Telescope Time Allocation (TTA): Use Cases

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Abstract

We develop a series of Use Cases to explore the interaction between user input and software actions necessary to generate preliminary Allocation Requests, the part of a proposal that specifies the details of the requested observatory resources.

History

0.1 Original draft—March 11, 2022 (dsb).

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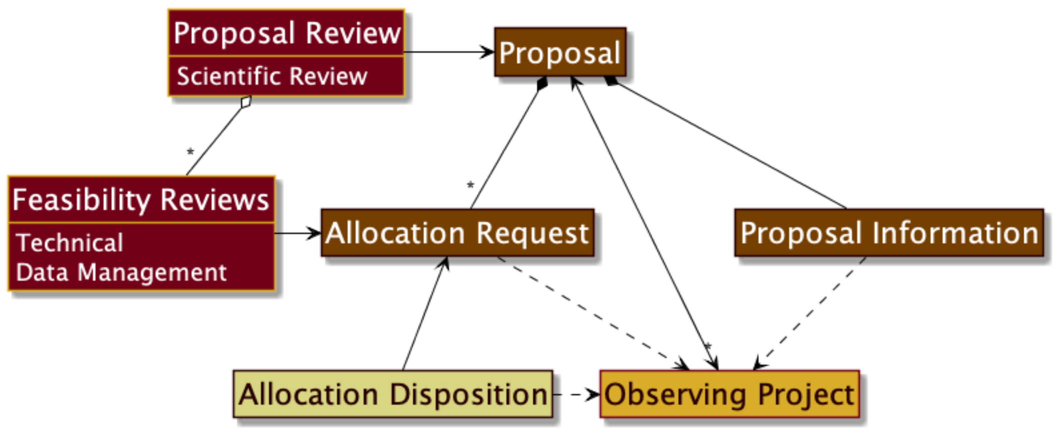

Figure 1: A conceptual representation of the system. The colors depict the process that creates the object. For example, brown is the proposal creation, maroon is the review process, yellow-green is the allocation process, and orange is the closeout process which may create an *Observing Project*. In this diagram unless otherwise specified the multiplicity of links is unity. Arrows denote links between conceptual objects and can be characterized by a "relates to" relation. Filled and Open diamonds denote a more hierarchical "belongs to" relation with open diamonds denoting that the object's lifecycle is not fully dependent on the parent (aggregation). Dashed lines denote that information from each of these objects is used to create the *Observing Project*, but the only linkage is to the proposal. (This diagram is intended to be conceptual and although it borrows from the symbology of UML is not intended to be a formal specification but to depict the "notional relations.")

1 Overview

An overview of the TTA system is shown in Figure 1. From the user's perspective the process begins with the preparation of a proposal in response to a *Solicitation*. A *Proposal* is composed of *Proposal Information* and one or more *Allocation Requests*. *Proposal Information* consists of identifying information (title, investigator names and affiliations, science category, etc.) and the scientific justification. Reviews of the scientific merits of each proposal are performed based on the *Proposal Information*. Each *Allocation Request* contains only one *Facility* and provides details about the proposed observations. For example, a proposal requesting time on both the VLA and GBT would have one *Allocation Request* for the VLA and one for the GBT. But a proposal can have multiple *Allocation Requests* using the same *Facility* (e.g., multiple VLA configurations). Feasibility reviews, which include technical and data management reviews, may be performed for each *Allocation Request*, but in practice will be connected to the *Facility*.

An *Allocation Disposition* is recommended by the Time Allocation Committee (TAC) and approved by the Director at the Directors' review. Since dispositions are primarily tied to the *Allocation Request*, a proposal may be awarded time or an approved scheduling priority on only some of the *Allocation Requests* within a proposal. At the conclusion of the review process *Observing Projects* are created at each *Facility* for proposals with positive *Allocation Dispositions*.

2 Allocation Requests

To generate *Allocation Requests* we first need to define the *Capabilities* that are available for the *Solicitation* in question. Figure 2 summarizes the components of a *Solicitation*. A *Capability* corresponds to the different ways a *Facility* can be operated and the resources available. *Capabilities* are often distinguished by different OBSERVING TYPES (e.g., continuum, spectral line, etc.), but may also include other aspects of the *Facility* (e.g., sub-arrays for the VLA). (See Section B for a list of OBSERVING TYPES.) Additional details are required, however, including the scanning modes of the telescope (e.g., OTF mapping), FRONT-ENDS (e.g., L-band receiver), BACK-ENDS and their configuration (e.g., WIDAR), etc. The *Capability Parameter Specification* allows the inputs to a *Capability* to be

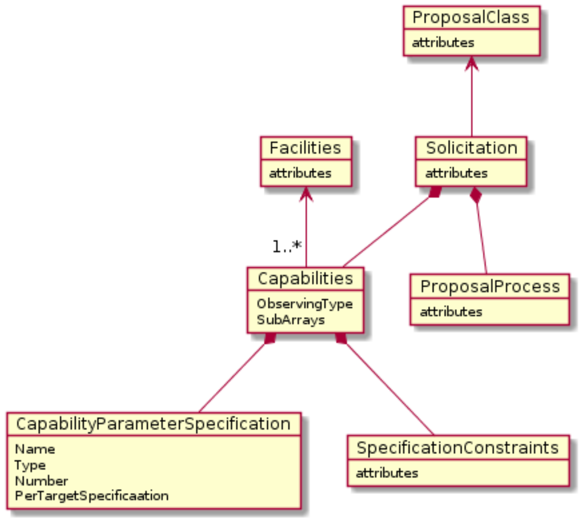

Figure 2: *Solicitation* object diagram. A *Solicitation* is composed of *Capabilities* and a *Proposal Process*. *Capabilities* consist of *Capability Parameter Specifications* and the *Specification Constraints*, which correspond to restrictions on the available resources. Each *Facility* can have one or more *Capabilities*. There are attributes associated with each of these objects.

configurable; that is, a way for the TTA Group to define the available *Capabilities*. The *Specification Constraints* indicate the restrictions on these resources (e.g., OTF can only be used for frequencies below X-band for general observing).

