ROUTING			
TO	NAME AND ADDRESS	DATE	INITIALS
1			
2			
3			
4			

	ACTION		DIRECT REPLY		PREPARE REPLY
	APPROVAL		DISPATCH		RECOMMENDATION
	COMMENT		FILE		RETURN
	CONCURRENCE		INFORMATION		SIGNATURE

REMARKS:

FROM: NAME, ADDRESS, AND PHONE NO.	DATE

SECRET
(Security Classification)

CONTROL NO. BIF-0107-20001-93

COPY 91 OF

Handle Via

BYEMAN

Channels

Access to this document will be restricted to those approved for the following specific activities:

NATIONAL SECURITY INFORMATION
Unauthorized Disclosure Subject to Criminal Sanctions

SECRET
(Security Classification)

Subject: Draft of Navy Project History ~~14~~ 21 April 1993

To: Jim Morgan

From: Dave Bradburn

Here is the draft of the chapter on POPPY and its predecessors in Program C. This will be the first of six "project" chapters in our SIGINT satellite history. The others are the [redacted] and [redacted]

To see where this fits in, here is the outline of the history:

The book begins with a chapter covering pre-history and an introduction to the organizations and the engineering concepts involved in SIGINT satellite operations.

Then there is a chapter on the early development of the NRO as an organization, covering about 1956 to 1962.

Then come the six separate project histories, each touching on the reasons for the project, the development history, processing, and results. Each of these starts whenever the project started and ends in 1975.

Then there are two concluding chapters, one on lessons learned and the final one on assessments and value judgements.

When we have the clean draft of the whole history ready, this summer, we will ask you to review it. In our SIGINT satellite history, we will refer our readers to the POPPY History as the best source on the subject.

In the meantime, we need your help in reviewing the draft we have made, which was written by John Copley---using the POPPY History you so kindly furnished---with big inputs from Ray Potts (processing) and [redacted] (results).

In particular, we need help with more names of the Navy people, especially in Section 3d, which covers the maturing years of POPPY [redacted]

Mark it up and provide me any other comments, and we'll try to have them fixed for the review this summer.

Could you get this back to me by the end of May?

Thanks, Jim, and all best!

Dave

Dave

WORKING PAPERS

~~TOP SECRET~~

N3AV2.JOC

Chapter 3. The Navy Program (Program C)

3a. Introduction (The Dyno Concept)

The Navy SIGINT Satellite Program, conceived in early 1958 by personnel of the Naval Research Laboratory (NRL), combined their long experience in the fields of radar and electronic intercept systems with the more recent space experience gained through their development of the Vanguard Satellite Program.

A precedent for the system proposed by NRL was set during WWII when German submarine crews used a hand-held crystal video receiver named ATHOS to detect pulses from Allied radars. This simple passive electronic countermeasure receiver enabled the submarine to take evasive action before the range had closed sufficiently for the returning radar echoes to indicate the submarine's presence to the searching warship or airplane (essentially similar to police radar detectors of today). After the war, crystal video receiver technology was adopted by the U.S. Armed Services, and in 1957, Naval Reasearch Laboratory (NRL) engineers were fitting crystal video receivers to U.S. submarine periscopes for defensive purposes.

In early 1958 the newly formed Advanced Research Projects Agency (ARPA) sent out a call for military space related projects. The Chief of Naval Operations (CNO) relayed the query to all Navy scientific and technical organizations asking, "All hands consider how they could use space in their design ideas for the Navy".

This call struck a responsive note with Reid Mayo, an engineer in Howard Lorenzen's Electronic Group at the Naval Research Laboratory (NRL). Mayo who proposed a crystal video receiver, such as the ones they had installed in submarine periscopes, to be mounted in a Vanguard type satellite in orbit around the earth. When connected to an appropriate antenna on the satellite, such a receiver could "see" (intercept) a signal from radar antenna beams on the earth when they pointed at the satellite. He further reasoned that if this signal were sent from the crystal video receiver to a transmitter on the satellite, it could be returned to any ground station which was able to see the satellite or, in other words, have a "line-of-sight" path from the ground station to the satellite.

Fortunately, this configuration fit the real life situation. The intelligence services of the U.S. responsible for cataloging hostile, primarily Soviet, radio and radar signals, had established a ground network of intercept stations ringing the Soviet Union on all sides except the Artic North. It was possible, by locating satellite receiving equipment at these stations in countries such as [redacted] to see a satellite in an orbit inclined 67 degrees to the equator, at 500 mile altitude, for many hours a day. At the same time, the satellite could see the signals from the radars of interest in the Soviet Union! This concept of "transponding" radar signals to peripheral listening posts became the foundation of the Navy satellite program starting with GRAB/DYNO, then POPPY, [redacted]

The response to the ARPA request, sent by NRL to the CNO, in March, 1958 featured a "transponder" designed by Reid and his fellow engineers of Howard Lorenzen's electronic group. The transponder was mounted in a spherical satellite, 20" in diameter, designed by engineers of the Vanguard Program Office under the leadership of Marty Votaw. The transponder, the ELINT system, utilized six monopole antennas deployed around the surface of the sphere in such a way as to provide omni-directional coverage of all radar beams impinging on the satellite. Each of these antennas was connected to a crystal video receiver consisting of a filter to determine the frequency coverage and a detector with adjustable sensitivity. The receiver system was adjusted to assure that it could see only the main beam signal from each radar as it looked in the direction of the satellite. The time between looks would determine the rate of rotation or "scan rate" of the radar. This adjustment also provided a "threshold" to mask out lower power signals which could cause interference to the desired main beam intercepts. Since the satellite was not stabilized in any plane, great care was taken to assure that no matter what the direction of arrival, all pulses would be received with equal sensitivity. Each pulse in the output of the receiving system was "stretched" to a length of [redacted]ermitting it to be transmitted to the ground stations by a transmitter connected to an omni-directional turnstile antenna. In that way, any ground station in line of sight could receive the signals.

