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VERY LARGE TELESCOPE
NaCo Calibration Plan

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CHANGE RECORD

ISSUE	DATE	SECTION/PARA. AFFECTED	REASON/INITIATION DOCUMENT/REMARKS
81	Oct. 30, 2008	All	Document re-written. New release

TABLE OF CONTENTS

1 Scope

This document replaces entirely the VLT-PLA-ESO-14200-2664, Issue 80 after a revision of the calibration plan was set as observatory-wide goal for 2008.

The new version will be probably implemented for p83 or p84. For P82 the old calibration plan remains the reference.

2 List of Abbreviations & Acronyms

This document employs several abbreviations and acronyms to refer concisely to an item, after it has been introduced. The following list is aimed to help the reader in recalling the extended meaning of each short expression:

4QPM	4 Quadrants Phase Mask. Comes in two versions: 4QPM_H and 4QPM_K
BB	Broad Band
CLR	Clear (weather conditions)
DCR	Double Correlated Readout
DIT	Detector Integration Time
FNS	Fowler N Sampling
FP	Fabry-Perot
HWP	Half Wave Plate
IB	Intermediate Band
LPO	La Silla Paranal Observatory
LW	Long Wavelength
NaCo	NAOS-CONICA
NB	Narrow Band
NDIT	Number of DITs
OB	Observing Block
PHO	Photometric
QC	Quality Control
RMS	Root Mean Square
RON	Read-Out Noise
SDI/SDI+	Simultaneous Differential Imager, SDI+ is the new, larger FoV SDI
SDI+4	SDI+ combined with coronagraphy with 4QPM_H
SM	Service Mode
SN	Signal to Noise
STD	Standard star
SW	Short Wavelength
THK	Thick (clouds)
THN	Thin (clouds)
UT4	Unit Telescope 4 (a.k.a. Yepun)
VLT	Very Large Telescope
VM	Visitor Mode
WFS	Wave Front Sensor
ZP	ZeroPoint

3 List of Applicable Documents

[1] The NaCo Calibration Plan, VLT-PLA-ESO-14200-2664, N. Ageorges, C. Lidman, Issue 80, March 03, 2007.
[2] Description of observing modes: www.eso.org/sci/facilities/paranal/instruments/naco/inst/
[3] ZPs in Paranal: why and what to do with, Draft, E. Mason, May, 2008.
[4] NaCo Quality control pages: http://www.eso.org/observing/dfo/quality/index_naco.html
[5] Reference calibration frames: www.eso.org/observing/quality/ALL/ref_framesref_naco.html
[6] Telluric Stars 101, P. Amico and C. Lidman, ESO Internal Document Release, Nov. 2007
[7] The Detector Monitoring Project, P. Amico, L. Vanzi, C. Lidman, VLT-PLA-ESO-10400-4387, Issue 2.2, Date 20/07/2008. Also presented in the Proceedings of The 2007 ESO Instrument Calibration Workshop, Garching, Germany, 2007, Springer-Verlag.
[8] The NaCo Contributed Papers library: http://www.eso.org/sci/facilities/paranal/instruments/naco/tools/library.html
[9] The NaCo pipeline Manual: ftp://ftp.eso.org/pub/dfs/pipelines/naco/naco-pipeline-manual-1.1.pdf

4 Introduction

The primary goal of the calibration plan is to provide the NaCo users with those calibration frames, such as darks, flat fields, arcs, zero points and telluric reference observations, which enable the effective removal of instrumental and atmospheric signatures from their science files.

NaCo is a very versatile instrument. Dichroics, masks, filters, polarizers, grisms, cameras and other more exotic elements can be combined together to provide a large number of observing configurations. For imaging in the broad-band H-band filter alone, one could in principle choose among 24 different configurations (4 NAOS dichroics, 3 CONICA cameras and two readout modes) and this does not include the possibility of polarimetric and coronagraphic configurations. Given the high number of possible scientific setups, the scope of the NaCo calibration plan had to be limited to the most popular modes, which provide also a meaningful set of interesting setups for instrument performance monitoring and trending. Less popular modes or custom made observations are usually calibrated on an irregular basis, typically when the corresponding science requires it (e.g. standard stars for NB filters) and/or whether the users requests special calibrations to be carried on.

