

The Alaska Satellite Facility Ground Station

Scott Arko¹ and Annette La Belle-Hamer.²

Alaska Satellite Facility, University of Alaska Fairbanks, Fairbanks, AK, 99775, USA

Kevin McCarthy³ and Bruce Thoman⁴

NASA, Goddard Space Flight Center, MD, USA

and

Rob Tye⁵

NASA, Wallops Flight Facility, VA, USA

For over 20 years, a satellite ground station comprised of two S- and X-band antennas has been operated on behalf of NASA by the Alaska Satellite Facility (ASF) at the University of Alaska Fairbanks (UAF) in Fairbanks, Alaska, USA. This ground station, while initially focused on downlink of synthetic aperture data, has developed into a full-service ground station, providing downlink, uplink, and coherent tracking services as a significant component of the NASA Near Earth Network (NEN). Supporting launch, early orbit, and routine on-orbit operations, the ASF demonstrates how a ground station can be operated in a University environment (to include a student intern position), while still maintaining the highest levels of operations for satellite project customers. Recent upgrades have focused on providing greater automation for operations, greater functionality for customers, and greater consistency with the other stations in the NEN. The addition of new monitor and control software and hardware has provided a new level of automation for the ground station as well as added functionality and commonality with other NEN NASA stations. Upgrades currently underway on the existing 11.28 meter antenna will increase the functionality in both S- and X-band. NASA is in the process of adding a third antenna that will provide an aperture for upcoming NASA missions, including those from the National Research Council's Decadal Survey Report. This paper will focus on recent and upcoming upgrades to the ASF ground station that will position it as both the predominant University-operated ground station in the world and the leading NASA ground station in Alaska.

I. Introduction

AS the spacefaring nations of the world continue to develop newer and more complex spacecraft for Earth remote sensing, there is a continuing demand for full-featured and economical ground stations supporting the complete needs of spacecraft projects. For many years, this has been the primary domain of a few organizations that focus on developing worldwide networks for apertures or large arrays of apertures providing high-quality, around-the-clock service.

Until recently, university-owned or operated ground stations have generally filled small, niche roles supporting specific projects or specific users. The ASF Ground Station was initiated in 1989 to support a niche role, but in recent years has grown to be a full-service ground station supporting a wide variety of spacecraft and serving as a primary station for the NASA Near Earth Network (NEN). The NEN is a global network of ground stations utilizing both commercial and government-owned assets to support the wide variety of NASA and partner-agency spacecraft. UAF provides operations and primary maintenance support for two antenna systems operating 24 hours a day, 365 days per year. Over the past five years, the ASF ground station has averaged over 7000 supports per year while maintaining greater than a 99.6% proficiency rating. The ASF Ground Station demonstrates on a daily basis that a

¹ ASF Deputy Director, Alaska Satellite Facility, 903 Koyukuk Drive, Fairbanks AK 99775, USA

² ASF Director, Alaska Satellite Facility, 903 Koyukuk Drive, Fairbanks, AK 99775, USA

³ NASA MetOp Mission Manager, Goddard Space Flight Facility, 8800 Greenbelt Rd, Greenbelt, MD 20771, USA

⁴ NEN NASA Stations Manager, Goddard Space Flight Facility, 8800 Greenbelt Rd, Greenbelt, MD 20771, USA

⁵ Electrical Engineer, Wallops Flight Facility, 34200 Fulton Street, Wallops, VA 23337, USA

university-owned and operated ground station can provide the highest level of service to spacecraft projects, while maintaining an environment that fosters research, education and community outreach.

II. ASF Ground Station Background

The concept for the ASF Ground Station began in the late 1980s as a collaborative project between NASA, the Jet Propulsion Laboratory and the University of Alaska Fairbanks. The purpose of this ground station would be to downlink data from the upcoming generation of synthetic aperture radar (SAR) satellites that were being developed. The initial concept for the station included a Scientific Atlanta (now ViaSat) 10m antenna to be installed atop the Elvey Building on the UAF campus. At the same time, the concept for a large-scale data center was being developed and the SAR data from the ground station would be transferred directly to the data center for processing and distribution to the worldwide scientific community. Fairbanks, Alaska was chosen as the site for a variety of reasons. First, being the most-northern urban area in the US and the most-northern city with a university, Fairbanks has an exceptional viewshed for polar-orbiting satellites. Given our position of nearly 65° North and a standard polar orbiting satellite with approximately 98° inclination, the ASF ground station will have 10 usable visibilities per day. The receiving mask for the ASF ground station can be seen in Figure 1.

