# HIRDLS

**TC-OXF-417**

## HIGH RESOLUTION DYNAMICS LIMB SOUNDER

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Subject/Title: **HIRDLS radiometric cross-calibration results**

Description/Summary/Contents:

Presents the data, the analysis and results of the radiometric cross calibration of HIRDLS during the pre-launch calibration at Oxford University.

Keywords:

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# Contents:

# 1. Purpose and Scope

This document is the report on the analysis and results pertaining to the radiometric cross calibration of HIRDLS taken as a part of the pre-launch calibration activities at Oxford University. It provides the definitive report and discussion of the results.

The scope includes the location of the events, the raw data, the data extraction and manipulation, the analysis and results. In addition, the data required to process the cross-calibration data are referenced or reproduced here as required. The analysis also includes an assessment of the errors or uncertainties and what further work may be desirable.

# 2. Introduction

The cross calibration refers to the use of the HIRDLS instrument as a transfer standard to provide a means of relating the thermometric calibration of the sensors in the three calibration targets – being the internal in-flight calibrator (IFC) the two full aperture external targets – being the earth (warm) black body (EBB) and the space-view (cold) black body (SBB). In some tests all three targets are brought to a coincident temperature, in others only two.

In the ideal case – the HIRDLS instrument introduces no 'error' to the incoming radiance from the targets but for the following reason this is not the case. The views may be different – so that the radiation falls on the scan mirror at different angles. The internal optics may contribute to the radiant energy falling on the detectors and this may vary between the different views. The gain and offset of HIRDLS may vary between views for other reasons. Stray light may influence the measurements.

In order to alleviate these uncertainties the HIRDLS optics (specifically the scan mirror, calibration mirror, the fore-optic lenses) are thermostatted to the temperature of the black body to be viewed (or as nearly as possible). There is not much that can be done directly to alleviate the scan mirror angle dependent emissivity.

# 3. Source data

Data for this study are available on the following occasions:

1. 2002/268-11:30 when EBB = IFC. SBB is cold.
2.
3.

# 4. Analysis and Results

### *4.1 Event 1 – 2002/268-11:30*

This event followed on directly from a complete radiometric non-linearity response measurement over the preceding three days. HIRDLS is powered on the prime (A) side. The IFC and EBB targets are arranged to coincide in temperature. The SBB is kept cold. The cross-calibration point is roughly 284 K. For the interval of the test (approx 10:30 to 11:50) HIRDLS scan mirror is performing a standard calibration cycle (i.e. views of the three targets in turn for a dwell of about 4 seconds each). At precisely 11:29:33 HIRDLS commences the raster scans of the three targets in turn (which takes about 4 minutes per target). For this analysis the data for the scan cycle immediately preceding the raster scan is used. This point is considered the best for coincidence by visual inspection.

The signal counts are averaged for each of the three views (SBB, EBB, IFC) subject to the constraint that the scan mirror encoders indicate that the view is within ± 0.05 degrees in both the azimuth and elevation directions of the centres of the targets. The DOS program 'DATA' is used to process the raw science files from the IEGSE and produce the signal averages.

The actual target temperatures were:

| | SBB | EBB | IFC |
|---|---|---|---|
| | | 284.190 ± 0.005 | 284.280 ± 0.005 |
| | | | |

Table 4.1-1 Target Temperatures

The Optics temperatures were:

| SCAN_MIR | CAL_MIR | M1 | M2 | FPA* |
|---|---|---|---|---|
| 278.7 | 284.2 | 285.9 | 283.3 | 61.68 |
| | | | | |

Table 4.1-2 Optics temperatures

* FPA is the average of the two sensors.

Table 4.1-3 shows the results. Column 1 is the channel number, Col. 2 the difference counts between the IFC and EBB (IFC-SBB), Col. 3 is the predicted counts difference calculated from the linear gain term of the channel response and the predicted radiance difference due to the difference in source temperatures (of 0.090 K).

| Ch # | ΔCnts(IFC-EBB) | Predict ΔCnts* | Col 2 – Col 3 | Equiv DT (K)** |
|---|---|---|---|---|
| 1 | 38.4 | 42 | -4 | 0.009 |
| 2 | 40.3 | 47 | -7 | 0.013 |
| 3 | 38.9 | 46 | -7 | 0.014 |

