SPIRE	Meeting Handouts	Ref: SPIRE-USK-MHO-000803
	Viewgraphs for Preliminary Design Review, COM DEV, Ontario, 17Jul01	Issue: 1.0 Date: 17Jul01 Page: 1

SPIRE Shutter

Preliminary Design Review

July 17, 2001

COM DEV Space
Cambridge, Ontario

Agenda

- Introduction
- Objectives (CSA)
- Overview of SPIRE (U. of Sask.)
- Introduction To Technical (CSA)
  - Shutter Requirements (U. of Sask.)
  - Compliance to Requirements (COM DEV)
  - Shutter Mechanical Design (COM DEV)
  - Shutter Electrical Design (COM DEV)
  - Shutter Development and Test Plan (COM DEV)
  - Shutter Ground Support Equipment (COM DEV)
- Management
  - Product Assurance Overview (COM DEV)
  - Risk Items (COM DEV)
  - Shutter Schedule (CSA)
- Key Open Issues (COM DEV)
- Closeout
- Tour of COM DEV

INTRODUCTION

OBJECTIVES

(CSA)

Objectives

1. Confirm that we are using the correct set of Governing Documents.
2. Review the Shutter Design Requirements and Constraints, and the Shutter Usage Forecast.
3. Review changes to the ICDs, in support of a request to the SPIRE Project that they be frozen:
   - IID-B Chapter 5
   - SPIRE Structure-Mechanical I/F
   - SPIRE Harness Definition
   - SPIRE Systems Budgets
4. Review the Preliminary Technical Designs of the SPIRE Shutter.
5. We will also discuss the Schedule for the various Shutter Models.

OVERVIEW OF SPIRE

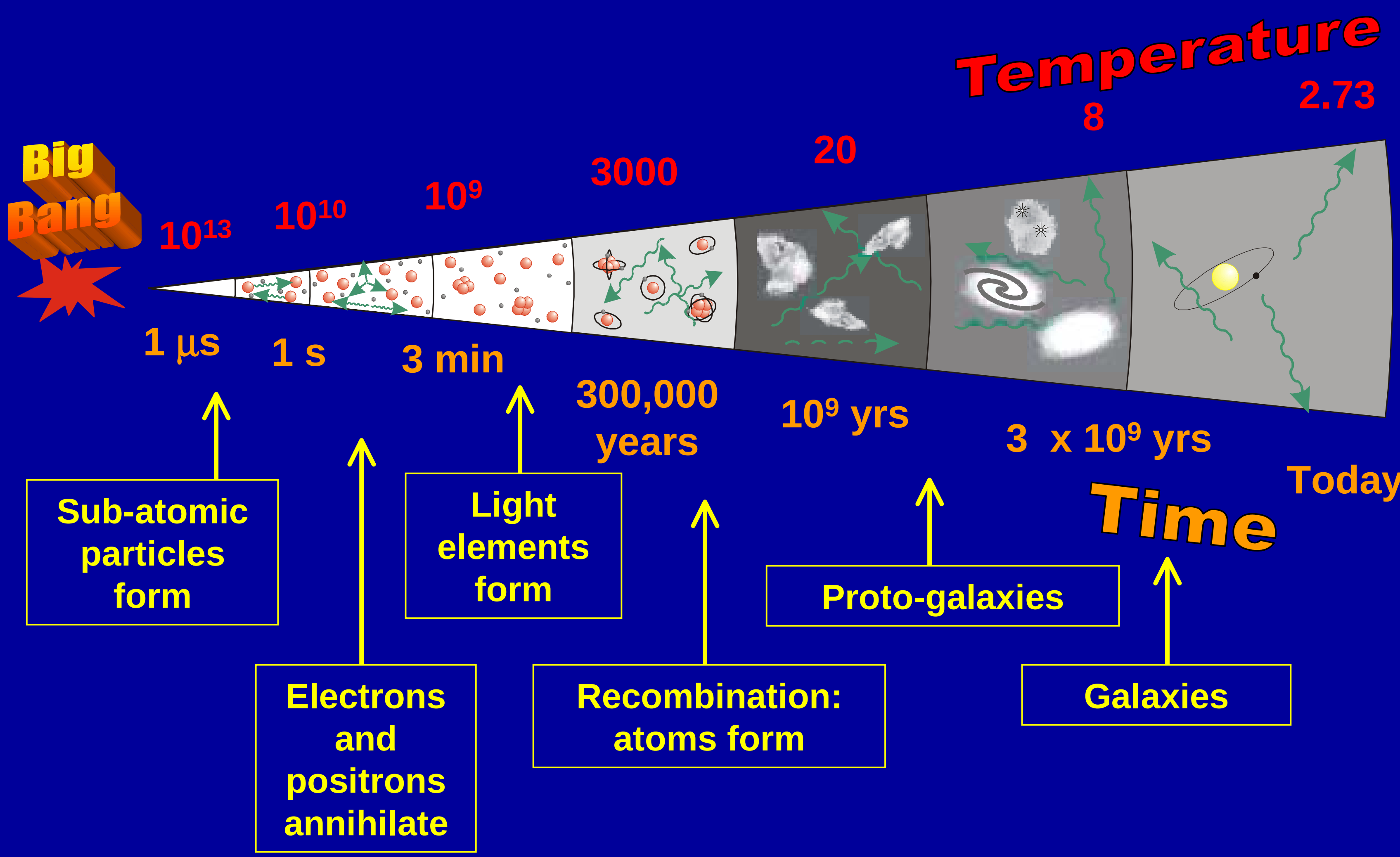
(U of S)

Introduction to SPIRE: The Spectral and Photometric Imaging Receiver

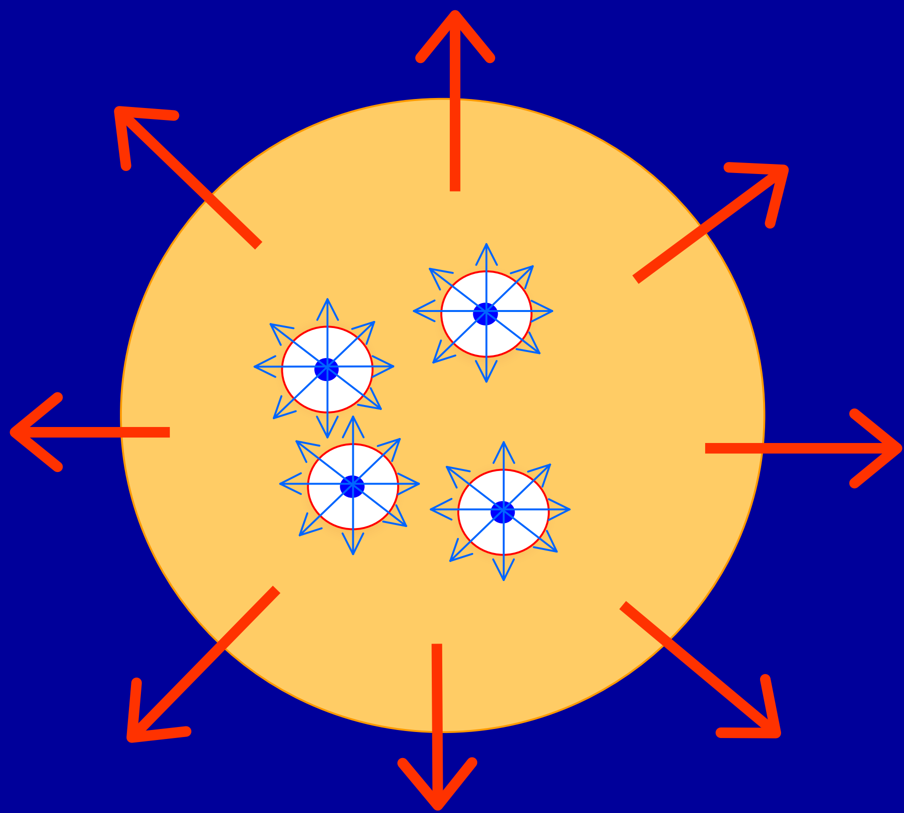
Topics:

- **Science Objectives**
- **The Herschel Space Observatory**
- **The SPIRE Instrument**
- **The SPIRE Consortium**

History of the Universe



Star Formation

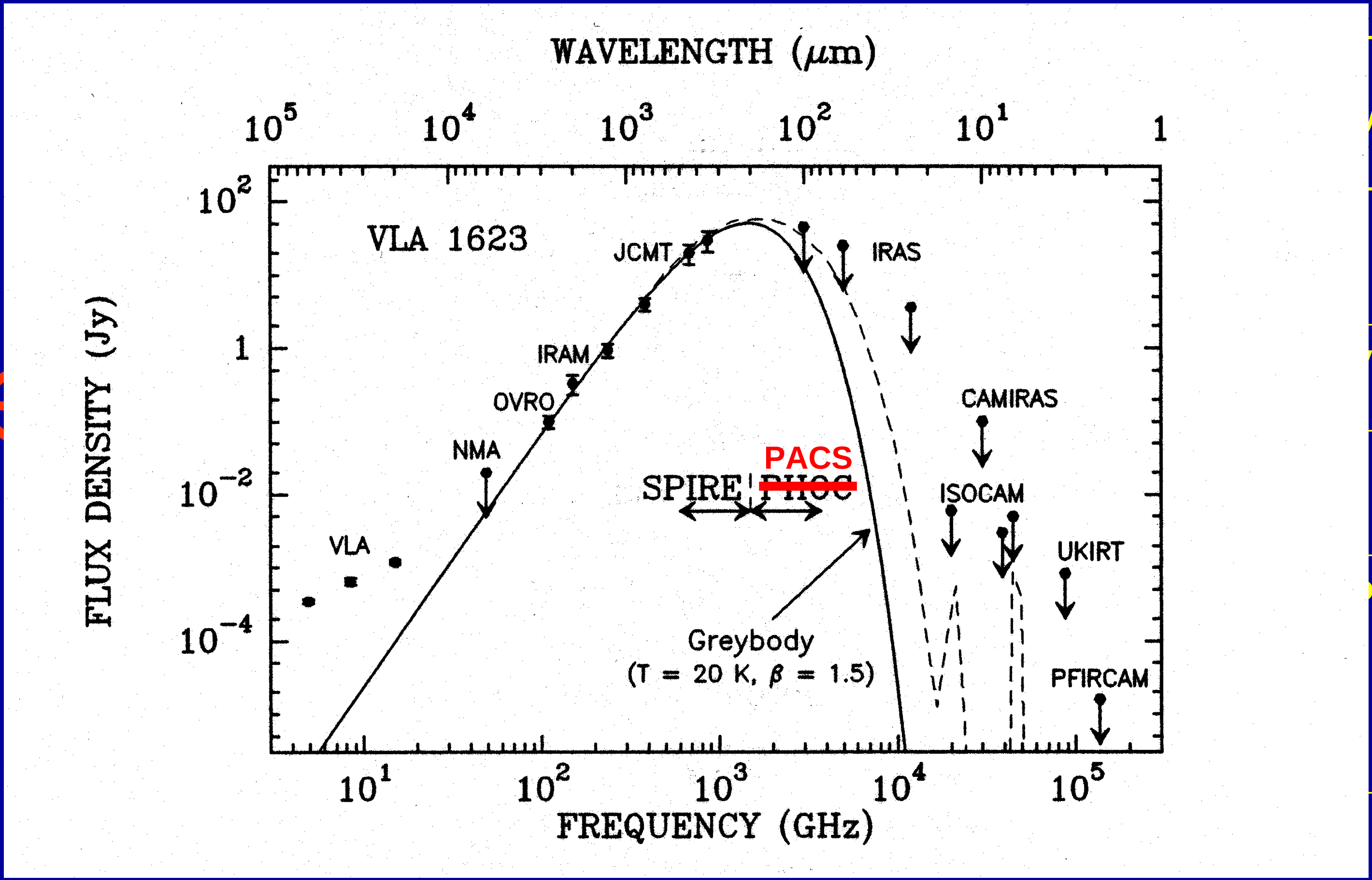


Massive hot stars (20–50,000 K) form in the cloud and emit mainly UV radiation ($\lambda \sim 0.1 - 0.3\ \mu m$)

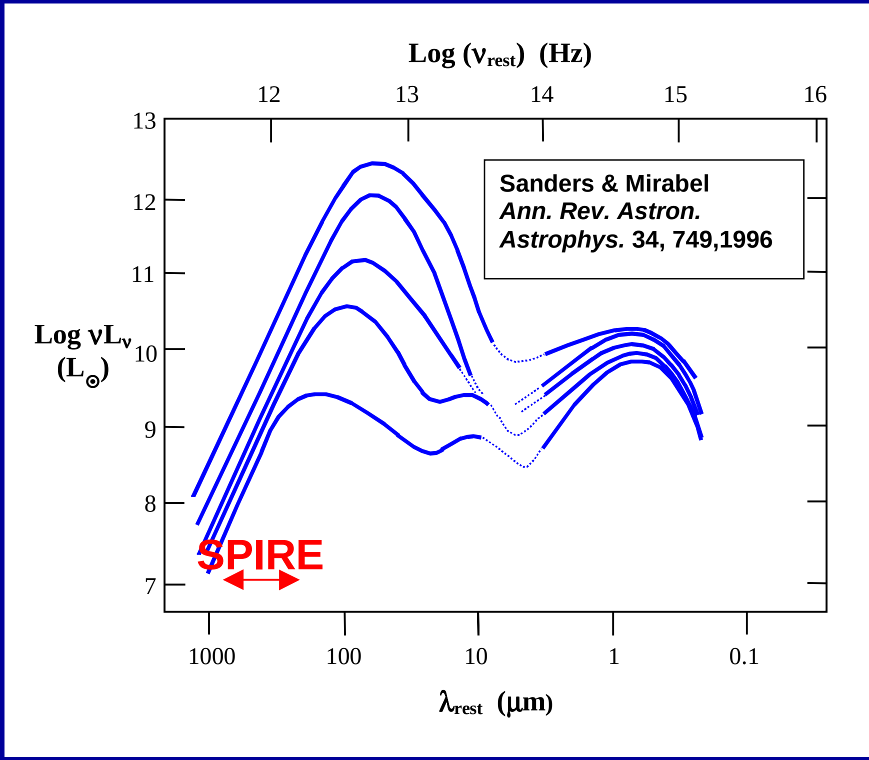
The UV radiation is absorbed by dust grains in the cloud

The grains are warmed up to about 40 K and re-emit the energy as
far infrared radiation
($\lambda \sim 50 - 100\ \mu m$)

Star Formation



Galaxy Formation



Galactic emission occurs in far-infrared due to reprocessing of stellar ultraviolet by interstellar dust

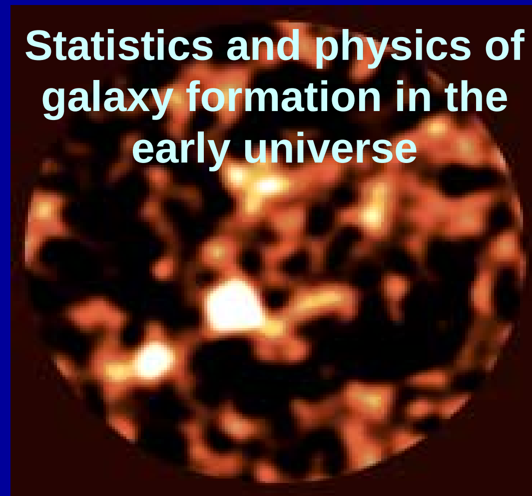
Optical/near-infrared spectrum is a poor indicator of the bolometric luminosity

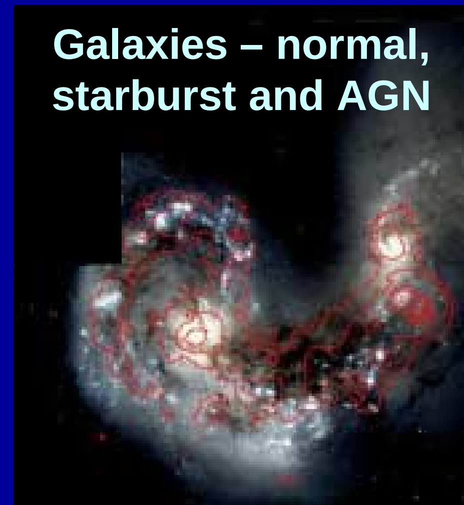
Recession of distant galaxies shifts primary emission into submillimetre wavelengths

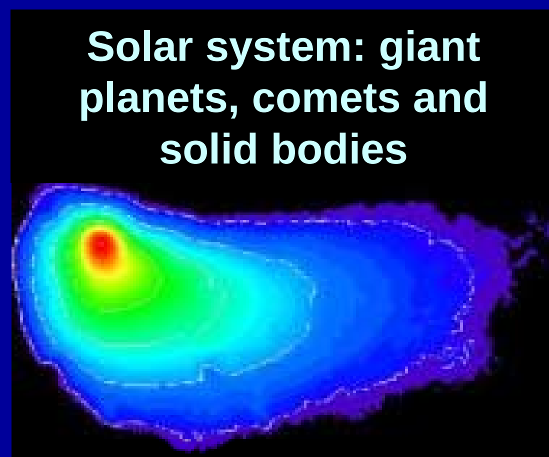
Science Objectives

Two requirements for submillimetre astronomy:

- **Space observatory**
  - ➢ ***To escape effects of terrestrial atmosphere***
- **Cold (LHe) instrumentation**
  - ➢ ***Sensitivity to cold sources***
  - ➢ ***Suppression of photon noise***
  - ➢ ***Suppression of thermal background***







The *Herschel* Space Observatory

Unique Features:

- Large (3.5m), low-emissivity (4%), passively-cooled (80K) telescope
- Access to poorly-explored spectral range
- Large amount of high-quality observing time

Vital Statistics:

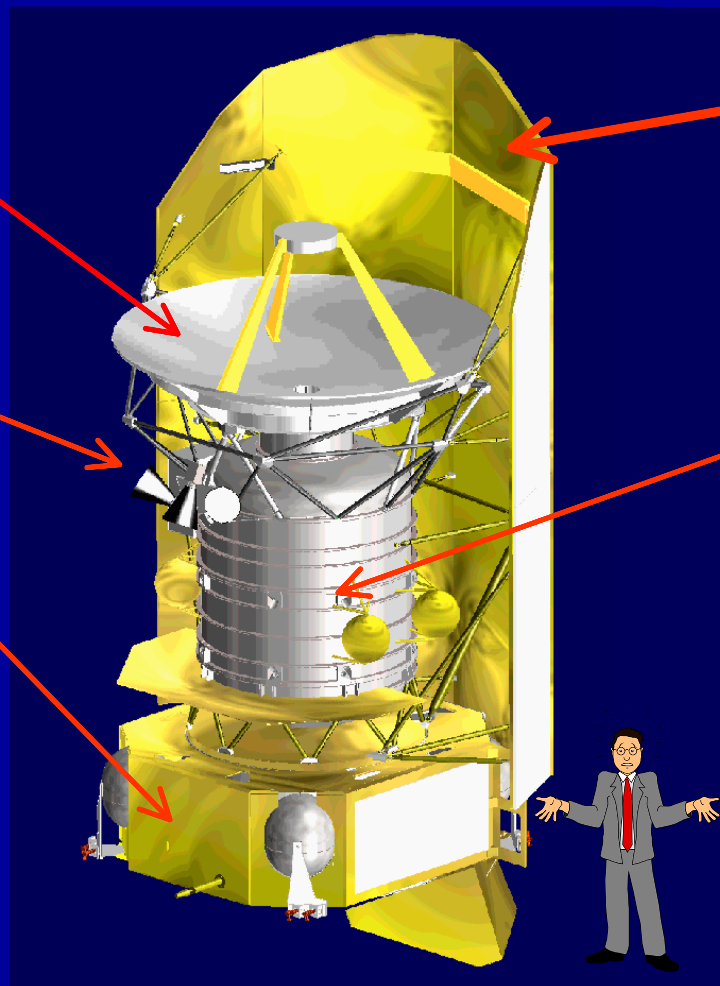
- ESA cornerstone 4
- Launch: 15 February 2007, Ariane 5
- Orbit: around Sun-Earth L2 point
- Cooling: ISO cryostat technology
- Lifetime: nominal 3 years, goal 4.5 years
- Operations: 21 hr/day science, 3 hr/day communications

Spacecraft

3.5-metre telescope, cooled to ~ 80 K

Star-trackers for pointing

Warm electronics and thrusters



Sunshield with solar panels on other side

2500-litre tank of liquid helium cools instruments inside to 2 K

Contractors:

- Alcatel
- Astrium
- Alenia

Payload

Heterodyne Instrument For First (HIFI)

- **PI: Thijs de Graauw, SRON, NL**
- **Heterodyne spectroscopy: 480-1250 GHz, 1410-1910 GHz, 2400-2700 GHz**

Photoconductor Array Camera And Spectrometer (PACS)

- **PI: Albrecht Poglitsch, MPE, D**
- **Photometry and spectroscopy: 80-210 μm**
- **Photoconductive and bolometric detectors**

Spectral And Photometric Imaging Receiver (SPIRE)

- **PI: Matt Griffin, Cardiff, UK**
- **Photometry and spectroscopy: 200-670 μm**
- **Bolometric detectors**

The SPIRE Instrument

Scientific Design Drivers:

- **design optimised for key scientific goals**
  - ***deep photometric surveys of high-redshift galaxies***
  - ***survey of our galaxy for young protostars***
  - ***imaging spectroscopy of the interstellar medium and nearby galaxies***
- **SPIRE concentrates on exploiting capabilities that are unique to Herschel**

Technical Design Drivers:

- **stringent spacecraft resource budgets (FPU power dissipation, mass)**
- **simplicity of operation, low risk**
- **Affordability**

Instrument Summary

3-band Imaging Photometer:

- **λ = 250, 350, 500 μm; $\lambda/\Delta\lambda$ ~ 3**
- **4 x 8 arcmin field of view; diffraction-limited beams**

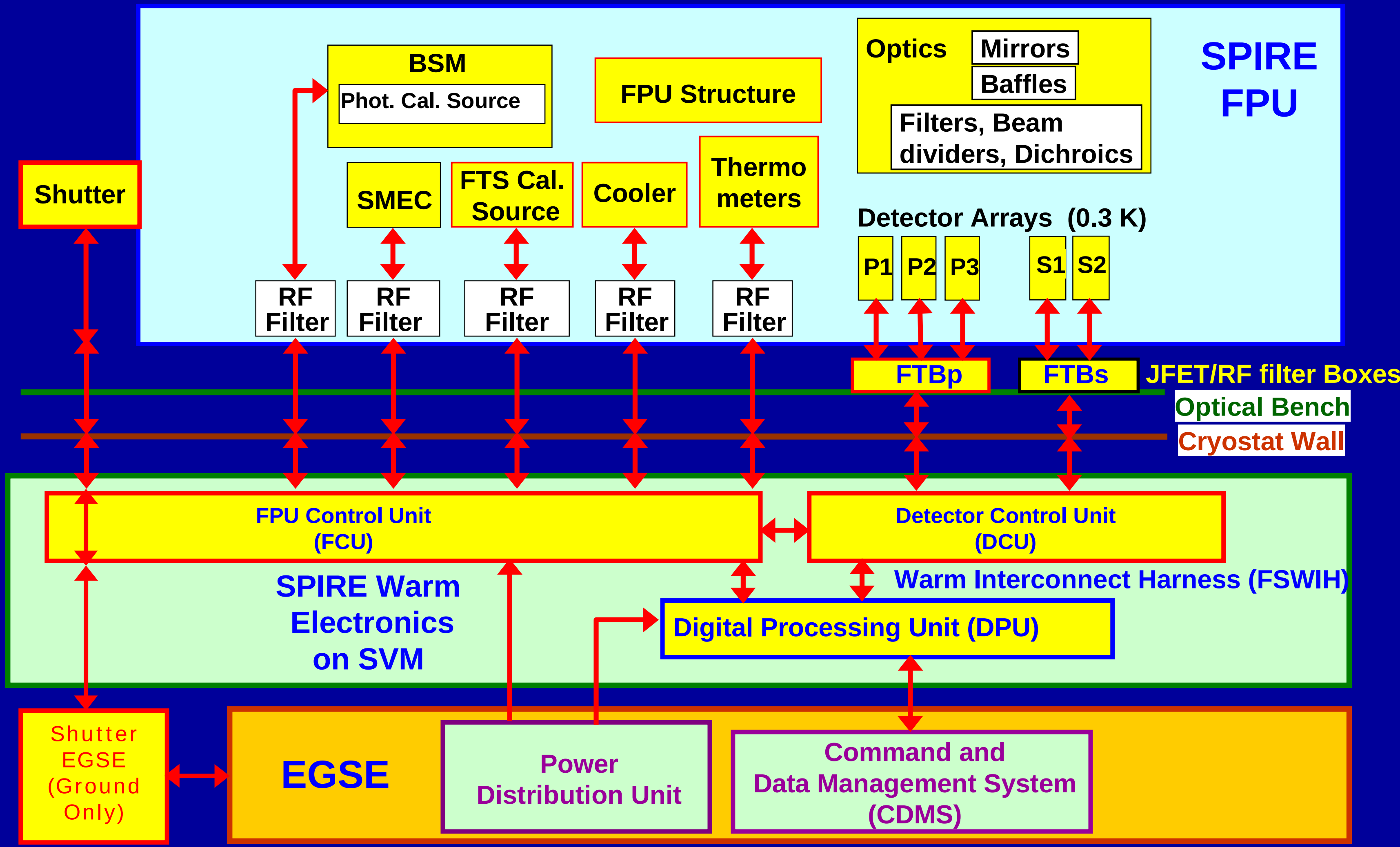
Imaging Fourier Transform Spectrometer:

- **λ = 200-670 μm; $\lambda/\Delta\lambda$ = 20-1000 (variable)**
- **2.6 arcmin field of view**
- **Novel beamsplitter design**

Design Features:

- **feedhorn-coupled spider web bolometer detector arrays**
- **detector arrays cooled to 0.3 K by ^{3}He fridge**
- **minimal use of mechanisms**
- **sensitivity limited by thermal emission from low-emissivity telescope at 80 K**

Instrument Block Diagram



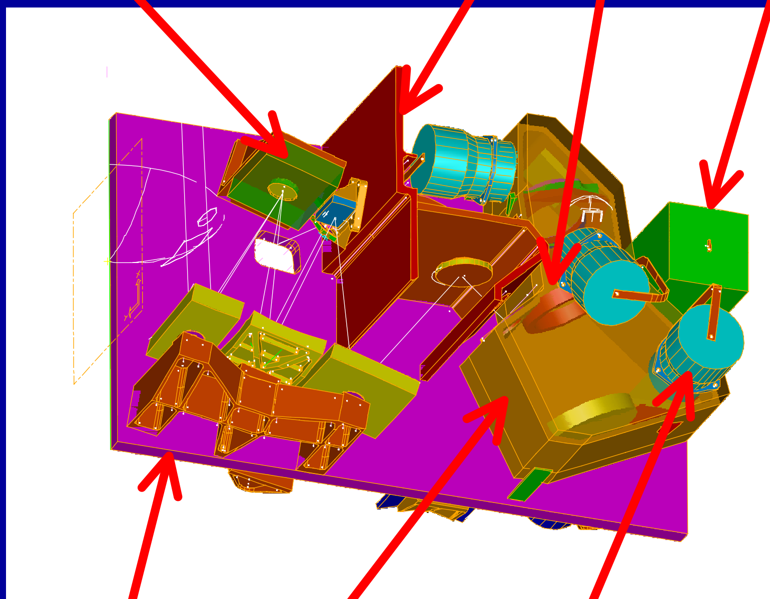
Photometer

Beam steering mirror

Baffles

Dichroics

^{3}He cooler



SPIRE optical bench (4 K)

