THE DMSP BLOCK 5 PROGRAM HISTORY
AT
WESTINGHOUSE AND NORTHROP GRUMMAN
As Remembered by some Participants

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Introduction

The Block 5 DMSP Program has had continuous and uninterrupted contracts with the same customer since November 1966. It is my understanding that the Program is currently under contract until 2004 with the prospects for another 10 year follow on

Block 5 satellites continue to operate. The last launch took place in October of 2003. The life of the spacecraft have been much longer than originally expected. There are enough systems in inventory to last another 10-15 years if the Air Force chooses to launch them

I participated in the originals studies and worked on the program continuously from 1966 until I retired in 1994. During that period, I held various technical positions for both the ground and space segments managing the ground segment from 1966 through 1975 and the space and ground segment from 1975 to 1980. From 1980 until retirement in May of 1994 I was assigned the task of Manager of Westinghouse Meteorological Satellite Programs in the Space Division which included the DMSP Block 5. Twenty eight years on one program, how about that for a career!

It is my objective, and the main theme, of this history to tell a little about the program background. Also I will tell about some of the design challenges we overcome, identify and highlight some of the more memorable moments on the program as well as recognize the technical and managerial skills and personal memories of those associated with this most successful program. I do not intend to get into any technical details in depth - only deep enough to understand the main theme of this history.

I have attempted to make this history as factual as possible. Very few reference documents going back more than 30 years could be located. Therefore much of the information contained herein is from the memories of those who participated and is subject memory errors. At this time there are no plans to revise or update this document.

Background

In the early 1960's, the secret National Reconnaissance Office (NRO) initiated the forerunner of Defense Meteorological Satellite Program (DMSP) low earth orbiting satellites. These early satellites were intended to be an interim measure, awaiting the completion of a national weather satellite, to support the operational needs of the film limited imaging satellites being flown by the NRO who was not interested in cloud pictures. By necessity the early program and its mission was highly classified and the data used only by the military. However, these early satellites performed so well that the program was declassified in 1973 when the under secretary for the Air Force, Dr. John McLucas, announced the existence of and that the meteorological satellite data from the Air Force Defense System Applications Program (DSAP) was to be made available to the world's community of meteorologists. The early acronyms of Program 2, Program 417, DAPP and DSAP were later superseded by the current name of Defense Meteorological Satellite Program (DMSP) and the program was allowed to continue as a DOD program for the next 30 plus years.

The early series of satellites ended with the Block 4 series. These satellites weighed about 160 pounds and carried a payload of a vidicon TV type cameras and other sensing devices. From these small, experimental and relatively simple spacecraft, the Air Force weather satellites grew in size, weight and complexity to a large scale sophisticated systems having an on orbit weight of over 1,800 pounds and carrying a payload of over 500 pounds. Using scanning radiometers to sense radiated and reflected energy from the earth and its cloud cover in the infrared, visual, ultra violet and millimeter wave spectrums, the Block 5 series of DMSP satellites can "see" environmental features on the earth such as clouds, bodies of water, snow fields, fires, pollution, and even features as small as streams and roads if they are not too narrow but sufficiently long, etc. Other sensors monitor solar activity, ocean surface conditions, etc. Information from all of the sensor is combined on the ground to determine cloud type, height, and moisture content; land and surface water temperature; land moisture content; snow and ice fields; ice age; lightning strikes; surface fires; ocean surface features and currents; etc. Through the use of this information, the weather forecasters can detect and observe developing patterns of weather and can track existing weather systems over remote and observer denied areas. The data can help identify severe weather such as hurricanes and thunderstorms, locate and determine the intensity of hurricanes and typhoons and gather imagery used to form three dimensional cloud analysis models which are the basis for computer simulations of various weather conditions.

At this time in our history, space business was in its infancy. (The US Air Force was still a teenager and fighting a major war!) Westinghouse was just beginning to become a player in the expanding space market areas. Our goal was to expand our markets in the space sector and eventually win space program contracts.

As Bill Parnell recalls: *"Years before Block 5, George Towner ask me to replace Dr. Andy McCourt to get Air Arm into the Space programs. Through contacts I had made when ARDC was in Baltimore I set about looking up these contacts and found that one was the Programs Planning Officer at SAMSO and another was in Programs Planning at Bowling Air Force in Washington, DC. Meetings with each were very successful; I briefed them on the capabilities of Westinghouse. They in return allow me to have information on sensor programs that were planned by the Air Force. This information told me what to expect in the forms of RFP's and I alerted our field Marketing Representatives what to be on the lookout for."*

These efforts resulted in a successful proposal for a one year study program. *"During the negotiations I had a breakfast meeting with Nick Petrou and at that time Nick said "Bill I want more highly classified Space Programs" These were the my charging orders. During the first program review Bob Finefrock (LA Sales) told me that TRW was going to request us to quote on a radar to go on a spacecraft that were proposing to the Air Force. After a couple meeting at TRW I was introduced to Mr. Bill Carlson and ask him what had to be done to get into the Black Space Programs. His reply was a bit shocking " Westinghouse will have to reply the RFPs with their best people and outstanding proposals for a period of ten years. Each proposal you submit will be reviewed carefully, then and only then if you come up to their standards they will open the door for you. The first contract you are given you will lose money, and if you deliver what you proposed then you are in." TRW was unsuccessful and as I remember and Boeing was award that contract. Our upper management wasn't too happy with that news but they allowed us to continue and I proceeded to develop contacts within the Air Force SAMSO in Los Angeles. The first result was a contract for a small study program called Mission 2A."*

In 1981 the Block 5 program celebrated its 15^{th} year. For this occasion, Jake Beser wrote a brief history for publication in the Westinghouse newspaper. in which he said: *"For several* *weeks, the Mission 2A team painstakingly analyzed a host of engineering alternatives and compiled comprehensive reports of their findings. A key part of this study was to do an end-to-end evaluation of a fully integrated system from a sensor in space to a set of data users on the ground specifically addressing ways to make the data user friendly. After a few weeks and all of a sudden without any advance notice, the study program was canceled. Needlessly to say, the team was disappointed. However all was not lost! Westinghouse had been introduced to the Air Force "space weenies" at SAMSO (Later Space Systems Division - SSD) and we continued our visits to SAMSO.*"

The SAMSO engineers and scientists were favorably impressed with the technical expertise exhibited in the presentations; the quality of the technical reports; and, the total system approach that Westinghouse had generated during the 2A studies. Just prior to my retirement in 1994 I was told that SAMSO knew nothing of the Westinghouse space capabilities and the Mission 2A contract had been a test which proved to them that Westinghouse did indeed have space capabilities.

Bill Parnell continues: "*Later I was on the west coast checking out a lead when Bob Finefrock told me that he had been called to attend a meeting over at SAMSO and he had made arrangements for me to go along. We did and as I remember it, this was the first time I met Maj. John Kulpa and Maj. Jim Blankenship. They told us that they were seeking a new payload for a spacecraft, and this would be an up-date of one they had in hand. They were happy with their present supplier so this would be a competitive fix price bid. I said we would appreciate the opportunity. They said go home and discuss this with your management and come back for a detail briefing.*

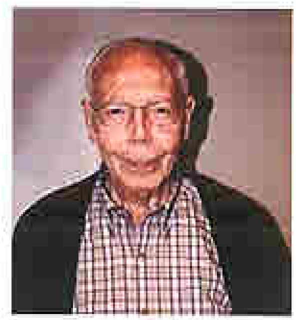
For the detailed briefing, I selected Jake Beser to go with me to the meeting and had planned that if we were successful Jake would become the program manager of the resulting program. Maj. Kulpa did the briefing and introduced his staff that laid out the requirements that stressed reliability, weight and power restrictions costs and security."

Details of this briefing were told to me by a former Air Force officer after I retired from Westinghouse. This gentleman had been a key participant in the development of the early Air Force meteorological satellites and in the preceding Program 2A studies. According to him, Bill Parnell was requested to visit a young Major (Kulpa) at his SSD Space Program office. After being sworn to secrecy the Major told him that the Air Force had about $200,000 which they were willing to give to Westinghouse to perform two studies and there was the potential for a future development/production contract. However there would be a number of conditions attached. Condition 1, the study is for a block change to an on-going program. The present system contractors will have study contracts for the block change. Condition 2, the program requires special access security clearances and the number of people to be cleared on the program would be very limited. Not even top management of Westinghouse would be cleared initially. Condition 3, the government had a good on-going program and were very happy with their present contractors. In order to win the block change production contract you have to be a lot better and offer unique concepts. Simply being better will not win. Neither will a lower cost using present concepts or moderate improvements on the present concepts and lower costs will not win. Condition 4, the Air Force will not tell you who the present contractors are but there will be two other well known contractors competing for each area. Now if you are still interested, go home and send us a study proposal for two studies. One for the sensor package and one for the ground data processing and display equipment. According to my source, Bill confirmed that Westinghouse was interested and caught the next plane home. This was mid-week. By the weekend a small group of engineers at Westinghouse were locked up preparing proposals including production cost estimates for something we knew almost nothing about. Within a few days of the original briefing at SAMSO the RFPs had been received, Westinghouse had responded and we were under contract for the two studies.

The RFP was unique. I had never seen one like it before! It was hand written with rough sketches. The one for the ground system described three sites which they defined as site alpha, site beta and site gamma, where system hardware would be required. It appeared to have been written by a college professor using text book terms such at kinescopes, albedo, DeVos cavities, modulation transfer function, "digital-analog signals", wow-flutter, etc. To complicate matters they never identified what they meant by some of these terms, the origin of the signals or how the sites tied together. In the case of wow-flutter we assumed that it was coming from an unknown tape recorder somewhere in the system.

Dave Balthis recalls the RFP and our proposal effort as follows: "*The weekend started when I was called into Fred Fischer's office on Friday. Fred said that he had been contacted by the East Building marketing stating that they were working on a system which required ground support equipment and that they strongly recommended that we immediately start support activity which would require working over the weekend.*

We were given very limited system information - only a copy of the unclassified handwritten RFP. As I recall, our activity continued a couple of days into the next week and that we were very busy getting state-of-the-art technical information from outside sources such as Eastman Kodak for color film capability and processing requirements, etc. I remember talking to a Capt. Geer a couple of times. It turned out that they were also working on system concepts and, in the case of Eastman, were talking to the same technical people. I believe this was true in other areas. At the end of our activity, it appeared from talking to Capt. Geer that our independently derived system concepts and conclusions seemed to match their analyses and conclusions. Capt. Geer also said in one of my last contacts that they were not aware that Westinghouse had overall system capability until we participated in the Mission 2A support equipment activity."



Dave Balthis

Dave Balthis and I worked through that weekend trying to determine what they were talking about in the RFP. There were many areas where we did not have the slightest clue as to what they meant or how to find out without looking stupid. But we had to get cost estimates for the three sites composing the ground system. Somehow we got the estimates done and fed it back to the customer (Capt. Geer) using his terminology (even though we did know what it meant) as if we were experts! In retrospect those rough cost estimates we generated that weekend turned out to be within ten percent of the actual costs of the system hardware.

The studies under the contract were initiated the first week of November 1966 and were to be completed by the end of the year. Needlessly to say we had to put together two study teams immediately and hit the ground running for the contract called for a mid-term review within four weeks.

Jake and Bill talked to Nick Petrou and we were able to get just about anyone in the company that we thought was needed to perform the studies. We scrambled to identify the key people for the study. I was assigned the responsibility for the ground system studies. Work was scarce in the east building at that time. We had several people in Dave Balthis' display group that could be made available. Also the Advanced Development group had a list of available people from which I got Jim Thompson and Gordon Ley. Jim was a brilliant mathematician whose expertise we desperately needed. Gordon possessed expertise in many areas including optics, photography and film processing, detectors, electronics and the system implementation techniques. His depth of technical expertise was impressive and many times later he was teaching the customer's Ph.D. scientists and engineers.

Since Westinghouse had no capability to design and build a film processor which was required Bill Roberson got the task of generating a specification and finding a subcontractor. Other people from Dave's display group were giving the job of hardware design and implementation. Larry Nix, who was very experienced in developing high resolution CRT displays, although not initially cleared for classified aspects of the program worked the CRT problems and analog electronics design concepts. Jim Geist and Maurice Hegwood worked the digital electronics design areas and assisted with the analog electronics. Tom Foley and Dom Barbiere worked the communication requirements and Jacques Pessin was in charge of the mechanical packaging.

Jim Geist Larry Nix Maurice Hegwood Jack Spangler

Dr. Roger Cortesi was placed in charge of the sensor studies. He pulled people from the Aerospace Division that had experience on the Apollo Radar and Lunar Camera programs. Names I remember include Paul Kiefer in mechanical design, Alan Bernstein thermal design, Marty Woolfson detectors and electronics design, Naomi McAfee reliability requirements, Russ Wood infrared detectors and optical design, Lee Magness test and test equipment design and Ralph Barra environmental tests.

A few days after we were under contract for the studies some Air Force officers and a civilian engineer from The Aerospace Corporation came to Baltimore and gave us a one day briefing on all aspects of the program, answered some questions, left their telephone numbers and wished us good luck .

Bill Parnell continues: *"After the Technical briefings the SAMSO team went on a fact-finding mission before they left. They got free rein of Air Arm building and checked every thing and observed even more. There wasn't one department they didn't check out! This was reported to our upper management and they approved. But our upper management could not yet be given security briefings.*

At this point I'm not sure what happened next, but with requirements in hand, I drew up a rough organization chart. Jake Beser Program Manager, Naomi McAfee, Reliability, Roger Cortesi, Spacecraft Sensor Design, Jack Spangler , Ground System Design, Lee Magness, Test Equipment. George Towner reluctantly approved the organizational chart and it was submitted to Maj. Kulpa."

During the technical briefing the SAMSO team described their concept for the Block 5 DMSP configuration. Specifically the mission of the Block 5 configuration was to collect and forward to ground stations for analysis, pictorial and metric data on the earth's cloud cover. The primary sensor should sense scene information in selected spectral regions in the range of 0.4 to 13.0 micrometers in order to provide unambiguous identification of cloud types; cloud amounts;

and, measurement of cloud-top height. The sensor would be carried aboard a satellite in a circular polar sun-synchronous orbit at an altitude of 450 nm.

Furthermore it was desired to have a Very High Resolution (VHR) channel in the extended visible spectrum (0.4 to approximately 0.8 micrometers), at a nominal resolution of 1/3 nautical mile. The primary purpose of this channel was to present very high quality images for analysis of cloud type and distribution, and the location of cloud masses with respect to areas of interest on the ground.

In addition to the VHR channel, a High Resolution (HR), also in the extended visible spectrum (0.4 to 1.1 micrometers), at a nominal resolution of 2 miles was required. The purpose of this channel was to:

(1) To provide images of good quality over very wide areas for global synoptic use.

(2) To permit measurement of scene brightness in terms of albedo.

(3) To extend coverage into the very low-light level range for both global synoptic and tactical use.

(4) An Infrared (IR) channel in the 8-13 micrometers atmospheric transmission window, at a nominal resolution of 2 miles was required. The purpose of this channel was to:

(a) To provide images of good quality over very wide areas, for synoptic use in conjunction with HR data.

(b) To permit measurement of cloud radiance and therefore inference of cloud-top height.

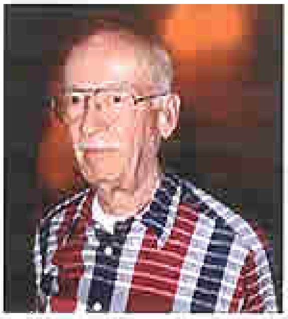
Since HR and IR data are used in very close conjunction with each other, exact point-for-point registration of the two data channels was desired.

All three types of data types must have contiguous equatorial coverage. It was required that the imagery be corrected for system errors such as tape recorder wow-flutter. In addition it would be desirable for the ground station to correct for the earth's curvature, spacecraft altitude and attitude, etc. and present the data to the operator in a user friendly manner as a photographic image suitable for direct overlaying on a standard map or latitude longitude grid at a scale factor of 1 to 15,000,000.

Within four weeks we had our system concepts fairly well defined and prepared for the mid term review. As usual this meant working weekends and holidays including Thanksgiving day. We had decided early that our system concept would employ a mechanical scanner and concentrated our efforts along those lines.

Larry Nix remembers his experiences during the study. *"It was decided early in the study that because of a number of complex problems associated with the spacecraft and sensor, a very flexible ground based reproduction system was required to achieve the user friendly interface the customer desired. Corrections had to be accommodated for a number of things such as earth's curvature; satellite altitude variations, roll and pitch, and other factors associated with the data collection and transmission of multi-sensor data types. All these corrections had to be highly accurate; handle wide variations of lighting conditions; have high spatial resolution; and, all had to be accomplished in a user-friendly manner. As if this was not enough, the system had to be packaged in a single 19 inch wide cabinet!*

Several film-recording techniques were considered for this application. Among them were laser recording, direct electron beam recording, and a cathode ray tube (CRT) with optical imaging. The first two had the best resolution capabilities; however, they had characteristic that were not compatible with a user-friendly tactical military application.



Larry Nix

The laser system was eliminated because of a lack of an acceptable beam scanning mechanism. Both the direct electron beam film recorder and the CRT optical film recorders shared many of the same features since both incorporated electron beams. This feature permitted incorporation of a flexible spot shaping and deflection system. The direct electron beam recorder has far superior resolution capabilities than a CRT system. However, the requirement or a demountable electron optical system of the former required the need for vacuum pumps and the problems of a vacuum film transporting system. These features made it unacceptable for a tactical military application.

The primary problem facing the utilization of a CRT optical recording system was that of meeting the system resolution requirements. Gordon calculated that such a system could be implemented employing a 5 inch production flat faced flying spot scanner CRT made by Westinghouse, Elmira Tube Division. His calculations revealed that while this CRT appeared to just be capable of meeting the requirements for the slower writing rate but high-resolution case, it would not provide sufficient beam current to reproduce the lower resolution but much higher writing rate sensor data. At that point I realized that Elmria's high resolution CRT could be made to satisfy all our system requirements by adding an external magnetic lenses to its normal electrostatic electron optical system. I knew that Larry White had on hand a suitable magnetic lens in his lab. I discussed the details of the experiment that I needed performed to verify my theory with Maurice Hegwood. He in turn, explained it to Jack over lunch. Jack immediately contacted Elmira and arranged for Larry White to perform my experiment. Before the afternoon was out, I had a phone call from Larry with the results of my experiment. Larry's data showed that my proposed solution provided more than sufficient beam current for our needs. This was indeed good news! I was satisfied that while many challenging problems lay ahead; for example, the brightness feedback loop and the along track line fill problems, the CRT would be the best approach. (This along track line fill problem was totally overlooked during the study and proposal process and possible solutions developed. However it showed up in subsequent lab tests after we were under contract and a solution was developed by having Elmira add a magnetic astigmatism coil to the CRT package that they were supplying to us for this job.)

Our studies showed that whatever method was selected to expose the film, it would require selecting complex corrections to properly exposed the film for anyone of ten different operating scan times with no further adjustments permitted other than selection by the front panel controls.

We selected the Westinghouse high resolution CRT with a hybrid magnetic and electrostatic lens system similar to a zoom lens used by present day amateur photographers as the most desirable method of exposing the film. The film processor we selected was a high temperature rapid film processor proposed by Fairchild."

We had listened closely to what the Air Force Briefer had told us during their briefing and tried to address all the hot topics. The mid-term review was held at Westinghouse and as I recall it was almost like taking an oral for a Ph.D. The customer was represented by several Air Force Officers and an engineer from Aerospace Corp. Each was an expert in his field and most held Ph.D. degrees. They were all attentive and seemed to like what they were hearing. They also ask probing questions and offered helpful suggestions. Some seemed skeptical about being able to implement the mechanical scanner without incurring uncorrectable data jitter problems. Others were concerned about our concept to collect albedo instead of brightness from the earth scenes. Otherwise they seemed pleased but had minor concerns with power, weight and thermal balance. They were especially happy with the surface resolution and the predicted low light level performance.

The major concerns for the ground system was the ability to package the required equipment including a high resolution CRT camera to expose the film line-by-line and the rapid film processor into one cabinet of the specified size. Otherwise they seemed pleased with the ground processing and display systems. They were interested in the user friendly aspects of the proposed concepts and seemed especially happy with the ability to produce a strip of imagery as a positive film transparency within 5 minutes of exposing the last scan line. They also liked the concept that an indefinite length of imagery could be produced that was corrected for scanner line-to-line jitter and spacecraft tape recorder wow-flutter; rectified for the satellite-earth geometry; scaled for spacecraft altitude variations; and, could be overlaid on existing weather charts, maps and grids. These system improvements would overcome many of the short comings of the earlier Block 4 ground equipment.

Bob Sempek

As I learned later the Air Force people went home and placed an increased emphasis on constructing and flight testing an engineering model of a mechanical scanner which they could fly in an airplane to prove that our concept could be made to work. Maj. Kulpa, the SPO Director, and Andy Rudomanski, a civilian, got with Aerospace Corporation Management and initiated a high priority task to design, fabricate and flight test a lab model line scanner. According to Bob Sempek of the Aerospace Cooperation *"All of a sudden our lab was sealed and a punch key lock was put on and it was made into a special access area. We were briefed on what was happening and started to work on the scanner model. We must have had special priority from Aerospace as everything we ask for we got right away." Within a few weeks a model was ready to fly on a T-39 aircraft. Capt. (later LTG) Chubb would pilot the aircraft and Andy and I would take the data."* According to Bob *"one thing about the testing. I found out that batteries don't like low temps and we were using some to power the scanner and the sync pulse for the recorder. They did not want us to use any aircraft power as they worried about power problems. We solved the problem by putting the batteries in the cabin in a battery box. We got a lot of good data and even went to the range in AZ with calibrated temps for the IR unit"*.

The final review was held in Los Angeles. As usual for meetings in Los Angeles, the conference room was large and filled with Air Force officers but only two or three Aerospace Corp. engineers. This review lasted three days and this time it was like defending your thesis for a Ph.D.! Unknown to us the Air Force engineers had the benefit of their flight experiments and used it effectively. The questions dealt with basic electronic fundamentals (from a helicopter pilot) to problems requiring a knowledge of theoretical physics to solve. I remember in particular the helicopter pilot giving Marty Woolfson a hard time by asking a lot of basic questions about insignificant design details. Finally he ask one about operational amplifiers. This gave Marty an opportunity which I think he had been looking for. Marty said "I am glad you ask that question". He then proceeded to give a tutorial on operational amplifiers 101 starting with E=IR! The Air Force Col. whom I talked with later said that the rest of his team really enjoyed seeing Marty telling the helicopter pilot to shut up in so many words for this was not the time nor place to be asking those detailed questions. Another interesting observation was one individual in civilian clothes who was never introduced other than by name who sat at the back of the room and said very little. However I noticed that all the Air Force people would watch his reactions to the presentations and questions. When he appeared interested in a particular area the questions or discussions would continue. When he appeared uninterested the topic would be dropped and something new brought up. I later found out that this man was probably an NRO representative. The studies were completed with a final report which was submitted in early January 1967. Naturally this meant working through the Christmas holiday.

After the Air Force had reviewed the final reports we received an RFP and were ask to submit proposals for both the sensor and ground segments. The RFPs mirrored our system technical performance which we had proposed in the studies and went to all three contractors. We knew we had home field advantage for we would be bidding our system! We continued to refine the system concepts during the proposal process which we described in our technical proposals submission. Printing multiple copies of the Technical Proposal was no easy task since we could not clear people in our Technical Publications Department. One person, Ron Mafia, had been cleared earlier on the program. He knew how to run the printing equipment. So one night all the Technical Publications people were moved out of the printing area and Ron with the help of other members of the proposal team printed and bound the Technical and Cost Proposals.

Both of our proposals were successful and on May 23, 1967 we were declared the winner of the technical competition and would be awarded a fixed price development/production contract provided a "mutually agreeable contract could be negotiated". The negotiations took place during the "Israel/Arab 7 day war". At every break in the negotiations Jake and Lee Gelwasser would turn on a radio to hear the latest on events in Israel.

The negotiations were fairly difficult. While the Air Force had little difficulty with the ground system cost proposal they had problems understanding the sensor cost proposal especially correlating the elements of cost to the hardware descriptions and work to be performed. To quote one of the technical evaluators, *"The sensor cost proposal was so confused that there was no way we* (the Air Force) *could associate the elements of cost to the work to be performed - but we assumed Westinghouse understood. In fact we could not find detectors in the material lists* (which we had inadvertly omitted but the Air Force did not call it to our attention) *but we assumed they were in there somewhere*".

Bill Parnell recalls: *"At the negotiations Jake's Security System, Naomi, with her cigar smoking and "make the bastards do it right the first time" attitude and the ground system things were on pretty firm ground, but from then on things fell apart. The sensor engineers had underestimated the number of components needed; the detectors were almost completely ignored; and, the test equipment and test concepts had not been fully developed. The customer had been in; done fact finding on the floor at WEC; and, knew more than WEC personnel. I as Program Manager had spent too much time with office and managerial problems and too little time checking the details of how things were going to be accomplished."*

After negotiating for about a week both teams were tired. During the study and negotiations I had developed a good relationship with one of the young Air Force officers. While on a break we were walking down the hall alone when he said "lets get this thing wrapped up this afternoon so we can all go home for the weekend. What if we offered you $XXXX, could you accept it?" I thought a minute and said "probably not but if the number was $YYYY and some minor changes made to the specs I suspect it would be acceptable". He then said why don't we give it a try. It was our turn to make a counter offer. I got with Jake during the break and suggested we caucus for I had reasons to believe we could settle the negotiations rather quickly. (I think Jake suspected that I had talked with someone during the break but he never said so.) During the caucus Jake and I convinced our team to make a counter offer very close to what I had discussed in the hallway not telling anyone about the discussions. Guess what? The Air Force went out to consider our offer and about a half hour later came back and said our offer appeared reasonable and was acceptable. Westinghouse was award two prime contracts - one for the sensor segment (SAP) and one for the ground display segment (OGE). RCA who had been the prime contractor for the previous spacecraft, sensor and ground displays was awarded a sole source contract for the spacecraft. By the way, it was RCA (Lou Gomberg) that coined the acronym SAP for the sensor so they could refer to the Westinghouse Program Manager as the "Chief SAP".

Sometime after completion of the testing of the ground segment of the Block 5 system, I remember comments attributed to Major Blankenship relative to our film recorder. This system incorporated a "wet film processor" which of course required periodic cleaning and chemical changes. He reputedly stated that he would not sacrifice a single feature or any of our user-friendly versatility of our system because of the need for a "mop bucket".

After I retired, I learned from a retired Air Force Colonel who was the Air Force Program 417 chief technical officer and the interface with the NRO and the meteorologists users at that time that while the Westinghouse sensor concepts were good and somewhat unique, by itself the sensor would never have won the competition since it could have been implemented by any one of the contractors. It was the Westinghouse ground processing and user friendly display system concept that really sold the Westinghouse system to most of the Air Force technical evaluators and especially to the user community.

The DMSP was, and is, very successful for both the Air Force and their contractors. Col. Will Botzong, the third SPO director, had a hand written note framed and displayed in his office. This was one of his most prized piece of program memorabilia. The note said "*Col. Botzong, your program is the most successful and cost effective program in the Air Force today*". The note was signed by the Under Secretary of Defense for the Air Force. I know of at least five former DMSP officers that have made General Officer rank and two who are CEO's of major corporations. Maj. Gen. Jack Kulpa, Lt. Gen. Don Cromer, Lt. Gen. Nick Chubb, Major Gen. Steve McElroy and BG John Weber were DMSP alumni. Terry Pittington and Kevin Daly both of whom left the Air Force with the rank of captain are cooperation CEO's.

Col. Wilbur Botzong

Throughout the 6 years that Col. Botzong was the SPO director there were only two Aerospace engineers and one or two technicians assigned. When Col. Botzong retired his replacement was a Naval Academy graduate and a B57G fighter pilot fresh back from Southeast Asia who could not understand how the program had survived and prospered with blue suit Air Force talent alone and who continued to rejected the support of a large number of Aerospace Corp. Engineers. He promptly "fixed the problem" by calling in Aerospace Corp. Engineers in large number to see what was "being done wrong". Program costs skyrocketed. One of the original program founders retired and went into the private consultant business. He and I were discussing the primary reasons for the rising costs of the program. He showed me a graph of the total costs to the program as a function of the number of Aerospace

Engineers assigned to the program without any improvements to the system performance. The results were startling! Costs went up almost exponential as a function of the number of Aerospace Engineers.

Block 5A,B,C Programs

After the contracts were signed the organization charts proposed by Bill Parnell under went some minor changes. Harry Smith named Bill Parnell the Program Manager (a job which he confessed that he never wanted but was directed to take by Harry to minimize internal personnel problems). Jake Beser was made Assistant Program Manager and placed in charge of security and sensor subcontracting. Dr. Roger Cortesi became Technical Director for the sensor segment and I was the Technical Director for the ground equipment segment. Bill and Jake hastened to establish and staffed a Block 5 Program Office. We were still not allowed to brief upper management on the program. This was an insult to some of our upper management and caused internal problems for Bill Parnell because they chose to believe that it was his decision not to grant them clearance. To quote Bill Parnell: *"one General Manager was so mad at me because the customer would not let us brief him, that he said "don't expect any help from me if you get in trouble" and he meant it."*

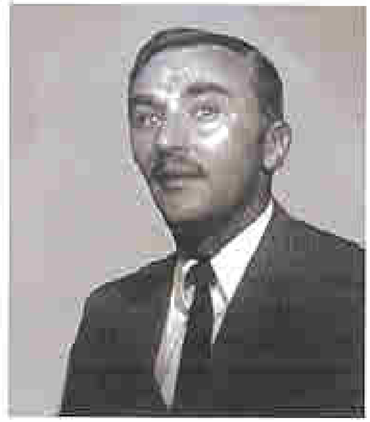
Special access programs were new at Westinghouse. Facilities with acceptable security had to be obtained. A program organization had to be established and engineering specialties identified. Personnel with specific talents had to be cleared and assigned to the program. A temporary program office was set up in the same location where we did the proposal while the "old shaker shack" in back of PQL was readied for occupancy. This building was originally built to house 30-mm cannons and ammunitions for earlier Westinghouse fire control systems and can best be described as a mess. It had no heat or rest rooms and was is a sad state of repair.

Jake prepared and negotiated a security plan with the SPO. This plan required all employees to sign in and out of the secure area as well as exchanging our normal Westinghouse badge for a special one while in the secure area and NEVER, NEVER wearing your special access badge outside the secure area. The badges were coded to identify four different levels of clearance and therefore the need to know. Very few of us were cleared at the highest level and had access to the real customer and the details of the mission. Our various subcontractors could only be referred to in program communications by codes such as Sub-A, Sub-B, etc. We all took these security issues seriously and probably more serious than our customer. I remember a tie clasp which RCA gave away with SPO approval. The tie clasp had the shape of a Block 4 satellite and also depicted a satellite in orbit. Underneath the figure were Roman numerals that clearly spelled out the number 417 which was the Air Force Program number. On the backside was the company logo RCA. I also remember an incident which happened when, during a brief case check by our security guard at the desk, he found an unwrapped secret document. The briefcase owner was the SPO Engineering Manager and he did not have a courier pass as was required. The man was detained until Jake, our program security manager, convinced the guard that it was OK this time but don't do it again.

When visiting other companies we were required to sign in as representing self (Not Westinghouse) and citizenship United States. Charlie Karr remembers an incident that occurred on one of his visits to a subcontractor as follows: *"On one occasion when I was visiting sub-A, their security guard confronted me after I signed in at the door. He asked me what I meant by "USA" as my country of origin. I replied huh-what? He smiled and told me that a few days before I arrived, someone signed USA and went on to view all the secret areas in the plant.*

Security found at the end of the day that he represented the Union of South Africa. To this day I always sign US period." When we quit keeping records of people cleared on the program in 1975 the list contained over 1000 Westinghouse employee names.

Within a couple of months the "shaker shack" (also known as the block house) facility was completed for occupancy; people were identified and cleared; and, the program hit the ground running. As Charlie Karr remembers "*The block house environment represented my first experience with Westinghouse's physical accommodations. It was a truly isolated building, adjacent to the BWI airport runway. It was situated well over a hundred yards from PQL, the nearest building. The path between PQL and the block house was unpaved. It was undoubtedly a very secure area. Although it held 20-30 people, there was no bathroom. Everyone had to sign in and out at the guard's desk, even to leave and return from the bathroom at PQL. This trek was really interesting in rainy and muddy conditions and snowy and icy days. After two seasons of this we were instructed by one furious supervisor (*Lee Magness*) to account for all bathroom time on our time cards. We gladly complied and charged the alphanumeric code 103P. With the old batch computer systems at that time, it took a few weeks or more for the (P) charges to accrue and become noticed by Accounting. The (P) charges hit hard after about a month and we got our in-house bathrooms. In the second winter season, John Fleig, one of our technicians slipped on the iced over grass along the path. He hurt his back, filed a grievance with the union and threatened to sue. We received a nicely paved path very promptly thereafter. Some years later, John graduated from evening college and later became a Westinghouse manager.*



Charlie Karr

The guard dog kennels were along side the building. Occasionally they were let loose for exercise. What a surprise for the dogs to appear as we were hurrying down the path at dusk or at night. Security responded to our complaints very well. The dogs were kept on leashes at all times thereafter.

The heating system broke down for weeks at a time during the winter. This lasted over two winters. We worked in overcoats, breathed vapor at each other and each plotted hourly temperature charts on the wall. Much of the time it was in the fifties all day. The supervisors' offices were adjacent to the outside wall and were definitely colder. At that time the Program Manager conveniently resided in the East Building. Finally, it was deemed cheaper for management to, at long last, expedite a planned move to an area in the East Building than to repair the system. Westinghouse solved the heater problem by moving the Program to the East building."

Fred Schaff also remembers the guard dogs and tells this story. "*One night I went back to the blockhouse for a bit of extra work and, as was required, went first through the link chain fence around the blockhouse and after dialing in the combination to open the door, called security to identify myself and have the alarms turned off. So far, so good.*

But, the guards said, didn't the dogs bother you? No, I said, what are you talking about. Oh, they said, we often allow the German shepherd guard dogs to run loose in the fenced enclosure when nobody is out there.

Ouch, thankfully the dogs either didn't see me, didn't want to bother with me or, as is likely, that without command, they were friendly. In any case, dogs were rounded-up before I left later that night."

Within a couple of months of receiving the contracts the SPO arranged a meeting between Westinghouse and RCA. The purpose was for Westinghouse to explain the sensor and display ground equipment to RCA who in turn would tell us about the spacecraft design; the spacecraft sensor interface; and, the integrated sensor/spacecraft and test and launch operations. Both companies had been told by the SPO that the competition phase was over and now the Air Force, RCA and Westinghouse are a team and don't try to hold anything back as propriety information. One perception still exists among many of the Block 5 engineers and technicians that RCA was the Prime Contractor with Westinghouse as a sub. This is not the case. Both companies were Primes - RCA for the Space Segment and Westinghouse for the Sensor and Ground Segments.

The first review at RCA went very well. It was almost like a single contractor talking to the Air Force. I do remember one exception. One of the RCA System Engineers, George Beck, was trying to pick holes in the Westinghouse test concepts and continued to needle Ed Gregory with obvious questions. Ed finally became a little peeved and said "*George, if you will please shut up and listen I am sure I will answer all of your questions. If not, please ask them when I finish*". After that everything went fine. In fact the working relationship with RCA and its successor companies has been great for over 30 years even though there has never been a prime - subcontractor relationship. Westinghouse has maintained a team of engineers and technicians in the RCA (GE, Martin, Lockheed-Martin) facility since 1969 to perform the integration and test of the sensors on the spacecraft. At one point Westinghouse wanted to reassign one of the Westinghouse field engineers who had been at RCA for several years. The RCA Test and Integration Director complained saying "you can't do that - he is one of my men".

At times during the early days of the contract management disagreements between the SPO and Westinghouse developed. When Maj. Chubb returned from Southeast Asia he was assigned the job of SPO Engineering Manager. Maj. Chubb was a high strung, aggressive and very hard driving manager as well as a capable engineer. The rest is sad history. We would get telephone calls at 7:30 AM our time for status then from time to time we would get calls at 4:30 PM west coast time to make sure we were was still in the plant. Weekend or holiday calls were not unusual .

Chubb had been a key player on the real early study effort but had to fulfill an assignment in Southeast Asia. He was not impressed with the Westinghouse management. I will always remember his *comment "Westinghouse management is the grossest you guys manage by osmosis*". During my first encounter with Chubb he seemed to have a chip on his shoulder and dared me to knock it off. Somehow I got through the meeting without knocking the chip off and we were great friends for the remainder of his tour on DMSP and even later. In fact years later when he was a LTG he, as a personal friend, stopped by Westinghouse to see me and others on the program. Neither the AFPRO Col. nor Westinghouse senior management were told about the visit until it happened. Both got bent out of shape.

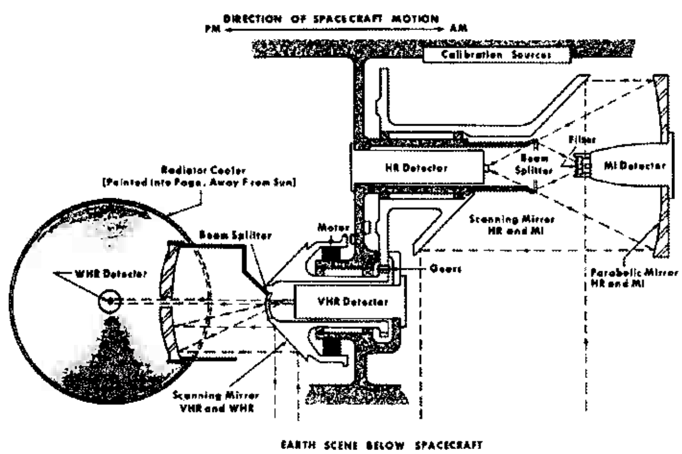
Bill Parnell our first Program Manager was not as lucky as I and fell victim to the aggressive vocal Chubb as well as the cost and schedule over run problems which were beginning to show up. Harold Watson, Bill's boss at that time, was named interim Program Manager and held that position for a short time until Bob Howell became available and was assigned the job. Bob Howell because of medical problems with flying really did not want the job since it required a considerable amount of flying to and from Los Angeles. After about a year or so on the job Bob was able to leave the program and was replaced by Tom Hollis. Tom left the program for bigger and better things in 1980. I had been named the Block 5 Sensor Programs Manager in April 1975 and succeeded Tom Hollis as Meteorological Satellite Programs Manager in July 1980. I held this position until retirement in 1994.

Bill Parnell Harold Watson Bob Howell

Block 5A,B,C Sensor Segment (SAP)

The pre-Block 5 imaging sensors provided by RCA were shuttered vidicon cameras. As the satellite rotated the vidicon camera snapped a photo when the earth was in the field-of-view. Each frame was stored as an fm signal on an analog tape recorder and later transmitted to the ground stations. The ground data display consisted of two raster scanned CRT displays equipped with Polaroid cameras similar to an oscilloscope camera. As each frame was received it was recorded by the Polaroid camera. The camera operators had to be fast to snap the picture, remove the exposed film and get ready for the next frame. Other operators applied the fixer to the developed film, trimmed the image along index marks and pasted them together to form a complete photo of the earth scene. Even though the Polaroid images contained a lot of information, it was hard to physically locate clouds with respect to a map unless ground features were visible in the imagery. This was because of the geometric distortion (known as pin cushion distortion) due to the earth's curvature. This was a major problem for the user.

