The calibration plan of the NISP spectroscopic channel

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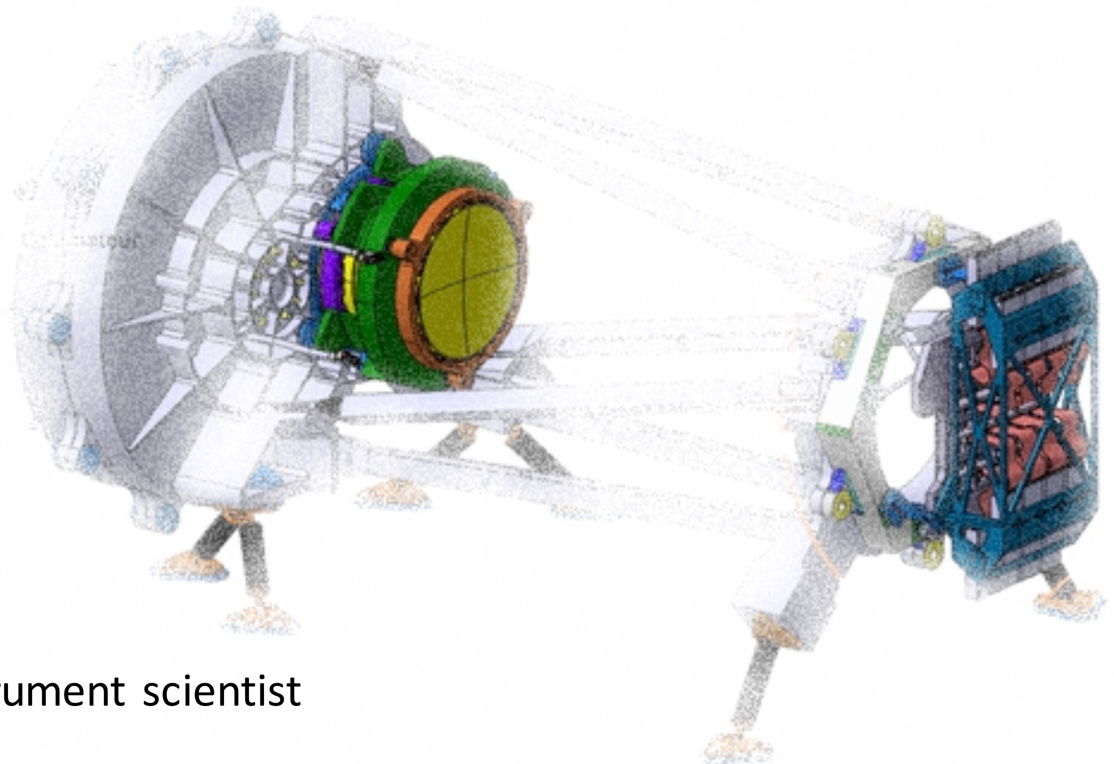

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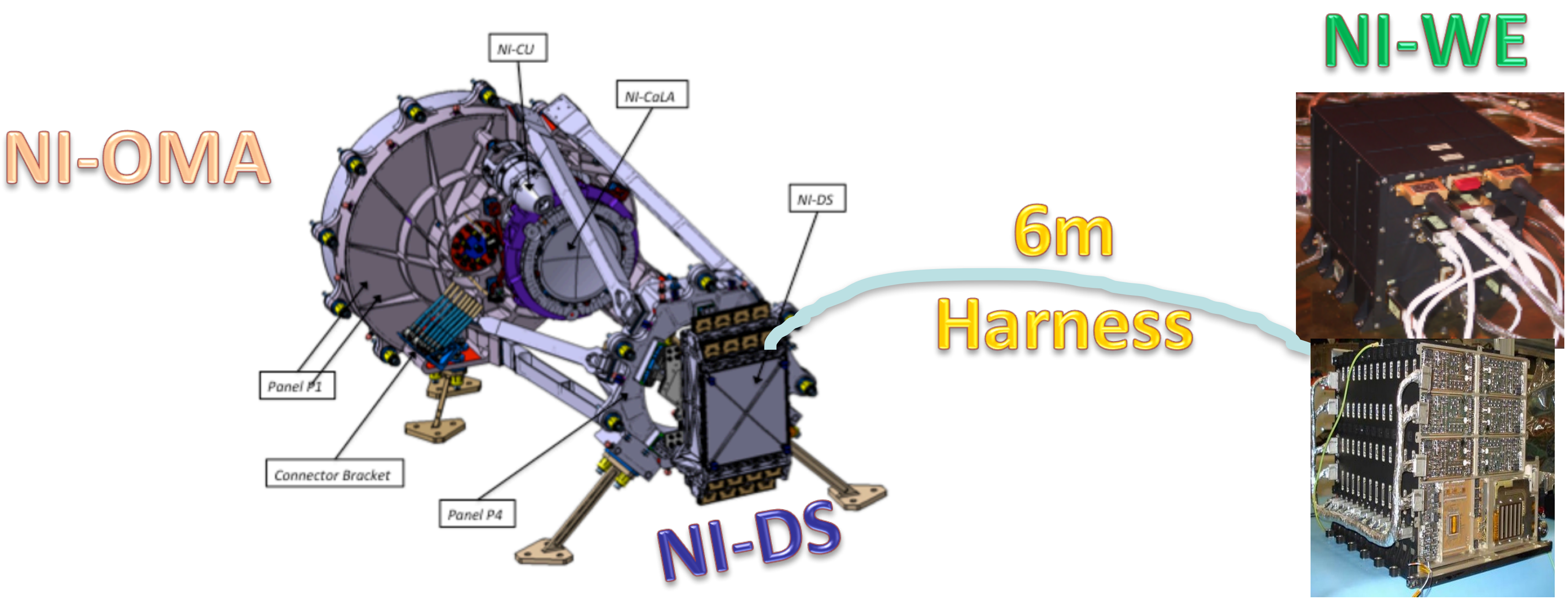
NISP-S instrument scientist