We remind users that non-standard calibrations usually are approved only in VM or at least require a waver. Time needed at night for special calibrations not included in the calibration plan will be charged to the corresponding observing program.

Other important parameters, such as the detector characteristics (gain, linearity, periodic noise, etc) are now monitored on a regular basis by the observatory staff, following the guidelines outlined in the Detector Monitoring Project [6].

The determination of complex and more exotic calibrations, such as instrumental aberrations, distortion maps, instrumental polarization, etc. are not part of the calibration plan, but are carried out as part of a maintenance activities. In 2008, two NaCo calibration proposals have been granted observing time: these proposals aim at calibrating specific aspects of the instruments (e.g. accurate plate scales) and are usually submitted by ESO's users who are willing to collaborate with the observatory staff to provide expert advice and help. The findings of these programs are immediately shared with the community via the manuals and the instrument web pages. Users interested in submitting a calibration proposal or, more generally, in sharing some of their results are invited to contact the NaCo Instrument Scientist at naco@eso.org.

Users are also invited to look at the NaCo Contributed Papers Library [7] for references to interesting papers on NaCo and to submit their own entries (email naco@eso.org), that is papers which discuss novel data reduction and calibration techniques, which can be of interest to the community.

Additional information about calibrations for the different instrument modes can be found in the NAOS-CONICA user manual.

5 2008 Calibration Plan revision

The revision of the calibration plan for each instrument in Paranal was one of the goals and objectives set by the Director of the LPO for 2008. The calibrations covered by this revision include daytime calibrations (e.g. darks, internal lamp flats, arcs, etc), nighttime calibrations (photometric standards, telluric standards, night-time internal flats, sky flats). Other miscellaneous calibrations (instrumental aberrations, detector performance parameters, etc) will be added later on. In particular, the detector characterization is taken care of in the frame of the detector monitoring project [6].

The revision addressed the following points:

1. **Reduction of redundancy:**
   a. Are we over-calibrating?
   b. Are we taking calibrations that are not useful?
2. **Completeness check:**
   a. Are we taking all the necessary calibrations?
   b. Are all observing modes characterized properly?
3. **Quality of calibrations:**
   a. Can we improve the quality of the calibrations we take?

The primary scope of the revision was to reduce the time spent on calibrations while keeping or increasing their overall quality and completeness.

The revision of the NaCo Calibration plan was done in two steps: a meeting in Santiago, which produced the first draft of this document and a mini review in Garching, which discussed the document, suggested improvements and changes.

As a result of this revision, the new NaCo calibration plan document has been issued. Since there are significant changes on the type and the frequency at which some calibrations are taken, users are invited to read this document carefully before submitting their proposals.

6 Calibration Plan

6.1 Introduction

This section gives an overview on all calibrations that are carried out at regular intervals in order to guarantee the calibration of scientific data. Such set of calibrations is the minimum necessary to ensure a good calibration of NaCo's data. Users who have specific requirements, such as for instance high S/N or higher accuracy, are requested to fill in the "Special Calibrations" Section in the proposal form. Once approved, a description of the special calibrations should be added in the README file.

Data products resulting from the calibration observations are archived, and available for science calibration, quality control and monitoring of instrument performance [4]. A detailed description of the data reduction recipes is given in [9].

A summary table is available in section 7.

6.2 Template Naming Convention

Observing templates are named following the convention: *NACO_mode_type_mnemonic* where:

- *mode* is img for imaging, spec for grism spectroscopy, pol for polarimetry, coro for coronagraphy, fpi for FP imaging, sdi for imaging with SDI+, sdi4 for sdi combined with phase masking coronagraphy, sam for sparse aperture masking, and all for templates applying to all modes.
- *type* is acq for acquisition, obs for observation, cal for calibration, and tec for maintenance, gen for general applications
- *mnemonic* describes the main function of the template.

