Survey update

	Criteria for RSD implementation and Verification	Ref. EUCL-OAR-RP-8-002 Version: 1.2 Date: 10/01/2022 Page: 1/171

CRSDIV: Philosophy document

Title:	Criteria for RSD implementation and verification
Reference :	EUCL-OAR-RP-8-002
Issue :	1.2
Date :	10/01/2022
Custodian:	R. Scaramella

MOCD-C: user manual for each survey & verification table

	Mission Operation Concept Document part C	Ref. EUCL-IA-RP-8-001 Version: 2.0 Date: 18/01/2022 Page: 1/55

Title:	**Mission Operation Concept Document part C**
Reference :	EUCL-IA-RP-8-001
Issue :	2.0
Date :	18/01/2022
Custodian:	Ismael Tereno

Astronomy & Astrophysics manuscript no. output
November 2, 2021

paper on the wide in press

Euclid preparation: I. The Euclid Wide Survey

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ABSTRACT

Euclid is a mission of the European Space Agency, designed to constrain the properties of dark energy and gravity via weak gravitational lensing and galaxy clustering. It will carry out a wide area imaging and spectroscopy survey (the Euclid Wide Survey: EWS) in visible and near infrared bands, covering approximately 15 000 deg^2 of extragalactic sky on six years. The wide-field telescope and instruments are optimized for pristine PSF and reduced straylight, producing very crisp images.

This paper presents the building of the Euclid reference survey: the sequence of pointings of EWS, Deep fields and Auxiliary fields for calibrations, and spacecraft movements followed by Euclid as it operates in a step-and-stare mode from its orbit around the Lagrange point L2.

Each EWS pointing has four dithered frames; we simulate the dither pattern at pixel level to analyse the effective coverage. We use up-to-date models for the sky background to define the Euclid region-of-interest (RoI). The building of the reference survey is highly constrained from calibration cadences, spacecraft constraints, and background levels; synergies with ground-based coverage are also considered. Via purposely-built software, we first generate a schedule for the Auxiliary and Deep fields observations. On a second stage, the RoI is tiled and scheduled with EWS transit observations, with an algorithm optimized to prioritize best sky areas, produce a compact coverage, and ensure thermal stability.

The reference survey RSD_2021A is the optimized result of a modern survey design. It fulfills all constraints and is a good proxy for the final solution. The current wide survey covers ≈ 14 500 deg^2. The limiting AB magnitudes (5σ point-like source) achieved in its footprint are estimated to be 26.2 (visible) and 24.5 (near infrared); for spectroscopy, the H_α line flux limit is 2×10^{-16} erg^{-1} cm^{-2} s^{-1} at 1600 nm; and for diffuse emission the surface brightness limits are 29.8 (visible) and 28.4 (near infrared) mag arcsec^{-2}.

Key words. cosmology – space vehicles – dark matter – dark energy – survey – all sky

APPENDIX A. Calibration requirements for routine operations

Calibration Requirements for Routine Operations (CIRRO)

Contents

To ESA: XML file with all pointings ad slews for the 6 years + blinding star file

Verification of calibration implementation

2 CALIBRATION REQUIREMENTS

CALBLOCK-F-001 Observe the Self Cal pattern of points regularly, at a give cadence. The Self Cal pattern is made of 60 pointings (listed in appendix A). A single pass of observation of a pattern is made by centering the FoV with each pointing.

Pointings of a single pass must be all observed with the same, arbitrary, orientation. Different passes may be observed at different orientations.

Pointings of a pass may be observed in any order.

The pattern must be observed at a cadence of 25 to 40 days.

Schedule time allocation is [1012] seconds, per pointing.

Note 1: Orientation of a pass may be chosen to suite the pass average timestamp.

Note 2: The 60 pointings of the pattern are clustered in groups of 4, around the Self Cal centre (R.A./DEC of 268.625, +65.600).

CALBLOCK-F-002 Observe the three deep fields repeatedly, up to 6 times the S/N of the average wide survey. The deeps fields are: deep-field north (EDFN), deep-field south (EDFS), and deep-field Fornax (EDFN). Each pass must observe a deep field completely, covering the fields shape with a tessellated pattern (with no inner holes). Fields in the tessellated pattern must overlap the same amount as in the wide survey (see MOCD-A).

The shape, centre, and number of passes required for each deep-field are given by:

Field	shape	R.A	Dec	passes
EDFN	10 deg^2 circle	269.7372	66.025	30
EDFS	23 deg^2 stadium	66.7876	−49.582	35
EDFF	10 deg^2 circle	52.9386	28.104	52

(see appendix B for description of stadium shape)

The total observed area of the deep-fields must grow at the same (approximate) pace as the total area of the wide survey.

Schedule time allocation is [{22}996−996−996−1006] seconds, (ROS), per pointing.

CALBLOCK-F-003 Observe two CPC fields 10 times each, at constrained orientations. The CPC fields are the CPC-north (CPC-N) and the CPC-south (CPC-S). Each pass must observe the CPC completely, covering the fields shape with a tessellated pattern (with no inner holes). Fields in the tessellated pattern must overlap the same amount as in the wide survey (see MOCD-A).

The shape, centre, and number of passes required for each CPC field are given by:

Field	shape	R.A	Dec	passes
CPC-N	20 deg^2 circle	269.7372	66.025	10
CPC-S	23 deg^2 stadium	66.7876	−49.582	10

(see appendix B for description of stadium shape)

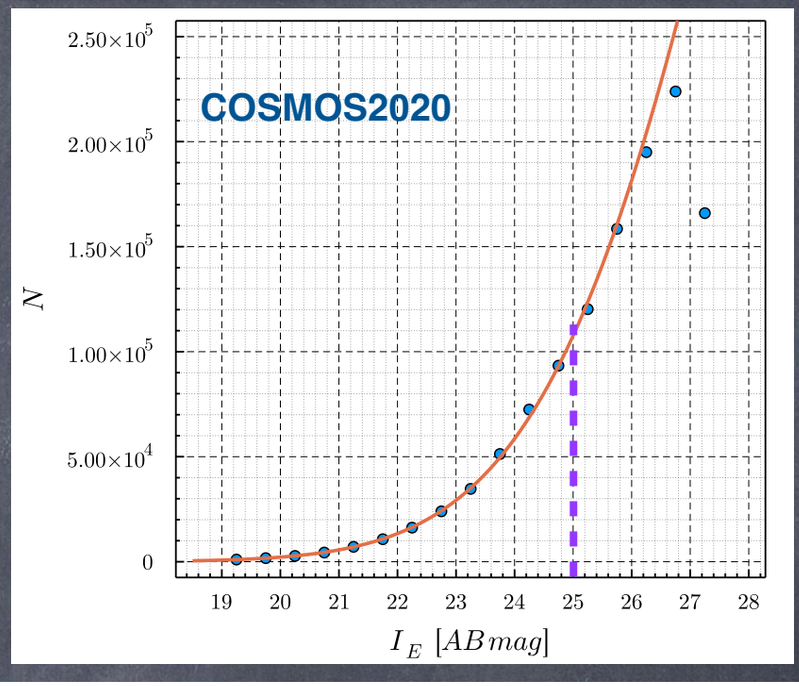
Survey status at MKP

Inputs: MOCD-A, CalF

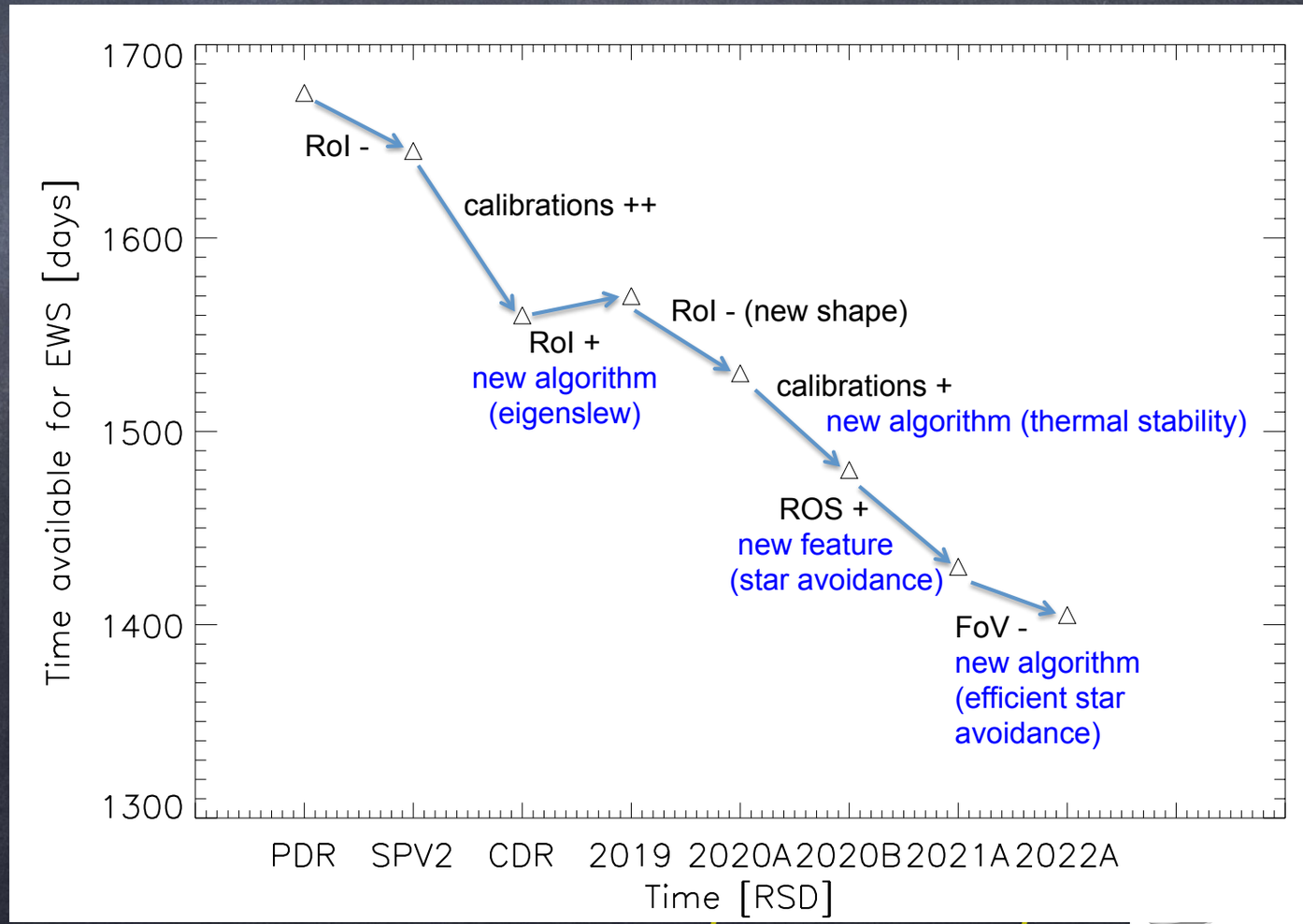
Verify in PV: SNR, number counts etc

We have a complex machine with solutions which are able to meet all constraints on:

