CAM calibration explanatory document

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Abstract

We discuss the calibration strategy for the ISOCAM instrument in the ISO Performance Verification (PV) Phase and throughout the Routine Phase. We discuss the various CAM calibration activities and report on the fate of calibration data. Separate annexes give a summary log of all CAM calibration measurements.

1 Introduction

The scope of this brief document is to give an overview of CAM calibration activities during the ISO Routine Phase. We describe the different activities and their relative time allocations within the allocated CAM calibration time-budget. Annexes give a complete list of all calibration observations, detailed instrument configuration, success of the calibration observation and the status of the calibration data reduction activities.

2 Calibration activities

The strategy for ISOCAM calibration in-orbit determined that the in-flight calibration should be self-standing - i.e. that the instrument could be calibrated operationally without direct reliance upon ground-based calibration. Nevertheless, the technical details of the implementation of the in-flight calibration relied heavily upon the experience gained during the extended laboratory tests of the instrument (Flight Model (FM) and Flight Spare (FS) models) conducted pre-launch (e.g. Perault et al. 1994) and during the pre-launch mission simulations at Villafranca.

The detailed approach, specified in the ISO In-orbit Calibration Requirements Document (ISOCAM IOCRD chapter, L. Metcalfe, M. Perault, L. Vigroux et al., in Salama & Metcalfe, 1992) was, naturally, slightly expanded and adjusted during the mission, following the experience gained under actual operational conditions, and in the light of the extended mission duration.

During the Performance Verification (PV) Phase of the mission, roughly every fourth revolution was allocated for CAM calibration. This amounts to about 14 full CAM revolutions between revolutions #22 and #78. These calibration observations were scheduled according detailed implementation strategies derived from the abovementioned plan, established well in advance, and exercised several times before launch viz,

(a) using a specially developed ISOCAM hardware simulator at CEA Saclay;

(b) during the instrument FS and FM tests at IAS Orsay; and

(c) during the pre-launch SOC simulations at VilSpa - using the Instruments S/W simulator.

Depending on the results of the measurements made during a PV Phase revolution, the succeeding CAM revolution (4 days later) could be updated or re-planned. The calibrations made in the PV phase were intended to secure, at the outset, a baseline conformance to the calibration requirements from the governing IOCRD. This was accomplished, as evidenced by the early achievement of Scientific Validation of the ISOCAM Data Processing Pipeline (OLP) only six month after launch.

The first round of in-orbit calibrations of ISOCAM implemented in PV Phase were coupled smoothly with the derivation of standard calibration files for the pipeline. [It is important to note that the ground-based calibrations - as well as allowing detailed testing and tuning of the technical and engineering aspects of the calibration system - also provided the initial default values for instantiating the standard calibration files. These ground-based values proved to be an excellent baseline and reference from which the in-orbit calibration could proceed. In the end, the consistency of the CAM calibration across the launch "barrier" was excellent (of order 10%).]

ISO calibration time was strictly budgeted. The baseline for the calibration planning at the beginning of the ISO Routine Phase was to allocate 1 revolution every week for the calibration of the four ISO on-board scientific instruments. This meant that every 7th revolution, CAM shared, on a roughly equal basis, the available calibration time with the 3 other instruments. Specifically, 3.8 hours were allocated for ISOCAM calibration per week. Later in the mission, the strategy reverted, for efficiency reasons and in the light of proven instrument stability, to the use of one CAM-dedicated orbit every four weeks.

The calibration activities at the beginning of the Routine Phase and during the first year of the mission can be seen as an elaboration of the PV phase measurements to greater accuracy and finer detail, and they implemented the monitoring for any drifts in the instrument's properties. The main calibration activities in this period were :

- **Dark current** measurements on both SW and LW channels.
- **Flat-Field measurements**, with the ICD (Internal Calibration Device) and on the Zodiacal light background.
- **Photometric** measurements on calibration stars, to derive and monitor the in-flight ISOCAM sensitivity, linearity and transient response to illumination changes.
- **PSF** measurements, in various configurations, on calibration stars, as well as estimates of the vignetting patterns of different optical configurations, and sampling of any stray-light contamination levels.
- **CVF** scans on calibration stars for Spectral Response Function (SRF) calibration.
- **Polarisation** calibration measurements.

The relative time allocation for these different calibration activities evolved throughout the mission with in-flight experience and better understanding of the instrument behaviour. For instance, the PSF measurements were concentrated at the beginning of the Routine Phase, the time spent for dark measurements also decreased with time (and evolved into a strategy of making dark measurements through the orbit in the parallel mode of CAM.) By measuring the dark signal in parallel mode - i.e. while another instrument was prime - we saved valuable time for science observations - or, putting it another way, we recovered vital calibration data at little cost. The time spent for flat-fielding also decreased through the mission, after it was confirmed that one can use deep rastering science observations to derive very good flat-fields.

With the time freed, more detailed and deeper calibrations could be initiated in the second part of the Routine Phase:

- **Straylight** measurements, both in CVFs and in LW filters, as certain straylight behaviour was found in-flight to be more complex than anticipated for some configurations.
- **Transients** measurements ie. detector responsive transient measurements, representative of a range of observational set-ups.
- **Astrometric** calibration measurements, and
- **Faint source photometry studies**
- other dedicated special calibrations, e.g. a 'hot dark' (a dark current measurement made when the filter wheel is moving, as is the case during a CVF scan!)

Some calibration observations were also scheduled for cross-calibration purposes, on the initiative of the Calibration Liaison team (CALLIA) and/or CAM Instrument Dedicated Team (CIDT)/CAM Instrument Support Team (CIST). They are listed together with all CAM-proper calibrations in Annex 2.

