User Information Report UIR-2014-001

Snapshot Programs

Information, Rules and Guidelines for Proposers and Observers

Bill Workman, Ian Jordan, George Chapman, Alan Patterson, Merle Reinhart, Denise Taylor, Dave Adler
Prepared January 07, 2014

ABSTRACT

This UIR describes Snap programs and shows some execution statistics to provide proposers with basic guidance for their Snap program development.

1 Introduction

Ideally, the schedule of *Hubble Space Telescope* observations should be constructed in a way that leaves no useful time unexploited. In reality, there are inevitable gaps in the schedule that cannot be filled with exposures from Regular General Observer (GO), Guaranteed Time Observer (GTO), Director's Discretionary (DD) and Calibration (CA) programs. The Snapshot program was designed to take advantage of these opportunities by providing a pool of short visits evenly distributed over the entire sky. A final step of the scheduling process uses these visits to try to fill any gaps left in the weekly schedule. Over the years this process has worked very well and has resulted in many important data sets for immediate use as well as later access via the archive.

Over time, we have gained experience and improved our scheduling tools to maximize the use of each HST orbit for science observing. Our goal is to schedule more orbits per week, and hence provide the TAC with a larger quota of orbits each year for allocation to full orbit HST science programs. This has led to a decrease in the number of opportunies for Snap visits over the years, as well as some shifts in the demograhics of scheduled Snaps. Even so, Snaps remain an important part of the HST observing program.

The purpose of this UIR is to provide current information on the scheduling of Snaps so that proposers can develop Snapshot science programs that will schedule successfully, if approved by the TAC and Director.

2 HST Scheduling and the Ecological Niche for Snapshots

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, including Snapshots, 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). GO and Calibration visits are each assigned a Plan Window or Windows in the LRP that range from less than an orbit to eight weeks in length, depending on the restrictions that have been imposed in the Phase II program. A Plan Window is the period of calendar time during which the visit is expected to be scheduled. The LRP is designed to optimally distribute observations throughout the cycle to maximize the efficiency of the observatory. Snapshot programs are NOT included in the LRP.

The LRP is frequently updated throughout the year as programs are changed, TOOs are activated, DD 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 schedule of HST observations is constructed in seven day units called *calendars*. A member of the Science & Mission Scheduling Branch builds a calendar using STScI-developed software tools to select the observations that may be executed. In creating a calendar, a scheduler works through several pools of visits in priority order. These pools are drawn from the LRP and include the subset of all non-Snapshot observations that can be scheduled in that week. From the pool of unexecuted GO observations, the builder attempts to schedule as many visits as possible on the timeline taking into consideration the GO and LRP-specified scheduling restrictions of each visit. The priority pools include "Must Go" visits that are planned to execute within that calendar period, "Should Go" observations that are planned to occur within the next one or two calendars, and finally, "Can Go" observations that have extended suitability and therefore have less urgency to occur on the current schedule. The pool of visits in any week will typically include a total of ~200 orbits, of which typically 80-85 orbits (three gyro mode) will actually be scheduled on that calendar. A typical cycle allocation includes about 4500 orbits from proposals of all types. The LRP allows us to reduce the number of visits considered in each week, rather than deal with the entire pool of 4500 orbits. For the GO, it provides an indication of when their data are most likely to be obtained.

Snapshot visits are scheduled after all available non-Snapshot visits have been attempted. The Snapshot process uses an automated scheduling algorithm to attempt each available visit in the remaining holes in the calendar. Depending on when in the observing cycle this takes place, 1000-2000 Snapshot visits are attempted. Historical scheduling results are shown in the figures below.

The Snapshot program is dependent on gaps that remain in the weekly schedule after all other GO program visit types have been attempted. Gaps of a full orbit duration or more can occur when the overall mix of GO visits available for a given calendar is depleted. Gaps of these durations were regular occurrences (1-2 per week) during the early years of HST operations. However, improvements in the process of developing and maintaining the LRP and in the scheduling process have significantly reduced the routine occurrence of multiple consecutive full orbit gaps. The more probable cause of gaps of this size today is an extended observatory anomaly, such as the loss of the ACS capability, or the delay of Servicing Mission 4 which resulted in the near complete depletion of the Cycle 16 GO visit pool. Short term execution rates for Snapshot programs benefit in these cases as they become an important component for maintaining the high science efficiency of the observatory. Visits may also have extremely restrictive timing requirements that force separations that prevent other Regular GO visits from scheduling between them. This situation is also rare, however.