- **SNR (use models for backgrounds)**
- **S/C angles**
- **dithers**
- **SOP time**
- **smooth changes of S/C attitude**
- **calibrations**
- **deep fields**
- **auxiliary fields**
- **96% of the wide (~14350 sq deg)**



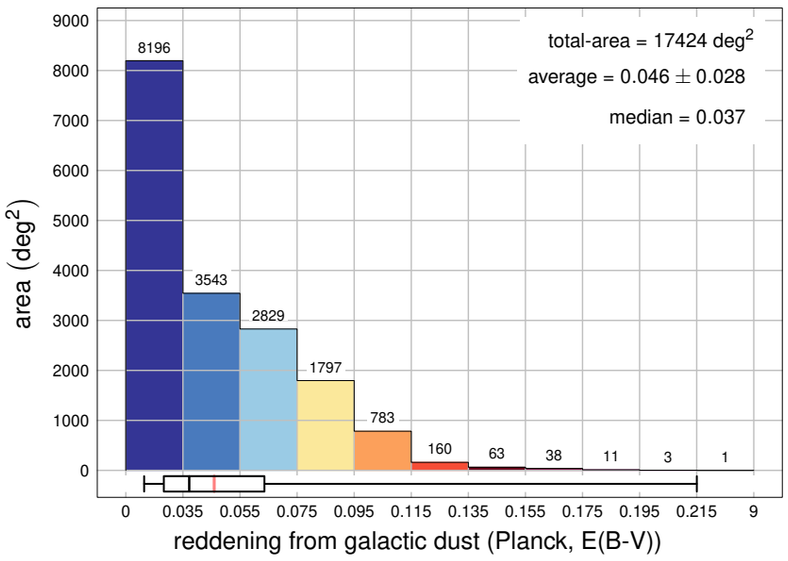
Over the years a large decrease in the time available for the wide: Δt = -9 mo ⇒ -2700η sq deg, η<1

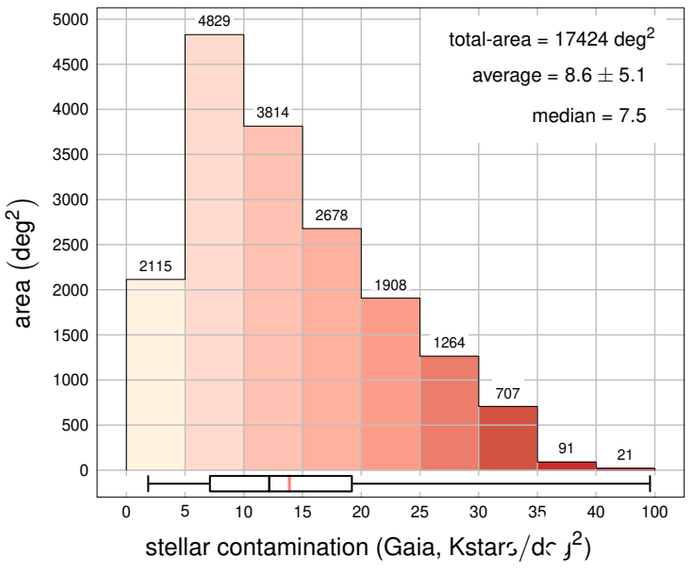


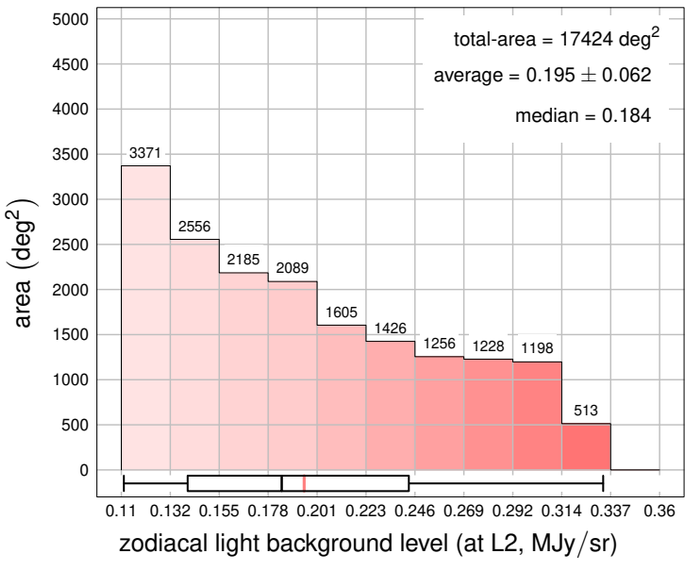
Background of the Region-Of-Interest

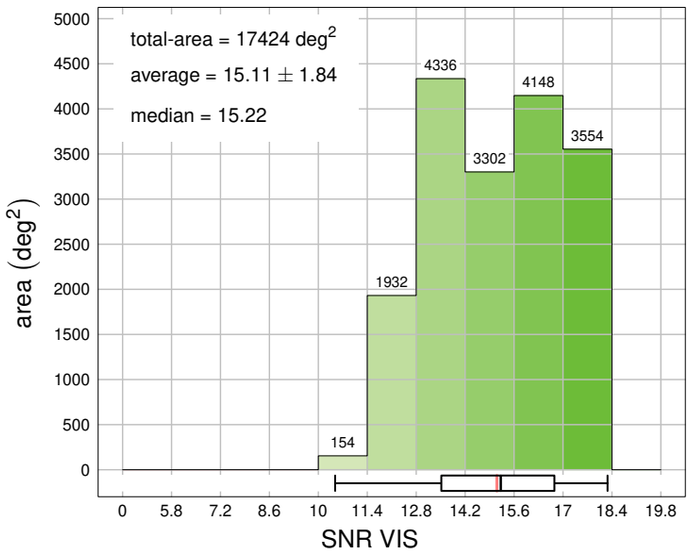
Full ROI

Latest System estimates









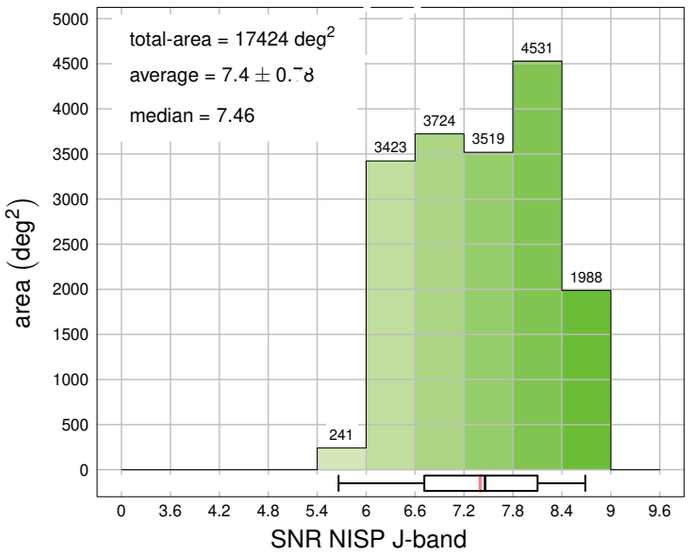


Table 7: SNR statistics for the RoI, for each channel: VIS band (boldface values refers to extended objects), NIR bands (Y, J, H, values refer to point like objects) and red grism band, S (italic values in the last column refer to 0.″5 diameter sources). The median depth here is evaluated for 5 σ point-like source.

	VIS	Y	J	H	S
Minimum SNR	**10.0**	5.0	5.7	5.7	*3.2*
Median SNR	**15.9**	6.5	7.8	7.2	*4.5*
Maximum SNR	**19.8**	7.8	9.0	8.5	*6.6*
Median depth [AB mag]	26.2	24.3	24.5	24.4	–

Better than required:
e.g. VIS on average is half mag deeper

10 is required

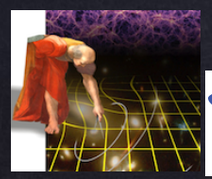
Avoid blinding stars (m<4)

standard tiling,
whole tile lost

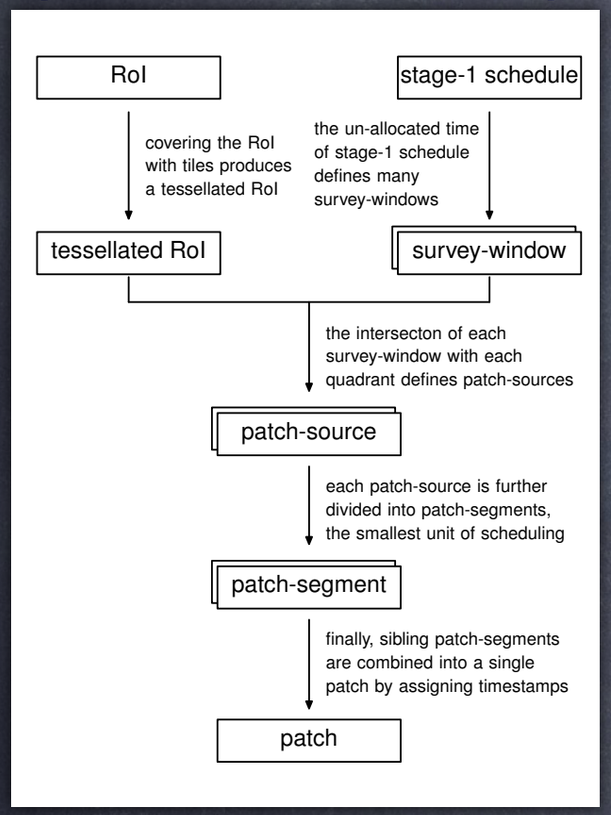
recall that dithering and
FOV are larger than a tile

