The relative angle between the payload boresight's (UVIT, SXT, LAXPC) before and after alignment corrections

The procedure followed to determine the relative angle between boresight w.r.t to Body Roll and UVIT boresight is as follows

- The mounting matrices of all the payloads are taken (DC matrix which transforms any vector from Payload frame to Body frame)
- The boresight direction of each payload in their respective frame is assumed to be [0 1 0].
- All the payload boresight vectors are transformed from their respective frames to the body frame by using the above said mounting matrices.
- The angle between the each payload boresight w.r.t Body Roll and also w.r.t UVIT are computed.
- The relative included angle between each payload boresight and Body Roll before and after the alignment corrections are as follows

Payload	Angle between Payload Boresight and Body Roll as on launch day (deg)	Angle between Payload Boresight and Body Roll as on today (after misalignment correction) (deg)
UVIT	0.02026	0.0419
SXT	0.11090	0.0512
LAXPC-10	0.04157	0.1605
LAXPC-20	--	0.1844
LAXPC-30	--	0.1486
LAXPC-Mean	--	0.1514

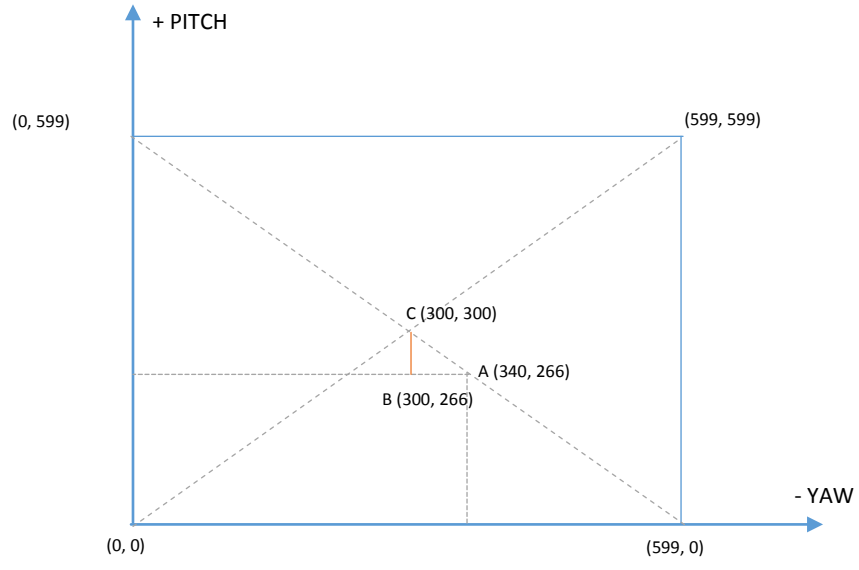
- The relative included angles between the payloads w.r.t. UVIT boresight are depicted in the following table,

Payload	Angle between Payload Boresight and UVIT as on launch day (deg)	Angle between Payload Boresight and UVIT as on today (after misalignment correction) (deg)
UVIT	0.0	0.0
SXT	0.0917	0.0721
LAXPC-10	0.0214	0.1395
LAXPC-20	--	0.1426
LAXPC-30	--	0.1185
LAXPC-Mean	--	0.1156

Thealignmnet correction carried out for SXT , UVIT and LAXPC are attached in this note for reference. Currently LAXPC-10 mounting is in place for the observation of LAXPC.

SXT pointing correction

The following diagram gives the definition of pixel and line numbers in terms of spacecraft body axes.



In the current attitude of ASTROSAT, the source is seen by the pixel A(340, 266).

