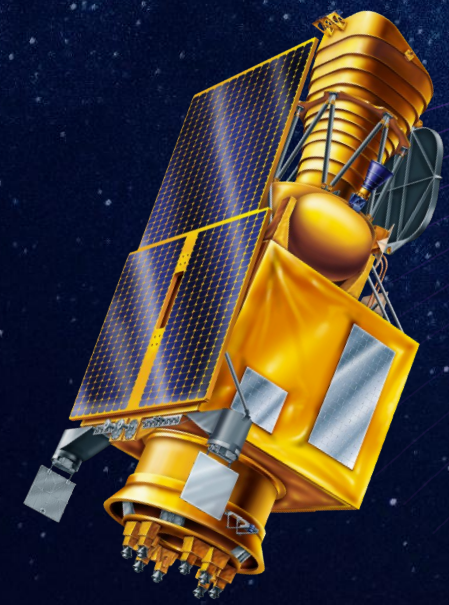


ULTRASAT Capabilities and Project status

ULTRASAT Collaboration workshop, July 11-13 2023



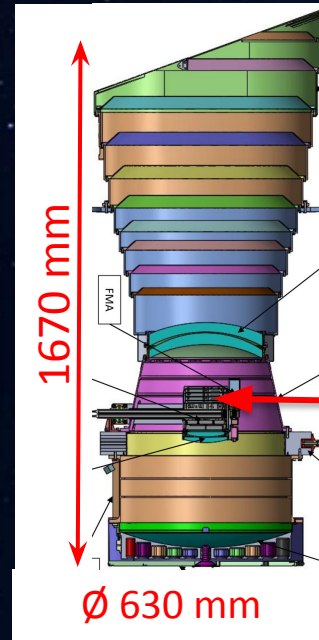
Yossi Shvartzvald | ULTRASAT Project Scientist | Weizmann Institute of Science

ULTRASAT implementation

Spacecraft: IAI

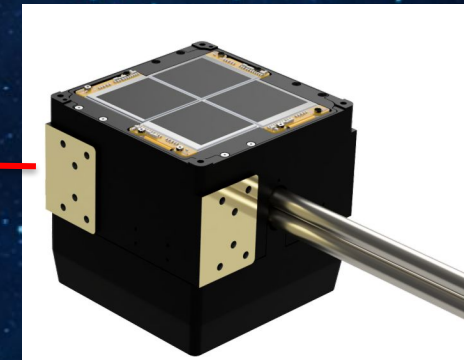


Telescope: Elop/Elbit



**Focal Plane Array
("Camera"):
DESY/Helmholtz**

Sensors: Tower



Hosted launch to GTO: NASA

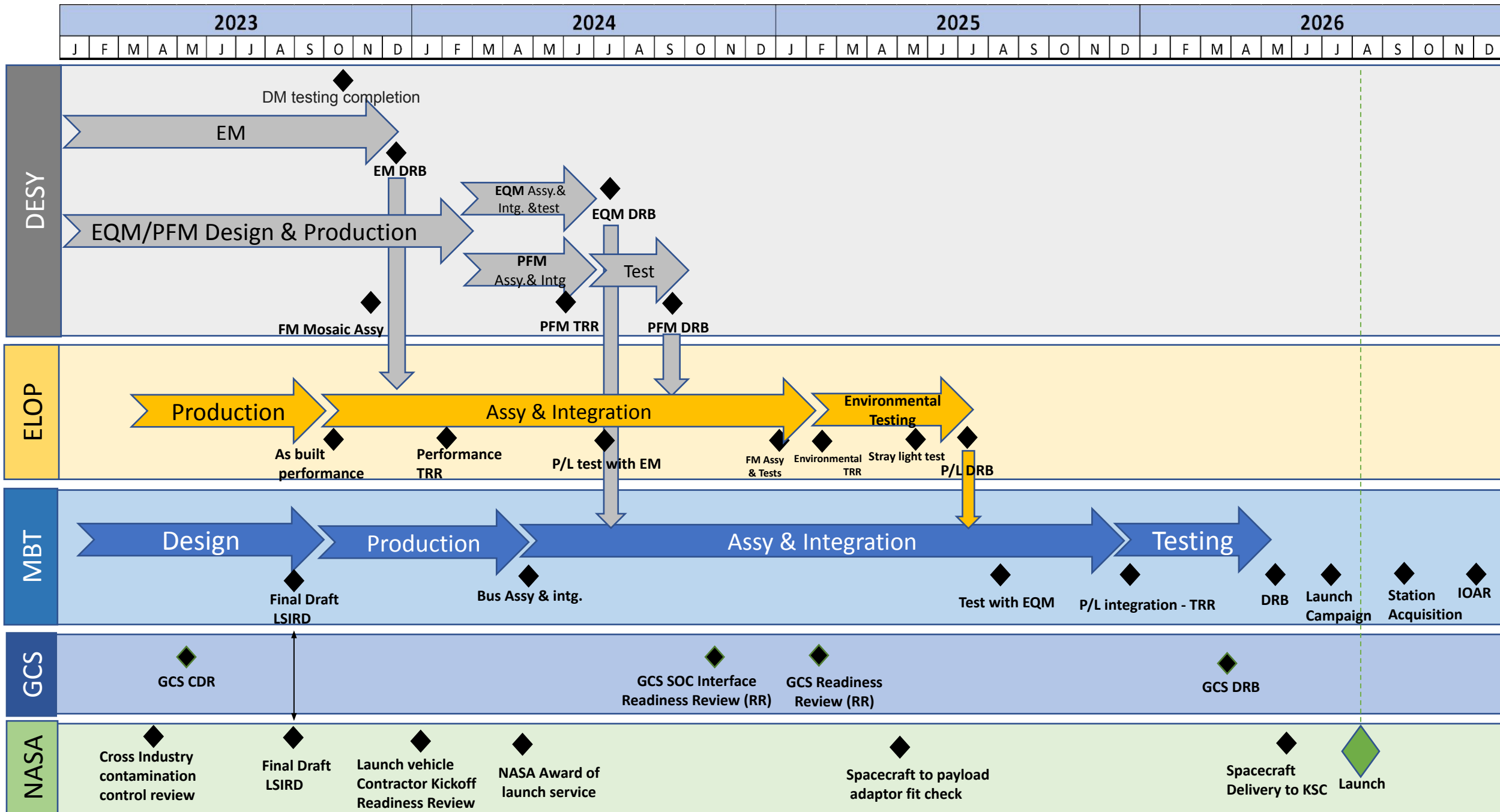
Launch Q2/Q3 2026

>3.5 year science mission (6 year fuel)

Dimensions: 1.5 x 1.9 x 3.6 (m³)

Power: 500 W

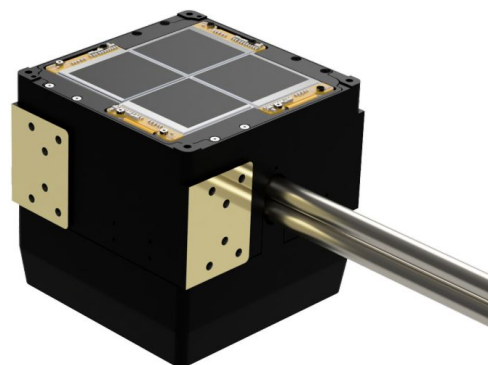
Mass: 500 + 600 (Prop) kg



*All MS are Finish MS

Focal Plane Array

- Developed and supplied by DESY
- BSI CMOS from TowerJazz - **production completed!**
4 Tiles aligned to $< 50 \mu\text{m}$
- High UV QE using:
high-K dielectric coating
Optimized anti-reflection coating
- Space qualified design (e.g., radiation hardness)
- Electronic design **passed full verification**
- Flight sensors diced and now are **being packaged**



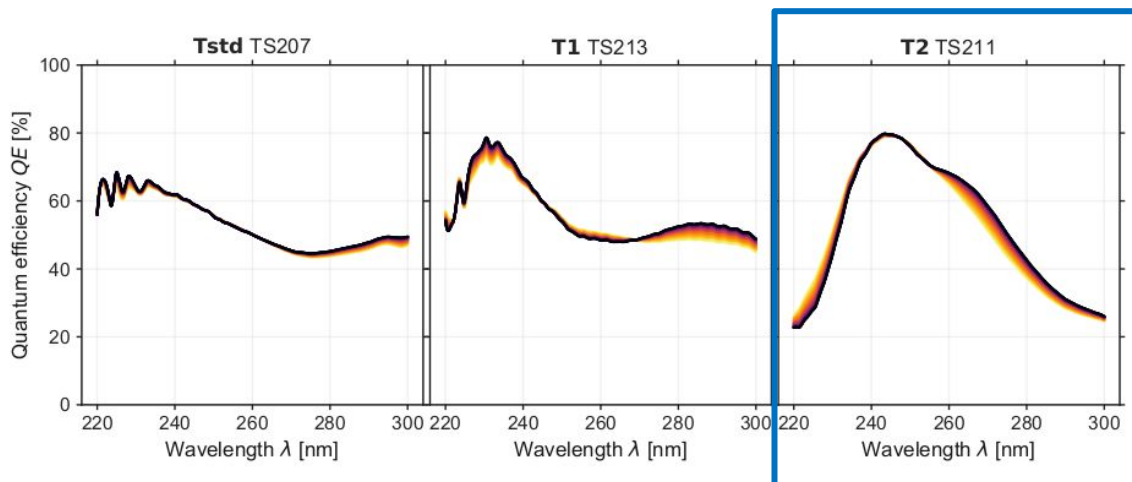
Sensor main Spec.

