The future of EGSE and Modems: Closing the gap between Large Satellites and Small/CubeSats

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ABSTRACT

As manufacturer of Electrical Ground Support Equipment (EGSE) and Modem solutions we have designed and delivered hundreds of units and systems. This EGSE equipment has mainly been delivered to the European space segment for predominantly medium (500kg to 1000kg) to large (>1000kg) ESA programmes/spacecraft (scientific/research). Given the high value of such missions, ESA has justifiably placed a large emphasis on the pre-launch test and validation of the spacecraft to maximise success rate as well as long term reliability. As such, EGSE has been recognised as having a high importance to the overall mission and associated budgets (time and cost). Typical large spacecraft rely on multiple 19" racks to provide the plethora of different types of interfaces covering power, on-board bus, bypass, discrete and RF. The complexity and risk associated with such missions also demand advanced testing for which sophisticated EGSE configurations are needed.

Since the launch of the first CubeSat at the beginning this century up to today, over 800 CubeSats have been launched. These light-weight platforms allow rapid time to flight due to off-the-shelf availability of platform and subsystems, providing a gateway for flying payloads at low cost. Where the early CubeSats had very low downlink rates (kbps) using predominantly UHF, today S- and X-Band transceivers are available reaching rates over 100Mbps using Phase Shift Keying and Forward Error Correction (PSK+FEC). The increase in available bandwidth allows projects that would typically target large scientific satellites now to carry significant instrumentation such as multi-spectral cameras on CubeSats. The result is a significant (and rapid) increase in the CubeSat market. However, many of the CubeSats launched and built today are lost during their first phase of operations (incorrect orbit, early failures or dead-on-arrival) [1][2]. To keep the overall costs of the missions as low as possible, CubeSat manufacturers have traditionally relied predominantly on small-scale manual testing. As the market continues to grow, so do the needs for automated, efficient, repeatable and reliable Assembly Integration and Test (AIT) facilities.

As the cost and number of interfaces within individual spacecraft reduces, EGSE design must go through an associated compression to provide an efficient, compact and cost-effective solution such that they can support these reduced test scenarios and campaigns.

This proverbial gap between Large Satellites and Small/CubeSats and their differences when it comes to the test and verification process is where the future of EGSE lies. Designing EGSE and Modems with the knowledge from Large Satellite programmes such that it becomes accessible to Small/CubeSats manufacturers will allow independent and more thorough (functional) testing with the aim to lower todays failure rates.

Celestia Satellite Test & Simulation has recently kicked-off the development of a platform to help tackle this gap and allow both Large Satellite Integrators and Small/CubeSat manufacturers to benefit.

INTRODUCTION

The need to reduce costs within the European space industry is becoming increasing important and this directly affects the spacecraft AIT activities. Partly driven by the increased popularity of CubeSats and their growing capabilities when it comes to their payloads and downlink bandwidths, EGSE manufacturer design strategies need to be adapted to allow cost reductions and to stay competitive within the market. This change in strategy allows for the widening of the market footprint, not only focussing on medium to large spacecrafts, but also to allow access to EGSE solutions for the Small/CubeSat manufacturers and integrators.

Celestia Satellite Test & Simulation (C-STS) designs and manufactures EGSE for Onboard Interfaces and Modem products (RF Interfaces), that can either be used as individual elements (Front-Ends) or integrated into a larger system to combine these to a complete AIT solution.

EGSE FOR ONBOARD INTERFACES

Onboard interfaces from an AIT perspective predominantly refer to all interfaces (both physical and protocol level) that connect the various sub-systems of a spacecraft. For medium to large spacecrafts designed and manufactured in Europe, these interfaces predominantly make use of the ECSS standards. These ECSS standards specify interfaces such as power (LCL, HLCL, etc.), discrete interfaces (e.g. thermistors, pulses, etc.), busses (e.g. MIL1553B, CAN, etc.) and serial/parallel digital interfaces (e.g. TM/TC, SpaceWire, etc.). For small spacecrafts (such as CubeSats), use of standard commercial interfaces is made (e.g. I2C, PWM, UART, GPIO, LAN etc.) as well as DC power (e.g. 3.3V and 5V).

Independently from the type of interface and spacecraft size, the goal of EGSE is to provide the facility to perform both electrical and functional testing of spacecraft (sub)systems during AIT phases.