| | | | | |
|---|---|---|---|---|
| 4 | 38.7 | 47 | -7 | 0.014 |
| 5 | 37.5 | - | - | - |
| 6 | 38.9 | 42 | -3 | 0.006 |
| 7 | 39.5 | 43 | -4 | 0.008 |
| 8 | 39.0 | 44 | -5 | 0.010 |
| 9 | 43.1 | 47 | -4 | 0.008 |
| 10 | 47.9 | 55 | -7 | 0.011 |
| 11 | 48.6 | 56 | -7 | 0.011 |
| 12 | 51.2 | 58 | -7 | 0.011 |
| 13 | 58.4 | 66 | -8 | 0.011 |
| 14 | 60.6 | 67 | -7 | 0.009 |
| 15 | 59.3 | 68 | -9 | 0.012 |
| 16 | 63.7 | 70 | -6 | 0.008 |
| 17 | 66.2 | - | - | - |
| 18 | 68.0 | 79 | -11 | 0.013 |
| 19 | 66.7 | 79 | -12 | 0.014 |
| 20 | 76.8 | - | - | - |
| 21 | 74.5 | - | - | - |
| | | | | |

Table 4.1-3 - Results

* The predicted counts difference is determined as follows:
**Radiance per Kelvin temperature difference (black body) for given channel, multiplied by the actual temperature difference (IFC- EBB), multiplied by the channel gain (expressed as counts per unit radiance).

The IFC temperature actually cycles with a peak-peak amplitude of about 60 mK and period of about 5 minutes which shows up clearly in the detector signal counts. This does not represent an error on the data since the location of a given sample is better than ±4 seconds but see the discussion below.

Analysis of the raster scan data that follows the sample listed in the tables above can be used to verify pointing accuracy, and in principle, be used to derive the cross-calibration point. In this case there is no value added by analysing them.

## *4.2 Event 2 – 2002/268 13:35*

This event was during the calibration mirror emissivity test. During this period the calibration mirror temperature was varied between about 280 K and 290 K (the heater was applied). At precisely 13:35:46 the temperature of the mirror was the same as the IFC and closest to the EBB – actual values are shown in the following table:

| | SBB | EBB | IFC |
|---|---|---|---|
| | | 284.121 ± 0.005 | 284.314 ± 0.005 |

| | | | |
|---|---|---|---|
| | | | |

Table 4.2-1 Target Temperatures

The Optics temperatures were:

| SCAN_MIR | CAL_MIR | M1 | M2 | FPA* |
|---|---|---|---|---|
| 278.67 | 284.31 | 285.81 | 283.79 | 61.679 |
| | | | | |

Table 4.2-2 Optics temperatures

* FPA is the average of the two sensors.

As in event 1 the scan mirror is performing the standard scan cycle. The data are extracted and averaged during the scan mirror dwell at each target subject to the same criterion of encoder angles in the same way as event 1.

Table 4.2-3 shows the results. Column 1 is the channel number, Col. 2 the difference counts between the IFC and EBB (IFC-SBB), Col. 3 is the predicted counts difference calculated from the linear gain term of the channel response and the predicted radiance difference due to the difference in source temperatures (of 0.193 K).

| Ch # | ΔCnts(IFC-EBB) | Predict ΔCnts* | Col 2 – Col 3 | Equiv DT (K)** |
|---|---|---|---|---|
| 1 | 81.9 | 89 | -7 | 0.013 |
| 2 | 93.0 | 100 | -7 | 0.013 |
| 3 | 91.8 | 99 | -7 | 0.014 |
| 4 | 93.1 | 100 | -7 | 0.013 |
| 5 | 84.0 | - | - | - |
| 6 | 81.0 | 90 | -9 | 0.019 |
| 7 | 83.7 | 92 | -8 | 0.017 |
| 8 | 84.3 | 95 | -11 | 0.022 |
| 9 | 90.7 | 100 | -9 | 0.017 |
| 10 | 104 | 118 | -14 | 0.023 |
| 11 | 105 | 119 | -14 | 0.023 |
| 12 | 110 | 124 | -14 | 0.022 |
| 13 | 125 | 143 | -18 | 0.024 |
| 14 | 127 | 144 | -17 | 0.023 |
| 15 | 131 | 147 | -16 | 0.021 |
| 16 | 136 | 151 | -15 | 0.019 |
| 17 | 142 | - | - | - |
| 18 | 149 | 169 | -20 | 0.023 |
| 19 | 150 | 170 | -20 | 0.023 |
| 20 | 164 | - | - | - |
| 21 | 161 | - | - | - |
| | | | | |

Table 4.1-3 - Results

The formulation of the predicted counts difference and the predicted equivalent effective brightness temperature error (column 4) is the same as event 1.

During this sample the IFC temperature was cycling as in event 1 and it was about half way down a cooling phase. The calibration mirror was warming at about 0.1K/minute.

