SPIRE

SPIRE PROJECT DOCUMENT

REDEFINITION OF THE SHUTTER SUBSYSTEM

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1 Scope of the document

This document proposes a revision of the rationale for the SPIRE shutter subsystem. Revised requirements and interfaces are proposed.

2 Documents

2.1 Applicable documents

Table 1: Applicable Documents.

	Title	Author	Reference	Date
AD1	Outline Requirements for the SPIRE Shutter	B.M. Swinyard	SPIRE-RAL-NOT-167 Iss 0.1	09.02.00
AD2	Instrument Requirements Document	B.M. Swinyard	SPIRE-RAL-PRJ-000034 Iss 0.30	05.00
AD3	SPIRE Interface Matrix	C.R. Cunningham	SPIRE-RAL-xxx-nnnnnn Iss 0.40	18.01.99

2.2 Reference documents

Table 2: Reference Documents.

	Title	Author	Reference	Date
RD1	FIRST Telescope Specification	B. Guillaume, T. Passvogel	PT-RQ-04671 Iss 1.A	01.98
RD2	FIRST/Planck Instrument Interface Document, Part B: SPIRE	A. Heske	PT-SPIRE-02124 Iss 0.4	15.05.00
RD3	SPIRE Structure Subsystem Specification Document	B. Winter	SPIRE-MSS-PRJ-0000427 Iss 1.0	13.06.00

3 Glossary

BOL	Beginning of Life
CDR	Critical Design Review
CQM	Cryogenic Qualification Model
CSA	Canadian Space Agency
DDR	Detailed Design Review
DM	Development Model
DPU	Digital Processing Unit
DRCU	Detector Read-out and Control Unit
ESA	European Space Agency
FPU	Focal Plane Unit
FS	Flight Spare
IID	Instrument Interface Document
OBS	Onboard Software
PDR	Preliminary Design Review
PFM	Proto-Flight Model
RAL	Rutherford Appleton Laboratory
TBC	To Be Confirmed
TBD	To Be Determined
USK	University of Saskatchewan

4 Revised Rationale for the Shutter

In the FIRST flight configuration, the background flux on the SPIRE detectors will be limited by emission from the FIRST telescope (temperature 80 K, emissivity ~4%). The detectors will be optimised for operation in this low-background environment (Figure 1).

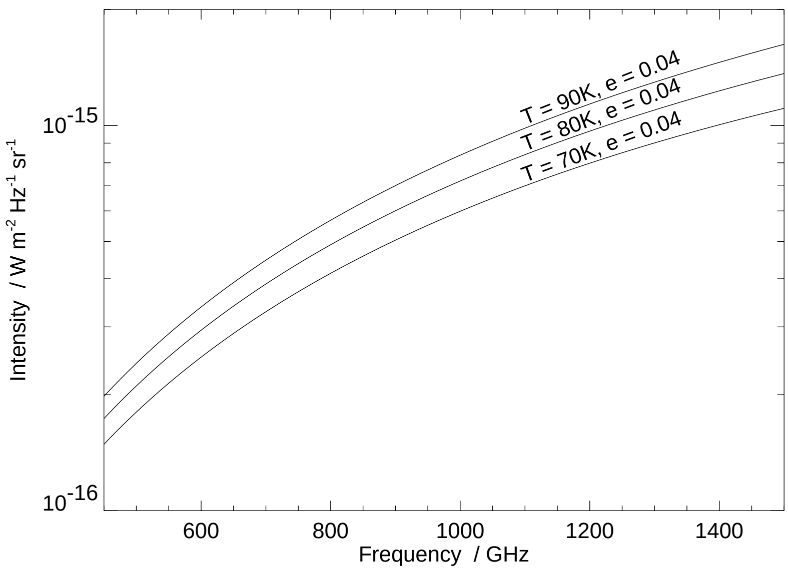

Figure 1: **Telescope thermal emission spectra.** The telescope emission intensity is shown over the SPIRE spectral range, 450–1500 GHz. The three temperatures indicated are the minimum, nominal and maximum telescope temperatures. The emissivity is 4% in all cases, which is the BOL value.

