COMMERCIAL SERVICES 2.0
REPURPOSING MULTI-MISSION GROUND NETWORK INFRASTRUCTURE FOR EMERGING, NEW SPACE APPLICATIONS.

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ABSTRACT

Access to space is becoming a reality to broader global community of students, scientists, and entrepreneurs. The CubeSat industry is furthering this access to space by standardizing affordable components/subsystem boards. Standards provide for clarity in design, repeatability, and risk reduction. Space to ground communications remains open to many variables, all of which add cost and risk to the mission.

SSC has been a leader in the commercial ground network market place since 2001 with the introduction of PrioraNet. SSC is now taking a lead role in developing new methodologies including standard configurations and automated operations to provide low cost services. This paper will present the problem of traditional approaches to satellite communications design. The new approach is is for the service provider now to provide options to the satellite for Standard Configurations that allows access to much lower cost communications service. The trade space is engineering individualized configurations, more testing, increased documentation and risk.

All of these elements add to the cost of specialized communications. How communications with the spacecraft occurs is usually a Mission Operations function. From the spacecraft developer side, the communications system operates as specified. The ground systems need to match these interfaces. Now starts the long process of engineering analysis, design, configuration, testing, and documentation. Each of these items requires each ground station to implement and verify mission specific configurations. This is time consuming and expensive.

To a service provider, like SSC, the customer is still always right! The adaptation is in who is writing the requirements and who is implementing the requirements. SSC is helping the industry identify what systems and configurations are compatible with the service being requested. The approach is to identify several vendors of radios that are all qualified to meet one or all of the pre-defined configurations. By taking this approach we "reduce" the compatibility risk and eliminate the need for costly development efforts.

INTRODUCTION

Owners of existing, large scale global ground station networks have much to offer the growing community of owners and operators of small satellites and constellations. Whereas, early cubesat projects routinely flew payload and telemetry communications packages that were based on amateur radio hardware and techniques, and therefore, could utilize extremely inexpensive ground antennas operating in the U/VHF bands. The availability of new software defined radios and technologies in much smaller packages has improved the utility of even the smallest satellites to the point where large volumes of data, in the gigabits per orbit can be easily gathered and formatted for downlinking to the Earth where it can be processed into products providing information of a higher integrity and value than ever before.

As technical improvements continue to occur on satellite hardware increasing sensor capabilities, recorder sizes and downlink capabilities, in parallel advances in low-cost access to space through inexpensive launches provided by new entrants into the commercial launch market literally adds another dimension to the utility of small satellites. When these small, high performance, high data volume satellites are placed into orbit in constellations of potentially hundreds or thousands, data volumes that are on the order of several petabytes per day can be achieved. This stunning volume of sensor data from space is only of use if the data can be downlinked from space and that requires highly capable ground stations that are also arrayed in constellations "of a fashion" to perform the data downlink and also satellite control functions on board the spacecraft.

Coupling low cost satellites that can be built and launched quickly with reduced-cost access to space has created an environment whereby it is possible to imagine, design, develop, launch and operate quite complex systems that can produce previously unimaginable volumes of data that can be used to support a variety of new applications. In addition to the aforementioned improvements, the internet has seen similar development and expansion of the capabilities to the point that large, globally distributed data archiving systems are readily available to satellite owners and operators and can be purchased as a service.

The above factors have conspired to create a new and exciting era in the space industry that has been called by leaders in both the industry and also in the finance community "New Space 2.0". This name pays homage to the actors in the late 90's and early 2000's who created some stunning and technologically advanced constellations of satellites for global telecommunications. That era, which in retrospect could have been called "New Space 1.0" witnessed Motorola building and launching the Iridium constellation and the Loral Corporation building and launching the Globalstar constellations, along with other constellations that were built for commercial global messaging, equipment and vehicle tracking applications. Although these constellations today remain in orbit today and are profit-producing entities, they were systems that required very high capitalization and consequently moved through bankruptcy which resulted in significant writing off of debt and equity.

New Space 2.0 carries with it a similar excitement driven-by technological achievements that enable significant improvements in quality of life, increasing scientific discovery especially with respect to monitoring the Earth, and producing unique business intelligence while producing immense financial gains. It's an very exciting story, and perhaps this time there is a much higher probability of success due to aforementioned advances in the industry. So, what does this have to do with commercial ground network services and how can a provider like SSC have an impact on this emerging industry?