In addition to the transponder, the satellite contained a power system consisting of a storage battery plus six 9" diameter round patches of 156 solar cells located symmetrically on the surface of the sphere so that one watt of power would be available for any orientation of the satellite. A telemetry system provided engineering data on the status of the satellite as well as the state of commanding of the transponder. The command system consisted of a receiver and decoder which translated tones transmitted from the ground command station into relay closures controlling such functions as data link on/off and timer start to turn on the transponder. The command system shared the turnstile antenna with the data link transmitters and could receive commands whenever it was in view of a ground station having a command transmitter.

NRL proposed to orbit this satellite as a piggy back payload along with the much larger TRANSIT II-A navigation satellite. This satellite would be launched from the Cape Canaveral Launch Base in Florida, using a Thor/Able-Star booster. Ground stations to receive the data transmitted from the satellite were to be located at intelligence community intercept sites in [redacted]

WORKING PAPERS

[redacted] The mission was very straightforward: to intercept and identify known types of radars in the Soviet Union and to discover and describe new types of radars, not previously intercepted by peripheral ground, sea, and airborne means. A further goal was to locate these radars as accurately as possible.

In order to utilize the facilities of the existing ground intercept sites, maintain security, and minimize interference with ongoing activities, the Dyno ground stations were installed in self-contained transportable shelters known as ESV Huts (for: Earth Satellite Vehicle Huts). These were lightweight, aluminum structures designed for worldwide service conditions. They were transportable by helicopter, aircraft, truck, rail, or ship. All equipment was installed at NRL and the huts were shipped as essentially stand alone facilities. Once at the sites they were mounted on concrete pedestals, pavement, or on elevated platforms equipped with carport-type canopy roofs. All that was required was electrical power and they were ready to go! Yagi antennas (similar to those used for commercial television reception) were installed on the roof of each van and rotated manually from inside the van to point in the direction of the satellite. Standard military vacuum tube radio receivers (R-390/URR) with a crystal controlled converter were used to tune in the radar signals transponded from the satellite and the telemetry containing satellite status. A two track magnetic tape recorder was provided for recording the intercept data. One track contained the radar signals and the the other, operator's comments prior to turn on of the intercept receiver and a digital representation of time during the intercept period. A chart recorder was installed to indicate the strength of the signal from the satellite as well as the state of the equipment on the satellite. A 250 watt transmitter provided the ability to send commands, in the form of audio tones, to the satellite via a second Yagi antenna mounted on the mast along with the receiving antenna. The plan was to deploy these transportable ground stations to ground sites operated by the Naval Security Group (NSG) with headquarters at Ward Circle on Nebraska Avenue in Washington, D.C.

These sites were manned and operated by NSG while the funding for operation would be provided as part of the Consolidated Cryptologic Program through the National Security Agency. In order to obtain adequate coverage of the Soviet Union it was also proposed to locate some of the ESV huts at stations manned by the Army, Air Force [redacted] It was proposed to forward the data collected on magnetic tape through the Armed Forces Courier Service to the National Technical Processing Center (NTPC). The center had been integrated into NSA in accordance with National Security Council Directive #6 (NSCID-6) dated 15 September 1958, which assigned responsibility for National ELINT data processing to NSA. Here the data would be interpreted and distributed to intelligence users as required.

On July 29, 1958 the National Aeronautical and Space Act became law and on October 10, 1958 the National Aeronautics and Space Agency (NASA) commenced operation, charged with responsibility for all non-military space programs. Vanguard fit this category, and was assigned to NASA shortly thereafter. The Dyno program was impacted by the departure of Marty Votaw and other spacecraft designers along with the Vanguard program. Most importantly for this story, NRL retained responsibility for TRANSIT and DYNO. Ed Dix took over design of the satellite and coordinated the launch efforts at Cape Canaveral.

Howard Lorezen along with John Trexler, Director of NRL expanded this concept and coordinated with other organizations to provide for inter-agency participation, the use of SIGINT stations for data collection, and forwarding of the data to NSA for processing and product dissemination. This information was furnished to the Office of the Director of Naval Intelligence who undertook the task of obtaining program approval through DOD, ARPA, and the Executive branch of the government.

Last Correction: 4/12/93 13:44. Word Count: 1587.

N3BV3.JOC

Chapter 3. The Navy Program (Program C)

3b. GRAB/DYNO-1 Development

RADM (need first name) Reed of the Office of Naval Intelligence (ONI) shepherded the NRL DYNO proposal through the Navy, ARPA, DOD elements, and the executive branch to obtain final approval by President Dwight D. Eisenhower in August, 1959. The DYNO program was to be carried out as proposed. It would be conducted at the DOD SECRET security level under the code name TATTLETALE.

The Director of Naval Intelligence (DNI), who was designated as the Program manager, formed the Technical Operating Group (TOG) to function as the steering committee or staff of the Director. The TOG consisted of representatives from NRL, NSG, NSA, and STIC (the ONI Scientific and Technical Intelligence Center at Suitland, MD).

The NRL member was designated as the project manager/technical representative. NRL was responsible for the overall system concept as well as satellite and ground station development and support; in addition, NRL provided engineering and technical direction through the operational exploitation phase, training of mission ground station personnel, and launch/on orbit monitoring of spacecraft status and data quality.

The Naval Security Group (NSG) member was designated the project operational representative. NSG was responsible for direction and coordination of all mission ground station operations (including commanding the satellite operations); acted as the focal point for all electrical communications associated with the operations of the project; and provided sites, support facilities and operating and maintenance personnel at the NSG mission ground stations.

The National Security Agency (NSA) member was designated as the advisor to the staff. NSA authorized the allocation of service cryptologic personnel to man and operate the mission ground stations; processed all intercept data, and disseminated the Electronic Intercept (ELINT) product to the intelligence community. With this responsibility, NSA also interpreted national intelligence collection and processing requirements and made recommendations for commanding satellite collection periods (tasking), and furnished the magnetic tapes for recording data at the mission ground stations.

The STIC member provided intelligence requirements to the director, provided signal analysis support to NSA, monitored the signal analysis program, and disseminated quality control technical data to the mission ground stations.

The Technical Operating Group (TOG) was located initially at the Headquarters of the Naval Security Group (NSG) at Ward Circle on Nebraska Avenue, Washington, D. C. Early members of the group

WORKING PAPERS

were Navy Captain [redacted] of OP-94 representing the DNI, [redacted] a senior analyst from STIC, Hank Decourt, Chief of COSA-5 (ELINT Processing Organization) of NSA, Howard Lorenzen, Dyno Program Director at NRL, and Navy Captain Frank Sperberg representing NSG.