6.3 Dark frames

Dark frames in CONICA are contaminated by thermal leaks, which vary with a timescale of some hours, up to 1 day. Thermal leaks are best seen on long darks (see for instance in [5] the DCR/HD darks with DIT> 30 secs), but present at all DITs: these leaks show up as brighter stripes in the frames. These stripes vary in intensity, a feature best seen in difference frame. A characterization of the phenomenon is being conducted and depending on the results, darks frames may be declared not useful for science, unless taken within a safe timeframe.

Dark frames, as well as science frames, show noise patterns at different frequencies: 50, 12, 10 Hz. These patterns can be "easily" removed in all frames (especially in cube mode) with the usual method of measuring the median value row by row and subtract it from the row itself; an alternative solution would be that of removing the "offending" frequency in

Fourier space: identify the relevant wave vectors in the power spectrum, masking all other wave vectors, inverse transforming, and subtracting.

Additional noise patterns can also be seen as a function of the rotator angle. Since darks are taken with the rotator at 0, the patterns may differ from what is seen in the science frames. For this reason and for the variability of the thermal leaks, the practice of dark subtraction from science frames is therefore not recommended.

Darks for cube mode science data are taken with the correct windowing setup (i.e. hardware windowing) even for the full frame option., but are however single frames (not cubes).

Template: NACO_all_cal_Darks
Purpose: Remove zero level offset, measure RON, measure hot pixels
Description: Dark frames are obtained at the end of the night for each detector setting (readout mode, detector mode, DIT and camera, window type (HW or SW)) that was used during the previous night. Three darks are taken for each setting. NDIT is set according to the formula:

if DIT < 10 NDIT=[INT(10/DIT)+1], if DIT > 10 NDIT=1

Observing Conditions: daytime, upper lights off, lower lights OK.
CONICA state: dark position, i.e. with two non overlapping NB filters in the optical path.
NACO State: Ignore
TCS State: Ignore
Frequency: once every three days
Duration: up to 1 hour
Pipeline recipe: naco_img_dark
Pipeline data products:

- median frames with the same DIT, detector mode, detector window, readout mode and camera.
- compute RON and median values
- produce hot, cold and deviant pixel maps.

Accuracy: limited by thermal leaks.

6.4 Other dark frames

For monitoring purposes by QC the following set of 3 darks per setup should be taken daily as the first calibration taken in the morning, to avoid frame contamination due to detector persistence problems.

Detector setup	DIT	NDIT
DCR/HD	0.5	100
FNS/HS	1.792	10
FNS/HS	300	1

6.5 Twilight Flat Fields

There are two types of twilight flats: SW and LW, both used for imaging applications, but also used for DI and coronagraphy. The SW twilight flats can only be executed during the day, typically one hour before sunset, the latter can be executed any time of the night, twilight or not.

6.5.1 SW twilight flats

The amount of work required to acquire SW flats in all bands which are observed is often too much for Operations, given that not more than 2-3 sequences can be acquired each day, whenever is not cloudy. The amount of time needed for taking SW flats for NaCo is now also not compatible with the additional needs imposed by HAWKI twilight flats. NaCo, at difference with HAWKI has the capability to acquire internal lamp flats. It is therefore decided to considerably decrease the amount of SW sky flats taken with NaCo.

Experience has shown that internal flats are equally good. In order to make sure that there is indeed no change in the system and sky flats and internal flats are comparable, it is recommended to still observe sky flats weekly or bi-weekly for BB (J, H, Ks)/S27/DCR and use them to control that the ratio with the internal flat is ~1. Internal flats should be taken every day for the setups observed the night before and in the same setup as the sky flats when those are taken.