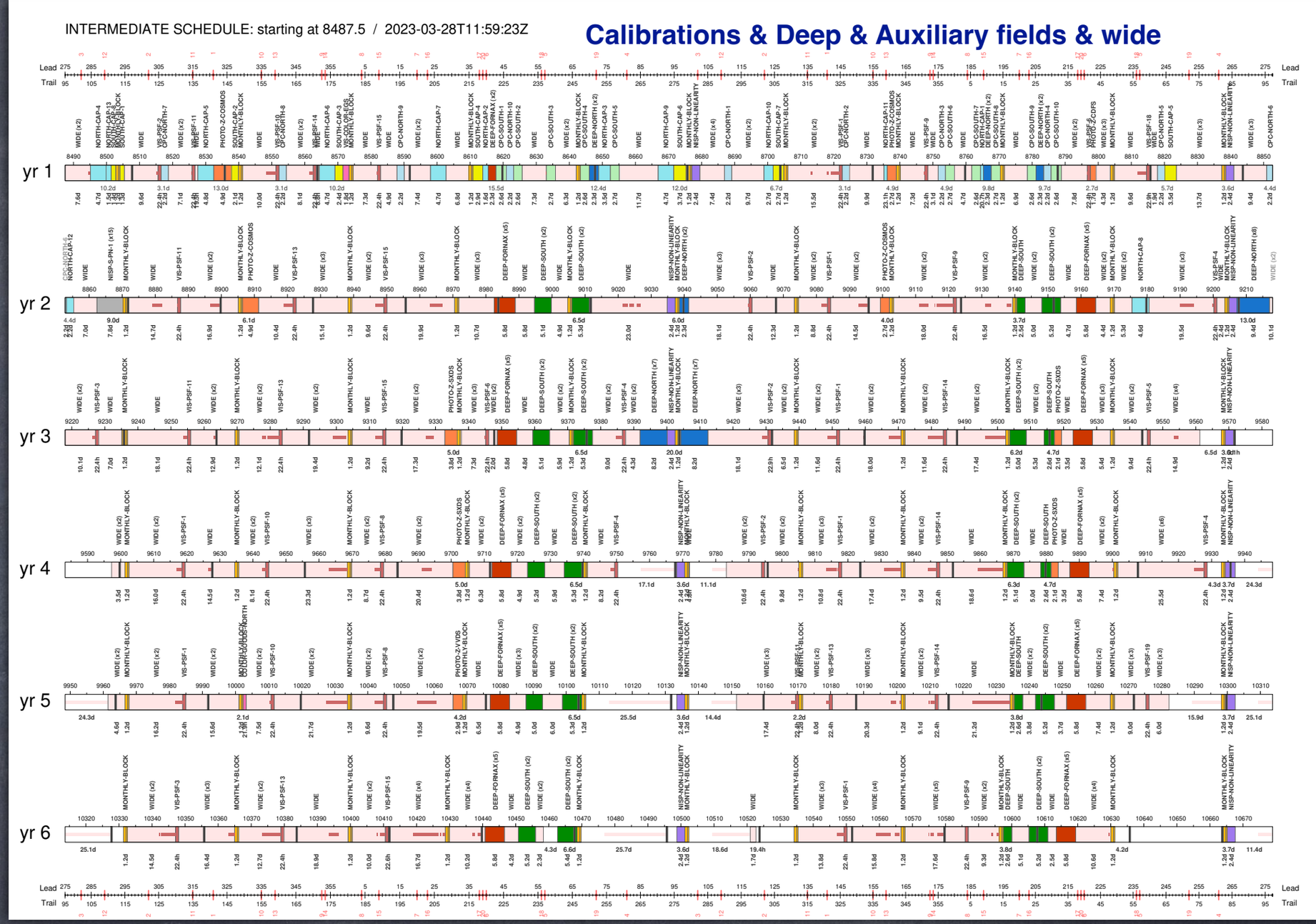
optimised tiling with
local overlaps and
recenter of tiles

J. Dinis



First optimise calibrations, + deep and auxiliary fields for sample characterisation then fill in wide (J. Dinis, I.Tereno)



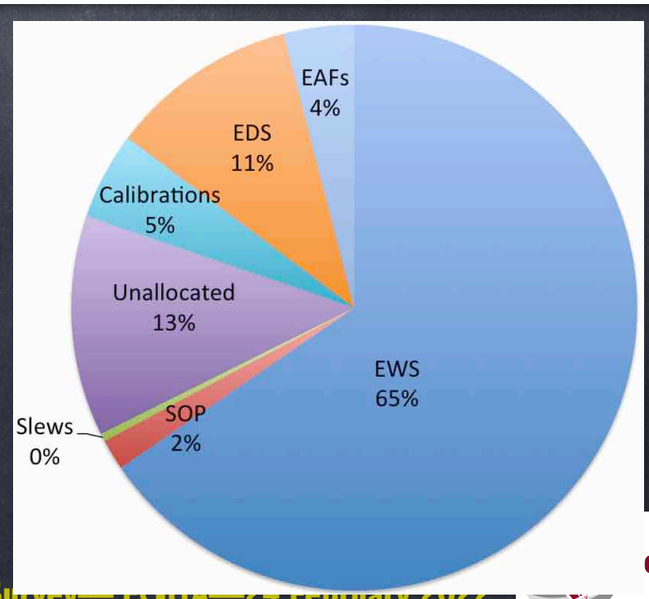


More work to do on PSF cadence, rest OK

time: 2/3 on wide survey, 1/3 on rest

time for

- **instrument calibrations: 5%**
- **Deep fields: 11%**
- **Auxiliary fields: 4%**
- **SOP: 2 %**
- **unallocated: 13%**

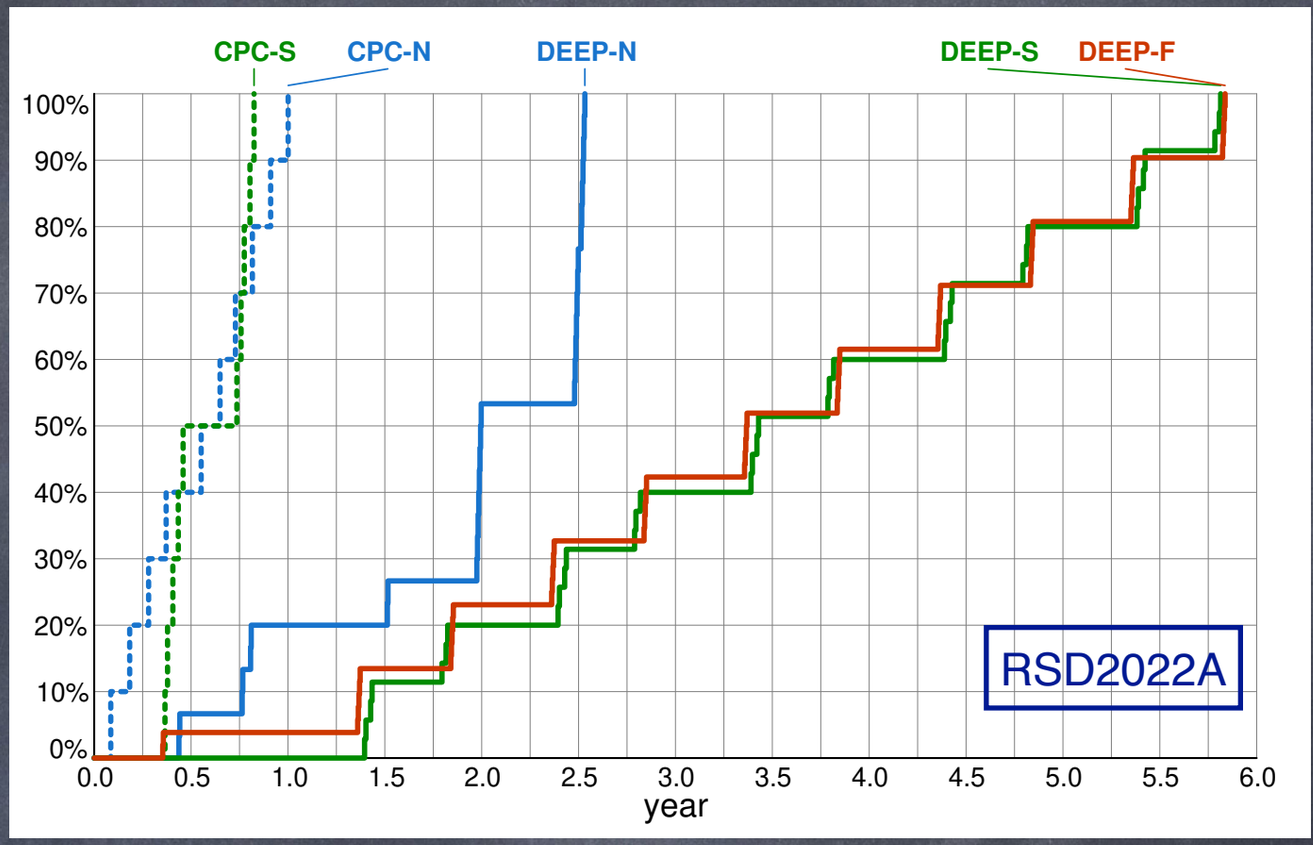


EDFs status

wanted depth: 2 mags deeper than average

(square deg x visits; number of latters will be increased to compensate for larger zodiacal background)

- EDFN (20 x 10 + inner 10 x 30) = (1/2) CPC + (1/4) DEEP; offset 1 deg from NEP; observed by Spitzer
- EDFF (10 x 40) = (1/4) DEEP; Fornax region; observed by Spitzer; Rubin drill field
- EDFS (23 x 40) = (1/2) CPC + (1/2) DEEP; observations done for Spitzer; Rubin optical coverage requested



