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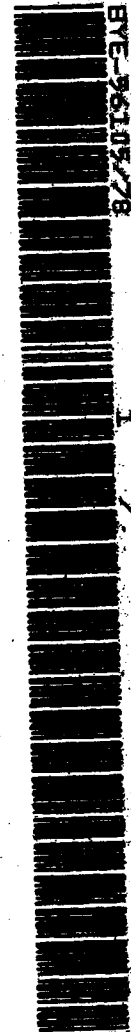
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HISTORY OF THE POPPY SATELLITE SYSTEM



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6 June 2012



HISTORY OF THE POPPY SATELLITE SYSTEM

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FOREWORD

This report describes the history of the POPPY project from its concept in 1958 through its termination on 30 September 1977. This history was compiled at the request of the Director, National Reconnaissance Office to the Director, Program C. Included in this report are the significant events during the nineteen years of the POPPY project, including the development and refinement of POPPY satellites, mission ground stations, ground readout equipment, analog analysis, and data processing. The impact of failures, problems and anomalies are evaluated. Successes of the POPPY project are measured against program objectives. Technical data, cost history, key contributions, a glossary of terms related to the POPPY project, and a bibliography are contained in annexes to the report.

Each of the chapters in the report is intended to be somewhat self-contained. Annex 1 contains a summary of mission characteristics and merges some information from the third through the seventh chapters in order to provide a chronological summary of the technological innovations in the order of the launches.

6 June 2012

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I. CONCEPTION

During the second world war, lookouts on German submarines used a hand-held crystal video type radar receiver named ATHOSS to detect pulses emitted from search radar on allied warships and airplanes. This simple passive electronic countermeasure receiver enabled evasion before range had closed sufficiently for returning radar echoes to indicate the presence of the submarine to the searching warship or airplane. After the war, crystal video receiver technology was applied in the direction finding systems for use on American warships and airplanes because of its simplicity, its small size and wide open frequency detection characteristics. By the late fifties, a crystal video receiver was being fitted to type 8-A submarine periscope; the first three receiver prototypes were developed by the Naval Research Laboratory (NRL) in late 1957.

On 4 October 1957, the Union of Soviet Socialist Republics (U.S.S.R.) launched the first artificial satellite as part of the thirty-month International Geophysical Year. Thirty days later, the second Sputnik was launched with a live dog as a passenger.

About one month later on 6 December 1957, with the whole nation watching on National television, the United States (U.S.) attempted its first satellite launch on a totally new sophisticated Vanguard missile. The payload was the grapefruit sized Vanguard satellite - weighing three pounds. The missile lost thrust after 2 seconds and crashed in a huge ball of flames. The tiny satellite fell out of the nose fairing and rolled away. Its antennas were bent and broken and charred black from the fire - yet it was still transmitting its signal. This national embarrassment triggered a number of things. The immediate results were a presidential decision to task the Army team, under Dr. Wernher von Braun at the Redstone Arsenal, to launch a satellite on the existing ICBM called Jupiter C. Fortunately, these efforts did meet with success and on 31 January 1958, the U.S. placed its first satellite, Explorer I, in orbit. This satellite discovered the Van Allen belt. The Navy Vanguard team succeeded on Saint Patrick's Day, 17 March 1958, by placing Vanguard I in a highly elliptical orbit. This satellite, powered by solar cells, 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 the discovery of the "pear-shaped earth" and initiated a series of sophisticated modeling efforts of the earth's gravity field which is so important for predicting satellite positions vs time and for ballistic missile accuracy.

But the Vanguard initial failure also had other longer range effects. It caused the nation to re-evaluate its position in the newly arrived space age. We felt threatened in that we seemed to be falling behind in this new high technology area. A frantic call went out to better educate more engineers and scientists in our colleges and universities. The gauntlet had been laid down and America would

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respond with a tremendous effort and close that gap. In retrospect the Vanguard program with its spectacular failure but subsequent success and its tremendous technology advances may have been the best thing that could have happened to the infant U.S. space program.

Also, of much more specific value to the Navy was the fact that Vanguard had developed a technology base in satellite design at NRL which formed the foundation for the subsequent POPPY program.

These first space exploration successes stimulated the Advanced Research Projects Agency (ARPA) to solicit other DOD elements for proposals for space related projects. The Chief of Naval Operations (CNO) relayed the query to Navy scientific and technical organizations by asking, "All hands to consider how they could use space in their design ideas for the Navy."

NRL responded to the CNO query with the proposal to launch a satellite into a 500 NM circular orbit. The satellite would be equipped with an S band crystal-video receiver to detect signals of sufficient power density and would use an uncoded radar beacon to transpond them (pulse-for-pulse) down to cooperative ground stations for recording and subsequent analysis. The proposal was reviewed and approved through the Navy and DOD and was approved by the President in August 1959 as Project TATTLETALE.

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by the President and to a presidential order to tighten security. A special security system was then established by the Office of Naval Intelligence (ONI). 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.

NRL developed the concept and designed the ELINT satellite and ground readout equipment which was continued as the top secret Project Walnut. 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 radiations above the earth's atmosphere. This cover experiment became the first of a series of SOLRAD satellite experiments designed and exploited by the Naval Research Laboratory. The cover name GRAE (Galactic Radiation and Background) was used for the intelligence and scientific satellite.

With the first launch pending, new importance was added to the project after the crash of a U-2 high-altitude reconnaissance aircraft in the U.S.S.R. on 1 May 1960. Subsequent cancellation of routine U-2 overflights ended the capability for deep interior surveillance of the U.S.S.R. Future overhead surveillance missions would require presidential approval.

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The first U.S. and reconnaissance satellite (photo or SIGINT) to become operational was successfully launched on 22 June 1960 from Cape Canaveral, Florida aboard a Thor-Able-Star. GRAB/Dyno 1, as this ELINT satellite was named, shared the launch vehicle with Transit 2A, the Navy's second navigation satellite. The purpose of the ELINT package, designated Dyno 1, was to collect ELINT data from the interior and infrequently covered maritime regions of the U.S.S.R. ELINT data is transponded by the Dyno 1 for a forty-minute period after interrogation. The mission ground station equipment was operated only when Dyno satellites were transmitting above their radio horizon; recorded data from the down link(s) on magnetic tape; and forwarded data recordings with collection logs to NSA via the Armed Forces Courier Service (ARFCOS).

