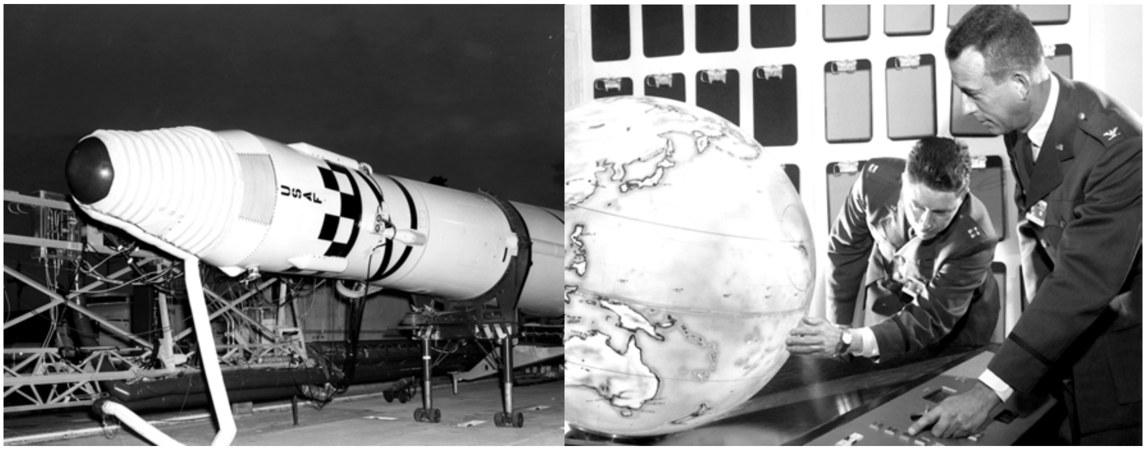
CHAPTER V: SATELLITE SYSTEMS

Military satellite projects were added to the mission of the Western Development Division in the mid-1950's and came to play an increasingly important role in the activities of the Division's successors. The first satellite program was known as the Military Satellite System, or Weapon System 117L (WS 117L). The commander of Air Research and Development Command transferred responsibility for the program from Wright Air Development Center to WDD on 10 October 1955. WS 117L was, in concept, a family of separate subsystems that could carry out different missions, including photographic reconnaissance and missile warning. However, by the end of 1959, WS 117L had evolved into three separate programs: the Discoverer Program, the Satellite and Missile Observation System (SAMOS),[15] and the Missile Defense Alarm System (MIDAS). Discoverer and SAMOS were to carry out the photographic reconnaissance mission, and MIDAS was to carry out the missile-warning mission.[16]

Reconnaissance Systems

The Discoverer program aimed at developing a film-return photographic reconnaissance satellite. The satellite would carry a camera that took pictures from space as it passed over the Soviet Union and China. Film from the camera would be returned from orbit in a capsule; a parachute would be deployed to slow the descent of the capsule; and the capsule would be recovered either in mid-air or in the ocean. However, Discoverer's photo reconnaissance mission was not revealed to the public at the time. It was, instead, presented as an experimental program to develop and test satellite subsystems and explore environmental conditions in space.[17]



Left: The Agena spacecraft for Discoverer 13, mated to its Thor launch vehicle, waits on the pad at Vandenberg AFB before being erected. The covering cooled and protected the spacecraft. Right: Colonel C. Lee Battle, Discoverer program director, and a project officer observe the ground track of a satellite in 1960, taking care not to look at the Soviet Union.

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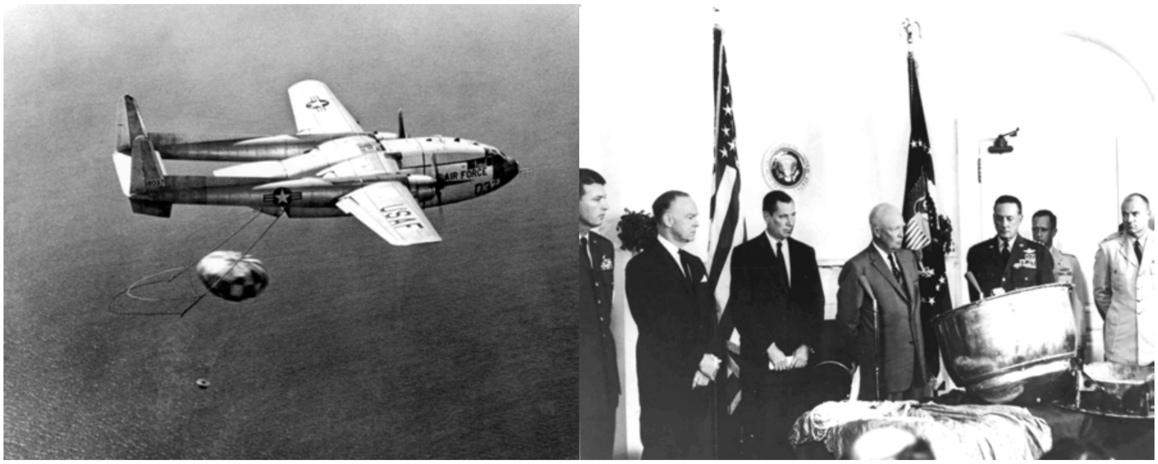
[15] SAMOS may have been made into an acronym after the name had been selected to go with MIDAS.

[16] Under the WS 117L program, the visual reconnaissance payloads (which became the Discoverer and SAMOS programs) were known as Subsystem E, and the infrared reconnaissance payload (which became the MIDAS early warning program) was called Subsystem G. The spacecraft, which finally became the Agena upper stage, was called Subsystem A for the airframe and Subsystem B for the propulsion elements.

[17] Nevertheless, some Discoverer missions carried experimental payloads instead of or in addition to their

The Discoverer Program carried out 38 public launches and achieved many technological breakthroughs. Discoverer I, launched on 28 February 1959, was the world's first polar orbiting satellite. Discoverer II, launched on 13 April 1959, was the first satellite to be stabilized in orbit in all three axes, to be maneuvered on command from the earth, to separate a reentry vehicle on command, and to send its reentry vehicle back to earth. Discoverer XIII, launched on 10 August 1960, ejected a capsule that was subsequently recovered in the Pacific Ocean, the first successful recovery of a man-made object ejected from an orbiting satellite. Discoverer XIV, launched on 18 August 1960, ejected a capsule that was recovered in mid-air northwest of Hawaii by a JC-119 aircraft, the first successful aerial recovery of an object returned from orbit. The capsule from Discoverer XIV was the first to return film from orbit, inaugurating the age of satellite reconnaissance. Satellite reconnaissance filled a crucial need, because President Eisenhower had suspended aerial reconnaissance of the Soviet Union just three months earlier after the Soviets had shot down the U-2 spy plane piloted by Francis Gary Powers.



Left: A recovery crew of the 6593rd Test Squadron (Special) performs a midair capsule recovery in a JC-119 aircraft. Recovery crews flew JC-119s for the first 29 Discoverer missions and JC-130s after that. Right: President Eisenhower holds a news conference on 15 August 1960 to exhibit the capsule from Discoverer 13, recovered from the ocean four days earlier. Behind the president, left to right, are Lieutenant General Bernard Schriever (commander of Air Research and Development Command), Dudley Sharp (Secretary of the Air Force), Thomas Gates (Secretary of Defense), General Thomas White (Air Force Chief of Staff), unidentified officer, Colonel Charles Mathison (commander of 6594th Test Group).

The Discoverer Program officially ended after the launch of Discoverer XXXVIII on 27 February 1962. In reality, however, it continued in clandestine form until 31 May 1972 (the date of the last film recovery), carrying out 145 launches[18] under the secret code name Corona. At the direction first of President Eisenhower and later of President Kennedy, the direction and management of Corona and other satellite reconnaissance programs passed to a new DOD agency, the National Reconnaissance Office (NRO),

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normal reconnaissance payloads. Mission 3 carried biological experiments, and mission 2 carried simulated experiments, but both were lost in launch failures. Missions 19, 21, 49, 52, 57, 73, 92, and 99 gathered infrared background data for the MIDAS program. Other missions carried geodetic payloads. For short descriptions of Corona payloads, see Curtis Peebles, The Corona Project, Naval Institute Press, 1997.

[18] Including the 38 Discoverer launches.

when it was created in 1961.[19] Corona's first major accomplishment was to provide photographs of Soviet missile launch complexes. It also identified the Plesetsk Missile Test Range, north of Moscow, and provided information about what missiles were being developed, tested, and deployed. These and other accomplishments came to light when the CORONA Program was declassified in February 1995.