NISP is a Large Field Photometer & SlitLess Spectrograph [0.9-2.0]µm

- NI-OMA : Opto Mechanical Assembly in the satellite Cold PayLoad Module (130K)
- NI-DS : Detection System mounted on NI-OMA (detector <100K)
- NI-WE : Warm Electronics in the warm satellite Service Module (ICU & DPU)



Cold Payload Module **Warm Service Module**

NISP Overview

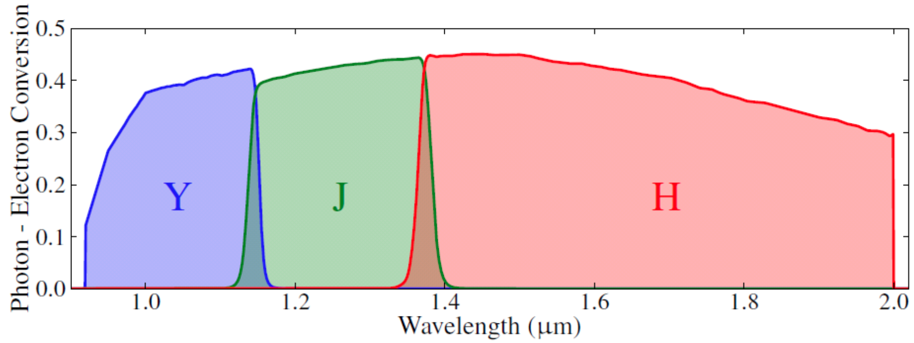
Near IR instrument :

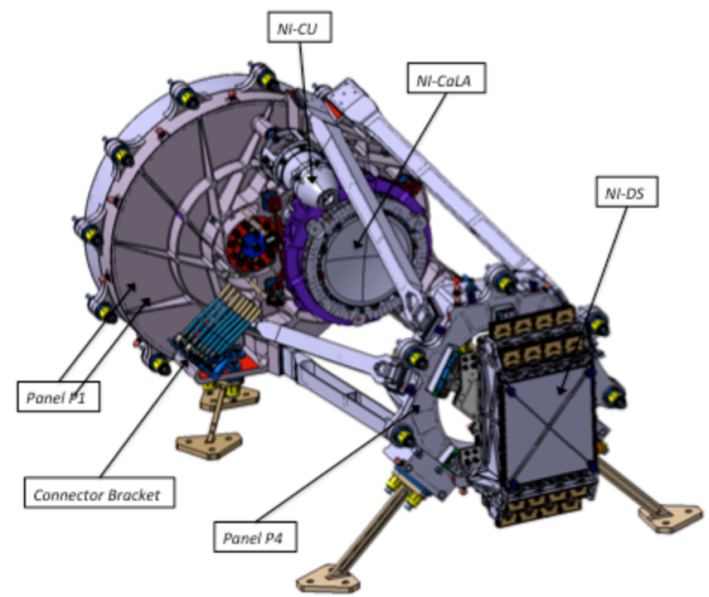
FOV : 0, 55 deg ^{2}
Pixel scale 0, 3''

Photometer : Y, J, H bands

1. Y 920-1146 nm
2. J 1146-1372 nm
3. H 1372-2000 nm

Spectrometer:
R bands grism , slitless
GWR 0°,90,180 disp. : 1250-1850 nm
A blue grism for deep survey only
GWB 0° disp. : 920-1300nm
Resolution > 380 for a 0,5'' object size

