ELT Project 6 Month Update

November 2018

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1. **Executive Summary**

The last 6 months were marked by several new significant concerns originating from the ELT contracts in place (or to be placed). The main one relates to the financial situation of Astaldi who, together with Cimolai, forms the ACe consortium building the Dome and Main Structure (DMS), the largest ELT contract. Due to its financial outlook, Astaldi (the biggest partner in the consortium) has recently filed a "concordato preventivo in continuità" (in Italian law terminology), which is a procedure allowing the company to continue to operate autonomously whilst performing a major restructuring. This process has the primary objective of saving the company, not to liquidate the company. ESO is monitoring the situation very closely and started discussing with Astaldi regarding any possible implications. These elements will very likely lead to delays of the telescope first light.

A second very acute concern is the difficulty currently being encountered in placing a contract for the M5 mirror (blank and polishing) which meets the performance, cost and schedule constraints simultaneously. Discussions with bidders are still on-going to find acceptable solutions. The expected FC approval was consequently moved from November 2018 to February 2019 (tentative). This puts the M5 mirror on the critical path for First Light.

Finally, a number of so-called “red-flag reports” were received from contractors (see below) that also endanger the date for ELT First Light.

The three above issues were discussed at the ELT Management Advisory Committee (EMAC) whose recommendations will be presented to Council on 4-5 December.

At strategic level, the period was marked by yet another important decision by Council, at its June meeting, to approve a new scheme concerning the Guaranteed Time Observations (GTO) for ELT instruments. This is a very important step to allow external funding of 2nd generation instruments MOSAIC and HIRES (currently only funded for their Phase-A studies that are essentially completed), but it also allows external partners to make contribution towards first-generation instruments and some of the deferred items.

According to this scheme, external groups will be able to join the instrument consortium. The consortium will be awarded additional guaranteed time in return for cash contributions to the instrument construction.

At global Programme level, two important reviews have been undertaken. The first one is the System Verification Review (SVR) by a panel of external and internal experts in management and systems engineering of large astronomical projects. The goal was to assess the processes and readiness concerning verification aspects. The documentation data package consisting in Verification Plans, system analysis reports and other key documents was sent to the reviewers in May for a review meeting held in Garching on 26-28 June 2018. The report has been submitted and a resulting action plan addressing the various recommendations has been prepared by the ELT team. Some of the key topics that came out are: better description of the governance and planning of the AIV and Commissioning phase, better documentation of Systems Engineering processes, verification of AO performance in collaboration with the instrument teams, verification of vibrations at system level and increased focus on
requirements and verifications related to operation and maintenance aspects. This review included the telescope up to the Pre-Focal Station. There will be a second part of the review including the first-generation instruments that will be done when the instruments have achieved a robust design stage.

The second Programme level review, the ELT internal cost review, is progressing well. The documentation package was delivered to the (internal) board end of May and a series of meetings were held with the management team and key team members. The review meeting took place mid-October.

Both reviews were also discussed at the last ELT Management Advisory Committee (EMAC#5) early November.

On the procurement side, three new contract awards were approved by the FC in May, signed and kicked-off: the M1 Coating plants, the three C-RED cameras for MAORY and the infrared science detectors for HARMONI, MICADO and METIS.

Contrary to the expectation, it will not be possible to submit the M5 mirror contract award to FC for approval in November 2018, as the offers evaluation is still in-progress. The current plan is to submit it in February 2019.

No new Call for tender is currently running. Several are foreseen to be launched in the next period.

On site at Armazones, ACE made very good progress in excavating the Platform for the foundations of the Dome and the Main Structure and started pouring the lean concrete (see ann18031 and picture below).
Following the successful commissioning of the Power Substations end of March, the Armazones Base Camp is now connected and supplied by the Chilean electricity grid.

As far as existing contracts are concerned, progress is generally good as evidenced by the amount of design reviews that remains very high (about a dozen per quarter). The associated internal effort required to perform those reviews remains a challenge and resource conflicts continue to be anticipated and solved on a case-by-case basis. Also, several reviews have required a complementary “delta-review” to meet their contractual objective, impacting schedule and resources. The most important contract reviews held during the period, as well as some key hardware produced, are mentioned in the achievements below.

On the other hand, a few “red-flag reports” have been recently issued by contractors announcing various difficulties impacting their schedule. Among them, a delay of about 6 months has been announced in some of the DMS activities due to the geotechnical situation encountered when digging for the foundations and for the interpretation of the fulfilment of some seismic Chilean Norms. Also, the Edge Sensors presented a Red Flag report due to design difficulties encountered in fulfilling some final requirement. The new schedules are used for the best-estimate financial projection and their impact on the overall ELT Schedule was analysed. This has been discussed with EMAC early November and it is proposed to delay the date of First Light by at least 12 months. This provisional measure also accounts for the still-evolving Astaldi situation. The plan is to update our baseline schedule accordingly while keeping all formal contractual delivery dates of running contracts unchanged.

The Programme is progressing with the planning of the Assembly-Integration and Verification (AIV) activities and related resources. As this is an important aspect for the Organization, due to the direct involvement of several ESO Staff (and contractor members), the Programme is
applying a detailed bottom up approach identifying the tasks and related timings and resources needed. The integration procedures, detailed with the ELT Project Managers and Work Package Managers responsible of the items to be integrated, are then implemented in the planning tool. A meeting took place on 19 November to present the results to all the involved ESO Directorates and discuss about the related resource planning including new recruitment and renewal of PAO maintenance service contract.

In parallel, the Operation and Maintenance plan is being prepared taking into account the progress of the contracts on these aspects. The AIV Team, in charge also of the operation and maintenance plan, is now strictly involved in following up the various contracts, receiving updates and implementing them in the related Operation & Maintenance plan. The draft plan was presented to ESC.

The Programme is also working on the Operational Concept Document (OCD), which describes the possible operational scenarios for the telescope and instruments. The aim of the document is to describe the various steps during a typical observing night like: pre-setting, acquisition, guiding, offsetting, handover between telescope and instrument. The document is in draft form and being reviewed internally, with the aim of releasing it within the next few months.

The significant achievements over the reporting period can be summarised as follows:

1) Council approval of the new scheme concerning the Guarantied Time Observations (GTO) for ELT instruments (June).

2) Approval by FC in May of all three new ELT contracts presented:
   a) The two M1 Coating plants; signed on 18th June with AGC Glass Europe (see ann18045)
   b) The three C-RED Cameras for MAORY; signed on 4 June with First Light Imaging (FLI)
   c) The Infrared science detectors for METIS (2kx2k, 5 units), and for HARMONI and MICADO (4kx4k, 17 units in total including options); signed in June with Teledyne Imaging Sensors (see ann18048)

3) Kick-off meetings for the following major contracts:
   a) ETF with ABENGOA (May)
   b) M1 Segment Support with VDL (May)
   c) PFS-A Main System with IDOM (May)
   d) Infrared science detectors for HARMONI, MICADO, METIS with Teledyne (May)
   e) C-RED cameras for MAORY with FLI (June)
   f) M1 Coating units with AGC Glass Europe (June)
   g) ELT Construction All-Risk Insurance (in force since April)
   h) M4 Cooling System (amendment to M4 Unit contract) (September)

4) Other procurement activities:
   a) Launched the Preliminary Inquiry (PI) for the M5 cell
   b) Evaluation of offers for M5 mirror
   c) Request for Information (RFI) for the procurement of the washing and stripping units for the M1 segments completed in March, showing the need for further market investigations before sending a Preliminary Inquiry
d) RFI completed for the M1 manipulator and the Local Optical Phasing Sensor (LOPS) (formerly “Phasing Gun”). Those two procurements have now been decoupled to enable faster progress on the manipulator and the Local Optical Phasing Sensor has been replaced by a LOcal COherencing sensor (LOCO) whose development is less urgent.