SAMOS, the second program that evolved from WS 117L, aimed at developing a heavier reconnaissance payload that would be launched by an Atlas Agena booster rather than the Thor Agena used to launch Discoverer. The payloads were intended to collect photographic and electromagnetic reconnaissance data. The photographic data would be collected by cameras in the Agena spacecraft, like the Corona payloads. However, the film would be scanned electronically in orbit and transmitted to ground stations. SAMOS had three unclassified launches from the west coast: 11 October 1960, 31 January 1961, and 9 September 1961. Only the launch in January 1961 was successful. In 1962, a veil of secrecy was drawn across the SAMOS program, and the Air Force stopped releasing information about it. After several more classified launches, however, it was apparent that the technology for the electro-optical film readout system was not yet sufficiently advanced, and Air Force undersecretary Joseph V. Charyk canceled further work on the payload.[20]

Although SMC did not directly manage the development of imaging reconnaissance satellites after this, it did manage programs that were linked to them or their products. One of the most important was the Defense Dissemination System (DDS), whose broad outlines were declassified in 1996. The Defense Dissemination Program Office (DDPO) was established at SAMSO in July 1974 to develop a means to securely and rapidly provide reconnaissance imagery in nearly original quality to both strategic and tactical users. The DDPO developed a system consisting of segments for processing, transmitting, and receiving. The system was deployed to four strategic sites during 1976-1978, providing the first electronic dissemination of digital imagery for targeting and strategic threat assessment. The DDS went through three more generations of increasingly sophisticated improvements for compressing, transmitting, receiving, and reconstructing imagery for military users in the field. One of the third-generation DDS units was deployed to the Persian Gulf to support Operations Desert Shield and Desert Storm. Fourth-generation DDS units were fielded to 70 strategic and tactical users by 1998. However, the DDPO itself ceased to exist as a program office on 1 October 1996,[21] when it was combined with other agencies to create the National Imagery and Mapping Agency (NIMA).

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[19] On 31 August 1960, Secretary of the Air Force Dudley C. Sharp created an Office of Missile and Satellite Systems. Reconnaissance programs under that office reported to the secretary of the Air Force through an undersecretary, Joseph V. Charyk. On 6 September 1961, the new Kennedy Administration established the NRO. Its joint directors, the undersecretary of the Air Force and the deputy director of the CIA, reported directly to the deputy secretary of defense for reconnaissance matters.

[20] However, the technology was secretly transferred to NASA, which used it successfully in its Lunar Orbiter imaging lunar satellites. See R. Cargill Hall, “SAMOS to the Moon: The Clandestine Transfer of Reconnaissance Technology Between Federal Agencies,” NRO Office of the Historian, October 2001.

[21] As an organization, the DDPO was characterized by unusually high *esprit de corps*. It received a larger number of Air Force Organizational Excellence Awards than any other program office in SMC’s history.

Infrared Early Warning Systems

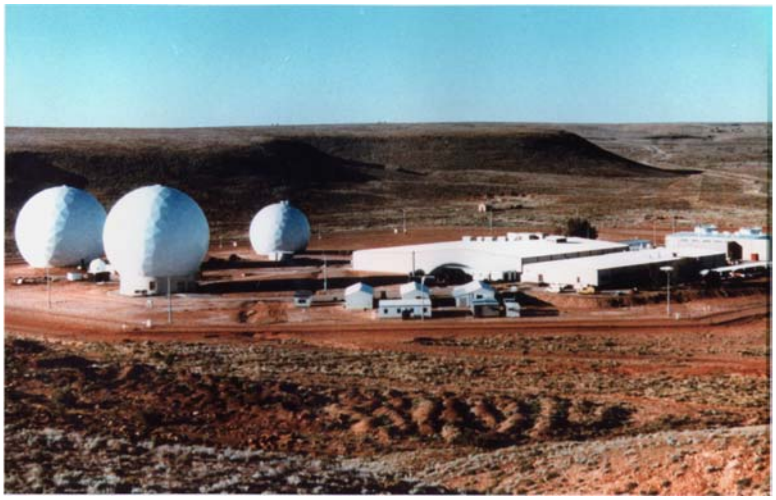
The MIDAS program, the third offshoot of WS 117L, focused on developing a satellite with an infrared sensor to detect hostile ICBM launches. It began its life as a separate program when AFBMD placed the infrared portion of WS 117L under a separate contract with Lockheed effective 1 July 1959. The payload consisted of an infrared sensor array and telescope inside a rotating turret mounted in the nose of an Agena spacecraft. Plans which were never carried out called for an operational constellation of eight satellites in polar orbits to constantly monitor launches from the Soviet Union. Unfortunately, the program's first four test satellites launched in 1960 and 1961 ended in a launch failure and early on-orbit failures.

DOD kept the program in a research and development phase rather than approve an operational system in 1962. The MIDAS program was lengthened and renamed Program 461. The next two launches in 1962 also ended in an early on-orbit failure and a launch failure. Finally, a satellite launched on 9 May 1963 operated long enough to detect 9 missile launches. After another launch failure in 1963, the last Program 461 satellite, launched on 18 July 1963, operated long enough to detect a missile and some Soviet ground tests. Data collection and analysis continued until 1968 under Lockheed's contract for Program 461 to support the next early warning program. Additional launches in 1966, using improved spacecraft and sensors, demonstrated the system's increasing reliability and longevity. Although a launch on 9 June 1966 failed, launches on 19 August and 5 October 1966 placed their spacecraft into highly useful orbits, where their infrared sensors gathered data for a year, reporting on 139 American and Soviet launches. The MIDAS program and its successors were declassified in November 1998.

Left: The Agena spacecraft for MIDAS I waits for installation on Atlas 29D before its unsuccessful launch on 26 February 1960. Right: The payload for an advanced version of MIDAS, known as AFP 461, is covered with the Agena's nose cone before its unsuccessful launch as MIDAS 6 on 17 December 1962.

DOD initiated a new program late in 1963 to develop an improved infrared early warning system, which ultimately became the Defense Support Program. After an early phase known as Program 266, a contract for development of Program 949, the Defense Support Program (DSP), was awarded to TRW for the spacecraft on 6 March 1967 and to Aerojet for the infrared sensor on 1 March 1967. The new concept involved placing the satellites into orbits at geosynchronous altitude, where only three or four would be necessary for global surveillance. Like MIDAS, the satellites would employ telescopes and IR detectors, but the necessary scanning motion would be accomplished by rotating the entire satellite around its axis several times per minute. An evolving network of two, and later three, large ground stations in Australia, Europe, and the continental U.S. controlled the spacecraft and data. The first DSP satellite was launched on 6 November 1970, using a Titan IIIC launch vehicle. A long series of increasingly larger, more sophisticated, and more reliable satellites followed,[22] all of them except one launched on

Right: The first DSP satellite, known as DSP Flight 1, is shown in testing at the facilities of TRW, the prime contractor. It was launched on 6 November 1970 from Cape Canaveral.



Left: The first operational fixed ground station for DSP, known as the Overseas Ground Station (OGS), was located at Woomera Air Station, Australia. It became operational in 1971.

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[22] DSP satellites launched during 1970-1973 weighed 2,000 pounds, had a design life of 1.25 years, and incorporated 2,000 lead sulfide detectors operating in the short wave infrared range; they could see targets only below the line of the earth's horizon. Satellites launched beginning in 1989 weighed 5,250 pounds,

Titan III or Titan IV vehicles.[23] By early 2003, twenty DSP satellites had been successfully launched.[24] They provided a level of early warning that was, by then, indispensable for both military and civil defense. They also carried sensors that performed nuclear surveillance, a mission inherited from the Vela system. Although designed for strategic uses, DSP proved to be more versatile. During the Persian Gulf War, it provided early warning against tactical missiles as well. By 1997, SMC and Air Force Space Command had exploited that capability by adding central processing facilities and tactical ground stations to provide DSP tactical data to battlefield commanders more rapidly and efficiently.

During the early 1990s, SMC pursued concepts and technologies for follow-on systems to replace the Defense Support Program (DSP). By 1994, the concept for a system to succeed DSP was known as the Space-Based Infrared System (SBIRS). SBIRS would be an integrated system that would support several missions: missile warning, missile defense, battlespace characterization, and technical intelligence. The SBIRS concept actually included two planned satellite systems, referred to as SBIRS High[25] and SBIRS Low.[26] Both were heirs of infrared technology developed for the Ballistic Missile Defense Program (earlier known as the Strategic Defense Initiative) during 1983-1995. SBIRS High was focused on the detection and tracking of missiles during the earlier phase of their flight, while their motors were generating heat and infrared signatures in short wave lengths. SBIRS Low would add the capability of tracking and reporting other data about missiles during the middle portions of their flight, when their infrared signatures were at longer wave lengths. SMC awarded a ten-year development contract for SBIRS High to Lockheed Martin on 8 November 1996. The SBIRS High program had to be restructured during 2001 to deal with potential cost and schedule overruns, but its technical progress continued. In December 2001, a consolidated SBIRS Mission Control Station (MCS) at Buckley AFB, Colorado, was declared operational. The MCS provided a central capability for command and control of all operational DSP satellites. The completion of this first segment of the ground system upgrade allowed older DSP ground stations to be closed. Plans called for the ground system to continue to evolve to

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had a design life of 3 years, and incorporated 6,000 lead sulfide detectors with an additional set of mercury cadmium telluride detectors operating in the short wave and medium wave infrared range; they could see targets both below and above the line of the earth's horizon. See Major James Rosolanka, "The Defense Support Program (DSP): A Pictorial Chronology, 1970-1998," SBIRS Program Office.

