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## FPU Failure Mode Effects and Criticality Analysis

Prepared by: K.J. Wildeman

date: October 6, 2000

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## 1. Abbreviations

COA	Common Optics Assembly
DU	Diplexer Unit
FMECA	Failure Mode Effects and Criticality Analysis
FPU	Focal Plane Unit
IF	Intermediate Frequency
LO	Local Oscillator
MA	Mixer Assembly
MSA	Mixer Sub Assembly
MU	Mixer Unit
SPF	Single Point Failure

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## 2. Introduction

This Failure Mode Effects and Criticality Analysis is an evaluation of the FPU functional failure Mode impact. The prime object is to assess the design in order to identify any deficiencies or weak areas that could reduce the reliability or integrity of the unit. The areas of interest are:

- Single point failures
- Redundancy

This analysis has to be carried out again for any subsequent modification to ensure they do not degrade the reliability.

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### 3. The Focal Plane Unit

The Focal Plane Unit (FPU) contains the mixers and the optics that couple the telescope beam and the Local-Oscillator beams to the mixers. The FPU resides in the FIRST cryostat, in the spacecraft Payload Module.

The FPU covers 7 frequency bands. The range from 480 – 1250 GHz is continuously covered in five bands. The ranges from 1410 – 1910 GHz and 2400 – 2700 GHz are covered in two sub-bands.

A sub-unit break down is shown in Figure 1. Each Mixer Assembly, containing two mixers for each polarisation, will cover a single frequency band. All bands measure both polarisations of the astronomical signal simultaneously for optimum sensitivity and redundancy.

The FPU provides 15 K, 4 K and 2 K temperature levels to the appropriate sub-units. The 15 K, 4 K and 2 K levels are provided by the spacecraft to the FPU. Both the SIS and HEB mixers will operate at 2 K.