5) Progress in running contracts including many reviews including the following major ones:
   a) PDR for the Metrology Setups for the M1 Segment Polishing (23-24 May) and delta-PDR (26 July).
   b) The M2/M3 Cell delta-PDR (20 June)
   c) The ELT Technical Facility (ETF) FDR (9 August)
   d) The M1 PACT Qualification Test Readiness Review (13 September)
   e) Critical Design Reviews for the Dome Structure (part III) (19 September) and for the DMS Civil Works (20 September)

6) Progress in manufacturing and hardware delivery in running contracts:
   a) Lean concrete pouring for DMS foundation at Armazones
   b) First M1 segment blank ready for delivery by Schott to Reosc.
   c) M2 Auxiliary Equipment including M2 dummy mirror (aluminium), handling tool, stand, transport container
   d) Prototype of the Extractor for the M1 Segment Support (whose first Qualification Model is now integrated into ESO’s M1 Test Bench)
   e) First (out of a total of 5) M1 PACT Qualification Model
   f) Second M4 shell completed
   g) Electronic hardware for the M1 Local Control System
   h) Excavation, pouring of the foundations, start erection of building metallic structure and installation of sewing pipes for the ETF at Paranal

7) Risk Register updated and discussed with EMAC
8) Alignment and Integration workshop held with instrument consortia (3-4 July)
9) Presentation of Wave Front Control (WFC) baseline internally at ESO, involving also instruments PIs.
10) Participation to SPIE Conference “Astronomical Telescopes + Instrumentation” in Austin, Texas with 15 papers from the ESO team (plus many from the community and our contractors) (10-15 June)
11) Participation to the IAU in Vienna (20-31 August)
12) System Verification Review held (26-28 June)
13) Cost Review held (16 October)

2. **ELT Programme Organisation**

During the reporting period, there was no change to the top-level Organisation Chart. On the other hand, minor changes were made to the Contract Manager Chart, to the Work Breakdown Structure (WBS) and to the Product Breakdown Structure (PBS) to reflect recent evolution in some areas of the Programme (e.g. moving the Laser Guide Star Unit from Opto-mechanics Project to Optical Control Project, removing of the M4 Cooling Work Package -now included in Adoptica contract scope-, clarifying responsibility for the various Networking Infrastructure components -fibres-, etc.). The Programme Office put great care into keeping the corresponding documents updated and consistent.
3. **ELT Construction**

3.1 **Programme Office**

3.1.1 **Programme Management**

During this reporting period (April 2018 – September 2018), the most significant milestones at Programme Management Level were the Council decision in June to approve the new scheme concerning the Guarantied Time Observations (GTO) for ELT instruments and the two programme-level reviews: the System Verification Review (SVR) and the Internal Cost Review.

The new GTO scheme is a very important step to allow external funding of 2nd generation instruments MOSAIC and HIRES (currently only funded for their Phase-A studies that are essentially completed), but it also allows external partners to make contribution towards first-generation instruments and some of the deferred items. On the other hand, it generated the risk that the already insufficient ESO human resources allocated to the ELT will need to be shared with those two new instruments.

The System Verification Review (SVR) was performed by a panel of external and internal experts in management and systems engineering of large astronomical projects. The goal requested by the ELT Programme Manager was to assess the processes and readiness concerning verification aspects. The documentation data package consisting of Verification Plans, system analysis reports and other key documents was sent to the reviewers in May for a review meeting held in Garching on 26-28 June 2018. The report has been submitted and a resulting action plan addressing the various recommendations has been prepared by the ELT team. Some of the key topics that came out are: better description of the governance and the planning of the AIV and Commissioning phase, better documentation of Systems Engineering processes, verification of AO performance in collaboration with the instrument teams, verification of vibrations at system level and increased focus on requirements and verifications related to operation and maintenance aspects. This review included the telescope up to the Pre-Focal Station. There will be a second part of the review including the first light instruments that will be done when the instruments have achieved a robust design stage.

The second programme level review, the ELT internal cost review, has also been completed by now. The documentation package was delivered to the (internal) board end of May and series of meetings were held with the management team and key team members. A first review de-briefing meeting took place mid-October.

Both reviews have been discussed at last ELT Management Advisory Committee (EMAC#5) early November.

Another significant Programme-level activity has been the finalisation of a plan to allow the construction of the LTAO module for HARMONI. A recommendation has been drafted and will be submitted to the various committees (ESC/STC, FC, Council) with the goal to reach a final approval by Council in December 2018.
Otherwise, the Programme Management office continued to support the critical situations encountered by some Contracts (see the Astaldi situation, the DMS presented delays, the Edge Sensors design difficulties) and the procurement activities to ensure timely signature of contracts. Three new contract awards were approved by FC in May, signed and kicked-off: the M1 Coating plants, the three C-RED cameras for MAORY and the infrared science detectors for HARMONI, MICADO and METIS.

Contrary to the expectation, it will not be possible to submit the M5 mirror contract award to the FC for approval in November 2018, as offers evaluation and negotiation are still in-progress. We are today aiming to submit it to a special Finance Committee in February 2019 that has been specifically requested for this critical procurement.

No new Call for tender is currently running. Several are foreseen to be launched in the next period.

As far as existing contracts are concerned, the Programme Management continued supporting the project and contract managers in various areas. One of them is the project reviews where the amount of design reviews remains very high (about a dozen per quarter). The associated internal effort required to perform those reviews remains a challenge and resource conflicts continue to be anticipated and solved on a case-by-case basis. For all major or critical reviews such as all PDRs and FDRs, the Programme Manager acts as the Executive Authority ultimately deciding, together with the relevant Project Manager, on the outcome of each review. Unfortunately, several reviews have required a complementary “delta-review” to meet their contractual objective, impacting schedule and resources.

In addition, the attention of the Programme Management is increasingly called to react to “red-flag reports” that have been recently produced by contractors announcing various difficulties impacting their schedule. Those are described in the Executive Summary above. The new schedules are used for the best-estimate financial projection and their impact on the overall ELT Schedule is being analysed. This has been discussed with EMAC early November and it is proposed to delay the date of First Light by about 12 months. This provisional measure also accounts for the still-evolving Astaldi situation. The plan is to update our baseline schedule accordingly while keeping all formal contractual delivery dates of running contracts unchanged.

Other activities included:

1) Managerial coordination and support to Project Managers, Programme Engineer, Systems Engineer and PA/QA Manager in various areas such as:
   - Strategy for QA consultancy services in Chile (civil work)
   - Bid evaluation and Contract negotiations
   - Handling red flag reports received from Contractors (DMS and ES) and related managerial meetings (internal & external)
   - Strategy for procurement (e.g. M1 Manipulator, LOPS/LOCO, M5 mirror, etc.)
   - Process for changes affecting Statements of Work
   - Executive Authority for all major subsystem design reviews
Implementation and participation of a quarterly Reosc-ESO Management meeting. The first one happened middle of June and the second in October

Supervision of the preparation of the System Verification Review and the resulting actions

2) Coordination of the actions to be implemented as a result of the HARMONI (and LTAO) PDR’s including final plan for H-LTAO construction go-ahead.

3) Continuing investigating opportunities for the provision of a power conditioning at Armazones (Phase 2 item)

4) Contributions to the ELT internal Cost Review.

5) Starting the ELT Construction All-Risk Insurance as of 20th of April through ESO’s broker Marsh Ltd. The claim procedure was sent to the relevant ELT site managers for information.

6) Initiating a new bi-weekly meeting with Technology Development Programme to follow up the status of the detector’s delivery to the ELT.

7) Releasing the new site access policy after site hand over to ACe.

8) Coordination of the participation to the SPIE Conference on Astronomical on Telescopes + Instrumentation in Austin, Texas (10-15 June 2018). Fifteen papers were presented by the ESO ELT team.

9) Participation to the AIU in Vienna.

10) Discussion with GMT about an overall NDA to facilitate exchanges and communication between the technical teams, in particular for the geotechnical situation GMT encountered on their site.

11) Publication of semi-regular public announcements and ELT internal newsletters to keep the public and ESO staff informed about the latest progress of the Programme.

12) Update of the Programme Risk Register in cooperation with each Project Manager

13) Organisation and participation to regular Programme meetings (bi-weekly oversight meeting with Directors, weekly Programme management-level meeting, Project Managers' reporting meeting, overall Status Meeting with the whole team, etc.)

14) The standard set of documents (Fact Sheet, 6-month reports, contribution to Council documents) was prepared and the ELT status was presented and discussed at the full cycle of Governing Bodies: ESC (April), STC (April), FC (May) and Council (June).