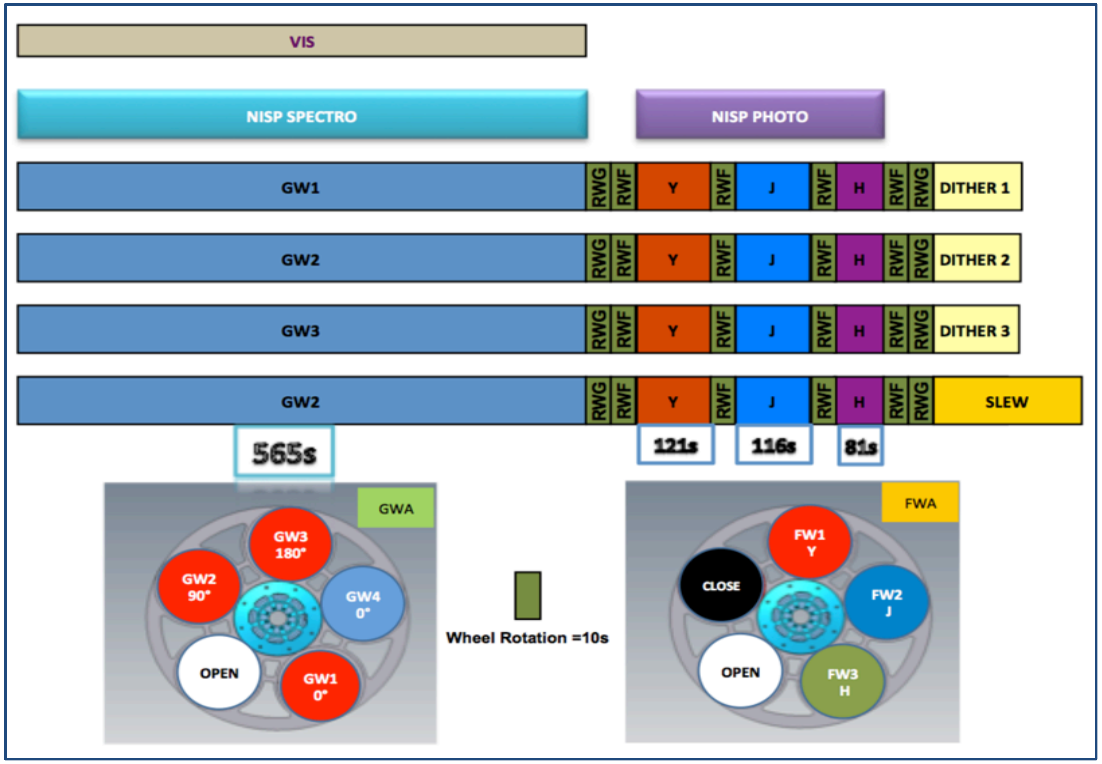




NISP OBSERVATION SEQUENCE

- 20 Fields per day; 4 Dithers per field (wide survey)

- For dither 1:
  - 565s with Grism red 0° (filter open)
  - 121s with Filter Y (grism open)
  - 116 s with Filter J (grism open)
  - 81s with filter H (grism open)
- For dither 2:
  - 565s with Grism red 90° (filter open)
  - Same photometry as dither 1
- For dither 3:
  - 565s with Grism red 180° (filter open)
  - Same photometry as dither 1
- For dither 4:
  - 565s with Grism red 90° (filter open)
  - Same photometry as dither 1



- The blue grism will be used during the deep survey

Central calibration requirements for NISP

Reference	Description	Requirement
	Photometry	
R-WL.2.1-21 R-CAL-A-NP-1000	Post Calibration Relative Photometric Error	< 1.5 %
G(R)-CAL-A-NP-3000	Absolute photometry	< 5%
	Spectroscopy	
R-GC.2.1-7 R-CAL-A-NS-1000	Wavelength calibration	< 0.8 pixel
R-GC-2.1.12	zero point of flux calibration within patch of 0.5 deg2	<0.7%
R-CAL-A-NS-2000	Relative spectro photometric calibration	<3%
G(R)-CAL-A-NS-3000	Absolute spectro - photometry	< 5%

Spectroscopic calibration strategy

- Wavelength and (spectro)photometric calibration pillars of successful redshift determination and control of non cosmological fluctuations

- Philosophy is to establish wavelength and flat field calibration on ground where good sampling of the wavelength range can be achieved

- In-flight calibrations then re-establish these calibrations in an intensive PV phase and are subsequently used to monitor accurate temporal stability

- Main difficulties are linked to Euclid specificities (large field of view, pointing accuracy, dithering strategy, one single pass for calibration, on board processing).

