The ISO Absolute Pointing Accuracy

OLP 9 Pointing Validation Interim Report

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1 Introduction

In the first months of the ISO mission, the SIDT inferred that errors of up to 4 arcseconds could be present in the ISO pointing, dependent on the target observed. The pointing appeared to be better than the specification (Absolute Pointing Error (APE) of 11.7 arcseconds), but it was suspected by the SIDT that some systematics could be present, which could therefore be corrected for.

A specific calibration programme was designed and executed in REV 137, by which a number of point-like sources were observed with ISOCAM. A simple configuration was chosen in order to fit as many as possible stars in a time deemed reasonable for such an exercise. Four hours were allocated by the Project Scientist for this experiment, as additional ISO calibration time. The experiment and its analysis are described in Ref. 1. 79 stars, selected by the CIDT from the GBPP programme, were observed in the LW9 filter (at 15 μm). The centroids of all these images were derived by the CIDT. 54 stars gave good centroid determination. These were correlated by the author with (i) the position of the guide star in the STR field of view, (ii) star ecliptical and galactic coordinates, (iii) the Solar Aspect Angle, and (iv) guide star magnitudes. It appeared that some correlation was present with the position of the guide star in the STR field of view. The S/N ratio was not very convincing, but still indicative of a possible improvement in the ISO pointing. A second attempt was made later in Rev. 264, with a more accurate star selection procedure taken by the author, based on the Hipparcos star catalogue and an ad-hoc empirical colour-colour relation between visual magnitude (quoted in the HIC) and the expected flux in CAM LW9 filter. This second experiment is described in ref. 2 and was also confined to last 4 hours. This time a convincing relation was found between pointing offset and the position of the guide star in the STR field of view.

SCC initiated then an independent investigation based on the absolute pointing reconstruction as given by the confirmation star, a second guide star used at the start of every revolution. This is described in Ref. 3. It appeared that a recalibration of the STR was possible, via the introduction of a focal length dependence on the angle of incidence of the visible radiation coming from the guide star. The model was applied to predict the offsets as measured in the REV264 experiment done with ISOCAM and the agreement with the measured offsets was excellent (see ref. 4).

SCREW 280 was raised to introduce the improvement in the ISO uplink. A verification exercise was performed in REV368. It consisted in a series of SWS AOT2s on and around the star HR6705 (see ref. 5). With the old STR calibration, the measured offsets from HR6705 were of 3.3 and -3.3 arcseconds along the Y and Z axis respectively. With the new calibration, these amounted to 2.4 and -1.0 arcseconds respectively. Further to this, the go ahead was given for the uplink implementation of the STR recalibration which became operative as of REV369. A second, but of lower magnitude, improvement in the ISO pointing was obtained by increasing the sampling of the Sun ephemerides as used by the on board software of the AOCS – ISO Z-axis has to point always towards the Sun. As of Revolution 452, a new so-called Sun-model was introduced, by which AOCS on-board Sun ephemerides related parameters were updated 4 times each revolution (ref. 6). The improved pointing algorithm (ref. 7) was also introduced in the downlink in OLP V6.1. All pointing improvements introduced in the ISO uplink are described in ref. 8.

A further refinement of the ISO pointing was introduced in OLP via SCREW 359, by which the guide stars proper motions and differential aberration are taken into account, together with a refinement of the ISO Guide Star coordinates via the Hipparcos output catalogue. This improvement is implemented as of OLP V8.6. More improvements and bug-fixes have been introduced in OLP V9.

Recently, a scientific validation of the pointing files have been introduced for the first time in the OLP validation programme. The results shown in this report come from the analysis of some of the test cases selected for this purpose in the course of the scientific validation 1 of OLP V9.

2 Analysis

In order to get a quantitative assessment of the ISO Pointing accuracy, the REV264 experiment data have been used, with three different approaches.

1. Comparison of best known coordinates of the stars in the corrected frame with the CAM images centroids as determined in OLP AAC.
2. Comparison of best known coordinates of the stars in the corrected frame with the CAM images centroids as originally determined by P. Gallais (CIDT) using a box-average centroid determination algorithm.
3. Comparison of the offsets derived from the pointing reconstruction in spacecraft coordinates with the CAM images centroids as determined in OLP AAC.