15) The ELT status was presented at the 50-years Zerodur ceremony organised by Schott (June), at SPIE (June), at Paranal for ESO staff (July), at meetings with Irish ILO and Irish Industry (September), to Chilean authorities (CONYCIT, Ministry of External relation) and to the 50-years Micro-Epsilon celebration

3.1.2 Systems Engineering

A central activity for SE during this period has been the System Verification Review (SVR). In preparation for this review, following on from the work started previously, the System Verification Plan was completed and released. In addition, a very advanced draft of the ELT System Verification Matrix as well as a draft of version 2 of the ELT Level 1 Requirements Specification were elaborated. In the scope of the preparation of these documents, the definition of the verification attributes of the Level 1 Requirements was concluded and the linking to the lower level specification documents was reviewed and significantly improved. These two aspects are important steps to organize the overall ELT verification and to help in
understanding the impact of change requests and requests for waivers/deviations on the system requirements.

In the review meeting itself the SE team answered a significant part of the RI\text{X}es raised by the reviewers and gave presentations on the System Verification Plan as well as on the SE processes and discussed with the reviewers. The Performance Analysis and Verification (PAV) group presented and discussed the system performance model.

Still on the SVR, SE actively participated in the analysis of the recommendations from the Review Board and in the definition of the derived actions. Some of the key actions have been taken by SE and will be performed in the coming months. Special attention should be noted for the update of the System Verification Plan, putting more emphasis on the verification of vibrations requirements at system level, on the validation of the mathematical models and on the clarification of responsibilities during the technical and scientific commissioning periods. Also, SE must provide inputs to update the part of the Programme Management Plan for what concerns the SE processes.

Regarding interfaces, there has been significant work on updating the interfaces between the Main Structure and the M2 Unit, the M4 Unit, the M5 Unit and the Laser guide Star Unit. Also, the interfaces to the instruments in the Nasmyth platforms in regards of additional attachment points and location of the Service Connection Points have been developed and discussed with consortia but not formalised in the relevant document yet.

Concerning the technical budgets, apart from the normal maintenance work, a new budget has been prepared and is ready for release, namely the transitions times budget, which refers to the time needed for the complete system to start up and shut down and to daily transition from maintenance to observation and vice-versa. In addition, a complete analysis to update the telescope exit pupil motion budget has been done. ESO is now ready to update the budget itself.

This period new change requests have been submitted and processed. Also, the number of non-conformities and requests for waiver on which SE has to perform technical assessment and provide recommendations is progressively increasing.

SE participated in the FDR of the ELT Technical Facility at Paranal, focussing on system and general architecture aspects. SE also took part in the review of the M5 Cell procurement documentation, looking in particular at system, interfaces and performances aspects, the latter covered mostly by PAV group.

The management of the Programme documentation has been performed in this period as usual, including a standing activity to improve the organization of the ELT archive in the ESO PDM system. The goal is to progressively optimize it to serve as a fully reliable tool not only for the archive of the documentation but also for configuration control.
3.1.3 Programme Science

The ELT Programme Science is providing continuous and proactive scientific input across the various ELT work packages, to facilitate the definition of the sub-system requirements and ensuring that the Observatory Top Level Requirements are met. Support has also been provided for the important System Verification Review held in June 2017 with the aim of assessing the processes and procedures for the management of the ELT requirements and their verification.

The ELT Programme Science continues supporting the development of the first-generation instruments (MICADO/MAORY, HARMONI and METIS) during their PDR phase, attending their science consortium meetings as well as reviews. In particular, substantial effort is being devoted to the Review of the Preliminary Design (PDR) for MICADO. The documentation – more than 4000 pages – has been delivered by the MICADO consortium and the review will be held in November 2018. With the support of the Project Science Team (PST), ESO has also analysed possible change requests from MICADO in preparation for the PDR.

The ELT Programme Science is also closely following the development of HARMONI towards the closure of the PDR actions and of its Laser Tomographic AO module (H-LTAO). The report on the risk mitigation study to use MAORY as the AO system to feed HARMONI has been completed and presented to the ESC and STC. The proposed solution to continue with the baseline of a separate H-LTAO has been recommended by STC. Following this recommendation in April, significant effort has been devoted to identifying possible ways forward for the H-LTAO, including the costing and funding possibilities, and in particular supporting the definition of the Technical Specifications.

The ELT Programme Science put significant effort in following the post Phase-A studies for HIRES and MOS. The ELT Programme Science has been actively supporting ESO Management in identifying possible way forwards for these instruments. Particular effort has been devoted to the MOS project following the recommendation of the review board of Phase A to better understand the scientific priorities of the project. The scientific capabilities of the proposed MOSAIC concept are now under evaluation with the support of the PST and several high-profile community scientists and the Consortium and will then be presented to the ESC/STC.

The ELT Programme Science also contributed to the ESO Data Flow System Development Review and started dialogues about specific requirements for ELT science operations and how to integrate them within the current VLT operation, with extensive and useful discussions also at the ESO Operation Workshop held in Vitacura in October 2018.

As part of the engagement with the public and the scientific community, the ELT Programme Science presented the status of the programme and its scientific goals to various conferences and workshops.

The ELT Programme Science in collaboration with the PST co-chaired the symposium at the IAU General Assembly on “Early Science with the ELTs” in Vienna. The symposium has been very successful, with a diverse programme spanning all key science cases of the ELT and
received very positively by the large international audience - with more than 500 people registered for the sessions across the 5 days. The week after the IAU as part of the programme we have also organized an International School for young scientists in Belgrade. We received very positive feedback from the 40+ students, which had a week of lectures, tutorials and practical sessions, including live remote observations using a telescope in Tenerife.

### 3.2 Dome and Main Structure (DMS)

**Executive summary**

This reporting period saw various important issues related to the DMS procurement contract. As already reported in an update covering the April 2108, the ACe Consortium cancelled the contract with their original DMS designer European Industrial Engineering, and activated various other subcontractors for completing the design to the final design status. This activity is still ongoing as detailed below.

The second important element, also mentioned in the April 2018 update, is the completion of the geotechnical prospection at the Armazones which confirmed the fractured and non-homogenous characteristics of the rock at the plateau specially in the area of the telescope pier with impact on the design of the foundations of the telescope pier, and to a lesser extent of the dome and auxiliary building.

The third issue is related to the financial situation of the ACe Consortium leader Astaldi, who at the end of September applied in court for a procedure of insolvency according to the Italian insolvency law. This is having an impact on the day to day operation of ACe both at the level of design and construction in Chile.

Despite these issues, advancement on the project was possible in various areas with the performance of a number of Critical Design Reviews related to the construction on site and to the start of manufacturing in Europe.

**Design activities: Subcontractor matters**

As reported in the previous report, the Main Structure PDR was held in February. The Board concluded that despite the design being rather advanced, a few technical solutions could not be agreed by ESO, due to lack of information and validation. For this reason, ESO had demanded a Delta PDR on specific matters. To complicate the matters further at the end of March 2018, the Consortium terminated the contract with their subcontractor European Industrial Engineering (EIE), initially charged with the design of the DMS. This could be done without previous consent of ESO, according to the ESO contract. The exact reasons for the termination of the subcontractor relation are not known to ESO, but considerable differences of opinions with ACe had become evident in the past on specific design choices and on the handling of the design of some key suppliers.

As a consequence of the severance from EIE, the Consortium had started the process of offloading some of the design activities for specific DMS subsystems to specialized suppliers, assuming complete work-packages from design, to delivery and in certain case up to commissioning on site. This includes the Belgian company AMOS, experienced in telescope design, and whose expertise is being used mainly for system aspects of the Main Structure
design. Dynamical and seismic analysis have been assigned to companies associated to the University Politecnico di Milano. In the past months other suppliers have been selected for the specific subsystems and design activities are on-going.

