SKEYP: AI applied to SOHO Keyhole Operations

Nicola Policella and Henrique Oliveira
European Space Operations Center
European Space Agency
Darmstadt, Germany
name.surname@esa.int

Tero Siili
SOHO Team, Goddard Space Flight Center
European Space Agency
Greenbelt, MD, USA
name.surname@esa.int

***Abstract*—This work presents an automated planner deployed to cope with the SOHO Keyhole Periods problem. This combinatorial problem arises from the limited telemetry downlink capabilities of the spacecraft during keyhole periods and the need to maximize the return of science data while respecting other constraints, such as limited on-board storage capacity.**

I. INTRODUCTION

The Solar and Heliospheric Observatory (SOHO) is a joint ESA/NASA mission to observe the Sun and the solar wind. For this purpose, SOHO is equipped with 12 scientific instruments. Communication links with the SOHO spacecraft are established primarily through NASA's Deep Space Network (DSN). Four times a year, SOHO faces the so called keyhole periods, 2-4 week timespans during which downlinking of telemetry is limited due to a late mission issue with the spacecraft's High-Gain Antenna. Since the spacecraft's data storage capabilities are limited (two recorders, the Solid-State Recorder and the Tape Recorder), there is a high risk of science data loss during these periods. To address this risk, a data production and dumping plan for these periods must be produced beforehand.

Currently, these plans are produced manually, with the help of a constraint checking and visualization tool. While this approach works, it is an overhead to the human planner, and involves a high learning curve, since the user effectively performs the optimization process based on experience. Therefore, a tool capable of producing an initial set of different pre-optimized plans for what-if analysis and fine-tuning by the planner is highly desirable for this mission. To address this need, the SOHO Keyhole Planner (SKEYP), an Artificial Intelligence based (AI) software tool, was designed.

II. RESEARCH AND ENGINEERING APPROACH

The main requirement of such a tool is to maximize the amount of science data downlinked during the keyhole periods, while respecting a given set of constraints. Hard constraints include limited on-board storage, limited availability of communication windows and maximum downlink data rate. Other softer, ”nice-to-have”, constraints include the minimization of transitions between instrument subsets or the robustness of the plan to cope with possible station pass losses.

To address this problem a specific algorithm has been designed to fit the specific characteristics of the SOHO Keyhole Periods problem; this approach extends the Max-Flow based algorithm proposed in [1] and it allows to maximize the science return during the keyhole periods.

III. RESULTS

As a result of this effort, the SOHO Keyhole Planner, SKEYP, has been designed considering the Max-Flow approach as its core solving engine. This tool, while not yet considering the full set of constraints in the problem, shows promising results and further developments are already planned to have an operative tool.

IV. BENEFITS FOR SPACE SYSTEMS

SKEYP allows for the rapid production of pre-optimized skeleton plans. These plans may then be evaluated and fine-tuned by the human planner, based on his operational experience. Since the planning process is configurable and very performant (a new plan may be obtained in a matter of seconds), SKEYP also allows for what-if analysis and comparison of several different solutions, enabling the user to choose which one better adapts to each keyhole period. Additionally, the prototypes produced so far, while not yet respecting the problem's whole set of constraints, show a considerable increase in data return when compared to the manual process used currently.

SKEYP, along with other similar developments such as MEXAR2 [2], is a further proof that Artificial Intelligence based systems may become an invaluable help to mission planning in the future, both in terms of costs and quality of science data produced.

V. FUTURE DIRECTIONS

SKEYP is currently in a prototyping phase. The current version is able to produce a valid plan, with a high data return, while respecting the constraints of the problem. In the future, some further functionalities have to be added in order to obtain an operational tool. A promising direction is to integrate SKEYP in the current SOHO workflow as a Decision Support System for the human planner. Finally, a formal evaluation of the tool's performance and the quality of the solutions produced must be performed. This includes the selection of metrics adequate for this purpose.

REFERENCES

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