Project management and status update for DAG (Eastern Anatolia Observatory) the 4 meter VIS/IR optical telescope

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ABSTRACT

The new 4 m Turkish telescope, DAG (East Anatolian Observatory, Fig. 2), will be located on the summit of the mountain Konakli-Karakaya, at an altitude of 3170 m, near the city of Erzurum, Turkey. First light is expected for August 2020. The telescope is a multi-purpose instrument, and will run observations both in the visible (VIS) and near infrared (NIR) domains, in seeing limited (SL) and adaptive optics (AO) correction mode. In his paper, status updates from DAG telescope will be presented in terms of; (i) DAG telescope optics, (ii) Nasmyth focal planes and platforms, (iii) current progress of the telescope, (iii) current progress of enclosure, (iv) current progress of the observatory building, (v) current process of the astronomical instruments & tendering phase, and (vi) status of the Optomechatronics Research Laboratory – OPAL.

Keywords: Project Management, DAG Telescope, DAG Enclosure, Observatory Building, Science Instruments

1. INTRODUCTION

1.1 DAG Telescope Mount Coordinate System

First, the telescope mount coordinate frame noted (xM,yM,zM) in the technical specification – that is fixed with respect to to the observatory, with zM oriented toward the zenith, xM along the altitude axis and yM oriented such that the frame (xM,yM,zM) is right-handed and orthonormal. The origin of the reference frame is at the crossing between the azimuth and altitude rotation (Fig. 1).

The center of the tertiary mirror (M3) is on the reference frame origin.

Then, the tube coordinate frame that moves with the telescope pointing direction, with zT oriented toward the pointing direction (optical axis), xT along the altitude axis and yT oriented such that the frame (xT,yT,zT) is right-handed and orthonormal. It is also centered at the crossing between the azimuth and altitude rotation axes.

Finally, there is a local coordinate frame for each of the mirrors, that is centered on the mirror vertex and has its zL axis oriented along the normal of the reflecting surface at vertex (pointing outward the reflecting surface), yL co-aligned with yT, and xL oriented such that the frame (xL,yL,zL) is right-handed and orthonormal.

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2. DAG TELESCOPE OPTICS

DAG is a 4 m telescope, with a Ritchey-Chrétien optical combination. It has two Nasmyth foci and no Cassegrain port (see Fig. 3). The design philosophy was to maximize the stability of all the focal plane equipments, because the telescope will have an adaptive optics (AO) operation mode, for which stability is critical. AMOS is the company in charge of building the telescope.

It must be assumed that the Nasmyth platforms (NP) will act as optical laboratories receiving stable non-rotating beams
DAG is an active optics (aO) telescope. M1 is controlled with 66 active back actuators and 24 lateral actuators. It can compensate up to the first 78 Zernike modes of elastic deformation. M2 and M3 are supported by hexapods and are also actively controlled in position (6 dof). The telescope optics data are given in Table 1.

Table 1. Telescope optics characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1 optical diameter (M1 is the entrance pupil)</td>
<td>3940 mm</td>
</tr>
<tr>
<td>Central obscuration optical diameter (on M1)</td>
<td>975 mm</td>
</tr>
<tr>
<td>Telescope focal length</td>
<td>56000 mm</td>
</tr>
<tr>
<td>Exit pupil diameter</td>
<td>727.069 mm</td>
</tr>
<tr>
<td>Exit pupil distance from M3 vertex</td>
<td>+6133.972 mm</td>
</tr>
<tr>
<td>Exit pupil distance from focal plane (FP)</td>
<td>+10333.972 mm</td>
</tr>
<tr>
<td>Distance between the telescope arm external flange and the focal plane</td>
<td>700 mm</td>
</tr>
<tr>
<td>Height of the optical axis with respect to the Nasmyth floor</td>
<td>900 mm</td>
</tr>
<tr>
<td>Focal plane radius of curvature (w/o FCL)</td>
<td>+1954.661 mm</td>
</tr>
<tr>
<td>Seeing limited focal plane scientific FoV</td>
<td>14’ diameter unvignetted</td>
</tr>
<tr>
<td>Seeing limited focal plane technical FoV</td>
<td>24’ with 20% flux loss on the edge due to vignetting</td>
</tr>
<tr>
<td>AO focal plane scientific FoV</td>
<td>7’ unvignetted</td>
</tr>
<tr>
<td>AO focal plane technical FoV</td>
<td>Same as science FoV</td>
</tr>
</tbody>
</table>

a M2/3 shadows are inside the central obscuration for the whole FoV. The central obscuration is defined by a ring around M1 central hole.

b for details, see Figs. 5 to 7

3. NASMYTH FOCAL PLANES AND PLATFORMS

One platform (see Fig. 4) is dedicated to seeing limited observations (SL), the other to AO aided observations. Optical derotators (one in-flange and one external both to be built by OPAM) will be located at the output of the telescope arms to stabilize the star field.