The routine source of gaps in current HST schedules is the SAA (South Atlantic Anomaly), a region of high particle background over South America and the South Atlantic. HST cannot maintain FGS guiding and none of the instruments can obtain quality data if they are operated in the SAA. There are 6-9 HST orbits each day during which the telescope passes through the SAA. These SAA passages last from 5 to 30 minutes. If the SAA passage occurs while a target is occulted by the Earth, then the orbit is fully usable for scientific observations. Over the years we have improved our scheduling techniques to identify and use the visits that can "hide" the SAA in this manner. The phase of the SAA relative to a target's visibility pattern shifts during the day such that "SAA hiding" is variable and dependent on target location and the planned epoch of the observation.

The prime "niche" for Snapshot programs is to provide visits that can be used in the "SAA impacted" orbits that cannot be used by other programs. For the overall pool of Snapshot visits to be successful in increasing the scheduling efficiency, they must be scattered uniformily over the sky to provide targets for different SAA hiding situations, and be shorter than a typical full visibility period in order to take advantage of partially impacted orbits. To minimize the manual effort required to prepare and use the Snapshot pool, the individual visits must be simple and without constraining requirements.

3 The History of Snapshot scheduling

Figure 1 shows the history of Snapshot scheduling including Cycles 11-13 operated in 3-Gyro mode, Cycles 14-16 operated in Two-Gyro mode and 3-Gyro mode again since Servicing Mission 4. In Cycles 14-16, Snapshot scheduling trended with the Regular GO scheduling rate in 2-Gyro mode which was less than in 3-Gyro mode due to the extra time and visibility requirements to support 2-Gyro acquisitions. With the return to 3-Gyro mode, we expected the Snapshot rate to rise again to pre-2-Gyro mode levels. However, the rates in subsequent cycles has remained lower due to excellent Regular GO scheduling rates. We attribute this to several factors including the availability of a reasonably broad distribution of Regular GO targets, the full complement of instrument observing modes that are result of the very successful Servicing Mission 4 (SM4), and significant improvements in the Long Range Planning and Scheduling processes that have led to record Regular GO execution results since SM4. The large peak in Snapshot execution near the end of Cycle 16 is directly attributable to the nearly 9 month delay of SM4 and Cycle 17. That delay resulted in the near complete depletion of the Regular GO visit pool well before the refurbished observatory was ready for operation. Here is a case where the Snapshot program significantly contributed to our ability to maintain the science efficiency of the observatory.