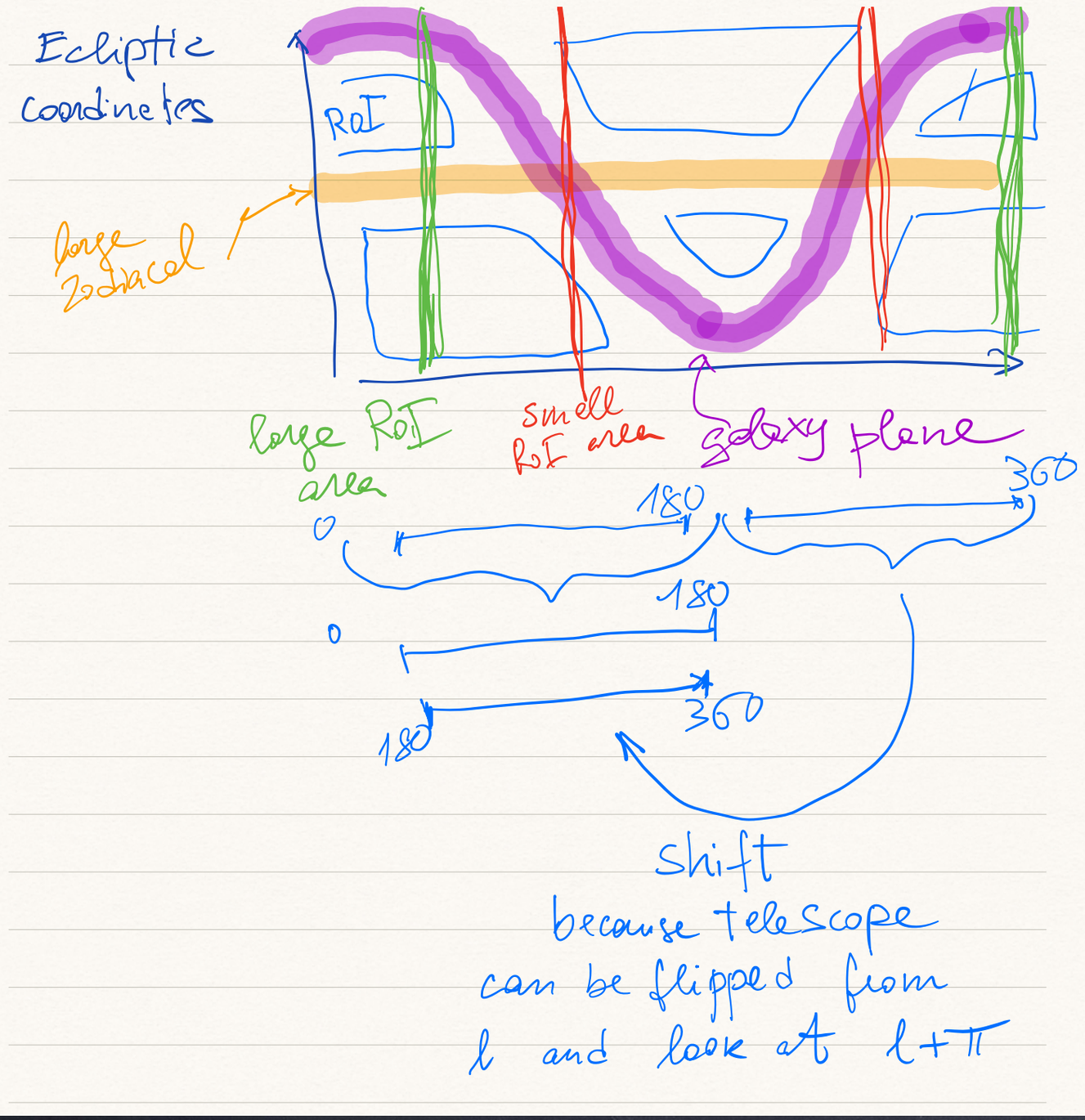
CPC visits are counted also as EDF visits

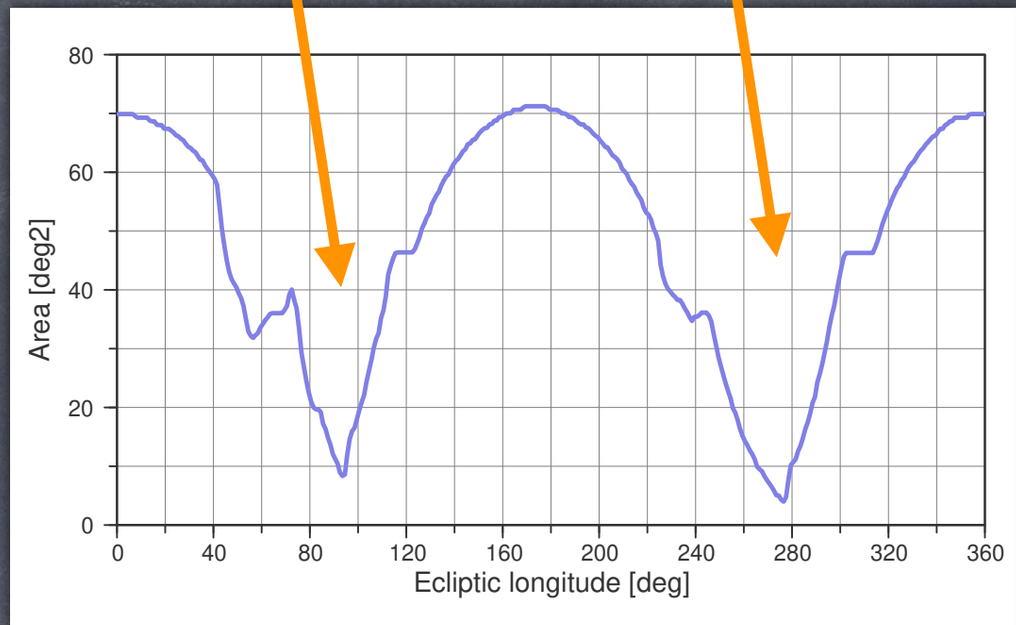
75% synergy between CPCs and EDFs

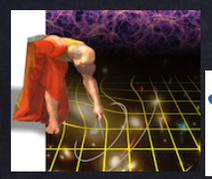
After one year can have 1 visit (all red spectra) on both CPC + EDF-F = 50 sq degs for Q1 release

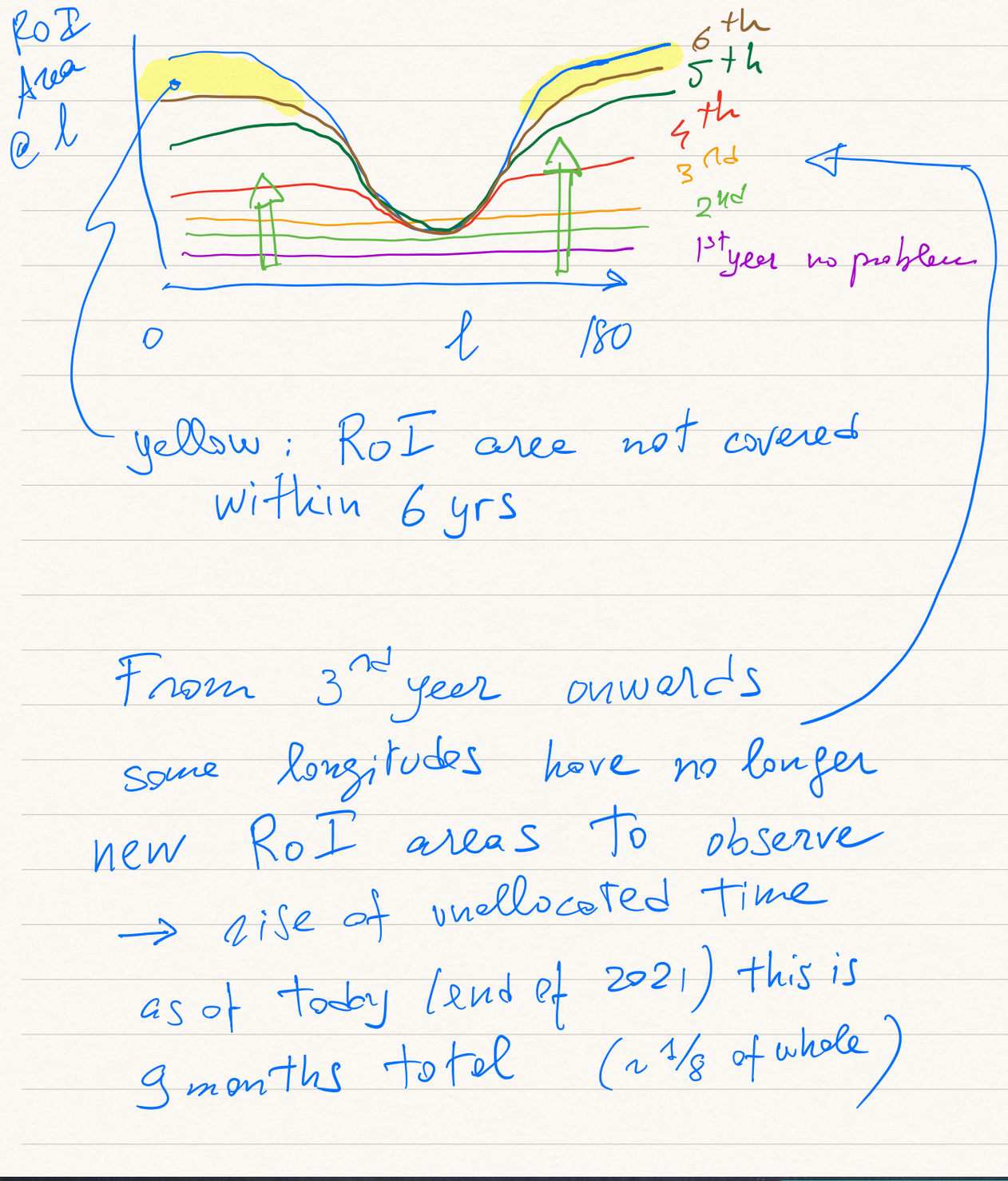
IF blue grism also needed for CPC (likely) then increase EDF-N to 20 sq deg [what if scenario #1: no harm to final wide area!!]

