Demo: Activity-based Scheduling of Science Campaigns for the Rosetta Orbiter

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Abstract

Rosetta is an ESA cornerstone mission that will reach the comet 67P/Churyumov-Gerasimenko in August 2014 and will escort the comet for a 1.5 year nominal mission offering the most detailed study of a comet ever undertaken by humankind. The Rosetta orbiter has 11 scientific instruments (4 remote sensing) and the Philae lander to make complementary measurements of the comet nucleus, coma (gas and dust), and surrounding environment.

The ESA Rosetta Science Ground Segment has developed a science planning and scheduling system that includes an automated scheduling capability to assist in developing science plans for the Rosetta Orbiter. While automated scheduling is a small portion of the overall Science Ground Segment (SGS) as well as the overall scheduling system, we demonstrate the automated and semi-automated scheduling software (called ASPEN-RSSC) and how this software is used. Specifically, the Rosetta mission uses an incremental planning process of successive refinement of the science mission plan beginning with skeleton planning, long term planning, medium term planning, and short term planning. These phases represent the evolution of the science mission plan from one year before execution running through just before execution. We also report on ASPEN-RSSC experience and usage during the pre-landing operations phase.

Introduction

Rosetta is an extremely ambitious mission by the European Space Agency [ESA, Factsheet] to conduct the most detailed exploration of a comet ever performed. The Rosetta spacecraft was launched in March 2004 and has circled the sun almost four times in a ten-year journey to comet 67P/Churyumov-Gerasimenko.

Science planning for the Rosetta mission is extremely complex with each of the eleven science instruments conducting multiple science campaigns and presenting numerous operational constraints on the spacecraft to achieve their science measurement including geometry, illumination, position, spacecraft pointing, instrument mode, timing, and observation cadence. Because of the challenges in effectively planning science instrument operations, ESA has a highly skilled team of liaison scientists and instrument operations engineers who work with the instrument teams using the SGS to develop science plans for the Rosetta mission.

The Rosetta mission has developed an automated science scheduling capability to support both skeleton plan development and operational plan refinement. While this scheduling system, called the Rosetta SGS Scheduling Component (RSSC) is but one part of the overall Science Ground Segment, this paper focuses on the RSSC because the target audience for this paper is the space automation community. Because the RSSC software at its core is an adaptation of the ASPEN automated scheduling and planning engine [Chien et al. 2000] we refer to the adapted/built system as ASPEN-RSSC. Readers interested in other components of the SGS are directed to other papers.

The ASPEN-RSSC Scheduling Algorithm

RSSC is implemented using an adaptation of the ASPEN scheduling framework [Rabideau et al. 1999, Chien et al. 2000]. RSSC ingests an XML formatted set of scheduling rules, science campaigns, observation definitions, observation opportunities, etc. and from this automatically generates an ASPEN adaptation for scheduling. This means that changes in campaign, pointing, observation, and other constraints can be made directly in Rosetta project systems and be automatically reflected in the ASPEN adaptation.

ASPEN-RSSC currently uses a constructive, priority-first scheduling algorithm to generate schedules. In this algorithm, campaigns are scheduled in priority first order. Within each campaign, each scheduling rule is also executed in priority order. Before scheduling each rule, adjustments are made to the packet store dump schedule in a way that results in more available space in the packet store for the instrument that will be schedule by the rule. For example, if ALICE observations are requested by the rule, extra dump time is allocated to the ALICE packet store without overflowing other packet stores. In addition, an initial search is performed for the type of observation being scheduled by the rule to pre-select valid start times that best match the preferred separations for *all* observations being requested by the rule. For example, if a rule requests a group of five OSIRIS observations every two days for a ten days, the scheduler searchers for valid start times for all 25 observations that satisfy intra- and inter-group separations, and minimizing the difference from preferred separations. However, because each observation changes the schedule in complex ways (e.g. resources), valid intervals are re-computed for each new observation and the pre-selected start time is used when available.

When scheduling each observation ASPEN-RSSC computes all valid constraint intervals as indicated below:

1. campaign interval
2. separation from other observations as specified by the scheduling rule
3. windows of opportunity
4. instrument, subsystem, and mechanism mode constraints
5. prime and rider attitude availability
6. availability of resource packet stores (e.g. data storage)
7. data transfer rate constraints
8. power

When computing the above intervals, ASPEN-RSSC computes valid intervals even where prior constraints have ruled out observation times. While this decreases the efficiency of the scheduler, it increases the utility of this constraint information that is also used to manually analyse the results of the automated scheduler in working towards a feasible plan.

Rosetta and ASPEN-RSSC Status

The Rosetta orbiter successfully exited hibernation in January 2014. Planning for the period MTP 3 began in January and proceeded directly with MAPPS. Pre-landing MTP 4-9 were planned in ASPEN, with a transition to MAPPS at or slightly after the planning periods entered Medium Term planning (~ 2 weeks after MTP kickoff). Plans covering periods after lander delivery (Nov 2014) have used ASPEN for long-term planning through 8 weeks prior to execution.

As an example of plan size: the MTP6 plan contains 58 scheduling campaigns, 2119 observations (including engineering activities), and 2130 spacecraft pointings and slews.

Currently a typical MTP plan requires 20 minutes to generate a plan with a single run of the greedy heuristic scheduler.

RSSC Demonstration

For the demonstration we will show:

Rosetta background video:

http://rosetta.jpl.nasa.gov/gallery/multimedia/videos/chase

the RSSC scheduler with Rosetta mission science data:

(We will highlight the constraint visualization and observation placement analysis capabilities.)

https://drive.google.com/file/d/0B4gKIo5pZb30WlJtNU5YclRlQUk/view?usp=sharing

and visualizations of the execution of Rosetta plans:

https://drive.google.com/file/d/0B4gKIo5pZb30TnBHRk1SNUJGd0k/view?usp=sharing

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References

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