A field correction lens (FCL) will be located after the derotators to compensate for off-axis astigmatism and the field curvature.
3.1 Attachment ports and surfaces dedicated to the science instruments on the platforms

The dimensions and location of the SL and AO platform wrt the optical beam are given to scale in Figs. 5 to 7. The forbidden spaces on the platforms are indicated in blue. The remaining of the platform is available for the instruments. The allocated surfaces are preliminary and will be confirmed once the design of the optical derotators and field correction lenses are finalized.

Figure 5: Seeing limited Nasmyth platform spaces, top view
The instruments will be bolted on the Nasmyth floor (the option to have a rotating instrument attached on the Nasmyth flange is not considered for 1st light). In this case an optical derotator (K-mirror) will be located at the output of the Nasmyth flange. Strips with M16 screw holes every 150 mm are attached on the platform floor to bolt the instruments and related equipments.

The height of the instruments is let free, but certainly will not reach more than 2000 mm. The incoming light beam axis is cantered to 900 mm from the NP floor (see Fig. 7).

The platform can support 2,000 kg. The exact allowed distribution of the masses will depend on the size of the instruments, but knowing that 4 instruments can be located on the platform, an initial guess of the maximum acceptable instrument mass is 500 kg. Each NP can bear a 3.0 kN/m² distributed load, in addition to the 20.0 kN permanent load due to the instruments.
3.1.1 On the seeing limited platform
A large flat mirror will be located after the derotator and the FCL to send the beam sideways to the different instruments - see Fig. 5. The instruments will have to manage internally the focal reduction and the pupil re-imaging, according to the instruments specifications.

3.1.2 On the AO platform
A mirror will be located inside the AO to feed the instruments with the AO corrected beam. It should be possible to use the instruments in non-AO mode (when the AO system is in maintenance).

3.2 Field Correction Lens
On the SL platform, a FCL approx. 400 mm in diameter will be located after the derotator, and will correct the astigmatism and field curvature over the whole scientific FoV of 14’ (or 24’).

On the AO platform, a FCL approx. 200 mm in diameter will be located after the derotator, and will correct the astigmatism and field curvature over the whole scientific FoV of 7’.

3.3 Electrical power
The power cables coming from the Enclosure and interfacing with the Telescope Main Power Cabinet (+FF-E01) are:

- 1 Normal line 400/230 VAC 50 Hz (5x(1x10,0)+SH, 3PH+N+PE), considering a peak power consumption of about 34 kW and a continuous power consumption of about 21 kW (cos $\varphi = 0.91$) during night observation;
- 1 Safety (UPS) line 400/230 VAC 50 Hz (5G2, 5+SH, 3PH+N+PE), considering a peak power consumption of about 10 kW and a continuous power consumption of about 9 kW (cos $\varphi = 0.91$) during night observation;

Earthing system : TN-S type. PE and N are separate conductors that are connected together to the ground only near the site power source.

3.4 Communication network
The communication cables coming from the Observatory and interfacing with the Telescope Control System (by means of the Ethernet switch installed inside TCS cabinet, +FF-E03) are:

- 1 RJ45 connector for Ethernet cables
- 1 optical fiber connection (Connector type MT-RJ Multimode)

3.5 Compressed air supply
Compressed air will be available on the NP. The characteristics are the following:

- quick coupling with shut-off valve at a minimum height of 600 mm from the NP floor
- Pressure range : 7 to 9 bars
- Minimum flow rate available : 2440 N l/min acc. to ISO 2533 (@1 bar)
- Main pipe size : 1”
- The delivery 1” pipe will be divided in the followings :
  - N°1 fluid connection 1” pipe with female threaded end,
  - N°1 fluid connection 3/4” pipes with female threaded end.

Degree of filtration class 2 according to ISO 8573-1:

- Particle retention > 1 $\mu$m
3.6 Liquid cooling supply

Cooling for equipments is available on the NP. The characteristics are the following:
- Type of coolant: water + 45% vol. mono-ethylene glycol.
- Inlet Pressure 6 bar
- Main pipes size: 2 pipes of 2” diameter (delivery and return)
- Coolant temperature always set above the dew point with a sufficient margin (1°C)
- Coolant temperature range: -25°C to +5°C
- Adjustable temperature set point. Nominal set point: ambient temp. minus 10°C.
- Liquid flow rate: 120 l/min
- Power that can be dissipated: 13 kW @ -20°C

4. CURRENT PROGRESS OF THE TELESCOPE

DAG Telescope’s optical and mechanical progress status is presented; the telescope is erected, prior to the telescope delivery readiness review at Galbiati premises at Lecco/Italy (Fig. 8, 9).

Figure 8: DAG Telescope’s – Alt-Azimuth Platforms

Figure 9: DAG Telescope
Other optical and mechanical units that have been completed and in testing and assembly status, along with the status of the telescope control system (TCS) are presented in Fig. 10, 11, 12).

