



ESA's Flyeye telescopes

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EU-ESA Workshop on Size Determination of Potentially Hazardous Near-Earth Objects - 13/11/2024

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→ THE EUROPEAN SPACE AGENCY

Strategic objectives

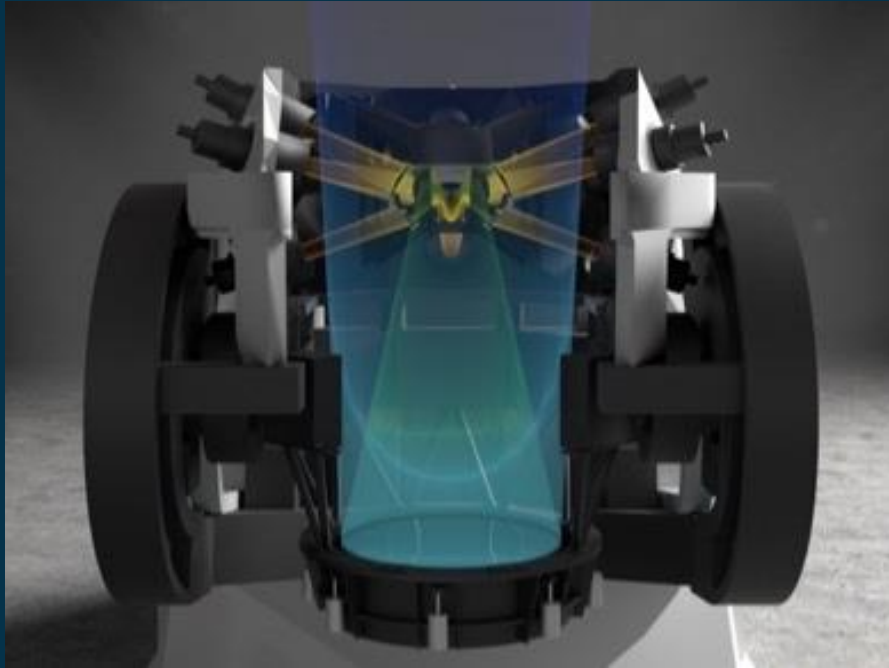
- Space Weather early warning system tailored to European user needs
- **Early warnings for asteroids >40 m about three weeks in advance,**
- Capability to deflect asteroids smaller than 0.5 km (2 years before)
- Established European players for a growing market of space-traffic technologies and products
- Prepare European industry for a zero-debris policy and a circular economy in space



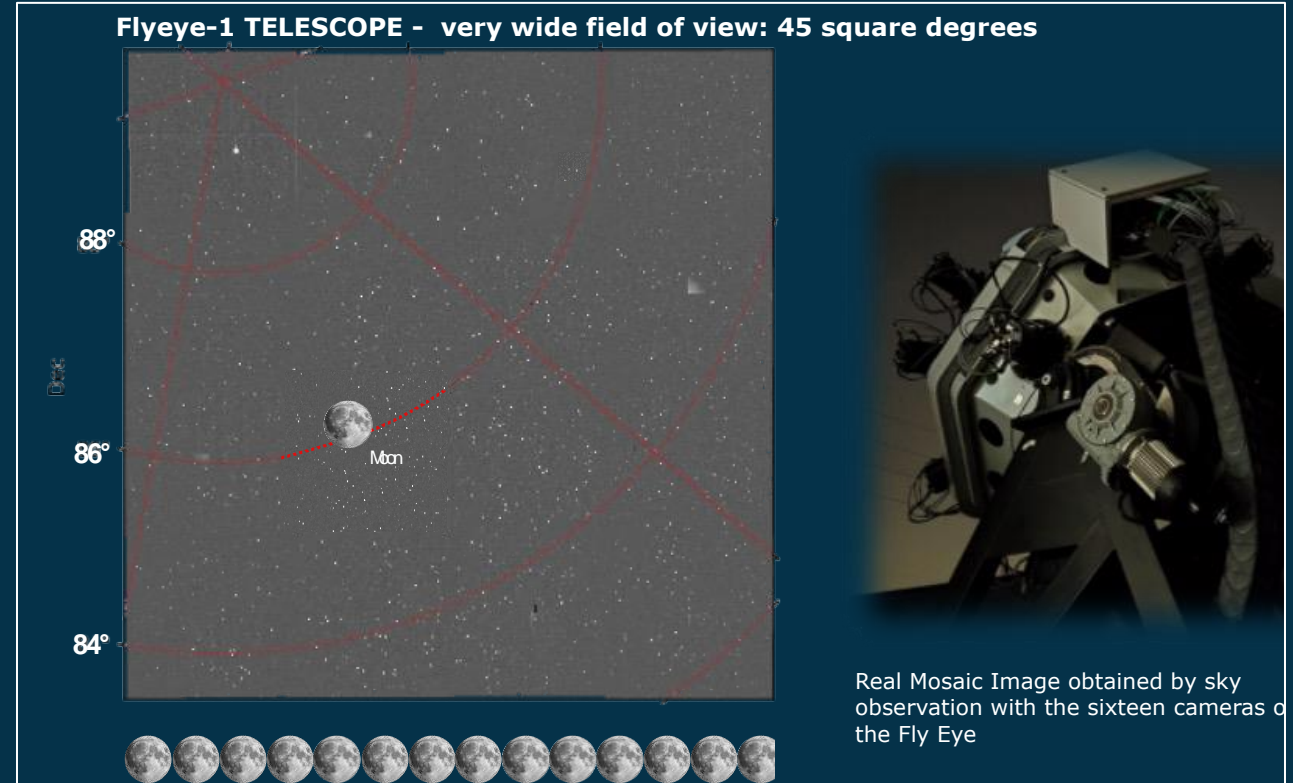
ESA's NEO Survey System



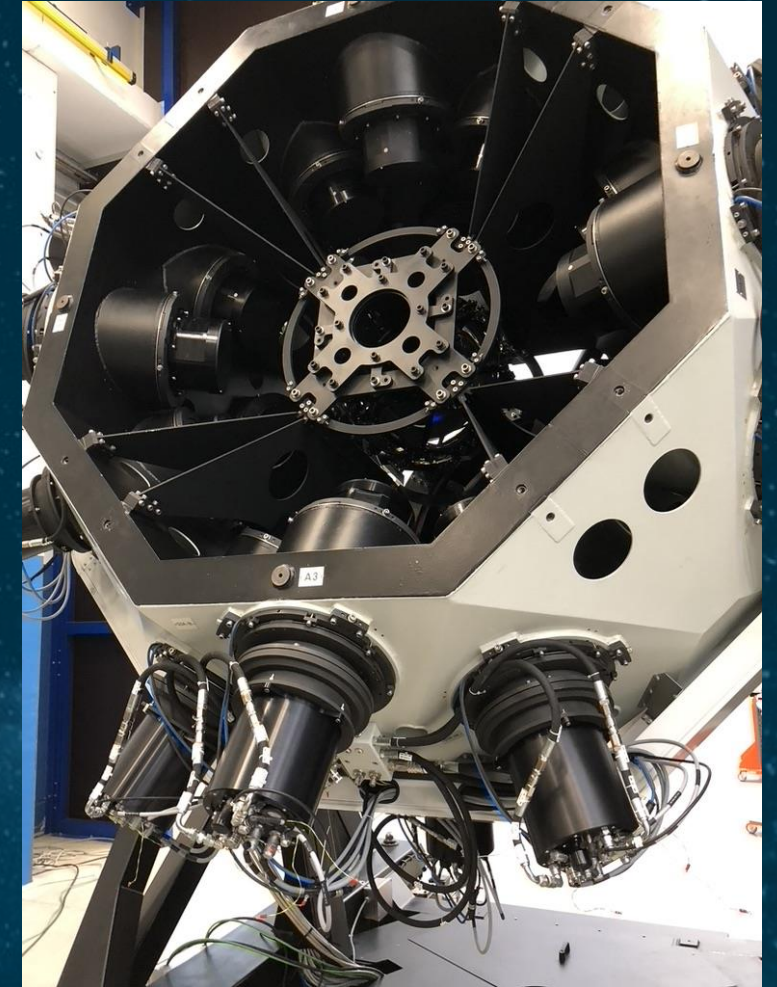
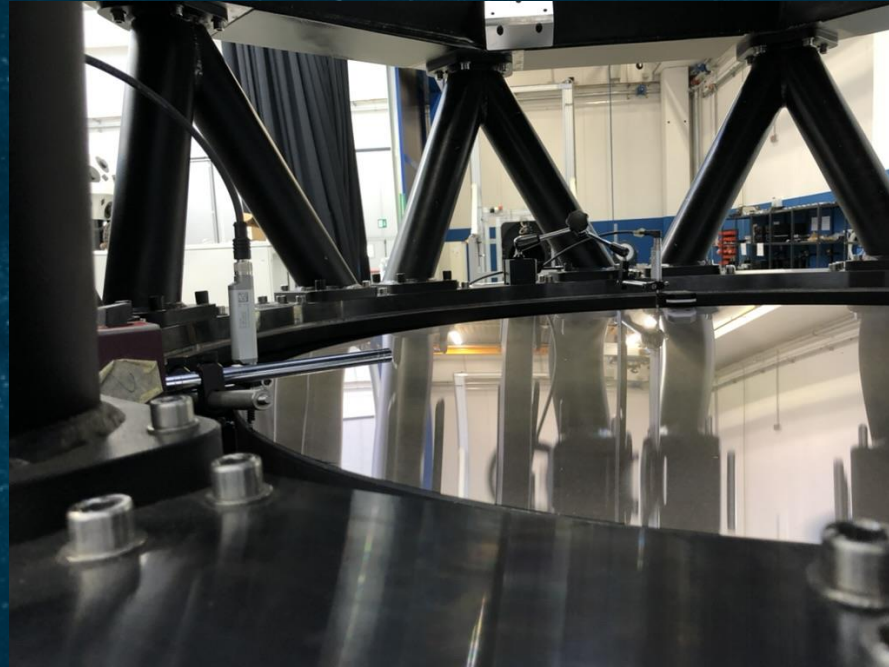
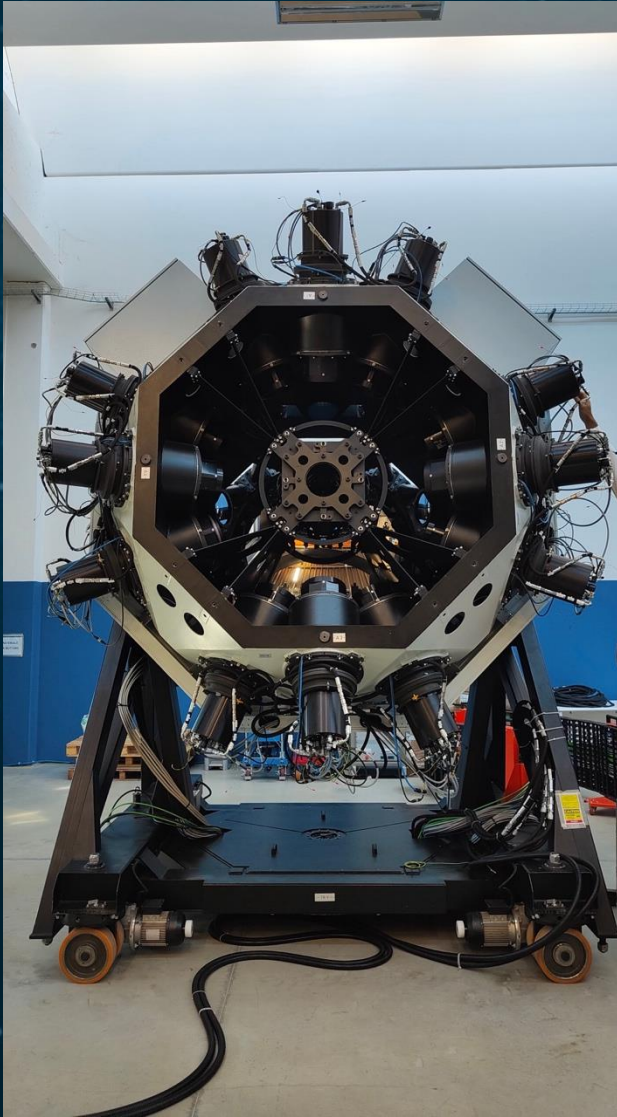
Flyeye-1 Telescope Overview