To create an *Allocation Request* the user needs to specify enough information so that the TTA Tools can generate a list of *Scans* that provide detailed instructions on how to observe, the *Observation Specification*. Figure 3 summarizes the process. Each *Allocation Request* is for a single *Facility* which has one or more available *Capabilities* for each *Solicitation*. The *Capability Request Parameters* are the user responses to the *Capability Parameter Specifications* defined in the *Solicitation* and make up the *Capability Request*. Following the ALMA OT they are organized into four areas (see Section C for details):

- FIELD SOURCES: spatial information (e.g., RA/Dec), together with other information about the object (e.g., velocity).
- SPECTRAL SPECS: frequency information (e.g., bandwidths) to help define the FRONT-ENDS, BACK-ENDS, and their configurations.
- PERFORMANCE PARAMETERS: sensitivity, spatial resolution, etc.
- CALIBRATION PARAMETERS: polarization, etc.

The goal is to produce the *Observation Specification* from the *Capability Request*. To do this a *Science Target List*, a data structure that contains the basic user information, is generated first as an intermediate step. The *Science Target List* contains the SOURCES, the HARDWARE CONFIGURATIONS (e.g., FRONT-ENDS and BACK-ENDS), REQUESTED TIMES, and some *Facility* specific information (e.g., array configurations for the VLA). An *Observing Strategy* is required to produce the *Science Target List* from the *Capability Request*. An *Observing Planner*, which consists of the *Calibration Strategy* and the *Scheduling Strategy*, transforms the *Science Target List* to the *Observation Specification*. The *Observing Strategy*, *Calibration Strategy*, and the *Scheduling Strategy* consist of detailed algorithms and heuristics that are used to produce the *Observation Specification* from the *Capability Request* (Costa, 2021).

During validation we need to determine whether the proposed observing is standard or has some shared risk; that is, the OBSERVING CONDITION. For example, general observing (GO), shared risk observing (RSO), or resident shared risk observing (RSRO).

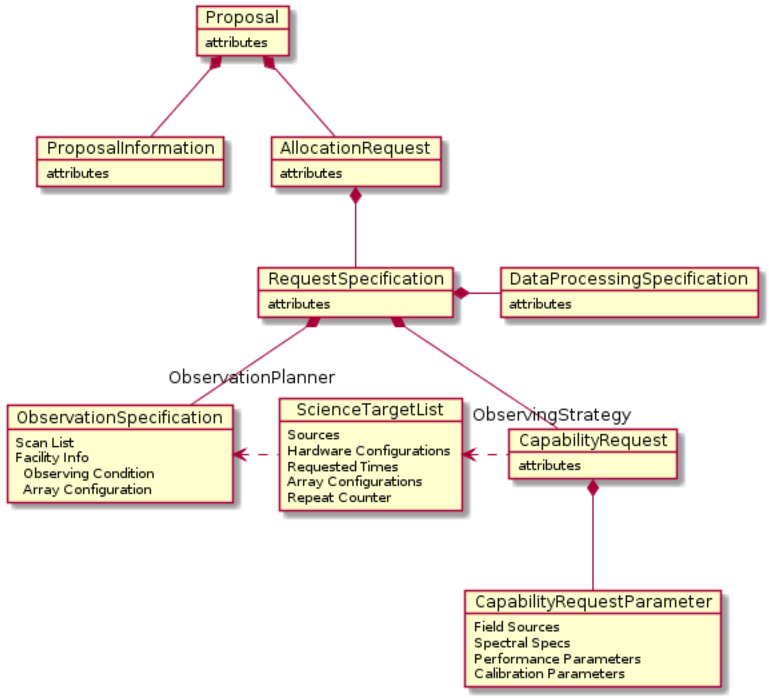

Figure 3: Proposal object diagram. A Proposal is composed of *Proposal Information* and one or more *Allocation Requests*. A *Capability Request* is generated from user input using the available *Capabilities* for the given *Solicitation*. The software generates an *Observation Specification* from the *Capability Request* via the *Science Target List*. The *Observing Strategy* and *Observation Planner* consist of algorithms and heuristics to make this happen.

3 Use Cases

Here we list a set of Use Cases that describe how an *Allocation Request* is generated. The amount of interaction between user input and software action is minimized but not eliminated. Essentially the user inputs information and the software acts to generate *Observation Specifications*. We have to capture enough information from the user and therefore need to decide what questions to ask. The Use Cases allow us to collect this information to determine best practices and the questions needed; that is, how to formulate the *Capability Request Specifications*.

The procedure involves the following steps.

1. **Select Facility:** The user selects one *Facility* that is available for the given *Solicitation*. Depending on this choice different *Capabilities* are available.
2. **Select Capabilities:** The user selects one or more *Capabilities*.
3. **Specify Capability Requests:** For each *Capability* the user creates a *Capability Request* that includes the FIELD SOURCES, SPECTRAL SPECS, PERFORMANCE PARAMETERS, and CALIBRATION PARAMETERS.
4. **Apply Observing Strategy:** The software generates the *Science Target List* from the *Capability Request* based on the *Observing Strategy*.
5. **Apply Observation Planner:** The software generates the *Observation Specifications* from the *Science Target List* based on the *Calibration Strategy* and the *Scheduling Strategy*.

3.1 (VLA) A Faraday Rotation Study of the Stellar Bubble and H II Region Associated with the W4 Complex

Probe the plasma structure of the stellar bubble and H II region associated with W4 using multi-frequency polarization observations of 2 background sources to determine the Faraday rotation measure.

1. **Select Facility:** The user selects "VLA" from a list of available *Facilities* in this *Solicitation*.

2. **Select Capabilities:** The user selects "Continuum" from a list of available *Capabilities* for the VLA in this *Solicitation*.

