SCUBA-2 FTS Project Office
University of Lethbridge
Physics Department
4401 University Drive
Lethbridge, Alberta
CANADA
T1K 3M4

Tel: 1-403-329-2771
Fax: 1-403-329-2057
Email: brad.gom@uleth.ca
WWW: http://research.uleth.ca/scuba2/

Document Title:	**FTS-2 Mechanical Design**
Document Number:	**SC2/FTS/MEC/001**
Issue:	**Version 2.1**
Date:	**9 November 2006**

Document Prepared By:	D. Triomphe FTS-2 Mechanical Design	Signature and Date:	Brad Gom	09/11/06
Document Approved By:	D. A. Naylor FTS-2 Project Lead	Signature and Date:	David A Naylor	09/11/06
Document Released By:	J. Molnar Canadian Project Manager	Signature and Date:		09/11/06

Change Record

Issue	Date	Section(s) Affected	Description of Change / Change Request Reference / Remarks
0.1	10/06/05	All	First draft
1.0	20/06/05	All	PDR version
2.0	8/11/06	All	CDR version
2.1	9/11/06	All	Minor fixes. Corrected section 8.1

Contents

Change Record 2
Contents 2
1. Introduction 3
2. Damped Optical Breadboard 4
  2.1. JCMT – Breadboard Interface 4
  2.2. Breadboard Specifications 4
3. Aerotech Linear Motor Translation Stage 5
  3.1. FTS-2 - LM stage Interface 5
  3.2. Function 5
  3.3. Specifications 5
4. Framework 6
  4.1. Framework interface 6
  4.2. Material 7
  4.3. Specifications 7
  4.4. Protective cover 7
5. Lifting and Installation Assembly 7
  5.1. JCMT Interface 7
  5.2. Lifting points 8
  5.3. Lifting frame 8
6. Mirror Mounts 8
  6.1. Design 9
  6.2. Function 10
7. Corner-cube (Rooftop) Mirror Assembly 10
8. Pickoff and Return Mirror Assembly 11
  8.1. Retraction Assembly 13
9. Beamsplitter Mounts 14
10. Blackbody Shutter 14
11. Overall System Dimensions 15
12. Dish, Beam and Walkway Interference 16
13. Fabrication Drawing Numbers 17

1. Introduction

This document presents the mechanical design of the SCUBA-2 FTS (hereafter referred to as FTS-2) and the design and operation of its major subsystems.

The instrument will be located on the N1 mirror support structure and will sit flush against the elevation bearing A-frame structure. The interface between FTS-2 and the JCMT telescope framework is very tight, with a clearance of ~75 mm between the FTS-2 framework and the path of the dish backing structure. During operation, the FTS-2 pickoff and return mirrors will be inserted into the SCUBA-2 beam as it exits the elevation bearing tube and will reflect 2 beams through the FTS-2 optics before passing them to mirror N1. When FTS-2 is not in operation, the pickoff and return mirrors will be removed from of the SCUBA-2 beam so that they do not interfere with it. For further details refer to the FTS-2 JCMT ICD document (SC2/FTS/SYS/007).

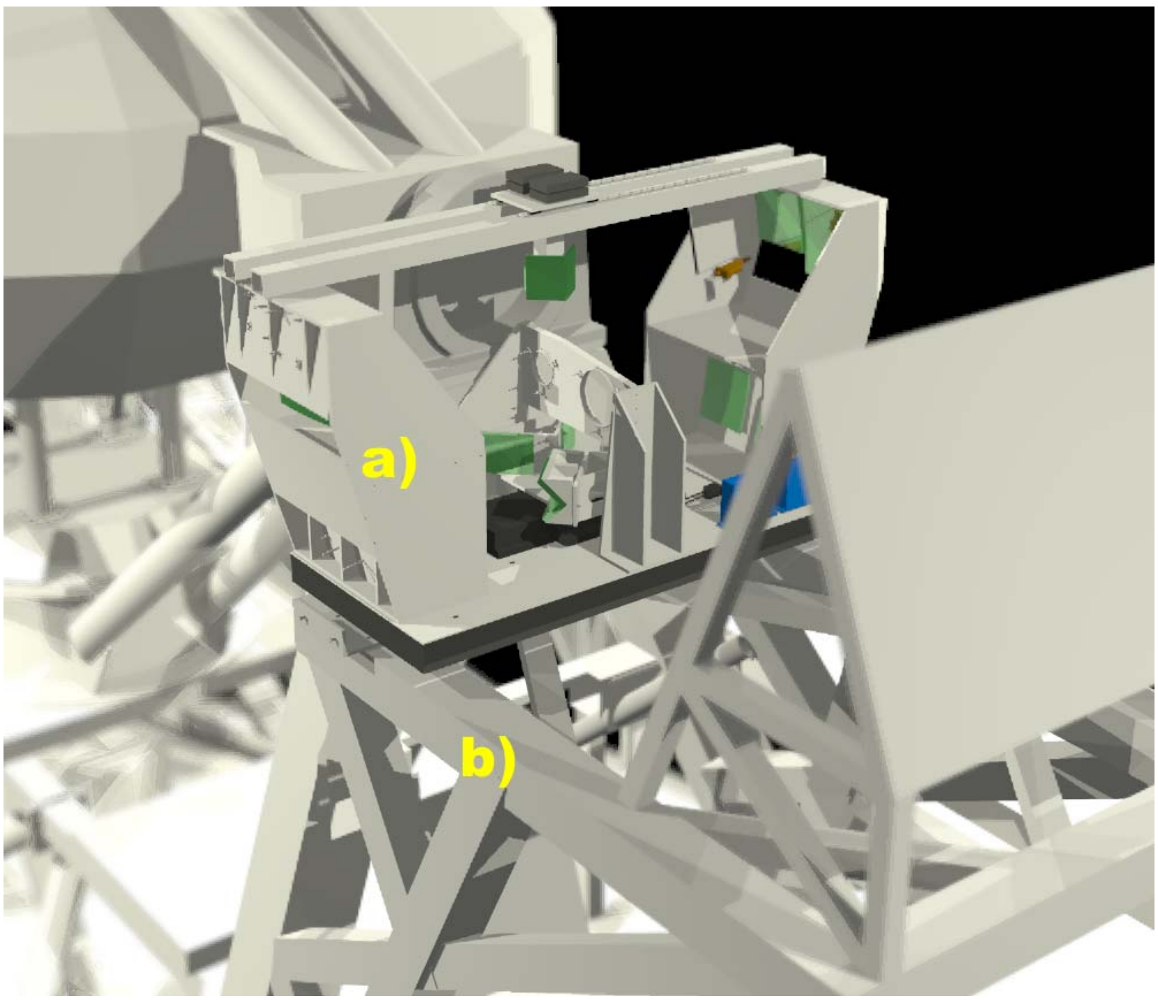


Figure 1. FTS-2 Instrument a) on JCMT N1 mirror support structure b). Protective covers not shown for clarity.