D: 1~m
Cameras: 16 4kx4k CCD
Pixel scale: 1.5"
FoV: **6.7°x6.7°**



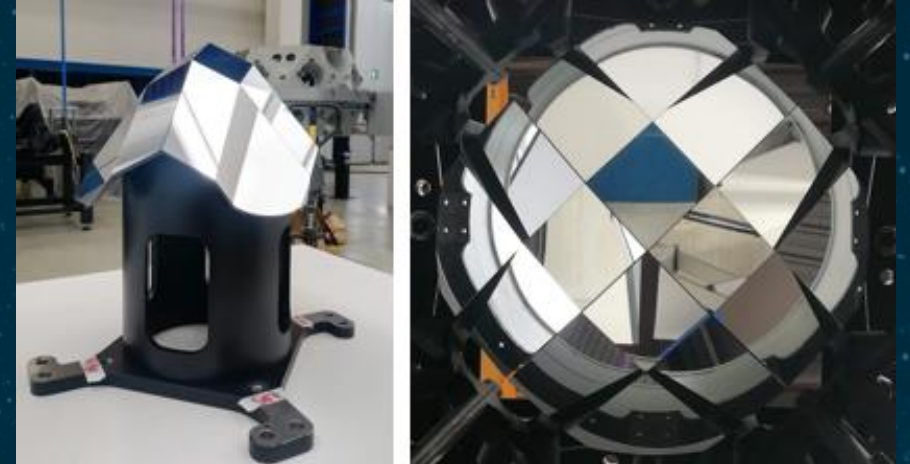
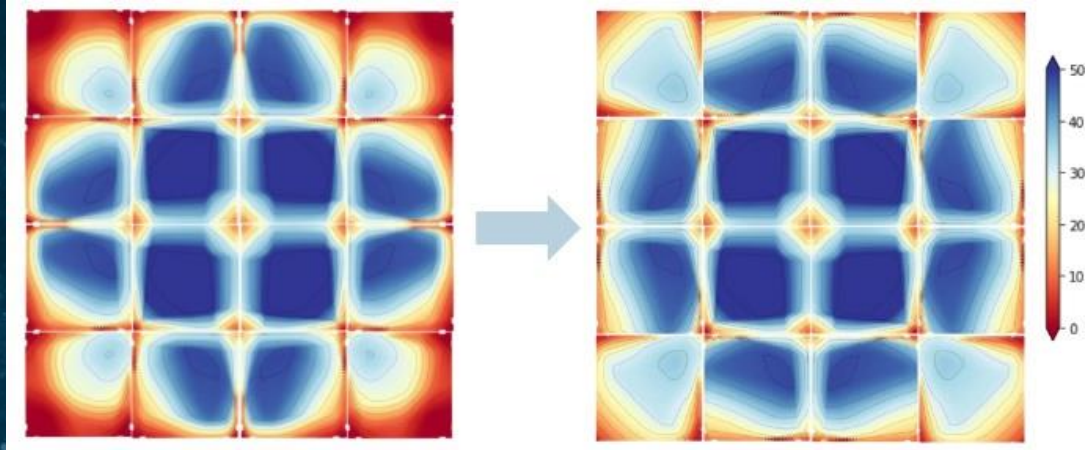
Flyeye-1 under construction - the optics



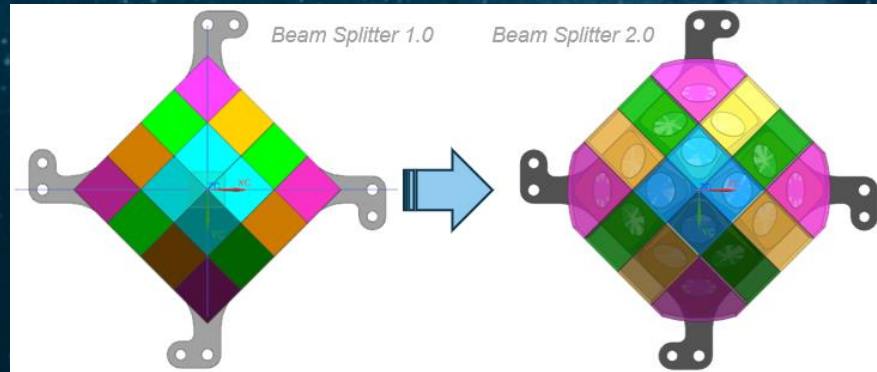
Telescope Primary Mirror and Secondary Structure

Flyeye-1 under construction - the optics

Telescope Vignetting Pattern



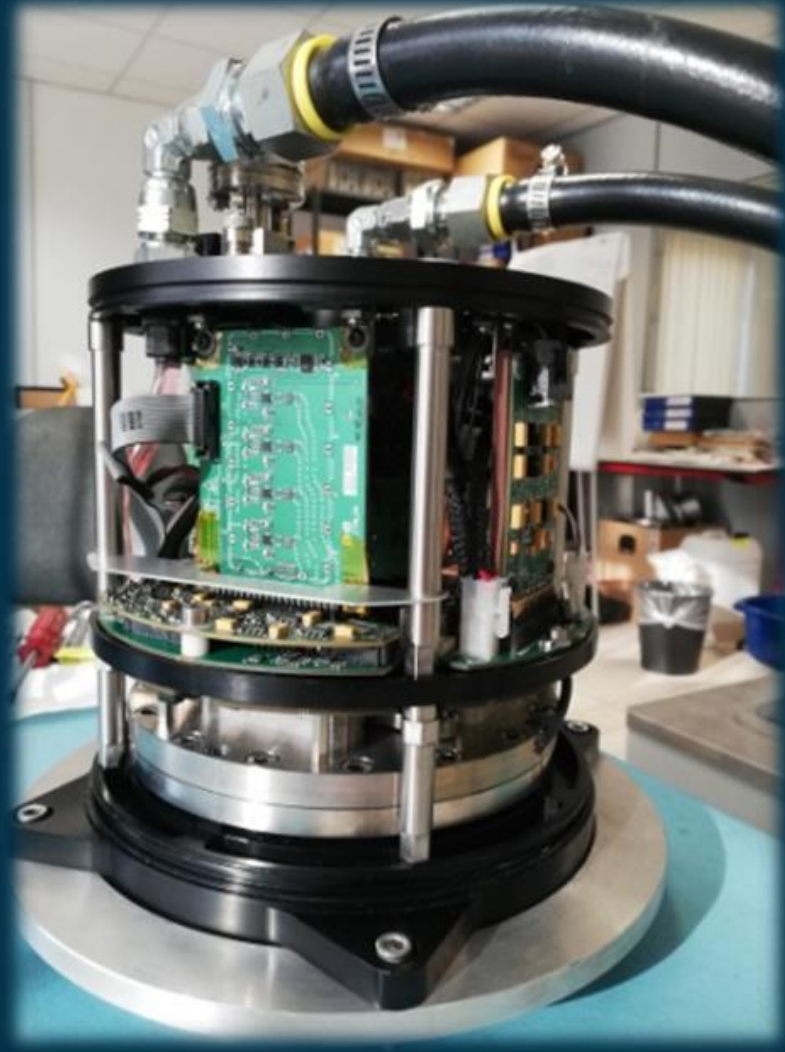
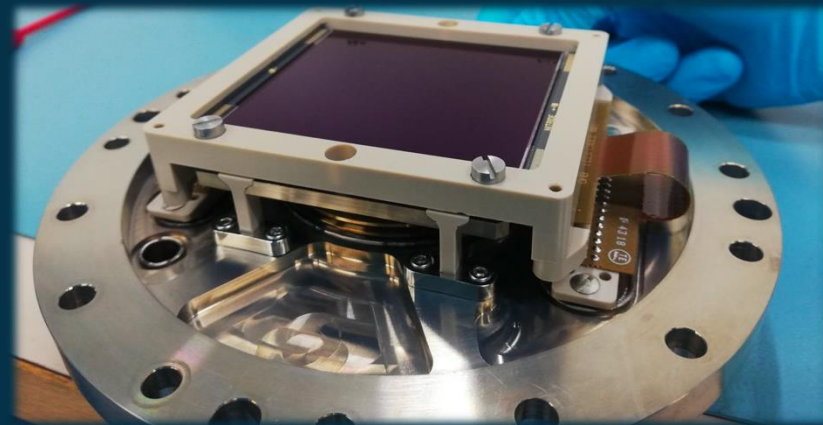
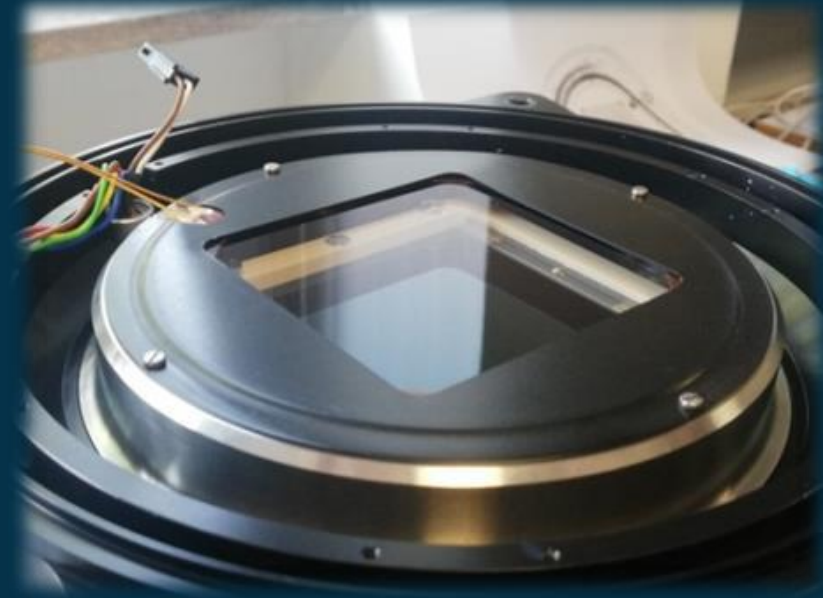
Beam splitter redesign introduced in 2023