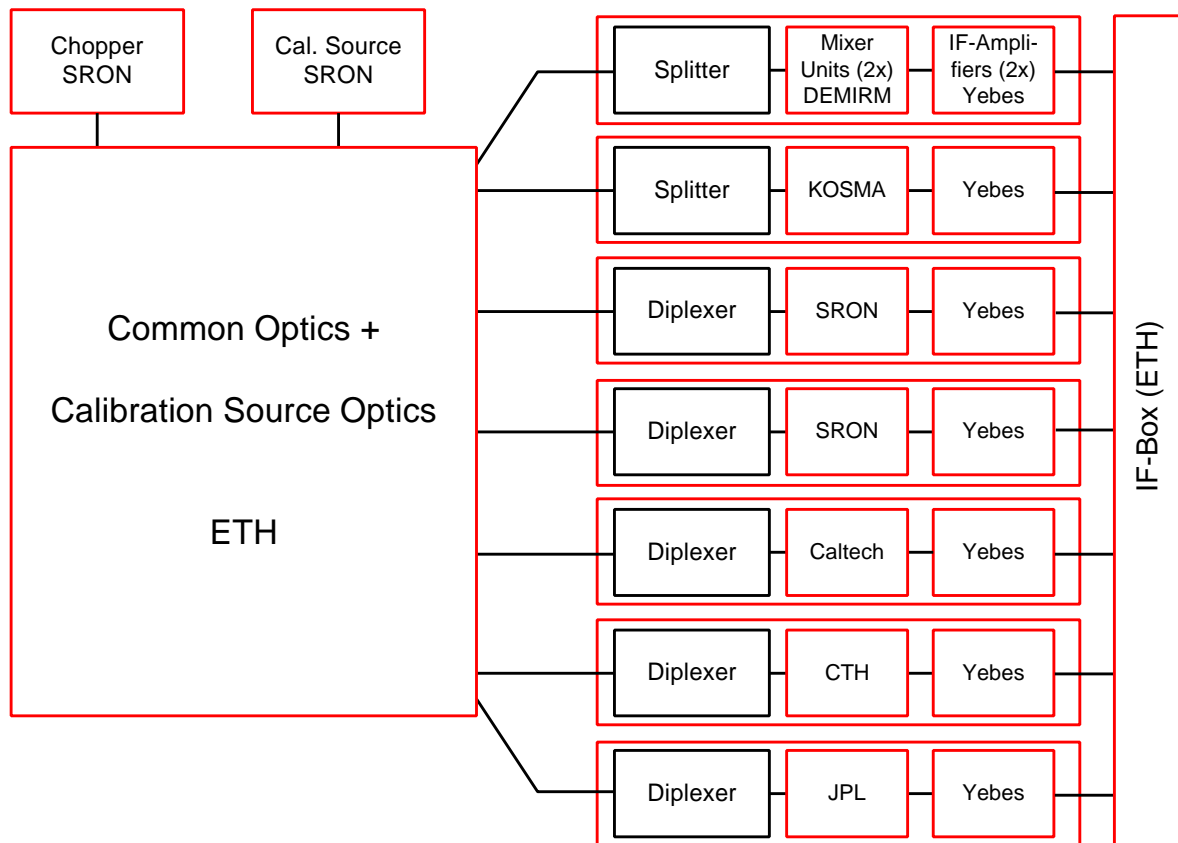


Figure 1 Sub-units of the FPU. The sub-units are indicated by a red box.

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#### **4. Redundancy Philosophy**

The reliability block diagram (Figure 2, next page) shows that full performance requires every module of the FPU, but there is redundancy at the Mixer Assembly level in the sense that a failure or degradation here only affects one band or one polarisation in a band.



