SKA TELESCOPE MANAGER – PROJECT STATUS REPORT

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Abstract

The Square Kilometre Array (SKA) will be the world's largest radio telescope once it is complete and will use hundreds of thousands of receivers, spanning Africa and Australia to survey the sky in unprecedented detail. The SKA will be ground breaking in many respects such as image resolution, sensitivity, survey speed, data processing and size to name a few. The SKA Telescope Manager Consortium is currently designing the SKA Phase 1 (SKA1) Telescope Manager Element that will orchestrate the SKA Observatory and associated telescopes. In this paper, we report on the current status of the SKA1 Telescope Manager pre-construction project, the development process and its high-level architecture.

INTRODUCTION

Telescope Manager (TM) is one of a number of elements within the scope of the overall SKA1 pre-construction project, where the TM element has three primary responsibilities [1]:

- Management of astronomical observations;
- Management of telescope hardware and software subsystems;
- Management of data to support system operations and all stakeholders;

The TM element can thus be seen as the nerve centre largely involved in controlling and monitoring the SKA telescopes by interacting with other elements, namely:

- Dish (DISH);
- Low-Frequency Aperture Array (LFAA);
- Central Signal Processor (CSP);
- Science Data Processor (SDP);
- Assembly, Integration and Verification (AIV);
- Infrastructure Australia and South Africa (INFRA-AUS & INFRA-SA);
- Signal and Data Transport (SaDT);

The TM pre-construction project was kicked-off in November 2013 and is primarily focused on performing requirements analysis, architectural design, interface definition and prototyping activities, with the aim to produce a data pack that enables procurement contracts to be placed during 2017. Once a contract has been awarded, the development of the TM will continue with low-level design, coding and testing, integration, qualification and installation related activities ultimately culminating with a transition of the TM into a fully operational state in 2022, as per current plans.

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At the time of writing, the TM pre-construction project had been in progress for roughly two years since kick-off. An international consortium, led by the National Centre for Radio Astrophysics (NCRA) in India, assumes responsibility for the delivery of the TM pre-construction phase data pack.

APPROACH AND STRATEGY

The development plan for the TM is based on a tailored set of lifecycle stages and associated processes derived from the IEEE 12207-2008 and ISO/IEC TR 24748-3 standards [2]. These standards have been chosen as a basis for the development plan given that the TM Element is predominantly comprised of software, and IEEE 12207-2008 is a recognised international standard that provides a comprehensive set of lifecycle processes, activities and tasks for *software* that is part of a larger system.

The technical processes are employed in an iterative manner at various levels within the TM product hierarchy, namely the element, sub-element and assemblies \ application levels [2]. Items at each level are subjected to a requirements and design review prior to a formal system-engineering baseline being formed. The baseline indicates that there is agreement in terms of what each item in the product hierarchy is required to do, what they will consist of, and how they will interact to achieve the required functionality. A critical design review (CDR) precedes the formation of the final design baseline during the pre-construction phase. Development of the various levels proceeds largely in parallel, however it is critical that a higher level be thoroughly reviewed and baselined before a lower level can be concluded.

The TM pre-construction project aims to deliver a detailed *system* design (element & sub-elements) and a high-level *software* design (applications). The construction phase project will commence with low-level software design.

A risk management plan sees to it that risks are identified, analysed, treated and monitored on a regular basis. Prototyping activities are aimed at mitigating many of the technical risks. Exploratory prototypes are used to prove design concepts, confirm technology choices, characterise interfaces and elicit requirements. These prototypes are not developed with reuse in mind; rather they will be discarded once they have served their purpose. This reduces their cost and time to delivery. The

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development of a system wide evolutionary prototype is outside the scope of the preconstruction phase.

WORK PACKAGES

The TM Consortium is organised into the following work packages (WPs):

- Telescope Management (TelMgt): Engineering management of the telescope;
- Observation Management (ObsMgt): Usage of the instrument for astronomical observations;
- Local Monitor and Control (LMC): Monitoring and control of the TM itself;
- Local Infrastructure (LINFRA): Computational, communications, power and facilities infrastructure for Telescope Manager;
- Prototyping (PROTO): Development of the required prototypes needed for design purposes;
- System Engineering (SE): Engineering artefacts related to requirements, architecture and interfaces;
- Project Management (MGT): Consortium coordination;

TOOLS

Various tools are used to facilitate the development of the TM, such as Alfresco© for document management, eB® Director for configuration management, JIRA© for issue tracking \ project management and Google Drive© for collaboration purposes. A Model Based Systems Engineering (MBSE) approach is employed using Systems Modelling Language (SysML) for requirements management, interface analysis and design.