Photosensitive area (single tile)	45 x 45 mm ² 7.14 x 7.14 deg²
Pixel size Pixel scale	9.5 μm 5.4''
Mean QE at 230-290nm	>60%
Operation temperature	200 \pm 5 °K
Dark current @ 200 °K	<0.03 e ⁻ /sec
Readout noise @ High-gain	<3.5 e ⁻ /pixel
Electronic cross-Talk	<0.01%
Readout time	<20 sec
Pixel sampling scheme	Rolling shutter + Dual gain

For more details see: Asif+2021
Bastian-Querner+2021
Liran+2022

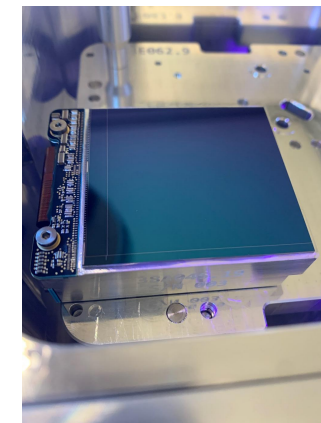
Focal Plane Array

“Scouts” QE measurements:
Optimal ARC selection

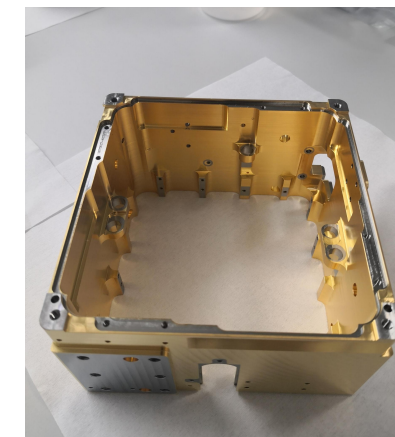
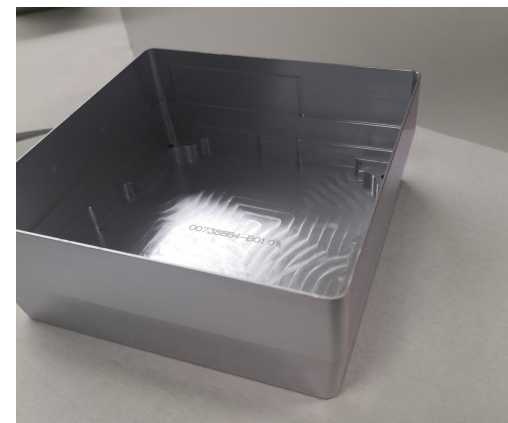


For more details see: Asif+2021
Bastian-Querner+2021
Liran+2022

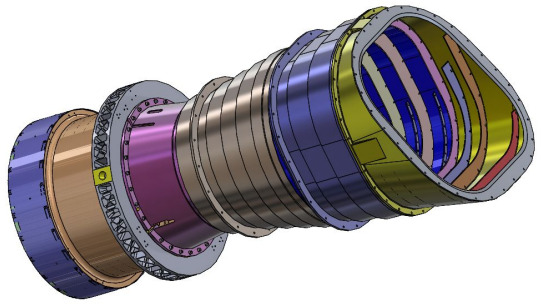
First Sensor Tile



Development camera structure

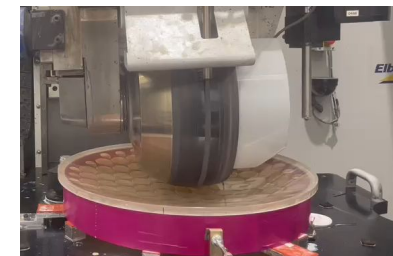
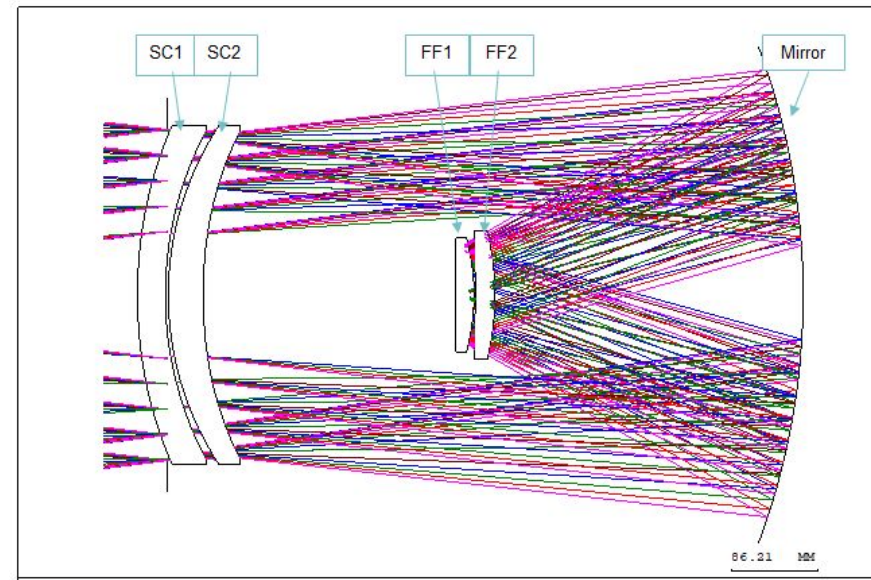
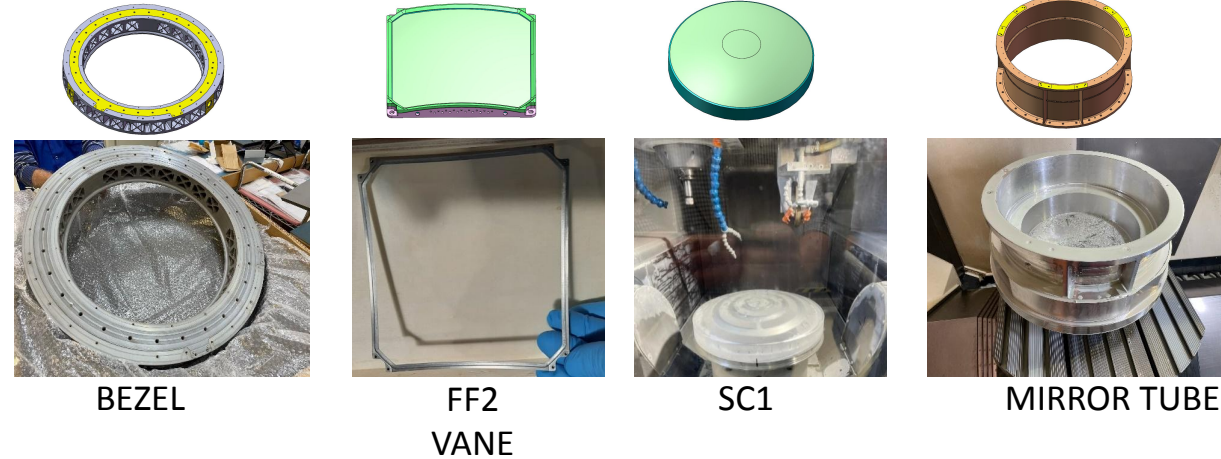