Spectroscopy calibration

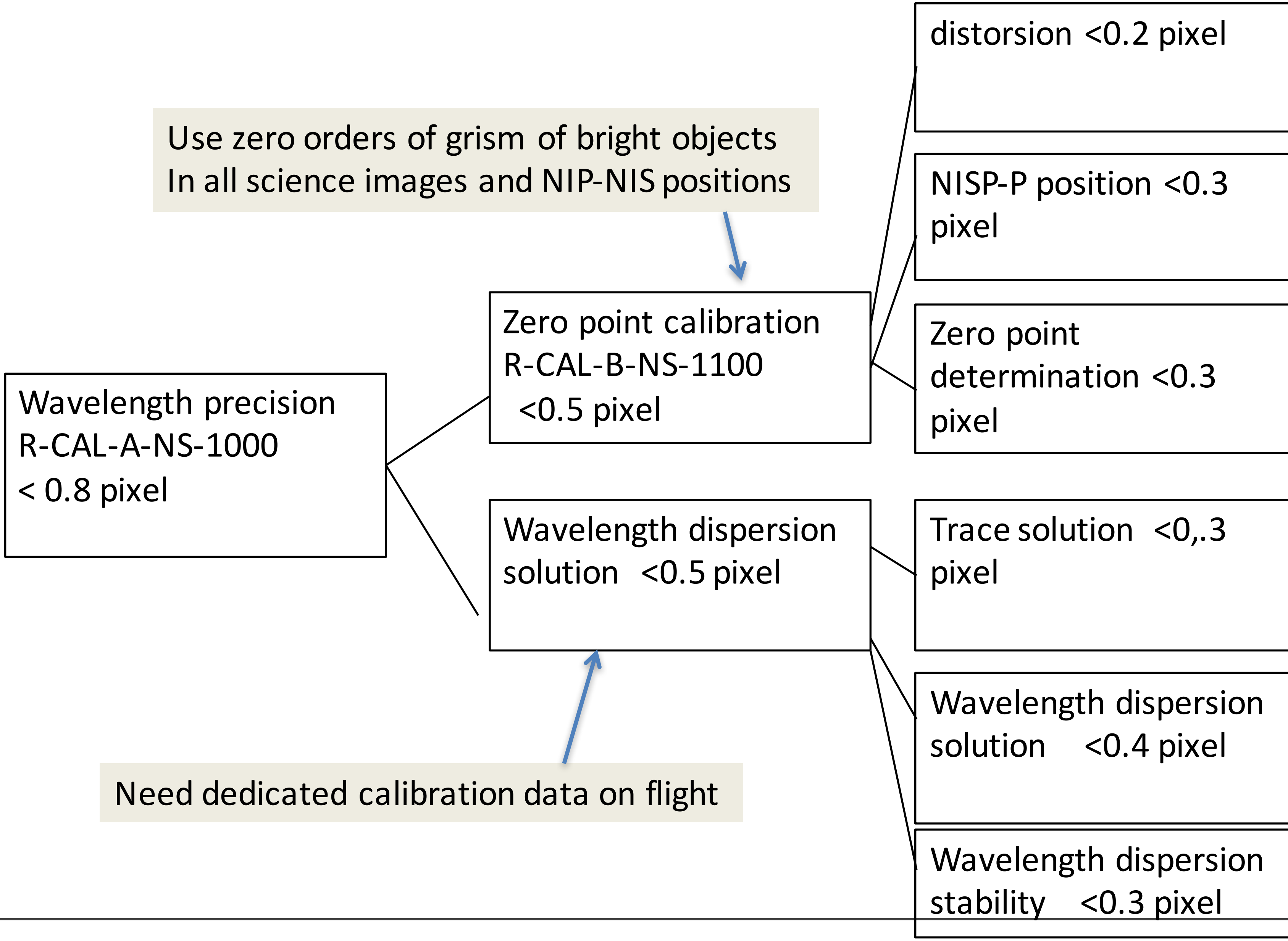
- Main differences with HST for calibration is:

- Instrument : larger FOV, larger PSF and larger zero point.
- Satellite: less pointing precision (order 1'' TBC)

- Field location:
  - there is not 'one direct image' just before the dispersed one in the same filter..
  - the NIR images (direct and dispersed) have a different coverage
  - there is wheel displacements and errors to correct.

- Survey: we cannot re-calibrate when we want :
  - calibrators should be known in advance in all the survey
  - Not a lot of redundancy
  - Use the deep field as a bridge (self cal field?) .

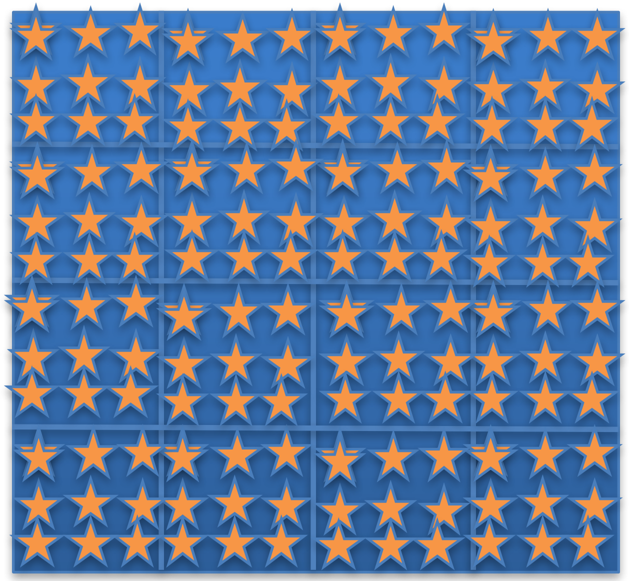
Budget for wavelength calibration



Wavelength solution calibration plan

- Determined on ground with monochromator and emission line source (Fabry Perot)
- In flight, use single planetary nebula with clear emission lines at different positions in each detector (PN) for adjustement and verification of lines + a deep calibration field for stability monitoring
- Use the deep field (self-cal field) to control the evolution by extracting 'standard wavelength calibrators'. This should be done during the PV phase to be used in all the survey.
- Evaluation is undergoing to estimate if other objects (K/M stars, open cluster) ..using template or cross correlation technics, are needed to improve precision and follow up.

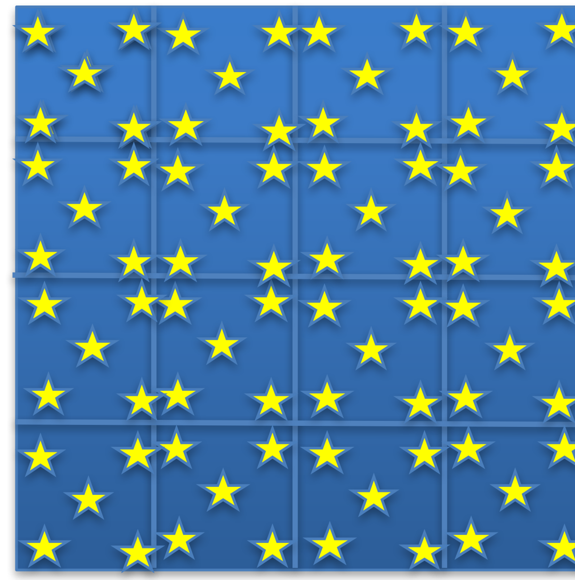
Procedure verification (baseline)



