GEMMA Time Domain Astronomy Scheduler Science Requirements

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1 Purpose and Scope

The purpose of this document is to provide the top-level science software requirements for the adaptive queue scheduler portion of the Gemini in the Era of Multi-Messenger Astronomy (GEMMA) project. The background and motivation of the OCS Upgrades Program are given in the OCS Upgrades Program Mandate and the GEMMA Project Execution Plan. The requirements and stories presented here are based on recommendations from the 2020-2030 strategic plan, previous software planning, the 2015 Science Operations Review, user interviews, discussions of the 2017-2018 OCS Upgrades Working Group, meetings of the Gemini operations teams (eg. SOS, SUSD, TAC teams) during 2018, and the 2019 OCS Upgrades staff working groups.

This document is written so that Gemini staff and external reviewers can understand the goals and requirements of the system for review and reference. Reference documents are listed in Section 2. Section 3 provides the motivation for building an automated Scheduler tool, Section 4 lists the top level goals we hope to achieve, Section 5 gives important operational concepts, and Section 6 lists the detailed requirements. Section 7 contains user stories - examples of how the tool is expected to be used. Many of the requirements listed in Section 6 were derived from these use cases, and links are provided in the requirements to the relevant stories.

2 Applicable Documents

Queue Scheduler Scoring and Metric
Scheduler Testing and Verification
Gemini Automated Scheduler Trade Study
Gemini Automated Scheduler Software Design
Gemini Scheduler Implementation Plan

3 Background and Motivation

It has been a long standing desire to have an adaptive queue scheduler to generate nightly queue plans for Gemini Observatory in an automated way. Currently a Queue Coordinator at each site is expected to spend 4 hrs of every day to generate queue plans for every potential permutation of weather conditions. The bulk of these condition variants are never used. The efficiency of this manual, time consuming process is therefore quite low. In addition, these plans are static and not updated at night when faults occur, rapid ToOs are triggered, or observations take more or less time than predicted. Because the plans are static, swapping between variants when conditions change has its own set of issues. There might not be an optimally placed observation to start in the new variant at the given time, or an observation may have been placed in both variants, and depending on placement in the 2 variants, it may mean that the observation is missed entirely or already completed thereby leaving a large gap in the plan. Observers must do what they can with the observations as provided in the plans in the various conditions variants or wake up a QC in the middle of the night in order to generate a new plan for the remainder of the night.

In addition, the NSF Vera C. Rubin Observatory is currently under construction on Cerro Pachón near La Serena, Chile, and will take Multi-Messenger Astronomy (MMA) and time-domain astronomy (TDA) to the next level. For the Legacy Survey of Space and Time (LSST), the Rubin Observatory will image the entire visible sky every few nights for ten years in order to identify variable and transient objects and make very deep stacked images. It will produce thousands of new alerts every few minutes from variable stars, AGN, solar system bodies, and all varieties of cosmic explosions. It will not be possible to understand the nature of many of these detections from the survey photometry alone, so follow-up observations in other modes and at other electromagnetic wavelengths will be required.

MMA is one of NSF's Ten Big Ideas. It combines the results from some of the NSF's major astrophysics facilities in order to elucidate the nature of new and rare events. In response to the NSF-sponsored report by the National Research Council on Optimizing the U.S. Ground-Based Optical and Infrared Astronomy System and the NOAO/LSST report on Maximizing Science in the Era of LSST, NOAO initiated a project to establish a transient follow-up network based on the Las Cumbres Observatory design and incorporating multiple facilities, including Gemini, all now under the umbrella of NSF's National Optical-Infrared Lab.

This work aligns Gemini Observatory squarely with NSF priorities. The TDA project (part of the GEMMA award) will allow Gemini to take a leadership role in this era of MMA and transients. Being among the largest of the optical-infrared (OIR) telescopes, Gemini has an important role to play in the follow-up study of fainter transients. Gemini already observes many transients under its Target-of-Opportunity (ToO) observing mode, but the process is somewhat manual and inefficient and cannot currently handle the expected increase in the number of ToO triggers. The overall objectives of the TDA project are therefore to:

- Allow Gemini to cope with the expected massive increase in follow-up ToO requests, interrupts and the resulting rescheduling,
- Satisfy user demand for transient follow-up while preserving our ability to support non-transient observational programs
- Ensure that the observatory is efficiently utilized in a wider network of telescopes for transient science in the MMA era

The scheduler is a critical component in the GEMMA/TDA award and will allow Gemini to efficiently handle the expected increase in ToOs.

Finally, the Scheduler project will take advantage of the timing of the Gemini Program Platform (GPP) project, currently underway. These upgrades are critical to provide the information that an automated scheduler must have in order to correctly schedule programs at the required times and intervals, with correctly associated calibrations, and taking into account minimum block sizes for the science observations.

One of the primary deliverables of the GEMMA TDA component of the OCS Upgrades Program will be an automated observation scheduler. The Scheduler will run in real time and generate new observing plans for both Gemini telescopes within minutes as events occur. This will make the telescopes much more adaptable to events at night, naturally handling changes in weather conditions, ToO triggers, other updates to the database, and loss of capabilities due to faults, as well as significantly reducing the workload of the QCs and observers.

In addition to the automated real-time scheduling, the scheduler will also be able to create observing plans over multiple nights to several months into the future in a simulation mode, using forecasts, weather statistics or simulated conditions, and the telescope calendar. Providing simulations for the next several nights will enable QCs to investigate the effect of instrument component changes and allow for automated public webpage updates with likelihood of target observation. Longer term simulations will be critical for initial testing of the Scheduler and of different metrics and rules in order to optimize these, but will also be used in operations by core QCs/Head of SciOps to investigate the impact on the queue for different timings of visitor instrument blocks, Priority Visitor (PV) runs, instrument exchanges, etc.

In summary, an automated Real-time Scheduler will enable both day and nighttime operations to be much more efficient and is critical to enable the expected quantity of TDA science in this new era of Multi-Messenger Astronomy. We further note that, although the current design is intended and optimized for Gemini Observatory use, the scheduling algorithm is capable of handling multiple telescopes and, with a modular design, it should be possible to include site specific scoring and optimization algorithms. The software will be written in python using APIs to communicate with the database, so in the future, it would be possible to extend the Scheduler S/W to other observatories within the NOIRLab network, further broadening the impact of this new tool.

4 Top Level Goals

The top-level goals for the scheduler effort are:

- Support the completion of the following high-level science operations aims:

    1. For TAC-approved science programs, within their natural term (e.g. currently, a Band 1 program's natural term is ~two semesters), aim to:
        a. Provide science data and all calibrations required by the proposal
        b. Complete to 100% the highest ranked programs within their natural term ("highest" defined in a way which may vary), irrespective of their length in hours
        c. Complete lower-ranked, non-filler (currently B2) programs to a level consistent with publication within their natural term (current evidence says that this level is 80%)

    d. Be flexible on priority within a band priority (e.g. foster Theses, time critical observations)

2. Be transparent on what trumps what (conditions, urgency, priority) and where we need to be flexible
3. Respect Partner shares in some agreed way (currently, allocated time)
4. Not run out of things to observe
5. Be able to handle all allocated ToO programs without more than some agreed degree of impact on the completion of regular programs as determined by the Board and Directorate.
6. Where visiting instruments or facility modes have to be scheduled in blocks, assign enough time for completion of higher ranked programs, but not so much time that regular queue is measurably compromised.

- Enable robust and efficient execution of observations at night by improving and streamlining the observer experience with respect to varying weather conditions, faults, and rapid target of opportunity observations (rToOs).

- Reduce staff manual queue scheduling to simple oversight and occasional human intervention.

- Prepare Gemini for its role in the next decade as the prime facility for efficient execution of flexible and innovative science programs.

- Keep Gemini productive compared to comparable observatories as measured by program completion statistics. Other things being equal, the observatory shall maintain or exceed current program completion rates.

- Support increasing rates of ToOs and Gemini's participation in time domain follow-up networks (e.g. AEON), while maintaining high completion rates for regular queue programs.

- Allow for better informed telescope scheduling (instrument changes, visiting instruments, classical and PV runs, etc) via a Scheduler simulation mode for longer term scheduling.

5 Scheduler Operations Concepts

The primary job of the scheduler is to drive science programs to at least 80% completion in order to produce publishable datasets. A *program* is the main organizational unit for a science experiment at Gemini that is allocated a number of hours and a science ranking (band). It consists of observations that define how to take data of a region of the sky with an instrument.

In GPP, programs will be able to contain observations for either Gemini site. Programs are "active" to be scheduled for a fixed period of time ranging from a few weeks to six *semesters*, each covering a period of six months.

