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PROJECT OFFICER'S REPORT - PROJECT 9.4b

POD and Recovery Unit Fabrication

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The mission of this project was to provide an prepare pods and associated support equipment for the Fish Bowl events. The main objectives of the project were to provide and prepare (a) pods which could carry an adequate amount of scientific instrumentation and which could survive a detonation and reentry environment; (b) pods which, with all instrumentation, could be carried by the Thor and be positioned at designated ranges from the burst; (c) a system for pod stabilization so that desired pod orientation with respect to the burst could be maintained; and (d) a system for recovery of pods and instrumentation in good condition.

The overall performanee of the Thor/pod system on this operation was considered marginal. The basic pod structure was excellent; however, placement, stabilization, and recovery systems did not perform as reliably as required.

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FOREWORD

Classified material has been removed in order to make the information available on an unclassified, open publication basis, to any interested parties. The effort to declassify this report has been accomplished specifically to support the Department of Defense Nuclear Test Personnel Review (NTPR) Program. The objective is to facilitate studies of the low levels of radiation received by some individuals during the atmospheric nuclear test program by making as much information as possible available to all interested parties.

The material which has been deleted is either currently classified as Restricted Data or Formerly Restricted Data under the provisions of the Atomic Energy Act of 1954 (as amended), or is National Security Information, or has been determined to be critical military information which could reveal system or equipment vulnerabilities and is, therefore, not appropriate for open publication.

The Defense Nuclear Agency (DNA) believes that though all classified material has been deleted, the report accurately portrays the contents of the original. DNA also believes that the deleted material is of little or no significance to studies into the amounts, or types, of radiation received by any individuals during the atmospheric nuclear test program.

OPERATION DOMINIC

FISH BOWL SERIES

PROJECT OFFICERS REPORT—PROJECT 9.4b

POD AND RECOVERY UNIT FABRICATION

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ABSTRACT

The primary objectives of this project were to fabricate and prepare instrument-carrying pods, together with their associated stabilization and recovery systems. These pods were carried by the Thor on Star Fish, Blue Gill, and King Fish events in the Fish Bowl Series.

The pod and recovery system utilized by this project was designed and manufactured by General Dynamics/Astronautics (GD/A) and consisted basically of a 30-inch-diameter, 80-inch-long cylindrical pod with an aluminum inner structure and a refrasil heat shield. Pod weight was 1,200 pounds. Pods were designed to withstand the most severe thermal and X-ray impulse loads predicted. Pod placement and the related pod release equipment were designed by Douglas Aircraft Company (DACO). Gyroscopic stabilization was employed to provide proper orientation of the pods at detonation time. Between Blue Gill Prime and Blue Gill Double Prime, minor modifications were made to improve the stabilization system.

All weapons effects instruments for these events were passive; therefore, re-entry and recovery of pods was necessary. The pods were equipped with a re-entry heat shield and a recovery system utilizing parachutes.

Results from Tiger Fish proved that the Thor/pod configuration was compatible and that pod placement accuracy could be satisfied. Because of an inadequate flywheel motor, two pods were unstable, and the third did not meet the desired $\pm 7\frac{1}{2}°$ attitude stabilization. More powerful motors were used on later events.

During the Blue Gill flight, two of the pods were not released from the missile as programed because of a malfunction within the missile. The warhead was destructed prior to burst time. All pods were recovered, exhibiting only normal re-entry effects.

The Star Fish missile was destroyed prior to pod release. The pod and one re-entry vehicle impacted on the island, incurring extensive damage.

Star Fish Prime was successful with the exception of prelaunch failure of one flywheel, the tumbling of one pod, and excessive pod look angles on the other two pods (40 to 45°). Re-entry and recovery were normal on all three pods.

The Blue Gill Prime booster burned on the pad; thus, no data was obtained. Subsystems from the pods were salvaged for later use.

Because of an early in-flight failure in the Blue Gill Double Prime Thor missile, little pod performance data was obtained.

On Blue Gill Triple Prime, the Thor/pod system was mostly successful. Pod locations with respect to burst were within the 20-percent tolerance. Orientation of the pod containing the Sandia transponder was very good and indicated orientation of the other two was only slightly over the design limit. Two pods were recovered in good condition. The third pod, because of a recovery system malfunction, had extensive impact damage.