Mounting Matrix of SXT(Optic Axis) wrt MRC (S/c Body Frame) currently used is:

0.999874333315128	-0.001362710003903	-0.015794321735195
0.001384249457960	0.999998126763056	0.001352894606904
0.015792448545673	-0.001374587874425	0.999874346644171

Current Mounting Quaternion from body frame To SXT Frame i.e. Q_BSXT is:

Q_BSXT = [00.000681892201989 00.007896942505767
-0.000686761601237 0.999968350339444]

Q_SXTB = [-0.000681892201989 -0.007896942505767
00.000686761601237 0.999968350339444]

To move the central pixel C(300, 300) towards source, following rotations are required,

i. a -yaw rotation of 34 lines (140.08 arc sec rotation to move from C to B) and
ii. a +pitch rotation of 40 pixels (164.8 arc sec rotation to move from B to A)

New Mounting Matrix of SXT (Optic Axis) w r t MRC (S/c Body Frame) to move the central pixel towards source is:

00.9998751116671	***-0.0005637345697***	***-0.0157937732039***
00.0005746480256	***00.9999995992708***	***00.0006864676911***
00.0157933798893	***-0.0006954578199***	***00.9998750349369***

New Mounting Quaternion from body frame to SXT Frame i.e. Q_BSXT (to move the central pixel towards source) is:

Q_BSXT = ***[00.0003454922*** ***00.0078970353***

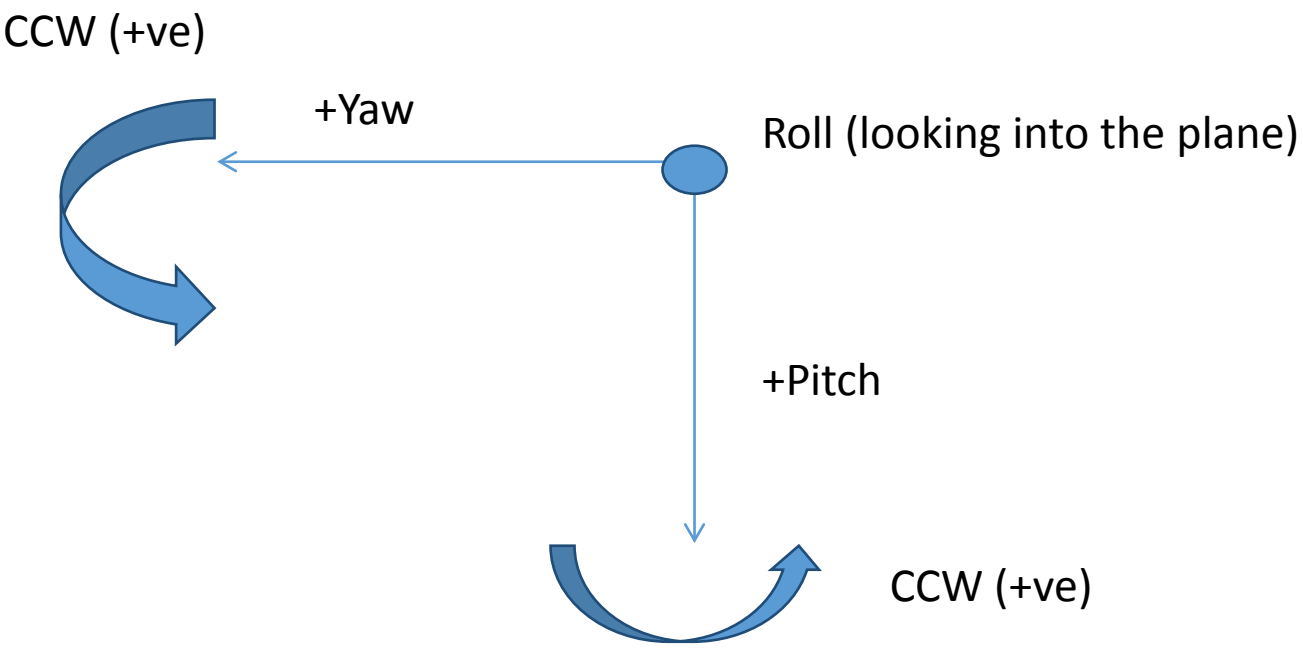
-0.0002846046 ***00.9999687177]***

Q_SXTB = ***[-0.0003454922*** ***-0.0078970353***

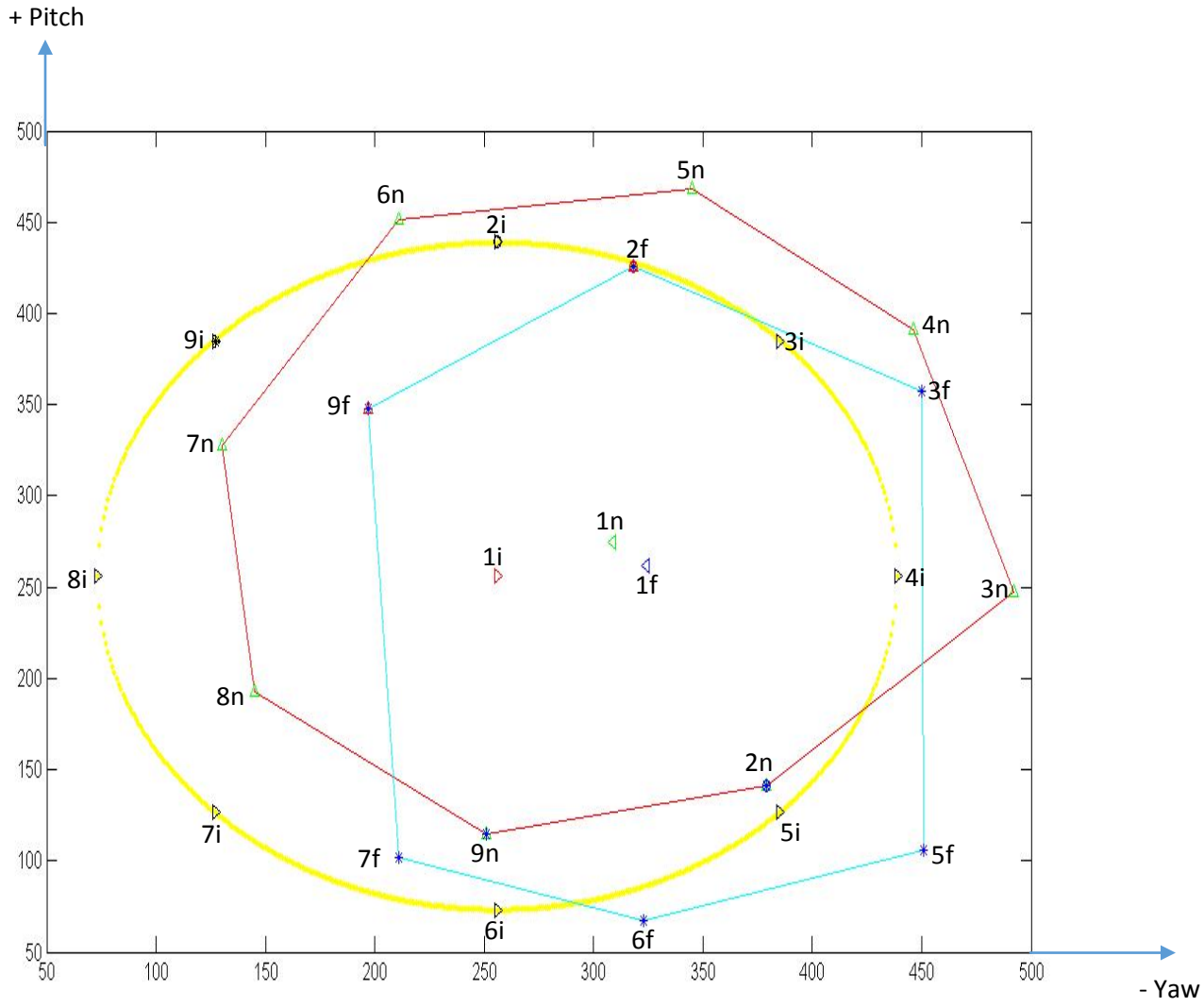
00.0002846046 ***00.9999687177]***

UVIT Misalignment correction:

The convention followed during UVIT 9-point calibration is as follow,

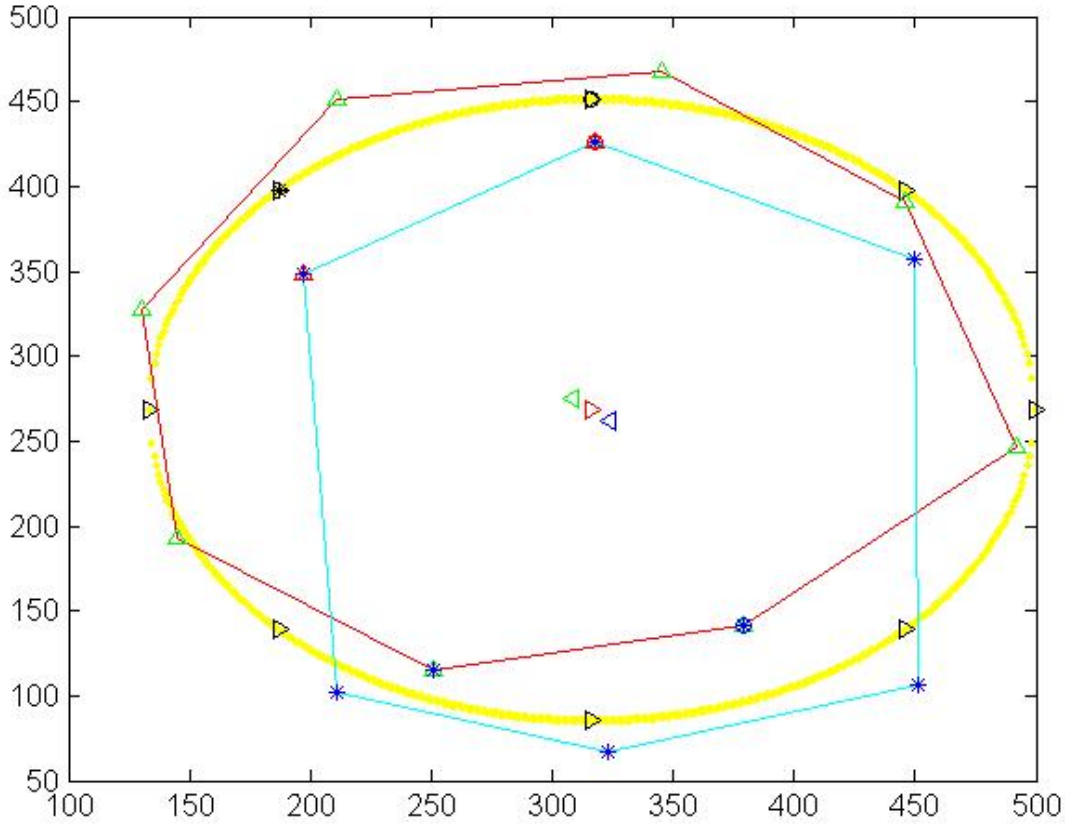


9-point profile observation against planned



The diagram indicates the 9-point calibration profile circle before the misalignment correction. The radius of the circle is 10 arc min. The circle with red line indicates the actual achieved points for NUV, the circle with blue line indicates the actual points achieved for FUV and the circle with yellow line indicates the ideal points.

9-point profile with misalignment correction



The center computed by taking average errors of both FUV and NUV is (316,268). With reference to this center, a pitch error of +60 pixels and yaw error of +12 pixels is observed. **Thus, for moving this center towards ideal center (256,256), a negative pitch rotation of 60 pixels and a negative yaw rotation of 12 pixels is required**. It is observed pictorially that, the corrected center appears to be in between the centers of FUV and NUV circles.