3. **Specify Capability Requests:**

   (a) Continuum

   - FIELD SOURCES: The user specifies the coordinates for two background sources with respect to W4: I1 and I5. These are point sources so the extent is effectively zero.
   - SPECTRAL SPECS: The user specifies two center frequencies (5 GHz, 9 GHz), bandwidths (2 GHz, 2 GHz), and spectral resolutions (2 MHz, 2 MHz). The two frequencies provide a wider frequency range to determine the Faraday rotation measure.
   - PERFORMANCE PARAMETERS: We are observing point sources so the angular resolution and largest angular structures are not relevant. Need a way to specify point sources. (In practice, the largest angular scales may matter here since we may want to resolve out some of the diffuse structures along the line-of-sight.) The rms sensitivity is $100\,\mu\mathrm{Jy\ beam}^{-1}$.
   - CALIBRATION PARAMETERS: The user selects that these are polarization observations.

4. **Apply Observing Strategy:**

   There is an algorithm that selects the array configuration(s) based on the user input. Since the sources are point sources any configuration is acceptable. (In practice, if there are diffuse structures along the line-of-sight we would want a more compact array configuration.)

   There is an algorithm that decides if wide-field is necessary or if a single-field suffices. Since the sources are point sources single-field is chosen.

   There is an algorithm that selects the FRONT-END based on the user input. The two observing frequencies of 5 GHz and 9 GHz implies C-band and X-band, respectively. The *Specification Constraints* include: the C-band and X-band receivers cover the proposed frequency and bandwidth; and these receivers are available for single-field continuum observations.

   There is an algorithm that selects the BACK-END based on the user input. For VLA Continuum observations the only BACK-END available is wide-band WIDAR. The *Specification Constraints* include: wide-band WIDAR is available with the C-band and X-band receivers; wide-band WIDAR is available for single-field Continuum observations.

   There is an algorithm that recommends how best to configure wide-band WIDAR given the user input. For example, the selection of the basebands and their placement. Since better spectral resolution is desired the default setup is not optimal. A better setup is [4×2 GHz (3bit) centered on 4.5, 6.55, 5.52, & 7.47 GHz] for C-band and [4×2 GHz (3bit) centered on 8.52, 10.57, 9.55, & 11.48 GHz] for X-band, both with a 1 MHz spectral resolution. The default dump time of 3 s would probably be sufficient. Full stokes would be selected since these are polarization observations. The *Specification Constraints* include: the dump time is within the specified range; and the data rate is within the specified range.

   $\rightarrow$ The output is a *Science Target List*.

5. **Apply Observation Planner:**

   There is an algorithm that partitions the *Science Target List* into subsets that share a common *Calibration Strategy* and *Scheduling Strategy*. For example, a clustering algorithm that decides how to group the sources together. Here the two field sources are nearby and the frequencies close, so they would probably be in the same partitioned group.

There is an algorithm that decides on the calibration. We will need to observe a Flux Density calibrator to set the intensity scale. An algorithm will select the best Flux Density calibrator given the relative locations on the sky and the LST range of the *Scheduling Block*. There is a phase referencing strategy to perform the complex Gain calibration. This would locate an appropriate phase calibrator on the sky (e.g, within $10°$). Even though these are continuum observations we still need to perform a Bandpass calibration since the continuum will consist of multiple, broad channels. Polarization calibration is required so we would need to observe a polarization calibrator. Since we are observing below 15 GHz pointing observations are not required.

There is an algorithm that generates a *Scan List*. At C-band and X-band we need to observe the Gain calibrator every 10 minutes, and therefore we have to interleave *Scans* of the Gain calibrator in with *Scans* of the two sources. If both frequencies are observed within the same *Scheduling Blocks* each calibration observation must be done at each frequency (e.g., Flux Density, Bandpass, Gain, and Polarization).

The length of the *Scan List* will depend on how long the SOURCE is above the horizon and otherwise be optimized to balance the overhead with the probability of being scheduled. Since we are observing at lower frequencies the weather is not a serious issue and we can have slightly longer *Scheduling Blocks*.

During validation the software decides if the OBSERVING CONDITION is GO, SRO, or RSRO based on the *Specification Constraints*. Here the OBSERVING CONDITION is SRO.

$\rightarrow$ The output are *Observation Specifications*.

3.2 (VLA) Continuum Image of the Orion Nebula

Detect ultra-compact or hyper-compact H II regions via free-free continuum emission in the Orion nebula.

1. **Select Facility:** The user selects “VLA” from a list of available *Facilities* in this *Solicitation*.
2. **Select Capabilities:** The user selects “Continuum” from a list of available *Capabilities* for the VLA in this *Solicitation*.
3. **Specify Capability Requests:**
   (a) Continuum
   - FIELD SOURCES: The user specifies the coordinates for Orion (J2000: RA=05:35:17.3, Dec=-05:23:28) and the extent ($1° \times 1°$).
   - SPECTRAL SPECS: The user specifies the center frequency (35 GHz) and bandwidth (8 GHz). In practice there will be defaults or options available to select.
   - PERFORMANCE PARAMETERS: The user specifies the required angular resolution ($5''$), largest angular structures ($30''$), and rms sensitivity ($100\,\mu\mathrm{Jy\ beam}^{-1}$). The user specifies that the requested purpose is a detection experiment and that the source type is compact.
   - CALIBRATION PARAMETERS: The user selects that these are not polarization observations.
4. **Apply Observing Strategy:**

   There is an algorithm that selects the array configuration(s) based on the user input. For example, the VLA D-configuration would probably be selected here since this configuration is the shortest baseline configuration that provides a synthesized beam less than $5''$ and a largest angular size larger than $30''$ at an observing frequency of 35 GHz.

   There is an algorithm that decides if wide-field is necessary or if a single-field suffices. That is, do we have to perform a mosaic? For example, the primary beam is about $1'.2$ so a single field is not sufficient to produce the requested image and a mosaic is required; that is, wide-field. Once wide-field is selected another algorithm decides if a pointed or OTF mosaic is recommended. For example, the exposure calculator estimates a time of 10 s for an rms sensitivity of $100\,\mu\mathrm{Jy\,beam}^{-1}$ at 35 GHz with a bandwidth of 8 GHz in the D-configuration. The short integration times would probably indicate OTF is optimal because of the reduced overhead.