Changes to the system that can affect the quality of the illumination pattern for internal flats are:

a. The telescope pupil gets misaligned
b. The integrating sphere is moved (intentionally or bumped into).

We therefore propose the following strategy:

Test 1 – Use the periodic BB sky flats to compare with internal lamps. These tests will be assigned to QC.
Test 2 - Once a week, take an image of the pupil imager, to see if the pupil is evenly illuminated.

In the long run, it is hoped that the frequency of lamp flats can be lowered (i.e. once every few days instead of every day). A template for this test has to be developed.

Other issues to be considered:

1) Stability of the flats. To be checked by QC using historical data. A first QC report confirms that flats have bee very stable.
2) Flats with different dichroics. Currently we take flats with the VIS dichroic. We think there is no need to use other dichroics because the amount of light changes, but pattern does not change (within 1%). This should be confirmed/re-tested.
3) **Polarimetric** flats: need to be taken on sky, since internal flats make use of an additional mirror, which changes the polarization. However, there is no need to put the polarizer in the beam, since flats are used to remove the detector signature, and standard flats can be taken with the desired setup (filter, detector, camera).
4) **Coronagraphic** flats (for C-1.4 and C-0.7) are currently not taken on sky for SM. They are taken in VM, but we think they are not useful. Normal internal flats with the same setup (filter, camera, detector, no mask) are enough. For the other coronagraphic masks internal flats will be taken mostly at night.
5) **SDI+** flats on sky can be also eliminated and replaced by internal flats.
6) Twilight flats with the neutral density filters, the Wollaston, the Fabry-Perot (FPI) are not supported in SM

In **visitor mode:**

- Twilight flats can be taken upon request, also with other readout modes as DCR, but visitors should note that some combinations of filter, objective and readout mode may be very difficult to do. Since this (internal lamp flat) is not possible with the half-wave plate, upon request in visitor mode, twilight flats can be taken with the half-wave plate in the beam.

- Twilight flats with the SDI (Simultaneous Differential Imager) are supported with a special template called NACO_img_cal_SDITwFlats. These flats are taken with the complete SDI set up, i.e. special SDI field mask, SDI double Wollaston, H broad-band filter and SDI objective present in the light path.

The count level in twilight flats taken in Double_RdRstRd and with DITs shorter than 60 seconds starts with an average count level of 6000 ADU and this decreases with deepening twilight to a few hundred ADUs. The count level in twilight flats taken in FowlerNsamp or for flats with DITs greater than 60 seconds start with an average count level of 2000 ADUs and decrease to several tens of ADU as twilight deepens. Generally, there are 5-20 images for each filter in a twilight sequence.

Template: NACO_img_cal_TwFlats
Purpose: SW sky flats
Description: sequence of images taken on sky during twilight.
Observing Conditions: Clear. No flats should be taken in THN conditions or worse.
CONICA state: Online
CONICA Setup: S27/J, H, Ks/DCR/HD
NACO State: Online
TCS State: Ignore, flats are taken at Zenith
Frequency: once a week
Duration: 30-60 minutes
Pipeline recipe: NACO_img_twflat**.**
It is identical to ISAAC twilight flats.

- Reject frames with counts above 6800 ADU.
- Subtract a dark with the same DIT and camera (optional)
- Compute the linear regression factors on every pixel.
- Extract the bad pixel map
- Normalize
- Issue a warning if the number of frames per filter is less than five or if the range of fluxes in the frames for any one filter is less than a factor of three.

Pipeline data products: SW gain map, bad pixel map
Accuracy: SN > 100 and <2% illumination error

For Polarimetry:

CONICA Setup: Filter, detector, camera setup as used by science. No Wollaston.
Frequency: when needed (i.e. when polarimetric observations are done).

6.5.2 LW twilight flats

LW sky flats have to be done on sky since internal lamps do not work at thermal wavelengths. Up until now we take three sets of flats at three different airmass. The following changes are proposed with the new plan: take only two sets, one at zenith and the other at airmass=2. Test the possibility to take flats with pupil angle constant as the telescope is moved down.