DYNO-1 was designed to operate in the radio frequency range of [redacted] This was the most densely populated range and covered a variety of radar types, including derivatives of many widely used U.S., West European, and Soviet WWII "S-Band" early warning and search radars (in the more recent JAN Frequency Channel Designators, these radars are designated in [redacted]). Since no formal national "requirements" for satellite ELINT collection had yet been established, it was up to the TOG members to determine the collection requirements for this first satellite ELINT mission. The intelligence community representatives felt that intercepts from this range, which contained many descendants of WWII prototypes, would provide a very productive harvest of significant radar information. This was to be a fortunate choice.

The initial mission ground stations were located at [redacted] All of the sites were operated by the Naval Security Group (NSG) except [redacted] which was operated by the Army Security Agency, [redacted]

[redacted] All the stations had the ability to collect data, but only [redacted] could transmit commands to direct the satellite when to turn on and off. Whenever the collection system was turned on, all the sites within range could receive the data. NRL also maintained an engineering data readout and interrogation site at Hybla Valley, Virginia until 1967 when it was moved to [redacted]

Unfortunately, the DOD SECRET security system did not provide the necessary security protection for the TATTLETALE program and shortly after its inception the New York Times printed a complete program description. Given President Dwight Eisenhower's "Open Skies" policy stressing peaceful uses of space, it was necessary to cancel the program at the DOD SECRET level in order to avoid any further disclosures which could lead to international embarrassment. To insure no further disclosures of this kind, the program was reclassified as TOP SECRET and was to be operated by the ONI under the WALNUT security system. Access was limited to individuals with a strict need-to-know and required the approval of ONI, ARPA, or the Office of the Special Assistant to the Secretary of Defense (Special Operations). Those individuals granted access were required to execute a project secrecy agreement.

Additional security was provided by adding an NRL scientific cover experiment designed to telemeter measurements of solar activity in X-ray, Lyman-Alpha, and ultraviolet radiation above the earth's atmosphere. This cover experiment became the first of a series of SOLRAD satellite experiments designed and exploited by the NRL. The cover name GRAB (Galactic Radiation and Background) was used for the combined Dyno intelligence mission and SOLRAD scientific mission. In the classified world the first satellite became known as GRAB/DYNO-1, but in the unclassified world it was called GRAB-1.

Word Count: 913. Corrected 4/12/93, 14:24.

Chapter 3. The Navy Program (Program C)

3c. GRAB/DYNO Program Launches

On June 22, 1960 the first U.S. SIGINT satellite, GRAB/DYNO-1 was launched from Cape Canaveral, Florida as a piggyback payload attached to TRANSIT II-A mounted on a Thor/Able-Star booster. GRAB/DYNO-1 attained a 330 by 565 nautical mile orbit, inclined at 66.7 degrees to the equator, with an orbital period of 101.6 minutes. Although it did not separate from the TRANSIT II-A this caused no problems since they had no common command or data links.

Following the shoot down of Gary Powers' U-2 on May 1, 1960, President Eisenhower directed that no reconnaissance overflight of the Soviet Union could collect intelligence information without his specific permission. Because of this strict limitation, the intercept payload could only be turned on for [redacted] minute periods during the two month lifetime of the satellite. On July 4, 1960, exactly four (4) years after the first U-2 mission, the payload was turned on and the ELINT capability of GRAB/DYNO-1 was checked out at Wahiawa, Hawaii, well out of SOVIET ground station range.

Despite the limited tasking, the collection technology in the satellite and the functions of the mission ground stations were clearly demonstrated. Processing and analysis of data received from the first DYNO SIGINT satellite system and the following POPPY satellites was an interesting and challenging adventure. In the beginning, the best all source estimates of the signal environment and the volumes of data available for analysis were far short of reality. The real magnitude and complexity of the processing and analysis job was not understood until the first satellite was on orbit collecting data. Each successive satellite had new/expanded capabilities and presented new challenges. For the first few years, the development of the processing systems was behind the "power curve". Frequently, processing was planned and developed based on poor estimates of expected data. Processing systems then had to be modified and sometimes invented to handle the actual data collected by satellites already on orbit collecting data. Fortunately, the early satellite collection systems were fairly simple and had short operational lives. This allowed for an evolutionary development of ground processing and analysis systems, and for feedback to the design of the satellite collection system. That resulted in later successful total collection/processing systems.

Manual analog analysis of the data was performed at the National Technical Processing Center, now relocated at NSA, Ft. Meade, Maryland. Hank DeCourt, who was leading the ELINT processing at NSA, directed the DYNO processing effort. Technical advice and recommendations were provided by [redacted] who was a senior analyst at STIC. John Conlon supervised the NSA analog analysis effort with major assistance from Ken Gallagher and James McAdam, both of whom supervised a number of military and civilian analysts at NSA. This group at NSA provided technical feedback to the mission ground stations.

This manual analysis produced the radar characteristics of Pulse Repetition Frequency, Scan Rate, and Radio Frequency band (in this case, E-Band). A very rough approximation of location could be determined by the first and last time the radar was intercepted at different ground stations (up and down times).

At NSA, a digital time search and control unit was used to rapidly position a tape to a time specified by the analyst. This unit enabled the comparison of signals recorded by two or more stations in an overlapping time frame. The analyst listened to the tapes to find signals of interest. The times that signals of interest were first heard on a tape and the times when the signal stopped were determined using a time code translator to read the recorded time signal. The pulse repetition frequency (PRF) was measured using a dual beam oscilloscope to display the data and to synchronize the PRF with an input frequency from a test oscillator. A frequency counter displayed the PRF of the reciprocal pulse recurrence interval (PRI). The intervals between successive bursts of pulses, or radar antenna scan period, were measured with a stop watch to the nearest [redacted] The radar characteristics produced by this manual analysis were; PRI, Scan and Radio

Frequency band only. Soviet early warning radars were found to be numerous and extremely powerful. Signal density was over four times that anticipated. This highlighted the need for some form of machine processing.

