Interface FMECA Qualification Status Report for CDR

B. Swinyard

Prepared by: Bruce Swinyard – RAL
Issue 2 March 2007 Update - DKG

Approved by: Eric Sawyer RAL
Ken King RAL

Digitally signed by Douglas Griffin
Digitally signed by Eric Sawyer
Date: 2007.03.13 14:40:38 Z
Digitally signed by Ken King
Date: 2007.03.13 15:05:25 Z

Distribution: SPIRE Project
SPIRE Sub-system Managers
ESA Project

0 Scope

This document reports on the qualification status of the possible failures of the interfaces identified in AD1. This exercise is done as part of the SPIRE Critical Design Review to ensure that the instrument level qualification programme has adequately addressed all possible system critical failures and reduced the criticality level to an acceptable degree.

1 Applicable and Reference Documents

1.1 Applicable Documents

AD1 – SPIRE/Herschel Interface FMECA SPIRE-RAL-PRJ-001260 iss 1.0 November 2002
AD2 - Space product assurance: Failure modes, effects and criticality analysis (FMECA) – ECSS-Q-30-02A

1.2 Reference Documents

RD1 – Design Description Document - SPIRE-RAL-PRJ-000620
RD2 – SPIRE Block Diagram - SPIRE-RAL-DWG-000646 issue 6.0
RD3 - DRCU - Architecture and Reliability Analysis Report - SAp-SPIRE-FLo-0039-01
RD4 – SPIRE Structure FMECA - MSSL/SPIRE/PA005.01
RD5 – SPIRE DPU FMECA - SPIRE-IFS-DOC-000785
RD6 – SPIRE Mechanical Interface Control Drawing pack – SPIRE-RAL-DWG-001409 issue 14

2 Document Status

ISSUE	DATE	Comments/Changes
0.1	24 June	Draft for comment from ESA PA
1.0	12 July 2004	Initial release
2.0	1 Feb 2007	Updated the effect of shorts in signal lines in the cryoharness. Corrected a typo (changed JPS to JFP)

3 Methodology

3.1 Definitions

As a reminder the definitions of Severity Number; Probability Number and Criticality number used in AD1 and throughout this document are as follows are as follows (taken from AD2):

Table 3-1: Definition of Severity Category

Severity category	**Failure effect**
Catastrophic 1S	Loss of life, life threatening or permanently disabling injury or occupational illness, loss of an element of an interfacing manned flight system.
	Loss of launch site facilities.
	Long-term detrimental environmental effects.
Catastrophic 1	Propagation of failure to other subsystems/assemblies/equipment.
Critical 2S	Temporary disabling but not life threatening injury, or temporary occupational illness.
	Loss of, or major damage to other flight systems, major flight elements, or ground facilities.
	Loss of, or major damage to public or private property.
	Short-term detrimental environmental effects.
Critical 2	Loss of functionality.
Major 3	Degradation of functionality.
Negligible 4	Any other effect.

Table 3-2: Equivalent Severity Number

Severity category	SN
1S, 1 catastrophic	4
2S, 2 critical	3
3 major	2
4 negligible	1

Table 3-3: Probability Number

Level	Limits	PN
Probable	P > 10E—2	4
Occasional	10E--4 < P ≤ 10E—2	3
Remote	10E--5 < P ≤ 10E—4	2
Extremely remote	P ≤ 10E—5	1

For the SPIRE interfaces to the Herschel system considered here there is no risk of personal injury; damage to the launch site or long term environmental effects; severity categories 1S and 2S therefore do not apply. Severity category 1 is considered appropriate to consider as it is possible that failure of a SPIRE interface may propagate to other parts of the system. Severity categories 2,3 and 4 are self explanatory and used as defined in table 4-1.

Whilst the epithets *probable; occasional; remote* and *extremely remote* are used to give a judgement on the likelihood of a failure when determining the criticality of an interface, placing a numerical limit on them as defined in table 3-3 is not realistic as the nature of the interfaces considered does not permit this type of analysis.

The Criticality Number for an interface failure mode is defined in the standard way as SN x PN. Any interface failure mode with a criticality greater than 8 is considered unacceptable to the SPIRE project team. The design of all interfaces has been analysed to ensure that the level criticality is always ≤8. Interfaces that are fully cold redundant are designated with a criticality number #R. Some interfaces, such as the connectors to the JFET units, are partially redundant only so are not designated #R

3.2 Assessment Method

Each interface identified in AD1 is listed in the table below together with the mitigation statement from AD1 and a note of any design changes since AD1 was prepared. Any test carried out the interface is also listed, the outcome of the test reported and the effect on the probability of failure of the test outcome is given as a new number in the PN column with NC for no change; I for increased or D for decreased . Some interfaces have yet to be fully tested. These too are noted and the level at which the test will be carried out is discussed.

