

Scientific Operation of the Large Millimeter Telescope

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ABSTRACT

The Large Millimeter Telescope Alfonso Serrano (LMT) is a 50-m diameter single-dish radio-telescope designed, constructed, and optimized to conduct scientific observations and to enable its user communities to analyze their science products. This paper describes the goals and objectives of the LMT’s science operation program and provides an overview of the life cycle of its science projects, including: (1) organization and activities of the user support staff; (2) review of scientific proposals; (3) operation of the telescope as a queue-scheduled, service observing facility; (4) pipeline reduction and data quality checks; and (5) initiation and maintenance of a scientific archive.

Keywords: science operations, user support, proposal handling and review, service observing, data reduction pipeline and QA, Large Millimeter Telescope

1. INTRODUCTION

The Large Millimeter Telescope Alfonso Serrano is a 50-m diameter single-dish radio-telescope designed, constructed, and optimized to conduct scientific observations and to enable LMT’s user communities to access the telescope and analyze its science data products [1]. Although the Observatory supports two distinct user communities in Mexico and in the US, both user communities are supported by a single integrated science operation plan that is designed to provide an efficient and uniform scientific support and data products to all user communities.

Science Operations Stages vis-à-vis Data Flow and Personnel

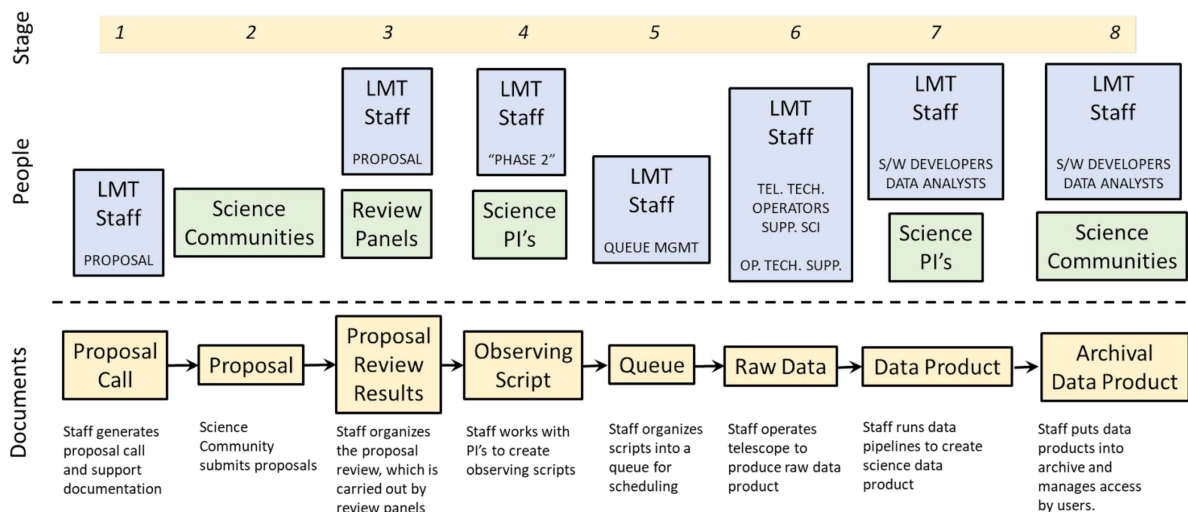


Figure 1. Life cycle of an LMT science project. Yellow boxes identify the tasks at each stage while the blue and green boxes identify the project and community members engaged at each stage.

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The LMT Collaboration seeks to establish the Large Millimeter Telescope as a world-class astronomical facility with high scientific impact. We are committed to providing our scientific user-communities with access to astronomical observations using world-class instrumentation that delivers high-quality science data products. The bi-national nature of the LMT collaboration offers unique challenges and requirements, and the LMT science operation plan reflects solutions designed to address them effectively and efficiently. This paper describes the science operation of the telescope and the support of its scientific users, following the flow a science project from the proposal call to the preparation of the fully reduced science-ready data products in the Science Data Archive, as summarized in Figure 1.