The ELINT capability of Dyno 1 was successfully tested on 4 July 1960 at Wahiawa, Hawaii, well out of Soviet range. Tense political climate following the U-2 incident dictated that this satellite would be tasked only by specific presidential authority. Thus only 22 data collection passes across the SINO Soviet bloc were collected and processed during the three month useful lifetime of the GRAB/Dyno 1 satellite.

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6 June 2012II. ORGANIZATION

Throughout its lifetime the POPPY project was managed, operated and supported by a number of DOD elements under overall Navy leadership. There were two distinct phases of organization, pre-NRO and the reorganization following establishment of the NRO in 1962. During both of these phases, multi-agency activities were coordinated by means of a Technical Operations Group (TOG).

A. PRE-NRO

Directorship of Project GRAB/Dyno (see Annex 3) was assigned to the Director of Naval Intelligence (DNI). The TOG acted as the steering committee or staff of the project director. The TOG members were drawn from designated DOD organizations and the National Security Agency (NSA). The participating organizations, their responsibilities, and the staff responsibilities of their representatives to the TOG were specified by the DNI.

1. The NRL developed the overall system concept; designed, constructed, deployed, and logistically supported electronic receiving, recording, and timing equipment at mission ground stations; designed, fabricated, tested, and calibrated the satellite systems from concept through launch injection into orbit, and provided engineering and technical direction through the operational exploitation phase; trained mission ground station personnel; controlled the satellite prior to launch; monitored the launch; and monitored on-orbit performance of the satellite. The NRL member of the TOG was designated as the project technical representative/project manager until January 1971.

2. The Naval Security Group (NSG) directed and coordinated all mission ground station operations; acted as the focal point for all electrical communications associated with the operations of the project; provided sites, support facilities and operating and maintenance personnel at the [redacted] NSG mission ground stations. The NSG member of the TOG was designated as the project operational representative.

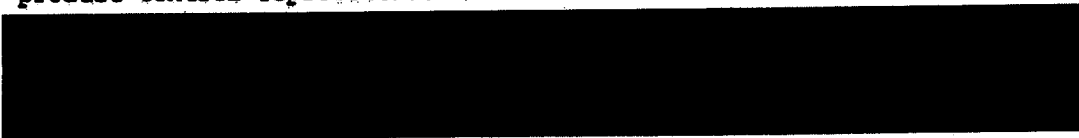
3. The NSA authorized the allocation of service cryptologic personnel to man and operate the mission ground stations; processed all ELINT data recordings and disseminated the ELINT product; interpreted national intelligence collection and processing requirements and made tasking recommendations; and furnished the magnetic tapes for recording data at the mission ground stations. The NSA representative to the TOG was designated as an advisor to the staff.

4. The DNI had the authority to review and approve all aspects of the project. The Scientific and Technical Intelligence Center of ONI (STIC) provided intelligence requirements to the director; provided signal analysis support to NSA; monitored the signal analysis

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program; and disseminated quality control technical data to mission ground stations. The STIC member of the TOG was designated as the product control representative.



6. As of 1962, the Army Security Agency (ASA) provided a site, support facilities and operating and maintenance personnel at the ASA mission ground station.

7. The sites where dedicated GRAB/Dyno collection and processing and spacecraft commanding systems were installed in the pre-NRO period are as follows:

SITE	FUNCTION
[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]
ADAK, ALASKA	[REDACTED]
HYBLA VALLEY VIRGINIA (Engineering Ground Station).	[REDACTED]
WAHIAWA, HAWAII	[REDACTED]

B. NRO PROGRAM C

Upon consolidation of all U.S. overhead reconnaissance projects into a National Reconnaissance Program (NRP) in 1962, DNRO established NRO Program C as the organizational component to continue operation and management of the Dyno satellites. By December 1962, the Byeman

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Control System was implemented throughout the project to govern security procedures. Byeman Project [redacted] replaced the Project Walnut security clearance. The satellites became designated as POPPY satellites, and subsequent launches would receive NRO mission numbers in the [redacted] series. The DNRO reviewed the organization and responsibilities within Program C as proposed by the DNI in the time frame July 1962 through January 1963. The following changes and additions to organizational responsibilities were implemented:

1. The NRO provided funding to support Program C based on annual program budget submissions by NRL beginning with fiscal year 1963. The Consolidated Cryptologic Program (CCP) continued to support mission ground station personnel, magnetic tape, and data processing.
2. The DNI became designated as Director, Program C. The ONI provided a POPPY project director responsible for supervising and administering all aspects of the project subject to the approval of Director, Program C.
3. The NRO Deputy Director for Operations prepared routine tasking schedules for the operational control of POPPY satellites with technical support from the TOG. Routine tasking was directed by the NRO Satellite Operations Center (SOC) through NSG. NSA directed quick reaction tasking of POPPY satellites through NSG following tip-off of Soviet space or missile activity:
4. Program A of the NRP provided the launch vehicle, launch vehicle/satellite integration, and launch services. The NRO separately funded this support.
5. The Naval Research Laboratory was designated the technical director responsible for design, development, and operational support.

C. LATER CHANGES

Program C and the POPPY project organization functioned in the same general manner as established under the NRO for the next fourteen years. Changes subsequent to 1963 were the result of realignments within the Navy, changes in capabilities leading to added responsibilities, and changes in participation. Significant changes and associated factors were the following:

1. Starting in April 1963, the requirement for detecting, electrically reporting and logging new and unusual signals was added to the responsibility of mission ground stations. The resulting on-line manual analysis produced the earliest possible recognition of [redacted] resources for exploitation [redacted] after it was couriered back to CONUS for processing. Various site facilities were upgraded

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and changes made to the satellite designs in order to enhance the detection and recognition of the new emitters as they were added to the Soviet radar inventory during their rapid build-up during the 1960's. These Soviet radar changes started with original designs in the landbased early warning [REDACTED]

almost all of which were initially detected [REDACTED] gained from POPPY.

2. In 1967, ONI became redesignated as the Naval Intelligence Command (NIC). COMNAVINICOM retained the responsibility of Director, Program C.