Flyeye-1 under construction - Astronomical Cameras



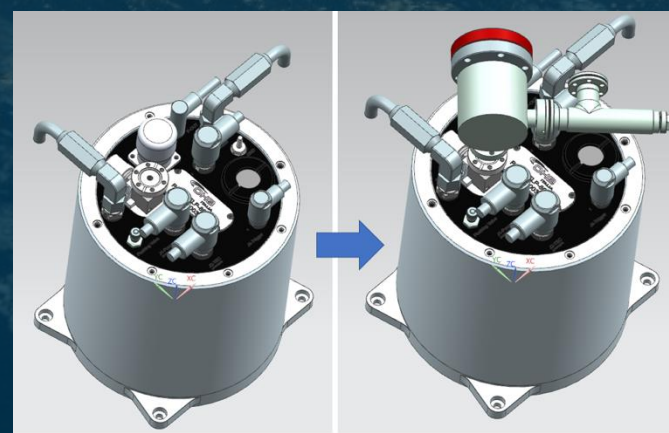
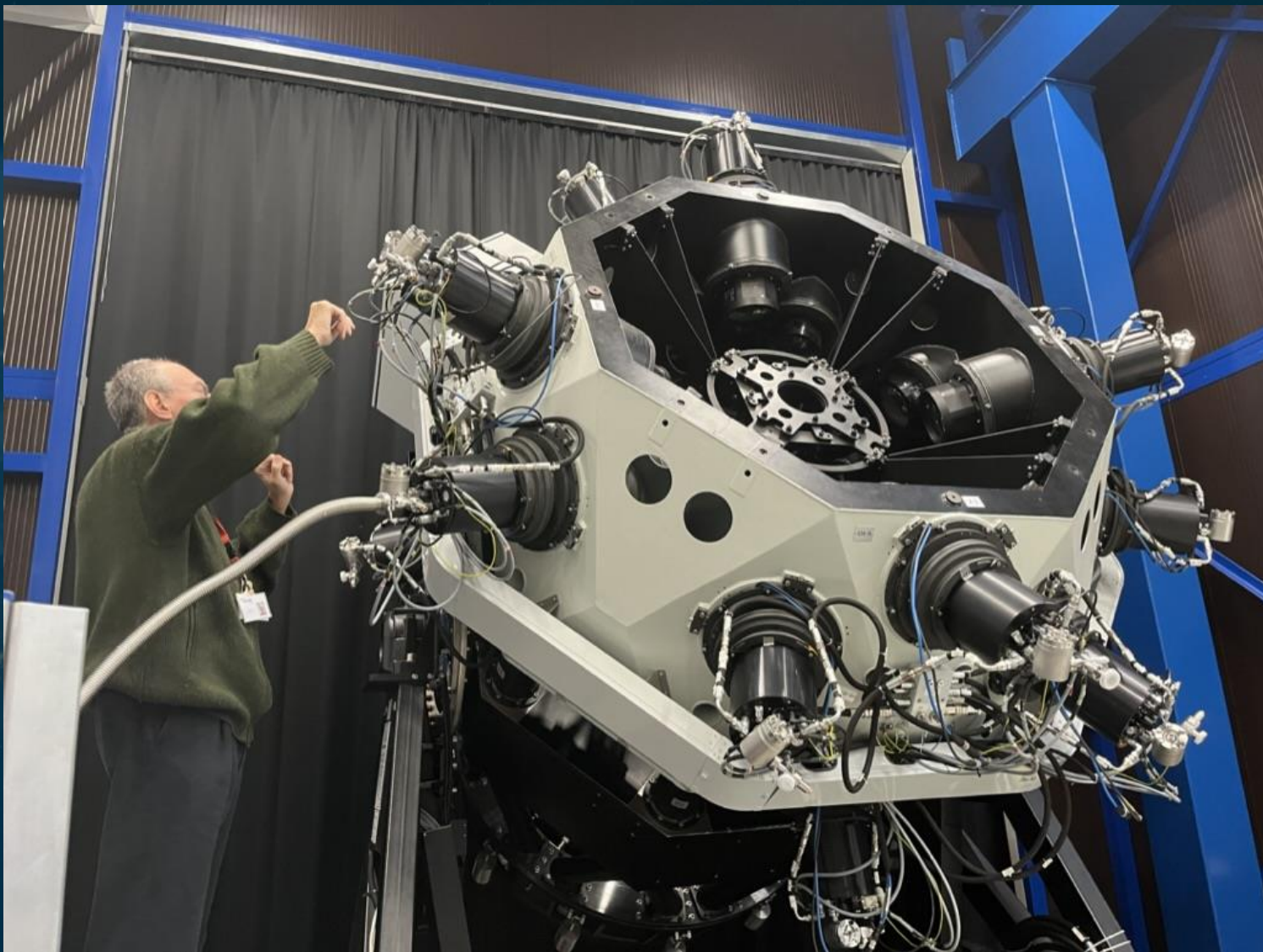
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Flyeye-1 under construction - Astronomical Cameras



esa



Improved vacuum chamber introduced in 2024



Flyeye-1 under construction – the mount

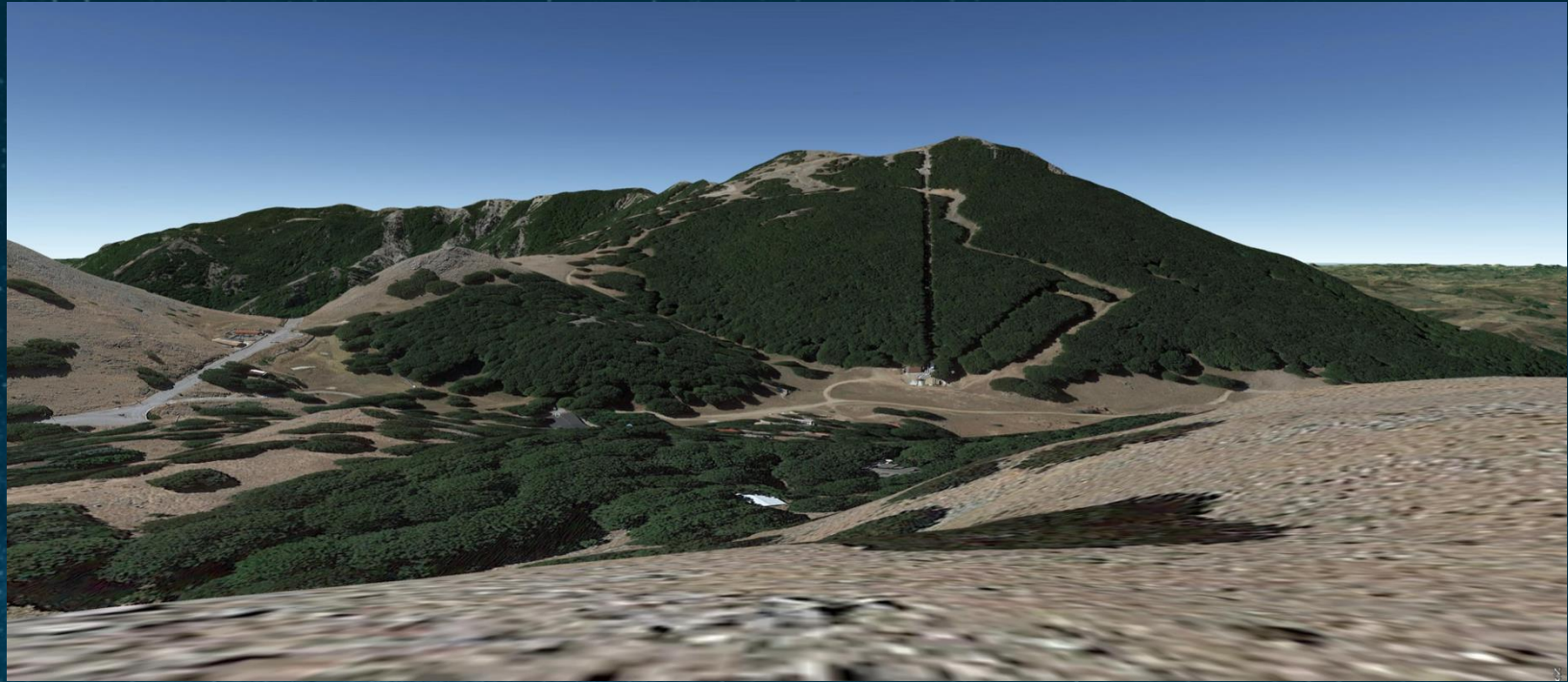
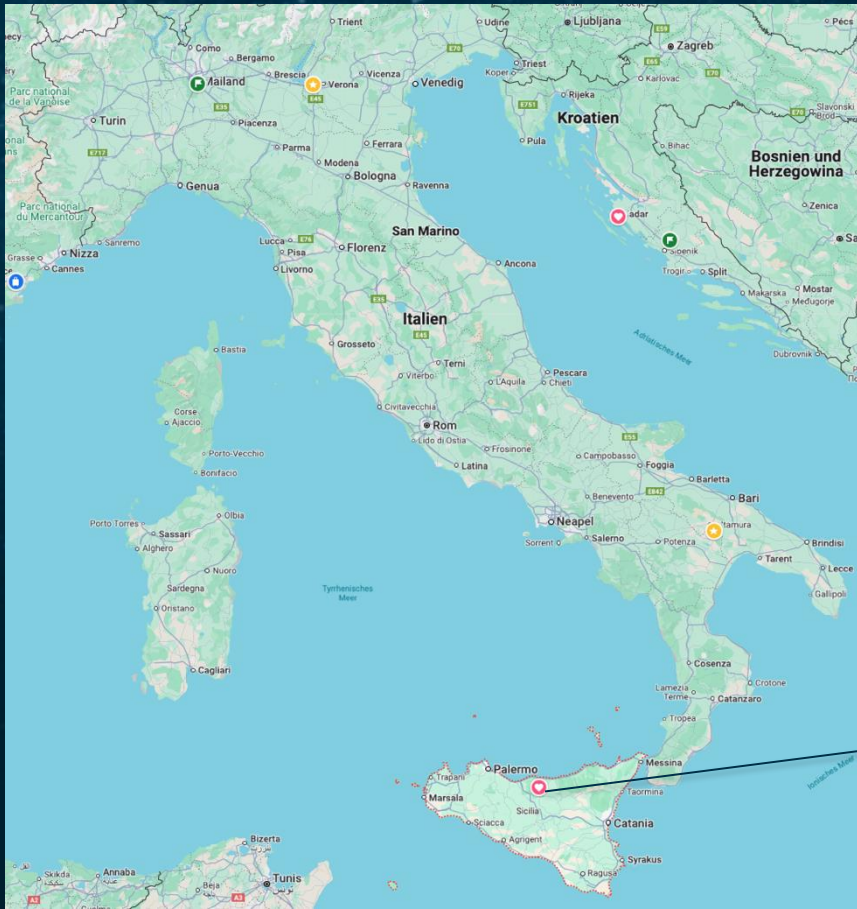