An *observation* comprises the information necessary to observe a position on the sky with one instrument and it includes targets, the requisite environmental conditions, timing constraints, and the necessary instrument and telescope systems configurations. For the purposes of time accounting, observations may be classified as "science", "program calibration" (charged like science), or "partner calibration" (charged to the Gemini partner(s) that approved the program, and not directly to the program). Program calibrations are defined by the science teams, but GPP will automatically generate the necessary partner calibrations. Partner calibrations, also known as baseline calibrations, are a minimum set of calibrations that will allow all data to be uniformly processed.

Observations and their requisite calibrations can be grouped together to form *observation groups*. (For the purposes of this document, we will assume that all observations belong to a group: thus, a single observation will be placed in a group consisting solely of it and its partner calibrations.) Groups can be hierarchical and the members of groups can be connected by timing or various logical constraints. The observations within a group can be connected with different logic. Some observations may be connected with an OR (e.g GMOS-N or GMOS-S) while others can be connected with AND logic (e.g. the included three observations must be done consecutively or on the same night).

A *target of opportunity* (ToO) is any target that is unknown when the proposal is submitted. The targets are usually identified in subsequent surveys, and they are often astronomical objects undergoing unexpected or unpredictable phenomena. Due to this, observing them is of particular importance since often they can only be examined for a limited period of time.

In many observatory scheduling systems the observation is the minimum schedulable unit, consisting of a slew, target acquisition, and the collection of science data with an instrument. These observations are often limited in length (e.g. one hour) and must be completely redone if they do not meet specifications. This can lead to a large amount of acquisition overheads and repeated steps.

Gemini has always had a more flexible concept for an observation. In general, an observation is a set of configurations and telescope actions that will result in data of a required integration time on a source with one instrument. Each observation is itself divided into individual steps that define the commands that will be carried out sequentially by the telescope. This list of steps is referred to as a sequence. Some steps of the sequence must be done together in order to produce a useful dataset. This minimum grouping of steps is known as the minimum schedulable unit, or atom. The atoms determine where sequences can be split.

Some observations must be executed in their entirety, but many do not. For the latter, Gemini maintains the flexibility to split them for scheduling purposes. The amount of splitting must be kept reasonable - preferably minimized - to keep acquisition overheads low. Experience has shown that the vagaries of weather often result in observations with some steps that meet requirements and a few that do not. Gemini will stop executing an observation when the conditions no longer meet requirements and will only repeat the steps that are out of specification or which are not part of a complete atom. This reduces the amount of repetition and can help the observation to be completed more quickly. This means that the scheduler and GPP must be capable of splitting groups / observations and repeating certain steps. While this approach is very flexible it means that the calculations of the amount of clock time that will be required to finish an observation will only be approximate.

The Gemini telescopes will continue to be operated at night by humans; the systems are too complicated to roboticize. Therefore, the scheduler is a tool to allow the observers to make the best possible decisions and to reduce their workload so that they can focus on taking the data correctly. The scheduler cannot assume that any plan will be followed or that an observation will start or stop according to the time in the plan. It will have to adapt to the actual situation and give the observers the best suggestion for the moment. Therefore, while it is expected that the scheduler will suggest new plans to the observers as conditions change, the observers will have the final decision and will be able to start, stop, and run the scheduler as needed. The use cases below provide more details about the expected interactions.

6 Adaptive Queue Scheduler Requirements[1]

1. General functional requirements

1.1 The automated real-time scheduler system shall create observing plans by maximizing a metric for selecting observations. The metric to be developed uses scientific ranking for prioritization, but the Scheduler will need to factor in matches to conditions, timing constraints, observation visibility, idle time (see 1.3), instrument configurations, and other considerations.

1.1.1 The real-time scheduler shall use a metric that will aim to maximize the number of Band 1 (or equivalent) programs (eg programs in the top third of science rankings) that reach 100% completion within their natural term, and maximize the number of lower ranked non-filler programs (currently Band 2) that reach 80% completion within their natural term, without penalizing longer programs. Any programs that are started (in any Band 1-3) should reach a minimum of 80% completion (or B3 minimum time, if still used). These requirements are extracted from Science Operations Top-Level Aims (Section 4).

[1] Requirements listed in bold are the minimum set needed for a basic working Scheduler. The first operational release will at a minimum include these. We also note that all numerical parameters in the requirements are currently subject to change.

1.1.2 The metric / scoring algorithm to be developed shall not penalize long programs by simply focusing on completing a maximum number of programs which would otherwise naturally lead to the highest completion rate for short programs.

1.2 The scheduler shall be able to schedule observations between sunset and sunrise. Although ‘charged time’ is by policy currently considered the time between nautical twilights, the scheduler must still schedule calibrations and other observations that can handle the brighter skies outside of the nautical twilight times, subject to rules for each site and instrument.

1.3 The real-time scheduler shall ensure that the total time that is planned (science plus baseline calibrations) during non-Priority Visitor (PV) queue observing with facility instruments is at least P% of the available observing time measured between nautical twilights (not including weather loss, faults, and engineering time) as long as there are observations available to fill the night. That is, not more than 100-P% of a night shall be lost to gaps in the plan. The statistics shall be determined using running averages of at least N months.

a. Threshold: P=TBD (98%), N=3
b. Objective: P=TBD (99%)

1.3.1 The automated real-time scheduler shall be able to deliver a new schedule to the telescopes on a timescale shorter than:

Threshold: 1min (typical of the time spent by observers to choose new observations on unstable nights),

Objective: < 1min in order to avoid much idle time (per 1.3).

1.3.2 The Scheduler shall minimize time wasted on sky due to failed attempts at observations requiring better conditions or aborts of current observations in order to slew to a new (non-rToO) observation before minimum block size is reached. This requirement should be factored into the metric/weighting system.

Threshold: No more than 1.5% of a night on average lost due to these causes, as is the case with the current manual scheduling.

Objective: No more than 1% of a night (on average) lost due to these causes.

1.4 The scheduler shall be able to generate automated plans for both Gemini North and South concurrently and coordinate observations that can be taken at either telescope.

1.4.1 For high priority time critical (site independent) observations including rToOs, it shall include the observation in the schedule for the current night at the more appropriate site based on weather conditions and priorities of other observations (along with instrument/component availability). Interrupting rToOs should be scheduled at the first available site.

1.4.2 The scheduler shall determine the more appropriate site for any other observation that can be observed at either telescope taking into conditions, AM, other observation priorities, and telescope/instrument/component schedules and availability.

1.5 The scheduler shall schedule both complete observation sequences and partial sequences, which must be split at appropriate locations in the sequence and include the full set of associated calibrations each time a sequence is scheduled. It shall not split a sequence beyond what has been defined as the minimum block size, which we will call 'atom' throughout the rest of this document. The atom will include any necessary associated calibrations.

1.6 The scheduler shall dynamically update the plan for the remainder of the night throughout the night due to incoming rToOs, other changes to the database, changes in weather, and faults/changes to the available resources (602).

1.6.1 The scheduler shall automatically update plans when current observations are taking more or less time than expected (608). The difference threshold will start at 10 minutes but will be adjusted based on simulations and experience.

1.6.2 The scheduler shall automatically update the plan whenever there are updates to the database. The scheduler should not interrupt the current observation (for bands < B4) before it reaches the minimum block size (atom) except in cases of interrupting rToOs or other much higher priority observations becoming available (607). In the case of non-interrupting observations, the metric should weigh the potential lost and uncharged time against the higher weight of the new observation.

1.6.3 The scheduler shall update automatically based on changes in conditions received from the Conditions server (which in turn determines conditions from weather sensors, the automated quick data reduction quality assessment pipeline (QAP), and/or operator entry) after some minimum time has passed in order to correctly assess changing conditions. These minimum times, TBD, will depend on the type of conditions (Cloud cover (CC), Image quality (IQ), Wind, Water vapor (WV)) that are changing. Changes in the plan should take into account the minimum number of steps and calibrations still needed for the current observation atom (608).

CC: (TBD)
IQ:
Wind:
WV:

1.6.4 The scheduler shall respond immediately to incoming rToOs, for both interrupting and non-interrupting types, and update the plan accordingly within the timescale listed in 1.3.1.

1.6.5 The scheduler shall automatically update the schedule when changes to LGS clearance windows occur (612).

1.6.6 The scheduler shall look ahead to, and fully schedule, the remainder of the night whenever deciding what to do next, since what to do next may be dependent on how the remainder of the night is best filled (604).

1.7 The Scheduler shall continue to schedule observations for active programs up until they use up the available allocated science time + buffer TBD (15min or 10% of program length), or they reach at least 80% completion (or some other defined minimum time), or they reach the end of their active window.