3. In response to the 1966 Presidents Scientific Advisory panel's urgent request to exploit overhead reconnaissance to determine if the Soviet Union was developing an antiballistic missile radar system the program site in [REDACTED] was equipped with analog-to-digital data conversion and a small data processing computer. This on-site computer-aided manual analysis system was installed in [REDACTED] and Adak, Alaska in late 1970. [REDACTED]

4. AFSS participation ended in October 1969 with the closure of its last POPPY mission ground station at [REDACTED]

5. ASA participation ended in August 1970 with the closure of its POPPY mission ground station at [REDACTED]

6. On 14 January 1971, the Navy Space Project Office was established as FM-16 of the Naval Material Command. The Manager, Navy Space Project (FM-16) was designated as the Director, Program C. POPPY project director functions were performed within the System Project Office (SPO) of FM-16. Liaison with NIC continued.

7. In June 1973, FM-16 was redesignated as PME-106 of the Naval Electronic Systems Command with its manager continuing as Director, Program C.

8. [REDACTED]

9. On 2 August 1977, the Director, Program C directed cessation of the POPPY Mission [REDACTED] operations. However, the Engineering ground station at [REDACTED] continues to perform power management activities to sustain spacecraft operational capability.

10. On 30 September 1977, DNRO directed termination of the POPPY program as the [REDACTED]

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III. SATELLITES

All of the GRAB/Dyno ELINT satellites contained scientific cover experiments of the SOLRAD type. Engineering evolution and innovative refinement of the spacecraft and ground station subsystems were continued by NRL in the POPPY program following the transition from GRAB/Dyno to POPPY. The satellites were designed for long-life high-duty cycle operation. All satellites were designed for full utilization any time a satellite was in view of a ground station. Eight satellites provided useful intelligence for periods in excess of [REDACTED]

[REDACTED] This combination provided a very efficient low-cost satellite system which continuously had [REDACTED] operating satellites on-orbit from 1963 until 1977 when the program was terminated.

A. CLUSTER SIZE

The GRAB/Dyno satellites were launched pickaback with other scientific and navigation satellites. Two of the five attempts to orbit Dyno satellites were successful. The first POPPY launch Mission [REDACTED] orbited a pair of ELINT satellites. The next two launches orbited POPPY [REDACTED]. Each of the final four launches carried [REDACTED] satellites [REDACTED]

B. ORBITAL CHARACTERISTICS

[REDACTED]

C. PHYSICAL CHARACTERISTICS

The GRAB/Dyno satellites were of spherical configuration with a diameter of 20 inches. The first Dyno spacecraft weighed 42 pounds; later Dyno spacecraft weighed up to 55 pounds.

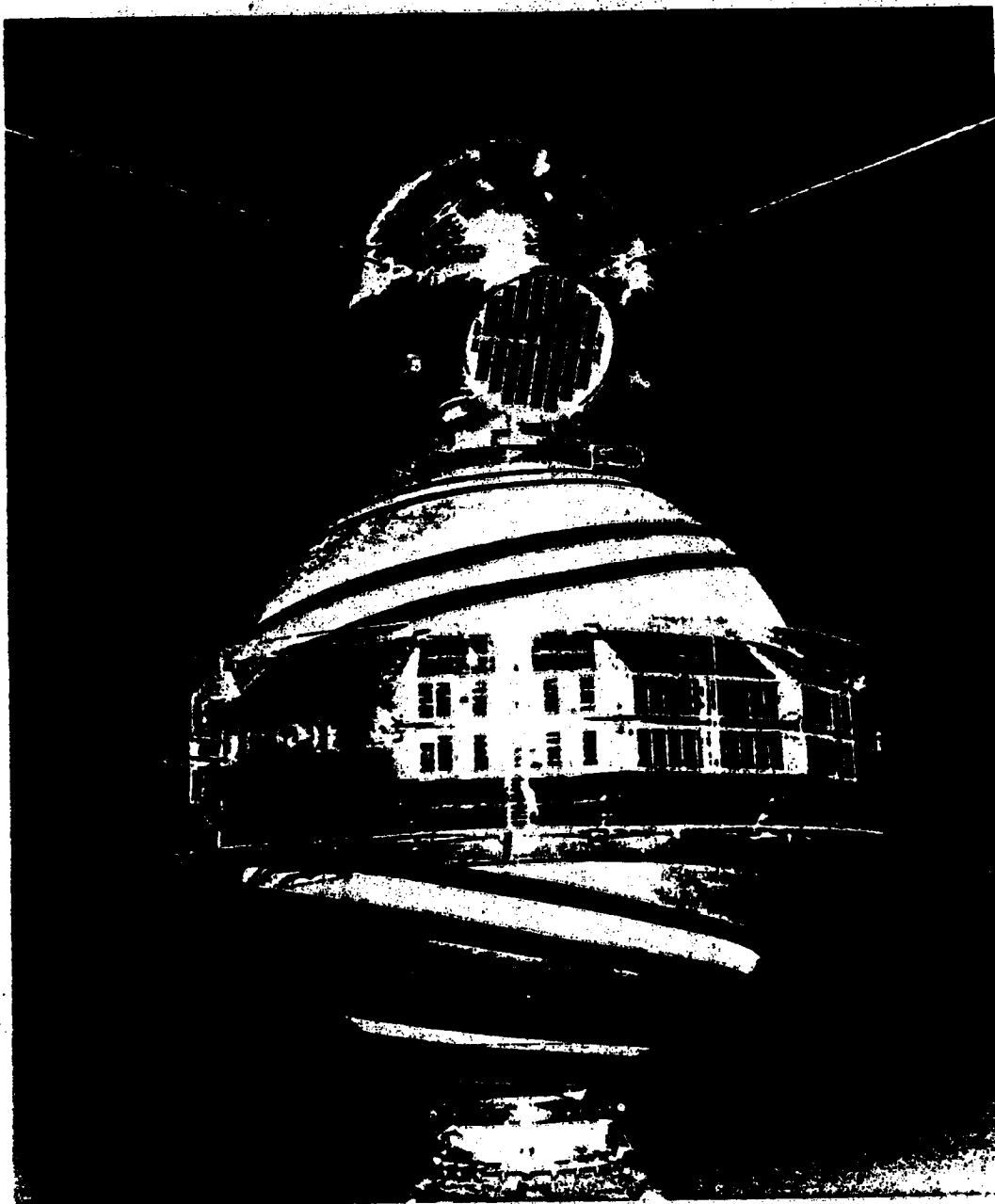
In the first POPPY launch, both of the satellites were composed of two 20-inch diameter hemispheres joined by a 4-inch wide equatorial band. The stretched sphere design was used for all satellites in the next three launches, either with 20-inch or 24-inch diameter configurations. These satellites weighed between 55 and 130 pounds.