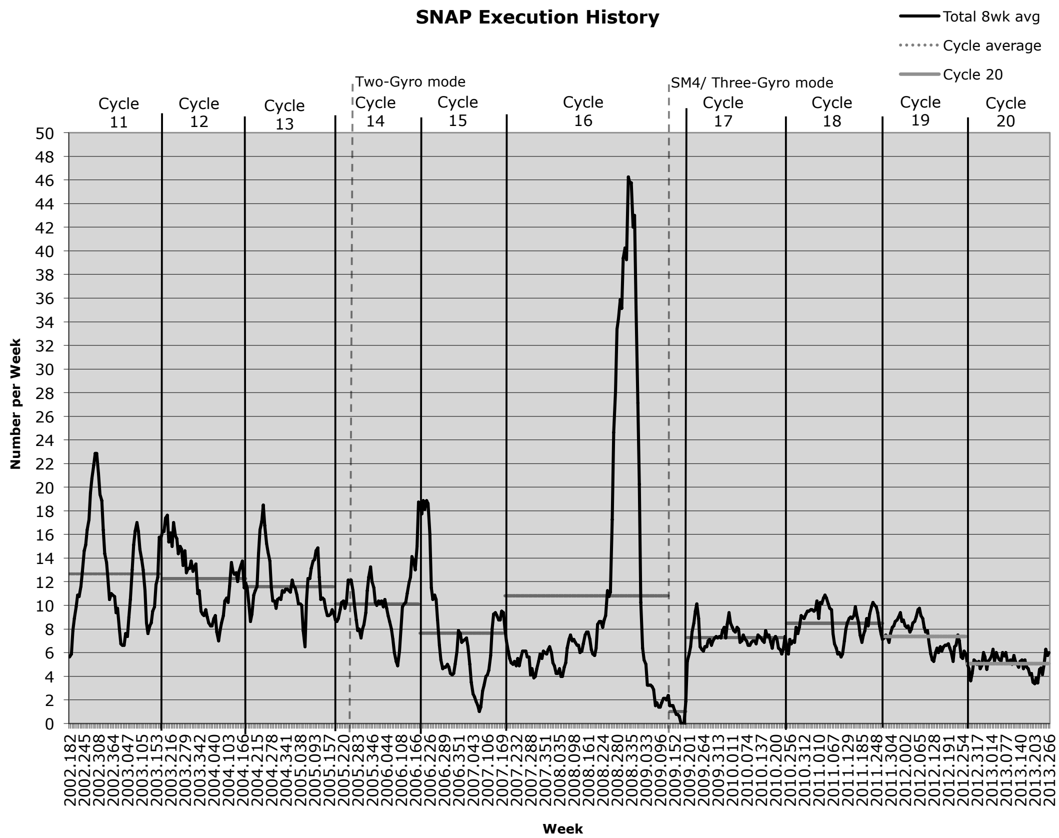

Figure 1: Snap Execution History; Cycles 11 – Cycle 20

<u>Instrument usage:</u>

Figure 2 shows that the balance of instrument use has shifted since Cycle 18. WFC3 Snaps have increased from 31% to 71% of the total accepted observations over this period, with a 10% increase between Cycles 19 and 20; about 50% of WFC3 Snaps use the IR channel. Note that IR images of bright targets can result in ghost images which persist for up to two orbits after the exposure. The schedule must account for this persistence to avoid impacts to subsequent IR obsevations. That can mean fewer opportunities for Snaps that use the IR detector. Note also that WFC3 Snap execution rates as a percent of total Snap observations accepted (Figure 3) remained relatively flat around 18%. ACS Snap acceptance rate was level while its execution rate dropped by 2/3 since Cycle 18. The combined COS and STIS Snap acceptance rate dropped from 41% to 9% after Cycle 18, and its execution rate declined to 2% in Cycle 20. These results suggest increasingly severe competition between Snap and prime GO observations, particularly for WFC3 and its IR channel, and that a limit is being reached for WFC3 Snap scheduling opportunities. This is also evidenced in Figure 4 which shows that use of WFC3 for prime GO observations continued its upward climb and reached 55% of the prime GO allocation in Cycle 20. COS completion rates were 45% and 50% for Cycles 18 and 19 respectively. COS Snap execution rates in Cycle 19 surpassed the current average Snap program completion rate of 33%. No COS Snaps were awarded in Cycle 20.