1.8 In poor weather, the Scheduler shall be able to schedule Band 4 observations, engineering (ENG) observations, calibrations such as spectrophotometric standards, or any other observation that can tolerate the conditions, whenever these observations exist, even if these have little to no worth in the semester quality metric. (614)

1.9 The scheduler shall be able to choose appropriate instrument configurations for the coming night or multiple successive nights (over eg a holiday weekend) factoring in upcoming timing windows, long term weather forecasts, and also an engineering personnel schedule. Until this capability is added, QCs will need to make these decisions and include swap dates in an instrument configuration calendar for the Scheduler in order to factor these in to upcoming observation visibility (602).

Threshold: The Scheduler will read a configuration (resource) calendar and factor this into the short term observation visibilities.

Objective: The Scheduler will read a resource calendar and weather forecasts and be able to choose appropriate instrument configurations for the coming nights.

1.10 The scheduler shall read a telescope and instrument schedule and factor this into both times when observations can be scheduled and also into observation remaining visibility.

1.11 It shall be possible to request observations to fill only specific portions of a night (in cases of e.g. a classical or priority visitor (PV) run that cannot fill the entire night, or due to some scheduled engineering task.) (605).

1.12 It shall still be possible for a QC to fully create a manual plan (602), to save/store these manual versions of a plan, and for observers to load and use these static versions at nighttime.

1.13 It shall be possible for a human operator to ignore or turn off reception of the automated plan, **with the exception of rToO alerts**, so that manual operation can be performed (605).

Simulation modes:

1.14 It shall be possible to use the system to predict the observing plan for the expected, or requested, range of conditions for the upcoming night and for different scenarios for instrument configurations. This is for eg the QC to be able to check what might be planned for the night in all possible conditions, for the Scheduler to be able to suggest component changes (and for the QC to be able to make alternate choices if it becomes necessary), and to allow eavesdroppers to be forewarned. (601, 602)

1.15 Total scores (or some value) shall be provided for each requested plan.

1.16 The Scheduler shall be able to make forward looking simulated plans at least N days in the future, where N is the typical weather forecast period, while accounting for weather forecasts and telescope/instrument/staff calendars. These short term forward looking plans will be used to update web pages with the probability of observation execution, allow the QCs to investigate instrument component changes, and compare Scheduler plans with expectations.

1.17 The Scheduler shall also be able to run simulated plans for a full semester/remainder of a semester starting with a snapshot of the database and provide final metric scores for the semester program completion outcome for each simulation. It will take into account the telescope/instrument calendars and day crew availability for component swaps, along with typical weather conditions and rToO rates. These simulations will be used both as initial tests of the Scheduler metric and rules (**validation mode**), and for coreQCs/Head of SciOps to investigate the impact on the queue for different timings of visitor instrument blocks, PV runs, instrument exchanges, etc (simulation mode).

Operations aims (Lower priority requirements or future improvements):

- The scheduler should try to minimize long slews between targets (time lost on-sky) within the same program in the case of equal priority options (602).

- The telescope schedule and some version of the forward-looking observing schedule for the coming night should be published on a public web page and be available via an API. Public information shall include available instruments and configurations, whether the night is queue, classical, PV, or engineering, whether rToOs are accepted, and scheduled observation identification but not target name and coordinates. This latter may simply be a list of observations that are expected to be observed given the forecasted conditions for the night along with probability of execution (601).

- For the upcoming night predicted plans, in order to inform PIs of the likelihood of their observations occurring, or to help choose instrument configurations, each different weather variant for each requested nightly plan could have the score adjusted based on the probability of that condition i.e. the most likely condition has the normalized peak score and other condition variants would have the scores lowered according to a normal distribution.

2. User interface and interaction

2.1 The Scheduler shall have an **Observer interface** (Observe) which the observer will use at night to receive the real-time observing plan, a daytime **QC interface** for short-term planning/checks of the upcoming night or few nights, and a long-term planning (Simulation) interface.

2.2 The Observer interface shall contain plots graphically displaying the plan for the upcoming night/remainder of the night for the current or requested conditions, including:

- Elevation/AM vs time (local/UT/sidereal)
- Alt/Az with wind direction included

2.3 The Observe interface shall highlight in some way the specific observation to observe at the given time.

2.4 The Observe interface shall indicate the remaining time left in an "atom" (including any required calibrations) in addition to the total time remaining in the scheduled sequence (610).

2.5 The scheduler shall provide important information for the observer: type of observation (science/associated calibration/rToO/do-not-split/non-sidereal), information about acquisition/finding charts/guide star, time limits for the observation, conditions requirements, eavesdropping, etc.

2.6 There shall be a way for the observer to skip a suggested observation (in the event of a Phase2 error or other uncertainty in the observation requiring later follow-up with PI) (602).

2.7 The scheduler shall prompt the observer to stop observations that are out of spec based on the current conditions (after waiting for a specified time delay after conditions have changed, as listed in 1.6.3). It should suggest an abort or stop after the current atom and to complete any necessary calibrations before switching observations. The suggestions can be ignored if the observer chooses (608).

2.8 For time critical observations with specific timing windows if, due to some delay, the science observation has not been started in time to complete the observation, or required portion of the observation, within the window, the Scheduler shall suggest to the observer to abandon the observation (stop or abort) and slew to a new observation.

2.9 When changes to the observing plan occur, the interface shall use audiovisual cues.

2.9.1 For interrupting rToOs, there shall be a pop-up window (requesting acknowledgement) and alarm sounds (and possibly different types of beeping sounds for change due to rToO, change due to weather, or simply changes to the database). The scheduler shall state what is expected of the observer (e.g. ‘Continue through step X, take the standard obsID yyy, and then slew to obsID xxx’, or ‘abort and slew to obsID zzz’).

2.9.2 For changes in the plan due to updates in the database, there shall also be a way for the observer to acknowledge the changes. Non-interrupting rToOs and other database changes which do not interrupt the current observation should update the plan automatically after the observer acknowledges the intended plan change.

2.9.3 For changes due to weather, the new current conditions shall be highlighted and the observation denoted as being out of spec (e.g. colored red). There should be a Suggest field in the interface where the suggestion for weather changes remains until the actions have been completed, or until it is no longer necessary (in the event that the observer chooses to ignore the suggestion for any reason). For changing weather conditions, it could be left up to the observer about if/when to change, eg the observer could hit a button to refresh the plan for current conditions after the prompt from the Scheduler.

2.10 There shall be a way for the observer to force the plan to update (in the event of e.g. changes in weather conditions or faults that cause loss of component availability), in the event that the update hasn’t already automatically occurred. The need for this will depend on the frequency of automatic updates.

2.11 There shall be a way for the observer to load/view and use a manual plan. It must also be obvious when the observer is in Manual or Auto mode. When using a manually generated plan, it shall still be possible to use the Scheduler to alert the observer to rToOs.

2.12 There shall be a way for the observer to specify conditions (through the Conditions server) and instrument/component/mode availability (Component/Resource server, due to changes from faults during the night) including any elevation or azimuth restrictions. (603)

2.13 The Observe interface shall have full functionality on all supported operating systems and browsers.

Operation Aims:

- There should be a way for the observer to request observations for only a specified time period, which could include e.g. a request for a short filler observation (605).

Daytime QC interface

2.20 There shall be a QC mode where the user can specify instrument/component availability for the upcoming night.

2.21 The QC interface shall allow conditions input and provide a predicted plan based on this user supplied set of conditions. (601)

2.22 It shall be possible to save and view different stored versions of the plan (for different conditions, simulated and manual). (601)

2.23 The QC interface shall include a graphic view of the plan (elevation-time and Alt-Az plots) for the upcoming night for requested conditions.

2.24 The scheduler shall provide a score or priority value for each observation in the simulated / predicted / realtime plan and total score for the plan so that it is obvious to the QC how the plan was chosen. It should also be possible to see which factors contributed to these scores. It shall furthermore be possible to see the scores for observations that were not included in the plan. (601)

2.25 It shall be possible for a QC to fix/insert an observation in the plan within a given time period and range of conditions. The Scheduler shall fill in around this fixed observation.

2.26 The QC interface shall have full functionality on all supported browsers (including e.g. Chrome, Firefox) and the operating systems that run them.

2.27 The system shall provide a list of observations that are not schedulable at any point in the semester for the given setup or conditions, with an appropriate flag that identifies the issue including e.g. missing ephemerides, target lost, no MOS mask available, no suitable OIWFS star, no remaining timing windows, constraints too restrictive (SB, elevation).

2.28 The system shall provide a list of programs which can no longer reach (> 80% or any other defined minimum) completion with the currently defined observations, in order to allow QCs/Contact scientists to suggest PIs change targets or relax constraints.

2.29 The system shall provide a list or quick access to the list of unfinished programs that have expired within the past week (and those which are about to expire) along with used and remaining time, instrument/mode, etc. so that the QC could manually adjust the end date if desired.