The rise of unallocated time, due to lack of RoI areas at given longitudes

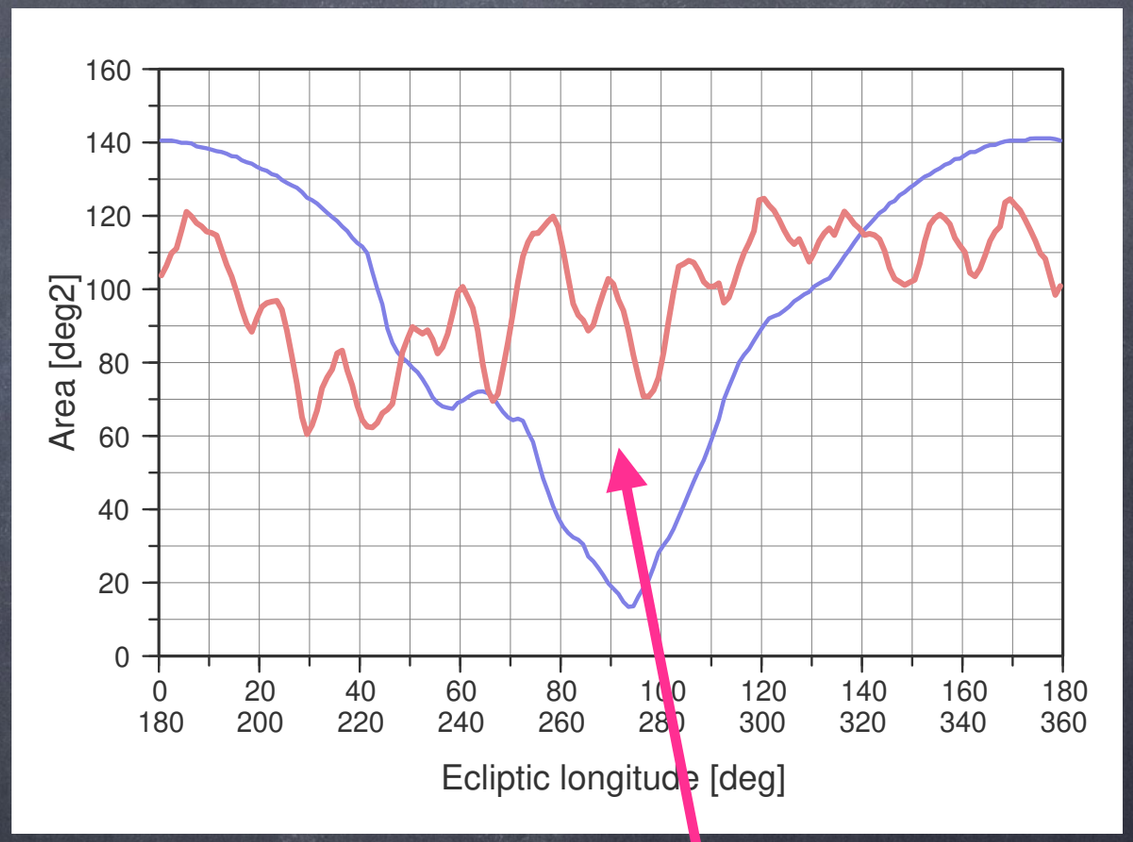








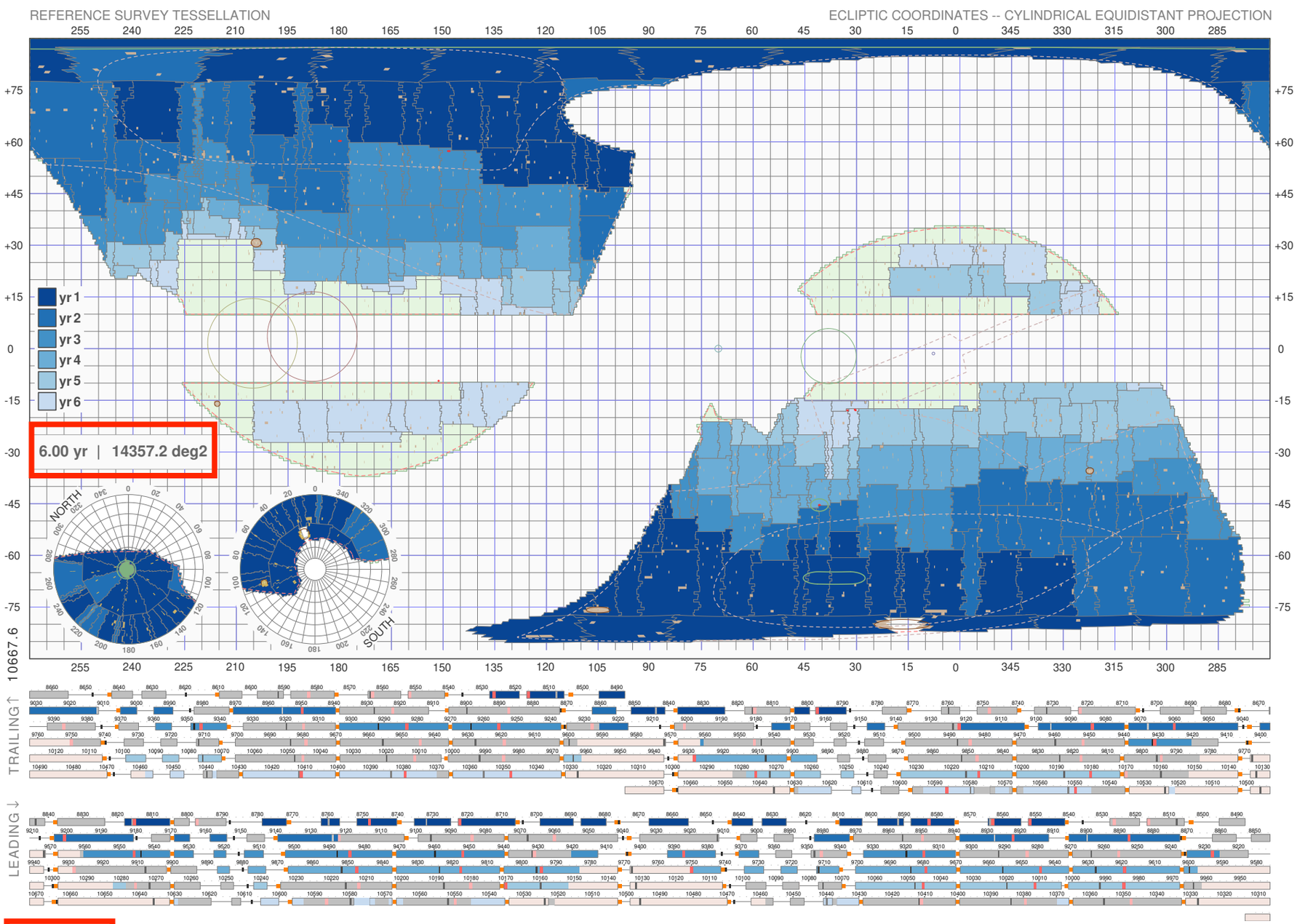
blue line: folded RoI area for longitude
red line: wide area that could be observed

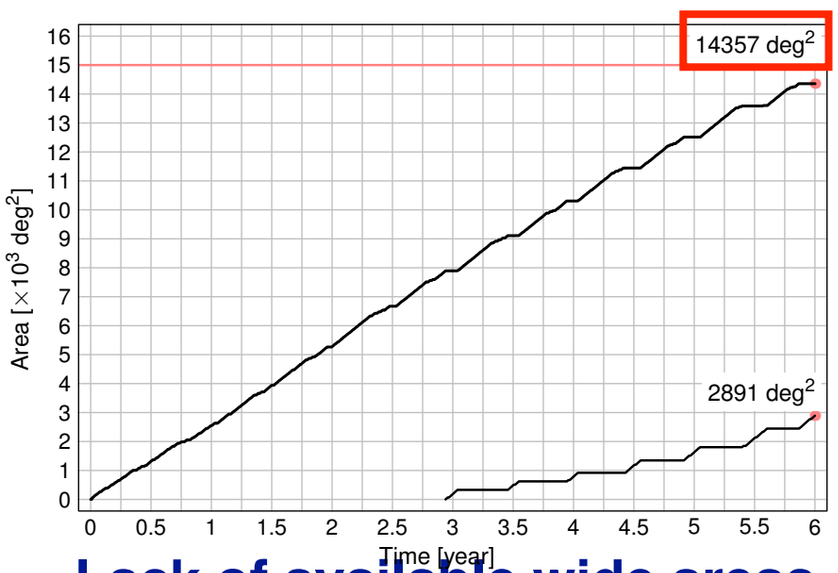


when the red line is above the blue line one can no longer allocate remaining time on the wide because lack of new areas to observe

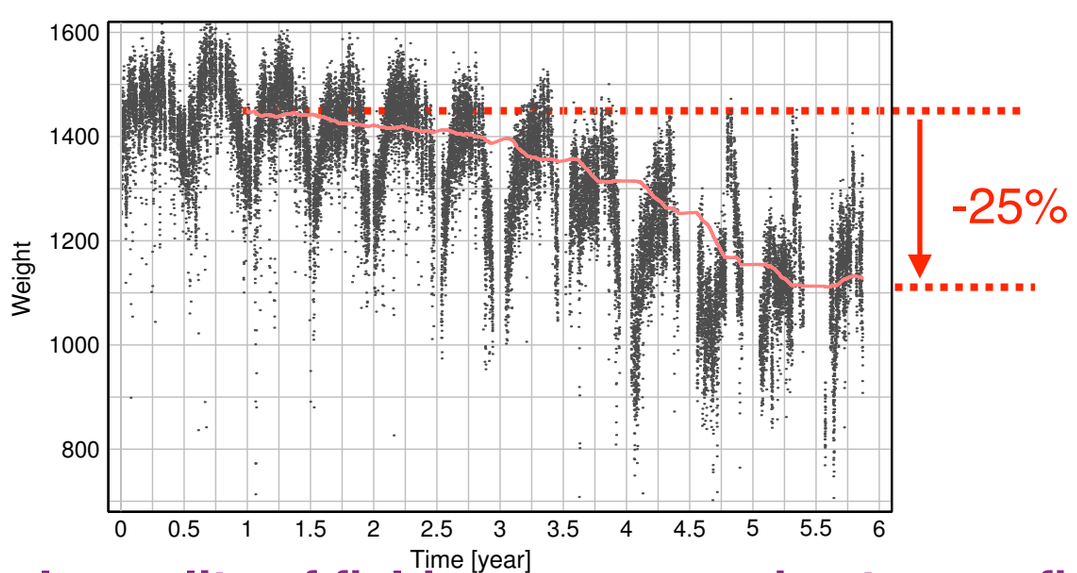
RSD 2022A

now cover 96% of target wide area; OK if for 15,000 sq deg the expected FoM > 418