PROJECT STATUS

Definition and Preliminary Design

The initial year of the TM pre-construction project focused on definition and preliminary design activities. Element level requirements were specified including functional and performance requirements, with traceability to higher-level system requirements. A top-level architecture for the TM was identified, including the next lower level assembly. Internal and external interfaces were identified and defined in the architecture. A parameterised cost model for the TM was developed, and a cost analysis report was prepared. Preliminary assembly, integration and verification (AIV) plans were prepared. A preliminary analysis with respect to hazards and safety, radio frequency interference (RFI), electromagnetic compatibility (EMC), failure-modes-effects-criticality (FMECA) was performed. Preliminary construction and maintenance plans were prepared. Draft sub-system level requirement and design specifications were prepared.

Preliminary Design Review

A preliminary design review (PDR) was conducted roughly a year into the project (Jan 2015), attended by members of the SKA Organisation (SKAO) and a panel of external experts. The primary findings of the review panel were:

- TM Consortium was found to be responsive and collaborative with a deep understanding of the key design issues;
- High quality PDR data pack had been submitted;
- Technology choices were outstanding;
- Telescope level operations concept was immature with the potential to impact the TM requirements and design;
- Scope changes as a result of construction cost constraints (referred to as 'rebaselining') needed to be considered;
- Graphical user interface (GUI) design and scripting approach was immature;

After some deliberation the SKAO indicated that a delta PDR review would be required to closeout the panel's observations.

The delta PDR review has been scheduled to take place during the 4th quarter 2015. A revised data pack addressing the primary PDR observations has been submitted to the delta PDR review panel. It is expected that the delta PDR can be concluded during 2015, with the formation of a *development* baseline.

Technology Framework Selection

The TM Consortium hosted a workshop in Trieste, Italy during March 2015 that was attended by the SKAO, representatives from all SKA element level consortia and industry experts. The primary purpose of the workshop was to work towards the selection of a monitoring and control framework technology to be implemented as an SKA wide standard. Three main candidate technologies were considered, EPICS, TANGO and Alma Common Software (ACS). Evaluation criteria included:

- Scalability and monitoring and control design concepts;
- Industrial standards and fresh module development;
- Modernity and future direction;
- User support and documentation;
- Integration and re-use of precursors;
- Risk reduction;

Although both EPICS and TANGO were deemed to fulfil the core requirements, TANGO was selected based on its product-oriented harmony versus a fragmented design in EPICS, where concerns were raised regarding the long-term support of particular modules.

The workshop concluded that TANGO was deemed to be the better choice for the SKA project with a future lifespan of several decades to consider [3].

The TM Consortium will be releasing a set of documents during 4th quarter 2015 that establish Local Monitoring and Control (LMC) interface guidelines, roles and responsibilities, and TANGO implementation

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guidelines, endorsed by the SKA Organisation as an SKA wide standard.

Detailed Design and Prototyping

The TM Consortium officially kicked off its detailed design and prototyping activities during the course of a face-to-face meeting in June 2015. Sub-element level development plans were presented at this meeting together with progress reports in terms of closing out the PDR observations. Additional inputs were received from the SKAO, and their implications were considered. Attention was paid to risks, gaps and effort estimates.

A prototyping plan was submitted to the SKAO in July 2015 detailing the types of prototypes that will be constructed, the associated technical risks that will be mitigated, the approach, strategy and planning for each prototype. A technology baseline, detailing key technology choices, was formed and described in the prototyping plan. At the time of writing, prototyping activities had commenced with a view to producing documented results by mid 2016.

Furthermore, significant progress has been made with respect to TM sub-element development. Figure 1 illustrates aspects of a workflow that forms part of Observation Management. It denotes actors that are involved in transforming a scientific proposal through a series of workflow stages into a set of scheduling blocks (SBs) for execution. Executed SBs result in control directives being forwarded to the Telescope Management sub-element for processing.

