

The NASA Ground Network Vision for the Future

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This paper will highlight the GN's mission, motivation, and future plans, specifically in relation to the increase of commercialization for routine services and partnership opportunities for routine and unique services with the goal that other agencies can benefit from our approach as they pursue their science and exploration goals.

I. Introduction

NASA operates a large fleet of scientific spacecraft in a broad range of orbital regimes as well as manned vehicles in the low earth orbit region. In support of these missions, NASA operates three distinct space communications networks to best service the diverse needs of the agency. While each of these networks has operated over a multi-decadal period, the Ground Network has undergone the most significant changes, evolving both its technical capabilities and business operations model. The purpose of this paper is to summarize the successes and lessons learned from this evolution and to highlight the GN's vision forward.

The GN is inherently different from NASA's other two space communications networks (i.e., Space Network and Deep Space Network). The GN provides spaceflight communications for short link distances with earth-based assets and is focused on providing best value communications and tracking services to spaceflight missions. A key enabler to providing low cost services is maximizing the use of the large commercial and international provider base to fulfill the majority of near-earth mission requirements. This has afforded the GN the opportunity to introduce a vastly different business model than its NASA space communications counterparts and establish the GN as the pioneer of large scale commercial usage for communications and navigation services.

The GN owns and operates very few assets, procuring the majority of its routine low-earth-orbit (LEO) and geosynchronous (GEO) services through commercial service providers and only providing assets to meet unique requirements where no business case exists for commercial providers. The commercial provider community has matured over the past 5-years, with several entities emerging with solid business cases. The GN capitalizes on these providers to provide low-cost routine services.

Today the GN provides over half of its services through commercial entities and existing partnerships. The future goal is to increase the services procured for routine support (e.g., LEO X- and S-Band) through commercial providers to achieve a pure price/pass model in order to achieve efficiencies as the NASA customer load changes. In addition, this model will increase the competitive pressures between commercial entities to achieve the best cost for GN services.

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Additionally, another goal of the GN is to expand partnerships with other agencies to continue to cost-effectively meet unique mission requirements. Today, the GN has agreements in place with other federal agencies such as the National Science Foundation and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO), as well as with other international partners, such as the European Space Agency to fulfill existing unique requirements. In addition, to meet new lunar requirements, the GN installed new NASA assets optimized for lunar and GEO communications, for which the first customer is the Lunar Reconnaissance Orbiter this year. These assets may provide the opportunity for international partnerships as world-wide interest grows in lunar and broader exploration-related activities.

This paper will highlight the GN's mission, motivation, and future plans, specifically in relation to the increase of commercialization for routine services and partnership opportunities for routine and unique services, with the goal that other agencies can benefit from our approach.

II. NASA's Space Communications Networks

NASA currently operates three distinct space communications and tracking networks to support human and robotic missions throughout the solar system. These three networks are each distinct components of NASA's space communications and navigation capability, centrally managed by the NASA Headquarters Space Communications and Navigation (SCaN) Program. Each network is optimized to provide communications services to a specific subset of NASA missions.



Figure 1. NASA's Communications Networks Support Science and exploration activities throughout our Solar System. Each network is optimized to provide services to a unique customer set.

The Deep Space Network (DSN) is optimized to provide communications services in support of solar system exploration. As such, it is focused on detecting and differentiating faint interplanetary spacecraft signals from stellar noise. The DSN is comprised of three tracking sites around the world with large ground apertures, which are placed approximately 120° apart to provide global coverage to the world's deep space missions. The DSN is managed and operated for NASA by the Jet Propulsion Laboratory (JPL), a division of the California Institute of Technology (Caltech) in Pasadena, California.

The Space Network (SN) is a global orbital satellite communications fleet that is optimized for continuous communications for spacecraft operating in low earth orbit. The SN is designed to be a highly automated, user-controlled system. It provides services to a broad user base from near-continuous, high data rate users to an opportunistic community of near-immediate, unscheduled, low data rate missions. Its 3-node architecture can provide global coverage for spacecraft up to 9,000 km, depending on orbital characteristics and requested services. While utilized for many low-earth orbiting spacecraft, the SN is critical for human spaceflight, such as Space Shuttle missions and the International Space Station. The SN is managed and operated by the Goddard Space Flight Center (GSFC) in Greenbelt, MD.