3.3 Conclusions

Of the critical interfaces tested so far, mostly the mechanical type, no test has revealed an increased probability of failure. In some cases the analysis of the testing is outstanding at the time of this report, for instance the RF filtered connector. This report will be updated following the CQM second cold test and again following the qualification programme for the SPIRE warm electronics. These programmes are expected to be completed in September 2004 and February 2005 respectively.

Table 4-4: FMECA WorkSheets for SPIRE Interfaces to Herschel

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSFPU	IF1.1-1.3	Mechanical mounting feet	Collapse or breakage due to launch environment	Mitigated by instrument level qualification program and instrument/system level acceptance testing. If failure occurs no recovery is possible.	Yes – will be changed from stainless steel to CFRP	SM and CQM vibration programmes tested instrument Test reports MSSL-TECHNOTE-SPIRE22 SPIRE-MSS-REP-002049 EM CFRP feet have been through static load test – no report.	Stainless steel feet survived multiple vibration warm and cold. CFRP A-frames passed test o.k. CFRP FPU cone failed and requires redesign. If CFRP development programme not successful instrument will fly with stainless steel feet.	4	1 NC	4
HSFPU	IF2.1-2.2	Level 0 Thermal Straps to cooler	Breakage of the strap supports due to launch environment. Strap remains connected to tank but may contact HOB or SPIRE instrument box	Mitigated by instrument level qualification program and instrument/system level acceptance testing. Depending on precise failure some instrument operation may still be possible with reduced efficiency	Yes – straps made larger with more robust supports. Engineering model straps vibrated on CQM instrument	Cold vibration test on CQM instrument SPIRE-MSS-REP-002049	Passed with no effect on instrument.	4	1 NC	4

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSFPU	IF2.1-2.2	Level 0 Thermal Straps to cooler	Breakage of strap support at light baffle due to launch environment. Strap remains connected to tank but may contact SPIRE instrument box	Mitigated by instrument level qualification program and instrument/system level acceptance testing. Depending on precise failure some instrument operation may still be possible with reduced efficiency	Yes – straps made larger with more robust supports. Engineering model straps vibrated on CQM instrment	Cold vibration test on CQM instrument SPIRE-MSS-REP-002049	Passed with no effect on instrument.	4	1 NC	4
HSFPU	IF2.3	Level 0 Thermal Straps to detector box	Breakage of the strap supports due to launch environment. Strap remains connected to tank but may contact HOB or SPIRE instrument box	Mitigated by instrument level qualification program and instrument/system level acceptance testing. Depending on precise failure some instrument operation may still be possible with reduced efficiency	Yes – straps made larger with more robust supports. Engineering model straps vibrated on CQM instrment	Cold vibration test on CQM instrument SPIRE-MSS-REP-002049	Passed with no effect on instrument.	4	1 NC	4

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSFPU	IF2.3	Level 0 Thermal Straps to detector box	Breakage of strap support at light baffle due to launch environment. Strap remains connected to tank but may contact SPIRE instrument box	Mitigated by instrument level qualification program and instrument/system level acceptance testing. Depending on precise failure some instrument operation may still be possible with reduced efficiency	Yes – straps made larger with more robust supports. Engineering model straps vibrated on CQM instrment	Cold vibration test on CQM instrument SPIRE-MSS-REP-002049	Passed with no effect on instrument.	4	1 NC	4
HSFPU	IF2.4	Level 1 Thermal Strap	Strap bolts directly to the SPIRE structure. No reasonable failure mode foreseen on SPIRE side of the interface	N/A	Yes change to location of electrical break point. Now should be more robust – still no reasonable failure mode	No test on changed design – will be tested on PFM only	N/A	-	-	-