2. Damped Optical Breadboard

The FTS-2 optics will be mounted on a Newport "Research Grade" damped optical breadboard. The breadboard has a metric bolt pattern, and will provide isolation from telescope vibration, as well as a flat mounting surface for all of the FTS-2 hardware. The breadboard location is currently 37 mm above the surface of the N1 framework, leaving room for a sub-frame to allow for locating the FTS to the framework during installation, and access to levelling feet.

2.1. JCMT – Breadboard Interface

The breadboard can be manufactured with 'microlocks' at arbitrary location which act as levelling support feet. The N1 framework has machined flats at the appropriate locations to accommodate 7 microlocks. The microlocks will also serve as levelling devices and can raise or lower the entire assembly. The microlock holes can also serve as mounting points for the lifting harness attachments for hoisting FTS-2 into location.

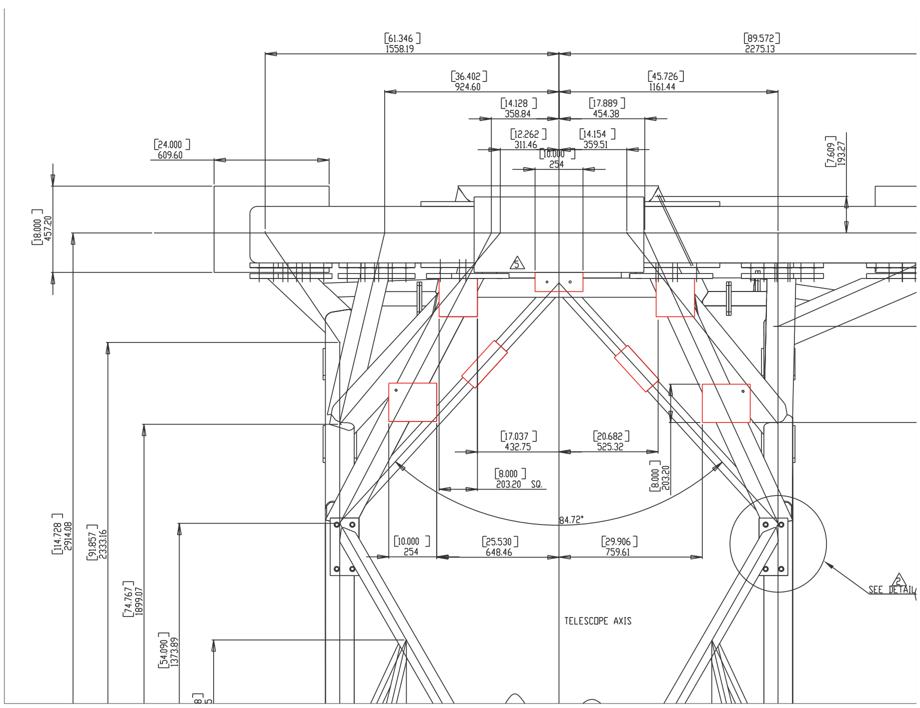


Figure 2. Microlock locations (red) on the top surface of the N1 framework.

2.2. Breadboard Specifications

The breadboard will be a Newport Research Grade Breadboard with constrained layer damping, a minimum of 1921 mm wide, 842 mm deep, and 112 mm thick. It is a composite made of steel honeycomb core sandwiched by two 3/16" precision ground steel plates. It has an M6 x 1 mm pitch metric bolt pattern with sealed holes, and self-damping side panels. Microlocks will be fabricated in the breadboard at locations corresponding to the N1 mounting pads.

3. Aerotech Linear Motor Translation Stage

The FTS-2 moving rooftop mirrors will modulate the OPD using an Aerotech ALS5000 series linear motor translation stage (hereafter referred to as LM stage). The LM stage has 450 mm of travel, and is a stock item provided by Aerotech. The stage has an integral dust shield to prevent wear on the bearings.

Figure 3. Aerotech ALS5000 series linear motor translation stage.

3.1. FTS-2 - LM stage Interface

The LM stage has a metric bolt pattern on its base which will bolt onto the breadboard. The bolts holes are slotted to allow for fine-tuning of the LM stage's final position. The rooftop mirrors will be mounted on the LM stage's moving platform using the metric bolt pattern provided. The Soloist controller and the power supply unit will be mounted on the FTS-2 between the LM stage and the lower fixed mirrors.

3.2. Function

The LM stage is a closed loop device with a non-contact Heidenhain linear encoder for feedback. The brushless linear servo motor features zero backlash, and is non-contact. The LM stage has limit transducers to prevent driving the moving platform beyond the end of travel.

3.3. Specifications

The LM stage is 838.2 mm long, 347 mm wide and 120.7 mm high. The mass of the LM stage is 52 kg, and its maximum permissible load is 135 kg. It can achieve accelerations of 30 m/s^2, and has a maximum velocity of 2 m/s. In FTS-2 configuration, it has a 20 nm resolution, which improves at the lower velocities required for normal FTS-2 operation.

The load handling and drive capabilities of the LM stage are more than sufficient to carry the ~30 kg mass of the moving corner-cube mirror assembly.

4. Framework

The FTS-2 framework will support all of the hardware which is not on the breadboard level, including the beamsplitters, the upper fixed mirrors, the pickoff mirror assembly, and the retraction assembly. It will also provide mounting features for the FTS-2 protective covers. As of the time of writing, the framework design is still in progress since the optical design has just been finalized. There is sufficient space around all the components to allow for a reasonable amount of flexibility in the design; stiffness can be increased as necessary by adding suitable bracing or increasing the tubing thickness. The final framework design will have sufficient stiffness to maintain the mirrors within the optical tolerances (~200 μm) and ensure that resonant frequencies are kept above 400 Hz.

The current design uses aluminum plate for the framework members, fastened together with bolts, as shown below. Precision is maintained with the use of locating dowels in all connections. The pickoff mirror assembly is supported by aluminum tubing of sufficient stiffness to support the ~10 kg load across the span. The mirror mounts for the 8 fixed mirrors are integrated with the framework to provide maximum stiffness.