Only two of the King Fish pods were recovered; one in good condition, the other severely damaged. Only the nose cone and flotation bag of the third was located, and it is presumed to have been destroyed on impact. This pod had to fly with a faulty recovery system because of insufficient time to accomplish repair of the faulty unit. Indicated orientation of the pods was marginal. Pod placement was good.

The overall performance of the Thor/pod system on this operation is considered marginal. The basic pod structure is excellent; however, placement, stabilization, and recovery systems did not perform as reliably as required.

Stabilization can be achieved by further modification in the direction of maintaining flywheel velocities above a critical level. This can be accomplished either by keeping power on the wheel at all times, or by putting the wheel in an evacuated capsule and increasing the wheel velocity at lift-off.

Recovery system improvement will require changes to make the unit a simple, reliable, field-serviceable recovery unit.

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Chapter 1

INTRODUCTION

The Pod Program in the Fish Bowl Series was initiated by the Chief, Defense Atomic Support Agency (CH/DASA) at the request of the U.S. Army and the U.S. Air Force (USAF). The experimental requirement originated from the need to measure the close-in weapon effects of scheduled high-altitude bursts. These weapon effects measurements include blast effects, nuclear radiation, thermal radiation, and X-ray impulse.

1.1 OBJECTIVES

The mission of this project was to provide and prepare pods and associated support equipment for the Fish Bowl events. The main objectives of the project were to provide and prepare:

a. Pods which could carry an adequate amount of scientific instrumentation and which could survive a detonation and re-entry environment.

b. Pods which, with all instrumentation, could be carried by the Thor and be positioned at designated ranges from the burst.

c. A system for pod stabilization so that desired pod orientation with respect to the burst could be maintained.

d. A system for recovery of pods and instrumentation in good condition.

1.2 BACKGROUND

Prior to selection of pods to carry scientific instrumentation on the Fish Bowl Series, studies were made of other systems such as sounding rockets. Due to normal dispersion of unguided sounding rockets, the necessary placement accuracies of ±20 percent in burst-to-instrument separation distance could not be satisfied. Based upon a feasibility study by Douglas Aircraft Company (DACO), which concluded that the Thor system could place pods designed by General Dynamics/Astronautics (GD/A) with this accuracy, this pod was selected to carry the weapon effects instrumentation.

GD/A had previously designed, fabricated, and flown scientific passenger pods on the Atlas Research and Development (R&D) missiles. Air Force Special Weapons Center (AFSWC), over a four-year period, had also been using Atlas pods as a primary technique of space experimentation. These pods were used as carriers for experiments by the USAF, Atomic Energy Commission (AEC), and others, primarily for the measurement of charged particles and electromagnetic phenomena in the lower regions of the Van Allen radiation belts, and for the determination of re-entry characteristics for certain materials utilized in the Satellite Nuclear Auxiliary Power (SNAP) Program. To date, in other programs, GD/A has built 21 non-recoverable pods and one recoverable pod. Thirteen of the non-recoverable pods and the one recoverable pod have been flown, with more flights programmed in 1963. The sub-contract for a nuclearly unhardened pod was awarded 8 January 1962 to GD/A by DACO, which at this time was prime contractor to Space System Division (TU 8.1.5) for the Thor boosters and the basic pod. A short time later, AFSWC was given the responsibility of contracting for a pod to meet all design criteria for the Blue Gill and Star Fish events.

Six pods were built to support Blue Gill and Star Fish, with three additional pods as backup for either event. Five pods were built for testing and certification of the pod and the Thor/pod configuration (two environmental and three for Tiger Fish, the certification test flight). After the unsuccessful Blue Gill and Star Fish events, four pods were refurbished for use on repeat flights. After failure of Blue Gill Prime, two Star Fish Prime pods were refurbished and four new pods built to provide pods for Blue Gill and King Fish events, plus back-up for either event.

Chapter 2
PROCEDURE

The pod developed by GD/A for this project was a modification of an existing pod design originally developed for use as a passenger vehicle on Atlas missile re-entry tests. The pod was approximately 80 inches long with a central cylindrical section 30 inches in diameter, a spherical nose, and a flared aftersection whose maximum diameter was 46 inches. Figure 2.1 shows the basic pod configuration and gives the dimensions of the various pod components. The basic construction consisted of an aluminum inner structure covered by a refrasil outer body that served as a heat shield, the two being bonded by silicone rubber. All vacant cavities in the cylindrical section of the pod were filled with polyurethane foam to increase water buoyancy. A flat aluminum bulkhead provided closure for the rear and served as a mounting surface for the instrumentation of the effects projects. A recovery system was mounted in a 15-inch-diameter tube that extended down the longitudinal axis of the pod. The total pod weight was 1,200 pounds including about 150 pounds of scientific instrumentation.

