INCREASING PERFORMANCE AND PRODUCTIVITY IN PLANNING ORBITER SCIENCE

P.A. Chaizy[(1)], T.G. Dimbylow[(2)], M.A. Hapgood[(3)], M.G. Hutchinson[(4)], P.M. Allan[(5)]

Space Science and Technology Department, Rutherford Appleton Laboratory Chilton, Didcot, Oxfordshire, OX11 0QX, United Kingdom, Email:
[(1)]P.Chaizy@rl.ac.uk, [(2)]T.G.Dimbylow@rl.ac.uk, [(3)]M.A.Hapgood@rl.ac.uk, [(4)]G.Hutchinson@rl.ac.uk, [(5)]P.M.Allan@rl.ac.uk

ABSTRACT

It is the role of a Science Operation Centre (SOC) to provide the technical support and expertise necessary to assist a science community to plan and operate the payload on board a robotic scientific spacecraft in an effective and efficient manner. This paper discusses the origin of the set-up and running costs, inherent to SOC activities, and what needs to be done to improve SOCs productivity. Examples of what is being done, currently, to reduce the costs are also provided. We believe that the search for further cost reduction will greatly benefit from a centralised co-ordination. Ultimately, the need to improve SOC productivity will undoubtedly lead to a redefinition of the role of the SOCs. We therefore propose what could be the future role of the SOCs and a strategy to identify the most effective ways of making the SOC evolves towards more productivity.

1. INTRODUCTION

The Rutherford Appleton Laboratory (RAL) currently has a team of about 15 people co-ordinating, for the European Space Agency, the payload operations of 3 missions: Cluster, Mars Express, Double Star (in collaboration with the Chinese Space Agency). By sharing our practical experience, accumulated over nearly 30 staff years of practice, we discuss what is done and what could be done to improve SOC productivity while keeping, or even improving, the science return.
We discuss the following areas:

- Purpose and key activities of Solar System Science Operation Centres (SOCs)
- Costs inherent to current Solar System SOCs
- Proposals for further cost reductions
- Conclusion

2. SOC PURPOSE AND KEY ACTIVITIES

The following sections concentrate on Solar System SOCs.

2.1 SOC purpose

A SOC is at the interface between the Principal Investigators (PIs) and the Mission Operation Centre (MOC). Using inputs from the PIs and MOC, the ultimate purpose of the SOC is to generate and send, to the PIs and the MOC, the timeline of command data (i.e. commands or command sequences) required to operate the payload (e.g., Hapgood et al., 1997). There are currently two organisations which run SOCs for ESA's Solar System missions:

- RAL for the Cluster, Double Star and Mars Express missions
- ESTEC for the Rosetta, Venus Express and SMART-1 missions

2.2 SOC logical components

A key issue for orbiter operations is the logical separation of spacecraft usage and command planning activities, as shown in Figure 1.

- **Spacecraft usage planning** is concerned with making a viable timeline of science observations, e.g. checking that the spacecraft can safely deliver the resources (e.g. power, pointing, data storage and downlink) needed for the observations, and also that there are no incompatibilities with the safe operation of other instruments.
- **Payload command planning** is concerned with converting the plan into a set of commands that can be uplinked to the spacecraft to operate the instruments. This is a substantial task for a science mission because world-class science requires instrumentation at the cutting edge of technology. The commanding of such instruments requires much care and attention throughout the mission.

The spacecraft usage planning is established on the basis of science requests constrained by (a) orbit and event data supplied by the mission operations centre (MOC) and (b) the overall mission policy. The latter comprises rules set by the MOC and science policy set by the mission's scientific management. The outputs from the planning include feedback on the assessment of science requests (to allow iteration of requests), planned resource usage (for assessment by MOC) and most importantly, the Science Plan which describes the timeline of science observations. This Plan is a key input to the payload command planning, where it can be used to generate a draft timeline of instrument commanding. This draft can be reviewed by instrument experts and adjusted before final delivery to MOC for execution.