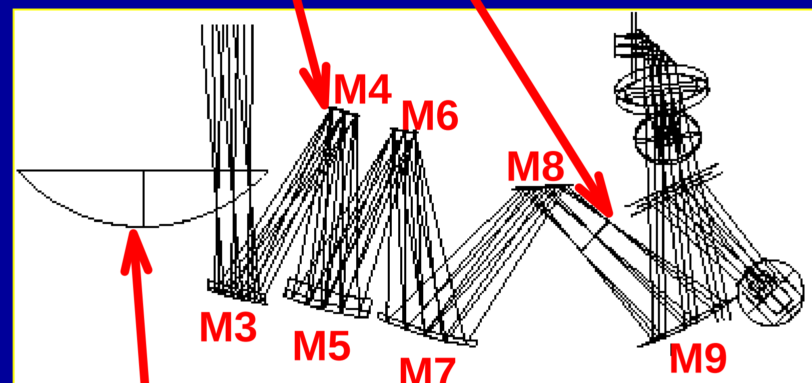
2-K box

Detector array modules

Beam steering mirror

2-K cold stop

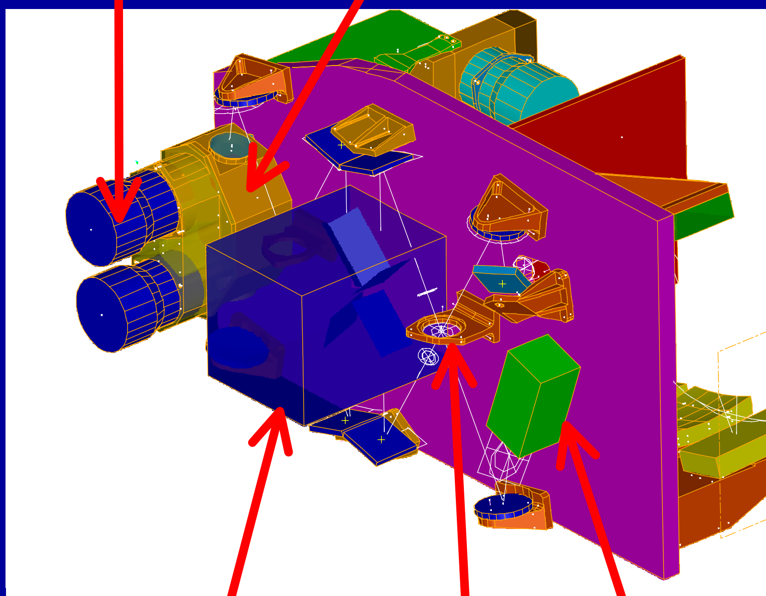
Dichroics and arrays

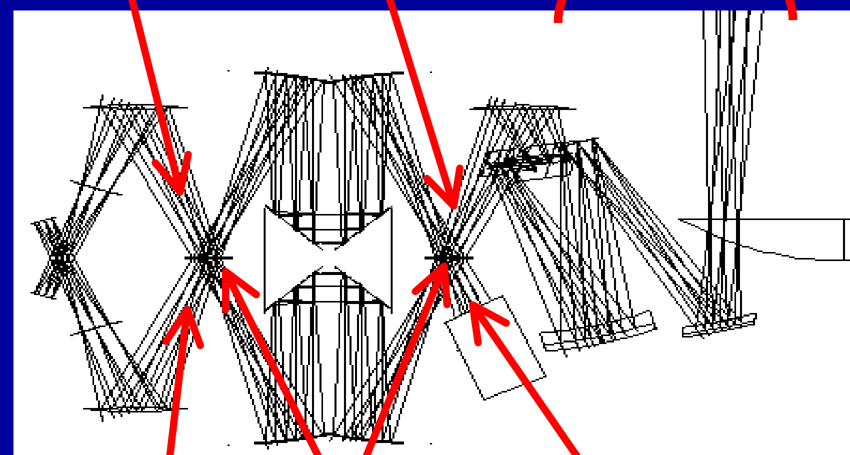


FIRST focal surface

Offner relay

Spectrometer





The SPIRE Consortium

Lead Personnel:

- **Principal Investigator: Matt Griffin, Cardiff**
- **Co-Principal Investigator: Laurent Vigroux, SAp, Saclay**
- **Project Manager: Ken King, RAL, Oxfordshire**
- **Instrument Scientist: Bruce Swinyard, RAL, Oxfordshire**

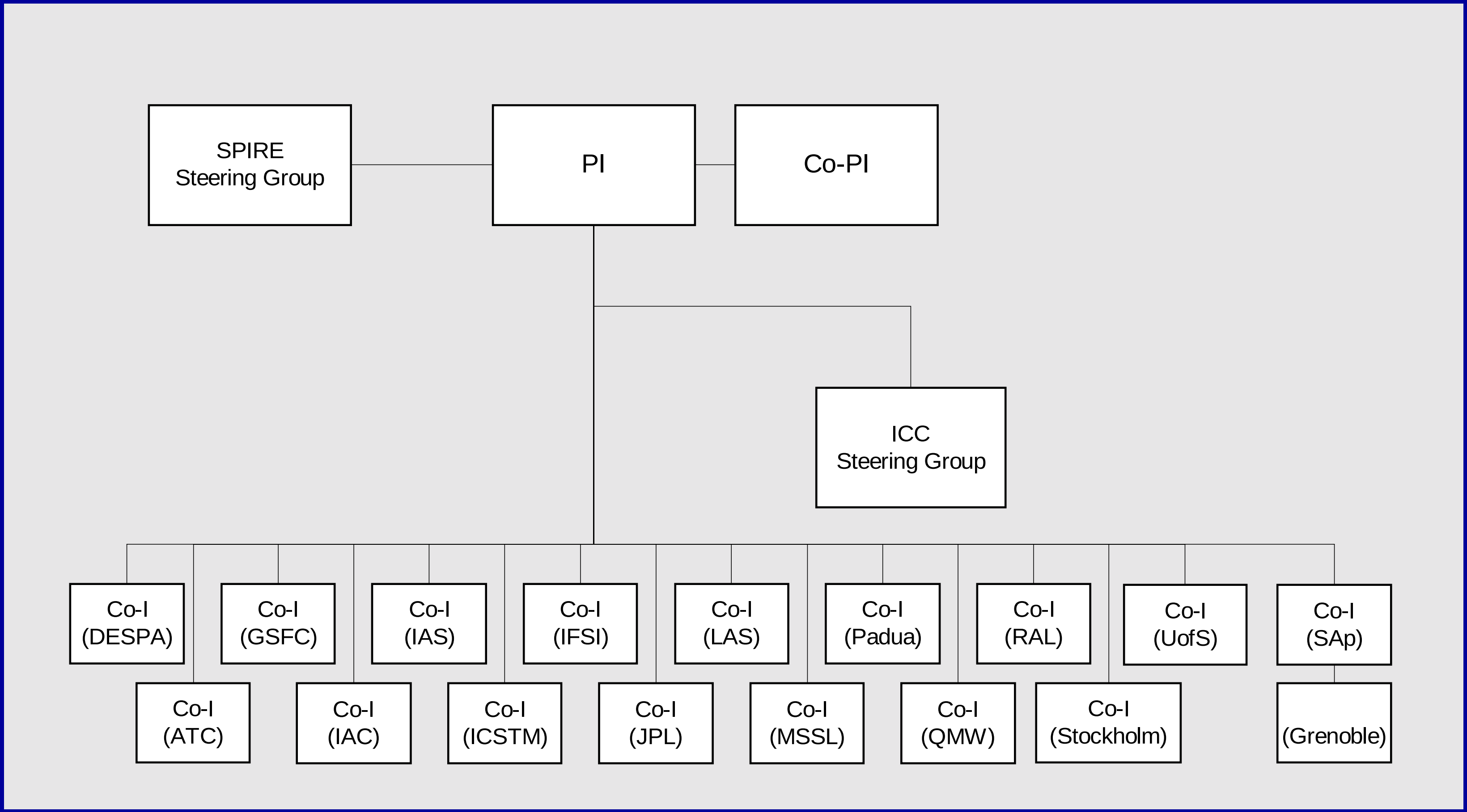
Participating Countries:

- **Canada**
- **France**
- **Italy**
- **Spain**
- **Sweden**
- **UK**
- **USA**

Consortium Institutes

- Caltech/Jet Propulsion Laboratory, Pasadena, USA
- CEA Service d'Astrophysique, Saclay, France
- Imperial College, London, UK
- Institut d'Astrophysique Spatiale, Orsay, France
- Instituto de Astrofisica de Canarias, Tenerife, Spain
- Istituto di Fisica dello Spazio Interplanetario, Rome, Italy
- Laboratoire d'Astronomie Spatiale, Marseille, France
- Mullard Space Science Laboratory, Surrey, UK
- NASA Goddard Space Flight Center, Maryland, USA
- Observatoire de Paris, Meudon, France
- Rutherford Appleton Laboratory, Oxfordshire, UK
- UK Astronomy Technology Centre, Edinburgh, UK
- Stockholm Observatory, Sweden
- Università di Padova, Italy
- University of Cardiff, UK
- University of Saskatchewan, Canada

Consortium Organisation



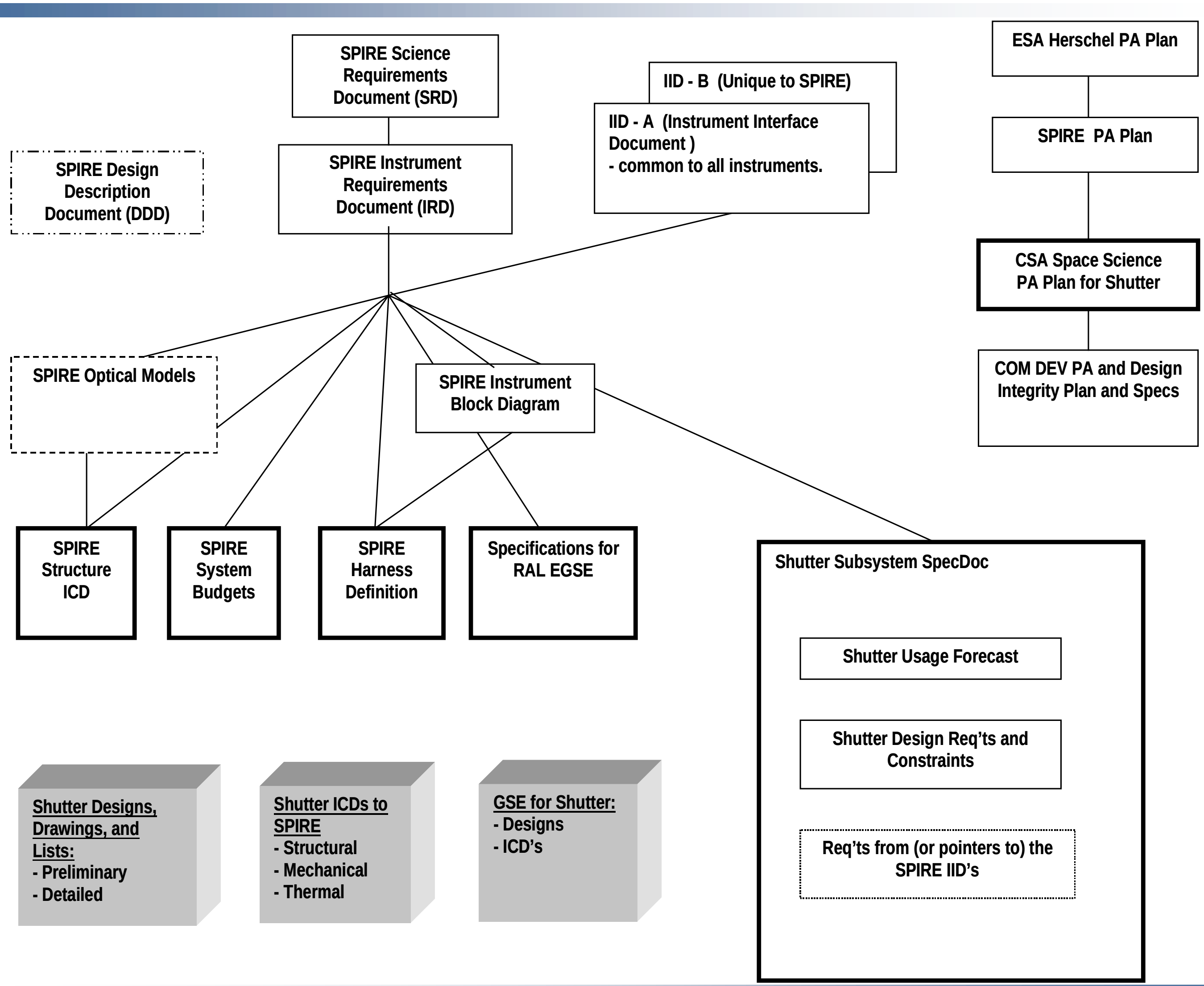
Canadian Personnel

- **Co-Investigator:** **Gary Davis, University of Saskatchewan**
- **Associate Scientists:**
  - ***Paul Feldman, Herzberg Institute of Astrophysics***
  - ***Mark Halpern, University of British Columbia***
  - ***David Naylor, University of Lethbridge***
  - ***Douglas Scott, University of British Columbia***
  - ***Chris Wilson, McMaster University***
- **Instrumentation Scientist:** **Joe Taylor, University of Saskatchewan**
- **Project Manager:** **Don Peterson, Canadian Space Agency**
- **Industrial Partner:** **COM DEV, Cambridge, ON**

INTRODUCTION TO TECHNICAL

(CSA)

Technical Document Tree



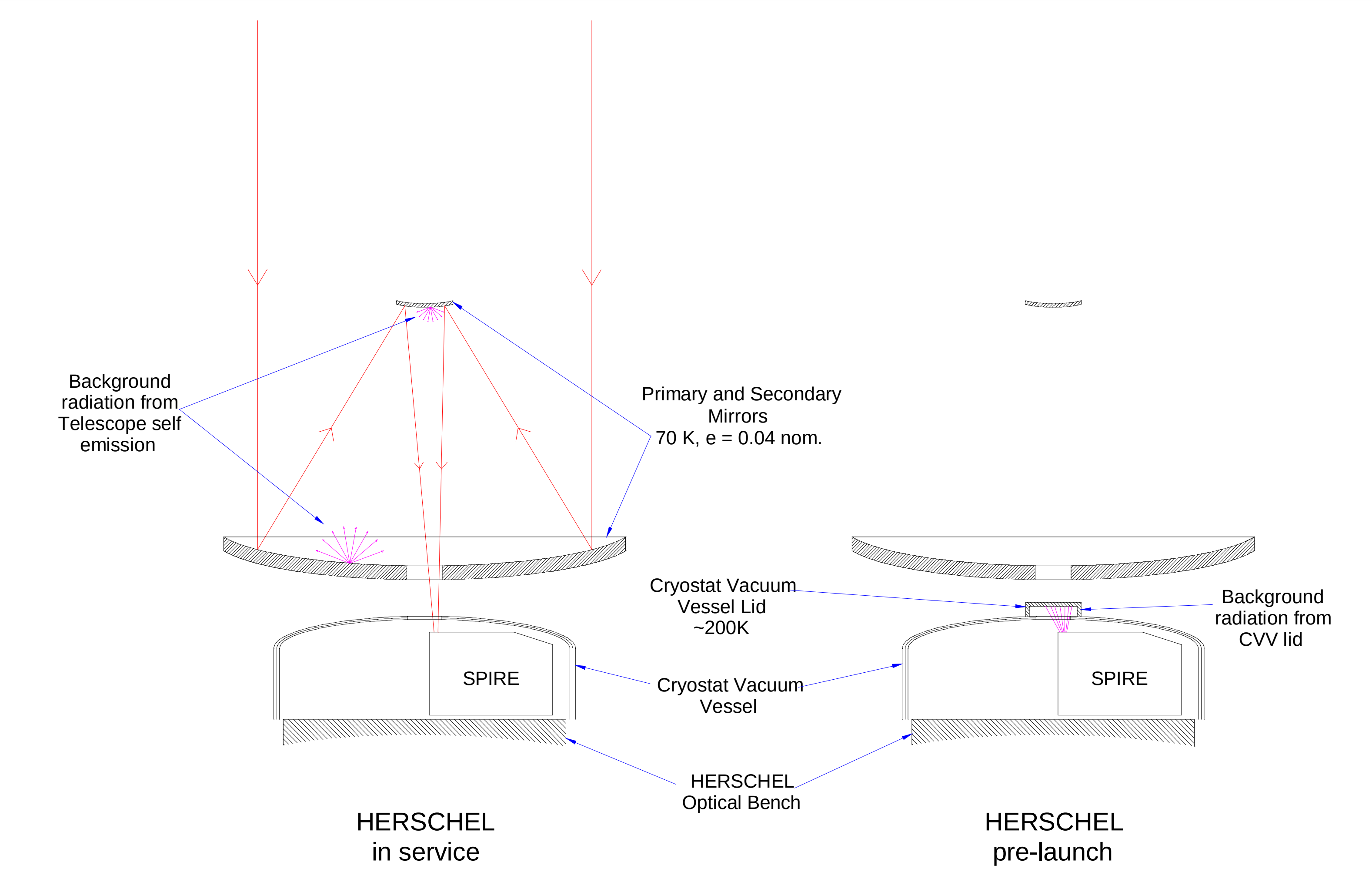
SHUTTER REQUIREMENTS

(U of S)

The SPIRE Shutter: Rationale, Design Requirements, and Design Constraints

GD-1	Instrument Interface Document Part A
GD-2	Instrument Interface Document Part B – SPIRE
GD-3	Instrument Requirements Document
GD-4	SPIRE Systems Budgets
GD-5	SPIRE Structure Interface Control Document
GD-6	SPIRE Harness Definition
AD-1	SPIRE Shutter Usage Forecast

Telescope and Cryostat Lid



Shutter Rationale

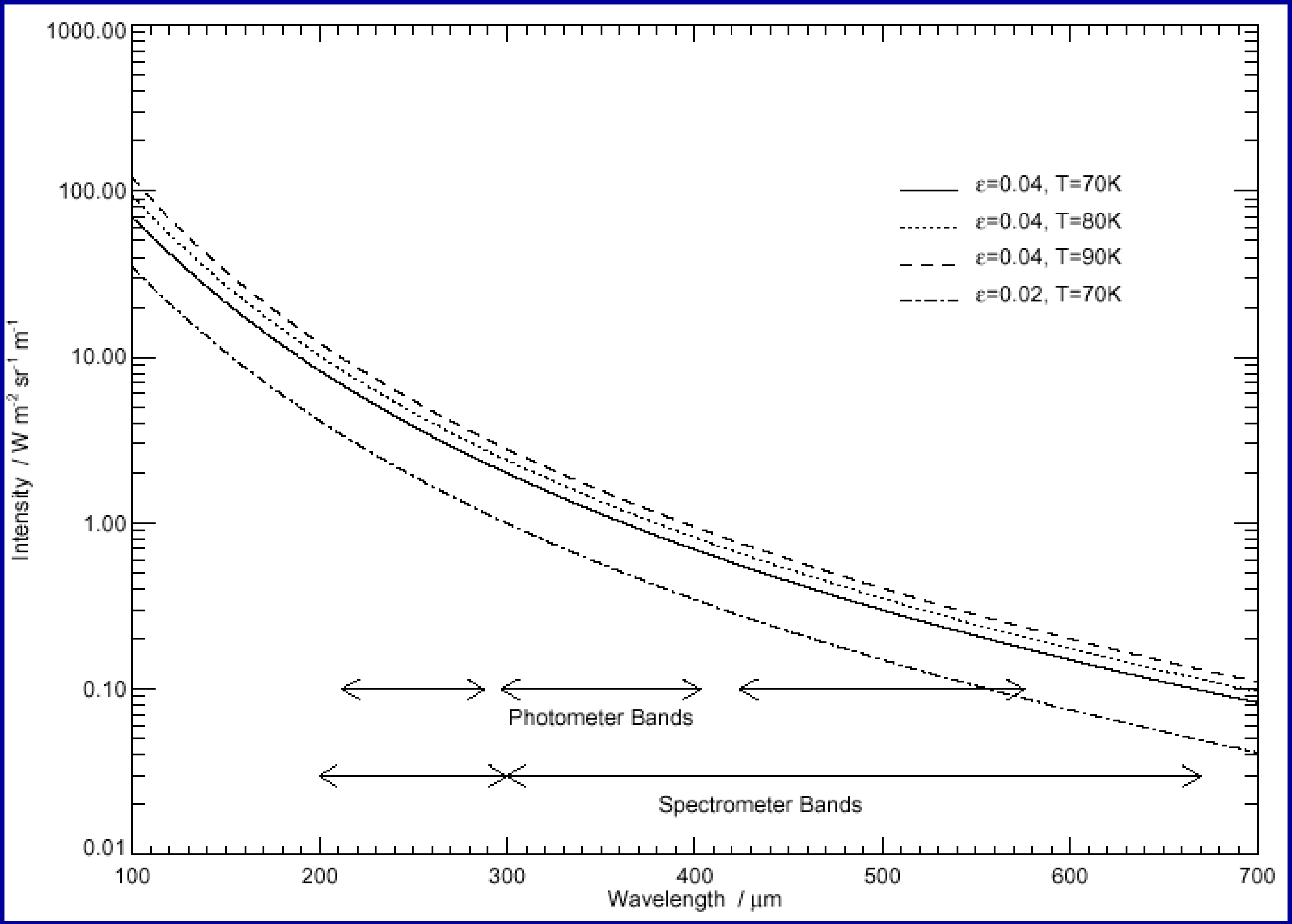
Detector Power Loading:

- **Responsivity depends on total absorbed power**
- **Detectors optimised for flight background conditions**
  - ***Background dominated by telescope thermal emission***
- **Spacecraft-level tests will be under non-representative conditions**
  - ***Power loading from cryostat lid will be up to 100 times higher***

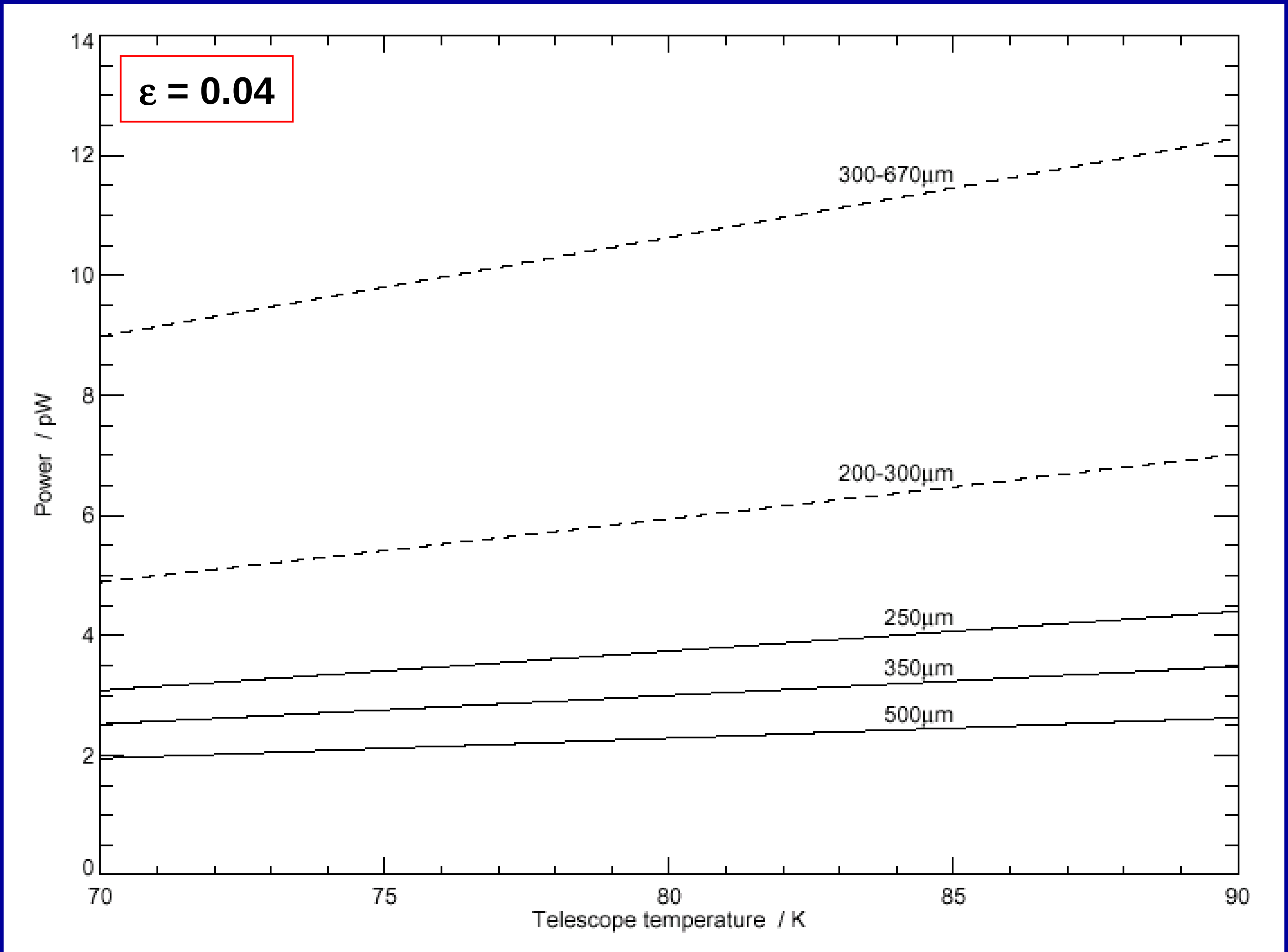
Functions:

- **Rejection of high flux from cryostat lid**
  - ***Lid properties currently not well defined***
  - ***Shutter design should aim to be independent of environment***
- **Simulation of background flux from HSO telescope**
  - ***Requisite power loading can be calculated for each channel using a simple model of the instrument (appendix of Design Requirements Document)***

Telescope Emission Spectra



Power Loading by Telescope



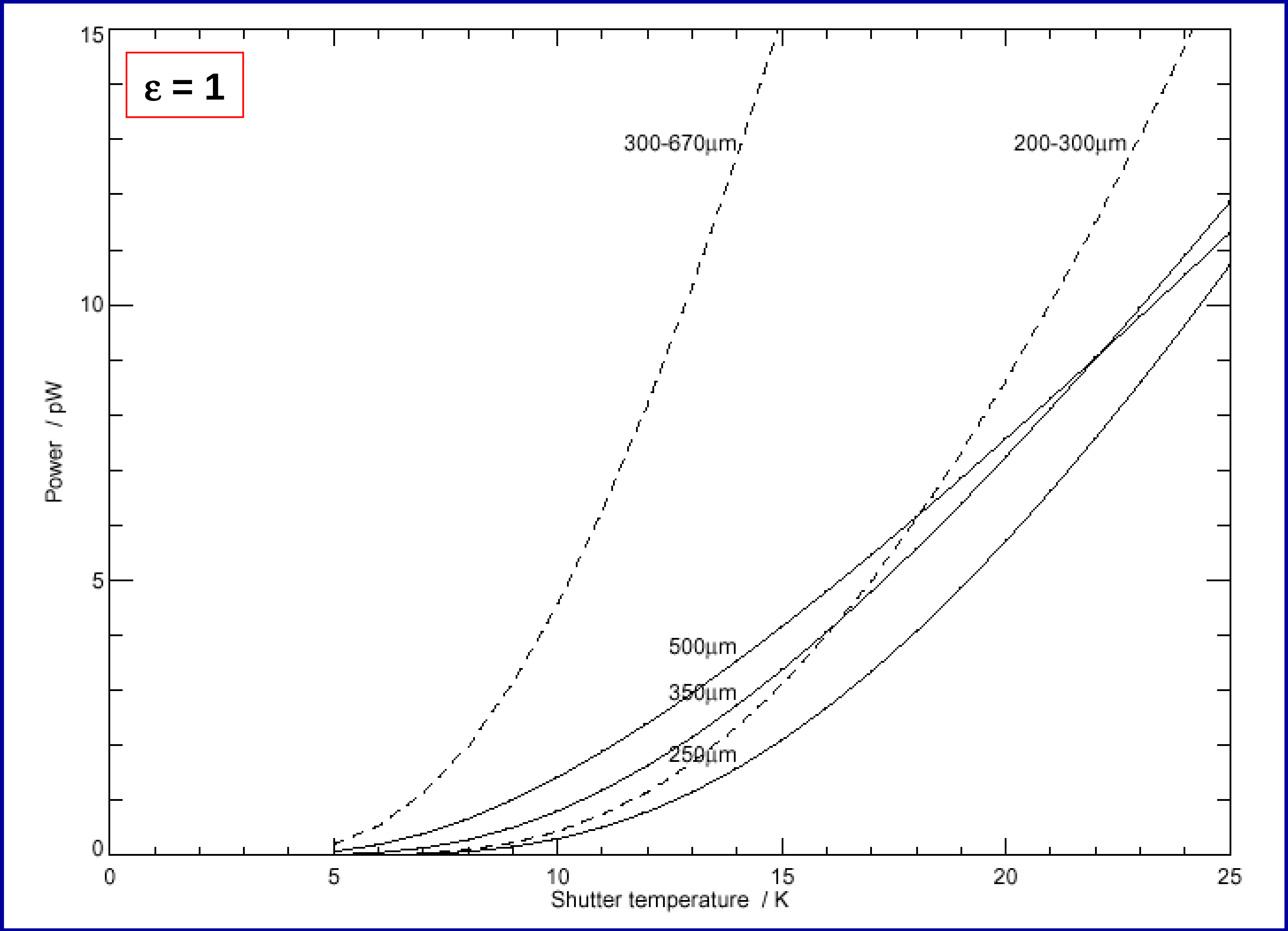
Power Loading Requirements

Channel	Power Loading (pW)
Photometer	1 – 9
Spectrometer Short	2.5 – 14
Spectrometer Long	4.5 – 25