LW flats are taken for the following setups: imaging, polarimetry (with no Wollaston) and coronagraphy (with no masks). Sky flats taken with neutral density filters, Wollaston, and coronagraphic masks are not supported in SM. Flats taken on Mp use a windowed detector setup.

Template: NACO_img_cal_SkyFlats
Purpose: Flat fields for thermal imaging, polarimetry, coronagraphy
Description: taken at two airmass values, 1 and 2. All flats taken with the VIS dichroic
Observing Conditions: late twilight, nighttime
CONICA state: Online
CONICA setup: same as for science frames. No Wollaston or HWP for Polarimetry no mask for coronagraphy.
NACO State: Online
TCS State: Online
Frequency: when needed for science observations.
Duration: 10-15 minutes
Pipeline recipe naco_img_twflats
Procedure:

- Take the median of the frames taken at the same airmass
- Subtract the X=1 from the X-2 extract pixel map.
- Extract the bad pixel map
- Normalize

Pipeline data products: LW flats

6.6 Internal lamp flat fields

Internal lamp flat fields are taken with a halogen lamp for every setup observed during the night. These are daytime calibrations and consists of series of lamp-on/lamp-of frames for every setup (filter, cameras, detector readout mode) observed at night. All readout modes are supported.

SDI+ flats are supported with a special template NACO_img_cal_SDILampFlats. These flats are taken with the full SDI+setup (field mask, Wollaston, H filter and SDI camera).

Lamp flats with the FP are also supported by means of the NaCO_fpi_cal_LampFlats which takes images with a setup matching the science targets (IB filters, FP setting and detector readout mode). Currently the FP is not offered.

6.6.1 Imaging Lamp flats

The setups covered by imaging lamp flats are:

- Imaging
- SAM, without the mask inserted
- Coronagraphy without the mask inserted

Lamp flats with neutral density filters are not supported. LW flats are not possible with the halogen lamp.

An additional lamp flat measurement is taken daily by QC to check the stability of the halogen lamp flats: this measurement is taken with a fixed setup (i.e. S27/J/imaging) One lamp-on/lamp-off pair is enough.

Template: NACO_img_cal_LampFlats
Purpose: take imaging flat fields with the internal halogen lamp
Description:
Observing Conditions: daytime, upper lights off, lower lights OK.
CONICA state: online, calibration mirror inserted
CONICA setup: matching filter, camera and detector setup (excluding windowing)
NACO State: ignore
TCS State: ignore
Frequency: whenever corresponding science setups observed.
Duration: depending on the number of setups
Pipeline recipe: naco_img_lampflat
The recipe does the following:

- Median combination of all lamp-on frames
- Median combination of all lamp-off frames
- Subtract lamp-off from lamp-on
- Normalize

Pipeline data products: lamp flats frames for imaging, SAM, coronagraphy
Accuracy: S/N> 100, <5% across the detector.

6.6.2 Polarimetric lamp flats

These flats have been discontinued. The additional mirror inserted in the light path changes he level of polarization. For polarimetry, sky flats without the Wollaston are taken in SM. See section 6.5 for more details.

6.6.3 Spectroscopic lamp flats

Template: NACO_spec_cal_LampFlats
Purpose: take spectroscopic flat fields for calibration of pixel-to-pixel variations.
Description: spectroscopic lamp flat fields are taken as a daytime calibration using the halogen lamp in CONICA for the spectroscopic setups used for science at night. Three lamp-on and three lam-off frames are taken for each setup.
Observing Conditions: daytime calibrations, upper lights off, lower lights OK.
CONICA state: online, lamp mirror inserted.
CONICA setup: same slit, spectroscopic setup and detector setup as for the science frames.
NACO State: ignore
TCS State: ignore
Frequency: within three days from the observing = run
Duration: depending on setups
Pipeline recipe: naco_spc_lampflats
Pipeline data products: spectroscopic lamp flats
Accuracy: S/N > 100, < 5% across the spatial axis.