Lack of available wide areas ~9.5 months to be allocated



yearly quality of fields: on average best areas first

Figure of Merit ∝ wide Area

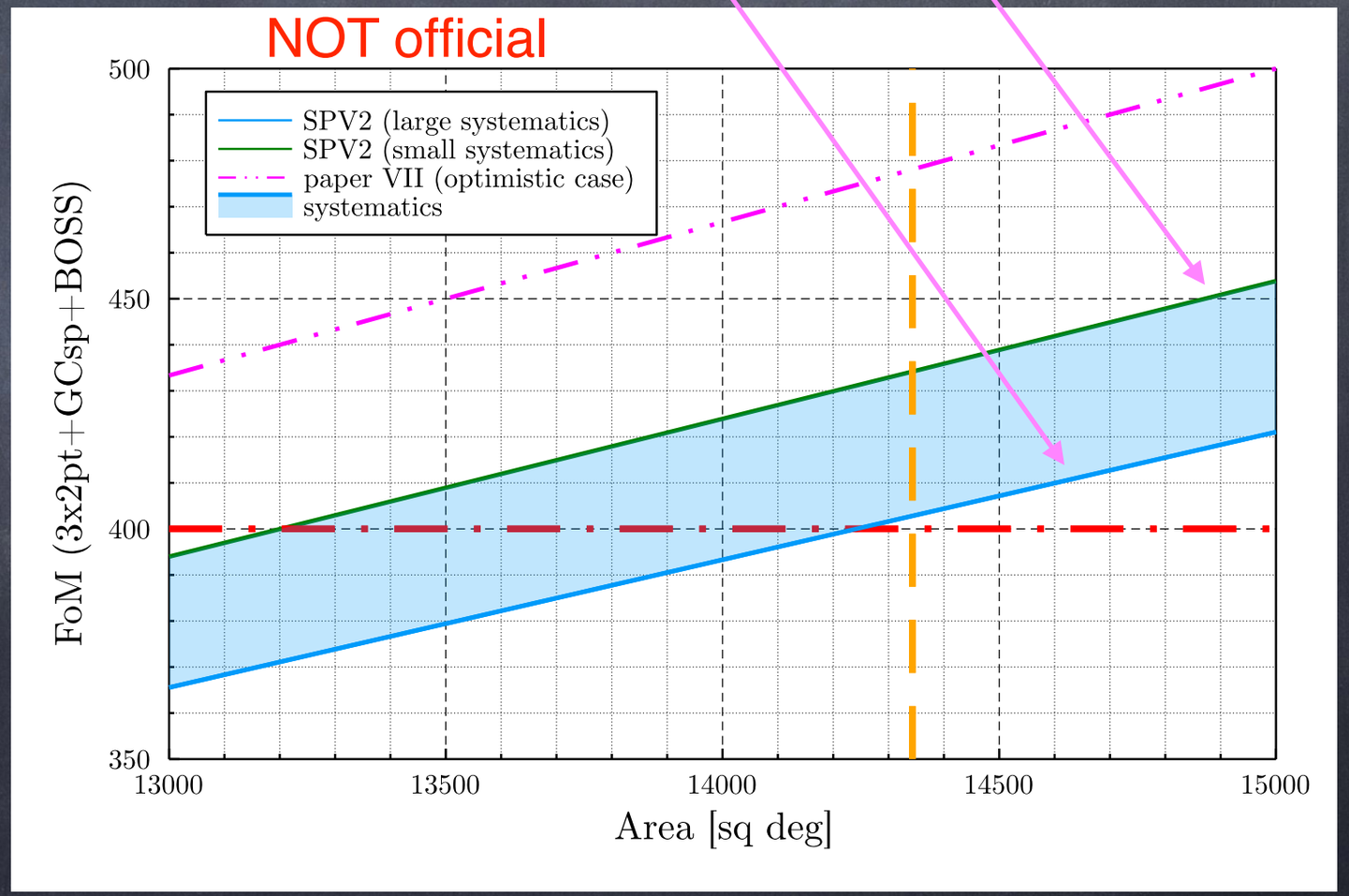
More than 10 years ago:
Figure of Merit ~ 400 ⇨ wide Area 15,000 sq deg

Since:

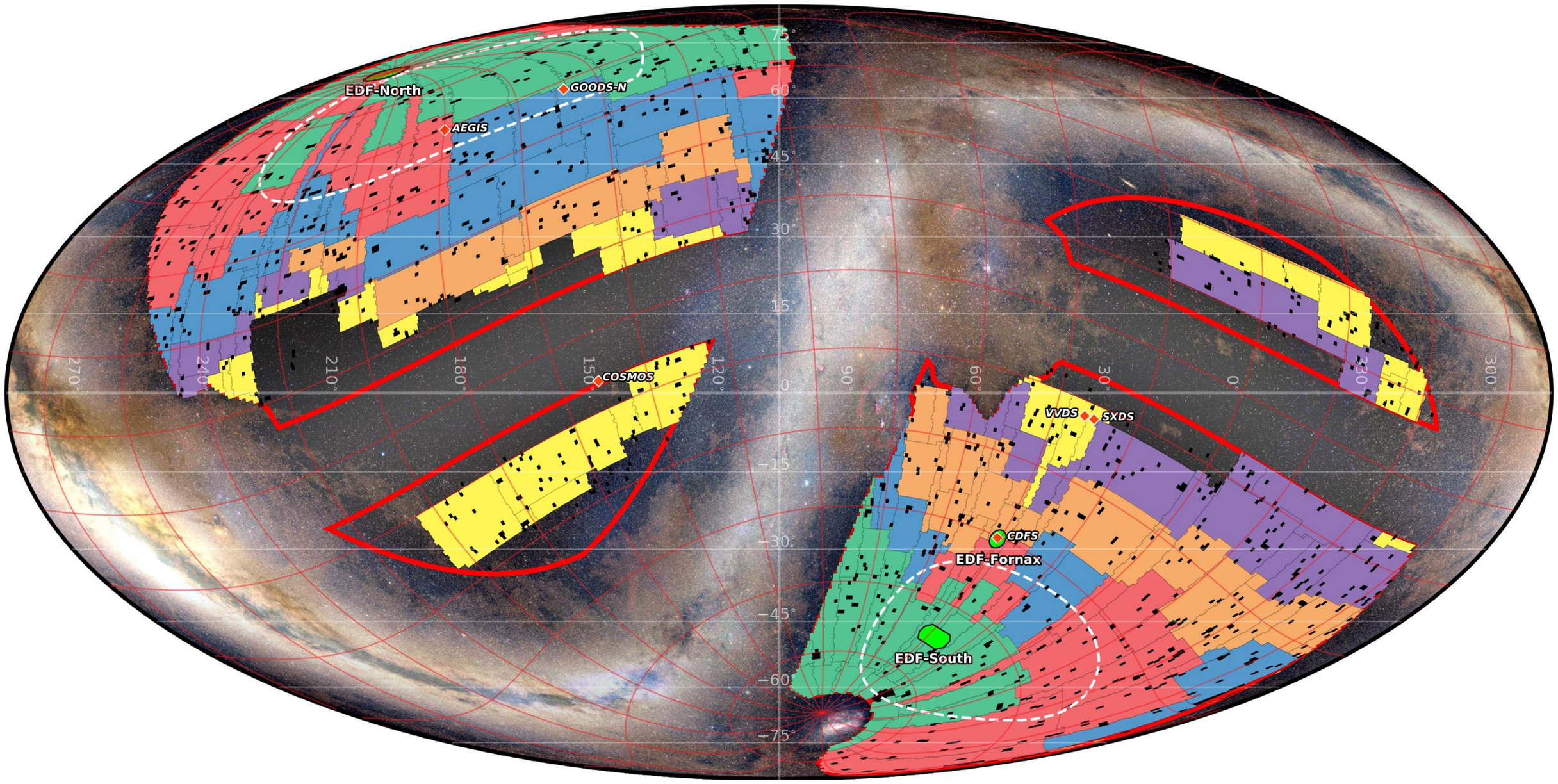
- **better theory and Xcorrs increase the FoM**
- **to consider systematic effects (very difficult) decreases the FoM**

To cover 96% of that area is a problem? Maybe…

⇛ **wait for SPV3 !!**



Carbone, Cardone, Sapone



RSD 2022a ECTile realization of a Euclid Wide Survey within the 17 Kdeg.^{2} RoI : 14,357 deg.^{2} over 6 years in 251 patches

Euclid Region of Interest (RoI) : 17 Kdeg.^{2} core science compliant, with 795 blinding spots skipped [black dots]

Best 1300 deg.^{2} (white) SNR areas per galactic cap

Euclid Deep Fields (EDF, from north to south): 10+10+23 deg.^{2}

Euclid Wide Survey chronology (2.5Kdeg.^{2}/yr)

Year1 Year2 Year3 Year4 Year5 Year6

Background image: Euclid Consortium / Planck Collaboration / A. Mellinger

RSD_2022A, several changes in inputs implemented

best areas covered timely for the two data releases

What if scenarios: perturb 2022A

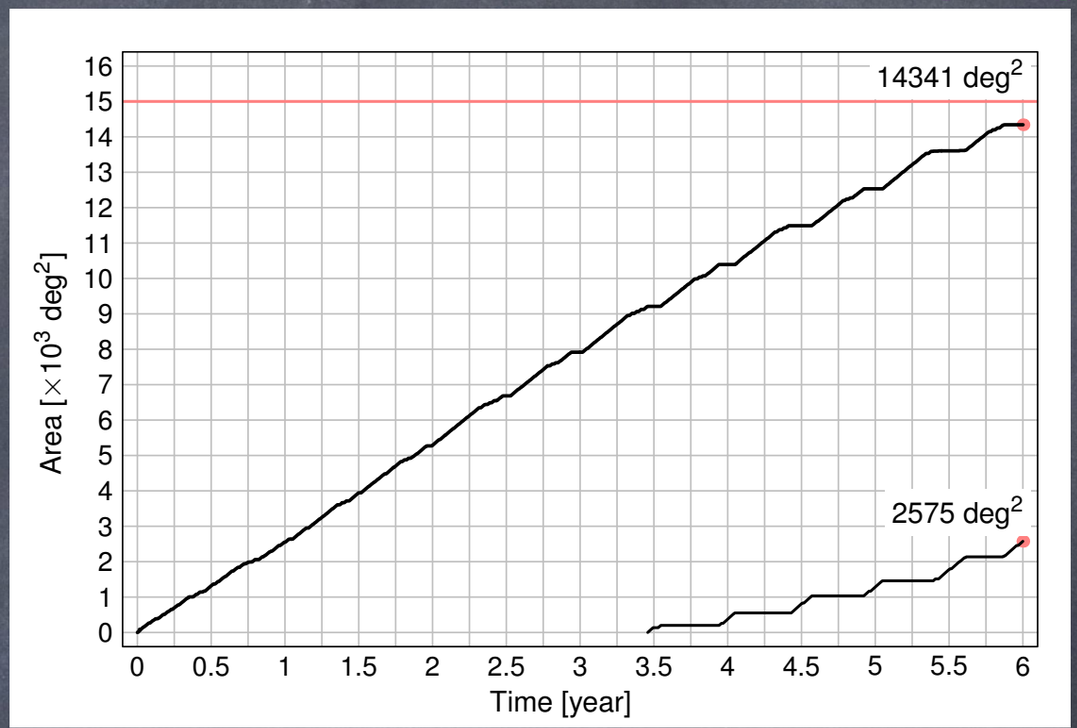
Idea: synchronise ad "hoc" non recurrent long calibrations (decontaminations +- if - PDC) in those days ≃ Δl which will give rise to unallocated periods.