**Dome and Auxiliary Building design**

Considerable progress can be reported for what concerns the civil works design, in particular that of the Dome and Auxiliary building, and to a lesser extent of the telescope pier. It is recalled that the design activities of the whole DMS had been impacted by the unilateral decision of the ACe Consortium to comply with seismic Chilean regulations. The adoption of these regulations, in addition to the Eurocode ones specified by ESO, had slowed down the overall progress by distracting manpower to the normal engineering work, and also affected the design itself, bringing considerable changes in the technical solutions adopted. ACe has abandoned the use of pendulum dampers presented at the Dome PDR (at disadvantage under the Chilean Seismic code) in favour of conventional high damping rubber bearings and has structurally connected the Dome base with the Auxiliary building, previously decoupled and not seismically isolated. This has pushed the excavation to an increased depth below the auxiliary building resulting in an increased volume of extracted rock of approximately 18000 cubic metres, accompanied by the design of a new foundation below the dome and auxiliary building. This new design, significantly different from the one presented at the Dome PDR back in June 2017, and also taking into account the most recent geotechnical investigation done by ACe (see below), was formally reviewed by ESO in a Critical Design Review in September 2018. By this CDR (CDR#1) ESO agreed to the start of the construction on site of the Dome, Auxiliary building, and chiller plant.

It is recalled that the use of the Critical Design Review procedure, foreseen in the Statement of Work for long lead items, was requested by ACe in order to move forward for specific items prior to the formal FDR (see previous report). ESO has been critically reviewing the opportunity of these CDRs in view of keeping the schedule and agreed to hold a few CDRs, after rating the technical risk for the DMS contract to be low. The CDR process does not relieve ACe from any contractual risk associated to later possible design changes detected at FDR but provides the comfort of an anticipated verification step by ESO. As per today ESO has agreed to hold, in addition to the CDR#1, CDRs for the metallic structure of the enclosure and one specific CDR for its rotating mechanism. Accordingly, in September 2018 ESO held the first CDR for the metallic structure (CDR#2) and is preparing the review of the enclosure rotation mechanism (CDR#3), to be held in October.

On the other aspects of the design, pertaining to the elements contained in the Dome and Auxiliary Building, considerable progress has been achieved. ACe is concluding the architectural design aspects, such as electrical sockets, sinks, doors, accesses to the seismic isolators and the like, in close consultation with ESO. Regarding the enclosure, the design of the windscreen, of louvers, cladding, crane and plants is well advanced. A few elements are nevertheless missing for the completion of the Dome FDR, until recently expected to take place within 2018. The recent cash flow issues and insolvency process initiated by Astaldi (see below) have pushed this date to February 2019, but this will need confirmation.
Main Structure Design

The progress achieved on the Main Structure is not at the level anticipated at the time of last reporting. The change of DMS designer complicated the design progress, causing the need for consultations and negotiations with potential suppliers. This process, well started for some key subsystems before the summer, slowed down later, and it has been affected by the poor cash flow of Astaldi. In particular the activities which have affected are the design of the hydrostatic bearing system, and the design of the lateral restraining system for the dome pier, both offloaded to external suppliers. The other subsystems, designed with the Consortium manpower, are slowly progressing, although not at the expected speed. In summary as per today there is not an agreed date for the MS delta PDR.

This said, it is worth to note, that the aspects of the civil works of the Main Structure were brought to a stable design situation. In June/July 2018 the effective geotechnical conditions of the rock, especially in the main Structure pier area were sufficiently clear. (see site activities below). Based on these, ACe has analysed the impact on the Main Structure performance, especially in dynamics. In order to secure the performance ACe has decided to increase the depth of the excavation and to construct a continuous slab as foundation, with an added concrete reinforcement zone around the South-East. The purpose of the latter is to minimize the impact of a fault crossing that area. Due to this and to other design choices, the excavation depth to be reached in the telescope area has grown to 7 metres compared with the original 2 metres, leading to an increase of volume of excavation of approximately 15000 cubic metres. For reason of technical and programmatic risk, ESO will not review the final design of the civil works of the Main Structure (not on the critical path) via a CDR before the Delta MS PDR has been concluded.

ESO is putting all reasonable effort in place to reach that milestone, with close interaction with ACe and their suppliers, by fostering meetings and exchanging technical information. The reported date of the Delta PDR of the MS is May 2019. This date appears feasible, if not impacted by the recent insolvency process.

Manufacturing in Europe

With the successful first CDR of the enclosure structure, the manufacturing activities have officially started. The associated steel was procured and inspected by ESO at Cimolai premises. The preparation of the Manufacturing Readiness Review (MRR) is on-going and in November the proper MRR will be held by ESO.

Testing of the first items of the seismic isolators of the Dome and Auxiliary building was completed. Serial production is contracted.
Chilean Activities

Excavation at the ATP started in January. In the latest biannual report, ESO mentioned the rock situation at Armazones, which had been reported by ACe not to be conform to the initial geotechnical prospections performed by ESO and to be heavily fractured. (It is recalled here that the geotechnical report by ESO was provided to ACe for reference only). Astaldi started a vast campaign of geomechanical and geotechnical tests on site. The final and overall results of the campaign were available only in September but already in summer the main results were known and were discussed in depth with ESO supported by the Ramboll experts.

Contractually ESO made repeatedly clear that the overall risk for the geotechnical situation rests on the Contractor and includes the adaptation of the design to the actual rock conditions. Despite ACe contesting this issue, they continued with the design activities, encompassing a significantly increased excavation volume, and continued with the excavation on site. At the time of writing, the excavation of the Dome and Auxiliary building area is completed and the one of the telescope area is approaching the final depth level.

In the Auxiliary building area, the Consortium has started pouring the blinding concrete and excavating trenches for the earthing grid.
The Armazones Base Camp installations by Astaldi are de facto completed. Astaldi has finished the dormitories and offices, including those to be put at the disposal of ESO, installed first aid facilities, ambulance and a heliport for emergencies. The camp is fully operational. In June 2018 the concrete production plant installation was finished with qualification activities for production in July. In August the first blinding concrete was cast in the Auxiliary Building area.

The ABC camp is now powered with electricity via the grid. The connections were effective within the contractual time limit agreed between ESO and ACe.

In order to perform an independent control of the civil works activities on site ESO has started a CFT in Chile for Quality Assurance services at ATP. The CFT is finished and ESO is finalizing the contract with the selected Chilean supplier.

**Contractual matters**

The DMS Contract has suffered significant delays in the previous months, only partially offset by starting of the activities on site and by having limited scope CDRs. As a consequence of the delayed design activities the cash flow associated to the project has not progressed as expected. There have been various unsuccessful attempts by ESO and ACe to align the payment plan to the progress on site in order to overcome the cashflow issue and to limit the impact on the activities on site. Recently an agreement has been reached on the adaptation of the short term payment plan.

ESO has received two Red Flags reports in spring, one related to the adoption of the Chilean norms and one related to the geotechnical situation, justifying a significant delay in the project execution. ESO has taken a formal position rejecting both claims and has started discussions with the Contractor on these matters. At the present time there is no firm conclusion on the
final Provisional Acceptance date of the DMS. Negotiations to find an acceptable agreement on these matters are de facto stopped by the recent Astaldi insolvency procedure.

ESO has agreed on a number of technical changes with ACe, to adapt certain aspects of the DMS design to evolutions occurred in the design of the optomechanical units. As previously reported, the cost of some of these changes is offset by the deal on electricity to ACe mentioned in the previous report.

At the end of September 2018, ESO received a formal letter from Astaldi advising that they had filed for insolvency, according to a specific paragraph of the Italian insolvency law. This paragraph foresees the preparation of a plan in parallel with the continuing activity of the Company (Concordato preventivo in continuita’). This specific article of the insolvency law has the main objective to avoid bankruptcy. The Italian court has approved the procedure, effective 17 October, and appointed a commission for the handling of the Astaldi activities. The insolvency process will last a minimum of 60 days but it may be prolonged to a total of 120 days, with unknown certain. ESO management met with Astaldi and is attempting to clarify the situation as well as the impact on the project.

3.3 Optomechanics

3.3.1 Summary

The Project has 13 contracts running, and 4 are in preparation. Most of the running contracts are still in design phase, although at FDR level. There has been a significant number of reviews, typically about one review every two weeks, sometimes one every week.

On M1 Unit, 6 contracts are running: the M1 Segment Blanks, M1 Segment Support Mechanics (Design and Qualification contract, and Manufacturing contract), M1 Segment Assemblies manufacturing (M1 Polishing), M1 Edge Sensors, and M1 Position Actuators. The M1 Segment Support Design and Qualification contract is finishing, and the contract for serial manufacturing has started. Two additional contracts are in preparation: the M1 Segment Manipulator, the M1 Phasing gun.

