Herschel-SPIRE Business Agreement

Provision of Hardware for the Detector Subsystem Subsystem of Herschel-SPIRE

SPIRE-UCF-PRJ-000822 Issue 3.0

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James J. Bock SPIRE Co-Investigator Jet Propulsion Laboratory, Pasadena, USA	**Matthew J. Griffin** SPIRE Principle Investigator Cardiff University, Wales, UK
Gerald Lilienthal U.S. SPIRE Detector Project Element Manager Jet Propulsion Laboratory, Pasadena, USA	**Kenneth J. King** SPIRE Project Manager Rutherford Appleton Laboratory, Oxfordshire, UK
Ray Carvell U.K. Herschel/Planck Programme Director PPARC, Swindon, UK	**Gary Parks** U.S. Herschel/Planck Project Manager Jet Propulsion Laboratory, Pasadena, USA

Title Page

Title: Herschel-SPIRE Business Agreement (Memorandum of Understanding)	
Scope: This document formalizes a Business Agreement (Memorandum of Understanding or MoU) between the US consortium lead by the Jet Propulsion Lab (JPL) and the California Institute of Technology (Caltech) and the UK SPIRE Project, led, by Cardiff University, Wales, UK, managed by the Rutherford Appleton Laboratory (RAL), and funded in the UK by the Particle Physics and Astronomy Research Council (PPARC). As a business agreement, it details the nature of the specific deliverables, the schedule upon which they are shipped and to whom, what expectations exist for receiving certain equipment, hardware and information in the form of decisions and documents from RAL/Cardiff and vice versa, and finally the specifications for certain performance features of the supplied flight hardware and ground support equipment. It also explains the agreements for joint calibration of the instruments and detectors and what support for the instrument test program will be required both at JPL/Caltech and at Cardiff and RAL.	
Authors:	JPL/RAL/Cardiff
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Approved by:	
JPL Co-I	J Bock
SPIRE PI	M Griffin
JPL SPIRE PEM	G Lilienthal
SPIRE PM	K King
UK Herschel/Planck PD	R Carvell
US Hershel/Planck PM	G Parks

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Rev	**Date**	**Approved by**	
1.0	**16 Aug. 2000**	**J Bock** **R Carvell** **M Griffin** **K King** **G Lilienthal** **G Parks**	Original version
2.0	**6 Sept. 2001**	**J Bock** **R Carvell** **M Griffin** **K King** **G Lilienthal** **G Parks**	• Text updated to reflect mission name change. • SPIRE Block diagram (Fig. 1) updated • Various minor changes in instrument terminology. • Some additions to the list of acronyms • Change of SPIRE PI institute from QMW to Cardiff. • Section 7 (Model Philosophy) updated • Section 9 (Rec/Dels) updated • SSSD has been updated in parallel • Sections dealing with calibrators deleted as NASA no longer providing calibrators
3.0	**4 Feb. 2003**	**J Bock** **R Carvell** **M Griffin** **K King** **G Lilienthal** **G Parks**	**Updated as per agreed change request** HR-SP-JPL-ECR-002

I. Table of Contents

1 Scope

This document serves as a Memorandum of Understanding (MoU) or Business Agreement between the US SPIRE team led by Jamie Bock of JPL, funded by NASA, and the Herschel-SPIRE Instrument Project. The SPIRE project is led by the Principal Investigator, Matt Griffin of Cardiff University, Wales, UK. It is managed by the Rutherford Appleton Laboratory (RAL), Oxfordshire, UK, and funded in the UK by the Particle Physics and Astronomy Research Council (PPARC). The agreement is applicable to fabrication, assembly, testing and delivery from JPL to RAL of hardware for the SPIRE instrument. As an MoU, it has sufficient detail to make possible the satisfactory delivery of critical hardware and documents between the implementing organizations, namely JPL/Caltech on behalf of NASA and RAL/Cardiff on behalf of the SPIRE project. This business agreement is a living document, and will updated when necessary to document any official changes between the parties. Only documents signed by both the US and SPIRE project managers are official agreements. Herschel (formerly known as FIRST) is scheduled for launch in February/March 2007. This document covers the period up to in-orbit commissioning of Herschel, scheduled to end approximately three months after the launch.

The agreement will describe:

(i) the nature of the specific deliverables;
(ii) the schedule upon which they are shipped and to whom;
(iii) what expectations exist for receiving certain equipment, hardware and information in the form of decisions and documents from RAL/Cardiff and vice versa;
(iv) the instrument requirements and specifications for certain characteristics and performance features of the supplied flight hardware and ground support equipment;
(v) the agreements for joint calibration of the instruments and detectors and what support for the instrument test program will be required both at JPL/Caltech and at RAL;
(vi) the arrangements for project management and PA activities.

2 Applicable Documents

Number	Document Name and Author	Reference
AD1	SPIRE Detector Subsystem Specification *J. Bock et al.*	SPIRE-JPL-PRJ-000456
AD2	SPIRE Major Milestone List *K. J. King*	SPIRE-RAL-PRJ-000455

3 Reference Documents

Number	Document Name and Author	Reference
RD1	SPIRE A Bolometer Instrument for FIRST (The SPIRE proposal to ESA) *The SPIRE Consortium*	SPIRE-RAL-PRJ-000020
RD2	The SPIRE Instrument for Herschel *M Griffin, B Swinyard, L. Vigroux*	Proc. ESA SP-460, *The Promise of the Herschel Space Observatory*, p. 37
RD3	Detector Array Selection Criteria For SPIRE *M Griffin*	SPIRE-QMW-NOT-000335
RD4	Herschel/Planck IID-A *H Schaap, A Heske*	SPIRE-ESA-DOC-000178
RD5	SPIRE IID-B *A Heske*	SPIRE-ESA-DOC-000275
RD6	SPIRE Scientific Requirements *W Gear and M Griffin*	SPIRE-UCF-DOC-000064
RD7	SPIRE Instrument Requirements Document *B Swinyard*	SPIRE-RAL-PRJ-000034
RD8	SPIRE Product Assurance Plan *G Douglas*	SPIRE-RAL-PRJ-000017
RD9	SPIRE Management Plan *K King*	Herschel-SPI-PRJ-000011
RD10	SPIRE Instrument Qualification Requirements *B Swinyard*	SPIRE-RAL-PRJ-000592
RD11	JPL SPIRE PA Requirements Matrix *T Larson*	JPL D-19164
RD12	JPL Management Plan *TBD*	TBD
RD13	Herschel/Planck Environmental Design and Test Requirements *B Shogrin*	JPL D-19155