The multiface design was first used on Mission [REDACTED] in 1967, three of the four satellites being multiface. The fourth was a

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First U.S. SIGINT Satellite,
GRAB/Dyno 1 mounted above TRANSIT 2A

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stretched sphere with a 9-inch equatorial band. The multiface satellite measured 27-inch diameter across flats at its 12-sided equator. Spacecraft equatorial bands varied in size to accommodate the increase in size and number of electronic and mechanical components necessary to satisfy the increasing mission requirements. The basic multiface structure was utilized on all POPPY satellites after Mission [REDACTED]. The weights of the multiface satellites ranged from 162 to 282 pounds.

D. POWER

The first Dyno satellite was powered from a 12-volt storage battery consisting of nine D size cells in series. The battery was charged by silicon solar cells and was designed to provide useful life of one year in orbit. Six 9-inch diameter round patches of 156 cells were symmetrically located on the surface of the sphere so that approximately one watt of power would be available for any orientation of the satellite. In full sun, a single patch could provide about two watts of charging power to the chemical storage battery. From Dyno 2 onward, +12-volt and -12-volt storage batteries were included.

In the 24-inch diameter satellites, more solar cells of smaller size were placed on 11-inch diameter panels. The six symmetrically placed panels provided about four watts of charging power to an 18-cell, nickel-cadmium battery pack. (NOTE: 9-inch diameter solar panels were used with the 20-inch diameter satellite and 11-inch diameters with the 24-inch satellite.)

E. TELEMETRY

The satellites continuously telemetered engineering data on the housekeeping condition of the satellite and status of the command of the ELINT collection receivers and options. [REDACTED]

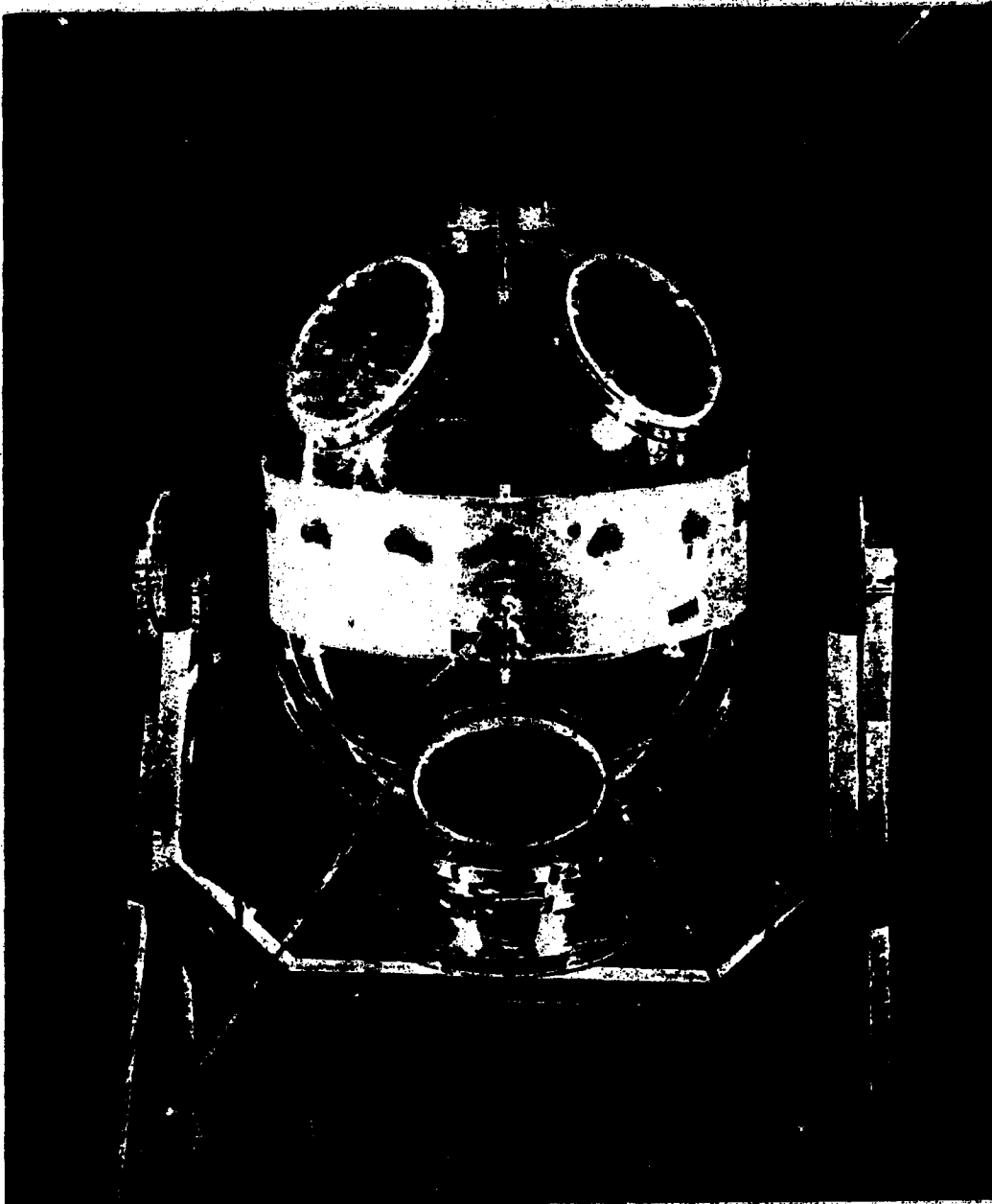
[REDACTED]. Satellite engineering data such as battery voltage, temperatures, etc. were sampled by the [REDACTED] commutator. Discrete or command status indicators were binarily encoded and monitored by the [REDACTED] commutator.

From 1969 onward, the satellites were equipped with a [REDACTED] telemetry subsystem in order to improve the speed and reliability of telemetry readout using a [REDACTED] display at the mission ground stations.

