



Title: Computing and Software System Design Description: PMN	Owner: Costa	Date: 2025-10-03
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Status: **RELEASED**

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Change Record

Version	Date	Author	Affected Section(s)	Reason
I	2025-08-11	A. Costa	All	Initial draft
A	2025-08-13	M. Archuleta	All	Minor edits and formatting for pdf and release.
B	2025-10-03	A. Costa	4.4 5 7.7	Actions from CoDR: Added 4.4 and Fig.4 (RID 463, 469) Clarified 6 (RID 471) Selected needs Sections 7.7 (RID 472) Trigger event



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I Introduction

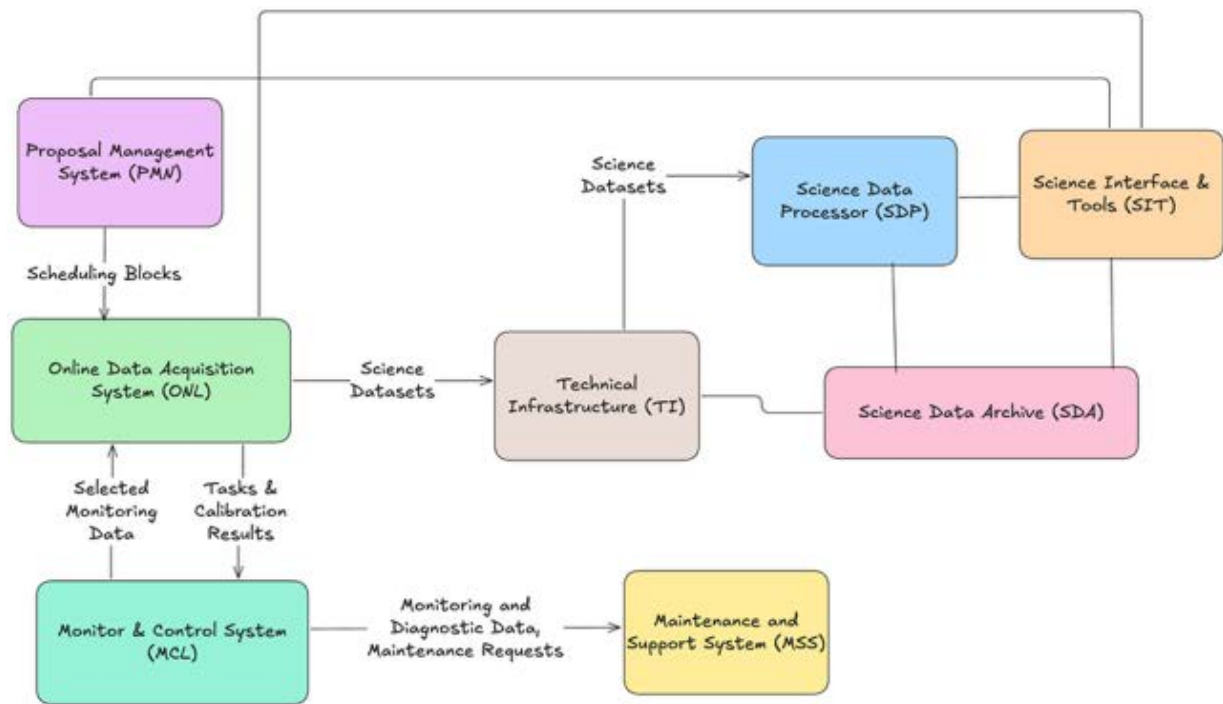


Figure 1 - General overview of the ngVLA Computing and Software System (CSS).

This document describes the ngVLA Proposal Management System (PMN) conceptual design and plan for evolving the design to the Preliminary Design Review (PDR). This system is part of the ngVLA Computing and Software System (CSS).

2 Related Documents and Drawings

Ref. No.	Document Title	Rev/Doc. No.
RD01	CSS Stakeholder Needs - PMN	020.50.00.00.01-0007 REQ
RD02	Telescope Time Allocation Tools Conceptual Architecture	
RD03	TTA Tools Gap Analysis	
RD04	Telescope Time Allocation: System Description	688-TTAT-004-MGMT
RD05	ngVLA Observation Preparation Concept	020.10.05.05.00-0010-PLA
RD06	Computing and Software System: Use Cases	020.10.05.00.00-0022 PLA
RD07	Concepts for ngVLA Spectral Windows	020.10.50.00.00-0007 MEM
RD08	Conceptual Narrative Time Domain	020.10.05.05.00-0016 PLA
RD09	ngVLA Proposal Process Concept	020.10.05.05.00-0011 PLA



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3 System Overview

PMN facilitates the submission of proposals, which express a request or intent for observatory resources, and project assembly, which contain the information needed for the execution of allocated resources. For both proposals and projects, PMN is a centralized entry point for the needs of the scientific community and observatory staff. This centralization ensures consistency in reporting (e.g., facility usage metrics), regulates procedures in and products of resource allocation, and systematizes the collection of metadata¹ and data. These metadata and data are essential for the Online Data Acquisition (ONL) and for further downstream systems such as the Science Data Processor (SDP) and the Science Data Archive (SDA).

3.1 Users and Roles

The users of PMN include both scientific researchers and observatory staff. For the scientific community, this lifecycle begins with a Call for Proposals. Researchers submit proposals in response to the call, which then typically undergo review to determine which requests are to be allocated. Both researchers and observatory staff may function as reviewers in these processes. Projects are created from proposals that are allocated observing and/or computing resources. While researchers may assemble projects, the Project Data Model (PDM) can be populated by the system.

In addition to supporting the scientific community, PMN also facilitates internal observatory operations such as facility testing, service observations, and commissioning activities. The roles of observatory staff vary. For example, staff scientists coordinate the Call for Proposals and manage the review process, while staff scientists and data analysts conduct technical, feasibility, and scheduling reviews. During project preparation, observatory staff (e.g., Scheduling Support Scientists, Validators, Approvers, Developer Observers, Data Analysts) can prepare projects, validate and approve projects, develop new observing modes, and support commissioning activities.

4 Conceptual Design

The functionality required of PMN [RD01] is delegated to two main components: one that supports proposal-related processes and another that supports the project lifecycle. The proposal functionality will be facilitated by the Telescope Time Allocation (TTA) Tools, which is an independent software suite under development by the NRAO to support proposal-related processes for observatory's North American facilities. The TTA Tools are designed around key quality attributes such as maintainability, configurability, sustainability, performance, and usability [Section 1.1.3.1 of RD02]. For project assembly and staging, an Observation Preparation System will be developed for the ngVLA. Additionally, PMN will provide services that are shared across the components, such as time and resource calculators, data volume estimators, and visualization utilities (e.g., uv-coverage, observing simulators).

¹ Proposal data consist of submitted material such as the Proposal's title, author information, scientific and technical justifications, etc. and a disposition letter, which contains scheduling priorities and review feedback. Proposal metadata consists of source positions, observation frequencies, integration times, etc. Project data include visibility data and all resulting data products. Project metadata include the positional, frequency settings, time on source, etc.



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4.1 Telescope Time Allocation Tools

The TTA Tools are under active development at the NRAO to support the proposal process for the GBT, HSA, VLA, and VLBA, and to accommodate proposal submission for the GMVA. The C4 container diagram provided in Figure 2 shows the main elements of the TTA Tools software system.

