User Information Report UIR-2012-002

Scheduling Large Programs

Information and Guidance for Proposers and Observers

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ABSTRACT

This UIR describes how Large programs can affect the overall schedule of HST and how observers can optimize their scientific return while minimizing difficulties in scheduling their program.

1 Introduction

A Large HST program is defined as one that uses 100 or more spacecraft orbits. The report of the "Second Decade Committee" emphasized the greater scientific productivity per orbit expended of programs that produced large datasets of consistent quality. Therefore, STScI now solicits Large programs for the *Hubble Space Telescope* in the expectation of increasing HST's effect on astronomy as a whole.

Before Large programs were actively sought, only a few of such size were recommended for approval by the Telescope Allocation Committee. Thus the overall pool of HST observations was usually drawn from many smaller programs with diverse goals. That generally led to an assortment of HST targets well spread on the sky and in time, even if occasionally there were heavy demands that created conflicts (e.g., in the Magellanic Clouds). Even with a diverse assortment of observations, many had restrictions of one kind or another imposed that made creating an efficient HST schedule challenging. In particular, some observers add timing constraints to visits. Others restrict the orientation of the telescope, and those are *de facto* timing constraints as well.

Since their inception, Large programs have added significant difficulty and complexity to HST scheduling. This is contrary to our expectation that having fewer but larger programs would lead to less effort needed per orbit of observation. For example, a Large program that requested two-orbit imaging visits for 200 separate galaxies that were spread over the sky at the high Galactic latitudes could lead to very efficient use of HST's time.

In reality, most Large programs to date have used their orbits within limited regions of the sky or on single targets. In addition, these programs often impose orientation restrictions so that the tiles of a mosaic align, or so that repeated observations of a field provide maximum overlap. Meeting all of these constraints while scheduling an overall HST program with competing needs has proved more than just challenging. These challenges are driven mainly by the characteristics of Large programs themselves and will never be eliminated even with HST's return to 3-gyro mode operation after Servicing Mission 4.

This *User Information Report* has been written to provide guidance to observers who wish to write a Large proposal or who have an accepted Large program for which Phase II details must be written. We have no intention of dissuading anyone from preparing such a proposal; STScI's commitment to the overall quality of the science has not changed. Yet there is information that you as a proposer can use to better understand how observations are scheduled, and that can lead to a superior proposal that the TAC understands better and which can be scheduled with less effort. That benefits everyone. Also, there is information that you can provide to us so that we understand your needs fully, and that too benefits us all.

2 Scheduling HST

Creating an observing schedule for the *Hubble Space Telescope* is not so fundamentally different than for a ground-based observatory. HST schedules are based on smaller units (viz., orbits) of variable length, and the telescope is available during a full 24-hour day, not just at night. As with ground-based telescopes, HST is usually pointed more than 90 degrees from the Sun, meaning that objects in Orion are mostly observed in the winter and Leo in the summer. HST has some additional and very different constraints, of course, such as a 96-minute orbit and regular passages through the high radiation background of the South Atlantic Anomaly (SAA).

The first step in creating a schedule of HST observations is to receive, validate, and accept the Phase II programs from all the observers. Most programs will be fully defined before a Cycle begins, but a fraction involve Targets of Opportunity (TOOs) or observations that are partially specified, with some details to be provided at a later date. Using all the available information, a team works to create a Long Range Plan (LRP). The LRP assigns a Plan Window or Windows to each visit in a program. A Plan Window is from one day to eight weeks in length, depending on the restrictions that have been imposed in the Phase II program, generally being a week or more. A Plan Window is the period of calendar time during which the visit is expected to be scheduled. Thus the LRP is the evolving plan for using the telescope in the future.

The LRP is frequently updated throughout the year as programs are changed, TOOs are activated, new observations are specified, and so on. But the first LRP constructed for a Cycle is a major event, for it lets us see potential problems and conflicts among programs that must be resolved. If the conflicts are minor, they can generally be worked out when detailed schedules are built or through modifications to individual programs made in consultation with a PI.

The detailed schedule of HST observations is called an Science Mission Schedule (SMS). With only occasional exceptions, an SMS is seven days long and begins at 00:00 GMT on a Monday morning. STScI starts to construct SMSs eleven days before they begin executing, allowing time to build the observing schedule, to verify that the SMS is safe for HST and its instruments, to schedule the communications links needed to send commands to and receive data from the spacecraft, and then to actually uplink the commands to begin observing.

In creating an SMS, a scheduler at STScI works through several pools of visits in priority order. These pools are drawn from the LRP and include a subset of all observations that could be done in that week. First to be scheduled are the "must go" visits, meaning observations whose constraints require that they be done in that one week and no other. Then come the "should go" visits that ought to be fit in if at all possible but which have at least one other opportunity if they cannot fit. Then the "can go" visits are added to the extent possible; they are all the remaining observations for which the week in question is an acceptable time. If unused time remains after this, SNAPs are added; this is described in a separate UIR ("All About SNAPs"). Finally, parallel observations are added to the extent possible. After all this the LRP is updated so that the visits scheduled are no longer available for subsequent weeks.