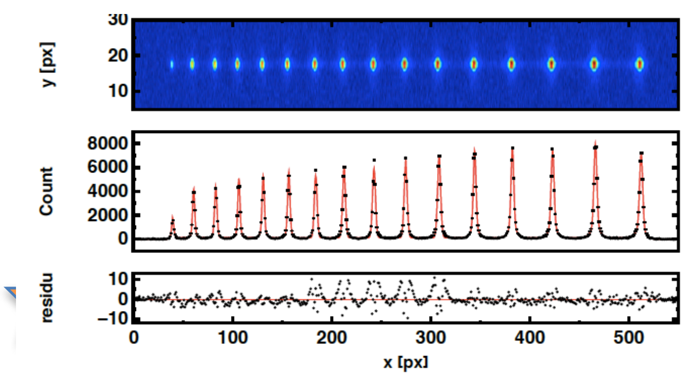
Ground (on FM)

1 object /image

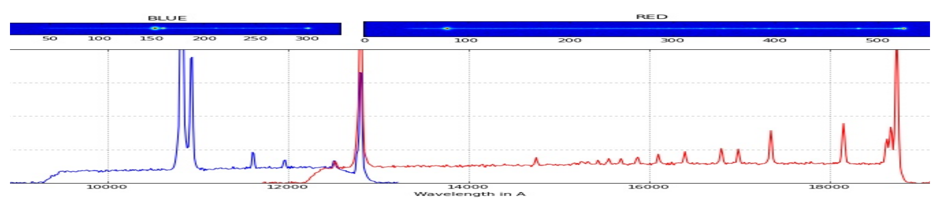
Reecover all the positions in wavelength with an accuracy of 1/10 pixel



PV phase



Monochromator (>14 wavelengths)
Fabry perrot



PV phase planetary nebulae

See W.Gillard talk

Spectro–photometry calibration requirement

Impact on calibration and processing of the new requirement of 0.7% zero-point stability, still to be assessed on all the survey.

=>Complete the assessment of the impact on calibration and update, if needed in flow down of requirement the MOCD-A (mission) , CALCD-A (calibration), GDPRD (processing).

Spectro-photometry calibration

Budget derived on 4 spatial scales :

1. the pixel to pixel response variations (NISP detector)

2. the single detector scale (NISP : small scale)

3. the full NISP field of view scale (large scale ‘self cal Field’)

1. The field to field scale

Possibilities for field to field -overlap

Repeated observations and the "after the survey" calibrations

Objects that are observed twice because of the overlap between adjacent survey fields can help to reduce zero point variation filed to field.

At the moment, the dithering pattern for the wide survey observations result in a small sky coverage overlap between adjacent detectors , and not allow for field to field fluctuation measurements accurate below the 1 % limit if there is 3-5 % of fluctuations in the field measurements.

GOAL was to demonstrated that it it possible to recover ~ a factor 2-3 in precision (TBD) using a better dithering strategy . This should help to consolidate this approach and reduce risk at instrument level.