2.1 Use of CAM calibration time

The total CAM calibration On-Target Time (OTT) in the mission amounted to about **660 hours**, out of 3300 hours of CAM observing time in the mission. The OTT excludes the slew time to arrive at the targets. About one third of this calibration time was spent in the PV phase. The amount of time spent on calibration in the routine phase (427 hours) was slightly less than 14% of the CAM observation time budgeted before launch.

This calibration strategy achieved that the CAM instrument is already well understood. This means that ongoing post-mission calibration efforts can focus on the more challenging aspects of the calibration - the correction of responsive transients, the extension of the photometric calibration accurately to the faintest levels (a few 10s of microJy), deconvolution and attempts to model ghost or straylight features, which affect some configurations.

The ISOCAM calibration time used for the main calibration activities, is outlined in Table 1.

The entry "*special*" in Table 1 includes various measurements, each of a few hours, targeted on very specific calibration problems, or aspects of the more general calibration topics which required particular attention and which are not assigned blocks of time elsewhere in the table. Among these were :

- Commissioning tests (ISO pointing/tracking accuracy, ISO focal plane geometry calibration (to determine exactly where CAM is in the focal plane, optically), lens wheel position-jitter studies (the rest position was not exactly repeatable), etc...);
- Dedicated responsive transients calibration ($\sim$ 10 hours);
- Specific cross-calibration measurements (Sirius, asteroids, NGC6543 ...);
- Astrometric calibration;
- Long Staring pointings for faint-source calibration/simulations (accumulating a data cube with real glitch and transient history, but with no specific raster pattern imprinted - a control set for use in modelling and simulations);
- Calibration on extended sources;
- Colour-corrections tests/studies on red/cold sources - like asteroids;
- CAM SW sky flat-fields & vignetting studies;

- Glitch studies.

Because only a small fraction of the CAM science time was spent by observers using the SW detector ($\simeq$ 3%), more calibration time was dedicated for the LW channel than for the SW channel. Notwithstanding that, the fraction of time spent on calibration of the SW channel was nevertheless larger than the fraction of CAM science time dedicated to the SW detector.

Around 20% of ISOCAM observations during PV phase were dedicated for Astronomical Observation Template (AOT) verification. This consisted in exercising the 3 main AOTs (C01: general purpose AOT (staring & rastering), C03: beam-switching and C04: CVF spectro-imaging) with different parameters (integration time, step-size, pixel-field-of-view, ...) to validate them technically and to find the best observing strategy. For example, a significant time was devoted to compare the performances and capabilities of beam-switching AOT vs. raster AOT.

Activity	Time (hours)	Relative Use
Photometry (total), of which:	138.55	21%
Photometry (3241,3231)	113.29	
ISOCAM TFPR	25.26	
PSF: (3411,3412)	94.04	14%
Zodiacal flats (3251)	54.72	8%
AOT Verification (in PV Phase)	51.83	8%
Darks (3232)	47.43	7%
Straylight	42.06	6%
CVF	38.11	6%
Faint Sources	~30.0	3%
Polarisation	21.66	3%
ICD flats	16.29	2.5%
Linearity tests in PV Phase	14.38	2%
Special	111.35	~17%
Total time	660.35	
PV Phase	233.06	35%
Routine Phase	427.29	65%

Table 1: Some CAM calibration-time statistics

2.2 Calibration strategy

Over 80% of CAM calibration measurements, corresponding to 60% of calibration time, have been performed with the CUS (Calibration Uplink System), mainly for the main calibration activities (darks, flats, PSF, photometry). More AOT-based calibration observations were performed as we progressed through the Routine Phase.

See Annex 1 for the explanation of the usage of the CUS versus the usage of AOTs. But we mention here that one of the great appeals of the CUS for the expert user was its capacity to support rapid programming of complex observation sequences.

From revolution #86 until #552, CAM calibrations were scheduled on a weekly basis in one revolution shared with the other 3 instruments. From revolution #552 onwards it was decided that the remaining calibration observations could be implemented more efficiently in dedicated CAM calibration revolutions. The remaining calibrations were unsuitable for cutting into small blocks without impacting the efficiency with which they could be scheduled, while also reducing planning flexibility. At the same time the stability of the CAM calibration characteristics had been demonstrated (photometric stability, dark current level ...), so that weekly calibration monitoring was no longer felt to be needed. Therefore, starting in revolution #576, one full revolution per month was devoted to CAM calibration instead.

This philosophy was followed almost until the end of the mission when, because of restricted target visibility, some calibration observations had to be planned again on a weekly basis in order not to loose them.

We refer to Annex 1 for the meaning of the COB/COIF numbering system coming from IOCRD requirements. For a detailed summary list of CAM calibration activities refer to the Annex 2 tables. Table 3 lists the CAM calibration observations executed during the PV and Routine Phases. Table 4 lists planned calibration observations which however were not executed because the exhaustion of the Helium cryogen intervened.

For more detailed and specific observation logs we refer to:

- the "ISOCAM Photometry report", Blommaert et al., 1998, for all **photometry** measurements.
- the "ISOCAM PSF report", Okumura K. et al., 1998, for a detailed log of all **PSF** measurements undertaken.
- **Annex 3** for a detailed log of all CAM calibration measurements, organized by TDT number for the full mission, together with a short description of the purpose, the outcome and the data analysis status of each observation. **Annex 3** covers revolutions #11 up to #874, including Spacecraft Commissioning Phase (SCP), Performance Verification phase (PV) and Routine Phase. The annex will be accessible through ISO PMA (the ISO Post Mission Archive) for internal users.
- See **Annex 4** for the full configuration parameterisation for all the CAM calibration measurements on a state-by-state base. The annex will be accessible through PMA for internal users.
- See **Annex 5** for a detailed log of all CAM dark measurements performed in parallel mode. The annex will be accessible through PMA for internal users.