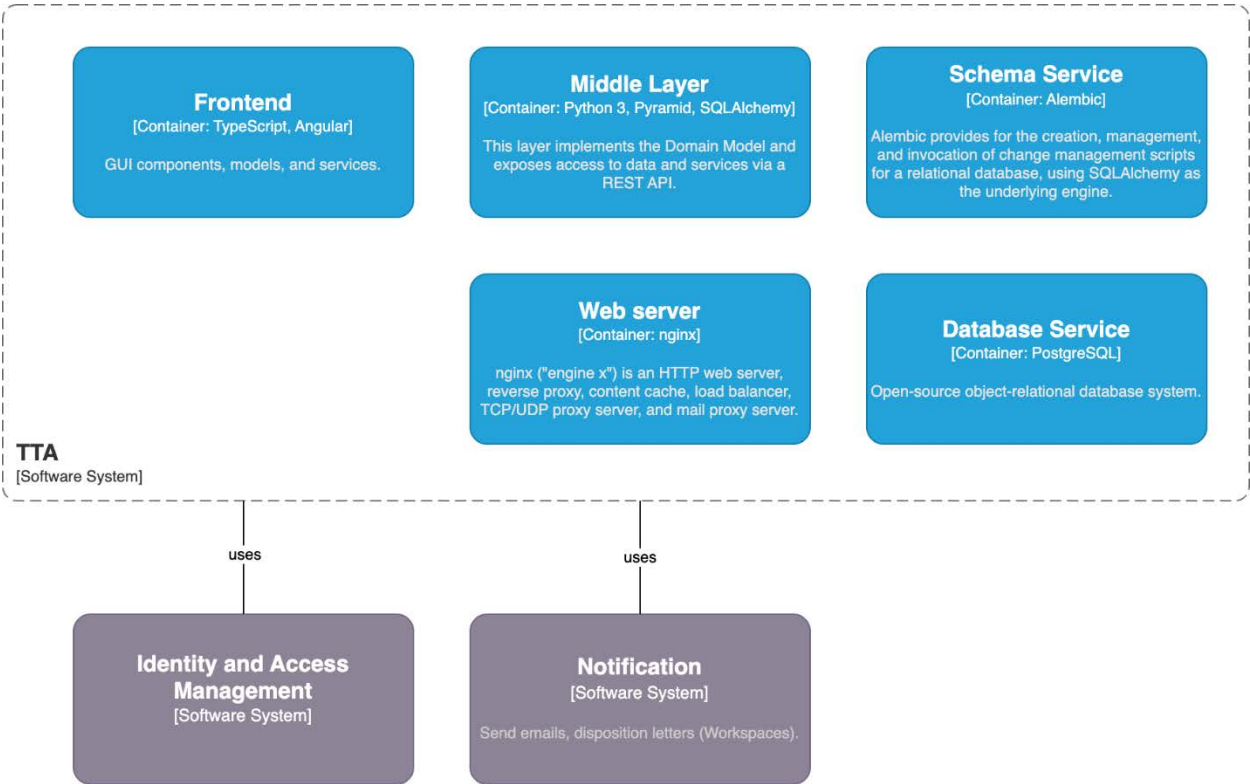


Figure 2 - TTA Tools Software System.

Architecturally, the TTA Tools software system exhibits two main features. First, the system is a client-server architecture. Second, since NRAO telescopes have their own distinct languages, models, and related systems for scheduling and executing observations, the architecture utilizes an Anti-Corruption Layer (ACL). An ACL is an approach derived from Domain-Driven Design (DDD) that creates a protective boundary insulating the TTA Tools domain model from telescope-specific domain models. This approach is intended to promote internal consistency and maintainability within the TTA Tools domain model over a long period of time. The ACL translates information in one direction from the TTA domain model to a given instrument’s domain model so that each system can operate independently according to its own domain language and structure.

The client-server and ACL architecture features provide a foundation for a suite of user-facing software capabilities. This software suite provides user interfaces for the configuration of calls, creation and submission of proposals, reviewer workflows, and reporting. The underlying processes are modular, well-defined, and have clearly scoped inputs and outputs; this design reduces risk and developer costs for future augmentation and feature development. The TTA Tools are conceptually sufficient to support



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ngVLA needs [RD03], and their design allows for functional augmentation to reflect evolving ngVLA policies and capabilities. Key capabilities that support ngVLA proposal workflows include:

- Solicitations as flexible proposal containers: A core concept within the TTA Tools is the Solicitation, which defines the capabilities of one or more facilities offered in a Call for Proposals. Solicitations can also be used to collect metadata and data for Observatory-driven activities such as commissioning, testing, or service observing. They define the review process flavor (e.g., Distributed Peer Review, Panel Peer Review) and can be instantiated concurrently to support diverse scientific and operational needs.
- Science-centric proposal creation: TTA Tools forms proposals through a scientific lens, so researchers provide science-focused information instead of facility-laden jargon to specify their requests for resources. Observatory-provided algorithms then transform this information into facility-specific data, reflecting best practices for the facility.
- Support for both novice and expert users: For expert users and nonstandard modes, the system allows direct resource specification and provides functional tools such as uv-coverage plots and exposure calculators. Coupled with the observatory-provided algorithms, this approach enables broad usability across experience levels in the astronomy community.

While the existing design of TTA Tools aligns with ngVLA's conceptual needs, several augmentations have been identified to fully support proposing concepts [RD05] and operational needs [RD01]. A selection of these, as outlined in [RD03], is provided below:

- Algorithmic selection of a reference sub-array and a prioritized list of subarrays during proposal creation
- Capture of Principle Investigator-specified ngVLA High Level Data Products (HLDP)
- Inclusion of ngVLA-standard calibration methods in algorithmic assembly of resource requests
- Algorithmic support for scheduling forecasts involving ngVLA compute and observing resources
- Implementation of new Proposal Review Processes within the TTA Tools, such as Distributed Peer Review

Though not identified in [RD03], the augmentation of the TTA Tools may also include:

- Implementation of a new Proposal Process to support Observatory Services
- Implementation of a streamlined Proposal Creation mode to support Observatory Services

4.2 Observation Preparation

The Observation Preparation System bridges the gap between the proposal system, which handles requests for resources, and the ONL system, which facilitates the execution of intents on the ngVLA. Within this component, the ngVLA PDM is assembled for downstream handling by ONL. Observation Preparation also supports validation and approval of projects prior to execution, along with tracking and status updates throughout the project lifecycle. The ngVLA PDM is a hierarchical structure with the following levels²:

² Note, not all levels of the PDM are represented here; see [RD05].



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- Project
 - Science Goal
 - Group Level Block (GLB)
 - Data Product Block (DPB)
 - Scheduling Block (SB)
 - Calibratable Scan Block (CSB)
 - Scan
 - Subscan

A dedicated service transforms proposal data into the ngVLA PDM, assembling the appropriate structure of Science Goal, Group Level Block, Data Product Block, Scheduling Block, etc. for a Project.

Scheduling Blocks define the observations to be executed by the ONL system and constitute the primary structure passed from Observation Preparation to ONL. When the transformation service assembles the Project, a Scheduling Block will generally

1. have declarations of calibration intents rather than assigned calibrators
2. have a prioritized list of subarrays rather than an assigned subarray.

