MANAGING CROSS SUPPORT WITH CCSDS SPACE LINK EXTENSION SERVICES

Hugh Kelliher and Paula Quintela

VEGA Group plc
2 Falcon Way, Shire Park, Welwyn Garden City, Hertfordshire, AL7 1TW, U.K.
E-mail: hugh.kelliher@vega.co.uk, paula.quintela@vega.co.uk

ABSTRACT

This paper outlines how Mission Managers may use the Space Link Extension (SLE) services that have been defined by Panel 3 of the Consultative Committee for Space Data Systems (CCSDS) to order and execute TTC Services for their spacecraft. The paper draws on the experience gained by VEGA in prototyping the SLE services in the QinetiQ ground segment in the UK.

OVERVIEW

The SLE Services provide a standard way of passing CCSDS telecommand and telemetry services across the ground segment. By implementing SLE services, TTC Services Providers will be able to provide a standard interface for supplying TTC services to Missions. This will reduce the cost of providing cross support services for spacecraft missions once the standard is in widespread use. In the near future, CCSDS tracking services and security will be added to the SLE capability, to facilitate the implementation of a fully operational SLE service.

In the last year, VEGA has successfully tested the first implementation of SLE Service Management, controlling the online Forward Command Link Transmission Unit (F-CLTU) and Return All Frames (R-AF) services in the TTC ground segment operated by QinetiQ in the UK. Successive tests involved VEGA's offices in Hertfordshire, England, QinetiQ's control centre at Farnborough, England and QinetiQ's ground station at West Freugh in Scotland. In the absence of an operational STRV spacecraft, the STRV engineering model was used in the tests.

The VEGA implementation is a prototype of the services defined in the most recent issues of the CCSDS SLE Service Management recommendations, [2] to [4]. The experience gained in developing the prototype was fed back into the development of the recommendations so that both the prototype and the recommendations have a greater maturity than would otherwise be the case.

The implementation uses web technology to enable spacecraft Mission Managers to check ground station availability, book passes and set up the data transfer services to be executed at the scheduled time. The service supports the complete life cycle from the initial service agreement to post pass reporting.

The service management software in the ground station interacts with the ground station computer to configure the ground station resources and provide monitoring information to the user on the status of those resources during a particular pass. In the case of problems within the ground station, the service management software posts notifications that are accessible to the user via the web interface.

The implementation includes both the data transport and service management layers of the SLE services and is therefore the first full prototype of these services.

The paper assumes a basic level of knowledge of the SLE services, such as provided in [1]. This reference can be downloaded from the CCSDS web site at www.ccsds.org.

OUTLINE OF THE UK IMPLEMENTATION

VEGA has developed the SLE software to implement a prototype of the F-CLTU and R-AF services in the QinetiQ TTC ground station at West Freugh in Scotland. The F-CLTU implementation was completed and tested successfully in May 2001 and the R-AF implementation was completed and tested successfully in February 2002.

The prototype implementation reflects the content of the latest versions of the SLE Service Management recommendations, [2] to [4]. These recommendations are under agency review and some changes will need to be made to the prototype to reflect the results of the agency review. So far, the only modification has been to add an XML interface.

The XML interface has been added to the prototype to provide a further option for a Mission to submit data to a TTC Services Provider. This will give Missions the option of either inputting information directly via a web browser or submitting standardised XML files already created by the Mission.

In order to lay the foundations for a fully operational system, the UK implementation includes additional services that are not included in the CCSDS SLE recommendations. These are the web-based user interface for the production of a service agreement and a ground station planning feature.

Figure 1 shows the high level architecture of the SLE implementation, which comprises an SLE Service Management Layer and an SLE Data Transport Layer. These both span the SLE User Site (the VEGA office) and the SLE Provider Site (the QinetiQ ground station at West Freugh). The SLE software interfaces with the existing spacecraft monitoring and control (M&C) software in the User Site and the existing ground station monitoring and control software in the Provider Site. The existing software is supplied by QinetiQ.