It is foreseen to have Annex 3 and Annex 4 fully queriable in PMA. This would enable the calibration specialist to extract, for example, detailed logs of flat-field and dark current measurements.

3 Detailed description of calibration activities

In this section we give a more detailed description of the main calibration topics studied in the Routine Phase, and an overview of the fate of CAM calibration observations. In separate annexes we will point out the specific fate of the individual calibration observations. Note that not all calibration observations have been analyzed up to now. Significant amounts of data remain to be studied during the ISO Post-operations Phase.

Note also that several measurements served a *multi-purpose* calibration goal. Many observations can be used for responsive transients studies. PSF measurements could be used, in some cases, for photometry, straylight studies or field distortion characterization. Also some photometric calibration measurements on faint sources (when there were many in the field) could be used for astrometric calibration.

For most of the calibration topics discussed below we refer to more specific detailed documents. These documents and reports can be found on the CAM Explanatory Library public WEB homepage.

3.1 Darks

The dark currents have been calibrated with four different kinds of observation:

- Darks measured during calibration-dedicated revolutions, i.e. revolutions that are specifically dedicated to calibration observations (typically, one dark measurement every week, selecting one of the possible CAM integration times). We call these measurements the *calibration darks.*
- Darks measured during the *handover* period, i.e. when the satellite tracking switches from the VILSPA antenna to the Goldstone antenna (this time typically lasts 15–30 min every revolution); we call these measurements the *handover darks.*
- Darks measured during the deactivation period (lasting typically about 1 hour every revolution). These were performed when ISO was entering the Earth's radiation belts, and scientific observations were no longer possible because of the high rate of glitch impacts. This was just before all instruments had to be switched off. We call these measurements the *deactivation darks.*
- Darks measured in the CAM parallel mode, i.e. taking advantage of the portion of the telemetry (1/12 of the prime mode telemetry rate) that was reserved to CAM when other ISO instruments were observing in prime mode; we call these measurements the *parallel-mode darks.*

The four types of dark measurement had different goals. The *calibration darks* are long measurements done throughout the mission to constrain the pattern of the dark image, i.e. the dark current variation from one pixel to another. The *calibration darks* are measured at regularly spaced time intervals, typically one measurement at all on-chip integration times (T_{int}) every month. These time intervals are not so dense as to allow a very clean characterization of the long-term drifts of the dark currents over many revolutions. As all ISOCAM observations they suffer from drifts triggered by preceeding observations. On the other hand, dedicated, repeated observations of the dark current throughout the same revolution allowed one to constrain the short-term drift.

A proper characterization of the long-term drifts is provided by the *handover darks*, which are shorter (and therefore noisier) measurements done on every revolution throughout most of the ISO mission, and more or less at the same time after the activation of the instrument.

The *deactivation darks* include LW dark measurements at T_{int} =2 and 5 s and SW dark measurements at T_{int} =6 s. One might think that the *deactivation darks* provide a monitoring of the long-term trend of the dark currents. Unfortunately, these *deactivation darks* are strongly affected by glitches as they are recorded close to the radiation belts, at the end of every revolution and just before the Perigee passage. (For further details, see Gallais 1998).

The unsuitability of the *deactivation darks* for tracking the global drift of the pure dark current is quite unfortunate, because it has the consequence that we must rely on *calibration darks* for constraining the SW dark long-term behaviour, as no SW dark measurement is done during handover (because of the limited time available) and *calibration darks* are not measured on every revolution.

Most of the measurements of *parallel-mode darks* were done in the last seven months of the ISO mission. These measurements have been done at all LW T_{int} , with the exception of T_{int} =0.28 s – unfeasible because of a software limitation on the total number of frames that can be accumulated on-board. However, several *calibration darks* have been measured at this particular T_{int} , to fill this gap.

Note that the duration of the *handover & deactivation darks* is not counted against the calibration-budget time, as they were performed during otherwise unused slots outside the science window. Neither is the duration of the *parallel-mode darks*counted against the budgeted calibration time, since they are performed in *parallel* to the science observations of other instruments.

All types of dark data measurements have been heavily used to derive the best dark correction for the LW detector, and to a lesser extent for SW.

A **CVF 'hot' dark**, which consists in a long Tint=2 s LW dark measurement recorded while the filter wheel was moving, was performed once. This emulates energy dissipation conditions encountered during a CVF scan. The objective was to search for dark-pattern variations during a CVF scan, as the dark correction appeared to be poor for several CVF scans.

We refer to the ISOCAM Dark current calibration report for more details (Biviano A. et al, 1998a)

3.2 Photometry

3.2.1 Introduction

The main purposes of photometric calibration are to provide the user with the conversion factor (called the "sensitiv" factor) from instrumental units (ADU/g/s) to physical units (Jy), appropriate to any given filter, and to check for any dependence of these factors on temporal variables, and on spectral shape of the calibration sources.

We refer to Blommaert (1998) for a full description of the photometry on point-sources performed to establish the calibration of the CAM filter sensitivities.

3.2.2 Photometry with standard stars from the ISO Ground Based Preparatory Calibration Programme (GBPP)

The absolute photometric calibration of ISOCAM relies primarily on observations of a set of standard stars established through the ISO Ground Based Preparatory Programme (GPBB) (Hammersley et al. 1998, Bliek et al., 1992, Bliek et al. 1996) or derived from the work of Martin Cohen. Most of these stars are of early spectral type, with quite a variety of flux levels (from 10 mJy to 10 Jy), and with a high visibility throughout the ISO mission. Their Spectral Energy Distributions (SED) were derived by fitting the visible and near-infrared photometry with Kurucz and Cohen models, so that ISO measurements of these stars could be calibrated against the models.

