Options for the calibration facility

The main ground calibration facility for the FIRST bolometer instrument will need to replicate the thermal and optical environment present on the FIRST satellite. Three options for the calibration facility present themselves:

1. A warm telescope simulator feeding an instrument cryostat that provides the necessary temperature interfaces.
2. An all up dummy telescope at 80K with realistic mechanical and thermal interfaces.
3. An 80K telescope simulator feeding an instrument cryostat with simulated, and possibly unrealistic, thermal and mechanical interfaces.

In an ideal world, and with sufficient resources and time, option 2 would be the first choice solution. However, this solution is likely to be very expensive and, given that work on building it will have to start very early in the project, it is also likely fail in its objective of a realistic themal/mechanical interface as this will evolve throughout the design and build phase of the project. Option 1 was used for the test of the ISO LWS: the major drawback to this scheme is that, whilst it is relatively inexpensive and easy to operate such a facility, the amount of filtering required on the instrument cryostat to cut down the 300K background prevents any source other than an FIR laser being useful. Also, in the case of FIRST it is important that the power falling onto the detectors is replicated as realistically as possible as this is the determining factor in the final instrument performance. It is hard to see how this could be done with a warm telescope simulator.

Outline description of the proposed calibration facility

The third option is then left. An outline sketch of how such a scheme might be implemented is shown in figure **1**. Here a large nitrogen cryostat houses a telescope simulator similar in concept to the one used for the ISO LWS, although the UKIRT or JCMT simulators may provide a more realistic model. At the input of the telescope simulator is a plate cooled to 4K or below for the calibration sources. The sources will be used to simulate on-axis point sources, uniformly extended sources and off-axis point sources. Both broad band and narrow band sources will be employed - see below for a more detailed discussion of the source types envisaged.

Before entering the instrument cryostat, the beam will pass through a separate He cryostat designed to house any filtering required on a filter wheel; a 2K bolometer for monitoring the input power of the beam and, if necessary, a tracking filter (Fabry-Perot) for isolating the spectral source harmonics. This cryostat could be a re-use of the LWS facility cryostat. This cryostat will interface to the instrument cryostat via a vacuum port that will allow either cryostat to be let up without affecting the other. This interface will also have to ensure a continuous nitrogen shield (at least) to prevent unwanted radiation from warm parts of the sytem entering the instrument. Detailed design of the this interface has yet to be carried out but some form of gate valve with a magnetically coupled sliding nitrogen shield should be possible.

The instrument cryostat itself will provide the same temperature interfaces as present on the FIRST cryostat and simulate as accurately as possible the thermal and mechanical environment of the FIRST cryostat. Some beam folding is likely to be necessary in the instrument cryostat in order to simplify the mounting of the instrument. Careful consideration must be given to the instrument mounting in order to trade off the complexity of the instrument cryostat against the need to provide a realistic mechanical environment and to ensure the correct orientation of the ^{3}He sorption cooler - see figure **2.** Each option has some drawbacks: option 1 has a folded input beam and the instrument will be in a different orientation compared to when it is integrated with the FIRST satellite - thus making comparisons between instrument level and system level test more difficult. Option 2 has a folded input with the instrument in the same orientation as in the FIRST satellite, BUT the cryostat will be complicated to build. Option 3 doesn't have a folded beam but the instrument is on its side and there may be complications with operating the cooler is this orientation (ref e-mail from Lionel Duband 20/11/97). Folding the beam is probably not a serious issue as long as the fold mirror is both cold and large enough although the cryostat will have to be larger than strictly necessary - i.e. the volume to be cooled is in principle rather smaller in option 3 than in either 1 or 2. Option 2 should be looked into carefully - if the cryostat can be built like this without major additional expense and operational complexity it should be the favoured option as it will make comparison of mechanism performance between the instrument and satellite level tests very much more meaningful. If this option proves to be too expensive then option 1 will be adopted.

