AstroSat – S/C and Instruments

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(Talk delivered by KP Singh)
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IISER Mohali

Space Astronomy from India - Journey so far...

Piggy-back experiments

- Aryabhata and Bhaskara-I
- SROSS series of satellites
  - The Gamma ray burst (GRB) experiment on SROSS- C2
- IRS satellite
  - The Indian X-ray astronomy experiment (IXAE) on IRS-P3
- Geostationary satellite
  - The Solar X-ray spectrometer on GSAT-2

Missions

- Chandrayaan-1
  - First Indian mission to the Moon
- Mars Orbiter Mission
  - First interplanetary mission to the Mars
- **AstroSat**
  - **First dedicated Indian astronomy mission**

Science Objectives

To understand high energy processes in binary systems containing neutron stars and black hole sources, estimate magnetic fields of neutron stars, study star birth regions and high energy processes in extragalactic systems, detect new transient X-ray sources and do limited high-angular resolution deep field survey in UV .

ASTROSAT-niche

- Simultaneous multi-wavelength observations using single satellite
- UV, optical, low and high energy X-rays. Most other satellites are for a narrow range of wave band
- Multi-wavelength observations conducted using co-ordinated observing using spacecraft(s) and ground observatories
- All major astronomy institutions and some Universities in India will participate.

Actual Spacecraft and PSLV

S/C in tilted position during pre-launch test at SHAR

PSLV C30 Lift off on 28th Sep 2015

AstroSat

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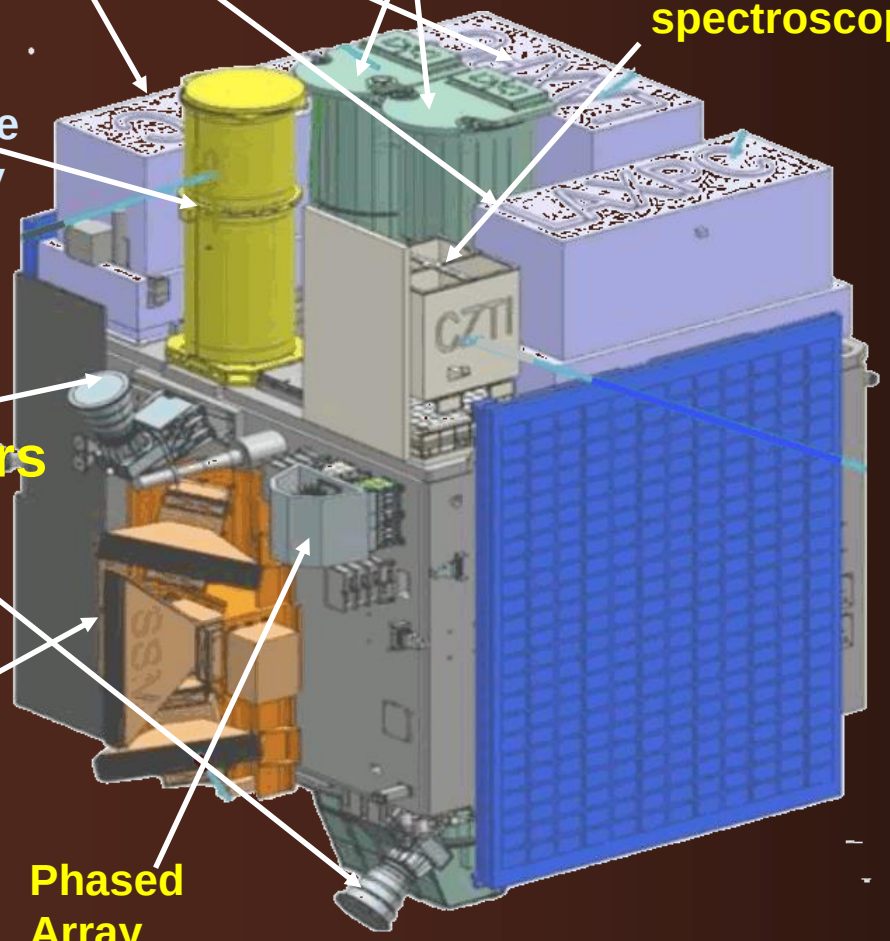
PMs: S.N. Tandon (UVIT),
J.S. Yadav (LAXPC),
K.P. Singh (SXT)
A.R. Rao (CZTI)
M.C. Ramadevi (SSM)