Blommaert (1998) has shown that repeated photometric measurements of several calibration stars converge to "sensitiv" factors that are very close to the pre-launch values ("ISOCAM observer's manual"), except for two SW filters, for which the pre-launch values are known to have omitted a correction for the Spectral response curve of the SW detector, which accounts for the discrepancy found in those two cases.

3.2.3 Photometry on other types of objects

The photometric monitoring of the so-called ISOCAM TFPR (ISOCAM Total Flux Photometric Reference) was initiated in revolution # 279 and was observed regularly 8 times until rev. # 770. The region of this field was repeatedly observed by IRAS for photometric calibrations and so it was adopted for ISOCAM calibration given also its high visibility throughout the mission. The field contains a starburst galaxy and a QSO, both expected to be very stable on time scales of months and even years. So these measurements could be used as an *independent* check of the stability of photometry found with the calibration stars. and as a means of comparing the ISO absolute calibration with the calibration of IRAS. This field could also be used for ISOCAM/ISOPHOT cross-calibration purposes as it was also observed by PHT. For internal CAM calibration purposes a CVF scan was performed on this target.

Additional photometry on very red sources was also performed - on OH/IR stars and Asteroids and also on the ISOCAM TFPR. For some of the targets CVF scans were also done. The objective was to cross-calibrate the flux densities derived from CVF scans with those measured in broad-band filters, as an exercise in colour correction validation.

3.3 Flat-fields

Flat-field observations were done either (a) on the sky, on selected zodiacal background regions of maximum brightness and at wavelengths giving sufficient flux, or (b) internally, with the Internal Calibration Devices (ICD). The SW detector flat-fields are entirely based on measurements done with the ICD because at short wavelength the zodiacal background is not bright enough to allow us to obtain a sky flat-field. The calibration observations have yielded flat-fields to an accuracy matching pre-launch expectations.

In obtaining flat-fields the emphasis was placed on external flat-fields on the zodiacal background. this was so because the CAM internal source (ICD) provides a wider beam than the nominal F/15 ISO beam, and it is thus more strongly vignetted. This results in a different flat-field pattern to that derived from the sky. Usage of the ICD is further limited by the slow thermal drift of portions of the instrument surrounding the source.

We refer to the ISOCAM flat-field calibration report, Biviano A. et al, 1998, where the main factors limiting the final accuracy of the calibration flat-field are analyzed.

3.4 PSF

The PSF measurements are done (mainly) with two purposes:

1. deconvolution;
2. to derive normalising factors for photometric correction.

However, one has to keep in mind that PSF measurements are also a valid data-base for transient studies, straylight, and photometry.
PSF measurements have been performed for different instrumental configurations on different parts of the arrays.

Since before launch it had been expected that the observed PSF would depend quite strongly on the position of a source on a pixel, at least for those cases where the PSF was comparable in size with a pixel. A dependence on position within the field-of-view was also considered a possibility. Hence the total signal recorded in the PSF at a range of positions over the array and relative to a pixel centre was expected to yield important correction factors for photometric measurements. Consequently, quite a lot of PSF measurements were made in PV phase and in early Routine Phase to derive these 'volume-factors'.

It has been gradually realized by all parties trying to work in detail with the PSFs (e.g. for deconvolution) that the derivation of PSF shape is a challenging task, because the combination of spacecraft pointing jitter and detector responsive transients induces signal variations between successive frames during a PSF measurement. This can be as large as 10%. Thus not only the position but also the shape of the PSF appears to change in each frame.

Recognizing this, the PSF calibration strategy was revised early in the Routine Phase to increase the dwell-time per position during the PSF-measuring rasters and, in the process, to increase the on-chip integration time used (from 0.28 s to 2.1 s) in PSF measurements. This was done mainly to try to at least reduce the effects of transients. The frequency of PSF measurements reduced greatly in the second part of the Routine Phase, by which time it was felt that sufficient data had been obtained to fulfil the IOCRD objectives. Subsequent efforts concentrated on occasional, more tentative, PSF measurements directed at better understanding the detailed behaviour.

A full description of the PSF calibration observations and their applications, is given in Okumura (1998a).

3.5 CVF

The CVF ground-based wavelength calibration was verified in-flight during the PV phase. The basic CVF Spectral Response Function (SRF) calibration had been achieved in the PV phase, especially for the 3" pfov. This was refined via higher S/N measurements on δ draconnis in the early Routine Phase. Afterwards a programme of CVF measurements was undertaken to extend the good-quality CVF calibration to the 6" and 1.5" pfovs. Standard stars have been observed to derive the Spectral Response Function. These measurements were done in $1.5''$, $3''$ and $6''$ pixel size and gave consistent results for the different lenses.

More specific measurements were made at the request of the CAM support team at Orsay. These were CVF line profile measurements on the Helix nebula and CVF/LW flat-fielding or photometry on extended sources.

All aspects of CVF calibration are detailed in Biviano et al. (1998d)

3.6 Polarisation

The overview of CAM polarisation calibrations is not discussed in this document, but rather referred to, Siebenmorgen et al. (TBW).

3.7 Straylight

A number of early PSF measurements revealed ghost reflections within the camera, especially in the 6" and 12" pfovs. Ghosts occur most visibly with the CVFs, and to a lesser extend with CAM LW filters. Some dedicated straylight measurements were already made in PV phase. These showed that point sources near the edges of the field-of-view (especially with the 6" lens) can have diffuse straylight structures in their vicinity which are dependent on the position of the source. This was studied in greater detailed in the second part of the Routine Phase.