UVIT FOV is 28 arc min and it is divided into 512 pixels, which implies 1 pixel = 3.28125 arc-sec. Therefore, 60 pixels = 196.875 arc sec and 12 pixels = 39.375 arc sec

Thus for correcting the misalignment, a **negative yaw rotation of 39.375 arc sec** and **a negative pitch rotation of 196.875 arc sec** is required.

The misalignment matrix is computed as follows:

B**oth -yaw rotation of 39.375 arc sec** and **–pitch rotation of 196.875 arc sec** are considered for misalignment correction.

Quaternions for -yaw rotation of 39.375 arc sec (0.0109375 deg) are,

-0.00009544769 0 0 0.99999999

Quaternions for –pitch rotation of 196.875 arc sec (0.0546875 deg) are,

0 0 -0.000477238 0.99999988

The current misalignment Qs used for UVIT are,

-0.000081236755706 0.000502642047313 0.000157120406035 0.999999858032360

The modified misalignment Qs are,

-0.0001769243 00.0005025426 -0.0003200695 00.9999998069

Note on LAX-PC misalignment computation based on the observation on 10-FEB-2016

By

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Astrosat is a stellar oriented satellite meant for Astronomical observations. The scientific goals of Astrosat Mission are to be met by various payloads namely Ultra Violet Imaging Telescope (UVIT), Large Area Xenon filled Proportional Counter (LAXPC), Soft X-Ray Telescope (SXT), Cadmium Zinc Telluride detector (CZT) and Scanning Sky Monitor (SSM).

All the payloads, except SSM, are mounted such that their boresight (FOV) is along the body +Roll direction. However the alignment matrices of each payload are evaluated on ground and the obtained numbers for each payload w.r.t body Yaw-Roll-Pitch are used in the payload programming for source pointing. Depending upon the prime instrument for the given source observation, the corresponding alignment is applied to enable that particular instrument boresight to view the source.

LAXPC has got three detectors (LX10, LX20 and LX30). On ground one alignment matrix (mounting matrix)common to all the detectors is worked out for source observation. The current alignment matrix being used for LAXPC source observation is

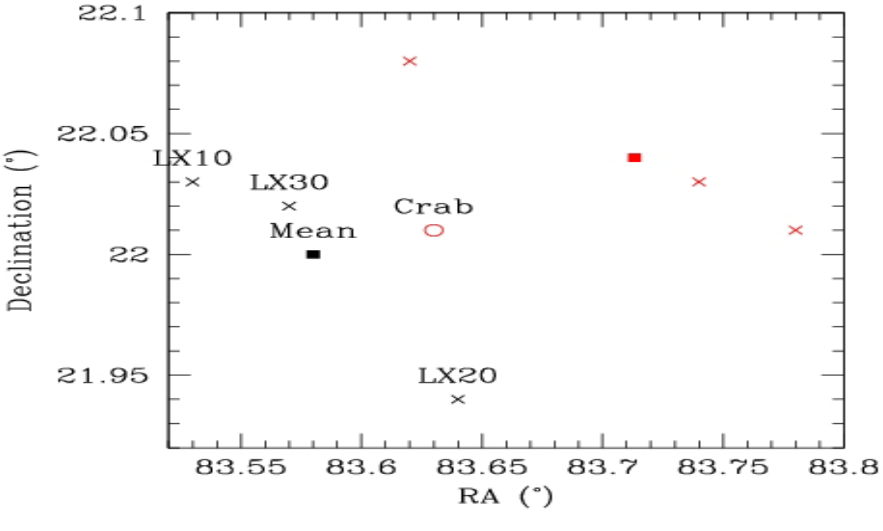
```
[ 0.9999777546036  0.0028172783768 -0.0060459275994
 -0.0028018238420  0.9999927900260  0.0025631385287
  0.0060531050832 -0.0025461418866  0.9999784383077 ]
```

In terms of Qs: **-0.0012773282 -0.0030247775 -0.0014047845 00.9999936228**

During the source viewing (with Ra: 83.63 deg and Dec: 22.014 deg (Name: CRAB)) on 10-feb-2016 by LAXPC, the following are the observations

- LX10 was viewing the Ra: 83.78 deg and Dec: 22.01 deg
- LX20 was viewing the Ra: 83.62 deg and Dec: 22.08 deg
- LX30 was viewing the Ra: 83.74 deg and Dec: 22.03 deg
- Mean was at Ra: 83.71 deg and Dec : 22.04 deg
    - **All coordinates above are in J2000 frame of reference.**

The same is depicted in the following figure **(these numbers were provided by instrument designers)**



Black points represent the detector position after misalignment correction of September 2015. Red points represent the detector position after misalignment correction in November 2015.