Equatorial Mount with dummy during factory tests
Nov'2021



Total weight: 19t
Max Speed: 7deg/s
Max Acc: 12deg/s²
Point.Accuracy: +/-5''
Tracking Accuracy: 0,3''RMS

Flyeye-1 under construction – the site

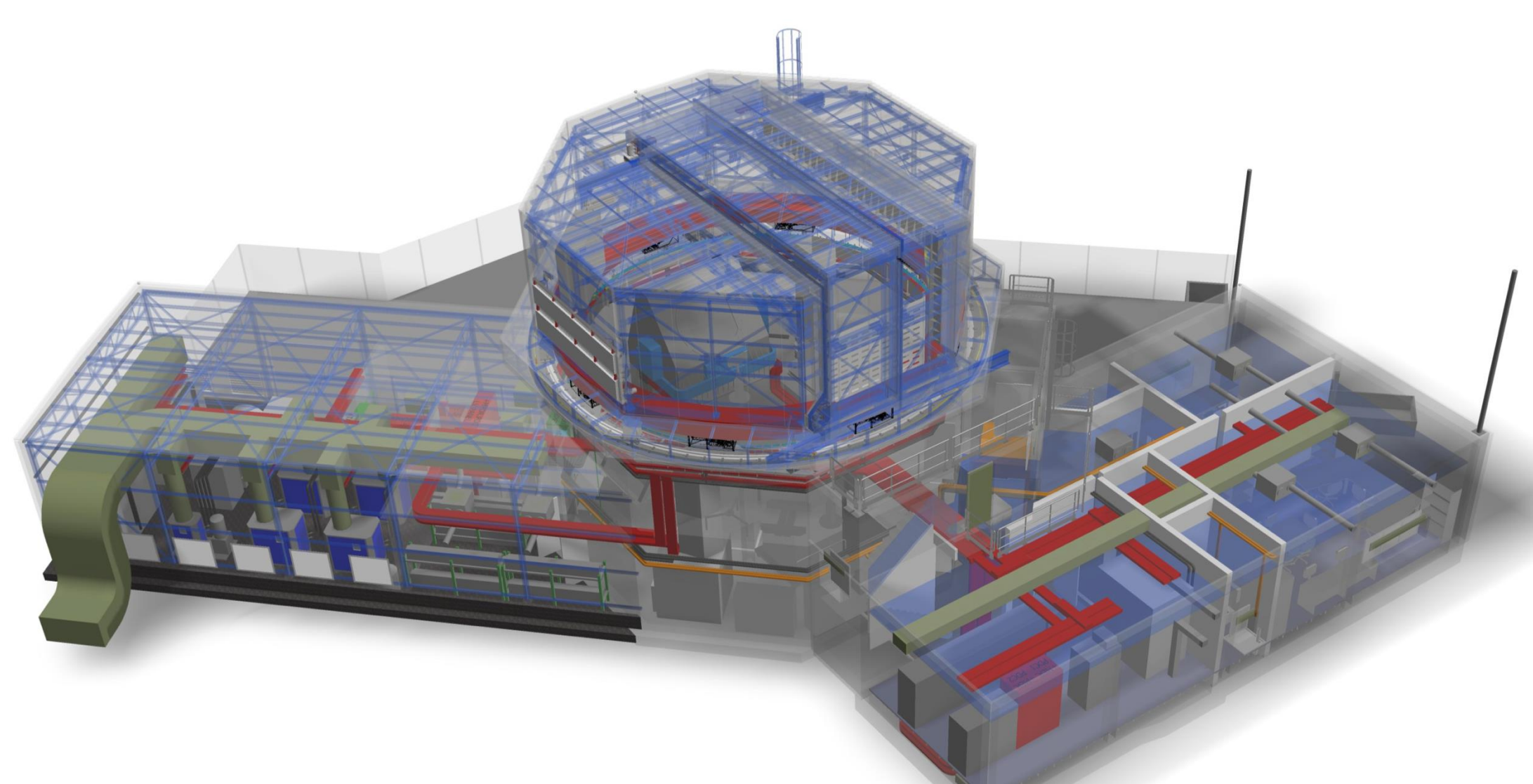


**Monte Mufara, Sicily
1865mts**

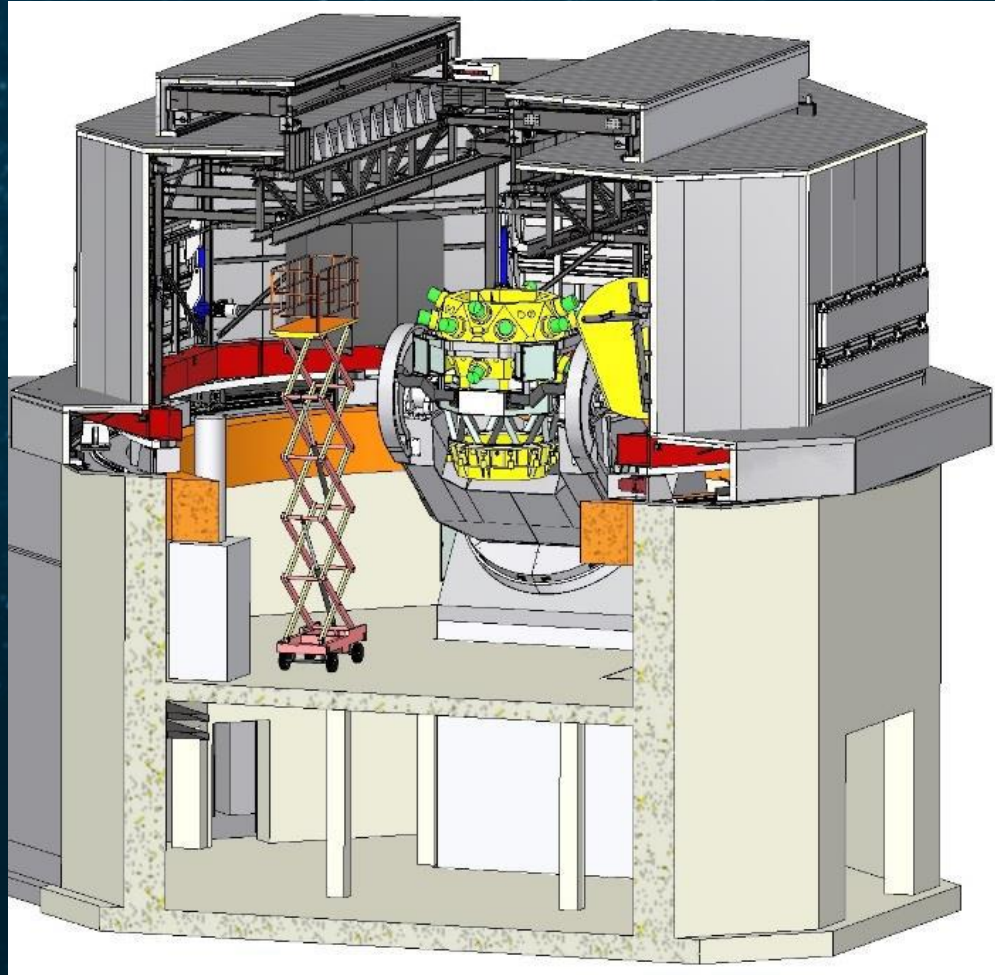
Flyeye-1 under construction – the Mt Mufara site



Flyeye-1 under construction – the observatory

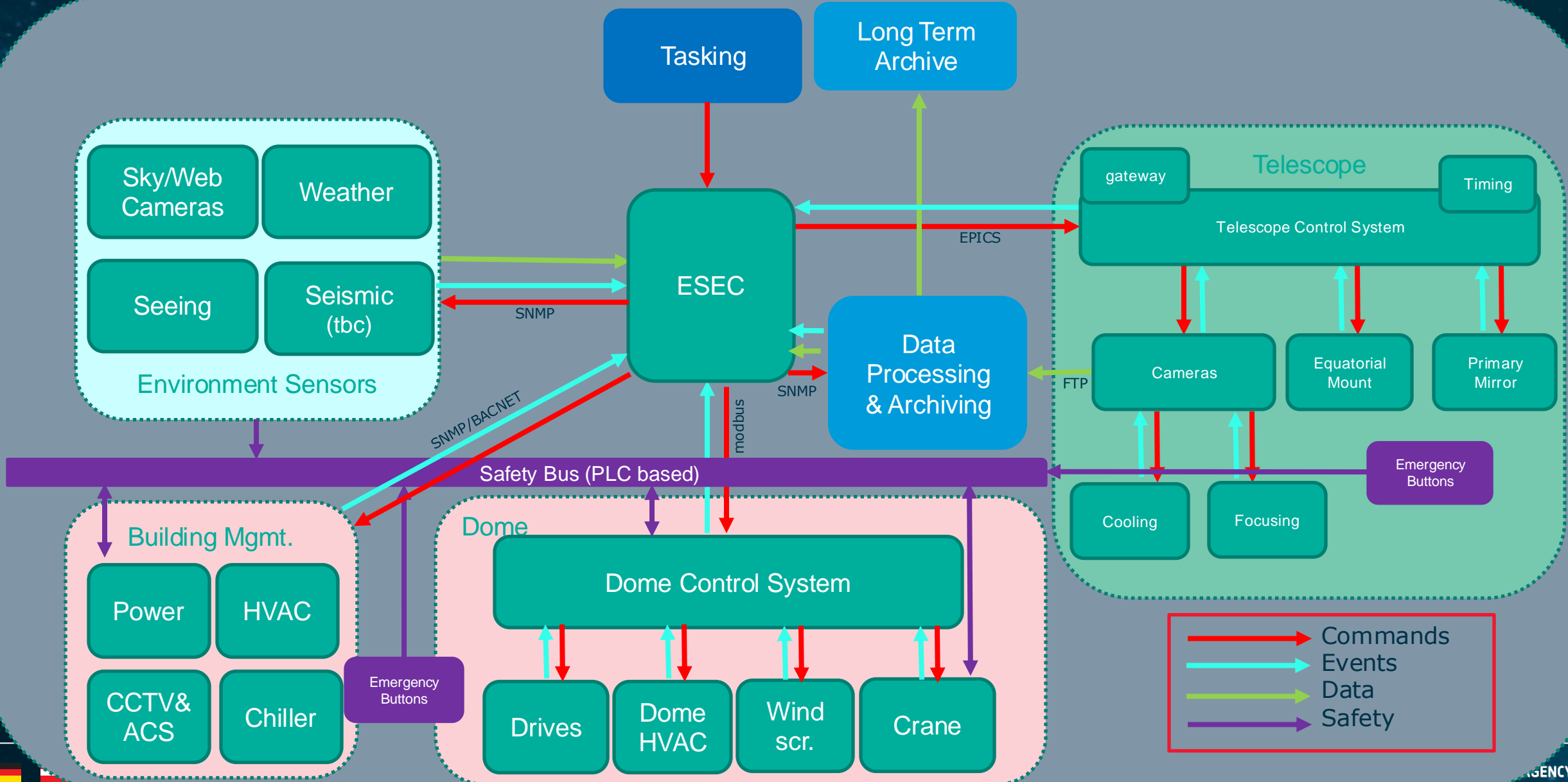


Flyeye-1 under construction – the observatory



Diameter: 13m
Height: 14m
Total weight: 56t
Max Speed: 11deg/s
Mac acceleration: 4deg/s²