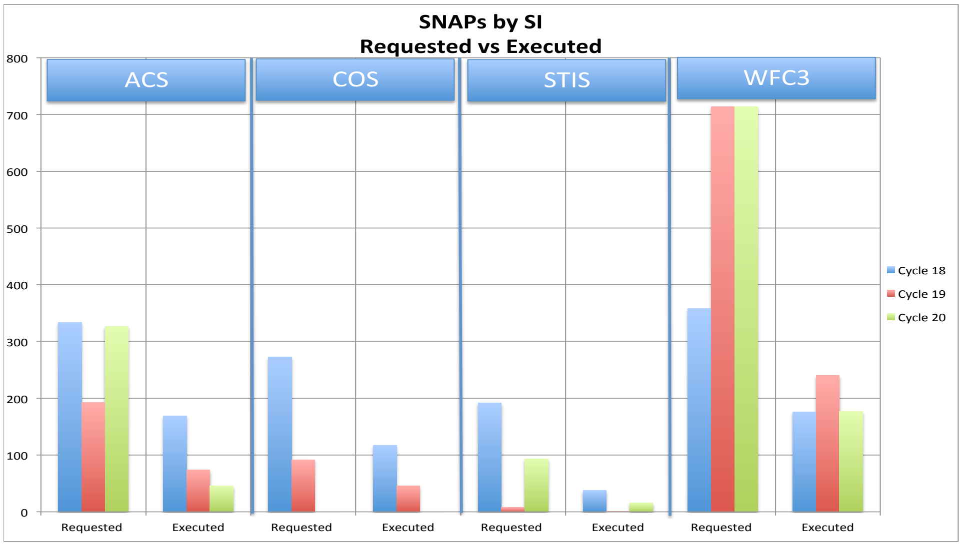

Figure 2: Snap SI Summary; Requested vs Executed; Cycle 18 – Cycle 20

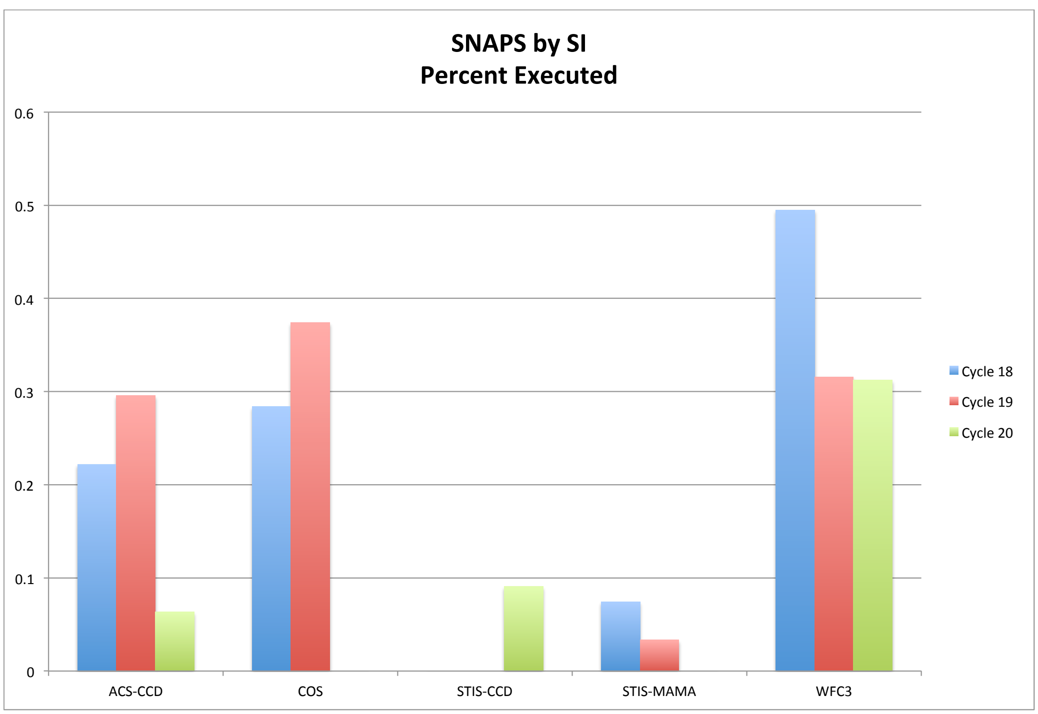

Figure 3: SNAPS by SI Percentage of Executed vs Requested – Cycle 18 – Cycle 20

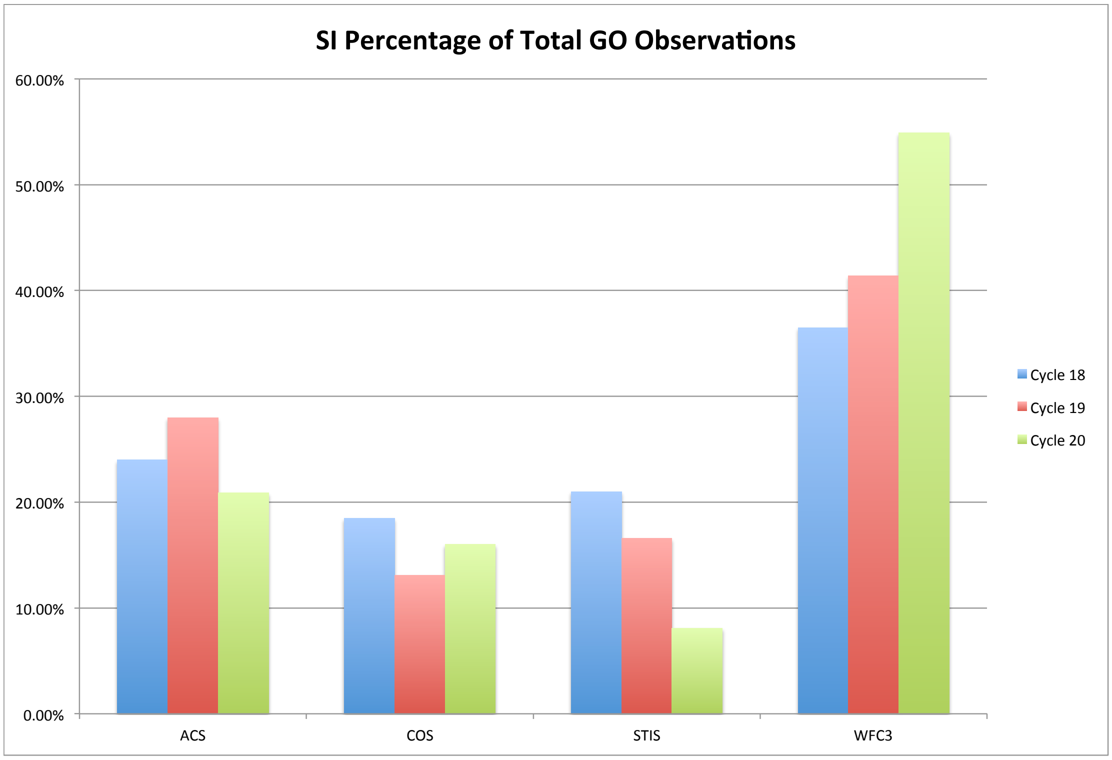

Figure 4: SI Percentage of Total Regular GO's – Cycle 18 – Cycle 20

<u>Visit Duration:</u>

As prime GO scheduling rates remain high, Snap duration continues to be an important factor in determining Snap completion results. The following charts show data indicating that shorter duration Snaps continue to have a higher completion rate. Figure 5 shows the executed visit durations for Cycle 11 through Cycle 20. The visit duration includes the exposure time plus any instrument overheads and guide star acquisitions. These data represent the actual scheduling *results* rather than the *potential* visit durations possible in these cycles. (Here again the effect of the SM4 delay is obvious in the Cycle 16 data.) Figure 6 presents the requested vs executed Snap numbers by visit duration for Cycle 18 through Cycle 20. A visual comparison shows that the 21 to 30 minute duration visits have the highest completion rates of all the bins, that the 31-40 minute duration visit scheduling rate seems to be constant around 80 visits per cycle despite an increase in request for visits of this size, that the 41 – 50 minute duration rate has declined despite a flat request level, and finally that the greater than 50 minute duration visit excution rate was less than 100 visits in Cycle's 19 and 20 even though the visit pool for this duration was more than 100% oversubcribed.