[23] DSP-16 was launched on a Space Shuttle (STS-44) on 24 November 1991.

[24] Two more DSP satellites remained in storage: Flights 22 and 23. No more were under contract because plans had called for DSP's successor, the Space-Based Infrared System, to reach operational status in time to take over operations from DSP's orbital constellation.

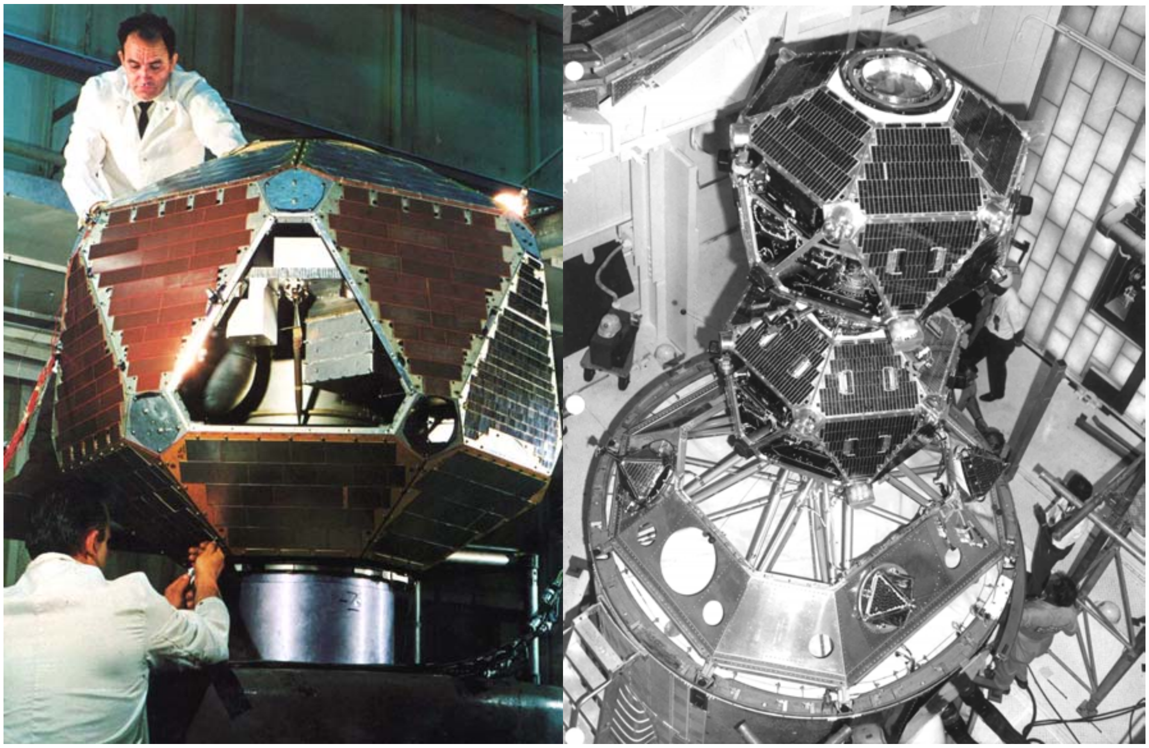
[25] The technological basis for the high-altitude follow-on system to detect missile launches was an earlier program under OSD's Strategic Defense Initiative (SDI) known as the Boost Surveillance and Tracking System (BSTS). It had been transferred to the Air Force in FY 1992 and had gone through several conceptual changes known as the Advanced Warning System (AWS), the Follow-on Early Warning System (FEWS), and the Alert Locate and Report Missiles (ALARM) program.

[26] The technological basis for the low-altitude follow-on system to track missiles in the middle portion of their trajectories had also been an SDI program. It had been known as the Space Surveillance and Tracking System (SSTS) during the mid and late 1980s and as Brilliant Eyes during the early 1990s.

support satellites of the SBIRS High system. By early 2003, a payload for elliptical orbits in SBIRS High was undergoing ground testing. To prepare for the development of SBIRS Low, SMC awarded contracts for on-orbit demonstrations to TRW on 2 May 1995 and to Boeing on 2 September 1996. However, the SBIRS Low program began a gradual transfer of oversight back to the Missile Defense Agency during the same period.

Nuclear Surveillance

In addition to reconnaissance and missile warning, SMC and its predecessors have developed satellites to serve a number of other purposes, among which are nuclear surveillance, weather observation, navigation, and communication. The first space system to accomplish nuclear surveillance was called Vela Hotel—later, simply Vela. Representatives of the Air Force Ballistic Missile Division (AFBMD), the Atomic Energy Commission, and NASA met on 15 December 1960 to initiate a joint program to develop a high-altitude satellite system that could detect nuclear explosions. Its primary purpose was to monitor compliance with the Nuclear Test Ban Treaty then being negotiated in Geneva. During 1961-1962, the Atomic Energy Commission developed detectors and flew experimental versions on Space Systems Division's Discoverer satellites. SSD issued a contract for the spacecraft to Space Technology Laboratories (later part of TRW) on 24 November 1961. The first pair of satellites was launched using an Atlas Agena on 16 October 1963, a few days after the Nuclear Test Ban Treaty went into effect, and two more pairs were launched on 16 July 1964 and 17 July 1965. Six Advanced Vela satellites, containing additional, more sophisticated detectors, were

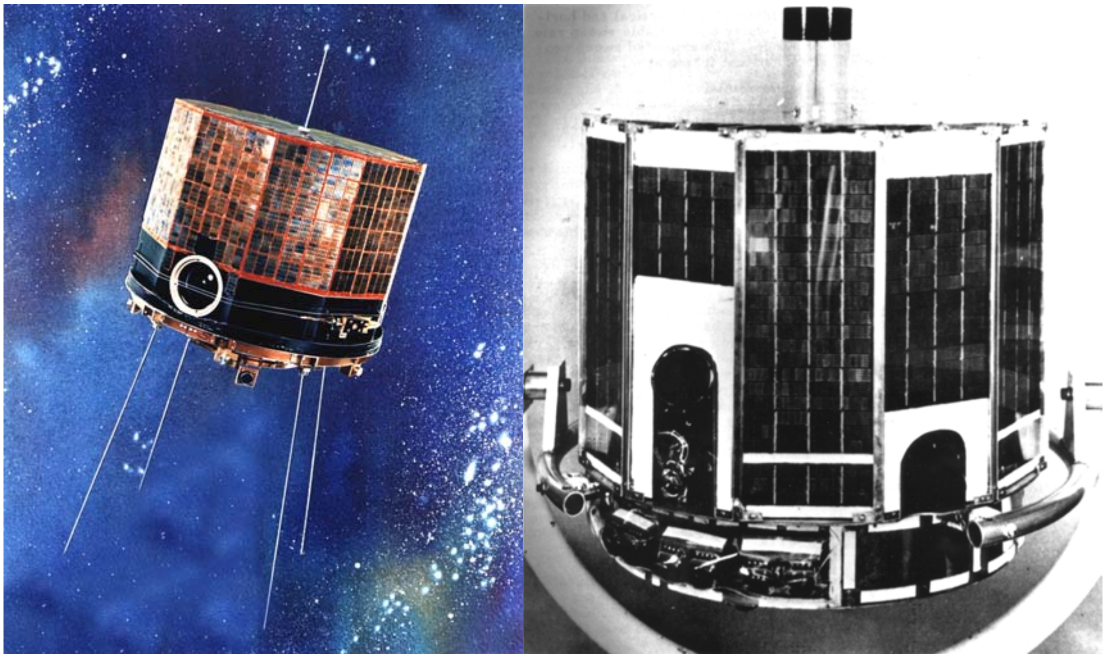


Left: A Vela satellite in fabrication at TRW's facility. Right: A pair of Vela satellites (Vela 5A and 5B) mounted on their Titan IIIC launch vehicle before installation of the fairing. They were launched successfully on 23 May 1969.

launched in pairs on Titan IIIC vehicles on 28 April 1967, 23 May 1969, and 8 April 1970. The Vela satellites successfully monitored compliance with the Nuclear Test Ban Treaty and provided scientific data on natural sources of space radiation for many years. The least successful of the original satellites operated for ten times its design lifetime of six months. The last of the advanced Vela satellites was deliberately turned off on 27 September 1984, over fifteen years after it had been launched.