Also it was seen that sources outside the nominal beam rarely inject light into the field-of-view. Bright sources were moved around outside the nominal CAM field-of-view and straylight features appeared only when the source fell at the position of a known and very localized scattering surface outside the nominal field-of-view.

Note that a rigorous handling of the straylight problem depends not only on observational data but demands an elaborate optical modelling of the instrument. This whole area is under investigation in the hope that those configurations affected by ghosts or straylight can be fully characterised during the ongoing ISO Post-operational Phase.

For the latest status of straylight studies refer to the report "Ghosts in ISOCAM images" by Okumura, 1998b.

3.8 Responsive Transients

Responsive transients are recorded with every measurement made with CAM. However for calibration purposes dedicated samples of transients have been recorded under precisely controlled conditions, to allow for later physical modelling. Dedicated measurements took place for instance on the Chameleon region, the ISOCAM TFPR, M51, and during revolution #16 (in the ISO Commissioning Phase) – among others. The global characterization of the transient behaviour of ISOCAM will be one of the main calibration challenges for the Post-operational Phase.

3.9 Faint Source Photometry

A number of observations were made towards a Gamma Ray Burst field (GRB970402), because this star-rich field was extensively studied at all wavelengths following the GRB, and so was a prime faint-source field for CAM photometric and astrometric calibration. This field was observed with various raster maps, with different raster parameters (PFOV, step size, redundancy and T_{int}) to understand their influence on the photometry of the sources. Some individual faint calibration stars were also observed in raster mode to understand photometry at these faint levels.

To provide a control data set for reference simulations of faint-source fields some long staring measurements were taken in the quiet time close to apogee, when the glitch rate is at minimum because the S/C is far above the radiation belts. We refer to the Faint Source document for more details on this and related work. (Altieri et al, 1998, in preparation).

3.10 Astrometry: Field distortion calibration

The first measurements to address this topic were targeted on the star cluster NGC4755, a globular cluster well studied in the optical. However, the analysis of this ISOCAM observation proved to be challenging because an AGB star in the cluster center was found to be very bright in the MIR, saturating the detector and spoiling the PSFs of the nearby stars.

In the end, the faint-source calibration rasters on the star-rich GRB970402 error-box field were adjusted to simultaneously provide the astrometric data needed to derive this correction. Many moderately bright (few mJy) stars were present in some of the raster maps. Other measurements intended for straylight and ghost studies proved also to be very useful for the characterization of field distortion.

We refer to the document 'ISOCAM LW Channel Field of View Distortion' (Aussel 1998), for the background information of this calibration topic, the rationale of the measurements and the results achieved.

3.11 Cross-calibration data

ISOCAM has a wavelength overlap with SWS and ISOPHOT. Therefore several sources were observed by ISOCAM for cross-calibration purposes, as consistency checks of the calibration with these 2 other instruments. The main targets observed chronologically were:

- 3 calibration stars: HR7310, HR7341, HR6436 (for SWS and PHT cross-calibration)
- Mrk 279 and a set of seyfert galaxy measurements obtained within science observations of Clavel et al. and using ISOCAM and PHT-S.
- Sirius, γDraconis and Neptune
- a set of asteroids, primarily for ISOCAM internal colour-correction test purposes, and also for cross-calibration with PHT mainly, but other instruments as well. (*Cybele* and *Hygiea*)

Other sources could be used also for cross-calibration purposes, such as the *ISOCAM TFPR*, which was observed with ISOPHOT, or NGC6543, which was observed with various instruments for several purposes.

Note that a small number of sources have been observed with *all* 4 instruments: Sirius & γDraconis (stars), NGC6543 & NGC7027 (planetary nebula), Neptun (planet) and Hygiea (asteroid).

We refer to Moneti & Breitfellner, 1998 for the End-operations ISO cross-calibration Report.

4 Summary

Most efficient use has been made of the precious CAM calibration time. Extensive pre-launch trials and testing of the calibration systems and strategy ensured that the calibration plan was very well tuned at launch, ensuring a rapid convergence of the in-flight calibration in the early mission phases. From early in the mission the CAM calibration results were rapidly propagated within CAM Interactive Analysis (CIA), Ott S. et al., 1996, used by the data processing pipeline and generally distributed as calibration files.

Throughout the ISO mission, CIDT and CIST sought every opportunity to put calibrations into every otherwise unused gap in the orbit. Where possible calibration measurements were made to serve several purposes. The calibration data was interpreted continuously and the results of new understanding fed back directly into the calibration strategy, so that the strategy evolved through the mission to optimally target the remaining problem areas. Concurrent events in other fields (e.g. the intensive study of some GRB fields) were exploited to uncover new calibration opportunities.

As a result, the CAM team secured an extremely comprehensive sampling of the CAM parameter space. This was accomplished without exhausting the time-budget assigned for CAM calibration. freeing time for additional science observations or for calibration of the other instruments. A substantial amount of time could be spent in the second half of the mission to address calibration topics which were not envisaged before launch, or to strive for greater accuracy than baselined in the pre-launch requirements.

The main adaptation of calibration strategy occurred in the middle of the Routine Phase, when the scheduling of CAM calibration was changed from a weekly to a monthly basis after the stability of the CAM instrument had been demonstrated.

Given the large number of CAM configurations, the variety of calibration topics to be addressed and the strong competition for observing time, the CAM calibration strategy had to be success-oriented, and the comparison of achieved results (Biviano et al. 1998c) with pre-launch expectations shows that this strategy has paid-off.