2.1 SPECIFIC DESIGN CONSIDERATIONS

The pod was designed to carry passive instrumentation to the vicinity of a high-altitude nuclear burst and return it intact for examination. To successfully accomplish this mission the following criteria had to be met:

a. The pods had to be at the proper distances from the burst at detonation.

b. The pod's instrument-carrying backplate had to be oriented toward the burst at zero time.

c. It had to survive the burst environment and atmospheric re-entry.

d. It had to have the capability of being recovered without damage to the exposed instrumentation.

2.1.1 Pod Placement. The proper placement of the pods with respect to the burst point was the responsibility of the Douglas Aircraft Company (DACO). The pods were carried aloft by the Thor missile containing the nuclear warhead. Three pods were located at 120° intervals around the boattail of the missile. Figure 2.2 shows schematically the pod locations on the Thor in relation to the flight path. The pod was oriented in a nose-down position with the backplate facing forward on the missile. Each pod was mounted beneath an external fairing (Figures 2.3 and 2.4) and attached to this structure by two explosive bolts contained within fittings on the pod backplate. A metal band around the cylindrical portion of the pod cinched the pod into a saddle on the Thor. The band was attached to the saddle with explosive bolts. The pod was released from the Thor by firing four explosive bolts on each pod.

DACO's original design concept was to release all pods during vernier engine solo (after main engine cutoff), giving the pods a differential velocity to obtain separation with respect to the warhead. On Star Fish and King Fish this method was used. However, due to the distance requirements from the burst, it was necessary on Star Fish for DACO to release the first pod after Main Engine Cutoff (MECO) but during main engine thrust tailoff. The signal to release each pod originated in the guidance system. When the missile attained one of the three predetermined velocities, the guidance system triggered the pod release system, thereby determining warhead and pod velocity for proper position.

On Blue Gill pods a different release design was required due to the closeness of the pods to the burst. To obtain the required differential velocity, each pod was ejected from the missile by a spring, each of a different spring constant. The pods were released simultaneously after vernier engine cutoff. The signal to release orginated in the guidance system.

Proper positioning at burst time was verified by the tracking of pod-borne transponders. Cubic Corporation (CC) provided a transponder in each pod to determine relative and absolute pod position during the flight. In addition, Sandia Corporation (SC) provided transponders in the warhead and in one pod to give relative pod/warhead position. An antenna designed by GD/A was located in the extreme nose of the pod to receive and transmit all transponder signals. The Cubic and Sandia tracking systems were located on Johnston Island. Transponder frequencies assigned to the pods for each flight are listed in Table 2.1.

In order to operate the transponders, part of the weapon effects instrumentation, and the added instrumentation on the Tiger Fish event, an electrical system was installed on the pods. This system consisted of a 28-volt electrically activated battery with a 9.5-ampere-hour capacity. The electrical system also contained a power change-over switch. The change-over switch was used to select from two sources of dc power for the pod, the first being a dc power supply in the ground support equipment (external) and the other being the battery (internal). Both the battery and power change-over switch were located in the nose section of the pod. (Figure 2.5 shows location of pod components.)