4 List of Acronyms

AD	Applicable Document
BDA	Bolometer Detector Assembly
CEA/SAp	Commisariat d'Energie Atomique/Service d'Astrophysique, Saclay, France
Co-I	Co-Investigator
CQM	Cryogenic Qualification Model
CU	Colorado University
DCU	Detector Control Unit
ESA	European Space Agency
FCU	FPU Control Unit
FEA	Finite Element Analysis
FIRST	Far Infrared and Submillimeter Telescope
FPU	Focal Plane Unit
FS	Flight Spare
FTS	Fourier Transform Spectrometer
GSE	Ground Support Equipment
HSJFP	Herschel SPIRE JFET Box (Photometer)
HSJFS	Herschel SPIRE JFET Box (Spectrometer)
ICC	Instrument Control Centre
ICD	Interface Control Document
IID-A	Instrument Interface Document (Part A)
IID-B	Instrument Interface Document (Part B)
JFET	Junction Field Effect Transistor
JPL	JET Propulsion Laboratory
MoU	Memorandum of Understanding
MSSL	Mullard Space Science Laboratory
NASA	National Aeronautics and Space Agency
PA	Product Assurance
PDR	Preliminary Design Review
PFM	Proto-Flight Model
PI	Principal Investigator
PPARC	Particle Physics and Astronomy Research Council
QMW	Queen Mary and Westfield College
RAL	Rutherford Appleton Laboratory
RD	Reference Document
SPIRE	Spectral and Photometric Imaging Receiver
STM	Structural Thermal Model
SVM	Service Module
TBC	To Be Confirmed
TBD	To Be Decided

5 THE SPIRE Instrument

SPIRE, the Spectral and Photometric Imaging Receiver, will be a bolometer camera and spectrometer for ESA's Herschel satellite. Herschel will give the scientific community access to a large space-borne far-infrared and submillimetre telescope equipped with a suite of instruments for imaging photometry and spectroscopy. As Herschel is an observatory mission, the design and scientific performance of its payload is a matter for oversight by ESA on behalf of the scientific community. ESA has established the Herschel Science Team to oversee and monitor the development and scientific optimisation of Herschel. Matters affecting significantly the scientific performance of SPIRE must be referred to the Herschel Science Team.

In June 1998, SPIRE was selected by ESA as one of three science instruments for Herschel, based on a proposal submitted to ESA by a consortium of European and US scientists [RD1]. SPIRE's main scientific goals are deep extragalactic and galactic imaging surveys, and spectroscopy of star-forming regions in own and nearby galaxies. It comprises a three-band imaging photometer covering the 250-500 μm range, and an imaging Fourier Transform Spectrometer (FTS) covering 200-670 μm. The photometer has a field of view of 4 x 8 arcminutes, observed simultaneously at 250, 350 and 500 μm, with dichroic beam dividers separating the three spectral bands. Its angular resolution is determined by the telescope diffraction limit, with beam widths of approximately 17, 24 and 35 arcseconds at 250, 350 and 500 μm, respectively. An internal beam steering mirror can be used for signal modulation, and observations can also be made by scanning the telescope without chopping, giving better sensitivity for source confusion-limited deep surveys. The FTS has a field of view of 2.6 arcminutes and an adjustable spectral resolution of 0.04 - 2 cm^{-1} ($\lambda/\Delta\lambda$ = 20-1000 at 250 μm). It employs a dual-beam configuration with broad-band intensity beam dividers to give high efficiency and separated output and input ports. The design and scientific capabilities of SPIRE are described in more detail in *The SPIRE Instrument for Herschel* [RD2]. The main elements of the SPIRE instrument are shown schematically in Figure 1.

SPIRE consists of the following units (designated HSXXX in the ESA terminology, with HS standing for "Herschel SPIRE" in this context):

HSFPU: Cold Focal Plane Unit (FPU)
This interfaces to the cryostat optical bench, and the 4-K and 2-K temperature stages provided by the cryostat. Within the unit, further cooling of the detector arrays to a temperature of around 300 mK is provided by a ^{3}He refrigerator which is part of the instrument.

HSJFP: JFET box for the photometer detectors.
This box is mounted on the optical bench next to the photometer side of FPU, and contains JFET preamplifiers for the detector signals. The JFETs operate at around 120 K, and are thermally isolated inside the enclosure.

HSJFS: JFET box for the spectrometer detectors
This box is mounted on the optical bench next to the spectrometer side of the FPU, and contains JFET preamplifiers for the detector signals. The JFETs operate at around 120 K, and are thermally isolated inside the enclosure.

HSDCU: Detector Readout Unit (on Herschel SVM)
A warm analogue electronics box for detector read-out analogue signal processing, multiplexing, A/D conversion, and array sequencing.

HSFCU: Focal Plane Control Unit (on Herschel SVM)
A warm analogue electronics box for mechanism control, temperature sensing and general housekeeping and ^{3}He refrigerator operation.

HSDPU: Digital Processing Unit (on Herschel SVM)
A warm digital electronics box for signal processing and instrument commanding and interfacing to the spacecraft telemetry.

HSWIH: Warm interconnect harnesses (on Herschel SVM)
Harnesses making connections between the SPIRE warm electronics boxes.

Following a two year evaluation and test programme in which three different detector array options were studied, feedhorn-coupled NTD spider-web bolometer arrays were selected in preference to US and French filled bolometer array options as the detectors for SPIRE at a major review in February 2000. This review also constituted the SPIRE Preliminary Design Review (PDR) for the selected detector option. The selection was based on the criteria given in the document *Detector Array Selection Criteria for SPIRE* [RD3]. Among the agreed principles at this selection was that a US option, if selected, should be fully funded by NASA [RD3, p1].

