ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-THCPL04

SKA SYNCHRONIZATION AND TIMING LOCAL MONITOR CONTROL - SOFTWARE DESIGN APPROACH

R. Warange*, National Centre for Radio Astrophysics - Tata Institute of Fundamental Research (NCRA-TIFR), Pune University Campus, Ganeshkhind, Pune 411007, India
R. Braddock, Jodrell Bank Centre for Astrophysics, Alan Turing Building, School of Physics & Astronomy, The University of Manchester, Oxford Road, Manchester M13 9PL, UK

Abstract

The Square Kilometre Array (SKA) is a global project that aims to build a large radio telescope in Australia and South Africa with around 100 organizations in 20 countries engaged in its detailed design. The Signal and Data Transport (SaDT) consortium, includes the software and hardware necessary for the transmission of data and information between elements of SKA, and the Synchronization and Timing (SAT) system provides frequency and clock signals. The SAT local monitoring and control system (SAT.LMC) monitors and controls the SAT system. SAT.LMC has its team members distributed across India, South Africa and UK. This paper discusses the systems engineering methods adopted by SAT.LMC on interface design with work packages owned by different organizations, configuration control of design artefacts, and quality control through intermediate releases, design assumptions and risk management. The paper also discusses the internal SAT.LMC team communication model, cross culture sensitivity and leadership principles adopted to keep the project on track and deliver quality design products whilst staying flexible to the changes in the overall SKA program.

SOFTWARE DESIGN

Methodology

The SAT.LMC software architecture [1] and design process is kept simple and informal within the SAT.LMC team with focus on timelines and the quality of design artefacts produced. The design process is incremental with design artefacts released as products by SAT.LMC to the SaDT consortium [2] in the form of 'pack releases' (Fig. 1).

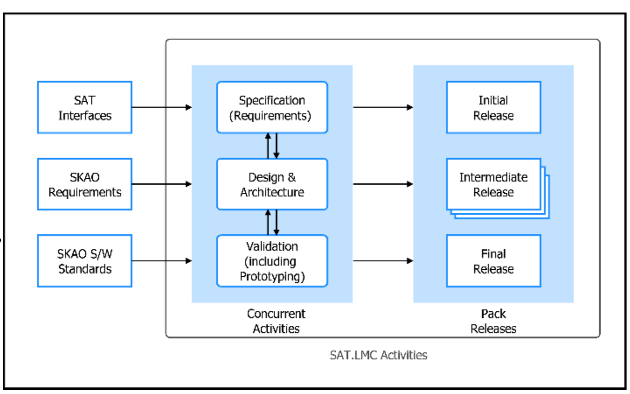

Figure 1: SAT.LMC Incremental Design Methodology.

These pack releases are checked for quality and consistency before releasing. The primary motivation for having pack releases is to enable the SaDT consortium to share consistent SAT.LMC design information with other stakeholders in the project. The pack releases also enable the SaDT management and the SaDT systems engineers to be kept up to date with the work package progress and provides a platform upon which comments, questions and critiques are presented allowing SAT.LMC to address them before progressing the with architectural activities.

Architecture Method

The SAT.LMC architectural artefacts are created and structured using the processes and structures recommended by The Open Group Architecture Framework (TOGAF) [3]. TOGAF provides a method, called the Architecture Design Method (ADM), for designing, planning, implementing and governing an architecture through a set of phases and iterations between phases (Fig. 2). The SAT.LMC architecture is modelled at four levels – Business, Application, Data and Technology.

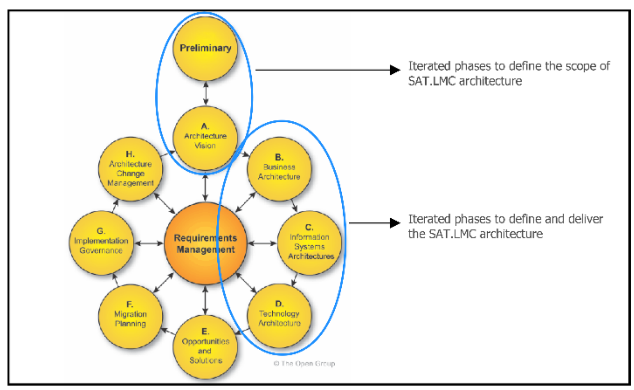

Figure 2: SAT.LMC TOGAF ADM phases and iterations.