Telescope components



Telescope structure and optics

- **Baffle**
- **Schmidt Correctors**
 - **33 cm clear aperture**
 - Fused Silica & CaF₂
 - Reduce Spherical aberration
- **Mirror 50 cm Zerodur**
- **Field Flattener lenses**
 - Fused Silica & CaF₂
 - Focus mechanism
 - Reduces Field Curvature
- **Out-of-band Sapphire filter**
- **Focal Plane array**



MIRROR

For more details see: Ben-Ami+2022

Baffle

Stray light

- Pointing limits:
 - No Sunlight enters at any time
 - Earth light required suppression
 - No direct moonlight hit the corrector
- **Enables >50% sky accessibility at any given moment**

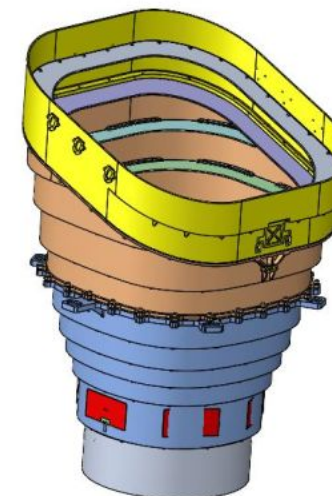
Trapped electrons propagating through the corrector

- Reduce Cerenkov radiation - the dominant background noise source!
- Reduce transmission degradation

For more details see: Ben-Ami+2022
Shvartzvald+ 2023

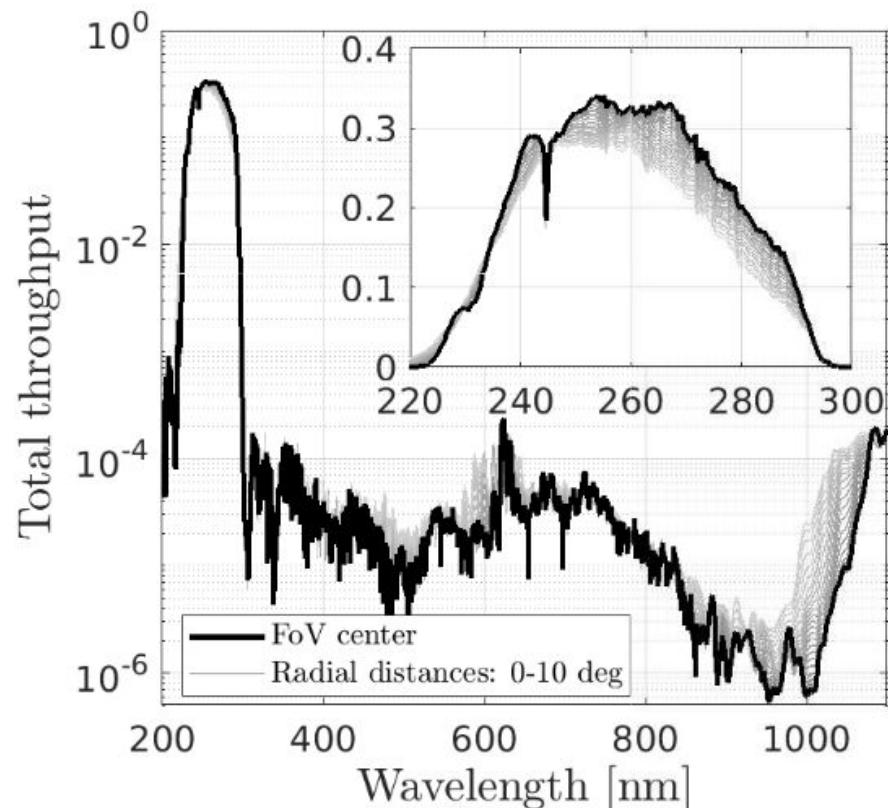
Baffle main Spec.

Sun pointing limit	>70°
Earth (center) pointing limit	>56°
Moon pointing limit	>34°
Stray light suppression factor	< 2 x 10 ⁻¹¹
Electron suppression (Cerenkov)	< 1/6

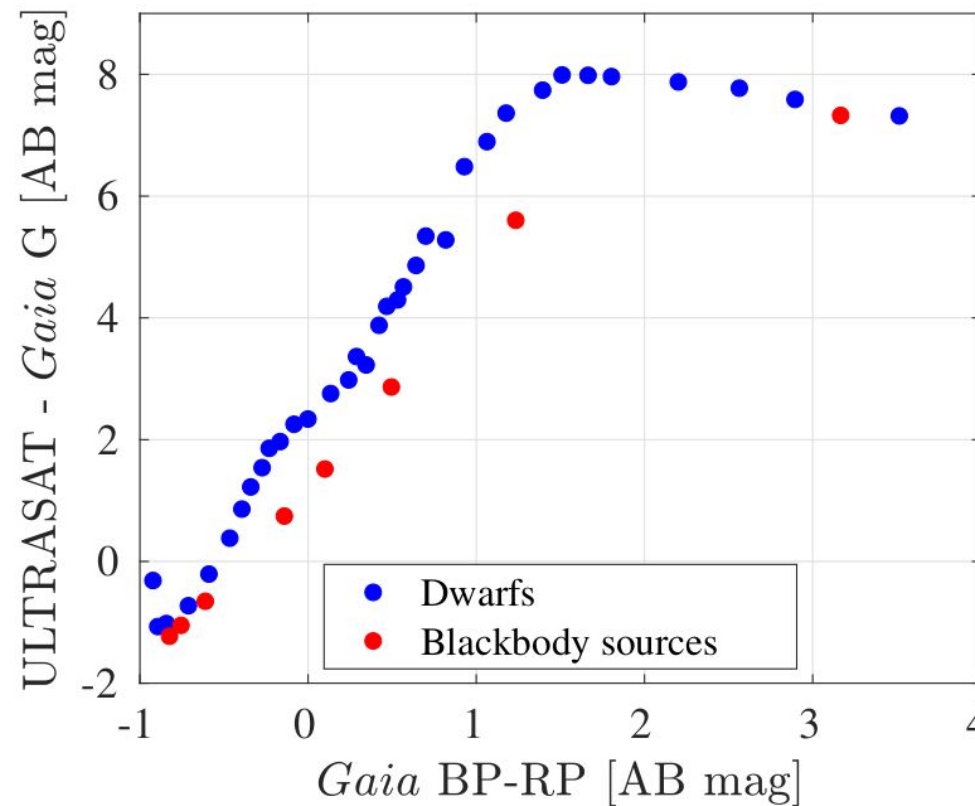


Optical Performance

Total throughput



Colors



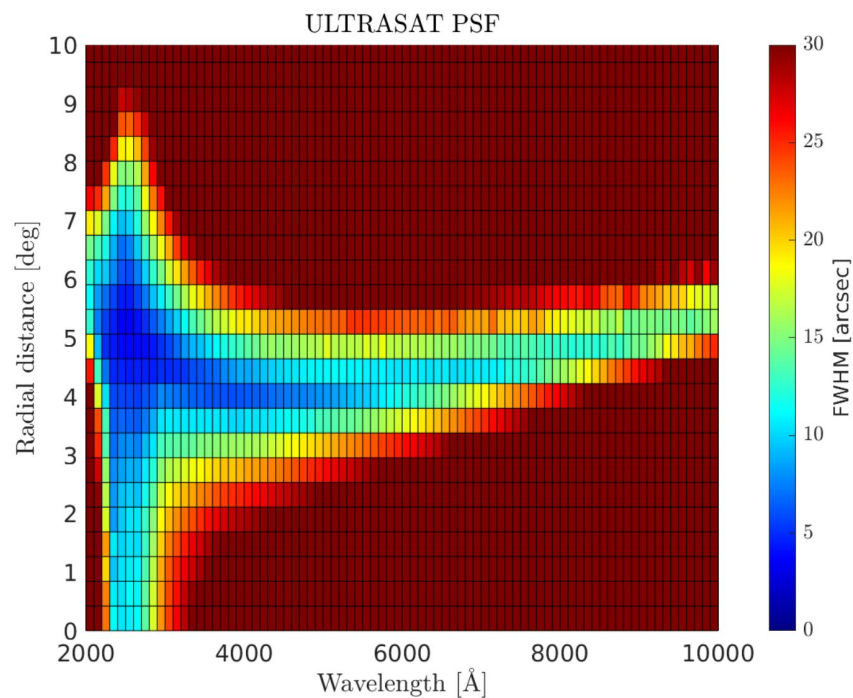
Shvartzvald+2023

Optical Performance

Chromatic position-dependent PSF

Optimized for:

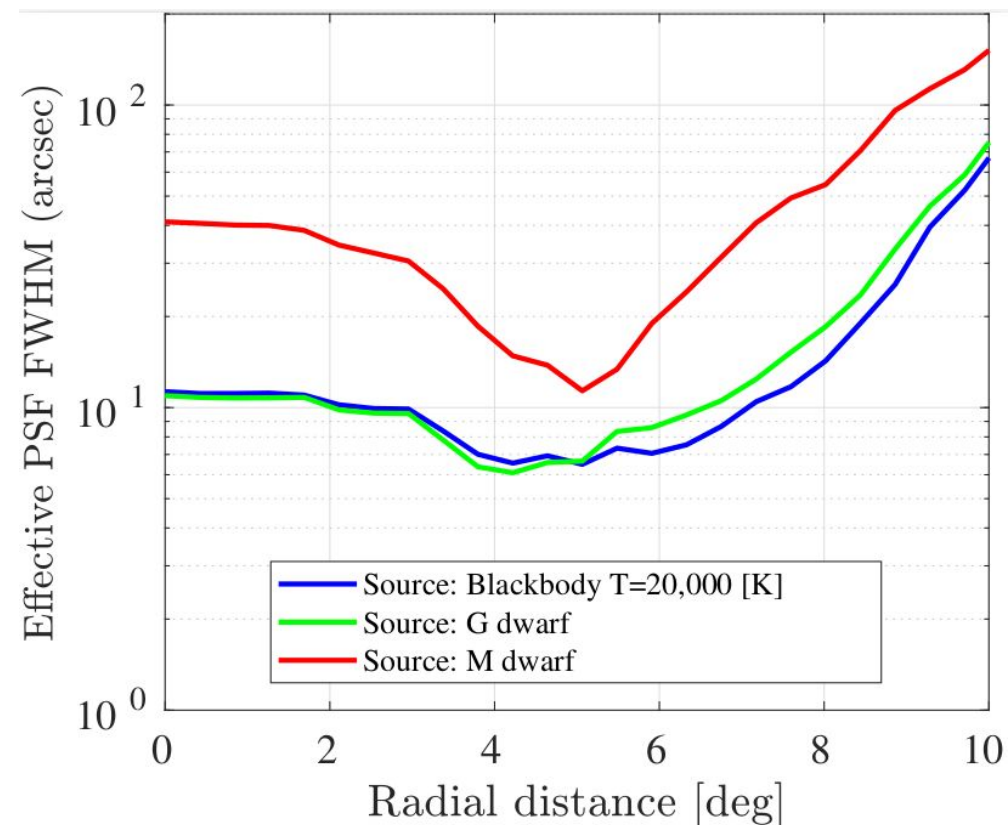
- ULTRASAT band: 230-290nm
- Central 170 deg²



For more details see: Ben-Ami+2022

Effective PSF

Source and position dependent

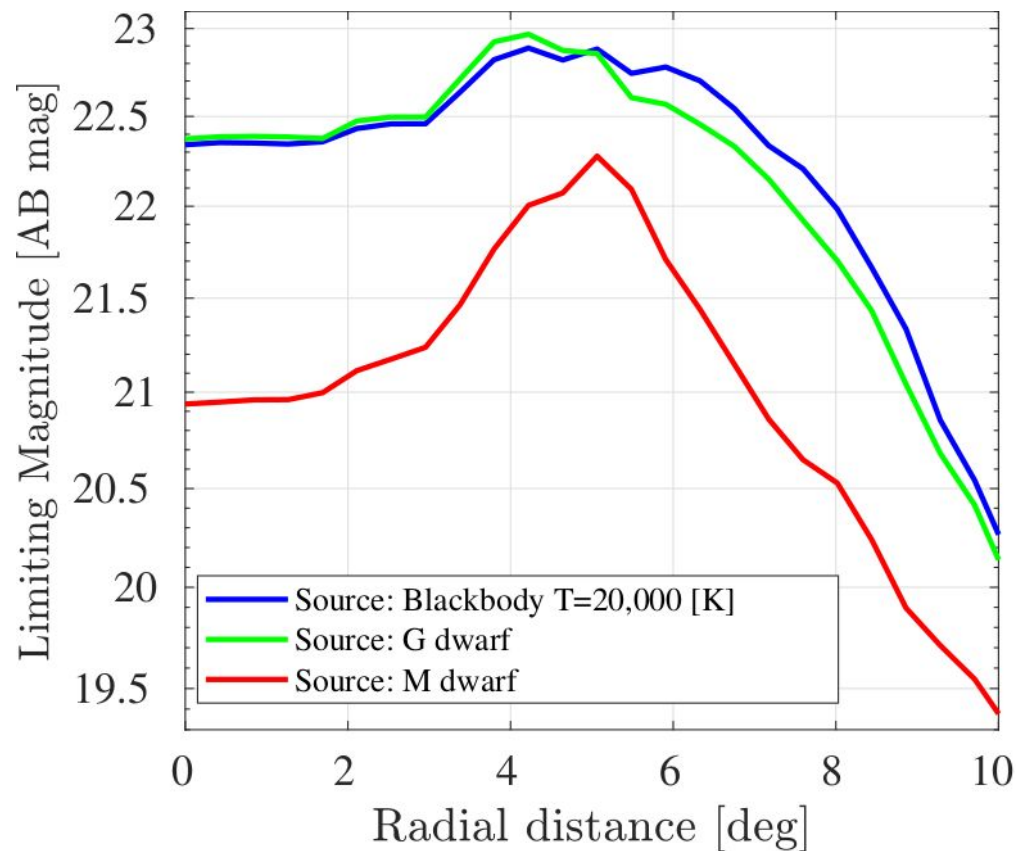


Shvartzvald+ 2023

Optical Performance

Limiting magnitude

- Source and position dependent



Shvartzvald+2023

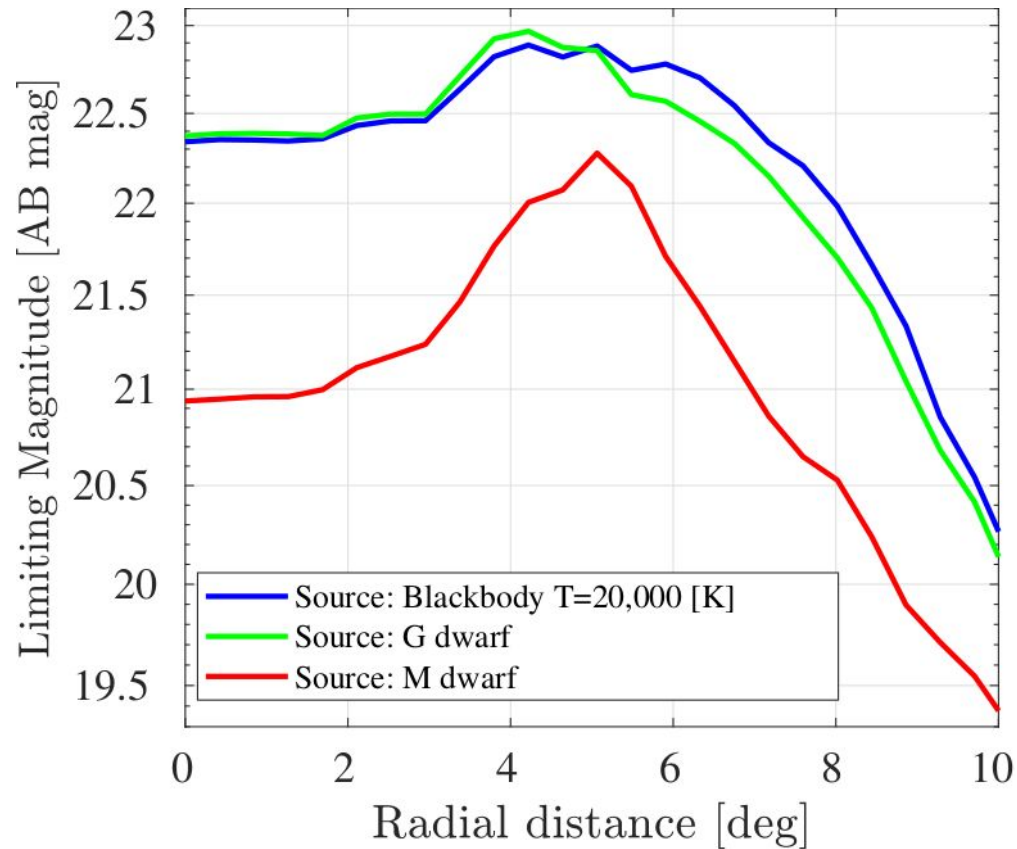
Background Noise

Source	Variance (e ⁻ /pix)
Zodiac (Survey)	27
Cerenkov (75%)	15
Stray light (max)	12
Dark current	12
Readout noise [²]	6
Electronic Crosstalk	2
Gain	1
Quantum Yield	<1
Total	75