The best known coordinates of the stars are the proper-motion corrected and precessed coordinates derived from the Hipparcos output catalogue. The offsets derived from the pointing reconstruction were obtained from the ATTRA, ATTDEC and CINSTRA, CINSTDEC, CINSTROLL values stored in the IRPH headers, and expressed in terms of spacecraft coordinates Y, Z, using quaternion operations as derived from the DERIVE_IPH software.

The three approaches are illustrated in Figure 1. A regression fit of type $y = ax + b$ has been applied to the data.

The large offset along the Y axis can be explained by the well-known poor reproducibility of the CAM wheel position when selecting different filters (the "CAM wheel jitter"). The effect was overcome in the REV264 experiment by not changing the instrument configuration (and thus the filter wheel position) for different pointings and therefore appears as an overall offset. The fit slope value shows the good correlation between predicted and observed offsets.

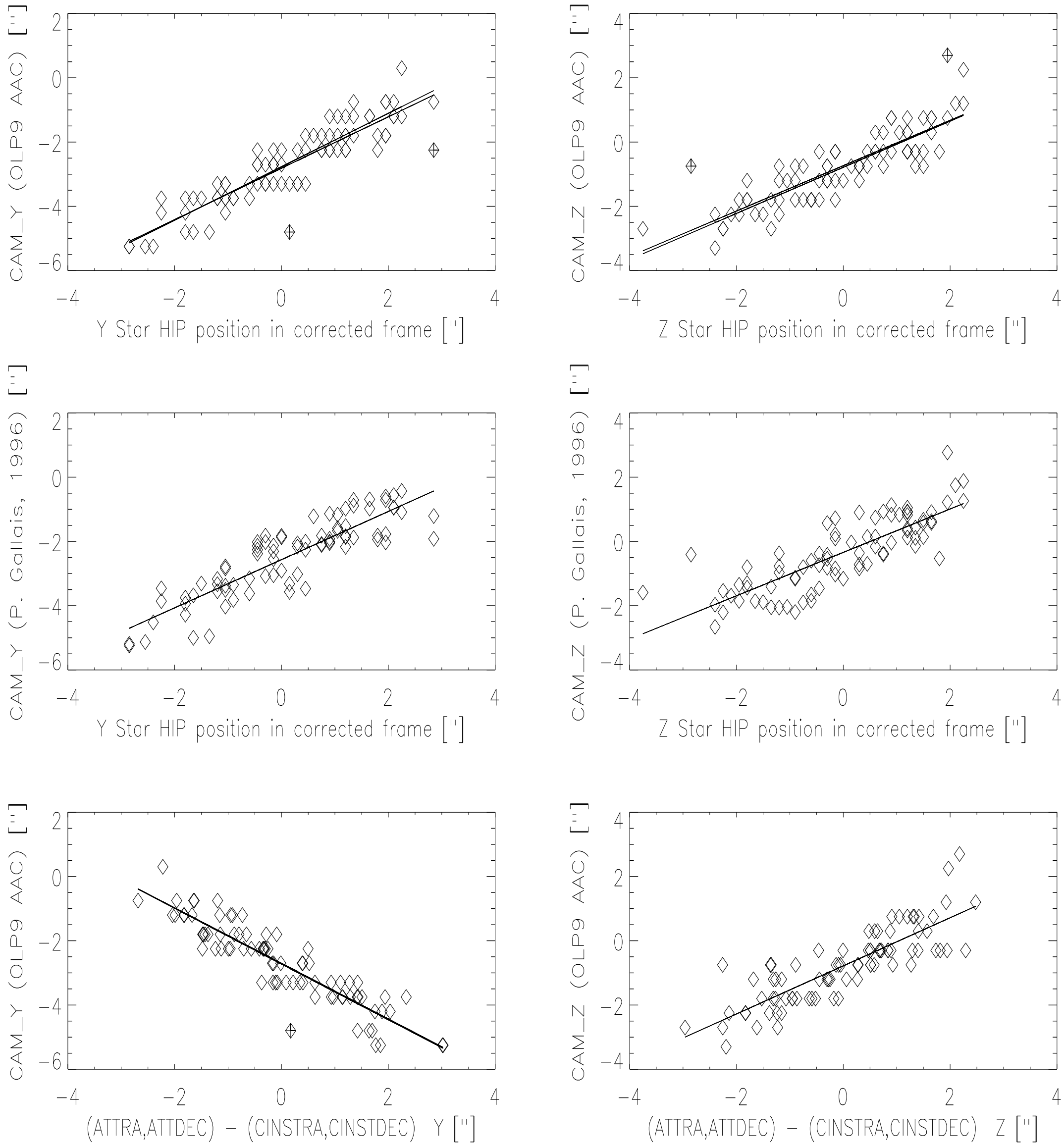

Figure 1: Comparison of the revolution 264 stars positions as expected with as seen on CAM. In the upper and centre pairs of plots, the best known coordinates of the stars in the corrected frame are compared with the CAM images centroids as determined in OLP AAC (upper pair) and as originally determined by P. Gallais (CIDT) using a box-average centroid determination algorithm (central pair). Note the quantisation in the upper plot, which comes from the given sampling of the CAM PSF ($0.5''$). In the central pair of plots, the error on each centroids was estimated by P. Gallais to be one fifth of a pixel, i.e. $0.3''$. In the lower pair, the offsets derived from the pointing reconstruction in spacecraft coordinates are compared with the CAM images centroids as determined in OLP AAC. A 3–σ clipping has been performed prior to the fit. Outliers are indicated by a cross.

