15. Maintenance and operations

15.1 Maintenance

15.1.1 Design provisions

The design of OWL takes in to account maintenance requirements and constraints. It incorporates the following principles:

- Easy. fast and safe human access to all subsystems.
- Provision for the integration of lifts. stairs. catwalks. platforms etc.
- Dedicated handling equipment for major subsystems.
- Disassembly and reassembly of major sub-systems.

15.1.1.1 Human access and handling

15.1.1.1.1 Human access

Two types of activities requiring human access: Normal and Extraordinary Maintenance:

- During normal maintenance activities. human access is allowed by several built-in lifts. platforms. catwalks (see Figure 15-1):
  - M1 segments assemblies.
  - Instruments.
  - Corrector.
  - M2 segments assemblies.
  - Periodic cleaning of the structure.
  - Etc.
- During extraordinary maintenance activities. human access may be allowed with mobile lifting and hoisting devices (to be defined) purchased or rented according to the particular need:
  - Repainting.
  - Cleaning.
  - Repair after seismic events.
  - Retrofitting activities.

    - Installation of new subsystems or new telescope functions.
    - Etc.

Table 15-1 indicates the allowable access to the various telescope sub-systems.

	During Azimuth rotation.	During Altitude rotation.	Vertical parking configuration. Figure 15-1	Horizontal parking configuration. Figure 15-9	During observation.
Technical rooms	Yes	Yes	Yes	Yes	Yes
Basement.	No	No	Yes	Yes	No
Azimuth structure.	Yes	No	Yes	Yes	Yes
Altitude Structure.	No	No	Yes	Yes	No
M1 Unit.	No	No	Yes	No	No
Focal stations.	No	No	Yes	Yes	No
Corrector.	No	No	Yes	Yes	No
M2 Unit.	No	No	No	Yes	No
Paved area around the telescope; radius 90m (Figure 15-9)	No	No	Yes	Yes	No

Table 15-1: Human access.

15.1.1.1.2 Handling Facilities

Two major handling facilities are built-in in the telescope structure (see Figure 15-1):

- Heavy pay load core lift:
    - Payload 150 tons
    - Volume: central hexagonal section which allows transport of the corrector
    - Operation not limited to the vertical parking position (see Figure 15-2)
- One Light pay load side lift per focal station:
    - Payload 6 tons
    - Volume 2.0 m width x 3.5m depth x 3.5 m height
    - Operation in vertical parking position.

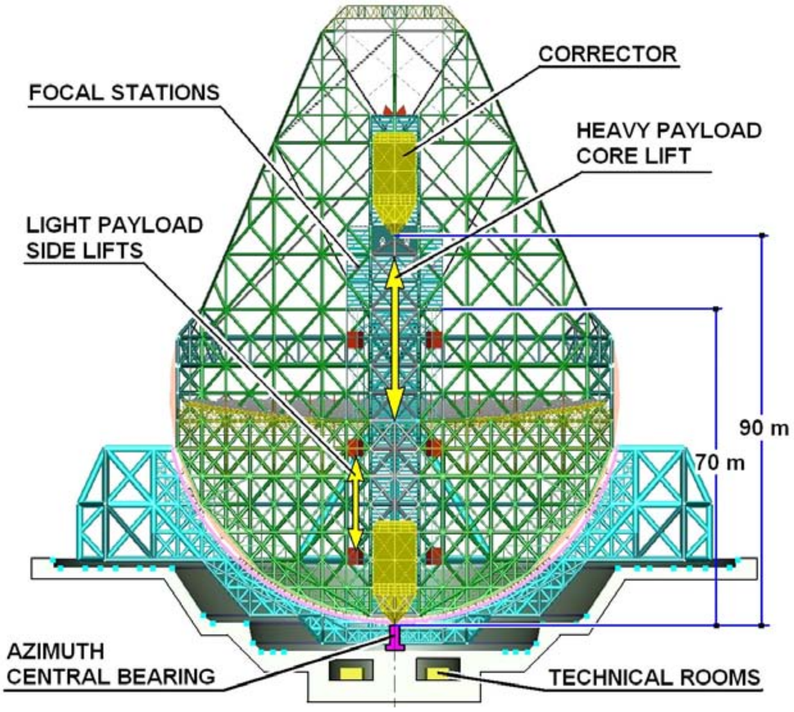

Figure 15-1: Accessibility

15.1.1.2 Corrector Handling

The corrector is the most bulky and massive opto-mechanical sub-system to be handled in one single part (see 9.4.5.2). A dedicated transporter will be designed and procured to transport the corrector from the integration laboratory to the telescope. In the integration laboratory. the corrector can be separated into several parts and each single mirror can be extracted for maintenance and re-aluminization. These operations are similar to the VLT primary mirror maintenance operations.