There is an algorithm that selects the FRONT-END based on the user input. The observing frequency of 35 GHz implies the Ka-band receiver. The *Specification Constraints* include: the Ka-band receiver covers the proposed frequency and bandwidth; and the Ka-band receiver is available for OTF Continuum observations.

There is an algorithm that selects the BACK-END based on the user input. For VLA Continuum observations the only BACK-END available is wide-band WIDAR. The *Specification Constraints* include: wide-band WIDAR is available with the Ka-band receiver; wide-band WIDAR is available for OTF Continuum observations.

There is an algorithm that recommends how best to configure wide-band WIDAR given the user input. For example, the selection of the basebands and their placement. The default setup for Ka-band would probably be selected here: 4×2 GHz (3-bit) centered on 30, 32, 34, and 36 GHz. The dump time would depend on the OTF mosaic details. Also, full stokes would probably be selected even though the user has not indicated polarization observations since the resources are available. The *Specification Constraints* include: the dump time is within the specified range; and the data rate is within the specified range.

→ The output is a *Science Target List*.

5. **Apply Observation Planner:**

   There is an algorithm that partitions the *Science Target List* into subsets that share a common *Calibration Strategy* and *Scheduling Strategy*. For example, a clustering algorithm that decides how to group the sources together. Here there is only one FIELD SOURCE so this is relatively simple.

   There is an algorithm that decides on the calibration. We will need to observe a Flux Density calibrator to set the intensity scale. An algorithm will select the best Flux Density calibrator given the relative locations on the sky and the LST range of the *Scheduling Block*. There is a phase referencing strategy to perform the complex Gain calibration. This would locate an appropriate phase calibrator on the sky (e.g, within 10°). Even though these are continuum observations we still need to perform a Bandpass calibration since the continuum will consist of multiple, broad channels. Polarization calibration is not required since polarization properties are not critical to the science. Since we are observing above 15 GHz pointing observations are required.

   There is an algorithm that generates a *Scan List*. We need to decide how to schedule the mosaic. At Ka-band we need to observe the Gain calibrator every 6 minutes, and therefore we have to interleave *Scans* of the Gain calibrator in with *Scans* of the Orion mosaic. This is a detection experiment for compact sources and therefore good uv coverage is not required. Therefore, there is no need to build up the mosaic with redundant scans at different hour angles.

   The length of the *Scan List* will depend on how long the SOURCE is above the horizon and otherwise be optimized to balance the overhead with the probability of being scheduled. Because the weather at Ka-band is an issue, however, we do not want very long *Scheduling Blocks*.

   During validation the software decides if the OBSERVING CONDITION is GO, SRO, or RSRO based on the *Specification Constraints*. Here the OBSERVING CONDITION is SRO.

   → The output are *Observation Specifications*.

3.3 (GBT) Search for Water Megamasers in 50 Candidate Galaxies

Search for water megamasers in external galaxies which can potentially be used to determine super massive black hole masses and constrain Hubble's constant.

1. **Select Facility:** The user selects "GBT" from a list of available *Facilities* in this *Solicitation*.

2. **Select Capabilities:** The user selects "Spectral Line" from a list of available *Capabilities* for the GBT in this *Solicitation*.

3. **Specify Capability Requests:**

   (a) Spectral Line

   - FIELD SOURCES: The user specifies the coordinates for 50 candidates, their extent, and their Barycentric velocity. Also included could be the expected line flux density and line width.
   - SPECTRAL SPECS: The goal is to tune to the rotational transition of H_2O. The user specifies the single H_2O rest frequency (22.2351 GHz), the necessary spectral resolution ($0.3\,\mathrm{km\,s^{-1}}$), and the velocity span ($2500\,\mathrm{km\,s^{-1}}$).[1]
   - PERFORMANCE PARAMETERS: The user specifies the required rms line sensitivity (6 mJy).
   - CALIBRATION PARAMETERS: The user selects that these are not polarization observations.

4. **Apply Observing Strategy:**

   There is an algorithm that determines if mapping is required. For example, since the extent of the nuclear maser disk should be smaller than the GBT's beam at 22 GHz ($30''$), mapping is not required. The algorithm recommends the best observing mode (e.g., Tracking, OnOff, etc.). For example, for spectral line observations at K-band total power nodding is appropriate. The algorithm needs to choose between using the main antenna to move the source from beam to beam (Nod) or for shorter integration times the subreflector (SubBeamNod). This is mostly frequency and receiver dependent. At K-band Nod is usually the best option.

   There is an algorithm that selects the FRONT-END based on the user input. The observing frequency of 22 GHz implies the KFPA receiver. The *Specification Constraints* include: the KFPA receiver covers the proposed frequency and bandwidth; and the KFPA receiver is available for Nod Spectral Line observations.

   There is an algorithm that selects the BACK-END based on the user input. For GBT Spectral Line observations the only BACK-END is VEGAS.

   There is an algorithm that recommends how to configure VEGAS. For example, mode 4 is appropriate here given the number spectral windows, spectral resolution, and frequency span. There is an algorithm that decides if full Stokes is selected even though the user has not indicated that these are polarization observations. In this case full Stokes would probably not be selected to keep the data rate down. The *Specification Constraints* include: the KFPA receiver is available for Spectral Line VEGAS; VEGAS can accommodate the spectral setup; the dump time is within the specified range, and the data rate is within the specified range.

   → The output is a *Science Target List*.

5. **Apply Observation Planner:**

   There is an algorithm that partitions the *Science Target List* into subsets that share a common *Calibration Strategy* and *Scheduling Strategy*. For example, a clustering algorithm that decides how to group the sources together. Assuming the 50 candidate galaxies are spread across the sky the algorithm would need to consider their separation, LST range above the horizon, and optimum DSS Session size at K-band.

   There is an algorithm that decides on the calibration. For example, since this is a detection experiment we do not need to know the flux density scale very accurately. We only need to observe a Flux Density calibrator in one or two *DSS Sessions*. At 22 GHz the pointing and focus will need to be performed every 1 hr.