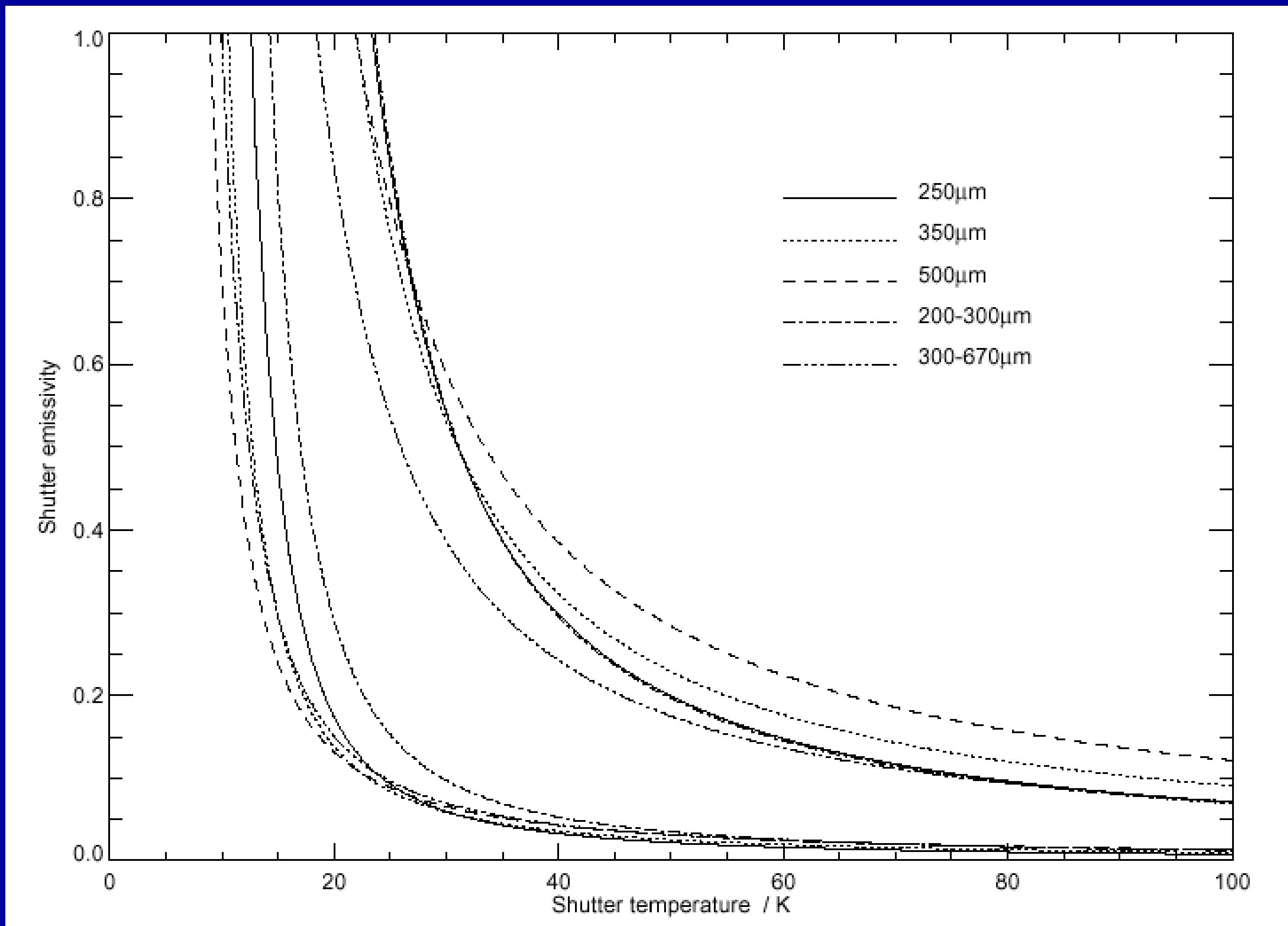
Notes:

- Margin of factor of 2 included to allow for uncertainty in telescope properties
- Shutter rationale driven entirely by Herschel-level test environment
- Shutter is not for absolute flux calibration

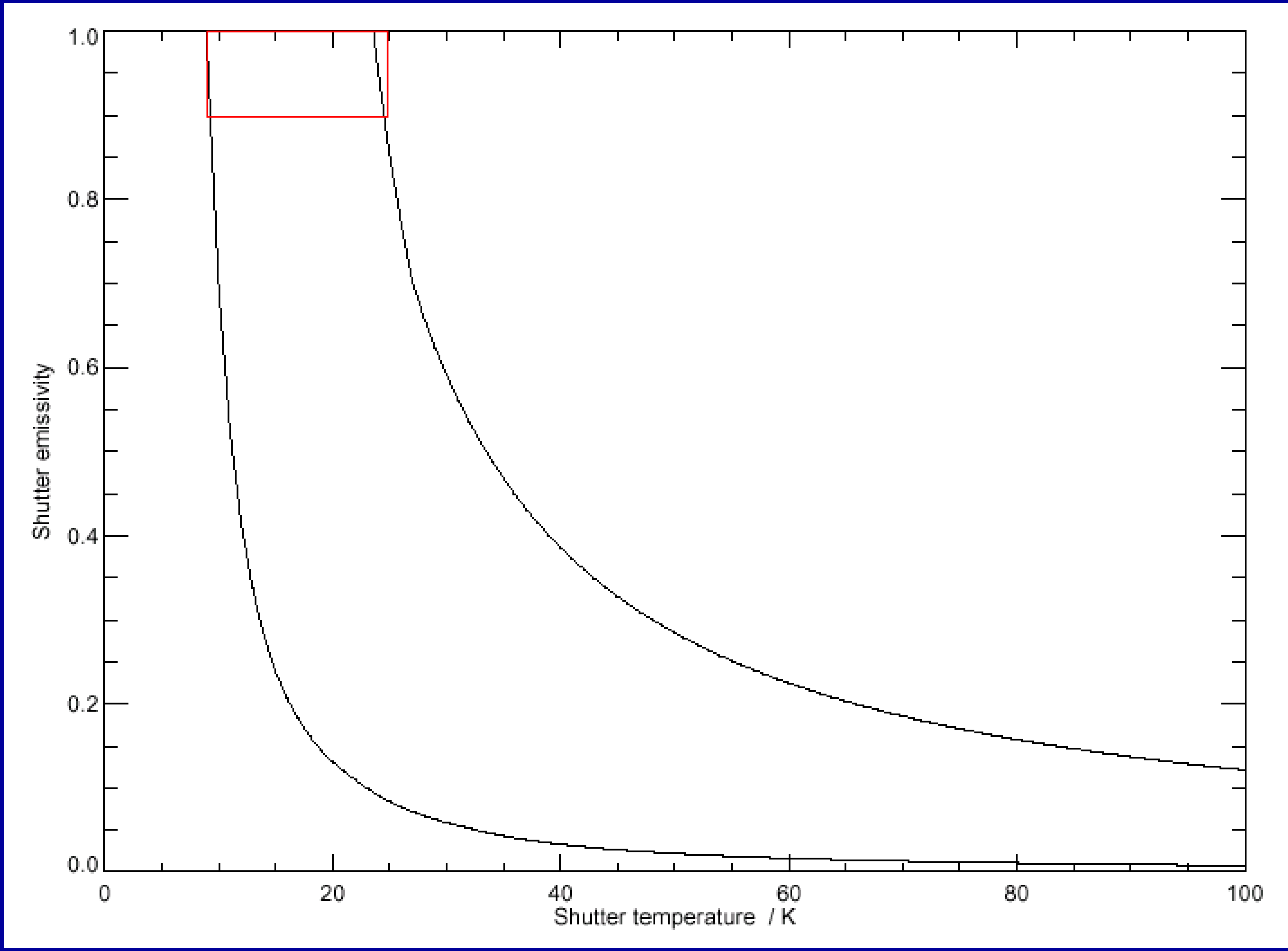
Power Loading by Shutter



Shutter T & ε

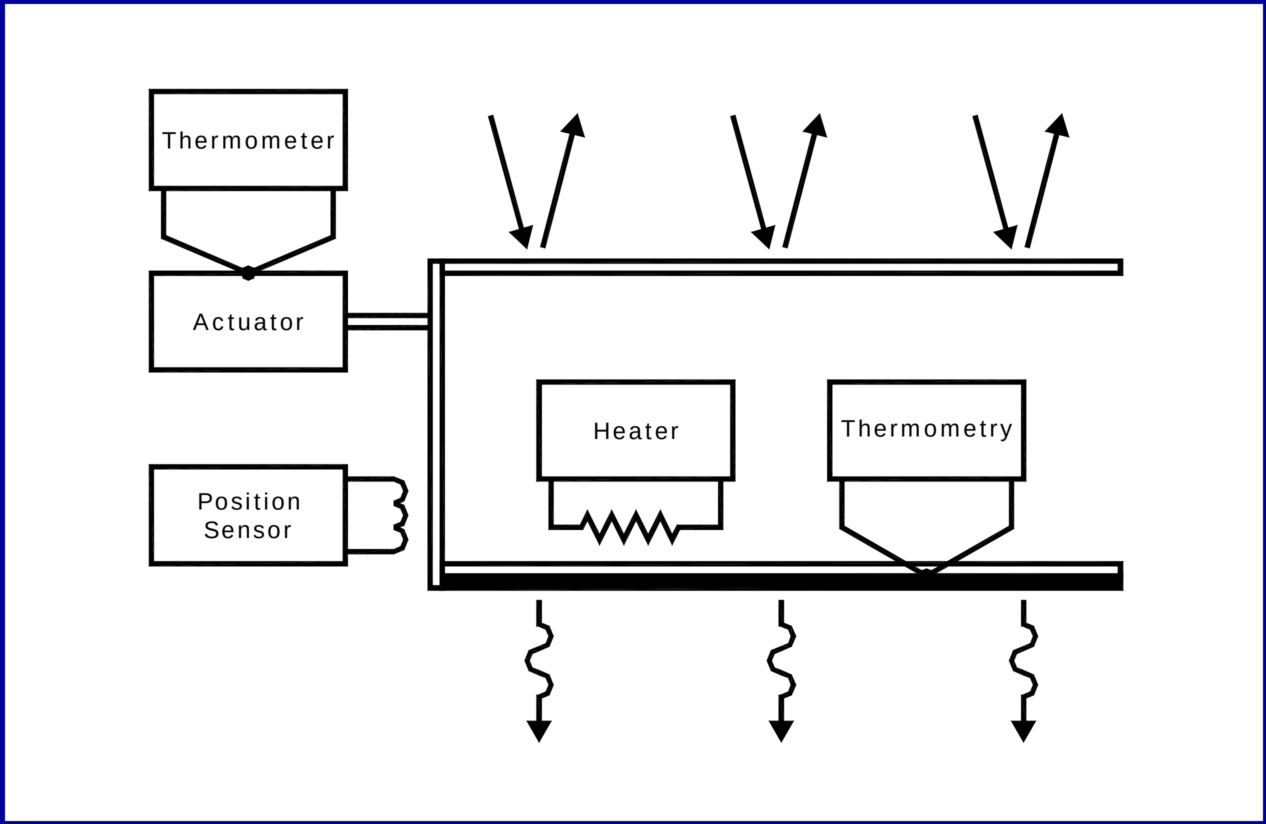

250μm
350μm
500μm
200-300μm
300-670μm
Shutter emissivity
0.0
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
100
Shutter temperature / K

Shutter T & ε

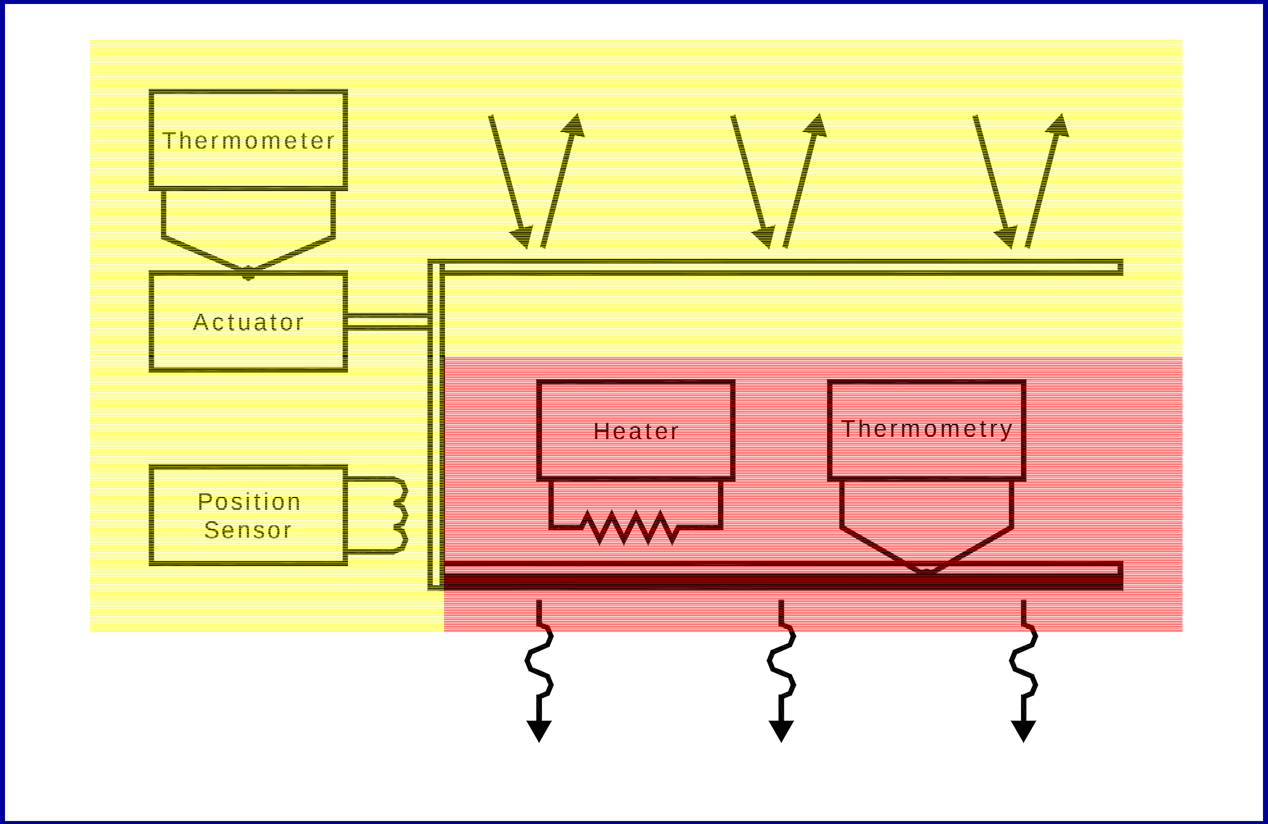


1.0
0.8
0.6
0.4
0.2
0.0
Shutter emissivity
0
20
40
60
80
100
Shutter temperature / K

Shutter Concept



Shutter Concept



Design Requirements

R-01	Rejection of direct flux
R-02	Rejection of indirect flux
R-03	Vane emissivity
R-04	Vane emissivity accuracy
R-05	Vane emissivity uniformity
R-06	Vane temperature
R-07	Vane temperature control
R-08	Vane temperature accuracy
R-09	Vane temperature uniformity
R-10	Vane temperature repeatability

Design Requirements

Requirement ID	R-01
Description	Rejection of Direct Flux
Value	The shutter vane must physically prevent thermal radiation from the Herschel cryostat lid from directly entering the instrument.
Comment	This requirement applies only to thermal radiation which is directly incident on the shutter vane from the Herschel cryostat environment. This requirement applies only when the vane is in the beam.

Design Requirements

Requirement ID	R-02
Description	Rejection of Indirect Flux
Value	The seal of the shutter vane shall be designed so as to reduce stray light entering the instrument to an acceptable level.
Comment	The meaning of "acceptable level" shall be determined by iterative modelling using the SPIRE stray light model at RAL. This requirement applies only when the vane is in the beam.

Design Requirements

Requirement ID	**R-03**
Description	**Vane Emissivity**
Value	**The emissivity of the instrument side of the vane at SPIRE wavelengths shall be greater than 0.9.**
Comment	**High emissivity is required in order to keep the vane temperature as low as possible. The Herschel-approved 'black' is therefore recommended.**

Design Requirements

Requirement ID	R-04
Description	Vane Emissivity Accuracy
Value	The average emissivity of the instrument side of the vane at SPIRE wavelengths shall be determined to an accuracy of ±2%.
Comment	The power loading depends linearly on vane emissivity. An emissivity accuracy of ±2% implies a power loading accuracy of ±2%. This is significantly smaller than the absolute photometric accuracy of the instrument.

Design Requirements

Requirement ID	R-05
Description	Vane Emissivity Uniformity
Value	The emissivity of the instrument side of the vane at SPIRE wavelengths shall be uniform to within 2% (rms).
Comment	Since the vane is not in a SPIRE focal plane, it will not be imaged onto the detector arrays. Variations in emissivity across the area of the vane will be averaged out. The uniformity of the vane emissivity is therefore not critical.

Design Requirements

Requirement ID	**R-06**
Description	**Vane Temperature**
Value	**The temperature of the instrument side of the vane shall be controllable over the range 9–25 K.**
Comment	**This requirement applies only when the shutter is being used at instrument temperature.**

Design Requirements

Requirement ID	R-07
Description	Vane Temperature Control
Value	There shall be at least 16 set points over the temperature range specified in R-06.
Comment	This allows for the provision of different power loadings to different channels.

Design Requirements

Requirement ID	R-08
Description	Vane Temperature Accuracy
Value	The temperature of the instrument side of the vane shall be monitored. The average temperature of the emitting surface must be known to an accuracy of ±0.1 K.
Comment	This requirement applies only when the shutter is being used at instrument temperature. This temperature accuracy corresponds to a power loading accuracy of ±2% for the nominal power loading and ±5% at the minimum temperature.

Design Requirements

Requirement ID	R-09
Description	Vane Temperature Uniformity
Value	The temperature of the instrument side of the vane shall be uniform to within 0.1 K (rms).
Comment	This requirement applies only when the shutter is being used at instrument temperature. Since the vane is not in a SPIRE focal plane, it will not be imaged onto the detector arrays. Variations in temperature across the area of the vane will be averaged out. The uniformity of the vane temperature is therefore not critical.

Design Requirements

Requirement ID	R-10
Description	Vane Temperature Repeatability
Value	The average temperature of the instrument side of the vane shall be repeatable to within ±0.04 K.
Comment	This requirement applies only when the shutter is being used at instrument temperature. It corresponds to a power loading repeatability of ±2% at the minimum temperature and ±0.8% for the nominal power loading.

Design Constraints

R-11	Reliability
R-12	Mass
R-13	FPU thermal dissipation
R-14	Cryoharness thermal dissipation
R-15	Structure interface
R-16	Harness interface
R-17	Operating temperature
R-18	Operating orientation
R-19	Transition time
R-20	Thermal stabilisation time

Shutter Life Cycle

	Failure Criticality
Fabrication	
Subsystem-level Tests	
Delivery to RAL	
SPIRE-level Tests	Inconvenient
Delivery to ESA	
Herschel-level Tests	Severe
Launch	
Flight Operations	Catastrophic

Design Constraints

Requirement ID	**R-11**
Description	**Reliability**
Value	**The shutter shall be designed to a reliability requirement of 0.9999.**
Comment	**The reliability constraint is driven by (a) criticality of the failure mode, and (b) lack of access after spacecraft Integration.**

Design Constraints

Requirement ID	R-12
Description	Mass
Value	The mass of the subsystem must conform to the allocation in GD-4.
Comment	The current mass allocation is 200g. This was based on an initial estimate before the shutter location had been identified and before the requirements had been finalised. It may be necessary to amend GD-4 on the basis of a realistic design; the allocation in GD-4 should therefore be regarded as negotiable.

Design Constraints

Requirement ID	R-13
Description	FPU Thermal Dissipation
Value	The temperature of the instrument structure in the vicinity of the shutter shall rise by no more than TBD K after TBD s when the shutter subsystem is energised.
Comment	The thermal response of the instrument to power dissipation in the shutter subsystem will be determined using the thermal model of the instrument at RAL.

Design Constraints

Requirement ID	**R-14**
Description	**Cryoharness Thermal Dissipation**
Value	**TBD**
Comment	**None**

Design Constraints

Requirement ID	**R-15**
Description	**Structure Interface**
Value	**The subsystem design shall conform to the structure interface specification in GD-5.**
Comment	**This specification shall include at least the following: selection of compatible materials; allocated volume; subsystem eigenfrequencies. This document should be regarded as negotiable as the design proceeds.**

Design Constraints

Requirement ID	R-16
Description	Harness Interface
Value	The subsystem design shall conform to the harness interface specification in GD-6.
Comment	This document should be regarded as negotiable as the design proceeds.

Design Constraints

Requirement ID	**R-17**
Description	**Operating Temperature**
Value	**The shutter mechanism (actuator and vane position sensor) shall be capable of operation at instrument temperature and at room temperature.The vane heater and all thermometry need only function at instrument temperature.**
Comment	**Operation at instrument temperature is a *sine qua non.* This requirement ensures that the mechanism can be functionally tested at room temperature before it is cooled.**

Design Constraints

Requirement ID	**R-18**
Description	**Operating Orientation**
Value	**The shutter shall be capable of operation in any orientation.**
Comment	**The SPIRE instrument will be placed in various orientations during the various test phases (AD-1). Operational problems can be avoided if the shutter can operate in any orientation.**

Design Constraints

Requirement ID	**R-19**
Description	**Transition Time**
Value	**The time required to move the vane into the beam on command shall be less than the thermal stabilisation time (R-20).**
Comment	**This requirement ensures that actuating the mechanism will not constrain the flow of the instrument test procedures.**

Design Constraints

Requirement ID	R-20
Description	Thermal Stabilisation Time
Value	The time required to establish a stable vane temperature, assuming that the vane is initially at the ambient instrument temperature, shall be less than 10 minutes.
Comment	The number is essentially aribtrary. This requirement ensures that heating the vane will not constrain the flow of the instrument test procedures.

Shutter Usage Forecast

Instrument Configurations

- SPIRE Instrument Level Testing (ILT)
  - Herschel Payload Module (PLM)
    - Herschel Spacecraft (S/C)

Documents:

Herschel/Planck IIDA
Herschel/Planck IIDB - SPIRE
Design Reqs for the SPIRE Shutter Subsystem
IQRD
SPIRE Instrument AIV Plan
SPIRE Schedule, 12 April 2001

SPIRE ILT - RAL Test Facility

Primary Function of ILT:

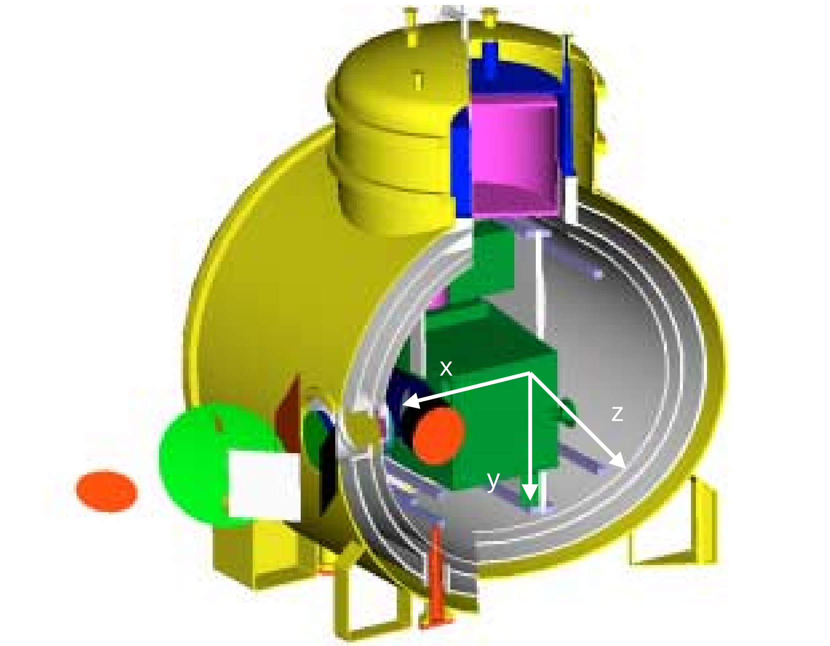
• simulate thermal environment in which the instrument will operate

• provide a telescope simulator and calibration sources to allow verification of the instrument specifications and its calibration

Additionally:

• desirable to test shutter performance and detected signal due to shutter vane emission during this level of testing

Shutter Usage during SPIRE ILT



Orientation:

- instrument +y axis downward
- *1g requirement for actuation of shutter vane*

Anticipated Shutter Usage:

- Vane cycles: 11
- Latch cycles: 7

Shutter Usage during SPIRE ILT

Cooler recycling (1)

IIDB 4.6.7: "the 3He cooler requires recycling every 46 hours (TBC). During this time the instrument will be switched off except for vital housekeeping and cooler functions"

- *will it be required that the shutter EGSE is switched off for cooler recycling?*

Cooler recycling (2)

Helium Sorption Cooler Summary Report RP/SBT/SC/2000-04:

"the cooler recycling needs to be performed at an angle of 15° or more (sorption pump above evaporator)...only relevant during ground testing"

- *the cooler will be at an angle of 90° (sorption pump directly above evaporator) at all times in the RAL Test Facility*

Herschel Level Testing

- *the shutter rationale is based on its use during S/C level ground testing of SPIRE*
- *successful shutter operation during this phase drives shutter design*

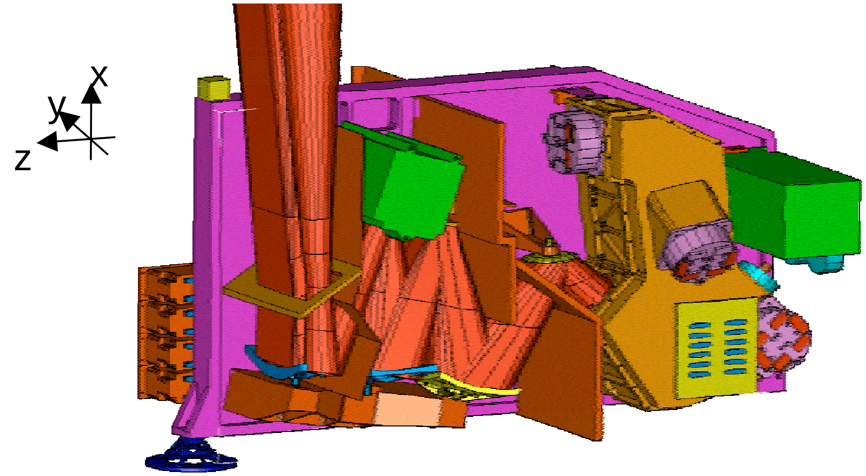
Two Herschel Test Configurations

1. *Herschel PLM PFM Testing (IIDA 7.3.3)*
2. *Herschel S/C PFM Testing (IIDA 7.3.4)*

Shutter Usage during Herschel Level Tests

Orientation:

- SPIRE -x axis downward
- *Testing of the FTS mechanism will require a 90° tilt of the PLM (or S/C) about the z-axis*
- *Recycling of the cooler will require a 15° tilt of the PLM (or S/C) about the z-axis*
- *1g requirement for shutter*



Anticipated Shutter Usage:

PLM

- Vane cycles: 5
- Latch cycles: 1

S/C

- Vane cycles: 5
- Latch cycles: 1

Shutter Usage: Summary

- *currently anticipated number of vane cycles: 21*
- *currently anticipated number of latch cycles: 9*

- *probable that additional tests will be scheduled as project matures*
  - *unforeseen tests and repetition of scheduled tests is also likely*
  - *therefore, shutter design will be based on an anticipated shutter usage of 100 cycles for both the shutter vane and latch*

SPIRE/Herschel Deliverables

Shutter Models and Compliance Requirements

COM DEV

SPIRE Deliverable Models

STM - Structural Thermal Model

CQM - Cryogenic Qualification Model (ESA)

PFM - Proto-Flight Model (ESA)

FS - Flight Spare - TBD (ESA)

Non-Deliverable Models

QM - Subsystem Qualification Model

STM - Structural Thermal Model

(STM Shutter and CQM Shutter Harness)

- *compare warm vibration response to FEM analysis*
- *determine vibrational levels transferred to subsystem*
- *qualify the cold instrument structure against proposed vibration levels*
- *validate thermal model at 2K, 4K, and 10K levels*
- *verify the optical alignment procedure*

Shutter Need Date:	*01 Aug 2002*
Compliance:	*FF, MC (NB: Thermal)*
Cold vibration campaign:	*28 November 2002*
STM Final Review:	*14 February 2003*

CQM: Cryogenic Qualification Model

- *used by SPIRE consortium to qualify the cold instrument design in the proposed thermal/EMC environment*
- *on delivery to ESA it will be used to ensure the compatibility of the FIRST payload and spacecraft by performing a series of cold functional tests and a set of cold conductive EMC tests*

Shutter Need Date:	*11 Jan 2003*
Compliance:	*FF, MC, EC, PC*
Critical Design Review:	*27 June 2003*
CQM Delivery to ESA:	*15 July 2003 (SPIRE: 1.10.2003)*

QM: Subsystem Qualification Model

- *ensure qualification at unit rather than instrument level*
- *built to flight standards*
- *must undergo rigorous environmental testing including cold vibration*
- *QM testing should happen in parallel with the instrument level CQM program*
- *QM results to be featured at the Critical Design Review (CDR) (27 June 2003)*

PFM: Proto-Flight Model

- instrument model intended for flight
- built to full flight qualifications
- the PFM cold FPU and JFET boxes will undergo environmental test to qualification levels

Shutter Need Date:	01 Oct 2003
Compliance:	Full
PFM Test Readiness Review:	09 December 2003
PFM Delivery to ESA:	15 July 2004 (SPIRE: 1.09.2004)