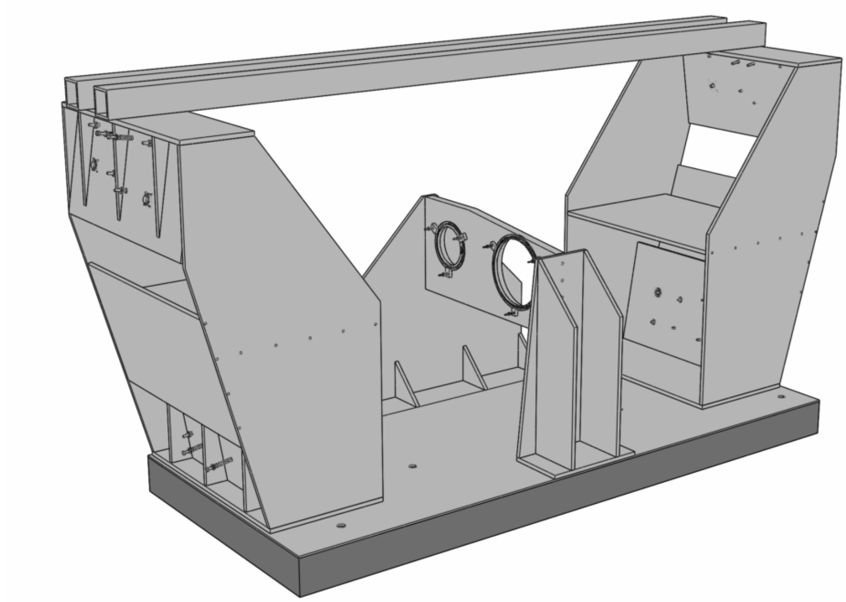


Figure 4. FTS-2 framework mounted on the breadboard.

4.1. Framework interface

The FTS-2 framework will be bolted to the breadboard through the bottom plates. Space has been provided to allow access to all internal components and the microlock adjusters, once the outer covers have been removed. The framework is designed to avoid interference with the SCUBA-2 beam and the JCMT telescope backing structure while maintaining high rigidity for resistance to vibration. All power inlets and control connections will be mounted to the framework near the cabin access walkway.

4.2. Material

The FTS-2 framework will be constructed of 6061-T6 aluminium plate. The 6061-T6 composition and heat treatment was chosen for its availability, good welding characteristics, and higher stiffness to weight ratio. The framework's sub-assemblies will be assembled separately in order to facilitate shipping of the instrument. Thickness of the plate will be determined through FEA analysis.

4.3. Specifications

The FTS-2 framework and fixed optical mounts will have a mass of ~200 kg and will be ~2 m wide x 0.6 m long x 1.3 m high. It will disassemble into several sections which can be packaged flat to a volume roughly equal to that of the breadboard, in order to minimize shipping costs.

4.4. Protective cover

A protective sheet metal cover will be attached between the flat surfaces of the framework to cover all openings except where the SCUBA-2 beam traverses the instrument.

5. Lifting and Installation Assembly

5.1. JCMT Interface

The FTS-2 will be lifted into position by the overhead crane at the JCMT. It will be located by means of an adjustable mechanical stop system on the dish side of the Nazmyth platform. The final optical model allows for extra space below the lower mirrors, and there is now ~37 mm of space available below the breadboard for a locating/adjustment framework to assist with locating the instrument during installation.

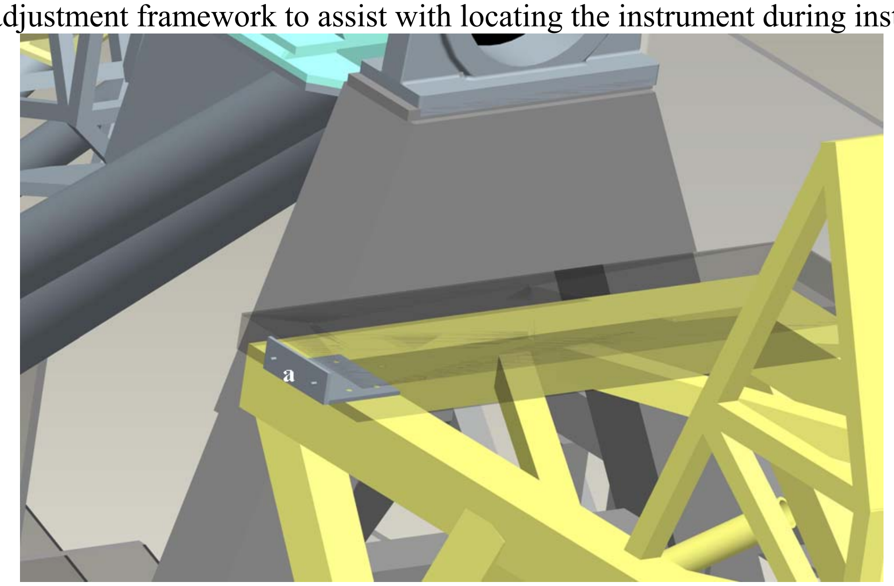


Figure 5. Mechanical stop assembly a), breadboard (transparent grey) and N1 platform interface.

5.2. Lifting points

Four microlocks in the outer corners of the breadboard will be used to lift the FTS-2. Lifting eyes will thread into each microlock to an appropriate depth and can be removed as required after installation.

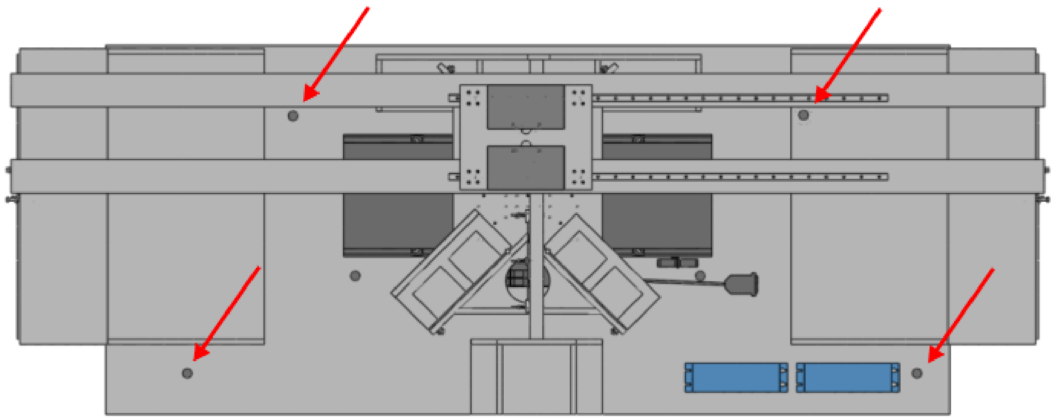


Figure 6. Top view of FTS 2, arrows showing lifting points.