It seemed to Howard Lorenzen (NRL Dyno Program Director) that machine processing could be used very effectively for this type of data and early in 1961 he approached Louis Tordella, the Deputy Director of NSA, for assistance in developing such a capability. Tordella asked Bassford Getchell, a mathematician who had been studying orbital trajectories (and published a technical article, "Determination of Missile and Earth Satellite Trajectories from Radar Observations"), and [redacted] who had been responsible for early missile and space data to join them for a discussion of the problem. Howard produced a roll of visicorder paper, a picture showing a longitudinal analog presentation of a few minutes of Dyno data collection. Tordella gave Getchell and [redacted] the job of automating the data reduction and processing of this data.

As was the approach at that time, NSA personnel designed a special purpose computer to perform data conversion and formatting of the data which had been digitized by an NRL analog to digital converter. This computer was called BOGART and was built for NSA [redacted] An IBM magnetic tape recorder was used for storage and input. This development led to later design of UNIVAC and then Control Data Corporation (CDC) commercial computers. The first use of this equipment was for the Dyno-2 mission.

Dyno-1 intercepted many powerful Soviet Early Warning radars including TOKEN [redacted] A unique TOKEN was detected [redacted] were extensively used and more powerful than anticipated. Only a few unidentified radar types intercepted, which indicated the accuracy of U.S. intelligence regarding high power Soviet emitters. [redacted] emitters were identified, [redacted] of which were approximately located and correlated to known installations.

On November 30, 1960 the second GRAB/DYNO was launched using essentialy the same configuration as GRAB/DYNO-1. Unfortunately, the THOR booster burned out twelve seconds early and was destroyed by the Range Safety Officer. Fragments landed in Cuba. This incident resulted in the prohibition of launch trajectories which passed over the land mass of Cuba, thereby causing future lauches to include a dog leg in the launch azimuth in order to obtain the desired 67 degree orbital inclination. Since this required more boost energy, it resulted in a reduced payload weight capacity.

The third launch, designated GRAB/DYNO-2, occurred June 29, 1961. It consisted of GRAB/DYNO-2 from NRL and INJUN, sponsored by [redacted] of the State University of Iowa. The two smaller satellites were connected together and mounted on top of the larger TRANSIT IIIB satellite using the Thor/Able-Star booster and launched from Cape Canaveral. An orbit 475 by 540 was achieved, inclined 66.8 degrees with a period of 103.8 minutes. Separation from the TRANSIT IIIB occured but the INJUN and GRAB/DYNO-2 did not separate from each other. As a result, it was necessary to operate the two satellites on alternate days, thereby cutting the collection time in half. Since this was the second failure of two satellites to separate on orbit, NRL took over future responsibility for this function from the launch integration contractor. There has not been a similar failure since.

In 1961, because of the apparent world-wide acceptance of overflight by peaceful satellites, the requirement for Presidential approval for each collection period (read-in) had been lifted. However, GRAB/DYNO-2 collected very little useful data. The alternate day tasking accounted for this in part and the choice of radio frequency bands accounted for the balance. Since the launch of Dyno-1, a national requirement for satellite SIGINT collection had been published by the United States Intelligence Board (USIB-D-33.6/8 dated July 5, 1960). To satisfy a requirement to search for new and unusual signals, particularly those associated with the Anti-Ballistic Missile (ABM), the radio frequency bands of [redacted] were selected by the TOG for GRAB/DYNO-2

WORKING PAPERS

~~TOP SECRET~~

collection. In order to identify the frequency band of the intercepted signals, a [redacted]s used on the downlink transmissions for each band. On subsequent launches, when more that two bands were intercepted, a separate pulse width would be assigned to each band. The satellite continued to operate until August 1962 although the lower band gradually lost sensitivity as the mission progressed.

Although ELINT collection results were sparse compared to Dyno-1, the gradual loss of sensitivity in the lower band demonstrated the extremely high power radiated by the [redacted] Early Warning Radar which was the only signal that could be received near the end of the mission. Earlier, in the low band, a signal called BUGH was classified as the first ABM type radar to be intercepted. [redacted]

Magnetic tapes with data from this launch were sent to NSA where, in addition to analog analysis, a new analog to digital converter called AUDICO, capable of digitizing data with a time interval accuracy of [redacted] for each count or machine unit was used to prepare the data for computer processing. These output pulse intervals were then condensed into the time-of-arrival of the last pulse in the burst, the average PRI expressed in machine units, and the number of pulses in a burst. The early software for

~~TOP SECRET~~ HANDLE VIA BYEMAN/TALENT-KEYHOLE/COMINT CONTROL CHANNELS JOINTLY a wide disparity in tape quality from the collection sites and a lack of repeatability in AUDICO runs. Short term tape speed variations were a problem. Comparisons with analog analysis did not produce very satisfactory results. Quality control efforts instituted in the conversion process and at the collection sites helped to improve this situation. Deinterleaving and scan sort techniques and programs were continually improved over the years and applied to processing all ELINT data collected by POPPY and all other SIGINT satellite systems.

Early attempts to produce radar locations from the GRAB single satellite system were very crude. Using up and down intercept times or an annulus of intercept created when the satellite passed in and out of the horizontal beam pattern of the radar did not produce very accurate or useful locations.

Because of political pressures within the intelligence community and lack of confidence within NSA, the USAF Strategic Air

Command's 544th Reconnaissance Technical Group (RTG) was provided copies of the GRAB/DYNO-1 tapes, thus duplicating processing for backup. SAC processing at this time was primarily visual analysis of the filmed version of the stream of intercept pulses. Late in [redacted]

The ground station program was developing right along with the satellite program. The first change was transfer of the

The fourth launch was from Cape Canaveral on January 24, 1962 using a Thor/Able-Star booster which was intended to launch five satellites into orbit using a single booster. The launch was unsuccessful due to a failure of the guidance system on the Able-Star stage.

The fifth launch on April 26, 1962 was from Vandenberg Air Force Base and used a Scout vehicle as a booster. These changes were made to avoid the dog leg necessary at Cape Canaveral and to provide a dedicated launch vehicle for the satellite. In this way, the orbit most suitable for reconnaissance could be selected. The launch was a failure. The Scout fourth stage had been launched with no attitude control gas and the entire system plunged into the Pacific Ocean within sight of the launch pad. Words: 2299, 4/13/93.