   There is an algorithm that generates a *Scan List*. We start with a Flux Density calibrator (at least one time) and then observe a test source (known maser) to check the spectral configuration. Then a sequence of Peak/Focus and Nod scans every hour.

[1] In practice four spectral windows with bandwidth 187.5 MHz are connected with a slight overlap to produce about 700 MHz ($9400\,\mathrm{km\,s^{-1}}$) coverage.

The length of the *Scan List* will depend on how long the group of SOURCE is above the horizon and otherwise be optimized to balance the overhead with the probability of being scheduled. A good compromise at this frequency is to have *DSS Sessions* that are 4 hours long.

During validation the software decides if the OBSERVING CONDITION is GO, SRO, or RSRO based on the *Specification Constraints*. (Currently RSRO does not exist for the GBT.) Here the OBSERVING CONDITION is GO.

$\rightarrow$ The output are *Observation Specifications*.

3.4 (GBT) Observations of ^{3}He^{+} toward the Planetary Nebula IC 418

Measure the $^{3}\mathrm{He}/\mathrm{H}$ abundance ratio in IC 418 to constrain mixing models in low-mass stars.

1. **Select Facility:** The user selects "GBT" from a list of available *Facilities* in this *Solicitation*.
2. **Select Capabilities:** The user selects "Spectral Line/Continuum" from a list of available *Capabilities* for the GBT in this *Solicitation*.
3. **Specify Capability Requests:**

   (a) Spectral Line/Continuum

   - FIELD SOURCES: The user specifies the coordinates for IC 418 (J2000: RA=05:27:28.20, Dec=-12:41:50.2), the extent ($1' \times 1'$), and the LSR velocity ($29\,\mathrm{km\,s^{-1}}$).
   - SPECTRAL SPECS: The user specifies the spectral and continuum setups. The goal is to simultaneously tune to the $^{3}\mathrm{He}^{+}$ transition (8665.65 MHz) and many RRLs to model the PN. The user specifies the 64 rest frequencies, the necessary spectral resolution ($1\,\mathrm{km\,s^{-1}}$), the velocity span ($500\,\mathrm{km\,s^{-1}}$), and the expected line width ($30\,\mathrm{km\,s^{-1}}$).
     The goal is to measure the continuum emission over the same bandwidths as the spectral line spectral windows. The user specifies the same rest frequencies, spectral resolution, and velocity span (bandwidth) as in the Spectral Line setup.
   - PERFORMANCE PARAMETERS: The user specifies the required rms line sensitivity ($1\,\mathrm{mK}$) and the required rms continuum sensitivity ($10\,\mathrm{mK}$).
   - CALIBRATION PARAMETERS: The user selects that these are not polarization observations.

4. **Apply Observing Strategy:**

   There is an algorithm that determines if mapping is required. For example, since the source size ($60''$) is smaller than the GBT's beam at 9 GHz ($90''$), mapping is not required. The algorithm recommends the best observing mode (e.g., Tracking, OnOff, etc.). For example, for observations with wide lines position switching instead of frequency switching produces the best results. The only receiver at 9 GHz is X-band which is a single beam receiver and therefore not able to nod. So OnOff is the best option.

   For the continuum observations the algorithm would probably select CrossScan[2] to determine a better reference. That is, the continuum observations would not be performed simultaneously with the spectral line observations.

   There is an algorithm that selects the FRONT-END based on the user input. The observing frequency of 9 GHz implies the X-band receiver. The *Specification Constraints* include: the X-band receiver covers the proposed frequency and bandwidth; and the X-band receiver is available for OnOff Spectral Line observations.

   There is an algorithm that selects the BACK-END based on the user input. For GBT Spectral Line observations the only BACK-END is VEGAS.

   For the GBT Continuum observations the VEGAS BACK-END would probably be selected since continuum observations could be made at all of the spectral line frequencies.

[2]Currently the only standard GBT procedure to do this is Peak, but here we use CrossScan to distinguish this from calibration procedures.

There is an algorithm that recommends how to configure VEGAS. For example, mode 21 is appropriate here given the number spectral windows, spectral resolution, and frequency span. There is an algorithm that decides if full Stokes is selected even though the user has not indicated that these are polarization observations. In this case full Stokes would probably not be selected to keep the data rate down. The continuum observations would use the same configuration. The *Specification Constraints* include: the X-band receiver is available for Spectral Line VEGAS; VEGAS can accommodate the spectral setup; the dump time is within the specified range, and the data rate is within the specified range.

→ The output is a *Science Target List*.

5. **Apply Observation Planner:**

   There is an algorithm that partitions the *Science Target List* into subsets that share a common *Calibration Strategy* and *Scheduling Strategy*. For example, a clustering algorithm that decides how to group the sources together. Here there is only one FIELD SOURCE so this is relatively simple.

   There is an algorithm that decides on the calibration. We only need to determine the flux density scale to 5-10%. Since the CAL noise diodes are pretty stable we only need to observe a Flux Density calibrator in a few of the *DSS Sessions*. At 9 GHz the pointing and focus will need to be performed every 2 hr. The OnOff observing mode will produce an OFF subscan for a reference, whereas the CrossScan observing mode will reference data at the ends of the subscan.

   There is an algorithm that generates a *Scan List*. We start with a Flux Density calibrator (at least one or two times) and then observe a test source (known RRL) to check the spectral configuration. Since the spectral line and continuum observations go together, we probably will want to interleave the OnOff and CrossScan observations. For example, after each Peak/Focus perform the CrossScan observations and then OnOff every 2 hr.

   The length of the *Scan List* will depend on how long the SOURCE is above the horizon and otherwise be optimized to balance the overhead with the probability of being scheduled. A good compromise at this frequency is to have *DSS Sessions* that are 4 hours long.

   During validation the software decides if the OBSERVING CONDITION is GO, SRO, or RSRO based on the *Specification Constraints*. (Currently RSRO does not exist for the GBT.) Here the OBSERVING CONDITION is GO.