Meteorological Systems

Providing the systems with which to conduct military weather observations from space is presently the mission of the Defense Meteorological Satellite Program (DMSP), which maintains a constellation of at least two operational weather satellites in polar orbits about 450 miles above the earth. DMSP satellites now carry primary sensors that provide images of cloud cover over the earth's surface during both day and night, and they also carry other sensors that provide additional types of data on weather and on the space environment. The first DMSP satellites were developed by a program office physically located with Space Systems Division but reporting to the National Reconnaissance Office (NRO),[27] which needed analyses of cloud cover over Eurasia to plan its photographic reconnaissance.[28] The program office awarded a development contract for weather satellites employing television cameras to RCA in 1961. DMSP



Left: A DMSP Block I satellite, launched 1962-1963. Blocks II and III were similar. Right: DMSP Block IV satellites, launched 1966-1969, included the first major improvements in DMSP sensors.

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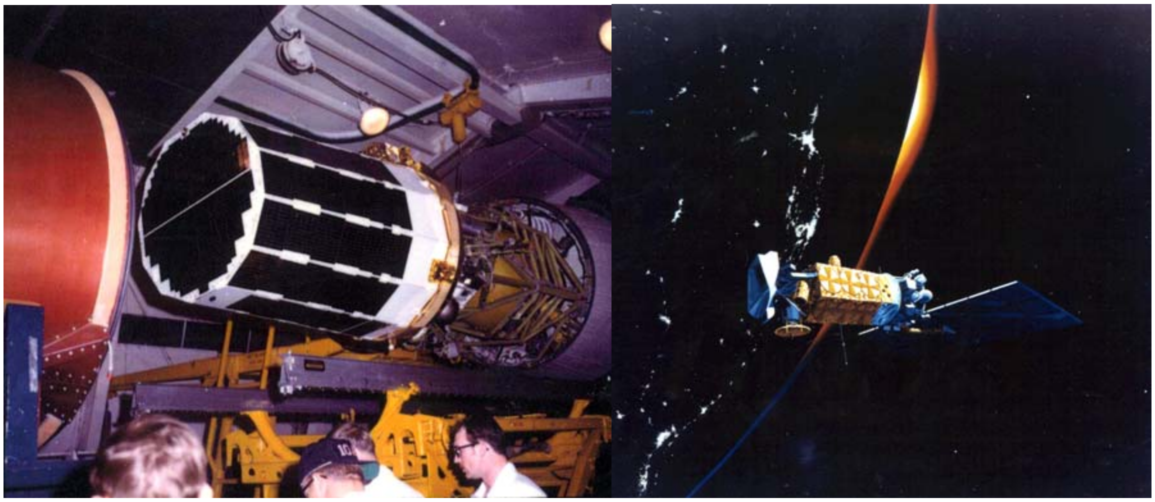
[27] See R. Cargill Hall, A History of the Military Polar Orbiting Meteorological Satellite Program, National Reconnaissance Office, September 2001.

[28] Although NASA was developing a National Operational Meteorological Satellite System, the NRO's director, Under Secretary of the Air Force Joseph V. Charyk, did not believe it would adequately support the NRO's missions. See note 27 above.

Block I began with five launch attempts on Scout launch vehicles during 1962 and 1963, all but one of which failed.[29] Later Block I launches on Thor Agena and Thor Burner I vehicles were more successful. DMSP Block II and Block III satellites, also launched on Thor Burner I vehicles, provided weather data for tactical applications in Southeast Asia.

Wider military uses for weather data led to an important change in the program's reporting structure when, on 1 July 1965, it became a program office under Space Systems Division. Development of more capable and more complex satellites also came to fruition with DMSP Block 4 satellites, seven of which were launched during 1966-1969. Television resolution improved from 3 to 4 nautical miles with Blocks I and II to 0.8 to 3 nautical miles with Block 4, along with many other improvements in the sophistication of secondary sensors. Block 5A satellites introduced the Operational Line Scan (OLS) sensor, which provided images of clouds in both visual and infrared spectra. Television resolution improved to 0.3 nautical miles in daylight. Three Block 5A, five 5B, and three 5C satellites were launched during 1970-1976 on Thor Burner II launch vehicles. Larger and much more sophisticated Block 5D-1 satellites were also developed during the 1970s, but only five were built. In 1980, the fifth 5D-1 satellite was lost in a launch failure, and the operational 5D-1 satellites in orbit ceased to function prematurely. From August 1980 to December 1982, when the first Block 5D-2 satellite was successfully launched, meteorological data was supplied to DOD entirely by civilian



Left: The payload fairing is being installed over a DMSP Block 5A satellite mated to a Burner II upper stage on a Thor Burner (LV-2F) launch vehicle about 1970-1971. Right: This artist's concept depicts a DMSP Block 5D-3 satellite in an early-morning orbit. The DMSP constellation consists of two operational satellites and two spares in sun-synchronous polar orbits. One of the operational satellites crosses the equator (northward) early in the morning, and the other does so at noon local time.

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[29] The first launch attempt took place on 23 May 1962, but it failed. The first successful launch was the second attempt on 23 August 1962. Later unsuccessful Scout launches took place on 19 February 1963, 26 April 1963, and 27 September 1963. Successful Thor Agena D launches were carried out on 19 January 1964 and 17 June 1964. Block I launches on Thor Burner I rockets took place on 18 January 1965 (failure) and 18 March 1965 (success). Block II launches on Thor Burner I vehicles were on 9 September 1965 (success), 7 January 1966 (failure), and 30 March 1966 (success). The only Block III satellite was launched successfully on 20 May 1965 using a Thor Burner I launch vehicle. See note 27 above.

satellites. Nine Block 5D-2 satellites were launched during 1982-1997 on Atlas E and Titan II launch vehicles. In 1989, Space Systems Division began the procurement of five Block 5D-3 satellites from General Electric (later acquired by Lockheed Martin). By early 2003, the first of these was scheduled for launch later in the year.

Civilian weather satellites were operated by the National Oceanic and Atmospheric Administration (NOAA). Proposals to merge the civilian and military meteorological systems had been made from time to time since the early 1970s.[30] On 5 May 1994, President Clinton issued a presidential decision directive ordering the convergence and eventual merger of the two programs into a new national space-based system for environmental monitoring. A Tri-Agency Integrated Program Office (IPO) made up of representatives from NOAA, NASA, and DOD would be responsible for carrying out major systems acquisitions, including satellites and launch vehicles. However, NOAA would have overall responsibility for operating the new system, which was soon named the National Polar-orbiting Operational Environmental Satellite System (NPOESS). A major step in convergence occurred on 29 May 1998, when NOAA's Satellite Operations Control Center (SOCC) took over satellite control authority as well as actual operational control of the existing DMSP system. The IPO issued competitive contracts to Lockheed Martin and TRW on 13 December 1999 for an early phase of the NPOESS development program called Program Definition and Risk Reduction, and it issued five development contracts for NPOESS sensors during 1997-2001. A flight demonstration satellite known as the NPOESS Preparatory Project (NPP) was scheduled for launch in late 2006. It would be a joint mission involving NASA and the IPO.

Navigation Systems

The world's first space-based navigation system was called Transit. It was developed by scientists at Johns Hopkins University's Applied Physics Laboratory in 1958. DOD's Advanced Research Projects Agency (ARPA) initiated the development program in September 1958 and assigned it to the Navy a year later. The Air Force Ballistic Missile Division launched the Navy's first Transit satellite on 13 April 1960. The system achieved initial operational capability in 1964 and full operational capability in October 1968. It used three operational satellites to produce signals whose Doppler effects and known positions allowed receivers—primarily ships and submarines—to calculate their positions in two dimensions. Transit established the principle and much of the technology of navigation by satellite and prepared military users to rely on such a system. However, it was too slow for rapidly moving platforms such as aircraft. Transit's signals were turned off deliberately in December 1996 because DOD had decided to rely on a newer, faster, and more accurate system.