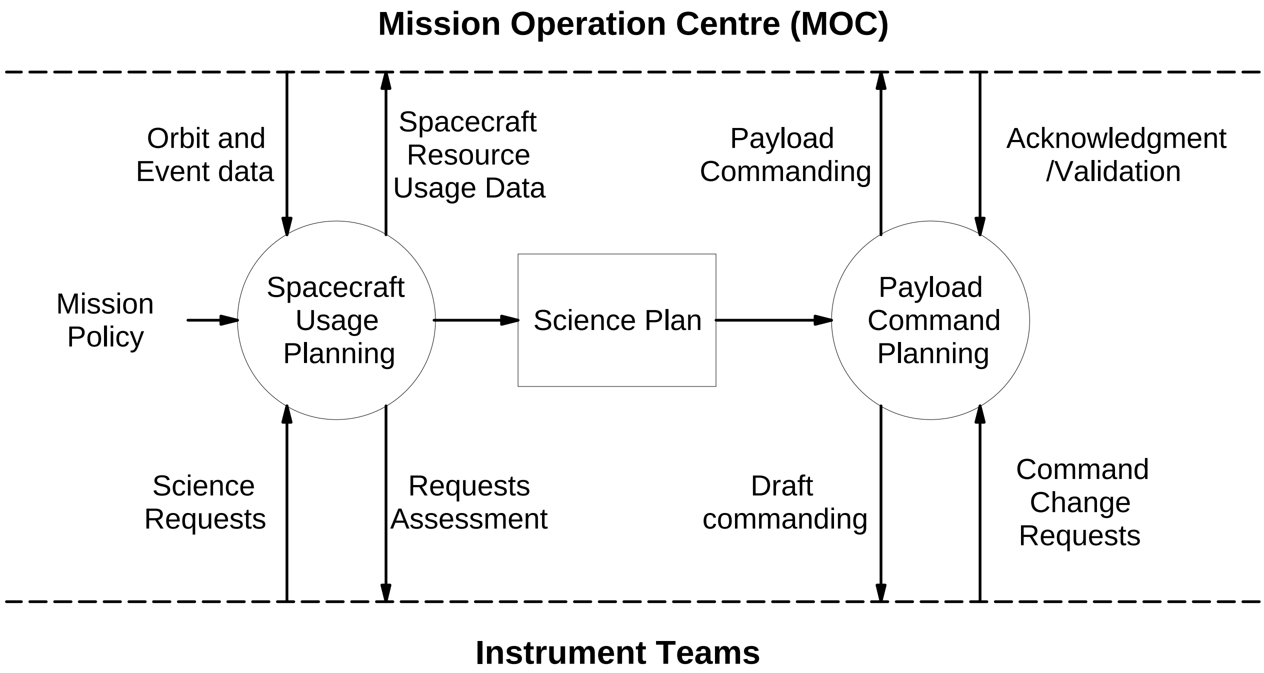

Figure 1: main data flows for spacecraft usage and payload command planning.

2.3 Iterative planning

A key aspect of orbiter science planning is a strong feedback loop between science requests, spacecraft activities and the resources available to deliver the science requests.

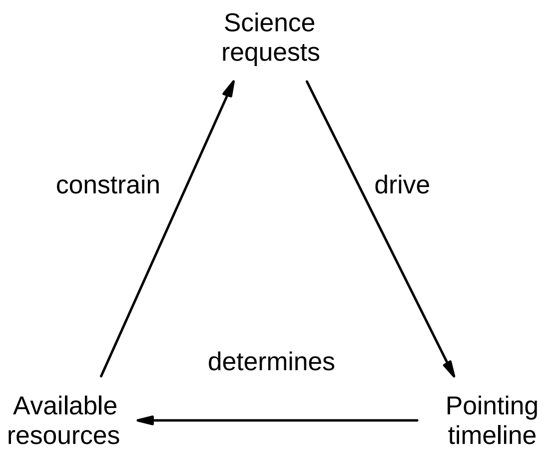

Figure 2: Planning is a circular process where the set of science requests, spacecraft activity timeline and available resources are iterated until a self-consistent solution is found.

This arises because science requests often require the spacecraft to undertake activities such as pointing at specific targets and Earth communications. These activities constrain the resources (e.g. power, data downlink) that the spacecraft can deliver and thus feedback as a constraint on science requests. This is illustrated in Figure 2, which shows that the planning is a circular process. The circularity of this process is critical. To maximise the scientific returns SOCs have to iterate the solution until a self-consistent set of science requests, spacecraft activities and resources is obtained. It is worth noting that the need to find self-consistent solutions, under strong feedback conditions, is a standard real world problem.

2.4 The need for plan update

Plans have to be optimised in discrete sections covering several weeks or months, called planning periods, and are generated several weeks or months before execution. It is therefore likely that between the generation of the initial plan and the completion of the execution of the plan the conditions used to optimise the initial plan, will have changed so much that the plan is not meaningful anymore. Examples of change of conditions include:

- Event time changes (e.g. unplanned orbit changes)
- Unpredictable situations such as technical failure or identification of new scientific targets
- Changes of planning rules
- Evolution of the performance of the instruments

To cope with those changes plans have to be finalised in smaller discrete sections covering, typically, one week of operations called operation periods. Change of conditions can also occur during the finalisation of those smaller sections of the plan.