   → The output are *Observation Specifications*.

3.5 (GBT) Search for Pulsars in 20 Candidate Point Sources

Search for pulsars with the PF 800 MHz feed in point sources with pulsar-like properties identified at other wavelengths (e.g. Fermi gamma-ray sources) or at lower time resolution (e.g. VLASS continuum sources).

1. **Select Facility:** The user selects “GBT” from a list of available *Facilities* in this *Solicitation*.

2. **Select Capabilities:** The user selects “Pulsar” from a list of available *Capabilities* for the GBT in this *Solicitation*.

3. **Specify Capability Requests:**

   (a) Pulsar

   - FIELD SOURCES: The user specifies the coordinates of the 20 candidates. (The user may optionally specify an estimate of the mean flux density, period, duty cycle, or dispersion measure; otherwise these would take on default or null values.)
   - SPECTRAL SPECS: The user selects from a list of receiver frequency ranges. For most pulsar observations the goal is to maximize sensitivity and therefore the user seeks the maximum available bandwidth at some frequency. In this case the frequency range is 680–920 MHz. (For the higher frequencies there may be multiple choices within the receiver band since the bandwidth is limited by the IF system.)

- PERFORMANCE PARAMETERS: The user specifies the required time resolution (40 μs) and rms sensitivity (0.1 mJy). (If the user provides an estimate of the mean flux density, etc. per source then this information could be used to estimate the rms sensitivity per source. In practice, however, there are many factors that go into the sensitivity and the user may want to specify a time. The user can opt out and specify a time but must include a justification.)
- CALIBRATION PARAMETERS: No flux density or polarization calibration is required. That is, flux density or polarization calibration sources do not have to be observed. But full stokes is usually desired. (In principle there are three choices for polarization calibration: (1) None: nothing is done; (2) Amp/Phase: turn on noise diode once per source; and (3) Full Mueller Matrix: need to observe a polarization calibrator. Here (2) would be selected.)

4. **Apply Observing Strategy:**

   There is an algorithm that determines if mapping is required. Since these are point sources mapping is not required. There is an algorithm that determines the best observing mode. Since pulsars are always observed in total power mode with no noise diode injection, there is no switching for the science observations. Here we would select the Track observing mode.

   There is an algorithm that selects the front-end based on the user input. In this case it is the PF 800 MHz receiver. The Specific Constraints include: the PF 800 MHz receiver covers the proposed frequency and bandwidth; and the PF 800 MHz receiver is available for Pulsar observations.

   There is an algorithm that selects the back-end. For GBT Pulsar observations the only back-end is VEGAS.

   There is an algorithm that recommends how to configure VEGAS. For example, if the total bandwidth is greater than 1.25 GHz then multiple banks will be used. In this case, the user selected a 200 MHz bandwidth, so only one bank will be used. If a dispersion measure is given then coherent dedispersion will be used, otherwise incoherent dedispersion will be used. Since polarization information is desired (option 2), both self and cross terms will be recorded.

   There is an algorithm that determines the frequency resolution and sampling time. For example, the quadrature sum of the sampling time and the dispersive smearing time across a frequency channel is less than the required time resolution. If a DM is provided then coherent dedispersion is used and the dispersive smearing time goes to zero. The Specification Constraints include: the PF 800 MHz feed is available for Pulsar VEGAS; VEGAS can accommodate the necessary bandwidth, sampling time, frequency resolution, and polarization mode.

   $\rightarrow$ The output is a *Science Target List*.

5. **Apply Observation Planner:**

   There is an algorithm that partitions the Science Target List into subsets that share a common Calibration Strategy and Scheduling Strategy. For example, a clustering algorithm decides how to group the sources together. Assuming the 20 candidates are spread across the sky the algorithm would have to consider their separation, LST range above the horizon, and optimum DSS Session size at PF 800 MHz.

   There is an algorithm that decides on the calibration. Flux density and polarization calibrators do not have to be observed. But the noise diode will have to be turned on for a short time (60–90 s) prior to every science observation of a target.

   There is an algorithm that generates a Scan List. Pointing is not necessary but a test observation on a known pulsar needs to be observed at the start of each DSS session. Then a sequence of Track scans on each source. The length of the Scan List will depend on how long a group of field sources is above the horizon and otherwise be optimized to balance overhead with probability of being scheduled.

   During validation the software decides if the observing condition is GO, SRO, or RSRO based on the Specific Constraints. (Currently RSRO does not exist for the GBT). Here the observing condition is GO.

   $\rightarrow$ The output are *Observation Specifications*.

A Definitions

Allocation Disposition: The disposition of a given *Allocation Request* to use observatory resources. This includes scheduling priorities, approved time, disposition comments, disposition constraints, and proprietary periods.

Allocation Request: The part of a *Proposal* that specifies the details of the requested observatory resources.

Back End: The instruments that exist on a telescope that usually reside at the end of the signal path. Primarily this refers to the detector, often a correlator.

Calibration Strategy: An algorithm or heuristic that decides on how to best calibrate the data. For example, is bandpass calibration necessary?

Call Period: The time period during which a user can created, edit, and submit a proposals for a given *Solicitation*.

Capability: The different ways a *Facility* may be operated. Examples are OBSERVING TYPES and sub-arrays. OBSERVING TYPES consist of Continuum, Spectral Line, Pulsar, and Radar. Each *Capability* is associated with one *Facility*.

Capability Parameter Specifications: Information provided by a TTA Group member that specifies the parameters that make up a *Capability* for a *Solicitation*. There can be different types of parameters. For example, FIELD SOURCES, SPECTRAL SPECS, PERFORMANCE PARAMETERS, and CALIBRATION PARAMETERS.

Capability Request Parameters: The proposer's response to the *Capability Parameter Specification*.

Capability Request: Information supplied by the proposer that specifies the observations being proposed. The *Capability Request* is composed of the *Capability Request Parameters*.