All of DOD's navigation and position-finding missions are now performed by the Global Positioning System (GPS). The system consists of 24 operational satellites that broadcast navigation signals to the earth, a control segment that maintains the accuracy of the signals, and user equipment that receives and processes the signals. By processing

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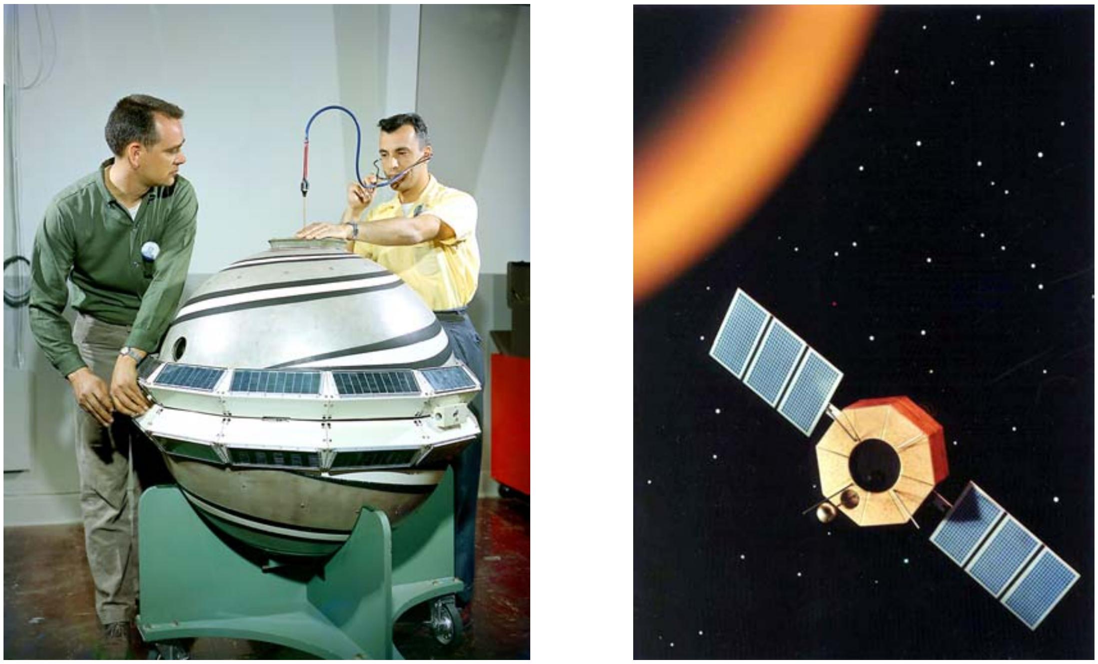
[30] The Defense Meteorological Satellite Program was declassified in 1973.

signals from four satellites, a user set is able to derive the location of each satellite and its distance from each one. From that information, it rapidly derives its own location in three dimensions.



Left: The second Transit satellite (Transit 1B) undergoes checkout at Cape Canaveral before launch on 13 April 1960. Right: This artist's concept depicts the second Navigation Technology Satellite (NTS-2) in orbit. NTS-2 was used as part of the GPS Block 1 test constellation.

Besides Transit, GPS had two immediate programmatic ancestors: a technology program called 621B, started by SAMSO in the late 1960s, and a parallel program called Timation, undertaken by the Naval Research Laboratory in the same period. 621B envisioned a constellation of 20 satellites in synchronous inclined orbits, while Timation envisioned a constellation of 21 to 27 satellites in medium altitude orbits. In 1973, elements of the two programs were combined into the GPS concept, which employed the signal structure and frequencies of 621B and medium altitude orbits similar to those proposed for Timation.

Deputy Secretary of Defense William P. Clements authorized the start of a program to "test and evaluate the concepts and costs of an advanced navigation system" on 17 April 1973, and he authorized the start of concept validation for the GPS system on 22 December 1973. GPS was acquired in the classical three phases: validation, development, and production. During the validation phase, Block I navigation satellites and a prototype control segment were built and deployed, and advanced development models of various types of user equipment were built and tested. During the development phase, additional Block I satellites were launched to maintain the initial satellite constellation, a qualification model Block II satellite was built and tested, and manufacture of additional Block II satellites was initiated.[31] In addition, an operational

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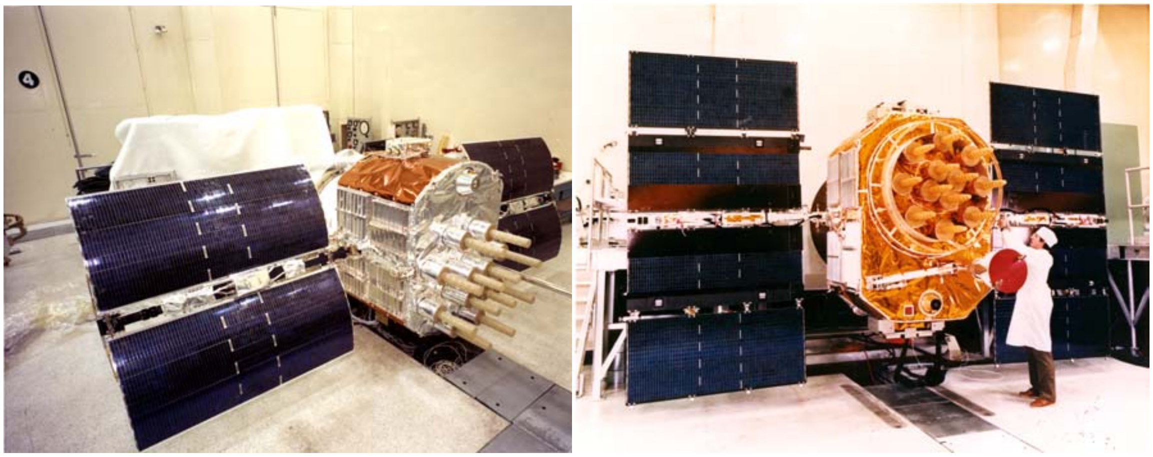
[31] Block I, Block II, and Block IIA satellites were built by Rockwell International, which sold its aerospace and defense divisions to Boeing in 1997.

control segment was activated, and prototype user equipment was developed and tested. During the production phase, a full constellation of 24 Block II and IIA (A for advanced) satellites was deployed. User equipment was also produced and put into operation by issuing it to foot soldiers and installing it in ships, submarines, aircraft, and ground vehicles. The full constellation was completed on 9 March 1994, allowing the system to attain full operational capability in April 1995. SMC began launching the next block of GPS satellites, known as IIR (R for replacement), in 1997.[32] The following block of GPS satellites, which incorporated further improvements, was known as Block IIF (F for follow-on). SMC awarded a contract for their production on 22 April 1996.[33] By 2003, they were scheduled to be available for launch beginning in 2006.



Top: A GPS Block I satellite (left) and a GPS Block II satellite (right) undergo acceptance testing at Arnold Engineering Development Center. Bottom left: An artist's concept depicts a GPS Block IIR satellite in orbit. Bottom right: An artist's concept depicts a GPS Block IIF satellite in orbit.

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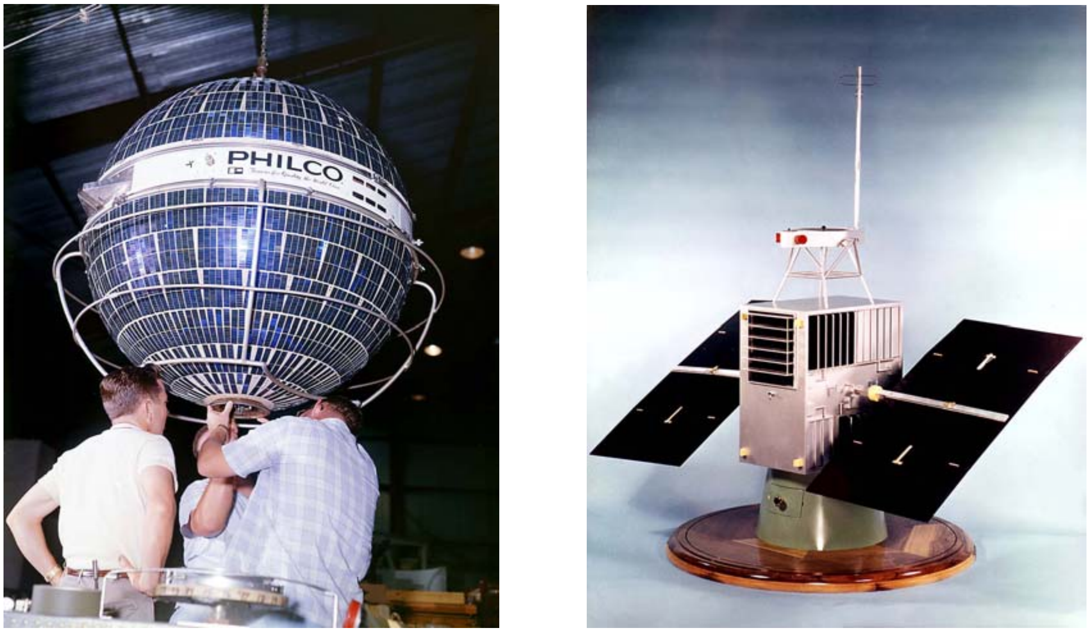
[32] The launch of the first IIR satellite on 15 January 1997 failed when the Delta launch vehicle exploded. It was the first failure of a Delta II vehicle and only the second launch failure in the history of the GPS program. The first GPS Block IIR satellite to attain orbit and become operational was launched on 23 July 1997.

[33] SMC (then called Space Systems Division) had awarded the contract for Block IIR satellites to General Electric (later part of Lockheed Martin) in 1989. It awarded the contract for Block IIF satellites to Rockwell International (later part of Boeing). See note 31 above.

