SpaceViews

A publication of the Boston chapter of the NSS

The U.S. Navy in the Space Age

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June 26, 2000

Like all the branches of the military, the U.S. Navy (USN) took an early interest in space research. The USN space program got its start with the country's first "official" satellite program, Vanguard (see **Vanguard: America's Answer to Sputnik** in the December 1997 issue of *SpaceViews*). Run by the Naval Research Laboratory (NRL), Vanguard and much of its personnel were transferred to NASA shortly after its founding in October 1958 (see **Vanguard and Its Legacy** in the February 1, 1999 issue of *SpaceViews*).

The Naval Ordinance Test Station (NOTS) also developed its own top secret air launched satellite capability called NOTSNIK. However the program never got the funding it needed to develop an operational system because of USAF objections (see **NOTSNIK: The Navy's Secret Satellite Program** in the July 1998 issue of *SpaceViews*). By the end of 1958 it became apparent that NASA would manage all programs with perceived civilian applications while the USAF, frequently under the aegis of ARPA (Advanced Research Projects Agency), would dominate programs of military or national security interest. Despite USAF dominance, the USN was still able to carve itself out a useful niche in space.

The Start of Satellite Navigation

One of the many university laboratories to work with the USN was Johns Hopkins University's Applied Physics Laboratory (APL). Since the 1940s, APL was involved in high altitude research using various sounding rockets including the USN's Aerobee. With the launch of Sputnik 1 in October of 1957, APL engineers were eager to monitor the Soviet satellite's transmissions. Among the first were William H. Guier and George C. Weiffenbach who also noted the Doppler shift in Sputnik's signal as it passed by. By knowing the location of their receiver and carefully measuring how the Doppler shift changed with time, Guier and Weiffenbach were able to accurately derive Sputnik's orbit.

On March 14, 1958, Frank T. McClure, a colleague of Guier and Weiffenbach's and chairman of APL's Research Center, realized that this tracking technique could be turned on its head: If you knew the orbit of the satellite, you could accurately derive your position on the Earth by measuring the Doppler shift of the satellite's signal. In 1958 ship navigation was still done by the time tested method of measuring the positions of the Sun and stars. But when the weather was bad, this proved to be impossible. Making use of a constellation of orbiting satellites, a ship could determine its position regardless of weather. After reviewing the concept in detail, McClure sent a memo to Ralph E. Gibson, Director of APL, on March 18 and the field of satellite navigation was born.

From the beginning, ARPA was interested in APL's satellite navigation concept which was named "Transit". This accurate, all weather navigation method would be ideal for the USN especially for their submarine ballistic missile fleet then under development. These vessels needed to precisely know their position in order to properly target their Polaris missiles. On December 15, 1958, ARPA funded the Transit program with APL as the prime contractor.

The first pair of prototype satellites, designated Transit 1, were spherical in shape with a diameter of 91 centimeters (36 inches) and weighing 122 kilograms (270 pounds). This shape made it easier to control the satellite's interior temperature and its attitude. In order to minimize any variations in signal strength that could compromise accuracy, attitude was held fixed using magnetic devices that worked using the Earth's own magnetic field. A spiral shaped, slot antenna painted on the satellite's fiberglass exterior also helped produce an even transmission pattern. Inside the satellite were all the electronic components including the transmitters and a thermally isolated, very stable oscillator. Power was provided by banks of solar cells mounted around the equator of the satellite.

A model of the Transit 1 prototype navigation satellite. (APL/JHU)

An operational Transit satellite constellation, planned to be in place by 1962, would consist of four satellites in 930 kilometer (575 statute or 500 nautical mile) high, near-polar orbits. From this vantage point, any properly equipped USN ship could update its position every few hours to an accuracy of about 150 meters (500 feet). In order to get each Transit into its required orbit, a new launch vehicle was needed: The Thor Able Star also known as the Thor Epsilon. Like the Thor Able upon which it is based (see **Operation Mona: America's First Moon Program** in the April 1998 issue of *SpaceViews*), the booster of this two-stage launch vehicle was a modified USAF Thor IRBM built by Douglas Aircraft. The second stage, built by Space Technology Laboratories, Inc., was 5.9 meters (19.3 feet) long and 1.4 meters (4.6 feet) in diameter giving it over twice the propellant load of the Thor Able second stage. This was needed because there was no third stage like on the earlier Thor Able.