Calibration sources
A number of types of calibration source will be required to fully test the operation and performance of the FIRST bolometer instrument:

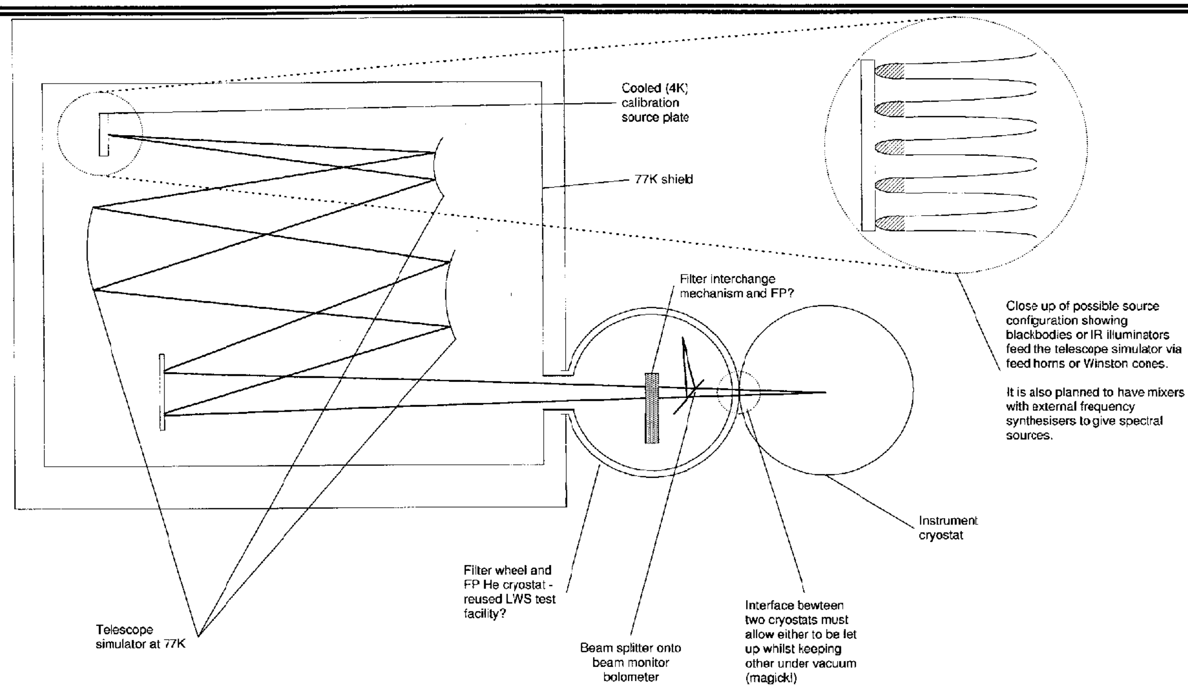
1. **Broad band point-like sources:** These could be "real" cryogenic black bodies with integrating cavities feeding the telescope simulator via feed horns or Winston cones to ensure a well controlled beam shape through the system. Alternatively the IR illuminator type sources could be used, again via feed horns or Winston cones or simply through the light pipe type feeds used on LWS (if they work at these wavelengths?). The advantage of using kosher black bodies is that they provide an absolute calibration of the system. However it may be difficult to get more than one into the field of view of the instrument. The IR illuminators are smaller and could be used to simulate a variety of positions in the field of view without the necessity for moving mirrors etc. In practice a mixture of the two maybe felt to be necessary: the black body for the absolute calibration of the on-axis position and IR illuminators for the relative calibration as a function of field position.

2. **Broad band extended sources:** A check of the response of the instrument to a broad band source that over fills the field of view will be required. This could be done by using a point like source and moving its image around in the field or by using a number of point sources placed at a variety of positions in the field and indivually controllable (see 1). Moving the image of a single source around the field of view is both slow and prone to problems with changes in the straylight environment when optical elements are moved. Whilst the option of having individually controllable point sources is attractive, and indeed necessary for testing the response of the instrument to off-axis point sources, in practice the number of such sources will be limited. Therefore to provide the final test of the instrument to

truly extended sources a calibration source of controlled temperature that fills the field of view will be necessary.