The Ground Network (GN) is optimized for cost-effective services for missions operating in the near-earth regime. The GN is comprised of a world-wide network of stations that evolved from fully NASA-owned to a portfolio of owned assets and procured commercial services. Because the GN inherently supports short link

distances, does not operate flight systems, and is part of a large customer and provider community, it can benefit from a different business model than NASA's two other space communications networks. The GN is able to capitalize on commercial and partner services, as well as existing COTS products to provide inexpensive, robust spacecraft communications services. The GN is managed and operated by GSFC in Greenbelt, MD.

III. Ground Network Background

The Ground Network emerged from over a half century of spaceflight communications at Goddard Space Flight Center. During the 1960's, NASA established the Manned Space Flight Network (MSFN), a world-wide communications network, in order to support the Mercury, Gemini, and Apollo Programs. This network evolved from earlier US Government initiatives, such as the National Advisory Committee for Aeronautics' initiatives in communications and tracking support for aircraft. With the emphasis on manned spaceflight, the MSFN stations were distributed at low-latitude sites in order to provide near-continuous communications with the equatorial manned spaceflight orbits.¹

During this same time, NASA also acquired the management of the military's Minitrack network, which was developed in the 1950's and was specifically intended for satellite tracking. This network was used to track the Project Vanguard (Explorer 1) and Sputnik satellites. By the mid-1960's, new classes of satellites requiring enhanced communications support drove the evolution of the Minitrack network into the Satellite Tracking and Data Acquisition Network (STADAN).¹

By the 1970's, with the decline of manned flight missions after Apollo, the MSFN merged with STADAN to form the Spaceflight Tracking and Data Network (STDN) to support both manned and unmanned spacecraft missions. During this time, many stations were closed due to redundancy, capacity, and cost constraints.¹

Roughly a decade later, STDN was expanded to fulfill Shuttle communications requirements during the delays in the SN development schedule. STDN reached its peak in the early 1980's: stations were upgraded to meet the new Shuttle requirements and new stations were acquired to provide sufficient coverage to Shuttle missions. However, by the end of the decade the SN became operational and roughly half of the STDN stations were decommissioned, marking the end of this world-wide ground-based network.¹

With the Mission to Planet Earth (MTPE) initiative in the 1990's, the need for ground-based stations emerged again. The goal of the MTPE was to understand the total Earth system and the effects of natural and human-induced changes on the global environment² [this program is known today as the Earth Observing System (EOS)]. With MTPE, there was an emerging emphasis in high-data-rate, low-earth orbit science missions. A two-year study to evaluate the trades of using ground stations versus the SN culminated in a decision by NASA Headquarters to utilize ground assets for these new missions.³

GSFC evolved what was left of the STDN into what we now know as the Ground Network. As GSFC evolved the GN to meet the new requirements of the science community, the emphasis shifted from the equatorial sites of the STDN to polar sites optimized for high-data-rate, sun-synchronous missions. More STDN sites were closed and new sites were added, such as the stations in Alaska and Norway. Further, with the enhancements in satellite communications and a growing satellite community, a commercial provider community emerged in the late 1990's and early 2000's. Today's Ground Network baseline reflects a series of asset decommissions, new implementations, a procurement of commercial services, and a partnering with other agencies to provide support to science missions.