The integration of the corrector in to the altitude structure will be performed with the altitude structure inclined (see Figure 15-2). The core lift transports the corrector from the transporter to its final location. The altitude of the altitude structure will depend on the final design of the telescope. A low configuration (see 9.6.1) implies less demanding overall sizes of the transporter.

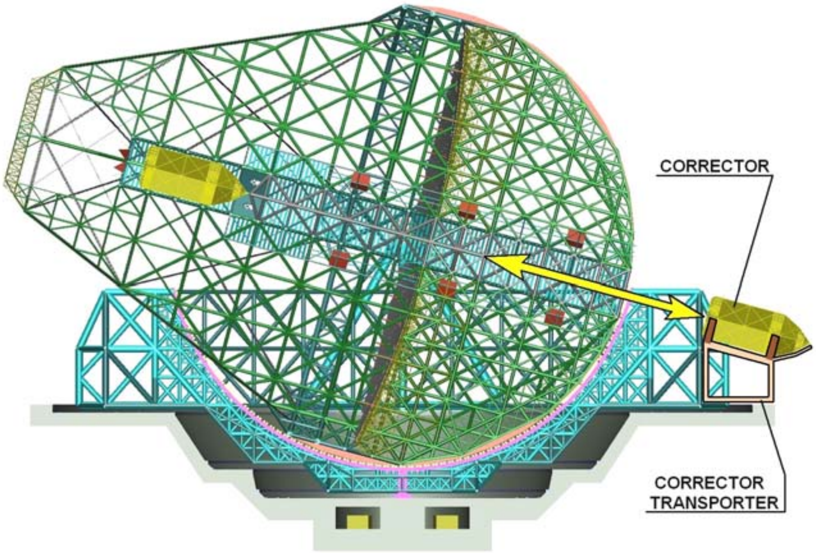

Figure 15-2: Corrector integration route

15.1.1.3 M6 Unit Handling

M6 Unit shall be assembled in the corrector when the corrector is already placed in its operational location. Frequent maintenance or upgrade activities are to be expected for M6 unit. Therefore the M6 unit maintenance routing has been studied in detail:

- The side lifts are dimensioned to be able to transport the M6 Unit and its handling device. (about 6 tons payload).
- Sufficient access inside the corrector (see Figure 15-4 and Figure 15-5).
- Provisions for handling operations inside the corrector are integrated in the design.
- Provisions against damaging the M5 Unit are integrated in the design.

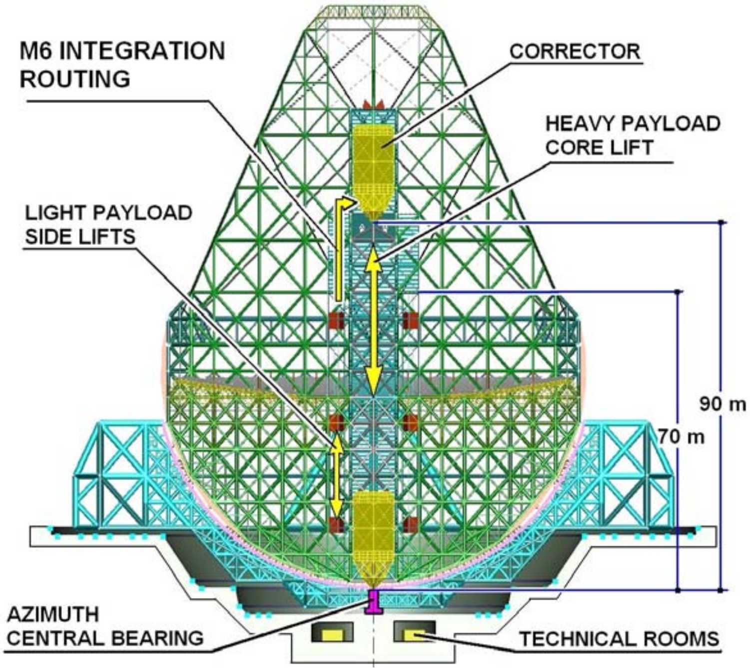

Figure 15-3: M6 unit integration route.

