br>**Systems Engineering** |
| SAp | CEA, Service | Provision of Detector Readout and Control Unit (DRCU) |

| | | |
|---|---|---|
| | d'Astrophysique, Saclay | Provision of ICC DAPSAS Centre (Fr). |
| USK | University of Saskatchewan, Canada | Provision of AIV support staff<br>Provision of ICC operations staff. |
| Stockholm | Stockholm Observatory | Provision of Instrument Simulator(s).<br>Provision of ICC operations staff. |

**Table 2-1 SPIRE major tasks**

## 2.2 Identification of Models

AD04 identifies the following models of the instrument that are to be delivered by the SPIRE Project to ESA. Each model will be tested and verified at RAL before delivery.

- Avionics Model
- Cryogenic Qualification Model
- Proto-Flight Model
- Flight Spare

### 2.2.1 Avionics Model (AVM).

This model is required to validate the instrument electronics and software and their interfaces with the S/C. This will include:

- verification of information exchange with the S/C computer, mass memory and attitude control systems
- verification of the instrument autonomy functions
- validation of on-board software updates
- validation of AIV procedures

At the instrument level the AVM will be used for qualification of the warm electronics subsystems. The following tests will be performed:

- EMC tests (Conduction, Emission, Susceptibility)
- Thermal Vacuum Test
- Warm Vibration

In addition the AVM DPU will be used, by ESA, during testing of the CQM (see below) and may temporarily replace the DPU during system level testing of the PFM in the event of a problem with the PFM DPU itself.

The AVM will consist of a DPU plus a DRCU Simulator. The DRCU Simulator will provide sufficient simulation of the operation of the FPU, FTB and DRCU to allow the activities given above to be carried out. The DPU will be built to flight representative standards (using extended range components) but redundancy will not be fully implemented.

### 2.2.2 Cryogenic Qualification Model (CQM) (including Structural Thermal Model (STM))

Initially, the STM, consisting of the CQM structure and cooler, plus mass and thermally representative models of other subsystems, will be used by the SPIRE consortium:

- To qualify the cold instrument structure design against the proposed environmental test levels and to derive the test levels for other subsystems.

- To verify the thermal design of the instrument
- To verify the optical alignment procedure for the instrument

Subsequently the CQM models of all subsystems will be integrated into the structure and the CQM instrument will be subjected to a series of functional and scientific performance tests. On delivery to ESA it will be used to ensure the compatibility of the Herschel payload and spacecraft by performing a series of functional tests and a set of conductive EMC tests in the ISO Flight Spare Cryostat.

The CQM units will be built to flight standards with full redundancy. The performance capabilities of the instrument may be less than the PFM - i.e. fewer pixels in the focal plane arrays, but it will mimic as exactly as possible the thermal, electrical and mechanical properties of the flight instrument and will be capable of under going the full environmental qualification programme.

This model consists of the FPU, FTB and DRCU only. It is assumed that the AVM DPU may be used for the duration of the CQM tests.

### 2.2.3 Proto-Flight Model

This is the instrument model that is intended for flight. It consists of all SPIRE Instrument Units. It will be built to full flight standards and will only have minor differences in thermal, electrical and mechanical properties to the CQM. It will have the same mechanical, thermal and electrical interfaces to the satellite as the CQM but, may, however, have minor internal design changes compared to the CQM. For instance the bolometer detector arrays may have many more pixels.

The PFM will undergo environmental test to qualification levels for acceptance times - this applies to both the warm electronics boxes and the cold FPU.

### 2.2.4 Flight Spare Model

The Flight Spare Model provides for replacement of failed, or damaged, units during system level testing.

The FS will consist of a full flight standard, calibrated, FPU and FTB, and tested spare parts (normally at board level) for the DPU and DRCU.

It is possible that the Flight Spare Units may be provided from refurbished AVM and CQM units.