6.7 Wavelength Calibrations

Currently an Argon pen-ray lamp is used for spectroscopic arcs. A preliminary report, which should be confirmed, recommends replacing with a Xe lamp. Ar and Xe together cannot be used, given the low resolution of NaCo the lines overlap too much. Xe is better for LW, which is currently no supported since there are no Ar lines above 2.5 microns. It is panned to have the Xe lamp installed in the near future.

LW setups are not supported. For slitless spectroscopy arcs with the 86 mas slit will be provided.

Template: NACO_spec_cal_Arcs
Purpose: arc lamps for wavelength calibration
Description: Daytime calibration for the spectroscopic science setups observed the previous night. One lamp-on and one lamp-of are taken for each setup.
Observing Conditions: daytime, upper lights off, lower lights OK.
CONICA state: online, lamp mirror inserted.
CONICA setup: same setups as for the science (filter, spectroscopic order)
NACO State: ignore
TCS State: ignore
Frequency: within three days of the observing run
Duration: depending on the number of setups
Pipeline recipe naco_spc_wavecal

- o Subtract frame off from frame on
- o Determine wavelength solution

Pipeline data products: 2-D wavelength solution
Accuracy: .5 pixels relative, 2 pixels absolute

6.8 Photometry – Zeropoints

Refer to [3] for details on the new policy for Standard (STD) stars proposed for all imaging capable instruments on Paranal.

Up until now very few combinations of filter + camera + detector + dichroic were supported and for imaging mode only: calibrating everything costs too much time. For example, Ks/S27/FNS was not calibrated. A better practice is that of always matching the detector readout and dichroic/AO setup to the science observations. This is being implemented with this version of the calibration plan.

Among the non supported setups, we still have imaging with NB, IB and ND plus polarimetry and coronagraphy: not supporting these modes goes against the spirit of the calibration plan, but it may end up being too much to support. Therefore those calibrations will not be routinely supported by the calibration plan but can still be performed when requested by the users and accounted for in their allocated time.

Frequency of calibration: once a night, at the beginning of the night in Broad Band (BB) filters with the S27 camera and/or BB/S13. Then, when moving to a PHO program, a standard star with the setup of the science OB (filter, camera, detector setup) must be observed. The standard star must also be observed immediately after the science, to check for stability: the ZP difference between the two STD observations should be less than 0.04 in order for the science OB to be classified as A or B.

No standard star will be taken in THN or THK conditions

When possible the standard star of the month will always be observed at the beginning of the night. Only low airmass measurements are taken.

An historical database of zeropoint measured with NaCo is maintained on the NACO QC web pages:
http://www.eso.org/observing/dfo/quality/NACO/reports/HEALTH/trend_report_ZEROP_HC.html

Template: NACO_img_cal_StandardStar
Purpose: measure zero points
Description: a standard star taken from a selected set is observed in close loop with the same AO setup (WFS/dichroic) as the science that needs to be calibrated. The star is imaged at the center and in the four quadrants of the array.

Observing Conditions: at night, CLR or PHO conditions.
CONICA state: online
CONICA setup: imaging, same filter/camera and detector setups as the science.
NACO State: online
TCS State: online, tracking
Frequency: at least once a night, bracketing science observations if condition PHO is requested, once if CLR requested.
Duration: 10-20 minutes
Pipeline recipe: naco_img_zpoint
Pipeline data products

- Subtract images in pair and divide by the flat
- Perform aperture photometry of the standard star at five positions
- Calculate mean zeropoint and associated error (RMS)
- Measure Strehl ratio

Accuracy: <5% on zeropoints and Strehl ratio

6.9 Telluric Standard Stars

The new guidelines for the selection of the telluric standard and the airmass difference (constraint have been published in [6].