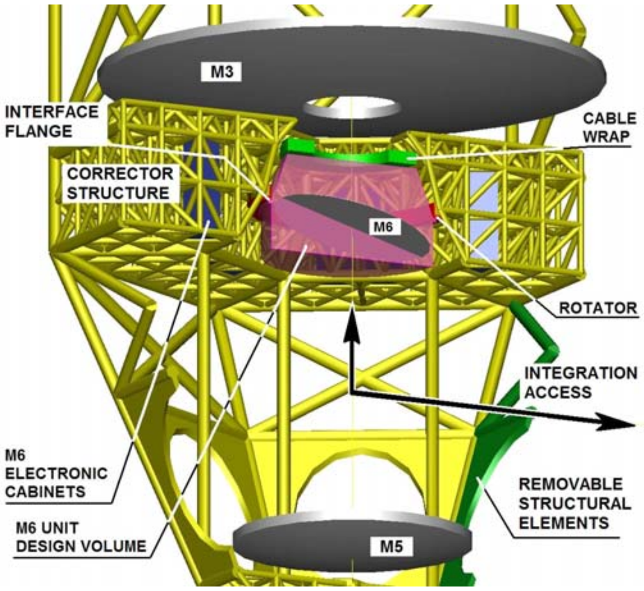

Figure 15-4: M6 unit integration route inside the corrector

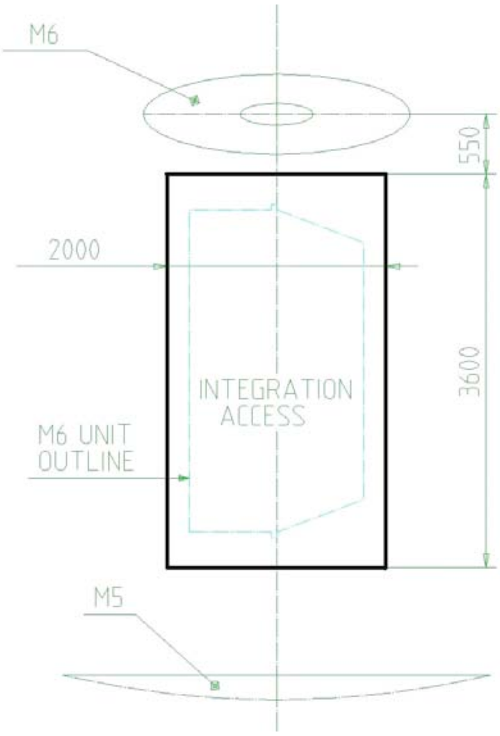

Figure 15-5: M6 unit integration access

15.1.1.4 Primary mirror covers handling

Due to the six fold symmetry of the altitude structure (see 9.4.2). the primary mirror is divided in 6 sectors. Each sector is protected during day time by a cover (see Figure 15-7). The main function of the cover are:

- To protect the mirror segments from dust. water and mechanical shocks
- To provide thermal insulation (not necessary with a SiC mirror substrate. see 9.6.3 and 9.4.9.1).
- After docking. to allow altitude structure rotation. without the need of counter ballast loads. Centres of gravity of the sectors are nearly aligned with the centre of the altitude rotation. Once at their docking location. these sectors do not hinder the altitude rotation. The imbalance is small and can be compensated by the altitude bogies.
- Segment handling and in-situ cleaning units. integrated in the maintenance cover (see Figure 15-7).
- The maintenance cover has a segments storage rack. where about 20 newly coated segments can be stored and exchanged.
- Each cover can be located over any of the six primary mirror sectors.