2. LMT HELPDESK AND PROFESSIONAL OUTREACH

The LMT Community Support Scientists (CSS) are the main science operations staff in a direct contact with the LMT user communities in the US and Mexico. A major CSS function is providing information to the user communities through the [LMT Helpdesk portal](#) as a direct point of contact, for addressing specific questions/requests, and for providing the knowledgebase on a wide range of topics (FAQs). The LMT Helpdesk operates using a help request ticketing system, which is used to facilitate and track questions and requests from the user communities to the technical and management teams (see Figure 2). The LMT Helpdesk team also maintains contact with the user communities by sending out information emails as well as organizing webinars/tutorials and hosting documents and recordings at the Helpdesk website. The CSS team also spearheads professional outreach activities such as hosting the LMT booth at professional meetings.

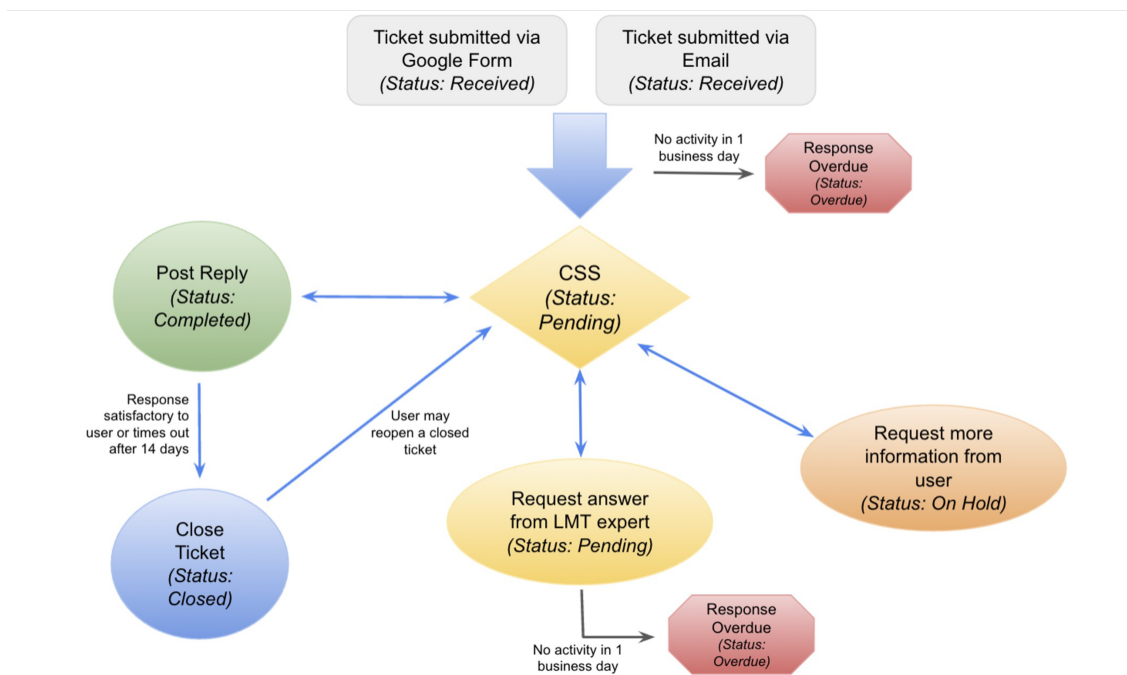


Figure 2. Flow of a help request ticket

Another important CSS role is a direct support of many aspects of the LMT scientific user functions, including proposal reviews, observing script generation (“Phase 2”), and science data QA processing and delivery. The CSS team reviews and maintains the [official LMT website](#) and the [Hedwig proposal portal](#) to ensure all appropriate science support documents (including the Call for Proposals and [Proposal Checklist](#)) are available and up-to-date. The CSS team also serves as the liaison between the successful PI teams and the telescope queue manager to help preparing the Phase 2

Hedwig proposal handling system was originally developed for JCMT by the East Asia Observatory (<https://proposals.eaobservatory.org/help/about>)

forms and the observing script generation. The CSS team runs the data QA checks for each set of science observations executed successfully at the telescope and runs them through the data reduction pipelines. All science data passing the QA check is transferred to the LMT Science Data Archive for delivery to PI teams. The CSS team also tracks the project completeness and sends the QA summary reports to each PI team as the projects reach their key project milestones.