In practice delay completion of RoI(l') but keep total area the same.

This will leave less "free" time for community non core proposals

⇒ but core mission has priority so it's ok

WIF #1: extend EDF-N to 20sq deg



WIF #1 excellent result: same wide area, use of unallocated time only (1 mo); likely the new reference

WIF #2: add 3 decontamination periods of 25 days (year 1, 3, 5) during inefficient longitudes (=in unallocated time)

WIF #3: add 3 decontamination periods of 25 days (year 1, 3, 5) during efficient longitudes (=max damage)

Proposal to the EST to extend the EDF-N area to cover the CPC-N using unallocated periods

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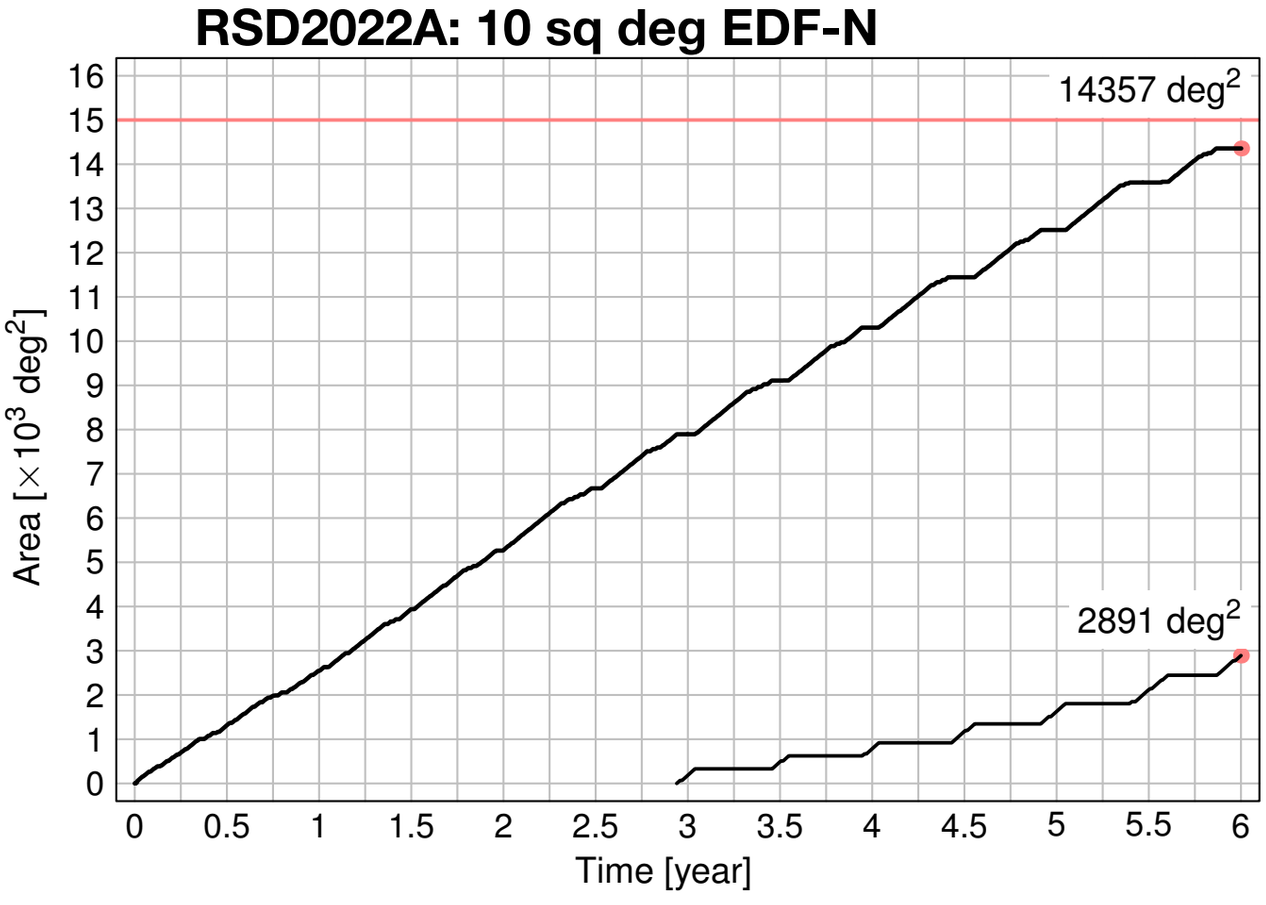
ON HOLD

(with contributions from ECSURV, CALWG, SWGs ubercoords, ILS, blue grism group)

Summary

The present baseline for the Euclid core mission foresees to cover a wide survey (greater than 15,000 square degrees extra-galactic sky) observed at least once, plus a minimum of 40 square degrees of deep survey subdivided in two or more fields in separated hemispheres (currently 3 fields), visited several times. Because of the many severe pointing constraints, during the core mission there are several periods (currently for a total of ~10 months) in which one cannot observe areas which are good enough for the wide survey, corresponding to what is called "unallocated" (yet) time.

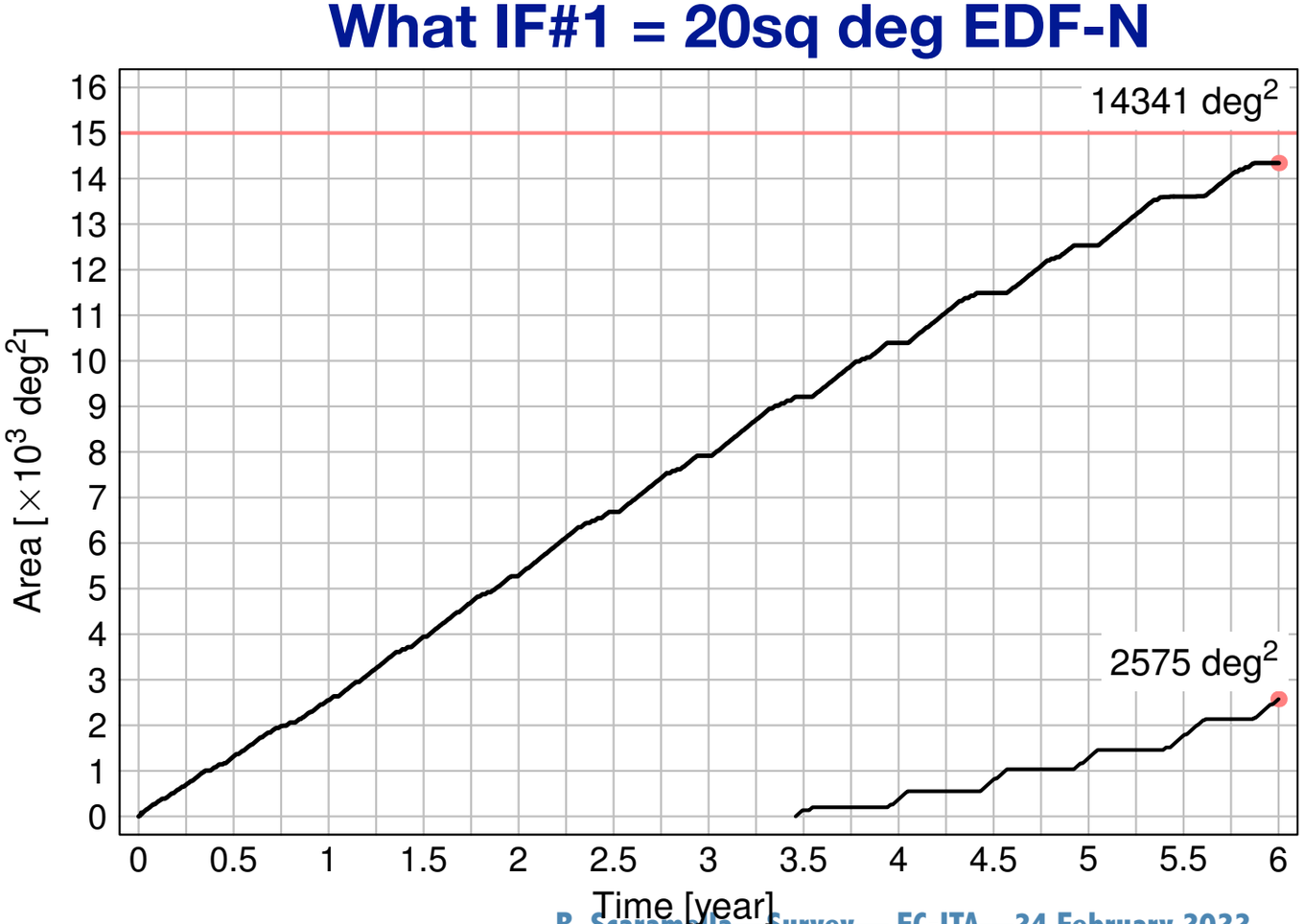
An excellent use of 1 month of that time, a mere 10%, would be to observe the always visible NEP region, extending the EDF-N (actually planned to be 10 square degree) to the same area of the co-centered CPC-N (20 square degrees). This increase in size for the EDF-N is fully within the scope and mandate of the main mission and is highly beneficial for both the core and the legacy science. Especially, it doubles the area covered by the blue grism in the NEP region, allowing full rather than partial coverage of the CPC with the blue grism. Moreover, because this proposed enlargement would use exactly the same standard modes of operations, pointing etc as in the core mission, there is no negative impact on the satellite, nor on operations, nor on the total wide area that can be observed.