When in this form, Scheduling Blocks are called “Phase I SBs” to reflect that key execution parameters are not yet fixed. This flexibility is advantageous for dynamic scheduling, as the Scheduling Block can be adjusted to meet operational demands while maintaining scientific and technical feasibility. Further selection of these parameters is triggered by the midterm scheduler, the dynamic (real-time) scheduler, or by an interactive process initiated by Observatory Staff. These Phase I SBs then progress into “Phase II SBs” as the parameters are selected. Phase II SBs differ from Phase I SBs in having:

1. All needed calibrations either determined to be provided by existing, valid Observatory provided Calibrations (OBC) or incorporated in the SB as a Scheduling Block Calibration (SBC).
2. One selected reference subarray from the prioritized list that is consistent with the needed calibrations.

While a Phase II SB is a more resolved state, its parameters may still be adjusted by the dynamic scheduler in preparation for execution. Once there is a QA_{obs} PASS Calibratable Scan Execution³ (CSE), the reference subarray used is identified as the SB’s **assigned subarray**. For many use cases, such as science-target imaging observations, subsequent executions of the SB will then be collected in that assigned subarray. Note, however, that for each execution the correspondence between the assigned subarray and the antennas actually used may not be exact, depending on antenna availability and other contingencies. The list of antennas used in a given CSE is called the **executed subarray**. Figure 3 is a conceptual diagram illustrating the narrowing relationship from all available subarrays to the executed subarray of a CSE.

³ A Calibratable Scan Execution (CSE) is the data resulting from a single Calibratable Scan Block (CSB) execution. This is the atomic unit that is evaluated by the observing QA system and given a pass or fail QA score (QA_{obs}).



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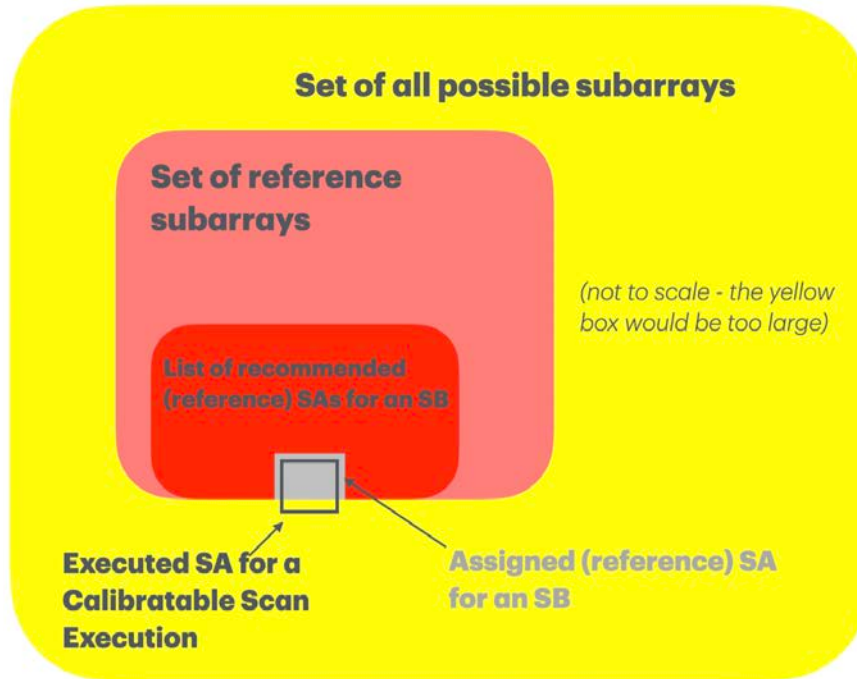


Figure 3 - Diagram showing the progressive refinement from all possible subarrays to the executed subarray.

For standard observing modes, the data from the proposal system shall be sufficient for the Observation Preparation system to automatically form Projects using the transformation service, such that users are not required to duplicate work after proposal submission. For non-standard modes, commissioning, testing, and service observing, the PDM may be only partially populated initially. Users will have access to visualization tools and functional tools for observational planning to further refine and assemble the PDM.

4.3 PMN Services

The PMN system includes a suite of services that support proposal preparation, project validation, and observatory operations. By adhering to a common service architecture, these services ensure consistency in computation and data interpretation across the full proposal-to-execution lifecycle. These services include

- Calculating time and resource estimates
- Estimating data volume
- Visualizing uv-coverage and simulating observations
- Viewing and querying source and resource catalogs
- Generating source uptime plots
- Displaying sky maps of calibrators and science targets
- Calculating antenna shadowing
- Performing coordinate conversions



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In support of operational needs, the services also enable observatory staff (e.g., Scheduling Support Scientists) to:

- Create, edit, and maintain instrument resources used during observations
- Ensure consistency of the instrument resource model with the online data acquisition system
- Create, edit, and manage records of astronomical pointings
- Enumerate astronomical coordinates across multiple frames
- Edit and maintain the observatory database of standard calibrators

Note, these services encompass both computational interfaces and interactive user tools.

4.4 Interoperability

Figure 4 illustrates the components of PMN and anticipated interactions with PMN-exterior systems, such as the ONL and Authentication services. Data flows unidirectionally from the TTA Tools component to Observation Preparation through an Anti-Corruption Layer, where Proposal data are transformed into the Project Data Model via a 'TTAT/ObsPrep transform service', as shown in the figure. The TTA Tools operates independently of the ONL; its 'schedule forecasting' function is an internal process that generates statistical projections of observing and compute schedules based on available facility time to support scheduling priority decisions. As detailed in Section 4.2, the Observation Preparation component interfaces with the ONL.



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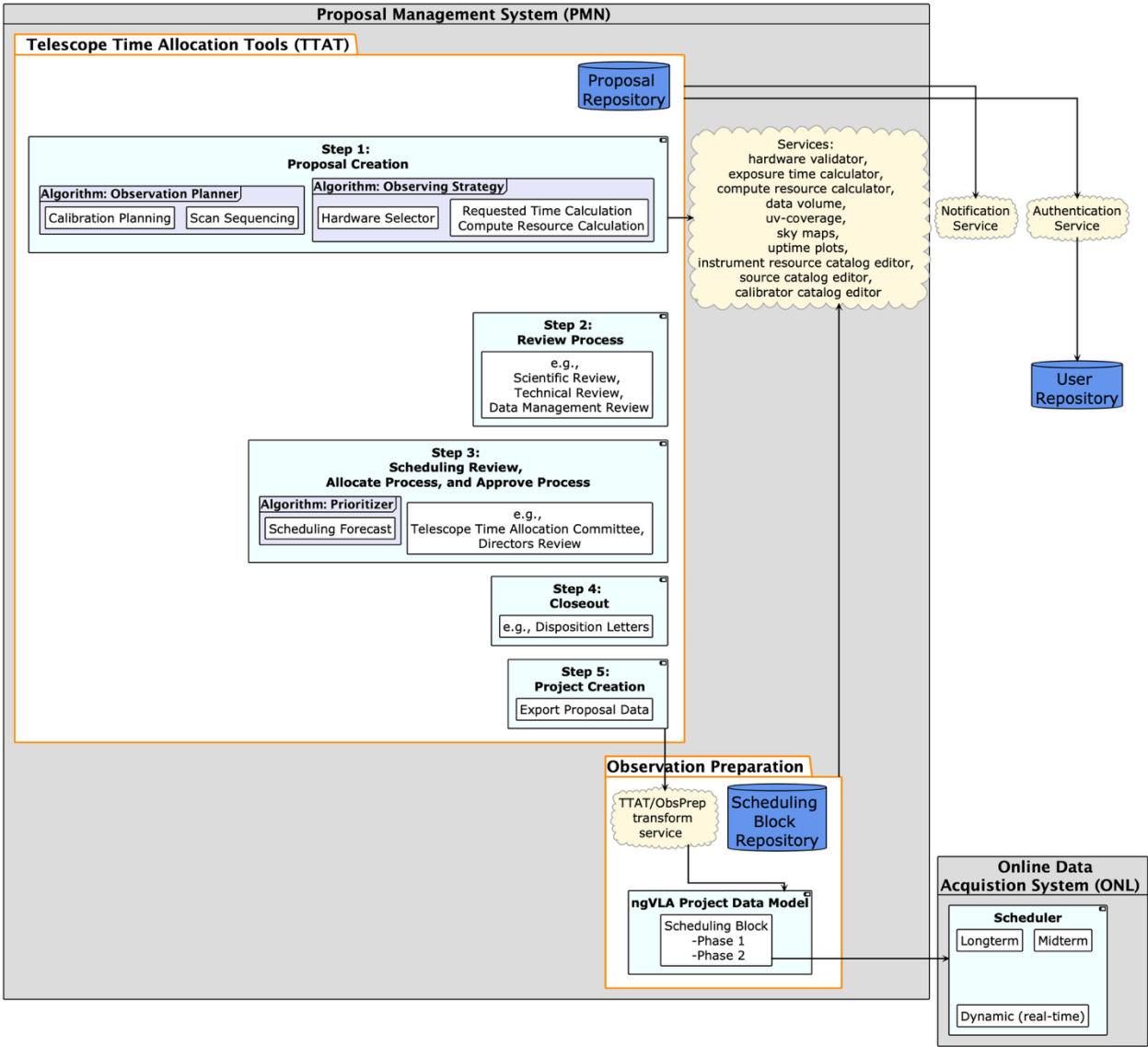