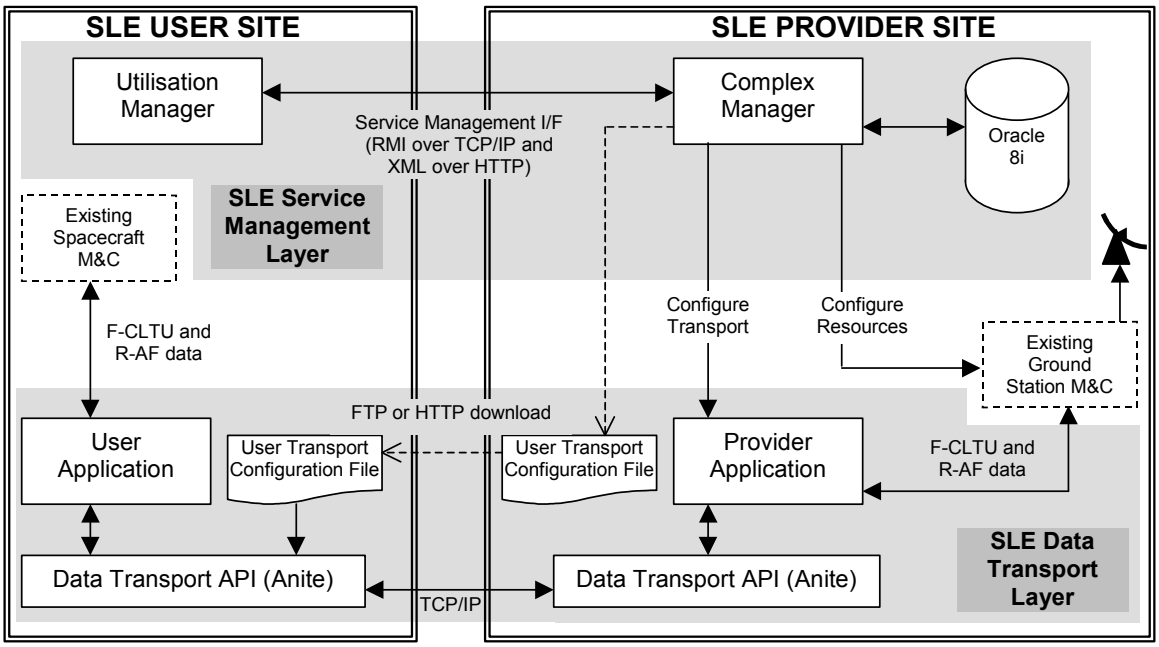

Figure 1: SLE High Level Architecture

Within the User Site, the Utilisation Manager provides a user interface for the creation of SLE service packages, containing combinations of F-CLTU and R-AF services. In the UK implementation, the Utilisation Manager is provided as a web interface by the Complex Manager, in order to allow users to access the service without the need to develop or buy their own SLE Service Management software. The service packages created by the Utilisation Manager are checked by the Complex Manager and stored in the Oracle 8i database on the Provider Site.

For each Mission, the Complex Manager creates a transport layer configuration file for the Mission to download. When the service is due to start the Complex Manager configures the TTC Services Provider's transport layer and ground station hardware ready to provide the service. The Mission configures its transport layer with the previously supplied configuration data and then the data units may flow between the spacecraft M&C and the space link. In the UK implementation, the application layer software that drives the SLE data transport API has been written by VEGA. The SLE API itself was developed by Anite GmbH for ESOC.

FURTHER FEATURES PLANNED FOR THE UK IMPLEMENTATION

Due mainly to funding limitations, the prototype implementation does not currently include some features that will be needed in a fully operational system. Some of these additional features are already covered by SLE, such as:

- *Resource allocation* – will be more complex when a TTC Services Provider has multiple resources available to support a service.

- *Security* – options exist in SLE to implement different levels of security, according to the needs of the Mission.

- *Additional SLE services* – for instance, CCSDS packet services or future IP-over-CCSDS services.

whilst others are not yet defined in SLE recommendations:

- *Tracking* – is recognised by CCSDS as an urgent requirement and is currently under discussion within CCSDS Panel 3.

- *Archiving* – some providers may want to maintain archives of old service agreements and service packages.

- *Billing* – an automated means of generating invoice data for the service may be required.

- *Schedule conflict resolution and emergency support* – when supporting many Missions, a TTC Services Provider may require a more sophisticated means of negotiating resources with the Missions and performing long-term, medium-term and short-term ground station planning.

- *Reliability / Availability* – depending on the requirements of the Missions, a TTC Services Provider may need to maintain high levels of reliability and availability, for instance by providing redundant SLE systems.

- *Non-SLE services* – the SLE approach could be adapted to manage, for example, bitstream services.