COMMERCIAL GROUND NETWORK SERVICES

In the late 1990's, a new space industry was born. Several organizations, with the first being Universal Space Network (USN), launched operations to build global ground-based infrastructure based on large and very expensive ground stations placed in strategic locations around the world, connected to a common control center by wideband terrestrial fibre circuits. The primary target for this new industry, however, was not the commercial space market. The impetus for the business model arose from executives at the National Aeronautics and Space Administration (NASA), who decided that the agency needed to reduce costs of space operations by outsourcing a part of its near-Earth tracking capability to the commercial sector in order to reduce operational costs.

NASA became the initial primary market and the new NASA Small Explorer series of missions (SMEX), among others, willingly adopted the concept and made it a part of its nominal operational system. Simultaneously in Europe the Swedish Space Corporation (SSC) found similar interest from the European Space Agency (ESA) and the space agencies and space boards operated by individual European and Asian countries. In 1999 a strategic alliance was formed between USN and SSC, called Apriora, and the resulting global network of stations was given the name PrioraNet.

PrioraNet, the world's first all-altitude, multimission commercial ground network

Exhibit 1: Global network of ground stations owned and operated by SSC, formerly known as PrioraNet, which was created in 1999 when SSC and USN formed a strategic alliance called Apriori. Map is current and accurate through March 2016.

PrioraNet was the brainchild of colleagues Mikael Stern (formerly of SSC and now with Spacemetric) and Tom Pirrone (formerly of USN and now with SSC). The concept was simple, by building a strategic alliance both organizations could pursue business from a larger base of ground stations. Since each ground station housed multiple large aperture antennas (13 meters in reflector size), the cost of these large multi-mission stations could easily be in the range of $10M to $20M USD. This is a very expensive capital outlay that also requires ongoing maintenance and renovations to maintain operational status. It is quite obvious to see that a network of the complexity above could consist of in excess of $150M in assets.

In the case of PrioraNet, one plus one really did result in more than 2. The Apriora alliance attracted other partners that provided antenna capacity at unique locations around the world to supplement the stations owned by the alliance members. Thus the collaborative ground station concept was created, which was instrumental in adding antenna capacity that was capitalized by someone else and was purchased and resold by the alliance member with margin added. In this way, the alliance was able to bring additional capacity to its subscriber-base without the need for additional capital investment.

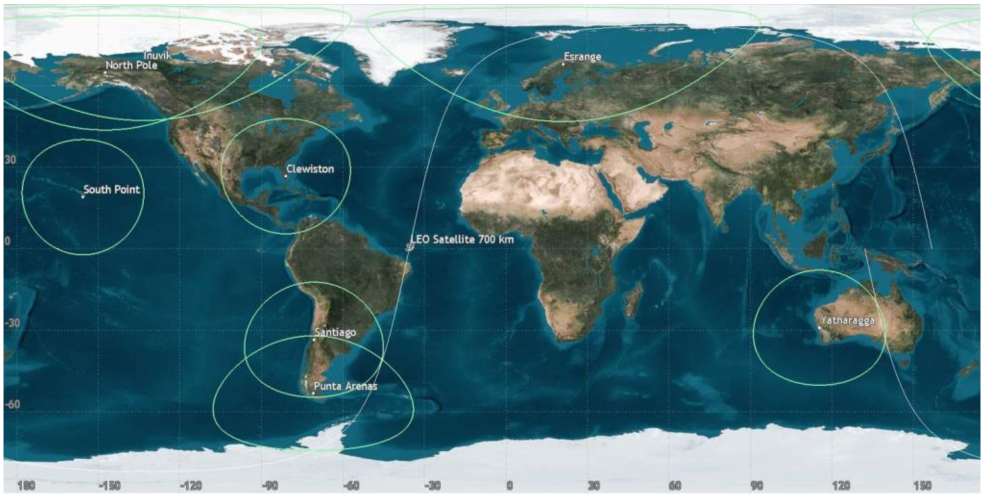

Exhibit 2: Coverage for a Low Earth Orbiting satellite, typically used for Earth Observation from the alliance-owned stations only. Adding the collaborative stations fills in gaps in coverage for no additional infrastructure cost.