Optical Performance

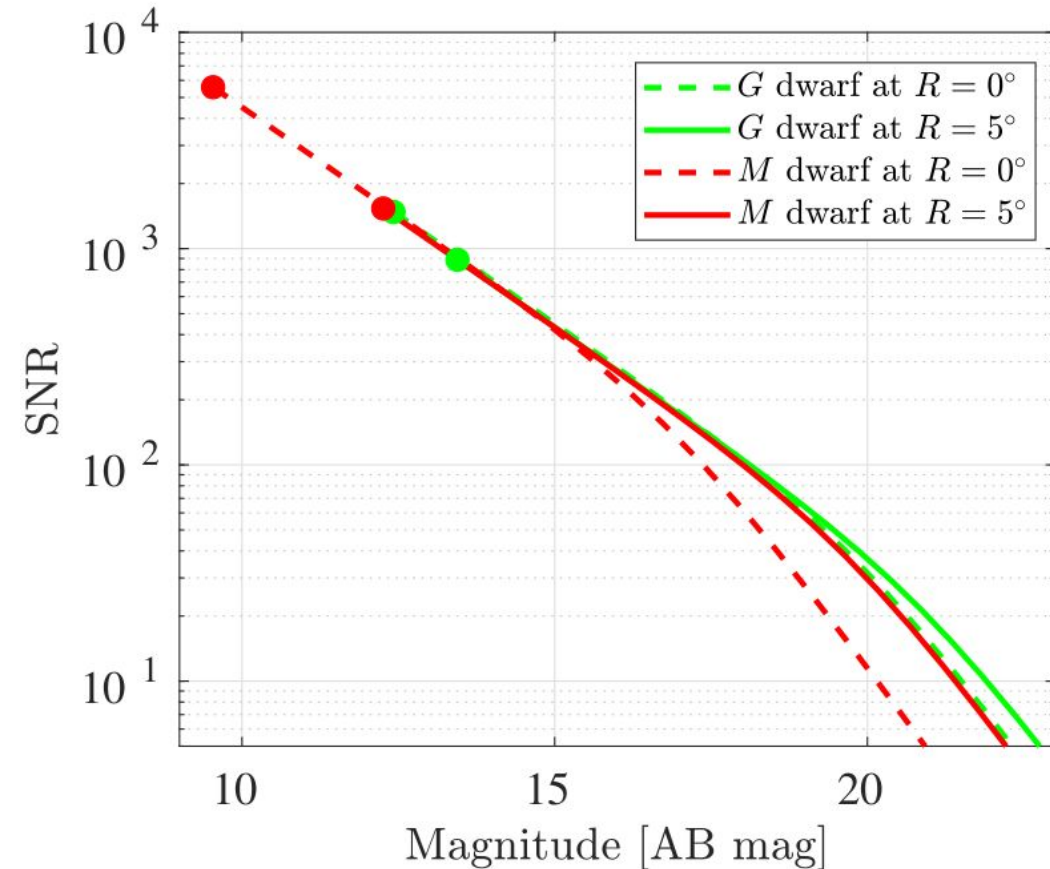
Limiting magnitude

- Source and position dependent



Shvartzvald+2023

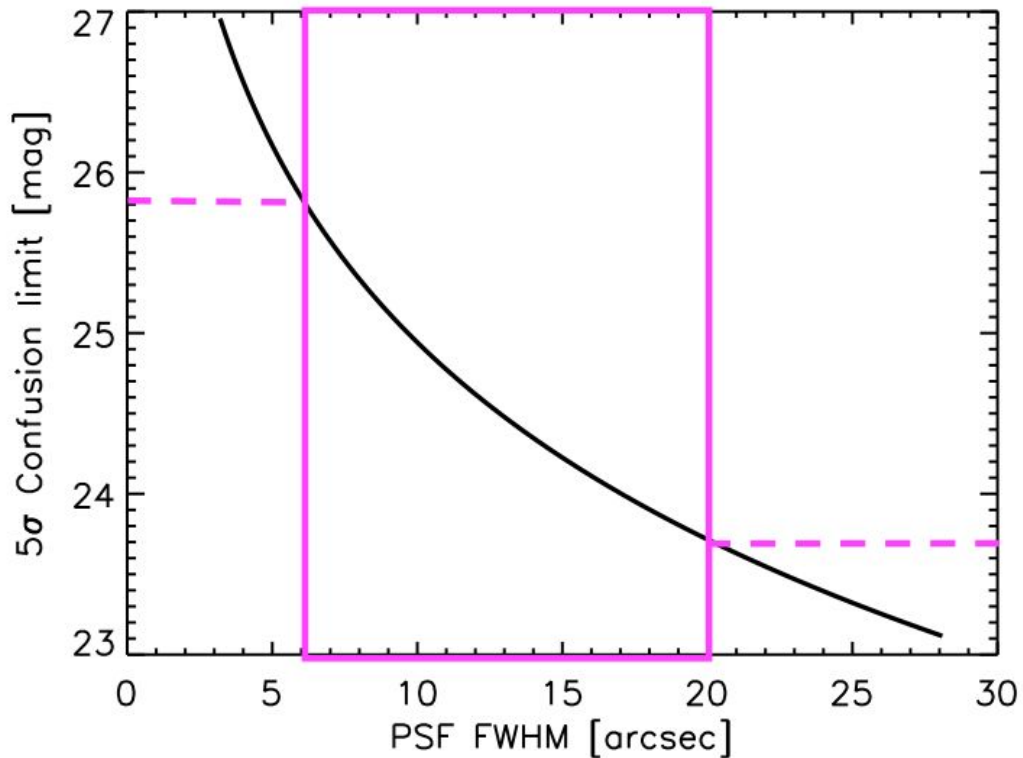
Sensitivity



Optical Performance

Confusion Limit

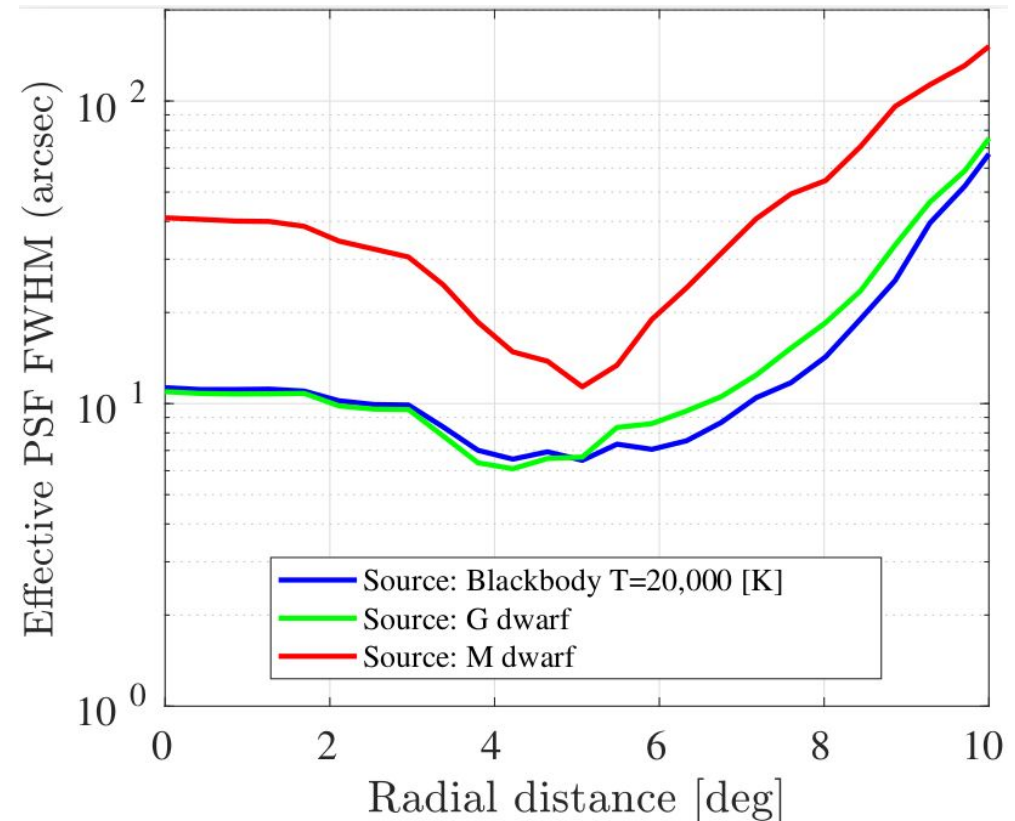
- Condon (1974) analytic formula
- Confirmed by simulated images