LAXPC
3-100 keV X-ray
Timing, broadband
spectroscopy

UVIT
1.4" UV
imaging

CZTI
10-250 keV hard
X-ray imaging,
timing,
spectroscopy

SXT
0.3-7 keV
imaging & line
spectroscopy



Star Sensors

SSM
rotating
(10°/10m)
2-10 keV
monitor

Phased Array Antenna

LAXPC: TIFR, RRI
SXT: TIFR, ISRO, UoL
CZTI: TIFR, ISRO, IUCAA, RRI, PRL
SSM: ISRO, IUCAA, RRI
UVIT: IIA, ISRO, IUCAA, CSA
Spacecraft: ISRO
Operations: ISRO
Ground software: ISAC, SAC, TIFR, RRI, IIA, IUCAA, NCRA, PRL

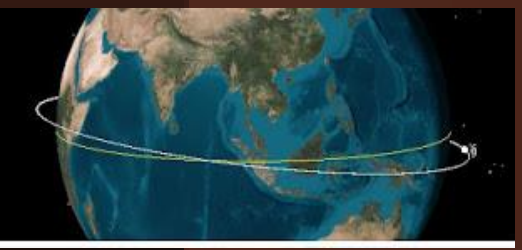
A broad X-ray Band and UV on one platform

AstroSat MISSION

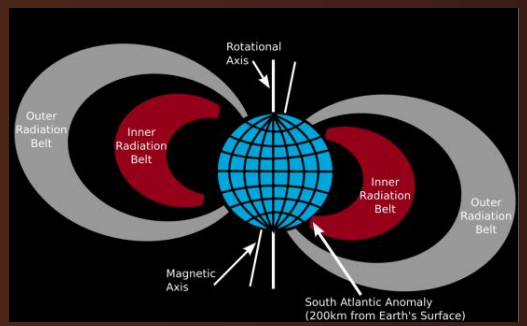
- AstroSat spacecraft and five astronomy payloads covering optical, UV and X-rays were designed, developed, realized and launched on 28th September 2015 by PSLV-C30 (XL) from Sriharikota.
- The spacecraft was put in 650km near-equatorial orbit with inclination of 6 degree.
- The payloads were switched ON in a sequence and are operationalised.
- The first six months were dedicated for performance verification and on-board calibration of payloads. Performance of all the payloads conformed to the parameters for which they were designed.
- Science observations from April 2016
- AO observations commenced on October 01, 2016.

Mission details…

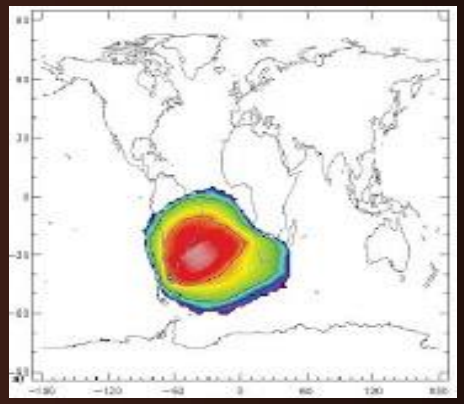
Satellite mass	1515 kg
Instruments (Payloads) mass	855 kg
Spacecraft	Cuboid shaped; 1.96 m x 1.75 m x 1.30 m
Power	1626 W
Launch Vehicle	PSLV C30 (XL)
Orbit	650 km; near equatorial; 6 degree inclination to reduce charge particle background



6 deg with respect to equator.



