The Legacy History Series

A History of the Military Polar Orbiting Meteorological Satellite Program

CENTER FOR THE STUDY OF
NATIONAL RECONNAISSANCE

A HISTORY OF THE MILITARY POLAR ORBITING METEOROLOGICAL SATELLITE PROGRAM

R. Cargill Hall

September 2001

OFFICE OF THE HISTORIAN
NATIONAL RECONNAISSANCE OFFICE

CONTENTS

ILLUSTRATIONS

Preface

In 1961, at the height of the Cold War, a director of the National Reconnaissance Office (NRO) authorized the construction and launch of a small meteorological satellite to support CORONA and other film-limited imaging satellite systems. Though undertaken as an "interim" measure while awaiting completion and launch of a national weather satellite, in the months that followed the NRO spacecraft would incorporate so many desirable features and perform so admirably that it became the template adopted for all American civil and military low altitude meteorological satellites. I researched and wrote the first installment of this history, which covered these actions and events, using available classified records while assigned temporarily to NRO headquarters in the mid 1980s. After returning to the NRO as its historian in the late 1990s, and upon declassification of the original work and endnotes in February 2000, I shared it with the early program participants and completed the story through the turn of the Millennium and the consolidation of American military and civil meteorological satellite programs into a National Polar-orbiting Operational Environmental Satellite System (NPOESS).

People act. They make decisions that trigger events. To the extent practical, this brief history turns on the people who shaped the story, particularly for the early NRO years when the effort was highly classified, handled in compartmented channels, and little known even to those who received and used the meteorological products. The people on which I focused in this story, the successive program directors and their immediate associates, brought to the meteorological satellite enterprise different technical skills and management approaches—all of them operating in a bureaucratic framework that changed with organizational realignments. Over the years, as the program moved from the NRO to the regular Air Force, and eventually to the Department of Commerce, they found themselves dealing with more federal regulations, more officials whose approval they required before choices and actions could be made or taken, and much more Congressional oversight. That they acted to identify and select the best outcome for this national effort I think goes without saying. That the choices made often produced outcomes that departed markedly from initial expectations is likewise apparent.

The scope of this work, limited primarily to the program itself, did not permit its treatment in the larger political and social context.* I touch on but do not explore and analyze the

---

*In terms of its social and economic ramifications, for example, nighttime images of the Earth furnished by program's interactions with the major contractors, with officials in other federal agencies such as the National Aeronautics and Space Administration and the National Oceanographic and Atmospheric Administration, or with Congressional representatives and their staffs who, by the mid 1970s, largely determined how many and what kinds of meteorological satellites would best serve the country. A comprehensive history remains to be written. In that effort, I hope the historian of record will find in this work a useful building block. Not all readers will agree with my interpretation of events, or with my skepticism about the outcome of a cost-effective, combined military-civil NPOESS. Noteworthy military attempts to specify and contract for "one size fits all," except perhaps for certain hosiery, mostly have failed in terms of meeting diverse performance requirements on a fixed schedule and at a reduced cost. I would be pleased, however, if the NPOESS team overturns precedent. Any errors of fact that remain are mine.

R. Cargill Hall
September 2001

---

defense meteorological satellites (such as Fig. 16. in this monograph), permitted geographers and social scientists to make informed estimates of population densities in various regions. Cf., C. D. Elvidge, K. E. Baugh, E. A. Kihn, and E. R. Davis, "Mapping City Lights with Nighttime Data from the DMSP Operational Linescan System," *Photogrammetric Engineering and Remote Sensing,* Vol. 63, No. 6, 1997, pp. 727-734; Paul Sutton, Dar Roberts, Chris Elvidge, and Hank Meij, "A Comparison of Nighttime Satellite Imagery and Population Density for the Continental United States, *Photogrammetric Engineering and Remote Sensing*, Vol. 63, No. 11, 1997, pp. 1303-1313; and Paul Sutton, "Modeling Population Density With Nighttime Satellite Imagery and GIS," *Computer, Environment, and Urban Systems*, Vol. 21, No. 3/4, 1997, pp. 227-244.

Successful operation of overhead photoreconnaissance satellites, the RAND Corporation had warned the Air Force in the mid 1950s,[1] depended on accurate and timely meteorological forecasts of the Sino-Soviet landmass. Such forecasts would make possible cloud-free photography over areas of interest. Indeed, pictures of clouds retrieved from a film-limited spacecraft cost dearly—a fact made plain in 1960-1961 by the images returned from early CORONA missions. When an interdepartmental study of the subject ended in April 1961, however, the National Aeronautics and Space Administration, or NASA, received the U.S. franchise to establish requirements and develop meteorological satellites for both the Departments of Commerce and Defense in the National Meteorological Satellite Program. This program, its proponents contended, would avoid duplicated effort and produce at less cost a single National Operational Meteorological Satellite System (NOMSS) to meet all civil and military forecasting needs, including presumably those of the National Reconnaissance Program (NRP).[2]

But in the Pentagon in 1961, Under Secretary of the Air Force Joseph V. Charyk, who also headed the National Reconnaissance Office (NRO), remained unconvinced. NOMSS, at best two or three years away, also was supposed to support international meteorological data exchanges, an objective inconsistent with contemporary NRP requirements for secrecy. Moreover, the television camera of NASA's first experimental, "wheel-mode" TIROS weather satellite, spin stabilized to inertial space and launched the year before on 1 April 1960, viewed only an oblique swath of the Earth's surface occasionally in each orbit instead of once each time it revolved. Charyk knew that NASA officials did not believe a spin-stabilized weather

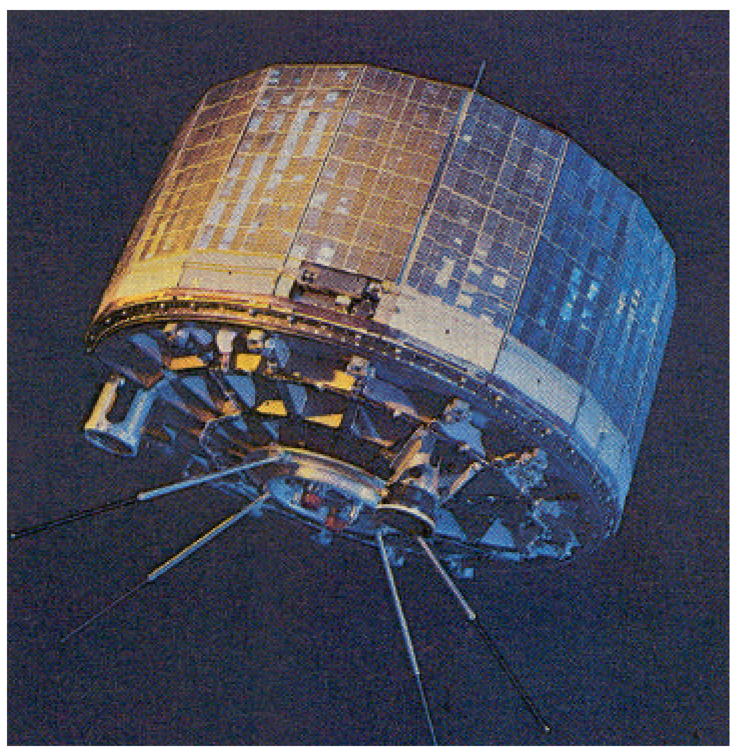

Fig. 1. TIROS Experimental Weather Satellite, 1960 (Note the vidicon lens at bottom left on the satellite.)

satellite that would keep its spin axis perpendicular to its orbit plane could be developed soon—and certainly not inexpensively and in time to furnish strategic meteorological forecasts for reconnaissance satellite flight operations in 1962.* He therefore acted to create an "interim" meteorological satellite program for the NRO. In the event, that program also would fashion the technology and flight operations for what would become the polar orbiting, low altitude national weather satellite system administered by the National Oceanic and Atmospheric Administration (NOAA).

A Temporary Meteorological Satellite Program

On 21 June 1961, Charyk spoke with Major General Robert E. Greer, Director of the Office of the Secretary of the Air Force for Special Projects (SAFSP) in El Segundo, California. He asked Greer to prepare a "minimum" proposal for four "Earth-referenced" wheel-mode weather satellites to be launched on NASA Scout boosters. Greer responded with just such a plan for a 22-month program, one that specified a small fixed budget and a first launch in ten months. The Deputy Secretary of Defense approved it, and the Director of Defense Research and Engineering, Harold Brown, made available to the NRO the necessary funding. On 27 July 1961 Greer's deputy, Colonel Harry Evans, appointed Lt. Colonel Thomas O. Haig the first director of the Defense Meteorological Satellite Program (DMSP).† Haig, a meteorologist and electrical engineer, accepted the assignment on condition that he would *not* have to use the resident "systems engineering and technical direction" contractor,‡ could select his own small staff, and could use fixed price, fixed delivery contracts under his direct control throughout the program. Evans added a "kill switch" of

---

*TIROS (Television Infrared Observation Satellite) had emerged from the Air Force WS-117L reconnaissance satellite competition back in 1956. After Lockheed won the primary contract, RCA officials, whose proposal had not been selected, sold the concept of a television infrared weather satellite to the Army Signal Corps at Belmar, New Jersey, which, along with the Advanced Research Projects Agency, funded further work. After NASA began operating in October 1958, it acquired TIROS along with a number of the key Signal Corps personnel. As the 1960s began, plans called for equipping TIROS with infrared horizon sensors that would determine horizon crossings and trigger picture taking of the scenes below.

†This program, needless to say, had a succession of numeric and alphabetic names, including Program II, P-35, 698BH, 417, and Defense Systems Applications Program (DSAP). In order to avoid confusion, the current designation DMSP is used throughout this history.

‡To Haig's view, an SE&TD contractor could only justify its existence by introducing changes. Since changes involved time and cost money, SE&TD support was incompatible with fixed price, fixed delivery contracting. See Thomas O. Haig, "'Technical Direction': Outmoded Management Concept?" in *Perspectives in Defense Management*, Industrial College of the Armed Forces, May 1967.

his own: if the first launch could not be met on schedule or if costs appeared certain to exceed the fixed budget, he instructed Haig to terminate the program and recover government funds immediately without further direction.[3]

In the months that followed, the DMSP effort operated on NRP funds under the NRO security blanket, but located physically outside the NRO Special Projects Office in El Segundo for purposes of cover and ease of operations.[4] Haig divided the work among those he initially selected: three officers and Renell LaBatt, "a very busy secretary."[*] He invested his own time in program management, with special attention paid to a contract he negotiated with RCA for the weather satellite. Captain Stephen Dvorchak, joined later by Captain Richard Geer, was assigned the Scout launch vehicle; a small, four-stage, solid propellant rocket built by Chance Vought and procured under NASA direction. To meet program performance requirements, Dvorchak substituted a high acceleration Lockheed Propulsion Company MG-18 solid-propellant motor in place of the standard Scout fourth stage Altair motor. Captain Luin Ricks handled ground support, tracking, command, and readout at the Air Force ground stations operated by the Lockheed Missiles and Space Division (LMSD). Finally, Major Charles Croft oversaw contract management at all the various firms involved, novel contracts that were "fixed price" instead of the customary "cost plus fixed fee."[5] The RCA fixed-price, fixed-delivery contract proved itself in December 1961 when a major structural member of the weather satellite, the base plate, failed during tests and company officials requested a three month delay for redesign. Croft, after discussion with Haig, advised RCA that it had ten days to produce a fix or the contract would be terminated under procurement regulations "at no cost to the government." The

Fig. 2. Lt. Col. Thomas O. Haig, First DMSP Program Director

[*]By the end of 1962 the program office staff had increased to five officers and two secretaries, including Etta Holt. Three or four SAC officers also were assigned at that time, involved primarily with the Scout launch vehicle and ground support. This small number grew to about 15 military and civilians by the mid-1960s, when the program transferred from the NRO to Air Force Systems Command.

RCA program manager appeared three days later with revised internal schedules that met the original launch date.

Neither the Scout booster nor the RCA satellite mounted redundant equipment, and a failure anywhere in the system meant the loss of a mission. All of those involved regarded the enterprise as a single purpose, minimum cost, “high-risk” program. Smaller and lighter than the original TIROS, the 100-pound TIROS-derived RCA satellite was shaped like a 10-sided polyhedron, 23-inches across and 21-inches high. A spinning motion, introduced on injection into orbit, was maintained on the early NRO weather satellites at about 12 rpm by small spin rockets. By adopting a concept advanced by Haig and Lt. Ralph Hoffman, however, the spin axis was maintained perpendicular to the orbit plane by torquing the satellite against the Earth's magnetic field, the forces supplied through a direct-current loop around the satellite's perimeter. A ground command would cause the electric current to flow in the desired direction to generate the torque. Those few NASA officials who knew about it viewed the NRO-Air Force program as a no-risk test of a modified four-stage Scout with an “Earth-referenced” wheel-mode weather satellite.[6]

If it operated correctly, the RCA shuttered television camera (a photosensitive vidicon tube) would be pointed directly at the Earth once each time the satellite rotated. At the programmed interval, when infrared horizon sensors indicated the lens was vertical to the Earth, the vidicon would take a picture of an 800-mile-square area of the surface below, with the image recorded on tape as an analog signal for later transmission to the ground. Launched into a sun-synchronous 450 nautical mile circular polar orbit, the RCA television system would provide 100 percent daily coverage of the Northern Hemisphere at latitudes above 60 degrees, and 55 percent coverage at the equator. Readout of the tape-recorded pictures was planned to occur on each pass over the western hemisphere; at the ground stations, the video pictures of cloud cover over the Eurasian landmass would be relayed to the Air Weather Service's Air Force Global Weather Central collocated with Headquarters Strategic Air Command at Offutt AFB, near Omaha, Nebraska.[7]

Haig's "blue suit" program team met its ten-month schedule, although, as the high-risk aspects of the effort suggested, without immediate success. The polar-orbiting DMSP satellites were to be launched from the West Coast range on Point Arguello, at Vandenberg AFB, located near the town of Lompoc, California. As events transpired, a standard four-stage Scout booster carrying an NRO GRAB satellite was first in line, and was viewed as a system test by the DMSP office. This vehicle, launched on 25 April 1962, ended in a Scout booster failure within sight of those in the blockhouse. The temperamental Scout booster, this time with an MG-18 fourth stage, failed again during launch of the first NRO weather satellite on 23 May when the vehicle self-destructed towards the end of second stage ignition. The second DMSP launch on 23 August 1962 resulted in success, although the Lockheed ground-control team failed at first to track the weather satellite. Each day at high noon the vehicle took pictures as it transited the Soviet Union. Weather pictures of the Caribbean returned by this vehicle two months later in October also proved crucial during the "Cuban Missile Crisis," permitting effective aerial reconnaissance missions and reducing the number of aerial weather-reconnaissance sorties in the region.[8]

Fig. 3. First DMSP Launch, 23 May 1962

Lt. Colonel Haig reported to General Greer at the NRO Special Projects Office in El Segundo, but Joseph Charyk took a personal interest in the affairs of the weather satellite program initiated to satisfy NRP requirements.* That program now possessed the first U.S. military satellite

*The DMSP Program Manager normally briefed Charyk monthly at NRO Headquarters in the Pentagon, and then back-briefed General Greer on his return regarding any directions he had received from the DNRO.