Unlike the earlier spinning satellites carrying vidicon camera systems, the Block 5 satellite was a three axis stabilized vehicle launched from Vandenberg AFB, California into a nominally circular 450 nautical miles above the earth with an orbital inclination of approximately 98.75 degrees to the equator. This combination yields a sun synchronous orbit plane precession, whereby the orbit plane drifts easterly in inertial space at the same mean rate that the earth moves about the sun (approximately 1 degree per day). This drift rate causes the spacecraft to pass over a given geographic location at approximately the same local sun time



SAP Optics

each day. The circular orbit also keeps the satellite a constant distance from the earth, which permits uniform acquisition of data. The earth's rotation (15 degrees per hour) beneath the orbit causes the satellite to observe a different portion of the earth's surface each pass. The combination of orbit altitude and the sensor field of view provides complete global coverage from a single satellite every 12 hours.

The Westinghouse sensor utilized the forward motion of the spacecraft and a constant angular velocity rotating mirror mechanism to generate the along and across track scanning. This design provided a quantum step improvement in the sensor state-of-the-art. It provided two channels of high resolution visible (VHR & HR) and one channel of infrared (MI) spectrum observations under both day and night illumination conditions. This was the first satellite three dimensional high resolution observations of cloud cover on a global basis! Especially important was the ability to provide predawn support for tactical strike missions and high altitude support for high priority DOD/NRO tactical and strategic missions.

The SAP designers had some very difficult problems to solve which included brush type motors and bearings operating in a vacuum; light weight, high resolution optics; light weight and low power electronics; light weight mechanical structural designs to withstand severe vibration and shock requirements; microphonic problems to deal with; state-of-the-art visible and IR detectors; space radiation environment; etc. Even though Westinghouse was advised by the Air Force where to find capabilities within the industry and in most cases we followed their advice we still had major problems to solve. These problems were eventually solved and a 5 watt, 25 pound sensor designed and qualified for flight but not within either the original time or cost estimates.

The SAP optical subsystem consisted of two scanning flat mirror assemblies and two parabolic mirrors. The scanning mirrors were positioned at an angle of 45 degrees with respect to the optical axis of rotation, thereby scanning a plane which was perpendicular to the optical axis. The larger scanning mirror which was about 8 inches in diameter collected scene energy for the HR and MI channels. The smaller mirror which was a two faceted 90-degree wedge provided two scans per revolution for the VHR channel. A 3 to 1 gear ratio between the large and the two faceted small mirror gave the required 6 to 1 scan frequency difference required for the VHR to HR/MI channels. A beam splitter separated the visible and infrared spectrum energy and directed it to the appropriate detector. When the high resolution channel was added for the 5C SAPs, a beam splitter in the VHR channel was added to direct the IR spectrum energy to a passively cooled HgCdTe detector.

The design and location of passive cooler for the HgCdTe detector which was used only on the 5C models presented some state-of-the-art design problems. The cooler needed an unobstructed view of free space at all times and sufficient heat radiation capacity to cool and maintain the detector temperature at a constant value around 110K and detector contamination problems had to be addressed. Paul Kiefer and his mechanical engineers identified a location for the cooler on the SAP structure and specified the requirements for A. D. Little to designed and build. The A. D. Little design was for a two stage cooler mechanically held together at room temperatures but were separated and thermally isolated at cold space temperatures. An outer stage radiator ring cooled the outer stage first to a temperature where the stages would separate. A cold patch radiator on the inner stage then cooled the detector to a temperature below the proper operating temperature. An electric oven surrounding the detector maintained its preset operating temperature. A conical reflector and shade protected the cold patch from stray radiation from earth or sun sources. The reflector was specifically designed for the sensor-sun-earth geometry to reflect out any stray radiation thus protecting the cold patch. To prove the concepts two instrumented coolers were flown as test models. Test data showed no problems with the concept except for possible contamination from out gassing products from the SAP and the spacecraft.

The primary structural member of the Block 5A,B,C sensors was a magnesium casting. This casting was very light weight and "skeletonized" to the greatest extent possible to reduce size and weight and yet be compatible with the mechanical environments yet maintain its functional integrity as an optical bench. It was so light that one could cause the drive motor to stall by pushing on the structure with one finger, yet it would withstand the launch qualification shock and vibration requirements that exceeding that required for fighter aircraft.

George Pollock tells an interesting story which illustrates the sensitivity of the structure to unusual stress. He recalls *"during an alignment accuracy test of SAP-1 I detected a serious alignment error. For this test the SAP was mounted on a flat surface in a test fixture at three tie down points and the mirrors were allowed to scan a test target. For some unknown reason the scan plane alignment was out of spec. Furthermore a slight finger pressure on the structure would cause the rotating mechanism to bind. Numerous tests were run and precious days of schedule time were lost trying to determine the cause of the problem. Eventually the problem was found to the thickness of one of the washers between the structure and the flat mounting surface. The test specification called for three washers of the same thickness to be used. Unfortunately someone has used at one location a washer about five thousands of an inch too thin. This was enough to cause the alignment error."*

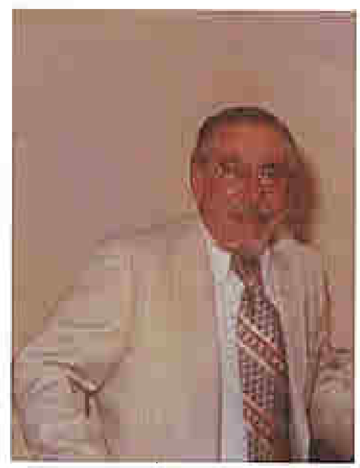
While SAPs 1 through 5 used a low power brush-type dc torquer motor (which were state of the art at the time and used less power) to drive the two scanning mirrors, consisting of a 8 inch flat mirror and a 3.5 inch wedge like mirror. Brush wear out in some of the early systems developed causing shorter lifetimes than expected. Because of this, systems 6, through 11 were modified to replace the brush motor with an ac synchronous motor.

Brush type motors running in the earth's atmosphere for a few years without service are not too difficult to build - just make the brush long enough to last that long and try to trap the debris so it don't get on something to cause a malfunction. However, in the atmosphere, a carbon brush runs with a long life because it pulls moisture out of the air, combines it with the oxide from the commutator along with the carbon debris and makes a slurry that lubricates the commutator. In space where no moisture exists, no slurry forms and carbon brushes become a pile of dust in minutes and problems develop . The solution which was developed by Ball Brothers was to take a carbon brush with some silver in it and lubricated it in a proprietary process such that it would last longer in a space environment. This provided longer brush life but the ac synchronous eliminated the problem.

Bearings and lubricants were of great concern to the mechanical designers. The temperature extremes can be controlled to be fairly reasonable while the unit is operating, it may be several days after launch before the system is turned on. In this period, orbits are adjusted, covers are removed, and batteries are charged from solar panels. So, lubrication of the bearings is very critical. This means that lubricants must stay thin at a fairly extreme temperature, yet it must also work at higher temperatures when operating. The best lubricant available at that time with a low vapor pressure that would give the needed low viscosity over the range was a specially formulated F-50 silicon oil. Bearings were procured by our supplier, GE, as parts i.e. balls, races, separators, retainers, etc. At GE they were run in a race connected to a microphone and individual balls were selected based on the noise they made when running in the special race. The races and keepers were selected and run in also after they were lubricated with a measured amount of lubricant. GE remained the lubricated bearing supplier throughout the Block 5 and OLS programs.

Silicon oil likes to creep. Since you don't want the oil to disappear in the 2 or 3 year life expectancy of the sensor, you have to keep it from creeping out of the bearings and evaporating into deep space or working its way onto the optical surfaces. Since the motor is not very powerful, you can't put a bushing on the axis to retain it. Also, it costs a lot of weight to hermetically seal the bearing housing. The solution is to make a labyrinth seal. Provide baffles so there is long path between the lubricated bearings and the vent to space. Use deep space to cool the outer areas of the labyrinth. Then as the oil creeps out, it becomes less viscous and stops creeping. Then since the bearing race is warmer, it creeps back to the bearings. Now you have a frictionless way of sealing the bearings. Jake Beser became the bearing and lube expert.

But, there is yet another part to this story. One system, F5 was stored for about 5 years and then returned for refurbishment and modifications. When we ran it, the brushes ground down to nothing in minutes! Replaced the brushes and the same thing happened. Why? In the sealed barrel, the labyrinth seal did not work (no deep space to keep the outer area cold). Some of the silicon oil crept out and got on the commutator. Then we found out something that the Navy has known for years. If you get silicon oil vapors on the commutator in the presence of a sliding brush with friction, the silicon oil becomes silicon oxide or sand which quickly destroys the brushes. So all those years running silicon oil and carbon brushes near each other was really a high risk situation, but we got away with it. While reworking this sensor, we looked for other lubricants and there still was nothing else available that would work. Because changing to an ac motor was a major modification, the brush type motor was not replaced even though the sensor was designated a Block 5B.


Jacob Beser

And now for the rest of the bearing/lubricant story. During the Block 5D1 we had a bearing failure of an OLS scanner on orbit. The 5D2 program was underway so we decided it was time for a bearing test which really simulated the on-orbit conditions. Paul Kiefer and his mechanical engineers developed a test. Test results quickly showed that the F-50 silicon oil which we had been using for years was a very bad choice. In fact, in a vacuum the F-50 turns to silicon oxide, a sandy like substance, after only a few hours caused by the relatively high temperatures at the ball to race contact points. The F-5 motor brush problem had provided a clue but we did not recognize it at the time. Our previous successes had just been a case of good luck. We had been operating with bearings destroyed early after launch with system failure occurring only when the ball retainers were worn out and broke apart causing the scanner to freeze. A new lubricant, a synthetic oil Nye 188B, was selected and tested at PQL. A 6000 hour test proved it far superior to F-50. The life tests continued for a number of years and all OLS systems on the ground were retrofitted with the new lubricant. OLS 12 which was launched in August 1994 was the first to fly with the new lubrication. To my knowledge the scanner is still operating with no lubrication/bearing problems at this time (July 2002).

The SAP signal electronics were basically three independent channels namely the circuitry associated with the infrared channel (MI as it was called), the low light level lower resolution channel (HR) and the very high resolution visible spectrum channel (VHR). As I recall the design of the channel electronics were assigned to Bill Stebbins, John Frech, Bill Geckle and Bill Turpin.

The MI channel, which was eventually Bill Geckle's responsibility, was simple in concept but required a lot of inventive ingenuity to implement. The specification required it to sense earth scenes over the temperature range of 210 to 310K using a free space cold reference and an internal hot calibration source with a satellite subpoint resolution of 2 nautical miles.

The detector was a singly-immersed thermistor bolometer with a shield compensating flake that sensed energy in the 8 to 13 micrometer wavelength spectrum. It was fitted with a germanium hemispheric lens which suppressed radiation below 8.0 micrometers. A barium fluoride coating acted as a long wave filter to reject radiation above 13 micrometers. A near constant bolometer temperature was maintained by a cold plate radiator to space and heated to control the ambient temperature.

The bolometer was operated in a bridge with its output coupled to a dual low noise field effect transistor preamplifier. Other electronics which included lead-lag compensating network, a non-linear shaper circuit to compensate for the non-linearity of the power law response of the bolometer and a post amplifier with gain adjustment capability were also necessary.

Bill Geckle remembers his experiences on the Block 5 program as follows: "*Since I started work on the Block 5 program many years have passed, many senior moments have occurred and a lot of water has flowed over the dam.*

The achievements of the Block 5 Program were probably the highlights of my 42 years with Westinghouse. The program was set up much like the Gemini Radar program in that a selected group of personnel were uprooted from their normal sections and pulled into the Block 5 program office for in some cases an enormous number of years. The selection of the particular people and the close teamwork due to working in the same area yielded fantastic results. The very low weight and very low power required by the early units was impressive. In the weight area I went along for the ride. In the power arena the analog engineering group of which I was a part did good.


Bill Geckle

In 1954 when I started with Westinghouse my first job was as a technician developing a tube type ring counter circuit for an engineer by the name of Tom Hollis. Many years later Tom wrote a nice letter that helped in my promotion to the rank of Fellow Engineer. In between on the Block 5 program I had my fingers in many pies. In the power supply area for the Block 5 Program I was responsible for the follow-on required of the Powercube vendor who provided the DC to DC inverters and converters. The converters output was coupled to very efficient linear regulators. On the Block 5D effort the customer questioned my power starved regulator designs but due to the fact that we were using selected high gain high power pass transistors they bought into the designs. On 5D I did the design of all the active filters for all the analog channels. In addition I did all the design for the initial IR bolometer cooled to minus 20 degrees Fahrenheit and then later HgCdTe IR detector channel including the heater loop on the cone cooler operating at 100 degrees Kelvin and the non linear shaping network used to produce a linear relationship between measured IR temperature and channel output. The final area of my effort was the high voltage power supply (HVPS) for the Block 5D PMT channel. Unfortunately, I guess I have to take responsibility for the development of the ATL hybrid T05 can operational *amplifiers used in about 40 places per system. These devices had very low power consumption; great gain-bandwidth; very low front end noise; and, low output impedance. These performance parameters were achieved with excellent stability margin but their cost was very high which caused a lot of heartburn, especially my very close friends Armin Mohr and Steve Nichols.*

In the analog engineering I give John Frech five stars group for his dedication and true technical design brilliance. I can remember him sleeping over night up on the table top in the blue room while working to solve the microphonic problem in the visible channel. John was the very best true analog design engineer I worked with at Westinghouse. Also, Ed Gregory was an extremely talented engineer who somehow easily handled all challenges assigned to him. Among those in the impressive mechanical engineering group it would be impossible to top the performance of Paul Kiefer. In my opinion the company never appreciated or rewarded the efforts of these top notch engineers adequately.

The technical challenges we overcame that impressed me and I believe should be recognized are:

- *low weight and low power*
- *non microphonic visible channel performance*
- *accurate IR measurement across a scan line*
- *visible channel log amp performance*
- *super regulated high voltage power supply for the PMT channel which generated approximately 10 very accurate high voltages (0.1%)*
- *low noise figure IR channel preamp with flat low frequency response to 0.02 Hz*

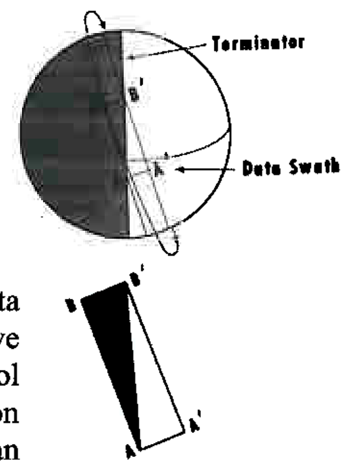
The HR channel electronics also simple in concept, required a lot of engineering ingenuity to design and implement. This channel was require to sense and process data from earth/cloud scenes in the 0.4 to 1.0 micrometer spectral range when illuminated in either sunlight or moonlight conditions with a satellite subpoint resolution of 2 nautical miles.

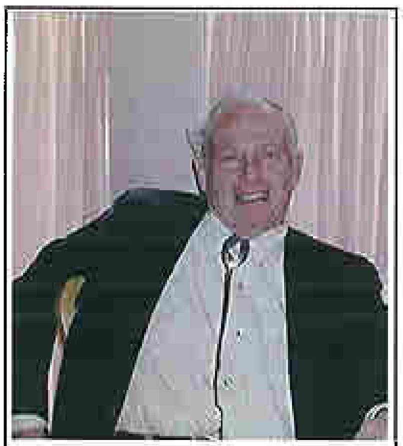
The HR detector was a single back-biased silicon diode with stringent noise and sensitivity requirements. The detector output was a voltage as a function of the incident light power and was required to operate over a range of more than 6 decades of input light. This signal voltage was fed into its preamplifier originally designed by Bill Turpin and later picked up by Bill Stebbins. Because of the extremely wide dynamic range requirements the load resistance of the diode had to be switched. For the higher illumination levels a load resistor of 0.6 megohms was used and for the low illumination conditions the value of 600 megohms was required. Other requirements included a ground commandable linear mode and a linear-logarithmic mode necessary to accommodate the large dynamic rang in scene illumination as well as the incorporation of internal calibration signals. Calibration signals were provided by the zero resolution radiometer (DZ) and an internal light source provided by a radioactive tritium activated phosphor.

The HR channel preamp had both high impedance input and high gain. During system tests in the laboratory the unit had to be tested "like it flies" i.e. mounted in the structure with the scanning mirror rotating. During these tests it was determined that the noise level was too high in the high gain mode. After weeks of tests it was determined that the noise was caused by michrophonics and had something to do with the high amplifier input impedance and the vibrations caused by gear cogging, etc. We were even able to correlate the michrophonic noise with conversations in the laboratory. It was finally determined that the noise was caused by slight movement of components and leads resulting in small changes in capacitance on the amplifier input. The fix was obvious.

The DZ was a unique feature of the system and extremely important to the data production. The DZ was a zero-resolution hemispheric radiometer mounted 180 degrees away from the sensor optics nadir line of sight. This radiometer measured the amount of sunlight incident on the spacecraft and, with the earth oriented sensor system, essentially measures the solar illumination incident on the scene at the data subpoint. The output of this radiometer, in conjunction with programmable gain in the HR channel electronics, controlled the level of the visual data. In other words, the visual data transmitted to the ground were normalized on the spacecraft for solar illumination. The clouds appeared to have the same brightness whether they are at the solar subpoint or near the day-night terminator.

These figures shows the orientation of a sun synchronous orbit to the terminator for an 0600 equator crossing at equinox. Notice how the sensor will have to scan from horizon to horizon through full brightness in the southern hemisphere progressing to full darkness in the northern hemisphere. Once the spacecraft reaches line A-A' the scene on the left begins to get progressively darker and the area of darkness expands. When the data subpoint reaches the terminator, half of the sensor scan is in the dark area and half in the light. At this point, scanning from horizon to horizon, the brightness change from far left to far right is spread over 26.8° longitude at the equator. This is a brightness change of six orders of magnitude. In order to receive meaningful data across the terminator, one must have more than the along-track gain control provided by the zero resolution sensor, one must also have along scan gain control. In other words, as the sensor scans from dark to light the gain for each scan line must change as the scanner moves into increasing brightness. As the spacecraft moves further into darkness, the along-scan gain must occur at a different location along the scan line. This compensation also will occur as the spacecraft leaves darkness on the other side of the earth. Additionally, the along-scan gain control must vary seasonally as the orientation of the terminator to the orbit changes.





Fred Schaff

Fred Schaff was assigned the task of designing the zero resolution radiometer. He recalls "*Once I had the power supply basic design done and the cries from the data channel designers down to a dull roar, I looked for bigger and better things and picked a sort of "data channel" for myself, (or, more likely was stuck with it to keep me busy), namely, the DZ-channel which was a large and circular silicon diode mounted on top of the spacecraft to look directly up from nadir of the spacecraft and utilize the cosine function of the electrical output of the diode as a function of the angle of the sun shining on the diode. This angle information was used to convert just plain "brightness" of the scene on Earth to, "albedo" which provided much better weather information.*

My tests showed that while an uncovered silicon diode array was an excellent rendition of a cosine function, (well within requirements), bare silicon is damaged by ultraviolet light *which it would be exposed to in space. The solution was to place a quartz dome over the diode to shield it from the UV. But measurements quickly showed that a uniform thickness dome took the cosine function response well beyond the required accuracy. Thus, the decision was two-fold where, first, the dome maker did an analysis of how to vary the thickness of the dome and, secondly, each completed assembly had to be tested under a solar illumination to prove it OK.*

Well, the sun is, effectively, a 5,900-Kelvin blackbody radiator while standard tungsten light bulbs more like 2,800-Kelvin and even filtered arc-lamps fall short of a good approximation of the sun.

I checked with observatories around the world for one that came close to "one solar constant". First player was the USAF observatory at Sunspot on Sacramento Peak above White Sands, NM which, each year from November until spring sandstorms had roughly 0.95 solar constant for about 2-hours each day, 11 AM to 1 PM on clear days.

OK, I spent week between Christmas and a few days after New Years, 1968/69 at the observatory which was 17-miles down a mountain-top dirt road completely snow-covered several feet deep with no other traffic except huge lumber trucks at high speeds, horns blowing and blocking the roads and, in that 17-mile there was only one inhabitant. If we got stuck or otherwise stopped it meant spending overnight in the sub-zero temperature.

Then, add to that, our set-up was on the flat roof of the observatory serviced by a long power cord and useable after we shoveled 3-feet of snow off the roof.

Well, that week got at least one or two qualified DZ sensors, no frostbite and only one accident which happened when my companion complained about my driving too fast on snow-covered roads. He then got the chance to drive but within 5-miles ran into a snowdrift with night coming on. Since he did it, he got to hike back the 2-3 miles to the rancher on the BLM land but, lucky for him, (and maybe me), the rancher came by within about a half-hour, hauled us out and I drove the rest of the trip.

By the following May there were more DZ sensors to check and spring sandstorms has ruined Sun Spot's "solar constant" so I looked for the next best thing and came up with Haleakala Mountain on the island of Maui where, for close to two weeks, I, my wife and two children suffered in Japanese style condos on the beach on the west side of Maui while each day I started out in shorts driving up the 10,000-foot mountain to then work outside in borrowed Air Force arctic survival outfits while we again took measurements for the 45-minutes or so each day that it was, again, at or above 0.95 solar constant. Regretfully shortly after that Ben Vester and Stan Lebar pulled me back to lunar cameras and the color TV job and Jim King was "forced" to make one or two additional trips to Hawaii to test more DZ sensors."

The very high resolution (VHR) channel design was similar in design of the HR channel but with less severe requirements. The design of this channel was assigned to John. It sensed and process visual spectrum data in the 0.4 to 1.0 micrometer spectral range with a satellite subpoint resolution of 1/3 nautical mile.

The VHR detector was also a silicon photo diode but since it's dynamic range was such that the load resistance switching was not required which greatly simplified the design. A dark referenced gain switched amplifier with a DZ gain control was provided.

Some of the channel electronic circuits were required to know the pointing angle of the system optics for timing, calibration and gain control purposes. Also the sensor video signals needed to be formatted and multiplexed for storage and transmission to the ground. This timing information was provided by magnetic shaft position encoders mounted on the two rotating scanning mirror shafts. Signals from these encoders was also stored on the onboard tape recorders and transmitted to the ground for use by the ground segment where it was used to calibrate the data and to correct for wow-flutter of the spacecraft tape recorders and scan to scan jitter of the sensor caused by bearing imperfections and gear cogging.

The SAP had to operate in space and survive its natural radiation environment for three years and perform in the Van Allen radiation belt including the South Atlantic Anomaly without significant performance degradation. This requirement was a part of the reliability assurance requirements in the system specification. Charlie Karr writes of his experience addressing the radiation effects problems: "*At the time I came aboard, there was one prototype under test and the first flight system being fabricated. I recommended that two additional analyses be done as part of reliability assurance which were somewhat unusual to WEC at the time. Each was based upon prior years of space related experience at Martin Co. The first was a worst-case circuit analysis and the second was a radiation effects analysis. Naomi and the program office agreed to let me do this.*

The first analysis simulated all reasonably possible combinations of adverse component tolerances and their impact on the sensor circuit transfer function. The advantage of this simulation was to, analytically, surface potential out-of-spec performance sources at an early point in the program. It considered production variations. Thus it could therefore detect problems normally found downstream in production that wouldn't necessarily surface early when testing only a few systems. Simulation enables needed changes to be made earlier, and therefore with less lost time and less costly program impact than to build-in tolerance related problems and then detect them through hardware testing.

In the first analysis, a frequency response was plotted from the equation that related this transfer function to the components. The computer group helped me apply one of the circuit analysis programs of the time (ECAP, Circus, SCEPTRE, etc.). It would have been nice to have had a PC version of SPICE then. The baseline frequency response and specified limit band was plotted by an x-y plotter, using nominal part values. A plot of each response to the other possible combinations of component tolerances was superimposed on the nominal plot and spec limits. The final plot showed the expected band of performance relative to upper and lower bounds of spec limits. These results incorporated the impact of initial purchased part tolerances as well as those due to drift and degradation over the mission. The findings corroborated the solid design I expressed above. One point was found slightly out of spec. I traced this to a small value change in single capacitor and stated that the effect does not appear to of major consequence; however, I recommended a change if there is no major program impact. It was promptly changed.

The second analysis was based upon the space environment. Typically, key areas of concern include micrometeoroid penetration, radiation effects and space debris. Space debris is much more a concern now than it was then and micrometeoroids were not a Block 5 Program Air Force concern then. The focus of the Air Force was limited to meeting the Van Allen Belt radiation effects spec limits of the contract. Two potential impacts of radiation effects were therefore analyzed. The first was component damage and the second was system saturation due to charge build-up. Component damage relates to inherent structural shielding and component damage tolerance to the specified fields. Charge build-up to saturation relates to shielding, component susceptibility and circuit design. Charge build-up causes no permanent damage and could be reversible through design. I analyzed both aspects and found existing levels to be higher than negligible, but well within limits. However, even though I had previously submitted deliverable reports in this subject, I recommended that the Radiation Effects Lab at R&D

provide a more expert opinion. When okayed by the program I wrote a test plan and set cost guidelines-with agreement by R&D. Circuits (without sensors) were duplicated using similar production parts and sent to R&D. R&D confirmed the results and documented a credible report for program submittal to the Air Force.. While testing, I would check on status from time to time. I discovered that Dr. Sun totally ignored the cost caps we agreed on. R&D continued testing until the end and we had to pay over double our agreed to amount. This was my first lesson in dealing with R&D-You can turn them ON, but you can't turn them OFF."

The SAP power supply used the spacecraft generated power supply voltages to provide all the power required. In particular the power supply controlled the -24.5 volts used by the drive motor and provided the other regulated voltages required by the electronics through two regulators. Switched regulators were required to optimize orbit average power for the operating and non-operating modes commanded by the spacecraft. Fred Schaff was assigned the power supply design task. He recalls his experiences as follows: *"Power supply design was always the butt of jokes and the very bottom of the design totem pole of engineering but, on the Block 5A, it became a premier design job assignment and the designer, namely myself, was designated "The Power Czar".*

I was briefed onto the program in September of 1967 on either a Thursday or Friday, assigned the power supply design problem and told to have an "acceptable" block diagram of final design by Monday. Lovely assignment for one who had just come from designing deflection circuits for lunar TV cameras and, never, never had anything to do with power supplies.

Basic electrical supply from the spacecraft was a -24.5±0.5VDC buss and, in addition to the motor drive, all electronics were supposed to run off of a +12VDC and a -12VDC supply plus a very small load of +5VDC for certain control applications. Simple, Yes until I read the specs which said the total drain off the spacecraft -24.5VDC buss, including DC-motor drive was to be 5-watts, averaged over orbit. Suddenly, the role of the power supply designer jumped from being picked on by the channel electronics designers to the status of absolute Czar.... .

Well, first task was to design one of the first-ever "switching regulators" to get that -24.5±0.5VDC input supply to six different, ±12VDC to each data channel users at ±0.1VDC regulation. Result - better than 92% efficient from loads of 710 mW to 10,650 mW; 83% efficient at 250 mW and 45% efficient at 25 mW.

That done, negotiations started in two directions. First, (and obviously most important), with the SPO to determine which channels they needed ON and for what amount of any given orbit. As one might expect, the SPO, (or their ultimate customers), wanted as much operating time as possible but they recognized the problem and equipment limitations. Second, with duty cycle figures in hand, I had the data channel designers report to me weekly on their design requirements accurate to 10 milliwatts and, in turn, I would either OK the design or tell them "back to the drawing board as you're using too much power". Oh the cries of trials and tribulations of a power supply designer with an engineering degree only 3-years old but somehow we got the job done".

Block 5A SAP Fabrication, Test and Launch

As with most engineering endeavors, perfection comes with great difficulty and the difference between failure and success is doing a thing almost right and doing it exactly right. Engineering breadboards as well as mechanical and thermal test models were built and tested. Because of the program special access security requirements, these breadboards could not be built and tested in the open electronic and mechanical labs in the east building. Also there were optics and low light level sensing requirements which required clean room facilities as well as a dark room for testing. The Lunar TV Program for NASA was winding down a this time. Westinghouse had built a special clean room facility for this program affectionately known as the "Blue Room". Incidentally, it got this name because, during the Lunar TV Program, the employees working inside did not like outsiders staring at them through the windows so they were all painted with an opaque blue color. The Lunar TV program also required testing in a low light level environment. Because of this requirement the clean room also had a clean black room attached. These facilities, while small, were ideal for the fabrication and test of the SAP as well as all of the follow-on units.

The manufacturing organization as well as the labor unions recognized the importance of Block 5 to Westinghouse and were very cooperative in setting up and staffing the Blue Room with the most qualified model shop machinist, assembly operators, testers, inspectors, etc. available. A lot of the credit for the high degree of reliability that was achieved should go to the Blue Room Staff. Two principles uncommon in the manufacturing organization at that time were implemented. First management and the union representatives permitted selection of personnel by skill levels as opposed to the seniority system that was required in the shop. Thus the Block 5 Blue Room staff members were selected by name. Some who were selected were not happy with the extreme requirements to follow high quality workmanship processes to the letter and they were cheerfully sent back to their old organizations without penalty. Those who stayed formed a close bond and developed great pride in their workmanship.

Second the operators were encouraged to suggest variations and deviations from the normal shop practices in order to make the product better. This management technique paid dividends in developing a manufacturing team that worked with engineering, quality control and, test personnel to identify problems in design and processes at an early stage so they could be corrected.

Memory or available documentation does not permit recalling the names of all of the Blue Room staff members who contributed to this effort but there were many. Roger Van Horn was the foreman for many years. Lou Woods was the senior inspector and John Tigue was the master machinist are some of the names I recall. Dave Brust, a FE&S mechanical technician did most of the precision assembly.

Westinghouse did not have the capability to fabricate the lightweight structure or the light weight, high quality optics required. Barnes Engineering and Kollsman Instruments were recommended by the Air Force and selected by Westinghouse as the provider the optics and structure for the SAP. Working very closely with the Barnes and Kollsman Engineers our mechanical and optical engineers design the main structure, the optics; the drive motor; the bearings; the magnetic encoders; and other mechanical components which composed the SAP structure assembly. One Optics Technician, Matthew Comer, did the assembly and optical tests of all the SAP systems. Later when Kollsman Instruments went out of business, he was hired by Westinghouse and assembled and tested follow on units until his untimely death from a massive heart attack. All of the electronic assemblies were designed and fabricated at Westinghouse and attached to the SAP structure assembly during system integration and test.

The SAP design and development problems were discovered either in the breadboards or in system tests and solved one by one but sometimes not in accordance with the contract schedule. Charlie Karr tells of his experience with one of the major problems. *"Roger Lieske, the systems engineer and George Pollock the test engineer and the rest of the test crew had run the prototype through many stressful tests without indication of unusual problems. However, it became obvious that a major problem was occurring when the first production flight system testing began. Audible squeals were heard when the sensor mechanism rotated. Grinding sounds were added to the noise. A serious bearing problem was becoming apparent. It then became especially important to have our ducks in order before we explained this to the Air Force, who were getting impatient to have the flight system delivered on time.*

Roger Lieske George Pollock

I, as the Reliability Engineer was asked by Jake Beser to take a look at the problem before it became worse. There was pressure to immediately disassemble the system to find the root cause. I suggested that before disassembly, perishable symptomatic data be documented. Jake agreed. We then promptly took tape recordings of the sounds during rotation. A spectral analysis plot was also made which represented the signature of the noise during rotation. And when the rotating mechanism was de-energized, an acoustic level response was recorded as it slowed from full rotation to stopping. The same process was used to benchmark the well-behaved prototype sensor system. These were presented as objective documented methods that could be reproduced in the future. Although not a solution to the problem's root cause, it was felt to give us a predictive early warning of similar defects in future systems. And we also had a comparison of recorded normal vs. abnormal systems.

I consulted with Frank Rushing throughout this event. He always had simple and elegant solutions. He told me that the human ear is probably the best sound discriminator and detector of all. He liked putting a screwdriver in his ear and holding it up against the mechanism. I remember us both kidding around about his trained ear with attached screwdriver being listed as test equipment that was available to anyone following these procedures.

When we admitted all to the Air Force, this documented process very temporarily appeased them. Of course this was as temporary as keeping a ski chair still by holding tight on the little cable slack—until you were swept off the platform by the cable mass and inertia. Following this exercise, the program office realized we couldn't go further without stopping all tests and disassembling the flight unit to deal with the problem. This had to be done at Sub-A's facility--pronto. This meant schedule delays and very close Air Force scrutiny.

Jake Beser then asked me to coordinate the tear down at sub-A. He told me who my helpers were. Our team of five WEC people included Frank Rushing and Dr. Clark Behler a prominent metallurgist from R&D Labs, two program mechanical engineers and me. Frank and Clark were to be kept away from Sub-A's management and political issues. I asked Jake to insist on the best cooperation possible from Sub-A personnel since on prior trips I had problems with their cooperation on sensitive issues. I briefly met with the team that day to plan our disassembly process. For obvious reasons, Jake Beser and Tom Hollis were totally occupied interfacing with WEC and Air Force program management.

Our team flew to Sub-A the next afternoon, checked into a motel, ate dinner and reported to their plant. By early evening we were set up with notebooks, drawings and a rough tear down *procedure. Sub-A provided a technician and someone to take photos. I asked that we proceed slowly, take copious notes and make many sketches of what we observed. We began the process.*

Each part we removed from the assembly was scrutinized first by Clark and Frank. We conversed about what we saw and recorded all. We were totally absorbed in the process and time flew by. It was after midnight when we finally reached the bearings. Clark said he saw black material on both the side of the bearing housing and on the wall of the surface against which the bearing was seated. And on the wall he saw a suspicious defect. A small part of the seating surface had caved in. Clark and Frank inspected the black substance with a magnifier and said it was made up of very fine metal particles. And then Frank tapped on his head and said "fretting corrosion". Clark replied, "That's it". I asked for a number of pictures. Sub-A complied and went off to develop them. We sketched the items also.

Clark and Frank briefed us on the discovery. They explained that fretting corrosion occurs when metal surfaces of slightly dissimilar hardness rub against each other in a rocking motion. The weaker surface wears at the points of contact. Parts of the weaker surface collapse which emit powdery metallic particles. In our case, the particles migrated to the inside of the bearings and were contaminating the balls. Unfortunately, this was the worst of all possibilities since it wasn't a component problem but a major dimensional and materials design problem (Years later it was shown that this was probably the first manifestation of the F-50 lubrication/temperature problem in a vacuum) Sub-A probably realized their culpability during tear down. When I asked for the Polaroid snapshots they said the camera broke and none of the pictures came out. I angrily insisted on another set and they reluctantly complied. Sub-A finally returned with one photo that was very faded. But we had plenty of sketches and notes to cover our findings. We got back to our hotel about 2 or 3 AM and flew back to BWI the next morning.

That day the Program Office debriefed us, then promptly informed the Air Force of the situation. Jake and Tom became preoccupied with Sub-A and I was asked to coordinate a technical report and write the white paper on the findings. This report was to include a detailed technical analysis and a recommendation for corrective action. It was to be delivered to the Air Force in about ten days. Frank Rushing and Dr. Clark Behler had the section, which discussed our findings at Sub-A. Their analysis was supported with a scholarly analysis by an East building Ph.D. metallurgist. I edited the overall report and wrote a detailed section on reliability.

When I summarized the findings and our team's estimate of corrective action and schedule impact, the "white paper" looked quite gray and grim. It was a good technical report and was painfully honest. A major redesign was necessary. It would be at least six months before we expected to return to the same point at which we stopped. It wasn't our fault, but it was our problem and responsibility because it involved our subcontractor. And sub-A was doing its best to minimize its liability and cost impact of the redesign. I was searching desperately to find something that would provide some glimmer of hope. I felt like I was in a wrestling match with a Suma wrestler covered with grease. Then the light turned on!

We were all reconciled to the necessary flight system redesign and its accompanying delay in implementation. Otherwise all future flight systems would suffer the same sad fate. But why was the prototype system so successful? I rushed over to Roger Lieske to review the prototype systems test records. It wasn't a fully qualified system in terms of parts control and deliverable standards, but it did amazingly well during testing. Tests had been successfully run in normal gravity conditions and extreme thermal vacuum conditions for very long periods of operation. These conditions were significantly harsher than the expected benign conditions of *space flight at zero gravity, even considering a short but stressful launch environment exposure. The statistics based on successful hours of prior operation clearly showed an extremely low risk of the prototype containing the generic problem we discovered in the flight system. I felt a great deal of relief and I was now able to change my bottom line recommendation.*

In the paper I confirmed, in no uncertain terms, that we needed a thorough and proper corrective action process to root cause that would be long and costly. However, because of the unusually good performance of the prototype system, I recommended that we fly the prototype system in place of the first flight system. I said the problem that was generically built into the design wasn't in this system. Why? Perhaps we'll never know. But we shouldn't tamper with the prototype or we could kill the goose that laid the golden eggs. If the prototype doesn't work in space, we would be no worse off schedule-wise. But, if it worked, we have a satellite to cover the Air Force through the redesign period. And, we have good reason to believe it will work. I never discussed this conclusion with Jake or Tom until I got my facts together on paper. They read my first draft. They had been so preoccupied with the fallout of the problem that they were reconciled to the program delay and the launch delay. They were excited with this new opportunity and supported my conclusions. The paper was expedited and sent to the Air Force who immediately agreed with the conclusions. Some light appeared in the tunnel."

Flying a prototype model would never have even been considered by NASA at that time. Their philosophy was "You just don't fly a prototype unit which does not contain space qualified parts; or which has been subjected to qualification level testing; or, which has been modified and handled without formal paper work". However the Air Force at that time had been flying such units on Blocks 1 through 4 without hesitation but had suffered from reliability problems. For the Block 5 they had stressed improved reliability as a key selling point for funding. They may have accepted portions of the prototype SAP as Flight 1 but I have been unable to confirm that as fact. All the meager documentation that is still available only talks about Flight 1 with no mention of its prior history. I have been unable to find any records of F1 being disassembled for bearing problems. I do find in the correspondence file a reference to F2 being disassembled. Maybe somewhere along the line a prototype structure, optics, drive motor and bearings were redesignated Flight 1. However the prototype electronics would probably have never have been considered for flight for workmanship reasons. In any case whichever unit was delivered to RCA it would have undergone temperature, acoustics, vibration and a 21 day thermal vacuum test.

In retrospect this SAP bearing problem was probably the first indication of the F-50 lubrication problem in a space environment that was found several years later with OLS systems. In all likelihood the "black substance" also contained the abrasive silicon oxide, a product of the F-50 thermal degradation. The silicon oxide caused the bearings to rapidly wear and reduce/eliminate the preload. Once the preload was relieved the ball to race contact temperature was reduced and the bearings continued to run in a sludge of oil and wear products until the retainers were destroyed. Had the root cause of the failure really been recognized at that time and a bearing-lubrication test performed, a different lubricant would have been selected and we would have saved millions of dollars!

Eventually deliverable units were declared ready to ship to RCA for mounting on the spacecraft for integration and test.

Charlie Karr also writes: *"Jake Beser had for a long time conveyed a recurring image of an Air Force General anxiously pacing in the early morning fog in his trench coat, alongside an empty rocket on its Vandenberg launch pad. Now, the rocket finally got its passenger. Shortly* *after the decision to fly was made, we received confirmation that the launch was successful and the system was working. There were lots of cheers, smiles and a great deal of relief. Not too long after we had a celebration dinner at Snyders ..."*

Fred Schaff remembers some of these first shipments: *"Somewhere early in the program, a SAP Thermal Mass model was ready to be shipped to RCA but I don't recall whether or not is was a working model or not. In any case I was asked to deliver it to RCA in my auto ALONE. Then, after it was loaded into my car all double-wrapped by security, I was "briefed" by security on handling of the box under all conditions including accidents and/or breakdowns. After the briefing I refused on the spot to go any further until Westinghouse agreed that an additional person was needed just in case, for any reason, the car had to be left, even to get a cup of coffee.*

A bit of argument ensued but, in the end, it was Dick Tracy was assigned to go along. As it turned out, all went well with on problems developing."

