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COMMERCIAL GROUND SOLUTIONS FOR CIVIL SPACE AGENCIES AND CUBESAT MISSIONS

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ABSTRACT

NASA, and other U.S. government space civil agencies, have long been a great supporter of CubeSat activities, especially within academic and emerging space communities. Over the past several years, these civil space agencies and organizations have provided funding for emerging space projects and also access to space. The result of this support is civil space agencies and organizations have served as incubators of new technologies and new businesses.

The Swedish Space Corporation's (SSC) history with civil space agencies dates back to 1958 with the establishment of the Santiago Ground Station, which SSC purchased in 2008, to support NASA. In fact, SSC's U.S. legal entity, SSC Space U.S., was founded by NASA Astronaut Pete Conrad, the third man on the moon. This U.S. business was originally called Universal Space Network and it continues to provide ground network services to NASA's Near Earth Network (NEN) and other civil agencies. In addition to the U.S. agencies, SSC has a long history supporting ESA.

This paper will explore how commercial companies, like SSC, can continue to support civil space agency endeavors, including their CubeSat activities. Earlier in 2016, SSC announced a new service, SSC Infinity, that is specifically designed for CubeSat and other smallsat spacecraft. SSC has also made great strides in 2016 towards creating Europe's first dedicated smallsat launch capability, called SmallSat Express. The SmallSat Express' first launch is projected for 2021. The launch capability is designed for sun synchronous orbits and with smallsat payloads of 1 to 200 kg. This smallsat payload range would serve, for example, NASA and other civil agencies very well.

Providing civil space agencies with additional capabilities specifically tailored for CubeSat initiatives could free up resources for other missions.

INTRODUCTION

The level of innovation and strategic focus in civil space development necessitates a similar level of innovation and strategic focus among the commercial companies that support civil agencies and their partners. The key trends influencing SSC's plans in the U.S. civil space sector stem from U.S. government policy and are 1) an increased focus on deep space initiatives with an aim to send humans to Mars by the 2030s and 2) the encouragement of viable solutions from the individual, institutional and commercial community versus building in-house. These two trends are directly linked. The civil agencies recognize the tremendous amount of innovation that is under development within the educational, institutional and commercial sectors. These groups can provide valuable contributions to advance the deep space initiatives and to support civil agencies' collection of earth observation data. In both cases, small satellites will play an important role in executing the civil mission. By encouraging civil agencies and the communities that serve them to focus on their comparative advantages, the agencies will be able to fulfil and expand their policy objectives.

SSC envisions playing an important role in bridging the gap between the many individuals, institutions and commercial entities looking to support the civil sector. As a longtime partner to NASA and other civil agencies, SSC has the knowledge, expertise and infrastructure to build solutions to deliver critical information to the entire civil community. SSC's capabilities span the entire lifecycle of the satellite, including sounding rockets that can test experiments in microgravity conditions, development of a small satellite launch capability, and providing

communication services during launch through ongoing operations. SSC provides nominal support for lunar and deep space missions today and is looking to augment the network with additional existing third party institutional assets in order to improve performance and service a greater portion of the deep space mission. Further, SSC is investing in a new service architecture to make it easier for individual civil customers to communicate with their satellites. This network can also serve as an aggregation point for individual civil single missions for distribution to NASA and other civil agencies.

U.S. NATIONAL SPACE POLICY

In 2010, then President Obama challenged NASA and the space industry to develop the capability to send U.S. astronauts to Mars by the 2030s. An important part of executing that vision included the partnering with American space related companies. The commercial space guidelines from the 2010 National Space Policy state that departments and agencies shall, "Purchase and use commercial space capabilities and services to the maximum practical extent when such capabilities and services are available in the marketplace and meet United States Government requirements." This vision led to additional opportunities for commercial space in low earth orbit including the commercial transportation of goods and, in the future, crew to the International Space Station. Commercial development in LEO will serve as a key building block for deep space human exploration.

With the establishment of the Next Space Technnologies for Exploration Partnership (NextSTEP) program under a Broad Agency Announcement in 2014, six companies received awards to study habitats in deep space. SSC supports some of these companies today by hosting their ground equipment at our stations and by providing communications to satellites travelling to the International Space Station. SSC's provision of communications services enables these companies to focus on their primary mission to develop and travel to deep space habitats.

