TECHNICAL REPORT

Title: Estimating JWST Visit Times	Doc #: JWST-STScI-000751, SM-12 Date: November 29, 2005 Rev: Baseline (-)
Authors: Peter Stockman Phone: 5007	Release Date: 30 January 2006

1.0 Abstract

We propose a simple method for estimating JWST Visit Times and show that it should be capable of an accuracy of 1.5% RMS and 2.6% systematic. In this Excel-style method, we use an average slew time for the proposal and long-range planning stages and recalculate the slew length during the short term scheduling process. We use a mission-average time for estimating filter and grating wheel motions. We do not model the history of these mechanisms. The RMS accuracy of this method is limited by the filter wheel and mechanism motions. The systematic error is dominated by our ability to estimate the average slew time prior to the initial GTO/Legacy program. These levels of accuracy should be acceptable for both the allocation of time by the Time Allocation Committee and for planning and scheduling in the S&OC. We anticipate that better understanding of the SI mechanisms and simple modeling of science observations (such as with the SO-DRM or PPS prototype systems) would improve these accuracies, particularly the average slew length.

Introduction

Event driven operations on JWST maintains high science efficiency without the need for detailed modeling of spacecraft activities. In particular, event driven operations moves from one activity to the next based upon the completion of the activity and not by timing. Activities such as guide star acquisition may have an indeterminate completion time for success since several guide star candidates may need to be sought before the FGS successfully transitions into fine lock. Relative time systems require a time pad for such activities and actually decrease the overall efficiency of the observatory.

Nevertheless, the S&OC needs to estimate the length of visit times to moderate accuracy for at least two purposes:

- Time allocation: In order to properly compare the relative science value of a proposal compared with the requested spacecraft resources, the proposal &

planning subsystem must assign an estimated time for each visit. To be consistent with the JWST AO, this time is intended to reflect the actual "wall-clock" time for the observation, including the time for slewing to the target. For the proposal process, overheads that cannot be known for an individual observation, such as the initial slew or the time needed to wait for a time-critical observation, will be fixed by the S&OC based upon modeling of the annual mission plan. Experience with the Hubble Time Allocation Committee (TAC) suggests that relative or systematic 10% errors in visit durations would be acceptable and considered fair by the TAC as long as these errors did not intentionally favor one instrument or area of science over another. We note that some programs in the SO-DRM have almost 100% overheads. While it is not clear how to deal with the large time uncertainties that such programs may have, this argues that overhead estimates should err on the conservative side (say 5% of the total overheads) until they are known more accurately. It is important that the method for calculating visit times for the TAC process not change during the cycle and thereby force astronomers to revise their programs

- Long and short range planning and scheduling: The estimated time for a visit is needed for creating the long-range plan (~1 year) and the short range schedule (1-3 weeks). While recent models have shown that these processes can succeed with relatively coarse estimates (~30%), it is clear that systematic errors approaching this level could potentially under or over-subscribe the overall science mission and may make scheduling time-critical activities, such as station keeping, very difficult or inefficient. Kinzel et al (2005) have shown that relative or systematic10% accuracies would be acceptable for the Planning and Scheduling processes.

2.0 Time estimates for JWST science observations

We can examine the various overhead contributions as developed by Lionel Mitchell (2005, for the SI case) for estimating total mission efficiency and discuss how accurately each of these contributions could be estimated for the average visit. Our assumed errors are based purely upon HST experience and intuition and could be in error by as much as a factor of two for an individual contribution. However we have been conservative when estimating the accuracies for the average slew time and mechanism motions -- the dominant contributors to our eventual visit length error budget. More importantly, these calculations suggest the needed accuracies (~ 10s of seconds rather than milliseconds) required for a visit time estimator tool.

The anticipated activities that occur within visits are (% of clock time shown in parentheses):

- Major slews & settling (16%): The time required for a major slew and settling can be calculated quite accurately given the appropriate slew algorithm and the starting and ending points (Euler angles). Nevertheless, we shall assume a random error of approximately 0.5 minute per slew to deal with modeling and settling time uncertainties and a 0.5 minute systematic error. This would amount to ~ 1.5% of the typical slew & settle time (~32 minutes with six wheels) respectively. However, our estimate for the typical slew length – which we would use in the proposal process – may be systematically in error. If we estimate that the systematic error is 10% at the time the first GTO and Legacy proposals are solicited, it would change the total length of that early program by approximately 1.5%, which is tolerable and can be absorbed as part of the deliberate oversubscription of 10-15% to achieve good scheduling efficiency throughout the year.