Months, or maybe a year or more later, the first SAP flight model was ready for delivery to RCA. This unit was sent by a courier and arrived at Princeton in late afternoon and was being unpacked when one an inspectors saw the nuclear tag on the tritium source and there was no accompanying documentation required for shipment of any radioactive materials.

So, about 3PM that afternoon, Westinghouse the Program Office got the call that RCA had evacuated the entire building and sent everyone home for the rest of the day until Westinghouse verified that there was no breakage of the tritium source and no radioactive releases.

Again the burden fell on me to investigate. First I called the tritium source manufacturer and asked about the risk if it was actually broken. The answer was a tongue in cheek reply that eating more than two or three could be a threat but breakage of any kind was no risk what so ever.

Armed with this information, I checked-out Westinghouse's only Geiger counter, called RCA and told them I was on the way and would be there that evening and headed for the exit from main gate to get underway to Princeton.

OOPs, at the guardhouse, they quickly discovered that I and the storeroom had filled out a "Personal Property Pass" instead of a "Company Property Pass". This meant that I was trying to take out a piece of company property illegally. So, quickly I went back to storeroom but, by this time, its 6 PM and no one was there so back I went to guardhouse to impress upon them the urgency of the situation and that, regardless of what type of pass it was, it said that the Geiger counter was allowed to leave WX and, by the same token, was required to be returned.

Nope, guards would only accept that if countersigned by SDD "executive" and I hadn't really seen any when I looked before. In desperation I grabbed the "Personal Property Pass" and, besides my name, I wrote HARRY SMITH, (FLS), picked-up the Geiger counter and left while the guards stood around debating what to do. Thankfully they decided to let me go!

Well, after a quick drive to RCA where staff was waiting for me, it was a big letdown as nothing was broken and there was no radioactivity and, after several threats of requiring me to take the entire system back home with me because it had been "illegally shipped" without proper documentation for the radioactive source, better judgment prevailed and they kept the system after requiring me to remove the tritium source and take it home with me to only be returned with proper documentation.

I then drove back to Baltimore arriving at home very, very late in Ellicott City and went to bed. Next morning, before going into the plant, I compared the tritium source radiation with *that found in my home. Guess what, the tritium source radiation levels were far below my bedside Baby Ben alarm clock and also less than my sandstone fireplace walls.*

That was my first and last experience with that damn tritium source."

The I&T program at RCA was long and tedious for this was a new generation sensor and essentially a new spacecraft design. Lots of design and interface problems had to be identified and corrected. There were temperature tests, acoustics tests, vibration tests and a 21 day thermal vacuum test. During and after major tests the complete integrated spacecraft was subjected to thorough testing to verify its electrical performance. Some of these tests included a simulated flight tests to exercise the integrated spacecraft as if it were in orbit.

The integration and testing of the SAP with the spacecraft was a Westinghouse responsibility. RCA technicians actually did the mounting of the SAP on the spacecraft but all electrical testing was performed by Westinghouse Field Engineers and Technicians at the RCA factory in close coordination with the RCA I&T Team. Art Cote headed this group and was considered a valuable member of the RCA Test Team by both RCA and the Air Force. At one point in the program, Westinghouse wanted to move Art to another field assignment. This brought a loud objection from the RCA I&T manager Jim Corr. He said "*you cannot do that, Art is one of my men*".

Yes, the Block 5 series of sensors represented a significant advancement in the design of DMSP satellites. But progress did not stop with the first design. Building on experience gained from on-orbit operations, Westinghouse continued to improved and enhanced the performance of the Block 5A sensor in terms of data resolution and other system capabilities. These upgrades were designated Blocks 5B and C.

The Block 5A group comprised four Sensor Auxiliary Packages (SAPs). SAPs five through eight were named Block 5B and SAPs nine through eleven were designated Block 5C. SAPs six through eleven were modified by replacing the dc scanner drive motor with an ac type motor.

SAPs six and seven contained instrumented passive radiative coolers to gain flight data necessary for the incorporation of the so-called 4th channel also known as the WHR channel into sensors eight through eleven. This channel allowed the users to ground select either VHR visible data or WHR infrared data. These changes increased the power required to 10 watts and the weight to about 40 pounds

The Block 5C upgrades included not only the Very High Resolution Infrared Channel but also an improvement in the HR channel along scan gain control circuitry by the addition of a solar AZ/EL sensor. Information from this sensor allowed the SAP HR visible channel gain to be programmed along scan and greatly improved the data when scanning across the day-night terminator.

The satellites of the Block 5A,B,C systems were built by RCA and were an outgrowth of the previous versions of DMSP satellites. Its structure and general configuration reflected this background, and as I recall many of the functional subsystems were identical to or quite similar to their predecessors.

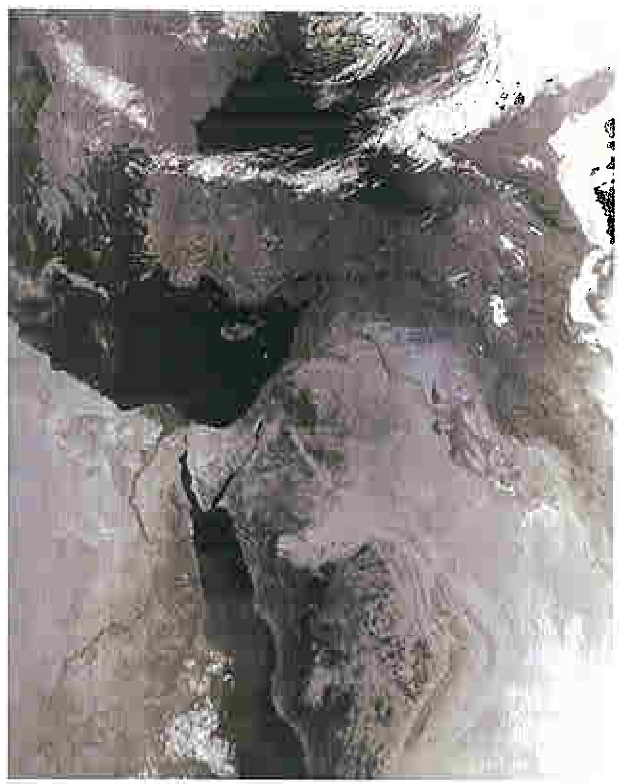
Block 5A Spacecraft

The basic structural element was a machined magnesium base plate which provided a mounting base for components. The satellite was three-axis stabilized so that the axis of rotation of the SAP scanning optics remained parallel to the orbital velocity vector and its line-of-sight was perpendicular to the center of the earth. These conditions gave the desired cross-track scan. The stabilization was achieved by concentrating the angular momentum in a flywheel, whose spin axis was maintained normal the orbit plane to control the pitch axis. Magnetic coils controlled the roll and yaw axis. Accumulated momentum in the flywheels was dumped by magnetic torquing over the earth's magnetic poles.

On February 11, 1970, the first DMSP Block 5A spacecraft carrying a Westinghouse sensor was launched from Vandenberg Air Force Base (VAFB) into a noon orbit. It immediately started sending back what was described by our customer as the "World's Best Weather Data". The first data was transmitted to the test and integration site at VAFB as the satellite passed overhead. The display equipment had a green light on one of the equipment drawers to signify the data is being received and the ground equipment is synchronized. Everyone in the Payload Test Facility (PTF) was watching this light. When it came on everyone cheered.

Larry Nix remembers this occasion: *"My memory of the scene that night bears an eerie resemblance to a police line-up in a murder mystery. This scene included the dimly light waiting room for high-ranking officers, important influential spectators, and others. This room included a viewing window connecting the brightly lit adjacent room. In this real life drama the officers were career air force personal and the others included managers and engineers associated with the program. In this case, the one way-viewing window in the police line-up was regular plate glass and the line-up consisted of the ground based camera processor, which was centered in front of the viewing window with Jack operating the equipment. As the time approached for the satellite to come within range of the ground receiver, the tension of all observers was rising since the reputations and careers of all those present depended on the outcome of the events of the next few minutes. All eyes were fixed on the green light on the camera processor. When it came on everyone cheered! I was standing in the center of the viewing window such that I could evaluate if everything was working properly. It was my function to be Jack's back up in case of a film jam or if some other problem should occur with film camera processor. In a short time after the "green light" came on, processed film started emerging from the processor which Jack caught hold of as it came out. As time passed, the apprehensions of the spectators began to rise again because the film appeared to be almost clear except for what appeared to be occasional random spots. When the satellite passed out of receiver range several minutes later and the "green light" went out, Jack pressed the film cutter button and with the film in hand headed for the door to the spectator room where a light box was located near the front of the room. One of the air force officers opened the door and took the film from Jack and put it on the light table for examination. (Jack told me recently that the air force officer was Major Chubb.) The other air* *force officers present crowded around the light table to view the film. The meteorologist, Major Blankenship, was in the center of the group. By this time the atmosphere was again quite tense and concern was rising as to what might have gone wrong as no one realized quite what to make of this almost clear film. After a few seconds of viewing the film, Major Blankenship pointed at two spots on the film; "THAT IS THE TWIN CITIES!" Pointing to another spot near the bottom of the film Major Blankenship's next words were, "THAT IS MEXICO CITY!" With that anxieties subsided as we realized the system had functioned properly. Then Col. Botzong requested an atlas of the area, which was promptly produced by an air force officer from a brief case in another room. This film was high-resolution data of a dark night between 2 am and 3 am and the black spots were in reality the city lights that were within the 1600-mile viewing coverage of the satellite as it passed within the receiver range of VAFB. Convinced that the "show and tell" had been successful, the decision was made that the recorded data on the tape recorders could wait until later for processing and viewing as all those present were convinced that system had worked. We then returned to the hotel for some much needed rest for it had been very long and suspense filled day!"*

The first daylight imagery was on a piece of 9 1/2 inch wide film about 12 inches long but it clearly proved the system worked. Within a couple of hours the first stored data for a complete orbit (about 9 feet of film) was transmitted to VAFB for processing and display. The Air Force officers were elated. Major Chubb said that if they did not get another bit of data from this satellite what had been received that night was worth the price of the satellite. He immediately scheduled the general's airplane to take Col. Botzong, himself and Major Blankenship to Washington, DC for "show and tell" sessions and to show that Block 5 was a success.



First Block 5 HR Stored Data February 12, 1970

The Flight 1 spacecraft remained operational for 78 days when its mission ended on April 30, 1970. During its short life, problems were noted with the spacecraft pitch control mechanism and also with the brush wear on the SAP. The race was on! Which would fail first? The SAP motor brushes outlasted the motor brushes in the spacecraft pitch control mechanism. But even with its short productive life the Block 5 system concepts had been proven.

Block 5A Satellite on Thor Booster

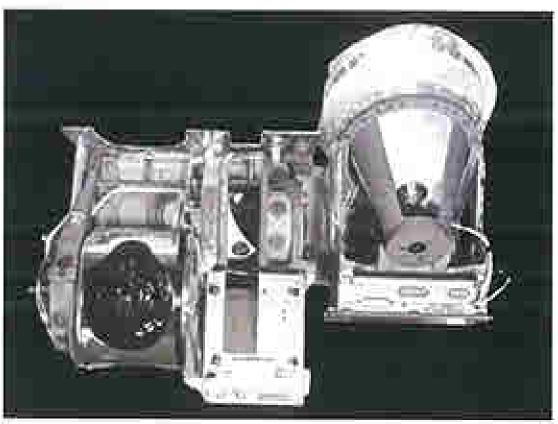
Flight 2 was launched on September 3, 1970. The Air Force once again had a DMSP satellite in orbit. However problems with motor brush wear developed and were noticed soon after launch which resulted in a life of 164 days when the SAP failed on February 15, 1971.

A third satellite, Flight 3 was launched on February 16, 1971. This system performed its mission for 746 days when SAP motor brushes failed due to excessive wear. This was the last Block 5A sensor system..

The first Block 5B system was successfully launched on October 14, 1971. This satellite mission ended 196 days later on March 27, 1972 when the satellite failed caused by rapid degradation due to damage from back flow of heat from the Burner IIA plume during launch.

The second 5B system was launched on March 24, 1972 and lasted until February 23, 1974 when its mission ended. Three more of the 5B series were successfully launched in 1972, 73, and 74.

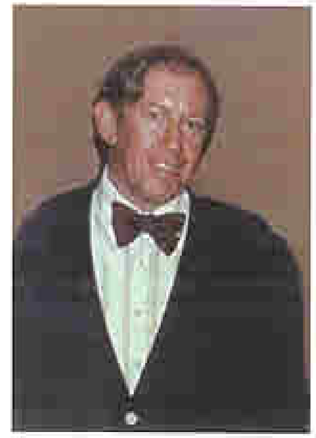
The first Block 5C system was successfully launched on August 8, 1974. This system continued to operate until December 1, 1977. A second 5C was launched on May 24, 1975 with its mission ending on November 30, 1977. The last 5C system was launched on February 19, 1976 but failed to achieve orbit because of an improper fuel loading. This performance data shows that this series of satellites performed successfully. The satellites were designed for a mean mission duration of 6 months but the mean mission duration achieved was almost 17 months. Only two of the Westinghouse sensors did not meet the 180 day life requirement. Flight 2 lasted 164 days and Flight 9 lasted 114 days. Flight 7 held the life record of 1224 days.



Block 5C Sensor

As with any first article, anomalies will occur. For the case of space missions they have to be analyzed and the cause determined. A Vehicle Anomaly Reporting (VAR) system was established by the SPO. Al Kimball was assigned the task of investigating each sensor anomaly; determining its cause, and its effect on the mission. Needless to say this kept him very busy from the first 5A launch in 1970 until he retired when he passed the task on to Bob Carrell.

Block 5D - The OLS



Tom Hollis

Sometime in 1971 Tom Hollis, who was now the Block 5 Programs Manager held a meeting with Col. Will Botzong (SPO Director 1968-1974) and Jim Blankenship (who was now a Lt.Col.) from the SPO. The topic was what are the SPO needs that the current Block 5C sensors do not provide. The number one problem they identified was the lack of constant resolution across track. Because of sensor-earth geometry's the ground resolution of the SAP data degraded by a factor of about seven from nadir to each edge of track. This was causing problems with the ground computer processing of the imagery data.

Tom and Ben Vester assigned Gordon Ley and Frank Rushing with the task to come up with a scanner concept which would provide constant resolution in both the along and across track directions which they did. Their concept, known as he Fixed Resolution System, (FRS), utilized a cassegrain telescope optical system which was scanned sinusoidal back and forth across a 112 degree subtrack field of view by a low power mechanically resonant electro-mechanical drive that includes two contra reacting coil spring sets and a pulsed "kick" motor - a mechanism similar to a driven pendulum. The optical system would simultaneously collected data in both visible and infrared wavelengths. The infrared system included a two segment passively cryogenically cooled HgCdTe detector sensitive to wavelengths of 10.5-12.5 microns. The visible system included a segmented silicon diode detector and an image dissector opaque photocathode photomultiplier tube responding to wavelengths of 0.4-1.0 microns. Detector cross track segment switching was necessary in conjunction with the sinusoidal scanning to achieve the constant ground resolution.

In order to demonstrate the feasibility or a low power mechanically resonant sinusoidal scanning concept, Westinghouse invested IR&D money in building a proof of concept demonstration. This model did not contain the optics or the detectors but it did show the mechanical resonant concept was based on sound engineering principles. As and added feature, the demo model was momentum compensated to also show that this could be done should this become necessary. After a demonstration to the SPO the concept was sold. Years later when I was talking to Col. Botzong, who had since retired from the Air Force, he mentioned how that simple demonstration had really convinced him and his associates to proceed with a development program using his 3600 money to be called later the Block 5D. Incidentally, the program nomenclature was originally Block VD but during a briefing for a SAMSO commander he said that nomenclature is unacceptable has got to be changed. The Air Force does not have “VD”. Thus the nomenclature was changed to the Arabic number 5.

A team of Westinghouse Engineers worked with the SPO Sensor Project officer to develop specifications for the FRS. A Harmonic Motion Simulator, nicknamed HOG, which simulated the uncompensated momentum was designed, built and flown on a 5B spacecraft to determine the effects of a 6 Hz uncompensated momentum on the spacecraft. I was still working the Ground Segment at that time. Bob Noll headed the initial effort and prepared the price quote. Later Ralph Strong and Dale Guhne picked up the proposal effort, helped with the negotiations, and found people to start work on the new contract

The FRS specification called for the development of the scanner and a Data Management Unit to control it. But one of the requirements was for the equipment to interface with the

Ground Segment and for Westinghouse to design and implement these modifications in the display engineering model (SAGE as it was known).

At the conclusion of negotiations I remember Bob Noll preparing a Work Statement (WSA) for the Ground Equipment effort which he brought to me to sign. Unfortunately no one had really investigated the FRS impact on the ground segment before the FRS price quote was submitted and negotiated. After looking over the work required I told Bob that the work described could never perform for the budget proposed. In fact it probably could not be performed for the value of the entire contract. Bob's comment was "*but you have to sign it.*" I still refused.

Next I read the FRS proposal and the sensor statement-of-work for the first time and generated a ROM cost estimate for the ground equipment impact. I then prepared a presentation which looked at the total system and how the FRS would fit in. I then set up a personal closed door meeting with Tom Hollis and proceeded to tell him of the magnitude of the change which the FRS would cause to the spacecraft and the ground equipment. I also highlighted what the FRS contract required Westinghouse to do and the associated cost problems that we would face with the just negotiated FRS contract. After understanding the magnitude of the problems his face became flushed and he ask me what did I suggest. My comment was that the only way I could see out of this dilemma is to generate a massive change to the FRS contract via the ECP route. I will never forget Tom's marching orders. He simply said "*you just got a new job - get out there and talk with Ralph and get busy with a ECP and sell it to the SPO*". This was my first introduction to working directly on the space segment.

Also about this time a young 25 year old 1st Lt. named Kevin Daly wandered into Col. Botzong's office at SAMSO for an interview. This young man had a Ph.D. in engineering from Princeton University. Col. Botzong recognized his capabilities and immediately hired him into the SPO and placed him in his systems organization. Kevin, who is now the CEO of a major corporation and on the board of directors of several companies, was one of the most capable engineers I had ever met. He had a wide range of knowledge and could even hold his own with Gordon Ley. He immediately became Col. Botzong's right hand man and went with him almost everywhere he went even to Pentagon briefings with the Undersecretary of the Air force. When at the next Program Management meeting at the SPO, Tom Hollis suggested that the FRS was only the start of a new era in meteorological sensors and needed to be supplemented with a completely new on-board data handling system Lt. Daly was present and immediately agreed. Major Chubb ask us to work with Kevin and Larry Fitzgerald to come up with an implementation plan. This was all it took to get the ball rolling in the right direction for us.

The definition of the new FRS Data Handling System was no easy task and took some time to accomplish for there were hundreds of areas to investigate as it now would include all the data handling and storage functions on the spacecraft. It also had to be performed at the same time the FRS was being designed and breadboards fabricated and tested under the original FRS contract. Dale Guhne assumed the tasks of managing the FRS development. Ralph Strong and I along with several others took on the job of defining the FRS Data Handling System.

The FRS was truly a development program. Concepts for the sinusoidal scanner had to be developed and their reliability proven. The mechanical ingenuity of Frank Rushing and Paul Kiefer was used to the fullest extent possible. Ideas such as a bearingless design or using a torsion bar instead of springs are only two of the concepts explored. Scanner motion purity had to be determined. Optics aperture size and appropriate detectors had to be selected. Lightweight construction and passive cryogenic cooling techniques for the infrared detector explored. Channel electronics had to be designed and the list could goes on and on!

The FRS was specified to fly on a spacecraft launched off a Thor Burner 2A combination. As the design proceeded weight became a serious problem. The mass properties reports were showing that the FRS was getting too heavy and the SPO would have to terminate the program unless the weight was brought back into line. All design work stopped for at least two weeks while an in depth weight analysis was started. Bill Volk was tasked to determine the latest weight as designed, account for the weight of every bolt, nut, washer, resistor, transistor, integrated circuit, capacitor, etc. in the unit and come up with methods to reduce the weight. A number of changes to the design were made. The structure material was changed from aluminum to magnesium; the refractive optics diameter was reduced as much as possible and the substrates changed to beryllium; electrical connectors were minimized; wire gage was reduced to a minimum; and, many, many more changes were made resulting in a unit light enough to fly.

Bill Volk

Even though it was expected (and did) change later, the FRS Data Handling Subsystem (DHS) as originally specified in the contract had to be designed, fabricated and tested. Since this subsystem was mostly digital, some people new to the Block 5 program were brought onboard. Harvey Michalski, a talented digital systems engineer as well as an experienced digital designer was brought in to head the DHS design.

Ralph Strong recalls: *"I was just off the B-57G program and was impressed by its programmable digital processor and with the flexibility for solving problems that later developed via software changes without having to make hardware changes. However, Col. Botzong was opposed to a software development and there was a lot of pressure for a hardwired processor. Despite this I went to John Gregory and he became excited about the issues. He then freed up Harvey to design the processor and we moved to a programmable processor in almost a stealthy mode.*

Possibly the biggest step was the move that got Ed Beaver on the job. He did the software so well, performance, schedule and costs were not a problem and the software horrors of the era never became an issue. The work to upgrade the reliability of the processor permitted Westinghouse later to successfully win the Harpoon hardware which fed into the F-16 and other digital processors."

Ralph Strong

At same time the FRS development was going on we were also defining the new FRS Data Handling System. We had to look at the spacecraft interfaces and try to minimize them. The down link data transmission was going from analog to digital. We needed to optimize a system that would minimally impact not only on the spacecraft but also on the ground stations both strategic and tactical. We had to consider spacecraft, booster and launch site impacts and the list goes on and on. Fortunately the SPO was willing to fund this effort as System Engineering Tasks (SETs) under a Support and Services contract which was in place. Tasks to this contract were written and work got under way. Eventually the ECP was completed and submitted.

The new definition of the FRS included all the hardware on the spacecraft associated with the collection, onboard processing, encryption and storage of the primary sensor data as well as collection and storage of data from all the other mission data sensors. Also included was the modifications of the ground equipment necessary to ensure compatibility with the existing systems. I remember once when we were defining the data capacity of the mission sensor data channel we ask Major Chubb how much capacity should we specify. The Block 5A had the capacity of 100 bits per second fitted in to the analog data. Chubb said make it 1000 bits per second for "*there is no way that would ever be exceeded*". Lt. Daly said OK but we made the specification 10,000 bits per second. Chubb was really off on that one! The current data rate of the mission sensor data channel is about 23,000 bits per second.

Simultaneously with the on going FRS developments, the SPO needed to promote the FRS in the Pentagon in order to assure continued funding. Jim Blankenship tells the story that he was about to present his case for FRS funding at the Pentagon when he found out the "good word of the day was operational". He quickly had all his vu-graphs redone changing the name FRS to Operational Linescan System (OLS). No one in the committee ever questioned what he meant by "Operational". They simply assumed that the system was in operation. The briefing was successful and the program was funded with the new name OLS.

One of the ground rules established by the SPO was that the data produced by the OLS must be compatible with the existing ground stations both strategic and tactical with only minimum modifications allowed. This was a "tall" order and significantly affected many decisions that were made. One example is the digital data formats. If one looks at the OLS data formats in terms of today's standards he would ask "why did anyone ever conceive such weird formats for the OLS data? The answer is as follows. The ground display equipment for both the strategic and tactical sites, of which there were many, were designed in the late 1960's and were tailored for an analog system. The OLS digital data formats had, and were made, to be compatible compromising simplicity in the process. In addition digital data needed to be relayed from sites in Maine and Washington state to Omaha where it was processed. Satellite communication links were not yet available. Therefore the data rate had to be compatible with existing telephone and microwave links. This required compatibility to synchronize the OLS data with and use the long lines data transmission data rate standards of the time which was 1.3341 mbps. I recall a meeting that Kevin Daly and I had in New York with ATT Long Lines Division. We were hoping that we could deviate from the existing data rate standards but soon found out that data rates were non-negotiable. You used their standard or you did not use their lines! However by the time the Block 5D systems became operational, communication satellite data links were available and used but the capability to use existing land links existed if ever needed.

The detailed design of the OLS scanner proceeded while the ECP was in process. Several items were identified as major subcontracts and Jake Beser was appointed Subcontracts Manager as his primary responsibility. His job was to work with the design engineers to develop performance specifications and select potential vendors. He also worked with our Purchasing Department to prepare procurement documentation and negotiate the subcontracts. For the OLS development phase the major subcontracts included the scanning telescope and relay optics; the image dissector photomultiplier tube; the passive cryogenic cooler for the IR detector; the IR detector; and the main structure.

The OLS optics was one of the major headaches during the development phase. Vern Williams, Frank Kaisler and Paul Kiefer designed and working with Jake specified the requirements for each of the optical subassemblies. The most difficult was the scanning telescope assembly followed by the relay optics assembly. A company called Diffraction Limited was chosen to provide the relay optics assembly. They converted the designs and specifications we produced into production drawings, built the individual lenses, filters, etc. and assembled them into a beryllium housing. The result was an Engineering test model which came close to theoretical performance. However the business situation for Diffraction Limited had declined to a point that the company could not be relied on to build the production units and the contract for those units went to Kaiser Optical. Kaiser was skeptical about being able to meet the same performance specifications as Diffraction Limited had met. Consequently we gave them the relay optics engineering test model to inspect, test and disassemble and evaluate the piece parts if necessary. After their evaluation they confirmed that the relay optics specifications could be met. I believe that they eventually made the relay optics for all the OLS systems. This subcontract did have some workmanship problems with installing a filter in backwards being the most common.

Jacob Beser **Paul Kiefer**

The scanning telescope assembly was more difficult to build. In certain times in an orbit the scanning mirror would be looking at night scenes which were only 5 degrees from full sun. To meet this requirement the primary optics had to have an extremely low light scattering characteristics. Procuring a thin metal (beryllium) parabolic mirror with these characteristics and be able to hold its figure in the scanning and thermal environments was difficult and never been done before. Several attempts with different vendors were made. The first vendor finally got an engineering model built. He then shipped it to Westinghouse in a plastic shipping container sealed with RTV which out gassed acetic acid. When the assembly arrived at Westinghouse the optical surfaces were green and totally useless.

Vern Williams

A new contract was placed with Kaiser Optical. They came up with a method of depositing a thin layer of nickel not only on the front side of the mirror but also on the backside. During the figuring process both the front and back surfaces of the mirror were ground to maintain the same thickness of nickel on both the front and back of the substrate. They developed methods of measuring the thickness of the nickel to assure the same thickness on both sides of the substrate. Once figured, a thin coating of silver was evaporated onto the nickel and super polished. The superpolish operation was a difficult process. It was done under a subcontract to Kaisler Optical by an old man in his 80's in his home kitchen using a propriety process which he would not disclose. I remember one instance where he fell asleep while processing a mirror and left it in the solution too long which ruined the mirror. Before the end of the OLS production program, Kaiser Optical had procured the low scatter finish process from the "old man" and were able to reproduce his results in their factory.

The photo multiplier was another major subcontract. In order to obtain the required low light level performance and to achieve the constant surface resolution it was determined that an image dissector photo multiplier tube would be required. John Wentz from the Electro Optical Group was given the task of specifying the requirements and testing samples to find the best candidate available. Eventually he concluded that a tube with an opaque ceasiated gallium arsnide photo cathode would best meet the sensitivity and spectral response requirements and EMR in New Jersey was selected as the vendor. The production yield of good tubes was very low - usually about ten starts to get one tube.

Larry Nix remembers his experiences in selecting the photo multiplier subcontractor. *"Sometime after completing my work on the film camera processor I also worked on some of the problems on the 5C and 5D satellites. One of these problems involved the low light sensors. In the course of this work from time to time, I made business trips to various vendors with Jake. Perhaps the most memorable trip I made with Jake was on my first trip to San Francisco. On this occasion, Jake and I arrived in San Francisco in late afternoon. We were to visit a vender the next morning and then on completing our business, to return to Baltimore late that afternoon.*

When we arrived in San Francisco we went directly to the hotel where we were to stay for the night. Jake wanted to know if I would like a drink soon and then later go out for dinner. I agreed and then he said that he had a few phone calls to make first.

To better appreciate what the evening held in store for me, one has to know more about Jake's background than most people probably know. Jake played a unique role in the history of World War II in that he was the only person to fly each of the B29 missions that made the atom bombing attacks on Hiroshima and Nagasaki. This fact made Jake a guest of many grateful people both in this country and Europe.

When we went to the bar for a drink we sat down at a table toward the back of the room in full view of all the patrons at the bar. Soon after ordering some character came in quietly and waited at the end of the bar. Soon this person exchanged a few words with someone behind the bar. Shortly, someone arrived from another room with a small package, which was handed to the person waiting at the end of the bar whereupon that person quickly left the same way he had come. After a couple of minutes, Jake explained that what we had just witnessed was in fact a Mafia payoff!

Later that evening we went to a fancy Chinese restaurant overlooking the bay near the airport for a many course dinner with all the trimmings. As I was Jake's guest all this was on the house for both of us!

Another trip that I made with Jake was to the vendor Princeton, New Jersey who made the low light level photo-multiplier tubes. On this occasion more photo-multipliers were to be purchased for the 5D system. Jake and I met with their engineer and the manager, Dr. Martin Rome. After technical discussions and lunch, Jake and I were given a tour of their facilities since it had been quite some time since they had made the earlier photo-multiplier tubes. Upon completing the tour, Jake excused himself out of earshot of the others and stated he and Martin had some "Jew business to conduct"."

The passive cryogenic cooler for the IR detector was the proven design previously used on the Block 5C SAPs was selected. This component was made by A.D. Little but because of it's high dollar value it was named a major subcontract.

By far the most complex development subcontract for the new OLS Data Handling subsystem was for the data tape recorders.

The DMSP had only two data readout stations known as Command Readout Stations (CRS) to collect down linked data from the satellite. Since Global coverage was required, this meant storing vast amounts of digital data on board to be down linked when the satellite was in view of a CRS. Also the location of the CRSs was such that there were two and sometimes three blind orbits when neither of the CRSs could receive data from the satellite. Furthermore it was required to also collect and store data during the down link times. These parameters determined the magnitude of the on-board data storage requirements. Based on these requirements it had been determined that three devices each with a capacity of about 1.7×10^9 bits of data would be required.

The state-of-the-art in solid state devices in 1972 had not been developed at that time to consider using a solid state memory. Core memories were considered but weight and power requirements prohibited their use. Digital tape recorders were in common use in ground based digital computer systems but the technology they used could not be applied to the spaceborne recorders again for weight and power considerations. A new digital data tape recorder needed to be invented on schedule.

Westinghouse in coordination with the SPO developed specifications and need dates for the new digital data tape recorders. Westinghouse was aware of tape recorders being built by Leech. RCA in New Jersey expressed an interest. The Air Force was also aware of the Leech recorders and RCA capabilities. While the Air Force was very happy with the RCA capability to design and integrate systems, they were not thrilled with their ability to build "black boxes" and suggested that we also talk with a small start-up company called Odetics in Anaheim, California.

We knew nothing about Odetics and had previous experience with small start-up companies not being able to deliver on subcontracts so we arranged a technical conference and an on-site review of Odetics and their facilities. This review was interesting. We found that the company had been founded by former employees of Leech who had developed and built the analog data recorders for the previous DMSP satellites. They had left Leech and formed their new company because they felt they would have a better opportunity to explore and develop new ideas.

We found the Odetics engineers to be technically impressive and they convinced us that they could do the job. Their facility in Anaheim was in a large building with a number of newly refurbished offices, a laboratory, a small model shop, and large production areas. They had a very few employees at this time. As we toured the facility we heard different people being paged over the intercom. Also we noticed that the same employees seemed to be moving from location to location "through the back way" and appearing to be very busy as we moved about the facility. I mentioned this to the company president later. He just laughed and said that they had everyone in the company including the board of directors present in the facility that day.

Our RFP went out to Odetics as well as Leech and RCA. Leech responded with a no bid. RCA and Odetics responded with technical and cost proposals. Our technical evaluation showed Odetics to be superior and we initiated fact finding and negotiations for a subcontract.

The evening before the negotiations were scheduled to start I was coming home from a meeting in Los Angeles. There were three gentlemen in the seats in front of me whom I did not recognize and they did not recognize me but I could hear them discussing a negotiation to take place the next day and how this contract would really help their company. The next day but who would appear for the Odetics negotiations? The same three gentlemen that were on the plane with me.

Data Tape Recorder

As the subcontract proceeded at Odetics development problems developed and had to be solved. Needlessly to say , both Jake and I got to know the Odetics key people very well. Problems were primarily with getting a good tape and a set of long life heads. Odetics procured and tested numerous webs of tape. Tape is manufactured in what is called a web which is 48 inches wide and 2000 feet long. When you buy a web you get all the one quarter inch wide rolls that can be sliced from the 48 inches. Odetics had a lot of tape on hand which had be stored in a temperature and humidity controlled atmosphere. We ended up selecting tapes from the best locations in a web, cleaning it to remove any loose particles and burnishing and burning it in order to meet the bit error and burst error rate specifications.

As it turned out Odetics could not procure heads meeting the long life requirements from the usual tape recorder head vendors and had to design and build them in house. They developed a hard tipped head designed for long life and became a head supplier to other tape recorder manufacturers.

Solid State Memory

The DMSP digital data tape recorder was state-of-the-art at that time. It stored about 1.7 giga bits of data on a 2000 foot reel of ¼ inch tape and had three record and two playback speeds. The recorder accepted a serial bit stream input at 66.5, 665.6 or 1.3312 mbps, recorded it on five parallel tracks on the tape and played it back during rewind as a serial bit stream at either 1.3312 or 2.6624 mbps. Each recorder weighed 22.5 pounds and consumed about 6 watts in the low speed record mode and 44.1 watts in the high speed playback mode. About 25 years later they were replaced with a solid state memory with approximately four times the storage and data speed capability, significantly less weight and approximately the same power consumption. The first unit was flown on F-15.

In order to meet the IR channel requirements a two segment HgCdTe detector was required. Specifications were prepared; proposals received and evaluated; and, Ford Aerospace in California was selected. The preferred supplier, Honeywell, decided to no-bid for business reasons. However after several tries Ford concluded that they could not make a detector that would meet our specifications and the subcontract was canceled. By that time Honeywell management had changed its mind and agreed to supply the detectors.

The OLS scanner structure design was an interesting design and production challenge. The structure had to be light weight, withstand a severe vibration and shock environment and yet be an optical bench and maintain dimensions with tolerances of millionths of an inch. Paul Kiefer assigned one of our most talented mechanical engineers, Bill Winn, the task of designing the structure which was indeed an optical bench. Typical tolerances required certain dimensions to be held to within tenths of a thousandth. We knew these would be difficult to obtain for a fabricated and welded structure. It took Bill almost a year to perfect the design. He had a model built in our model shop. When the measurements were taken the model was almost a tenth of an inch out of tolerance. So the structure was named a major subcontract and it was sent out to vendors for bids. Eventually Jake, with the help of Julian Eargle, a mechanical engineer, located a shop in Detroit that was experienced in manufacturing of precision, welded magnesium structures who was willing to give it a try. They reviewed the drawings, made adjustments for welding shrinkage and proceeded to build the structure. Each weld (and there were many) was x-rayed before proceeding to the next. At points in the fabrication process the structure was stress relieved. Upon completion of the welding process a final stress relief process was completed and the unit rough machined. This was followed by another stress relief process and a final machining. The results was an in spec structure but the price we paid for a single structure would have bought two new Cadillacs!

OLS SSS Structure Used For Spacecraft Vibration Modal Testing

Julian Eargle

A side story about the structure. We had determined that it was in the critical schedule path. Westinghouse had one of its many reorganizations and the Block 5 program now reported to a new Department Manager. Of course he demanded and received a thorough program briefing. In the course of the briefing he learned about the structure and the associated manufacturing problems. His belief was that the Westinghouse model shop was the best around and if they could not build a structure that met specifications, nobody could. He ordered me to proceed with a new design and look for multiple vendors for the present design. Following his orders would be extremely expensive and time consuming. Also I did not share the same beliefs about our model shop's ability to build anything and dragged my feet about starting a redesign and even looking for another vendor until I got the results from the structure fabrication which I currently had in process. Fortunately everything turned out OK and the new Department Manager never knew the difference.

The FRS was require to provide essentially constant resolution over the full 1600 nautical mile cross scan track width. This is provided by the combination of a unique scanner mirror drive mechanism and multi-segment detectors which are switched to control the field-of-view as a function of scan angle. This combination keeps the surface resolution parameter constant within a factor of less than 2:1 across the 1600 nautical mile track compared to over 7:1 for a constant angular velocity scanning mirror yet maintaining a near constant video signal-to-noise ratio from the center to each edge of track.

It turns out that a sinusoidal motion represents very closely the scanning motion we needed to vary the dwell time on each pixel as a function of the instantaneous look angle off nadir to maintain the near constant video signal-to-noise ratio and bandwidth from the detectors. The scan mirror drive mechanism consists of a scanning mirror driven by a mechanically resonant drive mechanism thus producing the near perfect sinusoidal scanning motion. Gordon Ley invented this scanning and detector switching concept. The drive mechanism is simple, produces a well defined sinusoidal motion, consumes very low power and utilizes long life components - springs similar to a watch balance spring - and requires only enough drive power to supply the mechanical losses. The scanning mirror is approximately 8-inches in diameter and requires only about 0.3 watts of mechanical power which equates to less than 2 watts of electrical power.

Gordon Ley along with Mechanical Engineers Frank Rushing and Paul Kiefer performed the analyses needed and produced the final design. The key mechanical components required were only two sets of contra rotating spiral springs and a scanning mirror assembly supported by accurate low loss bearings. Of course there were design details to work out. The unit had to run for years in a vacuum. The mirror would oscillate at $5.94 \pm .01$ cycles per second. The springs had to be made from a non-magnetic material and designed for a life expectancy in excess of $2x10^9$ cycles without breaking and manufactured to tight tolerances in order to produce the correct oscillating frequency.

Several problems were overcome before we were able to produce the springs. First the correct material had to be found. The first and most obvious choice was a material called Elgiloy. This is an alloy developed by Elgin Watch Company and is the material used for watch springs We located and purchased about 300 pounds of this material, made springs and subjected them to test. To our dismay, we found that this material was not suited for large springs and failed after only a few million cycles. Paul Keifer with the help of Frank Rushing and other mechanical engineers tackled the job. Several other materials were procured and tested. Finally 17-7PH stainless steel was selected. In months and years of life testing of the final design, only one spring broke under test. Analysis showed that this failure was from a small surface scratch left from machining and aggravated by corrosion after exposure to water from a leaky roof in the factory. No spring failures were experienced in a 5 ½ year life test or over 10 years of operations in space

The manufacturer of the springs turned out to be an art. Our program was fortunate to have an extremely skilled model shop machinist, John Tigue, who developed the process to machine, bend, heat treat and electropolish the springs. Incidentally, John not only developed the process and manufactured the springs but was our master machinist. Whenever a part was needed to be machined to tight tolerances (i.e. tenths of a thousandth), and there were many, we called on John to do his thing. Each two turn spiral spring is

Spring and End Clamps

manufactured from a flat sheet of steel approximately ½ inch wide and 0.087 inch thick. First both sides are surface ground and polished to remove any surface scratches and the edges rounded. It is then wound and electro polished to a bright smooth finish.

The clamps necessary to hold the springs to the structure were another complex mechanical design problem. While it would seem simple just to tie a spring to the structure with clamps or bolts, this was not the case. A method of adjusting the line-of-sight of the center of the scan was needed. Also the clamps had to be designed so as not to create points of excessively high stress which would cause the springs to break after a few million cycles. After several tries these problems were overcome.

