(AstroSat Calibration Meeting, IUCAA, Aug-2022)

Relative orientations of the detector-axes

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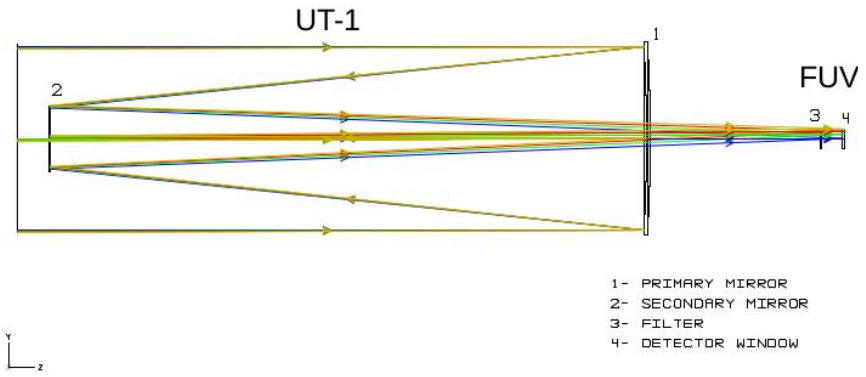
To remind :

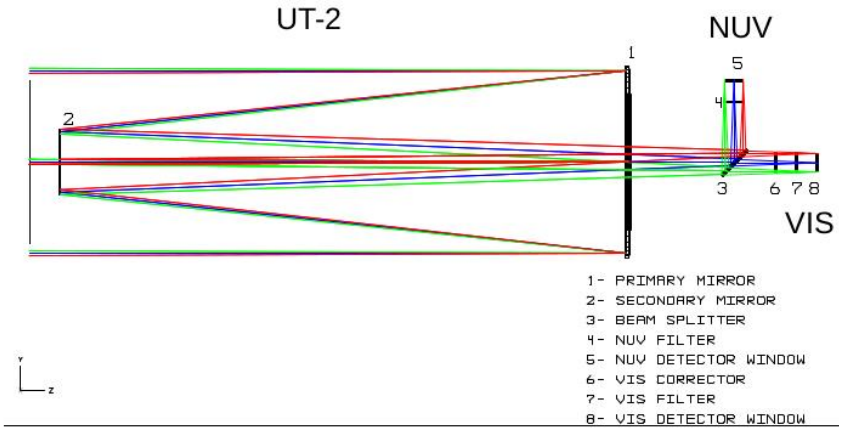
Schematic configuration of the 3 channels (FUV / NUV / VIS) of UVIT