5.3. Lifting frame

A simple lifting frame will be fabricated to maintain the separation of the harness cables as they pass the framework components to prevent damage. Tubular steel will be used for lifting frame, and it will be bolted to the upper framework to prevent unwanted travel or tilting of the lifting frame relative to the FTS-2.

6. Mirror Mounts

To accommodate the internal FTS-2 beams, some of the FTS-2 optics diameters will be ~300 mm. The mass for each of these mirrors is expected to be in the range of three to six kilograms. The mirror mounting features must be compact due to the proximity of the mirrors to each other, particularly the pickoff and return mirrors and the rooftop mirrors. As there are no suitable commercially available mirror mounts, the FTS-2 mirror mounts must be custom designed.

The same fundamental design has been used for all the mirror mounts in the system, with the exception that the pickoff mirrors require motorized actuators for adjustment since there is no space to access normal screw actuators, and the pickoff mirrors are more likely to require periodic realignment than the internal optics. The original design was prototyped using a Zaber Technologies NA11-16B stepper motor based actuator, however, refinements in the optical modelling have forced the input and output pickoff mirrors closer together and a smaller actuator is required. The New Focus Picomotor model 8301 piezo actuator has been selected, and is described in more detail in the pickoff mirror assembly section.

6.1. Design

A single pivot mirror mount design was selected which uses a spherical bearing to allow adjustment of the mirror angle in two orthogonal axes. A NTN 1200 angular misalignment roller bearing was chosen over a plain spherical bearing for the reduced friction, which allows for smoother adjustment. The design, shown in Figure 7, incorporates a spherical roller bearing for a pivot, two adjusters (in this case motorized actuators, shown in green) for the tip and tilt adjustment of the mirror, and a compression spring (shown in red) which ensures the stiffness of the assembly and forces the mirror to return to its position following a shock. The spherical bearing is fastened into a bracket plate, with the centre of the mirror supported by a bolt (shown in black) passing through the bearing. If required, a third axis of adjustment (translation) can be obtained by inserting shims in between the bolt and the mirror. The mirror mounts will be bolted to the framework using alignment pins to ensure they are in the correct location and orientation. The goal is to allow the mirrors to be mounted with their optical centres within 0.2 mm of their intended locations, although the positioning will have to be confirmed during alignment tests.

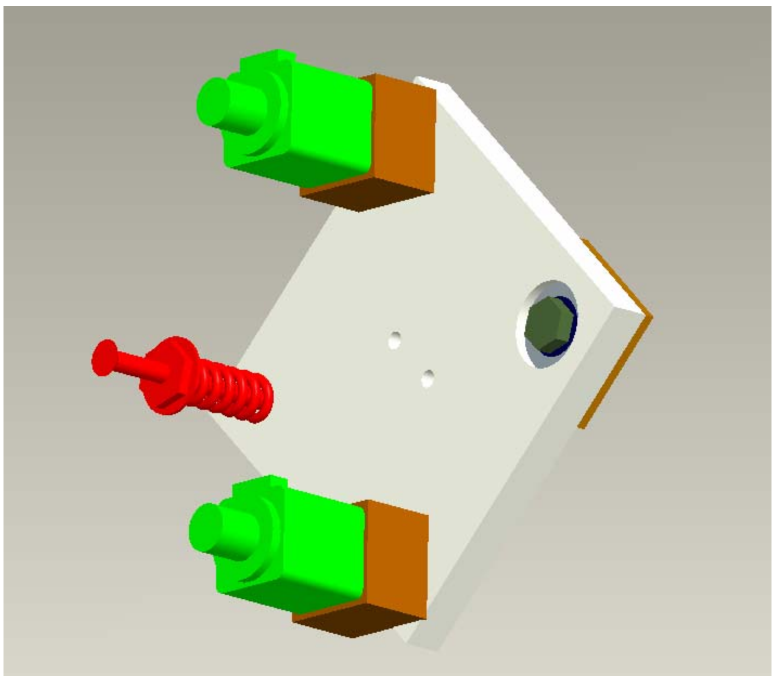


Figure 7. FTS-2 Mirror Mount, shown with motorized actuators. All mounts except the pickoff mirror mounts will use manual screw ball-tip adjusters.

The spring must provide a suitable force at the required compression distance to counteract the gravitational moment of the mirror while not overloading the adjusters. Two steel inserts are integrated into the mirror to prevent the adjuster tips from scarring the aluminium. The elevation insert has a V-groove to prevent rotation of the mirror about the axis of the spherical bearing. The elevation adjuster was chosen for this function as the moment induced by the mirror's weight acts on it and thus it will provide more stability. The machining of the bracket plate is minimal, making this design a very cost-effective solution.

The mirror is fastened to the bearing directly with a large bolt, as shown in Figure 8. The bolt is first tightly fastened to the bearing with a nut, and then threaded into a hole in the centre of the rear surface of the mirror. The mirror rotates about the center of the bearing rather than the mirror surface. Although there is some translation of the beam as the mirror is adjusted, it has been minimized to maintain the translation of the mirror centre within the optical decentre tolerances over the expected range of angular motion.

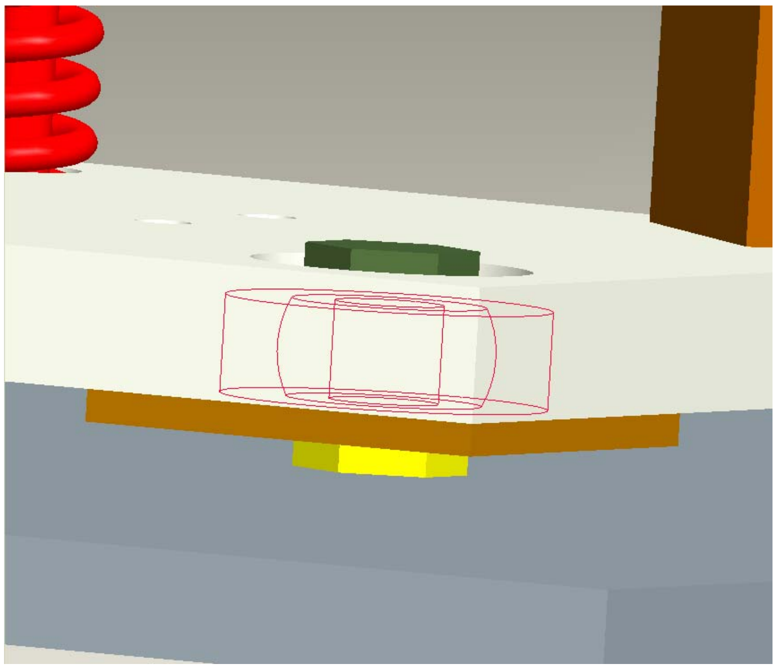


Figure 8. Attachment of mirror onto mount; mounting plate (white), M10 bolt (dark green), M10 nut (yellow), mirror (dark grey), spherical bearing (red outline).