The telluric calibrator is taken immediately after or before the scientific observations, at the same airmass the scientific target had mid-exposure ±0.1. Unless requested otherwise, the following guidelines for the choice of the telluric are followed:

Spectral Band of science OB	Star type	Notes
J	Hot (B, but also O and A). E.g. B0V-B5V	V-I should be negative. IR magnitude should preferably be known.
H	Very hot, e.g. O0V, B0V-B3V	V-I should be negative. IR magnitudes should be known.
K	G or B. E.g. G0V-G5V, B0V-B5V	Late B, e.g. B5/6, may contain strong Bracket lines.
H+K	G. E.g. G0V-G5V	
Lp	B,O,G, and A, K for N a& M bands	
Mp		

The recommended telluric star IR magnitudes and corresponding V magnitudes for a G2V star as a function of instrument mode for NACO are listed below; the last column lists the recommended flux level for the telluric star spectrum in the RTD.

Instrument Mode + dichroic	IR Magnitude	Approx V mag. range for G2V star.	Flux range in the RTD [ADUs]
SW + VIS	K=7.5-10	9-12	Depends on selected Read out mode: DCR <10000 FNS <5000
SW + K	H=7.5-10	9-12	
SW + N20C80	K=7-9.5	9-11	
SW + N90C10	K=5-7	7-9	
LW + VIS	L=5-7	7-9	
LW + JHK	L=5-7	7-9	

Template: NACO_spec_cal_StandardStar
Purpose: observe a telluric standard calibrator
Description: Nighttime calibrations taken immediately before or after the science OB. The star is typically chosen with airmass similar to the one of the science at mid-exposure ±0.1.
Observing Conditions: same as for the science target
CONICA state: online
CONICA setup: same as for the science targets. For LGS OBs a NGS telluric is observed.
NACO State: Online
TCS State: online, tracking
Frequency: one or two per science target
Duration: 15 minutes, including acquisition.
Pipeline recipe: naco_spc_combine
Pipeline data products: combined, wavelength calibrated spectrum

6.10 Other nighttime calibrations

6.10.1 Nighttime spectroscopic arcs and flat fields

Users can choose to take nighttime spectroscopic arcs and flat fields. Usually, these calibrations are not required if you wish to do spectro-photometry to an accuracy of 5% or less. If the option to take lamp flats is selected, n pairs of frames, where n is a number between one and three, with the lamp on and off will be taken. Likewise, if the option to do arcs is selected, one frame with the arc lamp on and one frame with the arc lamp off will be taken. Alternatively, one can select to do both lamp flats and arcs, in which case n + 1 pairs of frames will be taken.

6.10.2 Nighttime coronagraphic, SDI+ and SDI+4 flat fields

Optical elements on a glass substrate (c_0.7_Sep_10, 4QPM_H, 4QPM_K, SDI+, SDI+4) cannot be properly flat-fielded using daytime flats. The repositioning of the optical element is not accurate enough to produce a good flat that can be used to remove dirt and particles from the substrate. For this reason the new acquisition templates for these modes acquire one flat-on and one flat-off image of the mask/SDI+/SDI+4. These frames are taken at no cost to the user. However, if more sets of frames are needed, users should use the template NACO_coro_cal_NightCalib to acquire more flat-on/flat-off pairs. The template should be executed immediately after the science OB, to ensure that the mask is in the same position. Users are cautioned that for very long OBs, instrumental flexures may slightly shift the optical element.

6.10.3 PSF measurements for SDI+4 and 4QPM masks.

The acquisition templates for SDI+4 NACO_img_acq_SDIMoveToMask and for coronagraphy NACO_img_acq_MoveToMask (when used with 4QPM_H or 4QPM_K) allow taking a PSF image of the object off mask plus corresponding sky. The images can be used for PSF determination. PSF data taking is currently optional, and users interested in these images should mention it in their README files. The images are taken at no time cost to the users.

