ESTABLISHMENT OF A NASA TEMPORARY TRACKING STATION ON BERMUDA'S COOPERS ISLAND

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ABSTRACT

The National Aeronautics and Space Administration (NASA), Goddard Space Flight Center (GSFC), Wallops Flight Facility (WFF), Research Range Services (RRS) Program supports NASA's mission objectives by providing tracking, telemetry, meteorological, optical, and command and control services for flight vehicles including orbital and suborbital rockets. The RRS Program's mobile range instrumentation includes telemetry, radar, command and power systems. These mobile assets are used as needed to supplement instrumentation at existing ranges, or to establish a temporary range ensuring safety and collection of data in a remote location where no other range instrumentation exists. This complement of mobile systems can be deployed to provide complete range capabilities at remote locations around the world.

Just 100 miles up the coast from where the Wright brothers first flew their airplane at Kitty Hawk, North Carolina, Orbital Sciences Corporation is planning to launch its new Commercial Orbital Transportation Services (COTS) system from the the Mid-Atlantic Regional Spaceport (MARS), located at NASA GSFC's WFF. Orbital's COTS system design is based on the new Taurus II rocket with a liquid oxygen (LOX)/kerosene (RP-1) first stage powered by two Aerojet AJ-26 engines. The Taurus II second stage is ATK's Castor 30 solid propellant motor derived from their flight proven Castor 120. The spacecraft, known as Cygnus, is derived from Orbital's heritage DAWN and STAR spacecraft projects and International Space Station cargo carriers. The Program is driven by the retirement of the space shuttle, and the United States lacking domestic capability to send crew and cargo to the International Space Station. As a consequence, NASA faces a cargo resupply shortfall of 40 metric tons (approximately 88,000 pounds) between 2011 and 2015 that cannot be met by international partners' space vehicles.

Bermuda has played an important role in the United States space program since the 1960s. The former NASA Tracking Station on Bermuda's Coopers Island had range safety systems for command and control, and Missile Instrumentation Precision Radars (MIPRs) providing exact vehicle position and slaving for command destruct systems. Telemetry systems supported scientific spacecraft and manned space flight (i.e., Apollo, Space Transportation System [STS], and Spacelab) with high gain antenna systems. With the advent of the Tracking and Data Relay Satellite System and changes in the STS flight envelope in the late 1990s, NASA no longer

required Bermuda and deactivated the site. NASA instrumentation was removed in early 2000, and the property returned to the Government of Bermuda (GoB).

This paper defines the process undertaken to secure an agreement with the GoB to establish a temporary tracking site and describes the technical approach and analysis conducted that justifies bringing Bermuda back as a critical NASA tracking site as it was during the Apollo era and the early years of the Space Shuttle. The RRS Program plans to support the COTS Program with a mobile launch range in Bermuda.

INTRODUCTION

Since its inception in 1958, the National Aeronautics and Space Administration (NASA) has never failed to capture the imagination of the public. Crowds have gathered routinely in California, Florida, and Virginia to watch manned and unmanned rocket launches that made history. From Alan Shepard's first flight, to John Glenn's first orbit, to Neil Armstrong's first step, to the out of this world imagery from Hubble Space Telescope, to when Space Shuttle Atlantis blasted into orbit marking the final launch for NASA's storied fleet, success started with safety of the public and each effort would have been useless if the data could not be sent back to improve life here on Earth.

NASA Goddard Space Flight Center's (GSFC) Wallops Flight Facility (WFF) is one of those little known launch ranges where crowds continue to gather and as it's been home to over 16,000 missions spanning the past 66 years. Wallops Launch Range is one of only four active US space launch bases and is located on Virginia's Eastern Shore just steps from the Atlantic Ocean. Wallops was established in 1945 by the National Advisory Committee for Aeronautics as a center for aeronautic research. Today, the Wallops Launch Range consists of an integrated launch range and research airport. The two elements are located approximately five miles apart, with the inland airport and the coastal launch range contained within restricted airspace. The restricted area adjoins the offshore Warning Areas, allowing for continuous controlled airspace for runway or rocket-borne vehicles. Wallops is responsible for implementation of NASA's flight projects, including sounding rockets, ultra-long duration balloons, and scientific aircraft. Of less visibility is Wallops support of space launch through a history of more than 20 Scout space launches, seven Pegasus launches, and four Minotaur I launches, putting more than fifty small satellites into orbit.