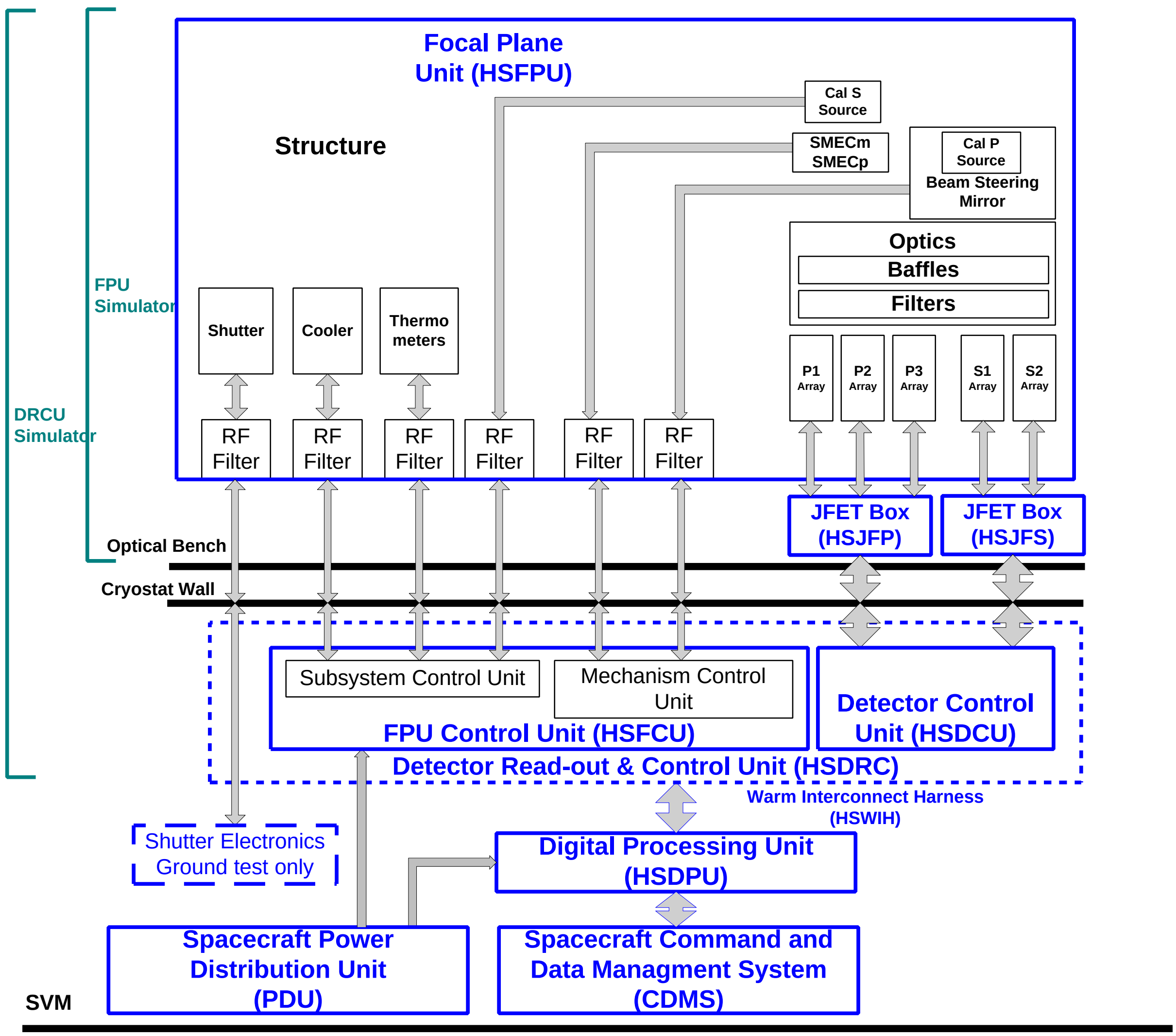

Figure 1: Functional block diagram of SPIRE

The SPIRE instrument is required by ESA to conform to the requirements laid down in the *Herschel-Planck Instrument Interface Document, Part A* (IID-A; RD4). The interfaces between the instrument and the spacecraft are described in detail in the *SPIRE Instrument Interface Document, Part B* (IID-B; RD5).

The top-level scientific requirements for SPIRE are given in the *SPIRE Scientific Requirements Document* [RD6], and the detailed requirements on the instrument systems and subsystems are given in the SPIRE *Instrument Requirements Document (IRD)* [RD7]. All SPIRE hardware delivered to ESA is required to conform to the *SPIRE PA Plan* [RD8].

6 The SPIRE Project and Consortium

SPIRE is a collaborative project with participation by institutes in Canada, France, Italy, Spain, Sweden, the UK, and the USA. The project is led by Prof. Matt Griffin of Cardiff University as Principal Investigator (PI) and managed by the Rutherford Appleton Laboratory, RAL, with Dr. Ken King as Project Manager. The PI is the formal point of contact with ESA's Herschel/Planck Project Manager and Herschel Project Scientist on all mission and science related matters. He has full responsibility in the eyes of ESA for the procurement, test and delivery of the instrument and its associated Instrument Control Centre (ICC) and supporting the Herschel Science Centre (FSC) in the operation and scientific exploitation of the instrument. Day-to-day authority for project management and responsibility and for coordination of the instrument design and development is delegated by the PI to the SPIRE Project Manager and to the SPIRE Instrument Scientist (Dr. Bruce Swinyard of RAL).

The formal arrangements for organisation and management of the SPIRE consortium are described in the *SPIRE Management Plan* [RD9), which has been formally approved by the SPIRE Co-Investigators and ESA. The following excerpt from Chapter 3 of the *SPIRE Management Plan* is given here for information:

Principal Investigator Responsibilities

The PI is the formal point of contact with the Herschel Project Manager and Herschel Project Scientist on all mission and science related matters. He has full responsibility for the procurement, test and delivery of the instrument and its associated Instrument Control Centre (ICC) and supporting the Herschel Science Centre (FSC) in the operation and scientific exploitation of the instrument. The overall responsibilities of the PI are given in [the Herschel Science Management Plan (ESA/SPC(97)22)] and are detailed in [the Herschel/PLANCK Instrument Interface Document, Part A] for the provision of instrument hardware and in [the Herschel Science Operations Implementation Requirements Document (PT-03646)] for the implementation and operation of the ICC. In this role he is supported (and, if necessary, deputised) by the Co-PI.