Figure 4 - Overview of PMN components and interactions with subsystems.

5 Future Work

This section describes activities to be done between CDR and PDR.

- Stakeholder-driven use cases are needed to define requirements for additional proposing processes to support observatory-led activities such as service observing, testing, and commissioning.
- The Observation Preparation system requires further design to fully support both researcher-led projects and observatory-driven use cases. Additional stakeholder-driven use cases will be valuable in refining and validating the design.



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- The PDM (Section 4.2) requires refinement and further definition to meet the operational and interface requirements of the Online Data Acquisition system. Terminology within the model may evolve to better reflect the intended scope and role of each hierarchical level.
- The concepts and boundaries of Phase I and Phase II Scheduling Blocks may evolve as scheduling strategies and operational needs are clarified.
- The scope of the PMN services (e.g., observatory database of standard calibrators; Section 4.3) is needs refinement, particularly where functionality overlaps with other subsystems and operational support tools.



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6 Appendix A – Selection of PMN Needs

The following sections contain a selection of the needs for PMN; the full set is available in [RD01]. The Needs presented here are selected to align with the concepts presented in this document.

6.1 Proposal Process

ID	Name	Text
CSS0052	Concurrent Solicitation	When a call for proposals is initiated, the Scheduling Support Scientists need support for concurrent solicitations.
CSS0053	Available Resources for Upcoming Proposal	The Scheduling Support Scientists need to define what resources are available during the upcoming proposal cycle for proposal solicitation.
CSS0057	Translation of Scientific Needs into Science Goals	The Scheduling Support Scientists need the augmented TTA software to translate their scientific needs into Science Goals.
CSS0059	Concomitant Computing Resources	During proposal preparation, ngVLA proposers need to calculate the concomitant computing resources needed for data processing of their science targets.
CSS0060	General Visualization Capabilities	During proposal preparation, ngVLA proposers need general visualization capabilities for planning.
CSS0061	Tools for Observation Planning	During proposal preparation, ngVLA proposers need tools for observation planning.
CSS0064	Override Default Observing Strategy	ngVLA proposers need to be able to override the default observing, calibration, and/or data reduction strategy.
CSS0072	Proposal Creation Customization for Different Types of Solicitation	The Science Operations Group needs the proposal creation process to be customizable to support different types of Solicitation, such as Sponsored Proposals, ToO Proposals and Observatory Services.
CSS0048	Distributed peer review	The Scheduling Support Scientists need the TTAT Review software to support distributed peer reviews.
CSS0077	Review of DDT Proposals	Observatory Staff need to be able to assign a binary metric to support the review of Director's Discretionary Time proposals as part of the Review Process.



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ID	Name	Text
CSS0078	Review of Observatory Services Proposals	Scheduling Support Scientists need an automated process to support the review of proposals for observatory services.
CSS0096	Science Review Panels	The Scheduling Support Scientists need the TTAT Review software to support science review panels
CSS0085	Observing Simulator: Inclusion of Past Proposals	Scheduling Support Scientists need the Observing Simulator to include the impact of any previously approved and allocated time from previous solicitations including “carry over” projects.
CSS0088	Allocation Approval Notification	After the overall observing program has been approved, Scheduling Support Scientists need to notify the PIs of the outcome.
CSS0089	Science PI: Notification of Proposal Outcome	The PIs need to be notified of the relevant reviews and the dispositions (execution likelihood, time, computing resources) of their Allocation Requests.

6.2 Observation Preparation

ID	Name	Text
CSS1015	Creation of Projects from Proposals	The Science Operations Support Staff need the ngOPS to create a complete observing Project from a Proposal.
CSS1017	Automatic Creation of Program ⁴ Blocks	The Science Operations Support Staff need Program Blocks to be automatically generated for the majority of observing modes.
CSS1018	Manual Modification of Program Blocks	The Science Operations Support Staff need to manually edit auto-generated Program Blocks.
CSS1019	Visibility of Status of Scheduling Block	The Science Operations Support Staff and Principal Investigators need to see the status of a Scheduling Block.
CSS1028	Automatic Generation of PDM Elements	The Science Operations Support Staff need the automatic generation of Project Data Model elements.
CSS1029	Manual Generation of PDM Elements	The Science Operations Support Staff need to manually generate elements of the Project Data Model.

⁴ The VLA Project Data Model have a “Program Block” level, which is similar to ALMA’s “Group Observation Units Set”. In the ngVLA Project Data model, this level is called the “Group Level Block”. The PMN Needs uses VLA terminology for traceability in previous documentation, such as in [RD05].



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ID	Name	Text
CSS1031	PDM Compatibility with Post-processing	The Science Operations Support Staff need the generated elements of the Project Data Model to be compatible with the post-observation calibration and imaging pipelines.
CSS1032	Additional User Input After the Proposal Process	The Science Operations Support Staff need the ngOPS to accept additional input for the Project Data Model from the proposing team after the conclusion of the proposal process.
CSS1036	Creation of SBs for Non-standard Observing Modes	The Science Operations Support Staff need to create Scheduling Blocks using ngOPS for NSDR.
CSS1039	Creation of Instrument Resources	The Science Operations Support Staff need to interactively create instrument resources to be used during an observation.
CSS1040	Editing of Instrument Resources	The Science Operations Support Staff need to interactively edit instrument resources to be used during an observation.
CSS1042	Sharing of Resource Instrument Model	The Science Operations Support Staff need the instrument resource model generated by ngOPS to be consistent with the instrument resource model used by the online data acquisition system.