Because of the low power requirements it was necessary to keep the bearings small. But the system had to withstand severe launch vibration and shock loads. This was solved by using very small bearings on a 1/8 inch shaft just to maintain the telescope centering. To withstand the launch loads a caging mechanism was employed. This mechanism firmly clamped the scanning telescope to the structure during launch and was electrically released after launch. During launch site testing of one of the OLS systems the unit was mounted on the spacecraft and on the ATLAS booster. During the final test of the caging release mechanism it failed to operate. This was considered a major problem and required the launch operations to stand down for several weeks while the malfunction was analyzed and a solution developed.

As it turned out the caging mechanism parts were made of titanium and not lubricated. Calculations and computer simulations were developed which showed that this design was marginally adequate. Lubricating the moving parts solved the problem. We had been lucky for the previous launches.

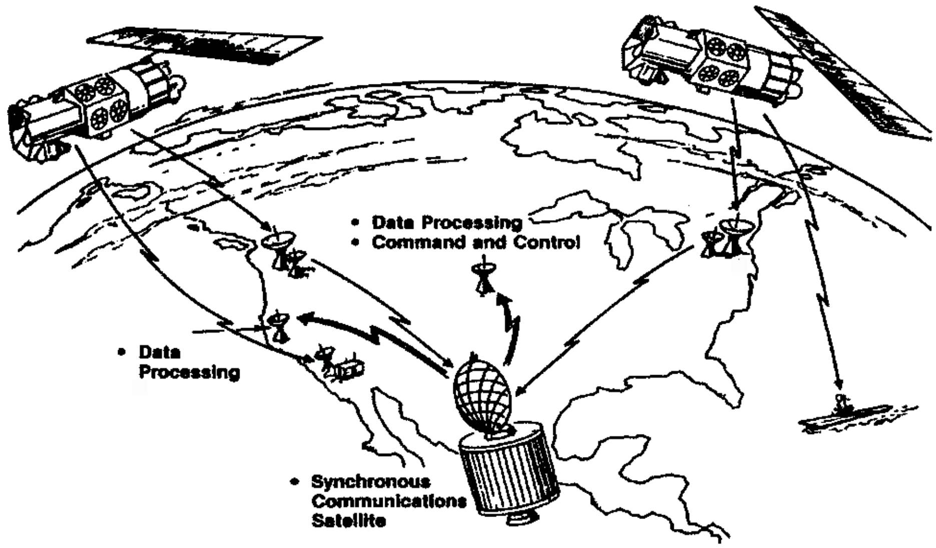
By mid 1971 the ECP for a new OLS Data Handling Subsystem was complete and submitted to the SPO. Stan Sachs remembers negotiating this ECP. He says: "*I was dispatched by either H.B. Smith or John Stuntz to work with Tom Hollis in the fall of 1971 as the program's business manager because you were technically sound but in a financial bind. The negotiators of the early program* (FRS Development) *had agreed to let the SPO use a special G&A rate that omitted the segment that paid for the Division's post-delivery E&S support. The argument was that it would take a very long ladder to spend any money to accomplish that task. Our books were not set up to do that, so, even if the program spent the direct costs as quoted, the program would not register a profit. The change was accomplished during the 71-72 negotiations by insisting we did not negotiate elements of our rates - they had been approved by the navy who were our plant representatives. We also insisted that as a fixed price contract, we negotiated total prices, not cost details. Using that strategy we ended up with a price that was only 1% less than the proposal.* As it turned out we needed every penny that Stan and his people negotiated. When the contract was finally closed we did not lose money but made only a very small profit.

My only other recollections were of the monthly meetings at SAMSO. We made a 5 PM fight out of BWI, had a 9AM meeting the next morning and returned on an afternoon flight home. It makes me tired just thinking of it. On one of those flights home, there were only 10 or 12 people on the entire plane. It was a TWA flight that had a bar amidships. George Traskowsky ended up as the bartender making free drinks for all the passengers. Scotch & coke was one order."

Upon completion of the ECP negotiation the new OLS including the onboard data handling and storage subsystems design and development tasks got underway. Capt. David Nichols, Ph.D., the SPO Sensor Project Officer at that time extracted information from the various Westinghouse Technical Reports and provided a good summary of the newly defined

OLS in a technical paper as follows: "*The Defense Meteorological Satellite System in an operational joint-service environmental sensing system that provides white-light and infrared spectra cloud cover imagery and other specialized meteorological, oceanographic, and solar geophysical data as required to support, in a timely manner, the worldwide DOD strategic and tactical missions and high-priority programs. This system is managed by the U.S. Air Force DMSP office. It's assets consists of meteorological satellites, communication links, and ground processing facilities that acquire, transmit, and perform the initial processing of the data to satisfy the DOD satellite data requirements.*

Defense Meteorological Satellite System



The Operational Linescan System is the DMSP primary data sensor. The OLS system gathers visual and infrared imagery data from earth scenes and provides such data, together with appropriate calibration, indexing, and other auxiliary signals, to the spacecraft for transmission to ground stations. The data is collected, stored and transmitted in fine (F data) or smoothed (S data) resolution. The OLS has a scanning optical telescope system driven in a sinusoidal motion by counter-reacting coiled springs and a pulsed motor. This motion moves the instantaneous field-of-view of the detectors across the satellite subtrack, with maximum scanning velocity at nadir and reversals at end of scan. Detector size is dynamically changed to reduce angular instantaneous field-of-view as it nears each end of scan, thereby maintaining an approximately constant footprint size on earth. The swath width is 1600 nm from a nominal altitude of 450 nm.

The optics consists of a cassegrain telescope, whose elements are common to both visual and infrared imagery, and a set of relay optics that separates the wavelengths and fields-of-view for the different detectors. On-board pre-processing of the data by the OLS provides for the various modes of data output. The OLS provides global coverage in both visual (L data) and thermal (T data) modes. Fine resolution data is collected continuously, day and night, by the infrared detector (TF data), and continuously during daytime only by a segmented, silicon diode detector (LF data). Fine resolution data has a nominal linear resolution of 0. 3 nm. Tape recorder storage capacity and transmission constraints limit the quantity of fine resolution data (LF or TF) which can be down linked from the stored data fine (SDF) mode to a total of 80 minutes of LF and TF data per ground station readout.

Data smoothing permits global coverage in both the infrared (TS) and visible (LS) spectrum to be stored on the tape recorders in the stored data smoothed (SDS) mode. Smoothing is accomplished by electrically reducing the sensor resolution to 1.5 nm in the along scan direction, then digitally averaging five such 3 x 1.5 nm samples in the along track direction. A nominal linear resolution of 1.5 nm results. 400 minutes of LS and TS data may be down linked in a single ground station readout. An additional detector allows collection of visible data (LS) with a 1. 5 nm nominal linear resolution under low light level conditions. In the fine mode visual (LF) channel, a 3-segment silicon diode detector is switched at ±400 nm from subtrack, using either of two segments from that point to end of scan. All three segments are used and summed together within 400 nm of nadir. Detector geometry and segment switching compensate for the optical rotation of the field-of-view, as a function of scan angle. A mirror in the telescope assembly is dynamically driven to accomplish image motion compensation by removing the satellite's along track motion of the instantaneous field -of -view to preserve scan line contiguity. The visual daytime response of the OLS is in the spectral range of 0.4 to 1.1 microns; chosen so as to provide maximum contrast between earth, sea and cloud elements of the image field. The visual fine mode is provided for day scenes only. The infrared detector, consisting of two segments, is switched at nadir to provide approximately constant ground footprint and image derotation. The detector is a tri-metal (HgCdTe) detector operating at approximately 105°K. The OLS infrared spectral response of 8 to 13 microns was chosen to optimize detection of both water and ice crystal clouds. The sensor output is normalized in terms of the equivalent blackbody temperature of the radiating object. A shaping network is employed to change the fourth-power-of-temperature response of the detector so that sensor output voltage is a linear function of scene temperature. This detector is passively cooled by a radiative cooler viewing free space. This tri-metal detector is accurate to within 1°K rms across the (equivalent blackbody) temperature range 210°K to 310°K. The noise equivalent temperature difference (NETD) of the infrared system is well within 1°K across this same range.

The OLS data processing subsystem performs command, control, data manipulation, storage, and management functions. Commands are received from the ground through the spacecraft command system, stored in the OLS and processed by the OLS according to time codes. The OLS executes commands, accomplishes the smoothing of fine resolution data, derives gain commands from orbital parameters for normalization of visual data and dynamic signal control, and outputs the data to the spacecraft communications system. All data is processed, stored and transmitted in digital format. The OLS also provides the data management functions to process, record and output data from up to six additional meteorological sensors.

A combination of either fine resolution data and the complementary smoothed resolution data (i.e. , LF and TS or TF and LS) can be provided in the direct digital transmission mode. Either encrypted or clear direct data can be output simultaneously with two channels of stored data. The OLS system includes and controls three digital tape recorders, each with a storage capacity of 1.67 x 10E9 bits. Each recorder can record at any one of three data rates and play back at either of two data rates. These rates are:

INPUT	***STORAGE PER RECORDER***
66. 56 Kbps (LS and TS interleaved bit by bit)	*400 minutes*
1.3312 Mbps (LF and TF interleaved bit by bit)	*20 minutes*
665.6 Kbps (LF or TF only)	*40 minutes*

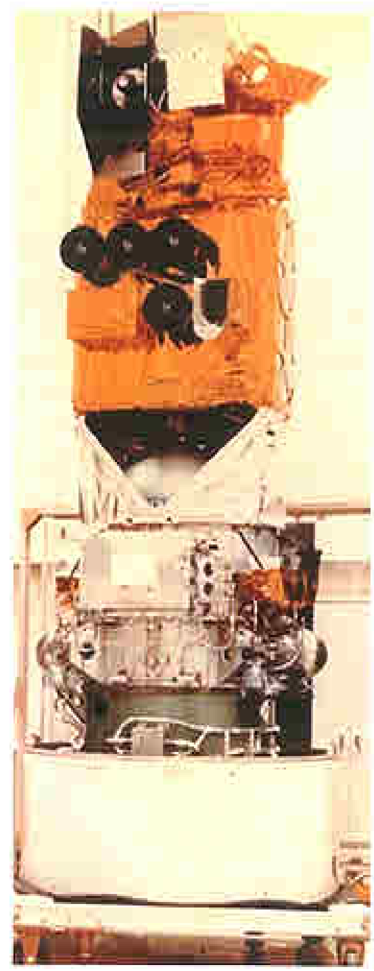
OUTPUT	***TIME/DATA***
2. 6624 Mbps	*10 minutes/All LS and TS*
2.6624 Mbps	*10 minutes/All LF and TF*
1. 3312 Mbps	*20 minutes/All LF or TF*

All tape recorders are interchangeable in function, providing operational redundancy and enhanced system life expectancy.

An engineering test model of the OLS was produced and underwent extensive testing. As one would expect we encountered unanticipated problems during system test. Probably the most difficult one was an optical problem discovered during scanner tests which took a very long time to solve. When the scanner was looking a fixed temperature target at different positions along scan, the infrared channel would sense a different target temperature at the different positions. Paul Kiefer, Vern Williams and Roger Lieske worked this problem for months. The problem was eventually traced to a black anti-reflective coating of a component in the optical path. The material which was supposed to be black in the visible and infrared spectral range was not really black in the 8.5 to 13 micron infrared spectrum range we were using. A change of the coating corrected the problem.

By mid 1975 the first OLS 5D1 flight unit was shipped to RCA to go integration and test with the spacecraft. At the same time that Westinghouse was developing the new OLS the Air Force had contracted with RCA to develop a new Block 5D spacecraft.

The Block 5D spacecraft was truly an integrated spacecraft in that specific functions of a launch vehicle upper stage had been integrated into the satellite. In particular, the Block 5D spacecraft provides ascent phase guidance for the launch vehicle from lift-off through orbital insertion as well as upper stage electrical power, telemetry, and attitude control. The spent third stage propulsion and reaction control systems are carried into orbit. The configuration affords considerable weight savings over the conventional booster/spacecraft configuration. The integrated spacecraft is also designed with an expanded solar array (not shown in the photo) subsystem to meet the expanded payload requirements.



Block 5D1 Spacecraft

The major structural sections of the spacecraft are: (1) a precision mounting platform for mounting sensors and other equipment requiring precise alignment, (2) an equipment support module which encloses the bulk of the electronics, (3) a reaction control equipment support structure which contains the spent third stage rocket motor and supports the reaction control equipment, and (4) a sun tracking solar cell array.

The design of the precision mounting platform in combination with an equipment support module allows for an increase in spacecraft payload capacity. The nominal on-orbit spacecraft weight is 1032 lbs which includes a 300 lbs payload.

5D1 OLS System

In July 1976 the integrated spacecraft was at VAFB for final testing and launch. Several months prior to the scheduled launch date for the SAMSO commander ordered an Independent Design and Launch Readiness Review (IRT) as had become customary for all launches from VAFB. The objective was to examine in detail the system specifications and the hardware as designed to be sure the program would have a high probability of success when the satellite was launched. The review team was tasked to look at the spacecraft as well as the sensor designs. As I recall the request was made to Bob Roush to support the OLS review but he quickly handed the job over to me. I recall the first meeting of the entire team. Lo and behold there were some "old faces" of Air Force people that I recognized from the program early days plus a lot of new Air Force and Aerospace people. Apparently they were still in the space business. Our portion of the review was thorough, in-depth and went off without a hitch even though it lasted for about a month.

By the first of July 1976 the spacecraft had arrived at VAFB, been inspected and was readied for launch site testing. This being the first of a new generation of satellites required extensive testing at VAFB utilizing new procedures and new test equipment. I along with my wife and children traveled to VAFB on July 4, 1976. We got to see fireworks displays all across the country from the air.

We knew that we had to make this launch successful and had a fairly large test team at VAFB including some design engineers just in case. Tests, while long, were completed without any major OLS problems. Probably the most "interesting" event from our perspective occurred during a simulated flight test (SIMFLT) when the spacecraft CPU crashed. This situation had occurred several times earlier at the RCA facility in New Jersey. When a CPU crash happens it's anyone's guess what commands it sends to the OLS and other spacecraft subsystems and lots of indicator lights on the spacecraft test console come on. Norm Huffmaster, the RCA I&T manager coined the name of "Christmas Tree" to describe what happens. Well on July 9 we had a Christmas Tree! Since this occurred at the launch site it was categorized a major problem by the Air Force Test Director Joe Pawlick. "Tiger Teams" were formed and Aerospace Engineers descended on the PTF by the dozens. It took about two weeks to get the "noise level" down, some test software changes made and the launch flow back on schedule.

By early September the testing complete, launch readiness reviews and commander briefings were complete. The spacecraft had been declared ready and the orders given to launch.

On September 11, 1976, about two years late, the first of the Block 5D satellite series was launched but once in orbit developed stability problems and went into a "spin mode tumbling end over end" causing loss of battery power (and the SPO Director to lose his job). Early in October of that year occasional communications with the spacecraft were established at times when the solar array was pointed toward the sun. During the next five months, techniques and software were developed to use the magnetic coils and the spacecraft attitude determination system to take over and stabilize the vehicle. During March 1977 the software was checked out and uploaded to the spinning spacecraft. By April 1, 1977 the spacecraft had been stabilized, checked out and was ready for operational use. During the spinning period the spacecraft electronics experienced uncounted numbers of temperature cycles between +50 and -40 deg C with very little damage to the electronics. Other than the loss of one of the three tape recorders the Westinghouse sensor was 100% operational and continued to function for over 30 months when the spacecraft batteries failed and the mission ended.

While the OLS was 100% operational we did see one anomaly in the data. For some reason and at a particular geographical region of certain orbits the imagery data would loose sync for a period of time. The problem area was traced geographically to a region known as the "South Atlantic Anomaly". This is an area where the van Allen radiation belt dips closer to the earth. Analysis showed that high energy particles were upsetting the OLS scan angle position encoder thus causing the loss of data synchronization.

The scan angle position encoder is an electro optical device utilizing an optical beam from a light emitting diode reflected off a faceted polygon on the scanner rotating shaft. The reflected beam scans across a silicon detector behind a reticle plate. This generates electrical pulses which define the instantaneous angular position of the scanning mirror.

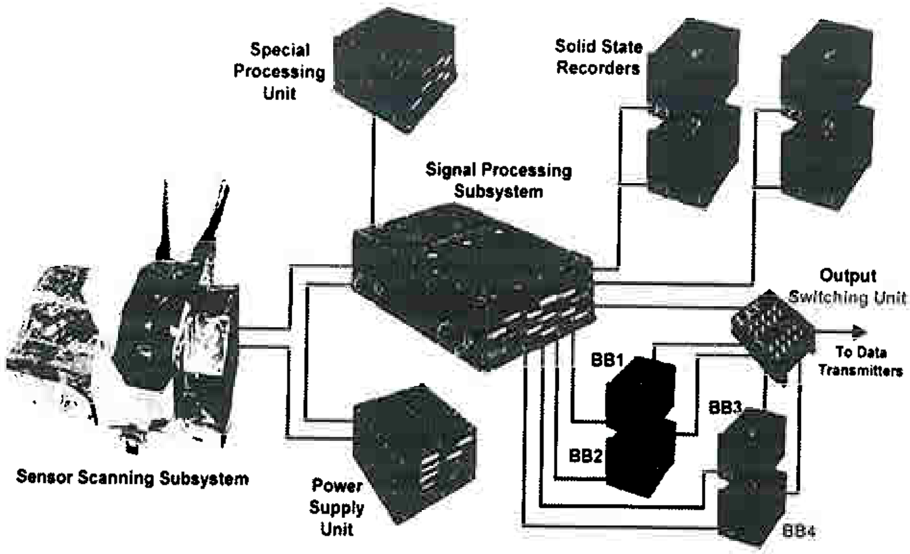
The silicon detector is physically large - about 3 millimeters wide, 1 millimeter thick and about 40 millimeters long. At first it was suggested that a shield be placed in a position to shield the sensitive device. A 2 ½ pound stainless steel shield was fabricated and installed on the next system. But before that system could be launched further calculations showed that this shield would not solve the problem - just require higher energy particles to cause upsets. What was happening was particles hitting the detector perpendicular to its 3 by 40 millimeter surface were not causing a problem. But particles hitting the 1 by 3 millimeter surface were causing the problem and it would be impossible to solve the problem with shielding. The solution for later systems was to raise the level of the desired signal pulses to a point where the spurious pulses generated by the high energy particles would not interfere.

The second OLS was launched on June 4, 1977. This system performed with minimal anomalies until March 19, 1980 when the mission ended with spacecraft gyro failures and spacecraft attitude could not be maintained.

Twenty OLS sensors representing three generations Blocks 5D1,2&3 configurations were built and delivered. One sensor OLS-4 was converted to OLS 11 as a part of the Block D-2 performance enhancement contracts. This accounts for the number discrepancy between units built and OLS serial numbers. More about the Blocks 5D-2 and 5D-3 later.

Block 5D2 Generation

In July 1980 disaster struck the program when the Thor Booster/Burner 2A combination failed to insert the Block 5D1 F5 satellite into orbit. This spacecraft was carrying OLS-5. This failure coupled with the earlier program launch date slip from 1974 to 1976 place DMSP in jeopardy of not being able to support its high priority customers with a constellation of two satellites at all times in the out years. The SPO made a decision to increase the probability of keeping a fully operational status they could increase the life expectancy of the OLS by adding switchable redundancy, to the greatest degree practical, for all future OLS electronic subsystems. Thus the 5D2 generation of sensors came into being. Life extension study tasks were assigned under a Support and Services Contract to define the modifications necessary to make the OLS fully redundant thereby significantly increasing the probability of success. The studies were completed and the SPO expedited contracts and contract modifications necessary to implement the changes. In effect he change required that any element of the OLS electronics that could be made redundant would be made redundant with the redundant elements command selectable from the ground. Of course this greatly increased the complexity of the system. In fact the electronics hardware would now contain approximately twice the original system plus the commandable switching hardware which would be needed. Needlessly to say the up-link commanding and the on-board software would also be more complex.



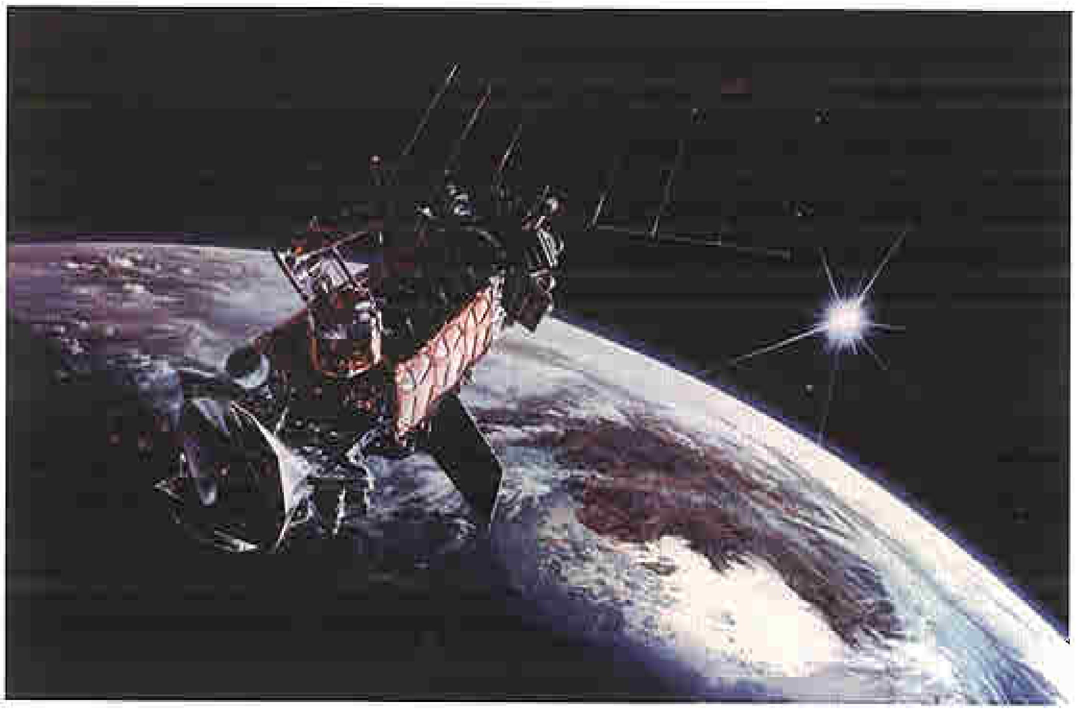
Block 5D2 Operational Linescan System

ATLAS E Carries OLS 13 Into Orbit

Dale Guhne and his group "hit the ground running" but the changes to the OLS and software were massive, some very difficult to implement and the schedule short. The modifications were to be incorporated into the 5D1 Engineering Test Model (ETM) and tested using 3600 moneys . This was to be followed by contracts to build OLS-7 through 10 from scratch as 5D2 models and convert OLS-4 for which there was no spacecraft under contract for it to fly on to a 5D2 model designated as OLS-11. As the design problems mounted and schedules slipped it became necessary to start the production of OLS-7 before the changes had been incorporated and tested in the BTM if we were to stand a chance of meeting its delivery date. Consequently OLS-7 had a lot of changes during production and still had design problems when it went into test. All of these had to be fixed and space qualified. In the meantime the business situation at Westinghouse was detoriating and every sale possible was needed to meet the year end sales numbers. A sale of OLS-7 was absolutely necessary in order to make the year end numbers. However the system was not yet ready for a complete sell off so Westinghouse made agreements with the SPO for a partial sale in return for Westinghouse to complete a number of additional OLS effort to their satisfaction.

Block 5D3

The last production lots of the OLS were designated the Block 5D3 series and included systems 17 through 21. These systems incorporated several performance improvements. By far the most significant change was with the computer, memory and software. The Air Force wanted a 1750A computer, 64K memory and ada as the software programming language. The ada software was to be accompanied with a full set of documentation including Development Plans, Requirements Specifications, Top Level and Detailed Design Documents, Product Specifications, Test Procedures and Reports, Versions Description Documents, and the list goes on. The days of minimal paperwork for DMSP were gone! Just the software and documentation for these systems cost more than the original Block 5A design, development and production for both the sensor and ground segments.



Artist Concept Block 5D3 Spacecraft

Other significant changes, but less costly than the computer/software change, included increasing the command uplink from 2 to 10 Kbps, increase the mission sensor read data rate to 25.6 Kbps, add real time data capability to small tactical sites, changes to the infrared channel gain to increase the number of gain states from 16 to 32, and implementation of an autonomous operational mode in case communications with the ground were interrupted for a period of time.

A few minor changes were also made. These included changes to the data formats; changes to optical coatings; modifications to the relay optics to allow for future incorporation of snow/cloud discrimination channels; and some tape recorder changes.

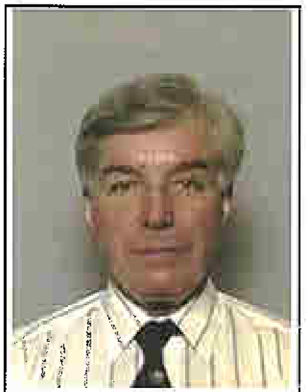
OLS Signal Processor and Software

Most of the OLS hardware functions are controlled by a programmable signal processor which is in effect a general purpose computer. This feature provides the maximum amount of flexibility to solve problems that may develop via software changes without having to make hardware changes. The Block 5 Program was lucky to have a team of extremely well qualified computer programmers lead by Ken Martin who were called upon at times to "perform miracles" in software to solve both design and in orbit problems. In many cases it was Ken's expertise with both the system hardware and software interfaces that made this possible.

The Block 5D1 OLS contained a space qualified version of the Westinghouse designed "Milli Computer" which has been used in a number of aircraft and missile systems. This processor was a 16-bit, functional, two's complement, stored program processing unit built with low power MSI technology. It consisted of eight registers, including four accumulators, a microprogrammed control matrix and decoding and execution control logic.

Joe Macey remembers his work designing this computer as follows: "*The original Milli Computer was designed by Jim Hudson at ATL for an aircraft power control system being proposed by Westinghouse of Lima Ohio. The proto type unit was a 1 MHz Computer built on two wire wrap Augat Boards, the Control and Arithmetic units. Lima did not win the contract so Jim went out looking for different applications.*

At the time I was on loan to John Gregory's group, I had worked for Harvey Michalski on the 2402 Computer for Mark-48, F-15, TM-3 and AWACS. Harvey had me working with Gray Miller who was currently testing a 3 MHz version that Jim was proposing for the Harpoon Missile System. Gray was suppose to move on to developing a low power version for Block-5 but had to take a lengthy personnel leave. Jim asked me if I thought I could handle the job myself. I told him that I had seen a similar concept, of a micro program controlled computer, in the Input Output Controller of the GE 600 series computer while working for GE in Phoenix AZ. Jim just smiled and said "I guess we never ran into each outer in Phoenix".



Joe Macey

In December of 1971 I started the design, fabrication and test effort on the prototype for the first Block-5 Low Power Milli Computer. The prototype milli was composed of four, 4" by 4" stitched wire boards which I wired, populated and tested in the lab at ATL. The original standard power design utilized Fairchild 9300 devices which for the most part had low power equivalents. Jim Buchanan supplied me with the power switching circuit for the standard power ROM0512 Micro Program devices. Jim Gentry did the Memory Controller and Ram/Rom Memory Boards. Jack Spann assisted in the extensive thermal cycling I performed while running processor/memory diagnostics on the prototype milli computer.

Officially released Board Assembly Drawings for the Block-5 OLS Milli Computer Flight Unit Boards are dated 10 May 72. This version of the Milli Computer flew on DMSP F01 through F15 Satellites with no reported on orbit failures."

The OLS had severe weight constraints. The state-of-the-art in radiation hardened and space qualified bulk memories had not yet reached the point where large capacity memories were practical. It was determined that the system would require 7680 16 bits words of Read Only Memory (ROM) containing the nonalterable operational programs plus a "scratch pad" of 512 words of Random Access Memory (RAM) as working space and 4096 18 bit words of nonvolatile, nondestructive readout random access memory for the along scan video integration function. Because of the weight limitations it was decided to put the operational program in integrated circuit ROM. However the along scan video integration function required a RAM. The best choice in 1972 was a plated wire memory.

Plated Wire Memory

Core Memory

The Milli Computer was also used in the Block 5D2 OLS configuration. The program and data storage for the processor was provided by the Operational Program Memory. 3072 16-bit words of non-volatile, nonalterable Read Only Memory (ROM) are allocated for an initial "bootstrap" program and lookup tables. 12,288 16-bit words of Random Access Memory (RAM) contain the main operational program which are loaded by way of the command uplink. The along scan video integration memory consisted of an additional 4096 18-bit words. By this time a magnetic core random access memories was feasible and were used.

The Block 5D3 OLS was designed in the 1993 time frame. It's CPU is built around a United Technologies radiation hardened CMOS reduced instruction set (RISC) microprocessor. This microprocessor utilizes the Harvard architecture with separate buses for instructions and operands.

Two modes of operation are possible for the CPU: RISC mode and 1750A mode. In RISC mode, instructions are stored in the RISC/instruction memory and operands are stored in the 1750A/operand memory. Processor thru put can be up to 6 million instructions per second (MIPS) in this mode.

In the 1750A mode, the operational program, coded in 1750A instructions, is located in 1750A/operand memory. RISC/instruction memory contains code that emulates the 1750A instruction set and optional built-in-functions (BIFs). This emulation code-maps the 1750A instructions into RISC macros to allow the UT1750A to act as a fully compliant MIL-STD-1750A processor.

It is possible to execute RISC instructions in 1750A mode by executing a 1750A BIF instruction. The user defined RISC instructions that comprise the BIF will execute at the 6 MIP rate. The 1750A has additional features which were utilized in this design

- Two 1750A timers
- 9600 baud UART built in
- Discrete outputs
- Wait states for interfacing to the slower I/O blocks

The CPU can operate at two software selectable clock speeds, 12 MHz and 3 MHz. The slower speed is necessary when running out of the startup code located in ROM because of device speed.

Interrupts from several OLS hardware functions serve to synchronize the processor with the operation of the scanner, gain algorithm, stored telemetry, and data formatting functions. The interrupts are disabled when running in the loader or in RISC mode.

The processor can execute RISIC instructions from two separate memories; the startup ROM and the RISIC RAM. At power up or after a reset, the processor is set to 3 MHz and begins to execute at location 0 of the startup ROM. The startup ROM consists of two CMOS 2K x 8 programmable read only memories (PROMs) and the RAM consists of 4 8K x 8 static RAMs.

Since a hard bit failure in the lower order addresses of the RISC RAM or ROM could leave a processor non-functional, a memory map switching feature was added. This feature swaps the lower order memory addresses with the upper order memory address depending on the state of a spacecraft supplied memory select signal.

The 1750A operational program and along scan video integration memory is a RAM consisting of sixteen radiation hardened 8K x 8 CMOS static RAMs divided into two sections of 64K x 8 each thus eliminating the core memory that was used in the Block 5D2 OLS configurations.

The true flexibility and value of the software controlled OLS processor and the dedication of the Westinghouse software engineers was recognized by Col. Stephen McElroy, Deputy for Defense Meteorological Satellite Systems, in a letter to the Westinghouse General Manager in November 1984. This letter said in part:

"We would like to commend Westinghouse for the fine job your engineers have done this year in supporting our program's needs. We owe a special thanks to Mr. Ken Martin of the Block 5D program for his outstanding performance.

Last November when we launched DMSP Flight 7, we suffered from having very few experienced Air Force "Blue Suitors" on the sensor team, so we depended even more heavily on our contractor engineers. Besides lending his technical expertise in support of successful early orbit operations, Ken took the time to explain things to our sensor engineers. This informal training has better equipped them to execute their responsibilities as project officers.

Ken Martin

In January of 84, one side of the F-7 OLS drive motor electronics failed and Ken was a critical member of the Tiger Team. He flew to Omaha on just two hours notice to assist in the commanding of the redundant side. His presence on site and his expertise gave us greater confidence in the operation, and it went quite smoothly. In a follow-up to this anomaly, Ken developed a "safing" software load that would prevent any similar anomaly from overstressing the scanning optics of future sensors. Again, he was on site to see that the software load to the on-orbit unit was successful.

During the summer, Spacecraft 10 (the first encrypted system) experienced a hardware problem in the authentication interface between the OLS and the spacecraft. Mr. Martin was able to devise a software patch on the WEC side of the interface to correct for the problem, thus preventing costly spacecraft rework and schedule impact.

On 9-10 Oct 84, Ken went to the Harris Corporation plant in Melbourne, Florida to support the first end-to-end command test of the encrypted/authenticated satellite system. He worked long hours during the test and had spent much time in the preceding weeks reviewing procedures. His efforts along with those of the rest of the team resulted in an extremely successful test. No major problems occurred. No rerun was necessary.

It's not just Ken Martin's system knowledge which makes him such a valuable program asset. His attitude is a perfect example of the team approach which we're trying to instill throughout OMSP. He gives 100% to the task at hand and obviously has pride in himself and in the satellite system he supports, Again, we thank him for a job well done."

The Ground Segment

The ground segment equipment was designed and built by the Surface Division located in the west building. The primary product line for Surface Division was ground based radar equipment. The primary contracts for both the space and the ground segments were booked by the Aerospace Division with the ground segment equipment funded by a partial order transfer (POT) to the Surface Division. The thought process of the Surface Division upper management was radar and radar alone. More than once I heard our engineering manager say *"if it* (a contract) *ain't radar or radar related I don't want it".*

My section which was responsible for the ground segment design and fabrication reported to the Surface Division engineering manager. Fortunately for us the program required special access clearance. The design and development was performed in a secure closed area and we were able to keep most of the Surface Division management in an uncleared status with access only to financial and schedule status. But as the program developed, the costing rates grew faster than expected. This was a fixed price development contract . This meant fewer hours to do the same job. Consequently both schedule and cost problems developed. The Engineering Manager demanded to be cleared so he could meet the customer and "fix the problems". So we gave him a comprehensive briefing on all aspects of the ground segment hardware including schedule, cost and technical problems and arranged for him to meet with Major Chubb, the SPO engineering manager. The meeting was held in a smoke filled conference room in the "shaker shack" and what a meeting! Both participants were very formal and polite but you could sense the "daggers" flying between them. Chubb had intimate knowledge of the details of the problems and ask embarrassing questions which our man didn't have a clue as to the answers. Consequently nothing resulted from the meeting except a lot of upper level management pressure to take shortcuts and get "that damn equipment out the door". Eventually the POT was canceled and moved back into the Aerospace Division and the key ground segment people transferred to the Aerospace Division.

Block 5 Display

The Block 5 display needed a bright, high resolution, flat face CRT to expose the 9 ½ inch wide film. This CRT was scanned only in the cross track direction synchronized to the scanning optics in the spacecraft. The along track scanning was provided by the film transport mechanism and was synchronized to the along track motion of the spacecraft. Corrections were provided by the ground data processing equipment in the display to correct for earth's curvature; spacecraft altitude variations; spacecraft roll and pitch; and, jitter of the scanner mirror and wow - flutter of the onboard data tape recorders. The data was recorded on the film with a scale factor which could be overlaid on standard maps. The film was exposed, processed and dry when it emerged from the film processor within 5 minutes of exposing the last line of data. This required processing about 30 feet of film in 5 minutes. The rapid film processor was

Automatic Film Processor

designed and built by Fairchild in Germantown, MD under subcontract to Westinghouse. It employed heated developer, fixer, washer and dryer tanks and fit into the standard 19 inch rack 25 inches deep. Film was automatically fed into the processor at the completion of the expose process.

Larry Nix remembers one encounter he had with our Engineering Manager during the design of the CRT circuitry: *"The CRT required a dynamic brightness control in order to properly expose the film. This came about because of the variations in writing speed necessary to correct for the earth's curvature and also to correct for imperfections in the faceplate phosphor. The mechanical design was tight and it was not possible to fit a detector and an elaborate optical system in the available space. We had tried many approaches without success. Finally I came up with an approach which used a supersensitive silicon detector with low "popcorn" noise characteristics made in Canada. We built an engineering test model which seemed to work fairly well but the detector noise level was still too high. I suspected that if we lowered the detector temperature our problems would be solved. So, I got some dry ice and placed it on the detector and watched the noise level immediately drop to an acceptable level. Success at last we thought until we turned the unit on the next time. Guess what - no signal at all! Investigations showed that since the detector was not hermetically sealed moisture had gotten into the unit and poisoned the detector. When our Engineering Manager found out he said "forget the optical feedback loop, take it out and ship the hardware." I said if you do that sir, you may as well ship it to the bay bridge and drop it overboard. Without this loop all the equipment will be useful for is for a boat anchor. I heard later that the Engineering Manager said that in all his long career no had ever talked back to him like that. Apparently he got my message. In an hour or so I heard that Fred Popodi had been summoned to his office.*

Well the feedback loop did not come out but Fred Popodi was dispatched to Canada with orders to stay as long as necessary to get hermetically sealed detectors and we proceeded to design a thermoelectric cooler for the detector. Fortunately the company in Canada had more detector chips which they could test and put in hermetically sealed cans and were willing to work with us. In a couple of weeks Fred came home with detectors in his pocket. Several days later a box containing a dummy detector arrived which had been through customs and the required duty paid."


Bill Roberson

The design and test of the display system went fairly smoothly with only the few problems considering it was a fixed price development program which was advancing the state-of-the-art in many areas. We experienced some minor design problems with the wow-flutter correction loop and the automatic gain control servo loop which included maintaining a constant CRT brightness for a varying screen writing speed and to remove the effects of the CRT phosphor noise. The incorporation of the AM/PM switch also was more of a problem than originally expected.

Westinghouse Elmira was able to design and build a high resolution flat face CRT with sufficient deflection linearity, spot size and screen brightness. Larry Nix, Fred Popodi and Frank Kulesza designed the display analog circuitry including the CRT deflection, dynamic focus, and CRT brightness control circuitry.

One of the engineering challenges was the requirement to wet process and dry approximately 30 feet of 9 1/2 inch wide photographic film within 5 minutes after it was exposed. Bill Roberson surveyed industry for someone who could build the film processor. Fairchild in Germantown, Maryland was selected and designed and built the film processors under a subcontract.

The big mechanical challenge was to package a lot of electronic equipment including a CRT camera and a rapid wet film processor into one cabinet which had to survive a sever transportation environment. Jacques Pessin, our mechanical engineer, and Jim Tracy a senior drafting designer solved these problems using a rugged cabinet designed to meet similar requirements for the 487L program. More specifically in the final design the cabinet weighed about 1200 pounds in its packaged for shipment configuration. During the vibration tests, the wood box under the straps holding the package to the shaker table caught fire because of friction. The shock test consisted of dropping the package on a corner a distance of three feet. The equipment passed both tests with only minor damage.

The ground segment equipment, primarily the display equipment, and the sensors were designed by independent teams. The displays were designed and built in the west building. The sensor work was done in the east building. The different schedules did not allow much end to end testing. As I recall only one or two tests were conducted to verify interface compatibility all of which were successful.

In real life the sensor and the display systems were interconnected by thousands of miles of telephone lines. The down link receivers from the satellite were located in Maine and Washington state. The displays were located at Omaha, Nebraska. Data collected by the sensor was stored on the spacecraft in analog tape recorders for the Block 5A,B,C series and down linked to one of these two sites where it was recorded and forwarded to Omaha. For the Block 5D series the data was stored on digital tape recorders and down linked to the same sites. Only one test of the data links was performed prior to the first Block 5A launch. This test, which was performed only four months before the scheduled launch date, showed a time delay problem between the video and wow/flutter channels which we had not been made aware of and needed a delay line to correct. Needlessly to say we had to scurry around and find a vendor to build these new hardware items in only three months!