⇒ See D. Markovic talk

Relative spectro-photometry

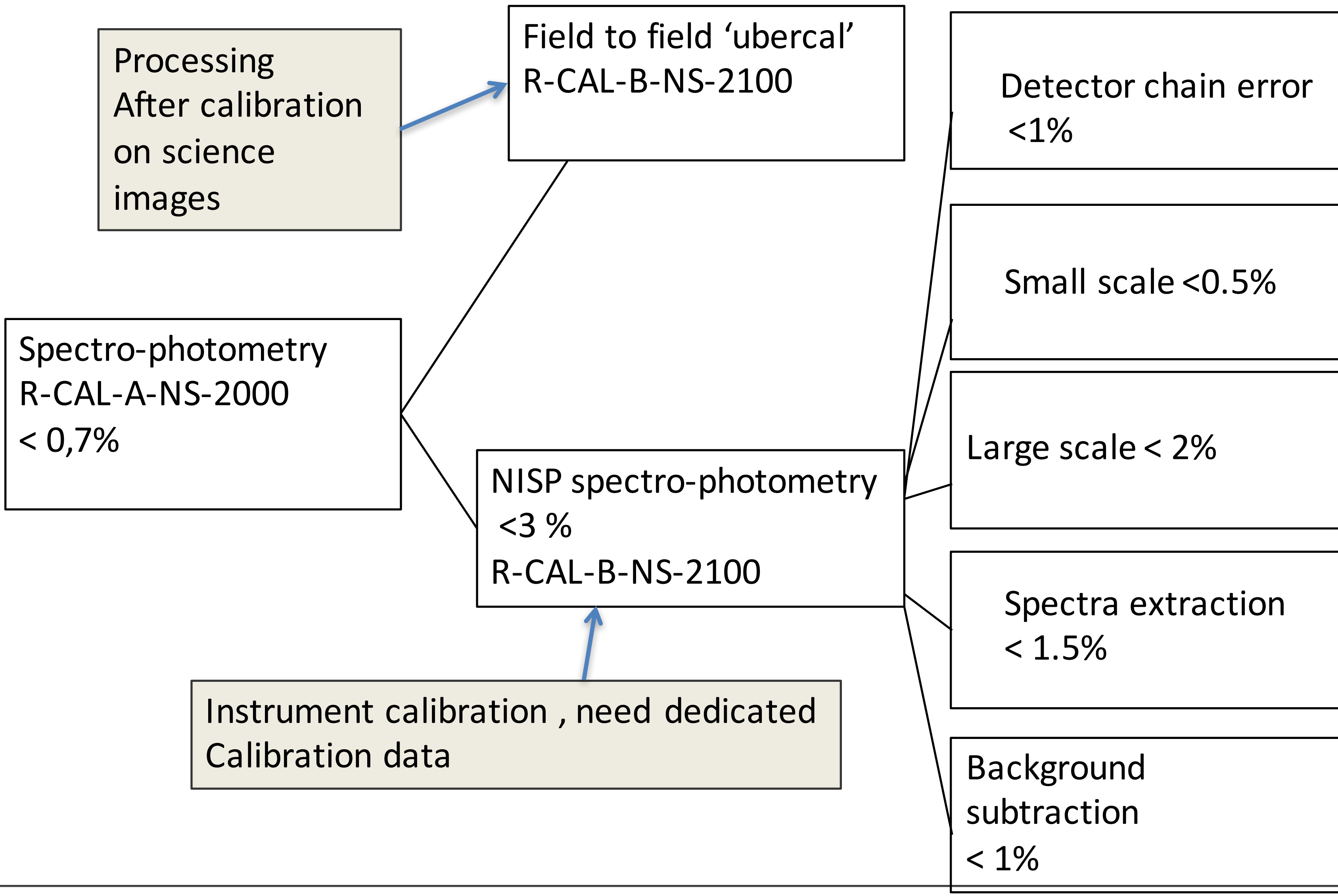
Reference	Requirement	Value
R-GC.2.1-12	Within patches of 0.5 deg2 area distributed over the whole survey, fluctuations in the zero-point of the flux calibration scale shall be smaller than 0.7% rms.	<0.7 %
R-GC.2.1-13 R-CAL-A-NS-3000	After all calibrations, the absolute spectrophotometric error of the NISP-S shall be < 5.0%.	<5%
R-CAL-A-NS-2000	the relative spectrophotometric error of the NISP-S should have an error < 3.0 % on scales (<0.5°)	< 3 %

Spectro-photometry calibration

- ✓ On the instrument side, the overall relative spectrophotometric uncertainty affecting a single survey exposure is to be limited below 3%
- ✓ The absolute calibration has to be within 5% (but is a goal not requirement) .

Trade off under going betweeen dithering strategy to improve overlaps or the need to require a dedicated repeated calibration 'self cal field' to ensure the final budget.

Budget for spectro-photometry calibration



Ref	**Description**	**Requirement**
		The relative response of the NISP in spectro-photometry should be normalized, such that fluctuations in the flux calibration scale inside the full field of view for all scales should be smaller than 3 % (rms) at any given time during the survey.
R-CAL-B-NS-2100	Small scale flat field	After calibration, the small scale (<100 pixels) instrument response sho[...] % on the relative spectrophotometry error
R-CAL-B-NS-2200	Large scale flat field	After calibration, the large [...] ould introduce an error < 2 % on the final s[...]ic error
R-CAL-B-NS-2300	Spectra extraction	The spectra extraction should introduce and error < 1.5 % on the final spectrophotometric error
R-CAL-B-NS-2400	Detector chain error (pixel to pixel)	The detector chain correction should introduce an error < 1 % on the spectrophotometric error
R-CAL-B-NS-2600	Background subtraction	Background substraction (sky+instrument) should contribute < 1% on the spectrophotometric error

Same than photometry

self-cal field?

Verification because of the on board processing

Deep field repeated observations

Objects that are observed multiple times because of repeated observations of some special fields, that could be either the Deep-survey or the Self-cal fields

- Repeated observations of a given field provide the significant benefit of an almost complete overlap between separate exposures, therefore maximizing the number of objects that can be used in any comparison, and thus the accuracy of the calibrations validation