Some contemplation of this process leads to the obvious conclusion that significant problems can arise from visits with few or short Plan Windows. This leads to "must go" visits in an SMS that can conflict with each other or which leave no room if a TOO is activated. Short Plan Windows result from an observer specifying, say, a small range of time during which an observation must occur (to catch a binary's eclipse, for instance, or to observe a planet at opposition). However, in most cases short Plan Windows come from a highly constrained orientation for the telescope. Limits on HST's roll angle (to keep the solar arrays well illuminated and to avoid overheating some components) then result, meaning specific times at which the visit must be executed. Observers have reasons for restricting the orientation, of course, but may not always be aware of the scheduling consequences.

3 Ramifications for Large Programs: "Structure"

All HST visits must schedule within the environment created by the sum of all the HST programs considered together. It is possible to write a single program that will execute with no problems in and of itself and yet cannot be scheduled. Large programs influence the overall scheduling environment in a significant way whenever they impose structure on the schedule. "Structure" could be intensive use during a set time, such as occurs when an observer uses nearly all the available orbits within a week to get deep images or to search for short-term variability. Structure could be many visits spaced over an extended time, such as a program that needs one orbit per day for 200 days. Structure could be repeated observations of a field with additional restrictions applied, for example, a supernova search done at the same orientation as a first-epoch observation and spaced every 45 days.

Structure means that many separate observations are tied together in some way that creates limitations on the remainder of the HST program. Structure adds stiffness to the schedule in place of flexibility. Large programs stand the best chance of being executed early and completely when they minimize the structure they impose, consistent with their science goals. Any program increases its chances of delays when it imposes unnecessary structure, leading to compromises that must be made to make it schedulable.

Our intention is not to limit structures that observers add to programs for good reasons. Rather, we wish to make proposers aware of the scheduling environment to facilitate the timely and successful completion of all HST programs. Therefore, proposers of Large programs are asked to discuss the scheduling of their observations in and of themselves and in the context of the overall HST program. We are seeking enough information about the observing requirements to understand how they may affect scheduling their program. What we most need to know are the areas of flexibility in specified observing constraint details. It may be helpful to think in terms of the minimum requirements, desired requirements, and optimum requirements. Minimum requirements are those that cannot be dropped without making the program largely meaningless. For example, the minimum requirement for a supernova search might be one first epoch and with subsequent epochs oriented at any relative angle.

Desired requirements tell us what you'd like to have to go beyond the minimum for a greater scientific return. In the supernova search example, restricting the orientation of the follow-on epochs increases the chances of finding a supernova by ensuring more overlap between exposures. Optimum requirements carry the desired to be best possible. In the supernova case, that might mean executing all epochs at the same orientation.

4 Considerations for Proposers

Target Visibility

A target's orbital visibility depends on its declination and varies with HST's 56-day orbit precession from a few minutes for near-ecliptic targets to tens of minutes for CVZ targets. In Phase I, the minimum visibility period must be used for planning Large programs in order to maximize scheduling flexibility in this factor. Beginning in Cycle 20, this minimum visibility (SCHED 100) will be enforced in Phase II as well. (Programs approved for CVZ observations in Phase I are still able to use full CVZ visibilities.)

Orientation

Observers have frequently used the ORIENT Special Requirement when designing their programs. In the case of Large programs, these ORIENT requirements affect the schedulability of the observations because an ORIENT determines not only when an observation can be done during a year, but also the total number of days during which the target is available in that year.

Mosaicing

Observers frequently use one of the cameras to image a region larger than the field of the camera itself. This is done by taking a series of overlapping images and knitting them together during data analysis. The degree of overlap between images and the orientation of the overall mosaic are usually determined by the nature of the object being studied. If the total region and number of orbits is small, then this will result in specific orientation requirements for the visits, but not create a particularly large scheduling problem.

If the total field requires many images to construct the mosaic, or if the field will be revisited several times, then it is important to consider the scheduling implications in designing the program. As seen in the discussion above, selection of an ORIENT (necessary for specifying the mosaic) limits schedulability of the program. Additional scheduling flexibility can be gained if the mosaic is designed to allow observations of different portions of the mosaic, or repeated visits to the field, at orientations offset by 90, 180, and 270 degrees from the nominal orientation. For square instrument fields of view, this simply means that the pointing tiles for the mosaic have sufficient overlap so that adjacent fields can be taken at an orientation offset by 90 degrees. In the case of the ACS and WFC3, the field is a bit distorted. Therfore, in order for this technique to work for these instruments, we strongly recommend that observers proposing mosaics use tile center spacings no larger than the values specified in the table below. Implementing mosaics in this manner ensures optimal tile overlap and scheduling flexibility.