6.2. Function

The spherical bearings allow an ~8 degree range of adjustment in each axis. Their static load rating is 1.19 kN, or 120 kg-force. The dynamic loading is well below the rated values for this bearing, thus rendering the bearings maintenance free.

Testing in the lab using a small telescope (see SC2/FTS/MEC/002) has demonstrated the resolution to be 0.1132 arc seconds per micro step of the actuator. The adjustment remains very smooth and predictable at this resolution, and the mirror returns to its desired position when subjected to shock.

7. Corner-cube (Rooftop) Mirror Assembly

A pair of corner-cube mirrors is mounted on top of the Aerotech stage moving platform, which provides the variation in OPD between the interferometer arms. Rooftop mirrors in the PDR design have been replaced with corner-cube mirrors in order to maintain the symmetry of the rays in the second half of the interferometer. Corner-cubes also reduce the possibility of misalignment due to non-parallel motion of the stage. Each corner-cube is formed by essentially replacing one of the mirrors in each rooftop with an equivalently sized rooftop mirror. The corner cubes will be aligned independently and installed as a fixed unit on the translation stage, which simplifies the alignment process and reduces the complexity of the optical mounts since adjustment will not be necessary.

Handles will be provided in the moving mirror framework to allow the assembly to be removed from the translation stage as a unit. The array of mounting holes in the translation stage platform will provide suitable registration of the corner cube assembly.

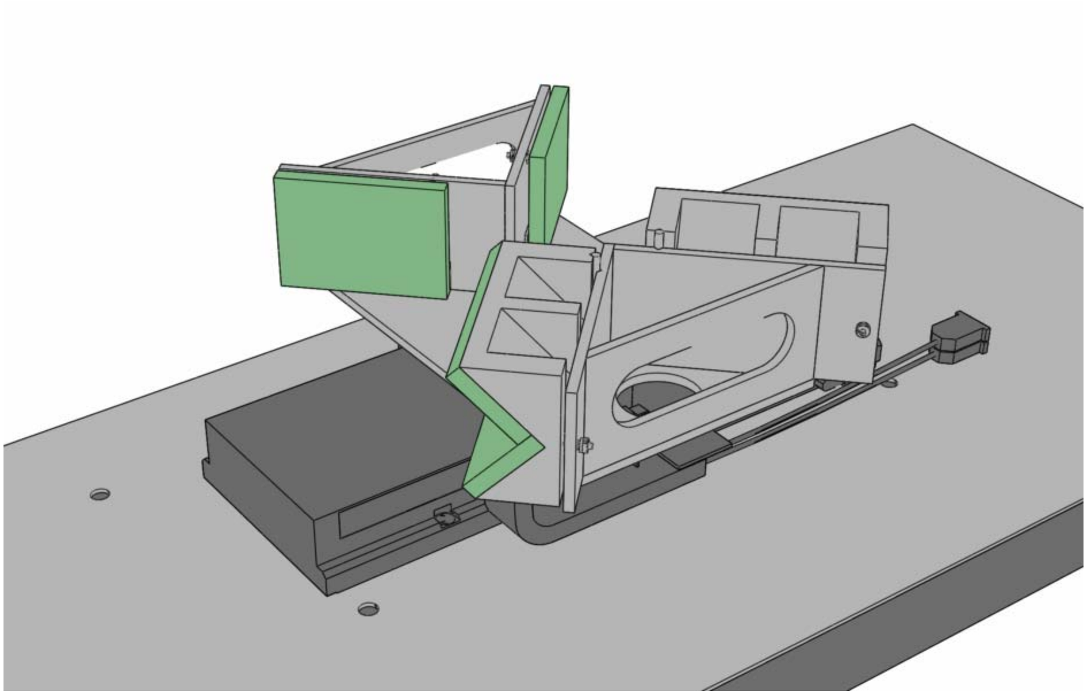


Figure 9. Rooftop mirror assemblies on Aerotech LM stage and breadboard.

8. Pickoff and Return Mirror Assembly

It is necessary that the FTS-2 pickoff and return mirrors be retracted from the SCUBA-2 beam when FTS-2 is not in operation. These mirrors also require remote adjustment as there is no space for manual access, and the mirrors will require adjustment to align the FTS optics with the SCUBA-2 system if the FTS-2 instrument is removed for maintenance. The pickoff assembly is the most complex mechanical structure in the FTS. It contains the support structure, eight motorized actuators, and associated control electronics, as shown in below.

The prototype mirror mount used Zaber Technologies actuators; however these will not fit in the space required for the final optical design. New Focus Picomotor Model 8301 actuators were selected as a replacement. These actuators have a maximum load of 22 N, which is less than the Zaber units but still acceptable for the smaller pickoff mirrors. The minimum incremental motion of 30 nm is much better than the Zaber model, although since the horizontal axis actuators are located only 30 mm from the bearing, the resulting tilt precision is slightly worse at ~0.21 arc seconds. Due to physical limitations of the small assembly, vertical actuators are staggered. Adjacent mirrors have different vertical actuator offsets: either 35 or 40 mm. This results in vertical tilt precision of either 0.18 or 0.16 arc seconds. Tilt range is about 2.5 degrees.

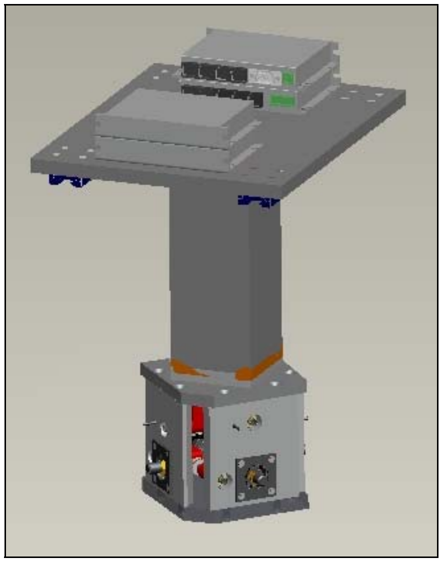


Figure 10. Pickoff mirror assembly.