Operation Aims:

- It should be possible for Gemini staff, usually QCs, to manually adjust the scheduling priority/weight of a program or observation in some way (601).

- QCs should be able to adjust the priority for certain systems/instruments/components (eg MOS masks or R831 grating etc) in some way. This would be for unusual cases such as an upcoming PV run that plans to use all mask slots in GMOS which requires all other masks to be removed and thus putting higher priority on getting those observed first, or for retirement of a particular component (eg grating) and thus priority to complete observations that were started with that component. This could be done by manually changing scores for a set period of time. [We note that as a work around, this could be done with timing windows or with the instrument/components schedules, along with having the scheduler take into account the long term forecast.] (601)

- It would be preferable if the scheduler could obtain the forecast probabilities directly and use these for the predicted plan but still allow the QC to check how the plan would change with different sets of conditions.

Long term planning / Simulation interface

2.30 The user shall be able to provide a range of time from the current night going forward over which the simulation should run.

2.31 The user shall be able adjust the fraction of rToOs in the time period (from a default value).

2.32 The user shall be able to adjust the fraction of nights with different weather conditions (from default values).

2.33 The user shall be able to adjust a simulated telescope schedule which initially is taken from the real schedule and can be reverted back to the actual schedule.

2.33.1 It shall be possible to save changes to the simulation telescope schedule and reuse these.

2.34 The scores for each night of the simulation and the program completion rates for each band shall be listed for each night of the simulation.

2.35 The final metric score at the end of the simulation (or **validation** run using data from a past semester for testing purposes) shall be listed along with the individual completion fractions for each program.

2.36 It shall be possible to save/store different simulation/**validation** runs.

2.37 It shall be possible, during the initial testing of the tool, to supply different metrics and priority/objective functions for the simulations/**validation** runs.

2.38 Simulations shall make use of the Resource service personnel calendar in order to know when to allow instrument component changes as the simulator will have to be able to make decisions about when to implement component changes.

2.39 The simulation interface shall have full functionality on all supported browsers (including e.g. Chrome, Firefox) and the operating systems that run them.

Operation Aims:

- It should be possible to use/input long-term forecasted conditions for the upcoming nights.
- It should be possible to see the plan generated for each night of the simulation.
- The simulator should be able to include observations at PhII or other intermediate states in addition to observations in the prepared or ongoing states. The user shall be able to choose which observation states should be included in the simulation. The user shall also have the option to include deactivated programs for specified semesters.
- The scheduler should provide statistics such as completion fraction per instrument for each simulation.
- There should be a way to change the weights of observations, in the same way as for the real scheduling, but which would be applied only in the simulations. This could be done in the same way as the calendar such that the real weights including any manual changes are used by default but can be modified and saved to a filename.
- The scheduler simulator should be available at the ITAC stage of the semester, before the database is fully populated, running simulations using PhI programs over the upcoming semester.

3. Program Types

3.1 The real-time scheduler shall only consider observations within 'active' programs (within their active window). It shall furthermore only schedule 'prepared' (or however that state will be designated in GPP) or 'ongoing' observations from those programs.

3.2 The Scheduler shall consider all prepared Queue (Q)/ Fast Turnaround (FT)/ Long and large (LP)/ Classical (C)/ Director Discretion (DD)/ Science Verification (SV) (and any other future designations) observations in all active programs (602).

3.3 The Scheduler shall also consider observations within ENG programs that have been set to Prepared. These contain throughput monitoring observations (currently equivalent to B2 programs) for each instrument.   (602).

3.4 The scheduler shall not consider classical programs outside of classical nights EXCEPT when somehow designated (which could be the case for giving back time post rToOs during classical runs, or if there is a decision to finish a classical program in queue) (602).

3.5 The scheduler shall not schedule long uninterruptible sequences on scheduled PV nights. All suggested queue observations shall have atoms of max length ~45min (TBD) during PV runs.

3.6 The scheduler shall consider shared calibrations (CAL or other programs) for particular instruments that currently live in separate programs and know the rules for when and how often to schedule them (602). Examples include shared calibrator standards for GRACES, MAROON-X, and Alopeke and photometric standards and imaging twilight flats for GMOS.

3.7 The scheduler shall be able to handle associated calibrations of all flavors - including nighttime partner cals defined within programs (within science sequences or separate observations and with various rules for frequency), partner cals shared among programs (residing in other programs and with various rules for frequency), partner daytime calibrations (automatically queue for the daytime), and program night cals (with PI defined rules for frequency/timing) (602).

3.8 For standard stars, the system shall be able to choose an appropriate target from a list and adjust exposure time based on target magnitude and conditions. If the system is not choosing specific targets from lists/catalogs, the scheduler must be able to schedule targetless observations, where the observer will have to choose targets and set exposure times (602).

3.9 On-sky/same night calibrations that are required for a program shall have the same weight as the science when determining the score for the plan. This is important since observations with longer overhead due to calibrations should not be penalized (610).

Operation Aims:

- ENG programs also include engineering observations such as on-sky checkouts. Depending on how these are defined in GPP, in terms of resources and timing widows, it may be possible for the Scheduler to schedule these types of observations as well.

4. Instrument requirements

4.1 The scheduler shall follow instrument specific rules for scheduling (609). These are detailed in another document and will be provided by each instrument scientist. These rules will also define the default minimum block sizes (atoms) for each instrument and mode.

4.2 Higher priority shall be given to blocked instrument observations during those blocks (this should automatically come out of the visibility calculations and weighting) (609).

4.3 The scheduler shall have enough information about visitor instruments (through the Explore tool) in order to correctly schedule observations using these instruments (609).

4.4 The scheduler shall be able to handle the scheduling of visitor instrument observations for which the current seqexec/Observe tool is not used and for which it may not know the status of the ongoing observation.

4.5 When the scheduler has the capability to provide suggestions for component swaps, it shall follow rules for the frequency of allowed component changes and for the amount of components that can reasonably be changed in a single request. It shall also use a personnel/resource schedule that includes the Engineering support availability.

5. Component availability/weather conditions/other factors

5.1 The scheduler shall be aware of what instrument configurations are available each night (602).

5.2 The scheduler shall be aware of what systems - instruments, modes, WFS, etc. are (un)available at each telescope each night. Scheduled changes could e.g. be read from a calendar. However, staff including the observer, shall be able to make changes to this in the case of faults or modes not yet checked out on sky after an instrument exchange. The scheduler shall not schedule an observation that uses an unavailable component/system/mode. This could be done through e.g. a Components/resource server (602).

5.3 There shall be a way to restrict observations to non-standard elevation and azimuth ranges for nightly observations in the event of dome faults, wind direction, and other issues such as generator exhaust direction. This could also be implemented through the Resource server (603).

5.4 The scheduler shall only schedule observations which require guiding when guide stars are available at the time of observation. This would be needed for parallactic angle observations with OI or non-sidereal observations. For NEO's and other fast moving objects, this means that it will require the usage of multiple guidestars over the length of the sequence. (602).

5.5 The scheduler shall not schedule non-sidereal observations that do not have an available ephemeris (602). These observations should also be flagged.

5.6 The scheduler, QVis equivalent, and any observing plan visualization shall use the ephemeris of a non-sidereal target to interpolate the coordinates as a function of time for scheduling, guide star searches, and target visualization (602).

5.7 The scheduler shall determine the current weather conditions (WV/IQ/CC/wind speed and direction) from either a Conditions server or input from the observer (602, 616).

5.8 Models will be required to estimate the expected seeing at different elevations, and at different azimuth angles wrt the wind direction, given data points from ongoing observations (602). The scheduler will require this information since IQ constraints will be for on-source measurements, and it will need to know if an observation at a particular location on the sky is expected to be in spec.

5.9 The Scheduler will need to have an estimate for CC attenuation wrt location on sky from either a skyprobe type system or from estimates based on satellite images and models.

5.10 Models will be required to estimate target sky brightness (SB) taking into account not only twilight/moon location and phase, but also cloud cover.

5.11 For delivered IQ, the scheduler shall take into account the AM throughout the observation length when determining if it will remain in spec for the duration. If it will not, according to the seeing model, it shall not schedule the observation or schedule only the portion that is expected to remain in spec (613).

5.12 The scheduler shall use a buffer (0.05, TBD) when determining the expected seeing at a given AM (613).

5.13 The scheduler shall take into account the sky brightness throughout the observation duration when determining if the observation will remain in spec in SB for the duration. If it will not according to the SB model, it should not schedule the observation or schedule only a portion that will remain in spec (613).