N3DV2.JOC

Chapter 3. The Navy Program (Program C)

3d. The POPPY Project

On July 23, 1962 the Director of the National Reconnaissance Office (DNRO) formally established NRO Program C as an organizational component to continue operation and management of the DYNO Elint satellites. The Director of Naval Intelligence (DNI) was designated to continue as Director, Program C, and funding by the National Reconnaissance Program (NRP) commenced as of Fiscal Year 1963. The Navy Bureau of Weapons (BUWEPS) provided a fiscal representative to the Technical Operating Group (TOG), responsible for preparing the annual budget, disbursing funds to the NRL, and submitting records of expenditures to the Director, Program C. Consolidated Cryptologic Program (CCP) funding was continued for manning and support of mission ground stations, magnetic tape costs, and processing/analysis by NSA. Program A was assigned the responsibility for launching Program C satellites and for launch vehicle/satellite integration.

To perform his mission of translating National Requirements as stated by the United States Intelligence Board into spacecraft commands the DNRO had established a Satellite Operations Center (SOC) in room BD944 of the Pentagon, primarily to direct operations of the photographic satellites of Programs A and B. In order to assure coordination with these requirements, the Director of

Program C transferred Navy Captain Frank Sperberg from the NSG Operations Center at Nebraska Avenue to the NRO offices in the Pentagon to work with the SOC personnel. Sperberg's primary responsibity was to assure that commanding of the POPPY system was responsive to requirements as stated initially by the United States Intelligence Board's Committee on Overhead Reconnaissance (COMOR) and SIGINT Committee. This direction was further clarified in the spring of 1963 when the SIGINT Overhead Reconnaissance Subcommittee (SORS) of the Committee on Overhead Reconnaissance (COMOR) was formed to have sole responsibility for all satellite SIGINT requirements. The Operations Center for translating these instructions into commands to the POPPY network remained at Naval Security Group Headquarters on Nebraska Avenue.

By December, 1962 implementation of the BYEMAN System was completed for Program C, whose ELINT satellites were designated as the POPPY series. The BYEMAN EARPOP compartment, formed by combining Program A's EARDROP with the Program C POPPY, superseded the Walnut security system. The final intelligence product, as delivered by NSA to the users, would be handled under the TALENT-KEYHOLE System which had been initially instituted for photo results. The primary reason for this arrangement was to make it unnecessary for all members of the Intelligence Community to be given access to BYEMAN information about satellites and collection operations.

WORKING PAPERS

~~TOP SECRET~~

With the arrival of the BYEMAN System, mission numbers in the 7100 series were assigned to POPPY launches. A switch to the Thor/Agena booster launched from Vandenberg Air Force Base permitted multiple satellite launches with much greater weight capability. Additionally, no cover payloads were required since there were frequent military Thor/Agena launches from Vandenberg Air Force Base which were not announced in the press except as classified launches about which no details could be revealed.

The initial Program C launch, mission 7101, on 13 December 1962 was the first launch using a Thor/Agena booster from Vandenberg Air Force Base. Unfortunately, the Agena vehicle failed to cut-off at the end of first burn and produced a very elliptical orbit 124 X 1500 nautical miles inclined at 70.3 degrees. This made reception of data at the ground sites difficult and but did produce a satellite lifetime of over [redacted] months.

The objective of the mission was to search parts of [redacted] Bands for new radars and new radio frequency bands in use by the Sino-Soviet Bloc.

The Thor/Agena launched another Van Allen INJUN payload and two other scientific satellites along with the two satellites of mission 7101. The POPPY satellites were somewhat larger than Dyno due to the addition of a four inch diameter "Belly Band" to accomodate additional capabilities, which made the satellites slightly elliptical. The number of receiving bands on 7101 was

~~TOP SECRET~~ HANDLE VIA BYEMAN/TALENT-KEYHOLE/COMINT CONTROL CHANNELS JOINTLY [redacted] per satellite. To accomodate these bands, additional [redacted] were added to the downlink so that pulses from each band were represented by a [redacted] Since the satellites of 7101 [redacted] they were represented by [redacted] on the downlink.

Initially, the frequency coverage was designed to provide some [redacted]

Following the launch of POPPY I, and as a result of the 1963

Page Denied

[redacted]

tape recorder. These recorders had been installed in late 1961 as upgrades to the mission ground stations. The analog tapes were later digitized by AUDICO at NSA using the stable reference tone recorded on the tapes at the time of collection to control the digitizer clock. The digitized data was processed on an [redacted] computer to deinterleave the signals [redacted] of interest were saved for further processing.

Soviet [redacted] early warning radars were selected for original location work because of that radar's stability and because the derived locations could be matched against photo data to validate the location processing. [redacted]

WORKING PAPERS

~~TOP SECRET~~

[redacted]

[redacted]

This highlighted a major problem, which was determining the exact location of the satellite. In the early 1960's, orbit determination programs were very elementary. Vanguard I was placed in a highly elliptical orbit on 17 March 1958 and transmitted its signal for over six years. This stable orbit with constant transmission from the satellite permitted the first long term observation of orbital dynamics. This resulted in a series of sophisticated modeling efforts of the earth's gravity field, which were important for predicting satellite positions vs time. This work was essential to the development of accurate emitter locations.

Papers appeared in many publications in the open literature providing new gravitational constants, new closed form solutions, new estimates of the size and shape of the earth, and many ideas on how atmospheric drag would change the orbits. Bassford Getchell published an article, "Maximum Likelihood Estimation of an Orbit" in 1961. At first, none of the calculated orbital elements were consistent. Orbital elements were available from the Navy Space Surveillance Center (NAVSPASUR) which had been established at Dahlgren, Virginia, on 9 April 1960. The prime responsibility of NAVSPASUR was operating NRL's space surveillance system. North American Air Defense Command (NORAD) also produced orbital elements.

NSA visited [redacted] at Lockheed Missile and Space Company (LMSC) and met with [redacted] to gather information. NSA attempted to use NORAD data but at that time it was frequently incomplete, not timely or, in some cases, inaccurate. As a result, NSA arranged for NAVSPASUR to provide magnetic tapes containing the satellite location and velocity vectors on a regular-time grid. NSA was greatly aided by the NAVSPASUR which provided accurate orbital data.