GPS can support a wide variety of military operations, including aerial rendezvous and refueling, all-weather air drops, instrument landings, mine laying and mine sweeping, anti-submarine warfare, bombing and shelling, photo mapping, range instrumentation, rescue missions,[34] and satellite navigation. GPS is also the focus of a growing civilian market. By 2003, it was widely used commercially, and some of those commercial applications, such as airline navigation, were critical. At one time, the GPS signal available to civil users contained intentional inaccuracies, a condition known as selective availability. At President Clinton's direction, the intentional inaccuracies were set to zero on 1 May 2000, providing significant improvements in the accuracy available to the system's civil users.

Communications Systems

The world's first communications satellite was launched by the Air Force Ballistic Missile Division, SMC's predecessor, on 18 December 1958. The SCORE payload consisted of commercial communications equipment modified by the Army Signal Corps and installed in an Atlas B missile as a proof-of-concept mission for orbiting communications repeaters. The project was executed under ARPA's direction.



Left: The Courier 1B satellite undergoes testing at Patrick AFB before launch on 4 October 1960. Right: A conceptual model of a satellite for Project Advent. No satellite was ever actually launched for Advent.

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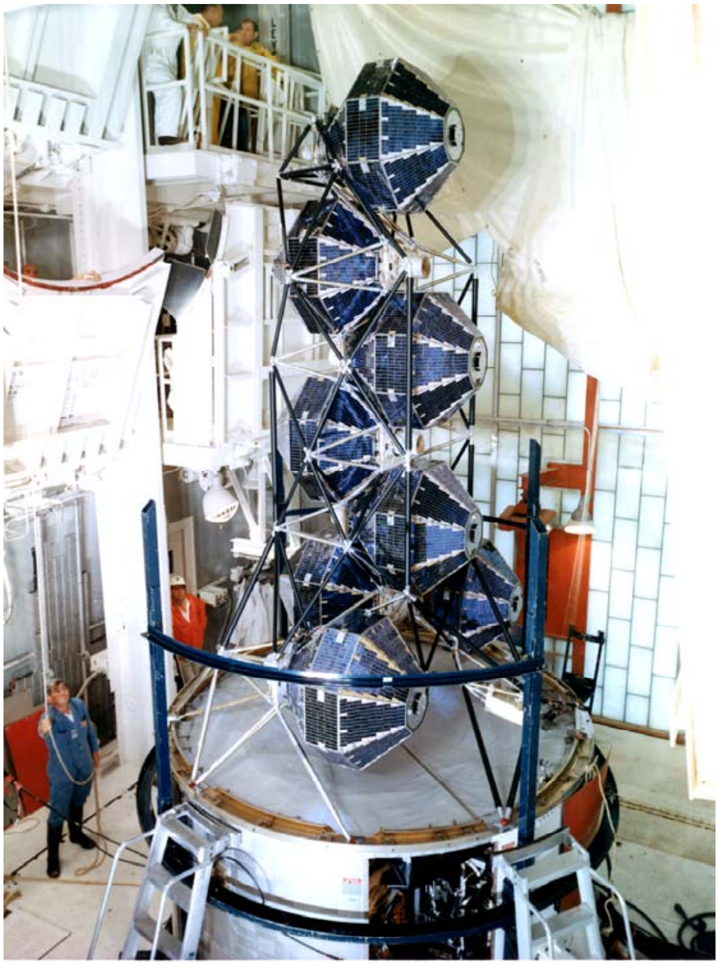
[34] We should take note of a particularly important military application of GPS known as the Combat Survivor Evader Locator (CSEL) system. CSEL was based on an earlier Air Force Space Command procurement called Hook-112 and was designed to enable rescue forces to find, track, and communicate with downed American pilots in hostile territory while making sure they were truly American personnel in need of assistance. It was a technologically sophisticated combination of hand-held radio unit and GPS receiver. Secretary of Defense William J. Perry approved the program in December 1995, and SMC issued a development contract to Rockwell (later absorbed by Boeing) in February 1996. A series of operational assessments and developmental tests were conducted between 1998 and 2002, and the first limited production units were delivered in late 2002. CSEL entered multiservice operational test and evaluation in June 2003 and was scheduled to begin full-rate production early in 2004.

AFBMD launched the entire missile, minus the spent half stage, into a low orbit, where it remained for about a month,[35] relaying voice and telegraph messages between ground stations in the United States. Among its first experimental transmissions was President Eisenhower's Christmas message to the world, the first time that a human voice had been transmitted from space. The world's second military[36] communications satellite was Courier 1B, developed by the Army Signal Corps under ARPA's direction. AFBMD successfully launched it on 4 October 1960, using a Thor Able Star launch vehicle. Courier further tested the feasibility of orbiting communications repeaters but did so with a spherical, self-contained satellite that included solar cells and rechargeable batteries. Unfortunately, the spacecraft suffered a command system failure after 17 days in orbit.

The first military satellite communications system to be used for operational purposes was known as the Initial Defense Communications Satellite Program (IDCSP). The development program began in 1962, following the cancellation of an earlier, unsuccessful development program called Project Advent. The IDCSP system consisted



Left: The payload fairing is being installed on Titan IIIC-16 at Cape Canaveral. Enclosed in a dispensing mechanism are the last eight satellites of the Initial Defense Communications Satellite Program (IDCSP), successfully launched on 13 June 1968. The IDCSP satellites were small and very simple, with no batteries and no active attitude control system. The dispenser ejected them one at a time into a near-synchronous orbit.

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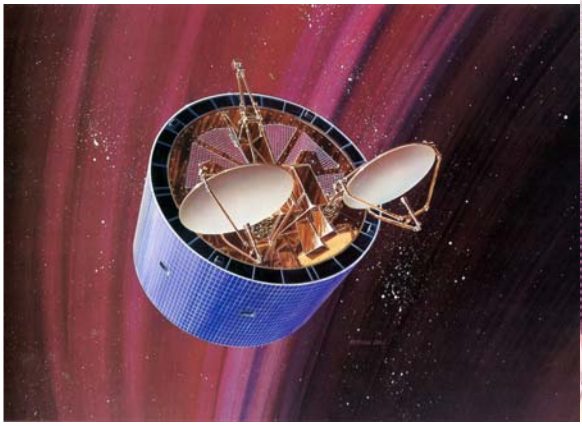
[35] SCORE stopped transmitting when its batteries were exhausted on 31 December 1958. It had no solar cells or other sources of power. It reentered on 21 January 1959.

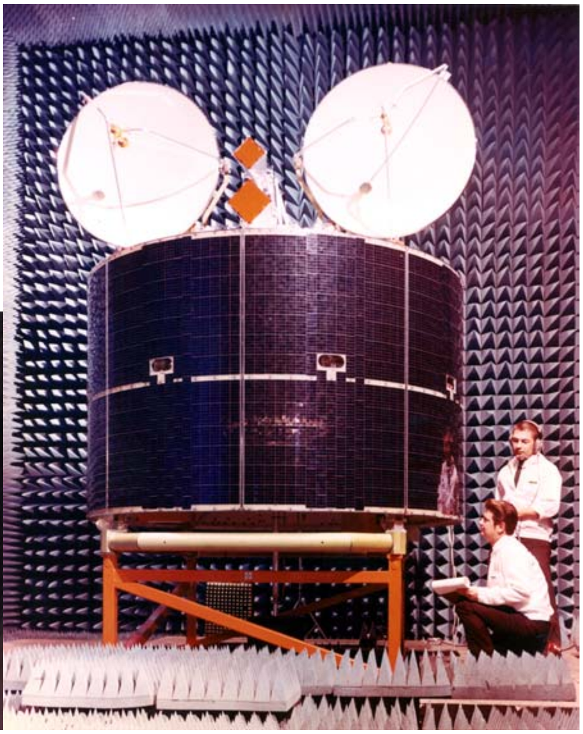
[36] Echo 1, a metallized balloon that acted as a passive experimental communications satellite, was successfully launched by NASA on 2 August 1960.

of small, 100-pound satellites launched in clusters. Twenty-six such satellites were placed into orbit in four launches carried out between June 1966 and June 1968.[37] Two fixed and thirty-four mobile ground terminals also became operational in 1968. IDCSP transmitted both voice and photography to support military operations in Southeast Asia. It provided an experimental but usable worldwide military communications system for the Defense Department for ten years until a more sophisticated system could be developed.

That more sophisticated system was known as the Defense Satellite Communications System, Phase II (DSCS II). The DSCS II satellites were much larger and more sophisticated than the IDCSP satellites, offering increased communications capacity, greater transmission strength, and longer lifetimes. In addition to horn antennas for wide area coverage, they had dish antennas that were steerable by ground command and provided intensified coverage of small areas of the earth's surface. SAMSO awarded a development contract for the DSCS II system to TRW on 3 March 1969, and the first pair of satellites was launched on 2 November 1971. It was the first operational military communications satellite system to occupy a geosynchronous orbit. Two launch failures delayed completion of the satellite network, but by January 1979, the full constellation of four satellites was in place and in operation. A total of 16 DSCS II satellites was built and launched[38] during the life of the program, with the last launch occurring on 4 September 1989.