With NASA's recent push towards Exploration, several new near-term mission thrusts are emerging which drive the need for further evolution of the GN. NASA is voyaging back to the moon, with the first robotic mission planned to launch later this year. The Lunar Reconnaissance Orbiter (LRO) is planned to launch in late 2008 to find safe landing sites, locate potential resources, characterize the radiation environment, and demonstrate new technology.⁴

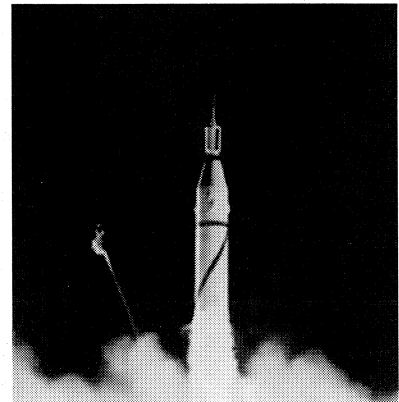


Figure 2. Explorer 1 Launch. America's first satellite lifts off the launch pad at Cape Canaveral, Florida on Dec 31, 1958 on a Jupiter rocket. (NASA Photo KSC-68P-17).

The GN will provide high data rate, near-earth Ka-Band (26 GHz) services to LRO, which will represent the first use of the near-earth Ka-Band frequency within NASA's integrated space communications and navigation capability. In addition to robotic missions, NASA is also planning a robust human exploration initiative to explore the moon and beyond. To respond to these new mission thrusts, the GN is implementing three 18m antennas at White Sands to meet initial lunar communication requirements and unique geosynchronous requirements.

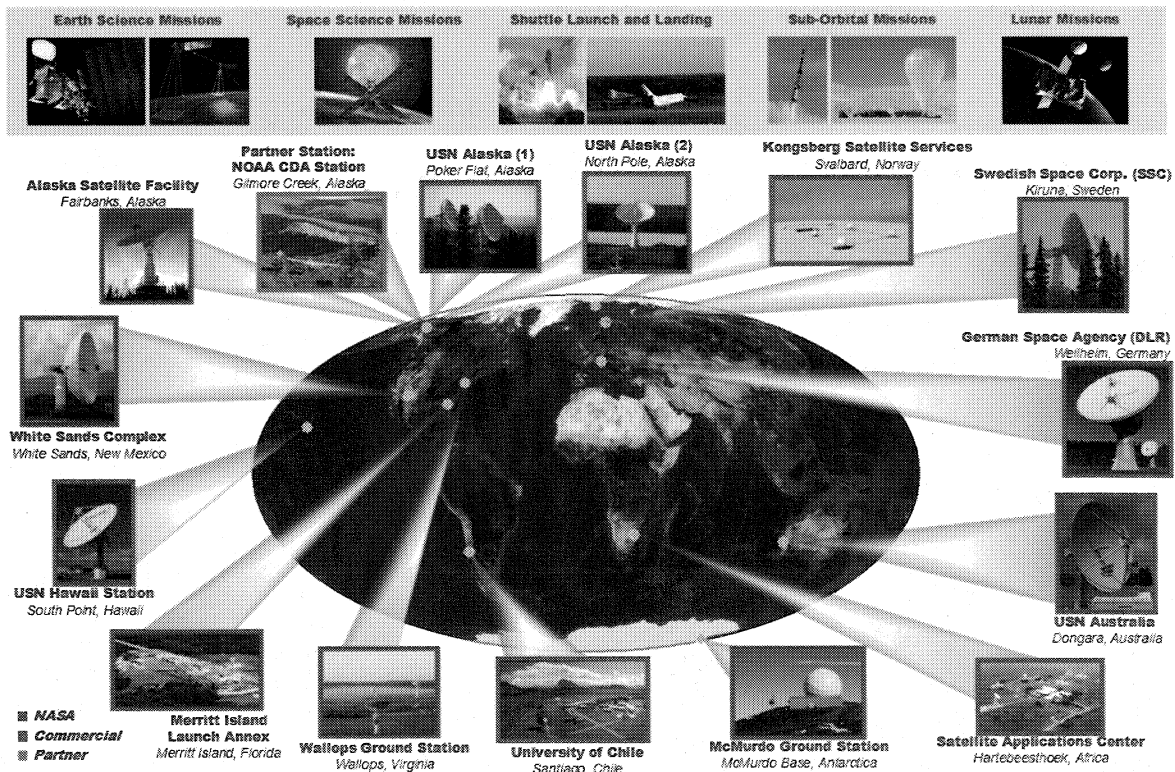


Figure 3. Current GN Configuration. *Today's baseline reflects a series of asset decommissions, new implementations, a procurement of commercial services, and a partnering with other agencies to provide support to high-data rate science missions operating in the near-earth regime. In addition, it includes the first COTS-based lunar asset in White Sands, NM.*