Architecture and Interfaces



NEO Tasking Application
Settings Help dfrohing

Schedule

- Calibration
- Survey
- Follow-up
- User Requests
- Schedule Generation
- Schedule Monitoring

Status

JPL Scout Import
Updated:

Risk List Import
Updated:

Sky Coverage Import
Updated:

Database Connection
Connected

Schedule Generation
Total Scheduled Items: 0
0 survey items (0%)
0 follow-up items (0%)
0 calibration items (0%)
0 user-requests items (0%)

Survey

Survey Parameters

Number of visits: 4 visits

Min. inter-visit time: 15 minutes

Desired max. inter-visit time: 60 minutes

Dither value: 10 pixels

Exposure time: 30 seconds

End Of Night Strategy: No special strategy

Use external observations

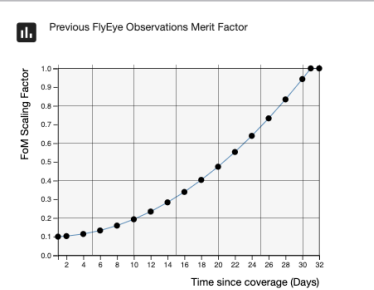
Use previous observations

Camera Configuration Profile: default

URL: <https://www.minorplanetcenter.net/iau/SkyCoverage.html> Reload Last updated: 2024-11-07T09:01:32.952

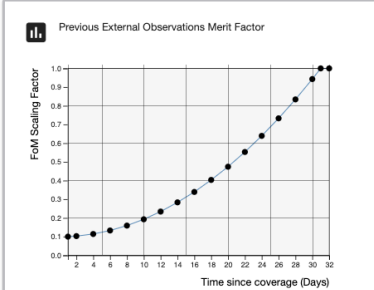
Previous Observations

Previous FlyEye Observations Merit Factor



Use previous Flyeye observations

Previous External Observations Merit Factor



Use external observations

NEO Tasking Application
Settings Help dfrohing

Schedule

- Calibration
- Survey
- Follow-up
- User Requests
- Schedule Generation
- Schedule Monitoring

Status

JPL Scout Import
Updated: 2024-05-14T10:12

Risk List Import
Updated:

Sky Coverage Import
Updated:

Database Connection
Connected

Schedule Generation
Total Scheduled Items: 644
644 survey items (100%)
0 follow-up items (0%)
0 calibration items (0%)
0 user-requests items (0%)

Schedule Monitoring

Object Identifier: R198D146 Date: 2024-02-21T05:06:54.781166447 UTC

Legend:

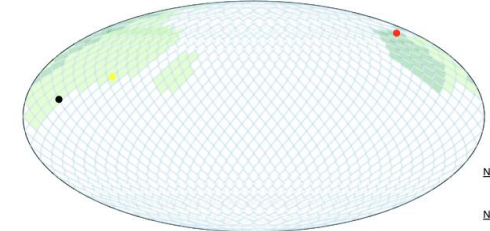
- Telescope pointing
- Moon position
- Anti-Sun position

Number of visits:

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9

No Go Zones:

No Slew Zones:



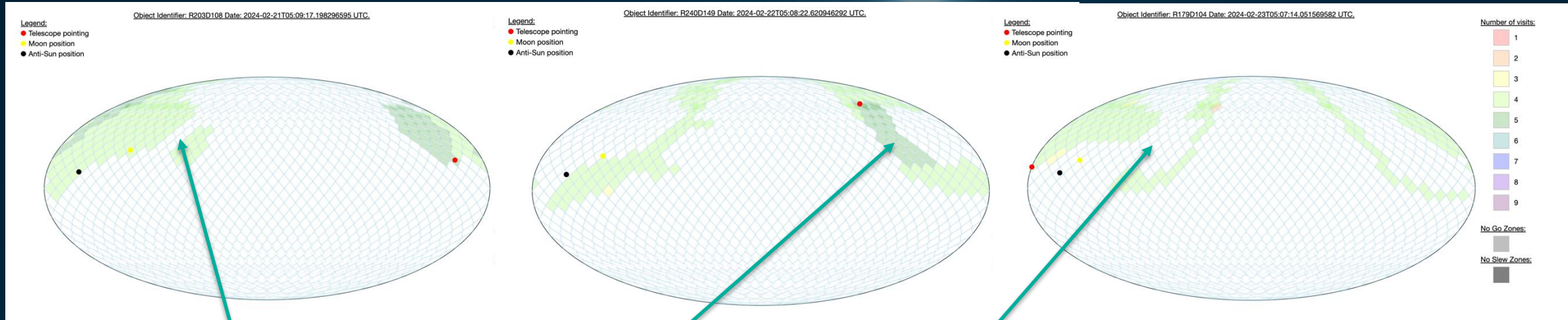
Reset Step delay: 500

Scheduler Observations

Filter

Date Time	Type	Object ID	Rigth Ascension	Declination	Successful
2024-02-20T19:08:04	Survey	R064D118	64.6154	28.4014	UNKNOWN
2024-02-20T19:08:46	Survey	R060D123	60.0255	33.5683	UNKNOWN
2024-02-20T19:09:28	Survey	R069D123	69.2563	33.5683	UNKNOWN

Survey Strategy



Gap due to Milky Way brightness being taken into account

Repeated observations due to end-of-night strategy

Region of sky observed in previous night is given low priority and not observed

Complete scan of the observable sky down to $V \sim 21.5$ every 2-3 nights.

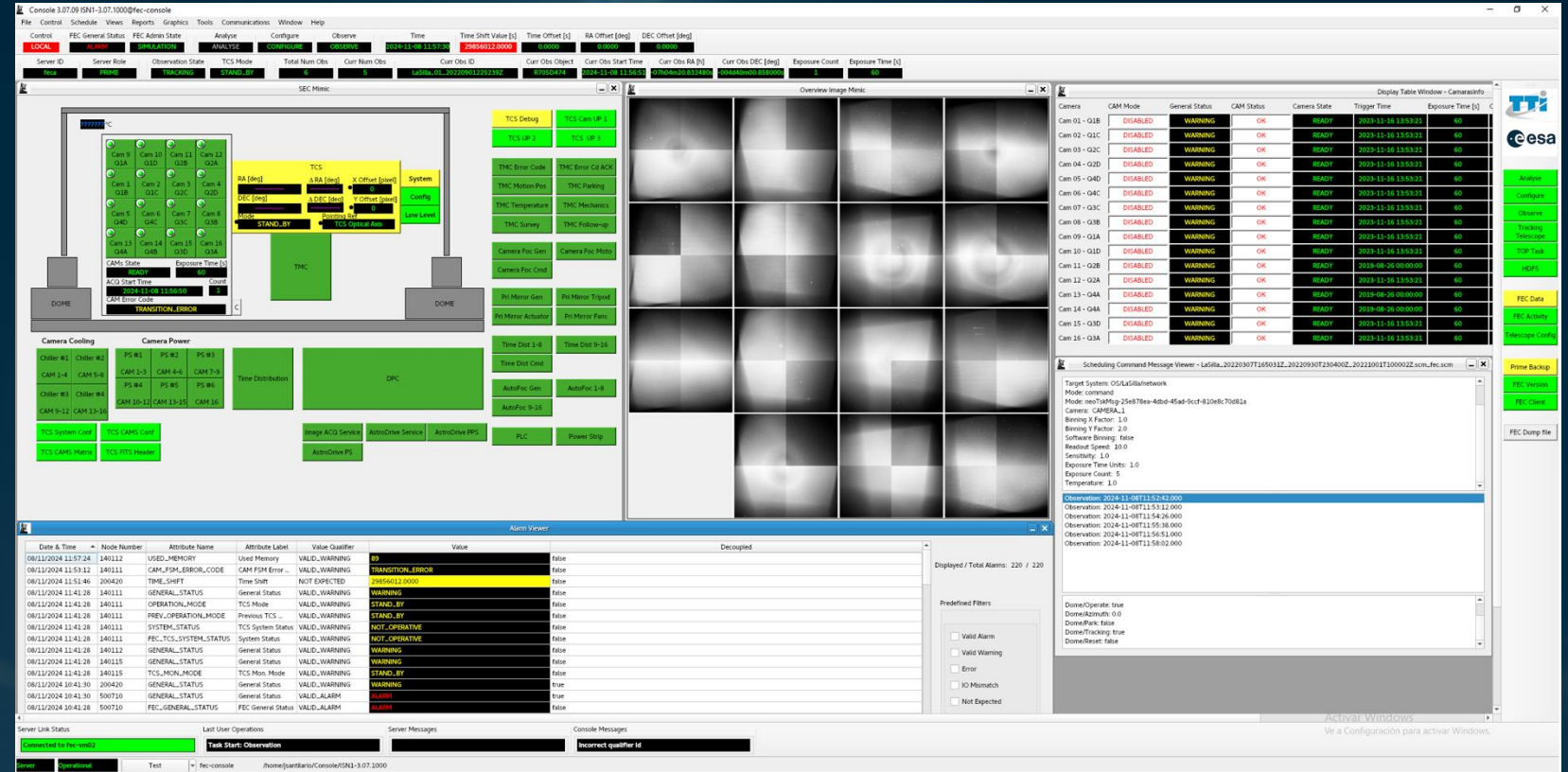
Initial survey strategy:

- 4x observations per target per night
- Revisit time: 20 min
- Cadence: 80 s (60 s exposure time + overheads)

Merit Factors determine:

- Priority of objects (can be set manually)
- Scaling with Moon brightness
- Exclusion of the Milky Way

- Operator Interface
- Monitoring and Control for:
 - Telescope
 - Dome
 - Site Infrastructure
 - DPC
- Processing of Scheduling Files (SCM) into high-level commanding
- Alarm and Error logging and debugging