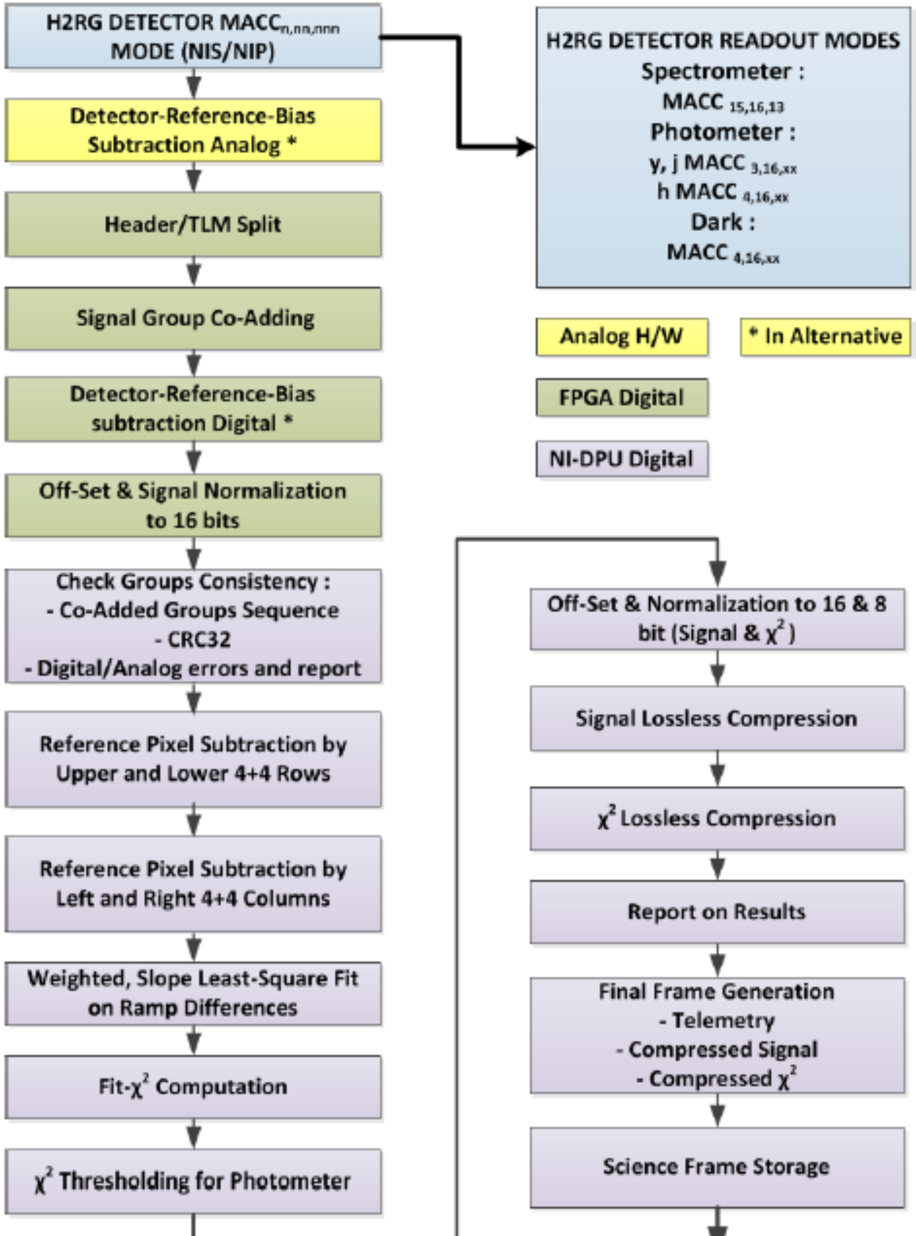
- it looks like the Deep survey observations should provide the best solution for repeated observations of a set of objects (gain ~ 100)

- Only implemented at the beginning of the mission to compute purity

- **Need to be complemented with self cal field time to time**

- Photometry/spectro-photometry monitoring. Explore how to calibrate simultanuously the 2 channels. It is the same detectors..

Detector on board processing (WE)

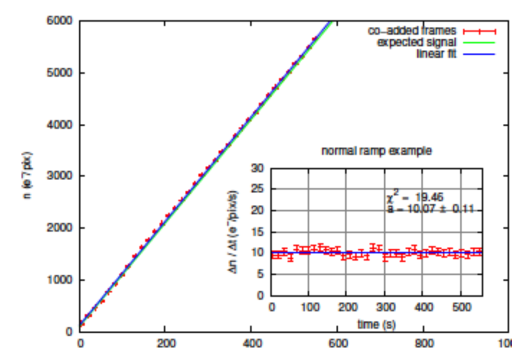


- read continuously
- make a fit on board
- send only the slope and the χ2 en ground

Science mode driver

Spectro: MACC[15,16,13] :
spec noise <13e- on 95% pixels)

Photo: MACC[3,16,4] :
spec noise < 9.e- on 95% pixels)



Detector calibration

- Use predefined multiaccum MACC (N,M,D) for science
- Only the final slopecomputed on board is send on ground
- Most calibration use also pre defined MACC mode
- Only some debug modes will send back groups (never samples)
- We receive with the science data, 5 lines of raw samples

Important is to correct non linearity,+IPC.. and detector flat field with a very good accuracy.

-> new procedures are developed on ground and on board to do calibration (as corrections for non linearity and persistence).

-> strong interface is needed with detector team and NIR and SIR

for more information on mode definition for photometry: EUCL-CPP-TN-7-007

Flat field small scale (<100 pixels)

-Very limited informations on board

Flat field NI-CU (5 LEDS : only 3 in the red grisms range)

--. Because of the on board processing + NI-CU , the calibration is mainly control by an' a prior knowledge' on ground and external observations.

-> a full knowledge of the pixel by pixel response (characterisation) is done on ground for each mode at detector level

-> A 3D cube flat-field with more than 10 wavelengths should be provided (TBC).

->A procedure to transfer the correction of flat-field images to the NISP-S images should be derived.