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Typical 24" Diameter Spherical Satellite
with 9" high Equatorial Band

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The first GRAB/Dyno satellites transmitted telemetry signals at 108 MHz. In later years, frequencies in the neighborhood of 137 MHz were used to avoid interfering signals.

In the spheres and stretched spheres, the power output of both the telemetry transmitter and the ELINT data transmitter(s) was fed into a single omni-directional, 4-element turnstile array. The same antenna served for reception of the command signals. The multifaces used two such turnstile arrays, one for command reception and telemetry transmission, the second for ELINT data transmissions.

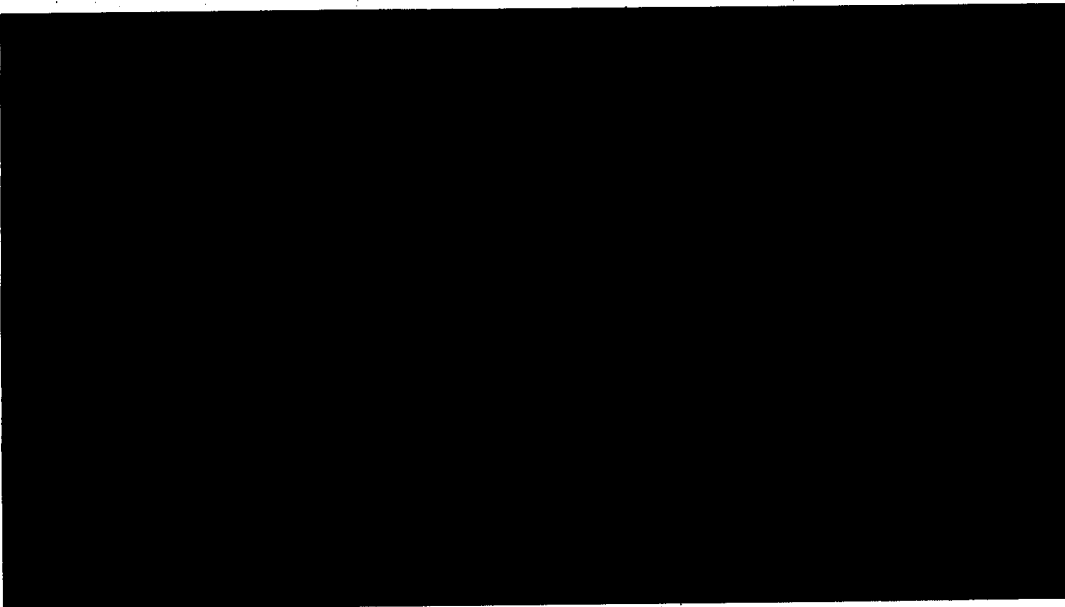
F. COMMAND

The command receiver in the GRAB/Dyno satellite was adapted from the system used with Vanguard. ~~_____~~

~~_____~~ The receiver was a double superheterodyne with crystal control on both the first and second oscillators to provide stability. Audio amplification of the proper tone activated the corresponding relay switches to turn on the data link transmitter and one of the two timers and to turn off telemetry at the end of useful life.

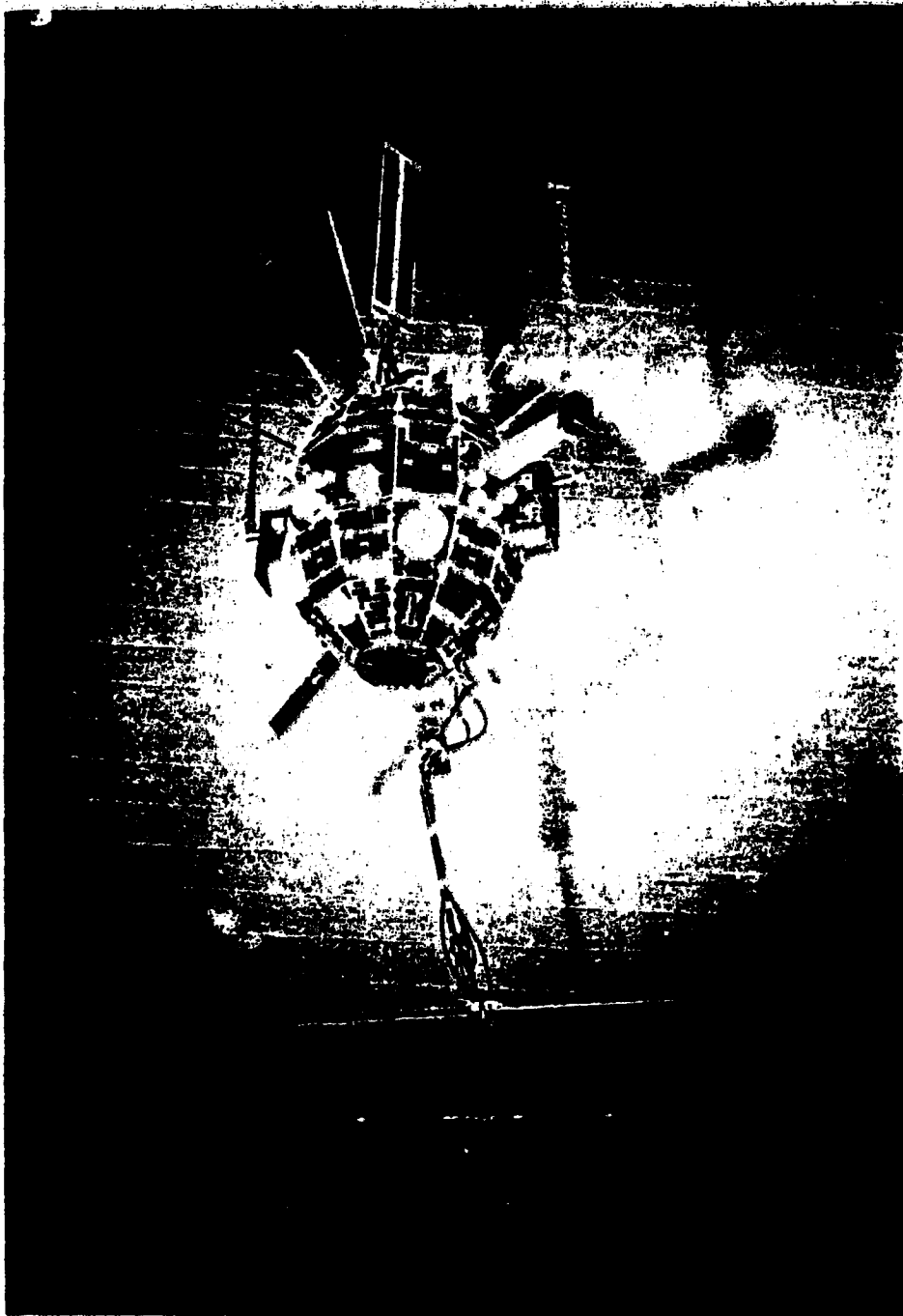
As command options increased to include more data receivers, data links, experiments, station keeping devices, etc. the basic command system was expanded from a simple tone system to a tone digital system utilizing ten frequency tones allowing over a hundred commands.