The Block 5 satellites also transmits data in real time to tactical sites. Two tests were performed on this interface. The first was performed in the lab which tested the interface between the Westinghouse equipment and the Harris data receivers. The data receivers was the source of the "analog digital" signal which had been mentioned in the original RFP. We had determined that "analog-digital" signal meant unfiltered NRZ-L digital data from an analog receiver and we needed a bit synchronizer. Space did not permit the incorporation of a commercially available Bit Sync so Ed Wallace designed our own using a "unique stuffing box" technique originally developed by Bob Wesen on another program but not knowing much about filtering requirement we had not yet incorporated any. Still the test showed close to theoretical performance. We then designed and incorporated a filter which increased the system signal to noise performance a few percent.

The other test was performed at Hickam Field in Hawaii. Here the tracking antenna and receiver were a Kaena Point with a microwave link to forward the data to the display equipment which was located at Hickam Field. The down link real time data is encrypted. During the microwave link test, a Russian trawler was stationed in international waters where it was able to monitor transmissions from Kaena Point to Hickam. All the data we transmitted over the microwave link was encrypted. During the test the an Air Force Lt. suggested we play some games with the Russians just in case they were monitoring. We encrypted and transmitted the real formatted data several times but over the voice link called it test signals. Only two people knew that we had encrypted random noise for the last test. Over the voice channel the test director announced "Are all uncleared personnel out of the room?" After an affirmative answer, he announced that "real formatted data was being transmitted". If somehow the Russians were able to decrypt the data I wonder if the they ever figured out what was going on.

For data calibration purposes the SAP was design was such that the scan must always be from dark deep space to earth scene and to deep space. The spacecraft could be placed in what was called a morning or an afternoon orbit depending upon the mission of that particular spacecraft. But the condition could exist where a morning bird could drift across the morning-noon timeline. If this occurred the spacecraft would be turned around so that the scanning direction would be correct. The scan direction of the CRT in the display had to match the AM or PM designation of each spacecraft. The SPO had left this requirement out of the ground segment equipment specification. Major Blankenship discovered this omission about mid way through the display design phase. He got with Lt. O'Hearn who was the ground segment Project Officer in the SPO and the two of them tried to convenience me that we were responsible for the omission in their specification and should put the capability in at no increased cost. We quickly evaluated the requirement, looked at the design, and it appeared relatively simple to do so I argued that while it was an error of omission by the Air Force in the specification but agreed to incorporate an AM/PM switch at no additional cost. When we went to implement the changes we found it was far more costly than originally thought to be. Those two guys had fast talked me into making a $250,000 change at no cost to the government. Lt. O'Hearn told me later that when Col. Botzong found out about this incident he promptly called him into his office and told him in no uncertain terms that the government expects and pays for changes resulting from omissions or errors in the government's specification and for him to never even think about doing the same thing to a contractor again.

Westinghouse produced 13 sets of ground station display equipment in three configurations - Sage, Central and Remote. The prototype or SAGE as it was known had the capabilities of both the Central and Remote site display equipment. It was initially used as both an engineering breadboard and prototype test bed and later used as a piece of test the sensors.

Two sets of Central site display equipment were built and used at the prime DMSP site at the Air Force Global Weather Central (AFGWC) at Offutt AFB, Nebraska. Here analog data from the spacecraft' tape recorders are read out to tracking sites at Fairchild AF, Washington, and Loring AFB, Maine. The role of these two sites is to relay the satellite data "dump" over special wide band communication links to AFGWC where it was received and processed twice daily for each spacecraft.

Ten sets of Remote or Tactical Site display equipment configuration were built and deployed about the world. At one time Tactical Remote Site vans were located at:

Hickan AFB., Hawaii
Elmendorf AFB, Alaska
Nakhon Phanom AF, Thailand
Patrick AFB, Florida
Fuchu AB, Japan
Ramstein AB, Germany
Howard AFB, Canal Zone

Kadena AF., Okinawa
Nimitz Hill, Guam

In addition a Tactical Remote Site van was also located at McClelland AF, California and kept ready for air deployment to support contingencies that may occur world wide.

In 1971 one of the Tactical Remote Site Displays was modified slightly and loaned to the Navy for installation on the USS Constellation which had been fitted with a prototype two antenna receiving system. The Navy resorted to duplicate antennas in under deck locations to avoid having to place a satellite receiving antenna on the ship's already crowded island and subject to intense radio frequency interference. The tests were successful and when the Air Force wanted its equipment returned the ship's captain is reportedly to have said "*This equipment stays! If you want it you will have to get by my marine guards who are authorized to use deadly force if necessary.*"

DMSP Antenna Saves an Airplane

The imagery produced by the Central and Tactical site display configurations is essentially the same but due to the different areas of coverage and formats of the data transmission, the two sets of equipment differ in their details.

When DMSP upgraded the sensors to the OLS version, the Air Force did not want to make major design changes to the ground stations because of their number. Consequently this compatibility requirement was a major drivers on the OLS data formats.

System Performance

Westinghouse designed the SAP and the ground station processing equipment as a system to provide high quality meteorological data and have it in the hands of the forecaster within five minutes after the data transmission terminated. The system approach was taken to ensure that the data resolution inherent in the sensor electronic signals would be faithfully preserved through the amplification, recording, transmission and eventful display on the ground. Following the initial deployment of the SAP and the ground stations an evaluation was performed to see if, indeed, the imagery available to the forecasters met the engineering specifications.

The spatial resolution at the satellite subpoint was specified as 1/3 nautical mile for the VHR data, 2 nautical miles for the HR data and 2.4 nautical miles for the infrared data. However the resolution which is apparent on the film which is used by the forecaster is a function of:

a. Sensor optics
b. Detector characteristics

c. Sensor electronics frequency response
d. Smear due to image motion
e. Tape recorder characteristics (Analog Tape recorders were used with the SAP)
f. Communications link characteristics
g. Ground station characteristics including maintenance
h. Satellite altitude
i. Contrast of the scene
j. Alignment of the "target scene" to the scan lines
k. Others

The Air Force conducted at least two tests that I know of to evaluate the SAP system performance. The first set of tests showed that the SAP design resolution and that achieved on the film imagery were nearly equal. Geographical features in the VHR imagery were examined and compared with their known sizes as indicated on aeronautical charts. Selected features as small as one half nautical mile were visible. For the HR daytime imagery it was found that features as small as two nautical mile in size were visible at the satellite subpoint. Nighttime HR Data spatial resolution was found to be much more dependent on light level and contrast than daytime data.

The second set of tests to determine the spatial resolution were more exhaustive. High altitude aircraft photographed clouds over the Pacific Ocean hear the Hawaiian Islands. The dimensions of low clouds and land features from known altitudes were compared with the VHR imagery from satellite passes within 15 minutes of the aircraft photographs. These tests showed that 39% of the features as small as 0.2 nautical mile were visible, 71% of the features 0.5 nautical mile were visible; and, 93% of the features 0.7 nautical mile in size were visible.

It is interesting to note that a significant percentage of the objects only 0.2 nautical were detected but not all features as large as 0.7 nautical mile in size were detected. There are at least two factors that contribute to this:

1. The land and cloud feature cases selected from the aircraft were not restricted to the satellite subpoint region. The cases were distributed throughout the area viewed by the satellite; therefore, image foreshortening effects would limit the number of small objects detected.

2. The spectral response of the aerial film used was different than the VHR detector response. The aerial film had very little blue and near infrared response. The VHR detector responded to a considerable quantity of near infrared reflected radiation and therefore the results were not directly comparable.

These tests concluded that as a general rule of thumb, the VHR resolution of the displayed imagery displayed in the 1:15 millions scale had a spatial resolution of one third to one half nautical mile within plus or minus 100 nautical miles of the satellite subpoint. From plus and minus 100 miles to plus and minus 225 nautical miles the resolution the resolution degrades to about one nautical mile and from plus and minus 225 nautical miles to plus and minus 800 nautical miles the resolution degrades to about two nautical miles. These degradation's are due to the image foreshortening caused by the scanner-earth geometry.

The infrared channel resolution and thermal accuracy was more difficult to obtain but their tests concluded that if there is an eight degree difference between a target and its background the resolution was 2.4 nautical miles at the satellite subpoint degrading to 14-17 nautical miles at the edge of scan.

The thermal accuracy was determined by correlating satellite imagery with measured sea surface temperatures. For cloudless conditions in relatively dry subtropical areas the temperatures indicated by the SAP were 1-2 degrees colder than the measured. For colder waters near 70 degrees north latitude the sea surface temperature was sensed about 3 degrees too cold. It was also the thermal accuracy was a function of the sensor scan angle with the surface measured temperature and the SAP sensed temperature differing by as much as 14 degrees 800 miles off satellite nadir.

I am not aware of the results of similar tests conducted on the OLS data.

Block 5 Quality and Reliability Program

Westinghouse produced 10 sensors of the Block 5A,B,C series which were successfully launched. The first of this series had a design life of 180 days in orbit. With the advent of Block 5D this life requirement progressively grew to a 60% probability of success for 3 years. All but two of the Block 5A series met or exceeded the life requirement. The units not meeting the 180 day requirement was Flight 2 which lasted 164 days and Flight 9 lasted 164. All of the Block 5D series met or exceeded the life expectations. As of March 2002, there were four Block 5D systems in orbit - Spacecraft F 15 has been in orbit 28 months, F 14 for 60 months, F 13 for 85 months and F 12 for 92 months. All were operating with no reported failures. Quite a record since each sensor has over 24,000 electronic piece parts.

As Chip Weems recalls; *"It is not accidental that the Westinghouse Block 5 sensors have been star performers by far exceeding the contractual life requirements as well as the predicted life expectancy based on reliability calculations using industry accepted piece part failure rates. This achievement has reduced the number of launches required and saved the US taxpayers millions of dollars."*

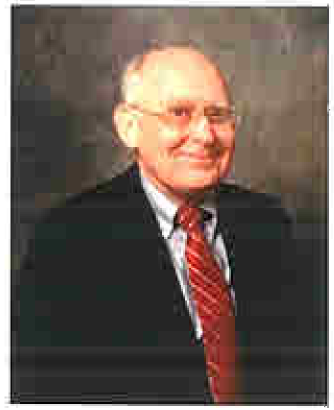
One of the initial points stressed by the Air Force during the 1966 studies was the need to improve the sensor lifetime over that being achieved by the Block 4 generation. Westinghouse had listened closely to the Air Force briefer and intended to build sensors which would fully comply with their desires.

Between 1967 and 1973 DMSP, being a "Black World" program, was exempt from most of the requirements of ASCM 375 series of procurement and system requirements. In order to satisfy the security requirements Westinghouse was permitted to clear only the minimum number of people necessary to perform the contract requirements. This meant selecting a team consisting of the best Engineering, Quality, Manufacturing and Test people available and collocating them in a secure area. Collocating the team members in a secure area permitted close coordination and timely communications among the various staff members representing each discipline. Each team member was indoctrinated in the stringent program quality and reliability requirements and the active participation of each was required by the program manager.

The Block 5 contracts did not require the manufacture and delivery of a large number of systems. Instead the sensor would be designed, manufactured and tested by a small number of individuals. This allowed deviation from the standard parts control programs and manufacturing techniques more applicable to production lots of equipment. This allowed us to place priorities, although is some cases very expensive, on individual piece part requirements and required higher workmanship standards.

Chip Weems continues: *"To assist Westinghouse in maintaining the high standards, the Air Force designated a single quality representative within the local NAVPRO (predecessor to DEPRO) organization with full and unfettered responsibility for monitoring Westinghouse* *activities and focus on specific program objectives. Issues of fitness for use of material and processes were resolved not by conformance to an arbitrary specification but by consensus of those most knowledgeable of its use and mission.*

As the Military and NASA gained years of experience, the bitter lessons of failures on many programs engendered a codification of these lessons into specifications and procedures designed to improve the probability of long term success of satellites. When the Black World security requirements were lifted from Block 5 in 1973, the program was no longer exempt from the AFSCM 375 requirements. About the same time the original staff of three from the "system engineering and technical direction (SE&TD) contractor" (The Aerospace Cooperation) was replaced by a large staff of engineers representing many disciplines. Also the Block 5 program had matured into a much larger system with more capabilities and multi-system contracts were written. It was inevitable that the new series of specifications for space programs were imposed. The Air Force and the SE&TD contractor did recognize the effectiveness of previous Block 5 experiences and agreed to a tailoring of some of the more onerous requirements. The principle new requirements that were imposed included:

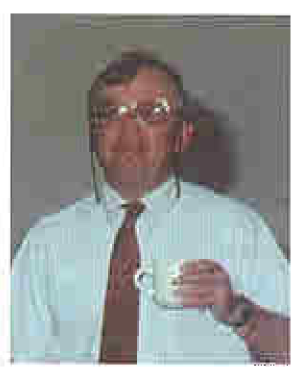


Chip Weems

1. *The requirement for a System Effectiveness Program Manager (SEM). Roland Bark was appointed to this position and reported to the program manager. His job was to coordinated all aspects of Quality Assurance, Parts Engineering, Reliability Engineering, Inspection, Test, oversight and sub contractor quality assurance and formally document all local procedures.*
2. *The SEM also served as the head of a Parts, Material and Process Control Board (PMPCB) which included representatives of AF program office, Aerospace Corporation and the local DEPRO QA office*
3. *Part program documents that identified each part by lot and in most cases serial number, incoming inspection requirements and applicable tailored Military Standards for design application was required.*
4. *The PMPCB was required to review all materials, parts or process deviations in addition to the normal Material Review Board. They also had to approve any deviation from the design application standard and all new processes.*

The close communications of the earlier program activity, however was not unduly diminished and even when the Deep Black shroud of security was lifted the Block 5 program team maintained cohesiveness. The new activities did however inherently increase cost and at the peak of the 5 lot contract from 9 to 12 dedicated people were engaged in these activities

At one point in 1991 the local DEPRO surveillance was changed from the exclusive direction of the appointed long time representative to a standard program with each area served by locally assigned personnel. This caused additional burden on the program and considerable effort was required to develop the mutual trust and understanding that had been enjoyed for so long."



Roland Bark

OLS Test Program

With the transition of the Block 5 sensor from the Block 5A,B,C series to the block 5D series, the complexity of the hardware increased significantly. The 5A,B,C series was only a multichannel sensor. The Block 5D system included not only the multichannel sensor but also the onboard data handling, processing, storage and control equipment for all mission data sensors, the encryption equipment and the data transmitters. Also the 5A,B,C sensors were basically analog design and had only a few modes of operation. The 5D sensors involved both analog and digital including digital storage of the mission and telemetry data and had many modes of operation. These new features made the Block 5D or OLS test program far more complex than that used on the earlier sensors. This meant building elaborate test equipment to: (1) simulate the spacecraft interfaces (2) generate uplink commands from the ground (3) control the generation of test targets, and (4) evaluate the data collected for conformance with the performance specification requirements.

Recognizing that testing at the system level would require the exercise of each of the many hardware functions multiple times under different test conditions of temperature and vacuum, Westinghouse designed and fabricated an elaborate computer based set of test equipment to provide the simulated inputs, control the OLS modes and collect and evaluate the resulting data. Because of the complexity of the test equipment it was a continuous nightmare keeping it functioning and properly calibrated.

The tests were software controlled by hundreds of computer files which had to be under rigid software configuration management and monitored by the appropriate Westinghouse and DPRO quality representatives.

Three versions of the OLS system test equipment were built - factory configuration, spacecraft integration site configuration and launch site configurations. Each of these sets of equipment basically did the same thing but in a slightly different manner.

An OLS Engineering Test Model (ETM) was constructed for qualification testing. It was simultaneously used to verify the flight hardware and test equipment design. The OLS ETM along with the field test equipment was later taken to the spacecraft contractor's facility and integrated with the spacecraft to verify the performance integrity of the DMSP satellite.

Jake Beser Sal Romano

Sal Romano was placed in charge of generating the test procedures, testing and qualifying the first Block 5D OLS at system level both in the Westinghouse factory and at the spacecraft contractor's facility. Sal was a true believer in the "test it like it flies" philosophy. On previous programs he had learned the hard way that perfection comes with great difficulty and the difference between failure and success can be as simple as getting the job done almost right vs. getting it absolutely right and being able to prove it. He also stressed to the Test Team that each and every anomaly, no matter how insignificant it may seem and even if it occurred only one time must be documented, evaluated and explained.

In order to thoroughly test the OLS, both at the factory and at the spacecraft level on the ground and in orbit, one must know and understand how the hardware on both sides of the interface functions. Sal took it on himself to thoroughly understand both the OLS and the spacecraft hardware. When the OLS ETM was shipped to the spacecraft contractor's facility for qualification tests Sal went with it and took with him his belief that everything must be absolutely right before considering the test program complete. These activities took the better part of a year during which time Sal was recognized by the Air Force, the Aerospace Cooperation and the spacecraft contractor as the expert whenever an interface issue developed between the OLS and a spacecraft component.

When the first OLS flight system was shipped to the launch site, Sal again went with it. Just before launch he went to Omaha to oversee the Westinghouse portion of the early orbit testing. Unfortunately these activities got delayed because of spacecraft problems which made it inoperable for several months.

Program Management Reviews

With the departure of Col. Botzong as SPO Director, the complexion of the Air Force Program Office changed dramatically. Now operating with Air Force funding; the security blanket lifted and, with a new SPO director, the effects of the AFCM 375 procurement and system requirement regulations were being felt. There was a large influx of resident System Engineering and Technical Direction Contractor personnel from the Aerospace Cooperation with technical expertise in many areas. Almost simultaneously the number of Air Force officers in the Program Office increased proportionally. The days of a few highly experienced Air Force officers and two Aerospace Cooperation Engineers making the technical decisions for the Air Force were gone forever.

Program Management Meeting at Westinghouse

Starting in the early 1970s the Air Force Program Office instituted formal Program Management Meetings to be held monthly usually alternating between the east and west coast. While called Program Management Reviews or PMRs, these meetings addressed both management and technical topics and included both Air Force and Aerospace Cooperation technical and management personnel. However the Aerospace Cooperation Personnel were excused from session where cost information was being discussed. The agenda for each PMR was prepared and distributed in advance to alert those that thought they needed to be present. Typically there would be 20 or more people in attendance for east coast meetings and more when the meetings were held on the west coast or when an especially difficult problem or issue needed to be resolved. Obviously these meetings increased the program costs significantly.

Needlessly to say these meetings were not the "back slapping type" of a mutual admiration society but got into the nitty gritty technical details of design, fabrication, quality control and test issues. It was not unusual for a PMR to go two or three days but issues got resolved in a timely manner by consensus of the technical experts with Air Force and Contractor management people participating.

On-Orbit Command & Control Support Unit (OTSU)

Westinghouse has had a team of field engineers and technicians located at the Air force Global Weather Central (AFGWC) at Offutt AFB, Nebraska since the launch of the first Block 5D Spacecraft to support the "blue suit" operators and ensure continued data quality. Turner Morgan describes his experiences at AFGWC in an article in the January 1986 issue of FE&S OUTFIELDER and in-house newsletter.

DMSP ... OR LIFE IN REAL-TIME *By: Turner Morgan*

The telephone rings at 2 a.m. The 1000th Satellite Operations Group (1000 SOG or 1G) Satellite Systems Director (SSD) says that Global Weather Central (GWC) reports bad data from the last stored data playback from one of the DMSP spacecraft.

They find no problems in the ground system and the 1G received stored mode telemetry from that playback is in good condition. (This doesn't fit in with an onboard tape recorder problem, but at 2 a.m. you're too groggy to think of it.) You tell them you'll be there in a few minutes.

You get out of your warm bed, pull on whatever clothes you can find in the dark, make sure you have your Restricted Area Badge and Russcard (you're beginning to think again), put on a down-filled coat (why can't these things happen in summer?) and step into a clear, sub-zero Nebraska night.

During the drive to Offutt AFB you mentally pick telemetry points to examine, using the Stored Telemetry Processing System (STPS), to check on recorder performance. Now, the SSD's comment about receipt of good stored telemetry data comes back (all data should have been fragmented if the problem were in the on-orbit recorder). This makes you feel better about the on-orbit *recorder, but there are other components on-orbit that could be ailing. You begin to think about Dual Formatter and other configuration changes.*

Upon arrival at the 1000 SOG you report immediately to the SSD. The Engineering Division (EN) on-call engineer is already there. He says the data are waiting up-stairs at GWC and that the Command Read-out Station (CRS) is about to start a reship of the data from one of their recorders (the data are recorded at the CRS during playback from the spacecraft).

On the next pass, the duty crew is prepared to Fast Forward the on-orbit recorder to replay the data, since the recorder is not scheduled for use again until two orbits later (you're lucky here!). You and the EN on-call engineer make the walk upstairs through a dark Building D to GWC.

The data they received from the original shipment is extremely noise-ridden. Very little contiguous scenery is visible. You go into the Operations area where re-ship is just starting. The Ampex tape drive starts moving tape and you look at the top of the Westinghouse-built Central Display Mod (CDM). As data are received the green "in-sync" light snaps on; you hold your breath waiting for the green light to wink out and the red "loss of sync" light to come on. It doesn't happen; the green light stays on. You watch that light for the entire two minutes and 30 seconds of playback (you have started breathing again), but it doesn't go out. In a few minutes the processed and dried film rolls out of the CDM. The data are noise-free.

Apologies are made for having dragged you out on a night like this, etc. You are so relieved you don't have a major sub-system problem that, right now, you don't care. You return home to sleep another couple of hours before getting up to go to work.

Such is the life of a Westinghouse Block 5 (DMSP) field engineer in Omaha. The DMSP spacecraft, with its Westinghouse-built Operational Linescan System (OLS), circles the globe every hour and 41 minutes, providing the military with weather information from all parts of the world. We can communicate with it for only 15 minutes (maximum) out of that 101 minute period. This means you have about one hour to determine the cause of a problem, plan what to do to correct it and get the commanding scenario to the duty crew. Life in a real-time environment can be trying at times!

As Engineer-in-Charge I am supported by Ben Pope, Senior Engineer, who monitors Mission Sensor state-of health on orbit and also keeps track of the Mission Sensor complement of future DMSP spacecraft, and Field Technicians Jack Post, who monitors data quality and ensures proper gain selection, and Bruce Ball, who maintains OLS Operational Program files which reside in 1G computers.

Supervised for many years by Gerry Dehm and now by Joe Kibelbek, the Westinghouse Omaha Technical Support Unit (OTSU) is the Block 5 program's field office at Offutt AFB, Nebraska, providing technical support for on-orbit SMSP OLS and Mission Sensors. We provide support for and are supported by Bob Carrell, Butch Einsel, Ken Martin, Roger Lieske, and Tom Birdsall in the Baltimore PMO.

Baltimore is kept abreast of happenings at the 1G that involve the on-orbit resources, both in anomalous situations and on a routine basis, as well as changes in ground system status that may affect display or availability of OLS/ Mission Sensor data, either telemetry or mission data.

We provide 24 hour on-call availability, seven days a week, primarily for anomaly analysis/resolution. In the event of an on-orbit anomaly, the on-call representative reports to the 1000 SOG as quickly as possible. Working with the 1000 SOG/EN on-call engineer, we attempt to resolve or explain the anomaly. If necessary, other members of the Westinghouse OTSU team *may be called in and a 24 hour support schedule is set up. Data, in the form of telemetry graphs or tables and/or hardcopy film, are forwarded to Baltimore by the fastest means possible. This support is provided regardless of weekends, holidays, or weather.*

Routine operations involve sending telemetry graphs/tables and hard copy film to Baltimore in support of the engineering studies going on there, training new 1G and GWC personnel in OLS and Mission Sensor operation, daily monitoring of the on-orbit resources for state-of-health (via telemetry) and proper operation (via hard copy film or analysis of numerical mission data) and assisting with checkout of the OLS/Mission Sensor model in the Flight Vehicle Simulator Facility (FVSF).

Additionally, after Joe Macey and his team at the RCA Hightstown, N.J. facility get a Spacecraft/OLS/Mission Sensor system readied for launch and sent to Vandenberg AFB, we support launch, early orbit testing, and post-early orbit channel calibrations. This involves preparation for three rehearsals prior to launch, the launch and early orbit subsystem checkout, written reports of subsystem status, and channel calibrations prior to turning the system over to AFGWC as an operational spacecraft.

Early orbit operations are conducted on a shift schedule, 24 hours a day, for approximately three weeks. Current on-orbit satellites continue to be monitored as well. Prior to the actual launch, Jerry Schoofs journeys to Omaha from McClellan AFB near Sacremento to "tweak" the CDM's at GWC so they are operating at optimum for the moment the OLS sends us its first data.

Westinghouse Field Engineering and Support Teams are doing their part so YOU CAN BE SURE.

Epilog

The DMSP System Program Office; its Blue Suit Support Organizations; its Contractors, the government Support Organizations at the contractor facilities such as DCAS and DPRO; its User Community; and, The Aerospace Cooperation have always been a team. This fact was first emphasized in the fall of 1967 when the Air Force scheduled the first meeting between RCA and Westinghouse. We were told in no uncertain terms that competition phase was over and we all were now a team and must work together to continue the program success story. Stepping out of line by any one of the organizations would not be tolerated. This team work continued for the 28 years I was associated with the program and I am told that it continues to this very date.

Early in the program history the SPO initiated the concept of holding a "Maxi Review" at least yearly rotating the location among the various Air Force organizations and contractor facilities. I believe this tradition continues today. At the Maxi Review a representative from each organization or contractor was requested/required to present the technical status for his area including problems, schedules and performance for everyone to hear with the responsibility for this presentation falling upon the Program Manager. After the formal meeting the SPO encouraged "Team Building" social functions such as golf, crab feasts, bull roasts, etc. under the firm rule that all Government employees must pay their fair share. In some cases the Maxi Reviews were held at the same time as a formal Dining Out or launch site data review to minimize travel costs.

The DPRO at Westinghouse was briefed by the SPO as to the program objectives and quality control requirements and designated as their in plant representative in Westinghouse. Bernie Ditch was then named by the DPRO as the Block 5 representative and immediately became one of the DMSP team members. Bernie had some prior experience on earlier space programs and was an asset to the program. For his performance on the program both Westinghouse and the Air Force gave him five stars. He was knowledgeable, level headed, cooperative and willing to work with our quality control people to get the program mission accomplished. He was aware of the time criticality of the job and established his own "in box-out box" and inspection point rules and made sure that the required DPRO effort did not interfere with the Block 5 work flow which, in some cases, was not the same as the usual flows set up for production programs. In fact the Air Force chose to honor Bernie with the coveted "DMSP Pioneer In Space" Award for his dedicated performance. This award was made by Col. John Goyette the DMSP SPO Director at a special ceremony at the DPRO Headquarters. At this ceremony Col. Goyette thanked Bernie for his cognizance over the Block 5 build and for his dedicated contributions to the Government and to the USAF Space Division during his tenure on the DMSP Block 5 Program.

Col. Goyette **Bernie Ditch**

Sometime in the early 1970's I received a call that I was wanted at the White House for a meeting and our Washington representative would make the arrangements. The subject of the meeting was unspecified. Our Washington man picked me up and we drove the White House gate where we showed our identification. Arrangements had been made by the White House contact for a Secret Service agent to escort us to an office in the West Wing. There I met alone with some Air Force officers whom I was assured were all program cleared. (I assume they were Air Force Officers but they were in civilian clothes). We chatted for a while about the Block 5 sensor capabilities and looked at some segments of film data on a light table in his office. I was ask a number of technical questions about the sensor performance and ask to explain what I saw on the film. I explained what I saw in the data and answered some more questions but never did figure out what they was looking for or why. Neither did I find out why I was requested by name to see them.

When I took over as the DMSP Programs manager in 1980 one of my first tasks was to review the schedule and financial condition of each of the contracts factoring in the ever increasing costing rates. To my dismay I discoverer that if we continued to spend at the current rate we were headed for a financial disaster even though our reports were still showing a green financial status. Also, certain agreements with the SPO were made in order to get some year end billings for OLS-7. Some of these agreements involved hardware changes and retest that were going to be expensive. A mid-course correction which reduced the burn rate by 25-30 percent was needed. It was a hard thing to do but I found it necessary to

Jack Spangler

reduce the number of people charging the contracts. Also I eliminated certain desirable but not necessary tasks; eliminated what I thought was some unnecessary paperwork; minimized travel; postponed some planned tasks; put the squeeze on subcontractors; reduced the 10% supervision tax we were being charged from supervisors who had people working our contracts; and, similar activities that were not needed. In one case I had an off-site supervisor charging full time because he had more than ten people working my programs. I had him moved into the program office where I kept him busy doing productive Block 5 tasks. I got a lot of flak especially from the engineers and supervisors and was not very popular for a while but the efforts paid off and the spending rate went down by over 20% and we got the program on track to come in at total cost if not make a profit for Westinghouse.

Sometime after I became Program Manager the SPO contracting officer begin "inventing" new types of contracts. Earlier contracts had been Firm Fixed Price (FFP) or in the case of services contracts Cost Plus Fixed Fee (CPFF). In fact the very first contracts were FFP for development effort - a risky business for us on which we lost money. Later they went to Fixed Price Incentive (FPI) another standard type of contract. Still later they added FPI with Award Fee (FPAF) contracts. These types of contracts were well understood and easy to operate under. But, the next step was not that simple. I remember talking with a Procurement Contracting Officer once and she suggested a Fixed Price Level of Effort with Award Fee for a Support and Services Contract. OK until she added she wanted the level of effort to be based on "equivalent supported hour". She wanted the equivalent hour rate to include all Other Direct Costs (ODC) such as travel, subsistence, material, etc. I ask how she would determine a costing rate for such an equivalent hour? She said go back to an old contract and take the total contract price and divide by the number of hours spent and that would be the costing rate. The contract was to have multi-year options. So I ask how do you handle rate escalation's? Her answer was to apply the rate escalation's to the basic contract. I thought for a moment (not very long) and said I think Westinghouse would respectively decline this type of contract and I know I would as the Program Manager.

After considerable discussions and involving our contracts people we finally agreed to a task type FPLOE contract with award fee which included the equivalent hour concept but the ODC was separate contract line items. In this case the equivalent hour rate was based on the costs of an engineering hour. So if you used a budget center with a lower costing rate you got more hours to do a task. This made cost estimating and task management difficult. With the costing rate and budget centers frequently changing during the period of performance of the contracts and the large number of tasks that eventually got added, the negotiations for final contract close out had to be a nightmare!

The later production contracts were FPIF with orbital performance incentives and some with award fee. The orbital performance incentives involved both negative and positive numbers based on a list of performance capabilities. Cindy Nitcher, my contracts representative, her manager Gus Elksnis and I wrote and negotiated the first Orbital Incentive Plan. The SPO argued that an orbital performance incentive would encourage us to spend money now to reap higher profits later. My argument was from my perspective we do what the contract says as far as spending goes and I get rated by my boss on "what have you done for me lately not what you might do for me three or fours years from now". We were very careful to write the orbital incentive plan to protect Westinghouse's interest as much as possible. We included a clause in the plan which said if the units were not launched on-time the negative incentives would go away but the positive incentives would remain and immediately become due. The government agreed to this at the time. However a few years later when the incentive became due and the unit had not been launched, the government reinterpreted the contract words to mean the incentives would become due after the unit was launched since paying orbital incentives for units not yet launched would not look good to an outside observer. We argued the point but finally accepted the government's position to "keep peace with the SPO".

Finally our General Manager agreed to accept the performance incentive plan and the contract was signed. I remember Harold Watson saying "*we are suffering the pain now and hate performance incentives, but I can see a general manager ten years from now looking at a check for one million dollars, which is all profit, and saying "I love performance incentive contracts"."* Harold was correct. So far the program has earned 100% of the orbital performance incentive money however Harold retired before getting any credit and I got credit for only two system. Northrop Grumman has already collected for 4 systems and can look forward to performance incentive checks totaling several million dollars.

A few days prior the launch of any satellite the SPO was required to have a Launch Readiness Review with various higher echelon general officers including the VAFB commander. These reviews were always rehearsed and the SPO Director knew in advance what would be briefed. Before the general gave permission to launch he would poll each of the contractor program managers as well as each of the participating Air Force Organizations. Everyone polled was expected to say "*yes sir we are ready for launch*". At the conclusion of the briefing each organization including the contractors signed a document which said that we were ready.

I remember one of the rehearsal reviews at VAFB when an Air Force captain in the launch organization stood up and said *"Sir, I have absolutely no confidence that this launch will be successful"*. His reason were based on an incident that occurred during processing at the pad when the integrated spacecraft/booster had been dropped a few inches. Aerospace engineers had analyzed the incident and could find no evidence of damage to either the booster or the satellite. The SPO Director, a colonel, really wanted to launch and became very upset. This particular colonel was a strict and formal military type. He always wore a neatly press and tailored uniform complete with service ribbons each day. In his staff meetings or other briefings at his home office he was always the last man to enter the room and expected a junior officer to yell "*Attention*" as he entered and for everyone in the room to rise and remain at attention until he was seated and said *"at ease, everyone please be seated"*. He even went to the extent of having "Military Academy" white glove type inspections of his troops and their offices!

The discussions became heated and the commander of the launch operations group, who also held the rank of colonel, intervened in defense of his captain. The argument then became a tug of war between two bull elephants! Finally they agreed to proceed with the launch.

Another review I remember was the formal Launch Readiness Review for the generals. When the RCA Program Manager was polled he did not make a firm "*we are ready*" statement but conditioned his readiness statement on the review of more data. The SPO Director had not expected this and was very upset. Within about two weeks RCA (now GE) had a different Program Manager.

The DMSP organization was always a close knit group of people. They worked hard and occasionally they partied hard. They usually scheduled two formal parties each year. One, a Dining-In was strictly for officers and invited civilian guests. The other was a Dining-Out where both officers and enlisted personnel were invited as well as invited civilian guests. As was tradition they always had a "grog bowl" where offenders of military etiquette were sent for punishment. They had two versions of the grog bowl - one with alcohol and one without. No one knew what was in either of the grog bowls. In one case I remember the grog bowl was a toilet bowel and had Payday candy bars floating in the drink. A young female Capt. was sent to the grog bowl for some offense either real or imagined. She took one look at the bowl contents and almost passed out.

At another Dining-In I attended with my wife was held in Los Angeles at one of the hotels on Century Blvd. For this occasion a former SPO Director had just been appointed to the rank of Maj. General. He was in attendance and dressed in a formal military attire with one exception. He was from Texas and had on his cowboy boots. Needlessly to say he, as well as a lot of other officers, were sent to the grog bowl many times. The party finally ended after a lot of silly string was appropriately sprayed on several high ranking officers and bread was thrown at about everyone. My wife was talking to a young Air Force Major and commented that the group was acting like high school kids. He responded *"give us some credit, it was more like a kindergarten kids party."* This party made the Los Angeles newspaper the next morning and the hotel told this group that they could not to have any more parties in their facility.

I retired in May 1994 and handed the Program Manager responsibilities over to Mike Barrett who was the Block 5 Systems Engineering Manager. Mike, a MIT graduate, had held many positions of increasing responsibility on DMSP and other programs within Westinghouse. In 1972 he came to the Block 5 Program as a digital designer of the Block 5D1 OLS configuration. Later he developed the system redundancy architecture and directed the system tests for the Block 5D2 systems. He left the Block 5 Program in 1981 to assume greater responsibilities and became the lead digital electronics designer for a major portion of the ASPJ, an Electronic Warfare System. In 1983 he returned to the Block 5 Program as the Engineering Manager responsible for directing the advanced studies for the Block 5D3 system improvement program changes as well as the associated cost. schedule, and customer interface responsibilities


Mike Barrett

In 1996 the Westinghouse Defense Center was sold to Northrop Grummam and the Block 5 Programs continued. Mike still had 5 OLS systems to deliver under the existing 5-lot contract. With the delivery of OLS 21 the program size diminished significantly but ground launch and on-orbit support was still required as the Air Force now has 5 systems on the ground each awaiting its turn to be launched.

The DMSP on-orbit assets were lasting years longer than originally expected. The state-of-the-art had increased significantly in many areas. The digital data tape recorders which were designed in the 1972 era were obsolete and had been a source of several on-orbit anomalies. Under Mike's direction Northrop Grumman secured contracts with the Air Force to replace them with solid state memories which had a higher storage capacity and were lighter in weight, smaller in volume and consumed less power. A mix of solid state memories and data tape recorders were flown on F-15 to prove the solid state design. All future systems will use the solid state memories and the old digital data tape recorders will become museum pieces.

Also the state-of-the-art in the ground processing of meteorological satellite data had steadily improved over the years. New spectral channels were highly desirable to improve the accuracy of the weather forecasts. In the Block 5D3 Westinghouse had made provisions (at a very low cost) in the optical system to latter add two additional spectral channels if they became a requirement but none of electronics were designed. Later the Air force funded Northrop

Grumman to complete the design of the additional channel electronics to be incorporated as retrofit kits if they could be funded. However funding problems were created when the Clinton administration merged the Air Force and NOAA/NASA and the retrofit was never completed.

Studies for the DMSP Block 6 generation of satellites were in process when the Clinton administration came into power and the DMSP and its mission transferred to NOAA and the hardware procurement responsibility transferred to NASA. The program name was changed to NPOS, later to POEES and still later to NPOESS. Westinghouse had a series of Phase 1 study contracts and submitted proposals for a new sensor suite consisting of arrays of visible and infrared channel detectors and a state-of-the-art on-board data processing system utilizing a 5-year projection of technology state-of-the-art. But Westinghouse was weak in the meteorological science requirements to generate Environmental Data Records (RDRs) from the data and had to depend upon subcontractors (of which there were few to choose from) for these aspects of the proposal. After the acquisition of Westinghouse by Northrop Grumman we lost the development phase and production contracts to historical NOAA/NASA contractors because of the "weakness in the scientific requirement to generate EDR algorithms". Thus it was "Payback" time to the Air Force for cutting NOAA/NASA out of DMSP almost 30 years earlier.

Historically, Westinghouse was responsible under a support and services contract for the integration and test at the spacecraft level of the OLS. This effort was significantly increased in the fiscal year 2000 with a Consolidated Sensor Support and Services (CSSS) contract covering the period May 2000 through November 2004. Under this contract Northrop Grumman is now tasked to support all DMSP sensors which include those provided by Aerojet, AFRL, APL and NRL. This effort and includes:

Spacecraft Integration and Test
Launch and Early Orbit Checkout Support
Maintenance of Test Equipment
Flight Software Maintenance
Engineering Support
On-Orbit Command & control Support (OTSU)
Study Tasks as Assigned

Aerojet Corporation in Azusa, CA is the prime contractor for three of the DMSP sensors. One of these is a new microwave imager/sounder known as the SSMIS. The SSMIS contract had a blemished history of customer relations, performance, cost and schedule problems. Cost over runs and legal problems caused the Air Force and Navy to have to go back to congress for additional funding in order to complete the project. When Northrop Grumman purchased Aerojet in Azusa, CA they became responsible for solving some SSMIS workmanship problems which surfaced after the units were accepted by the government. This is significantly increasing the support and services effort.

On July 1, 2002 Northrop Grumman Corporation and TRW Inc. jointly announced that they have entered into a definitive merger agreement. When this merger becomes final Northrop Grumman will again be in the NPOES program in a much larger capacity then during the Westinghouse DMSP years. On August 23, 2002 TRW was awarded a $2.9 billion contract to build the National Polar-orbiting Operational Environmental Satellite System (NPOESS), the nation's next-generation meteorological satellite system. TRW, as prime contractor, will be responsible for overall system design and development, system engineering, system integration, acquisition of instruments and assembly and test of the spacecraft. Its teammate, Raytheon

Company will provide command, control and communications, mission data processing and system engineering support. On August 29, 2002 TRW Inc. was awarded a systems engineering, management and sustainment services contract, potentially worth $119 million, from the Air Force Weather Agency, Offutt Air Force Base, Neb. With these contracts Northrop Grumman will be the major player in the next generation Weather Satellite Systems.