Radiation belts



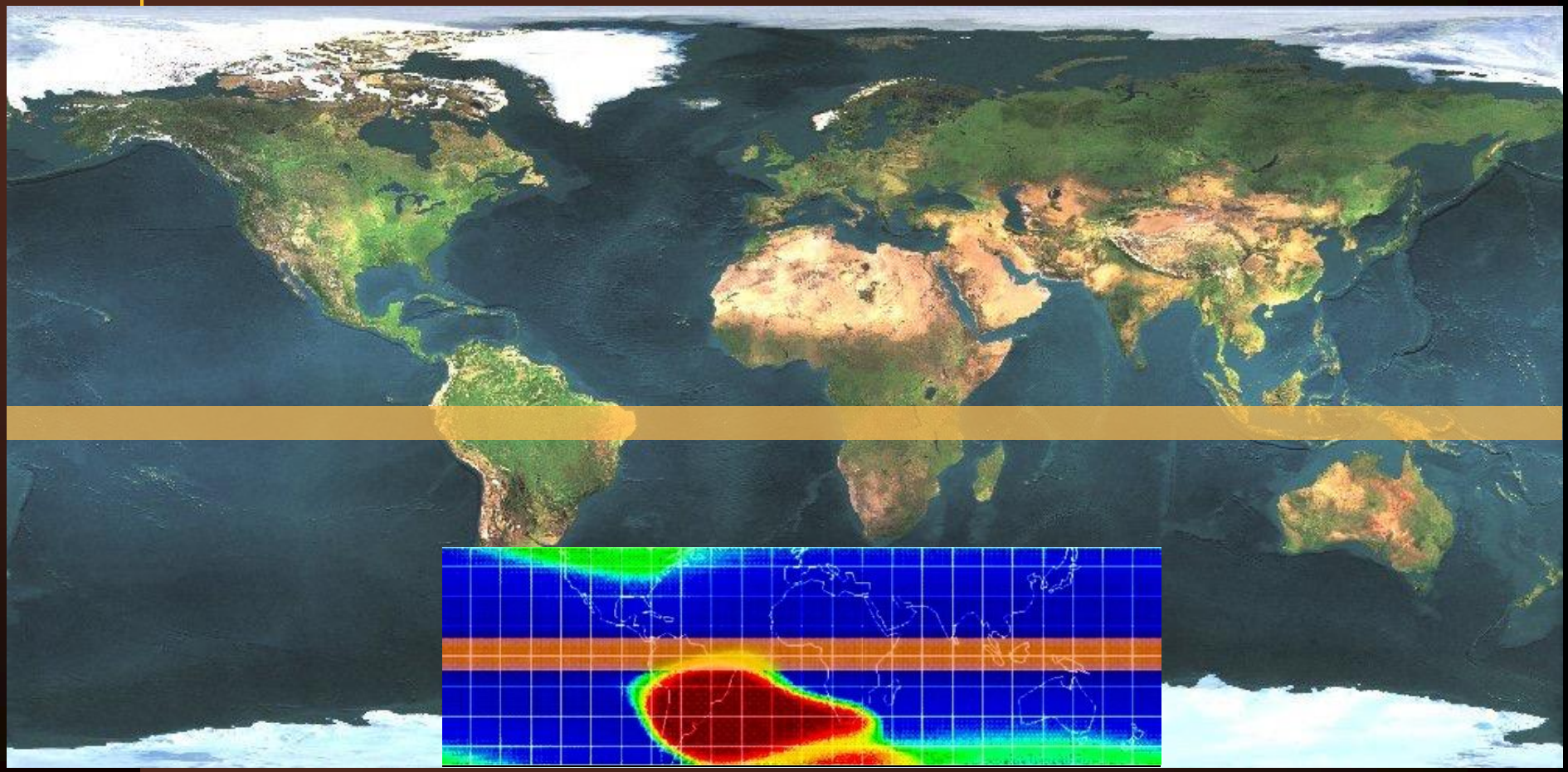
South Atlantic Anomaly (SAA) region spans -50^0 to 10^0 latitude and -90^0 to $+40^0$ longitude.