Fig. 4. Joseph V. Charyk,
Under Secretary of the Air Force

to be commanded and operated on orbit on a daily basis over an extended period of time. (The first spacecraft ultimately ceased transmissions on 23 March 1963.) At the Pentagon on the morning of 24 September 1962, Charyk advised Haig that NASA's planned Nimbus weather satellite, or NOMSS, would be delayed, and that he should plan one additional year for the interim NRO meteorological satellite program. Haig, who had guessed as much, had next year's budget charts ready. Lockheed claimed a major part of the total budget for ground-support operations, but, the Lt. Colonel insisted, he could build two ground stations and a control center, man them with blue-suiters, and operate the weather satellites in support of the NRP for one-eighth the amount bid by the contractor.[9]

Under Secretary of the Air Force and NRO director Charyk approved the cost-saving proposal on the spot. Then he picked up the phone and called Air Force Chief of Staff General Curtis E. LeMay and arranged for an appointment. That afternoon at the Pentagon, Haig explained to the Chief of Staff how Air Force personnel could man and operate two weather satellite ground stations and a control center. The general listened intently and, when Haig left an hour later, “it was with a promise of all the people I needed from the Strategic Air Command [SAC] and, ‘if anybody gets in your way, call me!’” from LeMay. At the General's direction, Haig boarded an airplane bound for Omaha and, next day at Headquarters SAC, briefed CINCSAC General Thomas S. Power and his staff. SAC’s leaders promptly committed to the Defense Meteorological Satellite Program all the personnel it required.[10]

During the ensuing weeks, program personnel worked at all hours, every day. They found surplus Nike anti-aircraft rocket sites in the states of Maine (near Loring AFB), and Washington (near Fairchild AFB), procured six large van bodies from Norton AFB in San Bernadino, located two abandoned antenna mounts on Antigua Island in the Caribbean, and wrote a fixed-price contract with Radiation Incorporated for two 40-foot radar dishes and associated electronic gear. In between, they helped screen SAC military personnel "until we had two groups of very good men" to operate the tracking stations. In July 1963, ten months after go-ahead, the program office transferred DMSP satellite ground tracking and readout from Lockheed to its own stations in Maine and Washington. About the same time, a command and control center for the DMSP manned by SAC personnel began operating one floor below Air Force Global Weather Central in Building D, the old Martin bomber plant, next door to SAC Headquarters at Offutt AFB, Nebraska.[11]

Fig. 5. Air Force Surplus Antenna Mount with 40 ft. Diameter Reflector Adapted for DMSP

The first DMSP weather satellite to be controlled at the ground stations manned by Air Force personnel was flight number three launched on 19 February 1963. At Vandenberg AFB, another Air Force team, the Systems Command 6595th Aerospace Test Wing, conducted launch operations.* In this instance, the Scout booster upper stages again malfunctioned and placed the satellite in an orbit unsuited to strategic weather reconnaissance operations for more than a few months at best. In late April, the satellite's primary tape-recorder control circuit failed and with it the storage of primary data for later commanded transmission, although direct vidicon readout continued for a few weeks more. A new experiment, however, continued to function nicely for

---

*A few years later, when the Thor booster replaced Scout as the DMSP launch vehicle, launch duties transferred from the 6595th ATW to SAC's 4300th Support Squadron, which had experience with Thor rocket launches. "It was a source of great pride to SAC," Richard Geer recalled, but the transfer proved "galling to some in the 6595th." Moreover, office reasoning held, "SAC would not tolerate launch failures."

many months: an infrared radiometer that registered the Earth's background radiation and indicated the extent of nighttime cloud cover.* At Global Weather Central, the 3d Weather Wing used computer programs written by Air Weather Service personnel to produce crude operational maps of the cloud cover at night over the regions observed until January 1964. Indeed, the infrared experiment proved so successful that it was mounted on all DMSP satellites through Block 4, eventually also providing measurements of cloud height and the Earth's heat balance.[12]

Fig. 6. Night Launch of the Third DMSP, 19 February 1963

The fourth and fifth DMSP launches on 26 April and 27 September 1963 resulted once again in Scout booster failures. The gap in weather reconnaissance that began in May 1963 would continue until January 1964. And, despite appeals for changes in design and testing that the program office requested to improve reliability, NASA officials who procured Scout vehicles for the NRP refused to make them. After considering other booster prospects, on 23 October 1963 Colonel Haig, with the approval of Joseph Charyk's successor, Air Force Undersecretary Brockway McMillan, cancelled the last two Scout vehicles on the original LTV contract and all six of them on a follow-on order. He followed that action by terminating completely all NASA Scout-related activities on 25 October.[13] Five launches in two years had yielded three Scout booster failures and increasing NASA intransigence. In the National Reconnaissance Program, the space agency and its erratic Scout booster had struck out.

Since the fourth Scout launch, Haig and Richard Geer actively had sought a replacement booster that would provide improved reliability and at least equivalent weight-lifting capacity. They knew that a number of liquid-propellant SM-75 Thor intermediate-range ballistic missiles, returned

*David S. Johnson, at that time manager of the TIROS weather satellite program in the Weather Bureau and one of the few persons there cleared to know about DMSP, referred various experiments to the NRO-Air Force program including a novel one conceived by Vernor Suomi at the University of Wisconsin that weighed about six ounces, including a tiny wire recorder, and produced course but useful data on the radiated heat of cloud cover, from a few months before from England as part of the U.S. concession in the Cuban Missile Crisis, were stored in San Bernadino. They also were acquainted with an FW-4S solid-propellant rocket motor produced by the United Technology Corporation. This rocket was cast in the same motor casing as the Scout fourth stage, and, mounted on the Scout spin table, would comprise the second stage of what would become known as the "Burner I" launch vehicle. For this launch vehicle, Douglas Aircraft replaced the IRBM inertial guidance system with a Bell Telephone Laboratory guidance package and added a cold gas coast attitude control section on top of the Thor to keep the axis of the FW-4S injection stage properly aligned.[14] Approved by the NRO director McMillan in December 1963, and by CINCSAC General Thomas S. Power (SAC personnel would now launch the new vehicle and control the weather satellite on orbit) in January 1964, DMSP personnel set to work ordering and testing the Burner I components. A few months later, in March, the Program Office received approval to plan for a new second stage, to be called "Burner II," for a Thor-based launch vehicle. Late in the year, a source selection board chose Boeing to produce the all-new self-guided solid-propellant upper stage. The more powerful Thor/Burner II combination, which eventually employed an additional solid-propellant third stage to increase the weight-lifting capacity, continued to be used in the program until the early 1980s.[15]

Before any "Thor/Burner" mission could be mounted, and to close gaps in strategic weather coverage of the Eurasian landmass after the final Scout launch failure of 27 September 1963, Brockway McMillan also had approved acquisition of two Thor-Agena launch vehicles as interim replacements. Haig's program office pressed them into service. The liquid-propellant Thor-Agena booster combination, also used to launch the CORONA film recovery satellites, was larger and more expensive than needed for DMSP, but it could carry two of the RCA weather satellites into orbit simultaneously. On 19 January and 17 June 1964 Thor-Agenas did just that, successfully placing a total of four DMSP satellites into orbit. In the months that followed, members of the National Reconnaissance Program and SAC had all the meteorological data that they wanted.* A Burner I, meanwhile, ascended properly in its first launch on 18 January 1965, but failed to place its satellite in orbit when the nose fairing refused to separate. Nonetheless, the DMSP Thor/Burner combinations in succeeding months and years achieved an enviable 86 percent launch success

---

which the heat balance of the Earth could be determined.

With the latitude this presented, in December 1964 Haig requested SAC operations personnel to program DMSP picture-taking on passes over Antarctica and have the Air Weather Service send the pictures to the Program Office. Cut and pieced together, the office produced a complete map of the Antarctic Continent that was record before the Atlas booster succeeded it in the 1980s.

At first extended from year to year awaiting the arrival of NASA's NOMSS, by mid-1965 the NRO's "interim" weather satellite effort looked and acted like a formal military space program. As its primary mission, DMSP furnished the NRP daily strategic (morning coverage, primarily, during the first few years) meso-scale observations of cloud distribution and organization over the Eurasian landmass. Beginning in 1965 two DMSP polar orbiting, sun-synchronous weather satellites would normally function in circular orbits at 450 nautical miles altitude. One, a morning bird, passed over the Soviet Union about 0700 local time and relayed weather conditions at first light. A second, late morning (but called a "noon") bird began the same track about 1100 local time, showing the change in cloud cover with the increase in atmospheric heating during the day.

Fig. 7. Night Launch of First Thor-Burner I, 18 January 1965

Reflecting on the accomplishment many years later, Haig counted four early DMSP contributions to astronautics. First, the novel management scheme made possible a small program office that exercised technical direction without the "assistance" of a systems engineering contractor, and its members could get a decision at the NRO and act quickly. The office used fixed-price, fixed delivery contracts, all blue-suit operations, and achieved an excellent success record at an annual cost less than one half that of equivalent NASA weather satellite development programs. Second, because the spin axis of the RCA wheel-mode satellite was maintained perpendicular to the orbit plane by electrically torquing it against the Earth's magnetic field, Haig reasoned that one also could control and maintain a constant spin rate electrically, driving it like the rotor of a direct

subsequently presented to NRO director Brockway McMillan who, by all accounts, was most taken with it.

*See Tables 1 through 8, DMSP Launch Record.

current motor. That would eliminate the solid rockets that produced a spin rate that varied with time and made it difficult to determine the location of the cloud pictures. Written into RCA's second-year contract for an additional four Block 1 satellites, the concept worked in space. Third, when the DMSP ground stations were assembled in 1963, the program office eliminated the costly “boresight tower” used routinely to determine a tracking/readout antenna's pointing vector and a transmitter used to check the receiving system sensitivity during operation. Program personnel substituted instead a technique of scanning the sun to establish the pointing vector with a hermetically sealed low-energy transmitter in the center of the antenna reflector used to check receiving sensitivity. The DMSP station test procedures worked just as accurately and at far less cost; they became standard practice for nearly all tracking/readout systems. Finally, DMSP altered established Air Force techniques of satellite tracking. Captain Luin Ricks refused to believe that the tracking problem was as arcane and costly as Lockheed personnel made it appear. Working with SAC personnel, Ricks prepared a much simpler tracking program* thereafter used with great success by the DMSP ground stations and adopted by the ground stations of other satellite programs.[16]

When in April 1965 Colonel Thomas O. Haig stepped down as the program director, DMSP had eclipsed all other overhead meteorological endeavors. Initial NASA skepticism notwithstanding, DMSP had pioneered the space technology so well, so quickly, and so inexpensively that the space agency, prodded firmly by the Department of Commerce, at that time embraced carbon copies of the DMSP wheel-mode Block 1 satellite, called the TIROS Operational System (TOS), as an interim polar-orbiting weather

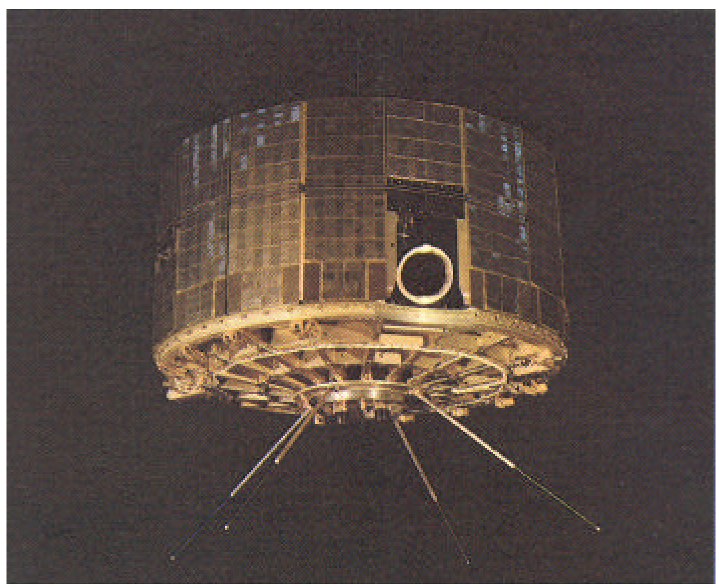

Fig. 8. TIROS Operational System (TOS), Based on the DMSP Block 1 Satellite (Note the vidicon pointing radially to take pictures on each revolution of the vehicle.)