Instrument/mode	Maximum Tile Center Spacing
ACS	190 arcseconds
WFC3/UVIS	145 arcseconds
WFC3/IR	118 arcseconds

In addition, proposers are urged to consider what if any tolerance is allowed in the orientation between overlapping tiles. Even a small tolerance on the orientation of an individual tile within the larger field may increase scheduling opportunities with little effect on the overall coverage of the field. Section 7.7.1 in the *ACS Instrument Handbook* and Appendix C in the *WFC3 Instrument Handbook* provide some additional discussions on mosaicing with these instruments.

Repeated Observations of a Mosaic or Field

Some observers may wish to revisit a mosaiced area several times during the year, as the GOODS program did in order to search for supernovae. In such cases there is usually a strong desire to have the field for the second-epoch observations overlap as completely as possible the field for the first epoch. This situation also calls for use of a target tile that allows for the 90 degree rotations just described. While the general timing between observing epochs will be fixed, proposers are here again urged to consider what flexibilities are acceptable in both the overall field and individual tile orientations.

Scheduling considerations

Observers who propose Large programs on a single target/field should consider the flexibility that the

STScI will have in scheduling their programs. A program of 100 orbits is the equivalent of about 1.2 weeks of observations for the telescope. As discussed before, we will have to schedule these programs among other Large programs, as well as the rest of the GO pool. We give here some examples of considerations for proposers, factors which our schedulers will have to deal with when scheduling accepted programs.

Some Large programs require a dedicated block of time during which they need continuous observations of the target. These programs often preclude scheduling other programs during that period. The typical pool of accepted GO programs will have quite a few observations with very time-constrained scheduling windows (such as planetary phenomenon, binaries, etc.), averaging more than one such program per week. In order to fit the Large program in among the shorter time-constrained programs, it is necessary to have considerable flexibility in when the Large program is scheduled. Relaxed ORIENT requirements (or none at all) help provide scheduling flexibility. Also, if proposers are planning coordinated observations with other observatories, they should consider whether the timing can be driven by the *HST* schedule, rather than specifying a day/week for the observations in the *HST* proposal.

Some Large programs require extended access to a target, making repeated observations over a period, but not requiring continuous observing. In these cases, the scheduling problem is related to the repeat cycle of the Large program. The pool of GO programs will contain many time-constrained programs to be executed during the period the Large program is carried out. Some of these will require a few to tens of orbits of dedicated time that must be squeezed into the repeat cycle of the Large program. Proposers of such Large programs should consider the level of flexibility they would have on the repeat cycle, and whether missing entirely a cycle would be acceptable scientifically. They should also be aware that *HST* typically can have a few (1-3) safemode entries each year, typically lasting from one to a few days, and these can interrupt cadence of observing after it has started.

Large programs that carry out surveys impose a different kind of structure on the schedule. A major consideration for these programs is the number of orbits per day that we need to average during their target availability periods in order to complete the observations during the Cycle. Over extended periods, the scheduling process typically can schedule 11-12 total orbits per day (the remainder are typically interrupted by SAA passages, and often used for SNAPshot exposures). Over the last few Cycles, we have found that Large programs that require an average of 1-3 orbits per day during their observing epochs are relatively low impact, and those that require > 5 orbits per day are very high impact to the rest of the GO program. We suggest that proposers consider observing strategies (use of ORIENT, mosaic overlaps, etc.) that help maximize the schedulability of their programs during the year.

Considerations for Phase I & II

Once the TAC has recommended an overall program, and the Director has allocated observing time, and notifications have been sent, STScI immediately begins to work with the PIs of the selected Large programs. One of the first tasks we must complete in order to lay out the observing plan for the full Cycle is to determine how the Large programs interact with one another, in a scheduling sense. The TAC does not consider scheduling while making its recommendations. It may be that the selected Large programs are naturally spread out during the year and easy to schedule. Experience has shown that it is more likely, due to target selection, that several of the selected Large programs will overlap, in the sense of preferring the same observing periods during the year. In these cases, STScI will work closely with each of the PIs and attempt to develop a solution, within the flexibilities of the selected science programs, that accommodates all programs without extending observations into the subsequent cycle. This work will have to be done between the notification date and the Phase II deadline.

HST proposers now have the ability, prior to submitting a proposal for Phase I peer review, to investigate how any observing constraints they have imposed may potentially affect the opportunities for executing their observations. Using the Astronomers Proposal Tool's Visit Planner will help you to evaluate how restricted your Large program is in time and to give you an indication of whether or not your program will be feasible in a scheduling sense. The Help link found in APT provides instruction for using the Visit Planner to verify program schedulability in Phase I and Phase II. Also, the *HST Orbital Viewing and Schedulability* webpage provides more discussion about HST scheduling in general and links to further information. Proposers of all Large Programs are strongly encouraged to go through this investigation.