3. COSTS INHERENT TO CURRENT SOCS

Set-up and running costs increase with the time required to perform the actions as well as with the required level of experience and performance (i.e. grade) of the staff.

Reducing the staff resources without decreasing the scientific returns, i.e. increasing productivity, requires to design and implement mechanisms speeding up the actions required to set-up and run SOCs. This means improving not only the intrinsic performance of the tools and procedure but also their ease of use.

3.1 Set-up costs

Currently set-up costs systematically include the design, development, installation and configuration of the SOC systems for each new mission.

A clear way of reducing the costs is to minimise the design and development phases and to simplify the installation and configuration phases. The design and development phases can be minimised by designing and developing generic SOC systems (architecture, tools, interface, etc…). Installation and configuration costs can be reduced by developing, as much as possible, tools and procedures which makes the installation and configuration of the generic SOC systems simpler.

The following sections provide examples of what is being currently done to reduce the set-up costs.

System architecture at RAL

First, there is a clear distinction between the spacecraft usage planning and payload command planning within the SOC system architecture at RAL. This modularity allows for flexibility across missions. For instance, the payload command plan generation is very similar for the Cluster and Double Star missions but the spacecraft usage planning is very different. For Cluster, the spacecraft usage planning is done by the RAL-SOC, while it is done by the Chinese for Double Star. Secondly, RAL tries to re-use and re-engineer as much of existing SOC systems to operate new missions. Thirdly, whenever possible, the re-engineering is done in a way that increases the generic nature of the system.

Interface

There is currently an attempt, driven by ESA, to produce a common SOC-MOC interface control document across the planetary missions, currently Rosetta, Mars Express and Venus Express.

Tools

The current SOCs have developed a series of tools that can be readily re-used across missions after reconfiguration. The main ones include the Experiment Planning System (ESA, February 2003), or EPS (command plan), the Event Handler & Associator (EVHA) (command plan). ESA is also developing the Automated Planning System (ESA, May 2003), or APS, to help the generation of both the spacecraft usage and payload command plans.

3.2 Running costs

Running costs include the execution and re-execution of the tasks required to generate the plan. The reasons why re-executions happen include the changes of conditions, leading to a plan update, and the pertinence of the data exchanged in between the components of the planning circle. It is worth noting that the pertinence of the data exchanged is not about syntax or formatting issues. Such latter problems, usually, can be relatively easily sorted out using software. It is about making sure that what is requested is technically feasible before it is validated.

To decrease the costs, ways must certainly be found to speed-up the execution of the tasks, i.e. to increase the performance and functionality of the tools and procedures that are used to execute those tasks. However, ways must also be found of avoiding the recurrence of certain activities, particularly the ones requiring the longest execution time.

The following sections provide examples of what is being currently done to reduce the costs.

System architecture

The likelihood of having a change of condition reduces with the decrease of the duration between the start time of the finalisation and the start time of the execution of the operation period. One may then think that costs can be reduced by concentrating a high amount of staff resources as close as possible from the execution start time because the chances of having a change of conditions will be lower. However, usually the cost increases with the decrease of the time between the start of the finalisation and execution of the operation period. This is simply because staff working during the weekend or nights are more expensive than staff working during traditional working hours. Therefore, the right balance must be found between the staff resources needed to pre-emptively limit any change of conditions and those required to react, afterwards, to a change of conditions.

Moreover, staff resources required to implement updates are decreased by limiting the need for re-validation after an update so speeding-up the planning process. This is particularly useful when some validations take a long time to execute. At RAL examples of such separation include:

- The possibility for the PIs to iterate the spacecraft pointing and resources and propose a solution which is then checked for thermal constraints. The former takes a few minutes to a few hours to execute but the latter takes about 1 week. In other words, having to check the thermal constraints each time the pointing is changed, e.g. due to a spacecraft resource violation, would be extremely time consuming.
- The possibility for the PIs to update the payload command plan without having to change the spacecraft usage plan if the necessary updates do not require a change of the spacecraft usage plan.

Finally, the pertinence of the data exchanged in between the components of the iterative planning are usually improved by defining empirical rules that are then used to formulate the science requests. Such rules can limit the likelihood of rejection of the requests very significantly.