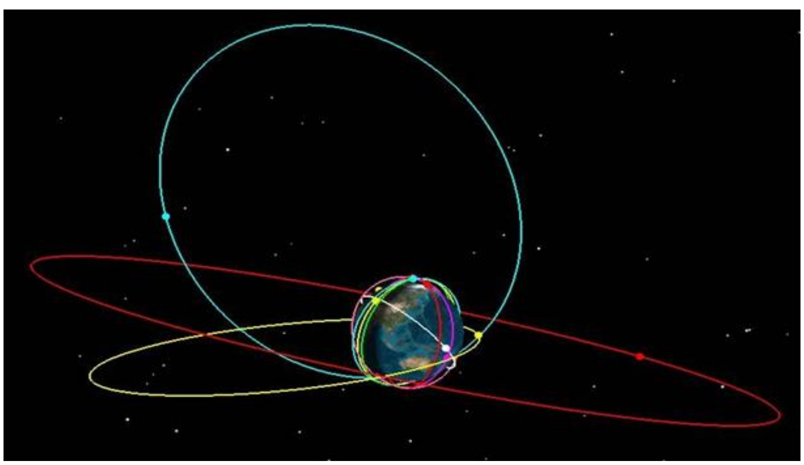

Exhibit 3: Diversity of orbit inclinations and altitudes routinely covered by the multi-mission, all altitude commercial ground station network. Earth Observation, Remote sensing, Geostationary communications, Space science and observation, Satellite Radio systems, Security and Space Situational Awareness, are among the myriad of applications supported routinely by PrioraNet.

Diverse applications requires capable, flexible ground stations

The flexible, multi-mission ground station is based on a standardized architecture to facilitate a reliable global operational model. The architecture allows for standardized configurations, standardized software applications and common hardware platforms to facilitate remote and automated operations. This architecture lowers the required NRE effort and the development time required to add a spacecraft mission to multiple sites, it simplifies troubleshooting of ground system issues and it lowers over all operations cost. However, since this model does not totally eliminate NRE, an alternative approach must be developed to allow the multi-mission ground system to support lower cost, small and cubesat model missions and constellations.

All stations are run remotely from a central control facility, in this case called the Network Management Center. The ground stations are configured for each support using a master configuration database that contains equipment settings for each customer mission and spacecraft mode. To meet high availability requirements these sites incorporate both Uninterruptable Power Supply (UPS) and generator back-up power. These systems are monitored and tested periodically to ensure functionality in the event of a power outage.