IV. Ground Network Vision

The Ground Network mission is to provide best value communications and tracking services to NASA and partner missions operating in the near-earth regime from ground based antennas, now and in the future. As such, the goal of the GN is to provide services of sufficient quantity and quality to meet customer requirements as inexpensively as possible. To achieve this mission, the GN has identified a three-part vision to enable future success:

- 1) Procure Routine Services from Independent Service Providers
- 2) Provide Critical and/or Unique Services with NASA-Owned and Controlled Systems
- 3) Employ Efficiency Mechanisms to Minimize Costs and Maximize Service Value.

A. Routine Services

The GN regards routine services as those services that are commonly available from the broad commercial service provider community. For instance, X- and S-Band communications for science return from low-earth orbiting and geosynchronous spacecraft are routine services. By providing these services through commercial providers, the GN can realize several benefits. First, the costs will be incurred based on service quantity and performance rather than infrastructure capitalization and sustaining requirements. Second, this approach will establish continual competitive pressure for the providers to minimize costs while keeping performance high.

Finally, the GN can continue to leverage the commercial market and their expertise in LEO and GEO services while focusing on higher-risk activities.

Because routine services are inherently less risky, the GN can take this approach with little risk to the missions. If an issue occurs with a service provider, the primary risk to the mission is the consequence of service loss is the loss of science data. To manage this risk, the GN takes a two-fold approach. First, the GN maintains sufficient capacity through other providers, partnerships, or even NASA-owned assets to transfer services from a provider that fails technically or financially. In addition, the GN employs financial performance incentives and penalties to promote high service quality from its commercial providers.

B. Unique Services

The GN considers unique services as those communications and tracking services which cannot be provided by commonly available providers, whether due to their technological challenges or, pragmatically, where no readily available market exists for commercial providers. For instance, the GN provides polar, southern hemispheric Antarctic Services from McMurdo with the partnership of the National Science Foundation. In addition, the GN supports critical manned spaceflight events for Shuttle missions out of MILA/PDL and Wallops (e.g., Launch, Ascent, and Landing). Further, the GN will provide lunar services from its White Sands facility initiating later this year.

The risk is often greater for unique services as compared to routine services. The consequence of service loss of unique services could be loss of communications with humans, and/or the loss of critical information required for post-event analysis. Because of this, the GN maintains responsibility for providing unique services to retain technical expertise, insight, and control. In addition, this approach allows the GN to sustain the NASA core competency in Space Communications.

C. Efficiency Mechanisms

The GN currently employs several efficiency mechanisms to minimize capability costs and maximize service value and will continue to employ these practices as the network evolves. The primary mechanisms relate to capacity, the use of COTS products, and the implementation of automated systems.

In order to maximize value and minimize costs, the GN optimizes communications and tracking service capacity. Service capacity is optimized through maximizing asset utilization and eliminating excess capacity. By maximizing asset utilization the GN can defray costs across a broader customer base. Excess capacity is eliminated to prevent sustaining and operating costs for assets that are no longer needed. Over the past 3 years, the GN decommissioned 13 assets. In addition, the GN is planning to decommission at least five more assets in the next three to four years based on the projected demand.

The GN maximizes the use of COTS products in its ground systems infrastructure solutions to minimize costs. COTS products are often less expensive to sustain as compared to custom software solutions, as the GN does not have to maintain a large software sustainment capability. In addition, as ground systems vendors continue to upgrade their individual software systems and their interoperability and performance with other ground-station-related software packages, the GN should benefit by the spreading of development costs across a larger user base.