AstroSat orbit

Circular, 650km altitude, 6 deg inclination, Period 98 min

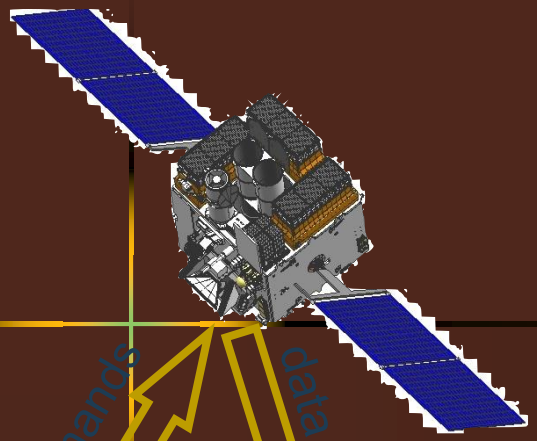
3-axis stabilization

Low Background



Operations

X and S bands



commands

data

ISTRAC, PEENYA

ISSDC, BYLALU

raw data

science products

POCs

LAXPC: TIFR, RRI

UVIT: IIA

SXT: TIFR

CZTI: IUCAA

SSM: ISAC, IUCAA

DATA ARCHIVE

USER

PROPOSALS

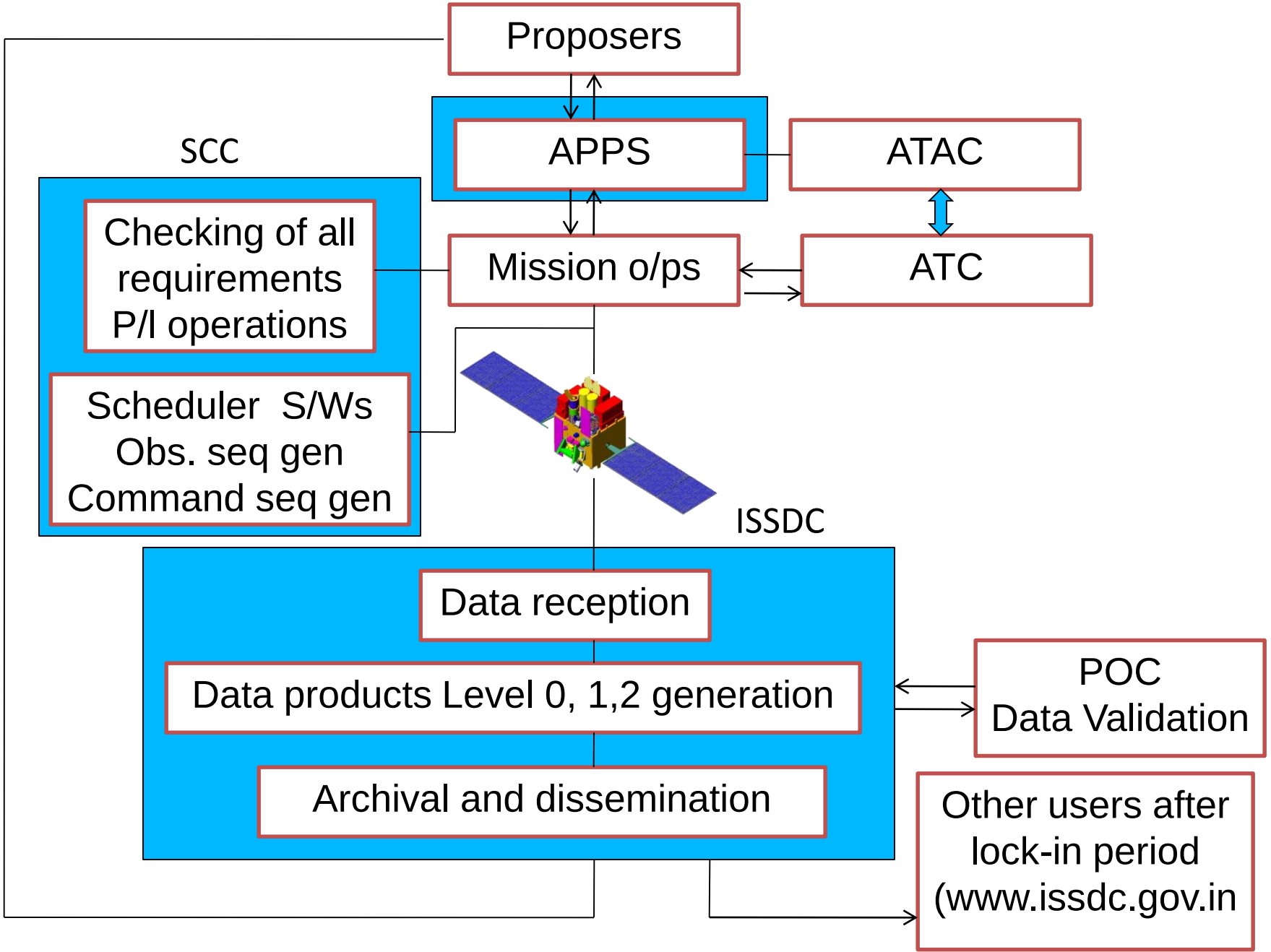
ASTROSAT SCIENCE SUPPORT CELL

REVIEW, TIME ALLOCATION, SCHEDULING

S/C and operations

- ✓ The AstroSat S/C has an onboard Computer (with redundancy) which is an ASIC based Bus Management Unit. It interfaces all the payloads with spacecraft subsystems. It also integrates the functions of sensors, controls, telemetry, telecommand etc.
- ✓ S/C pointing and attitude maintenance is through star sensors and Gyros and control system; Star sensors provide an accuracy of 40” along bore axis and 10” in cross axes;
- ✓ Pointing accuracy is 0.05 degree(3 sigma) in each axis and attitude drift is 3 x 10^ -4 deg/s (UVIT data is corrected for the drift by data from vis channel)
- ✓ Payload data is stored in the onboard Sold state recorder memory through a data handling unit and downloaded during each visible orbit.
- ✓ Satellite positioning system provides 1 pps signal from GPS to the STBG system for timing in LAXPC and CZTI
- ✓ Time correlation, Attitude and orbit files are provided along with payload data on ground to each payload operation Centre for validation after which it is provided to proposers.