*A single set of punched paper tapes at each ground tracking station eliminated the requirement to transmit an antenna programming tape before each pass. Every pass by a DMSP satellite in any orbit between 250 and 550 nautical miles altitude could be supported by the tape set with a maximum antenna pointing error of 1.5 degrees.

satellite.* And besides the strategic weather reconnaissance furnished to the NRP, the defense meteorological satellites also had begun to provide tactical weather reconnaissance of pre-selected regions to a transportable ground station overseas, with significant effects on military operations in Southeast Asia.[17]

Toward a Permanent Program:
From Strategic to Tactical Applications

Strategic weather reconnaissance recorded for the NRP might command the primary mission of the DMSP, but American military services wanted tactical weather data to meet a variety of operational needs. By 1963 it was plain that NASA's sophisticated, three-axis stabilized, low altitude Nimbus-NOMSS satellite would be extensively delayed and, when finished, likely too complex and expensive to satisfy Defense Department and NRP meteorological requirements—tactical or strategic.† On 23 January 1963 Harold Brown, Director of Defense Research and Engineering, requested a reassessment of tactical requirements by the Joint Chiefs of Staff (JCS). Would the National Meteorological Satellite Program and its planned NOMSS, Brown inquired, meet them? The JCS replied in the negative; its leaders urged that the Defense Department build and operate a commanded direct-readout weather satellite able to relay high-quality, day-and-night tactical meteorological data to transportable ground and shipboard terminals "ASAP."[18]

But the political and bureaucratic climate in 1963 did not favor an all-military tactical weather satellite system. All of the military meteorological satellite requirements would continue to be furnished to NASA and the Department of Commerce for the NOMSS.‡ To assess and combine those requirements, in early 1964 the Defense Department established in the Air Staff a Joint Meteorological Satellite Program Office (JMSPO). After further agitation by the military services, however, the Defense Department and the NRO approved a test of the defense meteorological

---

*The Weather Bureau had launched and tested TIROS 9, the first wheel-mode copy of the DMSP, in January 1965. The first of the TOS built to this standard, called ESSA-1, was launched a year later, in February 1966. Nine of these civil meteorological satellites were launched between 1966 and 1969 for the parent agency at that time, the Environmental Science Services administration.

†A Nimbus first launch scheduled in June 1962 had slipped to 1964; in fact, these vehicles would eventually be directed to research purposes, never to become the NOMSS.

‡The Bureau of the Budget issued BOB circular A-62 on 13 November 1963 that reaffirmed and established policy for Defense Department participation in the National Meteorological Satellite Program.

satellite applied to tactical operations in the 1964 Strike Command Goldfire exercise at Fort Leonard Wood in southwest Missouri. Air Force Global Weather Central at Offutt AFB relayed weather reconnaissance pictures directly to the Army and Air Force users supporting ground and paratroop exercises at the fort, and for the deployment of fighter aircraft on a transatlantic flight. Later in the year, between 24 and 26 November, Global Weather Central furnished tactical weather data over Central Africa to the Military Airlift Command, which proved crucial in the successful airlift of Belgian paratroopers from Europe to Stanleyville in the Congo, where hostages seized in an uprising were freed. The weather data proved to be of considerable value in these tactical operations, analysis revealed, but improvements were needed. Coverage had to be received daily at local ground stations before meteorologists could depend on a satellite as a primary source of data, and a resolution at the surface better than the three nautical miles provided by the DMSP Block-I satellites was judged "extremely desirable."[19]

Fig. 9. Program 417 (DMSP) Military Members at Dining-In, Late 1964
Back Row, Left to Right: Lt. Clifford B. Stearns, Capt. Luin B. Ricks, Lt. Col. Thomas Haig, Lt. Col. Melvin Weinstein, Capt. Richard L. Geer, Lt. Edward R. Foechterle, Lt. Ralph Hoffman, Capt. James F. Roberts, Capt. Calvin H. Markwood.
Front Row, Left to Right: Capt. Melvin F. Chubb, Jr., Capt. C. Neale Elsby, Capt. Harold E. Wakitsch, Robert Anderson (guest speaker), Maj. Richard Turner, Lt. Col. Jim Wayne, Maj. Tom Jones

In Southeast Asia, meanwhile, Radio Hanoi ceased broadcasting local weather observations in September 1964, and Air Weather Service Detachment 14 in Saigon faced forecasting with limited and unreliable data. When U.S. air strikes against North Vietnam commenced in February 1965, Det-14 personnel found themselves unable to meet the demand for weather information from the 2d Air Division and the Studies and Observation Group of the Military Assistance Command Vietnam (MACV), which conducted clandestine operations against North Vietnam. In response, the Air Force, with Defense Department and NRO approval, on 18 March 1965 launched a noontime military meteorological satellite that could be programmed to record and readout specific weather data in Southeast Asia to support tactical operations in the theater. In one of his last official acts in support of that effort, in January Haig planned and laid out the DMSP ground station at Tan Son Nhut Air Base, Saigon, in South Vietnam. The new station was erected and began operating in time to support the satellite launched in March. It furnished to military users, within 30 minutes of receipt, complete cloud-cover data for North Vietnam, South Vietnam, and parts of Laos, China, and the Gulf of Tonkin.[20]

All three military services and MACV put to immediate use the DMSP tactical meteorological data retrieved by Det-14.* In the spring of 1965 commanders could scrub, delay, or recall aerial sorties, or divert them to secondary targets based on hard weather information. The Naval Advisory Group and the MACV Studies and Observation Group used DMSP-generated forecasts to schedule the operation of their fleets of small boats that operated along the coast of the Indo-China Sea and the Gulf of Tonkin. Before long, mobile, air-transportable DMSP ground terminals were installed at Udorn AB, Thailand, and Osan AB, South Korea. Another fixed site, like the original one at Tan Son Nhut, appeared at Hickam AFB, Hawaii. Finally, on 20 May 1965 at Vandenberg AFB, SAC personnel launched a special defense meteorological satellite reserved exclusively for tactical meteorological applications. Weather data from this satellite so improved the timeliness and accuracy of forecasts in Southeast Asia that the military services, in October 1965,

---

*The TOS civil meteorological satellites could not be programmed to observe and record specific areas in Southeast Asia for later readout. They did carry Automatic Picture Transmission (APT) equipment that allowed anyone with receiving equipment to acquire television and infrared images of the Earth as they were being taken. But APT did not provide pictures farther north than its line of sight. DMSP satellites, however, operated in three modes: direct readout, like APT; programmed picture taking of selected regions, with the sequence stored in a tape recorder for readout by a local ground station; and preprogrammed picture taking over the Eurasian land mass. Thus, Det-14 personnel did not use TOS.

cancelled all daily, routine aerial weather-reconnaissance sorties.[21]

These impressive results were enough to prompt action from Defense Department officials who now sought to break the NASA/Department of Commerce franchise on a NOMSS and pursue openly a separate military weather satellite program for strategic and tactical applications. On 22 June 1965, Under Secretary of the Air Force and NRO director Brockway McMillan advised General John P. McConnell, incoming Chief of Staff, USAF, that the DMSP would transfer from the NRP to USAF funding and direction, effective 1 July 1965 (the beginning of FY 1966). The DMSP program office in El Segundo would move from NRO Program A, the Air Force Special Projects Office, to the Space Systems Division next door, in Air Force Systems Command, with Headquarters USAF and Systems Command assuming overall management responsibility for what McMillan termed an "ongoing development/operational program." The Strategic Air Command would continue to launch the satellites and operate the DMSP control center and ground terminals in the continental United States; Air Weather Service would man the direct readout terminals overseas, while continuing to operate Air Force Global Weather Central and process DMSP strategic weather data at Offutt AFB. This program, McMillan observed in closing, "has been entirely a 'blue suit' effort. The cost has been remarkably low; the results have consistently exceeded expectations." Perhaps anticipating an excess of public affairs enthusiasm on the Air Staff, he regretted to say that security restrictions precluded any public recognition of DMSP accomplishments.[22]

This change introduced a more complex dual-management chain. On the Air Staff, overall management responsibility devolved to the Deputy Chief of Staff for Research and Development because the DMSP was programmed and budgeted as an advanced development line item. The director of the NRO retained a strong interest, monitoring DMSP through Air Weather Service personnel assigned to his staff. Operational requirements flowed from the NRO through the Air Weather Service to the West Coast program office. Technical guidance now came from the Deputy Chief of Staff for Research and Development through Air Force Systems Command to the program office. The program office, the focal point at Space Systems Division, exercised authority for planning, directing, contracting, and system engineering.

Making the change to a permanent program complete, a few months later, on 28 September 1965, officials of the Defense Department and the Department of Commerce signed an agreement that eliminated the requirement for prior coordination of "aeronomy" and “meteorological reconnaissance programs.” Thereafter, except for periodic reassessments demanded by the Bureau of the Budget (later the Office of Management and Budget) and Congress,* the Defense Department all but withdrew from the NOMSS concept, and NASA leaders converted Nimbus into a research and development test bed.[23] A few years later, in December 1972, DMSP meteorological data also began to be furnished routinely to the Department of Commerce/National Oceanic and Atmospheric Administration and its National Weather Service at Suitland, Maryland. At that time, security restrictions on DMSP tactical applications were removed.† A few months later in March 1973, Under Secretary of the Air Force and NRO director John L. McLucas publicly announced the existence of DMSP in a Pentagon press conference.[24]

Back in 1964, when tests began of the meteorological satellite applied to tactical military operations at home and abroad, the NRO approved modification of three additional satellites for direct readout. These 160-pound vehicles, identical in size and shape to their 100-to-120 pound Block 1 predecessors, also mounted improved infrared radiometers and were known collectively as Block 2. Launched during 1965 and 1966, two of them attained Earth orbit and provided tactical meteorological data for operations in Southeast Asia. A fourth satellite, the one equipped and launched expressly for tactical uses on 20 May 1965, came to be called Block 3. The reason for this curiosity, a “one-vehicle block,” involved efforts to distinguish it from its Block 2 cousins that also supported the primary strategic cloud cover mission for the NRP. Shortly before he stepped down as DMSP director and control of the DMSP passed to the Air Force Systems Command, in early 1965 Colonel Haig secured permission to begin the design of a more powerful military meteorological satellite that met more completely the demands of its customers.[25]

The Block 4 satellite, slightly larger than those in Blocks 1 and 2, was 30 inches in diameter, 29 inches high, and weighed 175 pounds. Still spin-stabilized, the satellite nonetheless provided improved weather coverage. Previously, the single 1/2-inch focal length RCA vidicon television camera in Block 1 and 2 satellites furnished a nadir resolution of 3-to-4 nautical miles (nm) over an 800-nm swath, with significant gaps in coverage of the Earth at the equator. Block 4

---

*For example, in November 1979 President Jimmy Carter, overriding OMB protests, reaffirmed the positions of the departments of commerce and defense that favored maintaining separate civil and military polar orbiting weather satellite programs until future block changes were adopted. Even that restriction was removed by President Reagan in his 4 July 1982 National Space Policy.

†With the use of DMSP tactical weather data in Southeast Asia, knowledge of the program became widespread. In early 1969 word of this program linked to its tactical applications appeared in the open literature. Practical adjustments that acknowledged at least that part of the enterprise could no longer be avoided. (See "Industry Observer,"

vehicles carried two one-inch focal length vidicons canted at 26 degrees from the vertical that provided global coverage of the Earth (contiguous coverage at the equator), along a 1,500-nm swath. The resolution varied from 0.8 nm at the nadir to 3 nm at the picture's edge. Besides a multi-sensor infrared subsystem, Block 4 also incorporated a high-resolution radiometer that furnished cloud-height profiles. A tape recorder of increased capacity stored pictures of the entire northern hemisphere each day, while the satellite furnished real-time, direct local tactical weather coverage to small mobile ground or shipboard terminals.[26]

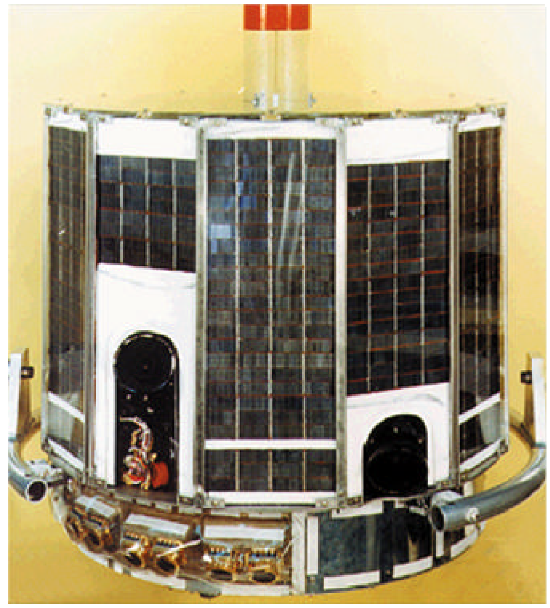

Fig. 10. DMSP Block 4 Satellite

Under the guidance of a new program director and graduate of the U.S. Military Academy, Major John E. "Jack" Kulpa, Jr., eight Block 4 defense meteorological satellites were delivered and seven successfully launched between 1966 and 1969.* Because of the 1965 change in command relationships, however, Kulpa found himself reporting to four bosses instead of two. Not only did the new NRO director Alexander Flax want to be kept advised, his subordinate, the director of the NRO's Air Force Special Projects Office also expected that courtesy, especially since Kulpa had just completed an assignment there directing a research subsatellite program. At Headquarters Air Force Systems Command, General Bernard Schriever took a personal interest in DMSP, while his subordinate, the commander of the Space Systems Division, became the general officer presumably responsible for DMSP. In the event, Kulpa later recalled, "each of them thought that one of the others was my real reporting official, and I was left pretty much alone to prosecute the effort."[27] But the program director could no longer claim the same NRO exemptions from the Air Force -375 series of procurement regulations, and his office staff found itself encumbered increasingly with "operational requirements," "development plans," and other accoutrements of the formal Air Force acquisition process.

Shortly after assuming command, Kulpa began work on the next series of weather

---

Aviation Week and Space Technology, 27 January 1969, p. 13.)