Operations aims

- The scheduler should be able to request/suggest changes to instrument configurations (including e.g. gratings, filters, masks, IFU) for the coming night based on observation priorities, weather forecast, and forward-looking simulations (602). The weather forecast should be dealt with as a probability for different conditions and these probabilities should be factored into the determination of the optimal configuration.

- The scheduler should be able to plan ahead for components changes needed over weekend/holidays using the engineering support schedule and long term forecast (602).

- The Scheduler should consider long-term weather forecasts and be able to adjust priorities based on this (e.g. losing a CC50 observation and forecast is for a period of clouds beginning in a couple days) (602).

- The scheduler should use information about forecasted conditions during the night and, whenever possible, condition stability of the night when scheduling long minimum block (atom) sizes (602). Condition stability in this case means that conditions have not exceeded the requirements for the program over the past X (TBD) hours.

- The scheduler should be able to schedule Engineering Nighttime Tasks (ENTs) based on a resource availability calendar, where the resources would include people who may need to support the ENT.

- The scheduler should be able to use the observer schedule available through the resource service to schedule only observations with instruments/modes that the observers for the night are trained on.

6. Priorities, factors to consider

6.1 The scheduler shall use a system that will schedule observations like a QC, factoring in:

a. Type (DD/FT/Q/C/LP/ENG/SV): ENG = B2. For the rest, use Band priority + remaining visibility
b. Band/priority ranking
c. Timing constraints/windows (which additionally reduce target visibility)
d. rToO (or prompt/urgentToO) scheduling rules
e. Observation visibility = Available time remaining in semester (or cycle or other active period) to observe (visibility is the current QVis “Sem Hrs” or “Sem Nts”) which should factor in timing windows, sky brightness (SB), instrument availability, elevation constraints, telescope schedule, classical runs, condition probabilities, grating availability probability, etc). This should also factor in remaining time available wrt length of full program (e.g. a Vis fraction for the

program = remaining observable time (∪ for all observations) / length of program). This is in addition to the visibility of each observation separately.

f. Instrument schedule - Which instruments are available and for how long (factored into observation visibility)
g. Instrument configurations available, which configurations are likely to be changed, when configuration changes can occur, and the frequency of these changes.
h. Pre-imaging - assume these should be completed at least 5 weeks before the associated MOS observations can be observed. This should be factored into the visibility of the MOS observations.
i. Whether an observation has been started
j. For B3, whether program has been started (should not try to start more programs than can complete to 80%)
k. How much time left in program (< 80, < 100)
l. Conditions requirements - factor in the remaining likelihood of having a condition for the remaining visibility time, i.e. merge visibility with constraint (f.ex if we have 20h left of visibility and IQ20 then that translates into 0.2*20h=4h)
m. Observation AM (minimize, see also 6.6). It might be possible to implement with IQ on target constraints + S/N constraints (when available) + AM/elevation constraints for programs that need it.
n. LGS shuttering windows (minimize, take into account as time lost on sky, see 6.8, 6.9)
o. PI observation priority within a program: intra program priorities particularly in cases of similar RA.
p. Weather forecast for upcoming nights which may have a significant effect on observation visibility (timing window, instrument coming off, etc)
q. Thesis programs (provide a small bump to the base score) with the aim of completing more programs that will be used for theses. The use and size of this bump shall be determined by the partners.
r. Wind speed and direction. (when the wind speed is expected to be above a limit, avoid pointing within 30-45 degrees on each side. There is also a GS constraint from generator exhaust to avoid pointing in certain AZ directions if on generator and the wind is from that direction.)
s. Whether a sequence can be split.
t. Near semester boundaries, completing observations/programs from a semester that is ending has priority over starting observations from a semester not yet officially started.
u. Program minimum length (e.g. B3 minimum or 80%)

The 2 primary factors to consider are priority score and remaining visibility (available time remaining to observe a sequence).

Most of the above considerations can be factored into remaining visibility (or time lost on sky). Some exceptions may include: bump for thesis programs, PI priority within a program, whether an observation has been started, and minimizing AM.

6.2 The scheduler shall use minimum block sizes/atoms to split observations as needed but will try to minimize splitting for < Nhr segments. N is the assumed frequency for acquisitions and will depend on the instrument, mode, and conditions and is typically ~1-2 hours (602).

6.3 The scheduler shall factor in all required calibrations to the minimum block size (and schedule these with the science). In case of weather changes, it will schedule any required calibrations before requesting the observer to slew to an observation in another program. The time for the required calibrations should also be factored into the time loss if the observation is aborted due to a rToO or weather changes. (602, 610).

6.4 The Scheduler shall be aware of nighttime calibrations that can be shared within a program and not schedule additional and unnecessary calibrations. It shall furthermore adjust the scheduling in order to allow for shared calibrations when proximity to science observations is critical.

6.5 The decision whether to continue to schedule a partial sequence shall take into account the remaining visibility. Once it is no longer possible to complete the sequence to at least 80% (or to achieve the required minimum S/N once that is a constraint) within the active period, the sequence should no longer be scheduled.

6.6 Observations with timing constraints shall be scheduled entirely within the specified timing window period, excluding the time assumed for the target acquisition.

6.7 All notes related to scheduling will have to be digitized: Relational groups and rules (And/Or), frequency, relational timing windows, do not split (min block size=full sequence), etc. These rules, windows, and observing frequencies shall be adhered to (602).

6.8 The scheduler shall try to minimize AM to the extent possible by adjusting scheduling time. This should be factored into the scoring (602).

6.9 The scheduler shall know which programs request eavesdropping, and better, which dates have eavesdropper availability. The scheduler shall give a heads up warning to the observer about upcoming eavesdropping 20 min before the planned slew time (611).

6.10 The scheduler shall take into account LGS shutter windows when choosing programs to schedule and the timing of the observations in order to minimize the time loss on sky. The scheduler should minimize both the number of shutter windows and the total laser shuttering time for a given observation when selecting the timing of the observation in a night. The time for any shutter windows (+ assumed overhead for pausing sequences) in the scheduled block shall be included in the unscheduled time on sky. This can be used to determine the priority of scheduling the observation even in the event of many/long shuttering windows. (612).

6.11 The scheduler shall take into account the extra time to complete an LGS observation due to any closure windows (612).

6.12 The scheduler shall communicate with LTCS in order to follow all lasing policies, including First on Target. For LGS programs that must be stopped or cannot be started due to these policies, the scheduler shall generate a new plan excluding this target until some time at which it can be observed. For non-LGS observations that are impacted by another observatory's laser system and cannot be observed due to these policies, the scheduler shall also generate a new plan excluding that target until a later time when it may be observed.

6.13 Observations within AND groups shall be observed together or with a defined relational timing. All observations in the AND group shall be scheduled in the denoted order, and each must be observed for at least a full individual atom. If the full set of observations (to at least the minimum atom sizes) in an AND group cannot be scheduled, then no parts of the group shall be scheduled. The visibility for the group as a whole must be considered. Any scoring for the observations shall be done as a single score for the set.

6.14 The Scheduler shall only schedule one observation from an OR group. After the observation is started, the other observation/s should be automatically deactivated. The scheduler shall only continue to schedule the already started sequence.

6.15 Observations that have already been started shall be prioritized. Less than 1% (as is the current case) of all observation sequences should be left incomplete at the end of a typical semester.

6.16 The decision whether to start a B2 or B3 program shall take into account remaining visibility for the targets in the program (B3 or other defined minimum or 80% should still be possible to complete) also factoring in RA demand at similar conditions for higher ranked programs or equal ranked already started programs.

6.17 For observations that can be taken at either site, baseline calibrations for a program shall be taken at each site where science has been taken.

6.18 For observations that can be taken at either site, once a sequence is started at one site, it shall be completed at that site. This only refers to the started sequence. Other observations within that program defined for both sites may still be observed at either site.

6.19 S/N as a constraint: This will not be included in the first versions of the Scheduler tool. Requirements will be drafted, in conjunction with GPP, when the observatory is ready to implement this capability.

7. ToOs

7.1 The scheduler shall be able to handle different implementations of rapid ToOs. This will include interrupting rToOs (slew now) and non-interrupting rToOs (slew when convenient) that must be observed within 24hrs, and preferably as soon as possible.

7.2 Both interrupting and non-interrupting rToOs shall force an update to the schedule. Interrupting rToOs shall prompt the observer to abandon the current observation and slew to the rToO. Non-interrupting rToOs will not interrupt the current observation until at least the current atom has been completed. The standard scores (factoring in the 24 hour timing window) will determine where the observation best fits in the schedule.

7.3 The Scheduler shall suggest to the observer to “stop” or “abort” an exposure when an interrupting rToO comes in (606) factoring into the decision the fraction of the exposure already completed, readout time, and any calibrations that will not be observed / atom completion. The observer will be free to choose which to apply. The Scheduler shall include the interrupt rToO as the next (current) observation and update the plan for the remainder of the night.