Initially operated under a grant from NASA, the ASF ground station migrated in 2003 to being a subcontractor to the prime contractor supporting the NEN. This integration with the prime contractor has allowed ASF to fully integrate with the other NEN stations, including automated scheduling from the NEN scheduling office, systems engineering and logistics support for equipment sparing and repair, when necessary. The integration of ASF into a common equipment, process, and sustaining engineering framework enables ASF to function seamlessly as part of the NEN.

III. Ground Station Description

The ASF Ground Station currently supports two S- and X-band antenna systems. The first, designated AS1 is a ViaSat 11.28m tracking system and the second, designated AS2, is a 10m tracking system. In 2013, these systems will be augmented through the installation of the AS3 system. This installation and the AS1 upgrade, described in Section VI., will allow the ASF Ground Station to support the next and future generations of NASA's and the international community's Earth remote-sensing spacecraft.

A. AS1 – ViaSat 11.28m

While it was the second system installed at ASF, the ViaSat 11.28m system has been designated AS1. AS1 is a three-axis (Azimuth/Elevation/Train) system that was installed in 1995 with the initial intention of supporting the Japanese ADEOS-I and ADEOS-II missions that were planned for launch in 1996 and 2001, respectively. Working within a University environment has a number of

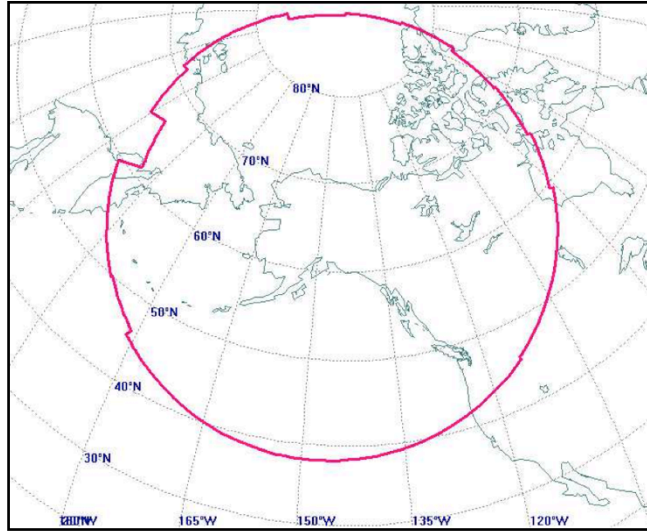


Figure 1. Reception Mask for the ASF Ground Station



Figure 2. AS1 Antenna System on UAF Campus

benefits, but it can also present challenges to be overcome, as was the case with the AS1 installation. At the time of installation, there were no buildings that could support the weight and torque loading of AS1. Therefore, it was decided to install the antenna in a forested region approximately 300m from the ASF control room. However, this area is heavily forested and the multi-use nature of the area negated any possibility of extensive tree clearing. In order to maintain an acceptable viewing mask, it was decided to lift the antenna on a concrete extension that would put the receiving feed approximately 18.9m above the ground surface. The AS1 antenna system on its concrete extension is seen in Figure 2.

The AS1 system was initially installed with receive-only capability. The command uplink system (e.g. waveguide, exciter, high-power amplifier, transmit feed) was installed in the system, but was not made operational. During 2004, NASA informed ASF that the AS1 system would be upgraded to support command telemetry uplink. At that time, the final pieces of the command uplink system were installed and the system was tested with a variety of spacecraft.

The technical specifications of the AS1 S- and X-band system are seen in Tables 2 and 3.

B. AS2 – ViaSat 10m

The AS2 system was the original antenna system at the ASF Ground Station. It is a receive-only, three-axis S- and X-band system. AS2 is also a three-axis system, however, in this case, the third axis is provided by a tilt stage that allows for a $\pm 3.5^\circ$ tilt to the east or west, thereby eliminating the zenith keyhole. This system has historically been the primary system supporting the SAR missions at ASF. The AS2 system atop the UAF Elvey Building is seen in Figure 3.

