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TIROS: The First Weather Satellite

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For almost anyone under the age of 40, satellite pictures of Earth's cloud cover have been a staple of television news weather segments for almost as long as we can remember. But just four decades ago such images and the other vital data returned by weather satellites did not exist. During this almost forgotten era, meteorologist had to rely on observations taken by ships at sea and fixed weather stations scattered across the continents to track the weather and make predictions. Tracking storms, especially those at sea, was especially difficult because of a lack of synoptic data. A satellite's potential for filling this data gap was recognized over half a century ago.

The Origin of the Concept

After World War II, a host of satellite studies were started largely because of the availability of German rocket technology. One of the most famous of these was "Preliminary Design for an Experimental World Circling Spaceship" performed by the Rand Corporation under the sponsorship of the US Army Air Force. Released on May 2, 1946, this report listed weather reconnaissance as a possible satellite application. Five years later Rand researchers produced another secret report entitled "Feasibility of Weather Reconnaissance from a Satellite Vehicle" which further addressed the attractiveness of weather satellites.

There was also growing interest in weather observations from space in more open sources of the time. In January of 1949 USAF Major D.L. Crowson published a paper on the use of television camera-equipped rockets to track storms. The first public mention of weather satellites themselves came in a 1954 paper written by H. Wexler of the US Weather Bureau. Later in October of that year, a US Navy Aerobee rocket took a series of photographs that gave a spectacular view of a tropical storm over the US -- the first time such a storm had been seen from space. Slowly the value of space-based weather observations was becoming apparent to a large number of weather experts.

But like most other spacecraft concepts during this time, weather satellite development languished for lack of substantive support. While potentially useful, no one had ever launched a satellite of any sort before. But in 1955 the first tentative steps towards launching a satellite were taken. In March of 1955 the USAF issued a secret directive for the development of a reconnaissance satellite which eventually lead to the WS-117L program (see **Spy in the Sky** in the March 1, 1999 issue of *SpaceViews*). On July 5, 1955 President Eisenhower publicly announced that the United States would launch a scientific satellite as part of the American contribution to the International Geophysical Year. Two months later the Navy Research Laboratory's satellite proposal, later named Vanguard, was chosen for the task (see **Vanguard: America's Response to Sputnik** in the December 1997 issue of *SpaceViews*). Among the experiments proposed for Vanguard were some that would gather data vital to the development of an operational weather satellite.

In one experiment, Verner Soumi of the University of Wisconsin proposed to measure the Earth's energy balance using simple radiometers. Knowing how much of the Sun's energy the Earth and its atmosphere reflected and how much infrared radiation it emitted is vital to understanding weather. Another experiment also approved for Vanguard was proposed by William G. Stroud and William Nordberg from the US Army Signal Research and Development Laboratory (USASRDL). They proposed to place small photocells on the exterior of the spinning satellite. Each would scan a slightly different part of the scene below during each rotation while the forward motion of the satellite would then allow a series of pictures to be built up line by line. The crude pictures from this experiment would provide data on the brightness and appearance of the Earth and its clouds from orbit - vital information for developing cameras for weather satellites.

While studies relating to weather satellites continued under the sponsorship of various military and civilian laboratories, real progress did not begin until the launch of the first Sputniks when many space concepts received renewed interest. As with most American space programs, work on weather satellites came under the purview of ARPA (Advanced Research Projects Agency) by the middle of 1958. While all the military services and the US Weather Bureau supplied inputs based on their own research, ARPA eventually gave responsibility for the development of a weather satellite (now considered a high priority) to USASRDL. They already had a satellite concept under development that could be used as a weather satellite.

TIROS is Born

Throughout the 1950s, RCA (Radio Corporation of America) worked closely with the Department of Defense examining a variety of applications for television-equipped satellites including in the WS-117L program. But after the WS-117L program opted for a photographic-based imaging system, RCA was forced to look for a customer elsewhere. After some convincing, the Army Ballistic Missile Agency (ABMA), which was busy pushing their own satellite proposal (see **Project Orbiter: Prelude to America's First Satellite** in the January 1998 issue of *SpaceViews*), issued a contract to RCA in 1956 to study television-based reconnaissance concepts. Shortly afterwards a second contract was let to RCA and control of the program, called Janus, was given to the USASRDL.

Originally Janus would be launched on a Juno I and, like the first Explorer satellites that used the same rocket, would be rod shaped with a total mass of no more than nine kilograms (20 pounds). But this shape had a tendency to tumble unstably once in orbit and the mass restrictions proved to be almost impossible to meet. In 1958 the Juno II, with a larger 39 kilogram (85 pounds) payload capability, became available. Now the television-equipped satellite took on a drum-shape which would spin more stably. Once the Army redirected the program towards developing a weather satellite to meet the ARPA mandate, the satellite design and its payload were optimized for its new role and christened TIROS (Television and InfraRed Observation Satellite).

Soon thereafter the launch vehicle was switched again to the still more capable Juno IV with a planned payload capacity of 230 kilograms (500 pounds). But ABMA cancelled the Juno IV in August of 1958 and redirected the funding to the development of the Juno V (see **Juno V: The Early History of a Super Booster** in the September 1998 issue of *SpaceViews*). After careful consideration, the Thor-Able was chosen as the new launch vehicle and the USAF took control of the TIROS program.

