Commentary on: "FUSE Planning and Scheduling Under One Wheel Attitude Control" by A. Berman et al.

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I. Introduction

This paper discusses the evolution of FUSE's (Far Ultraviolet Spectroscopic Explorer) process for planning and scheduling science observation tasks. After FUSE's initial launch into low earth orbit in 1999 three out of four reactions wheels ceased to work, with two stopping in 2001 and the third in 2004. Using an alternative method of stabilization and control, FUSE resumed operations in a limited capacity. Added constraints from these stabilization issues have altered the strategies of FUSE Mission Planning (MP) Team when planning and scheduling observation tasks.

After the loss of two reaction wheels in 2001, one additional constraint known as torque authority (TA) was introduced. The result of this introduced windows of opportunity of when observations could be scheduled (TA windows), thus initially decreasing visibility. However, by optimizing scheduling opportunities and relaxing constraints, full sky coverage was eventually regained. However, after the loss of the third wheel in 2004, an additional constraint of keeping the skew wheel (the only working wheel) within operating limits. This resulted in a loss of sky visibility yet again to targets with |declination| > 50 degrees.

The MP Team's strategy for planning and scheduling fell to the art and experience of planners on the team to handle a lot of the constraint considerations. The process of sorting science observation tasks into long term planning bins and further scheduling those as a MP schedule as a short term plan is shown in Fig 1 below.

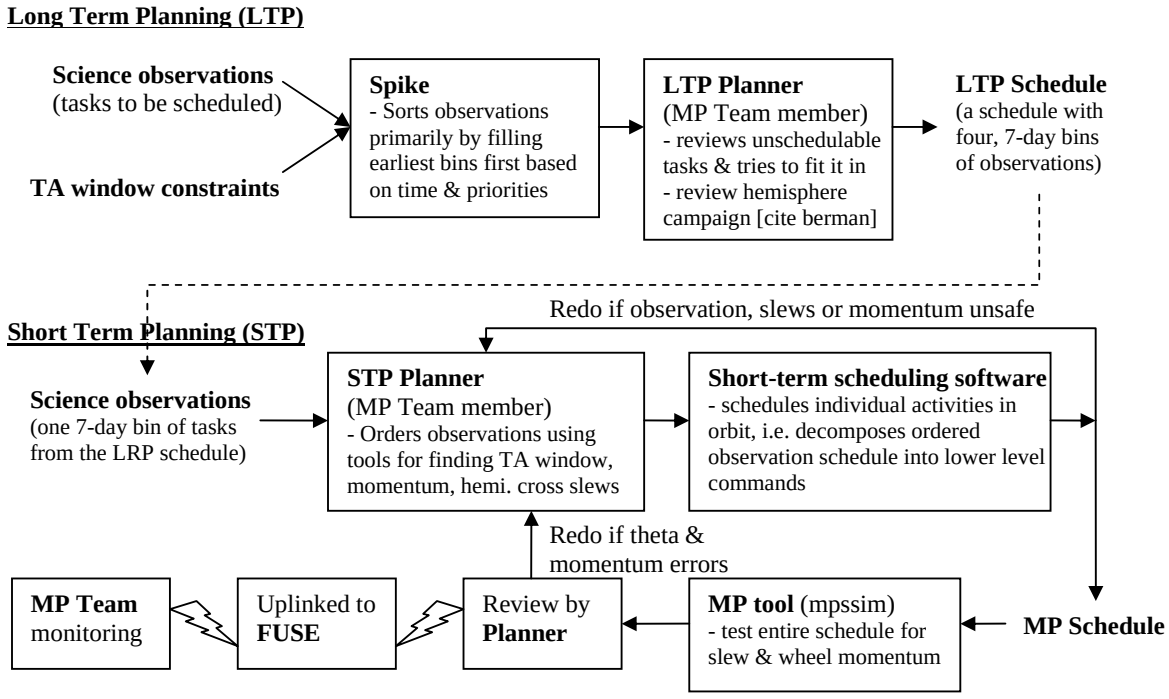

Fig. 1 Scheduling Process Flow Diagram

II. Commentary

Since the planning software, Spike, was not originally designed to manage the additional constraints imposed by the failure of reaction wheels, most of the scheduling work has shifted over to members of the MP Team. This tedious reiteration process on a weekly basis is very time consuming, taking 4-5 days to produce a weekly plan [1]. It seems that this manual scheduling, reorganization and reiteration could be automated especially for the short term planning process since there are already separate tools that compute the constraints.