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSFPU	IF3.1-3.14	MDM cryoharness connections at FPU wall	SPIRE side of the interface consists of MDM mounted firmly on FPU wall. System harness may yank on this due to differential movement of harness and FPU interface causing structural failure and possible circuit failure	Mitigated by instrument and system level qualification programmes and instrument/system level acceptance testing. Depending on precise failure only one side of the instrument (P or R) may be affected.	None	No test of system harness connection under vibration at instrument level Not tested until system level test?	Test not complete one possible failure	3	2 NC	6
HSFPU	IF3.1-3.14	MDM Cryoharness connections at FPU wall	Short or open circuit due to debris or poor workmanship under lunch environment	Mitigated by design and instrument/system level acceptance testing. Depending on precise failure only one side of the instrument (P or R) may be affected.	None	SPIRE side of interface tested during CQM test programme – no failures detected (so far) in RF Filter units. To be continued……	Test not complete – if no failures during whole CQM programme then PN will be reduced.	2	2 NC	4

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSJFP	IF1.1-1.5	Mechanical attachment points to HOB	Collapse or breakage due to launch environment leading to thermal short between JFET box and HOB. (Assume the box remain attached somehow and doesn't destroy the instruments)	Mitigated by design and instrument/system level acceptance testing. Operational – use SPIRE photometer mode less or reduce power dissipated from photometer JFETs.	None	CQM Cold vibration test SPIRE-MSS-REP-002049	Passed	2	1 NC	2
HSJFP	IF2.1-2.2	Level 3 thermal strap interface	Breakage of aluminium bar holding strap leading to poor thermal connection	Mitigated by design and instrument/system level acceptance testing. Operational – use SPIRE photometer mode less or reduce power dissipated from photometer JFETs.	None	CQM Cold vibration test SPIRE-MSS-REP-002049	Passed	2	1 NC	2

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSJFP	IF3.1-3.28	MDM cryoharness connections at JFET box	SPIRE side of the interface consists of MDM mounted firmly on JFET unit wall. System harness may yank on this due to differential movement of harness and JFET box interface causing structural failure and possible circuit failure	Mitigated by instrument and system level qualification programmes and instrument/system level acceptance testing. Many channels of detectors are present so loss of one JFET modules causes only partial loss of functionality – no recovery possible for loss of JFET module. Bias lines are cold redundant at instrument level.	None	No test of system harness connection under vibration at instrument level Not tested until system level test? CQM cold test cycles interface with test harness.	Test not complete but no failures so far	3	2 NC	6

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
~~HSJFS~~HSJFP	IF3.1-3.28	MDM cryoharness connections at JFET box	Short or open circuit due to debris or poor workmanship under lunch environment	Mitigated by design and instrument and system level instrument/system level acceptance testing. Loss of a single JFET module on the spectrometer causes a severe loss of instrument functionality – no recovery possible for loss of JFET module. Bias lines are cold redundant at instrument level.	None	SPIRE side of interface tested during CQM test programme – no failures detected (so far) in RF Filter units. Post vibration test not completed See: PFM4 JFET Power and Pixel Diagnostic Test Rep SPIRE-RAL-REP-002778.doc	~~Test not complete – if no failures during whole CQM programme then PN will be reduced.~~ Revealed that a short in a single detector wire can cause (1) loss of the channel, (2) degradation of 23 adjacent channels and (3) potential increase in JFET cryogenic dissipation	3	2 NC	6
HSJFS	IF1.1-1.4	Mechanical attachment points to HOB	Collapse or breakage due to launch environment leading to thermal short between JFET box and HOB. (Assume the box remain attached somehow and doesn't destroy the instruments)	Operational – use SPIRE spectrometer mode less or reduce power dissipated from spectrometer JFETs.	None	CQM Cold vibration test SPIRE-MSS-REP-002049	Passed	2 NC	1 NC	2

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSJFS	IF2.1-2.2	Level 3 thermal strap interface	Breakage of aluminium bar holding strap leading to poor thermal connection	Mitigated by design and instrument/system level acceptance testing. Operational – use SPIRE spectrometer mode less or reduce power dissipated from photometer JFETs.	None	CQM Cold vibration test SPIRE-MSS-REP-002049	Passed	2 NC	1 NC	2
HSJFS	IF3.1-3.10	MDM cryoharness connections at JFET box	SPIRE side of the interface consists of MDM mounted firmly on JFET unit wall. System harness may yank on this due to differential movement of harness and JFET box interface causing structural failure and possible circuit failure	Mitigated by instrument and system level qualification programmes and instrument/system level acceptance testing. Loss of a single JFET module on the spectrometer causes a severe loss of instrument functionality – no recovery possible for loss of JFET module. Bias lines are cold redundant at instrument level.	None	No test of system harness connection under vibration at instrument level Not tested until system level test? CQM cold test cycles interface with test harness.	Test not complete but no failures so far	3 NC	2 NC	6