It is intended to add the above features to the UK implementation as and when they are needed.

The implementation will be extended shortly to include the RAL ground stations in the UK.

USING SLE SERVICES

A Mission Manager wishing to procure SLE services from one or more TTC Services Providers will need to carry out the following simple steps, as shown in Figure 2:

1. Register with one or more TTC Services Providers
   - TTC Services Provider web-sites should provide information on their ground stations, including availability and typical prices for the various services on offer;
   - The Mission Manager registers with TTC Services Providers that have ground stations appropriate to the orbit of the spacecraft and the RF characteristics.

The registration process will be similar to registering on any secure web-site, such as a financial services web-site.

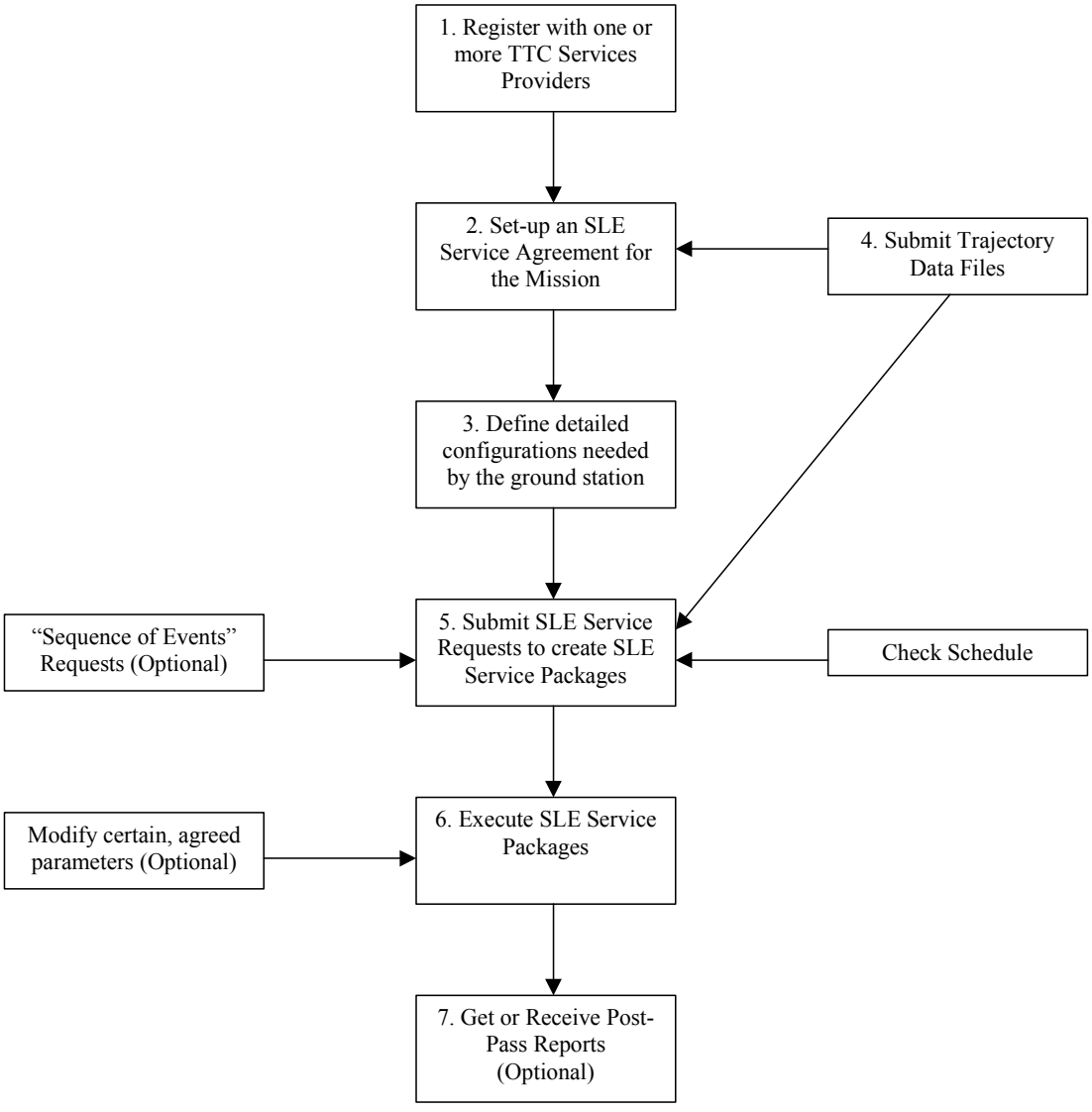

Figure 2: Managing SLE Services from a Mission Manager's Point of View

2. Set-up a Mission Service Agreement

   – The Mission Manager sends the TTC Services Provider:

     - ranges for the spacecraft parameters that are needed by the ground station e.g. uplink and downlink frequencies, data rates, etc.;
     - a preliminary trajectory data file, for the TTC Services Provider to verify the suitability of ground station geographical locations;
     - information such as the number of spacecraft contacts per unit time, and the likely start and end dates for the support, for the TTC Services Provider to roughly schedule and price the service;

   – The TTC Services Provider checks the data provided by the Mission Manager, points out errors, if necessary, and once the errors are corrected, quotes a rate for the work.

   – The Mission Manager compares quotes from different TTC Services Providers, accepts one of the quotes and 'signs' a contract.

3. Define Configurations

   – The Mission Manager sends the TTC Services Provider the exact configuration data needed by the ground station e.g. exact uplink frequency;

   – Several configurations may be provided, to accommodate different phases of the mission e.g. if different bit rates are needed at different times.

4. Submit Trajectory Data

   – Trajectory data files are produced by the Mission and sent to the TTC Services Provider;

   – A rough idea of the spacecraft trajectory is needed to set-up the Mission Service Agreement i.e. to allocate the subset of ground stations that could support the mission;

   – An accurate trajectory data file is needed to schedule the contacts, so it is referenced in the Service Request;

   – A more accurate trajectory data file may be needed just prior to the execution of the service.

5. Submit Service Requests

   – The Mission Manager may query the TTC Services Provider's ground station schedules for potential contact opportunities;

   – The Mission Manager submits a Service Request to the TTC Services Provider, containing a schedule of contact times and calling up one or more of the pre-defined configurations, as appropriate;

   – The TTC Services Provider validates the Service Request and sends configuration files to the Mission Manager to enable the SLE Data Transfer to take place at the agreed times.

The entire process from Registration to agreeing Service Requests can take as little as 30 minutes for Missions with an emergency …

… but equally, although each step only takes a few minutes, the overall process can be spread out over a period of years.

6. Execute the SLE Service Package

   – Having been configured by Service Management, the data transfer service can execute automatically or manually, depending on the capability of the Mission's systems;

   – Service Management provides feedback and notifications to the Mission Manager on the progress of the service, if required by the Mission Manager.

7. Receive Post Pass Reports

   – Service Management maintains information that can be:

      – viewed on a web interface by the Mission Manager; or be

      – downloaded by the Mission Manager.

In addition to the core SLE capability, some TTC Services Providers may provide Missions with the options:

   – to modify selected parameters of the service in real-time via Service Management; and/or

   – to pre-programme changes during the execution of a service, based on absolute or relative times via a "Sequence of Events" request. An example of this would be a change in bit rate.

The Mission does not have direct access to the TTC Services Provider resources so the provider retains control over how the resources within the ground station are used.

ADVANTAGES AND DISADVANTAGES OF USING SLE SERVICES

There would be little point in a Mission Manager using SLE services if the advantages did not outweigh the disadvantages. In the opinion of the authors, the advantages will be significant:

- SLE services will provide a simple, quick and reliable way for Missions to procure and execute TTC Services.

- Adopting SLE Service Management will cost nothing if Missions use the web browser interface option. Other options, such as submitting XML files, are still relatively cheap.

- Time consuming negotiations, paperwork and testing will be much reduced, resulting in typical costs savings of about $200K per mission.

- Pre-launch Mission to Ground Station interface testing will also be much reduced once Missions have confidence in the new system.

- Response times to emergency service requests could be reduced to minutes or even seconds.

The disadvantages are related to the current limitation of the SLE services to the CCSDS protocols, for Missions that might be using other protocols, and the initial set-up costs:

- New Missions that are contemplating non-CCSDS spacelink protocols or slight variations to the CCSDS spacelink standards will need to budget, say, $200K for time-consuming negotiations, paperwork and testing of variations to SLE, in addition to any new hardware that may be needed at the ground station.