* All seven successfully achieved orbit. The eighth vehicle, not needed for operational requirements, was

satellites, DMSP Block 5. He delegated instrument requirements and design of the spacecraft to two able subordinates, Captain Richard Geer who had previously shepherded launch vehicles, and Major James Blankenship, who had previously supported Haig while acting chief of the Technical Services Branch, Headquarters Air Weather Service (AWS). Blankenship had just returned from the Royal University in Stockholm where he had completed a Ph.D. thesis on Atmospheric Photo Chemistry. Brilliant with an eminently practical turn of mind, he played a predominant role in the payload design that made Block 5 especially user-friendly, such as formatting of the imagery to standard AWS weather chart scales. Moreover, Geer recalled, he possessed "excellent long-range vision, seeing data applications, technology solutions, and political ways and means far into the future. His expertise in weather phenomenology, his aggressive attitude, his persuasiveness, and a unique [NRO access via the AWS] . . . combined to make him arguably the most powerful person in the SPO [system program office]."[28]

Fig. 11. Col. John E. "Jack" Kulpa, DMSP Program Director 1965-1968

Indeed, the revolutionary Block 5 spacecraft that resulted from the efforts of Geer and Blankenship took the form of an integrated system; it departed entirely from the TIROS-derived technology of its predecessors. The two men visited meteorologists at work, and then examined what the industry could produce. Instead of starting with a sensor in space and determining what it might tell the user about the weather, these two based the Block 5 design on the users' wish to receive a product in a form that approached as closely as possible the weather charts and maps that they, the meteorologists, employed. Moreover, the product furnished the albedo of each scene, not its brightness, which varied enormously from full sunlight to partial moonlight.[29] A survey of the industry and new technologies revealed line scanning sensors and advances in highly sensitive visible light and infrared point (as opposed to array) detectors. Instead of using complicated

donated to the Chicago Museum of Science and Industry.

electronics to scan the raster of a TV camera, they reasoned, one now could let the motion of the satellite provide the scanning along the line-of flight. That would require a spacecraft that always "looked down," rather than one that wheeled along its orbit. But a satellite stabilized on three axes would make possible acquiring a strip of imagery of indefinite length, imagery that could be rectified at will.[30]

Some 200 hours of flight tests of experimental sensors, conducted by Captain Melvin F. ("Nick") Chubb in a T-39 aircraft, produced line scan images that a newly promoted Lt Colonel Kulpa used to secure the approval of the Block 5 design from his superiors in Systems Command. After a source selection competition in May 1966, Westinghouse won the contract to furnish the constant resolution oscillating telescope sensor and ground display equipment, and RCA won the contract to provide the spacecraft bus. The Westinghouse "Operational Line Scanner" (OLS), as it came to be called,* provided images of the Earth and its cloud cover in both the visual and infrared (IR) spectral regions. With this system, nadir visual-imaging resolution at the Earth's surface improved to 0.3 nm during daytime and 2 nm at night through quarter-moonlight illumination levels. The higher resolution (less than 0.5 nm) now satisfied the requirements of tactical users. The infrared subsystem furnished 2-nm resolution at the surface day and night, as well as cloud-height profile and identification of all clouds above or below a selected altitude, and heat-balance data. Complete global coverage was transmitted over encrypted S-Band digital data

Fig. 12. Left to Right: Maj. James R. Blankenship and Captain Melvin F. "Nick" Chubb, Jr. at Block 5 Design Review

*Originally called the "Oscillating Line Scanner," the name was changed by NRO-DMSP personnel who, about to present the case for it at the Pentagon, were advised that the military "good word of the day" was "operational." The OSL thus was sold for development with the new, "operational" name. (James R. Blankenship, letter to the author, 23 September 2000.

links. Block 5 simultaneously satisfied the meteorological needs of the military commander in the field for tactical support, while it met completely the "strategic" requirements of the National Reconnaissance Office. In the months that followed, Blankenship took "shameless advantage of that fact, telling tactical and strategic customers, in turn, that Block 5 had been designed entirely for them. It was true enough."[31]

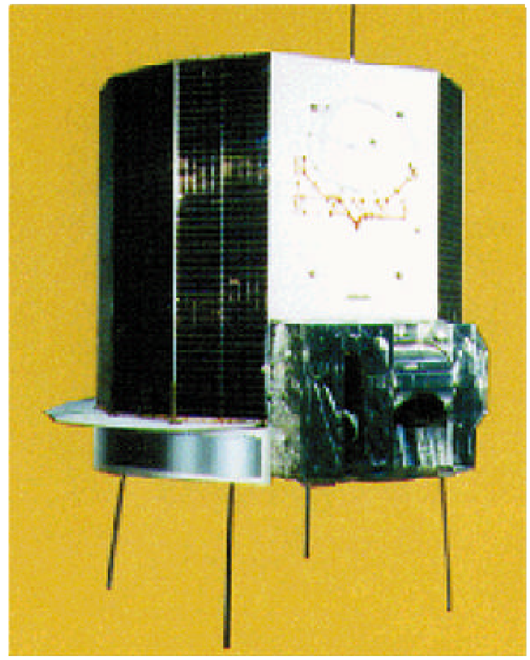

Fig. 13. DMSP Block 5A Satellite

To achieve the pointing accuracy required for the Block 5 line scan sensor, the spacecraft employed a novel momentum-bias attitude-control system. It consisted of a momentum wheel and horizon scanner, and magnetic coils. The wheel and scanner controlled the pitch axis, while the magnetic coils controlled the roll and yaw axes, replacing the momentum dissipated by friction in the bearing between the momentum wheel and the main body of the spacecraft. The slab-sided, tube-shaped Block 5 satellite remained 30 inches in diameter, but its height increased to 48 inches and its weight rose to 230 pounds. Positioned horizontally on orbit, it closely resembled an overturned garbage can. Three Block 5A spacecraft were built before military demands for greater tactical meteorological support dictated further changes.[32]

In 1969, all three military services looked forward to still more tactical weather support from the improved DMSP, and all three sought to obtain it on a daily basis. To that end, the three service assistant secretaries for research and development agreed on a "joint-service utilization plan" for DMSP.[33] On 29 March 1969, John S. Foster, Jr., Director of Defense Research and Engineering, approved the plan[*] and the funds needed to improve Block 5 spacecraft to ensure receipt of DMSP weather data on terminals on board ship.[34] The result was Block 5B and -C. Longer, at 84 inches in height, and heavier, at 425 pounds, these spacecraft exclusively required use

---

[*]The joint-service DMSP use plan would be revised and updated in June 1973, and again in late 1976. Shipboard readout terminals had by the mid 1970s been installed on board the aircraft carriers *USS Constellation* and *USS Kennedy* assigned to CINCPAC and CINCLANT, respectively.

of the uprated booster called Thor/Burner IIA. Block 5B spacecraft added a large sunshade on the "morning birds," a more powerful 20-watt traveling-wave-tube amplifier (TWTA) transmitter that radiated ample power for receipt of the signal on board ships (though it was never used for this purpose operationally), a second primary data recorder, and a gamma-radiation detector. Block 5C added a vertical temperature/moisture profile sensor and an improved IR sensor that now achieved a resolution of 0.3 nm at the Earth's surface.[35]

In all, three Block 5A, five Block 5B, and three Block 5C satellites were built and launched between February 1970 and February 1976.[36] Collectively they furnished the strategic (global, stored) and tactical (direct readout) weather coverage required by the NRO and the JCS, although their operational life expectancy on orbit averaged at best about ten months. Meanwhile, Kulpa had departed the program for another NRO assignment in 1968; Lt. Colonel Wilbur B. Botzong served as his replacement for the next six years, until 1974. Subsequently, a succession of program directors followed him, often in rapid order. Beginning in the mid 1970s, the DMSP staff at the Space Systems Division in El Segundo matured, expanded numerically, and adopted a more lethargic pace of operations. Its early peripatetic activity and corner-cutting solutions to bureaucratic and technical problems became things of memory. Transferring the military meteorological satellite program to Air Force Systems Command in 1965 had reduced security restrictions, to be sure, but it also had introduced bureaucratic layering (absent Colonel Haig's first rule, the Aerospace Corporation now provided systems engineering and integration support), it had returned the program to conventional Air Force contracting and procurement practices, and it had markedly increased the number of program personnel involved in decision-making. Bespeaking these less salutary changes, the program office authorized launch of

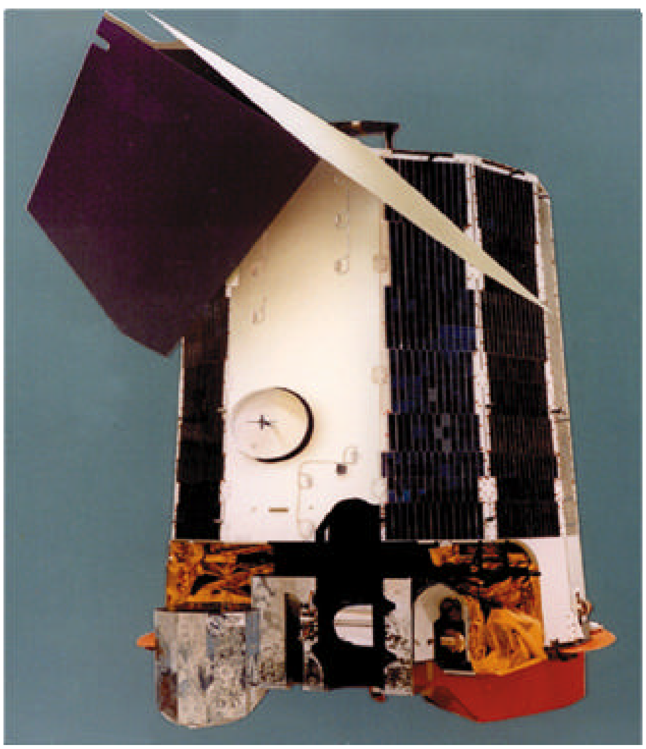

Fig. 14. DMSP Block 5B Satellite

the last Block 5C satellite on 19 February 1976 with incorrect weight-to-propellant-loading calculations. Launched from Vandenberg Air Force Base, the Thor/Burner II booster rose majestically through the atmosphere, reached the edge of space, exhausted its propellant, and the DMSP satellite whistled back to Earth—a total loss.[37]

Fine-Tuning the DMSP

The 10-sided, tub-shaped Block 5 polar-orbiting weather satellite had reached the end of its growth potential by the early 1970s. Moreover, this design, which took advantage of spin-stabilization for internal thermal control, was ill suited to Block 5 operation in a "de-spun" three-axis-stabilized attitude. An entirely new design tailored entirely to Earth-oriented orbital flight, one that met the demands of its military and civilian clients for increased pointing accuracy and more growth potential, appeared necessary. Indeed, beside offices of the National Oceanic and Atmospheric Administration in Suitland, Maryland, that began routinely to receive DMSP weather data in late 1972, a digital facsimile system had been installed in September 1972 at the National Military Command Center to receive weather data transmitted from Air Force Global Weather Central to the JCS. Shortly thereafter, a second digital facsimile system was installed at Headquarters Tactical Air Command at Langley AFB, Virginia, and a third at the Army's White Sands Missile Range in New Mexico, for its use in environmental research.[38]

Another reason for starting a new Block 6 military meteorological satellite derived from the short lifetimes on orbit of the Block 5 series. A larger, heavier machine would furnish space and power for redundant components. If one component failed, another could be activated in its place. Studies of the Block 6 satellite, which proceeded in the late 1960s on the basis of a mean-mission lifetime on orbit of 16 months minimum, began in earnest in the early 1970s under DMSP Program Director Botzong.[*] But DMSP Block 6 with that designation was not to be. In the partisan realm of Washington politics, a new block number meant "a new start." At best it would entail special justification before Congressional Committees and involve unusually close scrutiny in the Office of Management and Budget (OMB). And officials in OMB favored combining the civil and military

[*]Colonel Botzong would see this work completed before he retired in August 1974. Subsequently, he went to work for RCA.

polar orbiting meteorological satellite into one program the met everyone's needs. At worst, a Block 6 would fail to receive approval and spark an effort to merge the two programs. Air Force officials therefore elected to term the new spacecraft a modification: DMSP "Block 5D." For those acquainted with the nomenclature, the earlier Roman numerals used to identify DMSP blocks now converted to an Arabic numeral, which signified a block change. In Washington, politicians unacquainted with its significance appropriated funds for five of the "modified" Block 5D spacecraft in fiscal year 1972.

The program office, however, had introduced a requirement for an Earth-oriented pointing accuracy much greater than the one imposed on it predecessor Block 5C. In the design competition for the new spacecraft conducted between Boeing and RCA, only the latter firm was judged able to meet completely that requirement. A contract for five Block 5D satellites, signed with RCA in the fall of 1972, set a required launch date for the first of them in the fall of 1974. But the greater pointing accuracy and a complement of additional instruments also had increased the projected cost of these spacecraft compared with their predecessors, and it introduced the risk of delays in development.[39]

Whatever its pointing accuracy, and the numerical sleight-of-hand for "Block 5D" notwithstanding, in November 1972 the OMB requested that the Departments of Commerce and Defense reexamine a consolidated civil and military polar orbiting meteorological satellite program, and the possibility of using a single spacecraft to satisfy the demands of both. Either action could be expected to result in substantial dollar savings, and a steering group composed of representatives from NOAA, the Defense Department, and NASA was formed once again to consider these questions. Since the technical capability of the existing Block 5C already exceeded the capability of a planned NOAA successor, TIROS-N, the group's report, issued in mid-1973, concluded that the greatest savings would be realized in a single national meteorological satellite system managed by the Air Force, using a standard DMSP Block-5D satellite. This uncivil solution was quickly rejected by Henry Kissinger, President Nixon's National Security Advisor, who argued that it would violate the National Aeronautics and Space Act, which dictated a separation of military and civil spacefaring, and by officials made uneasy in the Department of State, who warned of adverse international repercussions. Subsequent interagency deliberations led by Air Force Under Secretary James W. Plummer, the director of the NRO, resulted in an agreement in July 1974 to achieve major cost savings by adopting a variant of the DMSP Block-5D military satellite for use in both the civil (replacing TIROS-N) and military polar-orbiting, low-altitude, meteorological space programs. The larger, joint-use version needed by the NOAA to support additional sensors, was identified as Block 5D-2. The five original Air Force-RCA spacecraft thus became DMSP Block 5D-1.[40]

The Block 5D-1 design that had emerged back in the early 1970s resembled in appearance conventional Earth-oriented satellites of this period. Sized to fit the space taken by the Burner IIA solid-propellant upper stage on the Thor, it was five feet in diameter and 20 feet long. The 5D satellite built by RCA consisted of three sections: a square precision-mounting platform on the forward end supported the sensors and other equipment required for precise alignment; in the center, a five-sided equipment-support module contained the bulk of the electronics and featured one or two pinwheel louvers on four sides for thermal control; and, at the aft end, a circular reaction and control-equipment support structure housed the spent third stage solid-propellant rocket motor and contained reaction-control equipment. A deployable, 6-by-16 foot sun-tracking solar array was also mounted aft, on this section. With its complement of additional sensors, the spacecraft weighed 1,150 pounds, making it more than twice as massive as its Block 5C predecessors. To heft the additional weight into orbit, the program office contracted with Boeing for a new, larger, solid propellant second stage. The original Burner-IIA second stage, now adapted as a third stage and fixed to the satellite, was used during ascent to inject the vehicle into its circular, sun-synchronous 450 nautical mile Earth orbit.[41]