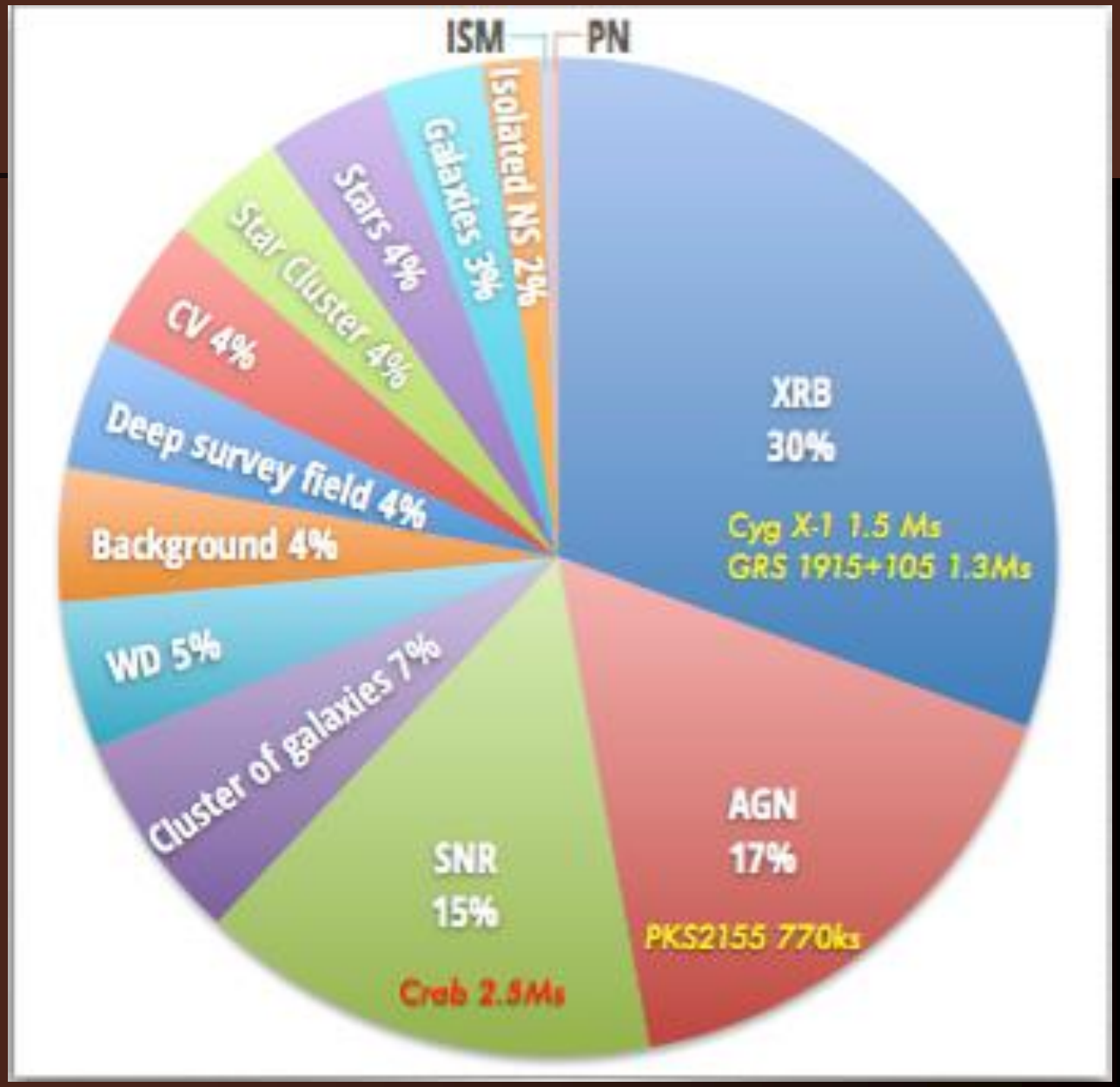
Brief outline of Observation plan



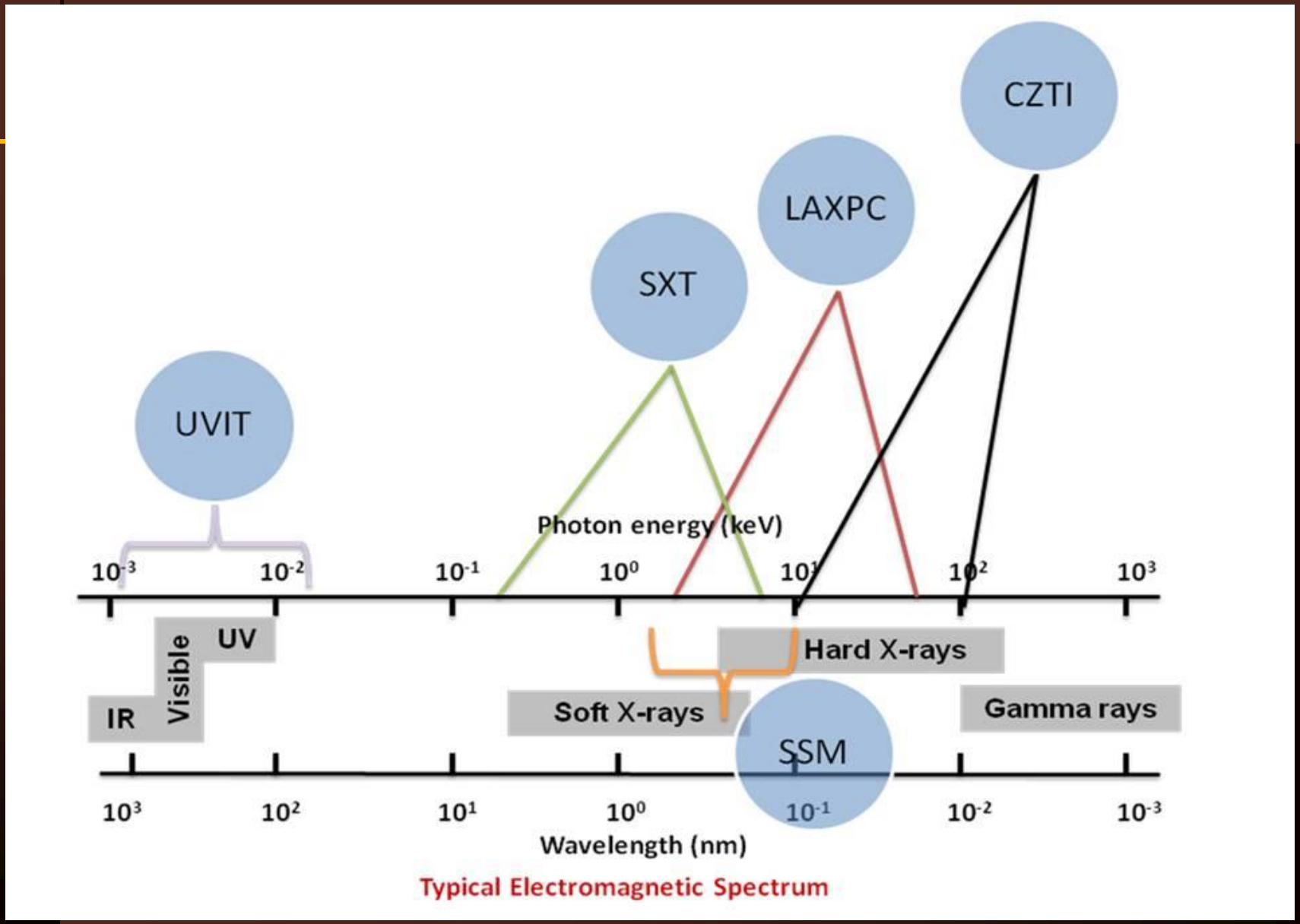
Time percentage observations from 2nd year

Year (after launch)	GT	Proposal		TOO	Calibration	Collaboration
		India	Intl.			
2nd year	50%	35%	-	5%	2%	8%
3rd year	30%	45%	10%	5%	2%	8%
4th year	-	65%	20%	5%	2%	8%
5th year	-	55% +7% legacy	20%	5%	5%	8%

