OPTIMIZED GROUND SOLUTIONS TO SUPPORT UNIQUE SMALL SATELLITE COMMUNICATION REQUIREMENTS

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ABSTRACT

Many considerations go into providing reliable communications to small satellites. This paper will explore how SSC is optimizing its existing global ground station network to support the unique requirements of small satellites, including the Cyclone Global Navigation Satellite System (CYGNSS) constellation of 8 microsatellites. SSC has provided the ground network for CYGNSS TT&C operations since the launch of the spacecraft late 2016. SSC and its customers focus on four key areas to provide superior service: availability, redundancy, performance and scheduling.

1) Availability – Strategically placed ground stations decreases the delivery time to receive critical data.

2) Redundancy – Multiple antennas allow for flexibility and ensure availability of service in the case of rescheduled or late scheduled passes based on new data requirements.

3) Performance – SSC has developed in-house software to implement a dynamic uplink that adjusts the power level for the duration of a pass in order to adapt to a small satellite's communications radio.

4) Scheduling – Southwest Research Institute (SwRI), the operator of the constellation, has incorporated SSC's scheduling data into its systems which reduces scheduling time as passes are scheduled based on availability. SSC is in the process of further automating its systems to enable its customers to schedule passes through a secure web based portal.

SSC can easily replicate the above model for the full range of small satellite communication requirements. Each spacecraft platform may have its own unique characteristics that require updates to SSC's service provisioning. Small satellite missions can leverage SSC's in-house expertise and existing global infrastructure in order to maximize their mission performance.

INTRODUCTION

The proliferation of standardization across small satellite platforms will similarly drive standardization on the ground. However at this time, SSC, operating as a global commercial ground network provider, still sees the need for a wide range of aperture sizes and associated engineering support. In the case of small satellite platforms, as an industry we have not yet reached a one-size-fits-all approach for ground station support. A number of factors drive the ground station support requirements, including spacecraft throughput, power, orbit and number of satellites that might be operating in a constellation.

Of course, commercial ground providers should invest in automation and if there are a large number of customers who can be easily supported by smaller apertures, it is a win-win for both provider and customer if a business case can be supported with less capex and a lower cost to the customer. There will be a set of customers that will not have the budget for pre-mission testing and commercial ground providers should validate as many standard systems as commercially reasonable. But in some cases, a small satellite operator may have to make too many tradeoffs to fit their desired performance into a certain ground station configuration. In these cases, an experienced ground system provider like SSC can leverage its existing network and engineering resources to maximize the small satellite operator's performance. By working with the customer early on during the design phase and participating in mission preparation testing, the customer can optimize the delivery of information over the short period of time they may have on orbit.

AVAILABILITY AND REDUNDANCY

The first consideration a small satellite operator may make is determining which locations are ideal for communicating with its satellite(s). SSC owns and operates 11 stations and has access to 8 collaborative stations. Locations are ideally suited to communicate with satellites in mid latitude or polar orbits. Many of our locations have multiple apertures ranging in size from 7m – 13m. In most cases the customer can manage just one connection to the SSC Network Management Center, depending on backhaul data requirements.

Exhibit 1: SSC Global Ground Network

As demand grows for small satellite connectivity, SSC will build out its capability either at existing or new locations. SSC commenced a new station build in Si Racha, Thailand in 2017 and expects the location to be completed by the middle of 2018.

SMALL SATELLITE OPERATIONS LIFE CYCLE: SWRI CYGNSS EXAMPLE

SSC's support of the SwRI CYGNSS constellation of 8 microsatellites provides an example of how a ground station provider can be much more than a vendor to the operator and in fact serve as an important partner during the development of the operations concept.

Mission Overview – SSC Perspective

- 8 microsatellite spacecraft in LEO orbit
- Weather/hurricane science objectives
- All spacecraft support same nominal TX and RX S-band frequency
- Limited navigation capabilities with each spacecraft in same orbital plane
- Nominal operational concept of 1 contact every X hours per spacecraft specified by customer

- Additional short notice contacts needed during hurricane activity
- Real time command and telemetry with X minute latency on science data specified by customer
- SSC supports all spacecraft from 3 ground stations
    - Western Australia ● South Point, Hawaii US ● Santiago, Chile
    - 3 equatorial and geographically diverse stations
    - Primarily use one 13m aperture at each station