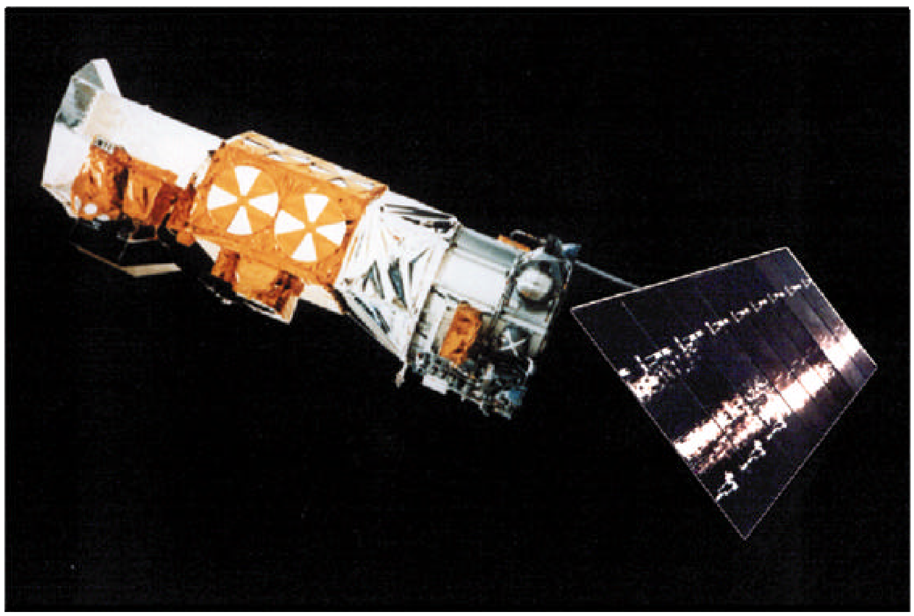

Fig. 15. DMSP Block 5D-1 Satellite

Once in orbit, the 5D-1 RCA spacecraft had to point and control the optical axis of the primary imaging sensor to within .01 degree, in effect making the satellite “a spaceborne optical bench.” This was achieved by automatic momentum exchange between three momentum wheels—

one each positioned in the yaw, roll, and pitch axis—and magnetic coils that interacted with the Earth's magnetic field and prevented the accumulation of wheel secular momentum. The wheels and coils were coupled with three orthogonal gyroscopes that measured short-term changes in attitude, and a star sensor that updated attitude position to bound the effects of gyro drift. A backup system, composed of an Earth sensor that furnished pitch and roll information, and a sun sensor that provided yaw information, ensured attitude control about one-tenth as accurate as the primary system. The software programs for both systems were stored in two redundant central computers and processing units.[42]

Besides performing spacecraft-control functions autonomously on orbit, the integrated 5D computers and attitude-control system also controlled the Thor booster and its upper stages during ascent and orbit injection. A pre-set (but reprogrammable in orbit) software code contained in both of the central computers made possible the autonomous orbital operations. All of these control and maintenance functions were directed to a single purpose: support of the primary imaging sensor, an improved Westinghouse electro-optical Operational Linescan System (OLS). The OLS consisted of a scanning optical telescope oscillated in a sinusoidal (side-to-side) motion by counter-reacting springs and a pulsed motor. In a nominal orbit, the OLS covered a swath width of 1,600 nm and furnished a nadir resolution at the Earth's surface of 0.3 nm in the visual and infrared spectra, with a resolution of 0.5 nm at the edges. The OLS also could produce “smoothed” images with a constant resolution of 1.5 nm across the scan. The visual and thermal data acquired on cloud cover and cloud-height profiles could be stored in three tape recorders for transmission on command to Earth in an encrypted, digital format. Direct readout, of course, also was available to tactical users.[43] The increased amount of data that could not be effectively transmitted over the leased land lines used previously, began to be relayed from the DMSP ground stations to Air Force Global Weather Central at Offutt AFB via commercial communications satellites beginning with the first launch of a Block 5D.

A variety of secondary sensors, some judged as “nice to have,” appeared in different combinations on Block 5D-1 missions. Five of them frequently appeared on the spacecraft. An atmospheric density sensor measured the major atmospheric constituents (nitrogen, oxygen, and ozone) in the Earth's thermosphere on the daylight portion of each orbit. A precipitating electron spectrometer counted ambient electrons at various energies. A scanning infrared radiometer furnished vertical temperature profiles, vertical water vapor profiles, and the total ozone concentration. A passive microwave-scanning radiometer profiled global atmospheric temperatures from the Earth's surface to altitudes above 30 kilometers. Finally, a gamma-radiation sensor furnished by the Air Force Technical Applications Center detected nuclear detonations as part of the ongoing Integrated Operations NUDET Detection System.[44]

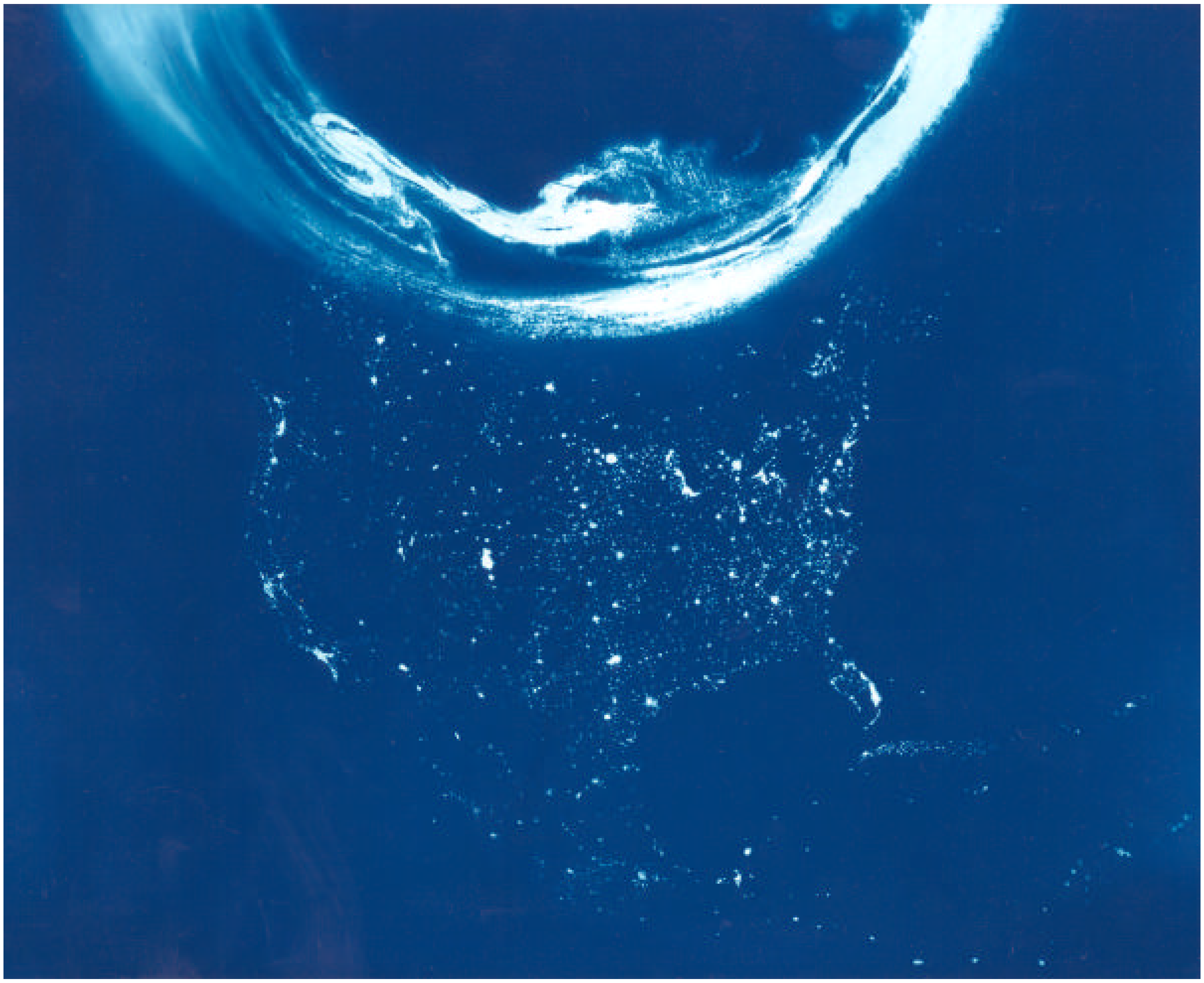

Fig. 16. DMSP Nighttime Image of the Aurora Borealis Taken by the First Block 5A Satellite in 1971 (Note lighted cities from Canada through Central America.)

The complexity of the new satellite and design changes introduced along the way, as some had feared, increased costs and delayed the first Block 5D-1 flight from 1974 until 1976. Air Force Systems Command dispatched an Inspector General's team to examine the program at Space and Missile Systems Organization (SAMSO, formerly the Space Systems Division) in El Segundo in January 1975. At Systems Command headquarters, Major General Nick Chubb, who years before had first flight tested the OLS for DMSP, found one of the findings most alarming: given the life expectancy of the Block 5C spacecraft already on orbit, the two year delay in launching Block 5D-1 could be expected to produce a significant gap in meteorological satellite coverage at the end of the decade. Worse, there was all but nothing that could be done to avoid it.[45]

The value of autonomous flight operation nonetheless was demonstrated during the first launch of the first Block 5D-1 on 11 September 1976. The spacecraft unexpectedly tumbled end-over-end in space. A few months later, intermittent communication with the tumbling satellite was established and ground controllers reprogrammed the computers. The attitude-control system thereafter slowed the rate of tumbling until the satellite stabilized on three axes and began operating properly. A flexible Block 5D design had made possible the recovery of a mission at first believed lost.[46]

Nevertheless, as the inspector general team had warned in 1975, the degraded performance of the remaining 5C spacecraft on orbit, the delay in launching the first 5D-1 vehicle, and the unanticipated loss of the last Block 5C at launch in February 1976 combined to produce poor DMSP weather coverage between 1975 and 1977. The program office was forced to change DMSP status from fully operational to partially operational. Then matters got worse. The second 5D-1 satellite, launched on 5 June 1977, vaulted into a drifting orbit and by the spring of 1978 it had moved so far out of position that most of the OLS data was all but useless to the National Reconnaissance Office. The third and fourth vehicles, launched from Vandenberg AFB on 30 April 1978 and 6 June 1979, respectively, fared better. With these two meteorological satellites operating on orbit, the last 5D-1 vehicle was held for launch as a replacement, when needed.[47]

While the Block 5D-1 enterprise moved ahead, work on the joint-use Block 5D-2, contracted with RCA in 1975, proceeded slowly. Technical changes introduced by the civilian and military co-users, and prolonged studies of the proper booster for the 5D-2, brought more delays and increased costs. In El Segundo, the DMSP program office at the Space and Missile Systems Organization found it necessary to slip the first 5D-2 launch from 1980 to 1982.[48] Meanwhile, between 1975 and 1980, a succession of six DMSP program directors arrived, were reassigned, and left. The era when a Tom Haig or a Jack Kulpa guided DMSP activity for several years at a time appeared to be a thing of the past. In Washington D.C., as the decade drew to a close, the sharp rise in cost of the new Block 5D-2 weather satellite moved cost-conscious members of OMB and Congress in 1979 to reduce the number on order for the Air Force from 13 to 9. Nine long-life follow-on satellites, according to those addressing the question in Washington, were more than enough for the country.[49]

The electronic components of the follow-on satellites remained essentially the same as those in 5D-1, but the 5D-2 structure increased in length from 20 to 22.5 feet. The extension increased the downward-facing sensor-mounting area and lengthened the equipment-support module amidships. That module now contained a second 25.5-amp-hour battery and sported two or three pinwheel temperature control louvers on four of its five sides. The solar array mounted on the aft reaction control equipment-support structure also increased in size to 10-by-16 feet, furnishing increased electrical power. Two important sensors were added to those in the 5D-1 complement: a topside ionospheric sounder provided detailed global measurements of the electron distribution in the Earth's ionosphere, and a microwave imager (flown on the last few 5D-2 satellites) defined the extent of sea ice and sea-state conditions (wave height and patterns) on the world's oceans. Withal, these changes increased the weight of the Block-5D-2 spacecraft to 1,792 pounds—a sum too great for the Thor/Burner booster combination. Heated debates took place between officials in the program office and Aerospace Defense Command, the launch agency at that time, about adapting Thrust Augmented Thors to the task, just to keep a "blue suit" launch squadron. Ultimately, however, the launch vehicle selected for the 5D-2 meteorological satellite in 1980—after 16 months of vacillation—was the General Dynamics Atlas E, an improved version of the liquid-propellant intercontinental ballistic missile deployed briefly in the early 1960s. The solid-propellant Burner IIA upper stage, fixed to the aft end of the satellite, was retained, again used at altitude to drive the vehicle into a circular 450 nautical mile polar orbit.[50]

Fig. 17. DMSP Block 5D-2 Satellite

A Change in Time and Circumstance

A conjunction of events precipitated successes and failures in late 1979. For some around the world, their time had arrived. In mid-October the Pittsburgh Pirates won the World Series in seven games. On 3 November in Tehran, Iran, Shiite militants seized the American Embassy, imprisoned the staff, and dared the United States to do anything about it. A few weeks later, on Christmas Day, the Soviet Union began airlifting military forces into nearby Afghanistan, intent it seemed on securing a vassal state. But for others time had run out. In September 1979 the first of the Block 5D-1 polar-orbiting satellites, which had begun to fail earlier in the year, ceased all effective operations. The third satellite failed to operate on orbit at the beginning of December 1979. Shortly after the New Year began, in March 1980, the second satellite used for tactical weather support in a drifting orbit, also failed. The fourth vehicle, meanwhile, encountered electrical problems, began to falter, and experienced a total telemetry system failure. On 29 December 1979 ground controllers placed it in a "backup mode." The fifth and last Block 5D-1 satellite held in reserve was quickly readied for flight and shipped to Vandenberg AFB. Now, officials in the DMSP program office could only hope for the best. With Block 5D-2 vehicles delayed in development, a first launch could not occur at least until 1982—two years in the future. The sputtering fourth DMSP satellite, to be joined now by the new fifth Block 5D-1 spacecraft, had therefore to function on orbit for an extended period if the nation's strategic and tactical military meteorological needs were to be met completely.[51]

On 15 July 1980, at Vandenberg AFB in California, a Thor/Burner launch vehicle carrying the last 5D-1 satellite roared to life and ascended skyward. For the first time in many years, a Thor/Burner combination failed. The second and third stage solid rockets apparently did not separate, and the satellite fell into the South Pacific. Four weeks later in August, high above the Earth, the fourth and last 5D-1 satellite completely ceased to function. Back in the mid 1970s the program had temporarily operated with a single satellite in orbit. Not since the early 1960s, however, had the program faced an absolute gap in military meteorological coverage. An investigation of DMSP by Air Force Systems Command identified funding cutbacks and program management fundamentally weakened by a rapid turnover of program directors to be the principal contributing causes. The requirement for an extreme pointing accuracy and the much-increased complexity of these machines, which contributed to spiraling costs and launch delays, appeared to escape notice. The deficiencies cited might be rectified by 1982; in the meantime, however, the military services and the NRP would have to rely on NOAA satellites and other programs for tactical and strategic meteorological coverage.[52]

Having to rely on NOAA for satellite meteorological data was a bitter pill for Air Force officials to swallow. For years they had defended DMSP before Congress and the public as "indispensable" to military decision-makers, especially in times of conflict.[53] To be sure, since the mid 1970s, data from NOAA weather satellites had been received on the East Coast and transmitted to Air Force Global Weather Central over an automated weather network, where it could be combined with information from the DMSP satellites and other ground and aerial observations obtained throughout the world. Between mid-1980 and 1983 these data, less that of the military weather satellites, would meet most military needs. Although the NOAA spacecraft were not designed specifically to satisfy fully the high-resolution visual and infrared strategic meteorological requirements of the National Reconnaissance Program, it would no longer be possible for Air Force leaders to claim that these civil spacecraft would not do at all.