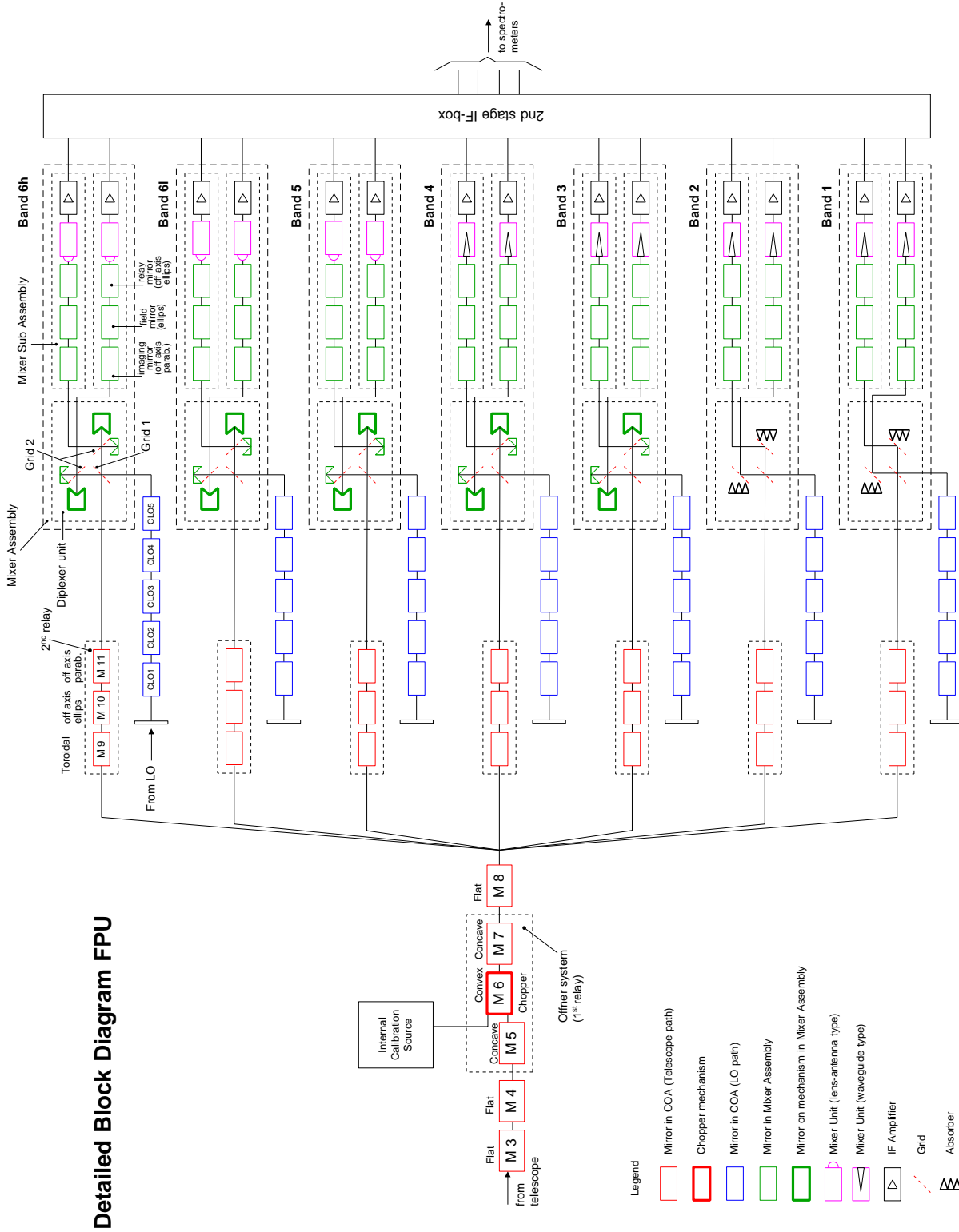


Figure 2 Detailed Block Diagram FPU

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## 5. Failure assessment methodology

This FMECA has been performed on a sub-unit functional level. Lower level of investigations shall be carried out by the sub-unit suppliers in those cases where the results of this FMECA indicate weak areas. The sub-units of the FPU are shown in Figure 1.

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## 6. FMECA Table

The main part of this note is the FMECA table on next 2 pages.

In the last column of this table the failure effects are classified in four categories of criticality:

1. Single point failure potentially loss of all bands.
2. Failures potentially degrading performance of all bands.
3. Failures potentially degrading performance of one band
4. Failures potentially degrading performance of one polarisation in a band

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	Case nr.	Component involved (group)	Failure Mode	Effects	Comments on effects	Cat.
<b>COA</b>	1.1	Mirrors M3 to M8 in the COA (3 flat mirrors, Offner system and chopper mirror)	contamination/misalignment	Degraded performance as a result from loss of image quality or reduced transmission.	<ul style="list-style-type: none"> <li>Control by visual inspection and test</li> <li>Affects all bands</li> </ul>	1
	1.2	Mirrors M9 to M11 (2 <sup>nd</sup> relay system)	contamination/misalignment	Degraded performance as a result from loss of image quality or reduced transmission.	<ul style="list-style-type: none"> <li>Control by visual inspection and test</li> <li>A degradation of one (group) of these mirrors only affects one band</li> </ul>	3
	1.3	Cold LO optics CLO1 to CLO5	contamination/misalignment	Degraded performance as a result from loss of image quality or reduced transmission.	<ul style="list-style-type: none"> <li>Control by visual inspection and test</li> <li>A degradation of one (group) of these mirrors affects one band only</li> </ul>	3
	1.4	Chopper Mechanism	failure in activator	Loss of or degraded chopper function.	<ul style="list-style-type: none"> <li>Control by test</li> <li>The chopper has redundant activators</li> <li>The chopper design is such that a non-operating (non-activated) activator will result in a neutral (on sky) position of chopper</li> </ul>	2
			failure in flexural pivots	Misalignment and/or loss of chopper function.	<ul style="list-style-type: none"> <li>Control by visual inspection and test</li> <li>A failure in the pivots may result in a sticking (non-sky position) chopper</li> </ul>	1
			failure in position sensor	Degraded chopper function.	<ul style="list-style-type: none"> <li>Control by test</li> <li>Sensor is redundant</li> </ul>	2
	1.5	Calibration Source	failure in heaters and in sensors	Degraded performance (sensor) or non operating source (heater).	<ul style="list-style-type: none"> <li>Control by visual inspection and test</li> <li>Sensors and heaters are redundant</li> <li>A failing internal calibration source does not directly affect performance but affects in flight calibration options and/of operations</li> </ul>	

see conclusions (chapter 7)