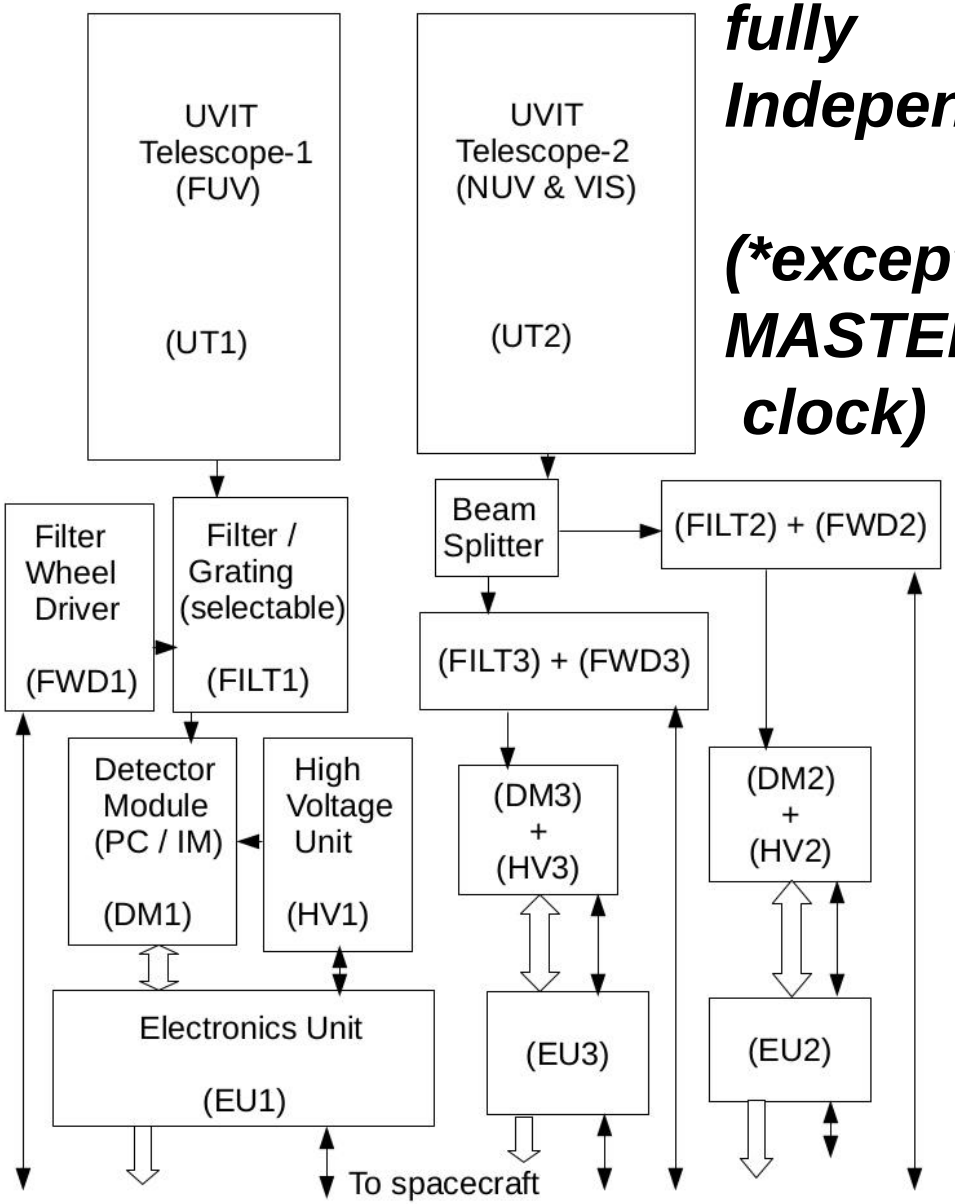
Channels fully Independent*

(*except MASTER clock)