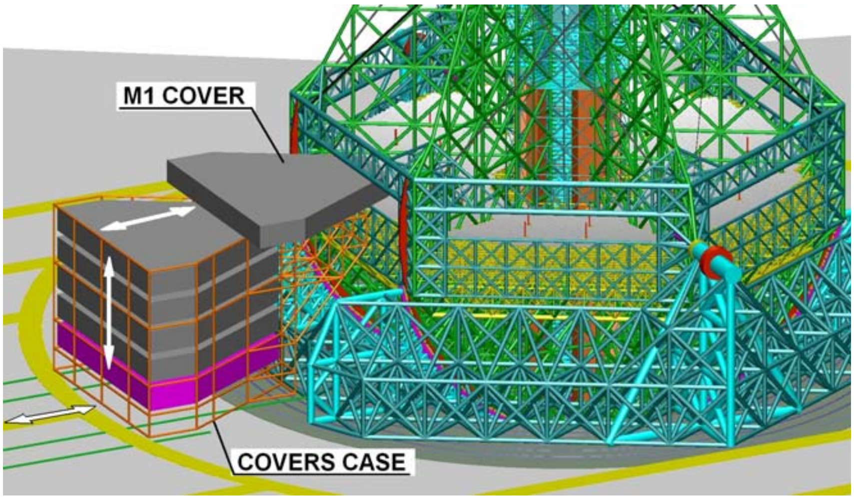

Figure 15-6: Primary mirror cover docking operation.

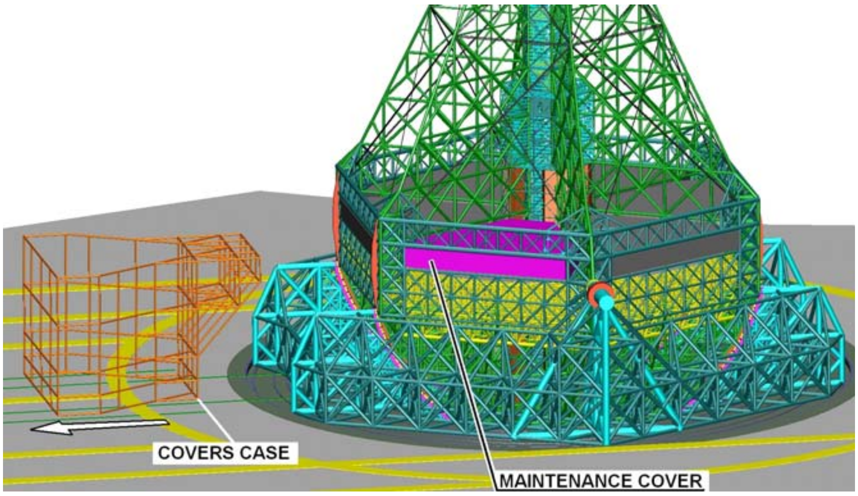

Figure 15-7: Covers on Primary mirror.

15.1.1.4.1 Covers Docking and undocking operations.

The covers docking operation steps (see Figure 15-6) are described below:

1. Store newly coated segments in the maintenance cover. which is located close to the ground level.
2. Move the cover case from its parking position to the telescope in vertical parking configuration.
3. Insert the first cover (presumably at dawn)
4. Withdraw the covers case (by about 25 m).
5. Rotate the azimuth axis by 60°.
6. Move forward the cover case by about 25 m.
7. Repeat steps 3 to 6 for the remaining covers.
8. Withdraw the empty cover case to its parking position -about 1 hour after sunrise.
9. Start maintenance operations inside the maintenance cover.

The covers un-docking operation steps (see Figure 15-6) are described below:

1. Move the empty cover case from its parking position to the telescope in vertical parking configuration. about 1.5 hours before sunset.

2. Withdraw the first the maintenance cover.
3. Withdraw the covers case by about 25 m.
4. Rotate the azimuth axis by 60°.
5. Move forward the cover case by about 25 m
6. Repeat steps 2 to 5 for the remaining covers
7. Withdraw the cover case to its parking position. about 0.5 hour before sunset.
8. Send segments to the aluminization plant if applicable.

15.1.1.5 Sliding Enclosure

The sliding enclosure is designed for minimum maintenance requirements. All active components are mounted at ground level. except the motors of the louvers allowing ventilation (passive thermal control).

The components which need maintenance are summarized in Table 15-1.