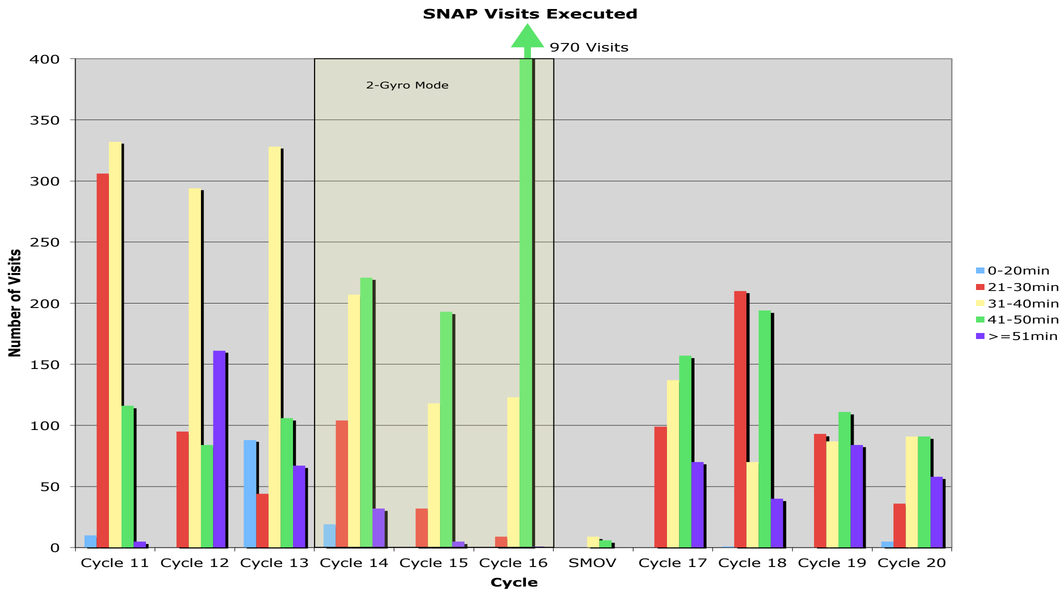

Figure 5: Snap Duration Summary; Cycle 11 – Cycle 20

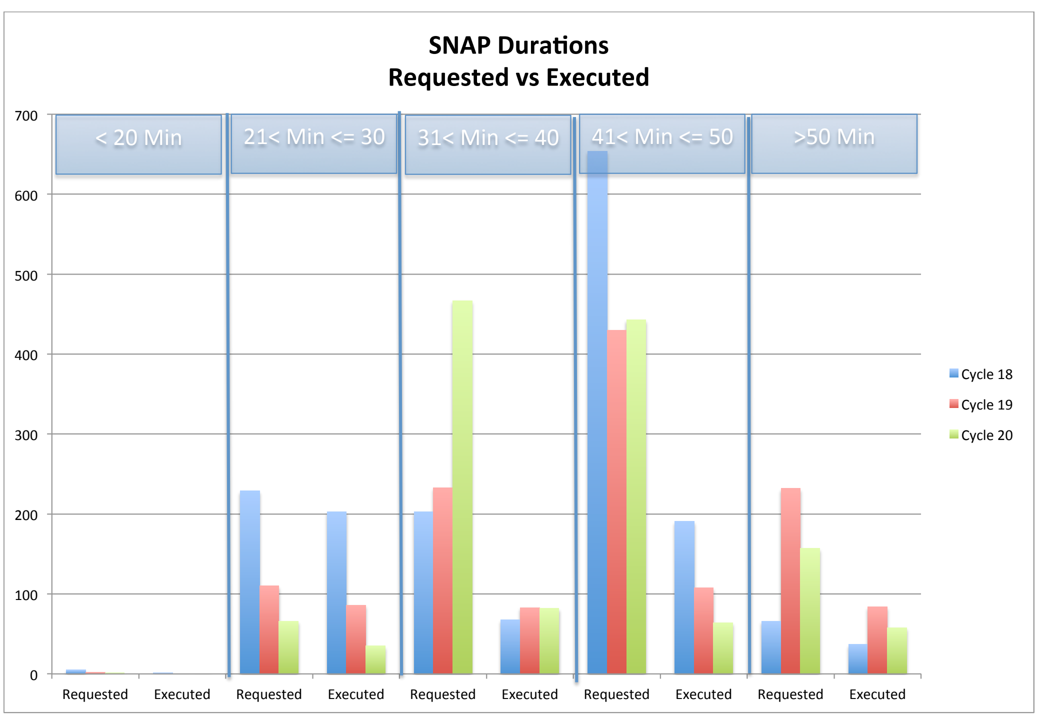

Figure 6: Snap Duration Summary; Requested vs Executed; Cycle 18 – Cycle 20

<u>Target Distribution:</u>

Figures 7 and 8 show the requested vs executed Snap targets for Cycles 18 through 20. Cycle 18 was the most evenly distributed in both requested and executed targets, and it also had the highest execution rate of the past three cycles.