In the winter of 2012, the AS2 system had a mechanical failure that led to the tilt axis becoming fixed at 2.5° west tilt. By working with the antenna manufacturer and the author of the station control computer (SCC) software, ASF and NASA were able to develop a workaround that allowed for continued operations of the antenna in this degraded state. A combination of correcting the pointing angles in the SCC software and manual support to acquire spacecraft, when needed, has allowed the AS2 antenna to function well during this failure.



Figure 3. AS2 Antenna System atop the UAF Elvey Building

IV. Routine Maintenance and Operations

A. ASF Operations Center

ASF provides personnel and equipment for routine maintenance and operation of the ground station under a cost plus subcontract to the NEN. The ground station is operated by university employees around the clock from the ASF Control Room located in the Elvey building on UAF. ASF's employees have a wide variety of backgrounds, but most have education in science or technical fields, such as physics, math, or engineering.

Table 1. Current and Potential Future Spacecraft

Current Certified Spacecraft	Future Spacecraft
QuikSCAT	SMAP
AIM	IRIS
SAC-D	OCO-2
GRACE-1/-2	IceSat-2
SciSat	NASA EOS Missions
RADARSAT-1	(Aqua, Aura, Terra, EO-1)
SAMPEX	
FASTSAT	
COSMIC	

Table 2. AS1 S-band Telemetry Characteristics

Characteristic	Value
Frequency	2200 – 2400 MHz
G/T	≥ 23.01 dB/K
System Noise Temperature	190 K
Polarization	RHC or LHC
Antenna Beamwidth	0.85°
Antenna Gain	45.8 dBi
Carrier Modulation	PM, FM, BPSK, or AM
Modulation Index	PM: 0.2 – 2.8 radians (peak)
Carrier Data Rate	NRZ: 100 bps - 8 Mbps Biφ: 100 bps - 4 Mbps
Carrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Subcarrier Frequency	≤ 2 MHz
Subcarrier Modulation	BPSK
Subcarrier Data Rate	≤ 1 Mbps
Subcarrier Data Format	NRZ-L, M, or S; or Biφ-L, M, or S
Decoding	Viterbi and/or Reed-Solomon (CCSDS Ver 1 & 2, Ref Para 1.3 v)

Table 3. AS1 X-band Telemetry Characteristics

Characteristic	Value
Frequency	8025 – 9000 MHz
G/T	≥ 37.16 dB/K
System Noise Temperature	92 K
Polarization	RHC or LHC
Antenna Beamwidth	0.23°
Antenna Gain	56.8 dBi
Modulation	SQPSK, UQPSK, or AQPSK
Data Rate	6 – 150 Mbps
Data Format	NRZ-L or M
Decoding	Viterbi (R-½) and/or Reed-Solomon

In the ASF Control Room are station control computers running the DeWitt and Associates Hardware Control (HWCNTRL) software for automated operation of the antennas and associated equipment. HWCNTRL provides for automated scheduling, antenna control and equipment control through an easy-to-use GUI interface. Operators are on duty to monitor supports, interact with project personnel through voice communication and intervene if the systems do not configure properly. Additionally, operators act as the first line of maintenance for the systems and allow for emergency changes to system configurations at the request of the spacecraft projects.

B. Networks and Interface

One of the reasons Fairbanks was chosen as the site for the ASF Ground Station was the availability of power and communication infrastructure. During the development of the Trans-Alaska Pipeline (TAP), Fairbanks was a logistical supply point and acted as one of the main hubs for the TAP work. This meant that when the AS2 antenna system was initially installed, the infrastructure was

available to make working in the harsh conditions of Fairbanks relatively simple. This continues to this day, as Fairbanks represents the most northerly point in the USA with available and reliable high-speed networking. ASF maintains three primary network connections that are used to interface with spacecraft projects.

Satellite commanding and low-rate telemetry pass over ASF's connection to the Open IONet. While this is only a T1 (1.5Mbps) connection, it is fast enough to support transmission of commands to the station and transmission of realtime telemetry to the projects with very little latency. ASF supports commanding and housekeeping for projects around the world via this connection.