**Figure 10:** DAG M1 dummy mirror (4 m) with active optics system actuator assembly & tests along with M3 mirror hexapod system assembly

**Figure 11:** DAG M1, M2, M3 mirrors polishing and coating progress
5. CURRENT PROGRESS OF THE ENCLOSURE

DAG Dome Structure’s: circular rails, trolleys, azimuth box beam, steel side walls & roof, and cladding progress status is presented in Fig 13, 14, 15, 16, 17, and 18;

![Figure 13: DAG Dome Structure's Circular Rail, detail](image-url)
Figure 14: DAG Dome Structure's Trolley, assembly with gearbox and manufacturing details

Figure 15: DAG Dome Structure's Azimuth Box Beam, final assembly
Figure 16: DAG Dome Structure's Steel Structure Roof, general detail

Figure 17: DAG Dome Structure's Steel Structure Walls, ready for shipment

Figure 18: DAG Dome Structure's Cladding panels ready for shipment
6. CURRENT PROGRESS OF THE OBSERVATORY BUILDING

Improvement have been carried out by Günarda A.Ş. on the roof and the terrace of the observatory to avoid wind and atmospheric turbulence effects (Fig. 19).

![DAG Observatory building final design](image)

**Figure 19:** DAG Observatory building final design

Construction on site is resumed and dome structure assembly will be finished by the end of 2018 along with the detail works of the service building.

![DAG Site and construction works](image)

**Figure 20:** DAG Site and construction works

7. CURRENT PROCESS OF THE ASTRONOMICAL INSTRUMENTS & TENDERING PHASE

The tendering phase for the focal plane instrumentation will resume by September 2018 for the astronomical instrumentation; however the derotator (see Fig. 4, and 21) and the adaptive optics system TROIA (see Fig. 22) funded by Ataturk University and entitled to OPAM have passed the final design review successfully and the production stage started.

![Focal plane instrumentation](image)
7.1 Specifications of the Derotator System*

- FoV: 7 arcmin
- Rotation speed: min 0.02°/s – max 1.1°/s (depending on elevation 0°-85°, & azimuth range 0°-360°)
- Continuous derotation range: ±340°
- Setting: Nasmyth flange
- Survival temperature: -20° - +35° (contractually)
- Operating temperature: -15° - +15° (contractually)
- Configuration: K-mirror
- Housing: Carbon fiber

*2 pending international patents: (i) EP18020209.5, and (ii) EP18020210.3

7.2 Specifications of the TuRkish adaptive Optics system for Infrared Astronomy – TROIA

- DM Number of Actuators: 468 (ALPAO)
- WFS Scheme: Pyramid (PWFS)
- AO FoV: 1 arcmin
- WFS Detector: EMCCD (Nüvü)
- Loop Frequency: max. 1 kHz
- Loop Time Lag: max 0.25ms
- Number of Corrected Modes: Adapted to the Seeing and NGS Magnitude (Flexible AO Concept)
- Control: Classical, Integrator at First Light, then Upgraded
- Survival Temperature: -20° - +35°
- Operating Temperature: -15° - +15°
- Near Infrared Science Camera FoV: 10” to app. 30” with Zoom Optics
- Near Infrared Filters: Y, J, H, K, with Room for other Narrow Band Filters

Figure 22: TROIA Optical Design
8. STATUS OF THE OPTOMECHATRONICS RESEARCH LABORATORY – OPAL

Optomechatronics Research Laboratory (OPAL) will be established on the allocated site to ATASAM by the Ataturk University. It extends to 150 decares and the architectural studies has been started; OPAL is planned to serve in the area of optics, optomechatronics systems for telescopes, science instruments, satellites, space equipments and will be used for testing, calibration, maintenance along with R&D activities. The construction for OPAL will commence by the end of 2018.

![OPAL site (150 decares)](image)

9. CONCLUSIONS

As the largest telescope project in Turkey progresses successfully, the FPI stage has been funded by the Ministry of Development of Turkey at the end of 2016. Işık University Center for Optomechatronics Research & Application has been awarded to build the derotator systems (one derotator in-flange 7” FoV, and design of 2\textsuperscript{nd} derotator with FoV 20”), along with the TROIA adaptive optics system. The outcome of DAG telescope project will not only serve the national astronomy but also to the international astronomical communities with it’s state of the art equipments and it’s valuable location. At this stage, Ataturk University Center of Astrophysics Research and Application (ATASAM) center, affiliated to Ataturk University Rectorate welcomes possible co-operations that are open in both research and development and instrumentation areas. It must also be stated that ATASAM, not on the first light but in 2021, also plans to have a 4 meter size coating unit to be placed on the service building at Karakaya summit that will serve internationally.

ACKNOWLEDGMENTS

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