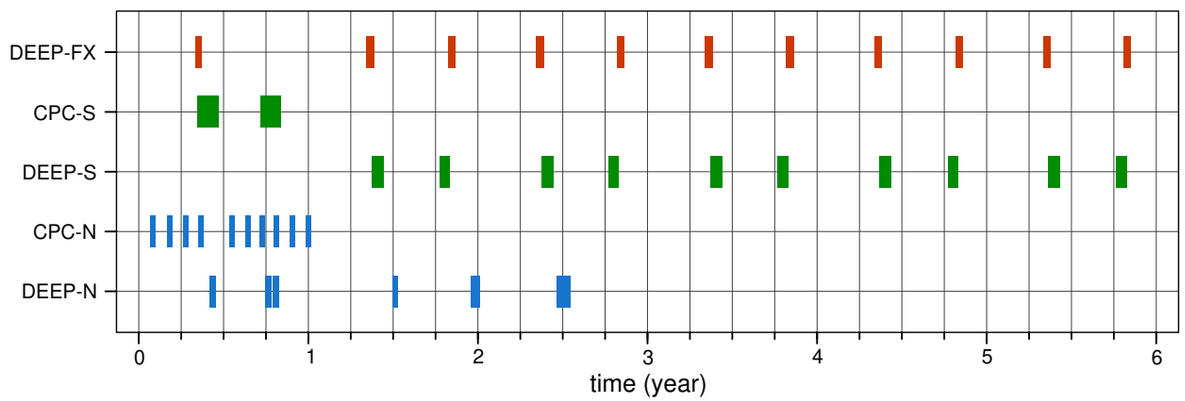
EDF-N —> 20 sqdeg allows the whole CPC to have blue grism observations

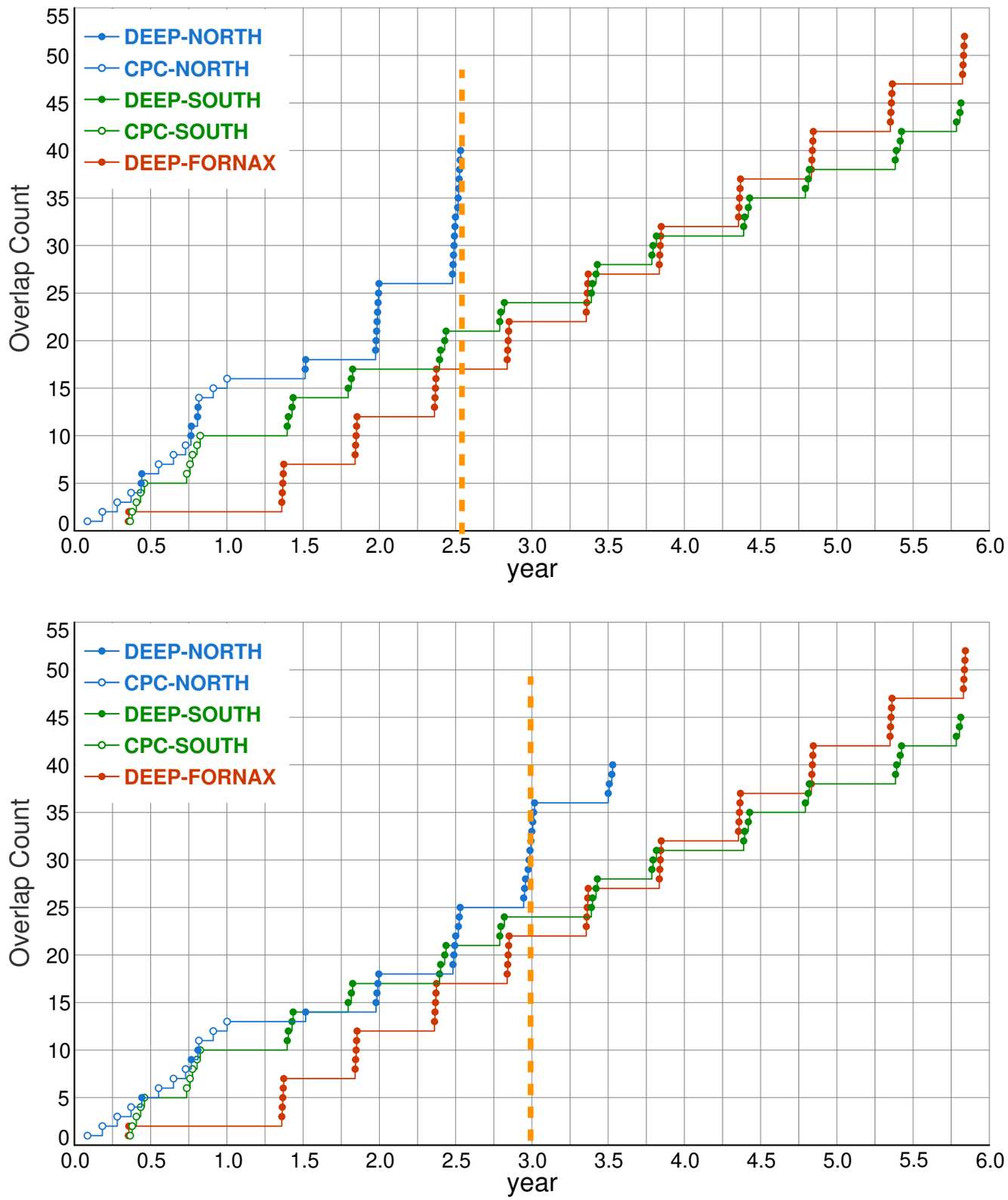
The needed ΔT is completely filled by otherwise unallocated time

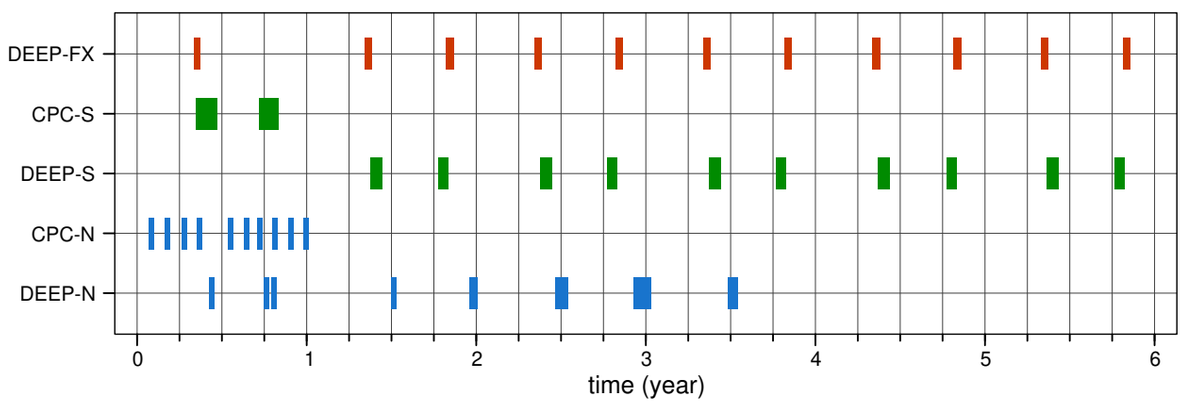
Likely the new reference



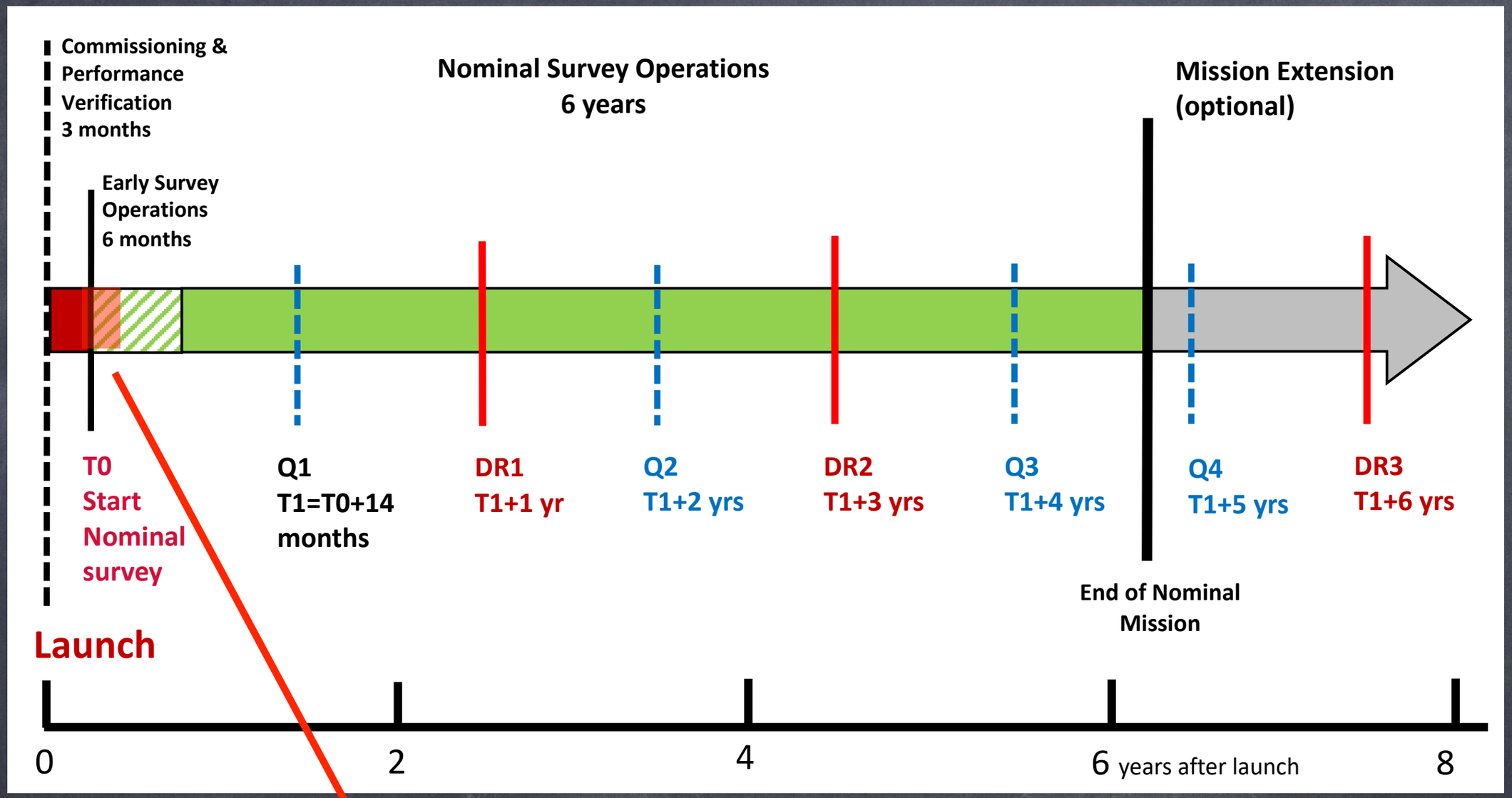
Cadence of the EDFs in the two cases







An additional complication



The actual survey (wide & deep & auxiliary fields) might need to start later than the end of PV phase so to complete the first Phase Diversity Calibration [needed Δt still TBC].
This is mandatory for the full PSF characterisation needed by the WL.
This late start for std operations would negatively impact the final area.