7 Appendix B – PMN Examples

The following examples are to demonstrate, at a high level, the workflow from Proposal Creation through Project generation for key use cases. The bold text represents key concepts in the TTA Tools. In some cases, figures are provided to illustrate the user interface or functionality of the TTA Tools application. As the TTA Tools is still under development, the figures are mock-ups, or “wireframes”, which are simplified representations of the intended user experience.

7.1 Proposal with Standard Observing from a Science Researcher

This example parallels Use Case 3.3, points 1 to 10, in [RD06].

A science researcher would like to submit a proposal in response to a Call for Proposals. As an authenticated user in the TTA Tools, they see that the Semester 32A Call for Proposals is open and the ngVLA is a **Facility** “on offer”. The user selects the “Semester 32A” Solicitation and selects “Create Proposal”. The **Solicitation** permits Proposal Classes⁵ of *Regular* or *Large*; the user selects *Regular*.

⁵ Other Proposal Classes exist beyond these listed here (e.g., Legacy, Target of Opportunity, Education and Public Outreach, Exploratory). One of the configurable parameters in a Solicitation is the list of permitted Proposal Classes.



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For this proposal, the user wants to map High- z CO gas (HiZ5) by imaging molecular gas tracers CO, HCO⁺, and HCN in high redshift galaxies with 100 mas resolution and an rms sensitivity of 10 microJy beam⁻¹ per 30 km s⁻¹ channel in each observing band. The targets are four galaxies at $z \sim 2$.

In the proposal, the user creates an **Allocation Request** for the ngVLA. In the **Allocation Constraints**, the user specifies that this request is not Triggered, Fixed Date, or Monitoring. The user selects the “Spectral Line Capability Request” from a list of **Capabilities** on offer in this Solicitation.

The user then creates a **Field Source** for each galaxy and specifies:

- coordinates (RA, Dec)
- Field of view (FOV) or angular extent
- source velocity (or redshift)
- typical line width (~ 150 km s⁻¹)
- Peak line flux per beam
- Peak continuum flux per beam

Allocation Request 1: ngVLA

↳ Allocation Constraints: None

↳ Capability Request 1: Spectral Line

↳ Field Sources

Name My Source 1	Peak Line Flux per beam xx mJy	Name My Source 2
Position HH:MM:SS DD:MM:SS	Line Width XX km/s	Name My Source 3
FOV shape Point	Radial Velocity XX km/s	Name My Source 4

↳ Spectral Specifications

Name CO 1-0	Spectral Resolution 30 km/s	Bandwidth 1000 km/s	Center Frequency 115 GHz
Name HCO+	Center Frequency 89.2 GHz	Name HCN 1-0	Center Frequency 88.6 GHz
Name CO 2-1	Center Frequency 231 GHz		

Figure 5 - Wireframe of Field Sources and Spectral Specifications for a ngVLA Capability Request.

The user specifies spectral information in four **Spectral Specifications**:

- Spectral Specification 1
 - o rest frequency of CO(1-0) (115 GHz)
 - o desired spectral resolution (30 km s⁻¹)
 - o velocity span (1000 km s⁻¹ or bandwidth in GHz)
- Spectral Specification 2
 - o rest frequency of HCO+(1-0) (89.2 GHz)



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- o desired spectral resolution (30 km s⁻¹)
- o velocity span (1000 km s⁻¹ or bandwidth in GHz)
- Spectral Specification 3
 - o rest frequency of HCN(1-0) (88.6 GHz)
 - o desired spectral resolution (30 km s⁻¹)
 - o velocity span (1000 km s⁻¹ or bandwidth in GHz)
- Spectral Specification 4
 - o rest frequency of CO(2-1) (231 GHz)
 - o desired spectral resolution (30 km s⁻¹)
 - o velocity span (1000 km s⁻¹ or bandwidth in GHz)

In practice, the spectral line transition could be selected from a catalog that contains the rest frequency; the user can specify frequencies for additional transitions in the same bandwidth to optimize the tuning.

Allocation Request 1: ngVLA

Allocation Constraints: None

Capability Request 1: Spectral Line

Field Sources
Spectral Specifications
Performance Parameters

RMS Sensitivity
10 Jy /beam per 30 km/s

Largest Angular Scale
5 arcsec

Resolution
0.1 arcsec

Calibration Parameters

Polarization Calibration
☐ Yes
☒ No

Standard Calibration
☒ Yes
☐ No

Figure 6 - Wireframe of Performance and Calibration Parameters in an ngVLA Capability Request.

In **Calibration Parameters**, the user specifies that these are not polarization observations. The user specifies that the default calibration is sufficient for their science needs. In **Performance Parameters**, the user specifies:

- required angular resolution (100 mas)
- largest angular scale (5 arcsec)
- rms sensitivity per bandwidth (10 Jy beam⁻¹ per 30 km s⁻¹).

The TTA Tools system then takes actions based on these inputs. First, the *ngVLA Spectral Line Observing Strategy* algorithm is called:



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- Given four Field Sources and four Spectral Specifications, the system determines how many **Science Targets** are necessary. A Science Target contains a pairing of a **Source** and **Hardware Configuration**.
 - It determines that the Field Sources are not duplicated by comparing the specified extent and coordinates, so it will build 4 Sources.
 - Given the source velocity of each Field Source and the requested rest frequencies of each Spectral Specification, the system determines that at least 3 Hardware Configuration are necessary, as two of the Spectral Specifications (SS 2 & SS 3) are encompassed a single candidate receiver.
 - The system plans to build 12 Science Targets (4 Sources x 3 Hardware Configurations).

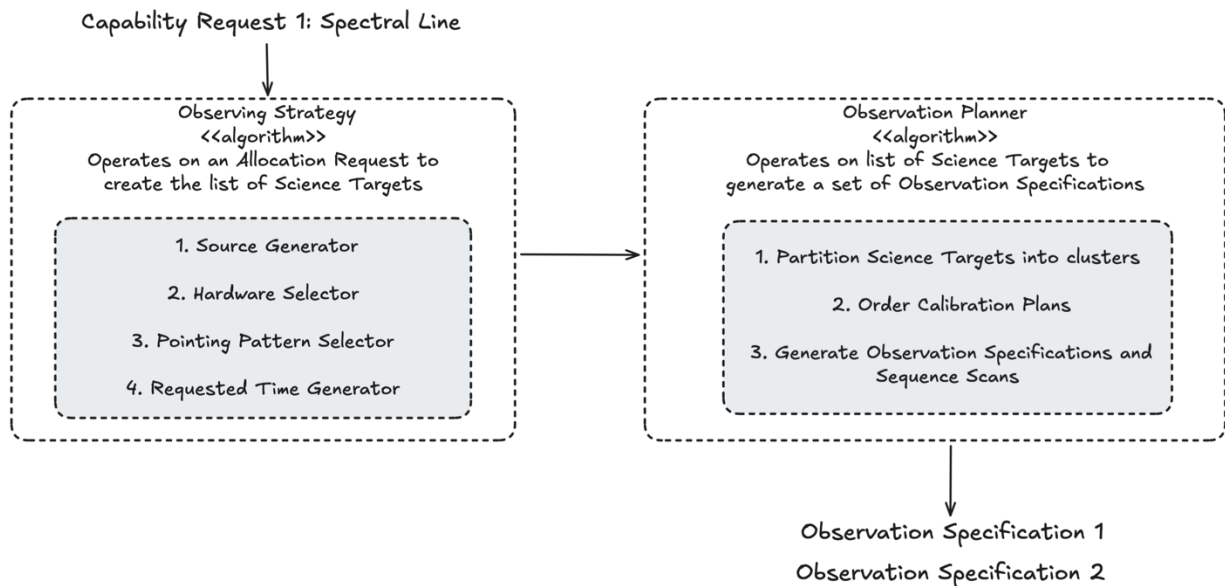


Figure 7 - Wireframe of TTA Tools algorithms to transform science-focused inputs into Facility-focused resource requests.