FS: Flight Spare - TBD

- *cold FPU subsystems and JFET boxes likely to be constructed from refurbished CQM*
- *FS warm electronics to consist of spare electronics cards*
- *FS to be fully integrated: TBD*
- *FS to be delivered to ESA: TBD*

Shutter Need Date:	*10 Jan 2005*
Compliance:	*Full*
FS Test Readiness Review:	*06 June 2005*
FS Available to ESA:	*29 Nov 2005 (SPIRE: 1.01.2006)*

COMPLIANCE TO REQUIREMENTS

(COM DEV)

Compliance to Requirements

ID	DESCRIPTION	VALUE	COMPLIANCE	COMMENT	VERIFICATION
R-01	Rejection of Direct Flux	The shutter vane must physically prevent thermal radiation from the Herschel cryostat lid from directly entering the instrument.	C		Analysis
R-02	Rejection of Indirect Flux	The seal of the shutter vane shall be designed so as to reduce stray light entering the instrument to an acceptable level.	C		Analysis
R-03	Vane Emissivity	The emissivity of the instrument side of the vane at SPIRE wavelengths shall be greater than 0.9.	C		Test
R-04	Vane Emissivity Accuracy	The average emissivity of the instrument side of the vane at SPIRE wavelengths shall be determined to an accuracy of ±2%.	C	1-2% measurement error	Analysis Test
R-05	Vane Emissivity Uniformity	The emissivity of the instrument side of the vane at SPIRE wavelengths shall be uniform to within 2% (rms).	C		Test
R-06	Vane Temperature	The temperature of the instrument side of the vane shall be controllable over the range 9-25 K.	TBD	Depends on Cryostat lid	Analysis Test
R-07	Vane Temperature Control	There shall be at least 16 set points over the temperature range specified in R-06.	C		Inspection

Compliance to Requirements

ID	DESCRIPTION	VALUE	COMPLIANCE	COMMENT	VERIFICATION
R-08	Vane Temperature Accuracy	The temperature of the instrument side of the vane shall be monitored. The average temperature of the emitting surface must be known to an accuracy of ±0.1 K.	C*	Annual Calibration 50 mK	Analysis
R-09	Vane Temperature Uniformity	The temperature of the instrument side of the vane shall be uniform to within 0.1 K (rms).	C		Analysis
R-10	Vane Temperature Repeatability	The average temperature of the instrument side of the vane shall be repeatable to within ±0.04 K.	C*	±50 mK Severe ±10 mK Typical	Analysis
R-11	Reliability	The shutter shall be designed to a reliability requirement of 0.9999.	C		Analysis
R-12	Mass	The mass of the subsystem must conform to the allocation in SPIRE Systems Budgets, SPIRE-ATC-PRJ-000450.	TBD		Analysis Inspection
R-13	FPU Thermal Dissipation	The temperature of the instrument structure in the vicinity of the shutter shall rise by no more than TBD K after TBD s when the shutter subsystem is energized.	TBD		Analysis
R-14	Cryoharness Thermal Dissipation	TBD	TBD		Analysis

Compliance to Requirements

ID	DESCRIPTION	VALUE	COMPLIANCE	COMMENT	VERIFICATION
R-15	Structure Interface	The subsystem design shall conform to the structure interface specification in ICD Structure – Mechanical I/F, SPIRE-MSS-PRJ-000617.	C		Inspection
R-16	Harness Interface	The subsystem design shall conform to the harness interface specification in SPIRE Harness Definition, SPIRE-RAL-PRJ-000608.	C		Inspection
R-17	Operating Temperature	The shutter mechanism (actuator and vane position sensor) shall be capable of operation at instrument temperature and at room temperature. The vane heater and all thermometry need only function at instrument temperature.	C		Demonstration
R-18	Operating Orientation	The shutter shall be capable of operation in any orientation.	C		Demonstration
R-19	Transition Time	The time required to move the vane into the beam on command shall be less than the thermal stabilization time (R-20).	C		Analysis Demonstration
R-20	Thermal Stabilization Time	The time required to establish a stable vane temperature, assuming that the vane is initially at the ambient instrument temperature, shall be less than 10 minutes.	C	Subject to allowable power.	Analysis Test

SHUTTER MECHANICAL DESIGN

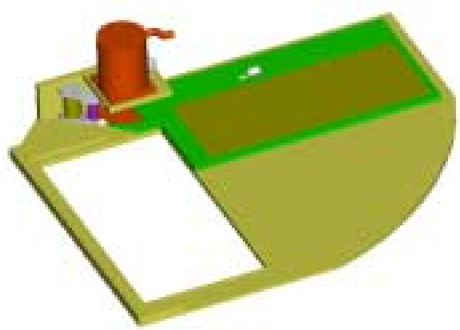
(COM DEV)

Mechanical Design Topics

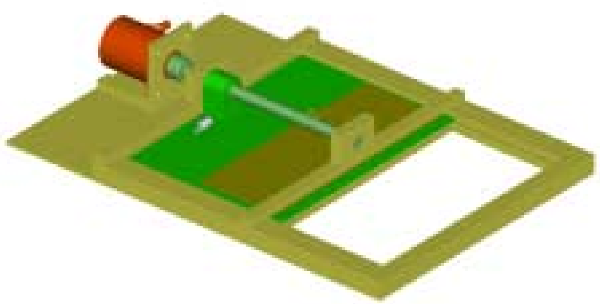
- Initial Design Concepts Trade-off
- Interface Requirements
- Current Shutter Design
- Interface Control Drawing
- Major Parts Description
- Mass Budget
- Thermal Analysis
- Vane Mass and Frequency
- Mock-up Testing and Material Evaluation

Shutter Design

- A number of design concepts were considered to meet the program requirements
- The concepts were evaluated and two potential solutions were chosen: the “cleaver” and the “slider”
- A trade was performed to decide on a baseline design



Cleaver



Slider

Trade Table

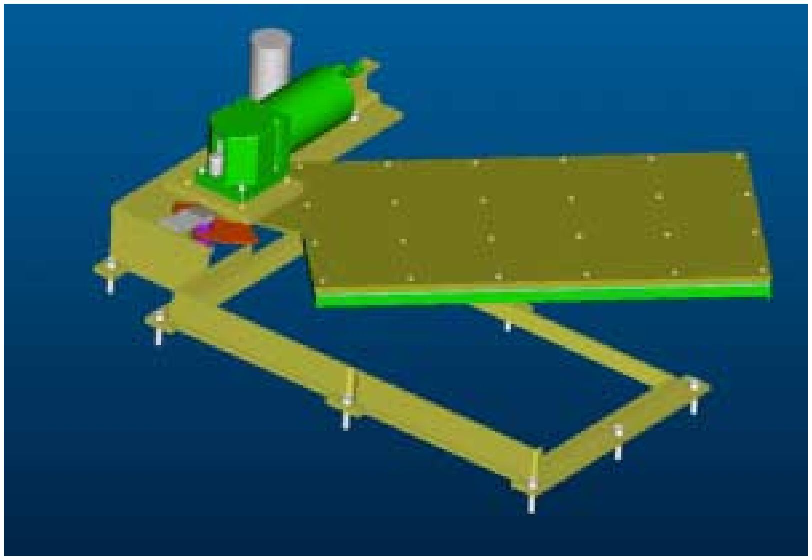
Issue	Cleaver	Slider	Comparison
Volume / Size - flight configuration	Design is below the 15 mm clearance zone to the cryostat.	Design is below the 15 mm clearance zone to the cryostat.	Slider motor height is approx. 1.5 cm lower than cleaver. Total height may be driven by the latch. Slider design requires more planar volume but stays within the instrument envelope.
Volume / Size - SPIRE test configuration	Higher profile may complicate MGSE; however, the motor on the side of the aperture could be clear of MGSE	Lower profile allows more height clearance for the MGSE but this is probably not enough. Motor is in the path of the black body.	Although the slider design is lower, it may complicate the MGSE more severely since the mechanism is in the path of the black body.
Mass	766 grams (incl. 165 g shutter extension harness and 147 g margin)	839 grams (incl. 165 g shutter extension harness and 142 g margin)	
Torque Capability (Motor power)	Gear ratio up to 180 (CDA)	Gear ratio up to 100 (CDA) plus lead screw mechanical advantage. (Gear train may not be required.)	Required gear ratios can be accomodated with both designs.
Elimination of 1G Operation	Could eliminate planetary gear train (angle gear box has some amplification). Might still need 1 stage or larger motor.	No gear train required	Elimination of the 1G requirement will be more beneficial for the cleaver design due to reduced mass and gear train complexity.
Flex Harness Design	Omega design requires the least amount of "free" cable. Other designs including clockspring are possible	Rolling loop design is likely required. Long unsupported section is required.	Cleaver design allows more design options and a shorter unsupported length.

Trade Table

Issue	Cleaver	Slider	Comparison
Position Sensor Design	Compact rotary style	Linear style required over full stroke	Slider design may require more volume and mass.
Debris / Contamination Risk	Only source of contamination is dry lubricant escaping from the gear box.	Risk of contamination from the slides and lead screw. Slides are located close to the beam opening.	Higher risk of contamination from the slider design.
Mechanical Robustness	Mechanical failure could be caused by failure of the gear box	Mechanical failure due to failure of lead screw, gear box (if existing), or jamming of the slides	More items can fail on the slider design.
Cold Operation Risk	Motor and gear train qualified (?) at 4K	Sliders rated at 33K	Most items seem to be compatible with 4K operation. The sliders would need to be qualified.
Latch Requirement	Latch required to maintain resonant frequency of the vane and to keep vane out of the beam during vibration.	Latch may not be required, but likely would be included.	Latch design is more critical to the cleaver design.
Light Seal	Adequate light seal can be achieved.	Adequate light seal can be achieved.	Light seal is not a major concern based on MSSL discussions.
Stray Light Effects	Motor and position sensor located near the aperture.	Slide rails located near the aperture. Motor, latch and position sensor are remote.	Stray light bounce does not seem to be a concern to MSSL.
Resonant Frequency	Achieving minimum resonant frequency on the vane will be difficult. Snubbers may be required.	Vane design should meet resonant frequency requirement if slides have close clearance.	Vane is better supported in the slider design.

Shutter Mechanical Design

- Design Status
  - Based on the trade study, the cleaver design was chosen as the preferred design.
  - This option was agreed to with MSSL during the June 23 conference call.



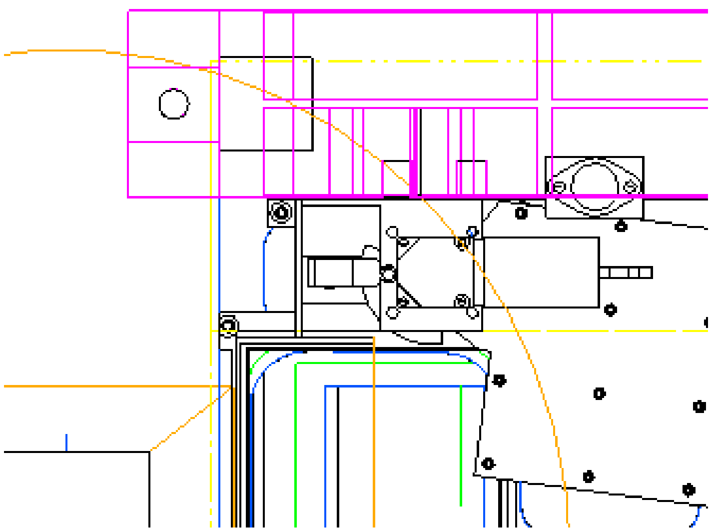
  - All future work concentrated on the cleaver design only, with the shutter mounted to the top cover of the SPIRE instrument.

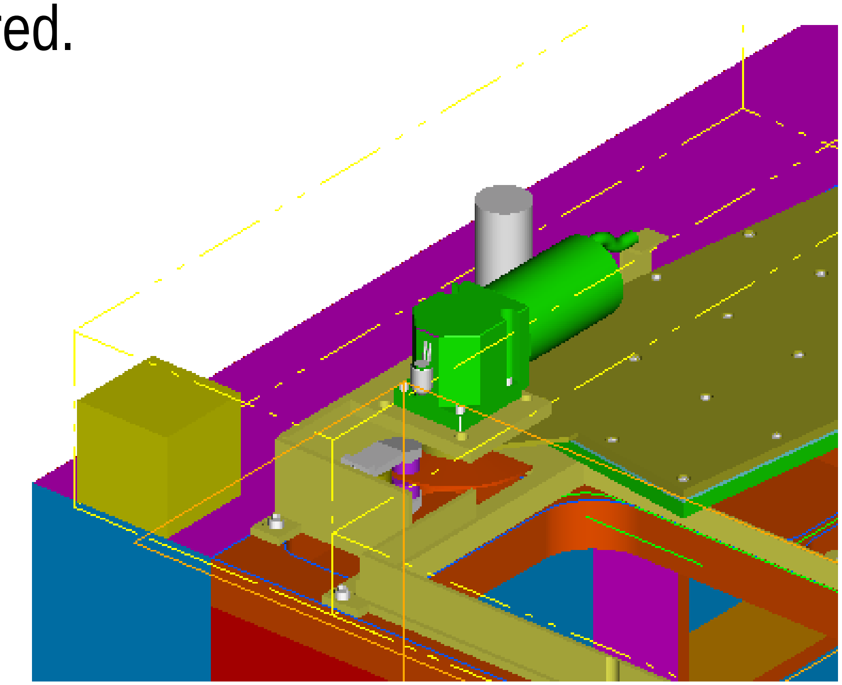
Shutter Mechanical Design

- Interface and Envelope Requirements
  - The shutter must be compatible with the SPIRE instrument, Herschel cryostat and the RAL SPIRE test facility.
  - All parties were informed of the shutter design and were supplied with a COM DEV shutter model.
  - RAL GSE team have integrated the shutter model and have stated that they should be able to accommodate the required shutter envelope.
  - MSSL are also working with the shutter model.
  - A new model will be provided based on the current design and ICD

Shutter Mechanical Design

- MSSL have integrated the model and are working on the interface
  - Shutter design fits within cryostat stayout zone.
  - Shutter envelope will need to be modified to allow for the optical cube and some envelope growth.
    - Final cube location is required.





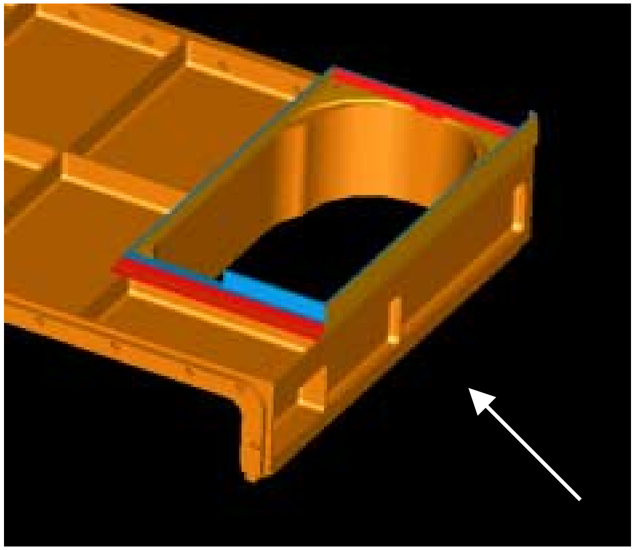
Shutter Mechanical Design

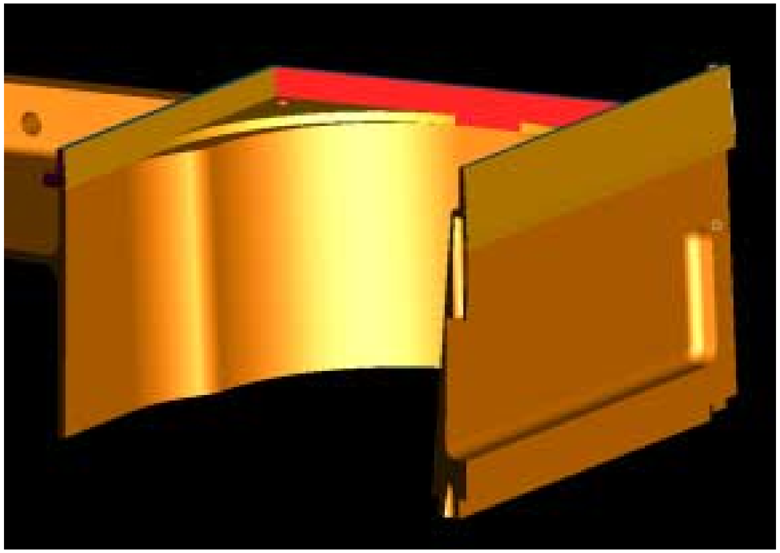
- The material available to fasten the shutter to the SPIRE cover has steadily been reduced along the +Z edge.
  - Original model received: 7.75 mm.
  - Tony Richards' memo May 15: 6.6 mm.
  - Model received May 25: 3.6 mm.
    - (Technical note SPIRE-RAL-NOT-000694)

- The changes are due to the aperture growth and clearance philosophy.

Shutter Mechanical Design

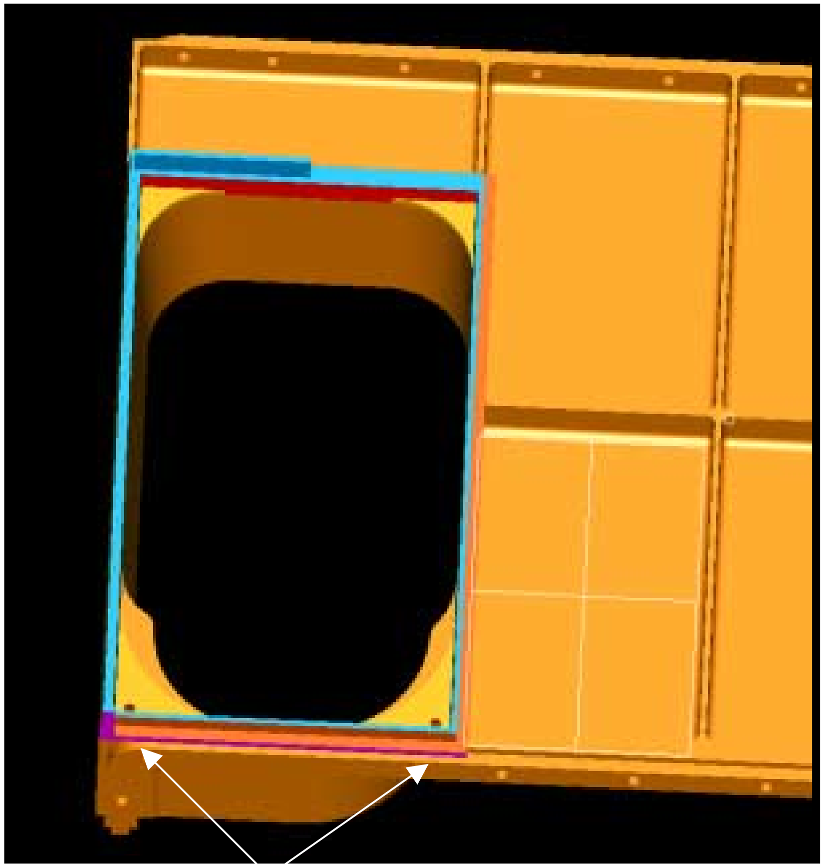
- A 2-56 screw will be used to screw into the shutter frame
  - 0.56 mm material left from hole to edge of frame
  - Tapered walls reduce wall to 0.36 mm at top
    - HiFi taper to be confirmed
  - No room for a helicoil
  - Negligible structural load on this screw





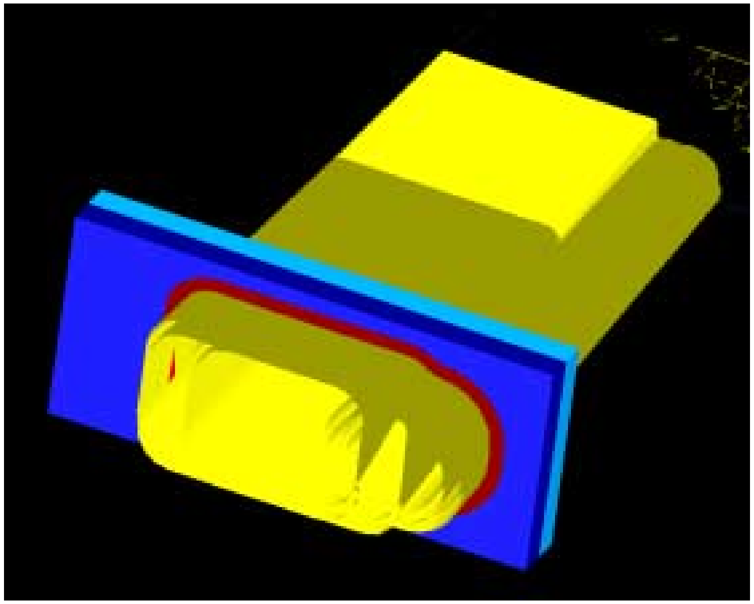
Shutter Mechanical Design

- Side wall interface has also decreased
- Screws have been moved to the inside of the frame
- Need to check dynamics if unsupported length.

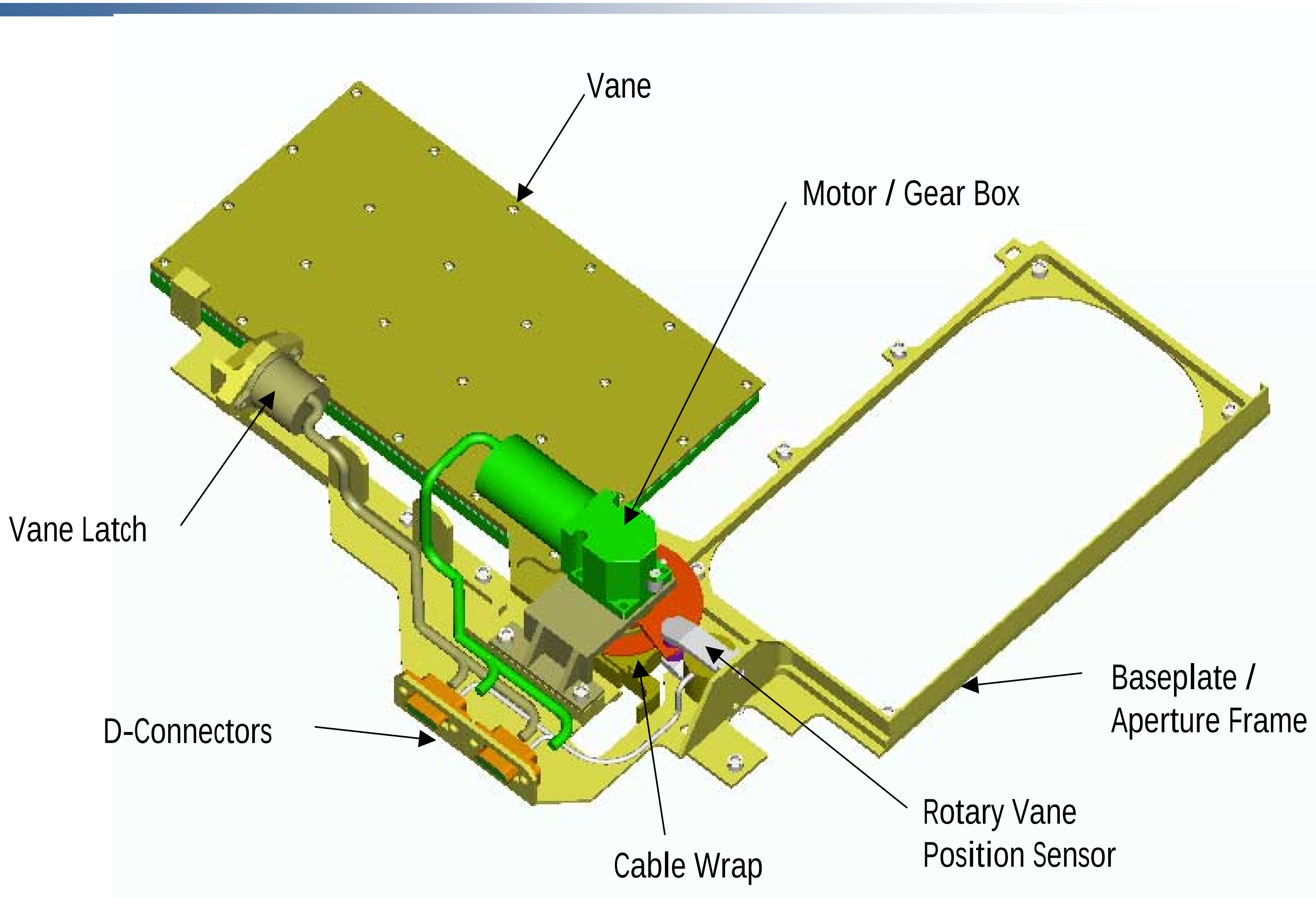


Shutter Mechanical Design

- An aperture description and clearance zone was issued by Tony Richards
- Solid models were provided by Tony to describe the stayout areas. Update was received June 29.
- These models are used by COM DEV to ensure that we provide the proper beam clearance.
- MSSL models were used for the structural interface



Shutter Mechanical Design

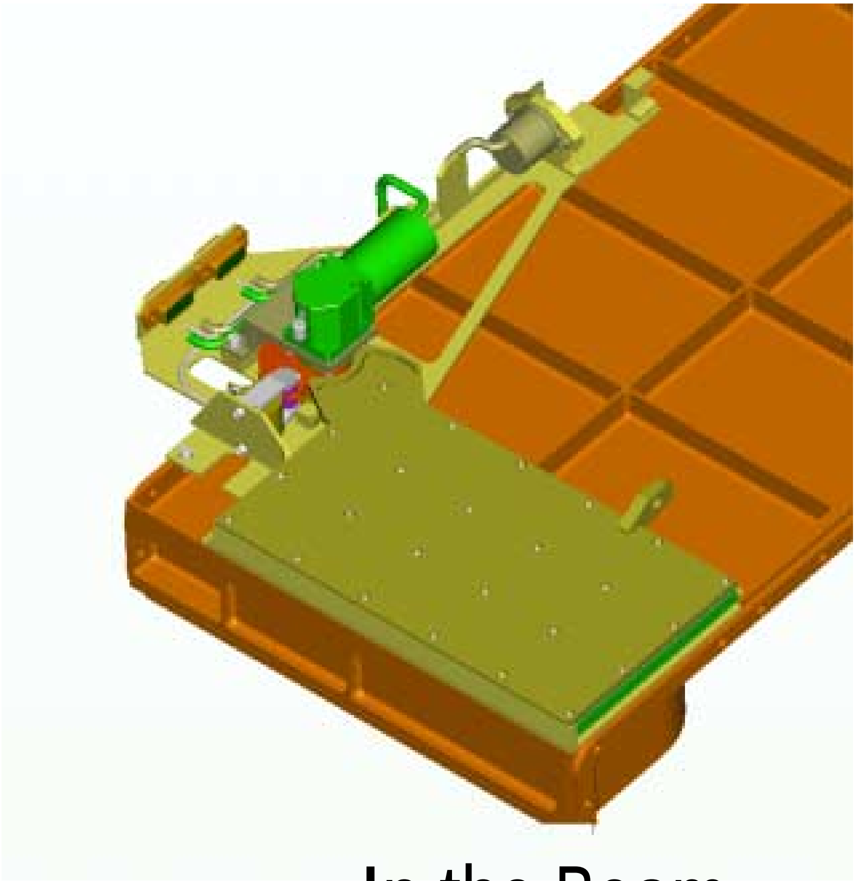


Shutter Mechanical Design

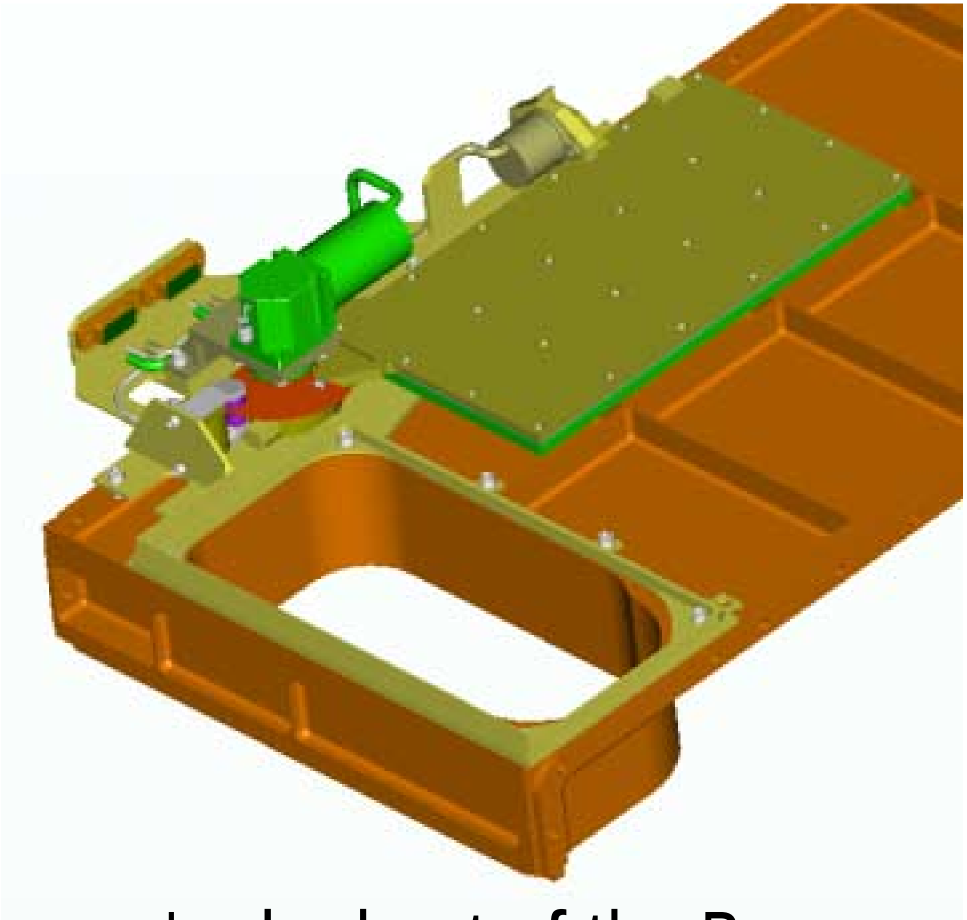
- The shutter design has been modified to meet the current interface requirements
  - Frame modified to meet interface
  - Shutter enlarged to cover larger aperture
  - Latch rotated to support vane and clear cryostat volume (allows room for latch sensor)
  - Two 15 pin D-Connectors added
  - Clockspring style cable wrap added (height clearance verified)
  - Hinge point shifted to allow screw access
    - Also allows increased area for optical cube
- Shutter must be installed in latched position to access screws
  - All screws are located over aperture panel