Finally, the GN is automating its stations to eliminate the need to staff its sites with large teams of operators. Several of the GN stations are already capable of autonomous operations. Future planned decommissions and upgrades will enable the GN to automate all of its systems, with the goal of being fully automated by 2011. Once automation is achieved, the GN can staff its sites with smaller teams of skilled field engineers to perform sustaining and upgrades activities, as well as respond to anomalies.

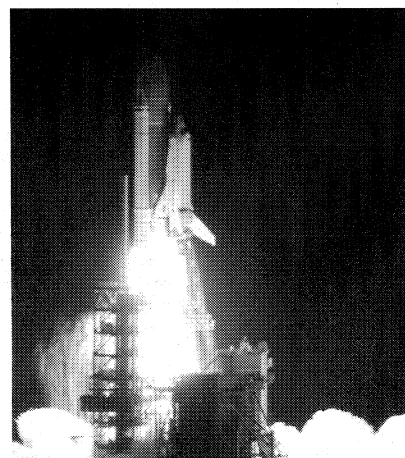


Figure 4. Space Shuttle Endeavour launch. *Unique services, such as communications for shuttle launches, are provided by NASA-owned assets to minimize risks. Photo credit: NASA/Jim Grossmann.*

V. Commercialization

The GN currently procures a majority of its routine services from commercial service providers. As demonstrated in the following figure, over 50% of the GN's services are procured commercially, and nearly 80% of the GN's routine services are commercially procured.

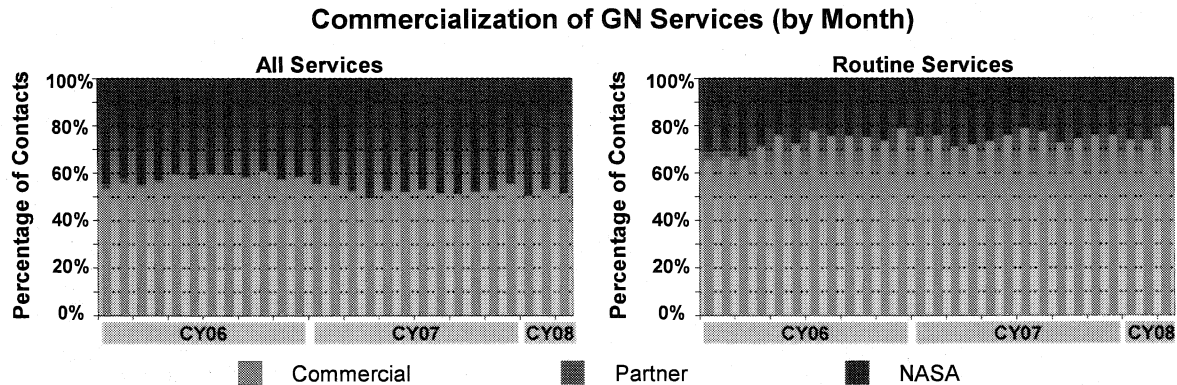


Figure 5. GN Commercialization. *The GN provides a majority of its services through commercial service providers (as depicted by the chart on the left) and nearly all of its routine support through commercial providers (as depicted by the chart on the right).*

This effort to “commercialize” the GN load has been an ongoing effort which started roughly a decade ago. As commercial providers emerged in the mid to late 1990’s, the viability of these organizations, both technically and programmatically, was not known. But, the GN embraced the community and helped them establish viable business cases. Initially, the GN bought all (or a significant majority) of a commercial provider’s capacity. While this did not provide the benefit of shared costs for the GN, it did give the commercial entity a stable base upon which to build and provided the benefit of the elimination of upfront NASA capital investments for new antenna systems. By exercising the commercial providers in this manner, the GN gained confidence in the providers and was able to continue to increase the services procured for routine support from commercial providers. This, along with the providers’ initiative to capture additional business, resulted in the emergence of several viable commercial providers in recent years. Most notable are Kongsberg Satellite Services (KSAT) and the Universal Space Network (USN). Throughout this evolution, the GN identified several key lessons learned when procuring satellite communications services from commercial providers:

- 1) Purchase services with a simple cost structure (e.g., price/pass)
- 2) Buy in bulk
- 3) Develop flexible contracts
- 4) Understand the provider’s business viability
- 5) Understand the provider’s service availability concepts and approach
- 6) Develop partnerships for contingency support

A. Purchase services with a simple cost structure (e.g., cost/pass)

Earlier this decade, the GN “commercialized” several of its assets. These assets were provided to commercial providers to sell the capacity and operate as their own. As part of this exchange, the GN remained responsible for the sustainment of the assets above a certain monetary threshold, for example to replace a significant and costly ground systems component. The GN found that with this structure it was difficult to compare costs between commercial provider services and thus fully evaluate market competition. In addition, this contract structure was difficult to budget for, given the unpredictability of failures. A future goal of the GN is to achieve a pure price/pass model in order to achieve efficiencies as the NASA customer load fluctuates and to increase competition among the providers. The GN successfully negotiated a contract with one provider to transfer all of the sustaining responsibilities to the provider, and a commercial buy-out of the DataLynx station in Alaska will eliminate the sustaining responsibility from NASA for that station, as well.

B. Buy in bulk

As the commercial market materialized, the GN embraced the community and helped them establish themselves as viable and sustainable businesses. During the early years, many commercial providers' contracts were held directly by the satellite missions or were used for short duration activities (e.g., launch services), which is contractually inefficient. In contrast, the GN purchased bulk buys with several providers to use for its NASA customers. A bulk buy is an agreement to purchase a minimum number of passes/day at a specific price, often with price/pass benefits for support above the minimum pass/day agreement. By buying in bulk the GN was able to achieve a price break for the passes it purchased. In addition, the provider benefits from this arrangement, as they can rely on a predominantly predictable revenue stream.

C. Develop flexible contracts

In order to give the customer agency flexibility and encourage high service quality and provider competition, service contracts should be flexible. While there are reductions in service prices through bulk buying, there is a need for flexibility in contracts to accommodate uncertain futures, such as when an agency's network requirements change. Agencies need the flexibility to reduce the contractual minimums and realize a reciprocal reduction in costs associated with purchasing fewer passes/day. One way of achieving this flexibility is to develop shorter-duration contracts. However, often when contracts are re-negotiated the price/pass increases. Predicting demand is key to being able to negotiate contracts with the appropriate balance between flexibility and cost stability.

In rare occasions, an agency may need the flexibility to move its load to an alternative provider or providers if its current provider is not meeting service quality expectations. Contractual proficiency and availability requirements and associated incentives and penalties can incentivize the provider to perform well, encourage competition, and give the customer agency the flexibility to terminate the contract and take its business elsewhere, if required.

D. Understand the provider's business viability

NASA played a key role as an enabler for the commercial service provider industry. The agency provided a predictable level of requirements to be fulfilled over a multi-year basis, thus the general industry could rely on a predominantly predictable revenue stream, albeit not a specific alignment to any one provider. However, understanding the business motivations of individual providers became a key attribute when considering individual

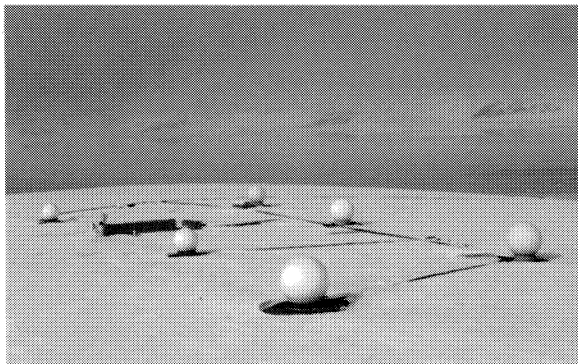


Figure 6. KSAT Facility in Svalbard. *KSAT is one of the more notable commercial providers that established itself as a viable commercial provider.*

service procurements. In a rather short period of time, it became clear which organizations had motivations to become providers to a "larger-than-NASA" customer base. A number of observable behaviors by the providers became recognizable discriminators of which organizations had the goals of capitalizing on NASA as an enabler in establishing broader business viability in the competitive global market place, as opposed to those which would enjoy the short-term revenue gains but not necessarily invest for longer-term viability. These behaviors included sharing of high-level marketing plans, recognizable behaviors of approaching other agencies for commercial contracts, and the willingness to negotiate service rates based on real requirements. In that regard, and as an excellent example of an individual provider capitalizing on the NASA investment as an enabler, the KSAT organization increased their customer base well beyond NASA, to the extent that