Below left: An artist's concept depicts a DSCS II satellite in orbit.
Right: A DSCS II satellite undergoes testing in an anechoic chamber.





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[37] There were five attempted launches of IDCSP satellites on Titan IIIC launch vehicles during 1966-1968, but the second launch was unsuccessful because of a structural failure in the Titan. Each launch dispensed from three to eight IDCSP satellites into near-synchronous orbits.

[38] DSCS II satellites were launched in pairs using Titan IIIC vehicles through 1979.

In 1973, planning began for the Defense Satellite Communications System, Phase III (DSCS III). DSCS III satellites carry multiple beam antennas to provide flexible coverage and resist jamming, and they offer six active communication channels rather than the four offered by DSCS II. The first DSCS III satellite was successfully launched on 30 October 1982, and a full constellation of five DSCS III satellites was completed on 2 July 1993. Two DSCS IIIs were launched into orbit from a Space Shuttle on 3 October 1985. The constellation was replenished with five launches from 28 November 1993 to 20 October 2000. By early 2003, only two unlaunched DSCS III satellites remained in the inventory. In view of the fact that the DSCS III system would have to support tactical military operations until a follow-on system could be acquired,[39] SMC began an initiative to improve the tactical utility and extend the lifetime of DSCS III satellites. Known as the Service Life Enhancement Program (SLEP), the initiative added improvements to the last four DSCS III satellites before they were launched. Lockheed Martin was placed under contract to carry out the SLEP modifications on 28 March 1996.

Left: An artist's concept depicts a DSCS III satellite in orbit.
Below: A DSCS III satellite is prepared for testing.

DSCS satellites were developed to serve users who transmitted message traffic at medium to high data rates using relatively large ground terminals. However, satellites were also needed to serve users who transmit at low to medium data rates, using small, mobile or transportable terminals. During the 1960s, experimental satellites were placed into orbit to test technology that might perform this tactical communications mission. Lincoln Experimental Satellites 5 and 6, launched on 1 July 1967 and 26 September 1968, were solid-state, ultra high frequency communication satellites built by Lincoln Laboratory. The 1,600 pound Tactical Communications Satellite, launched on 9

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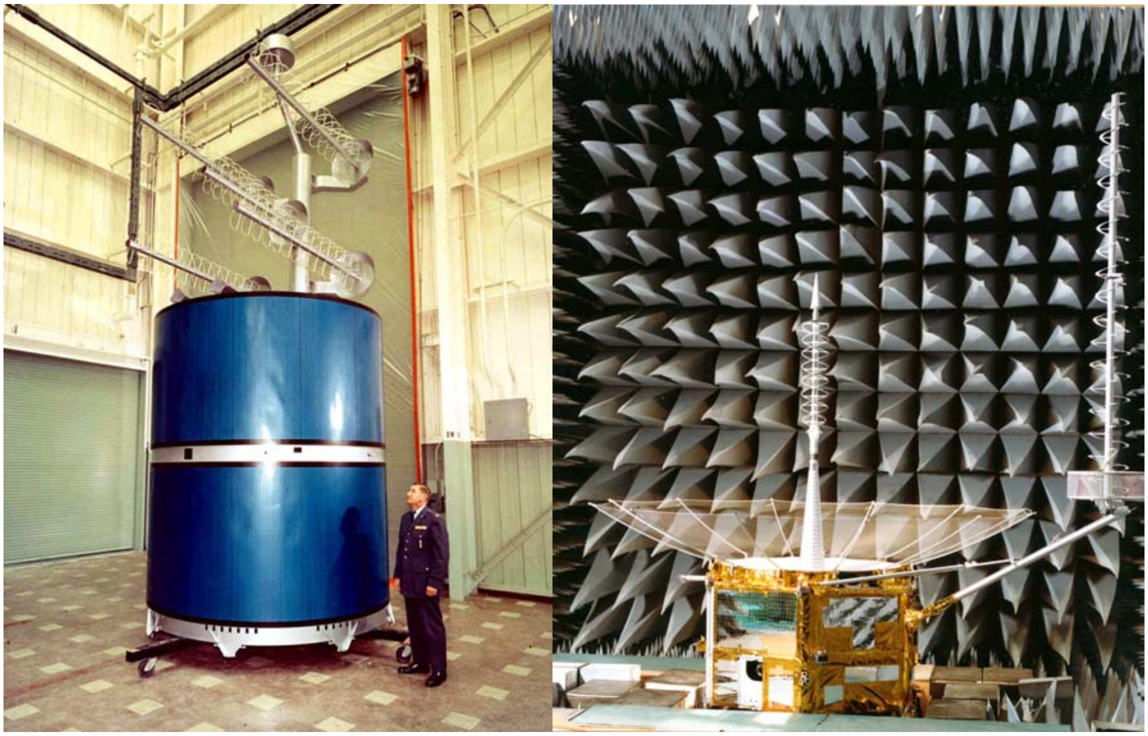
[39] See the Wideband Gapfiller Satellite (WGS) system discussed below.

February 1969, operated in both ultra high frequency and super high frequency and tested the feasibility of communications with small, mobile, tactical communications equipment that could be used by ground, naval, and air forces. In July 1970, an initial operational capability for tactical communications was established, using the Tactical Communications Satellite and Lincoln Experimental Satellite 6.

These experimental satellites paved the way for the Fleet Satellite Communications System (FLTSATCOM), the first operational system serving tactical users. The Navy managed the overall program, but SAMSO managed acquisition of the satellites. Development of FLTSATCOM was authorized on 27 September 1971, and five satellites were launched from 9 February 1978 to 6 August 1981. Four achieved orbit and went into operation, but one was damaged during launch and never became operational. Three replenishment satellites were launched from 5 December 1986 to 25 September 1989. Two reached orbit, but one was lost when its booster was hit by lightning.

In addition to the long-haul users served by DSCS and the tactical users served by FLTSATCOM, there was a third group of users—the nuclear capable forces—who could be satisfied with very low data rates but required high availability, worldwide coverage, and the maximum degree of survivability. The Air Force Satellite Communications System (AFSATCOM) was developed to serve their needs and allow the Air Force to command and control its strategic forces. The space segment of the system relied on



Left: SAMSO's TACSAT program director poses with TACSAT I in the testing facilities of the prime contractor, Hughes Aircraft Company, about 1969. SAMSO launched TACSAT using a Titan IIIC on 9 February 1969, and it operated successfully for 46 months. Right: A FLTSATCOM satellite undergoes testing in an anechoic test chamber.

transponders (receiver/transmitters) placed on board FLTSATCOM satellites and other DOD spacecraft. The space segment of AFSATCOM was declared operational on 15 April 1978, and the terminal segment attained initial operational capability on 22 May 1979.