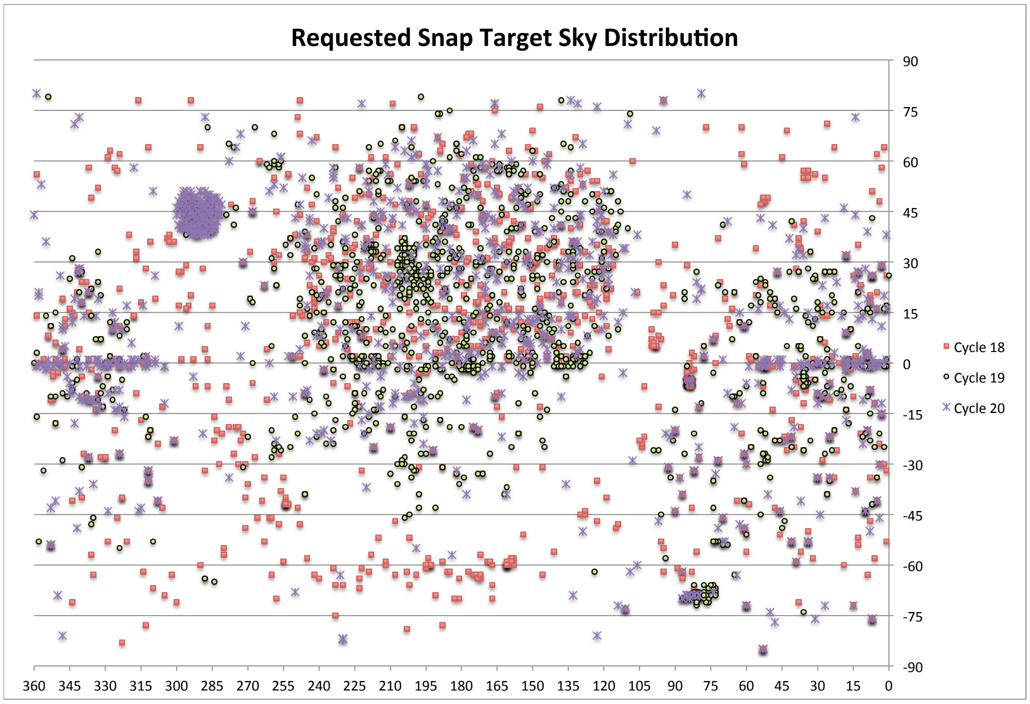

Figure 7: Requested Snap Target Distribution; Cycle 18 – Cycle 20

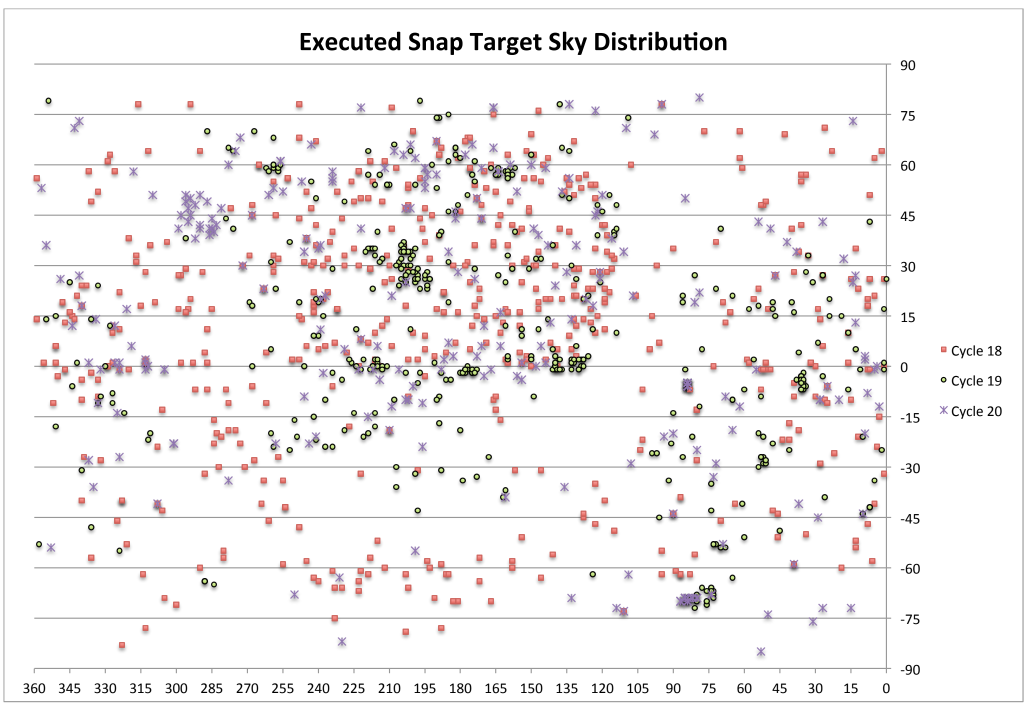

Figure 8: Executed Snap Target Distribution; Cycle 18 – Cycle 20

4 Defining Snap Programs

Because Snap visits are added to the observing schedule after all possible non-Snap visits are inserted, they need to have the fewest possible restrictions placed on them. As such, Snap programs have the following characteristics and restrictions:

- Snap programs should contain many targets well distributed on the sky to increase the probability that a visit can be selected for an available HST orbit on any given day of the observing cycle.
- The general guideline for visit duration is that *shorter is better*. As Regular GO scheduling rates improve, the numbers and durations of Snap scheduling opportunities decrease.
- Snap proposers may propose visits for only one cycle at a time. However, visits that remain unexecuted at the end of the observing cycle are kept available for scheduling for an additional year at lower likelihood of execution.
- The only Special Requirement permitted for a Snap visit is BETWEEN. Furthermore, these are allowed only for moving targets to facilitate guide star selection processing. BETWEENs must be specified in a way that allows the moving target visit to execute at any time within one or more one-week science schedules. In specifying BETWEENs for Snaps, bear in mind that HST schedules begin at 00:00 UT on Mondays (Sunday evening Eastern local time). In building a given weekly science schedule, there must be freedom to schedule a Snap visit anywhere within its timeframe.
- To minimize required labor resources, we do not ordinarily permit changes to Snap programs after the Phase II program is submitted.
- Due to their general ineffectiveness and difficulties with their use in past cycles, scheduling priorities will not be permitted on Snap visits.

5 Snapshot scheduling

The general process for HST scheduling, including Snapshots, is described in Section 2. We monitor this process to identify and address fundamental problems in Snap program execution.

