Integrating a Global TT&C Network

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Abstract
Global Networks come in a couple of different flavors; dedicated resources with a singular mission or shared ground system resources integrated into cohesive ground network solution. The dedicated network solution provides global coverage to a single mission or constellation, which has many benefits to the owner, however, also incurs substantial cost for implementation, operations, sustainment and other “ownership” issues. Priority access is normally a driving requirement for the development of a dedicated network. Shared Network resources provide an alternative to what could be a very expensive dedicated network solution. Many of the challenges and disadvantages of a dedicated, user-owned network are easily diminished by the utilization of a shared infrastructure. However, this is not to say that the Shared Network solution does not have its own interesting and unique challenges. This paper will discuss the issues and challenges associated with providing global coverage to space-based missions from a global, shared network infrastructure that is managed and measured by its ability to deliver the required services on a very tight budget.

Nomenclature

- CNES = Centre National d’Études Spatiales
- FCC = Federal Communications Commission
- GEO = Geostationary Orbit
- GNS = Ground Network Services
- IP = Internet Protocol
- ITAR = International Traffic in Arms Regulations
- KSAT = Kongsberg Satellite Services
- LEO = Low Earth Orbit
- LRO = Lunar Reconnaissance Orbiter
- NASA = National Aeronautics and Space Administration
- NEN = NASA Near Earth Network
- NMC = Network Management Center
- NOAA = National Oceanic and Atmospheric Administration
- RGS = Remote Ground Station
- SCaN = NASA Spacecraft Communications and Navigation
- SDO = Solar Dynamics Observatory
- SGLS = Space Ground Link Subsystem
- SSC = Swedish Space Corporation
- TLM = Telemetry
- CMD = Command
- TT&C = Telemetry, Tracking & Commanding

I. Introduction

This paper presents examples of global ground station networks, including government-owned and single-user systems, and also presents a world-wide commercial remote ground station network. The commercial network approach provides space systems developers with a tool that enables the development of new space technology capabilities and industry standards, and also to demonstrate operational concepts to meet new and challenging applications.
II. Government-owned Global Network examples

NASA Ground Network

This section provides several examples of existing global spacecraft communications networks, beginning with Figure 1, the NASA SCaN, Spacecraft Communications and Navigation network. NASA’s network, as depicted in Figure 1, is really a network of multiple networks including an Earth Relay Element, which NASA also refers to as the Space Network (SN), a Deep Space Element, referred to as the Deep Space Network (DSN), and the Near Earth Element, also referred to as the Near Earth Network (NEN).

With regards to NASA operation, this paper focuses only on the Near Earth Element. The Near Earth Network (NEN) is a NASA operational network that has been through many stages of evolution over the years from the NASA Spacecraft and Tracking Data Network (STADAN) which supported early NASA missions such as Gemini and Apollo, to the Spacecraft Tracking Data Network (STDN), which evolved to support NASA’s ongoing science mission and the space shuttle program, to the current Near Earth Network.

In response to diminishing budgets that consistently drive the need for lower cost spacecraft operations, NASA decided in the early 21st century to investigate the use of new commercial satellite tracking, telemetry & commanding (TT&C) networks for their utility as an augmentation to the NASA NEN. At that time, commercial networks, like PrioraNet, had been around for roughly 5 years and had successfully supported NASA, commercial and some Government military missions with a high degree of success. NASA’s early investigation and ongoing utilization of the commercial TT&C operational networks indicates the high degree of success that can be garnered through a strong cooperation between Government and commercial enterprises.

Today, the NASA NEN, which is depicted in Figure 2, is a fully integrated operational network that consists of ground stations that are owned by NASA, commercial industry, foreign suppliers and other Government agencies. This fully integrated, global NASA Near Earth Network is responsible for tracking and communicating with spacecraft that provides the world’s science community with a wealth of information on a daily basis about the Earth, the Sun and Moon, and our Universe in an extremely cost-effective manner. Overall ground network proficiency has actually improved over years to the point that the NEN can guarantee proficiencies in operations, on
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a routine basis, in excess of 99.1% to its diverse user community. NASA-owned ground stations in the NEN include antennas at NASA Wallops Island Virginia; White Sands, New Mexico; and McMurdo Bay, Antarctica. At the time of this writing, NASA has decommissioned and dismantled the former NASA Merritt Island (MILA) ground station and is now considering alternatives including government-owned and commercial that will be used to support NASA’s new Space Launch System (SLS) program. The NOAA ground station at Gilmore Creek Alaska and a University of Alaska - operated ground station together provides additional polar support to NASA. The remainder of the NEN is comprised of commercially-available services provided by Universal Space Network and its PrioraNet ground station network and KSAT, a polar network supplier.