This environment will be simulated in the SPIRE test facility by the use of neutral-density filters in the test cryostat. During the period between spacecraft integration and launch, however, this low background will not be available because the lid of the spacecraft cryostat will be closed and will not be cooled. The worst case is shown in Figure 2, in which the telescope emission spectrum is compared with that of the lid, assumed to be at 300K with an emissivity of 1. The background is roughly two orders of magnitude higher than in orbit. This makes it impossible to operate the detectors (and therefore also to carry out a wide range of other instrument tests) from the point of delivery to ESA until after launch, a period of nearly three years (July 2004 to April 2007).

It was to accommodate this situation that a shutter was added to the instrument design. The shutter was originally to be located in front of M4 and was applicable to the photometer only (see AD1). The existing requirements (AD2) were specified with this configuration in mind. Specifically, since the on-board photometer calibrator could not be operated with shutter vane in the beam, the shutter was required to provide a range of fluxes for calibration purposes. Further, some of the requirements are appropriate for flight operation of the shutter, when in fact it has not been agreed that the shutter should be flight-capable at all.

Since AD1 was issued, the shutter has been moved to a different location: the current design has it in the fore-optics of the instrument such that it will be the first optical element encountered

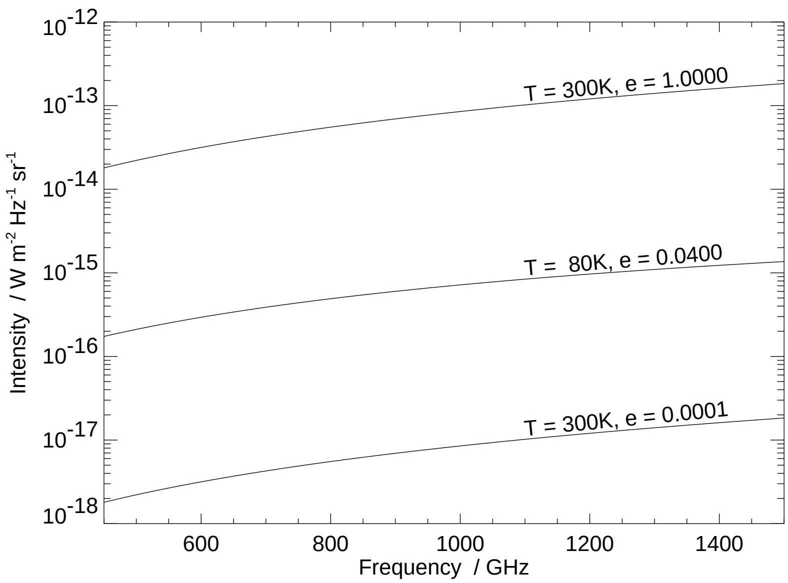

Figure 2: **Lid and shutter thermal emission spectra.** Thermal emission spectra are shown for three cases: the cryostat lid at 300K with an emissivity of 1 (worst case); the shutter vane at 80K with an emissivity of 4%; and the cryostat lid, attenuated by a factor of 10^{-4}.

by the input beam (Figure 3). The shutter thus has two roles:

1. to reject the (high) input flux from the cryostat lid; and
2. to simulate the background flux from the FIRST telescope.

This change has profound implications since it significantly alters the requirements to be placed on the shutter. For one thing, moving the shutter to the fore-optics permits the on-board calibrators to be used simultaneously, so there is no longer any need for the shutter to provide a calibration signal.