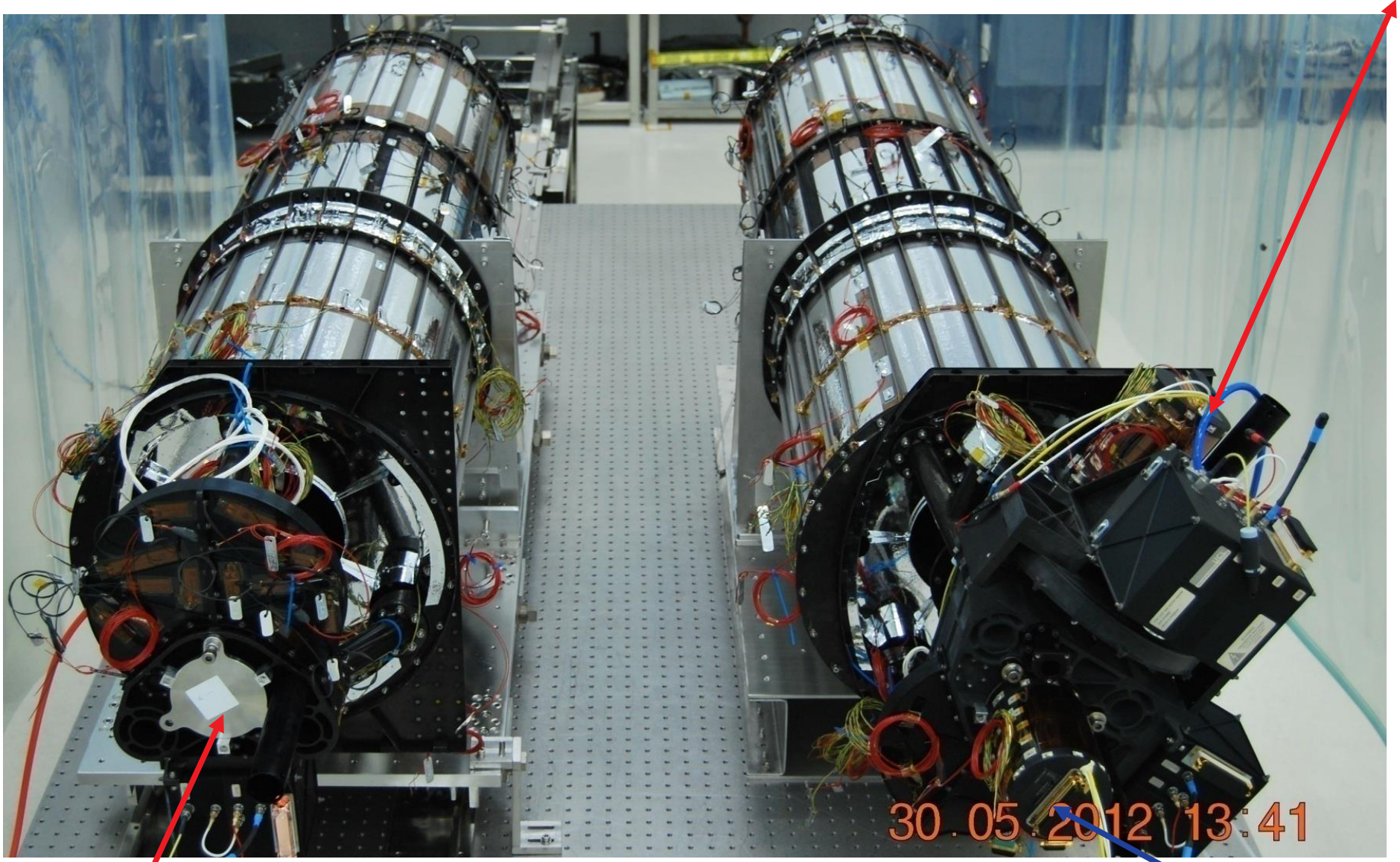
Optics





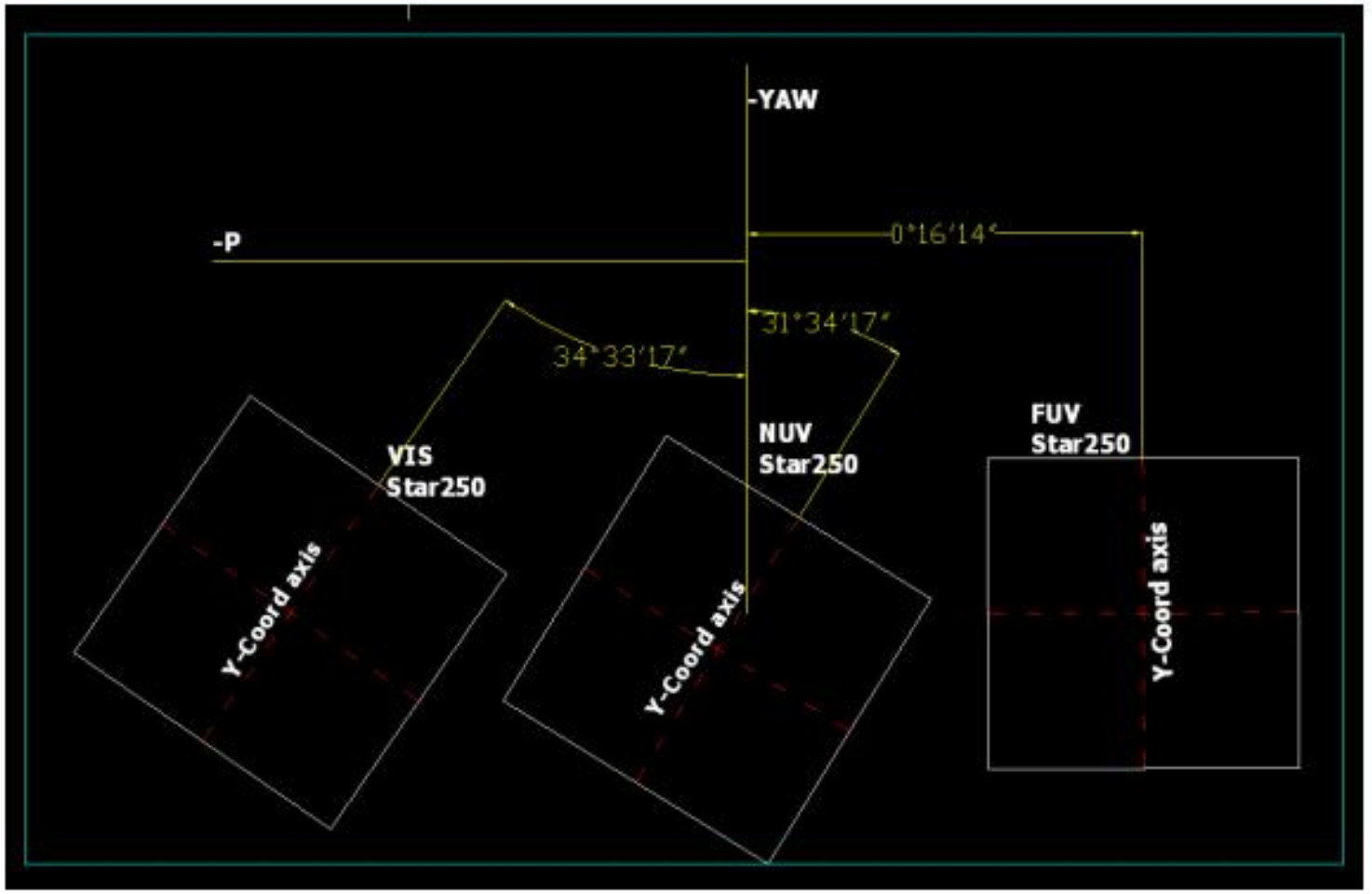


Locations of the Detectors -



Projected orientations of the UVIT detectors on sky (with reference to spacecraft axes)

The 3 Detectors of UVIT (X-Y axes for FUV, NUV & VIS) are NOT aligned parallel to each other, but subtend *NOMINALLY fixed relative angles* between them as per their mechanical mountings on the spacecraft structure



Need for knowledge about 'Relative orientation'

- ***Instantaneous orientation of individual Detector's axes (as projected) on sky needed to transform to astronomical coordinate system***
  (UV photon centroid measured in X-Y system of electronic sensor => RA-Dec);
- ***these angles are time dependent***
  (depend on spacecraft's ROLL angle, which undergoes slow systematic changes & disturbances / jitter);
- **Spacecraft's instantaneous aspect (Roll_ROT, Roll_RA, Roll_DEC) info need further refinement *(=> through Astrometry)*;**

- **nominal drift tracking is carried out using VIS images,**
  => hence need RELATIVE angles (VIS-NUV, VIS-FUV) of orientation to translate & apply drift corrections to respective UV channels;

To retain option of *drift tracking using selected UV channel*,

Level-2 pipeline used a modular design to implement this functionality :

=> Use of nominal spacecraft coordinate system (ROLL, YAW, PITCH : R-Y-P) as intermediary

[drift-tracking-channel's "X-Y-theta" => "R-Y-P" (VIS / NUV / FUV)

"R-Y-P" => science-UV-channel's "X-Y-theta"] (NUV / FUV)

Implemented using a set of three 2x2 rotation matrices : 'RPY_TO_XYTHETA_FUV', 'RPY_TO_XYTHETA_NUV' & 'RPY_TO_XYTHETA_VIS' & their inverses;

[In addition, Plate Scales of individual channels are needed.]

Corresponding directly observables equations connecting X-Y of channels :

e.g.

$$dX\_FUV = -0.85093 * dX\_VIS + 0.56645 * dY\_VIS$$

$$dY\_FUV = 0.56645 * dX\_VIS - 0.85093 * dY\_VIS$$

... etc

Calibration corresponding to Relative Time Alignment of channels :

