Commentary on
"Drudgery Relieving Commands for Mixed Initiative Planning"

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1. Introduction

The bulk of the paper "Drudgery Relieving Commands for Mixed Initiative Planning" is devoted to the detailed descriptions of the algorithms and capabilities that the MER staff needed but did not originally have available in their automatic planning system. The authors preface the discussion of the presented solutions with references to the problems that motivated their. Their specific cases are representative of the generic problem that all space science and engineering missions have in common to some degree; that of not having a complete set of algorithms and human interfaces for constructing mission plans and schedules at some point in their mission life cycle. When the details are filtered out, an underlying theme emerges and reveals the specific problem that MER operators were not able to easily build an efficient, executable science/engineering timeline using their existing automated planning system under the pressures of their strict and intense near real-time operations work schedule.

While the details of the particular solutions talked about in this paper are interesting and may well be applicable to other mission's, the authors also indicate their understanding that there is a root problem common to most if not all planning systems. Therefore, this commentary will focus on some topics that are implicit or described incompletely in this paper, and are important for understanding the need for the algorithms and system capabilities that are presented in the paper; These topics include a description of the general science operations goals for building a science/engineering timeline, some of the problems (including those referred to in this paper) that operations staff face in accomplishing those goals and an overview of some of the features that are needed in a operational planning system to accomplish those goals. Obviously, the views are mine alone and not necessarily those of the authors of the original paper. And finally, I will offer an opinion of how planning systems can and should be evolved with information such as that provided in this paper.

2. The Goals of Science and Engineering Operations

At the most simple level, our primary goal as operations planners and schedulers is to build an *optimal,* self-consistent timeline (sub: plan, schedule) that contains all of the *desired* science and engineering activities in which all of the associated science and engineering (hardware) constraints are satisfied. In the context of this paper, temporal constraints represent the requirements or preferences for when science activities should execute. The MUTEX constraints mostly refer to the health and safety constraints on the use of the instruments and host platform. A timeline is self-consistent, and therefore executable, when no science and hardware constraints are violated. On the other hand, when a timeline can be declared *optimal* depends on who (and possible when) you ask; e.g. – the scientists, engineers, operations planner/scheduler, operations manager!

Secondly, operators must accomplish this task *easily* and without undue pressure within the available wall-clock time as defined by the realities of each mission's operational scenarios. To do this, planning systems must have the necessary features and capabilities (algorithms, methods and user interfaces) that are most useful in those real world operational scenarios.

3. The problems

The basic problem is that automated components of planning systems likely do not provide all of the capabilities that real world planners need. However, I do not believe that the author's intended their introductory statement about the tools they have developed to imply that they never rely on the "machinery of an automated plan". Certainly for many missions the primary goal is met thanks in large part to the work that automated planning systems do in constructing an initial plan from which operators can build and refine to their final product. At the very least, the constraint checking (or "active constraint enforcement") components of an automated planning system are vital in constructing a valid plan to ensure that both the science and engineering constraints are satisfied throughout the plan. However, the underlying critical point of this paper is the fact that automated planning systems are not, and will never be, the beginning and the end of the real world science operations planning process. The reader who is the pure planning and scheduling theorist may take issue with this conjecture. However, let's look at just a few of the related, real life problems that face operations staff:

3.1 Onboard System Characteristics and Constraint Modeling Uncertainties

There is the real issue of the inherent uncertainties between activity (or event) modeling (which is represented in the plan) and the execution of the activity (the result of executing the plan). The fact is that a plan (or schedule) is simply an estimate of what will happen in real time. In some missions, the uncertainty in that estimation is small; in others it is much larger depending on the operating environment and state of the remote observer's (observatory) system components. Furthermore, the operating characteristics of the onboard system may be dynamic and change on relatively frequent timescales (months, days, hours). These dynamics may also result in changes to the engineering (health and safety) constraints under which hardware systems are permitted to operate. Planning system operators, like in HST, but especially in fast turnaround environments like MER, need to be able to easily and quickly adjust system characteristics and constraint parameters as operating conditions dictate.