Fig. 1. Typical EGSE Context

As different spacecraft architectures require a wide range of interface variations in terms of type and the number of channels a modular as well as scalable architecture is required to provide the required level of flexibility. The modularity can be achieved by a variety of standard pluggable modules, where each module can provide a specific interface type or a combination of these. These interface modules and their technological requirements can be targeted specifically towards the context (CubeSats, ESA Programs, etc.). As an example, where larger satellite sub-systems require Latching Current Limiters (LCL) to provide controlled bus power to a sub-system, standard DC voltages providing voltage and current readouts may be sufficient for CubeSat sub-systems. The latter requires lower complexity and therefore allows recurring costs such as hardware to be significantly reduced.

All interface modules will have a standardised interface to the EGSE platform that provides the infrastructure necessary to control and monitor them. Supporting a range of different standard platforms sizes will allow the EGSE's to be deployed for small as well as large AIT setups, again reducing costs as required. As an example, small AIT configurations might only require 3 types of interfaces, whereas larger AIT configuration could require 20 interface types.

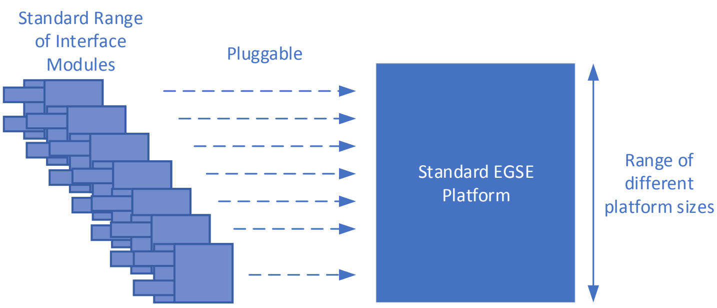

Fig. 2. Standard EGSE Platform with Pluggable Modules

By providing a range of different platform sizes, it allows for the downsizing of spacecraft EGSE from 19” rack mountable units to small benchtop units not much larger than lab DC power supply, as shown in Fig. **3**.

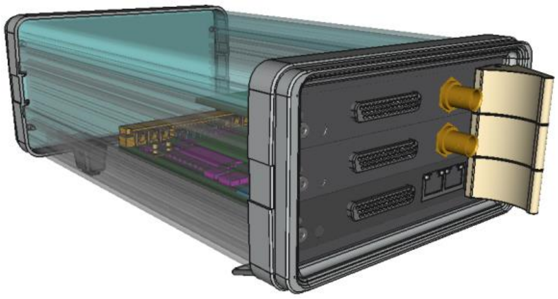

Fig. 3. Model of a mini-EGSE

In addition to reducing the EGSE hardware infrastructure and lowering hardware costs, the need of external Commercial Off The Shelf (COTS) equipment such as User Workstations can also be reduced (where the User Workstation normally provides overall system control and the local user interface).

In typical, large satellite integration setups, a Central Check-out System (CCS) is used control and monitor all EGSE equipment. The CCS uses a remote interface protocol (e.g. EDEN, C&C, etc.) to send telecommands (TC) to and receive Housekeeping Telemetry (HKTM) from the EGSE.

The need for the workstation can be removed by allowing the CCS to connect directly to the EGSE platforms. In cases where the user requires either graphical user interfaces, logging and/or archiving, these can be redirected via the network to for example Virtual Machines (VM’s) that run locally on the CCS.

EGSE FOR RF INTERFACES

One of the key set of interfaces used during AIT are the RF interfaces that are traditionally supported by the RF SCOE (Specialised Check-Out Equipment). Large ESA missions demand advanced testing of their RF links.

Earlier CubeSats used UHF interfaces whereas there is a growing trend towards X-Band thus closing the gap further between CubeSats and traditional larger missions. In a conventional RF SCOE, RF up/down conversion is accompanied by a modem performing modulation, demodulation and ranging. These are supported by a range of test and measurement equipment such as spectrum and network analysers. The modularity and re-use of "off-the-shelf" modules in CubeSats also means that the required scope of tests at spacecraft AIT level can be streamlined.