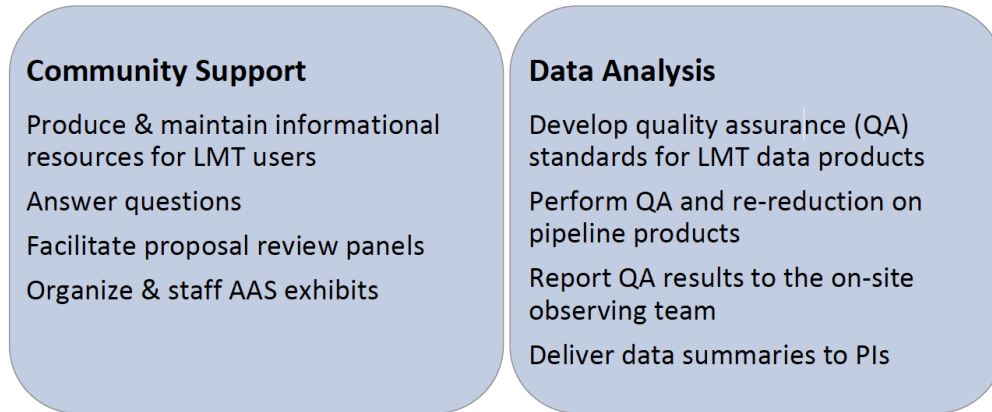


Figure 3. Summary of LMT Helpdesk user support functions

3. PROPOSAL HANDLING AND REVIEW

Nominally, there is one proposal call issued annually to cover the observing period from September through August of the following year, although the period covered has been modified for different reasons during the past 3 seasons. Proposal calls are announced by email to the LMT user distribution list and through other common astronomy forums. The proposal submission process is identical for all members of the eligible scientific communities.

The [Hedwig proposal handling system](#) hosts the proposal submission tool as well as much of the technical information, including the sensitivity calculators for all heterodyne instruments. The TolTEC instrument with its distinct observing modes has its own Observing Planner for sensitivity and mapping speed calculations.

The proposal review process is also identical for all member communities to ensure the best overall scientific excellence and operational efficiency and follows the flow outlined in Figure 4. The LMT's primary goal is to optimize the scientific impact, and proposal prioritization follows the scientific merit evaluated by external written "mail-in" reviews and the scientific expert panel reviews, utilizing the initial technical reviews by the observatory staff. Both proposal writing and review processes are required to follow the now commonly adopted [dual-anonymous guidelines](#) to achieve transparency and inclusion. The standard conflict of interest rules are also adopted, with one exception of easing the institutional conflicts by necessity. The science panel review is organized by three broad areas: Milky Way, Nearby Universe, and Distant Universe. The membership of the science review panels (typically 6-8 members each) broadly reflects the fractional time of the partner communities. A consensus review panel report is produced for each proposal by the primary and secondary reviewers, synthesizing the panel discussions and the "mail-in" written reviews (typically 2 per proposal).

Following the scientific review panel meetings, ranked lists of proposals are examined and adjusted by each user community reviews to reflect the programmatic priorities within each user community, such as promoting student thesis projects. The final telescope time allocation is done using the revised ranked lists by the International Time Allocation Committee (ITAC), which has the authority to resolve any potential source conflicts. Efforts are made to ensure that each partner community has access to its fair share of times in different weather conditions and LST ranges. *The final product of the proposal review is the prioritized list of observing queues for each partner community, which will be used by the observing queue manager during the observing season. The final scheduling priority and the panel summary are sent to each PI, and the final review summary results are posted on the Observatory website.*