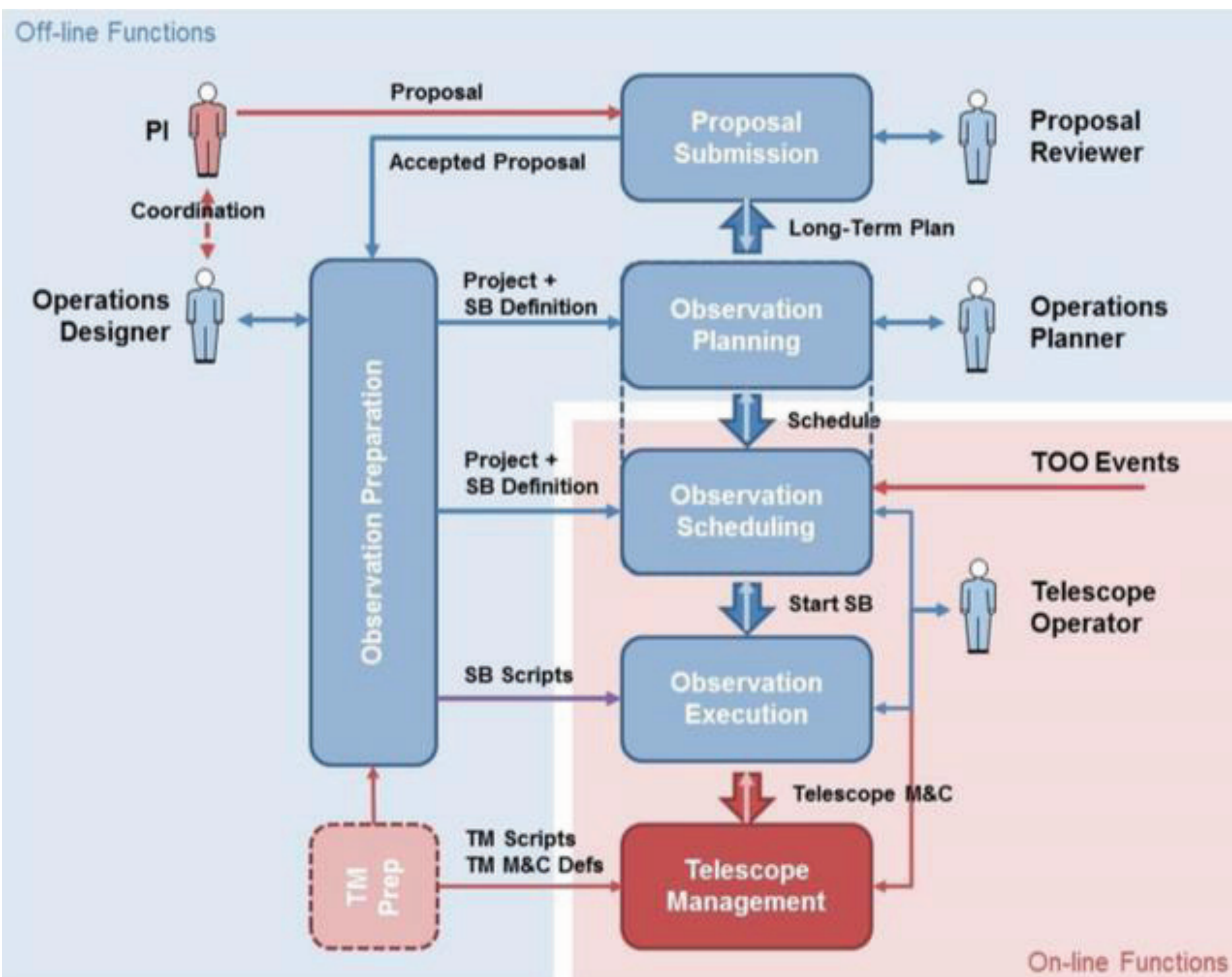

Figure 1: Observation Management High Level Functions [4].