- FGS acquisition times (1%): The time required for FGS guide star acquisition will depend on the slew accuracy, the quality of the guide stars, and the stellar density. We will be able to estimate the time for each activity in an FGS acquisition with moderate accuracy (~ 20 seconds). Another uncertainty will be the potential for FGS failures with selected guide stars. If we assume that a typical guide star acquisition takes 2 minutes, then an acquisition that requires multiple guide stars can take 4-6 minutes. We estimate that less than 20% of all guide star candidates will be binaries, unresolved galaxies, or too faint. Therefore the RMS acquisition time will be ~ 2.5 minutes with an RMS error of around 0.8 minutes or ~ 30% of the typical time. We will assume a better accuracy (10%) for the systematic FGS acquisition time.
- Minor motions (dithers, 4%): Like slews, the time required to offset the pointing by 1-20 arcseconds can be accurately estimated from ACS modeling and the motion dimensions. The uncertainties will probably be determined by the settling times immediately after each minor motion. We will assume that the estimates have 5% RMS accuracy and a 3% systematic accuracy for each standard dither pattern. (Here we assume that the standard dither patterns have standard scales as well as pattern shapes and that their estimated motion overheads and settling times have been pre-calculated based upon ACS simulations. This assumption should be revisited when we better understand the range of settling times following a dither motion.)
- Instrument overheads (8.4%): The science instrument teams provided average overhead times per visit. These included a number of activities which we broke out using information from Meixner (2004), Rieke (2004) and Valenti (2004):
    - Readout times overheads (6.4%). Typically 6 s uncertainty in the start of an exposure and one group at the end is ~ 40s. These times will be confirmed during I&T and can be calculated very precisely. In practice, these overheads may be estimated as part of the exposure time calculation but for this memo, we book them here. The typical uncertainty is a few seconds out of ~300s per visit or 1%. We assume a similar systematic uncertainty prior to launch.
    - Small angular motions, target acquisition calculations, and major motions (MSA reconfigurations, 0.6%): the number of dithers were predicted but not included in the SI budgets. However, the times required for target acquisitions (relatively small amounts of time) were included as well as

the time for calculations. Large mechanism motions will be accurately known during I&T. This is a disparate group of overheads and we estimate the overall relative accuracy of these activities as 20% with a similar systematic accuracy. The largest uncertainties may be for target acquisitions.

- Grating and filter motions (1.5%): The time required for individual mechanism motions can be accurately predicted using I&T experience. In event driven operations, however, the state of the mechanisms will depend on the nature of the previous visit. Filter wheels or the MIRI gratings, for example, may be left at whatever position marked the end of the previous exposure. In this case, the S&OC will use the typical time between filter-positions based upon a random placement of the filter positions. Since most or all of the filter wheels are bi-directional, this estimate would be approximately 50% of the worst-case motion (half a rotation). The RMS accuracy of such an estimate will depend on the nature of the annual science program and filter placements (most common filters placed together or separated by 180 degrees, etc.) We assume a relative accuracy of 50% per motion (for a given observation) and an initial systematic accuracy of 30% for the mission averaged overhead per filter motion.

- Exposures and readouts (64%): The time required for exposures and readouts will be known empirically to essentially perfect accuracy through I&T testing. As mentioned above, we have not booked the readout overheads and synchronization uncertainties in this area but rather in SI overheads. In practice, the readout overheads will probably be estimated with each readout.

We RSS these estimates weighted by the average overhead times and instrument usage to derive the overall accuracy for estimating the errors in an average visit length and the length of the science mission and obtain a relative and systematic accuracy of 1.4% and 2.5% of the visit and mission times. The dominant relative (random) error comes from using average times for the filter and grating motions and not tracking their history. The dominant systematic error comes from a 10% uncertainty in the average slew length. All other contributions are relatively negligible. Doubling the estimated errors or the percentage of the mission for grating motions or slews would essentially double our timing uncertainties.

3.0 Possible Implementation in a "Observation Form" paradigm for the PPS

The "Observation Forms" will have SI-specific selections for dither patterns, target acquisitions, filters, and exposures. Mosaic patterns will also be provided. Each selection will have a corresponding average time estimate developed by ground test experience and simple modeling. These time estimates should be reviewed and configured prior to each following proposal cycle based upon on-orbit experience. During the first year of operations, the estimates may be adjusted and used in the LRP/SRP systems if better accuracies are desired.

4.0 Conclusions

We have found that the estimated timing accuracies fall well within the 10% tolerance for either the TAC process or planning and scheduling and are dominated by the SI mechanism motions and our estimates for the average slew length. We expect that our ability to estimate the average timing will improve as we understand the workings of these instruments in more detail and separate overheads that are deterministic, such as the MSA, from those that depend on previous observations.

5.0 References

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