The most significant effect of the change of location is that there is now little need for the shutter to be flight capable. Once the instrument is in orbit the background flux will be provided directly from the telescope itself. The only cases in which we might want to activate the shutter are:

1. If the instrument calibration turns out to be significantly different from the calibration obtained on the ground, then inserting the shutter vane into the beam would permit us to re-create the ground test conditions. This would enable us to distinguish between a genuine change in the instrument calibration and some other mission-level effect such as a nonconformance of the telescope with its specification.
2. The shutter could conceivably be used as a safety mechanism automatically actuating into the beam if an anomalously high signal is detected. This could be caused by, e.g., the telescope being accidentally pointed at the Sun.

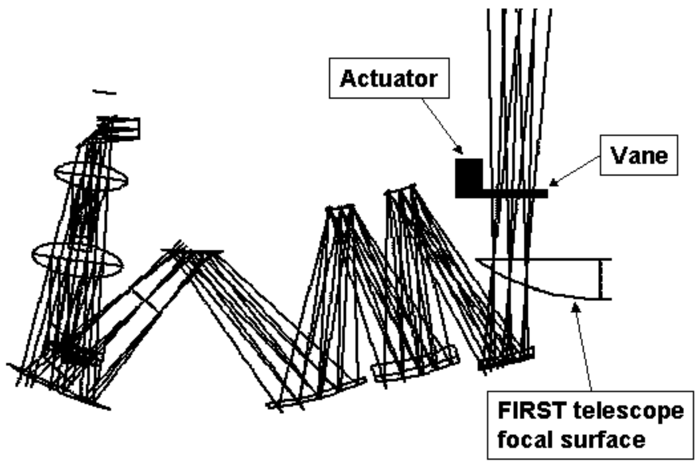

Figure 3: **Shutter location.** The shutter will be located near the focal surface of the FIRST telescope.

These eventualities must be weighed against the cost and risk of making the shutter flight-capable. In particular, making the shutter flight-capable would:

- increase the total cost of the subsystem (probably);
- increase the risk of a single-point failure in the instrument (if the vane fails in the beam in orbit, then all instrument capability is lost, but if the vane fails in the beam on the ground it is still technically possible to fix it);
- increase the risk of a schedule slip since flight electronics and flight software would be required. Given that we were late joining the project, interfaces with the DRCU and OBS will be difficult to define on the required time scale.

We therefore propose that the shutter be designated for ground use only. The case for flight use is weak and the technical and programmatic costs associated with flight capability are high.

5 Revised Performance Requirements

In this section, we propose that the performance requirements as specified in AD2 be revised as outlined in Table 3.

Table 3: Revised performance requirements.

Performance Requirements	
Requirement ID	**IRD-SHUT-R01**
Description	Beam rejection
Value	When the shutter vane is in the beam, the input beam from the cryostat shall be reflected back out of the instrument; less than 10^{-4} of the incoming energy shall remain in the beam into the instrument.
Rationale	The flux from the cryostat lid must be reduced to a level which is negligible with respect to the flux emitted by the shutter vane itself (IRD-SHUT-R02). As long as the shutter vane completely blocks the beam, this requirement should be easily met. The lowest curve in Figure 2 shows the cryostat lid emission attenuated by a factor of 10^{-4}.
Caveat	Not all of the reflected energy will go back out through the entrance aperture; some will remain in the instrument as stray light. This needs to be modelled and accounted for.
Requirement ID	**IRD-SHUT-R02**
Description	Vane emission
Value	The thermal emission spectrum of the shutter vane shall simulate the thermal emission spectrum of the FIRST telescope over the full range of expected temperatures and for the nominal BOL emissivity. The telescope temperature and emissivity are defined in RD1. There shall be at least 8 steps over the temperature range.
Rationale	As stated in Section 4 above, the role of the shutter is to provide a background flux to simulate the telescope emission spectrum. This essentially specifies that the shutter vane must have an emissivity of 4%, and that its temperature shall be controllable in the range 70-90 K.
Requirement ID	**IRD-SHUT-R03**
Description	Vane states
Value	The shutter vane shall have three states: • In: the vane is in the beam • Out: the vane is out of the beam • Locked: the vane is locked out of the beam All three states shall be commandable. The vane shall be capable of manual unlocking from its locked state.
Rationale	The vane will be commanded into the locked position before launch. At this time it will be inside the FIRST cryostat, so this must be a commandable remote operation rather than a manual one. The vane will also be put in the locked position whenever launch conditions are being simulated, e.g., during vibration. A manual unlocking capability is required so that it can be used again subsequently.