DMSP and NOAA Weather Satellite Programs Merge

The DMSP served the military needs for weather data for more than a quarter century and deserves an award for excellence. But in 1992 a new political generation took over the White House. Sometimes by policy it seemed that the fighting man's needs were secondary to political considerations. Early in 1993, at the direction of the OMB, congressional committees and prompted by Vice President Gore, the Air Force, NOAA and NASA formed a tri-agency committee to justify separate DoD and civil polar orbiting meteorological satellites. Hardly to anyone's surprise the committee reached the conclusion that a single system would eliminate duplication of satellites and ground stations and could be made to satisfy the requirements of both the military and the civilian users. Since a single system would require less hardware and fewer people to operate and it was concluded that a combined system would be inherently less expensive in the long run - a conclusion yet to be proven. History has shown that systems designed to do all things for all people with multi-agency management have a poor record of success and the new program with its tri-agency management must be alert for unintended consequences and remember that many times a complex bureaucratic process tends to use "super glue" as the lubricant of the wheels of progress.

On May 10, 1994 President Clinton issued the following Presidential Decision Directive:

THE WHITE HOUSE

Office of the Press Secretary

May 10, 1994 STATEMENT BY THE PRESS SECRETARY

The Clinton Administration's decision to converge into a single national system the planned polar-orbiting operational environmental satellite programs of the Department of Defense (DoD) and the Department of Commerce's National Oceanic and Atmospheric Administration was announced today by Vice President Al Gore. The National Aeronautics and Space Administration (NASA) will also participate in the converged system.

The decision implements a recommendation contained in the National Performance Review (NPR), published last September. The savings to the American taxpayer are estimated to be up to $300 million during fiscal years 1996-1999. Additional savings are expected after 1999.

Currently, the Departments of Defense and Commerce acquire and operate separate polar-orbiting environmental satellite systems which collect data needed for military and civil weather forecasting. While converging these systems has been a goal of previous Administrations, past efforts have failed to merge them into a single integrated program. Convergence is possible at this time because of clear direction provided by the President and Vice President, and recent technological advances.

In making the announcement, the Vice President said, "For the first time ever, U.S. civil and military environmental satellite programs will be joined. The President's decision will cut costs and eliminate duplication. It takes the nation's space-based environmental monitoring program into the next century. It will satisfy our critical requirements for timely environmental satellite data needed to support civil weather forecasting, global change research and military operations."

The Vice President said: "The decision to converge the satellite environmental system validates the principles that were the foundation of the NPR. Commerce, Defense and NASA have proven that highly motivated and dedicated public servants, empowered to get results, can change for the better the way government serves the people. Building on each other's unique knowledge, the agencies have forged a plan that is a model for interagency cooperation. It epitomizes the spirit and potential of reinventing government."

The President's decision requires the Departments of Defense and Commerce to converge DoD's Defense Meteorological Satellite Program and Commerce's Polar-orbiting Operational Environmental Satellite program. This will result in a single national polar-orbiting operational environmental satellite system which will provide data needed to meet U.S. civil and national security requirements, and to fulfill international obligations. NASA's Earth Observing System, and potentially other NASA programs, will provide new remote sensing and spacecraft technologies which could improve the operational capabilities of the converged system.

A single program office will be established to plan for, design, acquire and operate the next generation polar-orbiting weather satellite system. This Integrated Program Office will be staffed by DOD, Commerce and NASA representatives.

As part of the Administration's effort on international cooperation for environmental monitoring, the three agencies will jointly pursue negotiations with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) on a European-built and operated satellite as part of the converged system.

The Vice President also announced the President's decision to continue the Landsat remote sensing satellite program and to restructure Federal agency responsibilities for acquiring and operating the next satellite, Landsat 7. Acquisition responsibilities will transfer from DoD to NASA. The Department of Commerce will operate the satellite and its ground system in cooperation with the Department of the Interior, which will maintain the national archive of Landsat data.

This decision insures the continuity and availability of Landsat-type data. This data serves a broad range of users in the United States and abroad, including the agricultural community, global change researchers, state and local governments, commercial users, and the military.

Concurrent with the Presidential Decision Directive the White House also released the following implementation plan which established the Integrated Program Office and outlined the responsibilities of each participating agency.

THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release May 10, 1994 FACT SHEET

CONVERGENCE OF U.S. POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEMS

I. Introduction

For the past three decades, the United States has operated separate civil and military polar-orbiting environmental satellite systems which collect, process and distribute remotely-sensed meteorological, oceanographic, and space environmental data. The U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) is responsible for the Polar-Orbiting Operational Environmental Satellite (POES) program. Key aspects of the POES mission include collecting atmospheric data for weather forecasting, global climate research and emergency search and rescue purposes.

The U.S. Department of Defense is responsible for the Defense Meteorological Satellite Program (DMSP). The mission of DMSP is to collect and distribute global visible and infrared cloud data and other specialized meteorological, oceanographic and solar geophysical data to provide a survivable capability in support of military operations.

The National Aeronautics and Space Administration (NASA), through its Earth Observing System (EOS) development efforts, provides new remote sensing and spacecraft technologies that could potentially improve satellite operational capabilities.

The National Performance Review, led by Vice President Gore, called for converging the two operational satellite programs as well as incorporating appropriate aspects of NASA's EOS in order to reduce duplication of effort and generate cost-savings. On May 5, 1994, President Clinton approved the convergence of the civil and military polar-orbiting satellite systems into a single operational program. Details of the convergence plan are provided below.

II. Goals and Principles

The goal of the converged program is to reduce the cost of acquiring and operating polar orbiting operational environmental satellites, while continuing to satisfy U.S. operational civil and national security requirements. As part of this goal, the operational program will incorporate appropriate aspects of NASA's Earth Observing System.

The converged system on-orbit architecture will consist of three low earth orbiting satellites. This is a reduction from the current four satellites (two civilian and two military). The orbits of the three satellites will evenly space throughout the day to provide sufficient data refresh. The nominal equatorial crossing times of the satellites will be 5:30, 9:30 and 1:30. This converged system can accommodate international cooperation, including the open distribution of environmental data.

The converged program will be conducted in accordance with the following principles:

(1) operational environmental data from polar-orbiting satellites are important to the achievement of U.S. economic, national security, scientific, and foreign policy goals;

(2) assured access to operational environmental data will be provided to meet civil and national security requirements and international obligations;

(3) the United States will ensure its ability to selectively deny critical environmental data to an adversary during crisis or war yet ensure the use of such data by U.S. and Allied military forces. Such data will be made available to other users when it no longer has military utility; and

(4) the implementing actions will be accommodated within the overall resource policy guidance of the President.

III. Implementing Actions

The Departments of Commerce and Defense and NASA will create an Integrated Program Office (IPO) for the converged polar-orbiting operational satellite system by October 1, 1994. The IPO will be responsible for the management, acquisition, and operation of the converged system. The IPO will be under the direction of a System Program Director who will report to a triagency Executive Committee via the Department of Commerce's Under Secretary for Oceans and Atmosphere.

The Under Secretary-level Executive Committee will ensure that both civil and national security requirements are satisfied. The Executive Committee will also coordinate program plans, budgets, and policies and will ensure agency funding commitments are equitable and sustained.

The three agencies are developing a process for identifying, validating, and documenting requirements for the converged system. Those requirements will define the system baseline used to develop agency budgets.

The Department of Commerce, through NOAA, will have lead agency responsibility to the Executive Committee for the converged system. NOAA will have lead agency responsibility to support the TO for satellite operations. NOAA will also have the lead for interfacing with national and international civil user communities, consistent with national security and foreign policy requirements.

The Department of Defense will have lead agency responsibility to support the IPO in major systems acquisitions. NASA will have lead agency responsibility to support the IPO in facilitating the development and insertion of new cost-effective technologies to meet operational requirements.

The United States will seek to implement the converged system in a manner that encourages cooperation with foreign governments and international organizations consistent with U.S. requirements. The United States' European partners have been invited to explore incorporating the European METOP (meteorological operational mission) polar satellite series into the converged system. This effort underscores the importance that the United States places on environmental satellite cooperation with our European partners. The METOP is a joint undertaking of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Space Agency (ESA), and their member states.

Raytheon Awarded $152.8 Million Contract for Meteorological Satellite Imaging Sensor
Goeleta- Nov. 28, 2000

Raytheon has won a $152.8 million contract to provide the imaging sensor instruments for a polar-orbiting satellite system that will provide accurate weather forecasts for civilian science and national defense requirements.

The system, called the National Polar-Orbiting Operational Environmental Satellite System (NPOESS), will replace the Department of Commerce's Polar-orbiting Operational Environmental Satellites (POES) and the Defense Meteorological Satellite Program (DMSP) satellites.

"Raytheon offered the best value and lowest risk to the U.S. government for the development of a Visible Infrared Imaging Radiometer Suite (VIIRS) instrument to be carried by the new system's satellites," said John D. Cunningham, system program director at the NPOESS Integrated Program Office. "Raytheon was rated exceptional in system optimization, sensor system design, and systems engineering, integration and test."

Under this contract, Raytheon will perform the detailed design, development and testing of the VIIRS instrument. The company will deliver three flight units, plus provide options for five additional units.

The VIIRS will provide data for production of Environmental Data Records (EDRs), including imagery, sea surface temperature, low light imaging and ocean color.

EDRs will be produced on the ground from the data provided by the VIIRS using algorithms also developed by Raytheon. Design of the instrument is based on risk reduction studies performed by the company under a $36.8 million contract awarded in July, 1997.

"Winning this very significant contract reinforces the company's position as a major supplier of space-based technologies for both civil and defense missions," said William H. Swanson, president of Raytheon's Electronic Systems business.

"Our engineers, technicians and managers have successfully leveraged Raytheon's extensive experience in producing highly accurate and reliable remote sensing instruments to provide the customer with a VIIRS design that will provide information for a wide variety of data collection requirements, including meteorological, oceanographic, climatic and space environmental information."

Raytheon's Santa Barbara Remote Sensing (SBRS) operation in Goleta, Calif., where work on the VIIRS will be performed, is the world's leading manufacturer of precision, high reliability, remote sensing instruments for use in atmospheric, planetary, and land research science. With a combined operating life exceeding 324 instrument-years in space, and an actual instrument lives three times greater than design requirements, the company's instruments are the most reliable space-qualified sensors worldwide. The NPOESS Integrated Program Office

(IPO), which provides for the planning, development, management, acquisition and operation of the new system, awarded the contract.

The IPO is a tri-agency office reporting through the National Oceanic and Atmospheric Administration to an executive committee composed of under secretary/administrator level officials of the Departments of Commerce, Defense and the National Aeronautics and Space Administration. The U.S. Air Force will perform administration of the contract for the IPO.

CONTRACT AWARDED FOR ADVANCED IMAGER INSTRUMENT FOR ENVIRONMENTAL SATELLITE SYSTEM OF THE FUTURE, NOAA ANNOUNCES

A $297.6 million contract has been awarded to Raytheon Company, Santa Barbara Remote Sensing Group of Santa Barbara, Calif., to develop an advanced operational environmental satellite sensor that will significantly improve weather forecasting and climate prediction as part of an interagency program to make government less costly, more efficient and more responsive to public needs, Commerce Secretary Norman Y. Mineta announced today.

Mineta said the new instrument is part of the Administration's National Polar-orbiting Operational Environmental Satellite System (NPOESS) program, which will become operational later this year, and will save the taxpayers about $1.8 billion over its lifetime. The savings will accrue as a result of the administration's initiative to combine the nation's military and civilian environmental satellite programs into a single, national system that will satisfy both civil and national security requirements for space-based remotely-sensed environmental data.

"This program marks the most significant change in U.S. operational remote sensing since the launch of the first weather satellite in 1960," he said, adding that the program heralds a "new unified path for the United States in the development, acquisition, management and operation of environmental satellites.

"These satellite instruments will improve short-term weather forecasts and long-term climate prediction," Mineta said. "In this way, they will touch all of our lives and will ultimately benefit all sectors of our society, including families across the country, the scientific community, the private sector, and the business community."

The contract to Raytheon's Santa Barbara Remote Sensing Group is for a Visible/Infrared Imager Radiometer Suite (VIIRS), an advanced, high-spatial resolution imaging instrument to be flown aboard the nation's environmental satellites of the future. VIIRS will provide high-accuracy radiometric measurements of reflected sunlight in multiple spectral bands within the visible-to-thermal infrared range to determine sea surface temperature, cloud cover, atmospheric aerosols, soil wetness, surface albedo, vegetation index, snow cover, sea ice, and ocean color. VIIRS will continue the high-resolution cloud imaging and visual, nighttime low light imaging capabilities of the Defense Meteorological Satellite Program spacecraft to support the operational needs of the Department of Defense, as well as the civil applications of the National Oceanic and Atmospheric Administration.

The contract was awarded November 20 by the tri-agency Integrated Program Office, which consists of components of the Department of Commerce's National Oceanic and Atmospheric Administration, the Department of Defense, and the National Aeronautics and Space Administration. The contract, which encompasses design and fabrication of the new visible/infrared imager, totals approximately $297.6 million, including options, and will run through 2015, if all options are exercised. The contract effort will ultimately produce up to eight VIIRS units that will use advanced radiometric technologies at high spatial resolution to accurately image and measure atmospheric, oceanic, and terrestrial parameters. The more accurate VIIRS measurements are expected to yield significant improvements in the skill of short-to-long range weather forecasts and long-term climate predictions.

The first VIIRS unit will be flown on the NPOESS Preparatory Project mission, a joint effort between the NPOESS Integrated Program Office and NASA. The NPP mission will provide an early opportunity, beginning in late 2005, to test and evaluate VIIRS prior to the launch of the first operational NPOESS spacecraft, as well as test the ground-based data processing systems and demonstrate the utility of the improved imaging and radiometric data in short-term weather nowcasting and forecasting and in other oceanic and terrestrial applications, such as harmful alga blooms, volcanic ash, and wildfire detection. Of equal importance, NPP will ensure continuity of advanced imaging and radiometric data by "bridging" between the NASA Earth Observing System research missions (EOS-Terra and Aqua) early in this decade and the NPOESS operational missions that will begin late in the decade. The remaining VIIRS units will be flown on the operational NPOESS spacecraft.

In 1999, contracts were awarded to Ball Aerospace & Technologies Corporation of Boulder, Colo., for the development and fabrication of an Ozone Mapping and Profiler Suite instrument to improve the accuracy of Earth's ozone measurements and to ITT Industries, ITT Aerospace/Communications Division of Ft. Wayne, Ind., for the development and fabrication of a Cross-track Infrared Sounder (CrIS) to provide high spectral resolution measurements of the vertical distribution of temperature, moisture, and pressure in the atmosphere. Contracts were also awarded in 1999 to Lockheed Martin Missiles and Space of Sunnyvale, Calif., and TRW Space and Electronics Group of Redondo Beach, Calif., for preliminary system design and data processing demonstrations for NPOESS.

"With the award of the VIIRS contract, the NPOESS program is well along the path to creating a high performance, integrated polar satellite system that will cost less, be more responsive to user demands, and deliver more capability than those in use today," said John D. Cunningham, who is system program director of the NPOESS Integrated Program Office. An additional contract will be awarded in 2001 for development and fabrication of an advanced microwave imaging and sounding sensor for NPOESS. The NPOESS sensor suites will deliver higher resolution and more accurate atmospheric, oceanographic, terrestrial, and solar-geophysical data to support improved accuracy in short-term weather forecasts and warnings and severe storm warnings, as well as serve the data continuity requirements of the climate community for improved climate prediction and assessment and environmental monitoring.

The 1994 Presidential Decision Directive that established the NPOESS Integrated Program Office charged NOAA with overall responsibility for the converged system, as well as satellite operations and interactions with the civil and international user communities. The Department of Defense has the lead agency responsibility for major systems acquisitions, including launch support. NASA has primary responsibility for facilitating the development and incorporation of new cost-effective technologies into the converged system. Representatives from NOAA, DOD, and NASA participated in the NPOESS VIIRS source selection, which was held in Silver Spring, Maryland.

Northrop Grumman Corporation and TRW Inc. to Merge

LOS ANGELES and CLEVELAND, July 1, 2002 -- Northrop Grumman Corporation (NYSE:NOC) and TRW Inc. (NYSE:TRW) jointly announced that they have entered into a definitive merger agreement. The combination will position Northrop Grumman as the nation's second largest defense contractor with projected annual revenues of more than $26 billion and approximately 123,000 employees. Following the separation of TRW's automotive business and completion of the sale of TRW's Aeronautical Systems business, Northrop Grumman will be a Fortune 100 company.

Under the terms of the agreement, unanimously approved by the boards of directors of both companies, Northrop Grumman will acquire TRW for $60 per share in common stock in a transaction valued at approximately $7.8 billion, plus the assumption of TRW's net debt at the time of closing.

The exact exchange ratio will be determined by dividing $60 by the average of the reported closing sale prices per share of Northrop Grumman common stock on the New York Stock Exchange for the five consecutive trading days ending on and including the second trading day prior to the closing of the merger. The exchange ratio will not be less than 0.4348 or more than 0.5357 of a Northrop Grumman share.

After completion of the merger, Northrop Grumman plans to separate TRW's automotive business, either through a sale or a spin-off of the business to shareholders. TRW's previously announced agreement to sell its Aeronautical Systems business to Goodrich Corporation for $1.5 billion will remain unaffected by today's announcement.

Kent Kresa, chairman and chief executive officer of Northrop Grumman, said, "Today is a great day for Northrop Grumman and TRW. We're bringing together the superior technology and outstanding talent of two of our nation's premier defense companies, creating a powerful and highly competitive enterprise with excellent growth prospects. Today's acquisition adds the last critical node of space to our robust and well-diversified defense platform and systems capabilities that operate on the ground, at sea and in the air. We believe this transaction provides tremendous value to our shareholders, employees and customers.

"When we first proposed to acquire TRW, we stated that we were prepared to pay full and fair value for the company, subject to a comprehensive due diligence process. Our thorough due diligence made clear to us the strength and value of TRW's operations and the tremendous opportunities for the combined defense enterprise," said Kresa.

"The talents and creative energies of TRW's defense industry employees are among the company's greatest strengths and we look forward to welcoming them to the Northrop Grumman family. Following the completion of the transaction, we will seamlessly transition the defense businesses into the company as was done recently with Litton and Newport News," concluded Kresa.

Philip A. Odeen, chairman of TRW, said, "This is a real win for TRW shareholders. For the past several months, TRW's board has undertaken a comprehensive strategic review with the sole objective of enhancing shareholder value. This transaction achieves that objective. We have said from the start that this was all about shareholder value and this transaction delivers to our shareholders full value from their TRW investment. In addition to receiving a premium on their investment, TRW shareholders also have the opportunity to participate in the upside potential created by the combination of these two great businesses. Together, our companies will create a true industry powerhouse with an unparalleled portfolio of premier technologies, expertise and capabilities."

Northrop Grumman Confirms 2002 Guidance; Provides 2003 Guidance in addition to confirming 2002 economic earnings per share guidance of $6.60 to $7.10, Northrop Grumman said that with the acquisition of TRW, the company expects 2003 economic earnings to be in the range of $7.75 to $8.30 per share and GAAP earnings of $6.00 to $6.55 per share, with double-digit growth again expected in both economic and GAAP earnings in 2004. Prior to the B-2 related tax payment, the company expects cash from operations in 2003 to be approximately $1.25 billion, and to average well over $2 billion per year for the next several years thereafter. Including the effects of this transaction and the company's B-2 program tax payment, Northrop Grumman expects to have a debt to capitalization ratio at year-end 2003 near or below the low end of its 30 percent to 40 percent target range.

Following the close of the transaction, TRW's defense business, similar to the Litton and Newport News businesses, will be initially operated as a separate Northrop Grumman sector, reporting to the office of the chairman. Northrop Grumman will work to quickly integrate the operations of TRW's defense business operations. Northrop Grumman foresees little change in employment levels in the defense business as a result of this transaction.

The transaction is subject to the approval of shareholders of both companies and to review under the Hart-Scott-Rodino Act as well as other governmental and regulatory agencies in the U.S. and Europe. The companies expect to complete the transaction in the fourth quarter of 2002.

As a result of the definitive merger agreement, Northrop Grumman did not extend its exchange offer for all outstanding shares of common and preferred stock of TRW Inc., which expired at midnight EDT on Friday June 28, 2002, and will not accept any shares tendered. Northrop Grumman expects to amend its current Form S-4 registration statement shortly.

On July 1, 2002, Northrop Grumman Corporation and TRW Inc. announced that they had entered into a definitive merger agreement. The combination will position Northrop Grumman as the nation's second largest defense contractor with projected annual revenues of more than $26 billion and approximately 123,000 employees.

TRW Will Add New Space Capabilities

Northrop Grumman Circuit (July/August 2002)

On July 1, Northrop Grumman announced that it had signed a definitive agreement to acquire TRW—a transaction valued at $7.8 billion. This acquisition rounds out Northrop Grumman's well-diversified defense portfolio and systems capability and adds another critical node—space, increasing our space systems expertise.

TRW has industry-leading operations in spacecraft systems, systems integration, electronic communications systems, information technology and high-energy lasers. As TRW's automotive business does not fit with Northrop Grumman's defense strategy, it will be sold or spun off after the acquisition is completed. TRW's previously announced agreement to sell its Aeronautical Systems business to Goodrich Corporation for $1.5 billion will remain unaffected by this agreement.

"Assembling this impressive defense portfolio was no accident. It came out of our vision, conceived a decade ago, to transform Northrop Grumman into the nation's leading provider of systems needed for modern-day warfare," Kent Kresa, chairman and CEO, said.

TRW has grown, prospered and transformed from its beginnings in Cleveland, OH. The company was founded in 1901 and originally developed cap screws and other fasteners. By adapting its cap screw technology to create engine valves for the emerging auto industry, the company gained early competitive advantages in quality and cost management. Soon afterward, TRW's product line included the aircraft engine valves used in Allied fighter planes during World War I.

The company continued to grow its aircraft business and later entered the electronics, defense, space and information systems industries. The company changed its name from Thompson Products to Thompson Ramo Wooldridge (today's TRW) after a merger in 1958.

Among the capabilities TRW will bring to Northrop Grumman are the following:

- Great strength in communications from space to the land battlefield to local emergency command centers
- Missile defense, including a range of laser weapons, space-based warning systems and the battle management system for the mid-course defense system
- Intelligence capabilities ranging from space-based systems to extensive data management and analysis capability
- A major role with customers such as the Missile Defense Agency and the Army and other non-defense civil agencies

It is expected that the acquisition of TRW will close in the fourth quarter of this year, once the necessary regulatory approvals have been obtained.

NEWS RELEASES:

TRW Awarded $2.9 Billion NPOESS Contract

REDONDO BEACH, Calif., Aug. 23 /PRNewswire-FirstCall/ -- TRW (NYSE: TRW) was awarded a $2.9 billion contract to build the National Polar-orbiting Operational Environmental Satellite System (NPOESS), the nation's next-generation meteorological satellite system. The contract was awarded by the NPOESS Integrated Program Office (IPO), a joint effort of the Department of Commerce, Department of Defense and NASA. It follows a rigorous, three-year competitive preliminary design and risk reduction effort. TRW estimates that NPOESS could be worth in excess of $4 billion over the life of the program.

TRW, as prime contractor, will be responsible for overall system design and development, system engineering, system integration, acquisition of instruments and assembly and test of the spacecraft. Its teammate, Raytheon Company (NYSE: RTN), will provide command, control and communications, mission data processing and system engineering support.

"We are proud to be joining a partnership with the government to build and deliver a system that will significantly improve our nation's climate and weather forecasting ability," said Tim Hannemann, president and chief executive officer, TRW Space & Electronics. "By providing comprehensive global environmental information, NPOESS is a critical system that will touch the lives of everyone on the planet. Our team is committed to deliver an outstanding system, on cost, on schedule and with low risk."

"We're delighted to have the opportunity to work with TRW on this important mission," said Daniel P. Burnham, Raytheon's chairman and chief executive officer. "It underscores our breadth and depth in satellite remote sensing, weather and environmental data collection technologies for our commercial and military customers."

NPOESS merges the nation's current weather polar-orbiting satellite programs into a single, national program, providing increased capability at a reduced overall cost to the nation. The system will provide environmental remote-sensing capability for civil, military and scientific purposes, including timely and accurate data for long-range weather and climate forecasts.

TRW provides advanced-technology products and services for the aerospace, systems and automotive markets.

With headquarters in Lexington, Mass., Raytheon Company (NYSE: RTN) is a global technology leader in defense, government and commercial electronics, and business and special mission aircraft.

TRW Wins $119 Million Air Force Weather Systems Contract

RESTON, Va. and OMAHA, Neb., Aug. 29 /PRNewswire/ -- TRW Inc. (NYSE: TRW) has been awarded a systems engineering, management and sustainment services contract, potentially worth $119 million, from the Air Force Weather Agency, Offutt Air Force Base, Neb. The new contract will help the agency provide a more complete weather picture -- from earth to space. AFWA supplies weather services and products worldwide.

For the next five years, TRW will serve as prime contractor providing systems engineering, management and sustainment (SEMS) services to consolidate Air Force Weather system contracts to reduce the costs of maintaining individual weather systems. The contract also calls for TRW to modernize and enhance existing systems to enable AFWA to improve mission support.

"On today's modern battlefield, information dominance provides our nation's forces the winning edge. Continuous, complete, current and secure weather information is a critical component of the information needed by the warfighter to ensure victory," said Dr. Donald C. Winter, president and CEO of TRW Systems, the Reston-based TRW business serving as prime contractor.

Work on the program is expected to begin in September in Omaha, Neb.

The modernization effort also benefits DoD civilians and National Intelligence Community civilian agencies, by providing improved tropical cyclone direction and intensity tracking, analyses of high-level winds, and severe storm aircraft alerts.

"TRW will help the Air Force Weather Agency maintain its role as the operator's top choice for aerospace weather information," said Al Ronn, TRW's AFWA SEMS program manager in Omaha, Neb. "TRW has helped build and integrate vital weather systems used today. Our familiarity with these systems combined with our prime integration experience will provide the Air Force the knowledge and technology needed to 'anticipate and exploit the weather for battle.'"

Under related contracts in its growing weather business, TRW integrates high-resolution weather analyses, forecast models, and space weather applications into AFWA production systems and deploys regional weather forecast systems for worldwide support to battlefield theaters.

With headquarters in Omaha, Neb., AFWA runs the strategic center for weather for the Air Force and supplies all weather-related information to the Air Force, Army and many civilian agencies. AFWA derives information from satellites and other sources and analyzes it to provide predictions used by DoD, government agencies, and military units in the field.

TRW Inc. provides advanced technology products and services for aerospace, information systems and automotive markets worldwide. The company, which celebrated its 100th year of operation during 2001, had year-end 2001 sales of $16.4 billion.

APPENDIX

DMSP PIONEERS

The following is a list of the early members of the Block 5 Team.
From Briefing Log

NAME	DATE	NAME	DATE
Beser, Jacob	11/07/66	Bernstein, Alan	12/05/66
Finefrock, R. F.	11/07/66	Dyer, Edward F.	12/07/66
Parnell, W. S.	11/07/66	Barra, R. J.	12/07/66
Cortesi, R. S.	11/07/66	Deninson, A. L.	12/22/66
Harris, Bernard L.	11/08/66	Gregory, E. C.	01/09/67
Magness, Lee S.	11/08/66	Kulesza, Frank	03/27/67
Spangler, M. J.	11/08/66	Nix, L. A.	03/27/67
Kuhfuss, Mary	11/09/66	Geckle, W. A.	06/13/67
Foley, T. P.	11/09/66	Mohr, A. F.	06/16/67
Pugsey, Winfield B.	11/09/66	Eargle, J. R.	06/16/67
Hedges, Charles	11/09/66	Cote, A. C.	07/05/67
Woolfson, Martin G.	11/14/66	Volk, W. J.	07/10/67
Kiefer, Paul J.	11/17/66	Quigley, W. W.	07/31/67
McAfee, Naomi	11/17/66	Petrou, N. V.	08/01/67
Hegwood, Maurice	11/18/66	Kaisler, F. J.	08/10/67
Roberson, William C.	11/18/66	Elliott, R. W.	08/18/67
Ley, Gordon	11/18/66	Stebbins, W. J.	08/18/67
Barbiere, D.	11/18/66	Lieske, R. W.	09/05/67
Doeg, D. S.	11/18/66	Noll, R. E.	09/18/67
Thompson, James E.	11/18/66	Howard, C. E.	11/01/67
Steinbach, Frederick	11/21/66	Ditch, B. A.	11/03/67
Higby, Richard F.	11/21/66	Fleig, G. J.	11/06/67
Kline, Michael D.	11/29/66	Carrell, R. J.	12/12/67
Geist, James F.	11/29/66	Broden, R. G.	02/17/68
Donelan, E. J.	11/19/66	Kimball, A. W.	04/23/68
Pessin, Jacques H.	11/29/66	Winn, Bill	12/15/69
Sundry, John L.	11/30/66	Nichols, S.	07/??/69
Kirk, Jimmy	11/30/66		

The Block 5 Program has always been a closely knit organization of engineering, drafting, model shop, manufacturing and Field Engineering personnel. We worked hard and after significant events the company sponsored a party for the team. We were fortunate to have some "poets" in the organization. Several times they documented the events in verse and rhyme. While the verse was intended to be humorous it does contain an element of truth. As you can see here, I have saved some of their "outstanding" creations.

BLOCK 5 OF THE PAST
By Walter Hampe

It's the close of an era of 5 A-B-C
And Nostalgia runs rampant for you and for me
For the things which have happened over the years
Some funny, some good and some even with tears
They all can't be told and for saving time's sake .

We'll tell of the antics of good old Jake.
Now Jake Beser and a selected creative team
Consisting of the Westinghouse engineering cream
Produced the proposal which started it all
Although filled with wild statements, it was right on the ball.

Now Jake will spout off at the drop of a hat
About the program beginning and things like that
He tells of his good work and his profitable deals
On recorders, PMT's and shaft bearing seals.

But Jake is reluctant for some things to tout
About certain events which he brought about
Like "There's a spy" screamed Bernie when he happened to see
Jake with a red beret and a brand new goatee.

Where the red transit case went was a great mystery
As well as the charge number 103P.
Or like going off on his mysterious trips
His expense account covering fancy meals and sips.

Like intimidating subcontractors with his telephone shout
While making Jim Schoolden run wildly about.
And Parnell's complaining over his coffee cup
If you want to get me fired - Just keep this up.

And when he set down Bessie's security procedure
It confused one and all including Jake Beser
He said when ask if the parts on would stay
Don't worry we pull-test the welds every day.

Of the design big boner - it's a real bummer you know
We'll fix it I assure you - It'll just cost you some dough.

On his long love affair with Nick Chubb the SPO
While absorbing Nick's penchant for a wicked verbal blow
Like his favorite words "Damn, Jake that the grossest"

You Westinghouse management-you manage by osmosis.

But Jake responded his words were the kindness
It's hard to be humble when you are the finest
Now of Jake's colorful activities you have just a few
It is hoped in 5 years we'll have another review.

The launch of the first Block 5A was classified and none of the happenings during the prelaunch testing could be told. The poem Off to the Launch we go was composed by Walt, illustrated by our Technical Publications artist and presented to Col. Will Botzong at his retirement party.

Off to the Launch we go
By Walt Hampe

Hi Ho, Hi Ho, Hi Ho
It's off to the launch we go
With charts and books and very terse looks
And critical personnel in tow

Hi Ho, Hi Ho, Hi Ho
It's only a week to go
State your position Tom and Joe
It's now or never you know

Hi Ho, Hi Ho, Hi Ho
The countdown has begun
Let's have no division in command decision
For the Colonel has had his fun

During the test of the Flight 1 SAP many problems were uncovered in data review by Bill Quigley and Roger Lieske in the Systems Engineering Group. Because of the need for extra tests to resolve the problems, Bill Quigley got a reputation for asking for one more test.

ONE MORE TEST QUIGLEY
By Walter Hampe

Since '67 the Block 5 Engineers had given their best
in design, in production, and in test.
To create a sensor which would soon soar
and be mucho better than the RCA Block 4.

The concepts had been developed by many people you know,
to meet the tough requirement of the SAMSO SPO.
But like all good things, success didn't come quick
and at times the test data made Bill Quigley sick.

Over many moons, problems developed and some were not small
but all were eventually solved as I seem to recall.
And lo and behold after very much stress,
the SAP began to work and it was time for acceptance tests.

Time slipped by fast, and soon the pressure began
for delivery from Tom as well as good old Uncle Sam.
So the test team started shift work and a 7-day week
progress was made and in a short time. the schedule we did meet.

Now Bill would study the test data but then would exclaim
"Most of the data looks good, but one more test remains."
So back to the vacuum chamber the system went
and a lot more Westinghouse dollars were spent.

For days and days the test team labored hard with progress slow,
and Bill Quigley would say "Do this one more test before you go."
Finally after days in vacuum and overtime in excess,
Bill declared that today would be the final test!

A sigh of relief was heard from the blue room crew,
for APPRO had signed the DD250 and they knew tests were thru.
And they said fairwell as the SAP was placed in a crate,
but Quigley and Lieske were looking at data and engaged in debate.

They figured and they argued over the test data obtained.
soon Bill OK'd most all the data but one exception remained.
So our team looked on sadly and with fears of overtime galore.
as the SAP was placed back in test once more.

Fortunately for all. this one more test was quite absurd,
and the SAP was off to RCA to be integrated with the bird.
For the next year or so the tests were many and anomalies few.
as Bill Quigley sat back, reviewed all the data and laughed with the crew.

Finally in February of '71, the satellite was on the pad at VAFB:
awaiting for the command to launch from the Col. you see.
Seconds after the Thor had lifted off the pad with great speed
Bill Quigley jumped up and yelled "there's still one more test we need."

The OLS Engineering Test Model (ETM) was shipped to RCA for integration and tests (I&T) with the spacecraft to work out any remaining design problems on both sides of the sensor to spacecraft interface. The ETM had a long history of problems during design and test. All known problems had been solved prior to the shipment to RCA for I&T. After shipment we had a test team of Field Engineers located on site at RCA. This team was headed by Sal Romano, a systems engineer from Baltimore who had generated the ETM test requirements and had closely followed all (and personally performed many) test in the factory. When the ETM was shipped the Block 5 Program office sponsored a party for those that had participated on this program. Walt Hampe composed this poem for this occasion.

DER ETM IST GERSHIPPED

By Walter Hampe

Since '71 we have given our best
In design, production and also in test
To create a sensor which all could agree
Would be a damn sight better than our good 5C
The concept was developed by many you know
To meet the requirements of the SAMSO SPO
Like all good things it didn't come quick
At times the requirements made us quite sick
Over several moons, many problems we saw
With so many solutions, it is hard to recall
Like Paul K's struggle with the optical set
To cure the encoder and the blasted vignette
Or Bill, Sal and test team going on a spree
Of cussing and swearing at the sad STE
And summoning Ed and Larry with a terrific uproar
To come and fix the offending damn drawer
Or Roger searching test results for smooth data fine
And finding it missing for the umpty-umph time
Or Paul R and Rich trying to remain Van Horn's friends
While pushing to keep up with Harv's thousand R/N's
Or Tom's daily meetings to keep up with his team
Which lasted 90 minutes instead of 15
Or Jack's little talks with the technical SPO
Which ended in changes but without more dough
Or when SPO's, Schultz, and Runkle came out of their huddle
With multitudes of changes to add to the muddle
Or Traskowsky's bright smile as he sharpened the needle
But getting stuck instead when he tried it on Leedle
This epic could go on for many lines more
Telling of the individual struggles and good results galore
Like the girls who helped us in so many ways
By helping to brighten our many dark days
But as time slipped by, the pressure began
For delivery from Harold and Old Uncle Sam
So we started shift work and a 7-day week
So within a short time, Walt's schedules did meet
And 1o and behold after very much stress
The ETM began to work for the final test
When Marty studied the test data obtained
He OK'd most a1l but 3 exceptions remained
So with our team looking on with a tearful eye
The Phase I system which can never fly
Went aboard a truck on 3/18
Expedited by Bernie and the QA team
To RCA to integrate with the bird
To doubt it won't match is quite absurd
So here's a toast to the ETM and its mission success
And for the flight units following we're hoping the best

Spacecraft F-35 was the first launch of a Block 5D spacecraft carrying an OLS sensor. As was usual for first launches this spacecraft sat on the launch pad from July 1976 until September 1976 when it was finally launched. During this test period a number of problems were discovered and fixed. The so called "Christmas Tree" occurred when the spacecraft onboard computer crashed. THE STORY OF THE F-35 CHRISTMAS TREE recounts this event that occurred while testing on the launch pad.

THE STORY OF F35 CHRISTMAS TREE

By Jack Spangler & Jacob Beser

Hear ye. Hear ye, all you men in blue
The story which I will relate is reported to be true.
This tale began at the PTF during the month of July 76
After Gomberg had assured the Tiger Team that all S/C problems were fixed.
The spacecraft had been moved and the pad test anomalies were few
And everyone had forgotten the factory test agony, even Sal's lost screw.
The day was the 9th and the Sim Flight Test was one hour old.
Norm Huffmaster was at the helm and Mike Sisak was at the Console.
CPU1 had been loaded with all the ascent data It should need
CPU2 load was scheduled next and Norm told Mike to proceed.
All was going well until location 0067 had to work
Then all of a sudden the system went berserk.
In the MAGE van all the Indicator lights began to flash and blink
This caused Norm to yell "Christmas Tree" over the commo link.
Mike reacted to the situation as quick as a wink
But the computer had already commanded OLS to do its trick.
In the shelter, the weird and wonderful OLS responded as designed
Off came covers a other things happened that would boggle one's mind.
The situation developed so fast that Airman First Class Annie
Had to go home to change her panties.
The red flag report went out which caused the Colonel to fly in
And the waterfall schedule all over we had to begin.
Much sleep was lost as the days stretched long
But within 2 weeks Joe Pawlick was singing a song.
We are back on schedule now so let's have at it
And launch this bird into a perfect orbit.
So here we have gathered for food and booze
Thanking the Good Lord we weren't in Joe Pawlick's shoes.

Prelaunch parties were traditional for the DMSP launches. I composed The SAGA of F-35 and read it at the Flight 36 party which was held at VAFB

SAGA of F-36

By Jack Spangler

The game began in February of 1976
While F-36 was sill a skeleton of sticks.
The first play was a message to the SPO by TWX
Which said F-35 problems were fixed.
The SPO responded to this message in such a way
That on March 7, OLS-2 was at RCA.

Then all of a sudden F-35 problems reappeared one by one

And F-36 sat in the bay like a girl in the sun.
Except when it was used by the Test Team with drive
To troubleshoot problems that appeared in F-35.
Finally by July 3rd the F-35 problems were all cut and dried
And the long dormant OLS was finally tried.
Test proceeded but the schedule slipped a day or two
For F-35 was still on the pad and required the test crew.

The days slipped by one by one with no end in sight
As F-35 sat on the pad still with problems to flight.
By early September these problems we were beginning to hate
For they had made the F-36 schedule mighty late.
By mid September Gomberg announced with a laugh that only he can do
F-35 is now ready to go and the prelaunch party was held too.
Col. Schultz dressed in a new uniform of blue wearing ribbons galore
Went before the General with the message "F-35 is ready to soar".

The launch orders were given and with no problems to ponder
The launch crew sent that bird off into the wild blue yonder.
At lift off Norm gave a sigh of relief for now he could figure
He would have a full crew to test F-36 with vigor.
Alas! These thoughts were short lived for in about an hour
Lt. Healy announced that the solar array had no power.
From that moment on, we all knew of the trouble
But no one would admit that F-35 was space rubble.