The fit standard deviation gives an upper limit of the ISO pointing accuracy, as it also contains the uncertainty in the determination of the CAM images centroids and of the star coordinates.

For ISO, the quantity APE (Absolute Pointing Error) has been defined to characterise the pointing accuracy:

$$APE = 2 \times \sqrt{{\sigma_y}^2 + \sigma_z^2} \tag{1}$$

This is listed, together with all fit parameters, in Table 1.

Table 1: *Revolution 264 experiment fit parameters*

Case	a_y	$b_y('')$	$\sigma_y('')$	a_z	$b_z('')$	$\sigma_z('')$	APE($''$)
1	0.83 ± 0.04	-2.77 ± 0.05	0.48	0.72 ± 0.05	-0.79 ± 0.06	0.52	1.4
2	0.75 ± 0.05	-2.57 ± 0.07	0.58	0.68 ± 0.05	-0.34 ± 0.07	0.65	1.6
3	-0.86 ± 0.04	-2.70 ± 0.06	0.49	0.75 ± 0.06	-0.78 ± 0.07	0.62	1.7

The three approaches lead similar results, apart from a sign difference for the Y offsets in the lower plots (Case 3), obtained using modules contained in the DERIVE_IPH software, recoded in IDL and included in SIA. The best fit is obtained with approach (1), and leads to an APE of 1.4$''$. Without the fit, the APE is 3.4$''$, consistent with the measurements done during the Satellite Commissioning Phase, which led to an APE smaller than 4$''$ (see ref. 9).

Finally, the distribution of corrections during the ISO mission given by the pointing reconstruction is shown in Figure 2, using approach (3), in the three phase associated with the pointing improvements;

- Up to revolution 368
- From revolution 369 up and including revolution 451
- From revolution 452

The main improvement comes from the STR recalibration (upper plots) with a slight improvement given by the on-board update of the Sun emphemerides (center plots). The lower panels show the effect of SCREW 359. Note, the distributions are not poisson-like.

The Absolute Pointing Error APE is defined as 2σ, half cone. The specification was 11.7$''$.