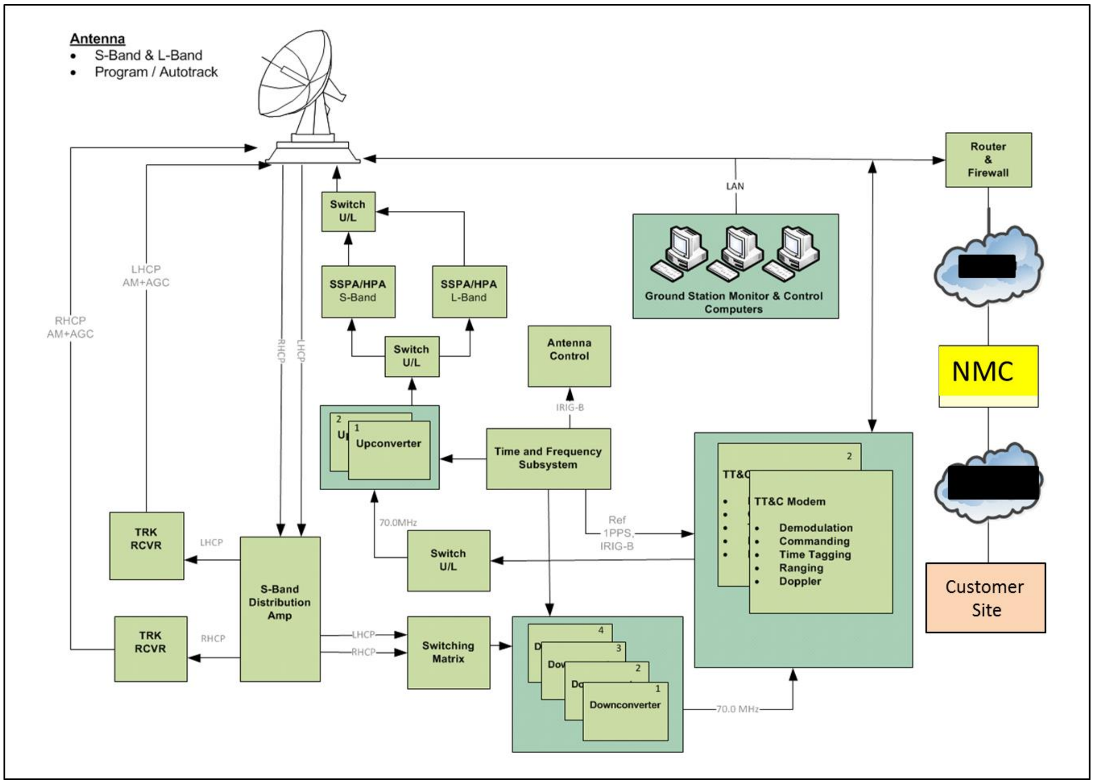

Exhibit 4: Highly capable, flexible multi-mission ground station system design with network interface to global control center and data flow to the customer's site.

Exhibit 5: Centralized control of the global ground station network, PrioraNet, is accomplished through a Network Management Center function.

The NMC provides connectivity for remote monitor and control (M&C) to all of the remote ground stations in the network, with the exception of the collaborative stations. Ground stations are configured, controlled and monitored from the NMC locations by automated software. The NMC is staffed by operations controllers who are responsible for monitoring the day-to-day operations. The NMCs provide a means for direct communication with customers, and provides the technical staffing for troubleshooting and maintenance.

The Operations staff is responsible for processing customer provided orbital elements used for antenna pointing data. The NCM accepts multiple ephemeris formats such as NORAD Two-Line Elements, State Vectors, and Track Table Files. Orbital elements can be sent from the customer through FTP/SFTP file transfers, or, as an ASCII text e-mail or ASCII text e-mail attachment.

Not all customers of the commercial ground network service require a voice interface during support. However, when required, NMC staff supports the establishment of a voice interface connection. The NMC hosts software applications that run at the NMC and perform scheduling and manage the resource allocation. The M&C applications are also responsible for generating the operations reporting data products.

NMC provides customers with two basic types of reporting: pass reports and anomaly reports. Pass reports are generated at the conclusion of each support and sent to customers on a daily basis. In the event there is a problem during any portion of a support, the on-duty operations staff member will create a problem report in the PR database. A Problem Report is created even if the anomaly event has no impact to a customer support. This allows the ground systems, operations and engineering staff to quickly identify and resolve issues.

ADAPTING FOR NEW SPACE 2.0

Commercial ground service providers, such as SSC with PrioraNet, have contributed greatly to the industry over the past 15 years. By investing in infrastructure that provides communications services for most of the world's space agencies and large industry players, SSC has enable more to be done with less budget than before the availability of commercial services. Utilizing the shared infrastructure model results in distributed costs over many users, resulting in distribution of benefits to all.

However, in order to support such a large array of clients, the commercial ground network provider must also provide engineering support to adapt network configurations, testing, and preparations in order to ensure support of the vehicle after launch. The tendancy within the space agencies and large industry players is to minimize risk, which is accomplished through precise engineering, redundancy, resiliency and testing. All of this adds expense to an already expensive mission. In the world of New Space 2.0, money for ground system development, deployment and testing is not in great supply, so alternatives must be developed by the commercial ground network suppliers in order to maintain relevance to the emerging industry.

Cost avoidance

There are several areas whereby the New Space 2.0 community could work together with the commercial services providers to reduce the costs of mission establishment and preparations for launch of a new satellite intending to use commercial services. For the purposes of this paper, the discussion will be maintained at a very high level and will focus on 3 areas that in the past have been cost-drivers from the mission side. Those three areas are loosely described as:

- Meetings: Design reviews, mission operations reviews, and other technical interchange meetings
- Testing: RF Compatibility Testing and Data Flow compatibility testing
- Documentation: Mission design documents, Mission operations concepts, Testing plans and results recording

Very simply, meetings cost money! In some cases budgets as high as $100K to $200K USD are established simply for meetings. In the world of cubesats, whose overall program budget may be on that order, there is no way to pay for this on such small programs. Larger, more commercially-oriented programs that are not based on Government programs typically don’t waste time and effort on meeting preparations, but focus only on what is required to move the program to the next phase.