1st year : 140 sources, 337 targets



AstroSat Wavelength coverage



AstroSat

Performance Parameters of the scientific Instruments

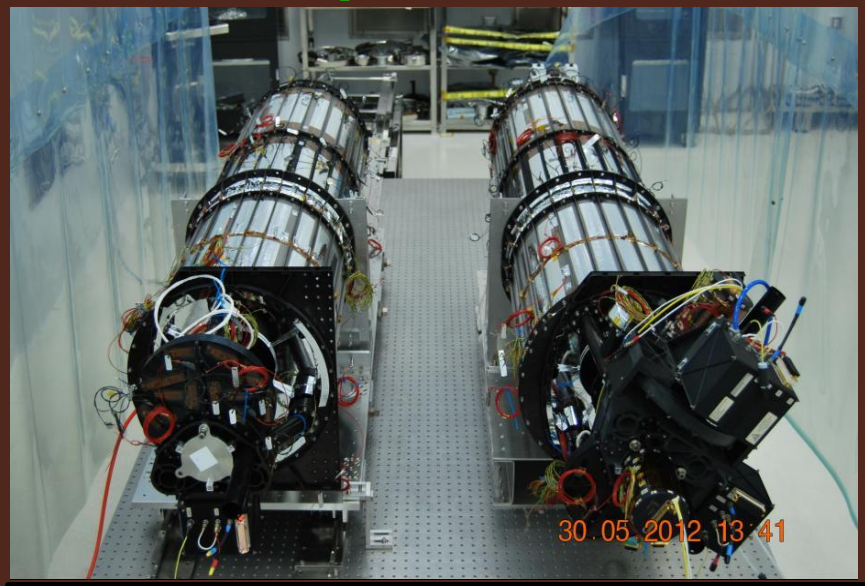
	UVIT	SXT	LAXPC	CZTI	SSM
Detector	Intensified CMOS, used in photon counting mode or integration mode	X-ray (MOS) CCD at the focal plane. (XMM & Swift heritage)	Proportional counter	CdZnTe detector array	Position-sensitive proportional counter
Imaging / non-imaging	Imaging	Imaging	Non-imaging	Imaging	Imaging
Optics	Twin Ritchey-Chretian 2 mirror system.	Conical foils (~Wolter-I) mirrors. 2-m focal length	Collimator	2- D coded mask	1- D coded mask
Bandwidth	1300-5500 Angstroms	0.3 - 8 keV	3 - 80 keV	10 - 100 keV	2.5 - 10 keV
Geometric Area (cm2)	~1100	~250	10800	1024	~180
Effective Area (cm2)	8 - 50 (depends on filter)	~128@1.5 keV ~22@6 keV	8000@5-20 keV	1000 (E>10 keV)	~11 @ 2 keV ~53 @ 5 keV
Field of View (FWHM)	28' dia	~ 40' dia	1^0 x 1^0	6^0 x 6^0	10^0 x 90^0
Energy Resolution	<1000 A (depends on filter)	~5-6%@1.5 keV ~2.5%@6keV	12%@22 keV	5% at 100 keV	25% @ 6 keV
Angular Resolution	1.8 arcsec (FUV,NUV) 2.2 arcsec (Vis)	~2 arcmin (HPD)	~(1-5) arcmin (in scan mode only)	8 arcmin	~12 arcmin
Time resolution	1.7 ms	2.4 s, 278 ms	10 μs	1 ms	1 ms
Typical observation time per target	30 min	0.5 - 1 day	1 - 2 days	2 days	10 min
Sensitivity (Obs. Time)	Mag. 20 (5σ) 200 s (130-180 nm)	~10^{-13} ergs cm^{-2} s^{-1} (5 σ) (20000 s)	0.1 milliCrab (3σ) (1000 s)	0.5 milliCrab (3σ) (1000s)	~28 milliCrab (3σ) (600s)

Ultra-violet Imaging Telescope (UVIT)

To image the sky simultaneously in three wavelengths: FUV (130-180 nm), NUV (200-300 nm), and VIS (320-550 nm).

Image resolution ~ 1.5″ or better; in UV compared to ~ 5″ of GALEX

- Twin Ritchey-Chretian 2 mirror system
- Intensified CMOS used in photon counting mode or integration mode
- Two telescopes are mounted on a cone-like structure of Titanium, which is attached to central cylinder of the spacecraft.
- In order to avoid contamination of the optics due to ultraviolet assisted reactions, bright-earth will be kept away from the axis by >12°, and the sun behind the sun-shield at all times even if UVIT is not observing.



WIDE ANGLE (~ 28′)

IMAGES IN :

FUV (130-180 nm),

NUV (200- 300 nm), &

VIS (320-550 nm)

SENSITIVITY IN FUV mag. 20 in 200 s

Lead: IUCAA, IIA. Collaboration with Canadian Space Agency (CSA)

Large Area Xenon Proportional Counter (LAXPC)

Variability studies of X-ray Binaries and other cosmic sources, and measurements of spectral continuum characteristics of different classes of X-ray sources over a wide spectral band of 3-80 keV. Nearly 4 – 5 times more effective area above 30 keV compared to the Rossi X-ray timing Explorer (RXTE).

- 3 identical gas-filled proportional counters
- Aluminized Mylar film of 50 microns thickness serves as the gas barrier as well as the X-ray entrance window for the detector.
- The detector is filled with a mixture of 90% Xenon + 10 % Methane at a pressure of 1520 torr.

Effective Area: ~ 6000 sq.cm (3 No.s) in 5-20 keV

Geometric Area: 10800 cm^2

Energy range: 3- 80 keV

Energy resolution – ~22% at 6 keV and ~12% > 22 keV

Time resolution: 20 μs

FOV : 0.9 x 0.9 sq.deg

Sensitivity: 1 milliCrab; 100s, 3σ

Lead: Tata Institute of Fundamental Research with RRI

Soft X-ray Telescope (SXT)

Timing and variability studies and spectral continuum in the X-ray bandwidth of 0.3 to 8 keV.