Tools

Tools are used to speed-up the generation and improve the quality (by reducing human error) of the data exchanged with, and within, the SOCs. They include the generic tools mentioned in the set-up costs section. They also include more mission specific tools such as:

- For spacecraft usage planning, the Mars Express Instrument Resource Analyser (MIRA)
- For file processing and management:
  - Cluster: Joint Science Operation Centre Control Centre (jcc)
  - Double Star: Double Star Control Centre (dcc)
  - Mars Express: Payload Operation Service Control Centre (pcc)

4. FURTHER COST REDUCTIONS

ESA has financed the design and implementation of two types of SOC, at ESTEC and RAL, to co-ordinate the science operations of similar missions: e.g. Mars Express at RAL and Rosetta, Venus Express and SMART 1 at ESTEC. This provides a unique richness of expertise. However, we believe that to develop further this richness, for the current and future SOCs, and to capitalise on it, some centralised co-ordination is required. We are convinced that allocating some resources for such a co-ordination would, ultimately, save very significant amounts of money in the funding required for SOCs for future missions. The discussion below proposes what could be the aim of the co-ordination.

We believe that the search for productivity will lead to a redefinition of the role of the SOCs. Therefore, to be efficient in the search for increasing productivity, one need to define and agree the future role of the SOCs as well as a methodology to identify the best ways for the SOCs to evolve efficiently towards their future role.

This is the purpose of the next two sections below. The last section proposes a list of practical areas in which costs could be reduced in the near future.

4.1 Proposed SOCs future role

Up to now, SOCs for Solar System missions have been responsible for designing, developing, installing, configuring and running science operation planning systems. However, in the search for reducing human interaction and costs, the new role of the SOC might be restricted to installing, configuring, running and improving the generic nature of the science operation system. The above would be true for both ground-based and on-board operational planning. Note that on-board planning could be considered as a more distant objective that is likely to change the detailed activities of the SOC and to improve productivity.

This means that the new role of the SOC could include the following activities:

- Installing, testing and configuring the system
- Assisting the PIs in providing their inputs, for instance by providing advice on how to format their inputs and resolve conflicts
- Implementing the MOC planning rules into the system
- Act as repositories to collect data in order to improve the system (including tools and procedures)
- Participate in the design and development of new tools/procedures or improvement of the existing tools/procedures.

4.2 SOC evolution methodology

We propose to increase the likelihood of finding efficient ways of making SOCs evolve towards their future role, even if it is not the one suggested above, by:

- Having more than one SOC team, setting-up and running the SOC systems for one or more missions, to increase the likelihood of identifying alternative ways of finding solutions to problems.
- Allowing comparison and ensuring continuity: By having SOC teams operating several missions it will be possible, for each team, to identify what are the components of the previous missions that cannot be re-used, why they cannot be re-used and, potentially, what could be done to make them re-usable. Also, the re-use of the identical SOC teams for several missions will reduce the training costs.
- Facilitating the exchange of the practical experience of the various SOCs for all type of missions, including Solar System and Astronomy missions. For instance, it is suggested that ESA supports regular SOC workshops of which benefits include:
  - Sharing lessons learned
  - Building best practice
  - Opportunities for collaboration

4.3 Proposed areas for improvement

This section proposes a list of areas where improvement would bring significant cost reductions.

System architecture

Develop a common system architecture across the SOCs (two different architectures are currently running in parallel - for similar missions, e.g. Mars Express at RAL and Rosetta and Venus Express at ESTEC)

Interface

The two key logical components of payload operation planning described above, namely the spacecraft usage planning and payload command planning, are well implemented within the SOC but not so well at the SOC-MOC interface. Indeed, the current practice used to distinguish between the spacecraft usage and payload command plans is more a work around than a proper consideration of the issue. A better distinction, at least at interface level and possibly within the MOC system as well, would provide an improved architecture and a more efficient ground segment.

Tools

The list below provide suggestions on how to improve the performance of the tools currently used:

- Improve the generic nature of the File Transfer System, a tool developed by ESA to manage the files exchanged between two operational entities (e.g. SOC and MOC)
- Develop the use of secure methods of public Internet for data transfer rather than use (expensive) private lines
- Carry on improving planning tools, e.g. like making MIRA more generic and/or supporting the development of tools like the APS.
- Work on simplification of the set-up procedures of the existing generic software
- Third party software: Move to the use of open source products for:
  - Operating systems
  - Databases
  - Development environments

Procedures

Based on the experience accumulated by RAL cost can be reduced by:

- Early involvement of the SOC in the definition of the content of the SOC system configuration variables (e.g. in the definition of the content of command sequences, of the mission policy etc…). Such involvement would allow a better set-up and configuration of the SOC and the SOC-MOC interface, thus limiting the need for corrective measures at a later stage (e.g. such as the command sequence naming convention, content etc…).
- Increased participation of the SOCs in the definition of interface standards.

5. CONCLUSION

We recommend more co-ordinations to enable the SOC role to evolve towards more productivity. We propose a strategy to more effectively allow the SOC role to evolve as well as a future role to reach. We also propose a list of practical areas in which costs could be reduced in the near future.

6. REFERENCES

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