List of abbreviations and Acronyms

- AOT: Astronomical Observation Template
- CIA: CAM Interactive Analysis
- CIDT: ISOCAM Instrument Dedicated Team (VilSpa Team)
- CIST: ISOCAM Instrument Support Team ("home" team)
- CO: Calibration Observation
- CUS: Calibration Uplink System
- CVF: Circular Variable Filter
- FM: Flight Model
- FS: Flight Spare
- GBPP: Ground Based Preparatory Programme
- GRB: Gamma Ray Burst
- IOCRD: In-Orbit Calibration Requirements Document
- OTT: On-Target Time
- PMA: Post Mission Archive
- PSF: Point Spread Function
- PV: Performance Verification phase

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5 Annex 1

An individual calibration observation or TDT is called a CO. COs can be generated via AOTs or via the Calibration Uplink System (CUS). Most calibrations are performed using the CUS. Essentially, these 2 approaches amount to using two different user interfaces to access the set of Instrument Command Sequences (ICSs), in order to build parts of the Central Command Schedule (CCS). The CUS is the more flexible interface and allows more freedom in the setting of instrument parameters. It is naturally preferred by instrument specialists. It also allows the calibrator to inspect the output command sequences in detail and to iterate with great flexibility before delivery, something much more difficult to achieve with AOT-OCT logic and the AOTs, or even practically impossible within the timescales available for calibration planning. In most cases the Instrument Command Sequence groups generated via the CUS will be similar, or even identical, to those produced by AOTs.

Individual calibration observations (COs), when produced by the CUS, are defined within an input file called a COB or Calibration Observation Batch. For CAM each IOCRD requirement maps onto one or more COBs.
These COBs always include in their names the four-digit number designating the parent IOCRD requirement. Routine Phase COBs tend to belong to families derived from a parent PV phase COB. Routine Phase COBs have in their name, along with the parent IOCRD requirement number, the three digit number of the revolution on which they are *planned* to be executed. During any given scheduling any subset of the COs contained within a COB can be enabled and delivered for execution. The COBs could be easily adapted to make slight modifications to the calibrations. The particular instantiations of the COBs used on any particular revolution, along with the associated CUS output file, or COIF, the associated timeline for execution of the COs, and ancillary information, were kept under configuration control in a revolution-specific, appropriately-named, VMS directory.

The COB/COIF numbering system comes from the IOCRD requirements chapter numbers.

The OBSID (Observer Id) of all CAM calibration observations is **CAM_CAL**, except for calibration initiated by CALLIA, where the OBSID is **CL_CAL**

The PROPID (Proposer Id) of COIB/COIF observations ie. calibration observations programmed via the CUS, follow mostly the following scheme:

Rnnnmmmm

where nnn is the revolution number and mmmm the IOCRD requirement number from table 2. However some time for planning optimization reasons, an observation was scheduled in an adjacent or nearby revolution.

For measurements of darks throughout the revolution, the 'R' was skipped and the PROPID chosen was bf nnn3232B.

For PROPID of calibration observations planned with AOTs, a self-explanatory string name was chosen on a less rigid basis than the above.

CUS #	Original IOCRD requirement	Calibration activity
3212	Electronics Gain and Offset Check	(once in PV (rev.#22)
3231	Responsivity Dependence on Ionising Radiation Flux History	Photometry monitoring on calib. star
3232	Ionising Radiation - Dark Current and Noise Degradation	Dark Current measurements
3241	Calibration of ICDs against astronomical standards	Multi-filter photometry measurements on calibration stars
3251	Linearity	(only once in PV, rev.#50)
32512	Extended calibration sources ... linearity and flat-fielding	Flat-field on zodiacal background
3261	Flat Fields with Internal Sources	ICD flat-fields
3311	Spectral calibration, Instrumental profile (CVF) PV phase	(only in PV, rev.#15 & #66)
3321	CVF wavelength calibration	(only in PV, rev. #54)
3411	Footprint of ISOCAM on the sky / vignetting	PSF measurements
3412	Point Spread Function (PSF) - Short Observations	PSF measurements
3413	Point Spread Function (PSF) - Long Observations	”
3421	Straylight from out of field sources, CAM f.o.v.	once in PV (rev.#46)
3423	Straylight from out of the f/15 beam	straylight measurements

Table 2: COB/COIF numbering system

6 Annex 2

The following table gives a chronological overview of CAM calibration activities in the routine phase.

Refer to Annex 3 for a more detailed log of all CAM calibrations, with the status of data reduction and the fate of the calibration data.

Refer to Annex 4 for the log of all CAM calibrations with the configurations used.

Refer to Annex 5 for the log of all CAM dark calibrations performed in parallel mode.

Table 3: Revolution log

Rev.	Activities and Comments
11	First Light on M51
13	ISO pointing performance verification
14	Focal plane geometry 3252 photometry on HIC74083 and HIC73005 ICD flat field 3412 photometry
15	ISO tracking performance verification Polarisation test on NGC4383 and IRAS2046 CVF wavelength calibration on NGC6543
16	transient measurements
21	Polarisation test on HR7469 Focal plane geometry AOT verification
22	AOT verification photometry on HIC89474, HIC85317 and HIC89474 zodiacal Flat-field Electronic Gain and offset check Dark measurements
26	AOT verification ICD Flat-fields 3231 photometry on HIC89474
30	AOT verification ICD Flat-fields 3413, 3241, 3423 and 3231 photometry on HIC87585, HIC89474, HIC102422 and HIC73005 Straylight test
34	AOT verification Dark measurements along the orbit Zodiacal Flat-field 3241 photometry on HIC70218 Cross-calibration on NGC7027
38	3241 photometry on HIC70873 3412 PSF measurements on various stars Polarisation on HR5154
42	AOT verification 3411 PSF measurements on HIC69713 and HIC74083

Table 3: Revolution log (ctd.)