The Tiger Teams were organized to evaluate all launch data quick
And the S/C designers had to answer questions until they were sick.
Theories of what happened were developed and on F-36 tested
As F-35 in a near perfect orbit in space rested.
Suddenly in October a CRS received a weak signal from space,
And there was joy in the SPO, RCA and all over the place
For F-35 had responded to a signal from the ground
And telemetry said that the old bird was reasonably well and sound.

Off to Omaha went Capt. Pittington and called the software cats out
Don't give up, we will save this turkey, they shout!
The days turned into weeks, the weeks into months, and F-35 was still sick
But this loyal crew worked while the Pentagon said "Get it fixed in '76".
By March of '77 Terry and his pals had the software needed
And F-35 stopped spinning for to commands it had heeded
In a few days the SPO and all their contractors were filled with joy
For F-35 was operational and the 4G and GWC had a new space toy.

Meanwhile back at the ranch, let us not become sick
When we learn of what was happening to F-36.
There had been Tenny, Vibe., Thermal Vac, O-tests and Acoustics too
And F-36 passed just as all spacecraft must do.
Then, from out of the woodwork came the Tigers on the run
With theories, conclusions and recommendations of tasks to be done.
Fix this! Fix that!, Change here!, Retest!, Retest
Were the words coming from these pests.

After all the shouting and roaring of the Tigers was through
The changes made were to hardware and software were few.

And now here we are all sit almost a year and a half from the day
That F-36 started integration and test in the bay.
Hoping that the launch which is about to take place
Will put this bird into the proper orbit in space
And within ten days of this time of joy
The 4G and GWC will have another space toy.

The Ode to the Wild Blue was composed by Walt and presented along with an illustrated memento to Lt. Col. Neale Elsby when he left the DMSP SPO for a new assignment. Neale was in Baltimore when he learned of his promotion to Lt. Col. That night he and his Air force buddies went partying at the local bars. The poem recounts a true story of the what happened when they returned to their hotel, The Colony 7.

Ode to the Wild Blue
By Walter Hampe

On a cold day in August '72,
After a rough OLS Program Review,
Three Air Force Officers went to slack their thurst--
But drank 'til they almost burst.

A Lieutenant Colonel with his martial model hair,
They packed out in an orange corvette without a care.
At high speed they went while they talked of his plans,
To design and build a helicopter with gold fans.

Finally at the Colony 7, it was 2 AM,
The Lt.Col. wanted to go for a swim.
The sign at the gate said too late, we're closed,
But the two Captains in blue to the occasion arose.

They pitched him head first up and over the fence,
Where he took off his clothes, to get them wet made no sense.
He dove into the water which was about 42,
When suddenly his body turned Air Force Blue.

Half drowned and half sober he was limply dragged out,
And got his clothes on without a pout.
To show everyone that he was still all right,
He went to his room, Kung Fuing everything in sight.

DEPARTMENT OF THE AIR FORCE
10TH WEATHER SQUADRON (MAC)
APO SAN FRANCISCO 96310

REPLY TO
ATTN OF: CC

SUBJECT: DMSP Support to Mayaguez Recovery

TO: SAMSO/YD

1. Reference AWS/DOSA ltr, dated 16 May 1975, same subject. The following information is submitted for your use.

2. The Nakhon Phanom Site 23 Defense Meteorological Satellite Program (DMSP) station played a very large and significant role in the weather support to the complex and sensitive Mayaguez recovery operation. The operation was conducted completely in a weather denied or void area (Cambodia, Gulf of Thailand and Koh Tang Island(approx 10 20'N, 103 10'E). The only surface observations were from Thailand, and later Navy ships on the 15th of May. As always, DMSP was the most powerful observing tool, but in this case doubly so for the above reasons - with DMSP data in many cases the only observations.

3. The 10th Weather Squadron Mission Control Forecasts during the period 131600Z to 151400Z were almost entirely built around DMSP observations. Of special note, the weather at Koh Tang Island during this period was much better than climatology, easily verifiable by DMSP. The impact was that no weather reconnaissance planes were required, based on a good 'weather' forecast versus the poor 'weather' forecast which would have resulted from climatology.

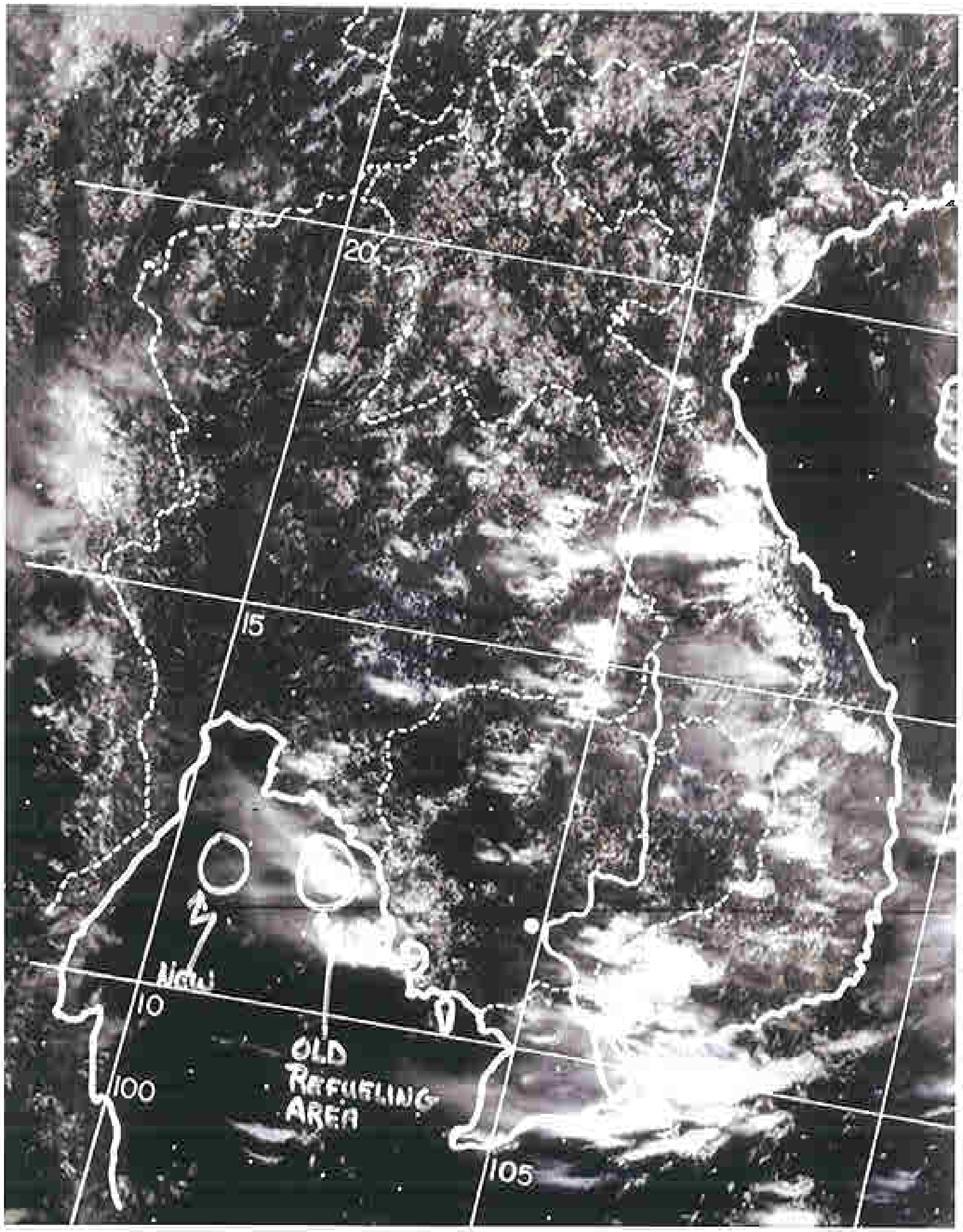
4. Other specific accomplishments were: the initial MCF was entirely based on DMSP products clearly delineating good and poor areas for operations primarily tactical air and refueling. One refueling area was moved on 14 May 1975 as a result of a DMSP (140447Z) based forecast. The original area was in the eastern portion of the Gulf of Thailand, and was moved to the west based on the data which showed considerable cloud cover in the eastern Gulf. In addition, decisions were made to recover some damaged helicopters on the Thai mainland rather than ditched in the sea. This was possible because there was no significant weather along the route as verified by DMSP (150147Z). In summary, the NKP tactical DMSP data provided outstanding support during this period, and when coupled with incountry resources resulted in unmatched support to this operation.

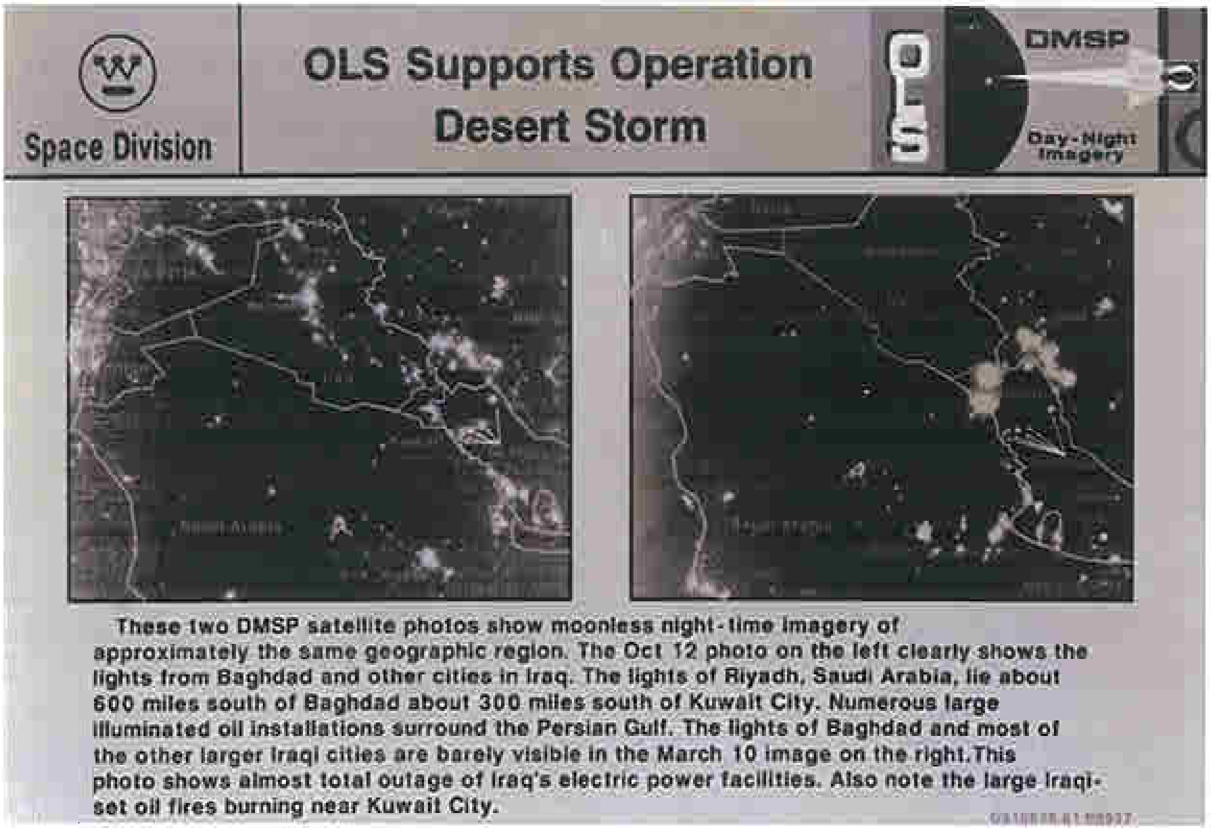
Keith R. Grimes
KEITH R. GRIMES, Lt Colonel, USAF
Commander

3 Atch
1. DMSP data

Cy to: AWS/DOSA w/o atch
AWS/OL-F w/o atch
1WW/DOK w/o atch

Mayaquez Recovery Operations





Operation Desert Storm was the first time the full range of the US space capabilities were effectively integrated into both strategic and tactical combat operations and were crucial to the outcome of the conflict. The Defense Meteorological Satellite Program (DMSP) was one of these systems.

DMSP data were crucial for a number of reasons. The weather data were used in weapons selection, loading and targeting process. Laser guided weapons are effective only when the weather is clear. By knowing the weather, the people who planned the air assaults knew which targets to attack with what kind of mutions. The results is well known.

In addition to weather concerns there were sandstorms and smoke from oil fires. DMSP data were also used effectively to track these conditions.

THE WORLD FROM SPACE
AS RECORDED BY THE OLS

A view of the world from space. It is a night photo with lights clearly >indicating the populated areas.

You can scroll East-West and North-South. Note that Canada's population is almost exclusively along the U.S. border. Moving east to Europe, there is a high population concentration along the Mediterranean Coast. It's easy to spot London, Paris, Stockholm and Vienna. Check out the development of Israel compared to the rest of the Arab countries. "Note the Nile River and the rest of the "Dark Continent." After the Nile, the lights don't come on again until >Johannesburg. Look at the Australian Outback and the Trans-Siberian Rail Route. Moving east, the most striking observation is the difference between North and South Korea. Note the density of Japan.

The DMSP history continues at Northrop Grumman.

January 2002
Defense Meteorological Satellite Program CRADA

The Space Vehicles Directorate and Northrop Grumman Corporation recently signed a $9.103 million Cooperative Research and Development Agreement (CRADA) to provide research and development capabilities for the Defense Meteorological Satellite Program's (DMSP) environmental sensors and to help assure continuity of mission support to the war fighter. The results of this research will address the needs of both the commercial sector and the Department of Defense (DoD) by advancing state-of-the-art satellite communications systems.

Recently the DMSP System Program Office assigned total system performance responsibility for the DMSP space sensors to Northrop Grumman. The directorate will provide continued technical support and services to the DMSP through this CRADA. The Air Force and Northrop Grumman expect to benefit from the relationship and the resulting shared data.

Air Force benefits include optimally sustaining the DMSP throughout its mission lifetime, compliance with DMSP developments with the Space Weather Transition Plan, and seamless transition of space weather support to the next-generation National Polar-orbiting Operational Environmental Satellite System. Northrop Grumman will benefit by allowing the combined technical staffs to develop and deploy advanced earth-monitoring space sensors in coordination with DoD needs.

(Mr. W. F. Denig, AFRL/VSXP, (937) 478-3484)

When Westinghouse (Northrop Grumman) acquired Aerojet, they inherited the SSMIS sensor along with its problems. The SSMIS sensor is a state of the art device and the contract was plagued with problems. This is one of the more recent problems of notarity.

Air Force grounds weather satellite launch again

SPACEFLIGHT NOW
Posted: September 22, 2002

For the second time this year a Titan 2 rocket has been destacked and hauled away from its California launch pad due to troubles with the U.S. military weather satellite it will eventually propel to space.

The two-stage booster, a converted Intercontinental Ballistic Missile, was originally assembled atop Space Launch Complex 4-West at Vandenberg Air Force in October 2000 for a planned liftoff in January 2001 carrying the Defense Meteorological Satellite Program (DMSP) F-16 spacecraft.

But problems with the satellite's guidance and propulsion systems, the rocket and scheduling conflicts have combined to keep the mission grounded.

This spring, officials decided to remove the Titan 2 from the pad after the DMSP's propulsion module was found to be contaminated by residual hydrazine fuel, forcing the system to be replaced. With the pad cleared, a different Titan 2 was stacked and ultimately the civilian NOAA-M weather satellite on June 24.

With the hopes to get DMSP F-16 in space on October 6, the Air Force put the Titan 2 back on the pad in July. But a new problem was recently uncovered with soldering joints inside a new instrument carried on this and future DMSP craft.

Faced with another extended delay to fix the weather sensor, the military opted to again destack the DMSP rocket earlier this month and place it in storage, clearing the pad for the launch of the Coriolis ocean-wind research satellite aboard a different Titan 2 booster on December 15.

Officials say DMSP F-16 should be fixed in time for a May 2003 blastoff.

This latest trouble began when a Special Sensor Microwave Imager/Sounder instrument, or SSMIS, was being tested for its launch aboard the DMSP F-17 satellite in 2004.

The new SSMIS, which debuts on F-16, combines into one instrument what previous DMSP craft need a couple sensors to do. It aligns temperature and water vapor readings within the same view of Earth to quicken the processing of weather data for war fighter forecasts.

After the F-17 failure was noted in the factory, other instruments were tested and similar problems were found. Investigations pointed to bad solder joints on small boards in the circuitry for the SSMIS instrument.

"When we had the failure in F-17 and we tested some of the other SSMIS's that we had available and did more specific testing on the (boards) themselves, we saw solder cracks in many of the units we physically inspected," said Col. Randy Odle, system program director for DMSP. "We did some thermal cycling on a couple of the boards on what we thought was the good solder joint and we saw cracking in the solder after a relative few thermal cycles."

Despite all of the problems in the inventory, the F-16 instrument has never experienced a problem. But in the end, officials said the lack of confidence that the sensor would operate for two to three years in space forced F-16 to be grounded so its SSMIS could be replaced with a repaired one.

"Because we saw these SSMIS failures in these other units, it cast significant doubt in the long-term mission capability of the F-16 SSMIS unit. If we had launched F-16 as-is and had SSMIS exhibited the same kind of failure mode we have seen in the F-17 unit and others when it got on orbit, there would be significant loss of SSMIS mission capability in the temperature and humidity profile, and these are key capabilities of this new SSMIS that we would like working properly when we launch it," Odle said.

"I think the decision the Air Force made here with regard to having to stand down to fix this problem was the right one," said Odle. "It's not the pleasant one, but it was the right one for the country and the best for the program."

The U.S. military uses two primary DMSP satellites in orbits around Earth's poles to collect the data that meteorologists need to generate forecasts for strategic and tactical planning. The spacecraft in the network today are getting old but still doing their job, officials said. They were launched in 1995 and 1999.

"To date, the DMSP constellation is healthy and is meeting all mission requirements. Our current technical assessment is that the DMSP constellation will continue to perform well and meet mission requirements through at least the next nine to 12 months."

The Air Force will maintain F-16 in a launch posture for the next few months just in case the constellation deteriorates and a new craft is needed immediately. The SSMIS hasn't been opened up for inspections and won't be replaced until February.

"If we had to launch it, we would accept the risk that the SSMIS on F-16 might have a failure on-orbit," Odle said.

It would take at least 90 days to call up the launch on an emergency basis.

Officials are still investigating how the solder problem occurred in the first place, whether it be poor workmanship and/or other factors.

The Air Force says the repairs to F-16 will cost about $4.6 million, pushing the total mission costs to $459 million, including the satellite and rocket.

Beating Swords Into Plowshares
Converting Military Intercontinental Ballistic Missiles to Peaceful Space Launchers
Rebuilt Titan 2 Launches Weather Satellite
Titan 2 launches DMSP F15

What was unusual about the launch of a weather satellite into polar orbit in December 1999?

The satellite, known as Defense Meteorological Satellite Program DMSP F15, was boosted into space aboard a U.S. Air Force Titan 2 rocket from Space Launch Complex-4 West at Vandenberg Air Force Base in California. Six minutes after blast off, an apogee kick motor attached to the satellite fired to place the craft in the proper orbit above Earth.

The gem in this story was the Titan 2 rocket, which once was an intercontinental ballistic missile (ICBM) stationed at McConnell Air Force Base in Kansas.

During the Cold War, America's fleet of Titan 2 ICBMs stood ready to rain nuclear destruction on the former Soviet Union. When the aging Titan 2 ICBM national defense system was replaced and deactivated by June 1987, the U.S. government decided to convert fourteen of the leftover missiles to launch U.S. government payloads to Earth orbit. The vintage Titan 2s decommissioned by the Air Force were remodeled in the 1990s by Lockheed Martin Astronautics to carry payloads into space.

Titan Rockets

The Titan family dates to October 1955, when the Air Force awarded Lockheed Martin (formerly the Martin Company) a contract to build an intercontinental ballistic missile (ICBM). Known as the Titan 1, it was the nation's first two-stage ICBM and first underground silo-based ICBM.

Later, more than 140 Titan 2 ICBMs were built as the vanguard of America's strategic deterrent force.

Deactivation of the Titan 2 ICBM system began in July 1982 and was completed in June 1987. The deactivated missiles are now in storage at Davis-Monthan AFB, Arizona.

The Air Force successfully launched the first Titan 2 space launch vehicle from Vandenberg AFB September 5, 1988.

All DMSP satellites are launched on Titan 2 boosters from Vandenberg. The most recent previous launch was April 4, 1997. That flight was the first DMSP launch on a Titan 2 booster. NOAA's own civilian weather satellites also are launched on Titan 2 rockets.

The December 1999 blast-off was the ninth for a converted Titan 2 and the second DMSP weather satellite launched by a Titan 2. All nine launched have been successful.

Earlier Space Flights

Titan 2s also flew in NASA's Gemini manned space program in the mid-1960s. NASA's Clementine spacecraft, which was launched aboard a Titan 2 in January 1994, discovered water on the moon in November 1996.

Titan 2 is a two-stage liquid-fuel booster able to lift approximately 4,200 lbs. into a polar low-Earth circular orbit.

From ICBM to Space Booster

Changing a Titan 2 ICBM into a space rocket required:

- Modifying the end of the second stage to hold a satellite,
- Manufacturing a 10-ft. diameter payload fairing, or cover, of variable lengths plus payload adapters,
- Refurbishing the Titan's liquid-fuel rocket engines,
- Upgrading the inertial guidance system,
- Developing command, destruct and telemetry systems,
- Modifying Vandenberg's Space Launch Complex-4 West for the launches, and
- Putting the payload on the rocket.

The DMSP Satellite

The DMSP system depends on two satellites operated in space by the National Oceanic and Atmospheric Administration (NOAA). Weather data sent down to Earth by DMSP satellites is used by the U.S. military for strategic and tactical forecasting over land, sea and air operations around the globe. In addition, the satellites are used by other parts of the government and by universities for detecting forest fires, monitoring volcanic activity, hurricane forecasting and helping long-term climate-change studies.

NOAA controls and operates the DMSP satellites in a cooperative program with the U.S. Air Force.

DMSP satellites circle the Earth at an altitude of about 500 miles in a near-polar, sun-synchronous orbit. Each scans an area 1,800 miles wide and covers the entire Earth in about 12 hours.

The main sensor on board a DMSP satellite is known as the Operational Linescan System. It observes clouds in both visible and infrared light.

A second important sensor is the so-called Special Sensor Microwave Imager. It provides all-weather capability for worldwide tactical operations and is particularly useful in typing and forecasting severe storm activity.

The spacecraft also carries a group of additional sensors that collect a broad range of meteorological and space environmental data.

Replacing Old Satellites

DMSP F15 replaces two older DMSPs with worn out systems. Five more DMSP satellites await launch in coming years.

At the time of the launch of DMSP F15, the U.S. Air Force had four DMSP satellites in operation. DMSP F15 replaced two of them. The two older satellites replaced, F12 and F14, each had tape recorder failures, although some other equipment aboard the satellites still was functioning.

DMSP F15 has more capability than the two replaced satellites combined. F12 and F14 use older reel-to-reel tape recorders. F15 has two solid-state recorders, which work something like RAM memory in a personal computer. The solid-state recorders are expected to have a longer operational life.

Weather Forecasting

Data from DSMP satellites helps identify, locate and determine the intensity of severe weather such as thunderstorms, hurricanes and typhoons. It also is used to form three-dimensional cloud analyses, which are the basis for computer forecast models. Additionally, space environmental data is used to assist in high frequency communications, over-the-horizon radar, and spacecraft drag and reentry tasks.

Ground Stations

Each DMSP satellite stores images of a geographic area as data on a recorder and then replays the data when over one of four ground stations located near Fairbanks, Alaska; New Boston, New Hampshire; Thule Air Base, Greenland; and Kaena Point, Hawaii.

From the four command stations on the ground, weather data is relayed to the Air Force Weather Agency at Offutt Air Force Base, Nebraska, to the U.S. Navy's Fleet Numerical Meteorological and Oceanographic Center at Monterey, California, and to the Air Force's 55th Space Weather Squadron at Falcon Air Force Base, Colorado. At those stations, the information is used to compile numerous worldwide weather and space environmental reports and forecasts.

The satellite also can transmit meteorological data in real-time directly to Air Force, Army, Navy and Marine Corps tactical ground stations around the world and to Navy ships worldwide.

On a Different Path

The December 1999 launch was unique for the DMSP system because the satellite was placed in an orbit different from usual. Its path through space 500 miles above Earth is designed to improve weather forecasting over global hotspots in which the U.S. military has an interest. For instance, the satellite passes above the Korean Peninsula and Kosovo at a time different from other satellites in space. That offers better nighttime weather monitoring in those areas.

DMSP F15 is first in a new generation of weather satellites built by Lockheed Martin Missiles & Space. They have a new spacecraft structure, two additional panels on the solar array for more power, an additional battery, larger computer memory, improved computer software and two solid-state recorders replacing older reel-to-reel tape recorders used in previous DMSPs.

Radar Calibration

DMSP F15 also carries an experimental payload called Radar Calibration (RADCAL) to collect and transmit C-band data to test C-band tracking radar performance at the 30th Space Wing at Vandenberg Air Force Base. It also transmits Doppler data for the Naval Research Laboratory's Coherent Electromagnetic Tomography (CERTO) experiment.

DMSP

The Defense Meteorological Satellite Program is managed at the Space and Missile Systems Center, Los Angeles Air Force Base, California Satellite command and control is provided by a joint-operational team at the U.S. Department of Commerce's National Oceanic and Atmospheric Administration, Suitland, Maryland. DMSP data also furnished to the civilian community through NOAA.

Long, surreal road for infamous satellite launch

BY JUSTIN RAY
SPACEFLIGHT NOW
Posted: October 12, 2003

It is a rocket launch like no other.

On the launch pad three times in the past three years, getting as close as 30 seconds from liftoff in early 2001, a $450 million military weather satellite mission could finally fly this week from California.

The Defense Meteorological Satellite Program F16 spacecraft is scheduled for blastoff Wednesday atop a refurbished Titan 2 ICBM missile from Vandenberg Air Force Base. The daily 10-minute launch window extends from 9:17 to 9:27 a.m. local time (1617-1627 GMT; 12:17-12:27 p.m. EDT).

The Lockheed Martin-built spacecraft will be placed into a 458-nautical mile orbit around Earth's poles to track global weather conditions for the U.S. military.

The first shot at launching the satellite occurred on Bill Clinton's last day as president of the United States. But an epic saga has played out in the following 33 months as the mission encountered a nearly unbelievable chain of postponement after postponement. Technicians have fixed numerous problems that, if left undiscovered, could have doomed the mission.

"Clearly nobody wanted to have issues that we couldn't fix on the ground and launch a satellite that may not have met its mission need," Col. Randy Odle, DMSP system program director at Los Angeles Air Force Base, said in a recent interview. "We had to deal with those kinds of issues a number of times. Then we had to deal with issues of how do we compete with other launches going on and how do you compete with the Range priority. It has been frustrating in some ways but it's been exciting."

The satellite has gone to the launch pad three times in its life, the first in December 2000 for a planned liftoff in January 2001. After resolving a handful of minor hardware issues, launch was set for January 20.

The DMSP satellite failed to make it off the ground that day when the countdown was halted at T-minus 3 minutes due to a ground support equipment glitch. Liftoff was rescheduled for the following morning.

The second countdown halted at T-minus 28 seconds when computers detected one of the rocket's fuel valves had not opened as planned. In the end, the valve worked just fine but a sluggish indicator switch didn't register the opening fast enough for the computers' liking.

Faced with just a 10-minute window to launch the Titan 2, officials tried to reset liftoff for the end of the period but simply ran out of time.

That afternoon, as workers were preparing to roll the protective mobile service tower back around the Titan 2, faint traces of hydrazine rocket fuel were detected in the air at the Space Launch Complex-4 West launch pad. The time needed to clean up the minor leak prompted officials to cancel plans to launch the next morning.

But later that night, ground controllers watched as the DMSP's Inertial Measurement Unit -- the craft's navigation brain -- began acting erratically. First, the gyroscopes within the IMU suddenly dropped out of flight mode. That incident was followed 20 minutes later by the AC and DC power supplies switching from primary to backup systems on their own.

"If those anomalies occurred during the ascent phase of the launch, the likelihood is we would have lost the satellite and the mission," Odle said at the time.

Without the IMU working properly, the spacecraft would have been unable to navigate itself during the climb to orbit. Most troublesome would have been the portion of launch when a kick motor attached the satellite fires to propel the craft the rest of the way to space after separating from the Titan 2 booster while on a sub-orbital trajectory.

Without the IMU functioning up to par, the satellite wouldn't have been able to point itself correctly, likely resulting in the craft failing to reach orbit and instead reentering the atmosphere.

Over the next month, the satellite's hydrazine thruster fuel was drained and the craft was detached from the Titan 2. After being hauled off the launch pad and returned to the processing building at Vandenberg, technicians determined that a cable on the satellite had broken due to of poor workmanship during assembly, causing the IMU trouble.

Rescheduled for launch in November 2001, another postponement was ordered to replace leaky engine turbo pump seals on the Titan 2's first stage. Officials said the rocket's extended wait on the pad -- it was assembled on the seaside complex in October 2000 -- caused the seals to leak.

The satellite headed back to the launch pad at the end of 2001, and the Air Force targeted February 1, 2002 to get the mission airborne. But in mid-January as workers prepared to re-load the hydrazine fuel into the satellite at the launch pad, one of the craft's thrusters failed a vacuum leak check.

The satellite features four of these thrusters, each delivering 100 pounds of thrust. They are crucial during the launch, providing the boost to separate from the Titan 2 rocket and then to keep the satellite on course when its kick motor is firing to achieve orbit.

"These are very critical to us in our ascent phase and clearly if we had a thruster malfunction that would be a serious problem for us. Obviously when we convinced ourselves that Thruster Four was not working properly we had to do something to fix that before we launched," Odle said in an interview at the time.

The satellite was removed from the launch pad a second time and transported back to its hangar. The craft's propulsion system was replaced after engineers discovered that carbazic acid residue, a by-product of hydrazine and air interaction, had contaminated the satellite's thrusters.

"Apparently, air was introduced into the thrusters/propulsion system during testing and interacted with residual hydrazine remaining from the hydrazine defueling accomplished after the January '01 launch abort," Odle said.

"The contamination found in the two thrusters also implicated the remaining two thrusters and the entire propulsion system. As such, we decided to replace the hydrazine-contaminated F16 propulsion system with one from another DMSP spacecraft."

The two-stage Titan 2 was also disassembled from the launch pad during this postponement, freeing up SLC-4W so another rocket could lift off carrying a civilian weather satellite for NASA and NOAA. That launch successfully occurred on June 24, 2002.

The DMSP's rocket was restacked on the pad in July to support launch on October 6, 2002. But concerns were raised with soldering joints in the circuitry for one of the satellite's weather instruments -- the Special Sensor Microwave Imager/Sounder (SSMIS).

Bad solder joints were found on the instrument for DMSP F17 and others in the factory. However, the instrument installed on the DMSP F16 never experienced a problem. In the end, officials said the lack of confidence that the sensor would operate for two-to-three years in space forced F16 to be grounded so its SSMIS could be replaced with a repaired one.

Faced with another extended delay to fix the instrument, the Air Force decided to again destack the Titan 2 rocket to clear the pad for the Coriolis ocean-wind research satellite launch. Coriolis successfully flew in January 2003.

The DMSP satellite returned to the pad in August 2003 for a mid-September liftoff. A summer launch attempt was passed up while engineers reviewed a possible concern with a gyroscope on the Titan 2. That was put to rest, but it bumped the DMSP mission until after the launch of a Titan 4 rocket from Cape Canaveral, Florida.

With a few weeks of separation needed between Titan rocket launches, and troubles that delayed the Titan 4 liftoff from mid-August into September, DMSP was re-targeted for liftoff in October.

Now, DMSP's day to fly is finally near.

"I am cautiously optimistic, but clearly as we approach launch again it is hard not to be excited about this and clearly our team is anxious to see a good mission, a good launch, a good early-orbit checkout," Odle said in an interview last week. "We are excited to be at this point in the launch flow."

But given the history of this mission, one can't help but wonder if another problem could arise.

"You get a little bit paranoid when you have done this a couple times already," Odle said.

Nonetheless, deploying a healthy satellite into space to serve U.S. military forces around the world will help erase the 33 months of frustration.

"Fate sometimes works in interesting ways. Because of all the issues that had to deal with the last two-and-a-half, three years, we now have F16 in probably best condition it ever has been in,"Odle said.

"Clearly mission success has been the foremost in everybody's mind...We have never veered from that mission success focus and we expect to see that pay off (Wednesday)."

U.S. weather satellite finally escapes grasp of hard luck

BY JUSTIN RAY
SPACEFLIGHT NOW
Posted: October 14, 2003

Leaving behind three difficult years of delays and disappointments, a seemingly jinxed U.S. military weather satellite finally enjoyed a reversal of fortune Saturday as it successfully soared into space.
Bolted atop the final Titan 2 space rocket to ever fly, the Defense Meteorological Satellite Program F16 spacecraft began its ride into orbit around Earth's poles at 9:17 a.m. local time (1617 GMT; 12:17 p.m. EDT).

Foggy conditions cleared just in time to permit a clear view of the liftoff from Space Launch Complex-4 West at Vandenberg Air Force Base, California.

Six-and-a-half minutes later, the satellite separated from the Titan 2's second stage while cruising on a sub-orbital trajectory. A solid-propellant kick motor attached to the satellite ignited to propel the craft into a stable orbit. The satellite's hydrazine-fueled thrusters then fired to circularize the altitude about 458 nautical miles above the planet.

The safe and successful ascent gave satellite managers a happy ending to the nightmarish saga that played out for 33 months as the $450 million mission was postponed again and again by technical gremlins.
"It's just a wonderful feeling and I really get closure to the last 33 months of trying to get F16 into the sky," Col. Randy Odle, the DMSP system program director, said in an interview a few hours after the liftoff.

"The whole ascent phase of the mission went extremely well. We have been checking out the spacecraft ever since the launch and all of the spacecraft checkout is going nominally. It has just been a very positive day for the entire launch and satellite team."

The mission was just 28 seconds away from blastoff in January 2001 before the being grounded three years by a chain of rocket and satellite problems. Saturday's countdown was the fifth in the mission's history.

"It was a beautiful launch today. The Titan 2 booster performed superbly. It is just great to see the F16 satellite rocket into space," Odle said. "The last Titan 2 surely went out in fine style."

The DMSP F16 craft, with its complement of eight instruments, will track clouds, storm systems and hurricanes around the world for weather forecasting, plus monitor ice and snow coverage, pollution and fires.

The U.S. military has a constellation of two primary DMSP satellites and older backups working in space, giving meteorologists the information needed to generate forecasts that commanders and troops rely upon in strategic and tactical planning.

"DMSP is in its fourth decade of service and continues to be an invaluable resource for successfully planning, executing and protecting military operations on land, at sea and in the air," said Odle.

In a time of battle, the weather data from DMSP satellites helps the military decide the type of weapons and method of delivering them during conflicts anywhere on the planet.

"In Afghanistan and even some of the other conflicts in the past, I think what we have seen is the weather support to the both operations planning and operation execution is very, very key," Odle said.

"We have gotten a lot of good comments from the leadership that without the weather data that DMSP provides, and in fairness the weather data provided by all of the weather satellite capabilities of the U.S. and our allies, just really makes a difference in deciding when to conduct an operation, whether to really conduct that operation and what kind of weaponry is best suited for that operation given the weather that we think we are going to encounter."

The Titan 2 rocket lifts off with DMSP F16 on Saturday. Photo: Pat Corkery/Lockheed Martin

It will take about 30 days to check out the DMSP F16 craft before it enters service.

"That is really going to be proof in the pudding...Launch is only part of it -- it is a major part of it, but it's only the first stage of our mission success efforts," Odle said.

"Once operational F16 will deliver unparalleled global weather and space environmental information in support of users worldwide. F16 will be the best DMSP satellite ever launched," he said.

The Lockheed Martin-built satellite is the first to carry a larger, more sophisticated package of sensors and instruments known as the Block 5D-3 upgrade. Four instruments are new, two are modified from previous spacecraft and two remain unchanged.

"We believe (the new sensors) are going to provide a lot more capabilities once calibrated. Their calibration effort will go for about 18 months beyond the launch date to fully calibrate these new science and information sensors. We believe those will help improve our models and certainly help improve forecasting and the weather capability support to the warfighters and other users,"Odle said.

The new satellite will replace DMSP F15, launched in December 1999, as the lead craft in the constellation's "mid-morning orbit."

Each satellite crosses any point on the Earth up to two times a day and has an orbital period of about 101 minutes. The constellation provides a nearly complete global snapshot every six hours.

"The Air Force Weather Agency is the user that takes information from our satellite, puts the products together and ships that out to other users worldwide. Another direct user of our information is the Navy," Odle explained.

In addition, there are so-called "tactical terminals" deployed with military forces that allow leaders to receive weather data directly from the satellites as they pass overhead.

"The terminals in theater allow for direct downlink of weather data without any delays," Odle said.

The next DMSP satellite is slated to fly in April 2005 aboard a Boeing Delta 4 rocket from Space Launch Complex-6 at Vandenberg. The F18 spacecraft is scheduled for October 2007 aboard Lockheed Martin's Atlas 5 rocket from Vandenberg's SLC-3E. Two more DMSP's will follow through 2011.

Saturday's flight was the final time a Titan 2 rocket will ever fly. Titan 2 is a decades-long program that began as a missile in the United States' arsenal against the Soviet Union, launched NASA's Gemini astronauts in the mid-1960s and in recent years carried smaller satellites into space.

More than 140 Titan 2 Intercontinental Ballistic Missiles were built during the Cold War as part of the United States' nuclear deterrent force. When the military deactivated the Titan 2 fleet in the 1980s, Lockheed Martin converted 14 missiles from nuclear-tipped weapons into peaceful space vehicles. The first refurbished space booster lifted off in September 1988.

The DMSP F16 mission used the 13th of the 14 refurbished Titan 2 ICBMs. That particular rocket was stationed on alert in a silo at McConnell Air Force Base in Kansas from 1967 to 1986.

The Air Force had looked to find customers for the 14th and final converted vehicle, including the Missile Defense Agency possibly using it as a target for intercept testing, but no takers were found. With the Titan program coming to an end, time ran out for the last rocket to be used, officials said. The booster could be headed for the U.S. Air Force Museum at Wright Patterson Air Force Base in Ohio.

"They're our focal point for disposal of an Air Force asset like this," said Col. John Insprucker, the Titan program manager. "Our hope is as they're building their new space and missile exhibit hall maybe they'll have room in the hall and in their hearts for a Titan 2."

If the Air Force museum gives approval, Smithsonian also is possibility.

"We stand ready if there's an authorized agency to help us move it out of Vandenberg."

In addition to the 13 converted ICBMs that were launched between 1988 and Saturday, all successfully, two unmanned and 10 manned Gemini missions flew atop Titan 2 boosters from Florida's Cape Canaveral between 1964 and 1966.

Flight data file
Vehicle: Titan 2 (G-9)
Payload: DMSP 5D-3-F16
Launch date: Oct. 18, 2003
Launch window: 1617-1627
GMT (12:17-12:27 p.m. EDT)
Launch site: SLC-4W,
Vandenberg AFB, California
Satellite broadcast: none

Daily News Report

SATOPS Morning Report:
Monday, October 27, 2003

Day 300

DMSP

DMSP F-16 Launch: Systems checkout continue. An activation of the SSMIS sensor on Friday, October 24 was not initially nominal, but after subsequent reconfigurations, the initial data has been evaluated and deemed acceptable. Analysis continues to determined the root cause of the observed anomaly.

All non-launch DMSP operations were nominal over the past 3 days.