With the end of the space-shuttle program NASA assumes a new role as partner of the private sphere. NASA has awarded contracts to two companies to carry cargo to the International Space Station (ISS). Orbital Sciences Corporation (OSC), of Dulles, Virginia, is developing the Taurus II rocket to carry its Cygnus spacecraft, and Space Exploration Technologies (SpaceX) from El Segundo, California, is developing the Falcon 9 rocket and Dragon spacecraft. OSC's new launch vehicle – the Taurus II will be based at Wallops Flight Facility for its initial missions.

HISTORICAL BACKGROUND

On June 11, 2008, Virginia Governor Timothy M. Kaine announced that Dulles, Virginia-based Orbital Sciences Corporation selected the Mid-Atlantic Regional Spaceport (MARS) as its base of operations for the company's new Taurus II rocket. MARS is a commercial entity who, in a partnership with NASA, manages the two space launch pads (Taurus II launch pad is shown in the figure below) currently used for space access on the Wallops Launch Range. MARS works with NASA to provide complete launch support services to commercial space vehicles launching from WFF.

Figure 1. Artist Rendering of Taurus II Launch Pad at the Wallops Launch Range

U.S. Government launch ranges such as Wallops Launch Range provide three basic functions: (1) an appropriate geographical location to meet orbital or other mission trajectory requirements, (2) project services such as processing facilities, launch complexes, tracking and data services, and expendable products, and (3) safety and property protection to participating personnel and third-parties. Wallops Launch Range offers a wide array of launch vehicle trajectory options (Wallops trajectories are shown in the Figure 2 below). The coastline of Wallops Island is oriented such that a launch azimuth of 135 degrees is perpendicular to the shoreline. In general, launch azimuths between 90 and 160 degrees can be accommodated depending on impact ranges. For most orbital vehicles, this translates into orbital inclinations between 38 degrees and approximately 60 degrees. Trajectory options outside of these launch azimuths, including polar and sun-synchronous orbits, can be achieved utilizing in-flight azimuth maneuvers. For example, wider northerly options are possible by maneuvering around Assateague Island after passing 5 nautical miles downrange. The North Carolina Outer Banks are generally the restricting landmass for southern launch azimuths. To provide launch range operations services, the Wallops staff is made up of highly skilled engineers, project managers, flight and ground safety officers, pilots, business managers, radar operators, telemetry operators, command operators, photographers, and technicians.