## 2.3 Work Breakdown Structure

The SPIRE Work Breakdown Structure is provided in AD05. Table 2-2 lists the high-level workpackages assigned to RAL:

| **FS1** | **Project-level Activities** | |
|---|---|---|
| FS10 | Project Office | |
| FS11 | Management | |
| FS12 | Project Control | |
| FS13 | Product Assurance | |
| FS1A | Parts Procurement | |

| | | |
|---|---|---|
| **FS2** | **Instrument Engineering** | |
| FS20 | System engineering | |
| FS22 | Design Documentation | |
| FS23 | System Design | |
| FS29 | Instrument Interfaces | |
| **FS4** | **Instrument AIV** | |
| FS41 | General AIV Tasks | |
| FS42 | Instrument Models AIV | |
| FS4A | Satellite AIV | |
| **FSZ** | **Instrument GSE and Facilities** | |
| FSZW | Special Facilities | |
| FSZX | OGSE | |
| FSZY | EGSE | |
| **GFS1** | **ICC Development** | |
| GFS11 | Management | |
| GFS12 | Instrument Operations | |
| GFS12X4 | Instrument Observations | |
| GFS13 | Software Development | |
| **GFS2** | **ICC Preparation** | |
| GFS21 | Planning | |
| GFS22 | Implementation | |
| GFS23 | Integration and Test | |
| GFS24 | FINDAS Support | |
| GFS25 | Operations Planning | |
| GFS26 | Training | |

**Table 2-2 RAL Workpackages**

## 2.4 Function Tree

The following table breaks down the activities allocated to RAL into functions to be implemented

| | | |
|---|---|---|
| Project-level Activities | | |
| | Project management functions | |
| | | Project Breakdown |
| | | Project Organisation |
| | | Project Planning |
| | | Configuration Management |
| | | Information/Documentation Management |
| | | Cost and Schedule Management |
| | | Risk Management |
| | | Interactions with ESA |
| | Provision of Project Office | |
| | | Documentation Administration |
| | | Information Administration |
| | | Project Support |
| | | Financial Administration (UK only) |
| | Product Assurance | |

| | | | | |
|---|---|---|---|---|
| | | Documentation | | |
| | | Configuration Management | | |
| | | Subsystem Acceptance | | |
| | Parts Procurement | | | |
| | | Coordination of inputs | | |
| Instrument Engineering | | | | |
| | System engineering | | | |
| | | Definition of Document Tree | | |
| | Documentation of the design | | | |
| | | Management of the Design Description Document | | |
| | System Design | | | |
| | | Definition of Instrument Requirements | | |
| | | Definition of Subsystem Requirements | | |
| | | Support to Optical Design | | |
| | | Support to Thermal Design | | |
| | Instrument Interfaces | | | |
| | | Management of IID Updates | | |
| Instrument AIV | | | | |
| | Assembly | | | |
| | | Test and Measurement of Subsystems Deliveries | | |
| | | Assembly into Instrument-Level Units | | |
| | Integration | | | |
| | | Integration of FPU into cryostat | | |
| | | Integration of FTB into cryostat | | |
| | | Optical Alignment | | |
| | | Bakeout | | |
| | | Integration of Warm Electronics with EGSE | | |
| | | Integration of Warm Electronics with Cold Instrument | | |
| | Verification | | | |
| | | Environment Control | | |
| | | Thermal Balance Check | | |
| | | Functional Testing | | |
| | | Performance Testing | | |
| | | | Beam Profile measurement | |
| | | | Throughput Test | |
| | | | Sensitivity Measurement | |
| | | Qualification | | |
| | | | Thermal Vacuum Test | |
| | | | EMC Test (TBC) | |
| | | | Warm Electronics Vibration | |
| | | | Cold Instrument Vibration | |
| | Calibration | | | |
| | | Photometric Calibration | | |
| | | | Closed Cryostat Tests | |
| | | | External Source Tests | |
| | | Spectroscopic Calibration | | |
| | | | Wavelength Calibration | |

| | |
|---|---|
| Instrument GSE and Facilities | |
| | Provision of Test Facility |
| | Commissioning of Test Facility |
| | Operation of Test Facility |
| | Provision of EGSE |
| ICC Development | |
| | ICC Development Management |
| | Data Processing Software Development |
| | ICC System Testing |
| | Ground Segment Testing |
| | Instrument Simulator |
| ICC Preparation | |
| | Instrument Database |
| | Operations Planning |
| | Training |