Shutter Mechanical Design

- Shutter states and operation



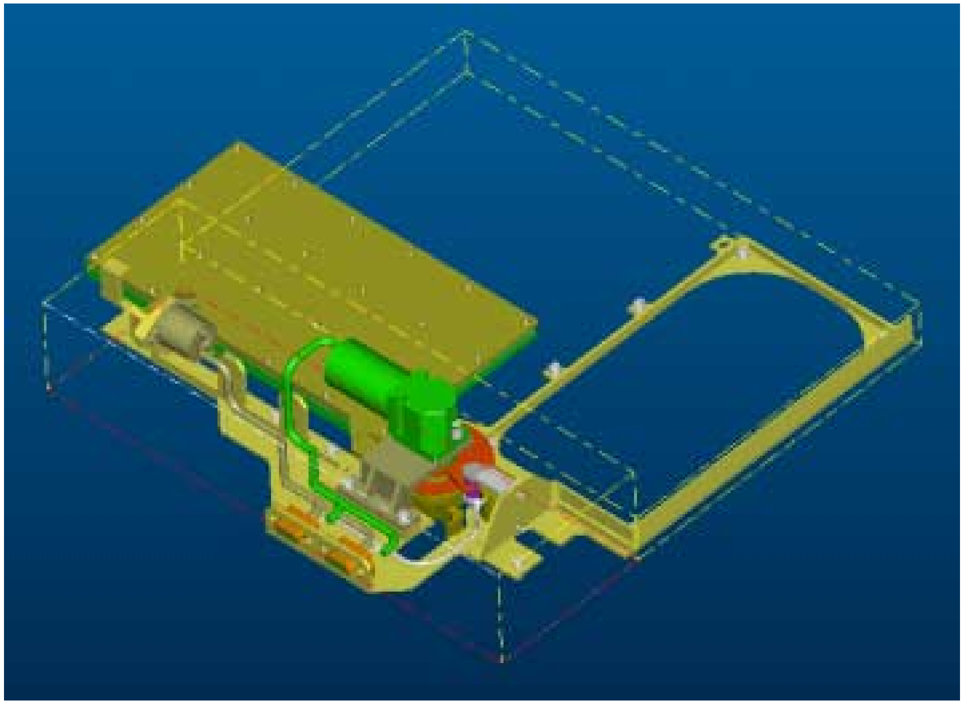
In the Beam

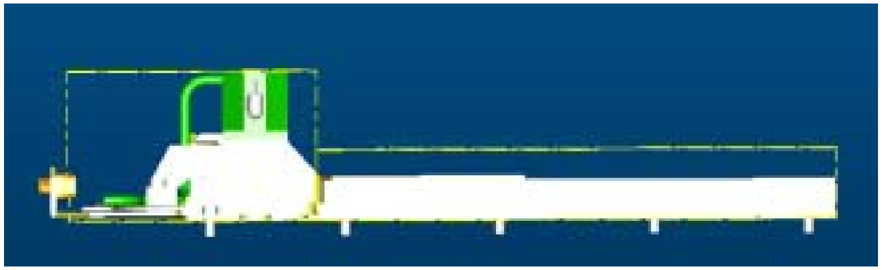


Locked out of the Beam

Shutter Mechanical Design

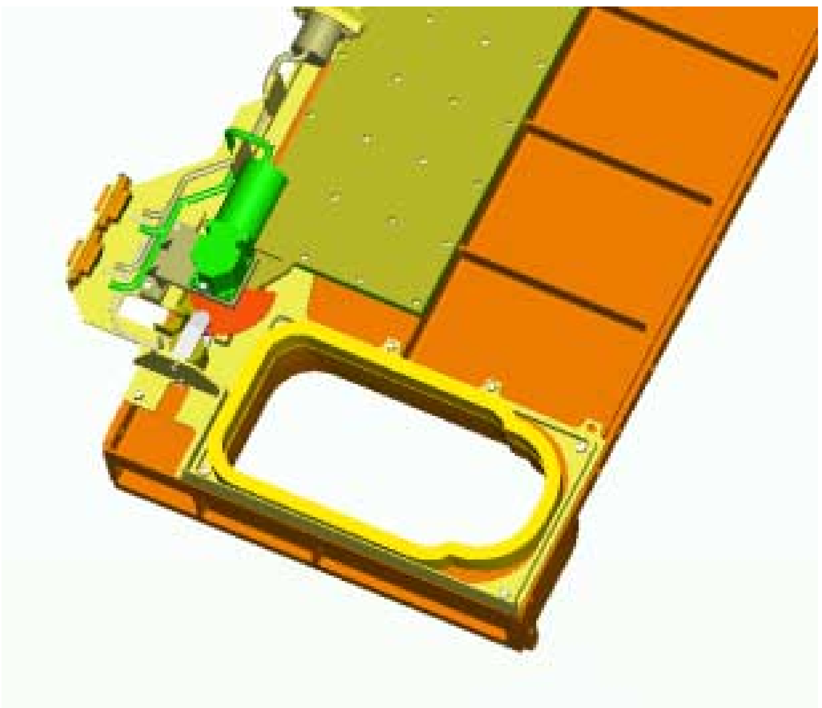
- Envelope has grown due to larger shutter requirement

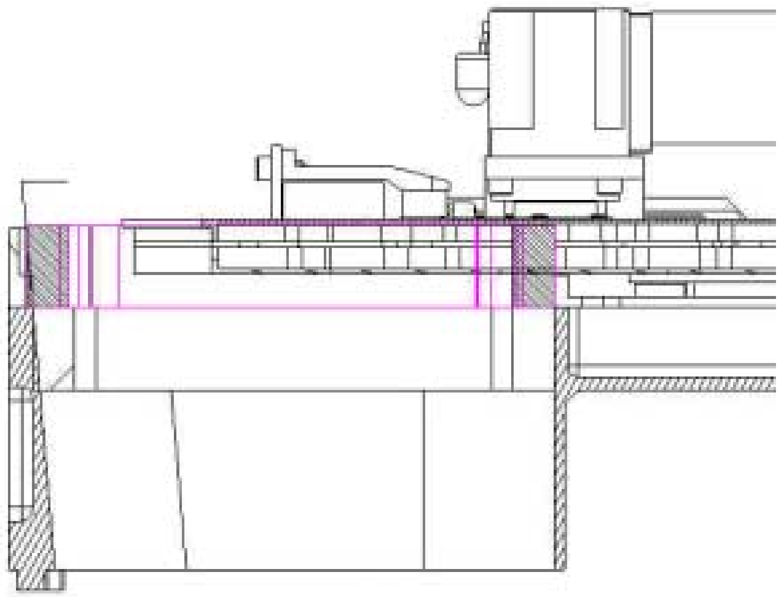




Shutter Mechanical Design

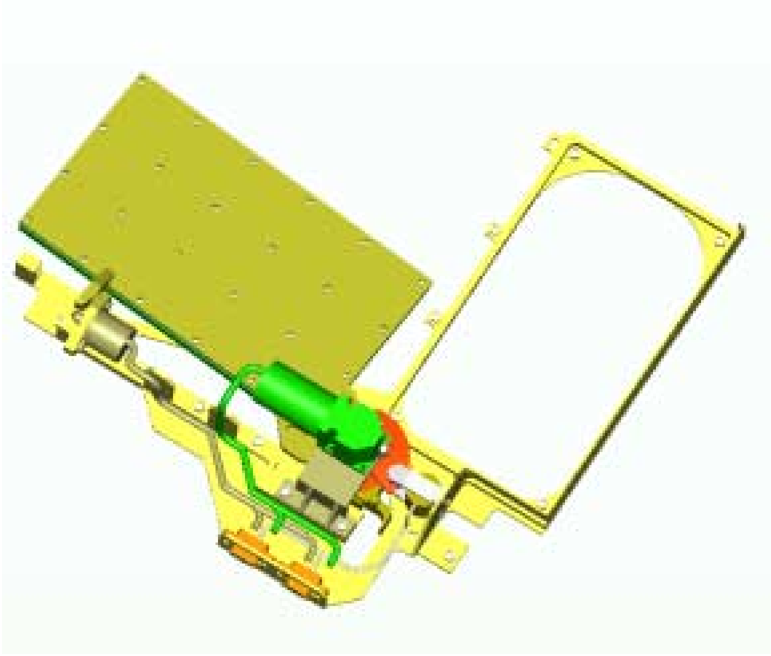
- Shutter provides clearance for the optical beam based on Tony Richards' models
- Shutter frame angles through the shutter clearance zone on the +Z side

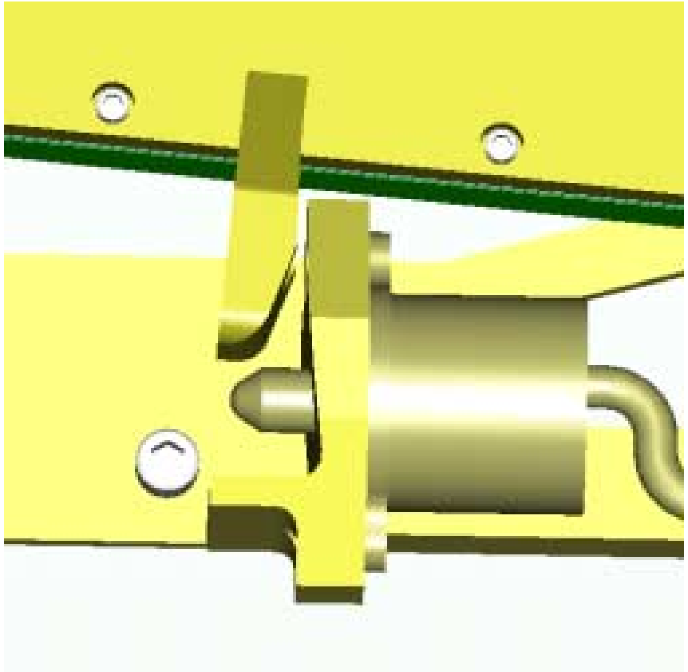




Shutter Mechanical Design

- Design allows for an open / unlatched position at 85°
- Door swings to 90° to latched position
- Cam provided on latch to allow latching if latch activation fails



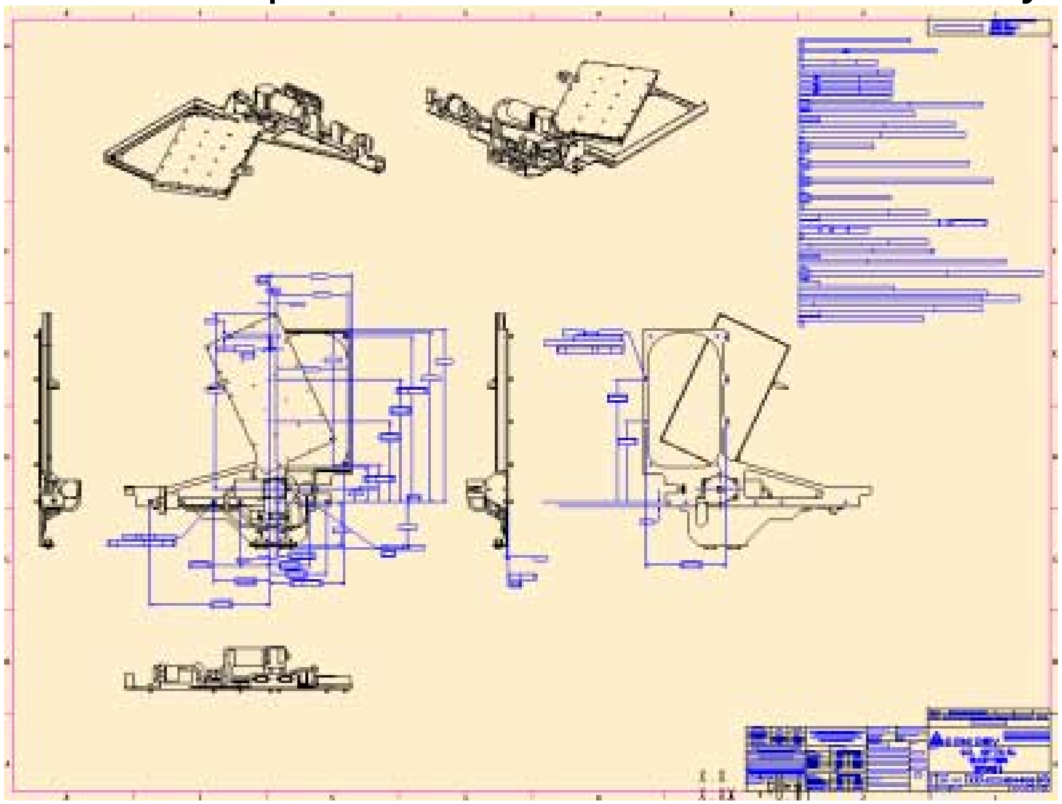


Shutter Mechanical Design

- Shutter will swing past the instrument cover by 16 mm.
- Needs to be checked by MSSL / RAL

Interface Control Drawing

- An ICD has been produced to show the required mechanical interfaces and envelope.
- A solid model will be provided for MSSL / RAL to verify the design.



Shutter Components

- Vane
  - Used to block the beam and provide a temperature controlled thermal surface
  - Two plane sandwich style construction with the panels thermally isolated by non-conductive stand-offs
  - Instrument side to have the Herschel approved black. Back of panel to have redundant heater and temperature sensors
  - Telescope side to be low emissivity or insulated (MLI). This panel will be connected to the motor.
  - COM DEV construction. Tayco heater. Diode temperature sensor.

Shutter Components

- Heater
  - Required to heat the vane to the proper temperature
  - Baseline Tayco heater construction
  - Was used at 4 K by NASA GSFC
  - uses Kapton and FEP construction
  - Nichrome 8020 alloy element

- Temperature Sensors
  - Measure the temperature of the vane
  - Diodes are preferred based on minimizing number of wires, minimizing measurement errors and simple mounting.
  - Based on accuracy requirements, the diodes will be GaAs.

Shutter Components

- Flex Cable
  - Required to route electrical leads from the instrument to the rotating vane for the heaters and temperature sensors
  - Tayco cryo-cable is preferred option pending mock-up testing results
  - 12 wires are required
  - Will use controlled cable flex – clockspring or roll-flex
  - Material evaluation tests to assess several types of wires
  - May be procured with heater as a single assembly

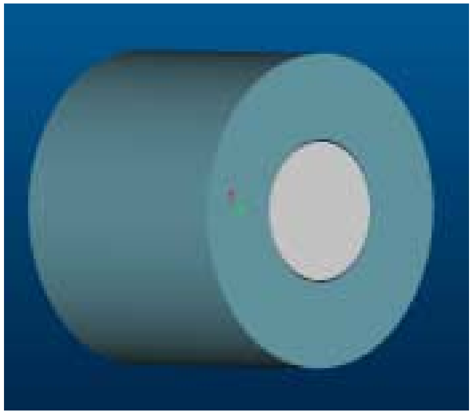
Back-up option is bare wire

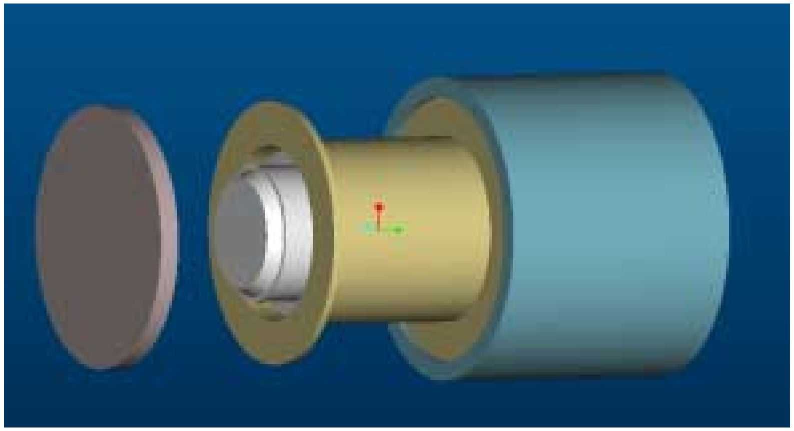
Shutter Components

- Motor
  - Drives the vane to the required position
  - 1.8° stepper motor with 90° angle gear box and a gear ratio of up to 200:1
  - Redundant windings?
  - Will use qualified vendor: CDA, Phytron
  - Dry film ball bearings are used based on angular range, stiffness, and torque
  - Stepper actuator with gear box is the best choice to meet torque and detent requirements, while simplifying electronics and minimizing mass

Shutter Components

- Vane Latch
  - Locks the vane out of the beam during testing and launch
  - Baseline is solenoid pin-puller
  - No qualified design has been located. (G.W. Lisk is close)
  - Internal design option is being pursued. We expect to produce a design with lower mass, longer stroke and higher shear capacity than the Lisk option. Will need to be temperature qualified.



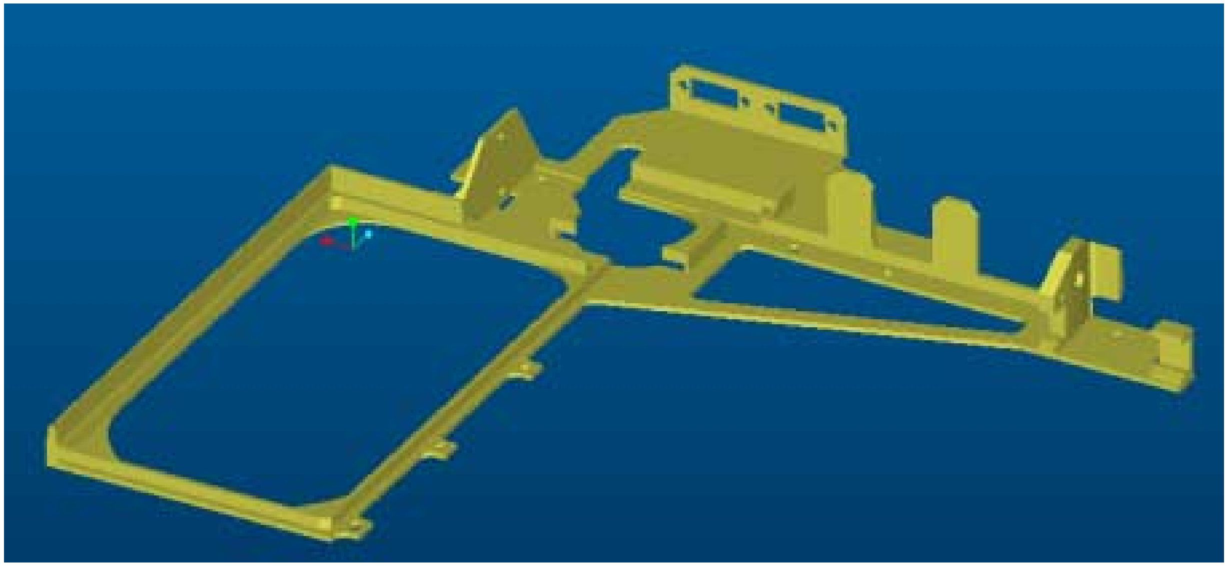


Shutter Components

- Rotary Vane Position Sensor
  - Measures the angular position of the vane
  - Trade was completed and a variable reluctance sensor was selected
  - Variable reluctance has a minimum number of leads, is low cost, and does not have the stray light concern associated with optical sensors.
  - COM DEV construction

Shutter Components

- Structure
  - Used to support all the components and provide the mounting structure to the instrument.
  - Al 6061-T651 material structure.
  - Frame seal, latch bracket, and D-Connector bracket integral to the structure.
  - Separate motor bracket required for assembly.



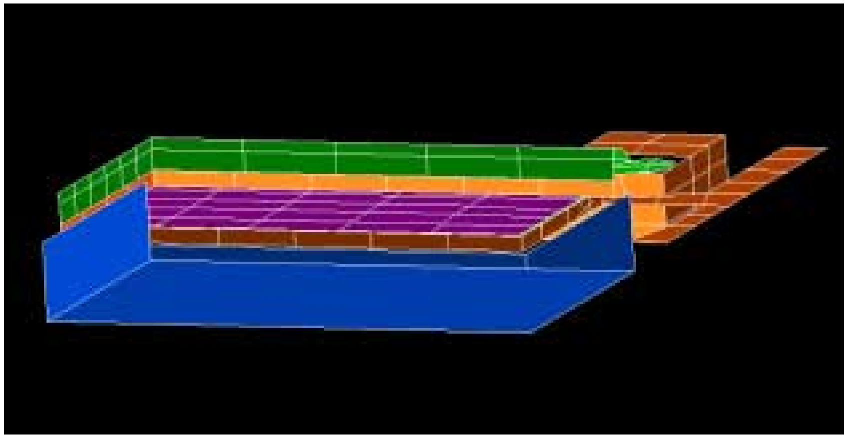
Mass Budget

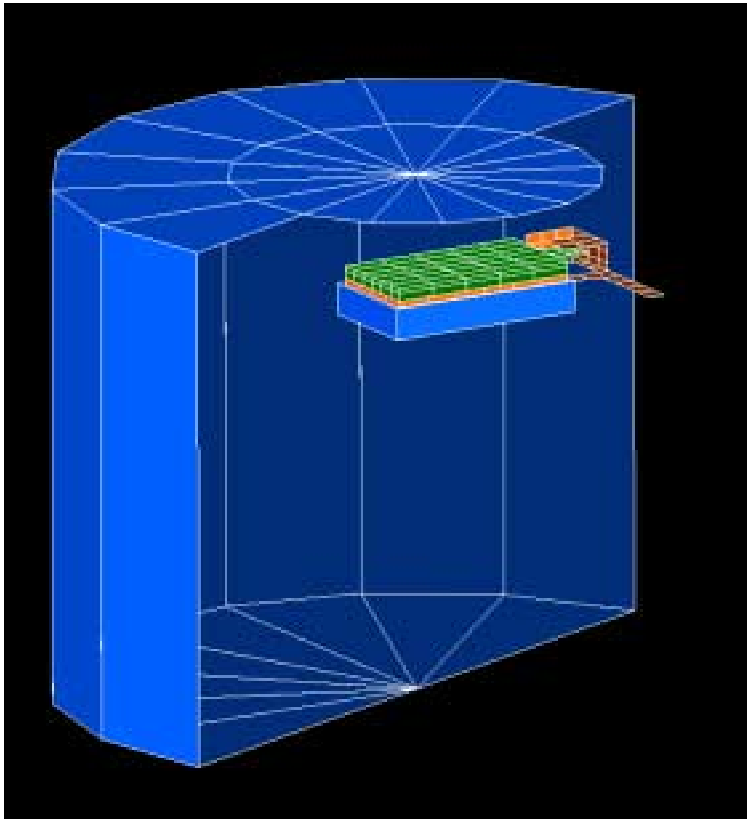
Item Description	Total Mass (g)
Vane	97
Motor (redundant windings)	144
Position Sensor	34
Latch (Solenoid 0.5" x 1")	30
Motor Bracket	9
Baseplate	75
Shutter Harness	61
Hardware:	23
Subtotal Mass (No Margin)	473
Total Design Margin	119
Estimated Total Mass	**592**

Shutter Extension Harness	165

Thermal Model

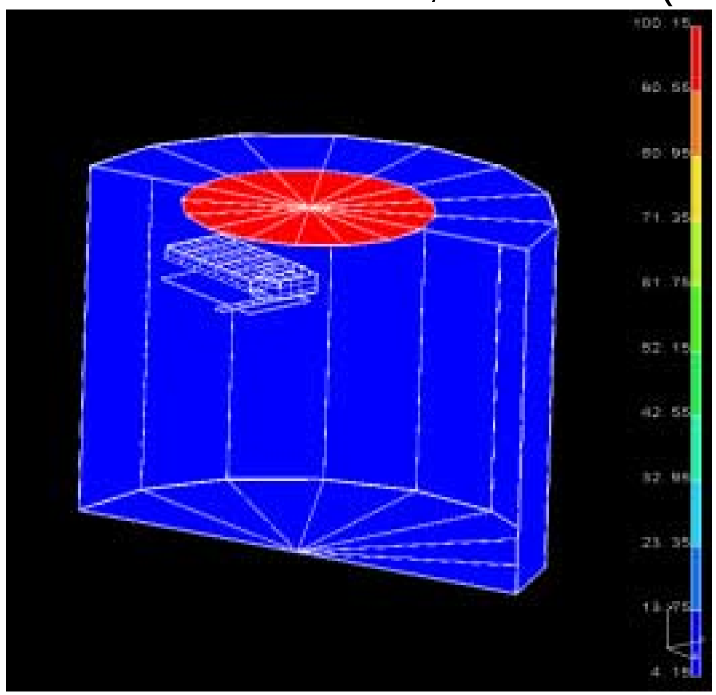
- A TMG thermal model was constructed to simulate the thermal behavior of the shutter design.
- The model included the shutter, instrument simulator, cryostat, and cryostat lid.





Boundary Conditions

- Boundary temperatures per S. Heys recommendation (spectrometer mode).
  - Cryostat held at 12.7 K, $\varepsilon = 0.05$
  - Cryostat lid held at 100 K, $\varepsilon = 0.1$ ("a complete guess")
  - Spire top cover at 5.6 K
- Instrument internal view assumed to be at 4K, $\varepsilon = 0.999$ (black body)

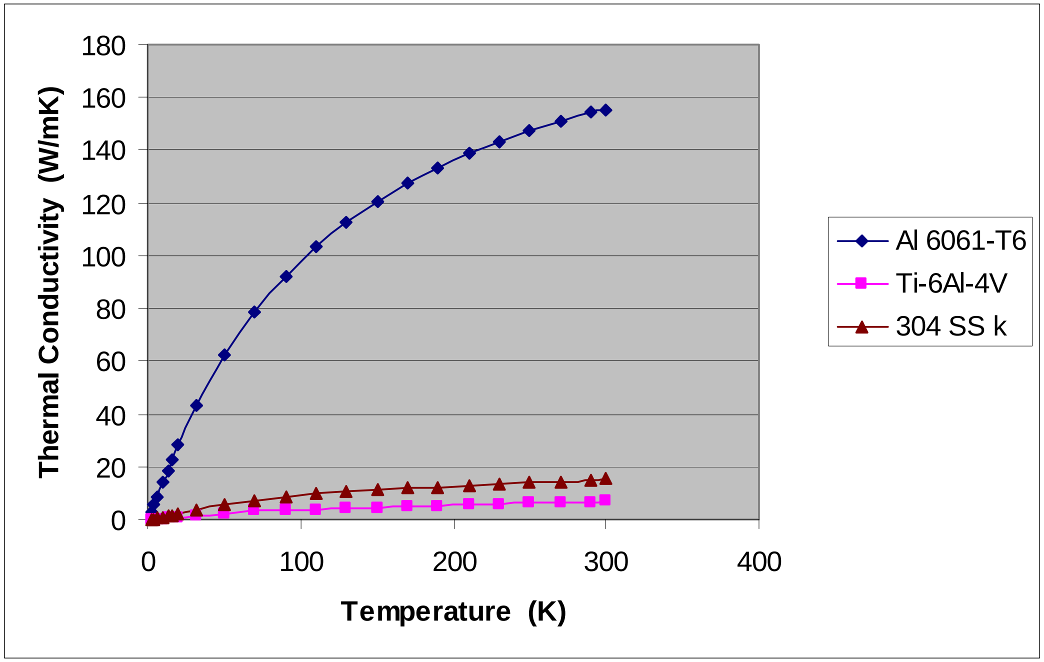


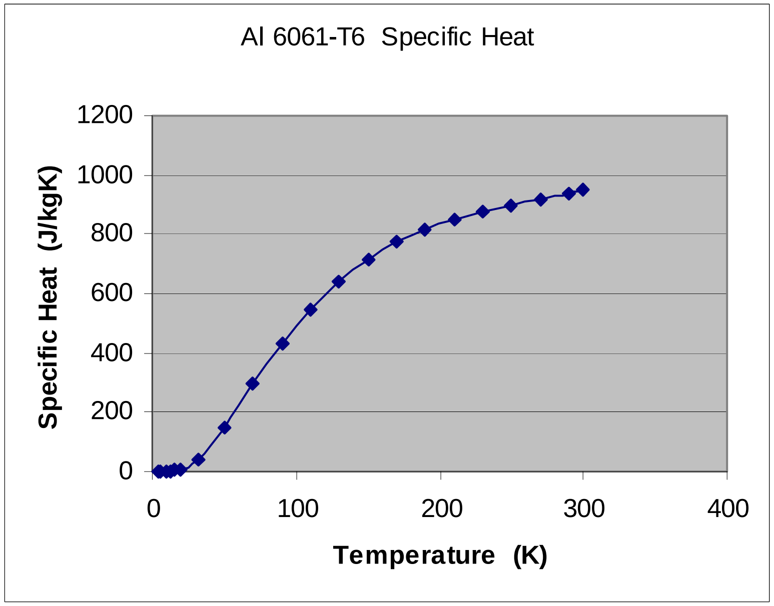
Modeling Assumptions

- Thermal path through the motor is through the shaft and bearings. Thermal conductance through gears and housing is ignored.
- Conductance through bearings assumes 304 SS at 6K. All other material properties are temperature dependent.
- Bearings assumed to be an SEA10, light preload
- Heat leak through heater and diode leads is equivalent to 12 x 0.05 mm. diameter 304 SS leads
- Vane coating is black with ε=0.9
- Aluminum surfaces are chemical conversion coating with ε=.06

Material Properties

- Material properties for Aluminum 6061-T6, titanium Ti-6Al-4V, and SS 304 are per NIST publication.