Procedure followed to correct the misalignment of LAXPC is as follows

- The absolute Qs for LAXPC-10 detector are computed and the delta Qs with respect to the source CRAB are computed. These delta Qs are absorbed in the misalignment Qs in such a way that LX10/20/30/Mean detector points towards the source.

- Qs for the source are :

  -0.046960900282 -0.980077202901 -0.192147140689 0.017967373853

- Qs for the LX10 detector view direction as per the above Ra and Dec are

  -0.045760021370 -0.980152390430 -0.192068061385 0.017809317082

- The change in the orientation from source view quaternion to the above LX10 view quaternion is

  -0.000106105043887 -0.000070773053481 0.001209434228343 0.999999260500598

- Modified misalignment Qs: (Current misalignment Qs x Delta_Qs), to make LX10 to view source is

  -0.001387189313045 -0.003093853966304 -0.000195587489366 0.999994232742859

- **The misalignment matrix is as follows**

  [0.999980779626338 0.000399756245041 -0.006187129612755

  -0.000382589200408 0.999996074902688 0.002775572863795

  0.006188214880255 -0.002773152387276 0.999977007546890]

- Similarly for LX20 , LX30 and LX-mean, the matrices are computed as below:

Lax-20_Qs:

-0.047091355302 -0.979970300004 -0.192696309961 0.017571212044

Lax-20 and source Delta Qs:

0.000579717419335 0.000385625469006 -0.000046887758924 0.999999756511095

Modified misalignment Qs:(Current misalignment Qs Delta_Qs)

0.000579717419335 0.000385625469006 -0.000046887758924 0.999999756511095

Misalignment matrix is as follows

[0.999981853121841 0.002904487312029 -0.005278009138152

-0.002897127646552 0.999994821193184 0.001401512829430

0.005282052480593 -0.001386196330155 0.999985089079496]

Lax-30_Qs:

-0.046094910450 -0.980103208311 -0.192245838936 0.017734083046

Lax-30 and source Delta Qs:

0.000087131019937 0.000058077821891 0.000896557639570 0.999999592609693

Modified misalignment Qs: (Current misalignment Qs x Lax-30_source_Delta_Qs)

-0.001192827515951 -0.002965676018307 -0.000508042638177 0.999994761896756

Misalignment matrix is as follows

[0.999981893316865 0.001023155033911 -0.005930108953104

-0.001009004874079 0.999996638110390 0.002388655915332

0.005932532982056 -0.002382629155859 0.999979563856543]

Lax-Mean-Qs:

-0.046342154381 -0.980073970401 -0.192337768849 0.017708753331

Lax-Mean and source Delta Qs:

0.000188479243100 0.000125567672576 0.000659385232092 0.999999756959696

Modified misalignment Qs: (Current misalignment Qs x Lax-Mean_source_Delta_Qs)

-0.001090667946572 -0.002898632414555 -0.000744993414911 0.999994926666314

Misalignment matrix is as follows

[0.999982085829874 0.001496302161548 -0.005795610336775

-0.001483656379694 0.999996510856484 0.002185643750621

0.005798860498527 -0.002177005902377 0.999980816747111]

Conclusions:

The above computed numbers for the LAXPC targets is planned to be uplinked one by one with the LAXPC team to provide the accuracy of observations as verification. If everything is fine, then Lax-Mean alignment will be permanently used for LAXPC operations.