7.4 For interrupting rToOs, the scheduler shall not suggest to interrupt observations with the same or higher priority such as ongoing rToOs or other time-critical observations (or those with non-interruptible status) (606). In these cases, the interrupting rToO shall be added to the schedule at an appropriate time after the current atom is completed.

7.5 The scheduler shall be able to choose between sites for rToOs which can be done at either site, taking into account the rToO visibility (and, when relevant, the current observation priority and any time loss caused by the trigger) and site conditions (606). Interrupting rToOs should be assigned to the first available (accepting rToOs) site as conditions allow.

7.6 The scheduler shall look ahead to ensure that the minimum block size for the rToO fits in the schedule (due to impending twilight or higher/equal priority observations). If it does not fit in the current night, the scheduler must attempt to schedule it at the appropriate telescope at the next available opportunity within the rToO timing window (606).

7.7 The scheduler shall calculate any time lost on sky when an observation is interrupted (for cases where complete atoms are not observed) and this time will be charged in some way to the rToO program (606).

7.8 There shall be a way to inform the system whether each site is accepting rToOs for the current night or particular portion of the night. This information will be available through APIs. (606)

7.9 Standard ToOs (sToOs, if this will be included as a ToO type in GPP) shall be treated as regular queue observations with standard priority. If triggered during the night, the Scheduler shall update the plan as with all changes to the database, and include the observation in the current night only if the score is higher than other options.

Operations aims

- The scheduler should handle scheduling of multiple incoming rToOs based on the competitive ToO policy and follow all rules from that policy (to be detailed).

7 User stories

The following are user stories illustrating how the tool might be expected to be used in different scenarios and by different users. These were used to define the resulting requirements which are now listed above in Section 6. There are no new requirements listed below.

601. Use Story: Manually adjusting priorities

- The GN QC reviews RA and instrument component pressure for the next two weeks:
- She reviews the scheduler's look-ahead plans for the current range of likely conditions and sees that conditions are promising for LGS operations. Recent technical problems with the laser have prevented LGS operations recently so laser programs need higher priority now in order to get up to 80% completion. The QC ups the priority on several LGS programs, including Felix and Janna's. Felix and Janna's observations are now very likely to be scheduled and they appear in the "most likely plan" displayed in the schedule viewer.
- She also notes that there is a PV run in the following week that will have 15 MOS masks. All 10 mask slots will need to be filled each night of the run, and there are currently not enough mask frames available to frame all 10. All of the masks currently in GMOS will need to be removed and a few will need to be de-framed. She knows that it will therefore be best if several of these masks could be completed ahead of next week to make frames available. She sees that 3 have already been started and could potentially be completed in the coming week. Although the weights for these are already probably very high, she bumps up the priority even higher in order to ensure they get completed ahead of the PV run.

Resulting requirements:

1. It must be possible to use the system to predict the observing plan for the expected, or requested, range of conditions.
2. It shall be possible for Gemini staff, usually QCs, to manually change the scheduling priority of a program or observation and the scheduler must include this in the weighting algorithm.
3. It should be possible to add an expiration date for manual weighting changes.
4. Manually adjusted weights should remain visible in a list until they expire or are manually removed.
5. The most likely forward-looking schedule for the coming nights is published on a public web page and is available via an API. Public information shall include observation identification and start/end times but not target name and coordinates.
6. In the plan for the night, the scheduler must make available the weights for all observations so that it is clear to QCs the reason for the choices made.
7. It should be possible to see the detailed breakdown of how a particular weight was calculated.

Operations aims:

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602. Use Story: QC checks of the Scheduler plan with QVis (overview of requirements)

In the morning, the QC sees that the scheduler suggests a grating change for the coming night. Using QVis (the long-term scheduling tool) and the forecast for the upcoming 3 day holiday weekend, she decides that it is better to keep the current grating, but makes a note to submit a grating change request after the weekend.
Later, the QC uses QVis to check the scheduler's plan for the night for the most likely sets of conditions and is satisfied with the results. The high priority observations are all there, and no calibrations have been left out. There is even a set of throughput monitoring observations that are needed by the end of the month.

Resulting requirements

1. QVis full capabilities (see DMT requirements)
2. Scheduler must consider all prepared Q/FT/LP/C/DD/SV (and any other future designations) observations in all active programs.
3. Scheduler must also consider throughput monitoring (ENG programs) observations for each instrument
4. Scheduler must consider shared calibrations (CAL programs) for particular instruments that live in separate programs and know the rules for when and how often to schedule them.
5. The scheduler should not consider classical programs outside of classical nights EXCEPT when somehow designated (which could be the case for giving back time post

rToOs during classical run, or if there is a decision to finish a classical program in queue)

6. The scheduler should consider LP(or Q) observations that are set to Prepared before and after a PV run.
7. The scheduler must be aware of what systems - instruments, modes, WFS are available at each telescope each night. This could eg be read from a calendar or be listed with checkboxes. The observer must be able to make changes to this during the night in case of faults.
8. The scheduler must also be aware of what instrument configurations are available each night.
9. The scheduler should be able to request/suggest changes to instrument configurations for the coming night based on observation priorities and forward-look plans.
10. The scheduler should only schedule observations which require guiding when guide stars are available at the time of observation. This would be needed for parallactic angle observations with OI or non-sidereal observations.
11. The scheduler should not schedule non-sidereal observations that do not have an available ephemeris.
12. The scheduler, QVis equivalent, and any observing plan visualization shall use the ephemeris of a non-sidereal target to interpolate the coordinates as a function of time for scheduling, guide star searches, and target visualization.
13. Must have a manual mode, where a QC can tweak an auto created plan or fully create a manual plan.
14. Must be able to store all iterations of a plan, auto and manual.
15. QC must be able to tweak weights for individual observations
16. QC must be able to adjust weights for systems/components (eg NIRI or R831 etc). It would be nice if QCs could bump the weight for a period of time rather than doing this daily for that period of time, and these weight bumps should remain visible until removed or expired. The scheduler should be able to read an instrument schedule so observations for particular instruments may already be properly weighted, but for unscheduled changes (including for eg GMOS configurations), there should be a manual method to change the weights.
17. The scheduler must use a weighting system that will schedule observations like a QC, factoring in:
    a. Type (DD/FT/Q/C/LP/ENG/SV)
    b. Band/priority ranking
    c. Timing windows
    d. rToO/pToO scheduling rules
    e. Time left in semester to observe (observability = QVis “Sem Hrs” or “Sem Nts”) which factors in timing windows, SB, instrument availability, elevation constraints, telescope schedule, classical runs etc)
    f. Instrument schedule - Which instruments available and how much longer available
    g. Instrument configurations available and which configurations likely to be changed

   h. pre-imaging
   i. Whether observation started
   j. For B3 whether program started
   k. How much time left in program (< 80, < 100)
   l. Conditions requirements (with higher wt to programs requiring good conditions (IQ20/CC50/WV50 etc) in those conditions) or calculate the remaining likelihood of having a condition for the remaining visibility time i.e. merge visibility with constraint (f.ex if we have 20h left of visibility and IQ20 then that translates into 0.2*20h=4h)
   m. Observation AM (minimizing)
   n. LGS timing windows (minimizing)
   o. PI observation priority within a program: intra program priorities especially in cases of similar RA.
   p. Weather forecast for upcoming nights (which may have a significant effect on observation visibility (timing window, instrument coming off, etc)

18. The scheduler must use minimum block sizes/atoms to split observations as needed but will try to minimize splitting for < Nhr segments. N is the assumed frequency for acquisitions and will depend on the instrument, mode, and conditions and is typically ~1-2 hours.
19. The scheduler will factor in all required calibrations to the minimum block size (and schedule these with the science). In case of weather changes, will schedule any required cals before changing the plan.
20. The scheduler must be able to handle associated calibrations of all flavors - including partner nighttime cals defined within programs (within sequences or separate sequences and with various rules for frequency), partner cals shared among programs (residing in other programs and with various rules for frequence), partner daycals (automatically queue for the daytime), and program nightcals (with PI defined rules for frequency/timing).
21. For standard stars, the scheduler should be able to choose an appropriate target from a list and adjust exposure time based on target magnitude and conditions. If the scheduler is not choosing specific targets from lists/catalogs, it must be able to schedule targetless observations, where the observer will have to choose targets and set exposure times.
22. Scheduler must be able to make forward looking plans.
23. The scheduler must be able to dynamically update these plans throughout the night due to incoming ToOs, changes in weather, and faults.
24. Scheduler must respond immediately to incoming rToOs. The scheduler will not interrupt ongoing r/pToOs or time-critical observations.
25. All notes related to scheduling will have to be digitized: Relational groups and rules (And/Or), frequency, relational frequency, do not split (min block size=full sequence), etc
26. The scheduler will determine the current weather conditions (WV/IQ/CC) from either a conditions server or input from the observer (or QAP).