For each Science Target, the system then refines the Hardware Configuration selection.

- Array Configuration(s) Selection algorithm:
 - This algorithm selects subarray(s) or array subset configurations. According to recommended observatory practices, the philosophy is to choose the configuration(s) that minimized the observing time on target, in the case that multiple configuration(s) could achieve the same performance parameters. For each Science Target, the system selects Main Array (214 18-m antennas) to achieve the requested angular resolution, LAS, and rms sensitivity at the specified frequency. The system will also prioritize a list of all subarrays that could also fulfill the request.
- Front-End and Back-End Selection algorithm:
 - The observing frequency of 38 GHz implies the Band 5 receiver. Band 5 is specified as "on offer" in the Solicitation for the Spectral Line Capability. For the ngVLA Spectral Line Capability, the only back-end available is the Central Signal Processor (CSP). The system calls a PMN service to configure the CSP for Band 5 with the specified observing



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frequency. The PMN service returns a Resource ID, indicating that it can construct a valid arrangement of basebands and line placements for the specified spectral line. This arrangement considers the number of lines within the band, as well as constraints on the total number of subbands that can be transmitted from the antenna. It also considers limitations on the aggregate number of channels due to data rate constraints [Section 7.4.4 of RD07]. The PMN service also returns the data rate and recommended dump time. Note, if the PMN service could not form a valid configuration, the system would attempt to adjust, for example, by adding additional Science Targets or returning to the user with feedback. Assuming in this case a valid configuration is found, the system sets this front-end/back-end configuration for 4 Science Targets.

- o The observing frequency of 29.5 GHz and 29.7 GHz implies the Band 4 receiver. Band 4 is specified as “on offer” in the Solicitation for the Spectral Line Capability. For the ngVLA Spectral Line Capability, the only back-end available is the CSP. The system calls a PMN service to configure the CSP for Band 4 with the two specified observing frequencies. With a valid configuration, the system sets this front-end/back-end configuration for 4 Science Targets.
- o The observing frequency of 77 GHz implies the Band 6 receiver. Band 6 is specified as “on offer” in the Solicitation for the Spectral Line Capability. For the ngVLA Spectral Line Capability, the only back-end available is the CSP. The system calls a PMN service to configure the CSP for Band 6 with the specified observing frequency. With a valid configuration, the system sets this front-end/back-end configuration for 4 Science Targets.
- **Pointing Pattern Selection**
 - o There is an algorithm that decides if wide field observing (i.e., pointed mosaic or OTF) is necessary, or if a single field suffices.
 - For Science Targets observing at 38 GHz, the primary beam is ~0.6 arcmin, so a single field suffices given the requested FOV. For these 4 Science Targets, the system selects a Pointing Pattern of “Single Pointing”.
 - For Science Targets observing at ~29 GHz, the primary beam is ~2 arcmin, so a single field suffices. For these 4 Science Targets, the system selects a Pointing Pattern of “Single Pointing”.
 - For the remaining 4 Science Targets observing at 77 GHz, the primary beam is ~0.3 arcmin, so a single field suffices. For these 4 Science Targets, the system selects a Pointing Pattern of “Single Pointing”.
- **Requested Time Calculation**
 - o The system calls the PMN’s ngECT to calculate a Requested Time for each Science Target, given the Hardware Configuration, selected Pointing Pattern, and relevant performance parameters indicated by the user (e.g., dynamic range). The ngECT returns a time.

The *ngVLA Spectral Line Observation Planner* algorithm is called to build one or more **Observation Specifications**. The Observation Planner

- Determines how to cluster the 12 Science Targets into groups for observation. In this example, let us assume the system determines two clusters are sufficient, so the system creates two



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Observation Specification. Clustering follows observatory recommended practices for the Facility, such as avoiding overhead (e.g., antenna slew time) dominated clusters.

- Determines the Calibration Plan for each Observation Specification. For ngVLA Spectral Line, the system orders a Calibration Plan with the scan intents of #CALIBRATE_BANDPASS, #CALIBRATE_COMPLEX_GAIN, #CALIBRATE_FLUX_DENSITY_SCALE, and #CALIBRATE_ABSOLUTE_POSITION.
- Sequences Scans and subscans for an Observation Specification. It realizes the Calibration Plan for a set of Science Targets to generate Scans with intents of #OBSERVE_TARGET. Scan sequencing follows observatory recommended practices for the Facility, which can adhere to upper limits on the total duration. For the ngVLA Spectral Line Capability, the algorithm limits scan lists to a duration of N hours and will increase the “Repeat Count”, as needed, to fulfill the Requested Time associated with each Science Target.
- Selects recommended/standard HLDPs to be delivered. For example, the Spectral Line observations would imply spectral cubes (Stokes I).

Science Targets			Observation Specification 1	Observation Specification 2
Source	Hardware Configuration	Time On Source	Duration: XX hr Overhead: XX hr	Repeat Count per Duration: N
My Source 1	HW 1	X hr		
My Source 2	HW 1	X hr	1 #SETUP Hardware: Setup Default	Duration: HH:MM:SS
My Source 3	HW 1	X hr	2 #FLUX Hardware: HW1	Duration: HH:MM:SS
My Source 4	HW 1	X hr	3 #FLUX Hardware: HW2	Duration: HH:MM:SS
My Source 1	HW 2	X hr	4 #FLUX Hardware: HW3	Duration: HH:MM:SS
My Source 2	HW 2	X hr	5 #COMPLEX GAIN Hardware: HW1	Duration: HH:MM:SS
My Source 3	HW 2	X hr	6 #OBSERVE TARGET Hardware: HW1 Target: My Source 3	Duration: HH:MM:SS
My Source 4	HW 2	X hr	7 #OBSERVE TARGET Hardware: HW1 Target: My Source 4	Duration: HH:MM:SS
My Source 1	HW 3	X hr	8 #COMPLEX GAIN Hardware: HW1	Duration: HH:MM:SS
My Source 2	HW 3	X hr	9 #COMPLEX GAIN Hardware: HW2	Duration: HH:MM:SS
My Source 3	HW 3	X hr	N #BANDPASS Hardware: HW1	Duration: HH:MM:SS
My Source 4	HW 3	X hr		

Figure 8 - Wireframe of system generated Science Targets and Observation Specification.



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The system also creates **Data Processing Specification(s)**, which hold the compute resources estimated for the Observation Specification(s).

The user may then inspect the system generated Observation Specification(s), Scan List(s), HLDPs, and Data Processing Specifications for accuracy and make modifications if desired, which may trigger additional Technical Justification questions. For example, the user could elect to maximize continuum bandwidth alongside their spectral setup within the data rate constraints. A PMN service could also make such recommendations for the user.

When the Call for Proposals ends, a submitted Proposal enters the **Proposal Process**. At this point, the system copies the requested data into new structures to preserve the original intent and to facilitate the review.