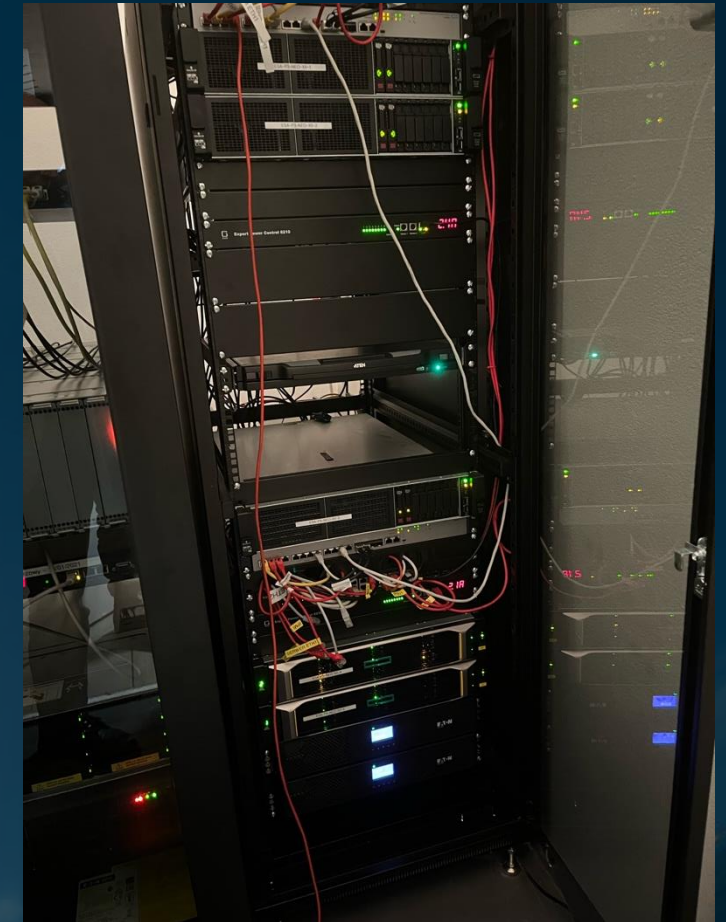
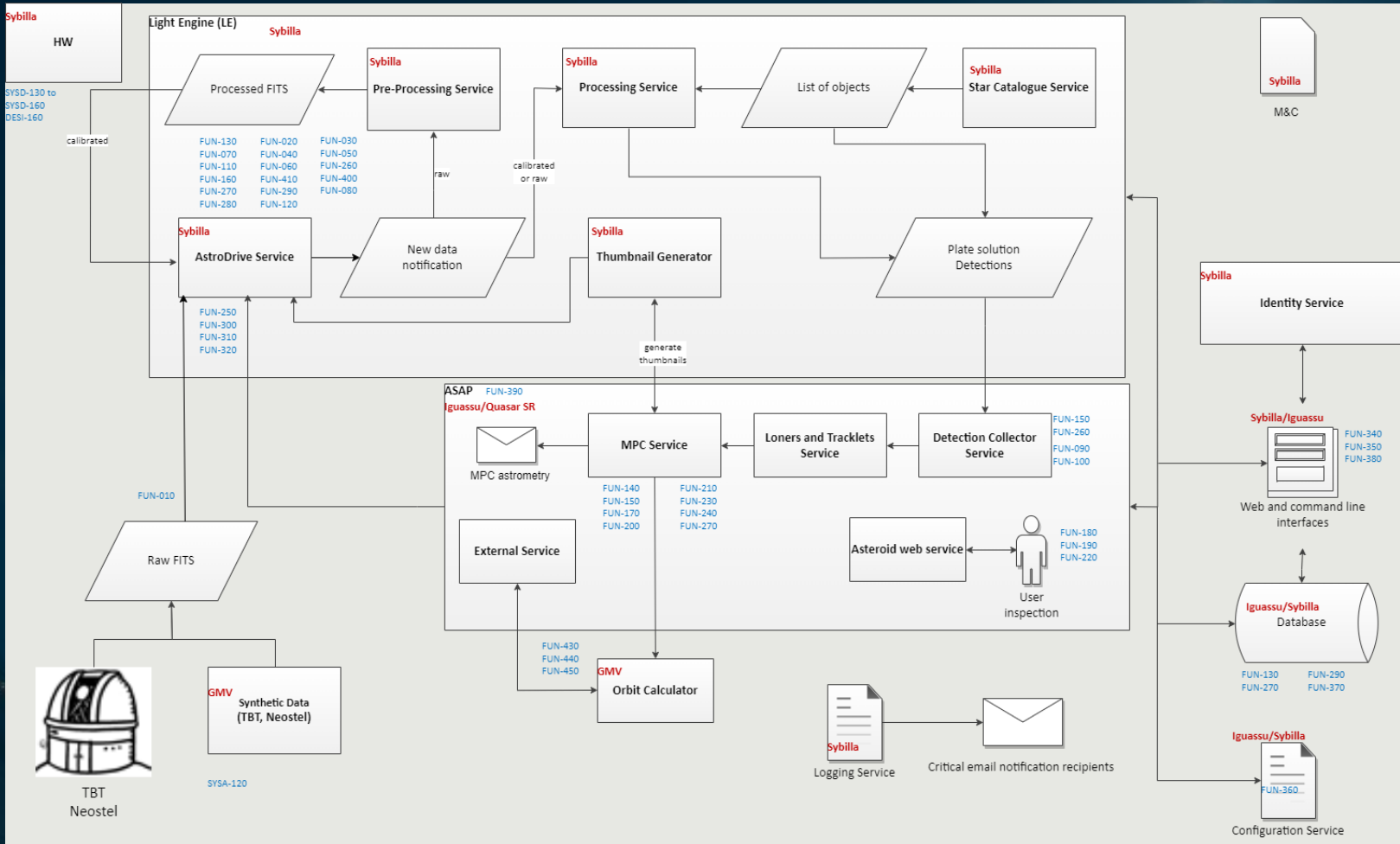
The screenshot displays the ESEC console interface with several key components:

- Top Panel:** Shows system status including 'LOCAL', 'ANALYSIS', 'OBSERVE', and '2024-11-08 11:37:24'.
- SEC Misc Panel:** A central control area with buttons for 'TCS Debug', 'TCS Cam AP 1', 'TCS Cam AP 2', 'TCS Cam AP 3', 'TCS Cam AP 4', 'TCS Cam AP 5', 'TCS Cam AP 6', 'TCS Cam AP 7', 'TCS Cam AP 8', 'TCS Cam AP 9', 'TCS Cam AP 10', 'TCS Cam AP 11', 'TCS Cam AP 12', 'TCS Cam AP 13', 'TCS Cam AP 14', 'TCS Cam AP 15', 'TCS Cam AP 16', 'TCS Cam AP 17', 'TCS Cam AP 18', 'TCS Cam AP 19', 'TCS Cam AP 20', 'TCS Cam AP 21', 'TCS Cam AP 22', 'TCS Cam AP 23', 'TCS Cam AP 24', 'TCS Cam AP 25', 'TCS Cam AP 26', 'TCS Cam AP 27', 'TCS Cam AP 28', 'TCS Cam AP 29', 'TCS Cam AP 30', 'TCS Cam AP 31', 'TCS Cam AP 32', 'TCS Cam AP 33', 'TCS Cam AP 34', 'TCS Cam AP 35', 'TCS Cam AP 36', 'TCS Cam AP 37', 'TCS Cam AP 38', 'TCS Cam AP 39', 'TCS Cam AP 40', 'TCS Cam AP 41', 'TCS Cam AP 42', 'TCS Cam AP 43', 'TCS Cam AP 44', 'TCS Cam AP 45', 'TCS Cam AP 46', 'TCS Cam AP 47', 'TCS Cam AP 48', 'TCS Cam AP 49', 'TCS Cam AP 50', 'TCS Cam AP 51', 'TCS Cam AP 52', 'TCS Cam AP 53', 'TCS Cam AP 54', 'TCS Cam AP 55', 'TCS Cam AP 56', 'TCS Cam AP 57', 'TCS Cam AP 58', 'TCS Cam AP 59', 'TCS Cam AP 60'.
- Overview Image Mosaic:** A grid of 16 camera images showing the field of view.
- Camera Status Table:**

Camera	CAM Mode	General Status	CAM Status	Camera State	Trigger Time	Exposure Time [s]
Cam 01 - Q1B	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 02 - Q1C	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 03 - Q2C	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 04 - Q2D	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 05 - Q4D	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 06 - Q4C	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 07 - Q3C	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 08 - Q3B	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 09 - Q1A	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 10 - Q1D	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 11 - Q2B	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 12 - Q2A	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 13 - Q4A	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 14 - Q4A	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 15 - Q3D	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
Cam 16 - Q3A	DISABLED	WARNING	OK	READY	2023-11-16 13:53:21	60
- Alarm Viewer:** A table listing system alarms and errors.

Date & Time	Node Number	Attribute Name	Attribute Label	Value Qualifier	Value	Decoupled
08/11/2024 11:57:24	140112	USED_MEMORY	Used Memory	VALID_WARNING	89	false
08/11/2024 11:53:32	140111	CAM_FSM_ERROR_CODE	CAM FSM Error	VALID_WARNING	TRANSITION_ERROR	false
08/11/2024 11:53:46	200400	TIME_SHIFT	Time Shift	NOT_EXPECTED	200000.0000	false
08/11/2024 11:41:28	140111	GENERAL_STATUS	General Status	VALID_WARNING	WARNING	false
08/11/2024 11:41:28	140111	OPERATION_MODE	TCS Mode	VALID_WARNING	STAND_BY	false
08/11/2024 11:41:28	140111	PREV_OPERATION_MODE	Previous TCS	VALID_WARNING	STAND_BY	false
08/11/2024 11:41:28	140111	SYSTEM_STATUS	TCS System Status	VALID_WARNING	NOT_OPERATIVE	false
08/11/2024 11:41:28	140111	FEC_TCS_SYSTEM_STATUS	System Status	VALID_WARNING	NOT_OPERATIVE	false
08/11/2024 11:41:28	140112	GENERAL_STATUS	General Status	VALID_WARNING	WARNING	false
08/11/2024 11:41:28	140115	GENERAL_STATUS	General Status	VALID_WARNING	WARNING	false
08/11/2024 11:41:28	140115	TCS_MONI_MODE	TCS Moni. Mode	VALID_WARNING	STAND_BY	false
08/11/2024 10:41:30	200420	GENERAL_STATUS	General Status	VALID_WARNING	WARNING	false
08/11/2024 10:41:30	100710	GENERAL_STATUS	General Status	VALID_ALARM	ALARM	true
08/11/2024 10:41:28	100710	FEC_GENERAL_STATUS	FEC General Status	VALID_ALARM	ALARM	true
- Scheduling Command Viewer:** Shows target systems and observation parameters.