G. ELINT COLLECTION



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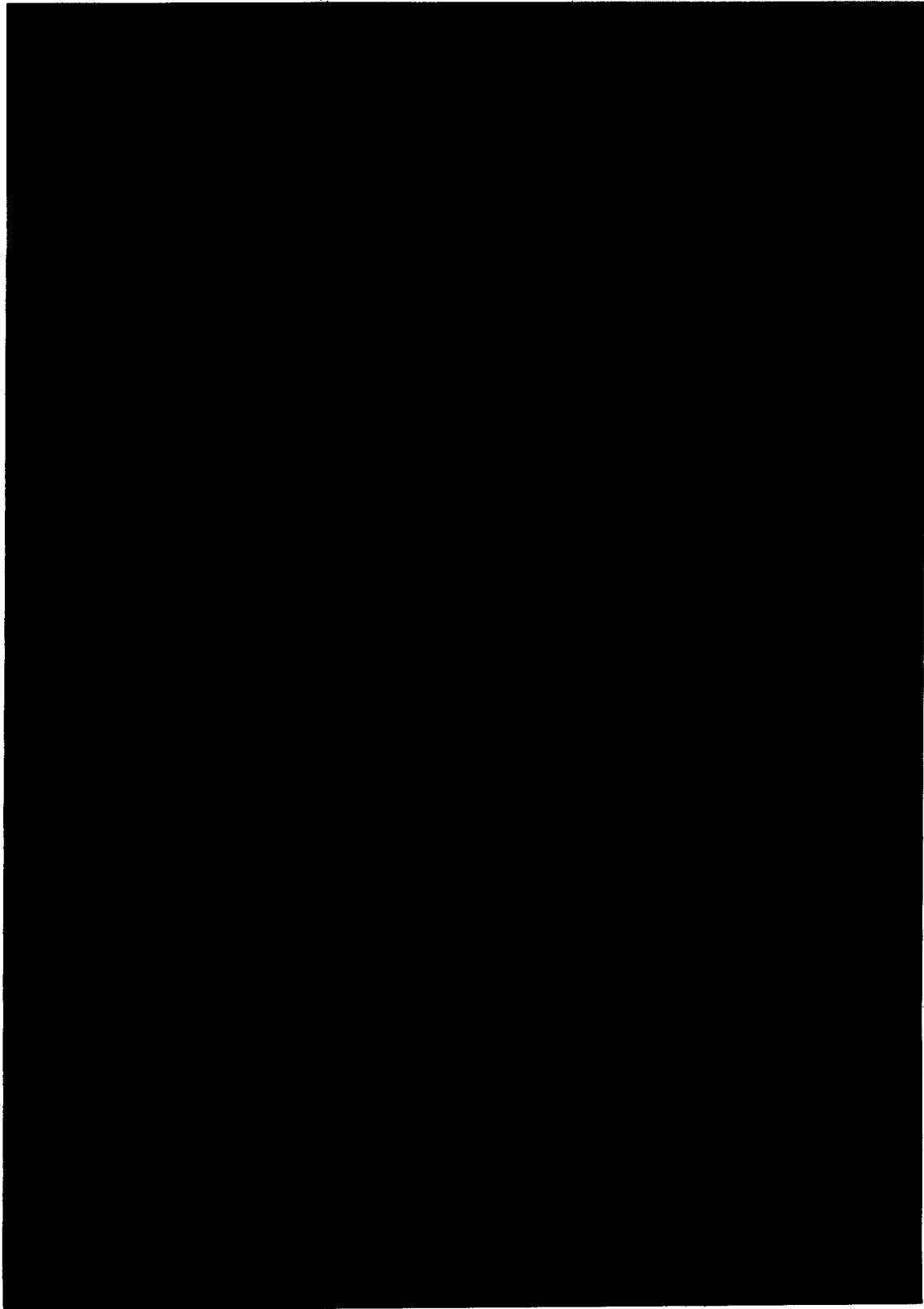


Typical 27" Multifacé Satellite
Mission [REDACTED]