SAT.LMC is primarily concerned with iterations involving the Preliminary phase and Phases A through to D of the ADM. The iteration between the preliminary phase and Phase A is to refine the scope of the architecture with changing requirements. The iterations from phase B through to phase D is used to architect and refine the SAT.LMC solution across the dimensions of business, application, data and technology. Phases E onwards are concerned with the implementation and the management of the SAT.LMC architecture, hence are not used.

* rajesh.warange@gmail.com

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TOGAF 9.1 encourages the use of ISO/IEC 42010:2007 [4] for describing the software architecture. (ISO/IEC/IEEE 42010 is an international standard for software architecture description).

The architectural views and viewpoints created by SAT.LMC are based on the principles of practicality and fitness-for-purpose. There are approximately 22 diagrams, 6 interface documents and 12 matrices/catalogues that are created across the four ADM architecture phases towards the SAT.LMC architecture.

Prototype

SAT.LMC prototyping activity [5] was carried out for a period of one year and was performed in phases (Table 1).

Table 1: SAT.LMC Test Phases, Types and Descriptions

Test Phase	Type	Test Description
Unit Functional Tests	In-house	Verify if monitor, control, logging, events, warnings and alarms.
System Test	In-house	Verify if all the functions of SAT.LMC work together as a system.
SAT Interface Tests	In-house	Verify if the SAT.LMC solution works with SAT simulators.
SAT Interface Tests	Field	Verify if the SAT.LMC solution work with representative SAT physical equipment belonging to the three SAT subsystems.
TM Interface Tests	In-house	Verify if the SAT.LMC solution works when connected with a TM simulator
Performance Tests	In-house	Verify if the SAT.LMC solution meets the alarm latency requirements of SKA.
Containerization Tests	In-house	Verify if SAT.LMC solution works with the containerization framework.
Containerization Performance Tests	In-house	Verify if the SAT.LMC solution performs as expected with containers.

It did greatly help SAT.LMC to have the interface tests performed in-house with simulators before initiating the field tests. The in-house tests were carried out by the SAT.LMC collaborating institutes. The field tests for testing the SAT.LMC interfaces with SAT subsystems were carried out in collaboration with the institutes leading the respective SAT subsystem work packages. The result of all the tests were positive.

Interfaces

Interfaces between SAT.LMC and SAT subsystems are recorded as specifications within a spreadsheet. Each row within the spreadsheet is a functional interface with approximately thirty specifications recorded across columns. These specifications include communication protocols, average data rate for the interface, periodicity of data exchange, mechanism (push/pull), TANGO attributes etc. There are six internal interface documents (IICDs), 3 for each telescope, led and created by SAT.LMC in collaboration with the SAT subsystem teams. SAT.LMC contributes to two Non-Science Data Network (NSDN) IICDs. NSDN provides the network infrastructure for SAT.LMC. Wherever required, the SaDT management and the SaDT system engineering are involved in the IICD discussions.

SAT.LMC contributes to the external interface document (EICD) led by the Telescope Manager (TM) consortium. The interfaces between SAT.LMC and TM are streamlined due to the control system harmonization efforts with respect to the control system design patterns and technologies between the element LMCs, TM and SKAO. SAT.LMC contributes to the EICD led by the INFRA element who help in providing the required rack space to hold the SAT.LMC server.

Changes to interface documents led by SAT.LMC are governed via an engineering change proposal (ECP) process led by the SaDT systems engineering team where the change is recorded, impact assessed and the change approved/disapproved based on the value proposition, costs and impact.

Assumptions

In the design process, several assumptions are made, especially in the early stages of the project, to help progress the design solution where key pieces of information aren't present. These assumptions are scanned periodically and status updated. These assumptions are further added to the Master Data Assumptions List (MDAL) used to manage the assumptions across all SaDT consortium work packages.

Extensibility and Flexibility

The external influences that affect the SAT.LMC deliverables are changes in the top-level SKAO requirements, SKAO control system policies and SAT system changes.

Changes to the top level SKAO requirements and SKAO control system policies have a direct impact on the fundamental SAT.LMC architecture. The changes caused by modifications to the SAT system are managed by keeping the architecture documentation at an abstraction that does not contain SAT system specifics. This way the changes to the SAT system are localized to the IICDs.