While the 2018 budgeting process is currently underway, commercial space will continue to play a vital role in advancing U.S. space policy. The first bullet of the White House's NASA budget recommendation states that the President's 2018 Budget, "Supports and expands public-private partnerships as the foundation of future U.S civilian space efforts. The Budget creates new opportunities for collaboration with industry on space station operations, supports public-private partnerships for deep-space habitation and exploration systems, funds data buys from companies operating small satellite constellations, and supports work with industry to develop and commercialize new space technologies."

NASA Implementation of U.S. National Space Policy

NASA has implemented a number of programs to execute U.S. National Space Policy. Below is a selection of current programs along with examples of how commercial companies such as SSC can play a critical role in enabling the success of these programs and the entities that participate in them.

NASA Century Challenges

NASA implemented the Century Challenges in 2005 in order to encourage advanced space technology development in areas of interest to NASA. The nominal budget recommended at the time was $4M per year in awards. This program continues to support U.S. National Space Policy through four ongoing challenges: 3-D Printed Habitat Challenge, Space Robotics Challenge, Vascular Tissue Challenge and Cube Quest Challenge. The Cube Quest Challenge offers $5M in total awards for the development of small satellite capability near or beyond the moon. The award criteria for the two "In-Space Prizes" all require some form of communications connectivity, to both track the satellite and to download data. Two of the four categories are predicated on downloading as much data as possible either in the shortest amount of time or over the longest period of time.

IN-SPACE PRIZE AWARDS

COMPETITION	PRIZES
Deep Space Derby Prizes	Total Available: $1,500,000 • Best Burst Data Rate: $250,000 • Largest Aggregate Data Volume Sustained Over Time: $750,000 • Spacecraft Longevity: $250,000 • Farthest Communication Distance From Earth: $250,000
Lunar Derby Prizes	Total Available: $3,000,000 • Achieve Lunar Orbit: $1,500,000 (shared) • Best Burst Data Rate: $250,000 • Largest Aggregate Data Volume Sustained Over Time: $750,000 • Spacecraft Longevity: $500,000

Exhibit 1: NASA Cube Quest Challenge In-Space Prize Awards published by NASA Centennial Challenges in Collaboration with Ames Research Center. Cube Quest Challenge Ground Tournaments, Deep Space Derby, and Lunar Derby Operations and Rules, December 4, 2014 Revision B, April 10, 2015

Contestants without access to the NASA Deep Space Network (DSN) will need to secure other options to establish the necessary communications needed to monitor the satellite and to download as much data as possible in order to secure a prize. While SSC can support launch and nominal tracking services, SSC will be required to establish partnerships with interested institutional entities that have large (> 18M) antennas available for shared commercial use in order to support higher download rates.

NASA CubeSat Launch Initiative

Launched in 2008, the CubeSat Launch Initiative finds secondary launch opportunities for small satellites developed by the civil, educational and non profit community by pairing them with other agency launches or with a mission launching to the International Space Station for later deployment. Since starting the selection in 2010, NASA has selected 152 missions with 49 CubeSats launching. While this initiative affords an incredible opportunity to the 85 organizations selected that would otherwise not be able to easily find or fund a launch, the number of CubeSats launched will be limited by the number of launch opportunities. This lack of launch ability mirrors the trend in the larger global civil small satellite sector where the growth in small satellites is significantly exceeding launch opportunities. SSC is currently investigating the development of a small satellite launch capability from its Esrange facility located in northern Sweden. SSC is well positioned to graduate to this capability considering its more than 50 years of experience conducting scientific sounding rocket and balloon launches.

NASA Small Satellite Constellations Initiative

In July 2016, NASA issued an RFI to industry in order to solicit commercial industry's interest in providing earth observation data to NASA. For fiscal year 2017, NASA requested $30M to develop the Small Constellations Initiative to collect earth observation data. Included in the initiative is the option to buy earth imaging data from commercial small satellite constellations[1]. While not commenting on an exact dollar amount, the White House's proposed 2018 NASA budgetary comments mention support for commercial data buys.