All the 5 contracts for the M2 and M3 Units design and manufacturing are running: Blanks (x3), Polishing (x2) and Cells (x1). They are all progressing well so far, and several important milestones have been passed successfully. The M2 Blank is being finished, the M2 Mirror Polishing facilitization is almost complete. M2 Mirror figuring can start in a few months.

The M4 Unit design phase is complete and is now in manufacturing phase. The issues and failures during the production of the Silicon Carbide Reference Body have been solved. The first two M4 shells have been finished and delivered to AdOptica.

The Call for tender for the M5 Mirror design and manufacturing has been responded to by industry. The selection process is being completed. The M5 Cell requirements have been consolidated, the Call for tender for design and manufacturing is being released.
3.3.2 M1

M1 Blanks Manufacturing contract (Schott – Germany)
The Interim Design Review, mainly relating to the Blanks and Blank Transport Containers definition, has been held. Some complements are pending for the design of the Blank Transport Container, however nothing is critical or impacting the production and delivery schedule.

The production process qualification, performed on six full scale blanks, has been completed. The production of the first blanks has started: the first ELT M1 Segment Blank has been finished and successfully tested. 5 more are in manufacturing to complete the first batch of the validation series.

In parallel, the production of the Zerodur Boules has continued. Seven Boules have been cast and are either in annealing, ceramization, or machining process.

The iterations with Schott and Safran-Reosc on technical and logistics aspects for blank transport, handling, and delivery for polishing have been completed. This contract is so far running according to the plans.

M1 Segment Support Mechanics Design and Qualification contract (VDL – The Netherlands):
The M1 Segment Support Design and Qualification contract has not yet passed Provisional Acceptance. Two significant issues had to be fixed: accelerations in the Segment Assembly Transport Container upon 20-cm drop test, and accuracy of the Segment Extractor.
The issue with the Transport Container has been fixed. The Segment Extractor has been redesigned, manufactured and tested. ESO is still challenging the test results and some design features are being fine-tuned; however, ESO believes it is now close to completion of the contract.

The changes do not affect the Segment Support design, the part that is delivered to SAFRAN-REOSC. It concerns the Fixed Frame, the part delivered directly to the Chilean site and installed on the Telescope Main Structure. This is then considered not critical in terms of delivery to another Contractor.

The six Qualification Models (QM) are currently being retrofitted with the latest Series configuration status (new extractor and few minor ESO CRE changes). One QM has already been delivered to ESO for system testing on the M1 Test Facility. The remaining five will be delivered in the coming months.

M1 Segment Support Mechanics manufacturing contract (VDL – The Netherlands):
The Segment Support Mechanics Manufacturing contract (serial production) was signed in April 2018 with VDL. Manufacturing release reviews for the pre-series has been passed with few minor actions. The assembly and test facilities are being set up, supply and production have started.
A few Changes Requests are still being discussed with VDL to solve late technical issues. Some delays have been announced from VDL subcontractors for the supply of connectors. However, there are no critical issues nor show stoppers and delivery of the first Segment Supports is still planned within a good margin with respect to the required date at SAFRAN REOSC.

**M1 Polishing contract (SAFRAN-REOSC – France):**

The Facility fitting work, of a 4000 m² existing plant in Safran facilities in Poitiers, France, has been completed. The Facility acceptance has been held. The Facility includes workshops for grinding, pre-polishing, polishing, machining, bonding, integration, metrology, the latter ones being in clean rooms. They also include the warehouses and storage areas, the maintenance rooms and grey areas. The air conditioning, fluid, energy, and data distribution networks are completed. Everything is ready for the machine’s installation and setup.

The supply of the production machines is running according to plans. Most of the deliveries will occur in the November-December 2018 period. The design of the production auxiliary equipment (handling, interfaces to production equipment) has been completed, manufacturing is ongoing as planned. The production of the metrology long lead items, i.e. 1.7-m Calibration Sphere and 1.8-m Silica, is progressing well.

There are two important issues. The first one is related to the adhesive bonding qualification and design of the Segment Mounting Pads. After thorough testing of the adhesive properties, and very detailed analysis of the pad design, it appears probably impossible to match ESO requirements in a few survival cases, related to transport and storage (accidental very low temperatures). This issue is peculiar, as the design would not be driven by the Telescope Performance but by accidental conditions with marginal likelihood of occurrence. It is believed this issue is solvable, and a priori without schedule impact.

The second issue is related to the development of the metrology means. Converging towards a satisfactory design of the Optical Test Setup (Talissman) has been slower than expected. FDR will be held with 3 months delay, and the setup should be available for Segment Assembly finishing with 5 months delay. SAFRAN-REOSC have produced a recovery plan where they pile up ready-to-finish segments in front of the means, and then can recover the delay after completion of the validation series, i.e. 18 segments produced. Still, there are assumptions that are challenging, this issue is being monitored closely.

**M1 Edge Sensors design and manufacturing contract (FAMES Consortium, Fogale (F) and MicroEpsilon (G)):**

The contract is still in preliminary design phase, supported by extensive testing on validation and qualification models.

The design of the Sensor Electronics has progressed well and is well advanced. The overall electronic design for the digital electronic parts is mature and close to FDR level. Final tuning of excitation frequencies allowed to solve a remaining issue on signal noise. The coils have been re-designed to include a double layer, this still needs to be finish tested but should a priori solve remaining small issues as well. Temperature drifts are now fully compensated and
within specification. The sensor mechanical design has much improved and does now fully match the performance requirements.

FAMES difficulties with the design seem to be behind them according to the latest progress. However they still must confirm that ES are compliant at system level. Additional Qualification Tests are ongoing, to be completed in November, the PDR is planned in January 2019.

Although the design phase suffers delays, FAMES latest planning shows there is no impact on production and delivery.

**M1 Position Actuators design and manufacturing contract (Physik Instrumente (PI) – Germany):**
The contract is still in the preliminary design phase, supported by extensive testing on validation and qualification models.

The Qualification Test Readiness Review was successfully passed in September 2018, with the complete submission of the updated documentation package.

PI has finalized the assembly of the first qualification model and has started the commissioning of the control. The assembly of the remaining 4 qualification models is ongoing.

The tests performed so far on validation models and breadboards are fully satisfactory. The PACT design seems fully compliant with the specifications. The tests on the qualification models will be more exhaustive and representative but so far no critical issues or showstoppers are expected.

This contract is running according to the plans.

**M1 Segment Assembly Manipulator (SAM) and Local Coherencer (LOCO):**
SAM is the ‘Segment Grabber’ that will be mounted on the M1 crane to load and unload the Segment Assemblies in/from the telescope.

LOCO, previously the Phasing Gun, is a non-contact optical sensor, attached to SAM, that measures the location of a segment with respect to its neighbours at the time of segment exchange.

The preliminary requirements, technical and managerial were set, a Request for Information has been released and responded to by industry.

The detailed specifications are now being written towards a Call for tender release early 2019.
3.3.3 M2

M2 Blank manufacturing contract (Schott – Germany):
The M2 Blank was successfully cast, annealed, and ceramized. It has been finish machined on all surfaces except optical one. Acid etching is ongoing, towards a pre-inspection on 19 November.

The optical surface will be finish machined, the M2 Blank Technical Acceptance is planned on 20 December.

The M2 Blank is planned to be delivered to SAFRAN-REOSC by mid-January 2019, in accordance with the contract.

M2 Mirror Design and Manufacturing contract (SAFRAN-REOSC – France):
Actions still need to be closed before passing the Metrology Means Final Design Review (held in March). In particular, there is a non-conformance on the precision with which the mirror spherical aberration can be tested. This one is not critical, ESO asked however for more detailed investigations on how to minimize the mismatch.

Besides this, the metrology means are being manufactured (long lead items): the M2 Test Matrix is being figured, its mechanical support has been received and is being assembled. The Mirror Metrology Support is being procured. The modifications of the VLT Test Tower have been completed.

The M2 Mirror Auxiliary Equipment have been manufactured, assembled, and tested. Minor non-conformances need to be fixed before delivery to SAFRAN-REOSC in November.

The production means have been installed. The 4-m figuring CNC machine, the polishing robots and CNC turn-tables, the large 3D-CMM have been delivered, assembled, tested, and are being commissioned (process implementation).