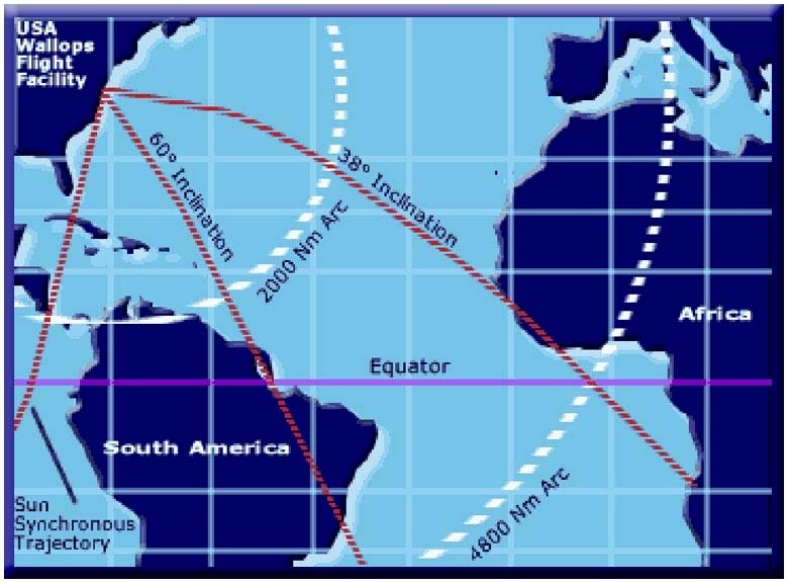

Figure 2. NASA Wallops Launch Trajectories

There are four related reasons why tracking stations are required. First, a satellite or launch vehicle is required to send back critical performance and instrument data. The launch vehicle information is used by ground controllers to monitor flight performance and systems performance during flight. In the case of the satellite, the tracking stations provide the mechanism to relay data to and from the satellite. This data is provided by the ground tracking stations to personnel who analyze the data coming from the satellite instruments or use the data to make changes to the satellite configurations or orientation. Second, the method by which we have to communicate with launch vehicles and orbiting spacecraft is called radio frequency communication. This method of communication, especially at the frequencies allocated for space to ground communication, only works when the ground station is in the direct line of sight of the launch vehicle or orbiting spacecraft. These transmissions don't bend (refract) significantly, nor do they reflect off certain layers of the atmosphere reliably to enable over-the-horizon communications often practiced utilizing lower frequency communication methods. Thus, tracking stations must be in direct view of the launch vehicle or orbiting satellites. Third, satellites are normally in relatively low earth orbits (from 120 to 500 miles above the earth's surface), so they cannot transmit to tracking stations for any great distance around the world due to the limited coverage area on the earth. Finally, NASA requires ground controllers to make a minimum number of contacts per day with each orbiting NASA satellite to ensure location precision and satellite systems performance.

NASA implemented its first ground-based communications network—the Manned Space Flight Network (MSFN)—in the 1960s. The MSFN was a worldwide communications network with stations primarily located at low-latitudes to support the Mercury, Gemini, and Apollo Programs. During this same decade, NASA also acquired management of the military's Minitrack system, evolving it into the Satellite Tracking And Data Acquisition Network (STADAN) to support an emerging class of satellites requiring enhanced communications.

One of the new stations was to be in Bermuda, located on Coopers Island. The Coopers Island station, located on the southeastern tip of Bermuda, is about 600 miles off the east coast of the United States in the Atlantic Ocean. The Bermuda station was certified operational in December 1960 just 13 months after breaking ground.

During the 1970s, NASA merged the MSFN and STADAN, forming the Spaceflight Tracking and Data Network (STDN) to support communications needs of manned and unmanned spacecraft missions. During the next few decades, NASA decommissioned and commissioned STDN stations in response to the Agency's communications needs. For example, NASA expanded the STDN in the 1980s to provide crucial support to the Shuttle while the Agency developed the Space Network (SN), and eventually reduced the number of stations as the SN became operational.

The NASA Tracking and Data Relay Satellite System (TDRSS) has been operating since 1983. This geosynchronous communications satellite network has essentially replaced the original NASA ground network stations as the primary solution for ground to space communication. These advances in technology and capability led to changes in spaceflight communications approaches and now make it possible for the TDRSS space network to provide the data previously provided by the S and C-Band ground systems located at Bermuda.

In January 1998, astronauts aboard Space Shuttle Endeavour said farewell to NASA's tracking station in Bermuda. It was the first time NASA's Bermuda tracking station had ever spoken live to astronauts aboard the Shuttle. Captain Terrence Wilcutt took the helm of the Endeavour to deliver a 15-second message in a live satellite uplink, thanking those at Bermuda who had provided all telecommunications to Johnson Space Center's Mission Control for almost seven minutes during critical Shuttle launch periods. Bermuda tracking station manager Bill Way said, "We've been here since 1961 and monitored every single NASA launch since then. Now we're closing down and our last shuttle launch was very emotional. It was nice to have the link-up with the astronauts and to know that they appreciated all the work we have done. At least that's official recognition for all the people who work here."