**Table 2-3 Functions to be executed at RAL**

## 2.5 Product Tree

Table 2-4 is a summary of the relevant major elements of the SPIRE Product tree identified in the SPIRE Product Tree (AD06) which have to be provided by RAL.

| Product | | | | | Number | RO |
|---|---|---|---|---|---|---|
| 4. | AIV/Ground Test Items | | | | | |
| | 4.1 | EMC test facility | | | | RAL |
| | | | Radiative emission test facility | | | |
| | | | Radiative susceptibility test facility | | | |
| | | | Conductive emission test facility | | | |
| | | | Conductive susceptibility test facility | | | |
| | 4.2 | AIV facilities | | | | RAL |
| | | | Integration Facility | | | |
| | | | | Clean Room | | |
| | | | | Clean Bench | | |
| | | | | Measurement Instrumentation | | |
| | | | Instrument Cryostat | | | |
| | | | Facility electronics | | | |
| | | | Clean Room | | | |
| | | | Infrastructure | | 1 | |
| | | | | Cryolab | | |
| | | | | Test Control Area | | |
| | | | | Cryogenic facilities | | |
| | | | | Vacuum facilities | | |
| | | | EGSE | | | |
| | | | | CDMU Simulator | 5 | |
| | | | | SCOS2000 | 2 | |
| | | | | TM/TC Interface | 3 | |
| | | | | Test Control Facility | 3 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | HCSS v 0.1 | 2 | |
| | | | | OBS Maintenance Facility | 2 | |
| | 4.3 | Calibration facility | | | | RAL |
| | | | Telescope Simulator | | | |
| | | | | Optical Bench | | |
| | | | | Optics | | |
| | | | Calibration Sources | | | |
| | | | | Black Body Source | | |
| | | | | Spectral Line Source | | |
| | | | Chopper | | | |
| | | | Facility electronics | | | |
| | 4.4 | Thermal Vacuum facility | | | | RAL |
| | 4.6 | Warm Vibration facility | | | | RAL |
| | 4.8 | Instrument Bakeout facility | | | | RAL |

| Product | | | Number | RO |
|---|---|---|---|---|
| | Ground Segment Deliverables | | | |
| | | Instrument Users Manual | 3 | RAL |
| | | Instrument Database | 3 | RAL |
| | | Calibration Database | 3 | RAL |
| | | Instrument Time Estimator | | RAL |

| Product | | | Number | RO |
|---|---|---|---|---|
| | Instrument Control Centre | | | |
| | | DPU OBS Maintenance System | 1 | IFSI |
| | | DRCU OBS Maintenance System | 1 | CEA |
| | | RTA/QLA Software | | RAL |
| | | Trend Analysis Software | | ICC |
| | | Interactive Analysis Software | | ICC |
| | | Science Processing Software | | ICC |
| | | Science Analysis Software | | ICC |
| | | Diagnostic Tools | | ICC |
| | | Calibration Analysis Software | | ICC |
| | | Infrastructure | | |
| | | ICC Operations Centre | | RAL |
| | | DAPSAS(UK) Centre | | ICSTM |
| | | DAPSAS(Fr) Centre | | CEA |

**Table 2-4 RAL Product Tree**

# 3. PROJECT ORGANISATION

### 3.1.1 General Organisation

The organisation of the SPIRE project is given in AD03. Within RAL, the project is organised along the lines described in the SSTD Management Plan (AD07) as shown in Figure 3-1. This structure is based upon a core team of project staff with responsibilities for areas of work within the project with support from teams within other divisions of the Space Science and Technology Department at RAL.