A. Some Questions About the Paper

1. It is not clear exactly how the observations are scheduled by the short term planner. The planner is described to have a set of goals to achieve and constraints to comply to, but the paper does not provide a clear methodology for scheduling.
2. Do the observation tasks inherently possess positive or negative momentum, or does it depend on where they are placed in the schedule? (The former case would be much easier to schedule compared to the latter.)
3. It seems like Spike is capable of taking into account quite a few of the constraints when it produces a schedule, including TA windows, beta and pole constraints, and hemisphere campaigns. What additional necessary considerations or constraints is it lacking? Can the short-term scheduling software that performs momentum and slew calculations be used in conjunction with Spike for automated iterative planning? This idea is discussed in Section B.

B. Automation of Planning & Scheduling Process

The scheduling of observations for FUSE is a combinatorial optimization problem. Since the scheduling is done offline, the task set is reasonably small (on the order of hundreds of tasks a week) and the problem is under constrained, it seems like there may be a tractable optimal solution. However, some of major difficulties for this would be computation time and resources. The constraints are global and order dependant (for example, A before B may be feasible but B before A would not be) thus a task would not be independent from the tasks scheduled before it. This fact makes an optimal solution difficult to find since it would entail enumerating and evaluating all possible permutations. It makes more sense to settle for a sub-optimal solution that is faster to calculate.

One possibly for automating the scheduling may be a greedy heuristic that keeps track of the additive effects of momentum and slew and compare them to the constraints. Following up on Question 3 (from Section A), automation seems possible if the short-term scheduling software could be modified to keep track of accumulated slew and momentum (i.e. satellite state) and take in one observation at a time to calculate its new state. This differs from the current method of running the entire schedule through the short term scheduling software after manual preparation to get feedback on slews and momentums. Other tools, such as Spike's pre-sorted list and TA and momentum plots can be used for smart selection of observations to include. This system would iteratively test whether a new observation added to the list is feasible (see illustration of idea in Fig 2).

III. Conclusion

Due to the unforeseen circumstances of losing reaction wheels, the original scheduling software designed for FUSE is no longer adequate. Much of the scheduling process has fallen upon human hands making manual iterations of the schedule. This time-consuming process can likely be automated in a better way, though it depends a lot on project limitations such as the remaining project lifespan and the cost of software overhaul compared to manual labour.

References

[1] A. Berman et al. "FUSE Planning and Scheduling Under One Wheel Attitude Control." IWPSS. Oct 2006.

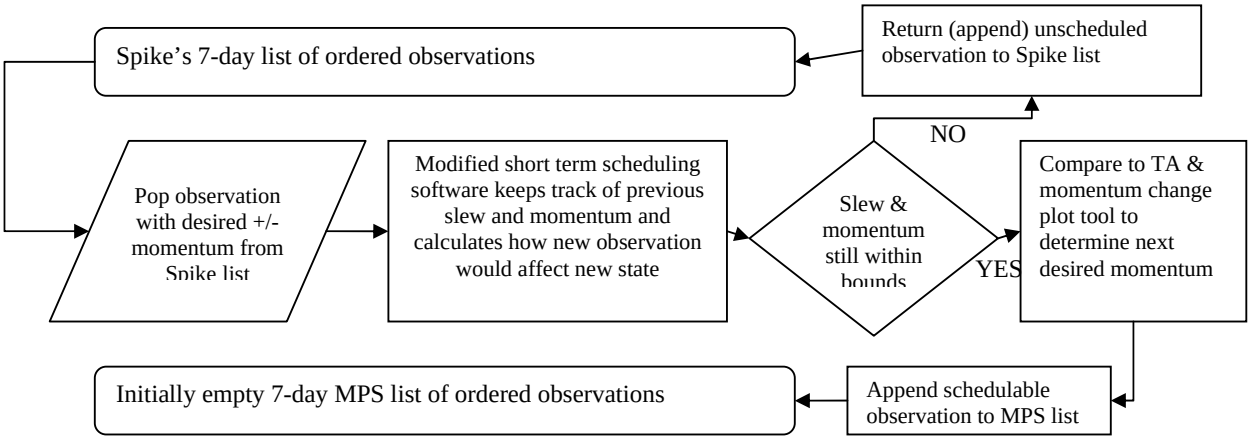

Fig. 2 Proposed Automation of Scheduling