Air Force Satellite Control Network – AFSCN

The Air Force Satellite Control Network (AFSCN), depicted in Figure 3, has been in continuous operation for over 50 years. As a pioneering capability in space communications, the AFSCN is responsible for tracking United States Air Force National Security assets. This fully integrated, global system is utilized on a daily basis for hundreds of satellite contacts with vehicles that are flying in all orbit architectures. The flexibility to transition from low-earth orbiting (LEO) satellites, to geostationary (GEO) satellites, and then to medium earth (MEO) or highly elliptical orbits and then back to LEO again in less than two minutes is a hallmark of the AFSCN.

The control node for the AFSCN is located at Schriever Air Force Base in Colorado Springs, USA, where the centralized scheduling and operations functions are located. This global network routinely takes 350 to 450 passes per day, every day of the year, with ongoing proficiency rating in excess of 99.5%. Its primary purpose is to provide TT&C communications to its large and diverse subscriber base. On a given day it is not unusual for the AFSCN to be involved in TT&C for simple operations, such as station keeping and monitoring telemetry from a fleet of spacecraft to much more complex operations such as Launch and Early Orbit Phase (LEOP) activities and critical maneuvers on several spacecraft.

Having been in operation for over 50-years and with the volume of spacecraft managed on a day-to-day basis makes the AFSCN, not only the busiest ground network in the world, but also the most utilized. That operation does come with a price, however, as the US Department of Defense (DoD) is faced with rapidly aging infrastructure that uses some technologies pioneered in the 1960’s, such as the old but reliable SGLS standard operating in L-Band.

A complete modernization process was started in the past decade to upgrade the AFSCN aging infrastructure and to incorporate newer spacecraft communications and operations standards, such as Unified S-Band, to ensure a bright future for this critical, US National defense infrastructure. The US Department of Defense, being subject to budget constraints and the encroachment of cellular communications services into its bandwidth may also look to migrate and evolve the AFSCN. Future architectures may include more commercial resources from suppliers like USN, and also will take advantage of existing inter-governmental partnerships to be more efficient in the future.
Another global network example is the system owned and operated by the Centre National d’Études Spatiales (CNES), the National Space Agency of France. With its Network Operations Center (NOC) based in Toulouse, the CNES network provides worldwide coverage of a variety of space science and remote sensing missions. Comprised primarily of S and X-band large aperture antennas installed in strategic locations around the world, this network supports a wide variety of French and other European agency missions.

Polar station coverage is provided by ground stations that are operated by SSC at Kiruna in northern Sweden and Inuvik in Northern Canada. Southern Hemisphere stations at Hartbeesthoek in South Africa, Kerguelen Islands in the southern Indian Ocean, Aussaguel in France, and Korou in French Guiana provides mid-latitude coverage for polar and lower-inclination missions. CNES is currently in the process of upgrading and adding new capabilities to the network, as indicated by the dates shown in Figure 4.

In addition to new and updated ground station equipment and antennas, the CNES NOC in Toulouse is also being upgraded with an emphasis on modernization and automated operations. Station Monitor & Control (M&C) upgrades will improve the efficiency of operations with no degradation of proficiency. Terrestrial network implementation and monitoring to accommodate future missions with larger volumes of data and lower latency requirements is underway at CNES. Currently the CNES network is supporting 17 on-orbit satellites on a daily basis and is expecting significant additional support opportunities in the near future.
III. Commercial Network

PrioraNet – Commercial Global Ground Station Network

PrioraNet is a fully integrated, global network of tracking stations owned by SSC and operated by SSC and Universal Space Network. This reliable and secure ground infrastructure provides responsive access to space from many regions on earth today. Not being reliant upon a single agency for its mission set or being dedicated to a primary mission requires that the commercial approach have a level of flexibility that isn’t present in other network approaches.