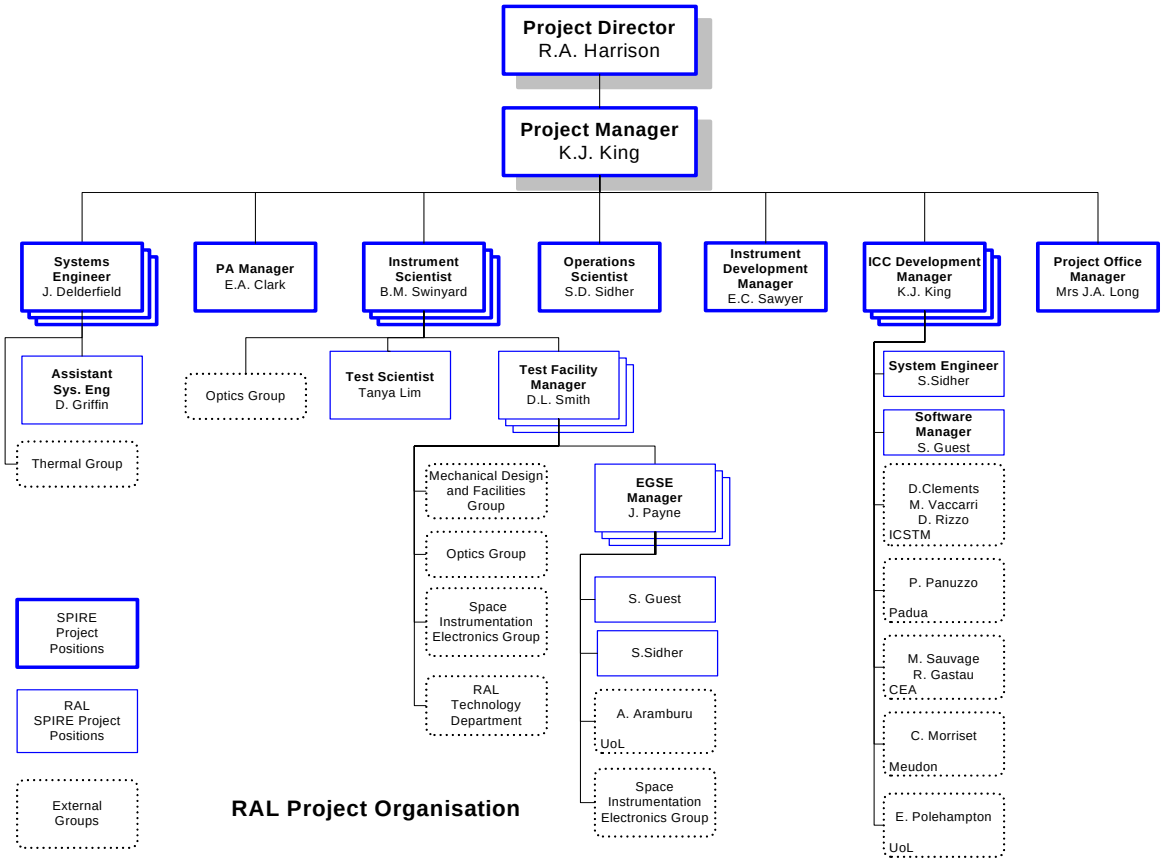


**Figure 3-1 RAL Project Organisation**

## 3.2 Management Interfaces

AD03 describes the project interfaces with ESA and with the other members of the SPIRE consortium.

Within RAL, the interfaces to facility teams within other divisions shall be described in Statements of Work, agreed between the relevant SPIRE manager and the manager of the SSTD facility or by annual agreement of resource allocation.

SPIRE Managers report to the Project Manager through regular teleconfereneces.

## 3.3 Roles, Responsibilities and Authority

Some members of the RAL team (Project Manager, Instrument Development Manager, Instrument Scientist, Systems Engineer, Product Assurance Manager, Operations Scientist and ICC Development Manager) have roles and responsibilities within the SPIRE Project as a whole. These are described in the SPIRE Management Plan (AD03).

Others (Project Director and RAL Project Manager) have roles and responsibilities within the SSTD project management structure, which are described in the SSTD Management Plan (AD07).

The remainder of this section lists each of the other key posts and gives the duties and responsibilities associated with that post within RAL.

### 3.3.1 RAL Project Manager

The management of the activities falling under the responsibility of RAL shall be under the control of the RAL Project Manager, who will:

(i) define the overall schedule necessary to meet the project milestones;
(ii) monitor the project-wide deployment of resources;
(iii) proactively manage technical and schedule risks;
(iv) monitor progress in the development teams;
(v) instigate project reviews, studies and assessments as necessary to resolve issues and ensure a successful project;
(vi) represent the SPIRE project to the SPIRE Project management team.
(vii) represent the RAL project to the PPARC SPIRE Programme Manager and the Herschel/Planck Steering Committee
(viii) represent the RAL Project to the SSTD Management.