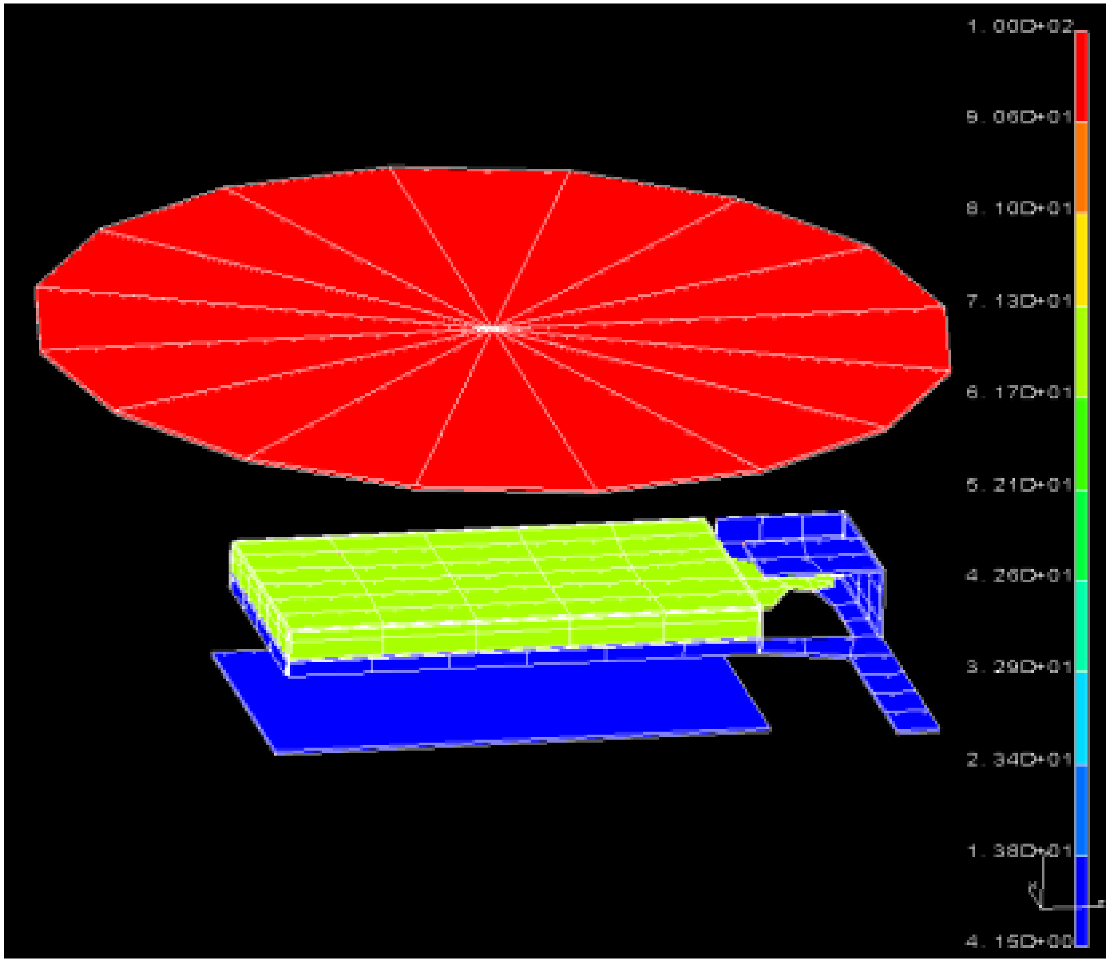


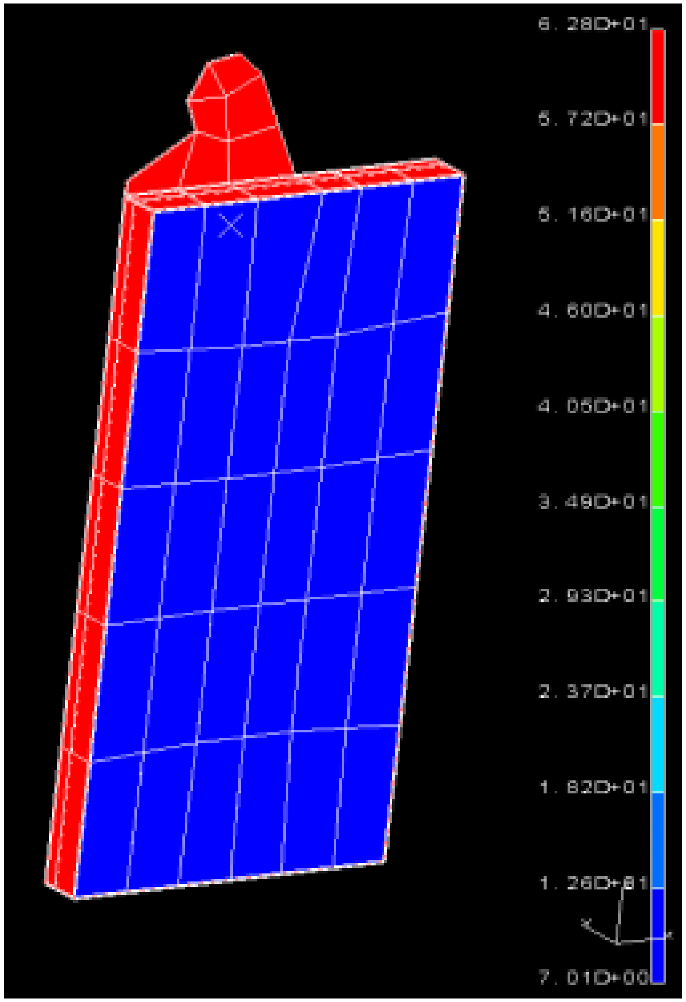
Reference Case

- Reference case was run with the vane conductively isolated from all thermal sinks.
  - Shutter bottom perfectly insulated from top
  - Perfect thermal seal between the shutter and frame
  - Shutter views instrument blackbody
  - No view from cryostat lid to shutter bottom
- Analyses were run to see the impact of each addition
- Reference case has a bottom vane temperature of 7 K and top temperature of 63 K

Shutter PDR - July 17, 2001

Reference Case Results





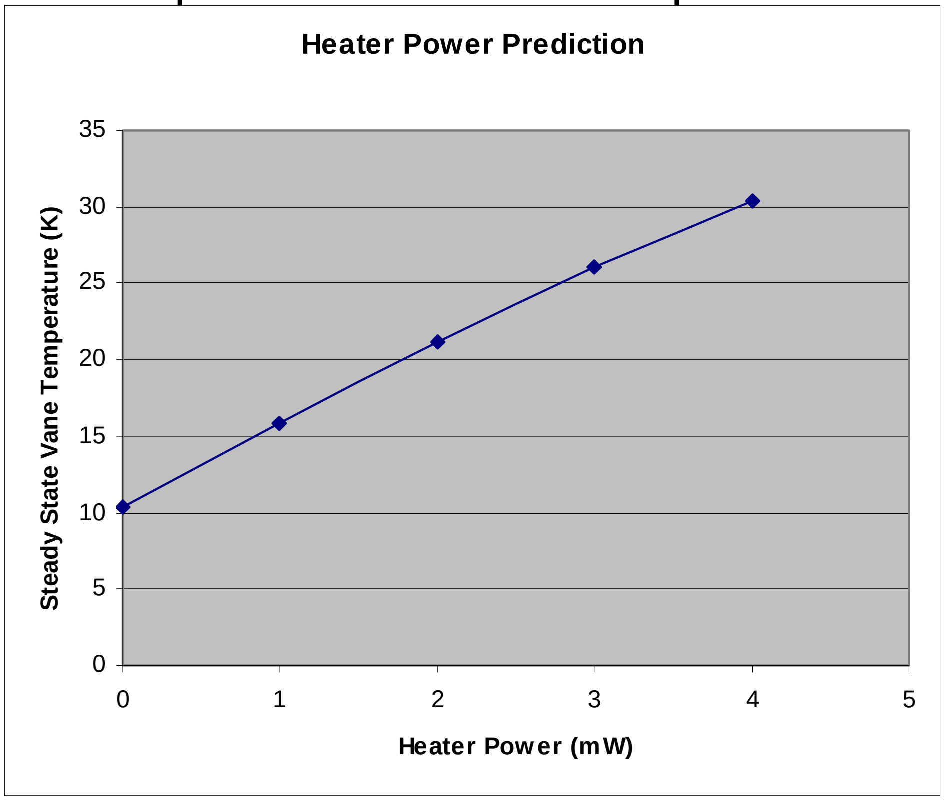
Effect of Additional Model Features

Model Addition	Bottom Vane Temperature (K)	Top Vane Temperature (K)
Baseline	7.0	63.0
Add motor (bearing) conductance to frame	6.9	10.3
Add radiation between top and bottom shutter plates. ε=0.8 for heater on bottom plate	8.9	10.3
Add flex cable	8.3	10.3
Add titanium vane connections	10.25	10.36

- Completed model vane temperature is 10.25 K.
  - Exceeds specification low end temperature of 9 K.

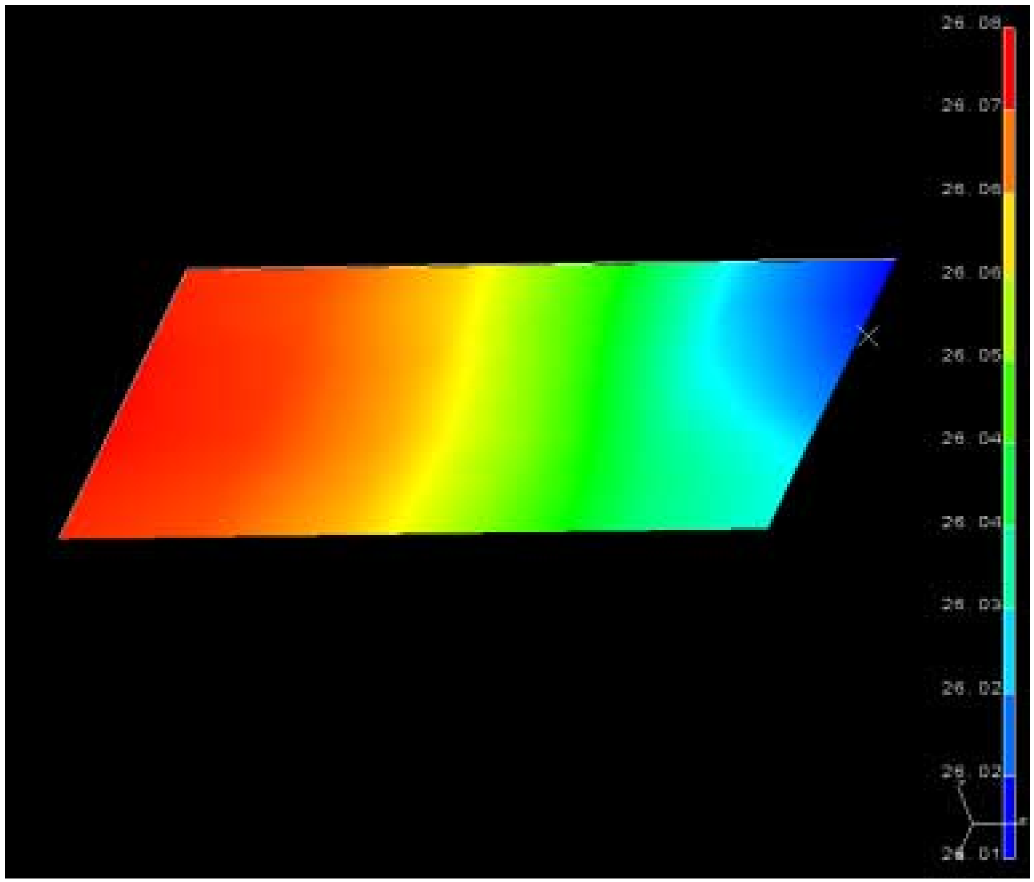
Heater Requirements

- Heater power was added to the bottom vane panel
  - Evenly distributed over panel
  - 3 mW power is required to meet 25° requirement



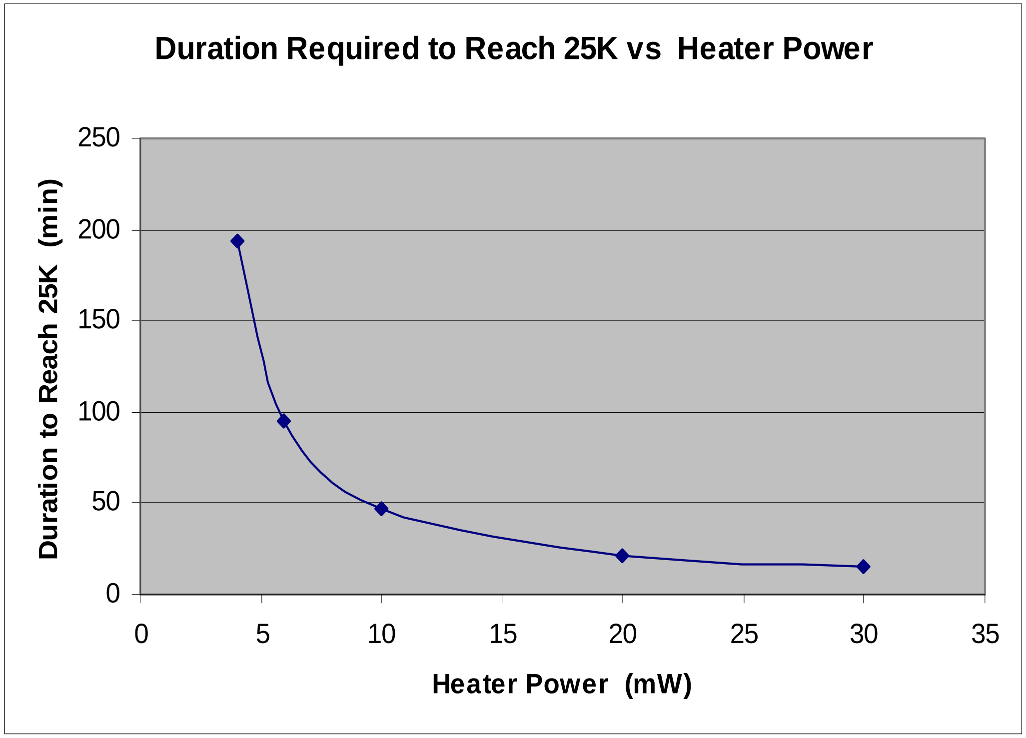
Temperature Gradients

- Temperature gradient at 3 mW steady state is 0.07 K which meets the 0.1 K requirement

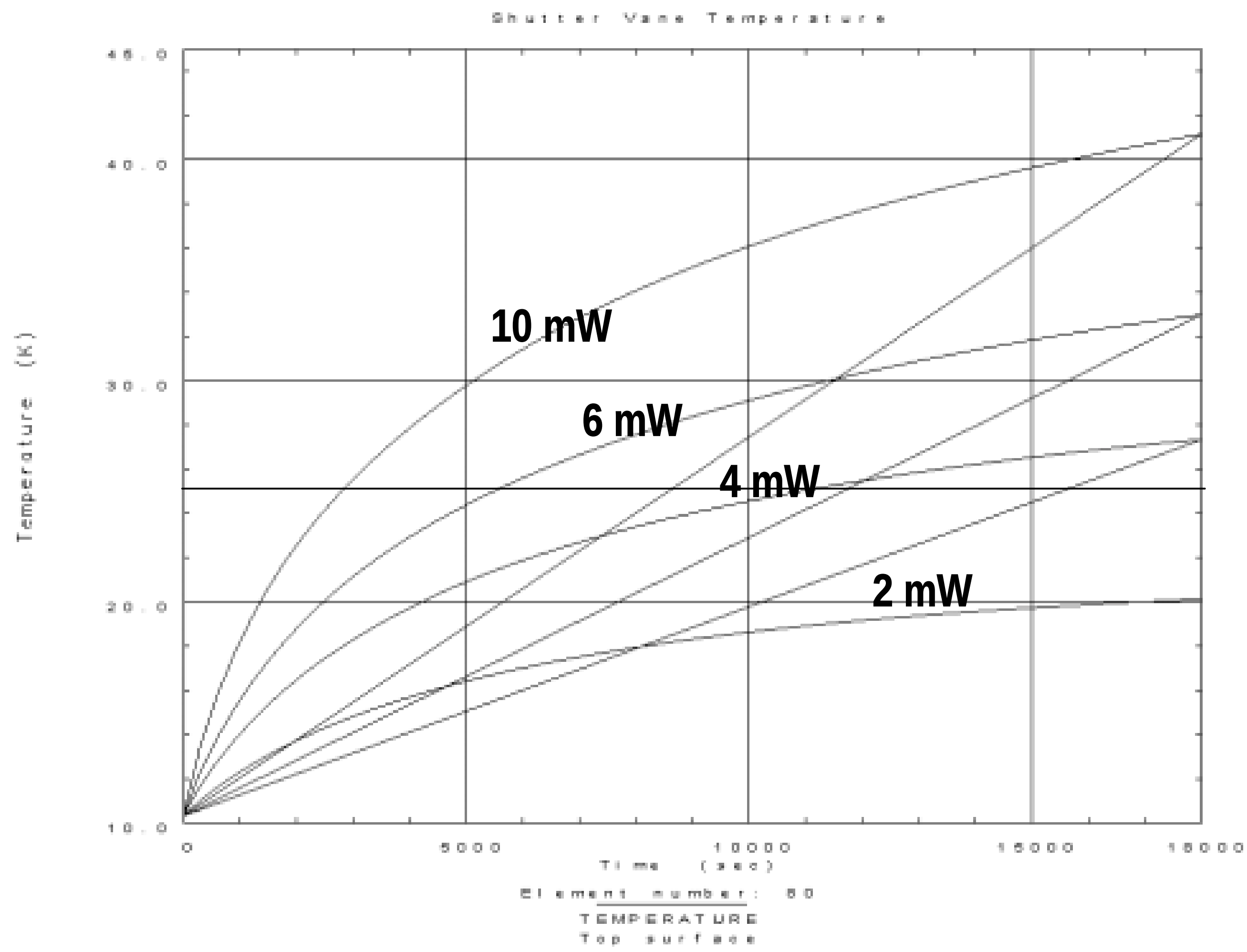


Transient Results

- Transient runs performed to determine the heat-up time
- To meet the 10 minute requirement, the heater power is 30 mW
  - At 30 mA current, heater would be 33Ω
- 4 mW heater requires 3 hours + 13 minutes.

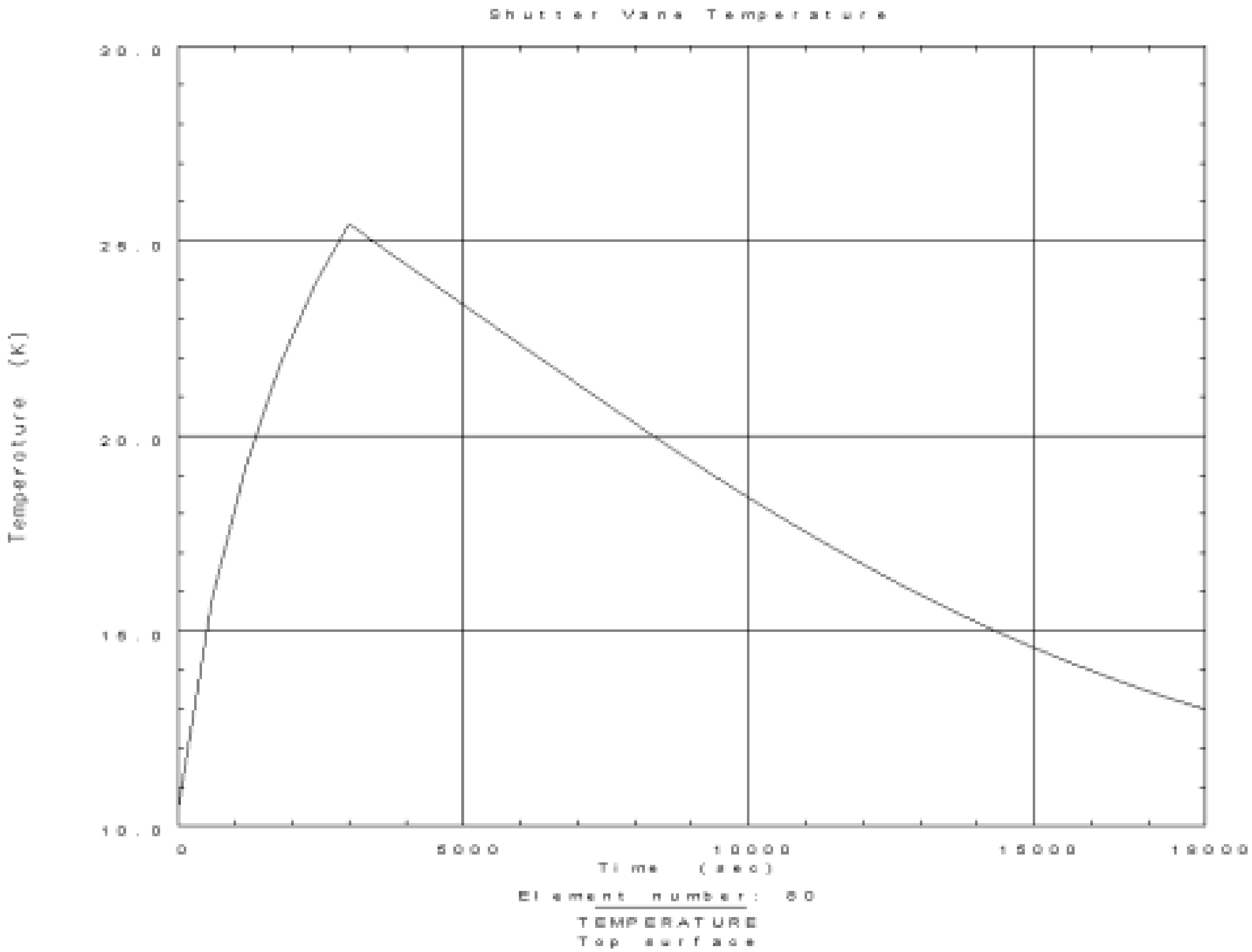


Warm Up Curves



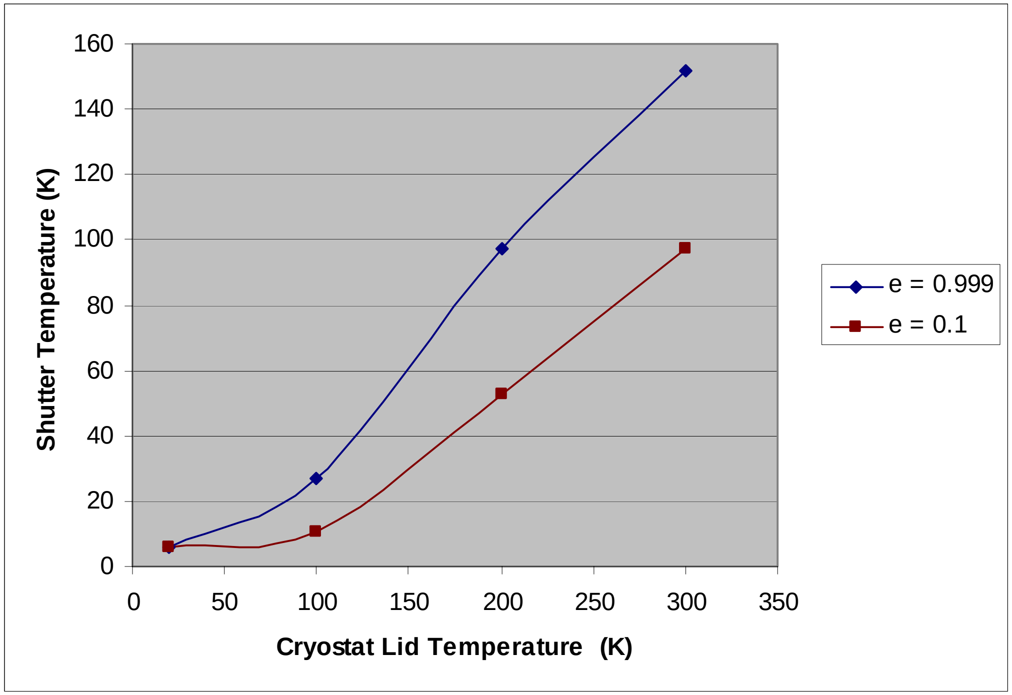
Cool-Down Time

- Cool-down time from 25 K to 13 K is over 4 hours.