RF Compatibility testing at the spacecraft manufacturing site, plus additional testing at the launch base have been routinely conducted on government and large commercial industry satellites in the past. This testing provides an opportunity to at a minimum characterize radio communications prior to launch, or at best find potential problems that would not be able to be fixed post launch when the satellite is on-orbit. In the era of high-end space programs and missions, this testing could save days, weeks or months of on-orbit testing, or in some cases could actually result in saving the mission. Commercial services providers have spent significant sums of money in developing equipment and expertise to support this effort. However, missions under the New Space 2.0 paradigm cannot support the budgets required for such an expensive activity. In a similar way, large government satellite programs spend significant amounts of money and effort in mission documentation to support one-off efforts.

Standardization

Innovative organizations like Vulcan Wirless, Inc. and InnoFlight produce a line of inexpensive, moderate to high performance radio systems for both terrestrial and space applications. They are well equipped for enabling low-cost cubesat missions by providing form-factor compatibility software-definable radio equipment that can be used to implement, small inexpensive missions. Developing radio standards in conjunction with suppliers like

Vulcan and Innoflight would greatly decrease the amount of time and effort spent on RF compatibility testing for low-cost programs.

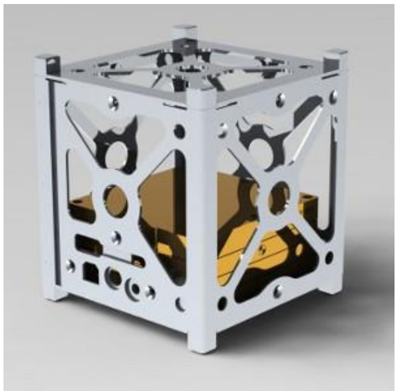

Exhibit 6: Vulcan Wireless, Inc. cubesat format radio

Exhibit 7: Innoflight cubesat format radio

One-stop shop for global logistics

Many small satellite programs that need to operate on a global basis, either for data downlinks or satellite TT&C often underestimate the time and effort that is involved in global logistics. The "can-do" mentality of a University program, or especially of a new and energetic space entrepreneur can cause a certain "blindness" to the realities of doing business outside of the United States and Western Europe. Global ground network services providers, like SSC, have years of experience and strong capabilities in the area of global logistics, including installing ground stations around the world, managing frequency allocations and licensing, dealing with export control and many other administrative and logistical challenges.

Expansion

Whereas it might seem counter-intuitive to the outside observer, expansion is a form of adaptation and the commercial services providers, like SSC, are in the process of expanding their offerings to meet the needs of New Space 2.0 programs. Expansion and adaptation occurs along 2 dimensial lines. In one dimension there is a need for an ever-increasing number of ground stations.   SSC is approaching this expansion concept with a new model of operations we have dubbed, SSC Infinity.   SSC Infinity is a service, not a network.   However, locations are needed in order to provide the required coverage for small sat programs. Building from Exhibit 1 above, exceptional coverage for low earth orbit can be provided by the SSC Universal Space Network shown in Exhibit 8 below.

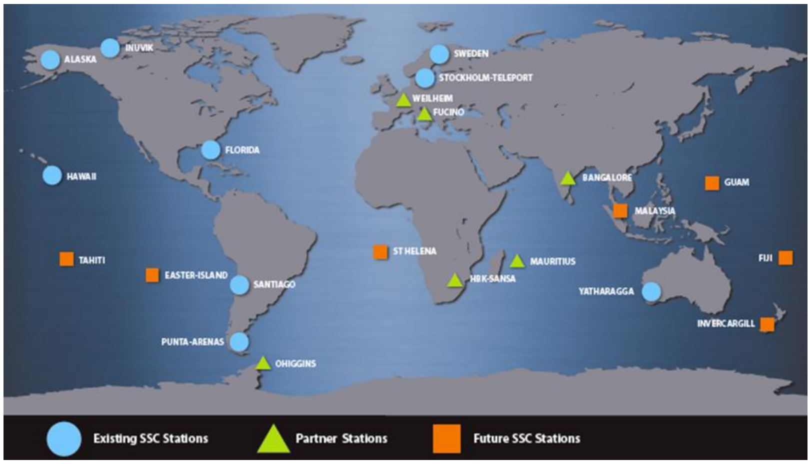

Exhibit 8: Newly configured and expanding Universal Space Network owned and operated by SSC.