- An **Allocation Disposition** is instantiated per Allocation Request. In addition to the properties of an Allocation Request, an Allocation Disposition has an “Approved” state which is set to False until the Directors Review is completed.
- An **Observation Specification Disposition** is instantiated per Observation Specification. In addition to the properties of an Observation Specification, an Observation Specification Disposition has a Scheduling Priority.

The Proposal Process is composed of phases:

- a **Scientific Review**, where a Scientific Merit Metric is determined and assigned by science reviewers.
- a **Feasibility Review**, where the proposal is reviewed for technical and data management.
- a **Scheduling Review**, where preliminary Scheduling Priorities are assigned to the Observation Specification Dispositions.
- an **Allocation Review**, where, for example, the Telescope Time Allocation Committee recommends Scheduling Priorities for the observing and compute requests.
- a **Directors Review**, where the Scheduling Priorities are approved.

A **Disposition Letter** is sent to the user to inform them of the outcome of the allocation process. Assuming the proposal was allocated resource, the TTA Tools exports to the PMN’s Observation Preparation System.

7.2 Observing Project for Standard Observing by a Regular Observer

This example parallels Use Case 3.3, point 11, in [RD06].

Continuing from the example in Section 7.1, the Proposal has requested and allocated resources for Standard Observing using default calibration strategies. Once the TTA Tools initiates the export of the proposal data, a Project is created in the Observation Preparation system. The Project Data Model (PDM) is assembled using the proposal data, which includes the number and hierarchy of the Group Level Blocks, their Data Product Blocks, and their Scheduling Blocks (e.g., Phase I SBs).

The user can view the Project hierarchy in an online user interface and view metadata that is used for scheduling, such as LST start range, duration, requested/remaining repeat counts, reference subarray,



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and dates of scheduling. The user can also track the status of the SBs e.g. “not submitted”, “on hold”, “expired”, “schedulable”; the user can also track when an execution of the SB should be recorded and the execution block’s real-time status e.g. “observing”, “completed”, “completed & archived”, or “failed”.

As the Project is a Standard Observing mode, the user may not make modifications to the Project and it will be validated and approved automatically by the system. The user can submit a Helpdesk ticket if they have a concern.

7.3 Proposal for Observing Services by Observatory Staff

This example generically represents the Proposal component of Use Case 5.3 in [RD06].

A Scientific Staff member needs to perform standard observations to monitor a potential new calibrator. These observations are considered Observatory Services. As an authenticated user in the TTA Tools system, they select the Solicitation that is continuously accepting internal submissions for Observatory Services. Access to this Solicitation is restricted to Scientific Staff for Observatory Service observing only.

The Scientific Staff member selects “Create Proposal” and uploads a file that specifies the details of the Allocation Request(s), Observation Specification(s), and Data Processing Specification(s). These details include the declaration of calibration strategies and desired HLDPs. The file upload also contains an abstract-like description of the observations and a title for the proposal; these metadata may be made available in public proposal data (e.g., Proposal Finder services and the Archive). The Scientific Staff member may inspect the Proposal for accuracy and then submit the proposal once validation passes. Note, if the proposal is testing new modes, the validation may be perfunctory.

The Proposal Process is minimal, as the requested resources do not undergo scientific, feasibility, scheduling, or allocation review processes. The Observation Specification Dispositions associated with the proposal are marked as positive allocations and exported to the PMN’s Observation Preparation system.

7.4 Observing Project for Observing Services by Developer Observer

A service automatically forms a Project from the Proposal data and assembles the PDM, eventually creating Phase I SBs. If the Proposal data was marked as Non-Standard Observing, then components of the PDM may not be formed. At a minimum, entries are created in relevant source and resource catalogs using Proposal data.

The Scientific Staff member may inspect the Project and perform modifications. Such modifications include

- Editing, creating, and deleting elements of a Scheduling Block
- Editing, creating, and deleting Scheduling Blocks, Data Product Blocks, Group Level Blocks, and Science Goals.
- Updating the resources associated with the Project
- Updating sources associated with the Project



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Within the Observation Preparation System, Scientific Staff have access to visualization tools and calculators to support Project modification.

For Non-Standard Observing, user roles of “Validator” and “Approver” will validate and approve, respectively, the Scheduling Blocks once the user submits.

7.5 Proposal for Transient Observing in a typical cycle Call for Proposals.

A science researcher would like to submit a proposal for transient science in response to a Call for Proposals. In transient proposals, the position of the target may not be known at the time of submission, the observation epoch may be uncertain, or the timing may rely on an external trigger. If submitted in response to a standard Call for Proposals, the Proposal Class is typically *Regular* or *Large*, though other Proposal Classes may exist.

The user submits a proposal in response to a typical Call for Proposals. In the TTA Tools, they select the appropriate **Solicitation** and choose the Proposal Class *Regular* during proposal creation. For this proposal, the user wants observations of a black hole–neutron star (BH–NS) system identified by a gravitational wave detection. The user requests an initial response within 2–3 days of notification in two frequency bands. Follow-up observations are needed within the first 6 months, with two additional follow-ups within one year, using four frequency bands.

In the TTA Tools, the user creates an **Allocation Request** for the ngVLA facility and selects “Trigger+Follow-up” in the **Allocation Constraint** field. Trigger information includes:

- 1 Number of triggers: 1
- 2 Multi-cycle: Yes (2 cycles)
- 3 Trigger expiry date(s)
- 4 Trigger event: gravitational wave detection of a BH–NS merger



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Allocation Request 1: ngVLA

↳ Allocation Constraints: Trigger+Follow-up

Trigger Source

Number of Triggers

1

Trigger expiry date

XXXX/XX/XX

Position (Optional)

HH:MM:SS DD:MM:SS

Number of Cycles

2

Trigger event

gravitational wave
detection of a
BH-NS merger

FOV shape

Point (default)

Radial Velocity (Optional)

↳ Capability Request 1: Continuum

↳ Field Sources

Name

Trigger Source

Peak Continuum Flux per beam

xx mJy

Figure 9 - Wireframe of a Trigger Source and corresponding restrictions on Field Source parameters.

Because *Trigger+Follow-up* was selected, the user is prompted to define a **Trigger Source**, with optional inputs:

- Coordinates (RA, Dec)
- Angular extent/FOV
- Source velocity or redshift
- Proper motion

In this case, the source properties are unknown at the time of proposal submission, so the optional fields (e.g., position, radial velocity) are not specified. The user leaves the default FOV of ‘Point’. The user selects the “Continuum Capability Request”. Because *Trigger+Follow-up* was specified, the **Field Source** is automatically linked to the **Trigger Source**. The user then provides:

- Peak continuum flux per beam

The user defines two **Spectral Specifications**, one per desired frequency band. In the **Calibration Parameters**, the user indicates that these are not polarization observations and that default calibration is sufficient.



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Allocation Request 1: ngVLA

- ↳ Allocation Constraints: Trigger+Follow-up
 - ↳ Capability Request 1: Continuum
 - ↳ Field Sources
 - ↳ Spectral Specifications
 - ↳ Performance Parameters

RMS Sensitivity

Resolution

Largest Angular Scale

Response Windows + Tolerances
- ↳ Calibration Parameters

Figure 10 - Wireframe of specification of time domain constraints such as “Response Windows”.

In **Performance Parameters**, the user rms sensitivity, etc. and then enters two response windows with associated tolerances:

- 2 days + 1 day
- 6 months ± 1 month

Because the user wants a different spectral configuration for the follow-up observations, the user adds⁶ a second “Continuum Capability Request” to the same **Allocation Request**. Because the **Capability Request** was added to the Allocation Request with a *Trigger+Follow-up* Allocation Constraint, the previously specified **Trigger Source** applies as well. If the user desires a different Trigger Source, they are required to create a new Allocation Request.