The second stage was powered by an Aerojet-General AJ10-104 engine (similar to the AJ10-series engines used in Vanguard and the Able second stages) burning IRFNA (Inhibited Red Fuming Nitric Acid) and UDMH (Unsymmetrical DiMethylHydrazine) to produce 35.1 kilonewtons (7890 pounds) of thrust. Unlike its predecessors, however, this second stage would have an in-orbit restart capability. During a typical ascent, the Thor and the first burn of the second stage would place the stage and its payload into a short-lived, elliptical transfer orbit. After a 20-minute coast where the attitude was controlled by nitrogen gas jets, the engine would reignite near apogee to circularize the orbit.

With the first satellite ready before its launch vehicle, the first Transit flight would use a Thor Able. On September 17, 1959, only nine months after the official start of the program, Transit 1A lifted off from Cape Canaveral. In addition to its navigation equipment, Transit 1A also carried an IR imaging scanner built by NOTS similar to those flown on NOTSNIK and the USAF Pioneers. As had happened all too often before, however, the Thor Able failed to place its payload in orbit when the third stage did not ignite and the payload fell to Earth 480 kilometers (300 miles) southwest of Ireland. Despite the failure, APL engineers were able to track Transit 1A during its brief ballistic flight and determined the impact site to within a few miles.

More Missions for the Navy

Although the Transit 1A launch failure was a disappointment, it was not totally unexpected. Its backup, Transit 1B, was nearly ready by the beginning of 1960 as well as its new, more reliable Thor Able Star rocket. On April 13, 1960, the 119 kilogram (265 pound) Transit 1B lifted off from Cape Canaveral and was successfully placed into orbit. The Thor Able Star made the first in-orbit engine restart, albeit purposely abbreviated, placing Transit 1B into a 381 by 764 kilometer (237 by 475 mile) orbit inclined 51 degrees to the equator. It was more than adequate to perform Doppler navigation tests.

Detailed tracking of Transit 1B confirmed the Earth's slight pear shape first observed by NRL's Vanguard 1 (see **Vanguard 1: The Little Satellite That Could** in the March 1998 issue of *SpaceViews*). Tracking was also able to determine smaller scale deviations of the Earth's shape from an oblate spheroid giving birth to the field of dynamic geodesy. Before Transit 1B began failing on July 11, it confirmed and measured the effects of refraction on its transmissions caused by the ionosphere. Able to provide positional fixes to within about 400 meters (a quarter mile), Transit 1B proved to be a very successful test of the satellite navigation concept. Three days after the launch of Transit 1B, a pair of APL-built transmitters launched on Discoverer 11 successfully completed a three-day test of Transit hardware providing APL engineers with even more data.

Another test Transit 1B performed was carrying an inert 18 kilogram (40 pound) test sphere to check the craft's ability to deploy a piggyback payload once in orbit. Future Transit launches would carry a NRL-built satellite to perform a new, top secret mission: Electronic intelligence or elint. Early in 1958 while he was stranded in a snow storm during a family trip, NRL's Reid D. Mayo came up with the idea of using a small satellite to locate Soviet radar installations. The elint payload could easily fit inside a modified version of the "standard" 51 centimeter (20 inch) in diameter Vanguard satellite thus greatly speeding its development.

The idea was simply to have the satellite relay in real time the S-band radar signals detected while over the Soviet Union to ground stations just over the border where it would be recorded. From its vantage point, the satellite could detect radars within a 2650 kilometer (1650 mile) radius compared to just 320 kilometers (200 miles) typical for electronic "ferret" aircraft that patrolled along Soviet borders. These recordings could then be analyzed to determine the position of Soviet radar installations and their signal characteristics. The six-watt power requirement for the mission would be supplied by batteries recharged by a half dozen banks of solar cells attached to the satellite's exterior.