### 3.3.2 EGSE Manager

The EGSE Manager is responsible for the procurement and development of the EGSE system(s) used for testing the instrument models at RAL and at ESA. He/she will:

1. define the requirements on the EGSE, taking into account the need to adhere to agreements with other instruments, and ESA, with respect to common development.
2. define the tasks necessary, and the required resources, to provide the EGSE.
3. identify appropriate staff/facilities for the tasks involved and negotiate their availability.
4. plan the development and implementation schedule to meet the overall project delivery dates.
5. monitor and manage the work, and staff, during the project lifetime.
6. report to the RAL Project Manager on the status of the EGSE development programme.

Note: Operation of the EGSE during AIV falls under the responsibility of the AIV Facility Manager.

### 3.3.3 Project Office Manager

The Project Office Manager is responsible for the implementation of the facilities required in the SPIRE Project Office (defined in the SPIRE Project Office Requirements Document, RD01) and the operation of the Project Office during the lifetime of the project. He/she will:

1. implement the SPIRE Project Office at RAL to meet the requirements
2. document the procedures required to operate the Project Office efficiently and correctly
3. operate the SPIRE Project Office at RAL
4. report to the RAL Project Manager on the status of the Project Office

Note: The Project Office has an extended role over the normal RAL model and therefore, though it uses the SSTD facilities , exists independently of the SSTD project Resources section.

### 3.3.4 AIV Facility Manager

1. define the requirements on the SPIRE Test Facility at RAL
2. implement the SPIRE Test Facility at RAL to meet the requirements and schedule
3. report to the RAL Project Manager on the status of the Test Facility

4. manage the execution of the AIV Plan at RAL
5. report to the RAL Project manager and the Instrument Scientist on the progress of the AIV activities

### 3.3.5 ICC Software Manager

The ICC software Manager is responsible for organising the design and implementation of the ICC software used both in the ICC and in the HCSS. He will:

1. define the ICC software requirements in terms of Use cases and translate these into an object - oriented design for the software
2. support the ICC Development Manager in producing the SPIRE SIP by producing workpackages for the software development activities
3. lead the ICC Software Development Team in implementing the ICC software.

## 3.4 Generation of Organisation Documents

The project documentation tree is given in RD08.

# 4. PROJECT PHASING AND PLANNING

## 4.1 Instrument Hardware

### 4.1.1 Sequence of Activities

Figure 4-1 shows the SPIRE overall hardware schedule as planned at May 2001. It is split into 4 phases:

#### *4.1.1.1 Design Phase*

During this phase the instrument and subsystem designs are completed. This phase ends with the completion of the Instrument Baseline Design Review.

#### *4.1.1.2 Test and Qualification phase*

During this phase the first models of the instrument are manufactured and tested. This phase ends with the Critical Design Review.

#### *4.1.1.3 Flight Model Manufacture Phase*

This phase covers the manufacture, test and calibration of the Flight and Flight Spare models of the instrument