2.1.2 Orientation and Stabilization. Experimental instrumentation carried aboard the pods required orientation toward the burst. Since the Thor missile had a near-vertical trajectory, orientation was accomplished by mounting the pods with the rear end forward on the missile and releasing them in this attitude (Figure 2.4). Approximately the same attitude was maintained by means of a gyroscope within the pod. Perturbations expected during release, such as vernier, main engine, and retrorocket flame impingement, spring thrust misalignment, explosive bolt impulse, and missile motion, were estimated by DACO. Using these estimates, GD/A designed a flywheel to limit the maximum coning angle to ± 7-1/2 degrees at burst time. This flywheel was 15 inches in diameter, weighed 65 pounds, and was designed to rotate at a speed of approximately 4,000 rpm at pod release. The flywheel motor was powered through the ground umbilical until lift-off. After umbilical separation, the flywheel coasted with no additional power. The flywheel was originally powered by a 1/7-horsepower direct-current motor. Because the dc motor had a relatively high drag compared to the flywheel assembly, a clutch was used between the motor and flywheel. In this way the motor would drive the flywheel, but when the dc power was removed from the motor (at lift-off), the clutch would disengage the motor from the flywheel. In the first Thor/pod shot (Tiger Fish) it became apparent that the dc motor was too small, so a larger three-phase 400-cycle motor was installed. At that time the clutch was still used. Tests run at GD/A showed that the clutch had more drag than the new ac motor and consequently did not disengage at all. Because the clutch also had a history of failure (shearing under high starting loads), another modification was performed on the flywheel before the Blue Gill Double Prime event. This modification consisted simply of replacing the clutch with a direct coupling. At the same time, the thickness of the flywheel cover was increased so that it would not warp under pod stresses. It had also been determined that warping was imposing additional drag on the flywheel assembly.

2.1.3 Burst Environment and Atmospheric Re-entry. Nuclear environmental data was provided by Projects 8A.3 and Project 8B for the Fish Bowl Series. This data indicated that the pod closest to the burst on the Blue Gill event would experience the most severe environment of the series. This environment consisted of a

for the remaining surface of the pod. This loading was the result of thermal blow-off. All pods were designed to withstand this loading. Impulse load tests indicated that the flare section of the pod would not withstand this loading. A redesign of the aft section and the nose cone attachment bolts on Pods B1, B3, BS1, BS2, and BS3 was then accomplished. Because of the limited amount of time available, Pods C1, C2, C3, S1, S2, S3, and B2 were not modified.

In addition to dynamic impulse loading, the pod was designed to withstand a radiation flux of

Units that were required to function after the event, especially the recovery system, were designed to survive without damage.

For ease of post-flight examination, pod materials were selected to minimize induced radioactivity. (See Table 2.2 for material weight breakdown.)

To permit proper atmospheric re-entry, pod shape and center of gravity limits were established to provide a stable aerodynamic configuration at hypersonic and supersonic velocities. The flywheel stabilization provided a nose-first attitude at re-entry, thus shielding the rear bulkhead instrumentation from direct re-entry heating. All portions of the pod except the rear bulkhead were covered with a re-entry heat shield. The shield was fabricated with spiral-wrapped refrasil phenolic cured under heat and pressure. Heat shield thickness at the nose was 1.00 inch. Along the cylindrical sides and flare, the heat shield was 3/8 inch. Design provided for ablation of this shield during re-entry to carry away heat, while insulating properties of the material maintained an ambient internal temperature.

2.1.4 Recovery System. Experimental instrumentation carried aboard the pods was passive and required recovery of the pods to secure the exposed instrumentation and its contained data. To accomplish this, GD/A subcontracted Northrop Ventura to develop and build a recovery system.

The predicted radiation environment made the use of nylon parachute material undesirable on most pods. Northrop Ventura selected DuPont HT-1 material for all fabric applications because of its superior resistance to radiation. Due to short supply of HT-1, it was necessary to fly some of the pods with nylon material.

A two-stage parachute system was designed to lower the pod after atmospheric re-entry and to reduce its water impact velocity to 80 ft/sec. The first stage served to stabilize the pod at subsonic velocities. Actuation of the stages was accomplished by a nitrogen gas system rather than by standard pyrotechnics because of the burst environment to which they would be exposed. The recovery unit was housed in a canister 15 inches in diameter and 49 inches long, and installed in a well from the aft end of the pod (Figure 2.6).

Bottled gas, valves, relays, and associated equipment were mounted in the forward end of the can. Parachute fittings were located at the aft end and bolted directly into the pod structure. To provide support for shock loading and make a smooth cavity for housing the parachutes and balloon, the fittings, plumbing, and gas bottles were potted with polyurethane foam. The recovery system rear cover was attached with bolts that were designed to be broken by the parachute ejection system. Three bolts, each with a 1,300-pound breaking strength, were used. A separate internal cover was used to retain the parachutes if the outer door bolts broke due to burst impulse loading. Figure 2.7 illustrates schematically the deployed recovery system. Figure 2.8 is a block diagram showing the functional sequence of the recovery system.

