Title – A combined Checkout and Control System for Small and Large missions

Category – Mission Operations - III

Authors: Terma:: R. Patrick[i], Siemens AG (Austria): H. Kubr[ii], Vitrociset SpA (Italy): F. Croce[iii]

ABSTRACT

The SCOS-2000 system, as developed by ESOC, has dramatically reduced the cost of Mission Control Systems for ESOC over the past 10 years – sometimes by a factor of as much as 10. This has been achieved by the increased standardization (CCSDS et al) and the use of lower cost technologies.

This is a considerable contribution to reducing the costs of the mission operations, but are there ways to find further savings beyond those already achieved? In this paper we cover a project currently underway, which based on this SCOS-2000 infrastructure will help to further reduce operations and life cycle costs.

This paper shows how this problem has been addressed from earlier in the spacecraft life cycle. SCOS-2000 has been selected for not only the mission operations but also the instrument and spacecraft checkout for the European Herschel/Planck program. There are a number of areas where this is anticipated to reduce costs, not just limited to the need to develop only one system. Costs will also be saved by lower data conversion costs, lower training costs etc throughout the lifetime of the programme.

This solution is also ideal for small satellite programmes with small budgets.

1 Introduction

The construction of the Space Segment and the construction of the Ground Segment have traditionally been split very early in the development phase of Space Systems. This approach has proved successful in launching many space projects. However, some people claim that this is as much driven today by the characteristics of the organisations that are building the system rather than technical or programmatic constraints.

There is a lot of information produced during the space segment construction which has to be reflected in the ground segment in order to perform successful satellite operations.

There has been pressure from many quarters to improve the level of commonality between the pre and post launch activities. This paper focuses on one specific area, the use of ***a common system for the checkout and control of the spacecraft***.

The cost savings from this approach are primarily two-fold:

- reduced system development costs
- reduced operations training/operations preparation costs

The latter is probably more significant because the operations preparation can benefit from the activities and products of the development phase, leading to a much smoother transition from one phase to the next

There are other potential spin-offs to this such as the use of a common spacecraft data base thus further increasing cost benefits and reducing schedule risks.

The system at the core of this work, is the ESOC SCOS-2000 system. This has matured considerably over the previous 2 years and is now widely accepted as a state of the art Mission Control Infrastructure with wide acceptance on both ESA and non-ESA Missions. The openness of the system also allows it to be taken into other domains, such as the pre-launch checkout.

The paper covers:

- The early work done on the ESOC SCOS-2000 Mission Control System infrastructure to furnish a highly functional, robust system based on low cost technology
- A first step of activities - the work to be done to extend the Spacecraft Control System to support instrument and payload testing activities
- The second and final step to support the system level testing of complex spacecraft
- Specific examples of the above where the system is used for experiment, payload and system testing as well as mission operations.

2 Background

Projects can vary quite considerably in size and complexity, and this drives the complexity of the tools required to validate the mission prior to launch and operate the system after launch.

The development model used by most missions tends to be rather similar, being broken down into a number of distinct phases.

As the system is developed, knowledge and information is built up about the space and ground system. The problem is how to ensure that this information is transferred efficiently between the different phases and/or groups involved in the project. This information can come in a variety of different forms. Typical examples are:

- The System Data Base defining the TM/TC characteristics and the relations between them
- Simulation Models
- On Board Software
- AIT and Flight Operations Procedures
- Other Space and Ground Segment Documentation

The mission will also use a variety of tools to either develop and/or exploit this information. Such tools include simulation environments, checkout systems, software validation facilities and control systems.

The relation between the phases, tools and information are shown diagrammatically in Figure 1.

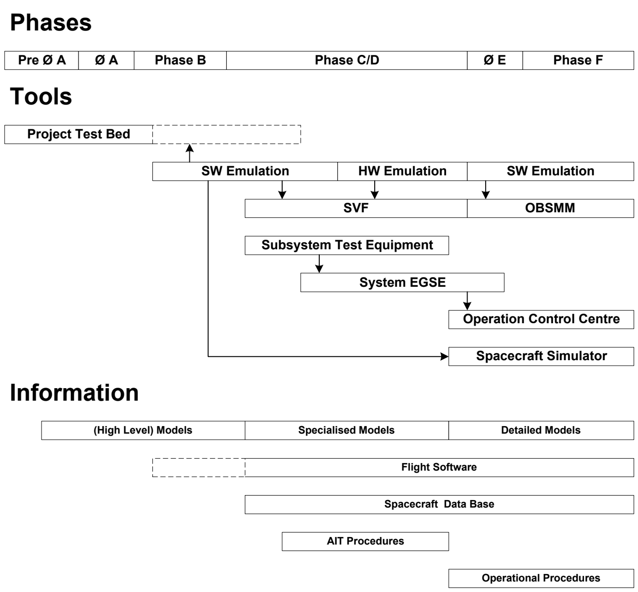

Figure 1: Phases, Tools and Information

3 Commonality

Commonality is a much used word when optimising mission development and operation costs. There are two aspects we consider here:

- Vertical Commonality - this is the re-use of common systems within a single mission. These systems are very good at preserving the information and knowledge for the missions - the different tools are passed between the groups involved in the different phases of the development, and these groups have to familiarise themselves with these tools
- Horizontal Commonality - this is the use of the same tool across several missions. For example, a checkout system will be familiar to an AIT team, and there is some advantage is re-using this by the same group for the next project. The knowledge from earlier phases of the project has to be "imported" in some manner into such a system.

It is necessary to point out that vertical commonality is has best been applied on small missions - in many cases the smaller budgets dictate it. Here it is not only the tools but the people as well who tend to be used throughout the mission. An extreme example of this is the Danish Orsted satellite, which was designed built and operated by a relatively small team within Terma (project budget was of the order of 10Meuro).

Horizontal commonality tends to be more or less mandatory on larger missions. The complexity and amount of work dictates the use of different groups of people, normally within different organisations/companies, where a particular group will be familiar with a particular tool and would prefer to use that, rather than bringing in a new tool for each project or group of projects.

4 From Integration to Operations

The problem of knowledge transfer is at it's greatest when the teams involved in the mission development are at it's largest. This is typically during the main integration phases of the system, where many people have detailed and specific knowledge about the system, subsystem or equipment. All this knowledge has to be consolidated in a form to allow efficient preparation for the operational phase of the mission - in many cases done by yet another team of people.

In Europe in recent years much work has been done to try to bring further efficiencies to this process, particularly for the more complex missions.

An example is the approach taken for the system data base for the Rosetta ESA Science Mission. Here a data base tool was defined by all the key stakeholders - Customer (ESTEC), Operator (ESOC), Prime Contractor (Astrium GmbH), Avionics Contractor (Astrium SAS) and AIT/AIV Contractor (Alenia SpA). The tool was then used by all these parties as a common repository for the information to be used for both the checkout and operation of the Satellite. The same concept will be applied on subsequent science missions (Mars Express etc). The AIT/AIV tools and the operations tools, both used the same data from the same data base, but the tools themselves were different.

Many studies have been performed into the potential re-use of AIT Procedures for Flight Operations, but these tend to have very limited benefit - the objectives and environment of AIT and operations are quite different resulting in rather different procedures. Re-use is therefore no a major benefit here.

5 The Next Step

On the Herschel/Planck programme - two major ESA Science Missions being procured under the same prime contract - the next step is being taken. The project will not only have the same common data base concept as pioneered on Rosetta, but the pre-launch checkout and post-launch operations will be based on the same command and control kernel - the ESA developed SCOS-2000 system.

This will bring commonality in the areas of the MMI and use of the system, archive structure etc. There will be some savings in the development of the systems, but there is a far greater potential saving in the more efficient transfer of information and knowledge as both the spacecraft integrators and operators will be "talking the same language". Even in the scenario where the AIT and Operations are done by different organisations, it can lead to simplification:

- The operators can more readily support AIT activities to familiarise themselves with the space system for which they will eventually be responsible - learning the checkout system is not a burden, as it is the same system that they will be using
- The spacecraft engineers will be able to more readily support the operations team during commissioning and troubleshooting activities.

In addition, during an AIT programme, numerous ad hoc tools tend to be produced to perform things very specific to that mission (analysis tools, data processing etc). These can then also be re-used by the operations teams.

6 SCOS-2000

6.1 Introduction

SCOS-2000 is the current spacecraft control infrastructure used by ESA/ESOC. It is a distributed UNIX based system and builds on many years of operational experience within ESOC.

Recently, development work has been done on the system in two main areas:

- Terma & Vitrociset have led the development of a version of the system that will run on both Solaris and Linux, rather than just Solaris, thus opening up the much lower cost PC Hardware market to the product
- Siemens have developed a number of tools around the kernel that allow it to be used for experiment level checkout

These activities are brought together, and under the leadership of Terma, building on their many years of experience in providing both checkout and operations systems, will be enhanced to support the system level checkout of the two highly complex spacecraft (Herschel and Planck).

