Integrating Planning and Scheduling in the ISS Fluid Science Laboratory Domain

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Abstract. This paper describes a Planning and Scheduling Service (Pss) to support the Increment Planning Process for the International Space Station (ISS) payload management. The Pss is described while targeting the planning of experiments in the Fluid Science Laboratory (FSL), an ISS facility managed by Telespazio User Support and Operation Centre (T-USOC) that has been identified as a representative case study due to its complexity. The timeline-based approach inside the Pss is evaluated against realistic planning benchmark problems.

1 Introduction

The collaboration among the authors started within the activities of Ulisse¹, a project funded by EU and indicated by REA as an example of successful FP7 project in the Space area. The project’s main goal has been (a) the data valorization around the International Space Station (ISS) experiments, but also (b) the synthesis of new tools to favor ISS management activities in a broader sense. One of these new tools has been studied to support the USOCs efforts during planning processes around ISS Payloads.

The USOCs (User Support and Operation Centres) are a network of scientific space facility operation centres that are established in various European countries with the support of national space agencies and are engaged by the European Space Agency to conduct the operations for European scientific experiments on board the Columbus as well as other modules of the ISS. Each USOC is responsible for a particular ISS on-board facility that is to be operated in order to perform scientific experiments and generate the related scientific data. In their ordinary operations, USOCs have to periodically interact with the Columbus European Planning Team (EPT), the center that coordinates nominal operations.

As a consequence of the ISS’s long operational lifetime, the mission planning process is performed in several distinct steps – Strategic, Tactical and Execution/Increment...
Planning – with distinct planning products covering different time intervals and ranging from several years to just a few days \cite{2}. In general, an \textit{increment period} lasts three months and it is defined as the time between two launches with ISS crew exchanges. Our focus has been on \textit{Increment Planning} whose goal is to develop increment-specific operations products and the associated information necessary to prepare and conduct real-time operations on payloads (also called facilities). The information generated through this process is exploited by users, ground controllers, flight crew, etc. to plan the preparation and execution of an increment plan and to help make management decisions. In producing the increment plan, an effective interaction between EPT and single USOCs is important. In common practice such a problem is addressed and solved without any decision support tool and dedicating a specialized human resource when needed. Indeed, after several interaction phases between the two centers, the need for a either complete or partial recomputation of the plan was identified. Manually generating a complete plan is not only time consuming but also an error-prone task, hence the idea of using automated planning and scheduling techniques. Our collaboration concerned the experiments in the Fluid Science Laboratory (FSL), an ISS facility managed by the Telespazio USOC on behalf of ESA. The FSL is considered a representative case study for Increment Planning due to the complexity of the involved constraints.

This paper describes our proposal for a Planning and Scheduling Service (Pss) for the Increment Planning of the ISS payload management by using a timeline-based environment for planning and scheduling. Section\cite{2} gives more details on the addressed problem and its constraints, Section\cite{3} describes the timeline based approach we have used, Section\cite{4} describes the current experimental performance of the Pss against realistic benchmarks. A concluding section ends the paper.

\section{The Increment Planning Process}

In current ISS practice, the Increment Planning process is divided into two main phases: the Pre-Increment Planning and the Short-Term Planning. As usual in space practice they have different time granularities and levels of detail. The Pre-Increment Planning delivers a list of all activities to be carried out during the increment and, possibly, identifies bottlenecks on the most critical on-board resources. The Short-Term Planning details portions of the increment, usually one or two weeks, developing more detailed plans and schedules. The main product of the Pre-Increment is the On-Orbit Operations Plan (OOS) consisting of a list of activities to be performed on a weekly basis, and if necessary on a daily basis. The Short-Term Plan is defined two weeks before the beginning date of actual execution, detailing one week of the OOS and giving a quite detailed view of the activities to be carried out during this week (Short-Term Plans are also named Weekly Look-ahead Plans (WLP)). Our work is currently devoted to solve the Short-Term Planning by capturing first a realistic domain model and then synthesizing the related complete plan. Once a WLP is identified, the subsequent plan management phase is also very important. As a matter of fact, the daily activities of USOC engineers involve two aspects: (a) to \textit{synthesize} in details feasible\textsuperscript{2} WLPs originating from the

\textsuperscript{2} i.e., compliant with a set of hard constraints provided by both the facility and the ISS.