As designed, the operational sequence of the recovery system was as follows: During the increasing deceleration at re-entry, an inertia switch armed the recovery sequencing system when 22.5 g was exceeded for 0.75 second. The arming sequence was scheduled to start at about 84,000 feet of altitude. When the g level decreased to 7.5, an inertia switch initiated thruster or actuator operation which ejected the aft cover of the recovery system. This occurred at about 29,000 feet. The rear cover extracted a 2.25-foot-diameter pilot chute, which in turn deployed a 4.5-foot-diameter conical ribbon drogue parachute, at a dynamic pressure of approximately 750 psi. This was designed to maintain stability at subsonic velocities. At the time the inertia switch initiated the cover removal, it also initiated a 30-second thermal time delay in the drogue parachute disconnect circuit. After 30 seconds, the drogue parachute released and extracted a 20-foot-diameter conical ribbon parachute at an altitude of approximately 13,800 feet and a dynamic pressure of 96 psi. At the start of the main parachute deployment, a 9-second thermal time delay was initiated. This delay disabled the main parachute release system until after the main parachute opening shock was felt by the pod.

At impact, a 5-g inertia switch actuated the main parachute disconnect system. As the main parachute released, a recovery aid flotation balloon was ejected by spring from the pod. After 9 seconds, it was inflated by a self-contained nitrogen system. It was attached to the pod by a 40-foot riser. During inflation, a Sarah radio beacon antenna on the bag ejected. The beacon and a battery-operated gas discharge flashing light, also on the bag, started operating. Shark repellent and dye marker attached to the 40-foot riser activated upon contact with the water.

Two 10-inch-diameter webbing loops were attached to the 40-foot riser at the recovery aid flotation balloon for helicopter or boat pickup. The 40-foot riser allowed a safe separation distance for personnel to retrieve the radioactive pod.

2.2 POD PROCUREMENT FOR FISH BOWL

This project participated in eight events: Tiger Fish, two Star Fish, four Blue Gill, and King Fish. For the initial phases of the operation, fourteen pods were built, twelve for use at Johnston Island and two for environmental testing at Stanford Research Institute (SRI). Because of failure of Star Fish and Blue Gill Prime, it was decided that nine additional pods were required, five to be previously used pods that had been refurbished and four pods to be newly manufactured. Table 2.3 gives the designation of the pods and indicates those that were reused. Table 2.3 in conjunction with Figure 2.2, indicates the positions on the Thor in which the pods were flown during the various events.

To insure the quality of the pods that were to be reused, the pods were refurbished by GD/A in their San Diego, California, plant. In the refurbishment, the following tasks were accomplished:

1. Inspection of each pod to determine extent of damage.
2. Sandblast or file a thin layer of charred refrasil from the body of the pods.
3. Peel the damaged layers of refrasil from the nose cones and patch if necessary.
4. Completely rewire the pods.
5. Rebuild the flywheels and install new or rewired motors.
6. Recovery systems were refurbished except for a few new parachutes. (Table 2.4 shows the position of the recovery system flown on all events).

2.3 INSTRUMENTATION

The pod instrumentation consisted of those instruments necessary to obtain weapon effects data on Star Fish, Blue Gill, and King Fish, and instrumentation necessary to measure pod performance on Tiger Fish. Performance instrumentation on Star Fish, Blue Gill, and King Fish was not used due to space and weight limitations and austerity of the program.

The Star Fish instrumentation was primarily furnished by Project 8B. Project 8B instruments were mounted on the backplate where some 50 holes ranging from 1.5 to 3 inches in diameter were drilled (Figure 2.9). To protect the backplate from X-ray damage, a carbon layer supplied by GD/A was installed around the instruments. To install the carbon sheets around the instrument holes, it was necessary to machine them in an intricate jig-saw pattern and then glue them to the backplate.

Blue Gill instrumentation was primarily furnished by Project 8A.3. The majority of instruments on Blue Gill were mounted internal to the flare section on a beam structure. The instrument faces projected through holes in the rear bulkheads. Other instruments were mounted directly on the backplate (Figure 2.10). Blank bulkheads were furnished to Project 8A.3 for drilling instrumentation holes and application of a refrasil layer on the exposed side of the backplate.

Two of the pods for King Fish were instrumented primarily by Project 8B. The installation of instruments was very similar to the technique used on Star Fish. The third King Fish pod was instrumented mostly by Project 8A.3. This installation was quite similar to that used on Blue Gill.