The mirror mounting interface design is nearly complete, waiting for the completion of the adhesive ageing and shear tests, and for the modelling qualification. As for M1 Polishing contract, there is an issue with the adhesive bonding qualification and mirror pad design. After thorough testing of the adhesive properties and very detailed analysis of the pad design, it appears probably impossible to match ESO requirements in a few survival cases, related to transport and storage (accidental very low temperatures). This issue is peculiar, as the design would not be driven by the Telescope Performance but by accidental conditions with marginal likelihood of occurrence. It is believed this issue is solvable, and a priori without schedule impact.

The M2 Blank will be delivered in January 2018 to SAFRAN-REOSC, grinding will start in February, interface pads bonding is planned in March, followed by fine grinding and polishing.
**M2 and M3 Cells Design and Manufacturing Contract (SENER – Spain):**

The M2 and M3 Cells are in design phase. The Preliminary Design Review, and a delta PDR, was held, some actions need still to be closed although nothing is critical anymore. The PDR should be formally closed in December. Change Requests, initiated by SENER and by SAFRAN-REOSC have been solved and closed.

The prototype Position Actuator has been procured and assembled. Qualification and ageing Tests are planned to start in November.

The test breadboards of the Load Limiter, Warping Harness, Actuator Flexure have been designed and are in procurement. Qualification tests are planned to start in December.

Clarifications are on-going with both SENER and SAFRAN-REOSC to detail the delivery of the M2 and M3 Cells for in-Europe M2 and M3 Units integration and testing.

The total delay of the design phase is 7 months so far. However, SENER states this delay can be mitigated by their contingencies and the delivery dates are not impacted.

**3.3.4 M3**

**M3 Blank manufacturing contract (Schott – Germany):**
The M3 Blank is now in ceramization. Production is running according to the plans. The M3 Blank production still has good schedule margins.

**M3 Mirror Polishing Contract (SAFRAN-REOSC – France)**
The M3 Mirror is in design phase. The Auxiliary Equipment Design Review was successfully completed (handling, transport, and storage equipment, as well as an aluminium dummy mirror). Manufacturing of the M3 Auxiliary Equipment is nearly complete.

The Metrology Means Preliminary Design Review was passed. Detailed design is finished.

The M3 Mirror Mounting Interfaces Preliminary Design Review was also passed. Detailed design is ongoing, pending the complete results of adhesive bonding qualification testing, same issue as M1 and M2 polishing contracts.

Regarding the production facilities, see M2 section.

**M2 and M3 Cells Design and Manufacturing Contract (SENER – Spain)**
See M2 section, as the M2 and M3 Cells are developed in a single contract.

**3.3.5 M4**

**M4 Unit Design and Manufacturing contract (AdOptica, Italy):**
The design phase has been completed and the FDR passed. The M4 Unit is now in production phase.
The actuators components are being manufactured: magnets, coils, brick mechanics, electronics. A first batch of magnets and bonding pucks has been received and is in testing.

All Silicon Carbide Petals of the M4 Reference Body have been manufactured. Repairs have been done where necessary or are being done for the last petals. An incident occurred when machining the last petal: this one is being repaired, and a spare one is being produced to secure the schedule. Brazing all petals together to make a single SiC Body is planned in February 2019.

The adhesive bonding tests are continued (thermal loads). The test results are expected in December.

The M4 Unit Optical Test Tower is in manufacturing. The blanks for the two main mirrors have been received, figuring has started.

Testing of the full segment prototype and interface with the Central Control System has been carried out successfully in September.

The issue of tip-tilt instability is being solved by off-loading towards some the M4 actuators and sensors. AdOptica is procuring the test hardware and foresees to verify the expected performance by early next year.

Final tests of the hexapod leg have been successfully done in September. This closed the last pending actions to pass the FDR.

The contract has been amended to include the M4 Gas Cooling facilities.

A Change Request has been submitted to AdOptica to manufacture, integrate, and test 12 shells instead of 8. This change is depending on the polished thin shells delivery schedule commitment from SAFRAN-REOSC.

**M4 Shells Manufacturing contract (SAFRAN-REOSC – France):**

The issues that have delayed the production of the M4 Shells (scratch occurrences, shell cracking, chipping, Ion Beam Figuring machine contamination) seem mitigated and production could be resumed with much less incidents.

The first 2 M4 Shells have been finish manufactured, tested, accepted and delivered to AdOptica.

The other M4 Shells are at various production stages, except one that required a new Zerodur blank procurement. This blank procurement has been done.

An additional shell working station has been set up to accelerate the production. Assuming no further incidents occur, the M4 Shells manufacturing should soon settle back to mastered steady production, and delay should be recovered.
3.3.6 M5

**M5 Mirror Design and Manufacturing contract:**
The Call for tender for the Design and Manufacturing of the M5 Mirror was responded to by industry. The selection process is not yet complete, as risk management of that procurement is an issue difficult to solve. It is expected to be ready for submission for approval by Finance Committee in February 2019, or by May 2019 latest.

**M5 Mirror Design and Manufacturing contract:**
The Request for Information and Preliminary Inquiry for the Design and Manufacturing of the M5 Cell have been completed.

The Contractual, Managerial, and Technical specifications have been prepared and are in the final internal review. The Call for tender is planned to be released early November 2018.

3.4 Optical Control

During the last period, the scope of Optical Control was changed to include the laser guide star units. Progress is reported per the Optical Control subsystem below.

**3.4.1 Pre-focal Stations**

The kick off meeting for the PFS-A Main system was held at the beginning of May 2018. IDOM have started the preliminary design phase with work taking place on design trade-offs for the drives and bearings, the optical design and refinement of performance analysis models. The preliminary design review is scheduled for Q1 2019.

The preliminary design review for the WFS Cameras, under development within the technology development Programme, was held in July 2018. The schedule remains quite critical for the PFS completion. A work package dedicated to the development of the complete camera systems for the PFS-A Main System and the Phasing and Diagnostic Station will start running in January 2019.

The definition of the phasing and diagnostic station and the telescope test unit requirements continues to be pursued in the frame of the MELT project. The PFS team has supported MELT during the last period in the area of opto-mechanics.

**3.4.2 Metrology**

Results have been obtained from the PFS-hosted metrology breadboard tests, and a final report is in preparation. The current concept for the PFS hosted metrology and associated alignment concepts was presented to the Nasmyth A instrument consortia in a workshop organized by ESO in June; feedback was provided by the instruments.
3.4.3 Calibration Unit

The telescope alignment beacon (calibration unit) will be used in conjunction with the PFS optical sensing to characterize various aspects of the telescope such as M4 response and phasing, M3 and M5 active control functions. Consolidated user requirements for the calibration unit are pending.

3.4.4 Telescope Test Unit

The definition of the telescope test unit requirements is being pursued in the frame of the MELT project.

3.4.5 Lasers Guide Stars

The work during the last period includes preparing the laser guide star system technical specification, which is now close to a first release, and refining the mechanical layouts for the laser guide star units on the laser support platforms and the cameras in the area of M2.

The laser sources manufacturing readiness progress meeting was held in June. A few minor changes to the electronics cabinet interfaces were agreed after the manufacturing readiness meeting. Production of the first set of line replaceable units (subsystems) has started, with a planned completion in Q2 2019.

The laser projection subunit technical specification and other procurement documents are in preparation. The launch of the Call for tender is currently planned for Q2 2019.

A breadboard test to characterise the vibrations from different cooling pumps has started.

3.5 Control System

Retrofitting of the MELT Optical Test bench has commenced with replacement/adaptation of the existing control electronics with equipment following the ELT control system architecture and implementing the control interfaces baselined for the ELT Control System.

The Central Control System requirements specification has been drafted and released for review. The review is on-going but has triggered important programme-level clarifying discussions on operations, acquisition and the instrument interface to the telescope.

The Instrument Control System Framework development progresses on-track, with the completion of the cryogenic controller, motor controller and setup of a small instrument test-bench. The requirements specification and CfT documentation for the Data Display Tool (for user GUI display of camera images) has been drafted, reviewed and completed. The CfT is now underway.