Shvartzvald+ 2023

Effective PSF

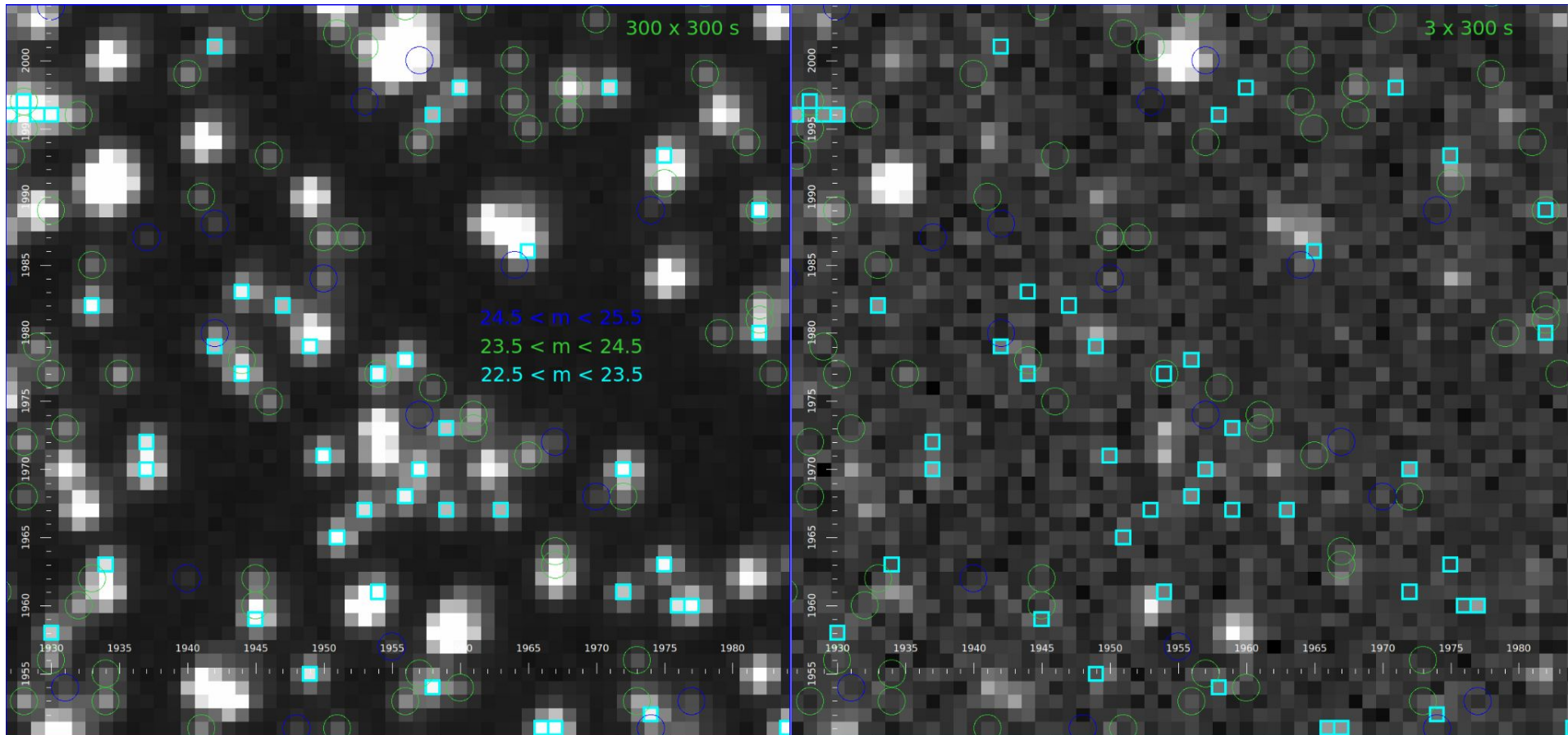
Source and position dependent



Simulated images

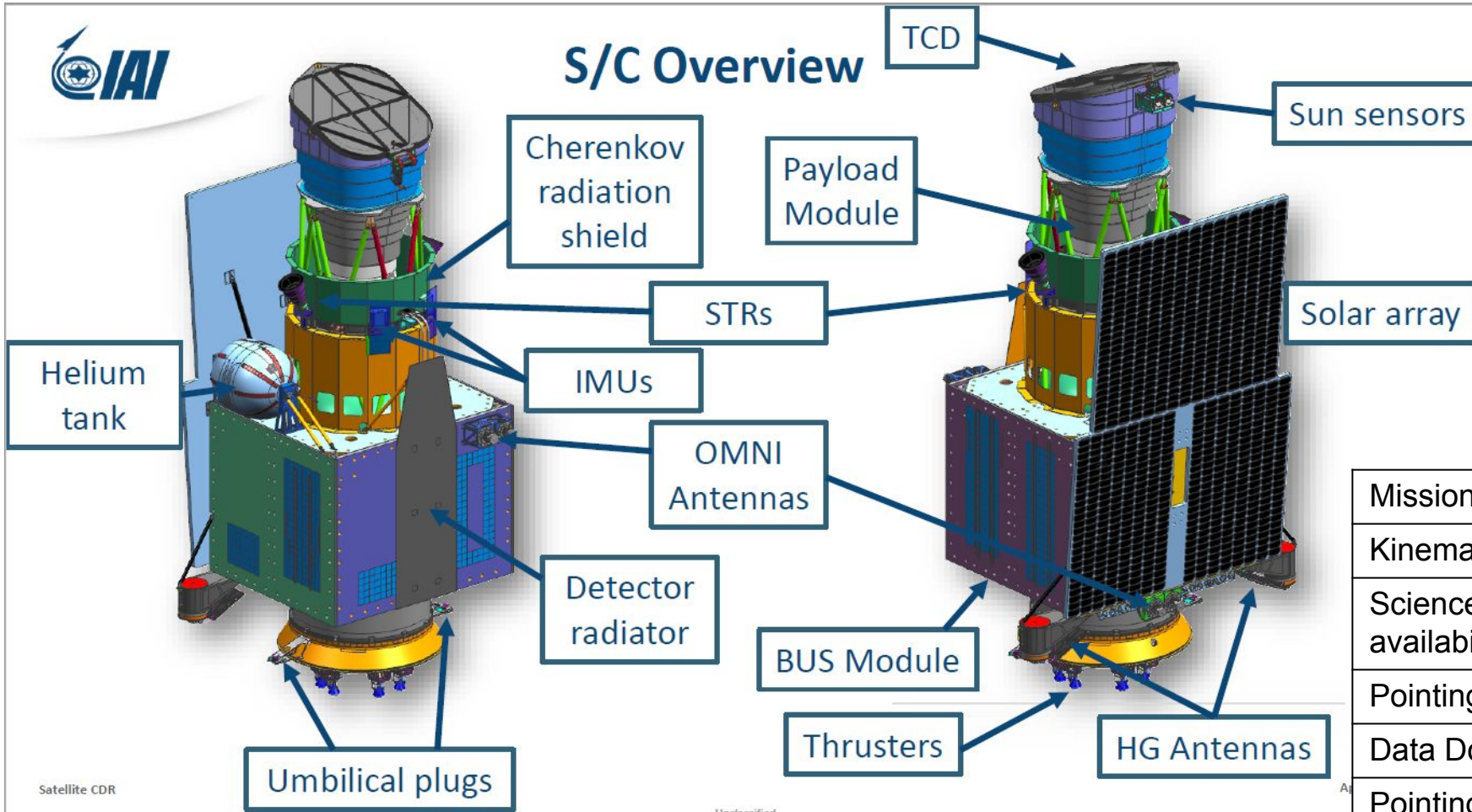
Preliminary work:

- Validate the confusion limit
- Validate sensitivity
- Tests of the SOC pipeline
- Simulated survey - for all WGs



R = 4.2 deg

Spacecraft



Mission lifetime	>3 years
Kinematic lifetime	6 years
Science observations availability	>90%
Pointing stability	<3.0" over 300s (3 σ)
Data Downlink rate	>5 Mbps
Pointing slew agility	>30°/min

Satellite.CDR

11hrFacceifard

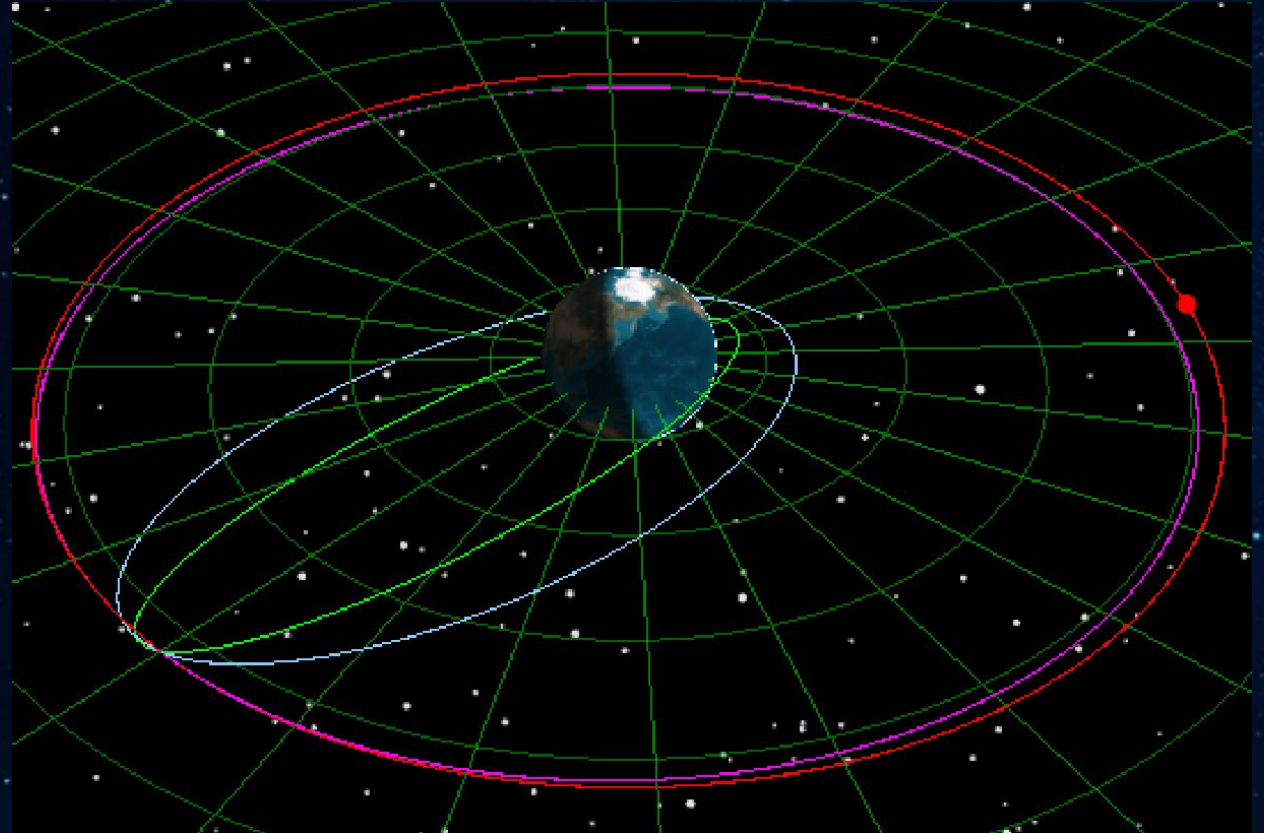
A1

Spacecraft

- Launch to Geo-Transfer-Orbit (GTO)
- GTO to Geostationary (GEO) maneuvers
- Main Mission: 3-6 years

GEO advantages

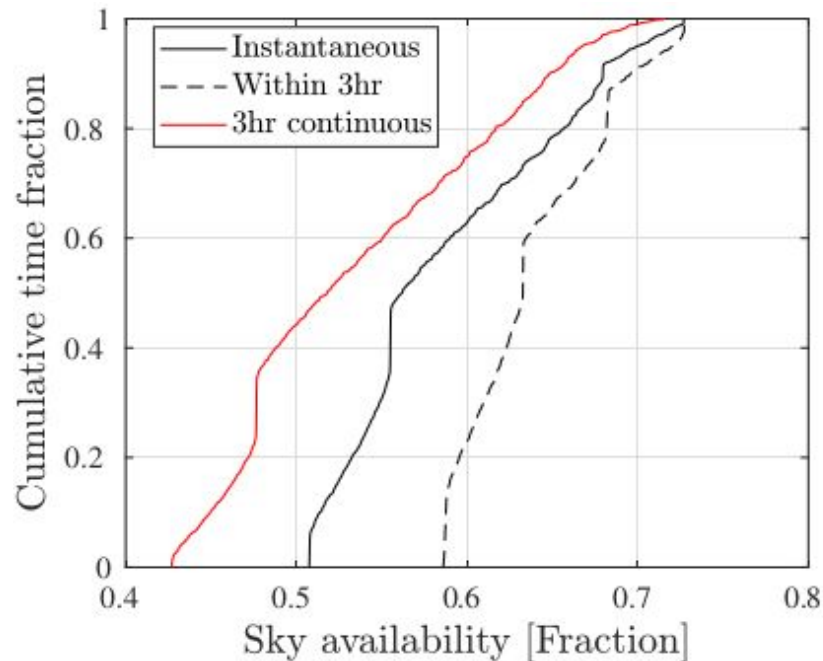
- Continuous communication:
 - Real-time data download
 - Instantaneous slewing
- Sky accessibility
 - >50% of the sky at any given moment
- Avoiding O₂ photo-dissociation line



Spacecraft

ToO:

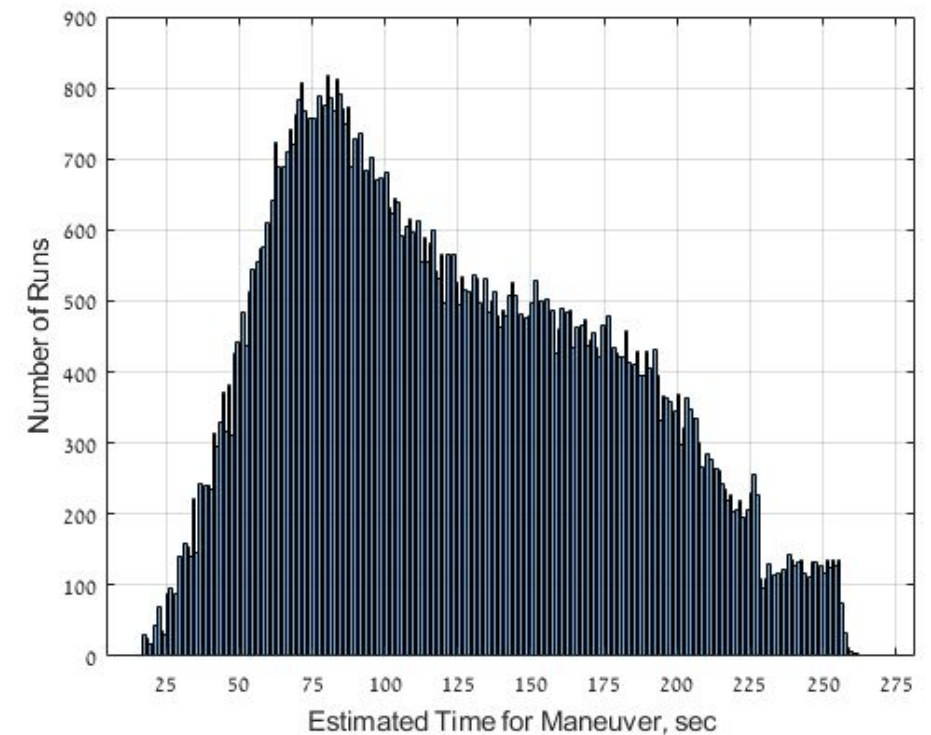
- **Continuous transmission** to the ground
- **Instantaneous >50% of the sky in <15 min**
- No limit on number of ToO's, except for max 25/yr with negative energy balance ("Hard ToO")
- Duration of Hard ToO: >3 h