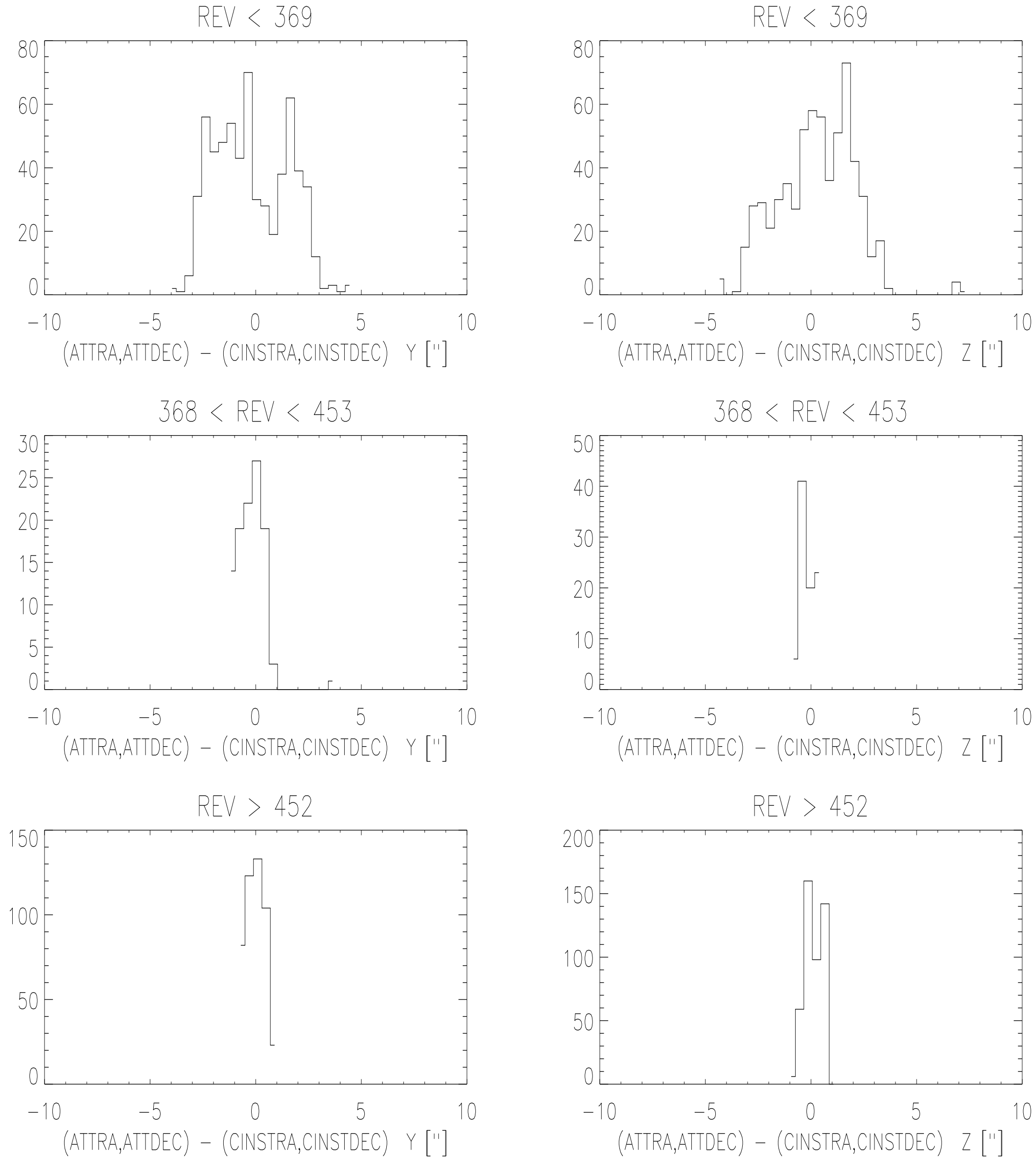

Figure 2: Distribution of pointing corrections for the three phases of the ISO mission associated with uplink pointing improvements.

3 Future work

This exercise should be redone by splitting the pointing reconstruction into its components (STR re-calibration, guide star proper motion, aberration, etc.) for thorough validation. For that, it will need CAM PSFs with a higher sampling than what currently available ($0.5''$).

4 Conclusions

The ISO Absolute Pointing Error has been assessed with a re-analysis of the REV264 pointing experiment, in which 84 isolated stars have been observed with CAM, with associated guide stars sampling the STR field of view. This analysis is part of the ISO Pointing Scientific Validation, started with OLP V9.0 validation. Better known star coordinates have been taken from the Hipparcos output catalogue and the star positions have been determined with the CAM OLP AAC via PSF fitting. The ISO APE changed from $3.4''$ to $1.4''$, the major cause being the STR re-calibration, implemented in the Uplink on REV 369. The relative weight of the various pointing improvements will be assessed during the next OLP validation processes.

5 References

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