At the top of the assembly are three Model 8753 driver modules, each able to control up to three Picomotor actuators. There is also one 8752 controller, which interfaces between the drivers and the computer system, via Ethernet cable. These components are stacked, then daisy chained (and powered) using the included proprietary cables. The eight actuators are controlled via eight proprietary cables (carrying power and data together) which run down the pickoff pipe toward the box. The required cabling between the moving pickoff assembly and the fixed framework consists of one Ethernet cable and one DC power cable, which will be shielded in a flexible cable track.

Required hardware from New Focus are the iPico Driver Kit Model 8766 (this includes two drivers, one controller, and power supply), an additional Intelligent Driver Model 8753, and an additional Assembly Kit Model 8760.

The pickoff assembly rides on two NSK PU15 AL rails mounted to the support framework. There are no mechanical constraints above the pickoff mirror system, so the rails, support structure, and cabling can be made as tall as required. The rails are available in lengths up to 1 m and are rated for 5 kN loads, which is well above the requirements for supporting the pickoff mirror assembly. Four matching ball bearing slides (included with the rails) are mounted to the bottom of the pickoff plate.

The actuators are mounted to “retainer” plates (Figure 11, dark grey). A spacer (silver) is also used, to supplement the thickness of the plates. The plate and spacer slide onto the smooth section of the actuator and the actuator nut tightens the assembly together. The plate is then attached to the pickoff wall using screws. The plate and spacer are necessary in order to move the actuator further back, away from the mirrors. Since the length of the actuator is fixed, this reduces the gap between the mirror and mirror mount, allowing for a reduced decentre when adjusting the mirror angles.

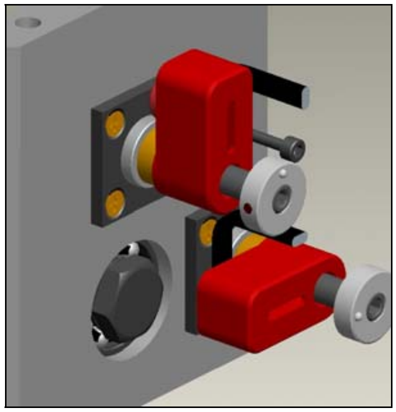


Figure 11. Actuator layout for one pickoff mirror mount.

The springs being considered are model 24554 from Dynaline Industries. The force in the spring should not exceed ~ 15 N, but this will be confirmed by testing. Since the nut can be moved to vary the amount of compression in the spring, the applied force is adjustable.

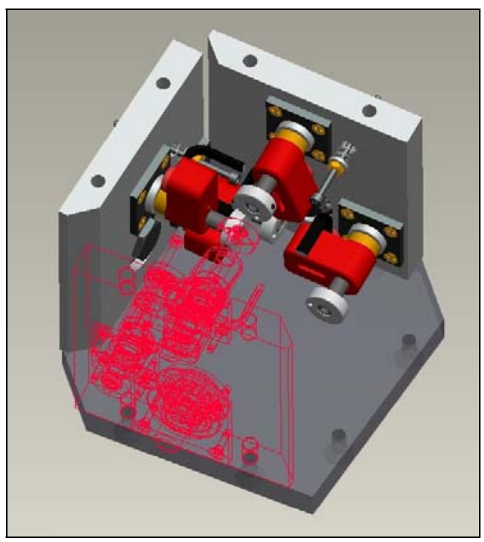


Figure 12. Staggered actuator arrangement.

8.1. Retraction Mechanism

The pickoff mirror assembly retraction mechanism is based on a lead screw driven by a Zaber Technologies stepper motor with integrated controller. The ball screw and stepper motor combination will allow the mirrors to be positioned in the beam with a resolution well below the positioning tolerance required by the optical design (a micro step size on the order of microns is the target). The stepper motor will be driven in past the final position and then stepped back to compensate for backlash. Optical sensors will provide a position datum, and mechanical switches will limit travel.

9. Beamsplitter Mounts

The beamsplitters are assembled in stainless steel rings which ensure the film surface is flat. These rings are mounted into a solid plate running parallel with the elevation bearing axis, using retaining springs to press the rings against 3 adjustment screws. The beamsplitter diameters are 120 mm for the input beamsplitter, and 200 mm for the output, well within the manufacturing limits set by Cardiff. The beamsplitter ring mount is shown in Figure 13. The outer beamsplitter is larger than the input, and is therefore closer to the diverging SCUBA-2 beam. Hence, the support plate will not completely surround the output beamsplitter.

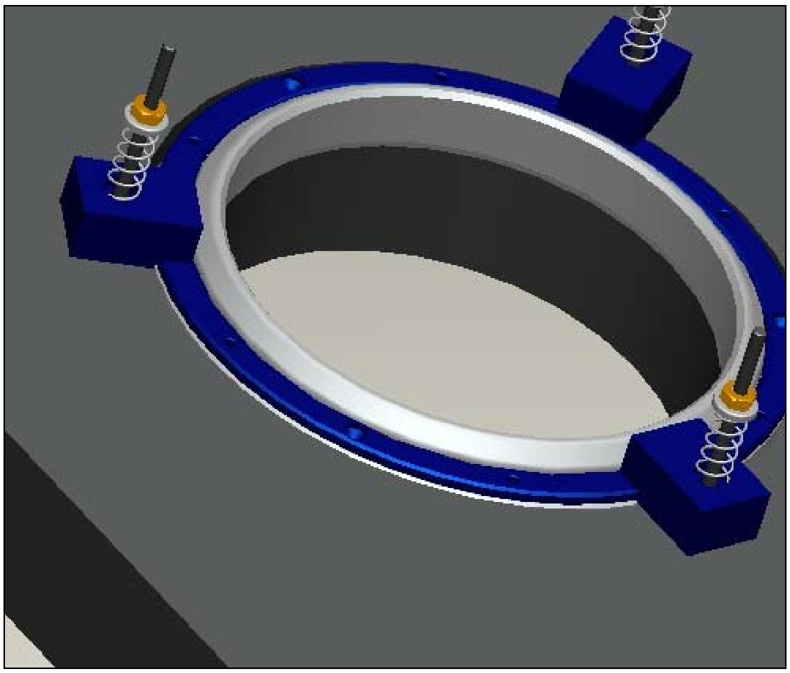


Figure 13. Beam splitter ring mount, showing spring clamps. Adjustment screws are on opposite side.