Data Processing Chain



DPC hardware rack during factory tests Feb'2024



Data Processing Chain: Interface



The screenshot displays the ASAP Web interface. On the left is a sidebar with navigation options: Home (selected), MPC Submissions, Fields, Nights, Query by orbit, Tracklets, Configuration, and Logout. The main content area is titled 'Home Page' and features a 'Summary' table:

	Total	Filtered
Nights	2	2
Fields	2	2
Tracklets	22	22
Unconfirmed Tracklets	21	21
MpcSubmissions	0	0
Users	6	

At the top right, there is a 'Use range filter' section with a date range from 01/03/2016 to To. Below this is a 'Tracklets' table with various action buttons: 'Apply selection', 'Clear filters', 'Real object [1]', 'Noise [2]', 'Not sure [3]', 'Send to MPC - auto', 'Send to MPC - man', 'ADES XML', 'ADES PSV', 'MPC80', and 'Delete'.

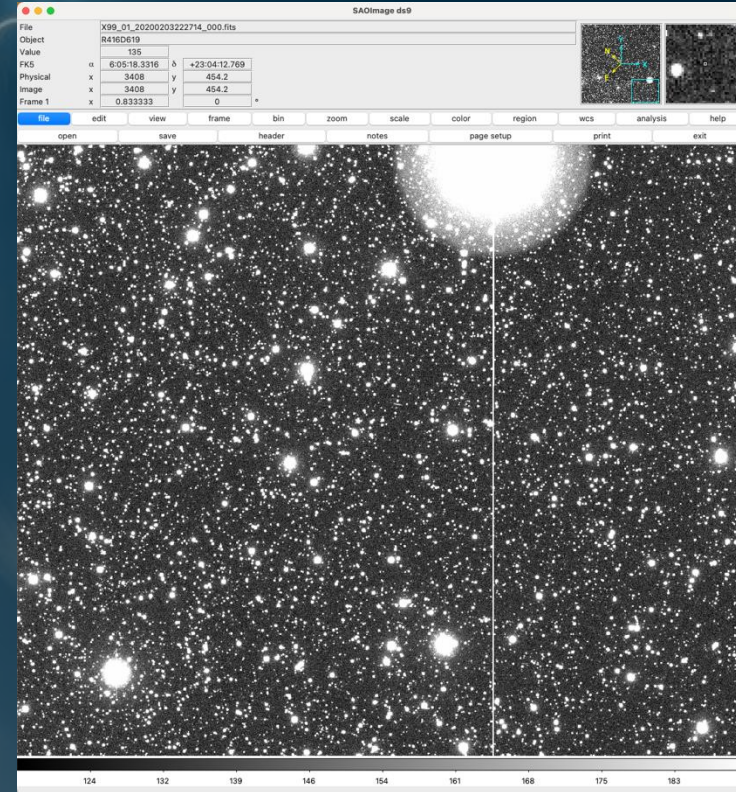
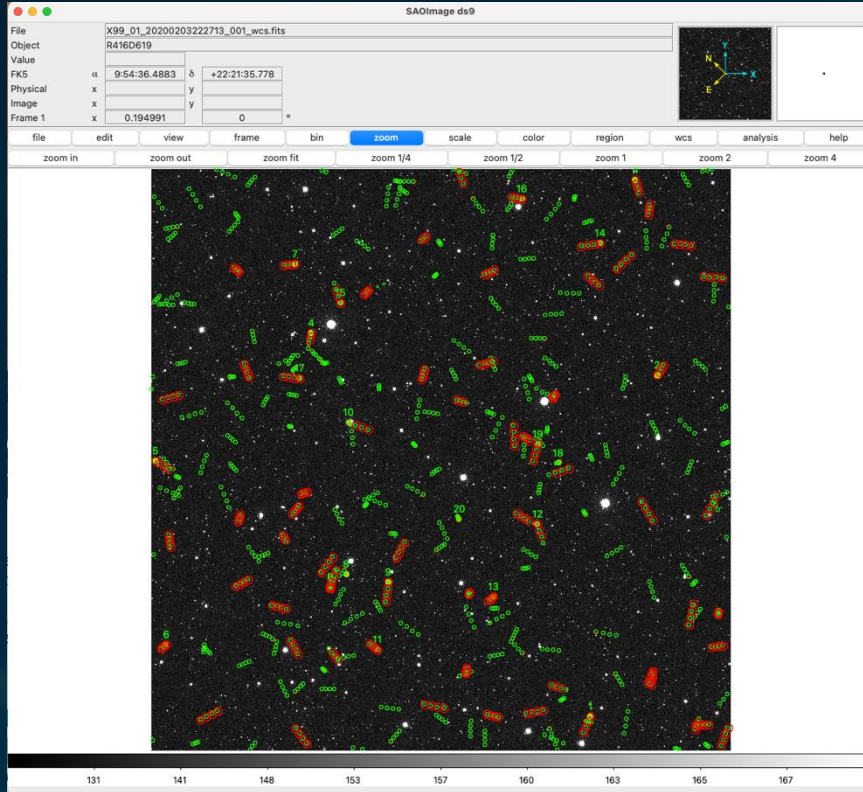
Selection	Object centered	Sky centered	Designation	Field ID	Night	Type	Positions	Speed [arcsec / min]	PA [deg]
<input type="checkbox"/>				min	dd/mm/yyyy		min	min	min
				max			max	max	max
<input checked="" type="checkbox"/>			FI610001	1	02/06/2018	POINT	4	0.624	263.35
<input checked="" type="checkbox"/>			FI610002	1	02/06/2018	POINT	4	0.567	271.05
<input type="checkbox"/>			FI610003	1	02/06/2018	POINT	4	0.527	285.14

ASAP Web Interface:

- Access to observation data, with pages for nights, fields, and tracklets, all filtered and navigable via a sidebar
- Detailed information on tracklets and observation fields, with tools for editing, filtering, and submitting confirmed objects to the MPC
- Orbit-based queries in historical images to check for asteroid presence



Data Processing Chain: Validation and Tuning



- Data Processing Chain Validation and tuning is underway.
- Data Retention: all imaging data will be made fully public within a few weeks