Project Management

The project management of SAT.LMC is kept light with the use of a spreadsheet to list and track tasks across timelines. Micromanagement is avoided. The ownership of tasks is based on artefacts. Percentage completion of artefacts is communicated regularly to the SaDT man-

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agement. Dependencies across artefacts are discussed, recorded and dealt with every week rather than tracked via a tool.

A risk register, enumerating the risks, their impact on costs and schedule, and mitigation strategies is maintained and brought up for discussions periodically with the SaDT management. These risks are then propagated up to the Risk Registers of the SaDT Consortium and the overall project as appropriate. The SaDT systems engineer is kept informed of all of SAT.LMC issues and concerns regarding artefact generation.

TOOLS

In the 4 years that the SAT.LMC team has worked together, the entire team has met face to face twice (once in Trieste, Italy, and once in Stellenbosch, SA), while the Indian and UK teams have met each other face to face three more times. The SAT.LMC team effectiveness in working towards the SAT.LMC monitor and control solution has been greatly helped by the use of a number of online co-working and communication tools (Fig. 3).

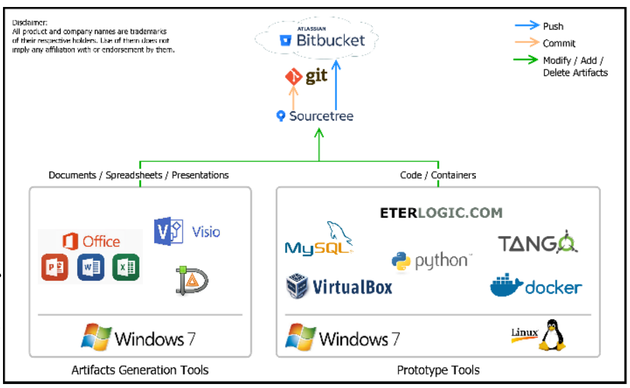

Figure 3: SAT.LMC Design Tools.

Artefacts consisting of documents, spreadsheets and presentations are created using Microsoft Office [6] tools. Microsoft Office is primarily used to facilitate exchange of artefacts across different research organizations. Diagramming is done using a free tool Dia [7] and a few of them using Microsoft Visio. Approximately 50 to 70 diagrams are created using the tool.

Python [8], the TANGO Control System Framework [9], MySQL [10], and the Docker Containerization Platform [11] are part of the SAT.LMC solution and are used for verification purposes. Eterlogic Virtual Serial Ports Emulator (VSPE) [12], a freeware, is used extensively for in-house prototype verifications between TANGO Device Servers which interface with an Ethernet port and SAT simulators that interface with serial ports. In the initial period of prototyping, TANGO running on an Ubuntu Linux [13] virtual machine was used. The Ubuntu Virtual Machine was run using Oracle VirtualBox [14] on Microsoft Windows 7. The SAT.LMC solution was later verified on Ubuntu and Scientific Linux.

Until Preliminary Design Review (PDR), Google Drive [15] was used to hold all SAT.LMC artefacts, but SAT.LMC moved to Git [16] and Bitbucket [17] as a repository to facilitate passing labels to all artefacts that are part of a release. Git, a free and open source version control system, was used for storing all SAT.LMC artefacts. Git was used as a repository for holding all the deliverable artefacts. It was also used for holding and sharing code developed during prototyping. Git is a local repository that sits with every individual. To enable having a consistent repository, commits made to Git were pushed to Bitbucket, a free (for 5 users) cloud based storage for Git repositories provided by Atlassian. Atlassian Sourcetree [18], a client for Git was used to commit items to the local repository and also push changes to the cloud repository. All team members would then sync their repositories by doing a ‘pull’ from Bitbucket and thus updating their local Git repositories.

Skype [19], as a communication tool has been key to the SAT.LMC collaboration, especially in the early days of the project. The features that helped the most were the consistent audio quality, and the ability to share computer screens. As the SAT.LMC team grew, Skype became a less viable means of communication due to its many incompatibilities with UNIX based systems which prevented sharing screens. Zoom [20] became preferable because it was accessible across the most popular operating system platforms (SAT.LMC successfully used Zoom with Microsoft Windows, Ubuntu Linux and OS X) (Fig. 4).