6 Revised System Requirements

In this section, we propose that the performance requirements as specified in AD2 be revised as outlined in Table 4.

Table 4: Revised system requirements.

System Requirements	
Requirement ID	**IRD-SHUT-R04**
Description	Failure mode
Value	Any failure of the shutter mechanism must result in the vane relaxing to the locked position.
Rationale	The vane must relax to the locked position since this is the launch position. This requirement is not relaxed at all by restricting the shutter to ground use only because SPIRE will be inaccessible after the tank is charged with cryogen.
Requirement ID	**IRD-SHUT-R05**
Description	Operating temperature
Value	The shutter shall be capable of operation at room temperature and at instrument temperature. The nominal instrument temperature is specified in RD2 (current value 4K) and the maximum instrument temperature is specified in RD2 (current value 6K).
Rationale	Operation at instrument temperature is a *sine qua non.* Testing the mechanism is considerably easier if it is capable of room temperature operation as well.
Requirement ID	**IRD-SHUT-R06**
Description	Operating orientation
Value	The shutter mechanism shall be capable of operation in any orientation.
Rationale	The instrument will be placed into different orientations at different stages of the AIV activity. Operational problems are avoided if the shutter can operate in any orientation.
Requirement ID	**IRD-SHUT-R07**
Description	Actuator Envelope
Value	**X** x **Y** x **Z** = 40mm x 30mm x 80mm, using the x, y, z coordinate system defined in RD3.
Rationale	Shutter envelope is limited by space available at the proposed location on the SPIRE optical bench.
Requirement ID	**IRD-SHUT-R08**
Description	Eigenfrequency
Value	The first eigenfrequency of the shutter mechanism in the locked position shall be greater than 200 Hz. In other vane states, the eigenfrequencies are irrelevant.
Rationale	This is necessary for compatibility with the design of the SPIRE structure.
Requirement ID	**IRD-SHUT-R09**
Description	Materials
Value	The shutter mechanism shall be constructed from materials which are compatible with the SPIRE structure.
Rationale	This is necessary for compatibility with the design of the SPIRE structure.

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Shutter System Requirements

Requirement ID	**IRD-SHUT-R10**
Description	Transition time
Value	The time required to change vane state shall be less than the thermal stabilisation time.
Rationale	This ensures that the moving the vane in and out of the beam will not affect the speed of the instrument test procedures. It is assumed that the vane heater will only be powered when the vane is in the 'IN' state.
Requirement ID	**IRD-SHUT-R11**
Description	Thermal stabilisation time
Value	The time required to establish a stable vane temperature shall not exceed 10 minutes.
Rationale	The number is essentially arbitrary. The aim is to ensure that bringing the vane from instrument temperature to telescope temperature will not hold up the test programme unduly.
Requirement ID	**IRD-SHUT-R12**
Description	Thermometry
Value	Two thermometers shall be included in the subsystem design, one on the vane and one on the actuator.
Rationale	The temperature of the vane must be monitored since it its temperature is to be controlled. The temperature of the actuator must be monitored as part of the instrument housekeeping.
Requirement ID	**IRD-SHUT-R13**
Description	Shutter subsystem thermal dissipation
Value	The temperature of the surrounding structure shall rise by no more than TBD K after TBD s when the shutter subsystem is energised.
Rationale	Since the shutter is for ground use only, dissipation of LHe is not at issue. This requirement is to ensure that the thermal state of the instrument is not perturbed by use of the shutter.
Requirement ID	**IRD-SHUT-R14**
Description	Cryoharness thermal dissipation
Value	TBD
Rationale	Thermal dissipation from the cryoharness is to be minimised.