MISSION REQUIREMENTS

Range operations often involve substantial hazards than can pose significant risk to life, health, and property. The goal of the NASA Range Safety Program is to protect the public, the workforce, and property during range operations. The NASA Range Safety Program is defined in NASA Procedural Requirements (NPR) 8715.5 Range Safety Program and is signed by the NASA Administrator. The goal of the program is to protect the public, the workforce, and property during ranges operations.

In order to provide the public protection from malfunctioning launch vehicles, a Flight Termination System is used to destroy the vehicle. The FTS is comprised of the ground portion, including the command transmitters and antennas, and the airborne portion on the launch vehicle. The airborne component of the FTS is termed the command destruct system and

typically consists of antennas, batteries, Command Receivers and Decoders (CRD), controls, relays, liquid propellant engine shutdown devices, arming devices, destruct charges, and associated circuitry. The flight termination system is controlled by a Flight Safety Officer (FSO), who will issue a radio frequency (RF) command to the vehicle to initiate the flight termination system, if required. Due to atmospheric effects, the great distances that the signal must travel, and the negative effects from the exhaust plume of the launch vehicle, engineers perform an RF "link" analysis before launch to ensure the command will reach the vehicle with adequate strength. For the Taurus II launch, the link analysis shows the command sites at Wallops and Coquina, North Carolina may not have adequate strength through the flight period when flight termination capability is required. This is primarily due to the exhaust plume effect, which "attenuates" or decreases the power of the signal as it flows through the highly-charged and reflective rocket engine exhaust.

In addition to analyzing the command frequency, engineers also perform a link analysis on the frequencies being utilized to transmit critical data from the launch vehicle to the ground. This data, commonly referred to as telemetry, contains information on engine performance, vehicle attitude, command destruct system health, vehicle position (based on GPS or inertial guidance system measurements), strength of the command signal being received by the vehicle, and other performance indicators. Much of this data is critical to the FSO in order to make decisions on whether the vehicle is performing nominally or otherwise, and how long the vehicle should be able to fly non-nominally before it needs to be safely terminated. Just as with the command link frequencies, the telemetry link frequencies are negatively affected by atmospheric effects, distance, and the exhaust plume. The link analysis performed on the Taurus II telemetry frequencies showed similar results to the command frequencies: Wallops and Coquina will not have strong signals from the launch vehicle, putting both Safety and Mission Assurance at risk.

Bermuda is situated in an ideal location, downrange along the flightpath, and will provide the extra coverage necessary for both the command links and the telemetry links.

PROPOSED SOLUTION

In order to provide the required safety coverage of the Taurus II launch vehicle as it travels down range from the Wallops Flight Facility and over the Atlantic Ocean toward Africa, the Wallops Launch Range will deploy mobile range instrumentation systems to Bermuda's Coopers Island and establish a temporary tracking station. Figure 3 shows a simulated aerial view of Coopers island and the location of the proposed tracking station. The inset image illustrates the Flightpath of the Taurus II vehicle as it flies past Bermuda, maintaining a strong link in both the command and telemetry frequencies. Engineering analysis confirms that the Bermuda location is ideal for this mission. With the selection of the site complete, the challenge becomes two-fold: a technical challenge for placing the right systems on Bermuda, and a political challenge for working an agreement to utilize Bermuda property.

Figure 3. Simulation System Product Showing Communication to Taurus II from Bermuda

Wallops maintains a full suite of mobile instrumentation that routinely deploys around the world to all types of operating environments (tropical, arctic, etc), and has recent experience in deploying mobile instrumentation systems to Bermuda. Shown in Figure 4 is a past deployment to Bermuda where Wallops Launch Range mobile instrumentation systems were configured to support a NASA launch from Wallops Flight Facility that needed over-the-horizon communications coverage for re-entering payloads to the point of ocean impact off the coast of Bermuda. For the pictured mission, mobile telemetry and radar antennas were deployed, along with their control vans and a special mobile power van. To provide Taurus II launch support, Wallops will deploy a telemetry antenna and new telemetry van, a radar antenna and its control van, a mobile command system with roof-mounted antennas, and a mobile power van. The radar is required to track the launch vehicle and point the command antennas in the right direction, and the mobile power system is required to provide uninterrupted conditioned power at the levels required for operating these high-voltage systems.