27. Models will be required to estimate the expected seeing at different elevations and at different azimuth angles wrt the wind direction given datapoints from ongoing observations.
28. There must be a way for an observer to tell the scheduler to skip an observation (in the event of a Phase2 error or other uncertainty in the observation requiring later follow-up with PI)
29. The scheduler must try to minimize AM to the extent possible by adjusting scheduling time (also listed in 217)
30. The scheduler shall minimize LGS closure windows to the extent possible by adjusting scheduling time (also listed in 217)
31. In the case of overfilled programs, the scheduler should only schedule observations up to the program allocation (+ some TBD buffer).

Operations aims

- The scheduler should be able to use the weather forecast and day crew schedule to determine and suggest the best instrument configurations ahead of a weekend or holiday. The day crew schedule would be used to determine when instrument configuration changes could (not) be made.
- Scheduler should consider weather forecasts for forward looking plans and be able to adjust weights based on conditions as needed (eg losing a CC50 observation and forecast is for clouds to come in 2 days). Until then, QC should be able to manually boost weights as needed.
- The scheduler should use information about forecasted conditions during the night when scheduling long minimum block sizes.

603. Use Story: Component (or observation) failure/availability during the night

The observer is smoothly sailing through the night, following the scheduler plan. The next observation for the current conditions is with GMOS. As the observer starts the acquisition, a fault occurs requiring a DC reboot. Due to the known bias level issue, GMOS is now unavailable for the next 20 minutes. The observer specifies that GMOS is unavailable on the system components availability list and requests a new observation. He is given a GNIRS observation and starts that acquisition but experiences a fault with P2. After calling the TTM and engineering support, 20min of trouble shooting determine that P2 will be unavailable for the remainder of the night. The observer notes in the system component availability list that P2 is unavailable, but sets GMOS back to available. The scheduler provides the best observation for the current time, which turns out to be the previous GMOS observation.

A little later in the night, the observer gets a seqexec error when trying to run another program. He cannot determine the source of the error but is pretty confident it must be a PhII error that will need to be resolved the next day. (Or he discovers that the finder chart is not adequate to identify the source to acquire). He requests from the scheduler an alternate observation.

The following night NIRI replaces NIFS on the telescope. Using QVis, the NIRI Instrument Scientist determines that f/6 +P2 is the most heavily used mode and will only spend the time to check out that mode. Other modes will be checked out on subsequent nights. The QC initially tells the scheduler that NIRI is unavailable. After the one mode is checked out, the observer sets NIRI + f/6 + P2 to available and requests the scheduler to provide the night plan for the remainder of the night.

The GMOS-S charge smearing issue has recently reappeared and thermal cycles have not been able to fix it. Therefore, the QC has listed the GMOS-S IFU and N&S modes as unavailable.

Resulting requirements

1. There must be a way to let the scheduler know which systems/components are (un)available at any given time.
2. The scheduler must not schedule an observation that uses an unavailable component/system.
3. There must be a way for the observer to tell the scheduler to skip an observation and provide another option.

Operations aims

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604. Use Story: Queue plan for the remainder of the night

A rToO comes in and the scheduler immediately prompts the observer to abort the current observation which is only 5% completed and to start the slew for the ToO. After completing the ToO, the observer checks to see what is next and finds that the scheduler has planned for a 20min ENG throughput monitoring observation which will fill the time before the 3am time critical observation.

Resulting requirements

1. The scheduler must look ahead to, and plan for, the remainder of the night whenever deciding what to do next, since what to do next is dependent on how the remainder of the night is best filled.

Operations aims

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605. Use Story: Filling holes during PV nights

The PV observers arrive with their own plan for how to run their observations during the subsequent 3 nights. It turns out they have a hole in the night for about 45min around 2am each night that will need to be filled by the queue. At night as it approaches 2am, they request an observation from the scheduler to fill the hole. They specify that it should fill about 45min. After they run the queue observation they return to their own plan to complete the night. At the end of the night, the scheduler has queued up all calibrations for the LP program along with the one queue program. On the 3rd night, they find that one of their final targets is too faint, and they abandon that observation. They request queue observations for that period of time.

Resulting requirements

1. It should be possible to request observations to fill only portions of a night.

2. It shall be possible for a human operator to turn off reception of the automated plan, with the exception of rToO alerts, so that manual operation can be performed

Operations aims

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606. Use Story: rToOs, non-interruptible observations

A rToO is triggered 18min into a 20min GMOS exposure. The scheduler instructs the observer to stop and readout the current exposure and then slew to the new target. It also generates a new plan for the remainder of the night in the current conditions. In addition, it calculates the time that has been lost on sky (due to a complete atom not being observed in the interrupted observation), and this time will be charged to the ToO.

A 48min rToO is triggered 30min before a very high priority (eg band 0) time critical observation is meant to start. The scheduler takes into account the minimum block size of 12min for a single exposure and flat, and prompts the observer to stop the current observation and slew to the ToO. It updates the plan for the remainder of the night to show that only the first 2 steps of the ToO should be taken, followed by the time critical observation, followed by the remainder of the ToO.

A 48min rToO is triggered 30min before a very high priority (e.g. band 0) time critical observation is meant to start. The scheduler takes into account the minimum block size of the full sequence and that the target is only visible from GN and updates the plan to show that the ToO should be observed immediately after the time critical observation. A web page has previously been updated to state that Gemini-N is not accepting ToOs for the 4 hour time frame during the time critical observation.

A rToO is triggered for GS in the middle of a 4hr observation that cannot be split. A web page has previously been updated to state that Gemini-S is not accepting ToOs for the 4 hour time frame. The scheduler generates a new plan, including the ToO as the first observation after the current one.

A rToO is triggered for either GN or GS. It is just starting to rise at GN and will reach the maximum AM in 15min whereas it is setting at GS and will not be accessible for the minimum block length. The scheduler warns the GN observer that a rToO has come in and that the observer should stop the sequence after completing the current AB pair and take the telluric standard and then slew to the ToO.

Resulting requirements

1. The scheduler should be able to suggest to the observer to stop or abort an exposure when a rToO comes in.
2. The scheduler must immediately register rToOs and update the plan accordingly.
3. The scheduler must be able to choose between sites for rToOs which can be done at either site, taking into account the rToO visibility (and, when relevant, the current observation priority and time loss caused by the trigger).
4. The scheduler must look ahead to ensure that the minimum block size for the ToO fits in the schedule (due to impending twilight/SB changes or higher/equal priority observations).
5. The Scheduler should calculate any time lost on sky (for complete atoms not being observed) and this time should be charged to the rToO

Operations aims

- Automatically update the ToO webpage to state whether each telescope is accepting ToOs, and the timeframe for which it is not.

607. Use Story: A sToO is triggered in the night

The observer is following the scheduler plan for the current poor conditions. There is not much to observe so they have been sitting on Band 3 programs for awhile. A Band 2 sToO is triggered in the night. Although there are no conditions changes or other prompts from the observer, the scheduler updates the plan taking into account this new observation and adds it as the subsequent observation.

Resulting requirements

1. The scheduler must automatically update the plan whenever there are updates to the database.

Operations aims

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608. Use Story: Adding steps to a sequence at night

The observer is near the end of a sequence when the observation is affected by seeing bubbles. She sets the last few steps to usable and waits a minute to see if the seeing will settle. She decides that it probably has and adds back the steps. Again a seeing bubble affects the final step and after another pause she repeats that one. She finally has enough good steps and is ready to move on. She updates the conditions server and the scheduler refreshes the plan.

Resulting requirements

1. The scheduler should automatically update plans when current observations are taking more or less time than expected.

Operations aims

- The scheduler should be able to update automatically based on changes in conditions received from the conditions server. The scheduler should prompt (suggest) to the observer to stop observations that are out of spec. It might also suggest to increase the exposure times or add more steps in order to maintain the required S/N. The exact implementation for maintaining S/N will be provided ahead of a future release which includes this feature.

609. Use Story: GRACES modes and other instrument peculiarities (if any)

It is a GRACES block and the scheduler is aware of the time frame for the block. The priorities for all GRACES observations are high due to the short visibility window. The observer, following the scheduler plan, starts the night with a NIRI observation that is being lost and then moves on to several Band 1-2 GRACES 1-fiber observations. In the middle of the night they are instructed to do a fiber mode change to 2-fiber and continue with another B1 GRACES observation. Just before starting the next GRACES observation, some clouds come in. The conditions server notifies the scheduler that conditions are now CC80 and the scheduler generates a new plan for the remainder of the night. Since the only GRACES that can take CC80 late in the night are in 1-f mode, and the scheduler knows that it started in 1f mode and has already made the single allowed mode change, it cannot go back. It therefore schedules a B1 GMOS observation for the end of the night dark time.