Consensus Science Review: A scientific evaluation of a proposal based on a consensus of the SRP formed during a discussion of the proposal by all reviewers using information from the individual science review. This includes internal (e.g., TAC) and external (P.I.) comments, plus an SRP SCORE.

Directors' Review Report: A report written by the TTA Group for the NRAO/GBO Director that summarizes the recommendations made by the TAC for semester *Solicitations*.

Disposition Letter: A letter (or email) sent to the authors of a submitted proposal that summarizes the results of the review process.

DSS Session: Information to schedule a continuous block of time on the GBT.

Execution Blocks: The results of *Scheduling Blocks*.

Execution Periods: The nominal time period during which a proposal will be observed for a given *Solicitation*.

Facility: One or more antennas that coordinate to perform observations. For example, the VLA consists of 27 antennas but is typically one *Facility*. The HSA may consist of all 10 VLBA antennas and all 27 VLA antennas but is considered as one *Facility* since the signals from all telescopes are correlated together. A *Facility* may also be a computing cluster to reprocess data.

Facility Report: A report created by a TTA Group member for each *Facility* that provides a narrative for the TAC and identifies any technical, resource, or scheduling issues. The report includes an LST (or GST) pressure plot.

Feasibility Review: A review of the feasibility (technical or data management) of a given *Allocation Request*.

Feasibility Review Group (FRG): Consists of one or more feasibility reviewers that are tasked to review the same set of *Allocation Requests*.

Field Source: Coordinate information for an observation that includes position, field of view, velocity, and time (when ephemerides are required).

Front End: The instruments that exist on a telescope that usually reside at the beginning of the signal path. Primarily this refers to the receiver.

Hardware Configuration: The specific details of the FRONT-END and BACK-END and their configurations.

Individual Data Management Review: An assessment of the data management plan of the *Allocation Requests* that includes internal (e.g., TAC) and external (e.g., PI) comments.

Individual Science Review: A scientific evaluation of a proposal that includes internal comments and an INDIVIDUAL SCORE.

Individual Technical Review: A technical assessment of an *Allocation Request* that includes internal (e.g., TAC) and external (e.g., PI) comments.

Joint Proposal: A proposal that requests time on multiple *Facilities*. This is handled by having different *Allocation Requests* for each *Facility* and therefore the term joint will not longer be used here. But this nomenclature is well established in the astronomical community (e.g., joint HST-NRAO proposals) and therefore will continue to be used in the documentation (e.g., the call for proposals).

LST (or GST) Pressure Plot: A plot of the allocated hours as a function of LST (or GST) for a given *Facility*, broken down by scheduling priority and weather.

Observation Planner: The algorithm or heuristic that converts the *Science Target List* into the *Observation Specification*. The *Observation Planner* contains the *Calibration Strategy* and the *Scheduling Strategy*.

Observation Specification: A *Scan List*, and *Facility* specific information (e.g., OBSERVING CONDITION, VLA array configuration, etc.).

Observing Condition: Indicates whether the proposed observing is standard or has some shared risk. For example, general observing (GO), shared risk observing (RSO), or resident shared risk observing (RSRO).

Observing Strategy: The algorithm or heuristic that decides how to observe the FIELD SOURCE (e.g., pointed map instead of OTF). The algorithm that translates the *Capability Request* to a *Science Target List*.

Observing Type: High level concept to distinguish different *Capabilities*. For example, Continuum, Spectral Line, Pulsar, etc.

Open-skies Proposals: Proposals that are submitted under a *Solicitation* that is open to the overall community.

Pointing Pattern: Describes the trajectory of the antenna over the course of an observation of a FIELD SOURCE. For example, single pointing, OTF, etc.

Program: Information provided in the *Proposal* that specifies the knowledge of how/when to combine *Execution Blocks* to produce *Science Ready Data Products*.

Project: An observatory construct to execute each approved *Allocation Request*.

Proposal: A request to use observatory resources that includes a scientific and technical justification. Here, observatory resources is typically telescope time but may also include other types of resources (e.g., correlator or computing cluster time). The information contained within a *Proposal* is sufficient for evaluating the request and for scheduling, executing, and processing of any approved requests.

Proposal Class: Provides a set of different validation rules within a *Solicitation*. For example, Regular versus Large proposals.

Proposal ID: An ID that is associated with the proposal *Solicitation*. The PROPOSAL ID is created once the proposal is submitted.

Proposal Information: The part of a *Proposal* that includes identifying information, title, abstract, and the scientific justification. The *Proposal Information* is independent of the resources that are being requested.

Proposal Process: How a proposal is processed through the system.

Proposal Review: An evaluation of the scientific merit and feasibility of the proposal. A proposal review consists of comments for the PI, internal comments, and a scientific merit metric.

Proposal Serial Number: A unique global number that is associated with a proposal when it is created.

Request Specification: Specifies the resources that are being requested in the *Allocation Request*. There are different types of *Request Specification*. For example, *Observation Specification* is the common type of *Request*

Specification where the *Facility* involves telescope. But the *Request Specification* could be a *Data Processing Specification*, where the *Facility* is a computing cluster.

Requested Time: The time spent on the SOURCE to account for the requested rms sensitivity, POINTING PATTERN, and additional considerations.

Proposal Summary: A summary of each proposal that provides an abridged view of the proposal that aids in the discussion during the TAC meeting. Specifically, the PROPOSAL ID, NORMALIZED LINEAR-RANK SCORE, SRP NAME, TELESCOPES, PRINCIPAL INVESTIGATOR, CO-INVESTIGATORS, TITLE, ABSTRACT, PRELIMINARY PRIORITIES, COMMENTS FOR THE PI, and INTERNAL COMMENTS.

Resource: Equipment and/or staff. Effectively the dictionary definition.

Review State: For individual science reviews this corresponds to the state of the review in time (e.g., blank, saved, completed, or closed).

Review Type: For individual science reviews this corresponds to the type of review that is assigned (e.g., primary, secondary, tertiary, or none).

Scan: A group of *Subscans* that share scan intent. All *Scans* have at least one *Subscans*.

Scan List: An ordered list of *Scans*.