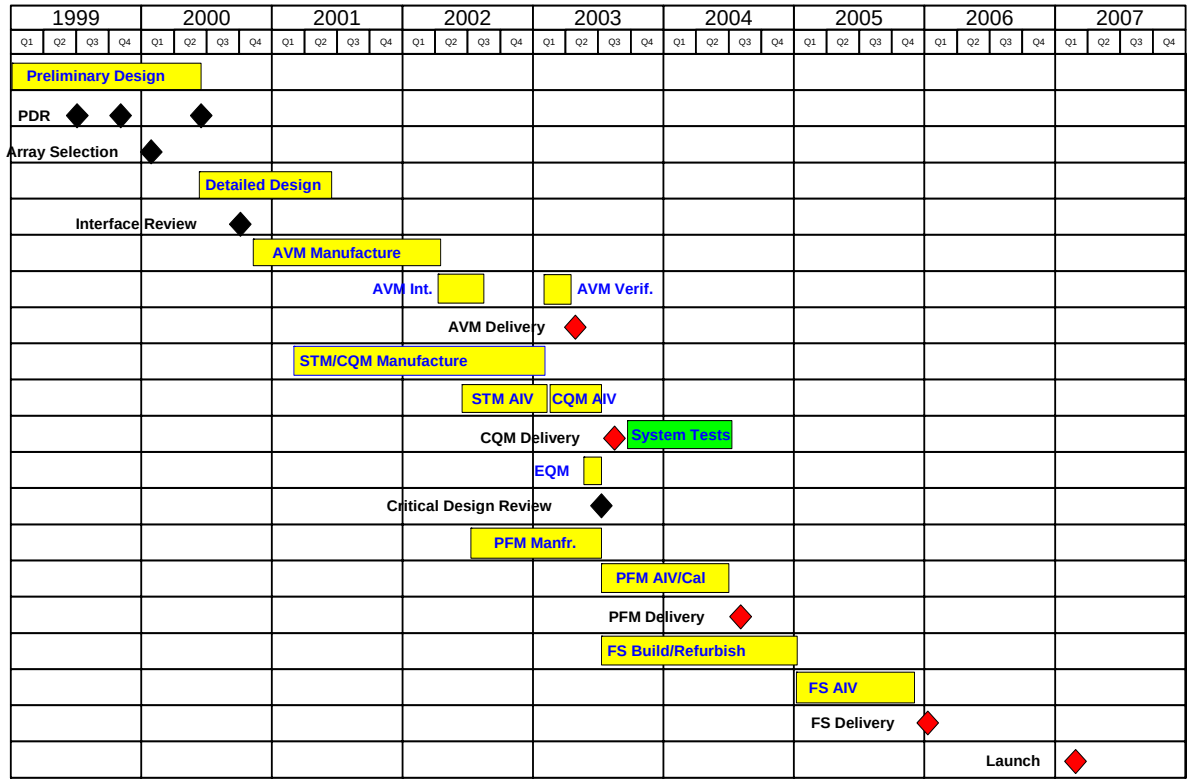


**Figure 4-1 SPIRE Overall Schedule**

A detailed schedule is maintained covering the next few months of activity throughout the development phases

### 4.1.2 Project Reviews

The project review plan is described in AD03. The dates of the reviews are listed in RD02

## 4.2 ICC

The planning for the ICC is described in the Science Implementation Plan (RD05).

# 5. CONFIGURATION MANAGEMENT

## 5.1 Configuration Management tasks

The plan for configuration management and control is given in RD03.

## 5.2 Implementation of Configuration Management

The project documentation is held on an external site (Livelink at ESA). Procedures for change control of the project documents are given in RD04.

The classes of document that are required to be under configuration control are defined in RD04.

Product Assurance documentation is also held on the project file server and maintained by the PA Manager

## 5.3 Configuration Baseline

See RD03

## 5.4 Configuration Items

See RD03

## 5.5 Change Control

See RD03

# 6. INFORMATION/DOCUMENTATION MANAGEMENT

Documentation management is described in RD04

# 7. COST AND SCHEDULE MANAGEMENT

## 7.1 Cost Management

The project uses monthly financial information provided by the SSTD Admin Group to monitor overall project spend. FRS is used to check the status of individual payments, where necessary.

Reports on project spend are made quarterly to the SSTD Departmental Project Review Board, the Laboratory Project Review Board, PPARC and the Herschel/Planck Project Director.

## 7.2 Schedule Management

RD02 contains the project milestones relating to deliveries between SPIRE institutes and between SPIRE and ESA. These milestones are reviewed regularly in the management telecoms and updated in the detailed schedule.

# 8. TECHNICAL REQUIREMENTS

Requirements on the instrument are generated from the SPIRE scientific requirements (RD09) in the form of a set of instrument requirements (RD10). The interface to the spacecraft is documented in AD04

The ICC requirements are given in AD08

# 9. PRODUCT ASSURANCE REQUIREMENTS

The requirements put on the SPIRE project are defined in RD06. The SPIRE response to these is specified in the SPIRE PA Plan (RD07).

# 10. SYSTEMS ENGINEERING

System engineering tasks are planned and monitored as part of the overall RAL activities by the Project Manager. Regular project meetings are used to identify specific system-related tasks and assigned to either the project System engineers or to appropriate SSTD groups.