The system must be designed with the ability to add new satellite missions from new locations/stations on the order of months, not years, as is traditionally the case with large ground systems programs. In addition to the ability to rapidly and cost-effectively integrate new missions from a variety of agencies and programs, the network must also maintain high levels of proficiency to ensure data access for a diverse user group. Users such as the DoD, NASA, commercial and international customers are supported with a sustained overall success rate of greater than 99.7%. PrioraNet boasts mission critical launch and early orbit support for 80 satellites and launch vehicles including Delta 2, Atlas 5, Arianne and the Falcon 9 as well providing over 300,000 on-orbit passes from a variety of spacecraft programs over the past 9 years.

PrioraNet includes a network of 7, 9, and 13-meter antenna systems that support a range of frequencies and protocols including X-band uplink and downlink, Unified S-band, Ku-band, Ka-band and SGLS L-Band commanding with telemetry data rates in excess of 300Mbps. The network includes a wide range of tracking and ranging services including those compatible with DoD requirements and standards such as SGLS. The ground stations are connected via IP based managed terrestrial communication circuits.

The ground stations are operated from redundant Network Management Centers (NMC’s). Ground stations operate autonomously with only maintenance staff on location. The NMC’s act as single point of interface for our customers and provide seamless access to our ground stations around the globe. The commercial provider must also...
address the regulatory management approval and coordination processes including frequency coordination and export authorities like the US Department of State in regards to ITAR and the Federal Communications Commission (FCC) to name a few.

IV. Single User Network

Missions requiring dedicated ground networks have driving requirements that push the cost of mission operations. These requirements can range from priority service, specific geographic access, full capacity usage, and primary control of the network. Missions that provide services to individual customers such as phone service tend to protect the entire value chain and therefore typically choose to operate a dedicated ground network. One of the major disadvantages of a Single User Network is that the owner and operator must bear the costs of the entire operation. In a shared network approach many users provide efficiencies in shared operations reducing mission costs to each user.

Several significant examples of single user, dedicated networks exist in the industry and have been successfully operating, in some cases, for decades. Prime examples of this are the networks owned and operated by Iridium, GlobalStar, and OrbComm. These companies have constellations of satellites that, based solely on their number of satellites and required ground contacts, supports the building and operating of their own network. Hundreds of contacts per day demands close control and priority services for both constellation management and contingency operations. These ground station designs are streamlined to meet the single mission requirements and have static or limited configurations.

Ultimately, the decision to build your own ground network comes down to money. Constellations may use 60% or more of the ground network capacity while individual missions taking two passes per day may use 20 minutes on a single antenna (less than 2% of capacity). The full lifecycle cost of ground stations and expected capacity usage are prime features to consider in the “build your own network” trade study.

V. Challenges of implementing a Global Shared Network

<table>
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<th>Architecture</th>
<th>To optimize the utility of the shared network, geographic locations must be chosen to provide support to all Near Earth orbit architectures.</th>
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<tr>
<td>Capabilities</td>
<td>Frequency bands, data rates, storage volumes, protocol definition, and system parameters selected carefully to support as many missions as possible.</td>
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<td>Performance Specifications</td>
<td>Balancing the performance of the global network with flexibility to support both low and high end mission requirements to meet available program budgets.</td>
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<td>Financial Contractual model</td>
<td>Minimizing the upfront investment costs by partnering with appropriate, existing resources reduces expenses, however, may limit the flexibility of the global implementation.</td>
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<tr>
<td>Pricing structure</td>
<td>Global network pricing must be consistent across the users while being flexible enough to fit within diverse program budgets. A &quot;pay as you go&quot; model composed of a price per pass or price per hour coupled with a preparation charge provides a starting point.</td>
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<tr>
<td>Approach to the marketplace</td>
<td>The Global network has the potential to be considered a &quot;community resource&quot; that is shared among many industry players simultaneously while in reality each customer believes their mission is the most urgent.</td>
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<tr>
<td>The Customer Interface</td>
<td>Utilizing the global network in a shared, diverse-mission environment, requires a scheduling system that can optimize utilization and thus maximize the financial impact to the owner and the users.</td>
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<td>Priority /Conflict management</td>
<td>Invariably, every user of the shared global infrastructure expects highest priority service for his mission. A well-defined priority/conflict resolution scheme that is based on mission status, must be developed and shared with all users of the global network.</td>
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VI. Blended Commercial Government Network