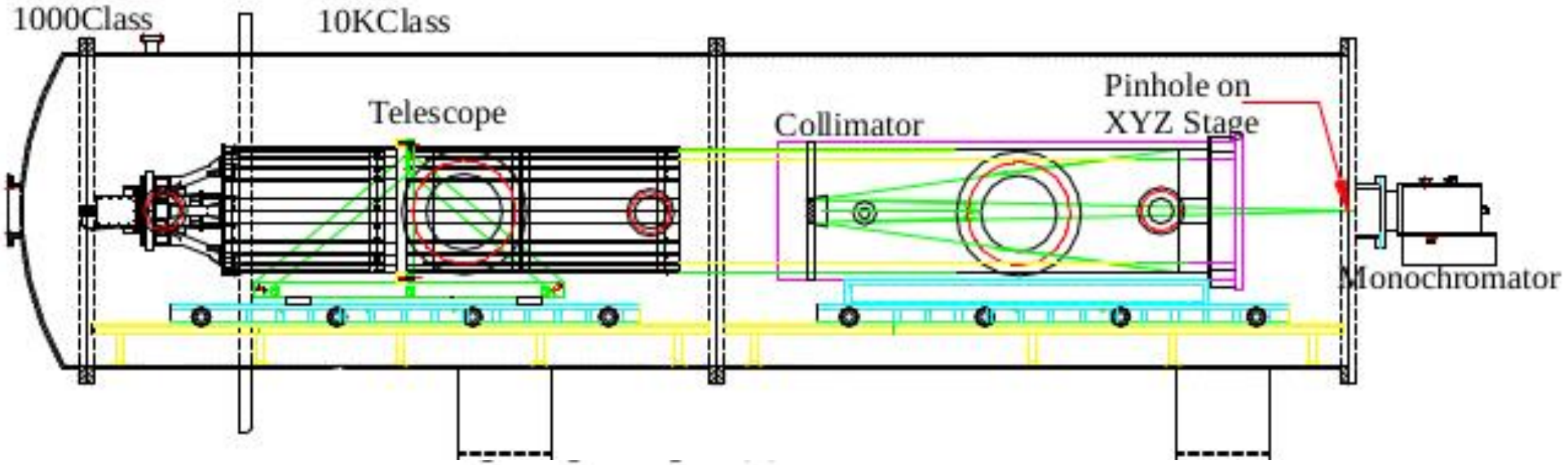
- **extracted drift is a time series which is interpolated to the time grid of UV frames for applying corrections;**

- **despite use of a single MASTER CLOCK for all channels, systematic relative time shifts get introduced due to scheme of on board time stamping of frames**

[depend only on selected frame Read Out Rates & Stacking option]

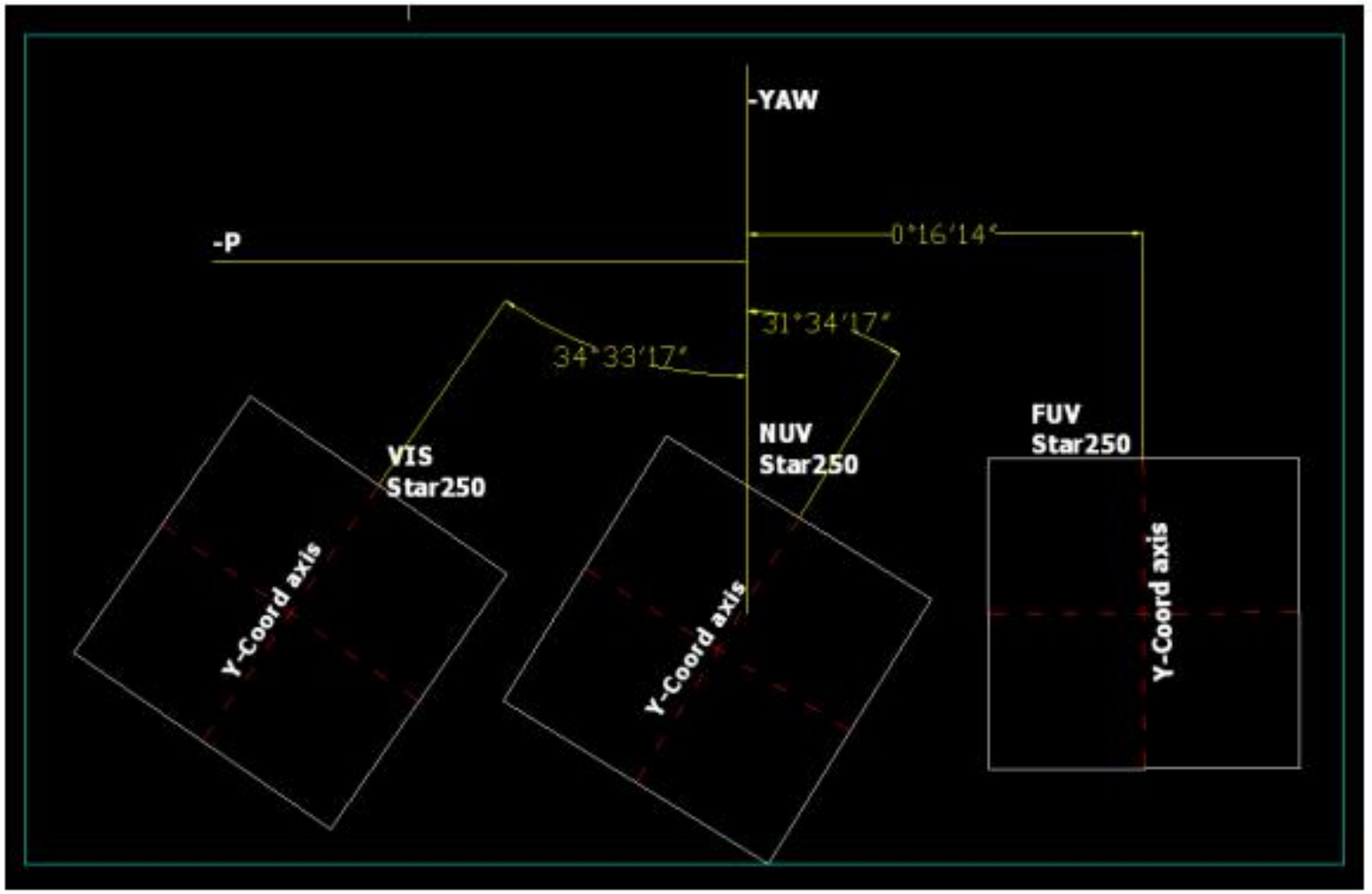
A) Calibrations from measurements carried out on ground