Co-PI

The position of Co-PI reflects the major contribution to the project from France and is indicative of the fact that all major project decisions shall be arrived at by consensus.

The SPIRE Steering Group

The SPIRE Steering Group will be responsible for the overall direction of the project, and shall agree all major policy and strategic decisions concerning the instrument development and the international allocation of tasks. It will also have the power to revise the list of SPIRE Co-Investigators and Associate Scientists. It will comprise the PI, the Co-PI and one member from each of the participating countries (Canada, France, Italy, Spain, Sweden, UK, USA). The members shall be senior figures representing the project within their own countries and before their national space agencies, and shall work to ensure that the project has the necessary support from those agencies. In particular, they shall assist the PI in solving problems associated with funding and manpower resources within their countries.

At the commencement of the project each contributing nation will commit to delivering an agreed package of work. This package can only be changed by agreement with the PI and the SPIRE Steering Group. Within each country, attribution of resources between contributing groups will be dealt with on a national level (e.g., within the UK, PPARC will set up a steering group to advise them of such issues and to act as an independent monitor of the UK elements of the project). The PI and the Steering Group will be given visibility of such attributions. In the case of problems that cannot be solved by the Steering Group, the matter will be decided through the intervention of an ad-hoc group representing the appropriate national funding bodies. The SPIRE Steering Group shall have the PI as chairman and the Co-PI as Co-chairman.

Co-Investigator Responsibilities

Each institute having hardware and/or ICC responsibilities shall designate one Co-Investigator. These shall be senior scientists or engineers with the authority to represent the SPIRE instrument within their organisations and their organisation to the SPIRE consortium, with the responsibility to deliver the work packages which have been assigned to their institute. They shall:

(i) support the definition and development of the work packages assigned to their institutes;
(ii) obtain the resources necessary to carry out the assigned work packages;
(iii) appoint a local Project Manager to handle the day-to-day management of their work packages;
(iv) appoint a local Product Assurance Manager to handle the PA responsibilities of their institute (this will involve enforcing the SPIRE project PA plan);
(v) assist the PI in solving any technical/programmatic problems associated with work allocated to their institutes;
(vi) participate in the definition and co-ordination of the Guaranteed Time programme.

They shall have an automatic right of access to Guaranteed Time data in recognition of these duties. Co-Is will be assisted by Associate Scientists, who have no formal responsibilities within the project, but may assist in the technical development and scientific optimisation of the instrument.

7 SPIRE Model philosophy

7.1 Introduction

The SPIRE instrument model philosophy conforms to the requirements of the IID-A. Three models of the instrument focal plane unit (HSFPU) and JFET boxes (HSFBP and HSFBS) are to be delivered to ESA: the Cryogenic Qualification Model (CQM), the Proto-Flight Model (PFM) and the Flight Spare (FS). In addition, SPIRE will construct and test a Structural Thermal Model (STM) for its own use. The main SPIRE FPU models are described briefly below. A more detailed account may be found in the *SPIRE Instrument Qualification Requirements Document* [RD10].

7.2 Structural Thermal Model (STM)

This is a model of the cold FPU and JFET boxes that will be used to verify the vibration levels that will be experienced by the cold sub-systems during launch and to verify that the thermal design of the instrument meets the instrument level performance requirements. A visible light optical alignment procedure will also be carried out on this model as the first stage in the verification of the SPIRE optical design. This model will also be used to qualify the design of the SPIRE structure. It will consist of the CQM structure, thermal hardware and optics, the CQM cooler and mass/thermal models of the cold sub-systems. In order to test the real vibration levels and thermal environment that will be experienced at the sub-system interfaces it will be necessary to have some of the sub-system STMs as mechanically representative as possible although there is no requirement that they should actually function. The FPU harnesses for the cold sub-systems and between the JFET boxes and the FPU should also be present to allow early test of the integration procedures and environmental robustness of the harness design. This model will be vibrated to full qualification levels at ambient temperature and, if possible, at cryogenic temperature. The model will be placed in the instrument test cryostat and full thermal characterisation will be carried out. This model is not delivered to ESA.

7.3 Cryogenic Qualification Model (CQM)

This is a model of the instrument that will be used to characterise and verify the instrument scientific performance with functionally representative cold sub-systems and warm electronics units. The structure, optics, cooler and FPU harnesses will be those used for the STM. All other cold FPU units need to function and have close to the expected flight performance, but do not need to be capable of withstanding the launch environment.

Further they do not need have the full reliability and redundancy or, in the case of the FTS mirror mechanism and beam steering mirror, necessarily have the correct power dissipation. The detectors provided for the CQM may not have flight like sensitivity or speed of response. The purpose of the CQM is to verify that the design of the PFM will be capable of meeting the instrument level performance requirements and that the instrument is compatible of integration into the Herschel satellite. The requirements on the SPIRE CQM sub-systems will be judged against these criteria on a case by case basis. This model is delivered to ESA.

7.4 Proto-Flight Model

This will be the instrument model that is intended for flight. It will be built to full flight quality. It will be the only fully integrated instrument model that has the full flight like performance characteristics. The PFM cold FPU and JFET boxes will therefore undergo environmental test to qualification levels for acceptance times (TBD). The SPIRE warm electronics units will have full qualification models built and tested, therefore the PFM warm electronics units will only undergo acceptance testing. This model is delivered to ESA.

7.5 Flight Spare Model

The IID-A requires delivery to ESA of a flight spare FPU which can be installed in place of a faulty PFM FPU during the spacecraft-level integration and test phase. The FS will be built by SPIRE, characterised and calibrated as above, and delivered to ESA. Subsystem providers have the option of supplying refurbished CQM subsystems for the FS.