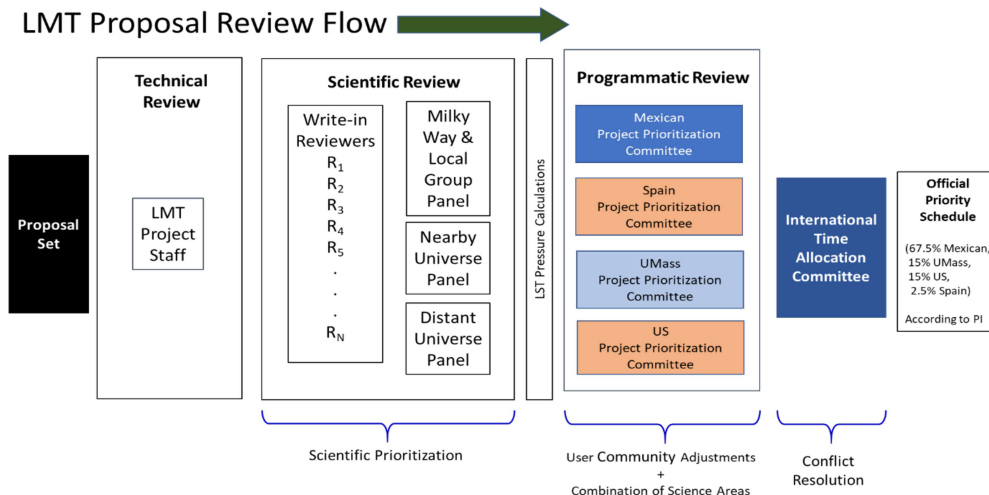


Figure 4. A sequential flow chart for LMT proposals and reviews.

4. SERVICE OBSERVING & QUEUE MANAGEMENT

All scientific observations at LMT are conducted in the service observing mode using a prioritized scheduling queue by trained professional observers. This operational choice is made primarily for safety and observing efficiency, given the complexity of the telescope operations at high altitude (15,000 feet or 4,600 meter) and to maximize flexibility to changes in the observing conditions and instrument availability. Each nighttime observing team at the telescope consists of two trained observers assisted by two site crew members, and they are also supported remotely by a team of experts (see Figure 5).

All modern telescopes have implemented a form of “queue scheduling” wherein projects are scheduled according to scientific priority during the weather conditions that are necessary to achieve the required sensitivity of the project. The LMT is implementing such a program in order to use the telescope time most efficiently. The queue manager in charge generates a nightly observing plan by tracking the scientific priority of top projects in each partner queue and the cumulative time allocations. Available LST range and weather conditions are also important input into the scheduling, and some flexibility is built into the observing schedule to allow real-time adjustments by the observing team. Priority is given to any projects that are already underway so that such a project already in progress can reach its completion first.

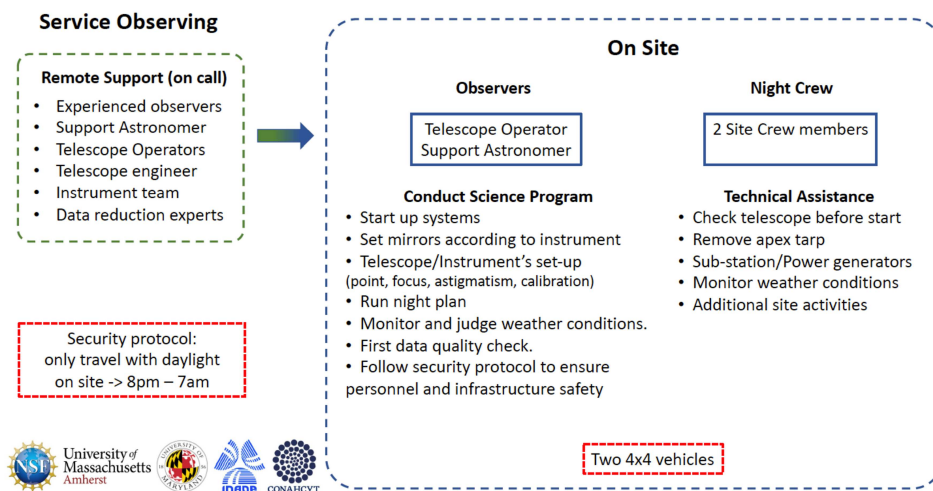


Figure 5. Organizational structure of the LMT service observing.