Absolute calibration

Absolute spectro photometry at < 5 % as photometry

-Observe a known standard star in different place of FOV
-Do ~ each year
-the standard star should be known at ~ 3 %

Prior information:

Require throughput (PCE) ground informations :

- NISP will do by analysis based on the sub-components (~ 5%)
- A verification will be done in the PV phase

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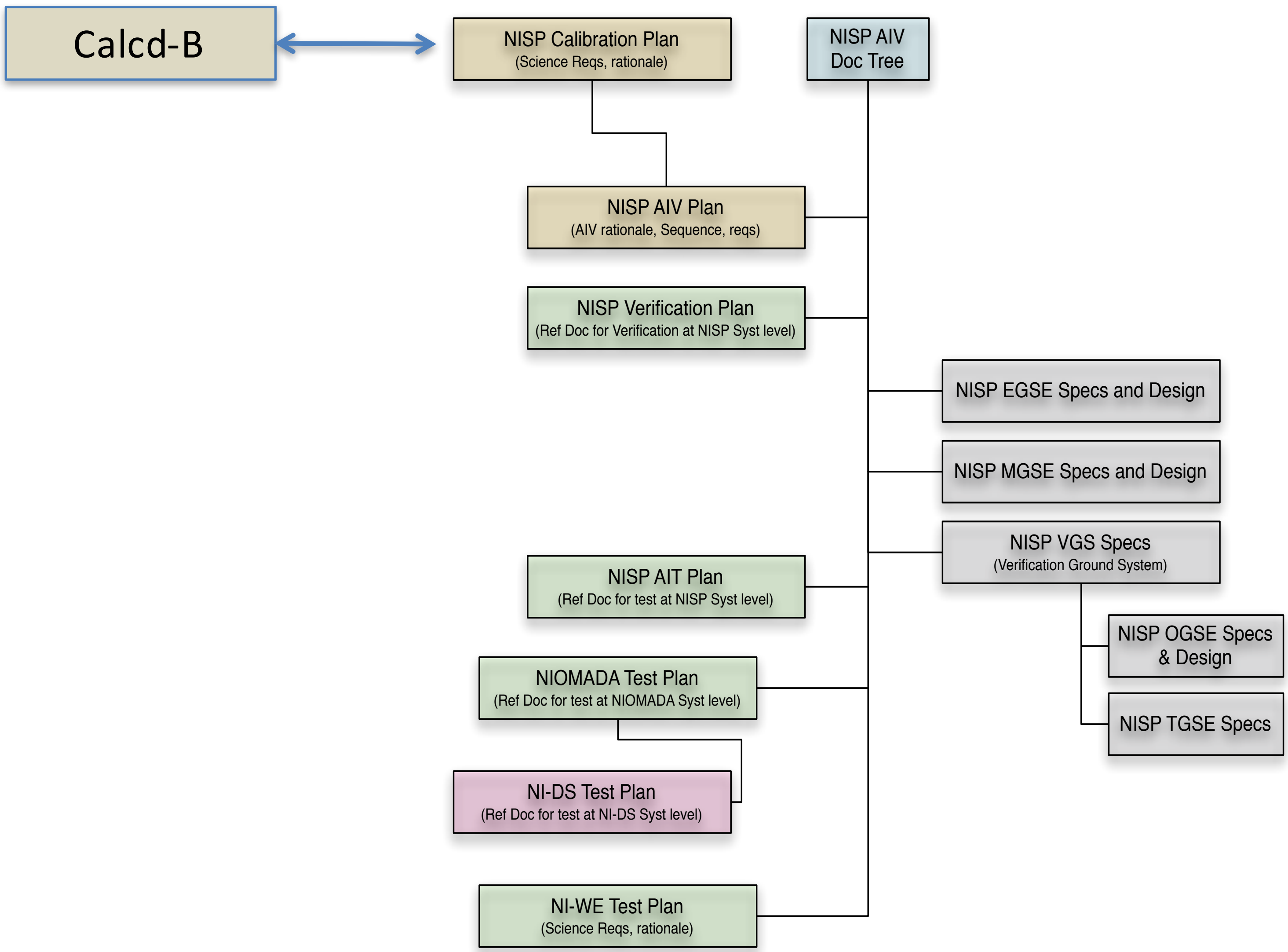
Calcd-B
NISP Calibration Plan
(Science Reqs, rationale)
NISP AIV
Doc Tree
NISP AIV Plan
(AIV rationale, Sequence, reqs)
NISP Verification Plan
(Ref Doc for Verification at NISP Syst level)
NISP EGSE Specs and Design
NISP MGSE Specs and Design
NISP VGS Specs
(Verification Ground System)
NISP AIT Plan
(Ref Doc for test at NISP Syst level)
NISP OGSE Specs
& Design
NIOMADA Test Plan
(Ref Doc for test at NIOMADA Syst level)
NISP TGSE Specs
NI-DS Test Plan
(Ref Doc for test at NI-DS Syst level)
NI-WE Test Plan
(Science Reqs, rationale)

Agreed summary

Euclid Consortium

Calibration budget	NISP cal Plan	Marco OUSIR	Agreed for CDR
Zero point			
Offset NIP image –NIS-spectro matching	0,5	0,2	0,3
NIP object position	0,3	0,3	0,3
Geometrical and distorsion	0,1	0,3	0,2
Trace distance 0th-1th order	0,2	0,45	0,3
Zero point subtotal	0,62	0,65	0,56
Local wavelength dispersion (by PN)	-	0,4	0,3
Interpolation in all the field	0,4	0,4	0,3
stability	0,3	0,3	0,3
Wavelength subtotal	0,5	0,64	0,52
Total	0,8	0,91	0,76