At Air Force Global Weather Central, DMSP high-resolution data had permitted its meteorologists to assess the cloud cover over the Eurasian continent and issue rapid forecasts that predicted the percent probability of obtaining cloud-free photography over areas about to be transited by reconnaissance spacecraft. These time-critical forecast probabilities of cloud-free conditions had been the key determinants in directing camera operations and film expenditure.[54] By mid 1980, however, many years accumulation of cloud-cover data from all sources permitted statistical modeling and forecasting. Combined with the NOAA weather satellite data, cloud-cover now could be predicted beforehand and that estimate used to direct overhead imagery operations.

Back in 1963-1964, only 50-to-60 percent of CORONA reconnaissance satellite photographs proved to be cloud-free *with* the support of DMSP meteorological satellites. Part of the difficulty stemmed from meteorologists at the NRO's Satellite Operations Center in the Pentagon who at first failed to properly define cloud cover in terms of the relative viewing angle to the target. Part of it stemmed from the differing terminology used by the intelligence customers who submitted target requirements to the Committee on Imagery Requirements and Exploitation (COMIREX). In 1966 COMIREX adopted as a single standard the World Aeronautical Chart and its subdivisions, called World Aeronautical Grid Cells, or WAG Cells. Each WAG Cell was a uniform 12-by-18 nautical miles on a side around the world. Intelligence customers thereafter submitted target requests to COMIREX identified by WAG Cell location and sorted by ephemeris—whichever satellite orbital trace crossed a particular WAG Cell and at what time. At Offutt AFB, the Air Weather Service's Air Force Global Weather Central began work on a three-dimensional cloud analysis. The programs merged all overhead imaging and civilian weather reports into a global cloud analysis with a spatial resolution of 25 nm on a polar stereographic grid, by date and time of day. By the late 1960s, employing a software program devised by the Air Weather Service, Air Force Global Weather Central could estimate the probability of cloud-free access on any day and time throughout the year for any required target.[55]

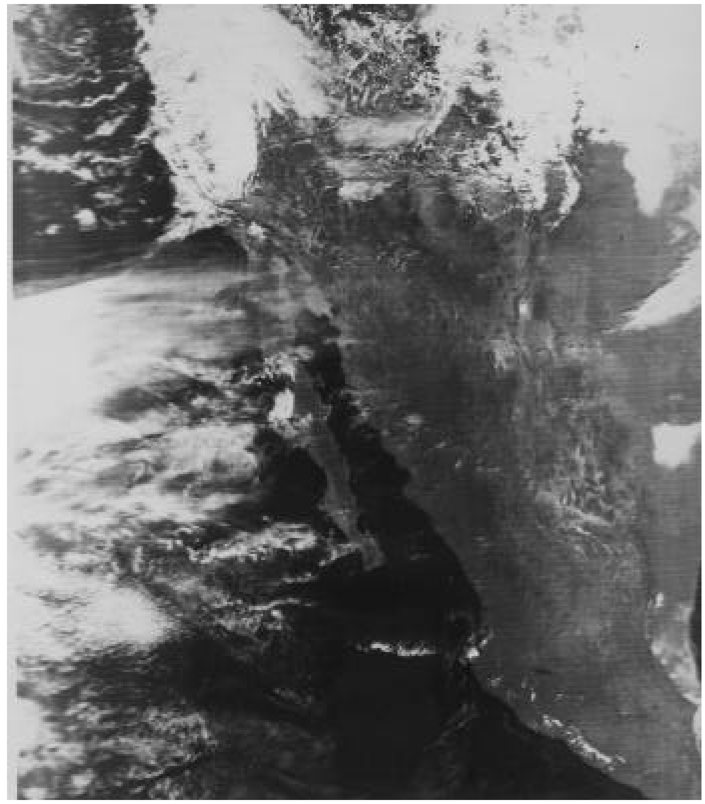

Fig. 18. DMSP Image of the Western United States and Mexico at 1/3 Nautical Mile Resolution, early 1970s

This effort assumed increased importance in 1972 when operation of a new imaging satellite began. The early morning "scout" military weather satellite furnished weather conditions over the Soviet Union at first light. These data, used in the cloud analysis and forecast system, provided cloud-cover estimates that were transmitted from Air Force Global Weather Central to the Satellite Operations Center in the basement of the Pentagon and used as a short-term forecast to program satellite camera operations in the reconnaissance satellites that trailed the weather scout. The late morning "assessment" weather satellite told how accurate the cloud forecast had been, determined whether target requirements had been satisfied, and also contributed data to the weather model. Finally, personnel in the Defense Mapping Agency scanned the film returned by reconnaissance satellites and reported actual cloud cover to Air Force Global Weather Central afterward, further contributing to the weather model data base.[56] By the late 1970s a high percentage

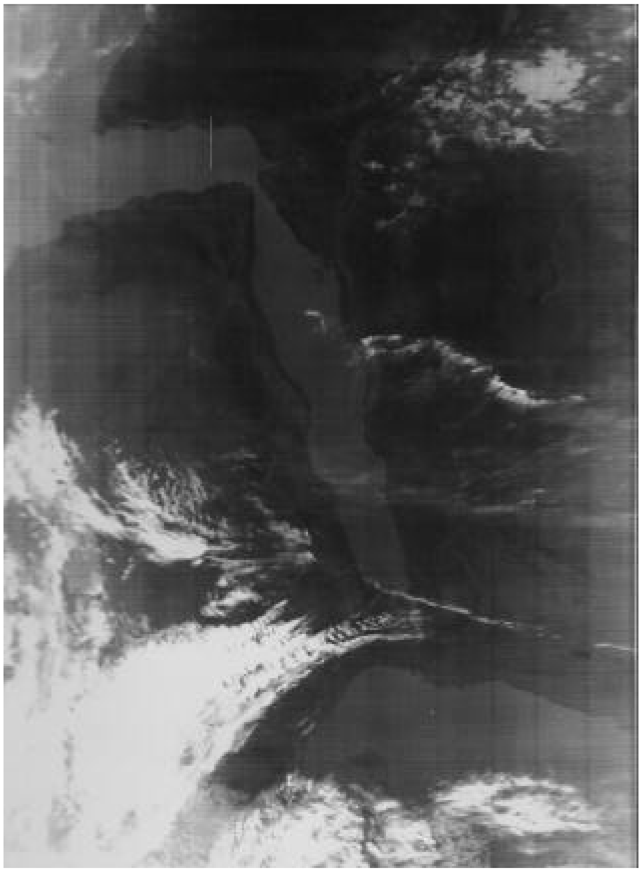

Fig. 19. DMSP Image of the Red Sea at 1/3 Nautical Mile Resolution, early 1970s (Mediterranean Sea at the top of the image.)

of satellite pictures taken of the Earth were free of cloud cover. Without these weather forecasts, only 38-to-40 percent of the imagery returned would have been cloud-free. Probabilities of cloud cover generated by the weather analysis model combined with low-altitude NOAA satellite data* thus met minimum NRP strategic weather forecast requirements during the 1980-1982 DMSP interregnum.[57]

In December 1982 the first of the Block 5D-2 military weather satellites, a morning bird, was launched successfully atop an Atlas booster. The second and third satellites followed the first one into orbit in November 1983 and June 1987, respectively. These military meteorological satellites once again supplied the global coverage needed by the country's three military services and the NRP—and did so for many months. Indeed, the primary OLS on the first 5D-2 satellite did not cease functioning until mid-August 1987, providing nearly five years of effective operation, while the second ceased in November of that year; the third satellite OLS continued to function until mid-August 1991. In the meantime, Defense Department and NOAA officials made plans for another improved version of what would become the standard U.S. civil and military low-altitude weather satellite, Block 5D-3.[58]

Design studies of a still larger and heavier Block 5D-3 satellite began in the late 1970s,† but funds for the military version were not appropriated until mid-1980. The 5D-3 satellites, though

---

*To meet separate NOAA weather modeling needs, a primary NOAA polar-orbiting satellite crossed the Soviet Union at about 2430 local time, while a second one followed at 0830 in the morning. These times and unavoidable delays in relaying weather data to Air Force Global Weather Central did not mesh well with NRP forecast requirements.

†Air Force officials briefly considered calling this series of DMSP satellites Block 6, but abandoned the idea when President Jimmy Carter issued a directive in late 1979 that specified military and civil meteorological satellite programs would continue to be conducted separately until the next satellite block change. (Presidential Directive 54,

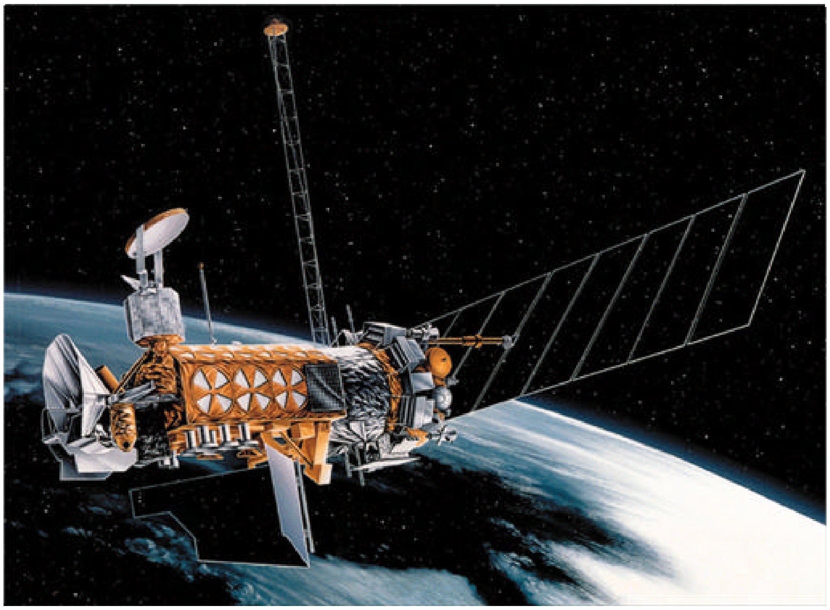

Fig. 20. DMSP Block 5D-3 Satellite

initially designed to be compatible for launch on NASA's Space Shuttle and be laser-hardened, ultimately would be launched on an unmanned expendable rocket. This satellite mounted an improved Westinghouse OLS and a larger combination of secondary sensors. The length of the satellite increased from 22 to 24 feet, while the weight rose to 2,278 pounds. The RCA spacecraft consisted of the same basic components as its immediate predecessors, but included a larger solar array, three 50-amp-hour batteries, and a redesigned sunshade. The center section now sported four pinwheel temperature control louvers on four of its five sides. These and other design improvements combined to give the 5D-3 an anticipated mean mission lifetime on orbit of five years (60 months). The first of six 5D-3 spacecraft was scheduled to be delivered to the Air Force in June 1990. Following the loss of the Space Shuttle Challenger in January 1986, however, all of them were rescheduled for launch atop modified Titan-II intercontinental ballistic missiles.

After the introduction of the DMSP Block 5D-1 satellites, Air Force leaders realigned the organization and operation of the program. Responsibility for launching DMSP spacecraft transferred in the mid-1970s from the Strategic Air Command (SAC) to the Aerospace Defense Command, and then to the Air Force System Command's Space Division. When the Air Force established a Space Command in September 1982, the new organization gained from SAC responsibility for operating the ground stations in Maine and Washington State,* and the DMSP Command and Control Center at Offutt AFB. Following the disruption that occurred with the gap in

"Civil Operational Remote Sensing," 23 November 1979.)

*In 1979-1980 the DMSP program also had arranged for data readout and relay of weather data from a third site, the Air Force Satellite Control Facility tracking station in Hawaii.

satellite coverage during the early 1980s, and despite the inter-command politics that attended the organizational realignment, in 1987 the operational DMSP received the management attention it deserved, met its strategic and tactical commitments, and could be judged reasonably fine-tuned.