Cryostat Lid Effect

- Cryostat lid greatly affects the temperature results
  - All results are highly dependent on a “complete guess”
- Sensitivity study performed for varying temperature and ε
- Performance could be improved using MLI on shutter
  - In this case, instrument would likely also need MLI

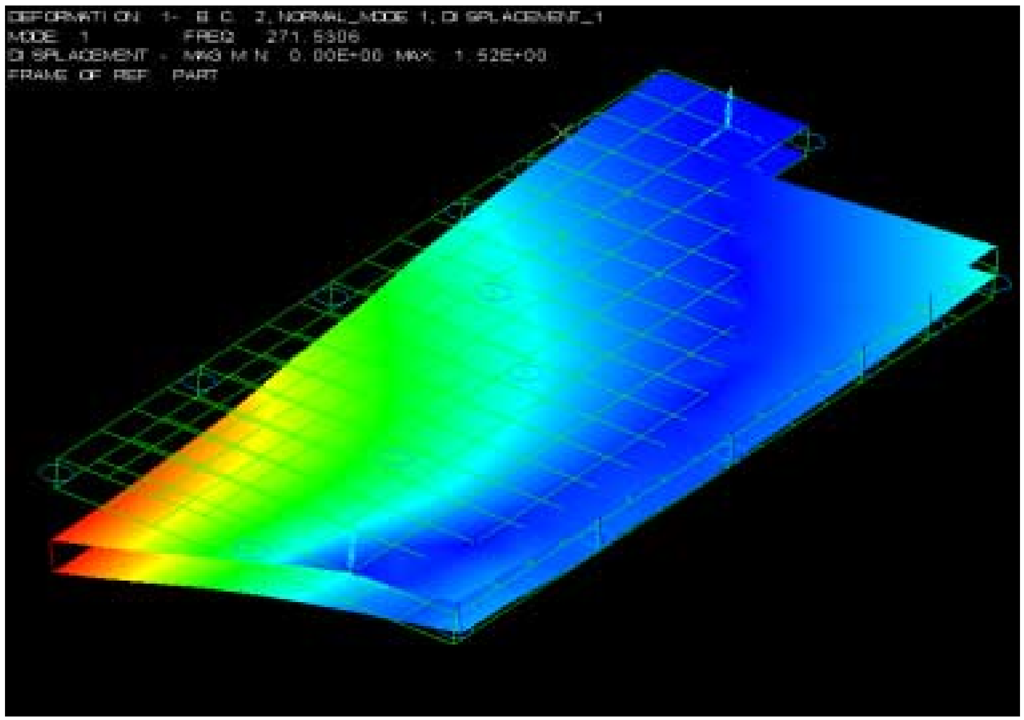


Vane Mass and Frequency

- A preliminary design study was performed to understand how latching the vane affects its mass and frequency.
- Positioning the latch near the motor results in a higher mass vane (to improve its stiffness).
- Positioning the latch at the free end of the vane results in lower mass vane but additional structure is required to support the latch (approximately 25 grams).
- Results are shown in the following viewgraphs.
  - Latch and Motor connections are assumed rigid
  - Heater, temperature sensor, and screw mass not represented

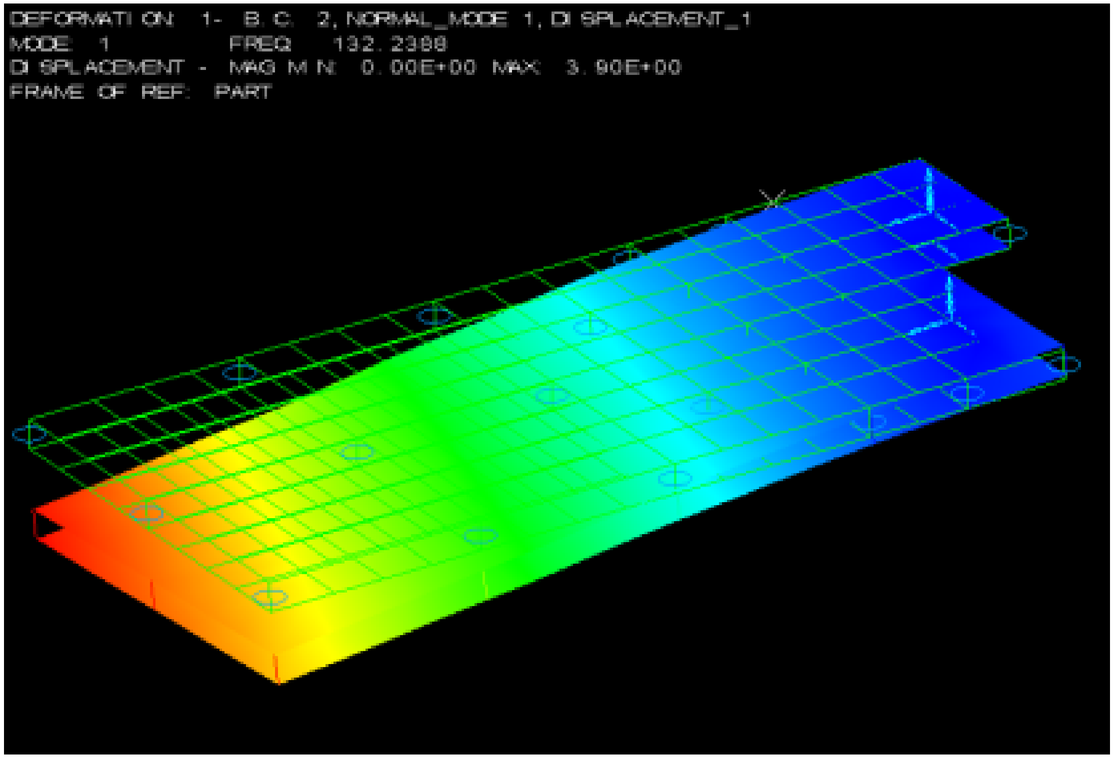
Vane Mass and Frequency

- 1.0 mm panels separated by 5.0 mm
- Latch at end
- Frequency = 271 Hz; Mass = 72 g (not including structure)



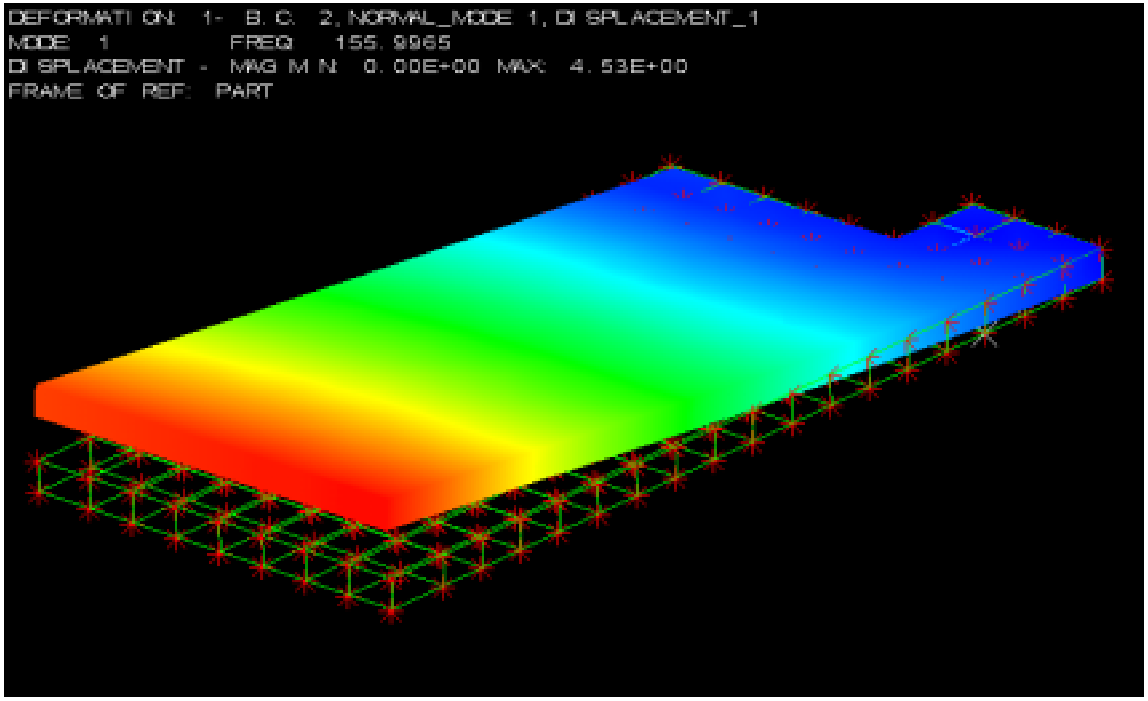
Vane Mass and Frequency

- Latch near motor
- Frequency = 132 Hz; Mass = 72 g



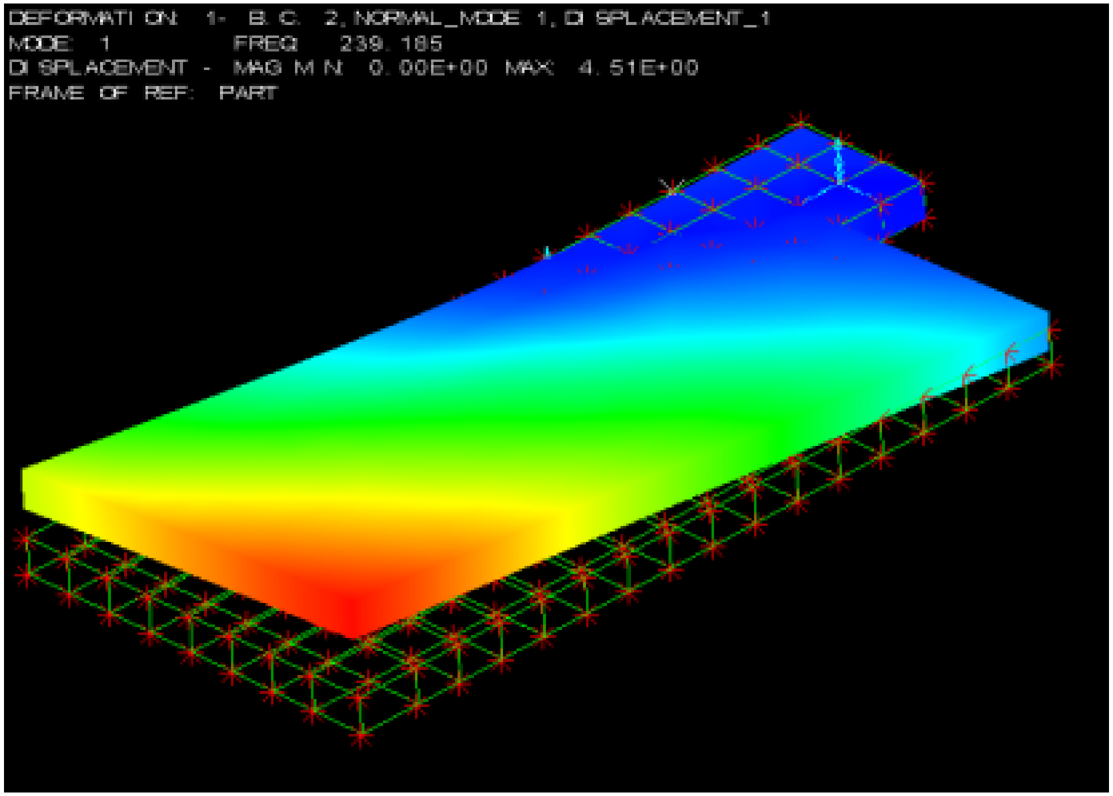
Vane Mass and Frequency

- Added edge connections. Latch near motor.
- Frequency = 156 Hz; Mass = 85 g



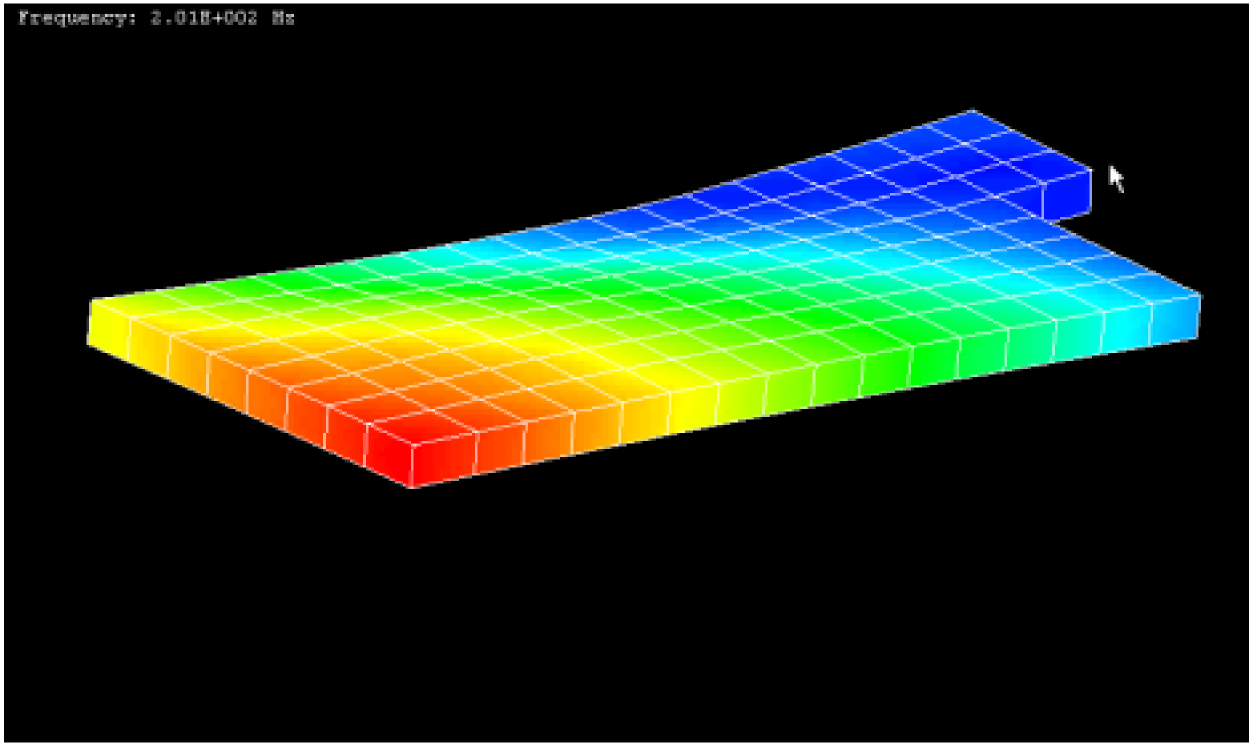
Vane Mass and Frequency

- Latch near motor. Increased vane thickness to 6.4 mm.
- Frequency = 239 Hz; Mass = 91 g



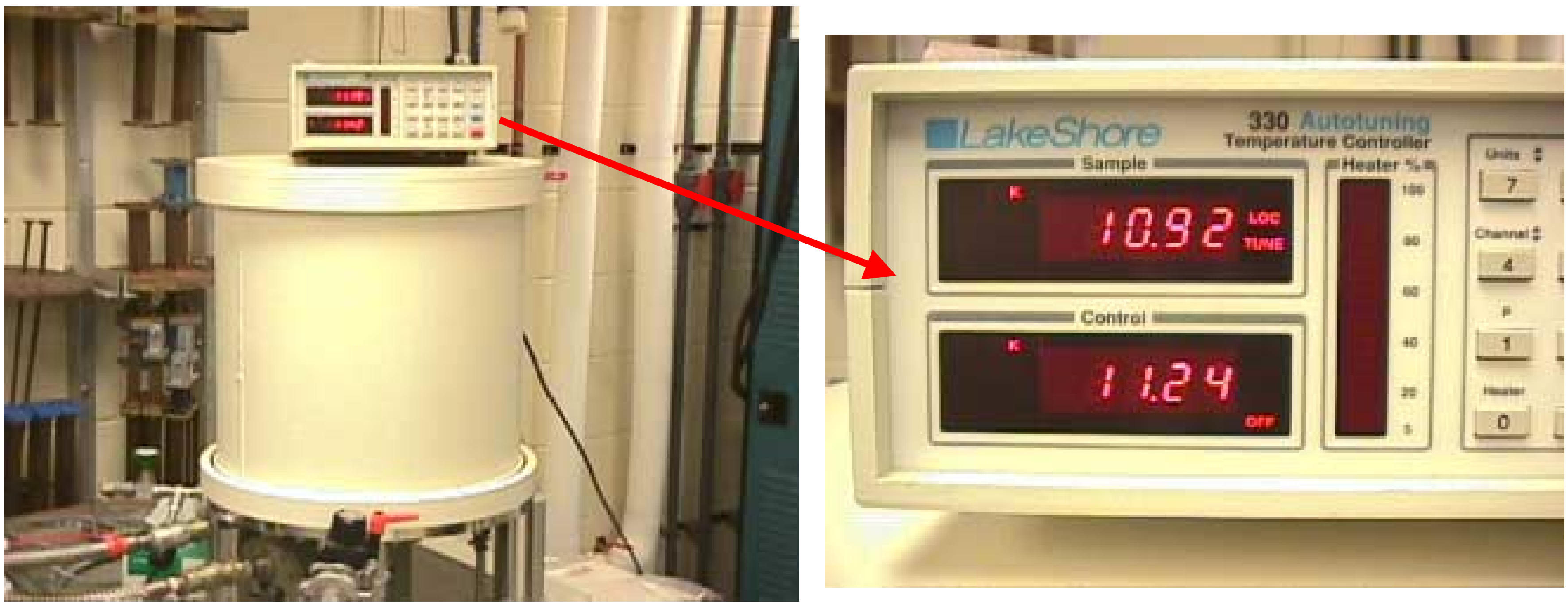
Vane Mass and Frequency

- Latch near motor. Reduced vane panel thickness to 0.5 mm.
- Frequency = 201 Hz; Mass = 62 g



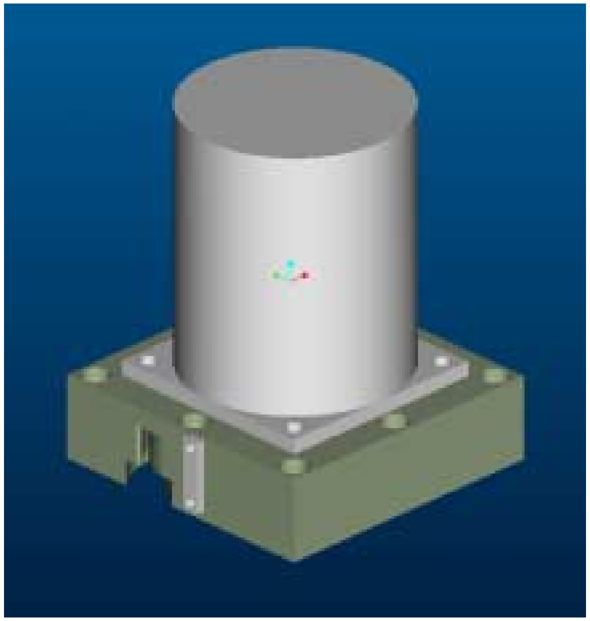
Material Evaluation and Mock-ups

- Cryorefrigerator to be used to perform material evaluation and mock-up testing at about 15K



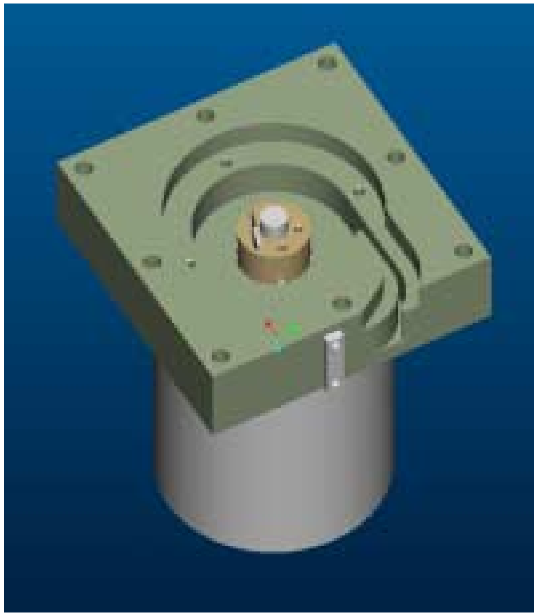
Material Evaluation and Mock-ups

- Flex Harness Tests
  - Test jig is completed
  - Harness soldering is still an issue



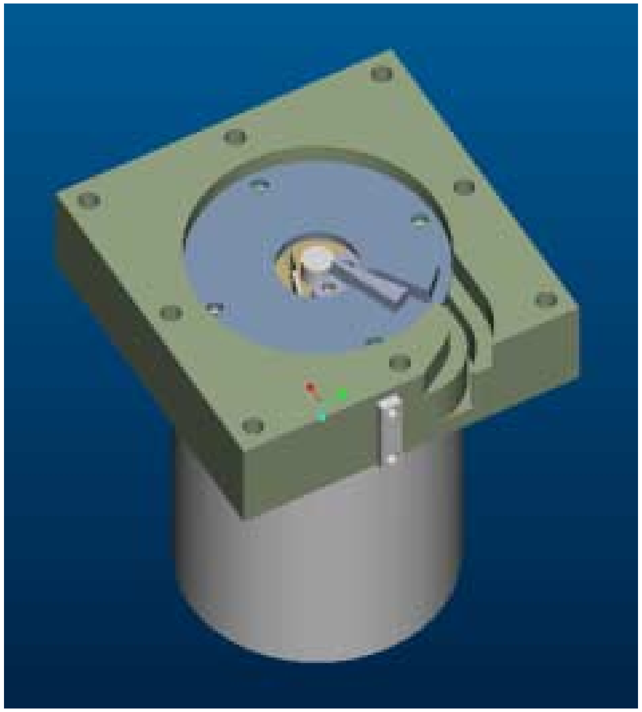
Material Evaluation and Mock-ups

- Flex harness mock-up designed to test SPIRE configuration
  - OD based on maximum volume
  - ID based on roll-flex design
  - Cable will be wrapped clock-spring style



Material Evaluation and Mock-ups

- Flex harness mock-up allows 324° of rotation between hardstop ends of travel
- End of travel sensors will indicate when rotation is completed



Material Evaluation and Mock-ups

- Adhesive Tests
  - Two adhesives rated to 4K with NASA approved low outgassing have been procured from Masterbond Inc.
    - EP21TCHT-1 thermally conductive 2 part epoxy
    - Supreme 10HT thermally non-conductive 1 part adhesive
  - Test coupons have been bonded and sample coupons were pull tested.

Material Evaluation and Mock-ups

- Heater Tests
  - Tayco heaters and diodes will be bonded to a copper sheet
    - Use supplied PSA and tack edges with EP21TCHT-1
  - Heater plate will be thermally sunk to the cold plate so that it can be cooled quickly
  - Heater will be operated and the heater resistance will be checked at cold temperature

SHUTTER ELECTRICAL DESIGN

(COM DEV)

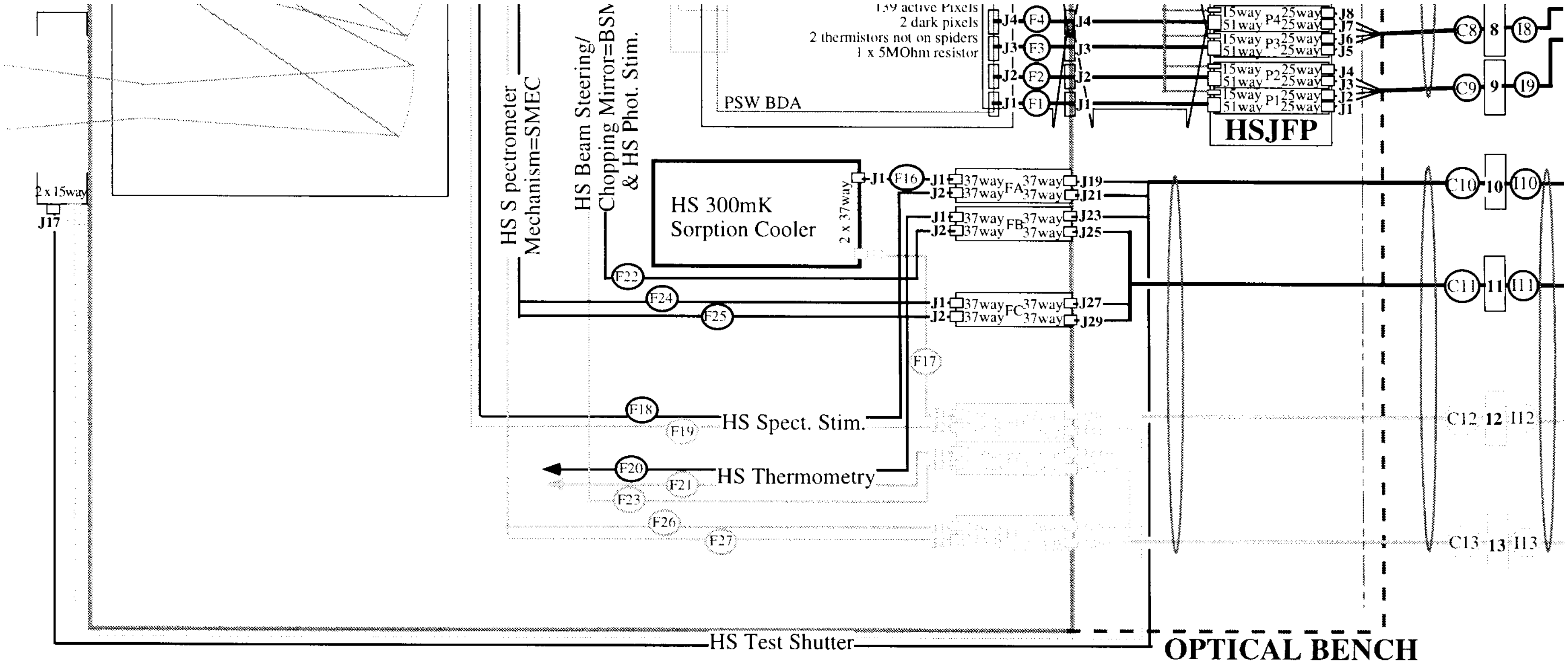
Electrical Design Topics

- Harness Configuration
- Vane Latch Sense
- Temperature Sensor
- FMEA Analysis

Harness Configuration

- Separate prime and redundant harnesses, each utilizing 15 pins at connectors
- All lines are isolated from chassis
- Shields are either terminated to signal ground at the EGSE or to the common return at the shutter, but not both
- Assumed that the SPIRE instrument will provide the harnessing from C10/12 to J17/18

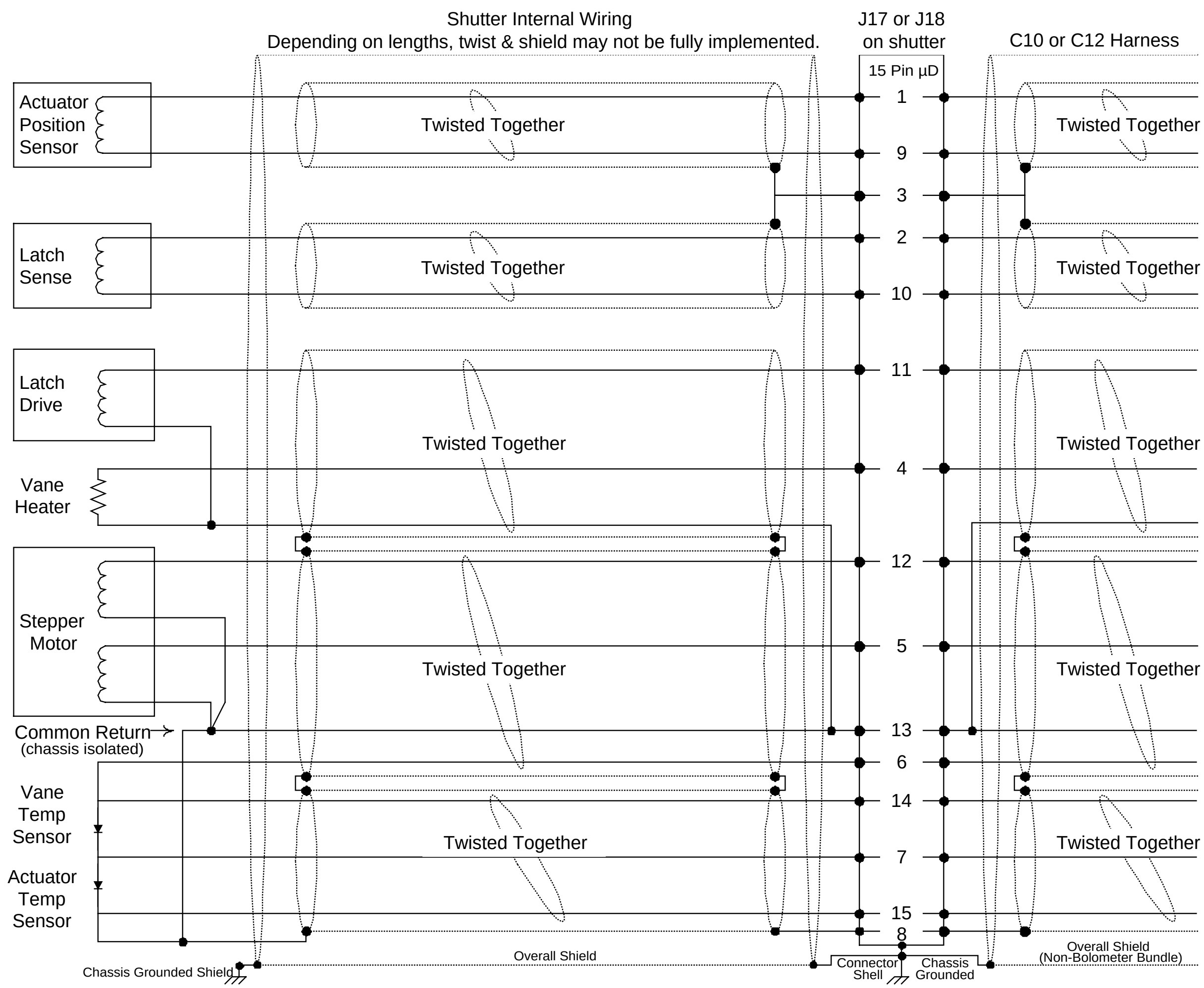
Harness Configuration



Harness Configuration

- Each harness has five shielded twist groups
  - Shields are isolated from chassis and grouped to two pins for connection through connector interfaces
  - Twist groups are 2, 3 or 4 wires all of the same gauge
  - Common return line is routed through each of two shield groups but uses a single pin at connectors
  - It is understood that there is an overall harness bundle shield shared with non-shutter harnessing

Harness Configuration



Shutter PDR - July 17, 2001

Harness Configuration

Function	Prime/Red.	Wires	Wire Pins	Shields	Shield Pins	Total Pins	Max Ohms
Actuator Position Sensor	P	2	2	1	1/2	2 1/2	1000
Latch Sense	P	2	2	1	1/2	2 1/2	1000
Latch Drive	P	1	1			1 1/3	10
Heater Drive	P	1	1	1	1/3	1	10
Return	P	1	1/2			1/2	10
Actuator Drive	P	2	2			2 1/3	10
Return	P	1	1/2	1	1/3	1/2	10
Temp Sensor Bias	P	1	1			1	10
Vane and Actuator Temp	P	3	3	1	1/3	3 1/3	1000
Totals Prime		14	13	5	2	15	

Function	Prime/Red.	Wires	Wire Pins	Shields	Shield Pins	Total Pins	Max Ohms
Actuator Position Sensor	R	2	2	1	1/2	2 1/2	1000
Latch Sense	R	2	2	1	1/2	2 1/2	1000
Latch Drive	R	1	1			1 1/3	10
Heater Drive	R	1	1	1	1/3	1	10
Return	R	1	1/2			1/2	10
Actuator Drive	R	2	2			2 1/3	10
Return	R	1	1/2	1	1/3	1/2	10
Temp Sensor Bias	R	1	1			1	10
Vane and Actuator Temp	R	3	3	1	1/3	3 1/3	1000
Totals Redundant		14	13	5	2	15	

Harness Configuration

- Current Rating on 10 ohm wires
  - 30 mA is a very difficult constraint, prefer 120 mA
- Possible options for increasing current rating
  - Heavier gauge wire
  - Multiple conductors per pin
  - Constrained pulse durations and duty cycles
  - Others?
- Other Issues
  - What is the tolerance on the 10 ohms?
  - Are there any room temperature integration/test issues?