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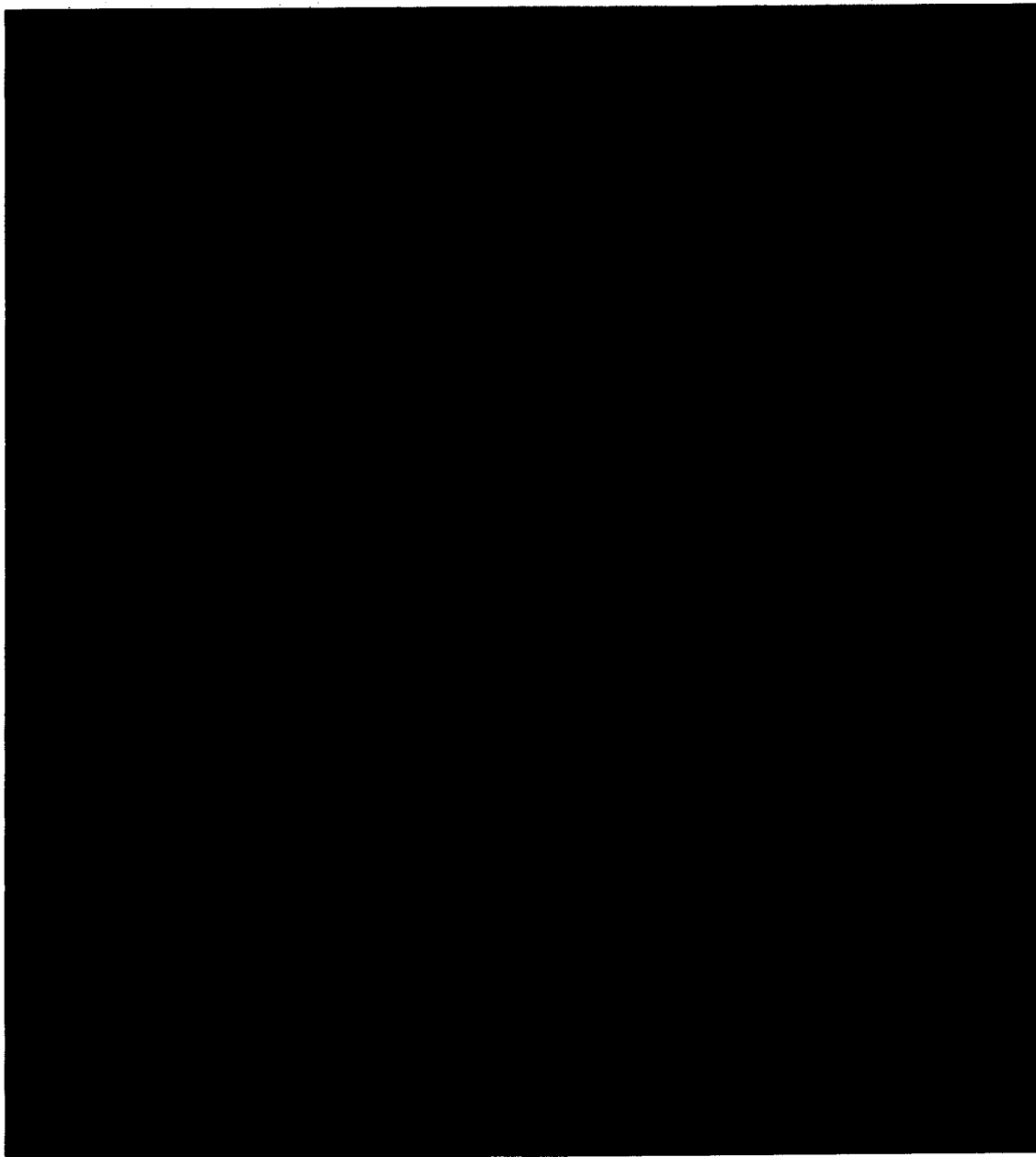
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H. ATTITUDE STABILIZATION AND STATION KEEPING

With refinements in the employment and placement of new directional antenna types, the orientation of the vertical axis of the satellites became a factor affecting performance. Satellites which tumbled or orbited upside down or sideways did not orient their ELINT antennas to produce optimum coverage in azimuth. To overcome this problem, a Gravity Gradient Stabilization Experiment (GGSE) was implemented in the eighth launch (Mission [REDACTED]). One satellite was

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fitted with an extendable 28-foot boom. A tip mass at the end of the boom

This 2-axis gravity gradient stabilization experiment succeeded in aligning the satellite's axis to within degrees of the local vertical and consumed no on-board power.

Gravity Gradient Stabilization was also implemented in Mission including 2-axis gravity gradient and 3-axis gravity gradient with two additional booms to provide yaw stabilization. In Mission two satellites were equipped with 2-axis gravity gradient stabilization, and two were equipped with the 3-axis system. One of the 3-axis stabilized satellites used additional booms; the other used a flywheel to provide active stabilization of the yaw axis. All satellites launched thereafter used the 3-axis, active system employing a single boom and flywheel.

Anhydrous ammonia was successfully used as the microthrust gas in one satellite in 1967 and in all satellites launched thereafter.

Three axis stabilization was a necessary prerequisite to the station keeping capability.

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IV. MISSION GROUND STATIONS

[REDACTED]

In addition, NRL operated an engineering data readout and interrogation site at Hybla Valley, Virginia until July 1967, when it was relocated to [REDACTED]

[REDACTED]

The [REDACTED] operation was relocated to Adak Island after Dyno 1 due to local interference [REDACTED] 1962 to preserve operational security. Due to the scheduled closure of the SIGINT station at [REDACTED] a mission ground station was established at [REDACTED] in 1962.

[REDACTED]

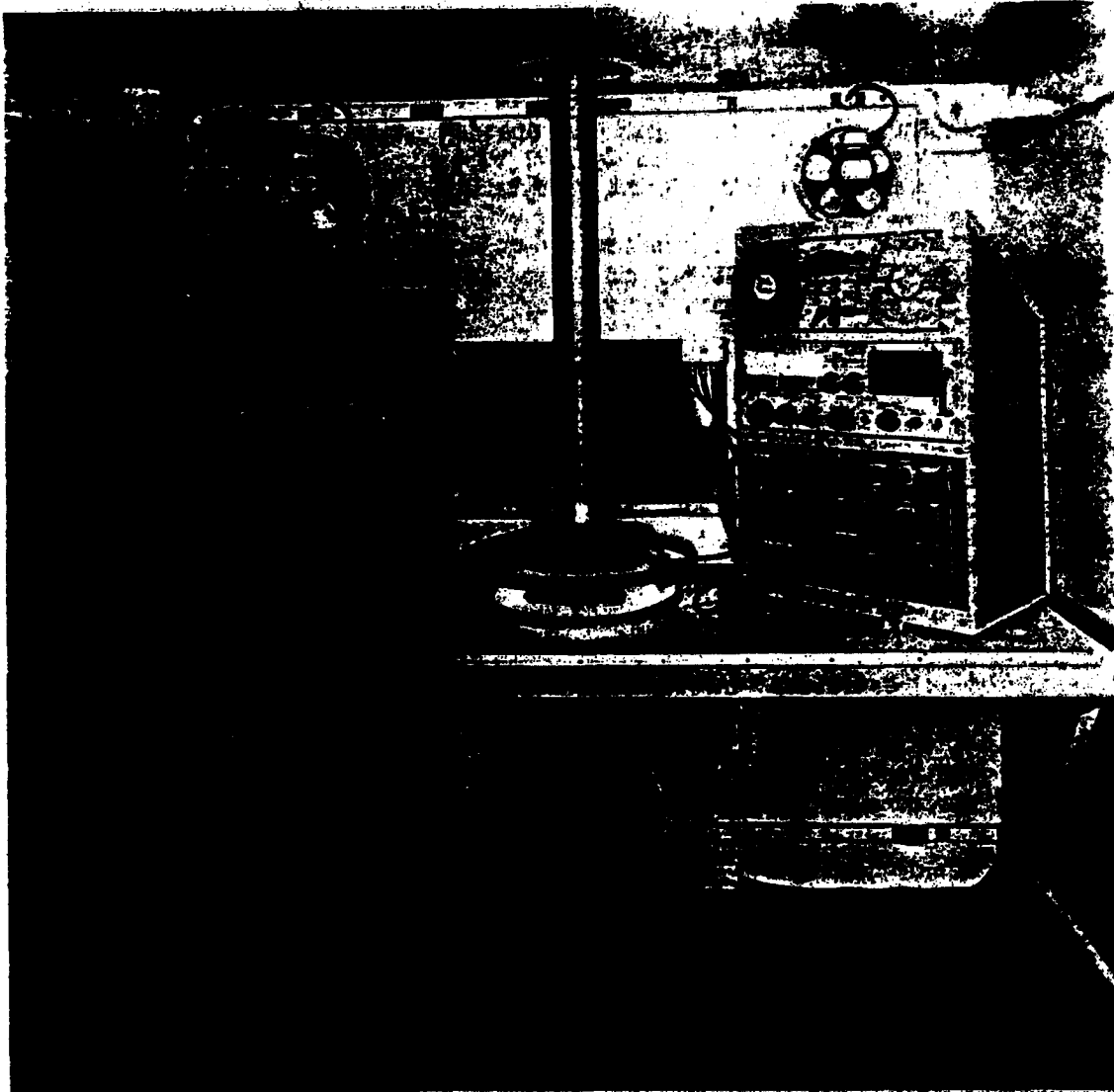
Adak was the only one of the GRAB stations to continue POPPY operations until project termination. Adak [REDACTED] ceased POPPY operations in August 1977.