7 Revised Interfaces

The current version of the SPIRE Interface Matrix specifies that the shutter subsystem has interfaces with 8 other SPIRE subsystems (AD3). If the shutter is designated for ground use only, then there will be fewer interfaces and the nature of those that remain will change. The interfaces are discussed individually in Table 5. A block diagram of the instrument, indicating the shutter control configuration, is given in Figure 4.

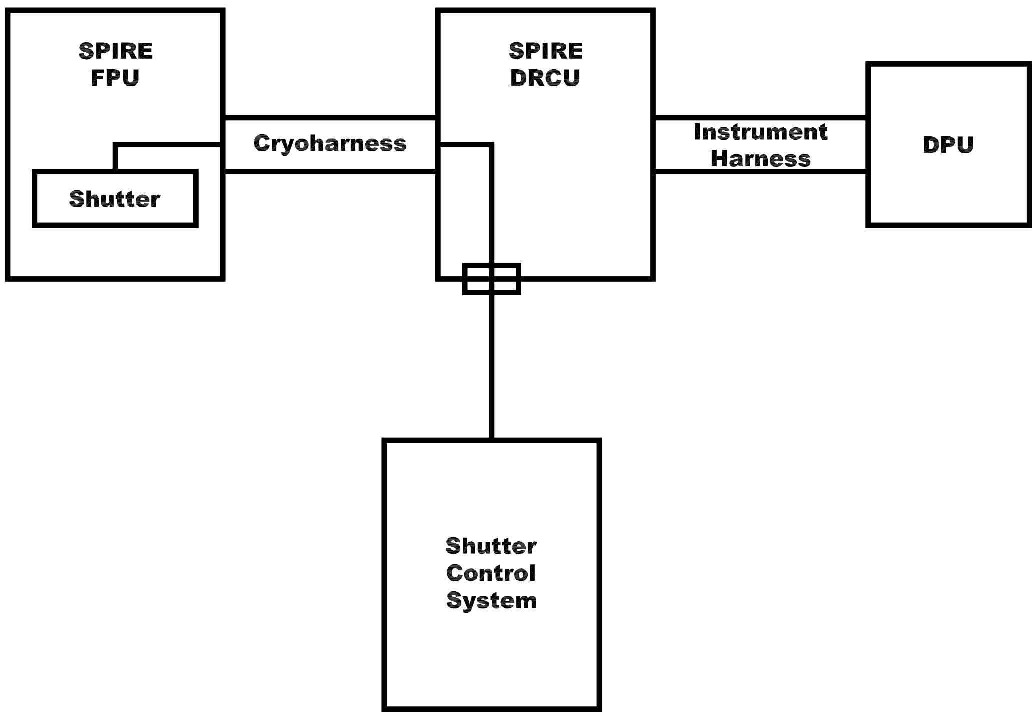

Figure 4: **Shutter block diagram.** The shutter subsystem will be connected to its control system through the cryoharness and the DRCU.

Table 5: Revised interfaces.

Interface	Description
DRCU	The DRCU will not contain any electronics for the subsystem. Wires for the shutter subsystem will be routed through the DRCU from the cryoharness to a test connector.
OBS	This interface should be deleted.
FPU simulator	This interface should be deleted.
DRCU simulator	This interface should be deleted.
Instrument Interface Document	This interface remains since the cryoharness will contain wires for the shutter subsystem.
Structure	The shutter subsystem will be mechanically attached to the SPIRE instrument structure. This interface will specify the attachment details, volume, mass, etc. It will also specify the routing of the shutter wiring harness.
Optics	The shutter interfaces with the optical system since its purpose is to reject the incoming beam and illuminate the detectors with a background flux. The location of the shutter vane will be specified through this interface.
Baffles	The shutter interfaces with the baffle system to ensure that stray light is adequately rejected when the vane is in the beam.