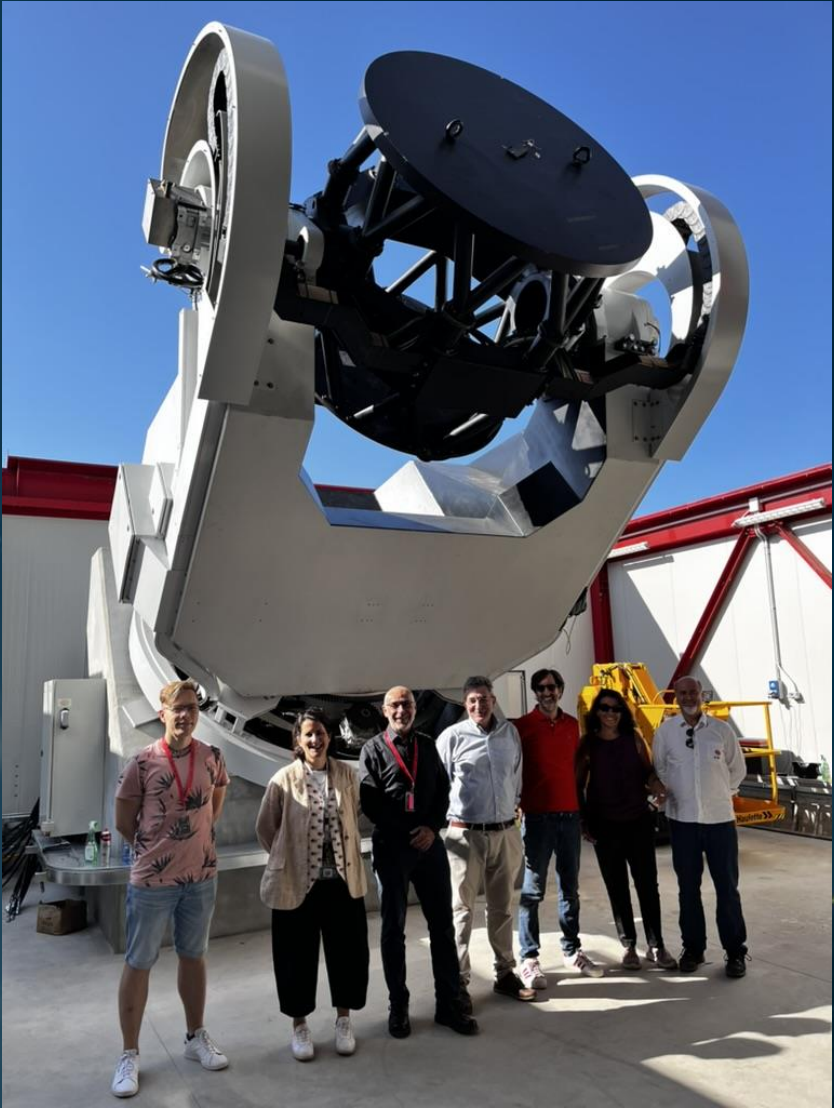
Telescope Testing Plan



Integration activities at Matera



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Flyeye-1 current status

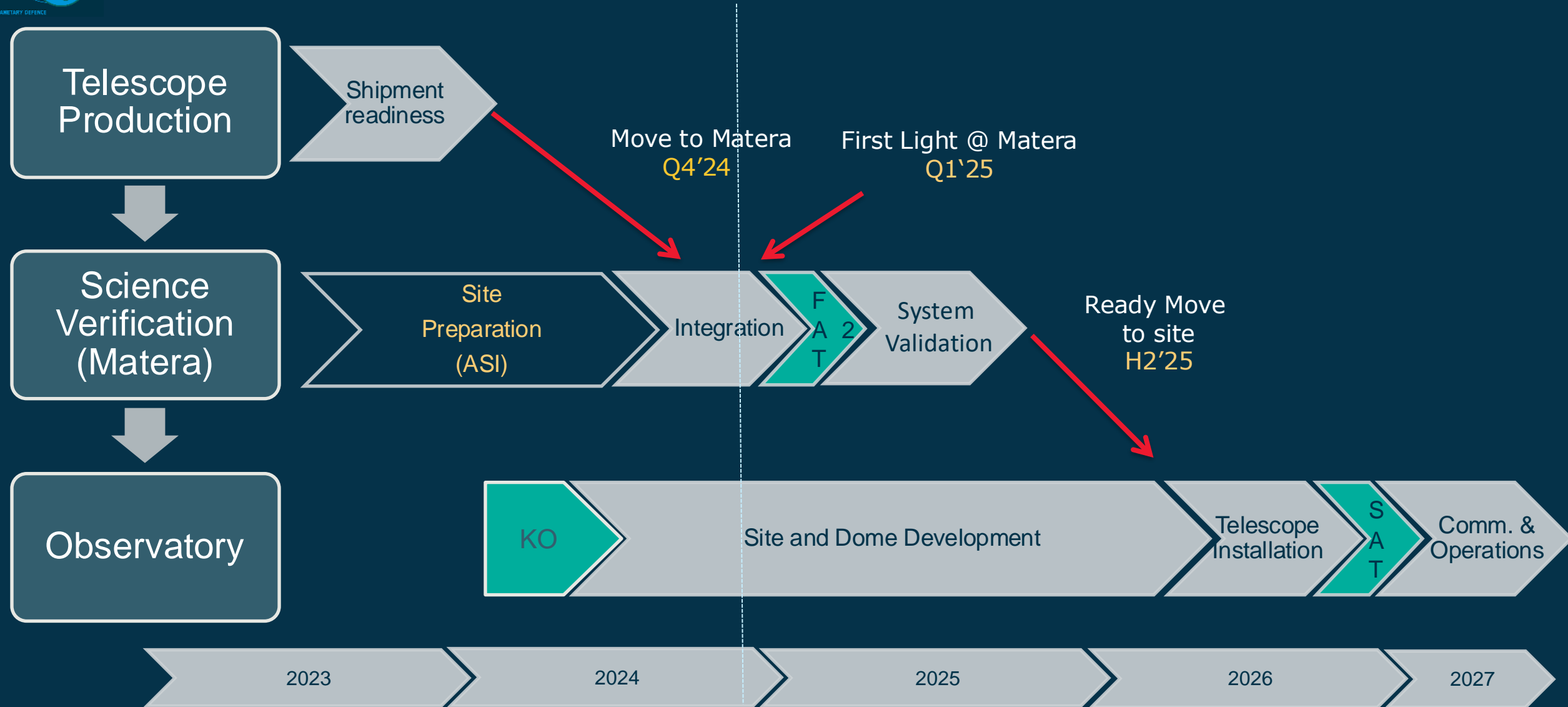
- Telescope
 - Manufacturing completed.
 - Installation at ASI facilities in Matera (temporary site, Italy) ongoing.
- Observatory
 - Design completed.
 - Construction works at Mt. Mufara (Sicily) started.



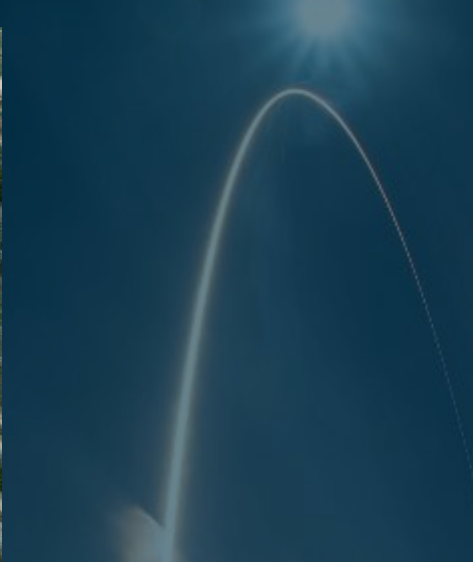
Equatorial Mount with dummy @ Matera (Sep'2024)



Flyeye-1 High Level Timeline



Telescope - Next weeks / months



Telescope Optics arrived at @ Matera (Nov'2024)



Observatory - Next weeks / months



Excavation Works @
Mt. Mufara (Oct'2024)



The Industry behind Flyeye-1



From Flyeye-1 to Flyeye-2

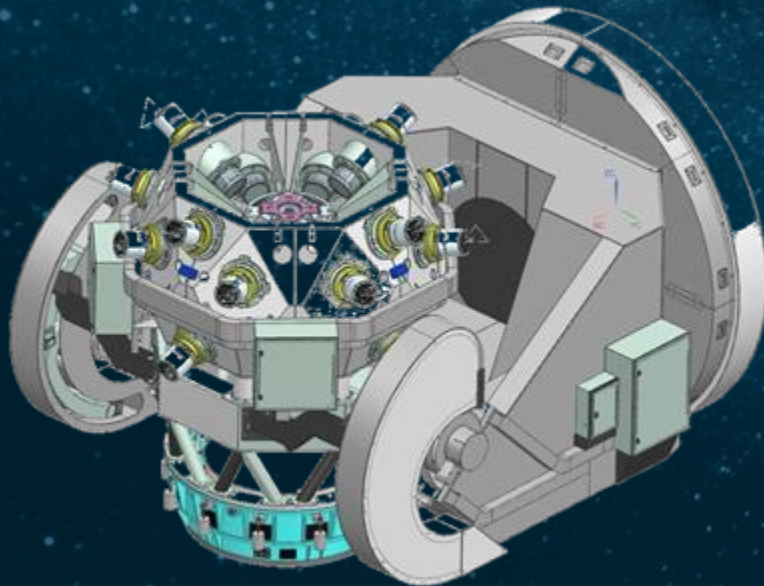


Flyeye 1.0

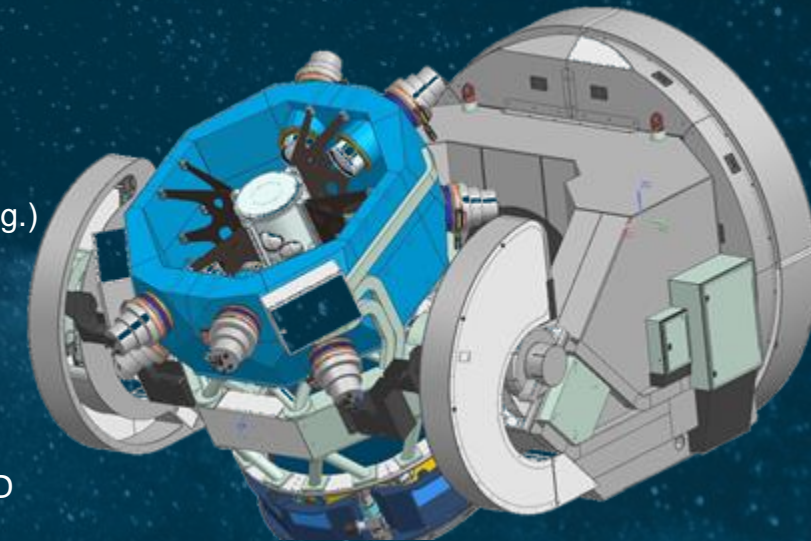
16 CHANNELS
OVERALL Field of View: 45sq.deg.
1m PRIMARY MIRROR
FOCAL LENGTH: 2m
CENTRAL OBSCURATION: 0,64m
CCD SENSOR RESOLUTION: 16Mpx

Flyeye 2.0

8 CHANNELS
OVERALL Field of View: 30sq.deg.
1,5m PRIMARY MIRROR
FOCAL LENGTH: 2,65m
CENTRAL OBSCURATION: 0,52m
CCD SENSOR RESOLUTION: 36Mpx

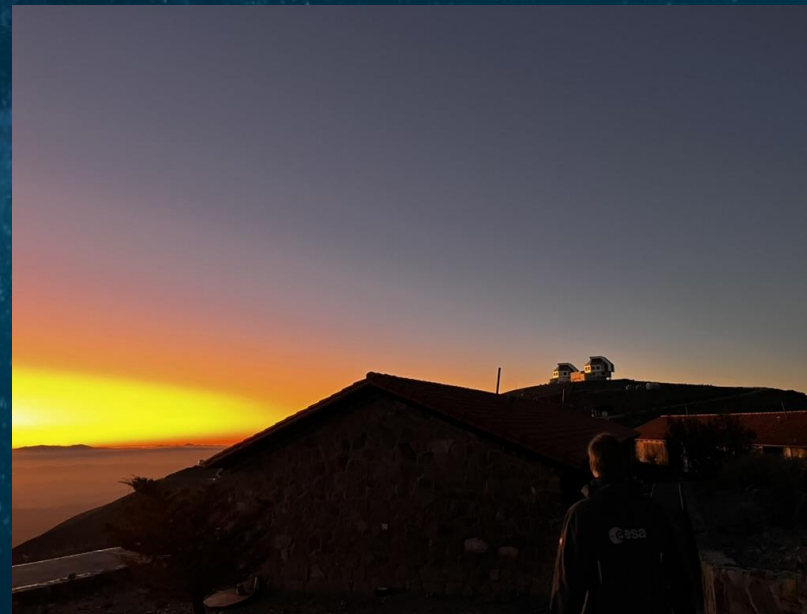
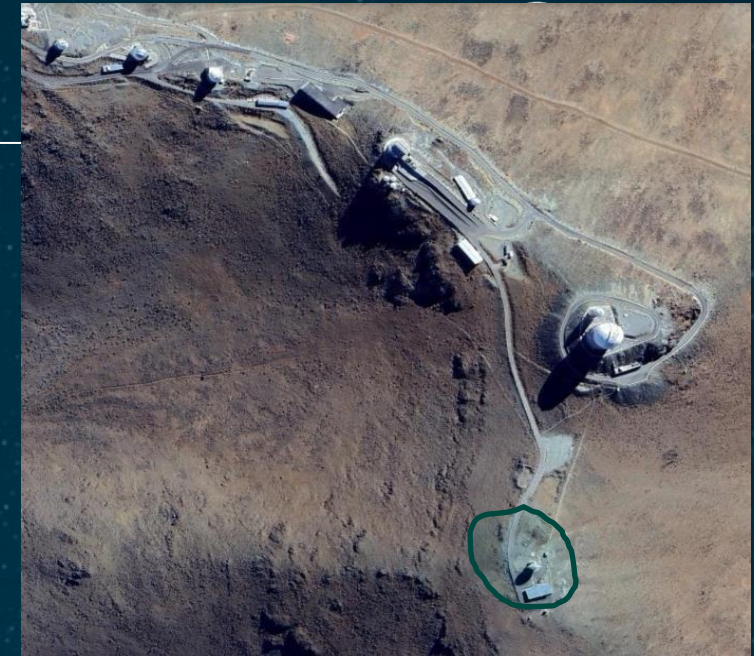


- Enlarged entrance pupil
- Enlarged primary mirror diameter and new off-loading system
- Increased focal length
- Reduced central obscuration
- New optimized relay optics (single channels FoV = 3,75 sq.deg.)
- Updated Equatorial Mount design
- New Secondary Structure
- New beam splitter
- New focusing system
- Adoption of new astronomical camera based on Teledyne CCD sensor



Flyeye-2 current status

- Telescope
 - Preliminary Design Completed
 - Critical Design and Procurement of Long-lead items ongoing
 - Manufacturing contract to start Q1-2025
- Observatory
 - ITT ongoing, site selection ongoing.
 - Preliminary Design to start Q4-2024
 - Detail Design to start in Q3-2025



Possible sites for Flyeye-2 in Chile and Argentina, under evaluation.

Start of Operations planned for 2029

Summary



- First Flyeye prototype reaching final development stages.
- Challenging implementation.
- Integration at Matera ongoing.
- Flyeye-1 to start early operations in 2026.
- Flyeye-2 development started.
- Teamwork key to success.