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSJFS	IF3.1-3.10	MDM cryoharness connections at JFET box	Short or open circuit due to debris or poor workmanship under lunch environment	Mitigated by design and instrument and system level instrument/system level acceptance testing. Loss of a single JFET module on the spectrometer causes a severe loss of instrument functionality – no recovery possible for loss of JFET module. Bias lines are cold redundant at instrument level.	None	SPIRE side of interface tested during CQM test programme – no failures detected (so far) in RF Filter units. See: PFM4 JFET Power and Pixel Diagnostic Test Rep SPIRE-RAL-REP-002778.doc	~~Test not complete – if no failures during whole CQM programme then PN will be reduced.~~ Revealed that a short in a single detector wire can cause (1) loss of the channel, (2) degradation of 23 adjacent channels and (3) potential increase in JFET cryogenic dissipation	3 NC	2 NC	6
HSDCU	IF1.1-1.N	Mechanical attachment point to SVM	Hard bolted to SVM panel according to interface specification. No reasonable failure mode foreseen on SPIRE side of interface.	N/A	ECR on bolt sizes?	STM Vibration test completed TR……?	Passed – original assessment confirmed.			

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSDCU	2.1-2.28	D-Type connections to SVM intermediate harness at DCU box	SPIRE side of the interface consists of connector mounted firmly on DCU unit wall. System harness may yank on this due to differential movement of harness and DCU box interface causing structural failure and possible circuit failure	Mitigated by design and instrument and system level instrument/system level acceptance testing. Loss of a single JFET module on the spectrometer causes a severe loss of instrument functionality less so for loss of photometer JFET module. No recovery possible for loss of JFET module. Bias lines are cold redundant at instrument level.	None	Not yet tested – to be done on QM2	N/A	3	2	6

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSDCU	2.1-2.28	D-Type connections to SVM intermediate harness at DCU box	Short or open circuit due to debris or poor workmanship under lunch environment	Mitigated by design and instrument and system level instrument/system level acceptance testing. Loss of a single JFET module on the spectrometer causes a severe loss of instrument functionality less so for loss of photometer JFET module. No recovery possible for loss of JFET module. Bias lines are cold redundant at instrument level.	None	~~No test possible until QM2~~ See: PFM4 JFET Power and Pixel Diagnostic Test Rep SPIRE-RAL-REP-002778.doc	Revealed that a short in a single detector wire can cause (1) loss of the channel, (2) degradation of 23 adjacent channels and (3) potential increase in JFET cryogenic dissipation~~N/A~~	3	2	6
HSDCU	3.1-3.4	D-Type connections to SPIRE warm harness	Short or open circuit due to debris or poor workmanship under lunch environment	Fully cold redundant at instrument level. Switch to redundant side of instrument.	None	No test possible until QM2	N/A	2	2	4R

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSFCU	IF1.1-1.N	Mechanical attachment point to SVM	Hard bolted to SVM panel according to interface specification. No reasonable failure mode foreseen on SPIRE side of interface	N/A	ECR outstanding on bolt size?	SCU STM vibration test TR…….?	Passed – original assessment confirmed			
HSFCU	2.1-2.2	D-Type connections to SVM primary power harness at FCU box	SPIRE side of the interface consists of connector mounted firmly on FCU unit wall. System harness may yank on this due to differential movement of harness and FCU box interface causing structural failure and possible circuit failure	Mitigated by and instrument and system level instrument/system level acceptance testing. Instrument is cold redundant so request CDMS to switch to redundant power line.	None	Not yet tested – to be done on QM2	N/A	3	2	6R

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSFCU	2.1-2.2	D-Type connections to SVM primary power harness at FCU box	Short or open circuit due to debris or poor workmanship under lunch environment	Mitigated by design and instrument and system level instrument/system level acceptance testing. Instrument is cold redundant so request CDMS to switch to redundant power line.	None	Not yet tested – to be done on QM2	N/A	3	2	6R

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSFCU	2.1-2.2	D-Type connections to SVM primary power harness at FCU box	Circuit failure within FCU causes excessive current demand on primary power line.	Mitigated by design (isolated supply and single component failure should not cause this failure); component selection (all interface circuits are level B) and instrument and system level instrument/system level acceptance testing. Instrument is cold redundant so request CDMS to switch to redundant power line.	None	Not yet tested – to be done on QM2	N/A	3	2	6R