Fine-tuned or not, between 1962 and 1994 the Defense Meteorological Satellite Program had sparked a revolution in overhead meteorology. It introduced the "wheel-mode" operational satellite, novel attitude-control systems, new satellite-tracking programs, and the operational use of infrared imagery to the field of meteorology. Beginning in 1966 it acquired a tactical as well as strategic capability and furnished the needed weather support for both activities. Indeed, DMSP significantly increased the image-search system effectiveness of NRO reconnaissance satellites and of SAC SR-71 and U-2 reconnaissance aircraft, while it markedly reduced the number of aerial meteorological sorties. The integrated Block 5 introduced the first systems approach that turned on the user's requirements. All the while, the mean mission lifetime on orbit of the military meteorological satellites increased from 90 days in Block 1, to five years on the most recent Block 5D-2 flights. These successes were tempered in the 1970s by the layering of management and the introduction of increasingly complex spacecraft that brought with them program delays, increased costs, and, ultimately, the gap in weather coverage that occurred in the early 1980s.

The Defense Meteorological Satellite Program, certainly during the early years and at least until the early 1970s, made do with less. In those years, DMSP development and production was accomplished with fewer personnel and at less than one-half the cost of equivalent NASA and Department of Commerce efforts.[59] Pushed to operational status within 24 months, the DMSP demonstrated remarkable technical performance for both strategic and tactical applications. Considering its cost and performance in the mid-1960s, Commerce Department leaders told their counterparts at NASA that they would adopt the DMSP wheel-mode spacecraft in place of Nimbus as the standard for low-altitude, polar-orbiting meteorological applications. That choice was made formal in the mid 1970s when the DMSP Block 5D three axis-stabilized spacecraft also was selected for use in both programs. But the choice of a common spacecraft bus highlighted the near identical content of the civil and military low altitude meteorological satellite programs.

Afterword

Early in 1993, once again prompted by the Office of Management and Budget and Congressional committees to justify separate military and civil polar orbiting meteorological satellites, representatives of the Department of Defense, the Department of Commerce's NOAA, and NASA reconvened to study the issue. Members of this group most likely were unacquainted with the interdepartmental study conducted by their predecessors thirty-two years before in 1961, a study that had produced plans for a National Operational Meteorological Satellite System. Because of security restrictions only recently lifted, they surely were unacquainted with the most significant aspects of the history that you have just read. But unlike events in 1961, the technology for space-based meteorological observation now was well developed, the international sensitivity associated with overhead reconnaissance had all but disappeared, and weather satellites were in operation in orbit around the clock. Hardly to anyone's surprise, and with much greater assurance, members of the 1993 study reached conclusions similar to those of 1961: a single program would eliminate the need for duplicate satellites and ground stations, it would reduce the number of people involved along with the corresponding costs, and it could be made to satisfy both civil and military requirements for "operational, space based, remotely-sensed, environmental data."[60] But this last proposition remains open to question. If history is any guide, attempts to acquire advanced weapon systems (e.g., the TFX/F-111) that will do everything for everyone more often than not have failed to achieve that goal, and have cost more in the bargain.

Nevertheless, the 1993 interdepartmental study, after appropriate departmental coordination and approvals, led later that year to the preparation of a "tri-agency" plan to combine the two weather satellite programs into one. But the word "combine," would not be used. Perhaps it suggested bureaucratic foot-dragging, if not myopia, and a substitute was selected in its place—one that implied a new initiative. On 5 May 1994 President William Clinton issued a Presidential Decision Directive announcing the choice,[61] and, coincident with it, the Departments of Defense, Commerce, and NASA released the "Implementation Plan for a Converged Polar-orbiting Environmental Satellite System." The plan created an Integrated Program Office that would develop, acquire, and operate the converged National Polar-orbiting Operational Environmental Satellite System (NPOESS). It formed an Executive Committee composed of senior officials from all three government agencies that would serve as a board of directors and ensure that the NPOESS indeed met the requirements of each. And, under the terms of the plan, each agency shared responsibility for different elements of NPOESS. The NOAA held "overall responsibility for the converged system," including operating the satellites on orbit and representing the program to the various civil and international communities involved. The Defense Department became responsible for contracting and acquiring the new meteorological satellites and for launching them. Finally, reminiscent of the division of labor in 1961 that produced Nimbus, NASA assumed responsibility for "facilitating the development and incorporation of new cost-effective technologies into the converged system."[62]

The NPOESS program office, located at a NOAA facility in Silver Spring, Maryland, opened its doors on 3 October 1994. Four years later, in May 1998, the NPOESS program director assumed responsibility for controlling DMSP satellites, along with the NOAA polar orbiting satellites. On 11 June the Air Force Space Command 6th Space Operations Squadron, which had previously operated DMSP satellites from a control center near the old SAC Headquarters in Omaha, Nebraska, inactivated. It brought to a close an effort begun in secret to meet the meteorological needs of the National Reconnaissance Office and its National Reconnaissance Program nearly four decades before, in 1961. After May 1998, civilians at the NOAA's Satellite Operations Control Center in Suitland conducted space flight operations for all polar orbiting U.S. weather satellites, though the Air Force established a backup satellite operations center, manned by USAF Reserve personnel, at Schriever Air Force Base near Colorado Springs, Colorado. Sometime late in the first decade of the new Millennium, NPOESS satellites will become available as replacements for the current Block 5D-3 DMSP and NOAA satellites, as they expire on orbit.[63] But that is another history in the making.

Acknowledgments

When in early 2000 the NRO declassified its meteorological satellite history, it became possible for me to share an early version with some of the original participants who had left the program and, along with it, their security clearances many years before. On receiving word of the declassification, several of them also corresponded with me, sent unclassified documents that they possessed, and two prepared written memoirs. Altogether, they corrected errors of fact and added details not otherwise found in NRO and Air Force documents, and in the process contributed mightily to this work. Among those who furnished vital records or recollections, I am most especially indebted to Thomas O. Haig, Richard L. Geer, Ronald E. Mintz, James R. Blankenship, John E. (Jack) Kulpa, and John D. Cunningham. At one time or another, each one of them were eye witnesses to and played active roles in the story; indeed, John Cunningham, who first served DMSP as an Air Force officer in the 1970s and 1980s, is currently the System Program Director for the Integrated Program Office/NPOESS. Finally, special thanks are owed to my colleague Matthew Doering who researched and prepared the DMSP Launch Record tables, and placed carefully the illustrations that appear in this work.

Table 1					
DMSP Launch Record					
Scout Rocket					
DATE	**LAUNCH VEHICLE**	**LAUNCH SITE**	**PAYLOAD**	**PERCENT SUCCESS**	**REMARKS**
5-23-62	Scout V-112	PALC SLC-5	DMSP Block 1	0%	Failed to Orbit; 2nd Stage Exploded *
8-23-62	Scout V-117	PALC SLC-5	DMSP Block 1	50%	Success; EMD 6-11-63
2-19-63	Scout V-126	PALC SLC-5	DMSP Block 1	66.6%	Improper Orbit; First DMSP with Infrared System
4-26-63	Scout V-121	PALC SLC-5	DMSP Block 1	33.3%	Failed to Orbit; 3rd Stage Exploded *
9-27-63	Scout V-132	PALC SLC-5	DMSP Block 1	16.6%	Failed to Orbit; 3rd Stage Failure

Abbreviations: DMSP = Defense Meteorological Satellite Program; EMD = End of Mission Date; PALC = Point Arguello Launch Complex; SLC = Space Launch Complex

* An investigation after the V-121 failure revealed that the Range Safety Officer (RSO) turned off the Command Destruct (CD) transmitter when the Range was pronounced "Clear" from any debris that might result from a catastrophic malfunction. What the RSO failed to consider was that with the CD transmitter turned off, the Scout receiver, equipped with an automatic gain control onboard the rocket, began searching for the next strongest signal. The next strongest signal turned out to be a radio station broadcasting music in the Los Angeles basin. Based on the investigation, when a male vocalist enunciated the consonant "p" the receiver interpreted it as the coded destruct signal.

Table 2					
DMSP Launch Record					
Thor-Agena D Rocket *					
DATE	**LAUNCH VEHICLE**	**LAUNCH SITE**	**PAYLOAD**	**PERCENT SUCCESS**	**REMARKS**
1-19-64	Thor-Agena D	VAFB SLC-1W	Two DMSP Block 1 satellites	100%	Success; EMD 7-10-64 & EMD 3-17-65
6-17-64	Thor-Agena D	VAFB SLC-1W	Two DMSP Block 1 satellites	100%	Success; EMD 2-16-66 & EMD 10-15-65

Abbreviations: DMSP = Defense Meteorological Satellite Program; EMD = End of Mission Date; SLC = Space Launch Complex; VAFB = Vandenberg Air Force Base

* The Thor-Agena launch vehicle carried two DMSP satellites simultaneously.

Table 3					
DMSP Launch Record					
Burner I Rocket					
DATE	**LAUNCH VEHICLE**	**LAUNCH SITE**	**PAYLOAD**	**PERCENT SUCCESS**	**REMARKS**
1-18-65	Burner I	VAFB SLC-10W	DMSP Block 1	0%	Failed to Orbit; Payload shroud failed to separate
3-18-65	Burner I	VAFB SLC-10W	DMSP Block 1	50%	Success; EMD 6-15-65
5-20-65	Burner I	VAFB SLC-10W	DMSP Block 3	66.6%	Success; EMD 2-16-67
9-9-65	Burner I	VAFB SLC-10W	DMSP Block 2	75%	Success; EMD 9-22-66
1-7-66	Burner I	VAFB SLC-10W	DMSP Block 2	60%	Failed to Orbit; Upper stage failed to ignite
3-30-66	Burner I	VAFB SLC-10W	DMSP Block 2	66.6%	Success; EMD 5-3-68

Abbreviations: DMSP = Defense Meteorological Satellite Program; EMD = End of Mission Date; SLC = Space Launch Complex; VAFB = Vandenberg Air Force Base

Table 4					
DMSP Launch Record					
Thor/Burner II Rocket, Block 4 Satellites					
DATE	**LAUNCH VEHICLE**	**LAUNCH SITE**	**PAYLOAD**	**PERCENT SUCCESS**	**REMARKS**
9-15-66	Thor/Burner II	VAFB SLC-10W	DMSP Block 4A	100%	Success; EMD 11-3-68
2-8-67	Thor/Burner II	VAFB SLC-10W	DMSP Block 4A	100%	Success; EMD 5-18-67
8-23-67	Thor/Burner II	VAFB SLC-10W	DMSP Block 4A	100%	Success; EMD 3-13-68
10-11-67	Thor/Burner II	VAFB SLC-10W	DMSP Block 4A	100%	Success; EMD 6-23-68
5-23-68	Thor/Burner II	VAFB SLC-10W	DMSP Block 4B	100%	Success; EMD 5-26-69
10-22-68	Thor/Burner II	VAFB SLC-10W	DMSP Block 4B	100%	Success; EMD 9-19-70
7-22-69	Thor/Burner II	VAFB SLC-10W	DMSP Block 4B*	100%	Success; EMD 3-19-71

Abbreviations: DMSP = Defense Meteorological Satellite Program; EMD = End of Mission Date; SLC = Space Launch Complex; VAFB = Vandenberg Air Force Base

* One Additional DMSP Block 4B satellite was manufactured, but not launched. The satellite, also known as 4B-4, was donated to the Chicago Museum of Science and Industry.

Table 5					
DMSP Launch Record					
Thor/Burner II Rocket, Block 5A & 5B Satellites					
DATE	**LAUNCH VEHICLE**	**LAUNCH SITE**	**PAYLOAD**	**PERCENT SUCCESS**	**REMARKS**
2-11-70	Thor/Burner II	VAFB SLC-10W	DMSP Block 5A	100%	Success; EMD 3-19-71
9-3-70	Thor/Burner II	VAFB SLC-10W	DMSP Block 5A	100%	Success; EMD 2-15-71
2-17-71	Thor/Burner II	VAFB SLC-10W	DMSP Block 5A	100%	Success; EMD 3-3-73
10-14-71	Thor/Burner II	VAFB SLC-10W	DMSP Block 5B	100%	Success; EMD 4/27/72
3-24-72	Thor/Burner II	VAFB SLC-10W	DMSP Block 5B	100%	Success; EMD 2-23-74
11-9-72	Thor/Burner II	VAFB SLC-10W	DMSP Block 5B	100%	Success; EMD 5-22-75
8-17-73	Thor/Burner II	VAFB SLC-10W	DMSP Block 5B	100%	Success; EMD 1-24-77
3-16-74	Thor/Burner II	VAFB SLC-10W	DMSP Block 5B	100%	Success; EMD 5-27-76

Abbreviations: DMSP = Defense Meteorological Satellite Program; EMD = End of Mission Date; SLC = Space Launch Complex; VAFB = Vandenberg Air Force Base

Table 6					
DMSP Launch Record					
Thor/Burner II Rocket, Block 5C & 5D1 Satellites					
DATE	**LAUNCH VEHICLE**	**LAUNCH SITE**	**PAYLOAD**	**PERCENT SUCCESS**	**REMARKS**
8-9-74	Thor/Burner II	VAFB SLC-10W	DMSP Block 5C	100%	Success; EMD 12-1-77
5-24-75	Thor/Burner II	VAFB SLC-10W	DMSP Block 5C	100%	Success; EMD 11-30-77
2-19-76	Thor/Burner II	VAFB SLC-10W	DMSP Block 5C	94.4%	Failed to Orbit; Improper fuel loading
9-11-76	Thor/Burner II	VAFB SLC-10W	DMSP Block 5D1	95%	Success; EMD 9-17-79
6-5-77	Thor/Burner II	VAFB SLC-10W	DMSP Block 5D1	95.2%	Success; EMD 3-19-80
5-1-78	Thor/Burner II	VAFB SLC-10W	DMSP Block 5D1	95.5%	Success; EMD 2-28-84
6-6-79	Thor/Burner II	VAFB SLC-10W	DMSP Block 5D1	95.7%	Success; EMD 8-29-80
7-15-80	Thor/Burner II	VAFB SLC-10W	DMSP Block 5D1	91.7%	Failed to Orbit; 4^{th} Stage Failure

Abbreviations: DMSP = Defense Meteorological Satellite Program; EMD = End of Mission Date; SLC = Space Launch Complex; VAFB = Vandenberg Air Force Base