SSC is already providing a number of ground related support services for small satellite missions, both to civil agencies directly and to the commercial companies capable of providing them with the data they require. Today, SSC provides the communications during launch and ongoing operations for small satellite constellations. As demand for commercial earth science and other data grows, SSC will be able to potentially aggregate data from multiple single mission or small constellation customers (subject to their agreement) and transport it using SSC's existing communication network to the civil agency centers.

SSC COMMERCIAL GROUND SUPPORT TO CIVIL AGENCIES

SSC's space related services date back more than 50 years, when SSC pioneered scientific sounding rocket launches from its Esrange facility in northern Sweden. Over time, SSC continued to invest in infrastructure and staffing in order to become the premier space services company. SSC boasts the largest civilian network of ground stations capable of supporting virtually any satellite orbit from launch to end of life of the satellite.

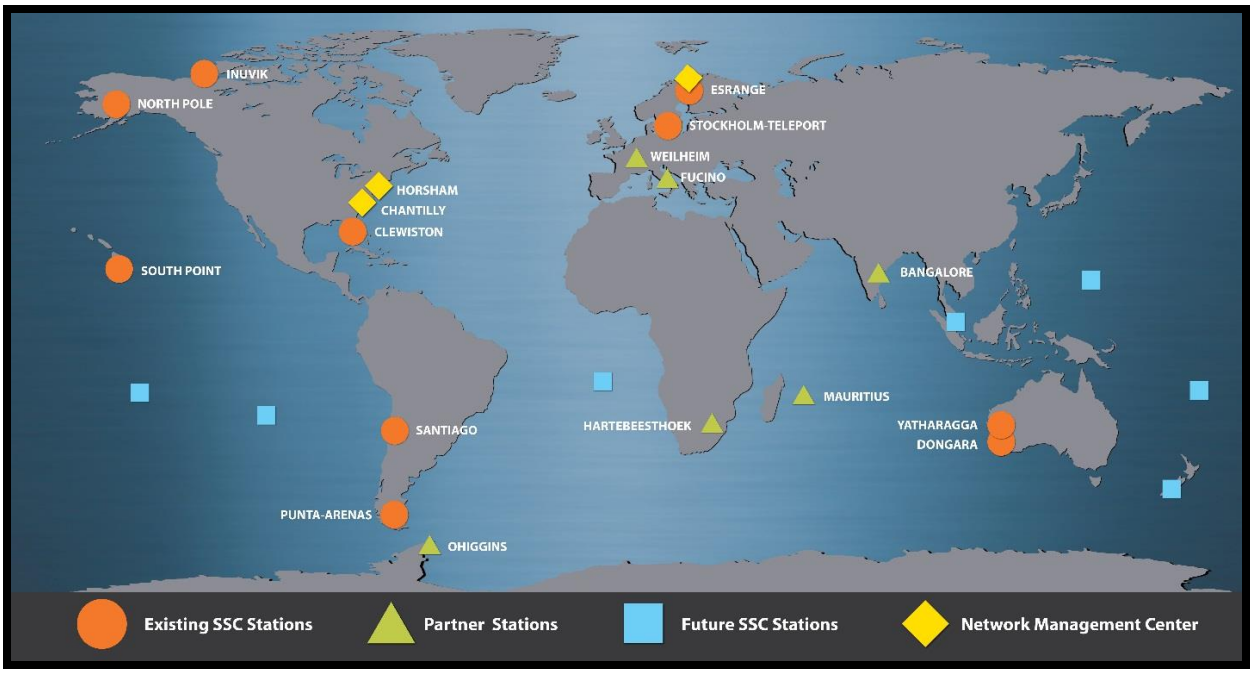

Exhibit 2: SSC Universal Space Network

SSC has a distinct advantage providing communications services because it has continuously invested in its infrastructure, both at its 10 wholly owned and operated sites as well at its partner stations. This investment allows SSC to incrementally add capabilities to its network in order to capture new opportunities.