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSFCU	3.1-3.16	D-Type connections to SVM intermediate harness at FCU box	SPIRE side of the interface consists of connector mounted firmly on FCU unit wall. System harness may yank on this due to differential movement of harness and FCU box interface causing structural failure and possible circuit failure	Mitigated by and instrument and system level instrument/system level acceptance testing. Instrument is cold redundant for all FCU sub-systems so switch to redundant side.	None	Not yet tested – test only possible at system level	N/A	2	2	6R
HSFCU	3.1-3.16	D-Type connections to SVM intermediate harness at FCU box	Short or open circuit due to debris or poor workmanship under lunch environment	Mitigated by design and instrument and system level instrument/system level acceptance testing. Instrument is cold redundant for all FCU sub-systems so switch to redundant side.	None	Not yet tested – to be done on QM2	N/A	2	2	4R
HSFCU	4.1-4.6	D-Type connections to SPIRE warm harness	Short or open circuit due to debris or poor workmanship under lunch environment	Fully cold redundant at instrument level. Switch to redundant side of instrument.		Not yet tested – to be done on QM2	N/A	2	2	4R

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSDPU	IF1.1-1.6	Mechanical attachment point to SVM	Hard bolted to SVM panel according to interface specification. No reasonable failure mode foreseen.	N/A	None	None – to be tested on QM	N/A			
HSDPU	IF2.1-2.2	D-Type connections to SVM primary power harness at DPU box	SPIRE side of the interface consists of connector mounted firmly on FCU unit wall. System harness may yank on this due to differential movement of harness and FCU box interface causing structural failure and possible circuit failure	Mitigated by instrument and system level instrument/system level acceptance testing. Instrument is cold redundant CDMS will switch to redundant power line.	None	Not yet tested – SPIRE side to be done on QM or PFM System level test required for Herschel side of interface.	N/A	3	2	6R
HSDPU	IF2.1-2.2	D-Type connections to SVM primary power harness at DPU box	Short or open circuit due to debris or poor workmanship under lunch environment	Mitigated by design and instrument and system level instrument/system level acceptance testing. Instrument is cold redundant CDMS will switch to redundant power line.	None	Not yet tested – SPIRE side to be done on QM or PFM	N/A	3	2	6R

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSDPU	IF2.1-2.2	D-Type connections to SVM primary power harness at DPU box	Circuit failure within DPU causes excessive current demand on primary power line.	Mitigated by design (isolated supply and single component failure should not cause this failure); component selection (all interface circuits are level B) and instrument and system level instrument/system level acceptance testing. Instrument is cold redundant CDMS will switch to redundant power line.	None	Not yet tested – SPIRE side to be done on QM or PFM	N/A	3	2	6R
HSDPU	IF3.1-3.4	D-Type connections to CDMS harness at DPU box	SPIRE side of the interface consists of connector mounted firmly on FCU unit wall. System harness may yank on this due to differential movement of harness and FCU box interface causing structural failure and possible circuit failure	Mitigated by instrument and system level instrument/system level acceptance testing. Instrument is cold redundant CDMS will switch to redundant 1553.	None	Not yet tested – SPIRE side to be done on QM or PFM System level test required for Herschel side of interface.	N/A	3	2	6R

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSDPU	IF3.1-3.4	D-Type connections to CDMS harness at DPU box	Short or open circuit due to debris or poor workmanship under lunch environment	Mitigated by instrument and system level instrument/system level acceptance testing. Instrument is cold redundant CDMS will switch to redundant 1553.	None	Not yet tested – to be done on QM and PFM	N/A	3	2	6R
HSDPU	IF3.1-3.4	D-Type connections to CDMS harness at DPU box	Circuit failure within DPU causes some sort of failure?	Mitigated by design (galvanic isolation? and single component failure should not cause this failure); component selection (all interface circuits are level B) and instrument and system level instrument/system level acceptance testing. Instrument is cold redundant CDMS will switch to redundant 1553.	None	Tested on AVM TR SPIRE-IFS-REP-001385 1.0	No failures identified during test. This interface has also been in constant use during the instrument level CQM programme. No failures detected in 6 months of near constant operation.	3	1 D	6R

Unit	Interface ID	Description	Failure Modes	Mitigation /Recovery	Design Changes for Flight	Test carried out	Result and effect	SN	PN	CN
HSDPU	IF4.1-4.6	D-Type connectors to SPIRE warm harness	Short or open circuit due to debris or poor workmanship under lunch environment	Fully cold redundant at instrument level. Switch to redundant side of instrument.	None	Not yet tested – to be done on QM and PFM	N/A	2	2	4R