Table 7					
DMSP Launch Record					
Atlas E Rocket					
DATE	**LAUNCH VEHICLE**	**LAUNCH SITE**	**PAYLOAD**	**PERCENT SUCCESS**	**REMARKS**
12-21-82	Atlas E	VAFB SLC-3W	DMSP Block 5D2	100%	Success; EMD 8-24-87
11-18-83	Atlas E	VAFB SLC-3W	DMSP Block 5D2	100%	Success; EMD 10-17-87
6-20-87	Atlas E	VAFB SLC-3W	DMSP Block 5D2	100%	Success; EMD 8-13-91
2-3-88	Atlas E	VAFB SLC-3W	DMSP Block 5D2	100%	Success; EMD 2-24-92
12-1-90	Atlas E	VAFB SLC-3W	DMSP Block 5D2	100%	Success; EMD 2-8-95
11-28-91	Atlas E	VAFB SLC-3W	DMSP Block 5D2	100%	Success; EMD 8-30-00
8-29-94	Atlas E	VAFB SLC-3W	DMSP Block 5D2	100%	Success; EMD 4-28-97
3-24-95	Atlas E	VAFB SLC-3W	DMSP Block 5D2	100%	Success; EMD N/A

Abbreviations: DMSP = Defense Meteorological Satellite Program; EMD = End of Mission Date; SLC = Space Launch Complex; VAFB = Vandenberg Air Force Base

Table 8					
DMSP Launch Record					
Titan II Rocket					
DATE	**LAUNCH VEHICLE**	**LAUNCH SITE**	**PAYLOAD**	**PERCENT SUCCESS**	**REMARKS**
4-4-97	Titan II	VAFB SLC-4W	DMSP Block 5D2	100%	Success; EMD N/A
12-12-99	Titan II	VAFB SLC-4W	DMSP Block 5D3	100%	Success; EMD N/A
11-14-01	Titan II	VAFB SLC-4W	DMSP Block 5D3		Projected Launch Date

Abbreviations: DMSP = Defense Meteorological Satellite Program; EMD = End of Mission Date; SLC = Space Launch Complex; VAFB = Vandenberg Air Force Base

REFERENCES

1. Any photography of the Earth's surface from space, RAND reminded the Air Force, had to occur when "weather permits ground observation." Robert M. Salter, Jr., James E. Lipp, and Richard S. Wehner, *Utility of a Satellite Vehicle for Reconnaissance* (Santa Monica: The RAND Corporation, R-217, April 1951), p. 80. See also, W. R. Cartheuser, *Weather Degradation of Reconnaissance* (Santa Monica: The RAND Corporation, D-4003, 10 December 1956). The first serious evaluation of a meteorological satellite and what it could be expected to do for synoptic weather analysis, needless to say, also took place at RAND at the same time. See Stanley M. Greenfield and William W. Kellogg, *Inquiry into the Feasibility of Weather Reconnaissance from a Satellite Vehicle* (Santa Monica: The RAND Corporation, R-218, April 1951). See also, Karl R. Johannessen, *The Meteorological Factors Affecting Photographic Reconnaissance from Very High* Altitudes, Air Weather Service Technical Report 154, May 1961. An informed review of early meteorological satellite developments can be found in David S. Johnson, "Evolution of the U.S. Meteorological Satellite Program, Some Reminiscences," *Bulletin of the American Meteorological Society*, Vol 75., No. 9, September 1994, pp. 1705-1708.

2. Lt Col James B. Jones, "The National Weather Satellite Program: Its Utility as a Contribution to Military Weather Support and as a Peaceful Instrument of U.S. Foreign Policy," Research Report prepared for the Air War College, Air University, 1965, pp. 1-2. The National Reconnaissance Program, created in 1961 by the Central Intelligence Agency and the Department of Defense, included all United States "satellite and overflight reconnaissance projects whether overt or covert." The National Reconnaissance Office (NRO), headquartered in the Defense Department, managed the NRP.

3. Ltr, Thomas O. Haig to Lt. Col. Richard Dickover, HQ AWS/DOD, no subject, 13 Nov 1984, p. 1. See also, Robert Perry, *A History of Satellite Reconnaissance*, Volume IIA – SAMOS, 1972, pp. 211-215;

4. Richard L. Geer, "Comments on the Early Years of U.S. Space Programs: Recollections of a Participant," 1999, p. 3.

5. Ltr, Haig to Dickover, p. 2.

6. Ralph B. Hoffman and Thomas O. Haig, "Space Uses of the Earth's Magnetic Field," Space Systems Division, Air Force Systems Command, October 1964; also, Robert L. Perry, *A History of Satellite* Reconnaissance, Vol IIA, SAMOS, pp. 223-224. The term "wheel-mode" meant a spin-stabilized satellite that took a picture of the Earth each time it revolved.

7. Perry, Vol IIA, pp. 221-222.

8. Rpt, *Program 417 - Military Meteorological Satellite System*, HQ AWS/OP, 1 June 1966, p. 7.

9. Ltr, Haig to Dickover, p. 2; Perry, Vol IIA, p. 254.

10. Ltr, Haig to Dickover, p. 3. SAC leaders had wanted for some time to get into the space business and the meteorological satellite operation, which was of particular interest, meshed nicely with that desire and with the command's requirements for world-wide weather data. See Ltr, General Thomas S. Power, CINCSAC, to General Thomas D. White, Chief of Staff, USAF, regarding TIROS weather satellite, 1 December 1960 (Thomas D. White Papers, Library of Congress, Box 34, 2-15SAC.).

11. Interview, Thomas O. Haig with the author, the Pentagon, 6 October 1995.

12. Perry, Vol IIA, pp. 268-70. The Block 5 satellites would mount vastly improved sensors, with the IR and visual line scanner viewing the Earth through a beam splitter, operating simultaneously. The resulting images thus could be overlaid.

13. *Ibid*., pp. 290-291.

14. Captains Richard L. Geer, James F. Roberts, and Calvin H. Markwood, "Development of the Burner Space Launch Vehicles," Space Systems Division Air Force Systems Command, 1966. Also, Geer, "Comments on the Early Years," pp. 8-9. Officials of the Douglas Aircraft Company that manufactured the Thor rockets put the new launch vehicle combination "on the front burner." Thus the name "burner (number) I."

15. *Ibid*. pp. 11-12;

16. Ltr, Haig to Dickover, pp. 2-3.

17. "Weather Bureau Rejects Nimbus for Operational Satellite Program," *Aviation Week & Space Technology*, 7 Oct 1963; DOC/USWB-NASA News Release 63-220, "NASA-Weather Bureau Announce Nimbus Agreement," 4 Oct 1963. For a description of NASA's NRO-derived TOS, see NASA News Release 64-125, "Operational Weather Satellite Study Completed, Contract to be Negotiated for TIROS Operational System," 28 May 1964; for its appearance as an operating weather satellite, see James F. W. Purdom and W. Paul Menzel, "Evolution of Satellite Observations in the United States and Their Use in Meteorology," in James R. Fleming, ed., *Historical Essays on Meteorology, 1919-1995* (Boston: The Diamond Anniversary History Volume of the American Meteorological Society, 1996), pp. 107-109; see also, Ltr, David S. Johnson, U.S. Weather Bureau, Department of Commerce (DOC), to Col. Thomas O. Haig, 29 June 1965, regarding Program 417 (DMSP) contributions to the NOMSS.

18. Rpt, *Meteorological Satellite Background*, HQ AWS/OP, June 1963, p. 2.

19. Rpt, *AFSC/AWS Ad Hoc Report on Meteorological Satellite Programs*, Appendix A, U.S. Meteorological Satellite Programs, 1 May 1966, p. A-13.

20. Rpt*, AFSC/AWS Ad Hoc Report on Meteorological Satellite Requirements and Systems*, Appendix F, Use of Program 417 Data in Military Operations, 1 May 1966, pp. F-1 – F-2.

21. *Ibid*., pp. F-2 – F-3; Rpt, *Program 417*, no author indicated, 8 April 1969, p. 1; and Rpt, *Program 417-Military Meteorological Satellite System*, HQ AFSC/MSFU, June 1966, pp. 11-12.

22. Memorandum, from Brockway McMillan, Under Secretary of the Air Force, to General John P. McConnell, CSAF, “Program 417 Management,” 22 June 1965; preliminary planning in Memo, Brockway McMillan, Undersecretary of the Air Force, to Chief of Staff, USAF, "Program 417 Program Management," 22 June 1965.

23. Rpt, *Review of the Defense Systems Application Program (DSAP), Program 417*, NRO document 77896-72, p. 35.

24. John L. McLucas, “A New Look From USAF's Weather Satellites,” *Air Force Magazine*, June 1973, pp. 64-67.

25. Rpt, A Review of the Defense Systems Application Program (DSAP), Program 417, NRO document 77896-72, p. 10.

26. *Ibid*., pp. 9-10; also, Rpt, *Program 417 Military Meteorological Satellite System*, HQ AFSC/MSFU, June 1966, p. 6.

27. John E. Kulpa, telephone interview with the author, 27 July 2000.

28. Geer, “Comments on the Early Years,” p.17

29. Brightness varies by many orders of magnitude and posed a data link capacity problem. The user, however, wasn’t as much interested in the brightness of a scene as he was in its albedo—its reflectance. As Geer described the solution: “We devised a simple scheme. We placed a suitably shaped light sensor on the spacecraft to ‘look over its shoulder’ to determine sun (or moon) illumination. What the satellite sees roughly corresponds to the illumination on the scene below. By dividing the brightness signal from the primary earth-facing sensor by the brightness signal from the illumination sensor, the albedo of the scene is left. Since albedo only varies over one order of magnitude (1.0 to 0, perfectly reflective to perfectly black), the [data] link problem was solved.” *Ibid*., p. 20.

30. Ltr, James R. Blankenship to the author, 23 September 2000; also, Geer, “Comments on the Early Years,” p. 18

31. Kulpa, telephone interview; Geer, “Comments on the Early Years,” p. 19.

32. Paper, “Program 417 (U),” no author indicated, 8 Apr 1969, p. 3; Rpt, *A Review of the Defense Systems Application Program (DSAP), Program 417*, NRO document 77896-72, p. 10.

33. Memorandum, from Alexander H. Flax (Assistant Secretary of the Air Force), Robert A. Frosch (Navy), and Charles L. Poor (Army), to John S. Foster, Jr., DDR&E, Subj: "Program 417," 5 March 1969.

34. Memorandum, John S. Foster, Jr., DDR&E, to the Assistant Secretaries of the Army, Navy, and Air Force (R&D), "Program 417," 29 March 1969.

35. Rpt, *A Review of the Defense Systems Application Program (DSAP)*, p. 10.

36. See DMSP Launch Record, Tables 5 and 6.

37. Interview, Lt. Col. Richard F. Picanso, DMSP Program Element Monitor, with the author, the Pentagon, 12 August 1987.

38. Rpt, *Defense Meteorological Satellite Program*, 29 January 1976, p. 2

39. Hist, Directorate of Space, DCS/Research and Development, 1 July 1972-31 December 1972, p. 63; Geer, "Comments on the Early Years," p. 22.

40. Hist, Air Weather Service, 1976, Vol I, pp. 189-190.

41. Rpt, "Block 5D, A Compendium," USAF Space and Missile Systems Organization, July 1975, p. 28.

42. *Ibid*., p. 30; Paper, J. R. Blankenship and J. J. McGlinchey, "Evolution of the Block 5 Spacecraft to Meet Changing Military Needs," September 1979.

43. "Block 5D, A Compendium," pp. 36-41.

44. *Ibid*., pp. 42-43.

45. Geer, "Comments on the Early Years," p. 23.

46. Blankenship and McGlinchey, p. 30.

47. Hist, Air Weather Service, 1976, Vol I, pp. 207-209; Hist, Space and Missile Systems Organization, 1 January 1977-31 December 1977, Vol I, p. 185.

48. Ltr, John D. Cunningham to the author, 18 September 2000, with comments on draft manuscript.

49. Hist, Space and Missile Systems Organization, 1 July 1973-30 June 1975, Vol I, p. 399; Interview, Picanso with the author, 12 August 1987.

50. Hist, Space and Missile Systems Organization, 1 October 1979-30 September 1980, Vol I pp. 2l2-213; Blankenship and McGlinchey, p. 306; RCA Chart, Defense Meteorological Satellite Program, n.d.; and Letter, Cunningham to the author, 18 September 2000.

51. Hist, Air Weather Service, 1979, Vol I, pp. 192-196.

52. Hist, Space and Missile Systems Organization, 1 October 1979-30 September 1980, Vol I, p. 205; Hist, Space and Missile Systems Organization, 1 October 1980-30 September 1981, Vol I, p. 270.

53. See, for example, Maj. Ernie R. Dash and Maj. Walter D. Myers, "The Meteorological Satellite: An Invaluable Tool for the Military Decision-Maker," *Air University Review*, Vol 24, No. 3, March-April 1978, pp. 15-24.

54. Rpt, *A Review of the Defense Systems Application Program (DSAP), Program 417*, NRO 77896-72, 1972, p. 20.

55. Interview, Donald E. Welzenbach, CIA Historian, with the author, 7 January 1987; Interview, Lt. Col. Robert E. Peterson, Air Weather Service Representative to NRO Staff, with the author, 15 October 1987; Geer, "Comments on the Early Years," p. 21.

56. *Ibid*.; "A Review of the Defense Systems Application Program (DSAP), Program 417," pp. 20-23.

57. Interview, Welzenbach with the author.

58. Hist, Space and Missile Systems Organization, 1 October 1979-30 September 1980, Vol I, p. 214; Minutes, DMSP User's Working Group (USWG) Meeting Minutes, 28 February 1986 and 11 January 1987; Directive, "Program Management Directive for DMSP," 20 October 1986.

59. Rpt, *A Review of the Defense System Applications Program (DSAP), Program 417*, Table 8, DSAP/ITOS Cost Comparisons, p. 33; See also, Memo, HQ USAF/RDS to SAFRD (Dr. Flax), "System Comparison," 28 February 1969, Atch 3, Cost Analysis.

60. National Environmental Satellite Data and Information Service News Release, "The National Polar-orbiting Operational Satellite System (NPOESS)," Public Affairs, 6 January 1999, p. 1.

61. Presidential Decision Directive/NSTC-2, 5 May 1994.

62. NESDIS News Release, 6 January 1999, p. 2.

63. *Ibid*., p. 3; Air Force News Release, "First Satellite-Flying Unit Inactivated," 12 June 1998.