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SPACE OPERATIONS PLANNING SYSTEMS: A NEW APPROACH...

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ABSTRACT

This paper aims at drawing the attention of the space operations planning (SOP) community and of the planning automation tools & technology (PATT) community, such as the Artificial Intelligence community, to the need to improve the performance and productivity of operations planning systems for space missions, in general, and for space science missions, in particular. Such an improvement is mandatory if we want to meet the challenges imposed by the increase in the number and complexity of the systems that control the execution of space missions (e.g. increase of automation and autonomy) in a shrinking budget environment. Money invested now will, in the future, either save money and/or enable us to reach higher objectives. This is an issue that is relevant for all types of missions, including small satellites missions, and that can best be proven using small satellites. We introduce the work that we have done, so far, at the Rutherford Appleton Laboratory (RAL) to reach this objective of improving the efficiency of operations planning systems. However, there is a lot that still needs to be done as well as a need for the SOP and PATT communities to act together in a coordinated manner and to increase dramatically the degree of communication, e.g. in journals or conferences, about top-down design and implementation of space operations planning systems.

THE ISSUE

The number, complexity and diversity of space science missions continue to increase. The only way this growth can be maintained is by increasing the performance, i.e. what can be achieved, and the productivity, i.e. the cost effectiveness of the achievement, of operations.

The biggest challenge in reaching this objective is to accommodate the technical, scientific and operation policy variability across and within missions. This variability is particularly true for small satellites which offer a very wide range of sizes, purposes and operations. Indeed, these small satellites are usually grouped by weight. These groups are traditionally the picosatellites (0.1-1 kg), nanosatellites (1-10 kg), microsatellites (10-100 kg) and minisatellites (100 – 500 kg) groups. In addition, a key point is that very often the term “operation” covers both “data processing” and “operations planning”. In this paper, we focus on “operations planning”.

Therefore, the purpose of this paper is to discuss what we have done, so far, at RAL to meet the above challenge for the specific issue of operations planning for space missions, in general, and for space science missions, in particular.

Consequently, hereafter, we first discuss the type of solution that is being used in order to address the above issue. We then review the current implementation status of this solution. The rationale for this review is that such an implementation provides practical tools. Therefore, reviewing the implementation status provides a list of the tools that are already completed, i.e. available for use, in the process of being completed or still at the level of a future work plan.

THE SOLUTION

Bottom-up design is the traditional way of designing Plan Management Systems (PMS) for new missions. In this case, existing systems, which have been developed to satisfy previous mission requirements, are adjusted to satisfy the new mission requirements. This approach can be most effective when the same people are involved in the design and/or operation phases of both the old and new missions. However, one of the major problems is that a succession of adjustments can quickly make the resulting systems very complex, cumbersome and hard to manage. This is why real progress can only be made if a top-down approach is used. See also Bindschadler, 2009 for additional discussions about the bottom-up and top-down approaches for ground systems.

Therefore, the solution that we propose follows a top-down approach. A key point is that in order for this approach to be generic, its principle must ignore the purpose of the PMS. It is only when it is applied that the mission specific requirements have to be introduced.

CURRENT SOLUTION IMPLEMENTATION STATUS

The implementation of the top-down approach that is proposed in this paper is being carried out at the Rutherford Appleton Laboratory (RAL) by the Satellite Operations Group (SOG). Currently the RAL SOG has a team of about 10 people participating, on behalf of the European Space Agency (ESA), in the generation of the payload plan for the 2 following missions: Cluster, and Double Star (the latter in collaboration with the China National Space Administration, CNSA). It has also designed and operated for more than 4 years the Payload Operation Service for the Mars-Express mission (European Space Agency).

In what follows, we discuss:

- What has been done so far
- What is currently being done
- What we are currently planning to do next

What has been done so far

RAL has published in Chaizy et al. (2009) the advantages and principles of the top-down approach applied to PMS.

We have shown that the reduction of tautologies and the definition of a terminology that is relevant for all types of missions, i.e. that is homogeneous across missions, are some of the key advantages of this top-down approach. Tautologies are difficult to identify. In addition, they are the source of several problems such as cumbersome implementations. Other examples of such problems include duplication of effort and poor appreciation of the implementation/cost difficulties; e.g. the wrong belief that two specific missions are dealing with two different types of requirements necessitating two different systems while in reality the requirements have just been expressed differently. Homogeneity provides a mean of comparing design and implementation procedures, across missions and teams, and, subsequently, a way of improving the latter.

Chaizy et al. (2009) first discusses the purpose of PMS as well as their key types of inputs and outputs. Then, they discuss the principle of the top-down approach to describe PMS functional design. The variability of mission requirements and design, by its very nature, prevents the development of one-fit-for-all operation systems and leads to systems with high levels of adaptability. This is why a major concept proposed by Chaizy et al. (2009) is the one called Functional Architecture Modules (FAM). PMS architectures are constructed as an assembly of building blocks, the FAMs, which can call each other. Seven FAMs have been identified so far. These appear to cover all the functional architectural concepts required to describe the RAL SOG missions. Specific requirements can allow, impose or forbid the use of particular modules so Chaizy et al. (2009) discuss the criteria to decide whether a given FAM is relevant in a given situation. This can help current and future mission planning system designers who may wish to use the FAMs, or something equivalent, to design the functional architecture of their system(s).