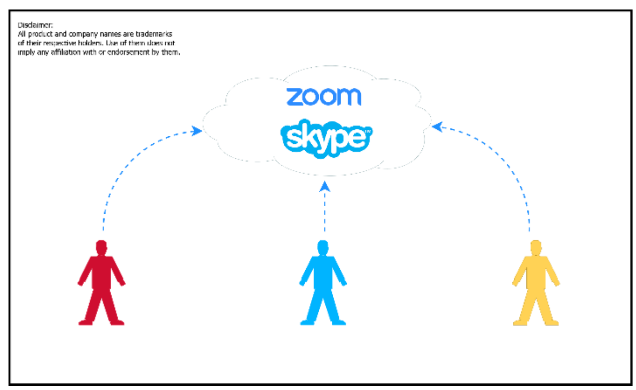

Figure 4: SAT.LMC Communication Tools.

Except for the Microsoft tools (Windows OS, Office and Visio), all the tools used were free (some with limited features).

TEAM

The SAT.LMC team is a collaboration between 3 countries and 4 research institutes (Fig. 5).

- National Centre for Radio Astrophysics – Tata Institute of Fundamental Research (NCRA-TIFR) / Giant Metrewave Radio Telescope (GMRT) [21], Pune, India
- Jodrell Bank Centre for Astrophysics, Jodrell Bank Observatory, School of Physics & Astronomy, The University of Manchester (UMAN), United Kingdom

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- South African National Research Network (SANReN), Pretoria, South Africa, and
- Science and Technology Facilities Council (STFC), Daresbury Lab, United Kingdom.

The collaboration is led and managed by NCRA with NCRA and UMAN contributing 1 full time equivalent (FTE) each with SANReN and STFC contributing for 0.5 FTE each (The FTE from STFC is based on a limited fixed term contract).

Figure 5: SAT.LMC collaboration.

SAT.LMC leadership evolved over time from a relatively flat hierarchy to a devolved responsibility arrangement. Each team member has distinct ownership of artefacts based on skills, with participation from the rest of the team with respect to reviews. This evolution is in part due to the geographical distribution of the team coupled with the individual team member key skills.

Commitment to quality work and respect towards the time for other team members played an important role in starting the collaboration and having an effective dialogue in a geographically separated setup. These professional values and ethics led to keeping the inter-team communications informal using Skype, further flourishing the collaboration. On an average 4 to 5 hours per week are spent talking with team members, sometimes working together on artefacts using screen sharing technology. This method, along with taking work forward over the last four years, helps the team understand and appreciate cross cultural sensitivity issues. Individual team member interests are understood and appreciated and a singular stance, as a team, is taken while collaborating with other institutes.

The vast majority of collaboration occurs between two time zones, British Summer Time (BST) and Indian Standard Time (IST). Over the years, it has proven to be the most effective use of time to collaborate via Skype/Zoom calling for up to half a day, during AM BST, and PM IST. This allows colleagues in India to work independently, or on other projects during their morning and colleagues in UK have their afternoon to work independently.

In terms of the group development model proposed by Bruce Tuckman in 1965 [22], the time taken to transition from 'forming' to 'performing' phase took around 6 months. There was no 'storming' phase involved which could be attributed to the professional work ethics of the team. SAT.LMC did submit its PDR deliverables within 9 months of forming the team consisting of approximately 15 to 20 artefacts and are currently working towards submitting the critical design review (CDR) deliverables.

CONCLUSION

In conclusion it has been our experience that this way of working lends itself well to small teams of globally distributed collaborators. This approach is not as structured as the Agile Framework methods. It has however evolved over the 4 years in which the team has been collaborating.

It is felt that the approach discussed herein was successful in large by the like mindedness of the team members and common ground shared, both from personal and professional points of view.

Computerised tools and features have made multinational, cross time-zone collaborations much more accessible than in times past. However there are fundamental pinch points, such as time-zones, which can only be overcome by team member's character and motivation by all parties. In the case presented here, this has been successful.

ACKNOWLEDGEMENT

The authors would like to acknowledge the help of the SAT.LMC team members, the system engineer for SaDT and the management of all the collaborating institutes for their cooperation and assistance. This work is being carried out for the SKA SaDT consortium as part of the SKA project. Fourteen institutions from eight countries are involved in the SaDT consortium, led by the University of Manchester. The SKA project is an international effort to build the world's largest radio telescope, led by the SKA Organisation with the support of 10 member countries.

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