10. Blackbody Shutter

Following the PDR, it was decided that it would be useful to have an ambient blackbody which could be used to blank of one of the input ports. While the single beam system will have much less sensitivity than the dual beam configuration as a result of atmospheric effects, it will provide useful diagnostic measurements. The shutter will be a simple aluminum plate covered with a thick layer of Ecosorb, mounted on a pivot. The shutter will be rotated into one input port immediately before the first fixed mirror (near a pupil location) by a linear actuator and lever. The blackbody mechanism is shown below.

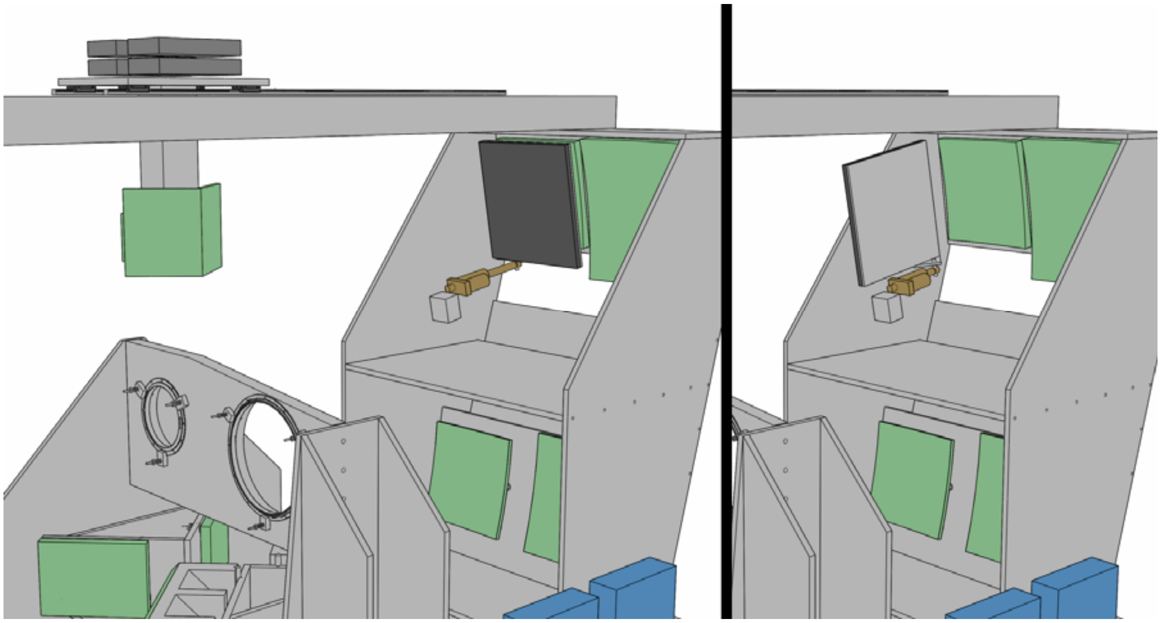
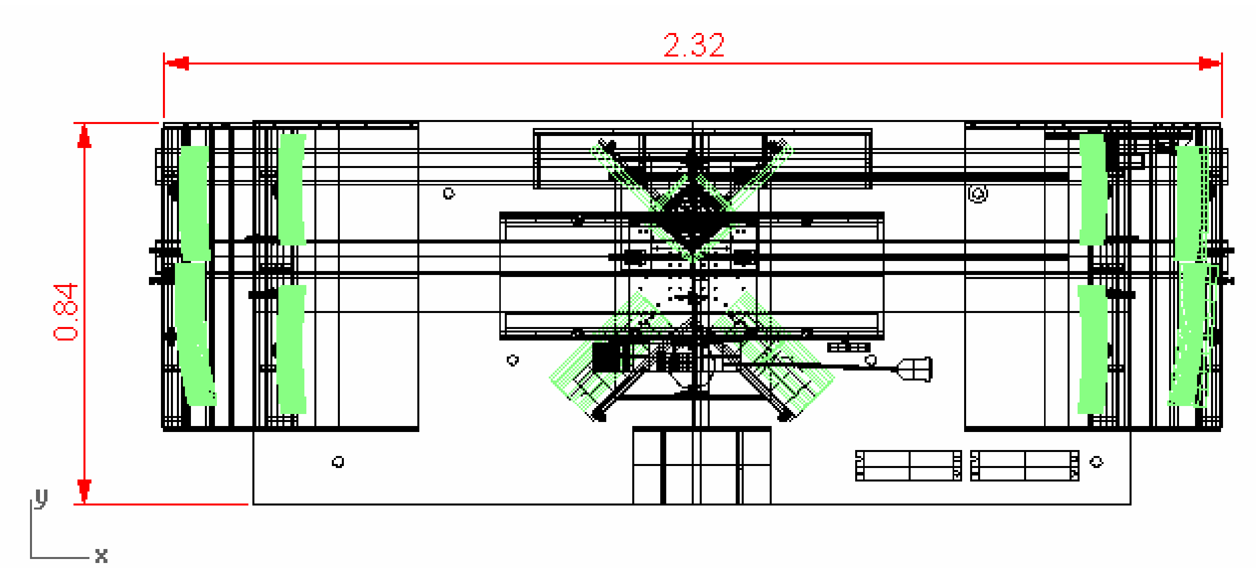
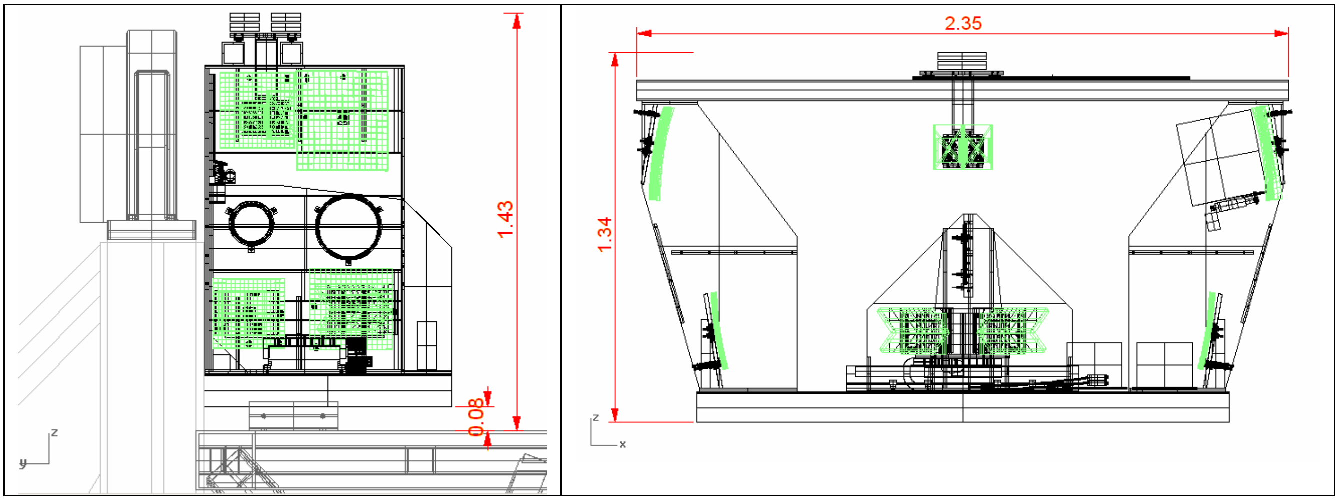


Figure 14. Ambient blackbody shutter inserted in the beam (left) and retracted (right).