NSA also prepared the predictions for the POPPY orbits which the Naval Security Group (NSG) sent to the sites to guide the antenna steering.

[redacted] Further details of mission 7101 configuration and operation will be found in Table 1, which includes all the POPPY missions, 7101-7107.

Mission 7102 was very similar to 7101 but covered, in large part, radio frequency bands not covered by 7101, continuing the mission of discovering new radars and frequency band useage.

Launch was on June 15, 1963 from Vandenberg AFB, California. This time, the Agena cut-off after the first burn but failed to circularize the orbit by means of a second burn. The resulting orbit was 95 X 495 nautical miles at an inclination of 69.9 degrees. The low perigee severly limited the orbital lifetime and the satelllites re-entered the atmosphere after 45 days. As a consequence, very little data was collected.

In the meantime, ground station up-grades were continuing and, in 1963, various site facilities were equipped to do field screening and analysis. The POPPY collection positions in the Earth Satellite Vehicle (ESV) portable aluminum shelter huts had a playback capability but limited analysis equipment. However, by 1963 all of the original magnetic tape recorders had been replaced by instrumentation type machines with 7 tracks using 1/2 inch tape. Solid state digital time generators were added. Later on, primary frequency standard oscillators were installed to further improve the accuracy of the time information on the tape recordings.

This led to avancements in the technical analysis of the analog data. As successive satellites were equipped with more RF bands and data links, analysts noted the RF band source of the signals by equating the recorder track and data link "stretched" pulse widths to the logged tasking for the pass.

The new collection tape recorders at the mission ground stations enabled the NSA playback recorder to use a frequency synthesizer to play the tapes at the same speed that they were recorded by the mission ground station during collection by reading the [redacted] reference signal. Other equipment could be used to record and repeatedly cycle through a short segment of data, to stop the recorder and display pulses on the scope, or print a chart of [redacted] versus time. This equipment aided in the measurement of intervals between [redacted]

Some of the sites also had been equipped with a quality-control position installed indoors in secure SIGINT spaces. These quality-control positions were used by collection operators for post-pass playback of recordings to verify verbal annotations, the presence of data, and correspondence with collection logs. With the aid of training tapes sent by NSA, collection operators were trained to listen for and recognize signals with the desired characteristics. The results stimulated the upgrade of the collection systems and the provision of analog analysis positions. Collection operators noted in their logs occurrences of NSA specified signals of high interest as well as new, unique or unidentified signals. After a collection pass, analog analysts played back the tapes at their analysis and quality-control positions and performed aural and visual scans of each of the recorded data links. Parameters of these signals of interest and unidentified signals were measured and tabulated. After verification of the parameters of unidentified signals, leading

WORKING PAPERS

~~TOP SECRET~~

signals analysts prepared a daily signal of interest tip-off report for transmission to NSA and other POPPY sites. This on-line manual analysis produced the earliest possible recognition of targets of opportunity [redacted] These alerts enabled NSA to prioritize the processing and technical analysis of the POPPY data after it was couriered back to NSA for processing.

Additional collection time was provided by the installation of an interogation capability at [redacted] for orbital passes not available from the [redacted] site.

Mission 7103, successfully launched 11 January 1964, achieved a planned near circular orbit, 490 x 506 nm. inclined at 69.9 degrees. This was the first mission boosted by a Thrust Augmented Thor (TAT) permitting heavier and/or more payloads. This was the second three satellite launch with some overlapping RF coverage on 7103 A & B. The axis of 7103C was aligned to within 8 degrees of vertical by means of 2-axis gravity gradient stabilization using a small sphere at the end of an extendable 28 foot boom devised by R. T. Beal of NRL. The sphere contained a magnetic anchor in viscous fluids to damp out librations. With this stabilization system, 7103C achieved approximately three times longer lifetime than the other two satellites. 7103A contained a [redacted] and 7103C had a [redacted] segmenting the [redacted] into five portions, identifying which segment each pulse occupied. These techniques were used in later missions very successfully. Although the 7103C continued to operate a record four years, 7103 A & B lost battery power after 18 months. However, considerable data for [redacted] was collected from the A and B satellites prior to their failure.

Mission 7104, launched 9 March 1965, acheived a 490 x 506 nm. circular orbit inclined 70.1 degrees. This was the first launch of four POPPY satellites. The 24" diameter satellites were launched [redacted] This was limited by the failure of the batteries in 7104B & D after 18 months, although [redacted] were achieved between the remaining satellites at a [redacted] 7104D also had a three axis gravity gradient system using an Eddy current damper to control librations and a micro thruster to maintain satellite spacing. Unfortunately, the satellite stabilized on its side, thereby making it impossible to conduct the micro thruster test. RF coverage was extended without a gap to [redacted] After a satellite commanding capability was installed at [redacted] in March 1966, the [redacted] facility was inactivated.

For these missions, NSA processing was upgraded to exploit the [redacted] and to accommodate the large volumes of data being collected. Figure ___ shows the increasing volume of data to be processed. The earlier manual correlation efforts using mechanical desktop calculators was converted to automatic computer processing. [redacted] This resulted in significantly increased EOB production, accuracy and timeliness.

[redacted]

Efforts by NSA to distribute the increasing processing work load resulted in an agreement with SAC in August 1966, negotiated by Raymond Potts, responsible for NSA processing. Under this agreement NSA processed all POPPY data except for mission 7103C which was assigned to SAC for processing. SAC was also assigned the processing of FANION, a P-11 satellite, described later.