Shvartzvald+2023

Maneuver duration

(10^5 cases)



ULTRASAT: Mission Profile



SURVEY (→ Key goal 2)

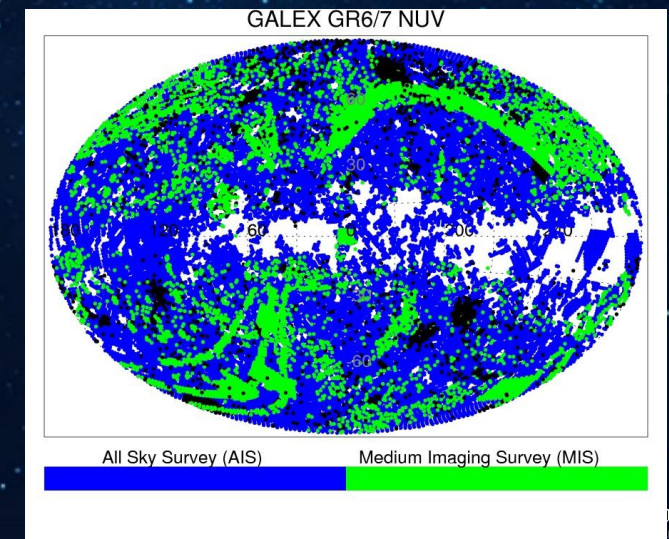
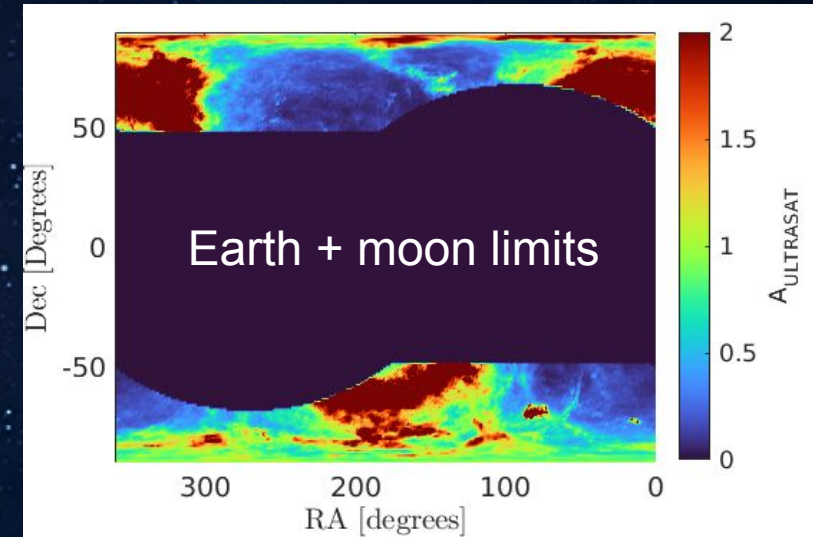
- High cadence - 200 deg² with 5 min cadence (21 hr/day)
- Low cadence - 8000 deg² with 4 day cadence (3 hr/day)
- Real-time data download and analysis - Alerts <15min of observations

TARGET OF OPPORTUNITY (ToO's; → Key goal 1)

- Instantaneous >50% of the sky in <15 min for >3 h
- No limit on ToO number, except for max 25/yr with negative power balance (33%)
- Continuous transmission to the ground

UV ALL SKY MAP

- 3hr/day during the first 6 months
- 10x deeper than current state-of-the-art (GALEX)
(>23.5 AB limiting mag @ |b|>30°)



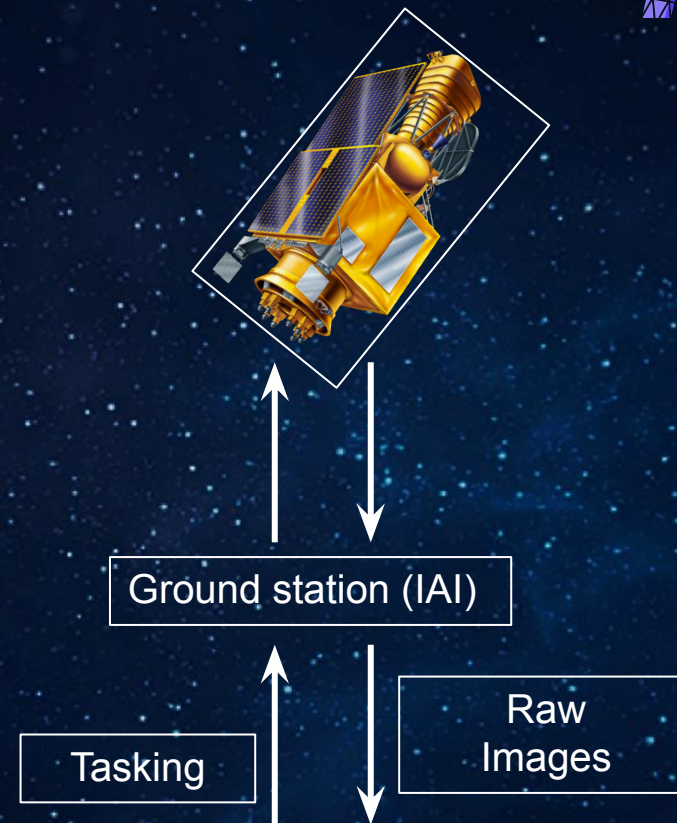
Operations

Ground Control Station (@ IAI):

- Command & Control, Telemetry Processing
- Immediate ToO tasking
- Receive imagery data, deliver to WIS (SOC)
- Perform ranging for orbit determination

Science Operation Center (@ WIS) :

- Observation planning
- Image and Data processing
- Scientific Data Products archiving
- Ultrasat Alerts generation



Data Policy

- ULTRASAT real-time alerts - publicly available immediately
- All other ULTRASAT data products:
 - Periodic public data releases (DRs), after full calibration and verification
 - Proprietary period - 12 months
- Members of the ULTRASAT collaboration and the science working groups will have immediate access to all ULTRASAT data products

Working Groups

Goals

- Maximize the science output of ULTRASAT.
- Coordinate the activity of involved researchers and prevent/mitigate conflicts.

Pre-launch

- Define specific key science questions to be addressed.
- Define key science papers to be written.
- Define key measurements and develop the required data analysis tools.
- Support the development of relevant theoretical analyses.
- Identify & advise SB on securing key required follow-up resources.
- Advise SB on modes of operation and on data products.
- Maintain a Wiki/Web page, presenting WG activity.

Post-launch

- Carry out ULTRASAT data analysis.
- Provide and analyze follow-up data.
- Write key science papers.
- Advise SB on modes of operation and on data products.

Working group	Lead(s)
WG1: Transient Stellar Explosions	Gal-Yam
WG2: Gravitation Wave Sources	Ofek
WG3: Planets & Star-Planet Connection	Ben-Ami & Shvartzvald
WG4: Cosmology	Kowalski
WG5: Stellar Structure and Evolution	TBD
WG6: Galaxies	Rhoads
WG7: Active Galactic Nuclei	Trakhtenbrot
WG8: Tidal Disruption events	Arcavi & Stone
WG9: Solar system	Polishook
WG10: Gamma-Ray Bursts	Cenko & Ho
WG11: Data analysis	Ofek & Shvartzvald
WG12: Transient alerts	Ofek & Shvartzvald
WG13: Followup	Gal-Yam

Working groups

WG meeting sessions - topics to discuss:

- Constraints/Preferences for the High cadence field(s) selection
- Required pre-launch studies (observations, analysis tools, theory)
- Required Follow-up Resources

WG reports - dedicated session on the last day. ~10 min per WG

WG documented reports - by the end of the year:

- Key science paper (first/second version)
- Planned pre-launch studies:
 - Observations
 - Analysis tools
 - Theoretical work
- Desired data products (content, format, access)
- Required Follow-up Resources

Tuesday (July 11)	
WG2: Gravitation Wave Sources	@ Library
WG7: Active Galactic Nuclei	@ Astro
WG9: Solar system	@De-Shalit

Wednesday (July 12)	
WG1: Transient Stellar Explosions	@ Library
WG3: Planets & Star-Planet Connection	@ Astro
WG8: Tidal Disruption events	@De-Shalit
WG4: Cosmology	@ Aquarium