Modems fulfil several different roles during the lifetime of the spacecraft. During AIT, they are used as translators between the baseband and RF domains as well as being a tool used during the RF and ranging verification process. After launch, modems must perform similar modulation, demodulation functions but now in a different environment where RF noise and Doppler effects among others must be considered.

With such a variety of roles to fulfil, the next generation of modems need to capture four primary use cases:

1) Traditional RF SCOE modem use (modulation, demodulation and ranging)
2) Compact RF SCOEs (modulation, demodulation, optional ranging + RF measurements)
3) CubeSat/Small Sat/ Mega Constellation Ground Stations
4) Full Telemetry Tracking and Command (TTC) Modems

In addition, further integration is possible for CubeSat/SmallSat EGSE environment by incorporating traditional Telemetry and Telecommand Data Front End (TM/TC DFE) functions within the modem.

The resulting system provides the following capabilities:

- Scalable EGSE architecture for CubeSat/SmallSat and large Satellite missions
- Integrated EGSE systems for automated testing
- Ground station modems for mass deployment

The Scalable EGSE architecture could incorporate, for CubeSat/SmallSat setups, RF SCOE up/down conversion, modem functions, TM/TC functions and provide signal analysis capabilities which could replace expensive test & measurement equipment such as spectrum analysers from production test setups. The modem can collect the RF samples such that the analysis and processing of the data could be performed inside or outside the modem e.g. by RF SCOE system integrators.

Fig. **4** depicts the typical functions of such a scalable modem and highlights the group of functions offered.

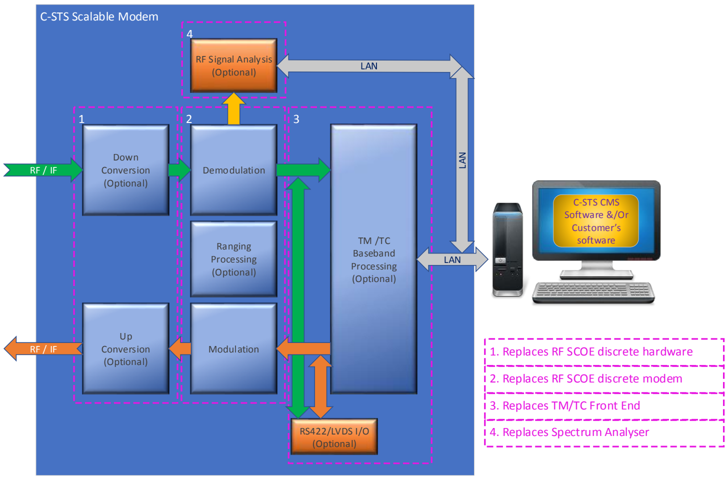

Fig. 4. Typical functions of a scalable modem

The system can be further enhanced by adding specific interfaces needed by CubeSats during AIT such as power and on-board bus interfaces. The result is an extremely integrated system that can be used during AIT as shown in Fig. **5**.

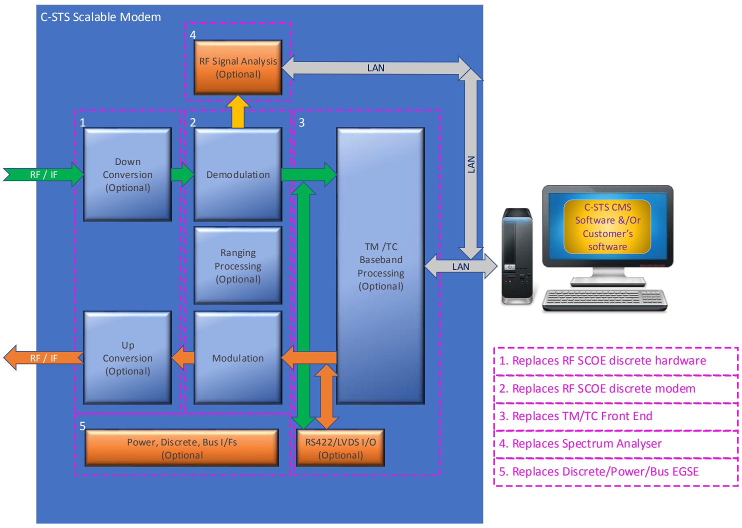

Fig. 5. Modem with integrated power and bus interfaces

By including / excluding the optional elements, the system can be scaled such that it can also provide a cost-effective ground station modem solution as shown in Fig. **6** suitable for deployments such as swarms and mega-constellations.