In December 1966, NSA started shifting from its [redacted] business computer to a [redacted] scientific computer which had a [redacted] bit word that could accommodate processing the digital representation of each pulse in one cycle of 1.1 microseconds per pulse. Other technical features such as expanded memory and disk storage made the [redacted] computer between three and four times faster than the [redacted] in processing POPPY data. These features further streamlined processing to reduce manual interventions when the [redacted] was converted to the [redacted] computer. The [redacted] Generally the pulse density was controlled by limiting the sensitivity of the satellite receivers. In general, processing was successful against the circularly scanning Soviet early warning radars. Attempts to relax the acceptance criteria to increase yield resulted in increasing the processing time and in associating bursts from different radars as a group of bursts from one radar, thereby producing aberrations in the location attempt. It was possible to manually review the processing residue in search of signals of interest and unidentified signals not meeting the acceptance criteria, but the sheer volume of tapes processed precluded review of the residue on a routine basis. In 1967, with seven mission ground stations each collecting four to seven passes daily from each of three satellite [redacted] satellite, the weekly analog input to AUDICO for [redacted] already was in the neighborhood of 1000 tapes per week.

Mission 7104 lifetimes from 17 to 52 months permitted the first intercepts of [redacted] in the [redacted] the

The launch of mission 7105 on May 31, 1967 demonstrated that the space and ground technology had come of age. The four satellites were launched into a near perfect 500 x 508 nautical mile orbit inclined at exactly 70.0 degrees! During the almost five year lifetime of this misssion a major advancement in system performance was realized.

The regular up grade process had been given a great boost on 18 November 1966 when the USIB approved an urgent requirement for satellite SIGINT collection directed against Soviet ABM/AES systems (USIB-D-41.14/303), giving this activity the highest priority in the satellite SIGINT program. As a result, the President's

Scientific Advisory Committee (PSAC) had directed modification of mission 7105 six months prior to launch to provide dual coverage of the [redacted] frequency range believed to cover the radio frequencies of the Soviet ABM Systems, plus complete coverage from [redacted] A multi-face design was first used for the B, C, and D satellites increasing their diameter to 27" and average weight to 180 pounds. Two of the satellites used telescoping booms for two axis stabilization, one used additional booms for three axis stabilization, and the last used booms for vertical stability and a flywheel for yaw axis stability. Following this launch, all POPPY satellites used a combination of booms and a flywheel for three axis stabilization. Three axis stabilization was required to assure antenna pointing and to permit micro thrusting to maintain [redacted] Anhydrous ammonia crystals were heated to produce control gas for thrusting, whenever a correction was required. This thrusting system worked so well it was used in all subsequent satellites. Other innovations on 7105 included attitude monitoring for all satellites, [redacted] measurement in any one of ten bands on 7105A, [redacted] measurement in any one of ten bands on 7105B, [redacted] in the [redacted] of 7105D, plus several operational versatility improvements.

In the ground station area, to meet the ABM/AES requirement, an analog to digital conversion system (ADDS) to convert the analog

WORKING PAPERS

downlink data to computer processable digital data was installed at [redacted] in order to allow on site digital processing (see details in processing discussion). Also, by this time a program to move all equipment into permanent facilities was well underway. This included remote control of the antenna installation, adding elevation control, and doubling the number of yagi antennas. Eventually vertical polarization was added to the existing horizontally polarized yagi antennas to improve communication irrespective of satellite orientation. In 1967 the engineering data readout and commanding was moved from Hybla Valley, Virginia [redacted]

The conversion of [redacted] data processing from analog to digital had other far-reaching consequences totally apart from the ABM problem. Because the digital manipulation of the data permitted the development of a [redacted] it appeared that the system could be used to locate and track Soviet ships [redacted]

Starting in 1967, solid state RS-1A receivers, developed at NRL, replaced the R-390A/URR receivers at the mission ground stations for ELINT collection. Each receiver was calibrated to minimize any time delay differences between receiving channels. The "Half Amplitude Threshold" included in the receiver design eliminated all time measurement error associated with amplitude variations in the data stream and in both the Recording and the

Playback systems. This highly stable data was furnished to the ADDS System which tagged each pulse with time to one microsecond and the receiver/channel number which equated to satellite, data link, and pulse width. This significantly reduced time variations in the data when the tape was digitally processed at the station or at NSA. With the high priority of the ABM search requirement, NRL was able to procure an [redacted] computer in three weeks, develop software to conduct ABM search, and deploy this system called CAMS (computer aided manual search) to the site four months prior to the launch of 7105 in May 1967. Mr. F. V. Hellrich of NRL was the architect of the [redacted] computer configuration. Mr. L. M. Hammarstrom of HRB specified the requirements for the initial field [redacted] software. Mr. R. Daniels of HRB developed the initial CAMS algorithms/software. Refinements and additions in the years following were made: by Lt. R. L. Potts, USN and Petty Officer C. [redacted] M. Keebaugh, J Riale, W. Bickam, and R. Daniels of HRB and Ensign L. A. Eichel at [redacted] Although originally these listings required manual analysis to determine the actual radar characteristics and location, by 1969 the routines had been automated by HRB-Singer so that they could be selected on demand.

This on-site computer-aided manual analysis system was installed in [redacted] in April 1969 and [redacted] in late 1970. Processing results were reported electrically to NSA and to consumers with major emphasis on [redacted] signals. NSA in-turn reported them electrically as preliminary ELINT technical reports (ELTs) to the intelligence community.

[redacted]

With the rapidly increasing volume of POPPY satellite data to be processed, NSA adjusted processing in 1967 to have several of the Navy ground stations do on-site screening of collected data and reporting results to NSA, forwarding only those tapes of special interest to NSA for technical analysis. Since several ground stations collected the same data, only tapes from the station with the best coverage were forwarded for location by machine processing. NSA identified in advance which POPPY site had the best intercept geometry for location processing. The site with the best geometry was notified which tape to forward for location processing. NSA also requested all POPPY tapes collected at the same time that other collectors intercepted signals of interest or when a high interest event took place. Recordings not forwarded were retained for 90 days and re-used unless requested by NSA for analysis. By this time the POPPY location system at NSA had been validated. The system was basically an all automatic computer process that was producing volume locations to about a [redacted] accuracy on a routine basis.

This Mission, 7105 and FACADE, Mission 7321, provided the

[redacted]

WORKING PAPERS

~~TOP SECRET~~

[redacted]

A number of special tasks were levied on mission ground stations to exploit new overhead capabilities. In August, 1967, NSG requested NSG mission ground stations to identify and report on a not-to-interfere basis, the details of intercepts of Soviet shipborne radars [redacted] located the first Soviet shipborne radar in [redacted] locations began in June, the first was a [redacted] radar illuminating 7105 C and D with three bursts over a 10-second period. In August, the timeliness potential was demonstrated by electrically reporting the Black Sea location [redacted] radar [redacted] after the beginning of the intercept. Other collectable Soviet shipborne radars were processed, analyzed and located on a not-to-interfere basis sufficiently often to show feasibility and establish processing techniques. However, the major emphasis was placed on the radars which could be correlated to ship platforms.