Lab test setup for finding orientation of Detector axes & Plate Scale



Telescope-Filter	Movement of spot in Pixels per arcsec of rotation				Plate sale on Yaw (arc Sec/Pixel)	Plate sale on Pitch (arc Sec/Pixel)
	On Yaw		On Pitch			
	X-Pix	Y-Pix	X-Pix	Y-Pix		
FUV- Caf2	0.002	0.2996	0.2997	0.0001	3.34	3.34
NUV-Silica	0.1571	-0.2554	0.2554	0.1586	3.34	3.33
NUV-B15	0.1567	-0.2546	0.2540	0.1577	3.34	3.34
VIS-Bk7	0.1719	0.2494	0.2500	- 0.1675	3.30	3.32

Orientation of Detector axes vis-a-vis Spacecraft system



Angle accuracy targeted in lab : < 30 arc-min ;
Actual difference with final In-Orbit values < 20 arc-min

Plate Scale accuracy achieved in lab : ~ 0.3%

B) In-orbit measurements during Performance Verification (PV) phase

- distribution of X / Y centroids for selected UV bright stars;

- final processed image quality (FWHM of PSF) across FoV (parameters tweaked following an iterative scheme)

Final angles between +Y axis of Detector with respect to Spacecraft -YAW (CCW +ve) :

FUV : +0.483 deg.; NUV : +31.515 deg.; VIS : +34.134 deg.

Activities currently in progress :

Goals -

- improvements in Absolute Aspect of Image products
  (for each individual Episode & final combined
  multi-Episode products)
- near 100% Images with Astrometric corrections
- improved precision of Astrometry

- near 100% success in combining multiple Episodes for
  all sky fields
  (beneficial for faint fields devoid of brighter UV stars)

Utility for other Instruments (e.g. SXT) -

- time series with very precise (< 1 arc-sec) spacecraft aspect
  (R-Y-P)
  (converting shifts in RYP to SXT's CCD axes;
  stacking CCD frames; ...)

WHAT IS NEW ?

Important change of strategy :

- use optical stars from drift corrected stacked VIS image for each Episode (instead of currently used detected UV stars)

for :