SCOS-2000 also has some other features that AIT users will find very useful and are currently missing in other checkout systems used in Europe:

- Ability to go back in time using VCR style control buttons - it is normally very easy to see what the state of the satellite is now, but with SCOS, it is possible to go back in time as far as the user wants through the same MMI
- A wide variety of tools for displaying the Telemetry and Telecomand dynamic and static data, both at parameter and packet level. Figure 2 shows the example of the Telemetry Packet History display.

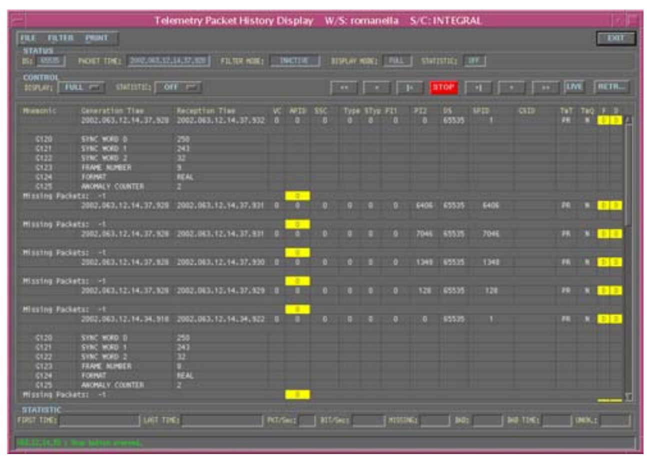

Figure 2: Telemetry Packet History Display

6.2 Exploitation of Linux and related tools

SCOS-2000 was originally conceived as a Solaris system using a modest number of COTS Software products in addition to specially developed software. Terma and Vitrociset were responsible for taking this system to a common source code that runs on both Linux and Solaris. In the process some of the proprietary COTS products were replaced with opensource equivalents.

The result of this exercise has been to drive down the cost of a basic SCOS-2000 installation to a few thousand dollars, without any degradation in quality. The recurring costs are limited to the PC Hardware and one or two remaining proprietary COTS products.

The other cost benefit is that many of the development tools (C++ compilers etc) are also not only robust products due to their wide usage but available at little or no cost. Without the need for any great investment in hardware or software, potential users can have a system for very low initial costs.

Despite being a sophisticated spacecraft control system, the tremendous reduction in the basic costs opens up new markets for the product, attracting interest from many organisations without the large budgets that are available to more established spacecraft operators. This makes it attractive to many of the experimenters who fly instruments on science missions. As a result it is used for the checkout equipment for the different experiments flying on the Herschel and Planck missions.

6.3 Using SCOS-2000 at the Experiment Level

The first use of SCOS as a satellite checkout equipment was in it's earlier SCOS-II form for the Proba mission. This added some building blocks for supporting a simple procedure language and a router for data to/from other elements of the EGSE.

This was later upgraded to SCOS-2000 with an improved Test Language (TOPE) and a modified EGSE Router - all exploiting the Evolution version (Linux) of SCOS-2000.

The system, in this guise, is capable of supporting testing activities on simpler missions or payloads - it is deployed to support the 5 main experimenters on the Herschel and Planck Missions.

7 Work to be performed

In taking the SCOS-2000 system out of the operations domain and into the AIT domain requires the following changes:

- Integration of a test language to allow automation of the tests. For complex space systems, it is also necessary to support a lot of parallelism
- More sophisticated configuration management tools for selecting the data (data bases, procedures etc) to be used during a test
- Additional diagnostic tools
- Providing the interfaces to equipment in the EGSE, rather than ground stations
- Ensuring the hardware is performant enough as AIT is a more demanding activity in terms of performance than operations
- Ensuring that the start up of the system is efficient, as the system is normally started and stopped several times a day during AIT activities

8 Conclusion

The use of SCOS-2000 for checkout of a complex satellite is proven to be feasible. They are clear cost benefits in reduced development costs for the system. The savings in the Operations preparation and in orbit commissioning costs are far less easy to quantify, but it is anticipated that there will be both quantitative and qualitative benefits in this area. This is the second major programme underway in Europe where this approach is being adopted. The other is the Columbus Orbital Facility - the major part of the European Contribution to the International Space Station. This will also use the same tool (albeit a different one) for the pre-launch checkout and in orbit operations.

[i] Roger Patrick – rmp@terma.com

[ii] Hannes Kubr – Hannes.kubr@siemens.com

[iii] Francesco Croce – Francesco.Croce@vitrociset.it