In July 1969 NSG obtained authorization and directed [redacted]

~~TOP SECRET~~

to use suitably tasked passes and ordinarily untasked fringe passes to locate and report elements of a Soviet North Atlantic naval surface force consisting of three warships equipped with surface-to-air missile systems. This effort was greatly enhanced by the [redacted] and first demonstrated in August 1968 when a Soviet [redacted] intercept was [redacted]

[redacted] By September 1969, NSG was able to report to Naval Intelligence Command (NIC) that POPPY derived Soviet shipborne emitter reports had established the potential capability of POPPY against naval targets. In spite of limited collection opportunities (satellite tasking optimized for general search), the POPPY mission ground stations reported an average of 150 shipborne intercepts per month.

Mission 7106 was launched on 30 September 1969 into a 491x506 nautical mile orbit with an inclination of 70.0 degrees. It consisted of four multi-face satellites with 82 bands weighing an average of 235 pounds each. Five other scientific satellites were also launched. The bands were arranged so that by proper tasking, entire weapon system complexes of emitters could be intercepted simultaneously. [redacted]

[redacted] was used on the telemetry links for the first time. Satellites 7106 B and D failed a few months after launch on 25 February 1970, thereby eliminating [redacted] coverage in [redacted] Low band coverage for ABM, early warning, and shipborne air search radars continued until the end of life at 28 months on 28 January 1972.

Four transponded pulse widths were used on each data link thereby doubling the collection capability. By this time, [redacted] had been closed, concluding the participation of the Air Force Security Service in the POPPY Program. This left five improved ground stations in the network: [redacted]

On 27 August 1969 the SIGINT Overhead Reconnaissance Subcommittee (SORS) responding to the Chief of Naval Operations (CNO) made ocean surveillance an official function of POPPY in SORS 10./96, BYE-1565-69, "Mission Guidance 7106", 27 Aug 69. NSG directed [redacted] in July 1970 to begin producing [redacted] to U.S. Navy fleet commanders.

Mission 7107 was launched on 14 December 1971 into a nearly circular 530x540 nautical mile orbit, inclined 70.0 degrees. It was to be the last POPPY launch and consisted of 4 multi-faced satellites weighing 270-280 pounds each containing a total of [redacted]

[redacted]

In July 1970 authority was granted by USIB for the general employment of on-going Missions 7105 and 7106 to engage in ocean surveillance in support of U.S. fleet commanders. Specifics of this mission were stated by COMNAVINTCOM in August 1970. By this time USIB mission guidance added search for new or unusual emitters in frequencies other that the [redacted] which might be associated with ABM [redacted] Also, in January 1970 an EOB production requirement had been added. Two new ground stations were added at [redacted] to enhance European collection, and [redacted] was closed, concluding the participation of the Army Security Agency in the POPPY Program.

NSA had added a [redacted] computer in 1968 to be used full time with the [redacted] computer to handle the increased vulume of POPPY data being collected. Mission 7106 produced 8200 locations in the first 15 months, many new/ unidentified signals reports were issued and technical measurements were made. During the first five months information was developed by NSA analysts on the [redacted] NSA analysts refined the [redacted] made by all four Mission 7106 satellites orbiting at fairly close [redacted] This data enabled [redacted] to analyze and report on the [redacted] The 8200 NSA machine processed EOB locations had accuracies of [redacted] or less.

The [redacted] Intercept Site, using POPPY during May & June 1970, located and reported 22 intercepts of two [redacted] carried [redacted]

When directed by NSG in July 1970, [redacted] began reporting [redacted] to U. S. Navy commanders. The [redacted] initially provided only intercept time, location coordinates, and platform identification, when known. The format was modified in June, 1972 to include PRF and [redacted] In September, 1971, CINCPACFLT recognized that [redacted] had established the [redacted] as a full fledged source of ocean surveillance information in the Pacific. This recognized the importance of POPPY as a valuable source at a time when conventional coverage was decreasing.

On 14 January 1971, the Navy Space Project Office was established as PM-16 of the Naval Marterial Command. The Manager, Navy Space Project (PM-16) was designated as the Director, Program C. POPPY Project director functions were performed within the System Project Office (SPO) of PM-16. In June, 1973, PM-16 was redesignated PME-106 of the Naval Electronic Systems Command with its manager continuing as Director, Program C. Coordination continued with the Naval Intelligence Command and NRL continued to be responsible for technical development.

[redacted]

[redacted]

[redacted]

On 2 August 1977, the Director Program C directed the cessation of the last POPPY mission, 7107. On 30 September 1977, DNRO directed termination of the POPPY program [redacted]

WORKING PAPERS

[redacted] but much of POPPY's elegant simplicity is unlikely to be duplicated in any future programs. It will be remembered as the <u>only</u> satellite reconnaissance program to be conceived, designed, constructed, and operated by government personnel both military and civilian. [redacted]

POPPY's strengths stemmed from its utilization of traditional concepts and methods and an insistence on proven hardware and techniques not only to guarantee success but also to hold costs to a bare minimum. Between 1959 and 1977, the entire program spent only [redacted] exclusive of launch and Consolidated Cryptologic Program (CCP) costs. It utilized existing personnel and facilities whenever it was reasonably possible, and although innovative in many ways, the designers added only those improvements that involved minimal risk to the program. It grew from a single satellite with limited capability to a sophisticated four satellite system capable of Ocean Surveillance, search [redacted] as well as a continual up-date of the EOB and parametric signal characteristics. This low cost success story is not likely to be duplicated.

This account of the POPPY Program is intended to introduce the reader to the highlights of the program. A more complete description will be found in, "HISTORY OF THE POPPY SATELLITE PROGRAM", BYE 56105-78 which should be available through the NRO. Word Count: 6616. 4/13/93 16:00.