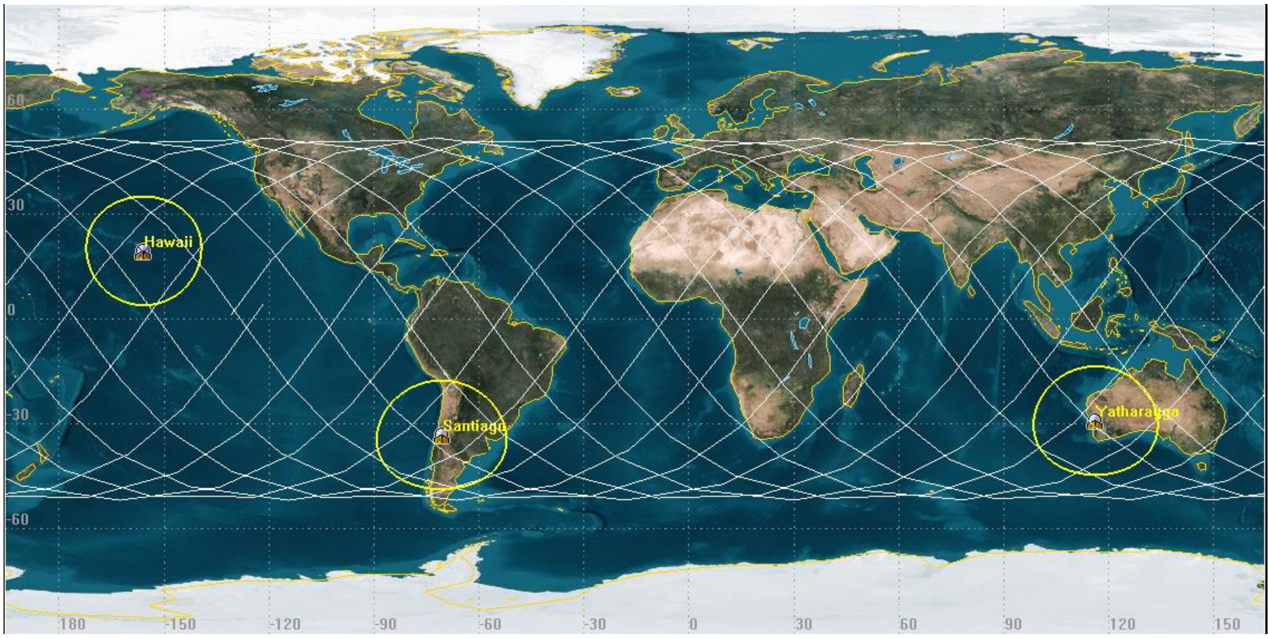

Exhibit 2: Indicative SSC Station Coverage Assuming International Space Station (ISS) LEO Orbit

Mission Timeline

SSC and SwRI had the advantage to work together early on in the process, while SwRI was working on its own proposal to develop the mission. Bringing in a ground communications expert near the beginning helped to identify any concerns or need for enhancements in time to develop a different way to use the ground network.

Exhibit 3: SSC Support to SwRI CYGNSS Mission Timeline

Engineering Services Phase

During the Engineering Services Phase, SwRI and SSC co-developed a unique idle pattern uplink protocol for autonomous operations. This protocol greatly improved the ease of operations. The team also performed and evaluated RF link budget analysis in order to determine the SSC stations to be used. SSC has a wide range of antenna apertures from which to choose and the team determined that the 13m class of antennas would best support mission objectives. By leveraging SSC's existing assets, the project did not have to worry about investing additional capital into an expensive ground network that it would only use on a periodic basis over a few years' time.

Mission Establishment

During Mission Establishment, the teams continued to have technical exchanges and performed 2 Radio Frequency Compatibility Tests (RFCTs). The first RFCT used an engineering model spacecraft while the second one used the first flight model spacecraft. In both instances, the RFCTs highlighted follow up actions to be taken prior to mission support. The second RFCT ended up validating changes made after the first RFCT. After the second RFCT, the teams determined that they should develop a dynamic uplink support capability to produce varying uplinks from the ground station throughout a contact with a spacecraft.

Another key component of the Mission Establishment phase was developing the launch and early orbit (LEOP) concept of operations in order to support multiple spacecraft during one contact between space and ground. SSC supported SwRI with documenting the Engineering and Mission Establishment phases as appropriate into an Interface Control Document (ICD). In addition, SSC supported and presented during the Flight Operations Review (FOR) and the Operational Readiness Review (ORR). SSC also participated in End-to-End and Mission Readiness Testing to validate pre-launch readiness.

Launch and Early Orbit (LEOP)

All eight CYGNSS spacecraft launched from the same rocket and after launch were within the beam width of an SSC 13m antenna. In order to accelerate contact with all spacecraft, SSC proposed a Time-Division Multiple Access (TDMA) operational approach to monitor multiple spacecraft over one station view period. With this implementation, SwRI was able to significantly increase its ability to contact its spacecraft. Time to first acquisition of each spacecraft was reduced by 50% compared to original estimates. At one point after the launch, the SSC network was able to contact 5 different spacecraft during a single 15 minute station view using a single ground antenna.

Operations

SSC proactively provides updates to customers on the availability of stations. SwRI ingests this information into their own systems which improves the scheduling process. Given that contacts may be scheduled days or weeks in advance, SwRI provides an update shortly before a scheduled contact which validates the support criteria in case any changes have been made. The CYGNSS spacecraft are capturing critical data in advance and during hurricanes and other severe weather events. Given the breadth of the SSC network, SSC has been able to accommodate additional passes on shorter than normal notice and increase the overall cadence of supports during the hurricane season. Continuous discussions with the customer to understand their future requirements have enabled SSC to provide critical science data when needed.

CONCLUSION

A commercial ground provider can play an important role in the development and operation of a small satellite constellation mission. The spacecraft manufacturer/operator and ground provider working together early on in the process improves the mission outcome. When initiating new programs, small satellite developers should consider the downstream financial impact of identifying any issues and possible improvements up front. In most cases, a financial analysis would show that it is worth investing some amount of budget for ground mission establishment if that investment yields more actionable data from the constellation.