8 Detector Subsystem Product Tree

It is agreed that JPL will provide instrument hardware for the SPIRE Detector Subsystem. These items and their specifications are described in AD1 . This section describes the constituents of these items, and Section 9 details the elements to be provided by JPL. The Detector Subsystem is made up of the following items (for a more complete description see AD1):

(i) five Bolometer Detector Assembly (BDA) units, three for the photometer and two for the FTS. Each unit comprises mechanical structure and fasteners, a bolometer array, a feedhorn array, a radiometric filter, cabling and connectors, and thermal interconnects.
(ii) two JFET boxes, comprising mechanical enclosures, fasteners, sets of JFET modules, sets of RF filter modules, and internal harnesses and connectors.
(iii) thermometers and heaters for thermal control of the ^{3}He temperature stage, cabling and connectors.
(iv) electrical wiring harnesses linking the BDA units and the thermal control components to the JFET module;
(v) RF filter modules for all wires going into FPU (including wires to other subsystems), with connectors and fasteners;
(vi) savers for all connectors except as noted;
(vii) ground support equipment (GSE), designed to facilitate integration and verification of the detector subsystem in the SPIRE instrument, comprises the following;
(viii) JFET and detector simulators for harness testing;
(ix) other items which may be defined and agreed by JPL and RAL after detailed design (mechanical jigs, protective shipping enclosures, specialised integration tools, etc.).

9 JPL Receivables and deliverables

9.1 Hardware

Table 1(a-d) lists the hardware deliverables and receivables for the SPIRE instrument which are covered by this agreement. Deliveries are to be made on a schedule compatible with the SPIRE Major Milestones List (AD2). The current agreed schedule for deliveries is as given in Annex A, and may be changed in the future by mutual agreement between JPL and the SPIRE Project

Table 2(a,b) indicates hardware required for testing the cabling for compatibility with the BDAs (all hardware required for cable testing is listed, although some items are not delivered or received by JPL) including hardware exchange required by the JPL and University of Colorado (CU) test programs.

The precise mechanical arrangement in which the JFET units and the RF filter units for the JFETS are to be delivered is currently TBD and will be agreed later by JPL and the SPIRE Project.

Table 1a: Hardware deliverables required for STM instrument

Item	**Del. by**	**Rec. by**
P/LW EM BDA[1]	JPL	RAL
P/MW STM BDA[2]	JPL	RAL
P/SW STM BDA[2]	JPL	RAL
S/SW STM BDA[2]	JPL	RAL
S/LW STM BDA[2]	JPL	RAL
8 JFET STM modules[3]	JPL	RAL
12 RF modules for FPU[4]	JPL	RAL
3 RF modules for JFET rack[4]	JPL	RAL
Back harnesses for JFET racks[5]	JPL	RAL

1. EM BDA is form and fit compliant, including connectors but without savers. The EM BDA has a Kevlar-suspended detector section with no active detection elements. Unit will *not* have resistors for harness checkout.
2. STM BDA is form and fit compliant, including connector stakes. Resistors at 1.7 K allow checkout of harness. A weak thermal link will connect to 0.3 K to simulate BDA parasitic dissipation.
3. JFET STM modules are fit and form compliant, including connectors, but without savers. Includes representative electrical connections and thermal dissipation. Units will be re-used in CQM instrument.
4. RF modules include savers and are fully functional and will be re-used for the CQM and FS instruments.
5. Harnesses include savers, and are to be re-used for the CQM and FS instruments.

Table 1b: Hardware deliverables required for CQM instrument

Item	Del. by	Rec. by
P/LW CQM BDA[6]	JPL	RAL
S/LW CQM BDA[6]	JPL	RAL
S/SW CQM BDA[7] (initial delivery)	JPL	RAL
3 JFET modules[8]	JPL	RAL
P/LW BDA far-infrared filter	CARDIFF	JPL
S/LW BDA far-infrared filter	CARDIFF	JPL
S/SW BDA far-infrared filter	CARDIFF	JPL

6. BDA is fully functional, but without connector savers. If the CQM BDAs provide reasonable functional equivalents, within a factor of 2 of the design NEP and time constant at optimal bias, to the flight units, the minimum performance values listed in Section 3 of the BDA-SSSD [AD1] do not have to be met. It is anticipated the speed of the detectors will increase by a factor of two under non-optimal bias. The array will be re-used for the FS instrument.
7. BDA is fully functional, but without connector savers. This unit will have been subjected to environmental testing prior to delivery, but will not have been subjected to performance testing in the BODAC array test facility. While the UK SPIRE Project accepts this de-scope as essential for schedule and cost reasons, it notes that this BDA's performance will not have been verified or characterised at unit level prior to installation ito the Flight Spare instrument. JPL is asked to assess the possibility of carrying out BODAC testing on this unit should any future schedule revision permit this.
8. JFET modules include savers and are fully functional. If the CQM JFET modules provide reasonable functional equivalents to the flight units, in the judgement of the SPIRE instrument team, the minimum performance values listed in section 3 do not have to be met. Modules to be re-used for FS instrument.

Table 1c: Hardware deliverables required for PFM instrument

Item	Del. by	Rec. by
P/LW PFM BDA[9]	JPL	RAL
P/MW PFM BDA[9]	JPL	RAL
P/SW PFM BDA[9]	JPL	RAL
S/LW PFM BDA[9]	JPL	RAL
S/SW PFM BDA[9]	JPL	RAL
8 JFET modules[10]	JPL	RAL
12 RF modules for FPU[10]	JPL	RAL
15 Harness between JFET modules and BDAs	JPL	RAL
Back harnesses for JFET racks	JPL	RAL
T/C thermometers, heaters, fixtures, and cable (TBC)[9]	JPL	RAL
P/LW BDA far-infrared filter	CARDIFF	JPL
P/MW BDA far-infrared filter	CARDIFF	JPL
P/SW BDA far-infrared filter	CARDIFF	JPL
S/LW BDA far-infrared filter	CARDIFF	JPL
S/SW BDA far-infrared filter	CARDIFF	JPL

9. Fully functional, without connector savers.
10. Fully functional, with connector savers.

Table 1d: Hardware deliverables required for FS instrument

Item	Del. by	Rec. by
P/MW FS BDA[9]	JPL	RAL
P/SW FS BDA[9]	JPL	RAL
S/SW FS BDA[10]	JPL	RAL
5 JFET modules[10]	JPL	RAL
T/C thermometers, heaters, fixtures, and cable (TBC) [9]	JPL	RAL
P/MW BDA far-infrared filter	CARDIFF	JPL
P/SW BDA far-infrared filter	CARDIFF	JPL
S/SW BDA far-infrared filter	CARDIFF	JPL