i) aligning individual Episodes for multi-Episode products

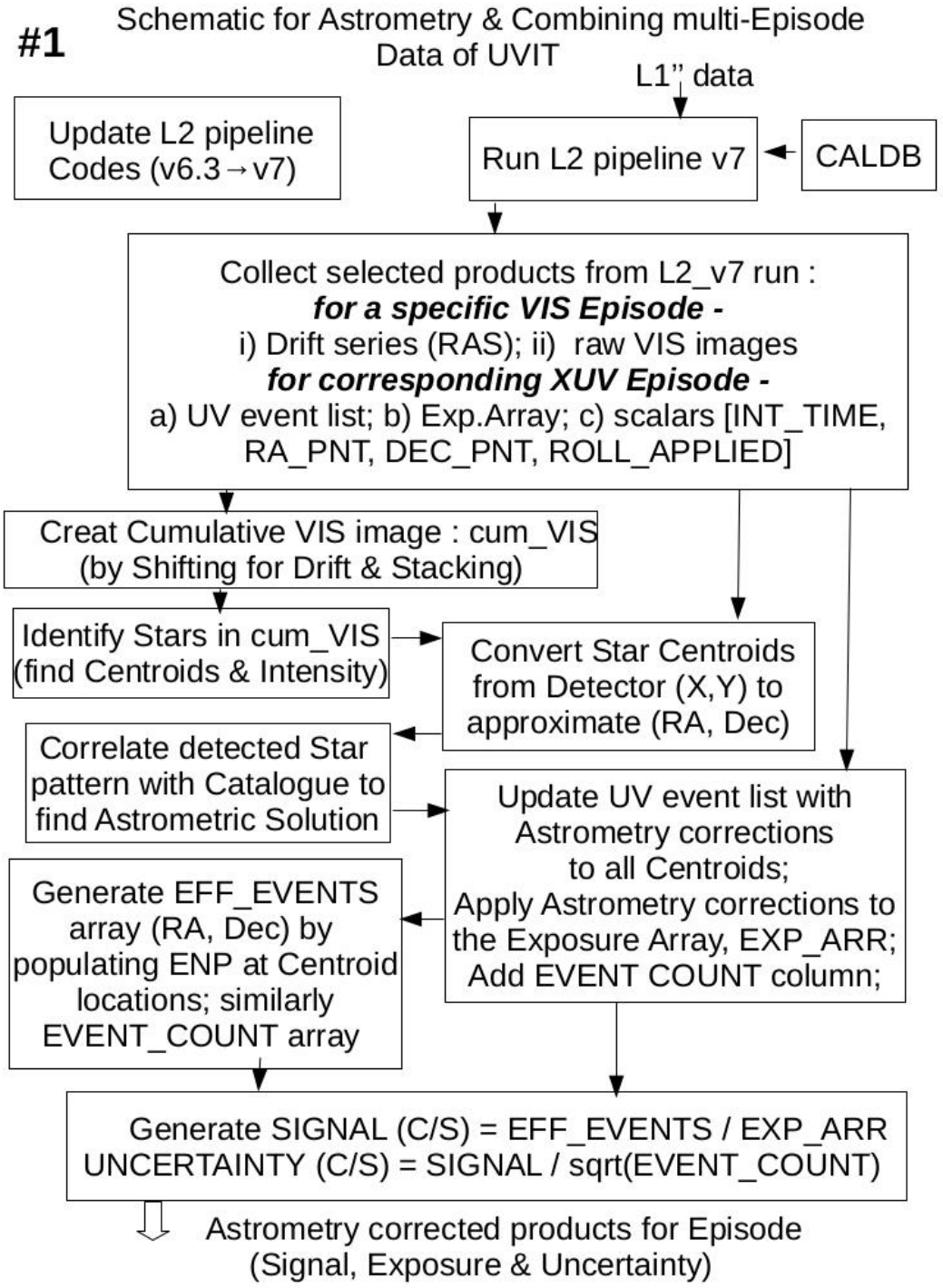
ii) final Astrometry

Implementation -

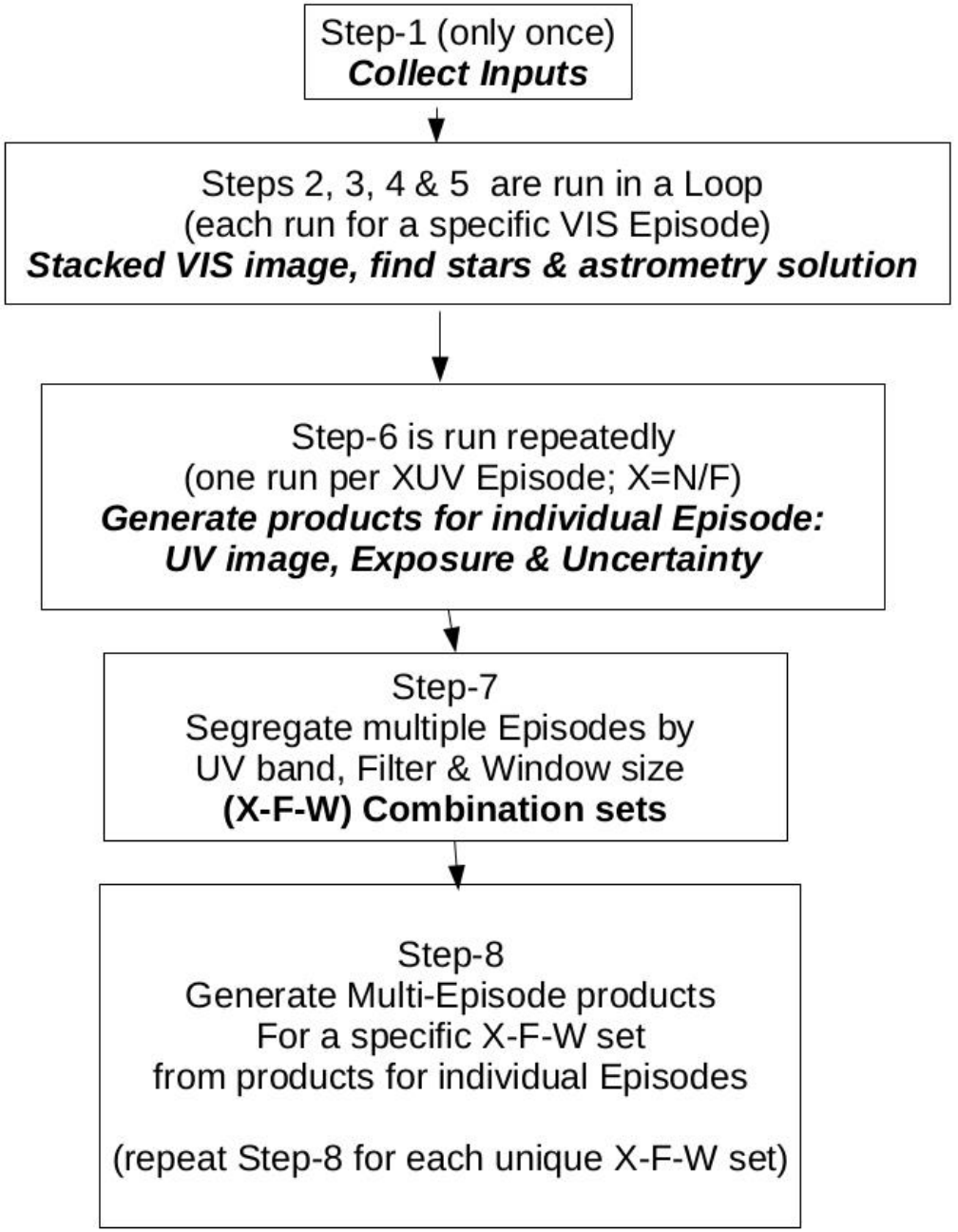
- Utilize currently available products & by-products from the L2 pipeline (with latest upgrades to address some 'weakness'-es discovered more recently; "v7")

- Develop fresh software

#1


Schematic for Astrometry & Combining multi-Episode Data of UVIT
L1" data
Update L2 pipeline Codes (v6.3→v7)
Run L2 pipeline v7
CALDB
Collect selected products from L2_v7 run :
for a specific VIS Episode -
i) Drift series (RAS); ii) raw VIS images
for corresponding XUV Episode -
a) UV event list; b) Exp.Array; c) scalars [INT_TIME, RA_PNT, DEC_PNT, ROLL_APPLIED]
Creat Cumulative VIS image : cum_VIS (by Shifting for Drift & Stacking)
Identify Stars in cum_VIS (find Centroids & Intensity)
Convert Star Centroids from Detector (X,Y) to approximate (RA, Dec)
Correlate detected Star pattern with Catalogue to find Astrometric Solution
Update UV event list with Astrometry corrections to all Centroids;
Apply Astrometry corrections to the Exposure Array, EXP_ARR;
Add EVENT COUNT column;
Generate EFF_EVENTS array (RA, Dec) by populating ENP at Centroid locations; similarly EVENT_COUNT array
Generate SIGNAL (C/S) = EFF_EVENTS / EXP_ARR
UNCERTAINTY (C/S) = SIGNAL / sqrt(EVENT_COUNT)
Astrometry corrected products for Episode (Signal, Exposure & Uncertainty)

#2 Schematic for Astrometry & Combining multi-Episode Data of UVIT



Thank you

for your attention ….