Harness Configuration

- Desired peak motor current is 120mA
- Motor resistance at 4K is approx. 2 ohms
- Harness resistance is 20 ohms round trip
- Power in motor winding would be 29mW peak
- Power in harness would be 288 mW peak
- Drive is current regulated
- Duty cycle can be kept low by extending the time to move the vane

Harness Configuration

- If Given Additional Wires (In Order of Preference)
  - Separate return for temperature sensors (1 wire)
  - Extra temperature sense line (1 wire)
  - Separate lines for vane latch sense to S/C (2 wires)
  - Independent stepper motor lines (2 wires)

Vane Latch Sense

- Variable Reluctance vs. Switch
  - Variable Reluctance
    - Provides more position information
    - Non contacting sensor
    - No grounding issues
    - Uses high resistance harness lines
    - Readout needs calibration

Vane Latch Sense

- Variable Reluctance vs. Switch
  - Switch
    - Contact resistance may be unreliable
    - Contact life would need to be qualified
    - Grounding may be an issue depending on configuration
    - Simple readout circuit (compatible with CDMU)
    - Harness resistance of 4 ohms max each direction required to meet Alcatel specification
    - Approx. 1mW would be dissipated in the cryoharness due to sense current. It is not clear if this is continuous for the whole mission or only during sensing.

Vane Latch Sense

- Need to clearly establish requirement before design options can be evaluated
- Is CDMU readout required if it can be shown that the shutter unlatching is extremely low risk?
- What needs to be sensed?
  - Latch plunger position?
  - Vane position?
  - Both?

Temperature Sensor

- Lakeshore TG-120-SD GaAlAs diode
- Sensitivity
  - 180mV/K @4.2K, 1.4mV/K @100K, 2.8mV/K @300K
- Repeatability
  - Tested to better than ± 50 mK over four thermal cycles
  - typically better than ± 10 mK
- Accuracy (Calibrated) ± 50 mK
- Long-term Stability
  - ± 15 mK at 4.2 K, ± 50 mK at 77 K per year

FMEA Analysis

- The failure modes for the SPIRE Shutter were tabulated following a standard COM DEV convention – a complete formal analysis will be performed in the next phase
- 28 failure modes were identified
  - 3 critical
  - 16 severe
  - 9 Inconvenient
- 2 of the 3 critical failure modes are less likely with analog vane latch telemetry

SHUTTER DEVELOPMENT AND TEST PLAN

(COM DEV)

Shutter Development and Test Plan

Hardware Plan

- STM Phase
  - 1 STM Shutter (Deliverable) & 1 Breadboard Shutter (Non-Deliverable)
- Qualification Phase
  - 1 CQM and 1 QM Shutter manufactured as a pair
  - CQM gets nominal testing and is delivered
  - QM gets comprehensive testing and is not delivered
- PFM Phase
  - 1 PFM Shutter

Shutter Development and Test Plan

- B/B will be fully functional and will undergo following tests;
  - Tests on piece parts
    - Vane will be coated and its reflectivity measured
    - Motor torque vs. drive current will be measured at room temperature and near 4K
    - Vane latch force vs. drive will be measured at room temperature and near 4K (and current for pull-in and drop-out)
  - Tests at Shutter level
    - Thermal cycling and operation
    - Mass
    - Vibration evaluation
    - Operation against 1-g at temperature
    - Life test evaluation may be performed

Shutter Development and Test Plan

- STM will be interface and mass representative, will function thermally only and will include;
  - Representative vane
    - Heater
    - Temperature sensors
    - Sandwich construction with flight coatings
  - Motor simulator (lump of metal that supports vane)
  - Aperture frame
  - Vane latch simulator (lump of metal)
  - Connectors

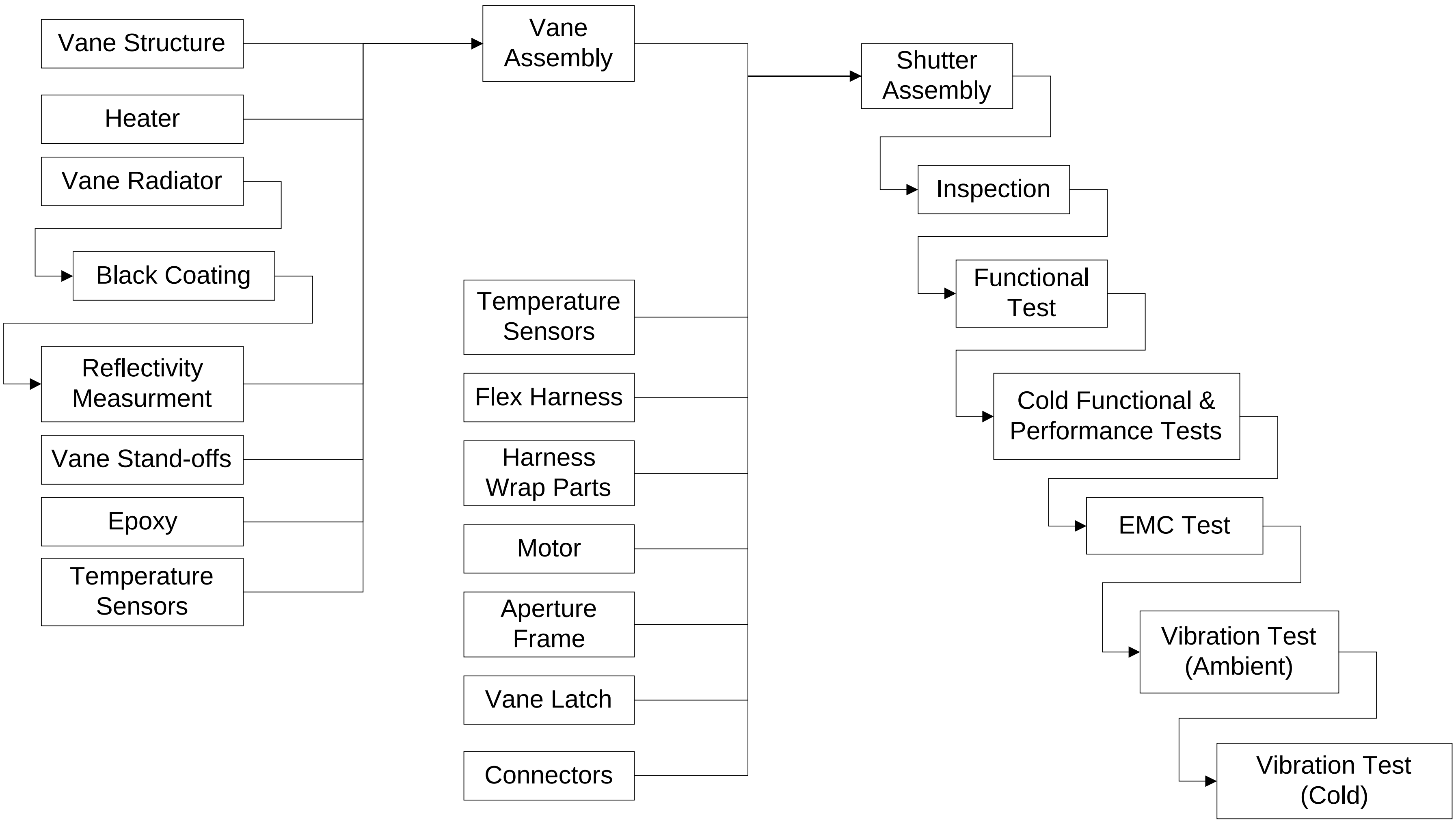
Shutter Development and Test Plan

- STM will undergo the following tests;
  - Tests on piece parts
    - Vane will be coated and its reflectivity measured
    - Heater and temperature sensors will be bonded to vane and thermal cycled
  - Tests at Shutter level
    - Thermal cycling and operation (heater & temperature sensor)
    - Vibration
    - ICD inspection (dimensions, mass, C. of G.)

Shutter Development and Test Plan

- CQM and QM will be fully representative of PFM
  - QM will undergo qualification and life tests
  - CQM will undergo workmanship testing and be delivered to SPIRE program to support instrument level qualification
- Protoflight Model
  - will undergo protoflight level testing

Shutter Development and Test Plan



SHUTTER GROUND SUPPORT EQUIPMENT

(COM DEV)

Software Development Environment

- Windows NT/2000
- LabVIEW Software (Professional Development System)
  - Application builder for standalone operation
- Custom Software written in C++ (as required)
- Commercial Off-The-Shelf (COTS) Software (as required)

Software Components

- Commanding (Prime and Redundant)
- Telemetry Monitoring (including trending)
- Telemetry Recording
- Event Logging
- Telemetry Playback
- Network I/F (to be defined)
- I/F Configuration and Control
- Rudimentary File Management

Software Operation

- Command Shutter in-beam or out-of-beam
- Command Vane Latch locked or unlocked
- Command Heater Setting
- Command Heater enabled or disabled
- Hot redundant operation
- Both prime and redundant circuits can be enabled simultaneously
- Both prime and redundant telemetry is active at all times

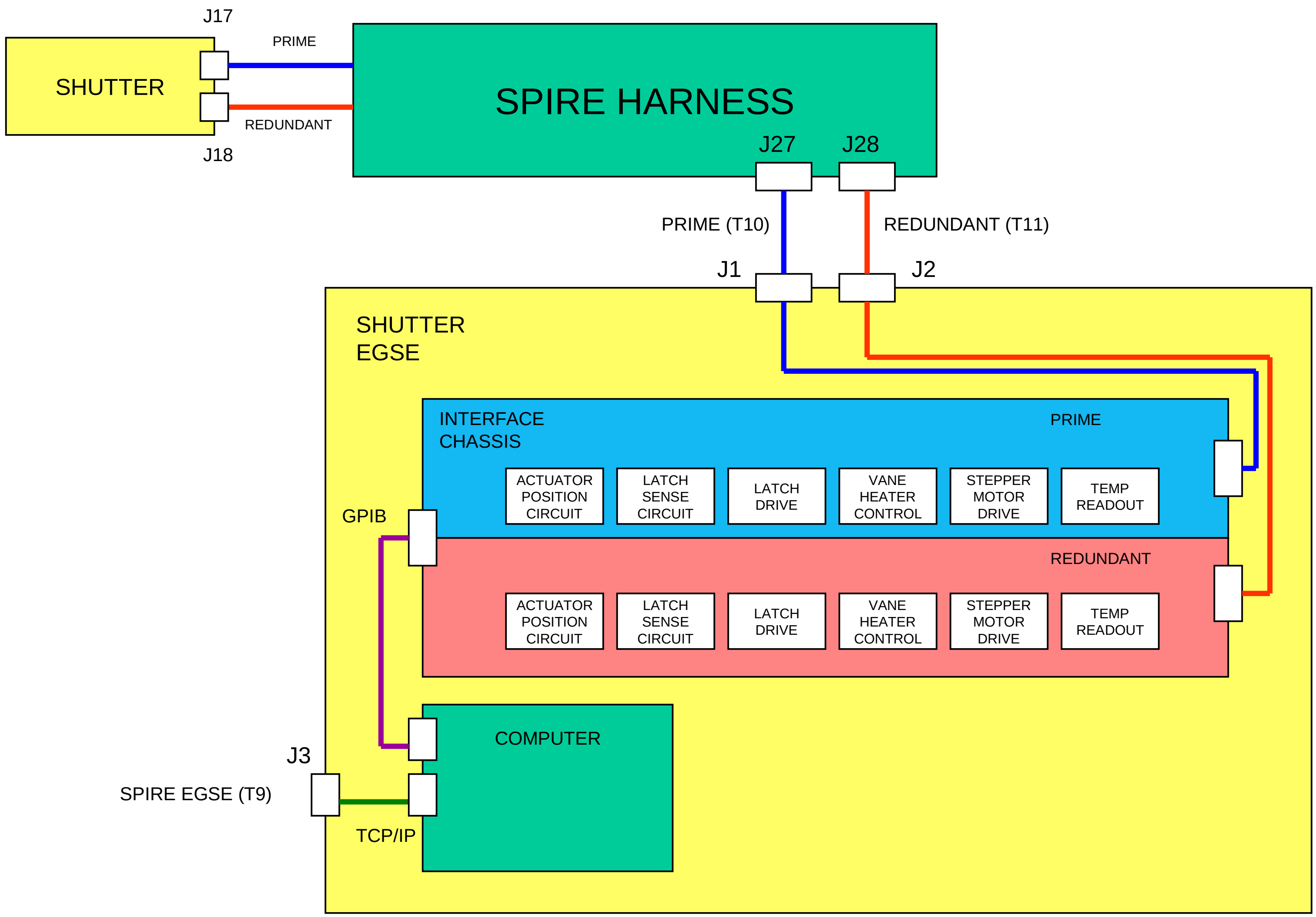
EGSE Hardware

- Standard PC based computer
  - Pentium III, 750 MHz, 5 Gb disk space
  - GPIB I/F
  - Network I/F to SPIRE EGSE (TCP/IP assumed)
- Interface chassis (PXI or VXI)
- Hot redundant operation on shutter I/F chassis
  - Combination of standard I/F boards, power supplies and custom electronics
  - EGSE fault propagation prevention in the electronics
- Shutter configuration not changed on power up or down

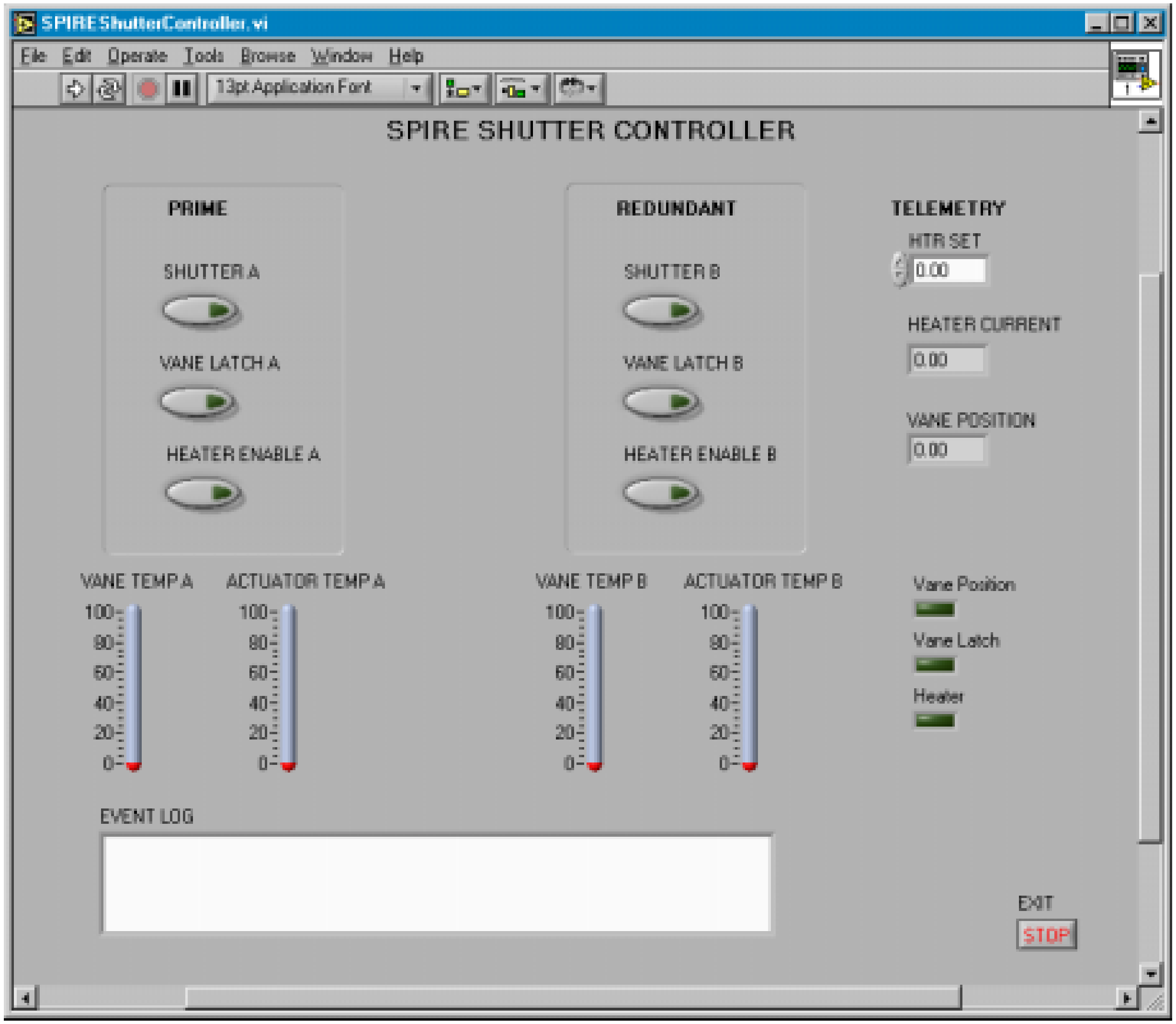
EGSE Hardware

- Linear current drive (not PWM) will be used for actuator EGSE
- Linear current control will be used for heater EGSE
- High resolution DAC for controlling heater set point
- Repeatability on vane temperature setting dependent on sensor repeatability
- Stable temperature readout circuit
- Digital filtering on temperature readout to suppress noise
- Temperature readout circuit based on stable bias circuit and buffer amplifier

SPIRE Shutter EGSE Block Diagram



User IF Prototype



Telemetry Packet Definition

- Will define the contents for a SPIRE shutter housekeeping telemetry packet
- May have other ancillary packets defined that are only applicable for shutter level assembly and testing

Telemetry Packet Definition

Date: 2001/07/16 - 09:15 File: TelemetryDefinitions.xls Sheet: HK Packet Defn

SPIRE SHUTTER HOUSEKEEPING PACKET							
TOP LEVEL	2ND LEVEL	3RD LEVEL	TL SIZE (BITS)	2nd SIZE (BITS)	3rd SIZE (BITS)	VALUE (DEFAULT)	NOTES
PACKET HEADER			48				
	PACKET ID			16			
		Version Number			3	0	
		Type			1	0	
		Data Field Header Flag			1		
		Application Process ID			11		Need to get apid for shutter. SPIRE has apid's from 0x500 to 0x57f
	PACKET SEQUENCE CONTROL			16			
		Segmentation Flags			2		
		Source Sequence Count			14		
	PACKET LENGTH			16			
PACKET DATA FIELD							
	DATA FIELD HEADER		80	80			
	SOURCE DATA		368				
		BS_SHT_HEATER			16		on, off
		BS_SHT_LOCK			16		locked, unlocked
		SS_SHT_SPARE00			16		
		SS_SHT_SPARE01			16		
		IR_SHT_HEATER			16		mA
		IR_SHT_HEATER_SET			16		mA
		TR_SHT_ACTUATOR_A			16		K
		TR_SHT_VANE_A			16		K
		TR_SHT_ACTUATOR_B			16		K
		TR_SHT_VANE_B			16		K
		SR_SHT_STATUS			16		raw status
		SS_SHT_SPARE02			16		
		SS_SHT_SPARE03			16		
		VR_SHT_HEATER			16		V
		SS_SHT_SPARE04			16		
		SS_SHT_VANE_POS			16		0..100 ?
		BS_SHT_LATCH_POS			16		open, closed
		SS_SHT_SPARE05			16		
		SS_SHT_SPARE06			16		
		SS_SHT_SPARE07			16		
		SS_SHT_SPARE08			16		
		SS_SHT_SPARE09			16		
		SS_SHT_SPARE10			16		
	PACKET ERROR CONTROL		16	16			16 bit CRC

Totals:	512	bits
	64	bytes
	32	words

MANAGEMENT

PRODUCT ASSURANCE

(COM DEV)

Product Assurance

- The COM DEV Quality System has been established to ensure that hardware is designed, manufactured and tested in accordance with high reliability space applications. The Quality System emphasizes a preventative approach, and ensures that documentary evidence of product quality is available in the form of inspection and test results.
- The Quality System is built upon the foundation of the ISO 9001 Standard. COM DEV's Quality System was certified to the ISO 9001 Standard in March of 1999 and continues to be subjected to rigorous auditing by internal and external sources.

Product Assurance Plan

- A Product Assurance implementation Plan governing the SPIRE Program will be generated in response to the Customer's PA requirements document at the start of the next phase.
- The Program Product Assurance requirements for the program will be passed down to lower tier suppliers.
- Each supplier not on COM DEV's approved supplier list will be visited to review their quality system and process capabilities for use on the program.

Design Integrity

Parts, Materials & Processes

- COM DEV will implement a parts, materials and processes program to ensure the requirements generated by the customer are met.
- Design Integrity oversee the qualification of parts, materials and processes as required by the project
- DCL, DML and DLP documents will be generated.

Design Integrity

Parts

- Motor/Gearhead
  - Vendor : CDA
  - Description : 30 degree stepper with 67:1 (TBC) right angle gear head
  - P/N : PR105B1
- Vane latch
  - Vendor : Lisk (or COM DEV)
  - Description : linear solenoid
  - P/N : L4

Design Integrity

Parts

- Diodes
  - Vendor : Lakeshore
  - Description : GaAlAs Diode
  - P/N : TG – 120 - SD
- Heater
  - Vendor : TAYCO
  - Description : Fine coiled wire embedded in Kapton film
  - P/N : (TBD Custom)

Design Integrity

Parts

- Flex Harness
  - Vendor : TAYCO
  - Description : TBD
  - P/N : (TBD Custom)
- Connectors
  - Vendor : TAYCO
  - Description : 15 Socket micro-D, electroless nickel finish, aluminum body, solder cup
  - P/N : M83513/02-BN

Design Integrity

Materials

- Aluminum Alloy 6061-T651
- Titanium Alloy Ti-6AL-4V
- Stainless Steel 300 series
- Solder – SN63
- Epoxy – Masterbond EP-21-TCHT-1
- Wire - M22759/33 (Cu multi-strand Ag coated, ETFE Insulation)
- Black coating

Design Integrity

Processes

- Soldering
- Chemical conversion coating
- Black coating
- Bonding

RISK ITEMS

(COM DEV)

Risk Items

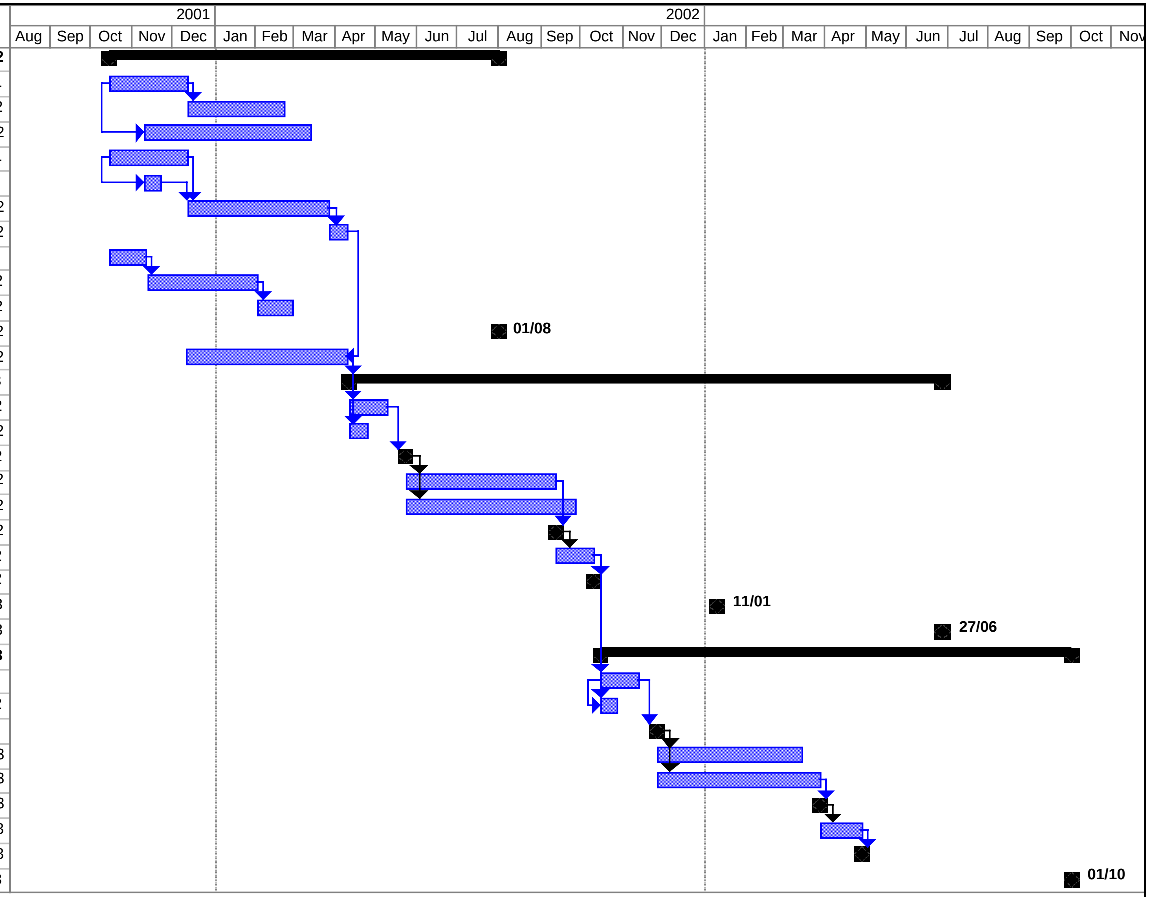
- Thermal environment lack of definition
  - Cryostat lid temperature and emissivity not well known
  - Will determine coatings for vane, hence effects design, materials, processes, temperature of vane, and heater power
- Flex-harness operation at 4 K
  - Cryo flex-harness has not been used before
  - Design concept will be evaluated by testing in August/2001

SHUTTER SCHEDULE

(CSA)

Shutter Schedule

ID	Task Name	Duration	Start	Finish
1	**B/B & STM Phase**	**198.53 days**	**15 Oct '01**	**01 Aug '02**
2	Design GSE	42 days	15 Oct '01	11 Dec '01
3	Manufacture GSE	46 days	12 Dec '01	22 Feb '02
4	GSE Software	82 days	09 Nov '01	13 Mar '02
5	Design B/B	42 days	15 Oct '01	11 Dec '01
6	Order B/B Long Lead Items	10 days	09 Nov '01	22 Nov '01
7	Manufacture & Assemble B/B	69 days	12 Dec '01	27 Mar '02
8	Test B/B	9 days	27 Mar '02	09 Apr '02
9	Design STM	20 days	15 Oct '01	09 Nov '01
10	Manufacture and Assemble STM	53 days	12 Nov '01	01 Feb '02
11	Test & Ship STM	19 days	01 Feb '02	28 Feb '02
12	STM Need Date	0 days	01 Aug '02	01 Aug '02
13	CQM Design and Analysis	79 days	11 Dec '01	09 Apr '02
14	**Qualification Phase**	**303.13 days**	**10 Apr '02**	**27 Jun '03**
15	Complete CQM/QM Design	20 days	10 Apr '02	09 May '02
16	Order Long Lead Items	10 days	10 Apr '02	25 Apr '02
17	Hold DDR	0 days	23 May '02	23 May '02
18	Manufacture and Assemble CQM/Q	76 days	23 May '02	12 Sep '02
19	GSE Networking Development	86 days	23 May '02	26 Sep '02
20	TRR for CQM/QM	0 days	12 Sep '02	12 Sep '02
21	CQM & QM Testing	21 days	12 Sep '02	11 Oct '02
22	Deliver CQM to SPIRE	0 days	11 Oct '02	11 Oct '02
23	CQM Need Date	0 days	11 Jan '03	11 Jan '03
24	QM Results (Need Date)	0 days	27 Jun '03	27 Jun '03
25	**PFM Phase**	**240.13 days**	**15 Oct '02**	**01 Oct '03**
26	Complete PFM Design	20 days	15 Oct '02	12 Nov '02
27	Order Long Lead Items	9 days	15 Oct '02	28 Oct '02
28	Hold CDR	0 days	26 Nov '02	26 Nov '02
29	Manufacture 2nd GSE	73 days	26 Nov '02	14 Mar '03
30	Manufacture and Assemble PFM	82 days	26 Nov '02	27 Mar '03
31	TRR for PFM	0 days	27 Mar '03	27 Mar '03
32	Test PFM	21 days	27 Mar '03	28 Apr '03
33	Deliver PFM to SPIRE	0 days	28 Apr '03	28 Apr '03
34	PFM Need Date	0 days	01 Oct '03	01 Oct '03



KEY OPEN ISSUES

(COM DEV)

Key Open Issues

- Cryostat temperature and emissivity, and Spire top wall temperature
  - May not allow 9 K, hence coatings impact
- Allowable current for motor and latch
- Vane latch telemetry monitoring by S/C
- Cube location
- HIFI beam
- EGSE interfaces
- Black coating details
- Confirm COM DEV understanding of cryoharness extension