### 4.3 Event 3 – 2002/276 20:00

On this occasion all three targets were brought to coincidence at about 282 K. As is normal it is not possible to achieve coincidence of temperature for all three targets at the same time so therefore there are a couple of events within this sample.

The objective was to drift the external BB targets through the IFC temperature. The IFC was controlling at 282.263 K with only a modest variation. The SBB (BB1) achieved coincidence at 20:03:30 and the EBB (BB2) achieved coincidence at 19:59:50. A third point occurs when the SBB and EBB are within 2 mK of each other at 19:50:20. Table 4.3-1 summarizes these points.

The Optics temperatures are summarised in table 4.3-2.

| | Time | SBB | EBB | IFC |
|---|---|---|---|---|
| i. | 19:50:20 | 282.128±0.005 | 282.130 ±0.005 | 282.270±0.005 |
| ii. | 19:59:50 | 282.208 | 282.264 | 282.265 |
| iii. | 20:03:30 | 282.261 | 282.328 | 282.263 |
| iv | 20:30:32 | 282.390 | 282.387 | - |

Table 4.3-1 Target Temperatures

The Optics temperatures were:

| SCAN_MIR | CAL_MIR | M1 | M2 | FPA* |
|---|---|---|---|---|
| 282.05 | 282.40 | 287.05 | 285.70 | 61.550 |
| | | | | |

Table 4.3-2 Optics temperatures

* FPA is the average of the two sensors.

As usual the scan mirror was performing the standard calibration cycle.

For point i) (SBB = SBB), the zero counts difference occurs at about 19:51:30 although the drifts are much slower than the succeeding two points. At the time of temperature coincidence the counts difference of the detector signals are between –11 and –6.

For point ii) (IFC=EBB) the zero counts difference occurs at about 20:00:20, some 30 seconds after the temperature coincidence. Remember that the EBB is warming slightly though this point. At the time of the temperature coincidence the signal difference counts are between (positive) 3 and 8 over all 21 signal channels. In this case we can not easily distinguish any cross calibration error (or at least any error terms cancel out).

For point iii) (IFC = SBB) the zero counts difference occurs at about 20:03:50, some 20 seconds later than the temperature coincidence. Remember that the SBB is warming. At 20:03:30 the counts difference for the detector signals are between –2 and +8 over the channels.

For point iv) (SBB = EBB), this has the slowest variation of temperature of both targets. By visual inspection the time of 20:30:32 is chosen from a possible range of perhaps 15 minutes. At this time the counts difference for the detector signals are between –2 and +7 counts.

# 5. Discussion

## *5.1 Event 1 and general considerations*

Possible error sources are:
1. EBB RIRT thermometry calibration error which is estimated to be about <TBD>. The contribution from the cavity emissivity which depends on the effective brightness temperature of the target surroundings with a significant view factor into the cavity.
2. The IFC PRT thermometry error, which is estimated to be about >TBC>. The contribution from the cavity emissivity which depends on the effective brightness temperature of the target surroundings with a significant view factor into the cavity.
3. The thermometry error of the calibration mirror and the emissivity of the mirror in the same manner as the cases 1 and 2.
4. Temporal variations in the HIRDLS gain and offset between the views – which is negligible by design.
5. Scan mirror emissivity (and spatial temperature variations) between the view of the external and internal targets – estimated to be about <TBD>.
6. The confidence limits on the actual average signal counts determined for each view – refer to the stability evaluation elsewhere.
7. Timing mismatch from the data processing utility.
8. Temperature gradients in the targets (most likely when the temperature is changing ‘quickly’).

In the analysis of event 1 there is a residual of about 10 mK effective brightness temperature error which is not accounted for in section 4.1 – with the view of the IFC looking relatively warmer or the EBB relatively cooler that expected. This is likely to be explained by the view factor into the EBB resulting in a cooler appearance (see elsewhere). If the IFC PRT thermometry lags the actual emission then the IFC may appear warmer as the sample was taken during a cooling phase of the cycling. (There is as 32 second interval for the update of a given PRT. With a cool- rate of about 60 mK in 3 minutes one could be stale by as much as 10 mK). Actually there is no lag between the temperature profile and the radiance signal.

### *5.1 Event 2*

The same potential error sources as event 1 are applicable. The min difference in event 2 is the warming of the calibration mirror. As can be seen from the table 4.2-3, the predicted counts difference is larger than that observed and there is a residual (excess) of about 20 mK that from the prediction. Depending upon the thermal lag between the mirror sensors, heater element and reflecting surface the effect could be to make the IFC look cooler than it really is. Since the prediction is greater than the observed this works in the correct sense.

### *5.3 Event 3*

## 6. Conclusions and further work.