The ground rules for scheduling Snapshots are:

- Snap visits are only scheduled after all attempts to schedule non-Snap visits have been exhausted.
- There is no guarantee that any particular Snap visit will be observed.
- There is no guarantee that we will be able to complete a specific fraction of a program's target list.
- If a Snap exposure fails for any reason, it will not be repeated. Once a Snap visit is placed on a schedule, it is no longer in the pool of potential Snap visits and will not be placed back into that pool if the visit fails. (Note, however, that visits *are* put back in the pool in the case of a telescope safing event that prevents a scheduled Snap from being executed.)

6 Summary

STScI's goal is to achieve program completion levels that result in useful data sets for each selected Snap program. As a working guide for proposal (target list and visit duration) development and selection, we advertise a numeric goal of 30% *average* program completion. However, there are many factors that contribute to the level of completion of a Snap program. Target distribution, visit duration and visit observing constraints all contribute to a Snap program's completion level. Programs that concentrate the targets, or have very long visit durations, will have fewer overall scheduling opportunities over a year than those with distributed targets and shorter visit durations. Because Snap opportunities are a limited resource, actual Snap scheduling results are dependent on the Regular GO visits that are actually scheduled on a particular calendar. Furthermore, these opportunities are highly dependent on the time order in which the Regular GO visits are scheduled and it is therefore not possible to accurately predict what Snap scheduling opportunities will exist. Because of this, the recommendations given to the TAC for Snap program allocations each cycle must be estimated based on past experience. The program selection process attempts to allocate a set of Snap programs to this estimated level that can achieve the advertised percent completion goal while taking into account the TAC science recommendations.