SSC's Legacy Supporting Civil Missions

SSC has provided ground communication services for a full range of NASA missions for more than twenty years as part of the NASA Near Earth Network (NEN), which primarily supports the launch and ongoing operations of missions located in orbits of GEO and below. The SSC earth stations included in NEN are located in 5 SSC owned (South Point, HI; North Pole, AK; Santiago, Chile; Kiruna, Sweden; and Dongara, Australia) and in 2 partner owned facilities (Hartebeesthoek, South Africa and Weilheim, Germany). These as well as other SSC stations are available to provide additional support to civil agencies, enabling the agencies to focus on their core mission of scientific discovery and analysis.

SSC has also leveraged its network to provide support services to missions beyond GEO. Our network of 13m antennas in S and X band have supported missions to the moon, to Mars and to the International Space Station. SSC will invest and train its staff as necessary in order to continue to provide ongoing services in multiple orbits to the NEN and to other civil agencies.

New Commercial Models to Support Civil Small Satellite Missions

The future growth in the number of civil small satellites, estimated to be on the order of hundreds over the next ten years, requires easy and cost effective access to communications in order to monitor the health of the satellites and to download mission data. Network automation will be key to a low cost, high volume ground network solution. A consumer oriented commercial model would enable new civil missions to easily sign up for passes as required. To the customer, it should not matter what specific antenna resources are behind the provision of services as long as the required orbit is in view, the communications parameters are met and the link closes. Similar to a consumer cellular plan, a user should be able to easily choose a plan based on a few number of feature sets.

SSC is in the process of developing its Infinity service to meet this customer segment. Users will be able to access a web based portal that will have options for different pre-qualified satellite radio configurations. After selecting a radio, a customer will be able to choose a certain number of parameters such as frequency and data rate. After SSC secures the necessary licenses for those antennas that meet the mission profile, a customer will be able to view pass availability and schedule passes. The portal will directly interface with the SSC Network Management Center (NMC) to automatically confirm, schedule and execute the pass. Standard configurations, automation and flexibility with antenna selection will drive efficiencies in order to increase the volume of individual users at a cost effective price point. SSC can leverage its existing network of antenna resources to initially service customers and as the volume of users grow, incrementally add on additional stations. Already, SSC has identified 7 new ground station locations, chosen based on customer demand and fiber availability.

A consumer oriented model will require an effective marketing effort in order to attract the numerous independent CubeSat developers. SSC plans to make readily available on its website the list of qualified radios and associated configurations. Use of online and print advertising will be necessary to direct users to the SSC website. SSC is also developing partnerships with the radio manufacturers in order to create a channel to help market our new Infinity service to the end users.

SSC Smallsat Express

As part of the Esrange modernization project, SSC is evaluating the establishment of a dedicated launch facility capable of launching small satellites weighing 1 – 200 kg into a sun-synchronous orbit. Esrange is located above the Arctic Circle (68^{o}N, 21^{o}) and encompasses a large unpopulated area (>5,000 km^{2}). Developing a small launch capability is a natural progression from conducting scientific balloon and sounding rocket launches. Further, it enables SSC to continue to provide a full range of capabilities to the civil sector, from providing satellite payload demonstration capability, launching the satellite, providing tracking of the satellite and capturing and transmitting the payload data. CubeSats will be the target payloads for this iniative with a targeted first launch is 2021.

CONCLUSION

The civil sector can help increase the use of commercial services by establishing additional industry days that bring together interested parties. While industry days do exist today, the pace of change and the growing number of civil players require continuous engagement. While SSC endeavors to provide an easy to use, cost effective

communications solution to the growing civil CubeSat sector, it may be necessary for the larger agencies such as NASA to fund a portion of the communications in exchange for the data the CubeSats provide. This arrangement would enable the CubeSat developers to focus on their scientific mission goals and not have to worry about how to fund the communications.

SSC is taking the steps necessary to continue to innovate in order to best support our current and future civil customer base. SSC is in a unique position to support the civil sector considering its dual public and commercial mission. This position enables SSC to foster expansive cooperation agreements with civil agencies to include making available its science services to the student community as well as providing its full suite of ground station communication services. Structuring broader relationships that include all of the potential services and cooperation efforts will enable SSC to offer the most compelling solution to the civil sector.

[1]Foust, J. (2017, January 11). NASA ready to proceed with small satellite Earth science data buys. *SpaceNews*. Retrieved from http://spacenews.com/