Table 2a: Test equipment required for testing at RAL

Item	Del. by	Rec. by
JFET STM modules (listed in Table 1a)	JPL	RAL
24-channel JFET cross-talk card	JPL	RAL
24-channel JFET termination card	JPL	RAL
24-channel bolometer cross-talk card	JPL	RAL
24-channel warm bolometer simulator card	JPL	RAL
STM BDAs (listed in Table 1a)	JPL	RAL
24-channel DC amplifier card	JPL	RAL
AC/DC bias generator	RAL	RAL
JFET power supply	RAL	RAL
Data acquisition system for DC testing	RAL	RAL
EM DRCU electronics	CEA	RAL
RF characterisation equipment	RAL	RAL

Table 2b: Equipment required for testing at JPL and CU

Item	Del. by	Rec. by
Filter specifications for JPL test dewar	JPL	CARDIFF
Filters for JPL test dewar	CARDIFF	JPL
Filter specifications for CU feedhorn testing	CU	CARDIFF
Filters for CU feedhorn testing	CARDIFF	CU

9.2 Documentation

Figure 2 defines the documentation of agreements on requirements and interface definitions for the JPL-provided deliverables to the SPIRE project, and their hierarchical relationship. Table 9-2-1 details who is responsible for delivery these documents and to whom. It is agreed that all of these documents will be reviewed and signed by both the SPIRE PI (or his designated alternate) and the JPL Project Manager. It is recognised by both sides that there will be other documents that duplicate some of the information in these agreements, but in all cases the agreement defines the overarching requirement. (An example of this is the SPIRE mechanical ICD, and in that case the SPIRE System Engineer is responsible for making sure there is agreement where there is duplication.)

Tables 3 and 4 itemise documentation exchange required for defining interfaces. The hardware deliverables and receivables are governed by these agreed documents, which take priority over all other documents either held within the European SPIRE instrument team, or at JPL. Signatories on the agreed documents are responsible for ensuring that the content of the agreed documents are consistent with unsigned documentation under their responsibility. Receivables and deliverables for the warm electronics development with CEA/SAp are documented in a separate business agreement for the warm electronics.

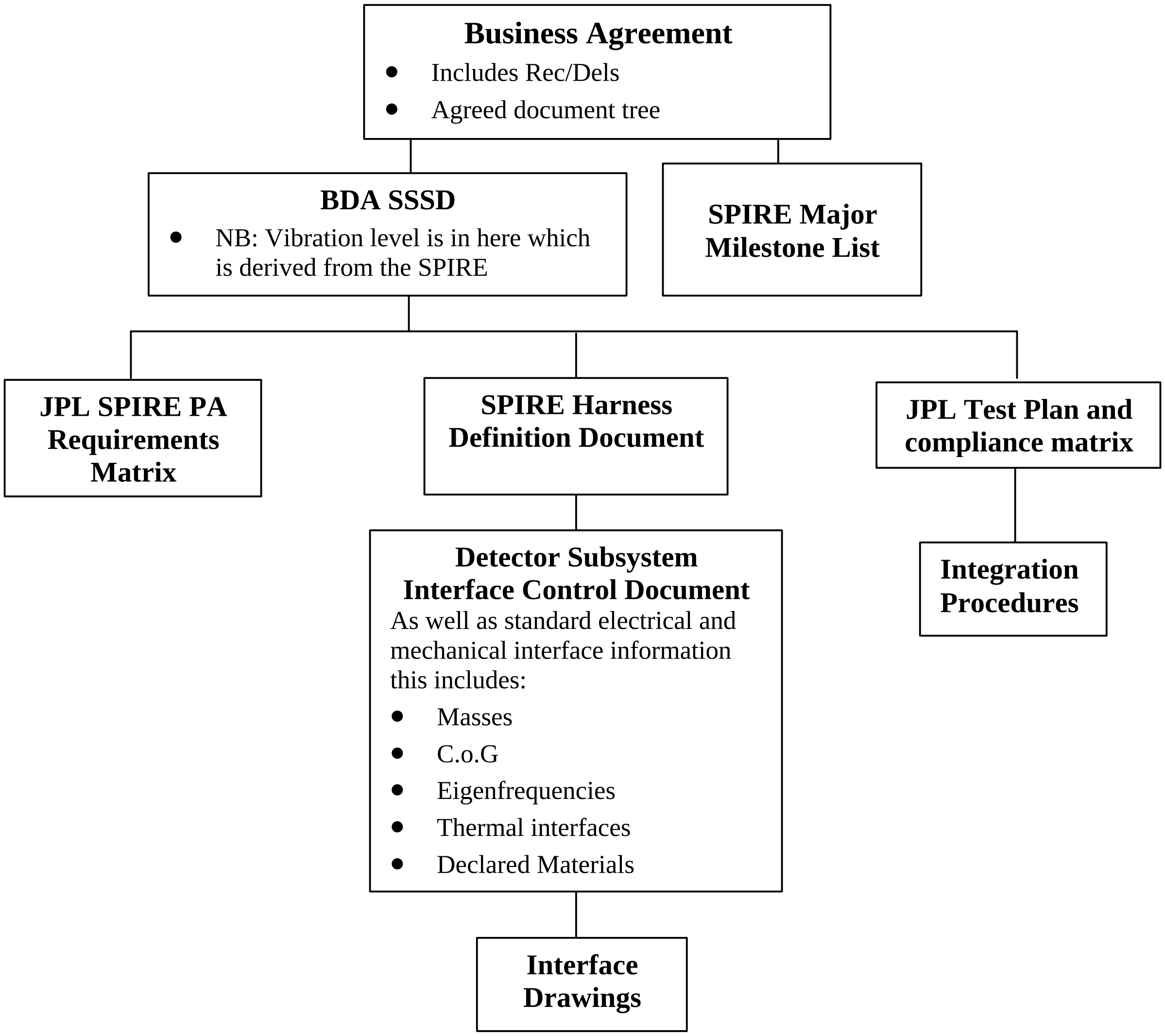

Figure 2: Official documents for JPL/SPIRE Project agreements on SPIRE

Table 3: Agreed Documentation List

Item	Del. by	Rec. by
ICD Master Document and Referenced ICDs	JPL	RAL
ICD: JFET rack	MSSL	JPL
ICD: cable length and routing	MSSL	JPL
SPIRE Harness Definition Document	RAL	JPL
Project Milestone List	RAL	JPL
Test Plan	JPL	RAL
Integration Procedures	JPL	RAL
JPL SPIRE PA Requirements Map	JPL	RAL

Table 4: Delivered Documentation

Item	Del. by	Rec. by
AIDS for all hardware	JPL	RAL
End-item acceptance package for all hardware	JPL	RAL

All documentation to be delivered is described in RD11 and RD12. Each hardware delivery shall be accompanied by an acceptance data package. RD8, the *SPIRE PA Plan*, contains details of what is normally expected by SPIRE for the acceptance data package.