All observing scripts must be in place before any service observing can begin, and the CSS team works with each approved proposal team to accomplish this by collecting completed Phase 2 forms that describe all telescope/instrument parameters or by collecting the observing script generated by the TolTEC Observation Planner (Figure 6). All completed observing scripts are stored in a common directory in the telescope monitor and control computer.

Nightly shift logs are generated automatically at the end of each observing session, and they are sent out by email to the queue manager (to update the project tracking database) and the CSS team (to trigger the QA process of the pipeline reduced data, as described below). The CSS team updates the project tracking database if their QA process identifies any full or partial failure of observations.

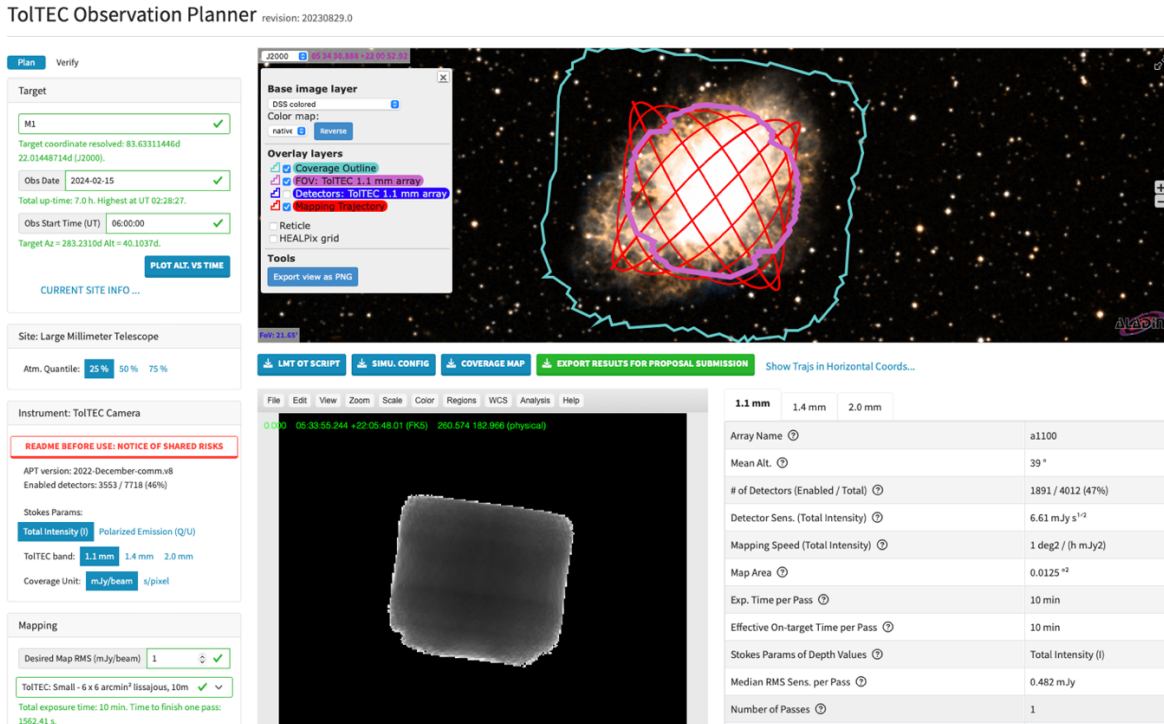


Figure 6. A screen shot of the TolTEC Observation Planner, which is a web based observing planning tool. Users can explore different scanning parameters to optimize sensitivity and coverage, and it can generate a configuration file (for technical review) as well as an LMT observing script. Adopting this framework for all other LMT instruments is currently under consideration.

5. DATA REDUCTION PIPELINES AND QA PROCESS

Computing resources are available at the telescope to conduct a quick-look, automatic pipeline reduction of all data, sufficient to assess data quality in real time. Decisions on observing queues are taken by the on-site observers based on these quick-look “timely analysis products” (TAPs). Both the TAPs and raw data files are immediately transferred via internet to the backup server located at the Basecamp and then to the data storage facility at UMass for full reduction.