6.10.4 Nighttime FP arcs

Since we have observed drifts of about 1 nm in the setting of the FP over a 24 hour

period, it is mandatory that users attach the NACO fpi cal Arcs template at the beginning of every OB that uses the FP The purpose of this template is to determine the transformation between x,y (detector coordinates) and z (FP plate distance) and x,y versus λ. Additional details are given in the NACO User Manual.
Currently, the FP is not offered for technical reasons

6.11 Detector Calibrations

Detector calibrations performed regularly on NaCo include noise, dark current, hot and cold pixels and are published on the QC web pages. An historical database, trend plots and statistical analysis are available in addition to the daily measurements.

Measurement of noise for DCR/FNS and UCR:
http://www.eso.org/observing/dfo/quality/NACO/reports/HEALTH/trend_report_RON_HC.html

Measurement of dark current:
http://www.eso.org/observing/dfo/quality/NACO/reports/HEALTH/trend_report_DARK_HC.html

Measurement of hot/cold pixels:
http://www.eso.org/observing/dfo/quality/NACO/reports/HEALTH/trend_report_HOTCOLDPIX_HC.html

As of P82 a new detector linearity template and corresponding pipeline recipe was released. It uses the method of the transfer curve to measure gain, linearity levels, saturation and noise. The observing template is run in daytime and collects a series o pairs of flat frames that cover the full dynamic range of the detector in a particular readout mode. Darks with the same DIT as the flats are also collected. The supported setups are:

Readout mode	**Detector mode**	**Instrument mode**
Double correlated readout (DCR)	High Dynamic (HD)	All SW modes
Fowler N Sampling (FNS)	High Sensitivity (HS)	All SW modes
Uncorrelated (UCR)	High Dynamic (HD)	NB thermal imaging
Uncorrelated (UCR)	HighWellDepth (HWD)	Lp imaging
Uncorrelated (UCR)	HighBackground (HB)	Mp imaging

Template: NACO_gen_tec_Linearity
Purpose: measure gain, linearity
Description: plots the transfer curve (Signal vs. noise) using sequences of flats taken at different DITs and covering the full dynamic range of the detector.
Observing Conditions: daytime, upper lights off, lower lights OK.
CONICA state: online
CONICA setup:
NACO State: ignore
TCS State: ignore
Frequency: every six months
Duration: 50 minute (10 minutes per setup)
Pipeline recipe: naco_detlin
Pipeline data products: gain, linearity**.**

7 Summary

The following table summarizes the list of templates, the corresponding calibration, the time of execution and the frequency. "When needed" means that science observations which require the calibration were performed the previous night. "When requested" means that it is either a VM request or a special calibration for SM programs.

Template	**Data product**	**Time**	**Frequency**
NACO_all_cal_Darks	Darks	Day	Daily
NACO_ing_cal_TwFlats	SW Twilight flats	Twilight	Weekly for checks
NACO_img_cal_SDITwFlats	SDI+ twilight flats	Twilight	VM only, or when requested
NACO_img_cal_SkyFlats	LW Sky flats	Twilight, night	When needed
NACO_img_LampFlats	Internal lamp flats (imaging, SAM, coronagraphy)	Daytime.	When needed (daily if NaCo used)
NACO_img_cal_SDILampFlats	SDI+ Internal lamp flats	Daytime	When needed
NACO_fpi_cal_LampFlats	Fpi internal flats	Daytime.	When needed. Not offered now
NACO_pol_cal_LampFlats	Polarimetry internal lamp flats	Daytime	When needed.
NACO_img_cal_StandardStar	ZP, standard star	Twilight, night	Daily if conditions CLR. When needed
NACO_spec_cal_StandardSar	Telluric star	Night	When needed
NACO_spec_cal_LampFlats	Spec internal flats	Daytime	When needed
NACO_spec_cal_arcs	Spec arc frames	Daytime	When needed
NACO_gen_tec_Linearity	Detector gain and linearity	Daytime	Every period or after an intervention