Component	**Maintenance interval**	**personnel**	**Comments**
Carriages	6 months	2 persons 1 day	
Bogies	6 months	2 persons 1 day	
Motors	6 months	2 persons 1 day	
Compressed air unit	In case of damge or 3 months	2 persons 1 day	Used to inflate seals
Pneumatic seals	In case of damage or 3 months	2 persons 1 day for 4 days	
Lighting	In case of damage		
Air louvers	12 months	2 persons 1 day for 1 week	
Winches and cables	6 months	2 persons 1 day for four days	
Cladding	In case of damage or 5 years	3 persons 4 weeks	From outside using permanent lift platform
Steel construction	In case of damage or 5 years	3 persons 4 weeks	
Rails	Daily	2 persons 1 hour	Verify cleanliness

Table 15-2 Sliding enclosure maintenance requirements

All components mounted above ground level can be accessed using ladders. Local platforms are installed to allow inspection and dismounting of the components if needed. The components mounted at the top of the enclosure (e.g. motors of the top louvers) will have to be lowered down to ground level. if needed. using jacks and intermediate platforms.

In case of repair of the cladding the same procedure (using locally mounted lifting devices) will be used to remove panels and to lower them down to the ground level.

Such platforms also routinely used for assembling and inspection are shown Figure 15-8

In case major maintenance / repair is required at the level of the hinge at the top of the arches. the same cranes as used for the construction may be needed. according to the level of damage. This operation would require a long time. therefore the top hinge has been over-dimensioned for resistance against potential damage.

Detailed maintenance procedures will be developed during the next phase of the project.

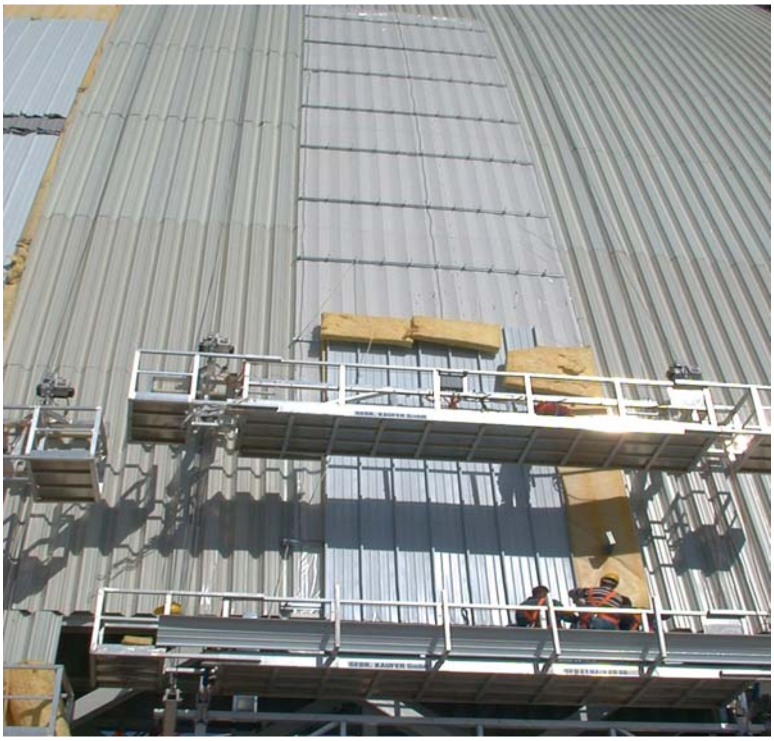

Figure 15-8 lifting platform for inspection and maintenance of cladding

15.1.1.6 Secondary mirror handling

The secondary mirror unit is not reacheable when the telescope is in a vertical parking configuration. Therefore maintenance operations are only possible in a horizontal configuration (see Figure 15-9). M2 unit handling facilities can be integrated in the sliding enclosure structure (see Figure 15-10). or they can be located in a platform standing on the ground level. As for the corrector transporter. a low configuration (see 9.6.1) requires less demanding overall sizes of the handling facilities.