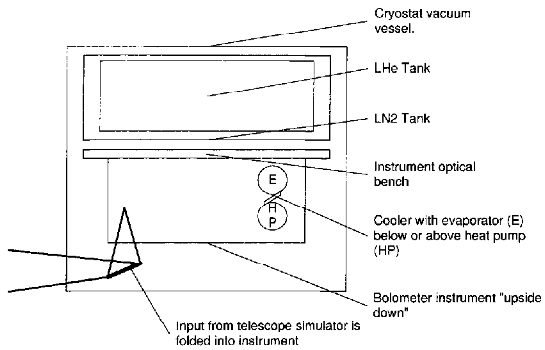
3. **Line sources - mixers:** Spectrally discrete sources will be required to verify the operation and wavelength calibration of the FTS. In addition this type of source will be used to map the filter response of the photometric channel of the instrument and to ensure that no fringing is present in the instrument optics. The type of source identified for this application employs a cold (4K) mixer fed by a co-axial cable from a laboratory frequency synthesiser. This has the advantage that the frequency generated can be externally controlled via a computer interface to the instrument EGSE. This type of mixer has been tested up to frequencies of 1 THz with output powers in the nW range - sufficient for the purposes of the FIRST bolometer instrument. Two device types may be required: one operating from 500 GHz to 1 THz and another from 1 - 1.8 THz. Some development work will be necessary to ensure the correct design of the latter device. These devices produce a frequency "comb" with harmonics separated by the base frequency of the sythesiser. Therefore, a tracking filter, a Fabry-Perot, may be necessary to isolate the frequency of interest. This would be placed in the filter cryostat as indicated above.

4. **Line sources - FIR laser:** Although, given the relatively low resolving power of the FTS spectrometer, an FIR laser is not strictly required, one could be useful for testing the response of the instrument to sources of radiation very far off axis. The advantage of the FIR laser is that it provides a collimated source of FIR and sub-mm radiation of up to 100 mW. It could be used, therefore, with the instrument cryostat detached from the telescope simulator and with suitable narrow band filtering to cut down the background power, to test the instrument response to radiation from far outside the field of view. The beam could either be steered into the cryostat via relay optics, or the cryostat itself could be rotated.

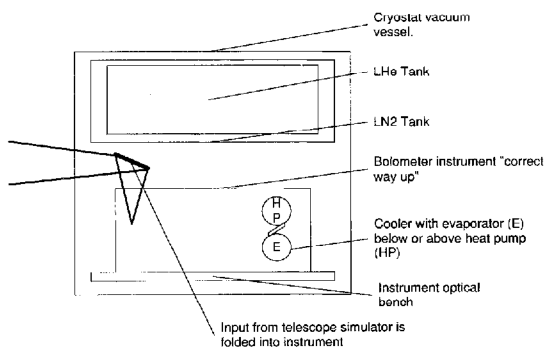


Concept for the FIRST Bolometer Instrument Calibration Facility

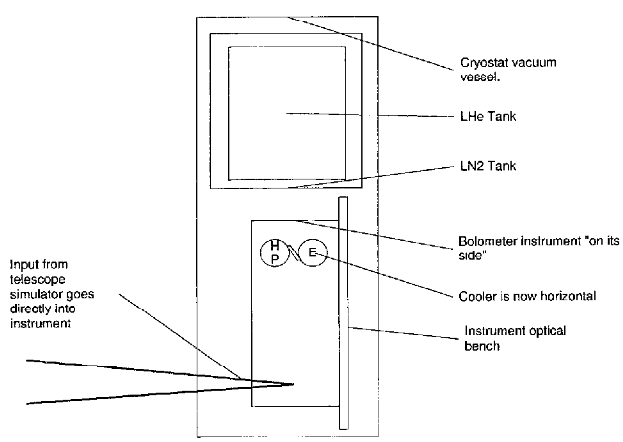
Figure 1:



Option 1:



Option 2:



Option 3:

Figure 2: The three options for the orientation of the instrument in the facility cryostat.