The full data reduction pipelines for all LMT instruments are run on the Unity high performance computing facility at UMass immediately following each observing session. The CSS team then runs its QA processing on the full pipeline TAPs (Level 1 data products) and re-runs the pipeline after editing data and pipeline script parameters, as necessary. The pipeline reduction script generator is maintained on GitHub, and the pipeline scripts with full parameters and data flagging information are preserved along with the pipeline version and QA comments in a GitHub depot. Assigning a

numerical QA grade to each dataset and transferring the reduction scripts, logs, and science ready data products (SRDPs) to the LMT Science Data Archive as Level 2 data products completes the QA processing by the CSS team.

First successful observation of a new program triggers an email by the CSS team to the PI team, notifying the start of their project and an invitation to examine the TAPs and to consult their assigned support scientist. Each PI is provided with a web link to their own project TAPs summary and a login credential. The QA comments are added to the TAPs summary as the CSS team proceeds with the QA processing of subsequent new data sets, and the CSS team issues interim and final QA reports to the PI team at different stages of their observing program.

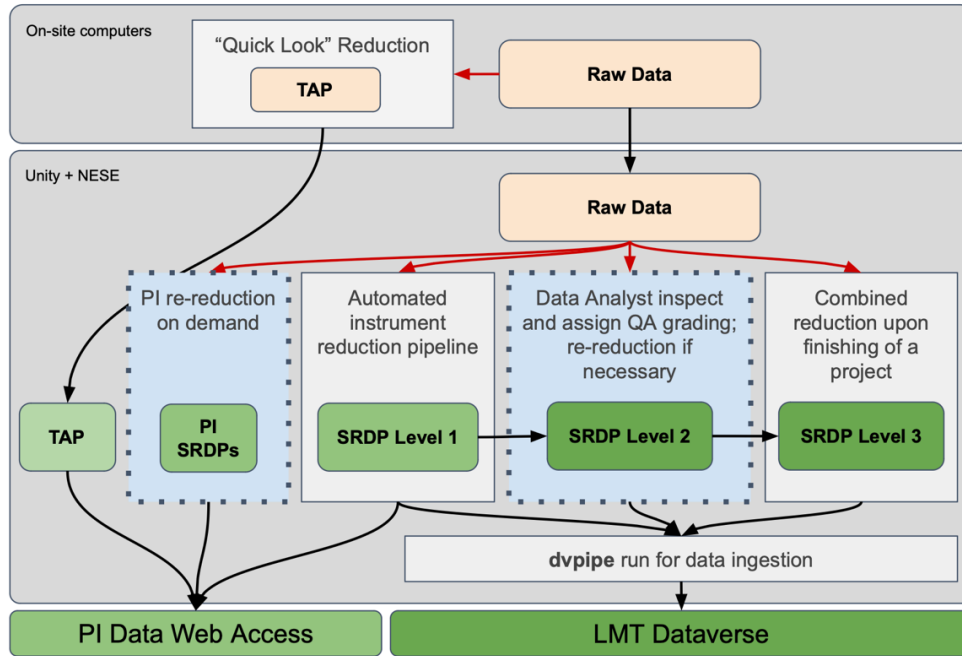


Figure 7. LMT data reduction, QA process, and data in-take workflow (see Z. Ma poster paper)

6. LMT SCIENCE DATA ARCHIVE

A schematic summary of the LMT data reduction, QA process, and data intake into the LMT Dataverse is shown in Figure 7, and a full description of this process is presented by Zhiyuan Ma in a separate poster paper at this conference. Readers are invited to view this poster and the accompanying paper for further details.

To offer a summary, the default pipeline processed data products (Level 1 SRDP) and the QA processed data products with QA grades (Level 2 SRDP) are ingested into the LMT Science Data Archive, which utilizes the LMT Dataverse framework. New PI program data have a proprietary period (typically 12 months after completing the QA review), and only PI team members with a login credential are allowed to access the data using a separate portal. A web-based tool that can generate and run a revised pipeline reduction script is also currently under development, and this should serve as a way for PI teams to produce their own custom reductions using the Unity high performance computing facility. All public data including archival PI data from previous seasons should be accessible through the LMT Dataverse interface.

ACKNOWLEDGEMENTS

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