Rev.	Activities and Comments
46	AOT verification Cross-calibration on SNR-1124-59 3241 photometry on HIC70873 Zodiacal flat-fields 3411 PSF measurements on HIC69713 3421 Straylight measurements Linearity measurements on HIC89474 Polarisation on HR5154
50	AOT verification Linearity measurements on various stars
54	AOT verification 3411 PSF measurements on HIC77760 Zodiacal flat-fields CVF wavelength calibration on NGC6543
58	AOT verification 3241 photometry on HIC77277 and HIC94890 CVF spectral response function on HIC94890 Cross-calibration on HIC96901 Dark measurements
62	3241 photometry and CVF spectral response function on HIC96441 and HIC85317 Zodiacal flat-fields Cross-calibration on HR7310, HR6847 and HR7341 PSF measurements on QSOs
65	AOT verification Polarisation on PV3C279T
66	AOT verification 3241 and 3241 photometry on HIC73005 and HIC94890 CVF test observations Ghost- and straylight observations 3412 PSF measurements on HIC69713
67	AOT verification Zodiacal flat-fields 3412 PSF measurements on HIC80331
70	AOT verification transient measurements on HIC70218 PSF measurements on QSOs and cold objects
71	Zodiacal flat-fields
78	PSF measurements on cold objects Photometry on HIC85317 Cross-calibration measurements on HR7341, HR6847, HR7310
86	3251 LW zodiacal flat-fields 3231 photometry on HIC89474
90	On-target flag (OTF) test
93	3251 LW zodiacal flat-fields PSF measurement darks
100	3241 photometry on on HIC77277 PSF measurement 3251 zodiacal flats

Table 3: Revolution log (ctd.)

Rev.	Activities and Comments
105	LW & SW Darks 3251 zodiacal flats 3241 photometry on HIC77277
109	additional zodiacal flat-field observations
111	polarisation measurement on NGC6265
112	LW & SW Darks 3251 zodiacal flats 3241 photometry on HIC77277
119	4 PSF measurements 3251 LW zodiacal flat-fields
126	3231 photometry on HIC89474 3251 zodiacal flats
133	2 PSF measurements 3251 zodiacal flats 3231 photometry on HIC89474
137	Spatial ISO pointing performance test for SWS
140	PSF measurement 3251 zodiacal flats 3231 photometry on HIC89474
147	LW&SW Darks 3231 photometry on HIC89474 3241 HIC101245
154	CAMPOL03 3231 HIC89474 LW dark 3241 HIC101245
161	3241 photometry on HIC101245
168	LW & SW Darks 3251 LW zodiacal flat-fields
175	LW Darks across orbit (1753232B) PSF measurements
182	3231 photometry on HIC89474 PSF measurements
189	LW darks PSF (3412) measurements
196	** LOST ** (ISO viewed the earth !)
201	Tests after spacecraft contingency of 30/05 (Rev.196)
203	CVF calibration R203CVFO on δDraconis LW darks R203TRN2
209	Zodiacal flats on flat20
210	3231 photometry on HIC89474 R210TRN2
217	zodiacal flats on flat20 3241 photometry on HIC69713
218	LW darks
223	LW darks 3412 PSF on HIC73005 32511 linearity on HIC67773

Table 3: Revolution log (ctd.)

Rev.	Activities and Comments
230	Polarisation calibrations on HR5154, RCW57 & HIC089474
237	LW darks 3241 photometry on HIC77277
244	3411 PSF footprint/vignetting PSF 3231 photometry HIC89474
251	Internal ICD flat-fields (3261) LW darks
253	polarisation measurement
258	Internal ICD flat-fields (3261)
264	new spatial ISO pointing performance test for SWS [6-aug-1996]
265	3241 photometry on HIC98962 & HIC76568 LW darks
272	PSF measurements NGC4577 (astrometric cluster) preview
279	1st TFPR observation 3241 photometry on HIC77277 PSF measurement
286	Deep 12x12 LW3 6” flat-field 3231 photometry on HIC89474
291	Special CAM astrometric calibration (4 hours on NGC4577)
293	LW darks LW zodiacal flat-field NGC_4755 astrometry
300	PSF measurements SW darks
307	New PSF measurement strategy (R307PSFC)
314	Photometry (3241) on HIC98962 & HIC77277
321	New transients study on ChamINNa LW darks
328	CVF measurement on HR7310 internal ICD flats (3261)
335	Linearity test (32511) 2nd observation of TFPR
342	(New) PSFs internal ICD flat-fields (3261)
349	Photometry (3231) on HIC85317 SW darks
356	Polarisation on HIC085371 (4 hours)
363	PSF measurements
370	CVF at PFOV 3” LW/SW darks
377	LW zodiacal flat-fields at PFOV =12”
384	Photometry (3241) on HIC77277
391	3rd TFPR observation PV like electronic gain check on Flat22

Table 3: Revolution log (ctd.)