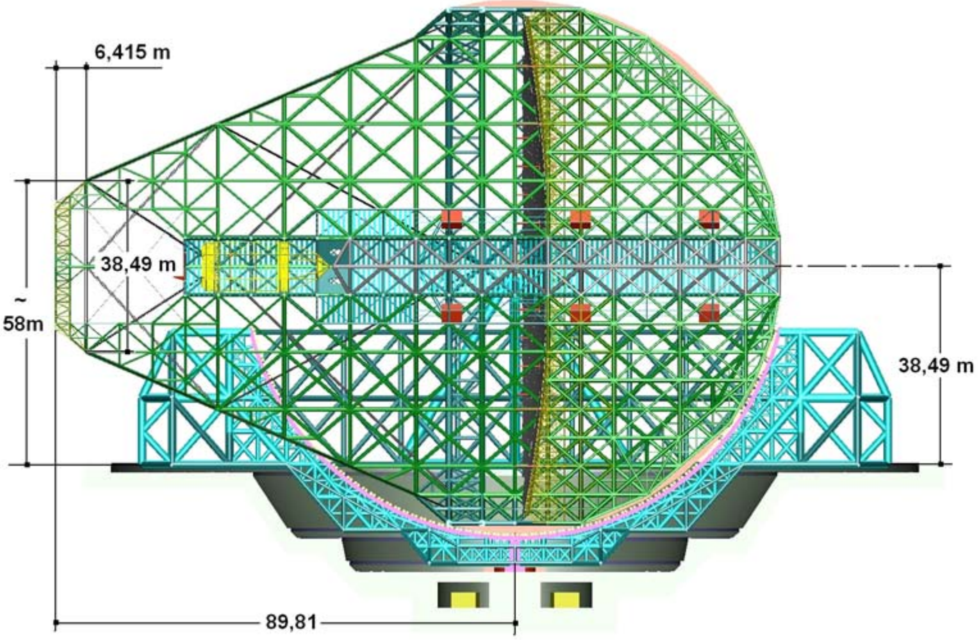

Figure 15-9: OWL horizontal parking configuration.

The major function. of the secondary mirror handling facilities are:

- Handling the complete secondary mirror unit.
- Handling of each individual flat segment.
- Maintenance of the mirror cover.

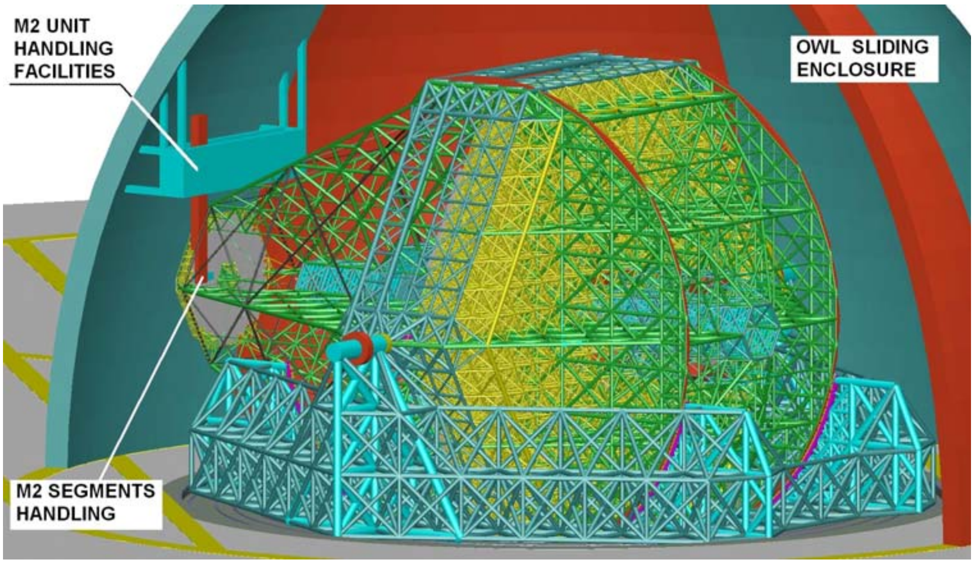

Figure 15-10: Secondary mirror handling facilities.

15.1.2 Safety

The safety precautions during operation and maintenance are partialy described and covered in section 13.2.2. However during the operational life of the telescope. which may extend over several decades. it is essential to establish maintenance procedures which also include traceability of all the eventual modifications. retrofitting and up-grades of the telescope. Special attention has to be dedicated to the implementation of the following methods:

- Continuous training and smooth transition of know-how from different generations of telescope operators and maintenance crews.
- Rigourous traceability of maintenance tools and parts which are transported to and from the telescope under the responsibility of the maintenance warehouse inventory.

