Commentary on: "Orbital Operations Planning and Scheduling for the MESSENGER Mission" Alice F. Berman, Deborah L. Domingue, Mark E. Holdridge, Teck H. Choo, R. Joshua Steele, Richard G. Shelton

by
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Brief Overview

The paper describes a fielded system that exploits a growing and mature collection of software and expertise to perform mission planning. In this case, the mission is the MESSENGER mission to Mercury, but the principles that govern the planning of orbital operations for this mission are similar to those that govern other orbital missions: the primary objective is to maximize science return, but the constraints are to preserve the safety and integrity of the craft and to maintain an appropriate communication traffic between the craft and Earth. The environment places more significant safety constraints than is the case in less extreme situations, due to the proximity to the sun.

Operations planning is performed at two levels: long term (advance science planning or ASP) and short term (near term science planning or NTSP). In the case of MESSENGER, ASP has a one year horizon and NTSP a one week horizon. ASP is reconstructed every five weeks.

Plans must allocate time windows to three key activity types: maintenance operations, science operations and communications. Each of these activity types carries constraints, both hard and soft. Science operations should, in general, be performed close to the pericenter, with nadir pointing (although some science requires other pointings), while communications must occur during windows of availability of ground stations, with soft constraints arising from the quality of the transmission opportunities within these windows. Maintenance must be carried out with a minimum density on the timeline and at appropriate periodicity. A complication for MESSENGER is that the orbital features change on successive orbits.

ASP blocks out time for activities, based on predicted demands and events. NTSP adds detail within the immediate time frame and leads directly to construction of TC sequences for transmission.

As with most planning and scheduling problems, the key challenges lie in completing actions within resource constraints. Here, the limited resources are data storage and communication windows, the prime science time windows and the operational time between maintenance windows.

Planning for MESSENGER

The planning uses a mixed-initiative approach coupled with a hierarchical structuring of constraints (and plans) into the ASP and NTSP elements. NTSP requires more than one week, so must be performed well in advance of the execution window. To maintain flexible responsiveness, the team plans multiple weeks in parallel.

Comments and Questions

It is clear that the software support for the planning process is mature and that there is significant experience of its use in previous operations. This context creates both a sense of trust in and also a dependence on the functionality it provides.

Does the long history of the development and deployment of these tools mean that it is possible to be more adventurous in migrating greater autonomous decision making into the tools?

Mixed-initiative planning offers scope for humans to build trust and confidence and also to make decisions where the evaluation criteria are hard to specify.

Is the use of mixed-initiative planning here mainly due to the continued need to maintain trust, or is it mainly because the decision criteria are hard to specify (multiple objectives, soft constraints, preferences and so on)?

One of the key decisions in the construction of a planning process (human or automated) is the appropriate horizon. The elements that influence this are the reliability of actions, the stability of the environment, the required reaction time to failures, the time it typically takes to execute an action and so on.

Why is the ASP horizon of one year and NTSP horizon of one week the appropriate choice?

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Reaction to changing environment requires replanning, but the replanning strategy can vary from clean-sheet replanning to local repair.

The ASP is reconstructed every five weeks. Why is this an appropriate cycle? How does the replanning interact with NTSP (ie how close to the current NTSP horizon are changes in the ASP allowed to occur?) and where in the above spectrum does the replanning lie?

Contributions from the Academic Research World

The problem of orbital operations planning is one that has attracted some interest in the academic planning research community. For example, Cesta *et al* (2009) have recently completed a study funded by ESA that explores exactly this problem. The problem is one of constructing timelines under a series of constraints and advanced constraint-satisfaction technology appears to be able to offer significant opportunities to improve the automation of the planning. The fact that NTSP requires longer to perform than the plan it creates takes to execute suggests that there is real scope for improved automation of the planning process.

It would be an interesting opportunity for the research community if the problem specification could be made open, with data sets describing problem instances, the quality metrics and the current best solutions supplied.

References

[Cesta *et al*, 2009] A. Cesta, G. Cortellessa, S. Fratini and A. Oddi "MrSPOCK: a Long-term Planning Tool for Mars Express", Proc. Int. Workshop on Planning and Scheduling for Space, IWPSS'09, 2009

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