Blended Commercial Government Network Example – LRO

The NASA Lunar Reconnaissance Orbiter (LRO) is an excellent example of how blended networks can provide a cost-effective solutions on a highly visible mission. The communications trade studies conducted by NASA provided an early look into the challenges of the LRO program, which is a NASA science mission that is in Lunar Orbit.

Global coverage using a dedicated network was cost prohibitive as was access to the busy resources of the NASA DSN for routine operations. It took close to eight months for the final architecture selection and in the end a blended network was selected.

The LRO primary 18 meter antenna is located in White Sands New Mexico and provides ~45% of the required global coverage, as depicted in Figure 6.

The White Sands station supports primary Ka downlink services as well as S-band TLM and CMD. There are two additional 18 meter systems belonging to the Solar Dynamics Observatory (SDO) that can be used in case of primary failure. When LRO is not in view of White Sands Complex (WSC) global coverage is provide though the PrioraNet global tracking network. Every LRO orbit around the Moon is supported from one of a five stations; WSC, Kiruna Sweden, Weilheim Germany, Dongara Australia, and South Point Hawaii, as illustrated in Figure 7.

S-band coverage from the PrioraNet stations provides TLM and CMD for routine health and safety. Tracking data was the real challenge in both accuracy and verification. This paper does not approach the technical issues however programmatically this was a challenge in that multiple teams spent considerable time and money ensuring consistency across the network. In the end the teams prevailed but we can say that this was a good example for the need for Cost Plus type US Government contracts.

Integration of the network was the responsibility of USN. The driving
requirement was a single interface to the LRO customer which is based on the INSNEC Cortex system allowing flexibility for multi-mission operations.

These systems are configured and accessed over a Wide Area Network (WAN) that is managed by SSC and USN. Control and monitoring of these systems is located in the Horsham, Pennsylvania Network Management Center (NMC). The NMC is the access point for all customers and provides a custom look and feel to fit the needs of each customer.

Beyond the look and feel of the network, the NMC provides network operations, scheduling and security. The NMC is a 24/7 operation providing the LRO operations team with routine and contingency support. LRO scheduling is coordinated well in advance of the desired contact. Automated email requests and confirmations are routinely the only piece of a very involved de-confliction process that the customer will see. This is the “single interface” to the customer concept. In the case of LRO even the pass prices are “one price” across multiple organizations.

Across these multiple organizations comes the challenge of security. For missions like LRO, USN has developed and qualified a unique approach to securing access to resources by schedule. PrioraNet provides a proxy service into the network that is controlled by schedule and closed to all customers when there is no pass scheduled. We won’t go into details for reasons of program security however security of our customer’s data is a very high priority.

VII Summary and Conclusion

In summary, the commercial ground network approach provides a level of flexibility not available to single-user networks and even many government-owned systems. A commercial network can be utilized to provide all of the required ground station coverage for a particular mission or constellation, or it can be utilized as a low-cost, highly effective augmentation to an existing single-user or government-owned network.

As demonstrated in the LRO example provided above, the commercial ground network can provide coverage and/or capabilities that aren’t available from single-user or government-owned network. Because no infrastructure investment is needed to utilize the commercial ground station network, the user can benefit from much lower life-cycle costs including reduced requirements for maintenance and ongoing operations. Utilizing the shared network model, allows individual network users to benefit from investments that are made by others to enhance, sustain, operate and upgrade capabilities. Redundancy and geographic diversity provides a level of overall system reliability that would be expensive to implement and maintain, thus significantly lowering the cost of mission operations, and increasing the probability of a successful space program.