15.2 Observatory operations

The operation of OWL as an observatory is expected to present demands significantly different from those of currently existing optical observatories hosting 8m-class telescopes. In many respects a closer comparison is provided by the operation of observatories hosting a facility that enhances the capabilities of pre-existing ones by orders of magnitude. or those hosting a unique experiment for which no similar precedent exists. By the time that the operations model of OWL becomes fully developed ESO will have gathered unparalleled experience in setting up operations in observatories with both of those characteristics. namely ALMA in the first case. and VLTI in the second.

Furthermore. depending on the chosen location of OWL its regular operations will benefit from the ESO VLT/VLTI experience in setting up an observatory designed to host a specific facility.

as opposed to classical observatories in which new telescopes are added to a previously existing infrastructure. Given the strong environmental constraints placed by the optimal scientific exploitation of a telescope with its characteristics. it is doubtful that the latter approach is at all an option for OWL.

Many fundamental principles of the operation and maintenance of the OWL as a facility derive from the observatory design as described in detail in chapters 6 to 13. Here we focus on additional demands not strictly related to the observatory design. but rather to the management of operations to the extent that they can be foreseen at the current stage.

The OWL observatory will include the telescope. its instrumentation. and the on-site infrastructure and technical and scientific operations groups. as well as a distributed network of remotely located sites hosting a number of activities related to development and operations. This network includes the locations where activity takes place in areas such as:

- Instrument building and upgrading.
- Hardware maintenance and repair.
- Telescope and instrument control software development.
- Scheduling.
- Development and maintenance of software for data reduction and scientific analysis.
- Data archiving. distribution. and publication in the Virtual Observatory
- User support.

As the VLT has proven it is fundamental to design OWL operations so that these activities are regarded as an integral part of the observatory. Special attention will be paid to defining clear interfaces among the groups in charge of all such tasks. The VLT/VLTI provides a framework for such a model. as well as a considerable amount of lessons learned after six years of regular operations at the time of writing this.

OWL will undergo an extended phase of partial completion (see section 2.7) in which science operations will be possible while the telescope is being completed. Such early operations stage has the twofold role of enabling an early scientific exploitation of the capabilities of the facility that are already unique even in the partial completion phase. and the progressive scientific verification and tuning of such a complex facility as it develops. The observatory operations plan will take into account such phase in which construction and telescope commissioning coexist with the scientific exploitation of the facility. A clear parallel with ALMA exists in this regard. where aspects such as staff recruitment and training. development of operations management tools and procedures. and the implementation of the end-to-end data flow system are designed to take place during the early operations phase. Furthermore. even once completed OWL will be in a continuous maintenance mode that will directly affect operations. Again. the experience to be acquired with ALMA. and in particular with the management of line-replaceable units (LRU) will play an important role in streamlining routine maintenance operations so that the impact on science operations is minimized.

The actual location of OWL may preclude the presence on-site of a volume of staff and auxiliary services beyond what is critical to ensure the safety and the most essential troubleshooting of the telescope. Most of the facility services will be located in that case in a remote facility with human-friendly environmental conditions and within a reasonable driving time of the site. The ALMA model. where such services are located in an operations support facility (OSF) located in San Pedro de Atacama. provides the baseline reference for observatory operations in this situation.

The ultimate scientific legacy of OWL will reside in the quality of its data products. At the VLT/VLTI the standardization of procedures across instruments. implementation of calibration plans. quality control and instrument trending procedures has led to the build-up of a data archive that follows in many ways the model of the HST science archive. leading to well-characterized data products whose further processing will form one of the main contributions of ESO to the Virtual Observatory. We elaborate on some of these aspects in Section 15.3. but what is relevant in the planning of observatory operations is that the hardware infrastructure (computing power. storage. communications bandwidth) and specialized support staff must not represent a bottleneck given the foreseeable demands placed by data rates and rapid data transfer needs. This is an area where the final design will heavily depend on the state-of-the-art technology by the time when OWL becomes operational. and can hardly be predicted now. Moreover. it is also important to keep in mind that technologies not yet developed. or in their early development stages at the present time. may drive fundamental operations design aspects. such as instrument capabilities. data rates. or the way in which users interact with the facility.[74] Superconducting Tunnel Junction (STJ) detectors or GRID computing are possible examples of technologies that may become mature early in the life of OWL.