- Thin conical foil (Wolter-I) Gold coated Aluminium Optical mirrors for grazing incidence;
- 2-metre focal length telescope
- Focal plane camera with a cooled CCD is from University of Leicester, UK

WIDE ANGLE (~ 40' dia)
PSF (FWHM) 70" on axis
Half Energy Width (HEW) 2' ± 10"
Effective area : 128 @ 1.5keV; 22 @ 6keV
Sensitivity-15 microCrab (5 σ) (10000 s)

Lead: Tata Institute of Fundamental Research (TIFR).
Collaboration with Univ. of Leicester, UK

Cadmium Zinc Telluride Imager (CZTI)

CZTI extends the high energy limit (bandwidth: 10 – 100 keV) and thus apart from the spectral studies afforded by the LAXPC; it may also be able to detect gamma ray bursts and study their early light curves.

- Passive Collimator above which there is a Coded Aperture Mask (CAM)
- 64 CZT detector modules

Energy range: 20 – 100 keV

Imaging with coded mask detectors in 4 quadrants

Geometric area: 976 sq.cm

Each module: 2.46 x 2.46 sqmm with 256 pixels

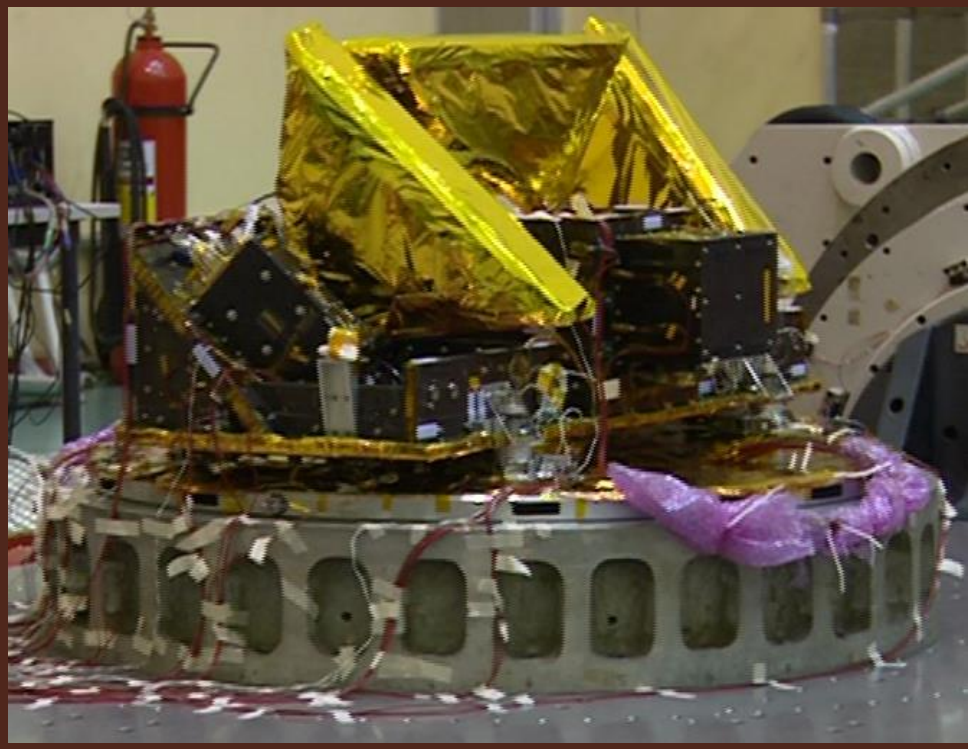
Sensitivity: 0.5 milliCrab (3σ) (1000 s)

Lead: TIFR in collaboration with VSSC

Scanning Sky Monitor (SSM)

To detect and locate X-ray transients

Scan the sky for Long term monitoring of bright X-ray sources in binaries, and detection and location of X-ray transients. which will then be studied in detail by other instruments on ASTROSAT.



- Three Position-sensitive gas-filled proportional Counters.
- Mounted on a rotating platform
- Window is aluminized Mylar of thickness 50 microns

sensitivity (3σ) each SSM

2.5-10 keV –10 min. – 28 mCrab

Lead: Space Astronomy Group, ISAC

Charged Particle Monitor (CPM)

To detect the flux of charged particle at the satellite location; output signal based on flux threshold crossing and provided to other payloads for high voltage lowering/switch OFF. Count rates detected also provided as input.

CsI (Tl) crystal with Kapton window to detect protons >1 MeV
CsI (Tl) size 10x10x10 cu mm.

Used for SAA entry and exit; (Alternately the SAA location can be programmed from ground and model uploaded to S/C).

Lead: Tata Institute of Fundamental Research, Mumbai

Announcement

The Seventh AO cycle is open now (08.03.2019) and the last date for submission is 9th of April, 2019.

https://www.isro.gov.in/update/06-mar-2019/announcement-of-opportunity-ao-soliciting-proposals-seventh-ao-cycle-observations

Thank you…