During the initial operations collections were conducted in Earth Satellite Vehicle (ESV) shelter huts. After the system stabilized in the sixties, the transition was made to permanent buildings.

A. ESV HUTS

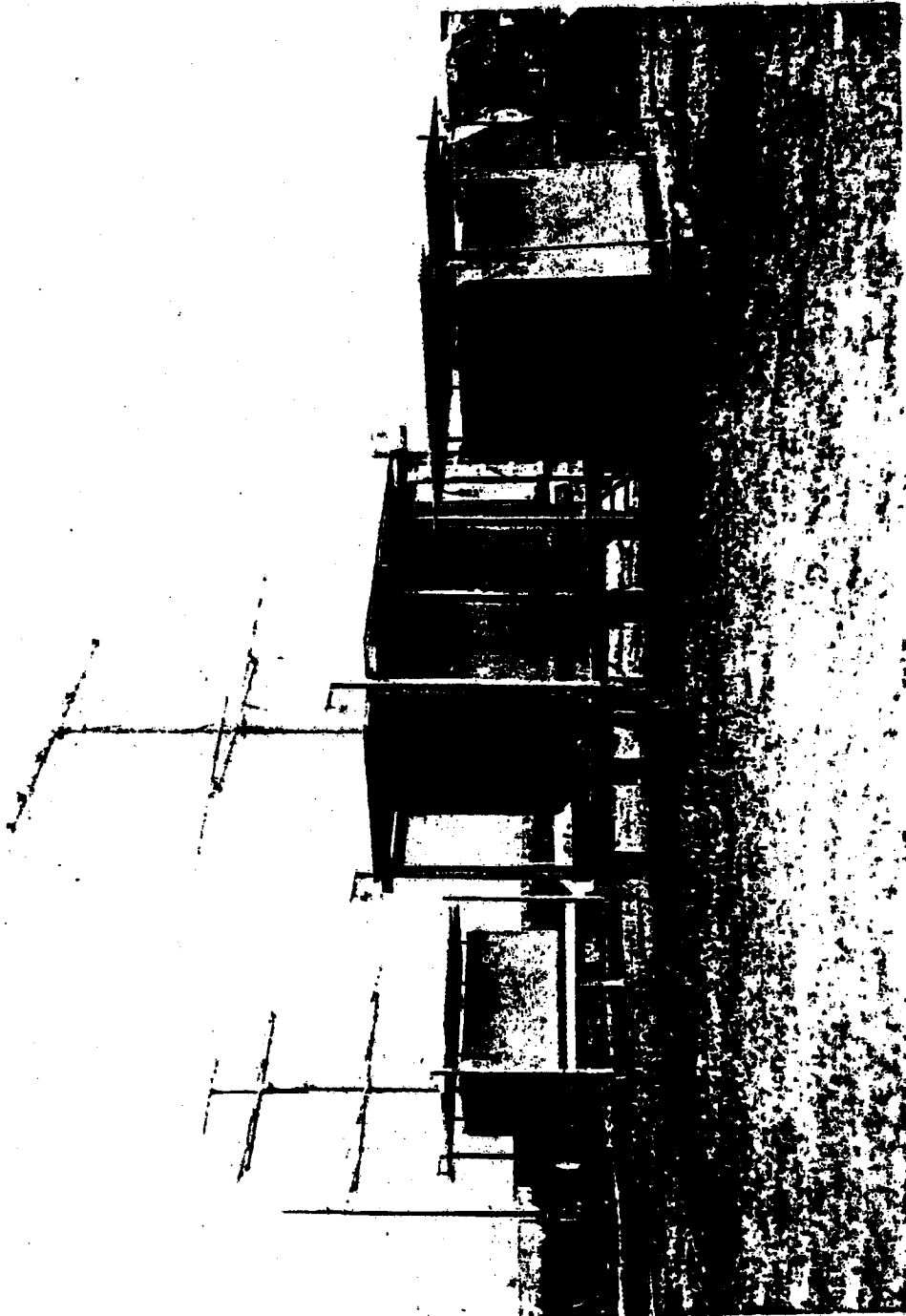
The ESV huts were procured from Craig Systems, Inc. of Lawrence, Massachusetts. These lightweight, aluminum shelters, designed for

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First Generation GRAB/Dyno 1
Receiving, Timing, and Recording Position inside ESV Hut

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[REDACTED]
POPPY Mission Ground Station
Typical Earth Satellite Vehicle (ESV Hut Installation)