For higher rate data, ASF maintains two connections used by NASA. The first, managed by NASA Integrated Network Services (NISN), is a private, fixed bandwidth connection at 81Mbps. This is used by NASA's Earth Observing System (EOS) missions for high-bandwidth transfers between the Alaskan stations and NASA's Goddard Space Flight Center. The second high-rate connection is managed by UAF and takes advantage of the distributed connection of various university and government agencies in the U.S. and overseas known as Internet2. This network is high speed (>600Mbps) and is dedicated to supporting the research and education missions of the University. As it is more tightly controlled than the commodity Internet connection, there is no conflict with university and recreational use of the connection. ASF is currently testing this connection with NASA under a variety of conditions to evaluate its stability and realized throughput.

C. Maintenance

ASF provides monthly and annual preventative and first-line emergency maintenance for both antenna systems and the associated hardware and software for the ground station. Having maintenance personnel on-site is required to meet the high performance standards that have been set for the ground station. Ground station technicians are on-

call 24x7 in case of an emergency and response time is under 60 minutes guaranteed and generally under 30 minutes. This is supplemented by reach back sustaining engineering from the NEN contractor team at Wallops Flight Facility.

V. Ground Station Internship Program

Since 2010, the University of Alaska Fairbanks has been the recipient of a NASA grant to promote Science Technology Engineering and Mathematics (STEM) education in Fairbanks. First, under this grant ASF Ground Station and NASA have collaborated on a ground station internship program to employ a UAF student part-time by the ground station specifically to learn the operating principles and background of the ASF Ground Station. The goal is to support and foster students graduating from UAF who are knowledgeable and trained in the basics of space operations. Second, NASA and UAF collaborate to identify students with interest in space operations who would be appropriate candidates for internships and Cooperative Education at NASA. NASA sends university outreach specialists to UAF during various opportunities to interview potential intern candidates. To date, a number of UAF students approached through this activity have pursued internships and potential careers in space operations with NASA. The final aspect of this program is a teaching component that is executed at Effie Kokrine charter high-school near UAF. This high school emphasizes the teaching of Alaska Native students. The ASF PI for the ground station internship program teaches both physics and chemistry at Effie Kokrine and engages with the students in after-school programs focused on developing and fostering engineering talent in the students. To date, the students have competed in statewide robotics competitions and built and flown their own quadthopter-type drone aircraft.

VI. Ground Station Upgrades

A. AS1 Upgrade

The upgrades to the AS1 system that are being completed in 2012 began in mid-2010 with the upgrade of the station control computer (SCC). Until 2010, ASF had been using the original SCC hardware and software that had been provided at the time the antenna was installed. This hardware was no longer supported, or maintainable, and the software could not support the addition of new system components as was required to support the next generation of satellites. ASF and NASA jointly contributed to a contract with DeWitt and Associates to receive an installation of their HWCNTRL software for controlling the AS1 antenna. This software was installed on new hardware that could be supported, and upgraded, in the future. The installation of HWCNTRL allowed the AS1 system to more closely mimic the similar system at WFF that is operated by NASA. This commonality allows for easier and less costly maintenance through common support agreements and shared system spares.

In 2011 an upgrade of the AS1 system was initiated to allow better support of the next generation of NASA spacecraft. A similar upgrade was also initiated at a duplicate antenna to the AS1 system at Wallops Island, Virginia, and many activities are tested on the Wallops antenna before being installed in AS1. The primary focus of the AS1 upgrade is not mechanical, but electronic. The baseband equipment for both S- and X-band receive systems are being replaced and the downlink system will be fiber-based from the feed low noise amplifiers (LNA) into the control room. The downconverters and intermediate frequency (IF) are being upgraded to support a 720MHz IF in X-band and a 70MHz IF in S-band. The IF upgrade will allow the AS1 system to double the current maximum data rate to 300Mbps in X-band. The existing ViaSat baseband receivers, demodulators and bit synchronizers are being replaced by Cortex XXL high-rate telemetry receivers for X-band and Cortex CRT low-rate telemetry receivers for S-band, common to the NEN NASA stations. Block diagrams depicting the upgraded S- and X-band systems are seen in Figure 4 and Figure 5.