The requirements specification for the Time Reference System (observatory clock and distribution network) were drafted, reviewed and released. The design and updated cost estimates are underway.
The Core Integration Infrastructure (CII) Software contract (approved at FC May 2017) has released its first software deliverable, the “Middleware Abstraction Layer” hiding the complexities of communication interfaces from upper layer applications. The software is under test and review at ESO, including use of suite of 30 servers to test scalability of the software.

A draft of the document "Interface Types for Interlock and Safety System" has been prepared. This document deals with implementation details for the interface between subsystem local safety units and the central interlock system, both for hardware and software.

The M1 Local Control System, (enabling deterministic control of the M1 segments, failure detection and isolation and power control and cooling of the M1 devices) passed FDR last 2017. (2nd generation) Prototypes of the ~150 cabinets and ~300 heat exchangers have been procured and integrated in-house. Assuming tests of the integrated prototype cabinets are successful, a CfT for their respective series manufacture and delivery will be carried out in 2019. Software development on the M1 control system is proceeding on-track and to a high quality. The development process is following the iterative approach prescribed for the ELT in-house software development.

M4 deterministic data interface tests were carried out at the supplier’s premises, the tests were performed with a complete and representative communication infrastructure setup, including the 2km of fibre cable expected between the computer room and the M4. The tests successfully demonstrated driving the M4 at 500Hz, 700Hz and 1kHz, micro-second level time synchronization and stable and compliant computation times on the M4 (saturation management, safety checks). This critical interface is currently in a good state.

The design and management documentation of the M1 segment deformation control (“warping harness controller”) is proceeding on-schedule. All electronics components and connectors for the 1000 controllers have been procured and delivered. Test controllers, documentation and demonstrations have been delivered to the M1 Segment Subunit manufacturer on-time.

3.6 Civil Infrastructure

The ELT road, connecting the Armazones mountain with route B710 (public road), is finished and in use since last year by the DMS contractor (ACe consortium). So far, the pavement has behaved very well, and the constant traffic of heavy trucks has been beneficial for the asphalt coating.

A small maintenance contract is in place to keep clean the drainage works, the signs and the road surface. The whole road length is being maintained and swept from time to time to keep it free from small amounts of debris that are freed from the rock cuts and or brought by wind.

The road has gone through rain and even snowfall episodes. The full length of the road has stayed drivable all the time, except when ice has popped up after snow fall close to the ATP. The dumps have remained stable and have behaved according to their engineered design. At the foot of the North West dump, a dynamic mesh against rock fall (for local instability) was
installed (between km 23,400 and km 23,700). The work was completed in April 2017 and so far remains as a preventive safety measure (no rock fall has happened yet).

The junction to connect the zig-zag road with the main ELT road around km 23,200 was contracted to ACe. It was completed by the end of September 2018 so currently the zig zag road is fully drivable from the ATP to the ABC.

The DMS works (executed) by ACe consortium have been started at the Armazones Top Platform (ATP), the Chillers, the Dry Coolers and the Storage platforms. Over the present period only ACe has executed works in those places, it will be uniquely ACe or its subcontractors the ones that will continue working there in the medium term.

Regarding the Armazones infrastructure (rooms for coating equipment, instrument integration, small workshops and the like), its implementation is directly linked to the Dome and Auxiliary Building design. The last CDR for this ATP infrastructure design (under the DMS contract), happened in September 2018; other CDRs and the FDR will continue to happen over the next 6 months.

Some changes to the existing observatory infrastructure have been planned at Paranal to accommodate the E-ELT needs.

For the ELT PAO based infrastructure, it is under development on the urbanization of a piece of land (6500 m2) located next to the fuel station and the Astrotaller building. On this surface are being built new circulation roads, new fire and potable water grids, a new sewerage grid and new power and data distribution grid.

The new ELT PAO urban area is called ETF, standing for ELT Technical Facilities. It consists of a roofed space destined to store the M1 segments and other delicate pieces as well as offices space. It also considers room to lodge the M1 segments maintenance area and room for the 5 m mirror maintenance area.

The formal tender action to design in detail and build the ETF was initiated in April 2017 and the contract was successfully signed in March 2018. The main contractor is the construction company named Abengoa Chile, and their engineering partner is Quadrante, which is a Portuguese engineering company installed in Santiago.

Currently ESO holds an Engineering, Procurement and Construction (EPC) contract to design and build the ETF with Abengoa. After the contract signature (held in March 2018) and the KoM (held in April 2018), the mobilisation to the site, the detailed engineering design and the earth works have been started on site.

On 9 July 2018 the EPC Contractor delivered to ESO the detailed engineering design package and the FDR process was formally started. On 9 August 2018 the FDR meeting was held, and it was successfully concluded with the active participation of the nominated review panel and the detailed design having passed (milestone D3 accomplished). On 15 September 2018, ESO received revision 2 of the detailed design for ESO's final perusal.
With respect to on site activities, over the period Abengoa has finished the installation of their camp and site facilities (milestone E1 accomplished). The execution of the earth platform where the ETF is being built has also been concluded (milestones E2 and E3 accomplished). The first milestone related the building construction has also occurred (ETF 1).

The activities on site are mainly focused in the local excavations for foundations and the materialisation of the reinforced concrete works that correspond to foundation elements such as connection beams and footings. The manufacture of the steel works has been concluded by an Abengoa subcontractor, named Edyce, whose facilities are located in the city of Talcahuano. Almost the totality of the steel structure is now on site and the first frames (beam-columns arrays) are being erected as of October 2018.

During the last semester a contract was successfully concluded to provide a Technical Inspection Service (TIS) for the Abengoa contract (TIS contractor is Cruz y Dávila, C&D). The 3 professionals assigned to the contract by C&D are already working at the site.

### 3.7 Supporting Systems

Over the reporting period, the Supporting Infrastructure Project managed the following topics:

- the CFT and contract for the M1 Segment coating plant
- the electrical substations for Armazones
- the M4 cooling infrastructure
- the CFT and contract for the 4 ETF bridge cranes

The supporting systems continued collaborating with the rest of the team, in particular AIV and Systems Engineering, to assure that all the installations related to mirror maintenance are properly considered.

#### 3.7.1 Washing and Coating (mirror maintenance)

Following the result of a Preliminary Inquiry (PI) in early 2017 for the washing, stripping and coating of the M1 Segments which showed that enough companies were interested to bid for the complete package, ESO decided to have only one procurement process for the complete plant of coating removal, re-coating and quality inspection, including the handling of the M1 segments between the different sections of the plant. Unfortunately, shortly before the closing date of the Call for tender, it appeared that not enough companies were indeed going to actually submit an offer. Consequently, a new Call for tender was released early December 2017 for the M1 Segments coating plant only. Finance Committee approved in May 2018 to award the contract for the design, manufacture, transport, and installation and testing on site of 2 M1 segment coating plants to the company AGC Europe, a subsidiary of the Japanese glass manufacturer AGC. The company has broad experience in building coating machines for their own glass manufacturing plants worldwide.

During the CfT the second plant was specified as optional as, after having received the tenders, ESO decided to place a contract for both plants at the same time, which allowed the successful negotiation for a substantial price reduction. The contract started in June with the kick-off meeting, and the scheduled PDR took place on 7 November. Although not finally
concluded the outcome appears very positive. The contractor will have a number of Action Items, but the overall schedule will remain valid and the PVA date is not affected.

The procurement process for the washing/stripping/handling units, started after the failure of the combined plant CFT with the preparation of a new Request for Information (RFI). After contacting many companies, it turned out that finding a sufficient number of potential bidders for a successful competitive tendering process was not easy, given the complexity of the requested plant involving several different technical disciplines. Therefore, it was decided to extend this search period and postpone the PI and subsequent CFT and postpone the planned contract approval by FC from May 2019 to November 2019. Several companies were contacted at different trade fairs with some positive feedback, allowing ESO to proceed slightly more confident in the further process.

In March 2018, tests for the in-situ cleaning of the M1 segments with a supersonic CO2 jet cleaning method were performed. The result had shown that the freshly coated optical surface was not attacked by the CO2/compressed air stream. No further results were obtained. To advance with the development of a suitable M1 in-situ cleaning system, a concept was drafted which would avoid a tendering process for feasibility studies. Following this concept, the planning to execute this study in Paranal with the participation of Paranal staff is ongoing, sharing efforts and results between ELT and Par.