11. Overall System Dimensions

The depth of the FTS-2 instrument is driven by the breadboard size, which is matched to the N1 framework support pad locations. The width is driven by the position of the upper fixed mirrors.

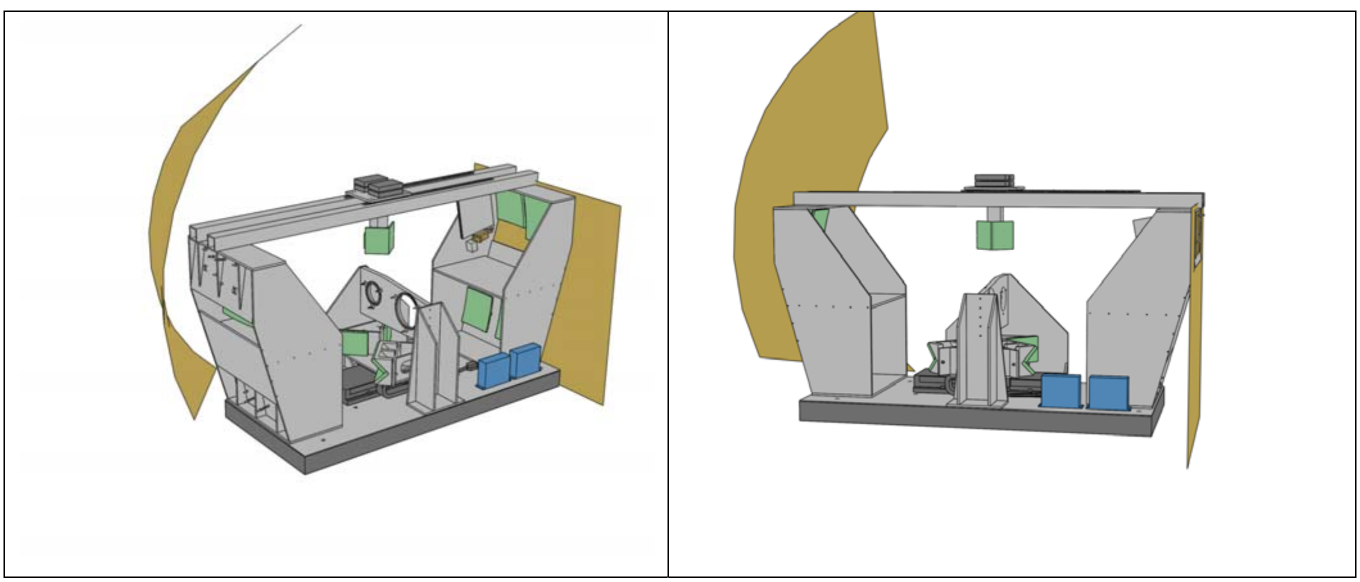




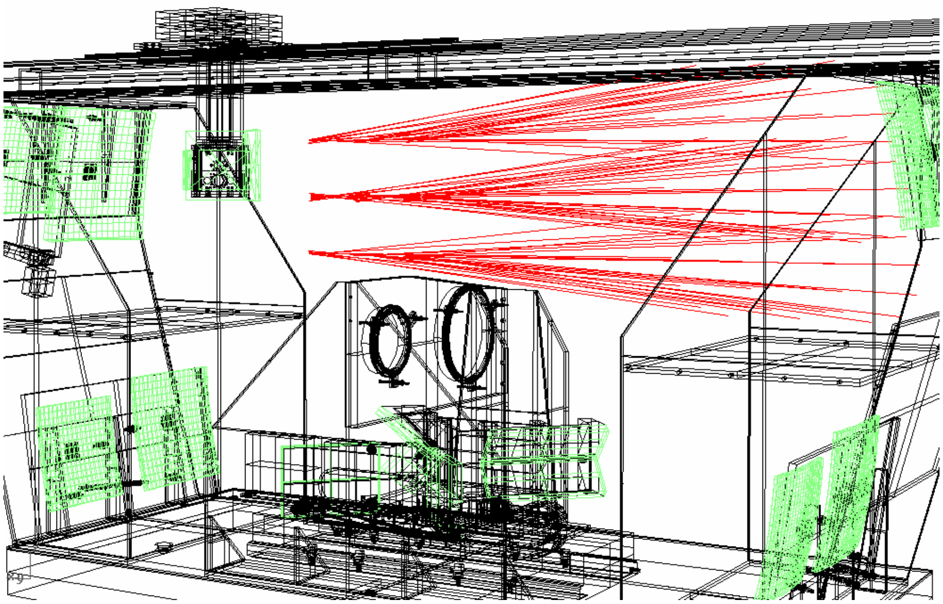
12. Dish, Beam and Walkway Interference

The space envelope of the FTS-2 system is determined by the cabin access walkway on one side, and the path of the primary mirror backing structure on the other. Furthermore, no part of the FTS-2 framework is allowed to interfere with the SCUBA-2 optical beam when the FTS in not in use. These constraints have been incorporated into the optical layout and the framework design.

In the diagrams below, the JCMT backing structure path and the plane of the cabin access walkway are shown in yellow. Measurements of the backing structure were taken by hand, whereas the walkway location was provided by JAC engineering. The framework clears the dish path by ~12 cm, whereas the walkway is directly below the mirror support.



Clearance between the beamsplitter mounts and the SCUBA-2 beam was confirmed in the optical modelling (see SC2/FTS/OPT/001). The rays corresponding to the outer field points in the SCUBA-2 FOV are shown below in red, as seen from the bearing tube side of the instrument looking towards N1. The clearance is described in the optical modelling report.



13. Fabrication Drawing Numbers

As per the JCMT numbering scheme, fabrication drawing numbers will have the first four characters “J318” followed by three digits provided by the U of L. For example, the top-level assembly drawing of the FTS-2 will be numbered “J318001”.