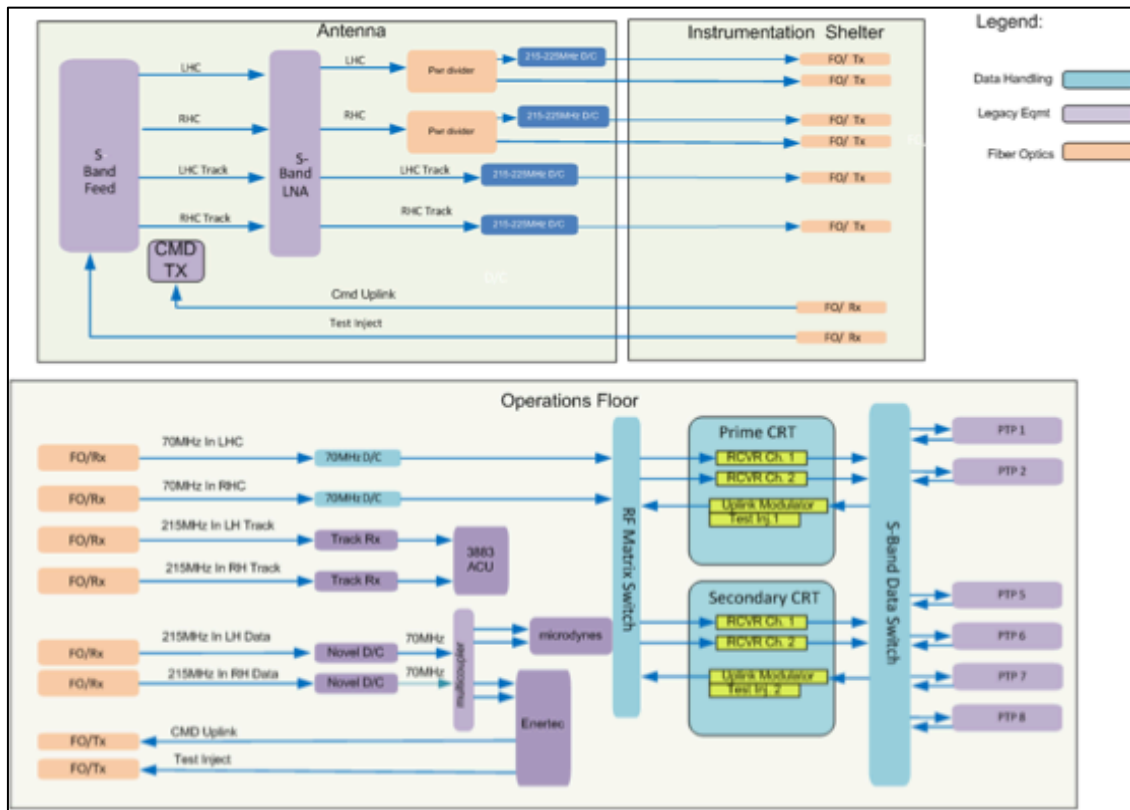


Figure 4. Upgraded S-band System Showing Parallel Operations Configuration

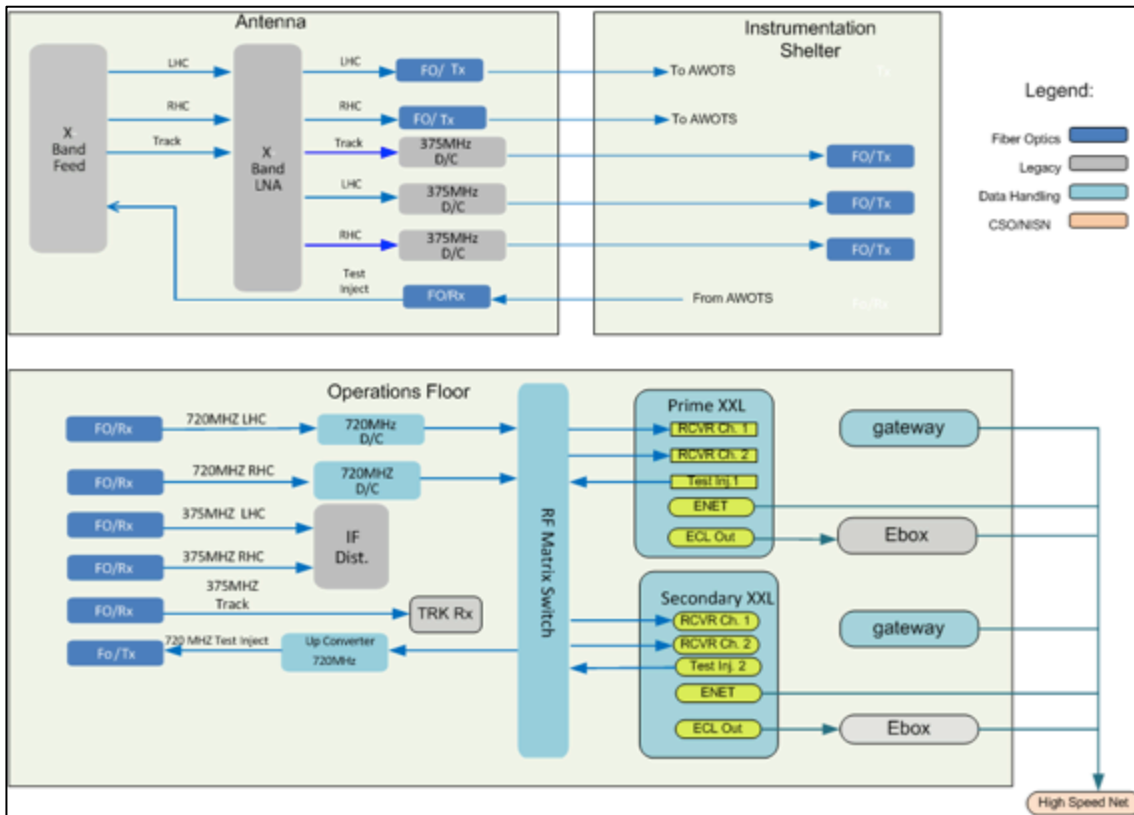


Figure 5. Upgraded X-band System Showing Parallel Operations Configuration

B. AS3 Installation

The AS2 system is over 20 years old and has been significantly hindered by a lack of quality spares and an inability to support upgrades. The technology used on the next generation of satellites has overtaken this antenna and renders it largely unusable for future missions. Knowing this, NASA informed ASF in 2010 that they would be conducting the purchase and installation of a new antenna system at ASF. Dubbed AS3, the new system will functionally look very similar to the current AS1 system. It will be a fully-featured S- and X-band receive system, as well as support S-band command uplink and two-way coherent Doppler tracking. This upgrade will give ASF two antenna systems capable of supporting most Earth-observing mission that NASA has in build or planning stages, including the NRC Decadal Survey missions.

Over the past 18 months, ASF has been working with NASA to identify and receive approval for the installation of this antenna system on the UAF campus. A number of sites were identified and evaluated for potential access to the UAF power grid, proper communication and viewshed. Following this analysis, a site near to the current AS1 site has been identified as the best site to meet the system requirements.