- Missions wishing to migrate to SLE for interoperability reasons will need to spend time and money adapting SLE to their existing systems. For example, Missions will need to procure an SLE Data Transfer API and either buy or develop the application layer software that drives it. This will then need to be integrated into the Mission's Spacecraft Monitoring and Control System. This is not very costly or difficult for CCSDS-compatible systems.

Overall, the adoption of SLE as a standard protocol for the management and transfer of TTC data streams should result in significant savings in time and cost for Missions.

SOME IMPACTS AND CHALLENGES REGARDING SLE SERVICES

Introducing a new, universal standard for the interface between Missions and TTC Services Providers will inevitably lead to changes in the way the space industry and agencies operate. Some of the changes we foresee include:

- COTS vendors will need to provide an SLE capability. A single standard for the TTC Services interface should increase the choice of COTS products for both Missions and TTC Services Providers.

- There will be less work for TTC ground station operators both in terms of designing new equipment and in supporting Missions. This could result in less staff for operational work. On the other hand, more effort may go into improving services for Missions and advancing TTC technology.

- Missions will no longer need to spend as much time planning TTC Services. Ignoring political and organisational constraints, Missions will also have a wider choice of TTC Services Providers. This should help reduce the costs of missions.

However, before any of these changes takes place, some challenges need to be overcome:

- Mission support software, including spacecraft monitoring and control and mission planning software will need to adopt SLE interfaces.

- SLE implementations at ground stations will need to be validated. Currently no validation process exists nor does any organisation currently have responsibility for validation. Once validated and used on one or two Missions, there should be little or no need for pre-launch interface tests.

- Mission Managers, as end users of SLE, need to become more involved in the standards process. Currently there is no direct involvement by Mission Managers in this aspect of CCSDS.

- The commercialisation of TTC services is at an early stage. TTC Services Providers and Missions from across the globe will need to get together to work out how to make commercial TTC Services a reality.

THE NEXT STEPS

CCSDS Panel 3 is now in the process of acting on the comments provided by the reviewers of the SLE Service Management documentation. This will result in more user-oriented features, including the addition of some optional functions requested by specific centres within the reviewing agencies.

In parallel with the improvement of the existing SLE Service Management specifications, additional capabilities will be added to the suite of SLE services, which will be reflected in due course in the UK implementation and which will lead to an operational service in about a year's time:

- Tracking Services

  Missions require spacecraft tracking services in addition to telemetry and telecommand services. Panel 3 has drafted a tracking service specification for the interchange of tracking data that accommodates the existing widely-used tracking data formats. This will be developed and prototyped in the next year or so.

- Security

  SLE allows for standard security protocols to be used. However, there needs to be agreement on which protocols to use, followed by implementations that support them. This is currently under investigation for the UK prototype.

- Billing

  Billing will be necessary for commercial TTC services. An initial estimate can be generated from the information in the Service Agreement (which will include an estimated number of contacts) and exact billing can be generated from information provided after the successful execution of Service Packages.

Various agencies are in the process of implementing SLE data transfer services in their systems. Most of these are focused on SLE data transfer, and some are restricted to the provider-side only. The UK implementation will continue to prototype the SLE service management as the specification evolves with the goal of implementing an operational system in the QinetiQ and RAL ground segments.

CONCLUSION

This paper has outlined how Mission Managers will be able to use SLE services offered by TTC Services Providers. It has described the first implementation that includes both SLE Service Management and SLE Data Transfer layers for the F-CLTU and R-AF services. Readers who wish to learn more about the UK Implementation are invited to contact one of the authors.

REFERENCES

[1] Space Link Extension – Executive Summary,
CCSDS 910.0-Y-1, Yellow Book, April 2002

[2] Space Link Extension – Service Management Specification.
CCSDS 910.5-R-2, Red Book, August 2001

[3] Space Link Extension – Service Management – Space Link Physical Layer Managed Objects Specification,
CCSDS 910.7-R-1, Red Book, August 2001.

[4] Space Link Extension – Service Management – Managed Object Formal Specification.
CCSDS 910.6-W-x.x, Draft White Book, in work

Acknowledgements

The generation of the SLE Service Management specifications has been a collective effort of the members of CCSDS Panel 3. We are grateful to them for their comments and suggestions on the UK prototype implementation. We are also grateful for the support and comments from our colleagues at QinetiQ and for the financial support of BNSC, without which this project would not have been possible.