They provide the same input for **Field Source** and **Calibration Parameters**. This time, the user creates four **Spectral Specifications**, corresponding to four frequency bands. In **Performance Parameters**, they enter two additional response windows:

⁶ The TTA Tools allow users to duplicate existing Capability Requests and modify them as needed, reducing redundant data entry. Furthermore, if the user did not desire additional spectral coverage in the follow-up alone, they could have specified all response windows within one Capability Request.



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- 12 months $\pm$ 1 month
- 18 months $\pm$ 1 month

As described in Section 7.1, the TTA Tools takes action to generate **Observation Specifications** and corresponding **Data Processing Specifications**. In this case, it creates two Observation Specifications:

- The first **Observation Specification** has a repeat count of 2 and covers the 2-day and 6-month windows, as both fall within the Solicitation's execution period with observing frequencies in the 2 desired spectral bands.
- The second **Observation Specification** has a repeat count of 2 for the 12-month and 18-month follow-up, with observing frequencies in the 4 desired spectral bands.

When the Call for Proposals concludes, the submitted proposals enter the Proposal Process described in Section 7.1. If this proposal is allocated resources, the TTA Tools exports the relevant data to the PMN's Observation Preparation System for project creation (see Section 7.7).

7.6 Proposal for Transient Observations for Director's Discretionary Time

A science researcher would like to submit a transient proposal for a Director's Discretionary Time (DDT) opportunity. In transient proposals, the position of the target may not be known at the time of submission, the observation epoch may be uncertain, or the timing may rely on an external trigger. The user selects the Solicitation identified in the TTA Tools for ngVLA DDTs and creates a new proposal. This Solicitation allows Proposal Classes such as *Target of Opportunity*, *Exploratory*, and *EPO*; the user selects *Target of Opportunity* during proposal creation.

The proposal is for radio observations of a newly detected supernova classified as Type II_n, expected to remain radio-bright for ~ 1000 days. The source lies in a complex environment with significant continuum emission on multiple spatial scales from extended HII regions to UCHII/HCHII regions and circumstellar dust. High-fidelity imaging, including self-calibration, is required. The user requests a triggered response time of 7–12 days after proposal submission, followed by two additional observations in the same configuration at 40–55 days and 150–180 days post-trigger. The observations are requested in 4 frequency ranges.

In the TTA Tools, the user creates an **Allocation Request** for the ngVLA Facility. They select “Trigger+Follow-up” as an **Allocation Constraint** and enter the following trigger information:

- Number of triggers: 1
- Multi-cycle: Yes (2 cycles)
- Trigger expiry date(s)
- Trigger event: immediate; external facility has confirmed SN as Type II_n

Because *Trigger+Follow-up* was selected, the user is prompted to define a **Trigger Source**, with optional inputs:

- Coordinates (RA, Dec)



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- Angular extent/FOV
- Source velocity or redshift
- Proper motion

The user selects the “Continuum Capability Request”. The **Trigger Source** information is automatically propagated to define the **Field Source**, and the user specifies the peak continuum flux per beam.

The user creates four **Spectral Specifications**, one for each desired frequency (see Section 7.1).

In the **Calibration Parameters**, the user specifies that the observations are not polarized and that high-fidelity imaging with self-calibration is required.

In the **Performance Parameters**, the user enters:

- Required angular resolution: 2–10 arcsec
- Largest angular scale: N/A
- Sensitivity: 4–6 μ Jy
- Three *Response Windows* with associated tolerances:
 - o 9 days $\pm$ 4 days
 - o 52 days $\pm$ 10 days
 - o 165 days $\pm$ 15 days

As in Section 7.1, the TTA Tools take action to generate **Observation Specifications**. In this case, it creates two specifications with largely identical Scan Lists:

- The first **Observation Specification** has a repeat count of 2 and covers the 9-day and 52-day windows, as both fall within the current observing cycle.
- The second **Observation Specification** covers the 165-day follow-up, expected to occur in the next cycle.

Data Processing Specifications are also generated.

Once submitted, the proposal enters the **Observatory Site Review** process. Observatory staff perform science, feasibility, and scheduling reviews. The Director’s Delegates Review approves Scheduling Priorities, and the final Disposition Letter is sent to the researcher.

If the proposal is allocated resources, the TTA Tools exports the proposal data to the PMN’s Observation Preparation System for project creation (see Section 7.2).

7.7 Observing Project for Proposal with an Unspecified Trigger Source

As described in Section 7.2, a service automatically forms a project from the proposal data and assembles the ngVLA Project Data Model (PDM), including the creation of Phase I Scheduling Blocks (SBs), even for proposals where the target position was not known at the time of submission. In such cases, the user provides the coordinates later, once they become available, within the Observation



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Preparation system. The Observation Preparation system does not support automated trigger responses; human intervention is required to submit Scheduling Blocks. This applies to both standard and non-standard observing modes. After coordinates are supplied, the process proceeds as outlined in Section 7.2.

7.8 *Rapid Response Filler*

Rapid Response Filler (RRF) requests are intended for events that demand rapid scheduling, potentially on timescales shorter than typical DDT-like workflows are designed to support [RD08]. The TTA Tools could accommodate this type of request by allowing users to request expanded authorization in their proposal to create and submit Scheduling Blocks with greater autonomy than is normally granted to standard or non-standard observers. These requests would be submitted during a regular proposal cycle, in advance of the anticipated observing opportunity, as described in the sections above. Alternatively, the Observatory could choose to streamline submission and disposition processes through existing concepts such as Proposal Class, Capability, and Proposal Process. Conceptually, the PMN's Observation Preparation system supports multiple levels of authorization, as well as the ability to automate the creation of Scheduling Blocks when appropriate. Decisions about how much autonomy users may have to initiate or finalize observations via RRF requests remain under discussion and will be determined by Observatory policy. The system is designed to remain flexible and can accommodate a range of review and approval models.



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8 Acronyms

Term	Meaning
AD	Applicable Document
AUI	Associated Universities Incorporated
CDR	Conceptual Design Review
CMMS	Computerized Maintenance Management System
CSE	Calibratable Scan Execution
CSB	Calibratable Scan Block
CSS	Computing and Software System
DDD	Domain Driven Design
DSC	Science Data Center
DPB	Data Product Block
GBT	Green Bank Telescope
GLB	Group Level Block
GMVA	Global 3mm VLBI Array
HLDP	High Level Data Product
HSA	High Sensitivity Array
IPT	Integrated Product Team
LRU	Line Replaceable Units
MCL	Monitor and Control
MSS	Maintenance and Support
ngVLA	Next Generation Very Large Array
NRAO	National Radio Astronomy Observatory
NSB	ngVLA Site Buildings
NSF	National Science Foundation
OBC	Observatory Provided Calibration
ONL	Online Data Acquisition
OPS	Operations Building
PDM	Project Data Model
PDR	Preliminary Design Review
PMN	Proposal Management
RID	Review Item Discrepancy
SB	Scheduling Block
SDA	Science Data Archive
SDP	Science Data Processor
SIT	Science Interface and Tools
TI	Technical Infrastructure
TTA	Telescope Time Allocation
VLA	Very Large Array
VLBA	Very Long Baseline Array