Ground breaking on this site is scheduled for June 2012, with initial site preparation and pedestal installation taking place in the Summer and Fall of 2012. Final installation of the parabolic reflector and the electronics is planned for Spring 2013. The installation of this system ensures that ASF will maintain its position as the preeminent University-operated ground station in the world and ensure support for the next decade of Earth-observing spacecraft from NASA.

VII. Conclusion

The multi-mission ground station currently operating at ASF at the University of Alaska Fairbanks represents a considerable evolution over the original designs and implementation of the ASF Ground Station. Originally designed to support a small number of missions with X-band downlink-only support, the ASF Ground Station continues to provide exceptional support to a wide variety of X- and S-band satellite missions with full-service operations, including telemetry downlink, command and two-way coherent tracking. As the ground station undergoes the latest round of upgrades to existing and new antenna systems, ASF has established itself as the premiere University-operated ground station in the world and continues to set the standard for excellence. Furthermore, it has established and fosters an ongoing and key role for a University-operated ground station in the NASA NEN.

Appendix A

Acronym List

AS1	Alaska Satellite Facility Antenna 1
AS2	Alaska Satellite Facility Antenna 2
ASF	Alaska Satellite Facility
EOS	Earth Observing System
HWCNTRL	Hardware Control
LNA	Low Noise Amplifier
NASA	National Aeronautics and Space Administration
NEN	Near Earth Network
NISN	NASA Integrated Services Network
SCC	Station Control Computer
SAR	Synthetic Aperture Radar
USA	United States of America
WFF	Wallops Flight Facility

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