15.3 Science operations

The 8m-telescope era has brought innovative science operations models that optimize the scientific exploitation of such facilities and converge in several ways with the operation of space-borne facilities. Science operations at OWL will ultimately depend on the combination of its science cases with design constraints on the telescope and the capabilities of its instrumentation. but in any case they may be expected to represent a further evolution over the most advanced models currently existing and a further departure with classical operations schemes. in which the astronomer directly interacts with the telescope and instrument using relatively simple interfaces and with limited assistance from observatory staff.

It may be questioned whether the types and scope of observing programs currently executed at facilities like the VLT. dominated by short-duration projects with limited science goals. will retain their validity in the OWL era. or rather emphasis will be given to the conduction of long-term experiments with specifically-designed instrumentation as some science cases suggest. In either case. the science operations scenario of OWL will implement rigorous calibration and quality assessment procedures based on data reduction pipelines to ensure the full characterization of the data. the proper instrument modelling. and to facilitate their reusability (see below). It is also to be expected that regardless of the actual breakdown of the programs. the principles and advantages underlying queue scheduling will continue to be valid for OWL and that the observatory staff will be the main or even the sole responsible for the execution of the observations. Staffing. policies. and procedures will be structured around an operations model in which queue scheduling will be the main or single mode of operation of the telescope.

The extensive use of metrology that is planned in the wavefront control of OWL will make possible a close link between the image characterization at the focal plane and the active and adaptive optics settings. Given the complexity of the PSF delivered by OWL. an attractive possibility is the customization of the PSF to the scientific goals of the observations. so as to enhance those features that are of greatest interest for the purpose of the observations (e.g. enhancement of the PSF core at the expense of having bright wings when high resolution is needed. versus reduction of wings at the expense of a broader PSF core when requiring high contrast imaging).

The OWL design will unavoidably lead to compromises that may disfavour scientific areas having particularly stringent requirements on the telescope. such as the possibility to preset to a given position and close the loop within a very short time. The science operations plan will identify such design compromises early. so that mitigating strategies can be devised and whenever possible factored in the telescope design.

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[74] A look back into VLT prehistory is illustrative in this respect: the generalized access to the world-wide-web was unsuspected only ten years before the VLT entered operations, and the applications of CCDs to astronomy were beginning to be considered only two decades before that date, at a time when the concepts of 8m-class telescopes were already well advanced.

The design of front-end tools for the operation of the telescope and instruments will strongly depend on state-of-the-art IT at the time when their technical specifications are defined. It is unlikely that. given the complexity of the OWL instruments. common users will be asked to interact with them to the same level of depth as is currently done at the VLT. in which instrument setups and exposure characteristics are normally defined by the user by means of templates. both for service and visitor mode observations. An alternative scenario seems more plausible. in which users will define the requirements of the observations at a higher level and the observatory staff will carry out their translation to instrument configurations. This would imply that the front-end tools are mainly designed for use by staff astronomers rather than by the common user. Besides this difference. it is to be expected that the baseline functionality of front-end tools will be similar to that of the existing VLT data flow system. which in turn have numerous aspects in common with the ALMA data flow system tools currently under development[75].

Dedicated software to process the output of the instruments must be regarded as an integral part of the instrument already in the VLT and an important part of science operations. and this will be even truer at the scale of complexity of OWL instruments. in which such dedicated software is likely to become mandatory to allow the scientific exploitation of the data. Instruments will have to be provided to the facility together with pipelines to be used at the observatory for quality control. trending and health check purposes. They will also be provided with interactive data reduction software packages allowing the full processing of data up to the point where they can be used for scientific analysis. The data reduction software will meet the appropriate requirements for its integration in data reduction facilities that may be expected to have become widely adopted standards when OWL enters operations. The output science-ready data produced by these data reduction packages will be compliant with Virtual Observatory protocols so that they can be directly published in the Virtual Observatory.

Data distribution in the OWL era may or may not involve the delivery of data packages to users in physical media. Distributed computing through the GRID may allow scientists to remotely process data and download only scientifically significant results. The decision on the distribution of data packages will be taken in due time based on a cost analysis of the possibilities offered by technology at the moment.

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[75] It is worth noting that most key front-end tools used for the preparation and execution of VLTI observations are essentially identical to those used in VLT operations, despite the great differences between observing techniques.