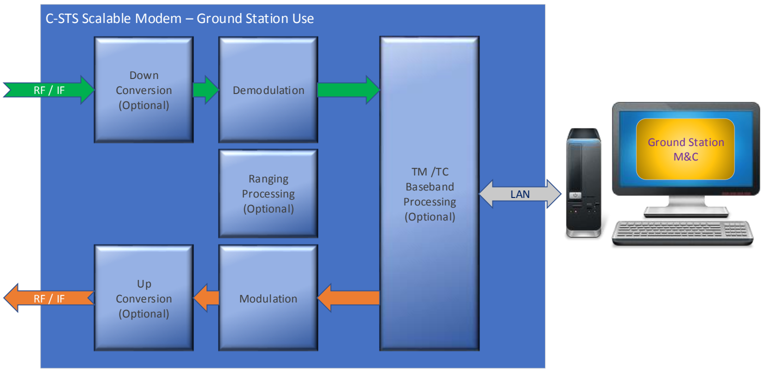

Fig. 6. Ground Station Modem for mass deployment

Common Software Architecture

Depending on the EGSE use case, onboard and RF interfaces may be closely coupled (e.g. RF Suitcases and RF SCOE's). This requires the interoperability of both disciplines within the same EGSE environment. This interoperability does not reflect the interfaces towards the spacecraft, but the control, monitoring and interaction between these functions.

To facilitate this interoperability between the two disciplines, a common software architecture is required that allows the various interface types and their functions to operate as a (hardware) service. Each service uses a standard protocol to interact and exchange data, either point-to-point or distributed. The protocol is independent of the physical interface used by the service. Each service uses a hardware abstraction layer that provides parameter access to all the available services independent of their underlaying hardware interface. This allows each service to interact with each other as a large bus architecture as shown in Fig. **7**.

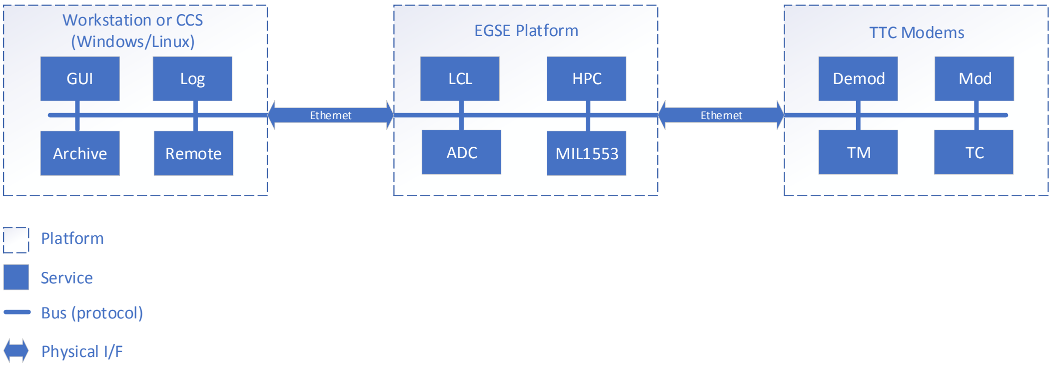

Fig. 7. Service Oriented Architecture

CONCLUSION

Within this paper a method is presented to close the gap between Large Satellites and Small/CubeSats in terms of EGSE used during AIT. Cost reductions can be achieved by modular designs that are designed for purpose and complexity; the complexity being driven by the customer requirements (e.g. ECSS compliant or standard commercial). Using a standardised interface, independent of the type of onboard interfaces allows for a large variation in EGSE solutions as well as different form factors (19" rack mountable or bench top). For the communication interfaces to/from the spacecraft a scalable modem platform with a common low-cost base allows for the implementation of various uses cases, such as RF SCOE's and CubeSat Receivers.

By providing a service-oriented software architecture, this allows for the direct interoperability between onboard interface platforms and modems that will lower the integration time and limit non-recurring engineering.

REFERENCES

[1] M. Langer and J. Bouwmeester, "Reliability of CubeSats – Statistical Data, Developers' Beliefs and the Way Forward" in press.

[2] C. Venturini, "Improving Mission Success of CubeSats" in press.