Any design information not included in the delivered documentation for reasons of commercial or national security should be kept on file until three years after the end of Herschel satellite operations to allow for the possibility of its being relevant to the proper understanding of the instrument's in-orbit behaviour.

10 Detector Subsystem Specifications

The scientific capabilities and success of SPIRE naturally depend very strongly on the performance of the detectors. The Detector Subsystem, including the BDA units, shall be designed in accordance with the design values listed in the document *SPIRE Detector Subsystem Specification* [AD1]. This document is based on the *SPIRE Instrument Requirements Document* [RD7]. The Detector Subsystem design values quoted in AD1 are compatible with the scientific performance estimates on which the detector array selection/PDR in February 2000 was based. It is accepted that the achievement of all of these design values is not guaranteed and may also depend in some cases on the availability of margin on system budgets. Allocation of such margin will be made by the SPIRE Systems Engineering Team following appropriate system-level tradeoffs based on optimising the overall instrument performance. JPL is not obliged to deliver hardware that matches the design values within the allocated margin. JPL agrees with the terms described in this business agreement, which takes precedence over other documentation within the project that is not signed and agreed to by the U.S. Herschel/Planck project. In particular, JPL does not necessarily agree to abide by the IRD, in the event of additional requirements or discrepancies with the business agreement. As with all other SPIRE subsystems, differences between the design values and the IRD are noted in the subsystem specification document, allowing the system and scientific impacts to be assessed by the SPIRE project and consortium.

Any change to the design of the BDAs, JFET modules or RF filter modules after the initiation of the CQM fabrication may represent an increase in scope for the JPL deliverables, in which case it must be negotiated as a contingency.

11 Collaborative Working Arrangements

This section describes the collaborative relationships between the SPIRE Project and JPL which have been formulated to deploy the overall resources and capabilities of all parties in the most efficient and cost-effective manner.

11.1 Interface Control Documents

Interfaces between SPIRE subsystems are to be described in full detail in Interface Control Documents (ICDs), which will be jointly drawn up by the engineering teams responsible for the two subsystems. Once agreed, these will become project controlled documents and be applicable to all relevant hardware deliveries.

11.2 Systems Engineering

The scientific success of SPIRE depends on achieving the best possible performance for the bolometer arrays, which are at the heart of the instrument. It is also strongly dependent on the optimisation of the complete instrument and spacecraft system: the electrical, thermal, optical and mechanical interfaces within the focal plane unit; system modelling of the feedhorns and SPIRE optics; RF shielding of the FPU; the overall grounding scheme, the implementation of the cryoharness between the FPU and the warm electronics, and the engineering of the warm electronics and on-board data acquisition. Success therefore requires a systems approach. Whilst all participants shall have clearly defined roles and responsibilities for deliverables, it is expected and agreed that the JPL and SPIRE project teams shall collaborate and interact closely to address such systems issues in an effective manner.

11.3 BDA Test Cryostats

Two test cryostat systems shall be built up and used at JPL to test the detector arrays. The costs of hardware purchases for these systems shall be borne by JPL. Cardiff will support the provision and use of the test systems as follows:

(i) the cryogenic and optical design of the BDA test cryostats shall be done at Cardiff (in consultation with JPL);
(ii) Cardiff shall provide several components through in-house manufacture (radiation shields, thermal straps, filters, cryostat window, mounts for optical components, internal blackening and baffles, etc.);
(iii) Cardiff shall assemble, commission and characterise the cryostats and their internal optical and cryogenic components prior to delivering them to JPL for integration of the electrical systems and final commissioning;
(iv) Cardiff staff will assist with array testing at JPL, within the limits of available resources.

11.4 FET Module Enclosures

The UK shall be responsible for the design, manufacture and qualification of the enclosures housing the JFET modules to be provided by JPL. The detailed design work and procurement shall be done by the UK following close consultation with JPL staff on the conceptual design and interface definition.

11.5 Feedhorn Modelling and Testing

In support of the provision of the feedhorn arrays, the UK shall, within the limits of available resources, assist with

(i) feedhorn optical performance modelling;
(ii) feedhorn beam profile testing using facilities at Cardiff and/or RAL;
(iii) provision of filters for the feedhorn test facility at the University of Colorado (CU).

These activities shall be organised by a joint US-UK working group led by Jason Glenn of the University of Colorado.

12 JPL Participation in SPIRE Instrument Testing and Calibration and SPIRE ICC Development

The U.S. SPIRE team will support at RAL the detector subsystem integration, instrument-level environmental testing, and instrument-level calibrations impacting the detectors. Within the limits of available resources, the U.S. SPIRE team will participate in the instrument evaluation at RAL, and participate in the development of the SPIRE Instrument Control Centre (ICC).

13 Working Relationship

SPIRE is a collaborative project in which all participating institutes and individuals will work together as partners; however, the SPIRE PI has final responsibility to ESA for the end-to-end performance of the SPIRE payload.

13.1 Reviews

SPIRE will hold a series of internal and external reviews of all SPIRE hardware subsystems that will be consistent with the review requirements of ESA as laid out in the IID-A. Additional reviews will be held as deemed appropriate by NASA and SPIRE. These reviews will be open to both Cardiff/RAL, NASA and PPARC. The SPIRE Project Manager or a representative nominated by him will have a seat on NASA’s internal review boards and NASA will have a seat on SPIRE’s internal review boards relating to JPL-contributed elements of the project. The SPIRE Project Manager or his nominee will have a seat on NASA’s anomaly review board.