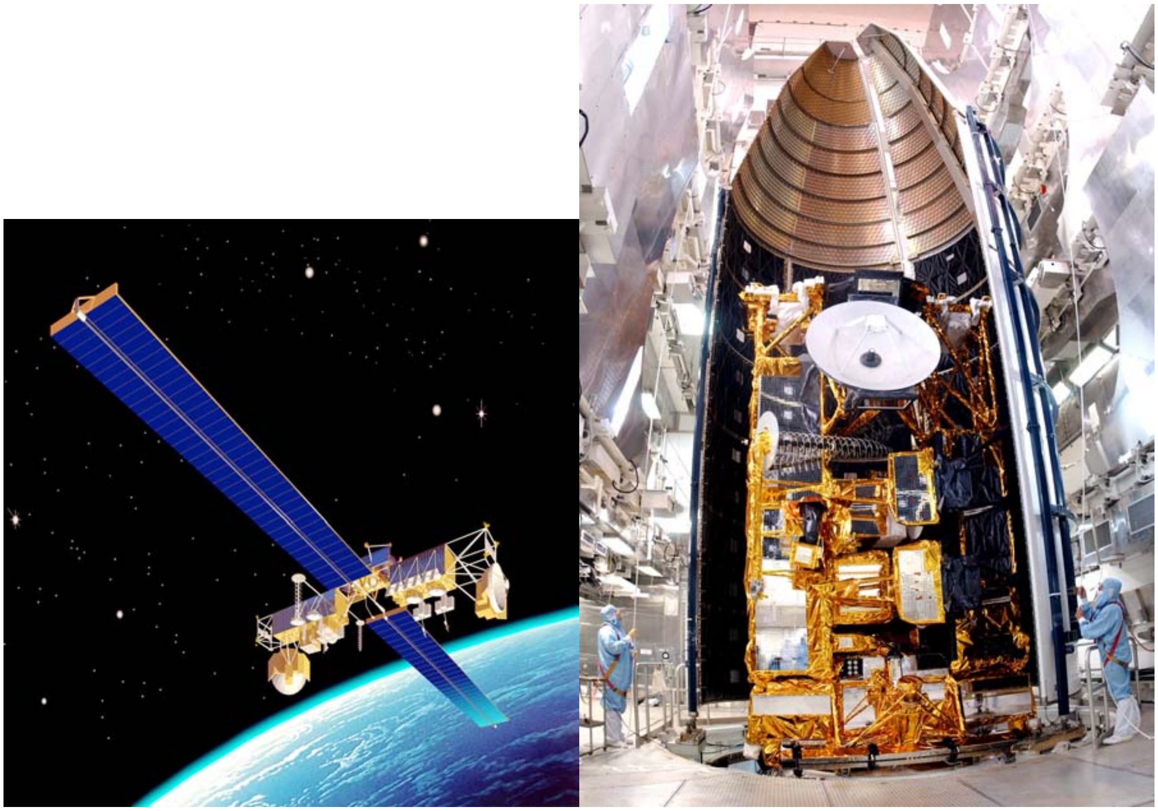
The communications satellites discussed above were all acquired for the U.S. military, but other communications satellites were acquired for the United Kingdom and the North Atlantic Treaty Organization during the 1960s and 1970s. The British Skynet program began in 1966. The first of two Skynet I satellites was placed into orbit on 21 November 1969 and provided the United Kingdom with its first military communications satellite system. The second Skynet satellite was launched from Cape Canaveral on 19 August 1970, but a malfunction in the launch vehicle caused permanent loss of contact with the satellite. In 1970, SAMSO and the United Kingdom began development of a more advanced Skynet II satellite system. The first Skynet II satellite was launched on 18 January 1974, but a malfunction in the launch vehicle again caused the loss of the satellite. The second Skynet II satellite, launched on 22 November 1974, attained orbit successfully and was turned over to the United Kingdom in January 1975.

Development of the NATO satellites began in April 1968, with the initial series of satellites being known as NATO II. One NATO II satellite was placed in orbit on 20 March 1970 and another on 3 February 1971. Both the Skynet and NATO satellites were designed to be compatible and usable with each other and with the Defense Satellite Communications System. Work on a more advanced system, NATO III, began in 1973, and three NATO III satellites were successfully launched between 1976 and 1978. The

Left: The first NATO III satellite (NATO IIIA) is prepared for testing by two technicians at Philco-Ford Corporation, the prime contractor. SAMSO launched the satellite successfully on a Delta launch vehicle from Cape Canaveral on 22 April 1976.

constellation was replenished in November 1984, when a fourth satellite was successfully launched.

The next space communications system to be acquired by SMC was Milstar. Milstar I satellites carry a low data rate payload that provides worldwide, survivable, highly jam-resistant communications for the National Command Authority and the tactical and strategic forces.[40] Advanced processing techniques on board the spacecraft as well as satellite-to-satellite cross linking allow Milstar satellites to be relatively independent of ground relay stations and ground distribution networks. Space Division awarded concept validation contracts for the satellite and mission control segment of Milstar I in March 1982 and a development contract to Lockheed on 25 February 1983. The first Milstar I was successfully launched[41] on 7 February 1994, and the second, on 6 November 1995. In October 1993, SMC awarded a contract for development of the Milstar II satellite, which carried both low and medium data rate payloads. The addition



Left: An artist's concept depicts a Milstar II satellite in orbit. Right: The fifth Milstar satellite is enclosed in the payload fairing on top of its Titan IVB launch vehicle. Its successful launch on 15 January 2002 completed the operational constellation of four Milstar satellites. (Images courtesy Lockheed Martin Missiles and Space)

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[40] Unlike DSCS, which operated in the SHF range (superhigh frequency: 3,000-30,000 megaherz), Milstar operated in the EHF range (extremely high frequency: 30,000-300,000 megaherz). EHF had rarely been used for military communications before Milstar. This frequency range provided natural resistance to jamming. EHF also allowed users to employ smaller, highly mobile terminals.

[41] All Milstar satellites have been launched on Titan IV or IVB vehicles.

of the medium data rate payload greatly increased the ability of tactical forces to communicate within and across theater boundaries. Only four Milstar II satellites were produced because DOD had decided in 1993 that they were to be replenished by a new, lighter, cheaper series of Advanced EHF satellites. Unfortunately, the first Milstar II satellite went into an unusable orbit on 30 April 1999. The next two Milstar II satellites were successfully launched on 27 February 2001 and 16 January 2002 to complete an on-orbit constellation of four satellites. The sixth and last Milstar satellite was successfully launched on 8 April 2003.

In view of the limited future of the Milstar system, SMC also began the acquisition of a follow-on EHF[42] military communications system, known ultimately as the Advanced EHF system or AEHF. The system would be compatible with Milstar elements and would incorporate them throughout their useful lifetimes. Like Milstar, but greatly enhanced, the AEHF system would feature on-board signal processing and satellite crosslinks to eliminate reliance on ground stations for routing data. Data uplinks to the satellites and crosslinks between satellites would operate at EHF, and downlinks would operate at SHF. Whereas Milstar offered low and medium data rate payloads, AEHF satellites would have high data rate payloads as well, providing up to 8.2 million bits of data per second. All services would use AEHF terminals, which would be located on a wide variety of platforms on land, sea, and air. By 2003, plans called for Delta IV and Atlas V launch vehicles to begin launching an operational constellation of three AEHF satellites into inclined geosynchronous orbits in 2006. SMC awarded two competitive contracts for system definition of AEHF on 23 August 1999.[43] On 16 November 2001, it awarded a contract to the team of Lockheed Martin and TRW for a System Development and Demonstration phase of the AEHF system, including production of the first two satellites and the Mission Control Segment.

In 2000, SMC also led a multi-service program to acquire a new series of communications satellites known as the Wideband Gapfiller Satellite (WGS) system to augment DSCS III after about 2004 and finally replace it. Ultimately, WGS would create an Advanced Wideband Satellite system beginning in about 2008. However, the capabilities of the WGS system would be vastly enhanced in comparison to DSCS. WGS would be able to support 96 channels of communication, and it would provide not only two-way tactical military communications, but also a network for a new one-way, wideband satellite broadcast system called the Global Broadcast Service (GBS).[44] SMC

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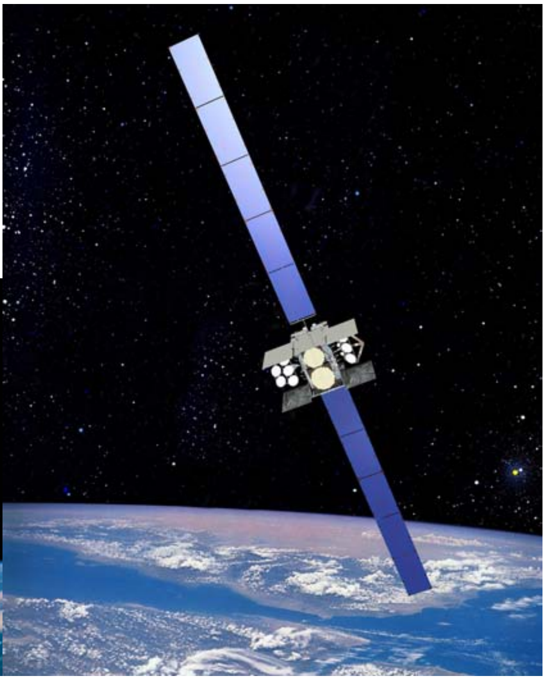
[42] See note 40 above.

[43] However, these contracts were later modified because of a change in acquisition policy. The System Definition Phase was completed with Lockheed Martin as the prime contractor and with TRW (acquired by Northrop Grumman in 2002) and Hughes as the major subcontractors.

[44] The Global Broadcast Service, a joint-service program, became operational about 1999, using its own transponders on the Navy's UHF Follow-on satellites. GBS was a system for extremely rapid, one-way transmission of high-volume data such as weather, intelligence, and imagery from higher echelons to large groups of dispersed users with small, mobile receivers.

awarded a contract[45] for design and advance procurement of WGS to Boeing Satellite Systems on 7 January 2001. Planners envisioned a constellation of three to six WGS satellites launched on Delta IV and Atlas V vehicles. On 31 January 2002, SMC authorized Boeing to begin production of the first two satellites, and it authorized production of the third satellite on 21 November 2002.

Below: Artist's concept of an Advanced EHF satellite in orbit. Plans called for these satellites to augment and replace the Milstar system.
Right: Artist's concept of a Wideband Gapfiller satellite in orbit. Plans called for these satellites to augment and replace the DSCS constellation.



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[45] The contract for procurement of the Wideband Gapfiller Satellite was a "near commercial" acquisition, one important feature of which was that little technological development was involved, since most of the components could be obtained commercially.