Resulting requirements

1. The scheduler must follow instrument specific rules.
2. Higher priority to blocked instrument observations during those blocks (this should automatically come out of the visibility calculations).

3. The scheduler must have enough information about visitor instruments (through the PhII tool) in order to correctly schedule observations using these instruments.

Operations aims

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610. Use Story: Required Calibrations

The observer is conducting a GNIRS observation when the seeing goes soft. She notes the new seeing values in the Conditions Server. The Scheduler prompts her to complete the current AB pair and take the on-sky calibrations followed by the after telluric standard before switching to an IQ85 observation.
A little later in the night a PI triggers a rToO just at the end of a 3 hour high priority ("Band 0") do not split observation. The scheduler instructs the observer to take the after telluric and then slew to the rToO.
Near the end of the night, the observer is just finishing another 3hr observation when another rToO comes in. It instructs her to abort the current exposure and slew. The short imaging rToO only takes 30min, so in the plan for the remainder of the night, the scheduler includes the after telluric for the previous observation immediately after the rToO in order to salvage the last hour of that observation.
On the following night, the observer is following the photometric plan when they note clouds low on the horizon but moving in. They request from the Scheduler the next break point (/atom), and the Scheduler indicates (in some way) that the next A-B pair + standard observation are required steps before the observation can be split without losing time.

Resulting requirements

1. Calibrations required for a program shall have the same weight as the science. Observations with longer calibrations should not be penalized.
2. The time for the required calibrations shall be factored into the minimum time required for each observing block, and this is then factored into the time loss if the observation is aborted due to a rToO or weather changes.
3. If conditions change, the scheduler should schedule any required calibrations (if possible) before requesting the observer to slew to an observation in another program.
4. The scheduler should indicate the remaining time in an atom in addition to the total time remaining in the scheduled sequence.

Operations aims

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611. Use Story: Eavesdropping

The scheduler includes in the plan an observation that has requested Eavesdropping. The scheduler is aware of this and 15min before the planned slew to that observation, it gives a warning to the observer that Eavesdropping is requested.

Resulting requirements

1. The scheduler should know which programs request eavesdropping, and better, which dates have eavesdropper availability.
2. The scheduler should give a heads up warning to the observer about upcoming eavesdropping.

Operations aims

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612. Use Story: New closure windows or blanket closures from LCH

LCH calls to notify the observers that they have uploaded new PAM files due to a space event (or calls to notify the observers about a long blanket closure). This now includes a 1 hour closure window right where an LGS observation had been planned. The scheduler ingests the new windows and automatically updates the plan. It now includes a short NIRI observation during that period, followed by a different high priority LGS observation that has few closure windows during the subsequent 2 hours.

Resulting requirements

1. The Scheduler must take into account LGS closure windows when choosing programs to schedule and the timing of the observations in order to minimize the closure time.
2. The Scheduler should automatically update the schedule when changes to the closure windows occur.
3. The Scheduler should attempt to minimize both the number of shutter windows and the LGS shuttering time for a given observation when selecting the timing of the observation in a night. This wasted time on sky should be taken into account in the metric/scoring used to plan the night to determine the priority of scheduling the observation even in the event of many/long shuttering windows.
4. The Scheduler should take into account the extra time to complete an LGS observation due to any shutter windows.

Operations aims

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613. Use Story: Unbinned delivered observing conditions, wind, seeing.

This story is included in the event that we switch to unbinned conditions and, in particular, delivered seeing requirements.

The conditions server updates automatically the information it can ingest and the observer also adds information about the current conditions at the location of the current target. The server includes the information about measured seeing from QAP and AM in its seeing model. It also includes a buffer in its model to account for the fact that there will likely be differences in different locations on the sky, especially with regards to wind direction.

The scheduler is aware that the current observations are no longer in spec as the seeing has deteriorated. It instructs the observer to stop the GMOS sequence after the current step and slew to an observation that can take worse seeing and will not be pointing directly into the currently high winds. That observation will start at an AM of 1.1 but reach an AM of 1.7 by the end of the sequence. It takes the maximum AM into account, along with the small buffer, when determining if the observation meets the current conditions requirements. Unfortunately, the model suggests that the observation will be out of spec by an AM of 1.5. The scheduler therefore schedules only a partial observation that will end when the target AM is just below 1.4 followed by the required on-sky calibration and then a slew to a lower priority target. While conducting this observation however, the seeing at this location as the target reaches higher airmasses is actually much better than expected, so the scheduler adjusts the plan to stay on this first higher priority target.

Resulting requirements

1. For delivered observing conditions, the scheduler must take into account the AM throughout the observation length when determining if it will remain in spec in IQ for the duration. If it will not, according to the seeing model, it should not schedule the observation or schedule on only the portion that is expected to remain in spec.
2. The scheduler should use a buffer when assuming the likely seeing at a given AM.
3. The scheduler will take into account the sky brightness throughout the observation duration when determining if the observation will remain in spec in SB for the duration. If it will not according to the SB model, it should not schedule the observation or schedule only a portion that will remain in spec
4. The Scheduler must take into account the necessary calibrations and ensure they are scheduled/taken before slewig away from a target. The required conditions and AM of the calibrations must be considered.

Operations aims

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614. Use Story: Terrible weather

The observer starts the night by providing information to the conditions server about the thick clouds blanketing the sky.   The observers attempt to tune, but clouds are too thick and the seeing seems to be terrible. This information is also added to the conditions server. The observer finds that the scheduler has updated the plan to include several specphots at the start of the night followed by several Band 4 observations that can take Any/Any conditions.

Later in the night conditions improve a bit and the observer follows the updated scheduler plan to observe several Band 3 observations. There is a short hole during which no Band1-3 or calibration data can be observed, so the scheduler fills that hole with a fairly short Band 4 observation.

Resulting requirements

1. The scheduler must always try to find something for the observers to do in any conditions, whenever there are observations available, including Band 4 observations which have no worth in the semester quality metric.

Operations aims

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615. Use Story: S/N condition

This capability will not be included in GPP initially. Requirements will be needed ahead of implementation.

Resulting requirements

1. Description

Operations aims

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616. Conditions Server

We will need a server that aggregates, models, and responds to queries about the site conditions at any location in the sky. This server will collect conditions information from many sources. At both sites it will collect absolute and directional seeing and extinction measurements from the QAP, absolute and directional seeing measurements from the weather tower, aggregate information collected from other local observatories, and relative seeing and extinction estimates from the WFS. For each acquisition image the QAP conditions measurements will be recorded and the WFS seeing and counts will be used to estimate the relative changes in seeing and extinction. The observer can input supplementary data into the conditions server, for example after measuring the FWHM of a spectral crosscut.   Additional conditions data could be extracted from external sources like the CFHT SkyProbe and CSO water vapor monitor. Each measurement will include timestamps, azimuth, elevation, and the waveband when appropriate. The conditions server will continuously fit direction-dependent models to the seeing and extinction. The server will calculate the sky background and apply offsets to match QAP measurements. The server could also keep track of when the telescope is closed, for bad weather or otherwise in order to supply the telescope status web page with the telescope open/closed information..

The server will respond to internal and external conditions queries. After each exposure the ODB will query the server to get the average conditions during the exposure, which will in turn be fed into the ITC to estimate the S/N of the exposure. The ODB will record and display both the conditions and S/N of each exposure. The queue scheduler software will query the conditions server to figure out the best observation to do next. It will use the conditions at the position of the next target to calculate the optimal exposure time and observation duration. The conditions server will also accept external queries from TOO programs and other observatories.

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617. User Story: Changing conditions

Apple the observer is observing a Band 3 program in IQ85 and cirrus (CC70) conditions. The Conditions server reports that the clouds have cleared (or the IQ has been stable for XXminutes in IQ70 or any sort of stable improvement in conditions). The scheduler reacts to the change in conditions and determines if there is a higher ranked observation that could be observed. If there is a higher ranked observation the scheduler informs Apple that there is a higher ranked observation and informs at what step in the ongoing sequence makes an ideal break point, in the event of extreme conditions like IQ20 the software may even inform Apple to switch immediately similar to a RToO case as the calculated gain in doing the high ranking observation outranks the loss of time by aborting.

Resulting requirements

1. The scheduler regularly queries the conditions server and calculates a new plan
2. When a new plan has significant changes in score the scheduler will inform the observer that observations must be stopped at a certain step or even aborted.
3. The previous suggestion can be de-selected/ignored by the observer

Operations aims

User Story: Template

Story

Resulting requirements

1. Description

Operations aims

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References