A video conference between TMT, GMTO, and ESO was held, to explore potential synergies in the development of suitable in-situ cleaning processes. At a first glance it appears, that ESO cannot benefit much from previous efforts of the other projects.

3.7.2 Power conditioning and backup system

Following the installation and commissioning of the electrical substations for Armazones, the ABC was connected to the public grid. After some minor observations during the test operation were fixed, the substations are ready for provisional acceptance.

The 23KV cable, which connects the 23KV substation with the ATP was removed from the supporting systems job, and the procurement and installation will be performed by the DMS contractor.

3.7.3 Chilled Medium Plant, Compressor and Cryogenic Plant

ESO is in contact with qualified companies, which can deliver cryogenics infrastructure and cooling equipment for the ELT instruments. The scope for a cryogenics infrastructure engineering study was defined, the study shall be launched in the second half of 2018.

3.7.4 Bridge cranes for the ETF

The contract for the delivery of 4 bridge cranes for the ETF was signed with the company Inamar, a representative of the German brand ABUS. The delivery is scheduled such that the cranes will be delivered on time to be integrated in the construction process of the ETF. The
construction company building the ETF will also install these cranes and the crane manufacturer will only be in charge of supervision and commissioning.

After a change in the configuration of the M1 area of the ETF the installation of an anti-collision system was added, as the physical separation by end stops of the two bridges’ travel will be eliminated.

3.7.5 M4 Cooling Supply

The M4 gas cooling unit was moved to the M4 unit project. Therefore job 5626 can be eliminated. No further activities of the supporting systems are expected for this deliverable.

3.8 Instrumentation

Progress continues on the four instruments in construction and the two-Phase A studies for ELT instrumentation. The instruments are:

- HARMONI, an AO-fed IFU spectrograph for the optical and near infrared;
- MICADO, an MCAO-fed near infrared imager with slit spectroscopy;
- MAORY, an MCAO module to feed MICADO and an auxiliary port;
- METIS, an AO-assisted imager/spectrometer for the thermal infrared;
- MOSAIC, an optical to NIR multi-object spectrograph (Phase A study); and
- HIRES and optical to NIR high resolution spectrograph (Phase A study).

The work on closing the actions from the HARMONI PDR review was an important focus of activity for this team. The review identified 70 items necessary to be completed before the PDR could be closed. All but one of these technical items is complete at the time of writing. In addition to these technical issues, the cost of the HARMONI design that will meet the instrument scientific requirements is in excess of the funds available from ESO. Following a review of the costs and scientific scope, it was agreed between ESO and the consortium to attempt to raise additional funds rather than to cut scientific functions. The PDR will be formally closed once the new funds are committed by the consortium; ESO has already committed to fund the near-infrared detector procurement from the ELT contingency. Meanwhile, technical work towards the final design review of HARMONI has continued and the HARMONI consortium still aim for a September 2019 Final Design Review.

A very important development for HARMONI has been the identification of possible ESO funding for the HARMONI LTAO module. The Agreement with HARMONI included the development of this module to Preliminary Design only; the continuation of the development of this module is a Phase 2 item. The scientific case for HARMONI is strongly dependent on the LTAO module. ESO is presenting the case for bringing forward Phase 2 funds for this module to its Governing Bodies. The hope is to obtain Council approval to advance this Phase 2 item in December 2018 and subsequently to obtain Finance Committee approval to finalise negotiations on the Agreement in February 2019.

The next Preliminary Design Review will take place in the week of 26 November and is for the near-infrared camera, MICADO. This PDR is on time with respect to the schedule for the instrument presented at the project Kick-off meeting. The documentation was delivered on
time and the review process is running. It was reported previously that the MICADO project office were reviewing the complexity and risks of the project. At the conclusion of this review, minor modifications to the MICADO technical specifications have been presented to ESO in a formal Change Request. These changes have been discussed with the ELT Project Science Team and will be finally accepted or rejected after the review of the MICADO design.

Work on the MICADO and MAORY interface continued with the level of detail in the interface increasing. The first release of the interface document is now planned for Q1 2019: it will be reviewed between the MICADO and MAORY preliminary design reviews. There is a delay in achieving the formal release of this interface. Nevertheless, both consortia have sufficient interface information to continue with their designs. It will be important to freeze the optical interface before Q2 2019 if MICADO are to achieve their schedule goal for early (pre-system FDR) procurement of their long lead time optics. This request is being evaluated by the ESO follow-up team.

MAORY have restructured the work within their consortium following their October 2017 INAF internal review. It was hoped that this restructuring would be completed by 22 March when ESO attended a Consolidation meeting of the consortium. However, it has taken until October 2018 for the consortium to unite around a single baseline concept for the instrument, following an extended period of examining alternative designs. ESO remain concerned at the lack of technical progress during this time and have increased support of MAORY by the follow-up team with the aim of maintaining forward momentum now that the MAORY baseline is confirmed. A new System Requirements Review took place on 5 November to ensure common understanding of the ESO requirements. MAORY have presented a schedule towards a PDR in June 2019. ESO considers this date to be still confirmed after MAORY demonstrate significant technical progress on their baseline design. Further changes in the Project management, mandated by INAF, are increasing the risk that MAORY will not be able to hold the current declared PDR schedule.

METIS have largely succeeded in overcoming the staffing issues reported last time and are now making steady progress towards their May 2018 Preliminary Design Review. As preparation for that, METIS plan a series of internal PDRs on each of their sub-systems. These reviews will be attended by ESO follow-up team members as observers. The baseline design has consolidated around the Aquarius detector. The METIS science team are evaluating the performance of the instrument with the Aquarius detector to confirm that the science case for METIS can be achieved. The results of this analysis will be evaluated at the PDR. A fall-back option for the detectors exists, but at low technical readiness level and higher cost.

The procurement of the near-infrared scientific detectors that will be used by MICADO and HARMONI (0.8-2.5µm) and also those for the METIS short wavelength functions (3-5µm) took place as planned, following approval by Finance Committee in May 2018. As previously reported, the detector costs are significantly higher than planned at the time of signature of the instrument agreements. Although the costs could not be reduced to their original levels, the placing of this contract removes a large source of budget uncertainty for these instruments.
The HIRES Phase A review took place on 13 and 14 November. The HIRES Phase A is now formally closed. Under the Armazones Instrumentation Programme the preparations for commencing the PDR Phase are underway.

The MOSAIC review was held on 7 and 8 March and the Phase A is now formally closed. In the case of MOSAIC, the optimum way to develop a scientifically productive instrument within the budget, volume and mass constraints for the instrument is not clear. ESO convened a panel of expert Astronomers from ESO and from the community to review the science case and concept. The outcomes of this review are being discussed with MOSAIC and with the ESO Governing Bodies. This instrument also moves to within the Armazones Instrument Programme and progress will no longer be reported under ELT Instrumentation.

ELT INS organised a workshop on Assembly, Integration and Test of the Nasmyth A instruments (MICADO, HARMONI, MAORY, METIS) in July 2018. This well attended workshop included presentations from ESO on AIV of the telescope and prefocal station as well as contributions from the instrument teams. The opportunity to develop a joint understanding of the possibilities and issues are AIV of the ELT system was appreciated by both ESO and the consortia.

4. Science Data Operations

The ELT science operations model assumes that ELT and VLT operations will be performed in an integrated environment. Therefore, the Data Flow System (DFS) will support both VLT and ELT operations. The integrated Data Flow System for the ELT and VLT seamlessly implements highly efficient science operations, meeting all high-level science policy requirements.

The project management and development plan for the Science Data Operations Project has been reviewed by an external expert team in May 2018. The review board fully supported the proposed strategy and applauded its efficient implementation and technological choices. The board recommended that "... an increased level of support within the Organization" is required in order to enhance the effectiveness of the plan. To this end, ESO took action (a) to fully integrate the VLT/VLTI/ELT Programme Scientists into the scientific prioritization of the individual projects and (b) to maintain the "agile" software development, adapting the outsourcing strategy with the help of Contract and Procurement to comply with the German law concerning hired manpower (AÜG). A Call for tender is currently under way, and a successful conclusion of the contract award process is critical to cover the ELT-DFS software development in the coming years.