What is currently being done

We are currently working in parallel on two types of projects. First, we are applying the top-down approach, described in Chaizy et al. (2009), to the development of tools and of PMS for potential future ESA missions. Second, we are further developing some of the concepts introduced in Chaizy et al.

(2009). These on-going projects are further described now.

Application of the top-down approach

P-REP

The Planning Repository (P-REP) project is being carried out, under ESA contract, by a consortium made of Grupo Mecanica de Vuelo (GMV) and of the Science and Technology Facilities Council (STFC), through RAL. The purpose of the project is to specify, design and develop a prototype for a centralized information repository to store any relevant operation planning data for any past, current or future mission. Typical planning information that can be stored includes the predicted or measured events, constraints and/or rules, plans as well as any information that can help users to generate the latter. The data to be handled by the P-REP can be files, file content (i.e. the content of the file is parsed into the repository) or any type of relevant planning information. To ensure its fast adaptability to new mission planning requirements, the P-REP provides a user environment that facilitates, in a secure and role-driven system, not only the access to the database content but also the adaptability of its external interfaces and of the user defined, mission specific data storage modelling. In addition, the architecture of the prototype itself is such that the P-REP core functionalities can be extended in the future with the potential to become a powerful complement to automated or manual planners. For more information, please, see Vallejo et al. (2009).

New Missions

The purpose of the ESA Cross-Scale mission is to study plasma coupling across time and space. It was proposed as an M-class candidate mission for the Cosmic Vision 2015-2025 programme. In October 2007 it was selected for further assessment and consideration.

At the workshop on Cross-Scale Coupling in Plasmas, 9-11 March 2009, Università della Calabria, Rende (Cosenza), Italy, SOG/RAL showed the importance of involving science operation planning expertise in the early phase of the mission design, regardless of the mission, in order to improve the performance and productivity of PMS during the PMS design, implementation and execution phase. This communication has been submitted for publication in a special volume of Planetary and Space Science entitled “Cross-Scale Coupling in Plasmas”.

In addition, SOG/RAL is also using the FAM to Assess Cross-Scale mission design issues (including cost and feasibility). The results of this study will be presented at the SpaceOps 25-30 April 2010 Conference, in Huntsville, Alabama, USA and the presentation will appear in the proceedings of the conference.

Development of new concepts

CREC

Currently, there is a need to bridge the gap between the Planning Automation Tools & Technology (PATT) communities (such as the Artificial Intelligence community), which develop technologies and tools and the Space Operation Planning (SOP) community, which can potentially benefit from the PATT technologies and tools. The SOP community is, generally speaking, not interested in understanding the details of the PATT technologies. The PATT community, therefore, needs to better explain what types of problems they can solve using a terminology that can be understood by the SOP community. In return, the SOP community needs to formulate its needs in a way that is usable by the PATT community. In other words, this means that a Constraint and Rule Expression Concept (CREC) that is common to both communities needs to be developed. The purpose of such a CREC is to structure the formulation of the constraints and rules that are regularly handled by the SOP community (see Chaizy et al., 2009 for a discussion about the difference between constraints and rules). Such structuring of the constraints and rules has already been attempted (see, for instance, Kaslow et al., 1996 or Smith et al., 2000). However, such discussions are either not focussing on bridging the gap between the two communities, thus using a terminology that is not targeting the SOP community, or are partially prescriptive and, subsequently, contain tautologies (see Appendix C of Chaizy et al., 2009 for more discussion on the Kaslow et al. proposal). This is why there is a need to develop such a common CREC. At the SOG/RAL we are about to produce an initial CREC using a problem representation approach that is biased toward the way the SOP community tends to formulate, explicitly or implicitly, constraints and rules. This CREC will not pretend to be the targeted common one but it will be a way of engaging the discussion between the PATT and SOP communities to produce the common CREC.

Update and iterative FAM detailed description

Two of the FAMs proposed in Chaizy et al. are the PMS iterative and plan update architectures. Only a high level description of these FAMs was given there. More detailed information can be provided.

What we are planning to do next

The project that is currently being considered as the next step, by SOG/RAL, is a formal standardisation of the FAMs or of equivalent concepts. Indeed, as already mentioned in Chaizy et al. (2009), standardisation will act as a common point of reference for the description of good practices. It is therefore a very good way of increasing the homogeneity and decreasing the number of tautologies of the future PMS functional architectures.

CONCLUSION

The work that has been done, and continues to be done, at SOG/RAL aims at improving the performance and productivity of operation planning systems by developing top-down approaches by capitalising on the bottom-up approaches largely used up to now. We have made some progress but more can certainly be done, not only by us but also by colleagues within other organisations. This is why we are inviting members of the SOP community to act together in a coordinated manner and to increase the number of communications addressing top-down approaches.

Overall, such progress should help reduce costs but also increase the scientific returns (typically by facilitating an increase in automation and, ultimately, autonomy). It should be relevant both for commercial and technology programs.

Finally, the small satellite communities should be particularly interested in these developments for several reasons. Firstly, small satellites are more likely to have simpler operations planning characteristics than larger satellite missions. Therefore, they are better candidates for testing the proposed top-down approaches. Secondly, for small satellites that do present operations planning characteristics as complex, or even more complex, as larger missions, the operations planning cost can represent a much higher percentage of the total cost of the mission than for larger satellites; note that for an average mission, they represent typically about 15% of the total mission cost; source: courtesy of C.P. Escoubet, ESA, ESTEC. Therefore, in these circumstances this proposed top-down approach may still provide a lower cost solution.

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