3.2 Incomplete planning scenario and activity sequence modeling in the planning system.

More problematic is the fact that while there are finite ways to build a sequence of activities, not all of the combinations are modeled completely or accurately (necessarily) in any planning system. In fact, even if a desired scenario is modeled, the automated planner may not choose a preferred solution depending on the algorithm and the control parameter settings being used for a particular run of the software. For example, there may be more than one valid order for a sequence of activities. However, one sequence may be more efficient than another in terms of power management. Depending on the runtime parameters, the automated planner may choose the less efficient solution from the operator's perspective. Another scenario involves operators that have knowledge or insights about planning resources that are not yet modeled in the automated planner. Due to schedule delivery deadlines, such knowledge deficiencies of the automated planner are better managed in the short term using manual planning functions. In each of these cases, the planning system needs to provide the ability to easily and quickly reorder sequences of activities in a way that does not create an engineering (health and safety) constraint violation.

3.3 Inability to easily adjust science and engineering constraints on the fly in the planning system.

In general, there are a variety of other reasons that an operator may need to manually move or place an activity in an existing plan. The assumption here is not that the results of the automated planner are invalid, but rather that the immediate needs of an ongoing science or engineering program call for such an action to be taken. It is simply a fact of life that the science and engineering program decision makers will decide, after a plan is built, that they want a set of activities to occur in the order A-C-B rather than A-B-C as originally specified, for example. Valuable time is wasted when it is difficult for an operator to modify the temporal constraints of a science activity. This is especially true in fast turnaround environments where quick action is necessary meet delivery schedules and still satisfy urgent activity change requests.

4. Planning System Requirements

A realistic operational scenario is enhanced by the existence of an activity planning system that includes both automated and manual planning capabilities. The automated planning capability is vital to producing an initial plan from which a final executable product can be developed. Manual planning functions are necessary for making changes to an existing plan locally in response to changes in science (or engineering) program requirements and contemporary knowledge about the observatory and its environment. An automated science (and engineering) operations activity planner can never adapt to the changes implicit in these types of operational scenarios on the short time scales that many missions must operate. Such a system must include at least the following capabilities to support a usable manual planning capability:

1. An interface and methods to allow individual activities (and transitive closure sets) to be easily added, deleted or moved from/to specific places in an existing plan.
2. To support #1, an interface and methods to easily allow individual science (temporal) constraints to be [modified, added, removed] without requiring time consuming rework of the activities and the plan.
3. To support #1 and #2, methods that allow active health and safety level (MUTEX) constraint checking without also requiring science complete constraint checking for the entire plan.

I think the authors and I agree on these points in principle if not in detail. Where we may disagree, is in their solution which involves the core planning engine. They seem to recommend a planning system implementation that begins with a set of deterministic algorithms and associated interfaces that are knowable and easy to use by the operator. These are employed for the manual operations tasks and are also combined to provide the core of an automated planning engine. This approach appears to have worked for MER presumably because the algorithms described in this paper were sufficiently efficient not only standalone (manual) but also when combined for use by the automated planner. The authors imply in their arguments that existing heuristic algorithms cannot be controlled and used in a deterministic way to achieve similar results for manual planning methods. I am not an expert on heuristic algorithms, so I will pose the following questions: Is it not possible to take an existing automated planning system built on heuristic methods and add interfaces and controls that allow the appropriate algorithms and components to be used deterministically for manual planning tasks? If this is indeed feasible, then in principle wouldn't the combined manual and automated system would be easier and less costly to maintain since both capabilities would be provided by a single scheduling engine?

5. A Case for Prototyping Operations Solutions

On a slight tangent, I am a big proponent of using operations staff to prototype new planning system capabilities. The descriptions in this paper represents prime examples of how solutions to problems in operations can be proposed and tested in real life scenarios at the source of their discovery. Operations and development teams can quickly examine ideas for solutions to existing planning problems using operations scripts and procedures for relatively low. Once proven, the solutions can be implemented in the operational system with operations staff directly providing requirements from their proven operational experience.

6. In conclusion

As a person who is only now becoming exposed to robotic explorer programs, I was interested to learn about the common issues facing planning (and scheduling) MER and HST operators despite our diverse mission profiles. While our individual planning system architectures are naturally different, many of the high level planning operations concepts and processes have very much in common. It makes sense for system operators, designers and maintainers from all science and engineering mission backgrounds to communicate and learn from each other's experiences.