In addition to exceptional locations, like those shown above, expansion requires a new way of doing business. SSC is adapting to this new business model with its new service release called "SSC Infinity". In another paper delivered at this conference, Mats Tyni, offered the following definition for SSC Infinity service scalability that is applicable in this paper.

"Scalable architecture on all levels

Ground station infrastructure, an attractive location with an antenna, radio, power and communication are the basic needs. To make the ground segment scalable and flexible, small apertures in combination with a fixed architecture is key. SSC Infinity ground station concept can be reproduced at any location of interest in a short period of time, lowering risk and giving our customers the service they need on time.

The scalability concept is then applied to customer interface, on-site virtual environment, the monitor and control system, using a process industry standard system, a combination of on premise and public cloud data storage, processing capability and data distribution to allow the network to grow with a maintained low cost of ownership, support and service quality." [1]*– Tyni, et al*

CONCLUSION

Experienced commercial ground network providers, like SSC, have much to offer to the cubesat and smallsat community. The entrepreneurial minds and energies behind the first commercial, multi-mission, ground network built by Universal Space Network are still engaged in the business and are actively expanding and adapting the business to suits the needs of New Space 2.0 era programs.

Continued success in this area, will be driven by SSC's new SSC Infinity service which provides automated operations and cloud-based services. In addition to the actual service of communicating with satellites, there is also a large amount of inherent knowledge and expertise that can be accessed to assist globally-oriented programs in working across geo-political borders for frequency coordination, export management, and other logistics.

One of the best ways to demonstrate the full utility of existing commercial ground network services is to apply the network and experience base to one of the most intensely involved operations in the life of a constellation of satellites, including those that are comprised if cubesats or small sats. The experiences gained over decades of operating in the launch and early orbit phase of programs have equipped the service providers, like SSC, for the intensities of orbit raising operations.

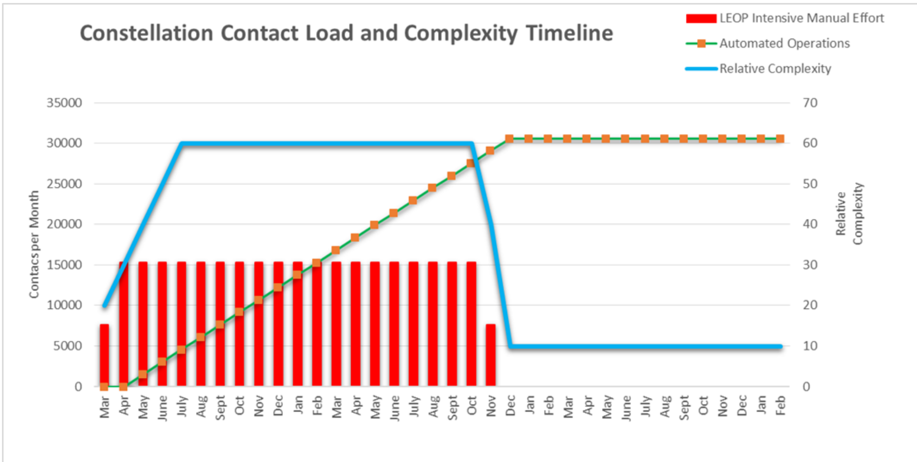

Exhibit 9: Constellation orbit raising intensity can last months or years, depending upon launch frequency and number of satellites. Load on mission operations increases throughout this period due to satellites being in different phases all simultaneously. Reaching a steady-state operational level is the desired state. SSC can provide a valuable service during this intense period of operations.

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[1] Cloud-based services, highlighting new ground stations and Ops Concept