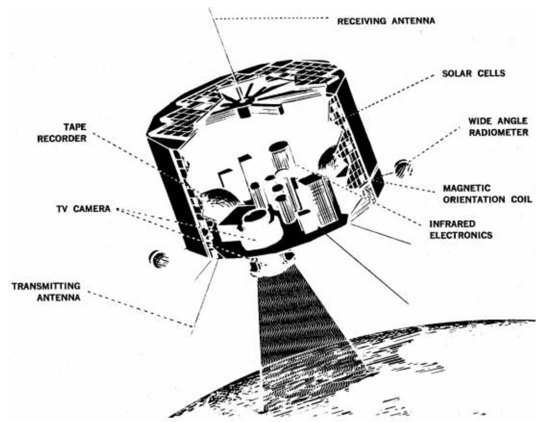

Diagram of the TIROS weather satellite. (NASA)

But as the TIROS design rapidly neared completion, project responsibility would change hands for one last time. Despite its obvious military application, the TIROS program was transferred by President Eisenhower to NASA on April 13, 1959 because of its perceived benefits to the peaceful promotion of space. And from the start, the new civilian space agency was committed to getting TIROS into space.

As with all of its space science programs, NASA administration gave responsibility of TIROS to their Goddard Space Flight Center (GSFC). At NASA headquarters, Morris Tepper led the program and Stroud was transferred from USASRDL to GFSC to run the project from there. Considering the advance state of development, it was decided that overall spacecraft design responsibility would remain with USASRDL and RCA would continue development of the camera system at least until the launch of the first TIROS satellite, now designated A-1. NASA also preferred to launch TIROS on their improved Thor-Delta (later simply called Delta) then under development. It was decided to stay with the temperamental Thor-Able for the launch of A-1 at least, again to keep the program on track. Afterwards a more thorough reorganization would allow NASA to assume more direct control of the program.

The First Missions

On July 29, 1959 assembly of the first prototype satellite, T-1, began. All of the satellite's components were mounted on a rigid structural base plate. When assembled, TIROS looked like a squat cylinder 1.07 meters (42 inches) in diameter and 0.48 meters (19 inches) tall. The sides of the spacecraft actually consisted of 18 rectangular panels covered with solar cells used to recharge the satellite's batteries. The spin stabilized TIROS would employ magnetic torquers to change attitude by "pushing" against the Earth's own magnetic field. The spacecraft could either be commanded directly from the ground in real time or be programmed to make observations automatically when out of contact with its tracking stations.

The instrument of most interest carried by TIROS was its pair of RCA-developed television cameras looking downward from the base plate. One camera was fitted with a wide-angle lens capable of imaging 1.6 million square kilometers (600,000 square miles) at a time from the nominal 740 kilometer (460 mile) orbit chosen. The second camera had a narrower field of view with each image covering only 13,000 square kilometers (5,000 square miles). The 500-line images could either be readout for direct transmission to a ground station or recorded for later transmission. The tape recorder, an early version of which was flown into orbit on Project SCORE (see **The Talking Atlas** in the December 1998 issue of *SpaceViews*), stored up to 32 images and could be downloaded to the ground in three minutes.

The first prototype of the RCA camera was connected to ground equipment on January 15, 1959 and worked as intended. On February 17, Vanguard 2 was launched into orbit carrying Stroud and Nordberg's cloud imaging experiment (see **Vanguard and Its Legacy** in the February 1, 1999 issue of *SpaceViews*). Although the satellite precessed uncontrollably once in orbit making it impossible to assemble pictures, this raw data plus photographs returned by other rockets did provide enough information to confirm the TIROS camera's specifications. The other set of instruments carried by TIROS were a trio of radiometers to measure the Earth's emissions in the infrared. Among these was a one built by Verner Soumi and his team. While his original instrument was a victim of a Vanguard launch failure, he did fly a similar one later on Explorer 7 launched on October 13, 1959 (see **The Early Explorers** in the August 8, 1999 issue of *SpaceViews*).

The second TIROS prototype, T-2 was completed on September 10, 1959 and performed satisfactorily during a demonstration 15 days later. Work then started on the first flight model, D-1, which would only carry television cameras. D-1 would not have the radiometer suite or the magnetic torquers to keep the mission simple and the schedule on track. The first TIROS could complete its mission in the attitude it assumed after an early morning launch. In November preparations for launch at Cape Canaveral began. While there were a number of problems found during testing that needed correction, final testing of D-1 was completed on February 28, 1960 and the satellite was shipped to the Cape a week later.

The launch of TIROS 1 on the last Thor-Able on April 1, 1960. (NASA)

Finally on April 1, 1960 the 119 kilogram (263 pound) TIROS 1 was successfully placed into a 690 by 750 kilometer (430 by 466 mile) orbit inclined 48.4 degrees to the equator by the last Thor-Able to fly. On its first day in orbit, TIROS 1 started returning pictures - dozens followed by hundreds then thousands as the mission progressed. The only major malfunction following launch was in the control system for the narrow angle camera. But after over a month in orbit, it began operating on its own.

Nine days after launch, TIROS 1 discovered its first cyclone north of New Zealand. The first samples of the ensuing flood of findings were presented to an eager audience later that month at a combined meeting of the American Meteorological Society and the American Geophysical Union in Washington, DC. TIROS 1 remained active until June 15 when a power failure knocked out the cameras. During its 77 day useful lifetime, TIROS 1 took a total of 22,952 pictures which meteorologists eagerly waded through to gain new insights into Earth's weather.

The first TV image returned by TIROS 1 from off the coast of Nova Scotia. (NASA)

With the value of weather satellites proven, the 126 kilogram (278 pound) TIROS 2 was launched on November 23, 1960 on the third flight of the new Delta. Unlike its predecessor, TIROS 2 carried a full complement of instruments and equipment. Although the picture quality was disappointing, it returned over 36,000 images over the next 76 days. Next came TIROS 3 on July 12, 1961 which was launched in time to watch for tropical storms. After this, NASA would almost continuously monitor the weather from orbit with a succession of weather satellites that continues to this day.

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