Scheduling Block: Information to schedule a continuous block of time on the VLA.

Scheduling Priorities: a grade that is assigned to each *Allocation Request* that sets the priority that the observations will be scheduled. This may also be to schedule a computing cluster to reprocess data.

Scheduling Strategy: An algorithm or heuristic that decides how best to generate a list of *Scans* which could be observed to obtain the author's scientific objective.

Science Category: The astronomical sub-field of the science related to a *Proposal*.

Science Ready Data Products: Processed data that in principle can be used for scientific analysis.

Science Review Panel (SRP): A group of people who are tasked to review the scientific merit of a *Proposal*. Each SRP has a chair and, potentially, a chair pro tem.

Science Target: One SOURCE, one HARDWARE CONFIGURATION, the REQUESTED TIME, the array configuration (VLA only), and a repeat counter.

Science Target List: A data structure that contains the fundamental user request. Consists of a list of *Science Targets*.

Scientific Merit Metric: A quantitative assessment of the scientific merit of the proposal. For a Panel-based review this is the NORMALIZED LINEAR-RANK SCORE. For an observatory site review this is binary.

Segment: Information to schedule a continuous block of time on the VLBA.

Solicitation: An announcement from the observatory to the community to submit a request to use observatory resources. Each *Solicitation* is composed of *Capabilities* and a *Proposal Process*. A *Solicitation* has attributes (e.g., call period).

Solicitation Capability: The *Capability* for a specific *Solicitation*.

Source: A normalized data structure that contains a name, POINTING PATTERN, and a nominal position for the POINTING PATTERN. A SOURCE is derived from a FIELD SOURCE or created for a calibrator.

Specification Constraints: The restrictions on the available resources within a *Capability* for a *Solicitation*.

Sponsored Proposals: Proposals that are submitted under a special *Solicitation* that is sponsored by a particular organization and is therefore not open to the community at large.

Subscan: Specification of the shortest unit of observation considered in the TTA Tools. Each *Subscan* consists a single SOURCE, HARDWARE CONFIGURATION, and time (e.g., acquisition and setup times). Also included is information about the antenna trajectory and the scientific intent.

Validation Constraints: The information necessary to check that the inputs to a *Proposal* are valid (e.g., the frequency range of a receiver).

TAC Report: A report written by the TTA Group for the public that summarizes the results of the TAC meeting for semester *Solicitations*.

Telescope: An instrument used to gather light from distant objects. The dictionary definition.

Triggered: An observation that is observed at an unknown time based on a precipitating event.

TTA Group: Authorized observatory TTA staff who are responsible for administering the TTA process.

B Observing Type

The OBSERVING TYPE provides high level information about the type of observations that are being requested. For example, the goal may be to measure the free-free emission which is continuous emission. Below we describe the different OBSERVING TYPES.

- Continuum. There are several astrophysical mechanisms that produce emission over a continuous range of frequencies (e.g., blackbody, free-free, synchrotron, etc.). The observing strategy is often to use large bandwidths to increase the sensitivity and to measure the spectral shape of the emission.
- Spectral Line. Atoms and molecules produce spectral lines that are relatively narrow features in frequency. The observing strategy is therefore to use several to many spectral channels depending on the scientific objectives, with the channel width itself also being dependent on the science (e.g., detecting a line versus spectrally resolving a line).
- Pulsar. These compact objects rotate fast and produce pulsed emission that requires fast sampling. Special BACK-ENDS are typically built for pulsar observations.
- Radar. Radio waves are transmitted by a *Facility*, reflect off an astronomical object of interest (e.g., asteroid) back toward the Earth, and are received on one or more *Facilities*.

For some science both spectral line and continuum OBSERVING TYPES are required for the science. This can be accommodated in some cases (e.g., VLA spectral line).

C Capability Request

Following ALMA we organize the user input into spatial, spectral, performance, and calibration information. Here we call these FIELD SOURCES, SPECTRAL SPECS, PERFORMANCE PARAMETERS, and CALIBRATION PARAMETERS. Below are some examples of the required information.

C.1 Field Sources

- Name.
- Coordinate system (e.g., FK5 J2000).
- Longitude (e.g., 05:03:43.2).
- Latitude (e.g., 43:02:05.3).
- Parallax (e.g., $0\,\mathrm{mas}$).

- Proper motion RA (e.g., $0\,\mathrm{mas\,yr^{-1}}$).
- Proper motion Dec (e.g., $0\,\mathrm{mas\,yr^{-1}}$).
- Source radial velocity (e.g., $-5.3\,\mathrm{km\,s^{-1}}$).
- Velocity reference frame (e.g., LSRK).
- Doppler type (e.g., Radio).
- Extent (e.g., $1\,'$ circle).
- Position ephemeris (e.g., file with coordinates as a function of time).

C.2 Spectral Spec

- Continuum.
  - Name.
  - Center frequency (e.g., $35.0\,\mathrm{GHz}$).
  - Bandwidth (e.g., $8\,\mathrm{GHz}$).
- Spectral Line.
  - Name.
  - Center frequency (e.g., $9.0\,\mathrm{GHz}$).
  - Bandwidth (e.g., $500\,\mathrm{km\,s^{-1}}$).
  - Spectral resolution (e.g., $1\,\mathrm{km\,s^{-1}}$).
- Pulsar.
- Radar.

C.3 Performance Parameters

The parameters to specify the performance will depend on the *Facility*.

- VLA
  - Angular resolution (e.g., $1\,''$).
  - Largest angular structure in the source (e.g., $30\,''$).
  - Sensitivity (e.g., $2\,\mathrm{mJy\,beam^{-1}}$).
- GBT
  - Sensitivity (e.g., $2\,\mathrm{mK}$).

C.4 Calibration Parameters

Whether or not these are polarization observations. This is not the polarization products (e.g., single, dual, full), but whether accurate polarization properties are necessary.

References

Costa, A. H. (2021). *Telescope Time Allocation (TTA): Algorithms*. Tech. rep. 688-TTAT-xxx-MGMT. National Radio Astronomy Observatory.