Bermuda is a maritime tropical environment, which is a challenging environment to maintain and operate these types of systems. Water intrusion, high humidity, severe rust and corrosion, and insect damage are a serious threat to these systems. Prior to deploying these mobile systems to Bermuda, they will have several upgrades and enhancements to improve their resistance to the environment. New ventilation and cooling systems have already been installed to help keep humidity and temperatures inside the vans at a safe level. Fluids have been replaced with high-temperature fluids to improve the movement of machinery and antenna components. The systems will all have corrosion control treatment, consisting of scraping off old paint and rust, and re-painting with an epoxy-based paint that will resist the caustic salt air. Additionally, the vans will be re-sealed around doors, hatches, and expanding sides to prevent water and insect intrusion. Despite these best efforts, normal wear and tear on the systems will be compounded by the environment, so frequent maintenance trips are being planned by Wallops to service the systems.

Figure 4. Recent Wallops Launch Range Deployment to Bermuda

In addition to preparing the systems for deployment, the site itself must be prepared. The vans and the antennas themselves are mounted to tractor trailers, so these systems will take up a substantial footprint on Coopers Island. Currently, the desired area of Coopers Island is a nature preserve, and has some other obstacles, including a weather radar (visible in figure 4) and some other old buildings remaining from the deactivated NASA Tracking Station. In order to position the systems in an ideal arrangement for tracking the launch vehicle from horizon to horizon, a significant amount of site work is necessary. Wallops Launch Range will work with the local Bermuda contractor to remove and relocate some existing infrastructure to make room for the systems. In addition to taking up a lot of room, the mobile instrumentation systems are heavy, and in the case of the telemetry and radar antennas, they also move quite rapidly, which can create immense moment forces. A Wallops Civil Engineer will perform an analysis of the

ground conditions and supervise ground work to pack and level the earth so it is suitable to support these heavy, high-moment systems. This work will be accomplished in a manner to limit the impact to the nature preserve.

Fielding mobile instrumentation systems to locations around the world is performed routinely by Wallops Flight Facility in support of NASA and United States Department of Defense missions. The systems configuration required for the temporary tracking station at Bermuda's Coopers Island is typical of past deployments performed by Wallops. However, what is not typical is the international cooperation that is required to ensure the location at Bermuda remains a long term solution for NASA and the United States. Wallops Launch Range personnel have. In April, 2011, NASA officially entered into negotiations to conclude a formal agreement with the Bermuda Ministry of Transportation. Since then, the draft agreement has gone through several revisions as Bermuda and US government agencies carefully lay out the provisions, not in an attempt to take advantage of the situation, but rather making sure that the agreement is sound and can prevail for the years to come without requiring additional revisions once the agreement is in place. In the coming months, this international agreement between NASA and the Government of Bermuda is expected to be signed by both parties paving the way for future deployments to Bermuda in support of NASA's new space transportation initiatives, including supporting continued commercial ISS resupply services from NASA's Wallops Flight Facility.

CONCLUSION

As Wallops prepares to support the newest fleet of ISS resupply vehicles, the need for a downrange mobile tracking site at Bermuda is as critical to safety and mission assurance now as it was during the Apollo and Shuttle programs, and re-establishing the site is nothing short of a challenge. But the RRS Program and the committed staff that execute the Wallops mission have a solid plan in place to ensure success. The history Bermuda brings to this endeavor in supporting NASA's space flight programs for many years will solidify the bond between the United States and Bermuda as we venture into this new era of space flight. The inspiration this will bring to the children of Bermuda as we develop this new partnership will also be recognized due to the vision of the fine men and women of Bermuda and NASA striving to see another generation take part in the growth of a new era in NASA space flight.

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