NASA is now a minority user. Thus, the GN benefits monetarily by reduced per pass service costs. Arguably, only through NASA's reliable and predictable revenue stream could KSAT demonstrate an extended exceptional level of performance, thus providing confidence for future procurers of service – which in turn provided a larger user base to share costs. Thus, this provider, as well as others, have established themselves as viable long-term business partners.

E. Understand the provider's service availability concepts and approach

While there is a strong desire to procure services on a per pass or per use basis, it is imperative to understand the providers underlying philosophy regarding service availability. Overly focusing on attractive service prices could introduce risk without an understanding of both the provider's technical competencies (such as their approach to architectural redundancy, sparing, documentation, and preventative maintenance) and their business practices and

corporate commitment. For providers without a strong corporate or organizational commitment, nor reliable access to funding, there exists the potential for a complete venture failure if presented with a significant cost challenge associated with a major ground systems failure. Successful industry partners have provided NASA insights into their practices, as well as have demonstrated responsiveness when presented with significant, unplanned challenges.

F. Develop partnerships for contingency support

A key risk reduction activity for the GN has been the establishment of agreements with other agencies to provide reciprocal contingency support at no cost. During contingency situations this option provides additional flexibility to meet mission requirements. Anything from an asset failure, to a spacecraft emergency, to a launch event can cause contention for resources. Reciprocal agreements for contingency support can help mitigate these events when they occur. Currently, the GN has agreements in place with the National Oceanic and Atmospheric Administration (NOAA) for reciprocal contingency support in Alaska.

VI. Current Ground Network Evolution Activities

The Ground Network has extensive experience in efficiently and effectively integrating COTS-based solutions and deploying world-wide assets. Over the past decade, the GN has deployed (or is currently deploying) 10 assets in Alaska, Norway, Antarctica, Virginia, and New Mexico. A key advantage to deploying COTS-based and ground-based systems is that the development can often be done quickly and inexpensively. As such, the GN is able to remain responsive and flexible when new requirements arise. Currently, the two key thrusts for the Ground Network are the completion (and potential expansion) of its initial Lunar Network Site and the expansion of its current Antarctic service capabilities.

To meet new lunar requirements, the GN installed new COTS-based S- and Ka-Band NASA assets in White Sands, NM, which are optimized for lunar and GEO communications. With the planned launches of LRO and SDO later this year, these 18m assets will support 100 Mbps return rates from the moon and continuous 150 Mbps return rates from geosynchronous orbit in the near-earth Ka-Band frequency band.

These COTS-based 18m antennas can serve as the building block for a low-risk, cost-effective Lunar Network as requirements for further lunar exploration emerge. As requirements evolve, these assets can be deployed around the world to provide continuous lunar coverage. Three sites can provide continuous or near-continuous coverage for lunar missions, and additional sites could be implemented for service availability contingency due to rain attenuation at Ka-Band frequencies. Deploying multiple assets at each site can provide redundancy and/or excess capacity, as needed. Further, there is significant availability to support scientific missions in many orbital regimes when the assets are out of lunar view. These assets provide the flexibility support LEO spacecraft to highly elliptical missions to libration point missions, depending on the communications requirements.