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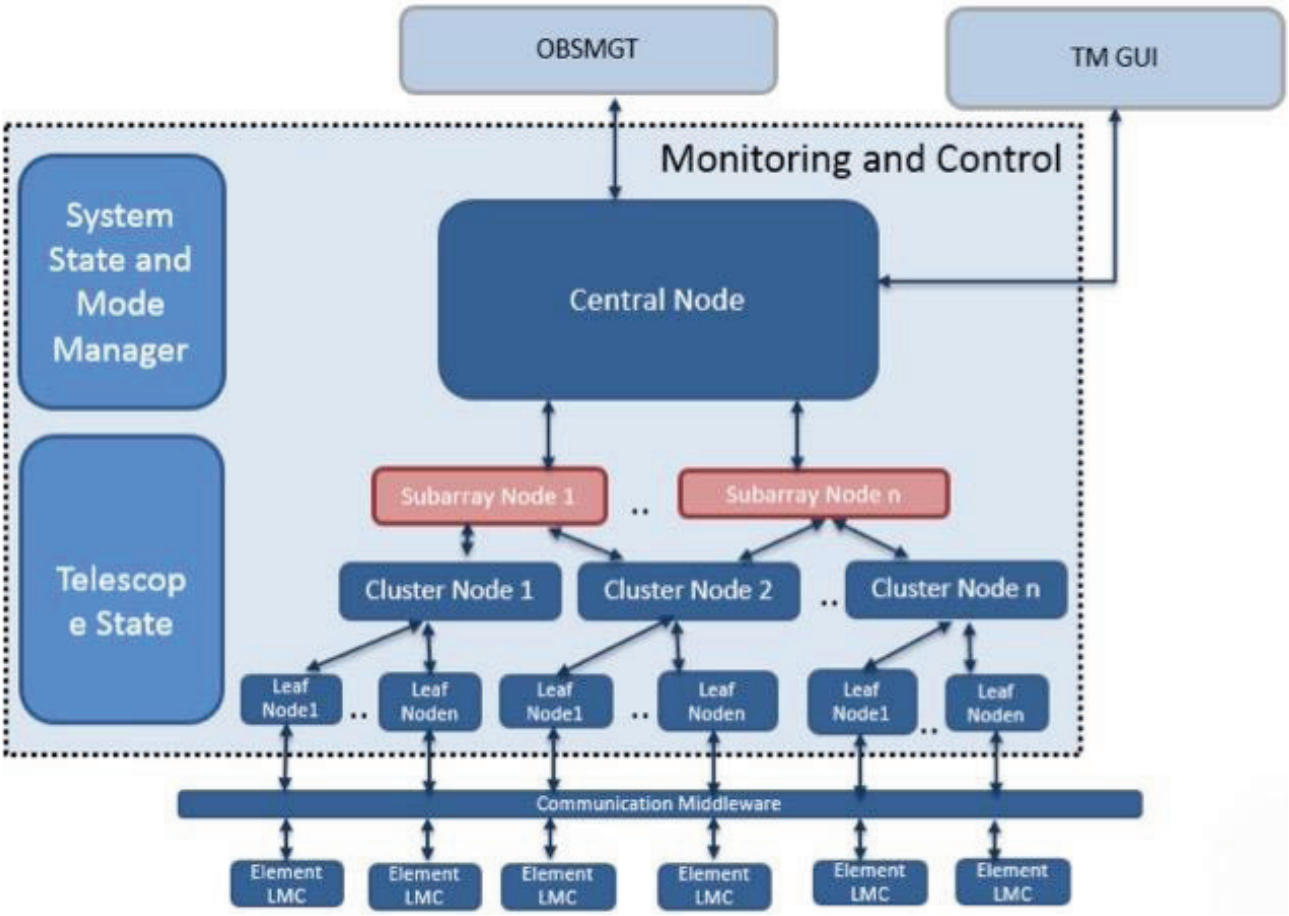

Figure 2: Monitoring & Control Interactions with Elements and Sub-elements [5].

Figure 2 depicts a hierarchy of control nodes, which form part of Telescope Management, responsible for gathering data from all Elements to obtain a real-time view of the state, health status and performance parameters of each Element, and the system as a whole. The control hierarchy enables execution of astronomical observations by configuring and controlling all Elements through commands. Interactions with other Elements are channelled via *leaf nodes* and Element LMCs.

CONCLUSION

The SKA Telescope Manager is an integral part of the SKA Observatory responsible for observation, telescope and data management functions. Significant progress has been made in developing the TM since project inception roughly two years ago. At the time of writing, a requirements and design baseline had however not yet been formed, and a schedule risk was beginning to manifest itself. Dependencies on higher-level artefacts and their level of maturity were contributing to the schedule risk. In order to mitigate the risks, the TM Consortium has adopted a strategy of making assumptions and continuing with the development activities. The next six to nine months would prove critical for the SKA1 TM project, as the assumptions would either be confirmed or shown to be false.

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