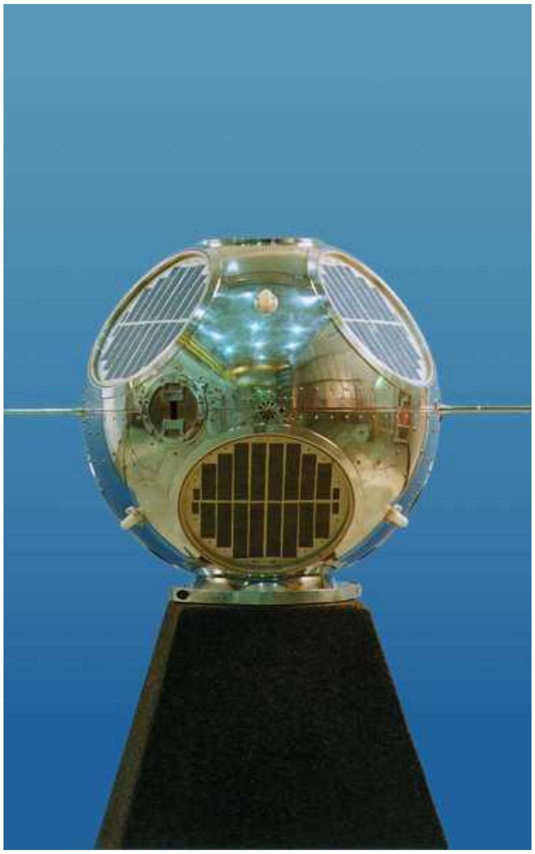
In July of 1958, NRL proposed the concept under the codename "Tattletale" and received approval from President Eisenhower on August 24. As with other forms of satellite surveillance, Eisenhower was concerned about the perception of the US spying even on a secretive, potential adversary (see **Spy in the Sky** in the March 1, 1999 issue of *SpaceViews*). As a cover story and a means of making good use of available payload space inside the satellite, NRL scientists installed sensors to monitor the Sun's emissions in the Lyman alpha line of hydrogen in the ultraviolet as well as X-rays to perform some legitimate science. Publicly the 19 kilogram (42 pound) satellite was called "SOLRAD" for SOLar RADiation. Its secret cover name was "GRAB" for Galactic Radiation And Background although an altered, leaked version of the name "GREB", for Galactic Radiation Experiment Background, has also been used. While the scientific mission of the satellite was well known, its elint mission would remain classified until 1998.

More Launches

On June 22, 1960, Transit 2A and SOLRAD 1 were successfully launched into orbit as the first successful piggyback satellite. Because of some bugs in the Able Star stage, a 624 by 1070 kilometer (388 by 665 mile) orbit was achieved instead of the desired 930 kilometer (575 mile) circular orbit. Transit 2A was an improved version of the earlier Transit 1. It sported enlarged banks of solar cells and many hardware upgrades to improve accuracy and reliability. It also carried another NOTS IR scanner and a Canadian built receiver to test equipment for an upcoming NASA-sponsored international mission.

Launch of Transit 2A on June 22, 1960 using the then new Thor Able Star launch vehicle. (NRL)

The public scientific and secret elint missions of SOLRAD 1 were also very successful. President Eisenhower was reluctant to give permission to use the elint payload especially after the Gary Powers U-2 incident the previous May. He feared that the Soviets would detect the satellite's transmissions causing another international incident. Before Eisenhower left office in January 1961, he had only approved elint operations for two dozen passes. The Kennedy administration made greater use of the elint package until it ceased functioning in August of 1962. During its 26 month mission, GRAB provided a veritable treasure trove of data for the US intelligence community. SOLRAD's scientific instruments operated until April 1961.



The secret mission of SOLRAD 1 was to gather elctronic intelligence over the Soviet Union. (NRL)

Continuing the test program, another pair of Transit transmitters were launched into orbit on August 18 on Discoverer 14 but they failed to operate. A repeat on Discoverer 17 launched on November 12 worked for three days until the batteries ran down. The next Transit launch, Transit 3A with SOLRAD 2 on November 30, 1960, failed because of a Thor malfunction. Reportedly some debris fell on Cuba killing a cow in the process.

A backup, Transit 3B, was launched into orbit on February 21, 1961. This time the second stage failed to restart stranding the payload in a low 188 by 822 kilometer (117 by 511 mile) orbit. Transit 3B also failed to separate from the second stage as did its piggyback payload, LOFTI 1. Built by NRL and based on the SOLRAD design, LOFTI 1 (Low Frequency Transmission through the Ionosphere) was designed to provide information on LF transmissions for future Navy communication satellites (and possibly elint applications as well). Although the low orbit resulted in the satellites reentering the atmosphere after only 39 days, both payloads returned useful data. With a good start, the way was now set to launch new USN navigation, elint and scientific satellites.

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