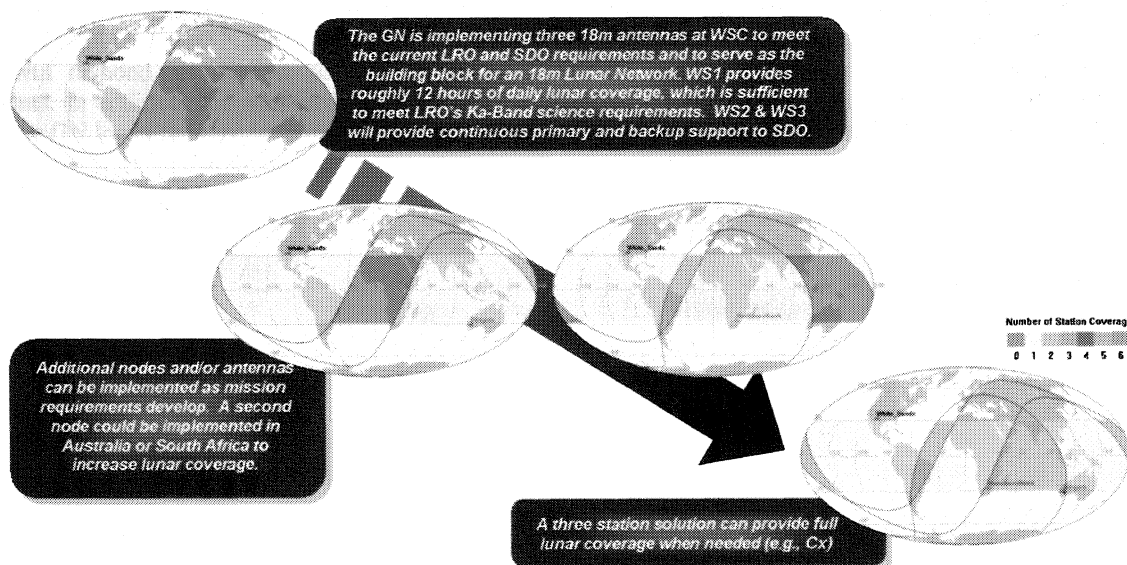


Figure 7. Potential Lunar Network Expansion. *The existing 18m assets in White Sands can be deployed around the world to achieve a COTS-based solution for lunar support.*

In addition to its current lunar initiatives, the GN is also expanding its Antarctic service capabilities. Since becoming operational in 1996, the GN has supported over 30 different missions from the McMurdo Ground Station (MGS). Currently the station supports 12 missions, with committed support extending through 2014. MGS is operated by NASA with significant support from the National Science Foundation (NSF), which operates and maintains the McMurdo facilities, as well as provides logistical support including transportation, lodging, and subsistence of personnel and transportation and storage of equipment.

This Antarctic station is uniquely positioned to “see” all orbits of polar-orbiting spacecraft from the southern hemisphere. As such, this station provides multiple benefits and is often used for unique purposes, such as for elliptical orbiting spacecraft during Southern campaigns, SAR missions, launch support, and even sub-orbital campaigns (e.g., Balloon Program). Several successful partnerships have benefited from the GN ground station in McMurdo. For example, NASA acquires data for the European Space Agency (ESA) and the Canadian Space Agency (CSA) from the ERS-2 and Radarsat-1 satellites at MGS. Due to a failure of the ERS-2 on-board recorders, MGS support enables the recovery of more data per orbit than would otherwise be possible. And the collaboration between NASA and CSA enabled the development of the first maps of the entire Antarctic continent from space.

Today, the GN is upgrading the existing McMurdo asset and deploying a new asset to support a subset of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) missions, as well as potential NPOESS IPO missions. Further, the bandwidth off the ice will be dramatically increased from kilobit/sec rates to Megabit/sec rates, making MGS a robust and viable option for continued South Pole satellite communications.

VII. Conclusion

The GN is inherently different from its NASA space communications counterparts (i.e., SN and DSN), and as such is able to capitalize on a vastly different business model. As the pioneer of large-scale commercial usage for communications and navigation services the GN has learned many valuable insights which can benefit other organizations procuring space communications services through commercial providers. In addition, as other space agencies increase their dependence on commercial providers, we can collectively benefit from the advantages of shared capacity.