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<b>MA</b>	2.1	Grids nr. 1	misalignment/ contamination/ rupture	Degraded performance as a result from loss of image quality or reduced transmission. Ultimately loss of a band (in particular as a result from rupture).	<ul style="list-style-type: none"> <li>• Control by visual inspection and test</li> <li>• Affects one band</li> </ul>	3
		Grids nr. 2 and 3	misalignment/ contamination/ rupture	Degraded performance as a result from loss of image quality or reduced transmission. Ultimately loss of one polarisation in one band as a result from rupture.	<ul style="list-style-type: none"> <li>• Control by visual inspection and test</li> <li>• Affects one polarisation in one band</li> </ul>	4
	2.2	Rooftop mirrors	misalignment/ contamination	Degraded performance as a result from loss of image quality or reduced transmission.	<ul style="list-style-type: none"> <li>• Control by visual inspection and test</li> <li>• Affects one polarisation in one band</li> </ul>	4
	2.3	Diplexer mechanism (bands 3 to 6)	failing activator	Degraded performance	<ul style="list-style-type: none"> <li>• Control by test</li> <li>• Affects one polarisation in one band</li> </ul>	4
			failing pivots	Degraded performance	<ul style="list-style-type: none"> <li>• Control by visual inspection and test</li> <li>• Affects one polarisation in one band</li> </ul>	4
			failing sensor	Degraded performance because of less position reproducibility and position stability.	<ul style="list-style-type: none"> <li>• Control by test</li> <li>• Affects one polarisation in one band</li> </ul>	4
	2.4	Imaging optics in MSA (3 mirrors per MSA)	misalignment/ contamination	Degraded performance as a result from loss of image quality or reduced transmission.	<ul style="list-style-type: none"> <li>• Control by visual inspection and test</li> <li>• Affects one polarisation in one band</li> </ul>	4
	2.5	Mixer Unit	degradation or loss of one function (coil, heater, junction)	Degradation of performance or loss of a mixer unit	<ul style="list-style-type: none"> <li>• Control by test</li> <li>• Affects one polarisation in one band</li> </ul>	4
	2.6	IF-amplifiers	degradation or loss of function	Degradation of performance or loss of an amplifier	<ul style="list-style-type: none"> <li>• Control by test</li> <li>• Affects one polarisation in one band</li> </ul>	4
	<b>IF-Box</b>	3	IF-Box	degradation or loss of a function	Degradation or loss of one or more bands	<ul style="list-style-type: none"> <li>• Control by test</li> <li>• Failures may result in degradation or loss of more bands depending on detailed design</li> </ul>

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## 7. Conclusions

The analysis established that three areas with failure modes potentially could cause loss of all bands (Category 1).

The first area is the mirror group M3 to M8. The probability of such a drastic degradation however, can be ignored and is left out of account.

The second area concerns the chopper, in particular in case one of the flexural pivots fails, but other areas within this sub-unit might have failure modes of the same category. Further analysis at sub-unit level shall be carried out.

The third one is the IF box. For the time being it is put it in Category 1. It will depend on its internal design whether this is correct. A detailed analysis shall be carried out by the supplier of the sub-unit.

Finally the calibration source is mentioned. Although it has no Category 1 failure mode and a failure would not even have a direct effect on the performance of the FPU, loss or degradation of the calibration source might affect in-flight calibrations and operations. An analysis of these effects is beyond the scope of this technical note and should be done at higher level (system level).