Rev.	Activities and Comments
398	SW internal ICD flat-fields (3261) 5x 3231 on HIC89747 through orbit
406	LW CVFs (1.5",3",6") & SW CVFs (1.5"&6.0") 3231 photometry
412	LW zodiacal flat-fields at PFOV =12"
419	3241 Photometry on HIC85317, HIC67485 and HIC89474
426	3411 PSFs with HIC98962 cross-calibration on HR6436 (CALLIA)
433	3412 CVF PSFs HIC77760, HIC78276 & HIC67459
440	3412 CVF PSFs HIC77760, HIC78276 & HIC67459
450	Polarisation on the zodiacal light background (LW2, LW8 & LW9 at 6")
453	TFPR (4th round) SW/LW darks
461	CVF flat-fields on 'flat24' at 3 wavelengths
468	SW vignetting profile measurements (16x16 raster at 3")
475	Photometry COB 3241 on HIC77760 & PSFs COB 3411 on HIC85317
482	Photometry COB 3231 on HIC89474 & CVF on γDraconis
489	SW vignetting profile measurements (16x16 raster at 6")
496	LW darks & CVF measurement on δDraconis
503	Darks throughout the orbit (3232B) PSF measurement
510	PSFs measurements (3411 and 3412)
517	Photometry (3251) on extended source throughout orbit
524	PSFs (3411)
531	TFPR monitoring (5th round) straylight CAMGHOST OSNs 1&2
532	Straylight CAMGHOST OSN 5
538	Photometry 3231 on HIC89747 straylight CAMGHOST OSNs 3&4
544	Polarisation with new COIF on extd source for AOT release
552	Photometry 3241 on HIC65280 & HIC77277 (faint photometry) darks (3232)
576	Rasters on M51 (LW2,LW3) as in PV for transients correction tests TFPR (6th round), regular photometry monitoring CVF straylight measurements in pfov=3" and 6" LW3 6" straylight/ghost measurement Dark measurements (LW: 0.28s & 10s, SW: 0.28s, 2.1s & 6s)
621	TFPR regular photometry check (7th round) Photometry measurements 3231 & 3251 (HIC89474), 3241 (HIC89474, HIC77760) Polarisation measurements on NGC7023 Faint sources photometry on April GRB field at 3" & 1.5" pfov
626	CVF straylight measurements at 1.5" pfov (5x5 rasters) on γDraconis LW straylight measurements: 9x9 rasters, LW2 at pfov = 6" (HIC77760) & LW3 at 3" (HIC80331) Field distortion & faint sources photometry on GRB field at 1.5" pfov

Table 3: Revolution log (ctd.)

Rev.	Activities and Comments
655	LW darks (0.28 sec) throughout revolution, straylight test by moving wheels transient measurement on the TFPR transient measurement by changing T_int photometry on faint calibration star: COIF/raster compatibility LW straylight measurement: LW2 at 3" pfov (HIC77760), 9x9 raster
690	Several rasters on the april GRB field at 1.5",3" & 6" pfov with different step sizes to test faint sources photometry
692	rasters on the april GRB field (continued)
694	last rasters on the april GRB field
720	cross-cal CAM CVF observation on SIRIUS
727	cross-calibration CAM CVF observation on Neptune
730	Transient studies on the TPFR galaxy: TFPRTRS2 & TFPRLONG CVF on TFPR & multiphotometry: TFPRCVF CVF Straylight on δDraconis, 3" pfov, SM-FM: CAMGHST3,5,7& 9μm LW straylight rasters at 3" & 6", LW1, LW10 & LW7: GHOSTLW4 Photometry monitoring: R7303231 on HIC89474
740	Polarisation measurements on the zodiacal background ($\sim$ 10 hours) 'AOT photometry' on standard stars CVF straylight measurement (fine sampling around discontinuities)
741	LW filter straylight raster (OSN 6 of GHOSTLW4 rev.730) ctd. block 7 of polarisation COIF R74035_7 from rev.740
754	CVF line profile measurement (HELIXCAL), on Helix nebula
770	Last TFPR regular photometry monitoring, (AOT: TFPR1) CVF/LW flats/photometry (AOT: CVF_FLT1) CVF straylight on γDraconis, 1.5", 9, 12 & 15 microns CVF Straylight on δDraconis, 3", SM-FM : CAMGHST5, 9,12 & 15μ Very red source photometry on asteroids, on Cybele Darks throughout revolution at 0.28 sec (6 times 4000 readouts) Photometry COB3231 on standard star HIC89474
801	Photometry on standard star HIC89474 throughout revolution CAM CVF spectrum on γDraconis until 17.34μ (extension of SRF) SW transient measurements on NGC 7023 SW darks at 6 Very red source photometry on one OH/IR star (AOT: REDSTAR) Straylight measurement in LW2
825	CVF 'HOT' dark Darks at T_int = 0.28 sec throughout revolution 6 times: Ghost measurement with a filter (LW1)
832	Glitch study near handover a 4 CAMTUs T_int Cross calibration on Hygiea (LW1, LW4 + CVF scan)
833	SW flat-field on extended emission of M17
839	CAM CVF on Sirius (2 hours) to repeat the failed observation in rev.#720 Long staring observations near handover in LW2 at T_int=10sec for simulations purposes
846	OH/IR star cold PSF Photometry on relatively faint standard star (hic96062) Jitter on ghost on δDraconnis

Table 3: Revolution log (ctd.)

Rev.	Activities and Comments
851	Faint sources photometry on GRO J0422+32 field Photometry on ISOGAL fields Photometry on red source IRAS02408,+5458 CVF/filters calibration on extended source
853	Ghost study at pfov=3" on δDraconis with better S/N
854	Photometry (R8533241) on HIC89474 at 1.5" pfov
860	Photometry (R860PHOT) on HIC102422, HIC98073, HIC96441, HIC101245 HIC99663, HIC89474, HIC96258
867	Photometry (R8673241) on HIC85317, HIC101245 Long staring observations near handover in LW3 at T_int=10sec for simulations purposes Dark at T_int = 10 sec SW photometry (R874PHOT on HIC89474)

Table 4: Planned Revolution Log

Rev.	Activities and Comments
876	Observations that had failed in rev.#851: XCALCVF3 (OSNs 1 to 6) & GAL_CAL2 (OSNs 1 & 2)
881	photometry throughout the revolution (HIC89474) Dark at T_int = 5 sec
882	Measurement of the band-pass of the CAM polarizers through the CVF