13.2 Disagreements

Any disagreements that cannot be resolved between the NASA Herschel Project Manager and the SPIRE Project Manager will be resolved by the NASA Associate Administrator for Space Science and the SPIRE PI.

Herschel-SPIRE Business Agreement
Annex A: Need Dates for Receivables and Deliverables

Table A1: Need dates for hardware deliverables for STM instrument

Item	Del. by	Rec. by	Need Date
P/LW STM suspended BDA	JPL	RAL	20 Jan. 2003
P/MW STM BDA	JPL	RAL	20 Jan. 2003
P/SW STM BDA	JPL	RAL	20 Jan. 2003
S/SW STM BDA	JPL	RAL	20 Jan. 2003
S/LW STM BDA	JPL	RAL	20 Jan. 2003
8 JFET STM modules	JPL	RAL	15 Mar. 2003
12 RF modules for FPU	JPL	RAL	28 Feb. 2003
15 Harness between JFET modules and BDAs	JPL	RAL	1 Apr. 2003
Back harnesses for JFET racks	JPL	RAL	15 Mar. 2003

Table A2: Need dates for hardware deliverables required for CQM instrument

Item	Del. by	Rec. by	Need Date
P/LW CQM BDA	JPL	RAL	30 May 2003
S/LW CQM BDA	JPL	RAL	30 May 2003
S/SW CQM BDA (untested delivery)	JPL	RAL	30 May 2003
3 JFET modules (a)	JPL	RAL	30 May 2003
P/LW BDA far-infrared filter	CARDIFF	JPL	1 Dec. 2002
S/LW BDA far-infrared filter	CARDIFF	JPL	15 Jan. 2003
S/SW BDA far-infrared filter	CARDIFF	JPL	15 Jan. 2003
P/LW CQM BDA (b)	RAL	JPL	1 Jun. 2004
S/LW CQM BDA (b)	RAL	JPL	24 Jul. 2004
S/SW CQM BDA (b)	RAL	JPL	6 Jan. 2004

Notes to Table A2:
(a) An earlier delivery (beginning of April) would allow cold harness check-out
(b) These need dates are dictated by the requirement to refurbish QCMs in order to deliver FS BDAs

Table A3: Need dates for hardware deliverables required for PFM instrument

Item	Del. by	Rec. by	Need Date
P/LW PFM BDA (a)	JPL	RAL	1 Jan 04
P/MW PFM BDA (a)	JPL	RAL	1 Jan 04
P/SW PFM BDA (a)	JPL	RAL	1 Jan 04
S/LW PFM BDA (a)	JPL	RAL	1 Jan 04
S/SW PFM BDA (a)	JPL	RAL	1 Jan 04
8 JFET modules	JPL	RAL	1 Jan 04
12 RF modules for FPU	JPL	RAL	1 Jan 04
15 Harness between JFET modules and BDAs	JPL	RAL	1 Jan 04
Back harnesses for JFET racks	JPL	RAL	1 Jan 04
T/C thermometers, heaters, fixtures, and cable (TBC)	JPL	RAL	1 Jan 04
P/LW BDA far-infrared filter (b)	CARDIFF	JPL	3 Feb 2003
P/MW BDA far-infrared filter (b)	CARDIFF	JPL	3 Feb 2003
P/SW BDA far-infrared filter (b)	CARDIFF	JPL	3 Feb 2003
S/LW BDA far-infrared filter (b)	CARDIFF	JPL	3 Feb 2003
S/SW BDA far-infrared filter (b)	CARDIFF	JPL	3 Feb 2003

Notes to Table A3:

(a) Need dates for the PFM BDAs are determined by the PFM instrument AIV schedule. This is not currently compatible with JPL schedule. Options for work-around around are:

(i) Project accepts lower level of testing on the final BDA

(ii) JPL request waiver on delivery of final BDA

The Project recommends that one of the spectrometer BDAs be delivered last.

(b) Phased delivery to be defined that matches JPL test schedule.

Table A4: Need dates for hardware deliverables required for FS instrument

Item	Del. by	Rec. by	Need Date
P/MW FS BDA	JPL	RAL	10 Jan. 2005
P/SW FS BDA	JPL	RAL	10 Jan. 2005
S/SW FS BDA (a)	JPL	RAL	10 Jan. 2005
5 JFET modules	JPL	RAL	10 Jan. 2005
T/C thermometers, heaters, fixtures, and cable (TBC)	JPL	RAL	10 Jan. 2005
P/MW BDA far-infrared filter	CARDIFF	JPL	1 Sept. 2003
P/SW BDA far-infrared filter	CARDIFF	JPL	1 Sept. 2003
S/SW BDA far-infrared filter	CARDIFF	JPL	1 Sept. 2003
P/LW CQM BDA	JPL	RAL	10 Jan. 2005
P/SW CQM BDA	JPL	RAL	10 Jan. 2005

Note to Table A4:

(a) The baseline plan is that this BDA is shipped, without BODAC tests, for use in the CQM and subsequently the FS without return to the US for testing in BODAC. The above delivery only applies to the alternative option of returning the unit after the CQM programme for testing and return to the UK for use in the FS.

Table A5: Need dates for test equipment required for testing at RAL

Item	Del. by	Rec. by	Need Date
24-channel JFET cross-talk card	JPL	RAL	1 May 2003
24-channel JFET termination card	JPL	RAL	1 May 2003
24-channel bolometer cross-talk card	JPL	RAL	1 May 2003
24-channel warm bolometer simulator card	JPL	RAL	1 May 2003
24-channel DC amplifier card	JPL	RAL	Delivered
AC/DC bias generator	RAL	RAL	1 May 2003
JFET power supply	RAL	RAL	1 May 2003
Data acquisition system for DC testing	RAL	RAL	1 May 2003
QM1 DRCU electronics	CEA	RAL	1 May 2003
RF characterisation equipment	RAL	RAL	1 May 2003

Table A6: Need dates for equipment required for testing at JPL and CU

Item	Del. by	Rec. by	Need Date
Filter specifications for JPL test dewar	JPL	CARDIFF	Delivered
Filters for JPL test dewar	CARDIFF	JPL	Delivered
Filter specifications for CU feedhorn testing	CU	CARDIFF	Delivered
Filters for CU feedhorn testing	CARDIFF	CU	Delivered