WRITTEN STATEMENT
BY
GREGORY W. WITHEE
ASSISTANT ADMINISTRATOR FOR SATELLITE AND INFORMATION SERVICES
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)
U.S. DEPARTMENT OF COMMERCE
ON NOAA's SATELLITES, DATA AND INFORMATION SERVICES
BEFORE
THE SUBCOMMITTEE ON ENVIRONMENT, TECHNOLOGY AND STANDARDS
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES
JULY 15, 2003

Thank you, Mr. Chairman and Members of the Committee, for the opportunity to testify before you regarding National Oceanic and Atmospheric Administration's (NOAA) satellite, data and information services. Vice Admiral Conrad C. Lautenbacher is unable to attend this hearing today due to prior commitments. I am Gregory Withee, Assistant Administrator for NOAA's Satellite and Information Services and am responsible for end-to-end management of NOAA's satellite, data and information programs.

NOAA's satellite program is well on its way to addressing the exciting challenge of incorporating new technologies to improve the capabilities of our operational satellite systems to better serve the American people. My testimony today will review the steps we are taking and the lessons learned over the past 43 years as the Nation's operational civil space agency. It will lay out our plans for satellite data continuity as we move to the first National Polar-orbiting Operational Environmental Satellite System (NPOESS) spacecraft, the follow-on to the NOAA Polar-orbiting Operational Environmental Satellite (POES). The first NPOESS satellite (C-1) will be available for launch in 2009 and will continue our polar satellite data series, as well as provide important continuity for select National Aeronautics and Space Administration (NASA) research missions and climate activities. I will also address our plans for the next series of Geostationary Operational Environmental Satellites (GOES) - GOES-R - with a planned launch date of 2012.

While these dates seem very far in the future, our experience developing, launching and operating environmental satellites dictates that early planning, accompanied by rigorous risk-reduction activities, is essential. Equally important is the thorough preparation of the end-user to accept, use and benefit from the full economic and scientific value of these data streams, and the establishment of a comprehensive scientific data stewardship program that includes long-term access and archive infrastructure.

This Subcommittee has been a strong advocate of our programs, and we look forward to continuing the dialogue to keep you informed of our progress.

NOAA's Satellite, Data and Information Program

Since the 1960s, when the United States launched its first civil polar-orbiting weather satellite (1960) and its first civil geostationary weather satellite (1966), the importance of data from these satellite systems has grown far beyond any planning assumptions made during their conception in the 1950's. Today, NOAA's satellites support all of NOAA's critical missions; numerous civil and military activities within Federal, state and local government agencies; academic endeavors; the private sector activities; the public; and international communities. NOAA's satellites are critical for all sectors of the U.S. economy, and are now considered environmental versus just weather satellites.

NOAA's mandate is to provide to its customers and users - without interruption - satellite data from its geostationary and polar-orbiting systems. As we move to the next generation of satellites, our operational mission requires that GOES-R and NPOESS are available to ensure continuous global satellite coverage essential to ensure the health and safety of our citizens. Additionally, these satellites provide data critical to unlocking the secrets of nature which are fundamental to our ability to reduce the uncertainties in important environmentally related decisions associated with long-term forecasts and global climate change.

NOAA's policy implements this mandate through a carefully planned and balanced requirements-based acquisition strategy which is detailed in the annual President's Budget Request. These budget requests include the annual funding required to enable NOAA to manage the technology and schedule risk inherent in these challenging satellite programs.

Requirements-based Mission Planning

NOAA uses a formal satellite requirements management process to identify, collect and assess validated environmental satellite observation requirements and allocate these requirements to specific observational systems. These requirements include satellite-based observations of all regions of the Earth's atmosphere; the Earth's oceans, coasts, and inland waters; observations of the Earth's land masses, including the mapping of high-resolution geospatial characteristics; and observations of the sun and near-Earth space environment.

This process provides important input into budget, planning, and management systems, and allows tracking of requirements from agency missions through to system allocations. As such, this process and its requirements documents represent the balance achieved among user needs, system technical capabilities and program affordability constraints. The credibility of the requirements process lies in the ability of this planning document to fulfill user needs within cost and schedule. This process has been used to develop the instrument and sensor suite on the GOES-R and NPOESS satellites.

The GOES-R Program Requirements Document (PRD) represents twelve agencies/groups needs from the U.S. civil, U.S. military, European and climate communities. The specific segment level documents to address all specifications for the end-to-end GOES-R system will be generated from the PRD.

For NPOESS, the Department of Defense (DoD) requirements process was used by the partner agencies (NOAA, DoD, and NASA) to develop an Integrated Operational Requirements Document (IORD). All three agencies worked with their user and customers throughout the Federal, state and local governments, academia, and industry to develop inputs into the mission and sensor performance requirements. The original IORD was approved by all agencies in 1996 and updated in December 2001. All sensors are traceable to specific requirement for one or all of the partner agencies. In many cases, a single sensor is required to meet different but equally important requirements of all three agencies and their customers and users.

Scientific Data Stewardship of NOAA's Archives

The concept of end-to-end management starts with the requirements process and ends with the access and archive of these data. NOAA continues to keep its data access and archive facilities at its NOAA National Data Center current with the latest technology to facilitate user access to its archived data.

NOAA Satellites and Information FY2004 President's Budget Request

All aspects of the $837.5 million in the FY2004 President's Budget Request have been carefully developed to ensure continuation of our existing operational programs, allow seamless transition to future satellite and data management activities, and satellite data continuity. Our partners - NASA and DoD - have worked with us to help manage the risk, schedule and funding estimates required to support the activities necessary to develop and launch the satellites and build the ground systems needed to maintain data continuity. The FY 2004 budget request will allow us to continue essential activities in support of GOES, POES, NPOESS, critical support for command and control of the spacecraft, product processing and distribution, and data management including access and archive functions.

NOAA Geostationary Program

The FY2004 President's Budget Request includes $277.55 million NOAA's GOES program. Of that amount, $0.6 million to support GOES I-M activities; $172.23 million to continue development of GOES N series satellites and ground systems; and $104.7 million to support GOES-R preliminary design and risk reduction activities.

NOAA is responsible for the end-to-end aspects of the GOES program. NOAA's constellation of two operational GOES satellites and one on-orbit spare now provide continuous coverage of the Western Hemisphere, seeing as far east as the western tip of Africa and as far west as the eastern tip of New Guinea. These geostationary sentinels provide critical data to weather forecasters, and detect and track severe weather, such as tornados, hurricanes, flash floods, blizzards and other hazards (to include volcanic ash plumes and wildland fires). In addition, GOES data collection system (GOES DCS) platforms provide communication data relay capabilities for scientific surface platforms such as automated observing stations, ocean buoys, stream gauges, tide gauges, and rain gauges. The system relays environmental information such as river flooding, snow melt, ocean temperature, and wind measurements to forecasters and emergency managers. GOES also monitors space weather events such as radiation and geomagnetic storms though the Space Environment Monitoring sensors.

NOAA has a requirement to maintain two operational GOES satellites, one at 75 degrees West longitude (GOES-East) and another at 135 degrees West longitude (GOES-West). In order to ensure that a two GOES constellation is continuously available, an on-orbit stored spare is required. NOAA launches a replacement satellite once the on-orbit spare is placed into operation. NOAA also requires that a satellite be ready for launch within a year of the previous satellite launch to back-up a launch failure. The placement of the operational satellites ensures continuous satellite coverage of U.S. interests on the East Coast, its territories in the Caribbean Basin and continental U.S., and West Coast, Hawaii, and U.S. territories in the Pacific.

This constellation is based on over 40 years of experience and our understanding of satellite and launch performance and incorporates the lessons learned from past future development.

First, launch of the satellite is the most vulnerable part of the entire mission from production to operational use. NOAA maintains an on-orbit spare, so it can recover quickly from a launch failure. This approach allows NOAA to replan another launch campaign, thus avoiding an extended outage in our on-orbit two operational satellite constellation. This was not possible when GOES failed on launch in 1986, resulting in one-satellite geostationary coverage for many years.

Second, having an on-orbit spare allows rapid replacement on failure of an operational satellite and ensures "no loss" of coverage or data for users in the event of a failure of one of the GOES operational satellites. By activation of the on-orbit spare, NOAA can restore full instrument operations and data within 7 days of failure of the previous satellite, and provide continuous data during the approximately 30-45 days it takes to move the spacecraft from the storage location to the operational location, as either GOES-East or GOES-West. Key users - NOAA's National Weather Service, Department of Defense, Federal Emergency Management Agency/Department of Homeland Security, state and local emergency managers, Federal Aviation Administration - demand uninterrupted access to satellite data to support their mission-critical activities.

Third, NOAA can perform systematic on-orbit post-launch testing of the spacecraft and instruments to ensure that instruments are performing according to specifications and will meet customer and user requirements. This on-orbit testing is a more complete evaluation of performance than is achievable on the ground. The approach of systematic on-orbit testing prior to putting a satellite into on-orbit storage also allows a more thorough investigation of, and if necessary, appropriate corrective action of anomalies without the pressures of meeting an operations schedule. A prime example of NOAA's recovering of potentially failed assets was GOES-10 and its failed solar-array drive in the forward direction. Creative engineering solutions allowed GOES-10 to become our operational West satellite in July 1998 which continues to the present.

Finally, having an on-orbit space can avoid launch pad conflicts. Due to limited launch facilities and NOAA's use of commercial launch services, if NOAA were to experience a failure during launch, it would take 12-18 months for the earliest possible launch of a replacement satellite because of existing commercial launch pad schedules. Commercial launch schedules maintain a rolling firm launch manifest of 12-18 months into the future. By Congressional directive, commercial launch services for NOAA programs require a rigorous process before NOAA could "bump" another commercial customer off the manifest. NOAA's launch policy avoids having to address this situation. Only under a multiple failure scenario would NOAA ever consider bumping another customer.

The GOES I-M Experience

In 1983, a decision was made to competitively procure follow-on satellites (GOES I-M) in the GOES program. Incremental changes to requirements were deemed achievable, with the only major advancement being a new requirement for full-time atmospheric sounding to monitor evolving temperature and moisture structure of the atmosphere to meet validated NOAA's National Weather Service requirements. This new requirement drove a design change in the basic spacecraft platform requiring full time Earth pointing versus the previous spin stabilized platform design. The satellite contract called for a launch availability in 1989. This need date was originally anticipated to protect against a GOES-G or GOES-H launch failure.

The new technology had no risk reduction program associated with it on the basis that instruments of this type had been flown in polar orbit, making the transition to geostationary orbit reasonably straightforward. It also assumed that the body stabilized technology had been proven sufficiently on geostationary commercial communication satellites.

The instrument and spacecraft development were found to be much more technically complex than originally thought, once the design was finalized. Changes in thermal characteristics between the polar and the geostationary orbit were not fully understood, and the original design for the instruments was found, in tests, not to work. On the spacecraft, stabilization for meteorological instruments was far more challenging than for a commercial communications platform. These problems led to almost five additional years of design effort and a billion dollar overrun.

Since GOES I-M Series had no end-to-end system architecture, no risk reduction was planned for algorithm development and data assimilation into numerical models. Therefore, the forecasters had no advance data, prior to launch, with which to learn and train and NOAA's National Weather Service required the better part of a year to make the image data operational, and almost four years to make the sounder data operational in forecast offices.

With the failure of one on-orbit GOES and a failure in 1986, by 1989 (the intended launch date of GOES-I), only one GOES satellite separated the United States from being completely unable to provide high temporal resolution monitoring of hurricanes at an early stage, monitor severe weather wherever it occurred, and miss important sounding information for short-term weather forecasts and warnings. This situation continued until GOES-I was launched in 1994.

GOES-R Planning

In response to validated user requirements for improved geostationary spatial and temporal observations, NOAA has started planning activities for the GOES-R series which is anticipated to launch its first satellite by 2012. History and experience have shown that it takes 10 years to develop a new satellite series. NOAA and our partner NASA have learned that environmental sensors for geostationary orbit are difficult to develop and build, and need the full 10 years for development, even with the excellent research provided through NASA or DoD. The GOES I-M and GOES-N series instrument technologies were first developed in the 1970's/80's. While they have served the Nation well, our customers' and users' validated requirements for data are beyond the capability that these heritage instruments can provide.

NOAA has incorporated the experiences of GOES I-M into GOES-R planning with the inclusion of rigorous and comprehensive concept, design, and risk reduction phases which includes an end-to-end system with its associated product generation, distribution, and archive and access. GOES-R is scheduled for readiness to back up the development of the last GOES-N series launch in 2012.

GOES-R will, for the first time, offer further benefits for other observations such as coastal and lightning data, provide improvements in spectral coverage (number of instrument channels), temporal coverage (how fast the satellite scans the Earth), spatial resolution (how sharp the images are horizontally for images and vertically for temperature and moisture profiles), and radiometric accuracy (how true are the temperatures measured). These improvements translate to product improvements such as 3-hour temperature forecasts (25% accuracy improvement) and Atmospheric Instability forecasts (90% improvement in 2-hour ahead Convective Weather watch area) which in turn are important to utility, transportation, agriculture, recreation, and other industries, and are vital to protecting lives and property in the event of severe weather. Preliminary estimates place the incremental benefits of the improvements from the GOES-R series of satellites at more than $4 billion over the life of the program. These benefits are in addition to the baseline benefits that the current GOES satellites provide.

In order to ensure a smooth transition from the GOES-N to the GOES-R series, NOAA needs to have all phases of a sound acquisition development in place: Phase A (Concept Definition); Phase B (Design and Risk Reduction); Phase C/D (System Production/Implementation). In the case of GOES I-M, the Phases A and B efforts were omitted. The result of skipping these key functions resulted in a 5-year slip in the program with significant cost overruns.

To address alternative approaches to end-to-end solutions for GOES-R, NOAA is releasing to industry a Broad Agency Announcement to look at technology advancements in the following four areas: spacecraft; command, control, and communications; product generation, distribution, archive and access; and end-to-end systems integration. This will afford NOAA the opportunity to dialogue with industry to entertain their best and brightest ideas to minimize risk during GOES-R development.

Full funding of the FY2004 GOES-R budget request of $104.7 million is needed to continue these activities and strengthen the overall risk reduction program to ensure that NOAA is developing the most appropriate system to meet our operational requirements and program funding constraints, and that NOAA will have retired sufficient risk to ensure that the GOES-R system is delivered on time to support the continuity of the essential GOES mission.

NOAA's Polar-orbiting Satellite Program

The FY2004 President's Budget Request includes $391.1 million NOAA's polar-orbiting satellite program. Of that amount, $114.4 million is requested for POES satellites (NOAA K-N' series) and ground systems; and $276.7 million for NOAA's portion of NPOESS.

a) Polar-orbiting Operational Environmental Satellites (POES)

The POES mission is to provide an uninterrupted flow of global environmental information in support of operational requirements. The POES mission is comprised of two satellites, one in a morning orbit, and one in an afternoon orbit, to collect global environmental data, including the 3-D measurement of multiple parameters, which are critical for accurate forecasts beyond three days. In addition, they are important for establishing long-term global data sets for climate (stratospheric ozone, oceanic, vegetation, global warming) monitoring, change detection, and prediction. Data sparse areas such as the world's oceans are also observed primarily by NOAA POES. Like GOES, POES data collection platforms provide services such as search and rescue, and relay of tide, buoy, flood, and tsunami data from global and remote locations. POES sensors also make observations that support timely forecast of space weather events.

NOAA has established a POES program policy that a spacecraft and launch vehicle be available on or before the date of the launch of the preceding spacecraft. This helps protect against coverage gaps caused by a launch failure, early on-orbit failure of the satellite after launch, and sets a need-date for the next satellite to be produced.

In the scenario of NOAA N' failure and lack of access to timely backup, DoD, research, and international satellite data, significant impact to protection of life and property and climate monitoring services are possible. Potential impacts include degradation of hazard monitoring such as volcanoes, especially at high latitudes; breaks in the climate record which degrade the long-term climate record; loss of the ability to generate ozone and ultraviolet (UV) analyzes and forecasts used for public heath; and decreased forecast accuracy in global models, estimated to be 1-4% in Northern Hemisphere and 3-25% in the Southern Hemisphere.

The annual President's Budget Request is based on the anticipated need-date of the satellites. However, depending on launch success, and operational satellite life, these need dates may shift. Nominally, the time between call-up and the actual replacement of a POES is 180 days.

The normal replacement of a POES takes place whenever the flow of operational scientific and related instrument engineering data from designated critical satellite instruments is either interrupted or degraded significantly. In practice, any decision to launch a replacement satellite requires the consideration of several additional factors, such as: availability of older POES spacecraft in the orbit with functioning instrument(s) that can provide data continuity on an interim basis; operational condition of in-orbit NOAA POES spacecraft, in particular are other spacecraft or instruments displaying indications of early failure; availability of launch vehicles and spacecraft-to-launch vehicle integration facilities; the possibility of conflicts in access to launch pads and launch support facilities; the possibility of conflicts in availability of skilled personnel for launch preparations and other critical activities; ability of the ground system to support the launch, operations, and data processing and distribution for the replacement satellite.

b. National Polar-orbiting Operational Environmental Satellite System (NPOESS)

In May 1994, the President directed the convergence of the Department of Commerce/NOAA POES program and DoD's Defense Meteorological Satellite Program (DMSP). These two programs have joined to become the NPOESS which will satisfy both civil and national security operational requirements. In addition, NASA, through its Earth Observing System (EOS) efforts, offers new remote-sensing and spacecraft technologies that are being incorporated to improve the capabilities of the NPOESS.

The tri-agency NPOESS Integrated Program Office (IPO) and NPOESS contractor has established a design and production schedule to derive the maximum benefit from the risk-reduction missions of the NPOESS Preparatory Project (NPP) and the Windsat/Coriolis mission for critical risk reduction for the NPOESS C-1 satellite. The schedule will also provide a bridge between the transition from NOAA POES and DoD DMSP satellites, while providing continuity of select NASA EOS missions.

NPOESS FY2004 Budget Request

The FY 2004 President's Budget Request for NPOESS is $544.4 million, of which DOC/NOAA's portion is $276.7 million, and DoD's portion is $267.7 million. This will support continued development of NPOESS, including the risk reduction missions, Windsat/Coriolis and NPP.

In the letter of invitation to testify at this hearing, the Subcommittee asked for a response to the $70 million reduction from the funding requirements included in the FY2003 estimates. The FY2004 President's Budget Request reflects the Administration's program needs for continued development of the NPOESS Program. IPO has directed the NPOESS contractor to conduct a replan, which resulted in deferred procurement of sensors and non-recurring engineering for NPP and the NPOESS satellites. Adjustments to the satellite launch schedule are reflected in the President's Budget Request.

Full funding of the total DOC and DoD NPOESS FY2004 President's Budget Request is imperative to keep the program on its revised schedule.

NPOESS Risk Reduction Missions

The WindSat/Coriolis satellite, which was launched on January 6, 2003, is serving as risk reduction for the NPOESS Conical Scanning Microwave Imager/Sounder (CMIS). CMIS will measure ocean surface wind direction from space using polarimetic passive microwave technology, which requires a sensor with the capability to sense passive microwave emissions that are on the order of one-tenth as strong as the signals used by presently operational passive microwave sensors. This has not been done before from space and constitutes the highest technical risk associated with NPOESS.

The NPP satellite scheduled for launch in October 2006 will significantly reduce NPOESS program risks by demonstrating on-orbit sensor functionality and allowing scientists to develop NPOESS algorithms using data collected by actual sensors on-orbit instead of having to approximate data through synthetic generation as is usually done for new sensors. History demonstrates that the risk associated with advances in algorithm developments is dominated by how accurately the data used to develop the algorithms resemble the data that will be collected by the sensor on-orbit. This rationale applies to the following NPOESS sensors and their associated algorithms.

* Cross Track Infrared Sounder – 3 environmental data records (EDR)
* Visible/Infrared Radiometer Suite – 23 EDR
* Advanced Technology Microwave Sounder – 3 EDR
* Ozone Mapping and Profiling Suite – 1 EDR

NPP will also demonstrate proper functioning of the NPOESS Command and Control System

Transition between POES and NPOESS satellites

The Subcommittee's letter of invitation also expressed interest in the transition between POES and NPOESS, specifically an estimated 21-month gap between the launch of NOAA N' and the availability of NPOESS C-1.

As a polar-orbiting satellite program, the NPOESS satellite availability strategy is similar to that noted earlier for NOAA POES with the additional constraints of required overlap with NPP for cross calibration and meeting the DoD early morning spacecraft requirement. Under the IORD, the first NPOESS satellite (C-1) is required to back up NOAA N' (the last of the NOAA POES series) or DMSP F20. While the replan has delayed the availability of the first NPOESS satellite by as much as 21 months, there is no projected gap in coverage, as long as the NOAA N and N' satellites are successfully launched, and are meeting operational lifetimes.

NOAA continues to monitor the status of the instruments on its operational POES to maximize the capability of those spacecraft. Our transition planning calls for the launch of the NOAA N (June 2004) and NOAA N ' (March 2008) into the afternoon orbit and the use of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) METOP polar satellite to fill the morning orbit requirement.

With respect to the Subcommittee's interest in contingency planning in the event of the failure of NOAA N', NOAA is working closely with EUMETSAT to ensure launch of the first METOP satellite in 2005 which will assume the morning orbit responsibilities. In the event there is a loss of NOAA N' prior to the launch of NPOESS C-1, NOAA would rely on the METOP satellite in the morning orbit.

For the afternoon orbits, NOAA would reassess the capability of older spacecraft that have been taken out of operational service and use the best available data. NOAA would also assess the utility of all available satellite data from DoD's DMSP, NASA EOS satellites, NPP missions, and foreign sources.

Status of the NPOESS Program Sensors

The Subcommittee has expressed an interest in any cost-savings that may be accrued from reducing the NPOESS sensors and impact this would have on meeting operational requirements.

The NPOESS Program Office, in consultation with the NPOESS Program Executive Committee, reviewed the status of the program, the FY2003 Appropriations, FY2004 budget request against the operational requirements in the IORD and satellite schedule. They determined that there will be no changes to the technical content of the program, specifically the number and types of sensors and their performance, the number of satellites, number of weather centrals. The NPOESS Program recommended, and the Committee approved, adjustments to the schedule to accommodate the available funds. The basis of the recommendation was that no single sensor, even if totally deleted, would provide significant reduction in the overall program cost. Additionally, the impact to the customer of the loss of data and services if sensors were reduced would be incalculable. Appendix 1 contains a list of the NPOESS sensor suite.

For illustrative purposes, the following is a review of the impact of deleting the Visible/Infrared Imaging Radiometer Suite (VIIRS) and the Conically-scanned Microwave Imager Sounder (CMIS) from the NPOESS sensor suite. VIIRS is designed to meet NOAA and DoD operational requirements and to continue the NASA EOS Moderate Resolution Imaging Spectroradiometer (MODIS) data to meet the climate community imagery requirements, provide continuity of the Sea-viewing, Wide-Field-of-view Sensor (SeaWiFS) instrument for ocean color, and provide enhancement on heritage NOAA POES and DMSP sensors. SeaWiFS data continuity is a critical requirement for the ocean sciences community.

CMIS is used to image the Earth's surface through clouds, which is especially important for sea and lake ice, for ocean surface wind speed and direction, and for soil moisture measurements (a key performance parameter from the DoD and useful for civilian agricultural and flood warning applications). The development costs of the VIIRS visible and infrared imager and the CMIS are approximately $180 million for each sensor suite. This amount includes three VIIRS sensors (NPOESS Preparatory Project, NPOESS C-1 and C-2), two CMIS sensors (NPOESS C-1 and C-2), and all the algorithms and software for both. Development of the sensors is far enough along that there would be no program cost savings from reducing the number or type of sensors from the NPOESS Program. In fact, deleting the VIIRS sensor eliminates all the imaging capability from NPP, C-1 and C-2. This would negate two thirds of the EDRs on NPOESS and result in NPOESS' inability to meet IORD performance requirements.

During the assessment to converge DMSP and POES into NPOESS, NOAA and DoD conducted cost benefit analyses and it was estimated that the program will realize cost avoidance of $1.3 billion over its life. Therefore, we have already realized a major cost benefit from effectively reducing the number of instruments in orbit. If further budget adjustments require that select sensors are dropped, NOAA would not be able to meet the mission requirements directed in the IORD.

NOAA would be affected more than DoD, since NOAA does have unique sensors such as Total Solar Irradiance Sensor (TSIS) and Earth Radiation Budget Sensor (ERBS) that do not meet DoD requirements, but do meet NASA and NOAA climate and scientific mission requirements. Removing any of the "critical" sensors, VIIRS, Cross-track Infrared and Microwave Sounding Suite (CrIS), Advanced Technology Microwave Sounder (ATMS), or CMIS, would result in violation of the key performance parameters of the IORD, which, according to DoD acquisition rules, could result in cancellation of the program. Since these sensors provide critical data for numerical forecasting to NOAA and the weather and climate community, the impacts would be significant and unacceptable.

Further, the near-term impact of the reduced funding results in loss of efficiency at the contractor facility, and instability in production schedules. The impact to the customer and user is an increased uncertainty whether they should develop programs based on the availability of NPOESS data. It also leads to inefficiencies in our customers' and users' readiness plans to invest in the critical information technology (IT) infrastructure required to facilitate use of NPP and NPOESS the data on "Day One of Its Availability."

NOAA's Preparations for NPOESS and GOES-R Data Streams

A discussion of NOAA's satellites and its preparation for future systems must also include the concept of end-to-end utilization of satellite data. As discussed at last year's hearing before this Subcommittee, NOAA is committed to ensuring that the data from NPP, NPOESS, and GOES-R will be incorporated into operations on the first day of its availability, and the academic community, industry, and other users will be able to access climate-quality data from NOAA's archive.

The President's FY2004 budget request contains $91.2 million to support our Environmental Observing Services. Within these amounts are activities designed to support current operations as well as prepare NOAA to utilize NPOESS and GOES-R satellite data on "Day One of Its Availability." A sampling of these activities include:

Use of Precursor NPOESS Sensors

NOAA has started to use and incorporate data from NASA EOS research instruments that are NPOESS precursor sensors (both sounders and imagers) into NOAA operations on a limited and experimental basis. As such, NOAA's National Weather Service, NOAA Oceans and Coasts, NOAA Research and other users are beginning to become familiar with the increased volume, variety, and complexity of the data. Indeed, already we have seen improvements in operations from these data and expect to realize further improvements as operators realize the full potential of the available data and make greater use of them.

NOAA has been systematically working on upgrading and enhancing current product development, processing and distribution capabilities to begin acquiring and exploiting in near real-time data from MODIS and

Advanced Infrared Sounder (AIRS) on the NASA EOS Missions Terra and Aqua missions to directly support NOAA's operational missions that require remotely sensed data. Because the MODIS instrument is very similar to the VIIRS and the AIRS instrument is similar to CrIS that will be flown on the NPP mission and on the operational NPOESS spacecraft, these early NOAA efforts are critical to reduce the risk and gain experience with similar instruments; data handling, processing, storage, and communication of high volume data sets; and allow the users to gain early, pre-operational experience with NPP and NPOESS-like data sets, well before the first operational NPOESS spacecraft is launched.

Similar efforts are being pursued to build the capability to handle and process data from the future CMIS that will be flown on NPOESS to measure, among other parameters, the ocean surface vector wind field. Current efforts at NOAA (and the Navy) address the operational/tactical use of ocean surface vector winds from active scatterometer missions (e.g., SeaWINDS). Beginning with the launch of the joint DoD/DOC Windsat/Coriolis mission (a NPOESS risk reduction flight for the CMIS instrument), NOAA's processing capabilities for SeaWINDS will be transitioned to processing and utilizing data from the WindSat/Coriolis mission, in preparation for the first launch of NPOESS. Additional development work that is required to prepare for the NPOESS era will be performed in close cooperation with IPO and through the Joint Center for Satellite Data Assimilation, further described below.

Use of Surrogate Data Sources

NOAA actively assesses the utility of non-NOAA data to fill its mission. NOAA purchases data from Orbital Imaging to fulfill NOAA's operational requirement for ocean color data. NOAA also uses data from the joint NASA-European Space Agency's altimetry mission. These two cases are examples where NOAA has utilized alternate risk reduction activities to assess the utility of currently available data streams to support NOAA's missions prior to transitioning these capabilities onto NPOESS satellites.

Collaboration with the Science Community

In response to recommendations from the Chairman and this Subcommittee at last year's hearing, we continue to actively seek collaborative partnerships with Universities and the broader academic community to address meeting the need for science or climate research quality data from NPOESS and GOES-R missions. NOAA is harnessing the best and brightest minds to work with us. Highlights include:

* Establishment of the Cooperative Institute for Oceanographic Satellite Studies (CIOSS) with the College of Oceanic and Atmospheric Sciences (COAS) at Oregon State University. COAS is rated among the top five oceanographic institutions in the Nation by the National Research Council. This partnership between COAS and NESDIS builds on COAS' recognized leadership in the fields of oceanographic remote-sensing and coastal ocean research.

* Continued relationships with the Cooperative Remote Sensing Science and Technology Centers (CREST) located at the City University of New York (CUNY). CREST is a partnership among NOAA, CUNY, Hampton University, University of Puerto Rico at Mayaguez, University of Maryland at Baltimore County, Bowie State University, and Columbia University. In addition to training future remote-sensing scientists, students within the CREST consortium have already started rotations within NESDIS's science programs in Wisconsin and Maryland.

* Continued partnerships with University Corporation for Atmospheric Research (UCAR) and the National Center for Atmospheric Research (NCAR) in Boulder, Colorado.

* NOAA continues to harness the knowledge through existing collaborations at the Massachusetts Institute of Technology, University of Maryland, University of Wisconsin, University of Colorado, Colorado State University, and other academic institutions.

NOAA's Science Advisory Board (SAB) is considering the establishment of an NPOESS Science Panel to assist in these efforts.

Not only do these opportunities fertilize NOAA's scientific programs, they create a demand for young scientists to enter fields that are critical to NOAA's future to build a workforce with which NOAA can initiate personnel succession planning.

Satellite Data Assimilation - Joint Center for Satellite Data Assimilation (JCSDA)

The FY2004 President's Budget Request includes $3.35 million to support activities with JCSDA. NOAA appreciates the strong support this Subcommittee has provided for JCSDA. JCSDA, initially a partnership between NOAA and NASA, has been expanded to include DoD, and is addressing the development of common algorithms that will be used by all the NPOESS customers.

The goal of JCSDA is to make better use of all sources of satellite data in operations including preparing for, assimilating, and using data from NPOESS sensors. This will ensure that operational users are ready and eager to use NPOESS data ***on day one*** of its availability. We already have some positive results from these efforts, such as a better way to use satellite data to locate hurricane centers, but we need to continue this work with the brightest minds in our government and universities. Accomplishments of JCSDA in the past year include: committed partnership among NOAA Line Offices (NOAA's National Weather Service, NOAA Research, and NOAA Satellites and Information), DoD (US Air Force and US Navy), NASA, and the academic community; incorporation of EOS AIRS data into NOAA' s National Weather Service models; upgraded communications lines between NASA and NOAA in order to move data to operations processing centers at NOAA; improved computing capacity. JCSDA will also play a critical role in GOES-R risk reduction activities.

Information Technology Reviews

The NPOESS partners and NPOESS contractor continue to undertake rigorous reviews of IT infrastructure and capacity to support NPOESS data assimilation at the NPOESS operational centers. We recognize and constantly monitor IT advances to ensure that we are harnessing the best technology available to address the challenges before us in the most cost-effective way. As noted above, the ability to develop the appropriate IT infrastructure to ensure that ground and processing systems are ready in time for NPP and NPOESS depends on available funding.

Partnerships with other Space Agencies

In addition to NASA, DoD, academia, and industry, NOAA continues to develop and nurture critical partnerships with foreign space agencies in Japan, China, India, and Europe, (such as France, Italy and Russia). These partnerships allow us to leverage select data from these satellite systems at tremendous cost savings to the U.S. taxpayer by not flying duplicative satellites and sensors on NOAA spacecraft.

User Training and Education, and Public Outreach

NOAA continues to work with UCAR, the American Meteorological Society (AMS), DoD and other partners to develop and implement teaching modules for operational users regarding applications of NOAA satellite data in the classroom and through distance-learning such as E-learning. NPOESS and GOES-R will use these avenues to ensure that operators are ready and able to use satellite data from those systems when they become available. NOAA anticipates that advances in IT and E-learning will provide opportunities to increase training in the future. NOAA has also sponsored a number of national and international user workshops and meetings to discuss the NPOESS and GOES-R programs.

NOAA's Satellite Data Access and Archive

The NOAA National Data Centers - located in Maryland, Colorado, North Carolina and Mississippi - routinely incorporate the latest technologies to facilitate rapid and easy user access to the data, products, and information under NOAA's stewardship. The President's FY2004 budget request of $59.074 million for NOAA data centers and information services continues the work to ensure that these invaluable data are available for many generations.

The IT revolution is changing the expectations and demands that customers have for access and use of observations, data, information, products, and services. Customers are now able to transfer and process vast quantities of data and expect easy and efficient web-based access and search capabilities via the worldwide web and broadband Internet. Entrepreneurs in the application of information and intellectual property are finding numerous innovative applications for NOAA data and information. This in turn, is driving the NOAA data centers to provide more rapid access, more timely and improved quality assurance and quality control of these data. The objective NOAA "quality assurance" stamp is critical to private industry and decision-makers who require confidence in the data when considering capital investments and annual business plans, as well as long-term policies.

In anticipation of the increases in data from NASA EOS, NPP, NPOESS, and GOES and the demand for access to these data on the first day of availability, NOAA has requested $3.6 million in the FY 2004 budget request to continue to develop the Comprehensive Large Array-data Stewardship System (CLASS) and an additional $3.0 million to incorporate the NASA EOS data into the CLASS infrastructure.

CLASS is NOAA's integrated enterprise archive architecture and management system that will provide rapid access and long-term scientific stewardship of large volumes of satellite, as well as airborne and *in-situ* (surface: land and ocean), environmental data, operational products, and respond to on-line users' requests. Full funding of these data management activities will help us to prepare for NPOESS and GOES-R data archiving challenges. CLASS is a critical foundation for the scientific data stewardship of NOAA's vast archive, a national treasure and resource. The CLASS program is NOAA's principal avenue to meeting the challenges of rapid advances in information technologies and a much more informed and demanding customer.

We are at a critical juncture in the development of CLASS in order to meet user requirements for NPP and NPOESS. NOAA received $2.9 million in appropriations of the $6.6 million requested in FY 2003 President's Budget Request to develop CLASS and provide the initial capability to include EOS Archive data into the CLASS infrastructure. Full funding of the FY 2004 budget request will allow NOAA to develop the enterprise architecture to ensure the stewardship (access and archive) for the NPP data and to meet the critical requirement of the climate research community.

In conclusion, Mr. Chairman and members of the Subcommittee, NOAA is pleased to have had the opportunity to provide you an update on the GOES-R and NPOESS, and our data management programs. We are actively managing the scheduling and technology risks associated with these systems, and look forward to working with the Congress and the Administration to minimize the funding risks. Support of the FY2004 budget request is imperative to successful development, launch, and operation of the next generation of satellites. The validated, requirements-based data from these systems will vastly improve the health and safety of the people, the U.S. economy, and our global environment. A key element to our strategy is partnering with other agencies, such as NASA and DoD, the space industry, our international partners, and academia. These partnerships have proved to be wise investments for NOAA and the Nation. We have also greatly appreciated the continued support and interest expressed by this Subcommittee.

Mr. Chairman and Subcommittee members, this concludes my testimony. I would be happy to answer any questions.

__Appendix 1__

National Polar-orbiting Operational Environmental Satellite System Sensors:

* ***Visible/Infrared Imaging Radiometer Suite (VIIRS)***:

Three orbits, high precision, near constant resolution, multi-spectral imagery (22 "colors").

* Imagery *[1]
* Sea*, Ice and Land Surface Temperature
* Aerosol Particle Size and optical thickness
* Surface Albedo
* Cloud cover, layers, particle size, optical thickness, height, and pressure/temperature of tops
* Ocean color/chlorophyll
* Precipitable water and suspended matter
* Sea Ice characterization
* Surface type and vegetative index

* ***Conically-scanning Microwave Imager and Sounder (CMIS)***:

Three orbits, imagery through clouds and sounding.

* Sea Surface Winds*
* Soil Moisture*
* Cloud Base Height and Ice/Liquid Water
* Atmospheric pressure, moisture and temperature vertical profiles (low resolution)
* Sea, Ice and Land Surface Temperature through clouds
* Precipitation type and rate
* Snow cover and depth
* Atmospheric Total Water Content
* Surface type and sea ice characterization

* ***Cross-track Infrared and Microwave Sounding Suite (CrIMSS)***:

Pair of sounding instruments on two orbits (comprised of the Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS)).
* Atmospheric pressure, moisture* and temperature* vertical profiles (high resolution)
* ***Ozone Mapping Profiler Suite (OMPS)***:
Single orbit of ultraviolet down looking and horizon viewing instruments.
* Ozone total column map and vertical profile (Treaty Requirement)
* ***Space Environmental Sensing Suite (SESS)***:
Collection of instruments to measure ionospheric and electromagnetic space conditions.
* Auroral Boundary, Energy Deposition and Imagery
* Electric and Geomagnetic Fields
* Electron Density and Neutral Density Profiles
* Energetic Ions and Medium Energy Charged Particles
* Supra-Thermal-Auroral Particles
* In-situ plasma temperature and fluctuations
* Ionospheric Scintillation (in-situ)
* ***Global Positioning System Occultation Sensor (GPSOS)***:
Ionospheric sounding instruments on one orbit.
* Electron Density Profile
* Ionospheric Scintillation (horizon)
* ***Earth Radiation Budget Sensor (ERBS)***:
Single orbit to record balance of reflected and emitted energy. Used to help model the Earth's energy balance to understand climate.
* Downward Radiance, long and short wave
* Net heat flux
* Net solar radiation, top of atmosphere
* Outgoing long wave radiation, top of atmosphere
* ***Total Solar Irradiance Sensor (TSIS)***:
Continuously measures energy from the Sun from a single orbit. Used to help model the sun's energy input to the Earth. With the ERBS, helps understand Earth's energy balance to understand climate.
* Solar Irradiance
* ***Altimeter (ALT)***:
Single highly precise radar altimeter.
* Ocean Wave Characteristics
* Sea Surface Height/Topography (used to see if the ocean is rising)
* Wind Stress
* ***Aerosol Polarimetry Sensor (APS)***:
Single sensor. Measures the distribution and shape of small particles suspended in the air. This gives indications as to source – natural or man-made.
* Aerosol Optical Thickness, Particle Size and Refractive Index
* Cloud Particle Size and Distribution
In addition, some satellites carry the following instruments:
* ***Search and Rescue Satellite Aided Tracking (SARSAT)*** - All satellites
* ***ARGOS Data Collection System (ADCS)*** - Two orbits
* ***Survivability Sensor (SS) attack warning sensor*** - All satellites
Three orbital planes are polar sun-synchronous orbits with local ascending node times of **1330**, **1730** and **2130**.

Instruments in 1330 orbital plane:

• VIIRS	• CMIS	• CrIS/ATMS	• OMPS	• SESS
• GPSOS	• ERBS	• SARSAT	• ADCS	• SS

Instruments in 1730 orbital plane:

• VIIRS	• CMIS	• CrIS/ATMS	• ALT
• TSIS	• SARSAT	• ADCS	• SS

Instruments in 2130 orbital plane:

• VIIRS	• CMIS	• APS	• SARSAT	• SS

All satellites can accommodate all instruments. The configuration launched is determined at the time of call-up depending on the operational needs of the environmental satellite data using community.

These strategies allow NOAA to develop and fund these activities at the best cost-benefit to the taxpayer while minimizing the risk of interruption of satellite data.

* Note: Environmental data types with Key Attributes which would require replacement of a satellite if a sensor becomes unable to perform.