The instruments furnished by Project 1.1 were mounted in the nose of the pod on all flights. Several of these were mounted on the back side of the pod ballast plate (Figure 2.11).

Projects 2.1 and 2.2 also participated in all flights. One set of their instruments was mounted on the backplate, and an additional set on an inner structural member approximately 18 inches forward of the backplate.

The weapon effects instrumentation is discussed in detail in the experimenters' respective reports and will not be discussed here.

The instruments necessary to verify the pod performance on Tiger Fish were of both active and passive types. Pod instrumentation is listed in Table 2.5. Pod instrumentation is shown in Figure 2.5. The measurements listed are for Pods C1 and C3. The functions of these instruments are given in the description column of the table. Pod C2 was not instrumented, because it was to fly without a recovery system. However, Pod C2 did carry both Cubic and Sandia transponders to obtain pod tracking data.

Besides the listed instrumentation in Table 2.5, a Milliken DBM-10 camera was installed in both Pods C1 and C3 to provide photographic coverage during release. The cameras were supplied by DACO. The two cameras had different focal lengths, 50 and 10 mm.

An FM/FM interrange instrumentation group (IRIG) telemetry system was used to transmit pod performance data on Pods C1 and C3. The telemetry transmitters had 3 watts of RF output with carrier frequencies centered at 256.2 and 258.5 Mc, respectively. Power input was 3.5 amperes at 28-volt dc. Channels 10 through 16 and E were the IRIG subcarrier oscillators used.

The USS Range Tracker instrumentation ship was used for primary telemetry reception and recording of the pod data for Tiger Fish.

A standard Bendix telemetry trailer from AFSWC was provided for checkout and backup. Figure 2.12 shows a block diagram of the receiving station.

2.4 GROUND SUPPORT EQUIPMENT AND POD CHECKOUT PROCEDURES

2.4.1 Electrical Ground Support Equipment. The original Thor launch pad that was used for early Fish Bowl tests was destroyed on 26 July 1962. Before Blue Gill Double Prime, the destroyed pad was rebuilt and an additional Thor pad constructed on Johnston Island. The rebuilt pad was designated Pad 1; the new one, Pad 2.

The pod ground support equipment installed at each pad consisted of two general types. In the launch control trailer (LCT), GD/A supplied a launch control monitor panel and a flywheel rpm monitor (Figure 2.13). The pod launch control monitor panel was used to determine mode of operation or status of the pods and to control the external-to-internal power change-over switch, transponder power, flywheel motor power, and internal-power or battery activation. The flywheel rpm monitor was used to determine flywheel motor speed or rpm by converting motor current used into an equivalent rpm. In the missile checkout trailer (MCOT), five GD/A chassis were installed (Figure 2.14). Three of these chassis were dc control relay panels for controlling all the dc functions on the pods. One relay panel was used for each of the three pods. An additional panel was an ac control relay panel and was used to control the 400-cycle ac power to the flywheel motors. This chassis also had the capability of sampling the motor current for the rpm monitor. The final GD/A panel was the circuit breaker panel for the three-phase 400-cycle power. Douglas Aircraft Company (DACO) furnished, for each pad, a dc power supply for external power, all land lines between LCT, MCOT, and launch pad, and 115-volt ac power to GD/A equipment.

2.4.2 Mechanical Ground Support Equipment. Ground support equipment for shipping and handling pods consisted of pod pallets, rear bulkhead handling pallets, and vertical and horizontal pod pickup slings.

2.4.3 Pod Checkout Procedure. In order to insure reliable operation of the pods, a complete electrical and mechanical check was performed on all systems both before mounting on the Thor and also after mounting, but prior to Thor launch.

To insure proper performance of the tracking systems and their pod-borne transponders, pre-flight checks were conducted. The Cubic tracking system employed two ground tracking stations, a distance measuring equipment (DME) and an angular measuring equipment (AME). The Sandia Corporation used a DME system for pod tracking. To verify performance of the transponders, their reception and response was checked from the ground station. The Cubic DME system was checked, also, by checking the response from the pod transponders while the pod was located over a surveyed point.

The gyroscope stabilization of the pod was checked by verifying rotational speed of the flywheel, since degree of stabilization was a function of flywheel rpm. The check involved a run-up test, plotting motor current and rpm both with respect to time. Abnormal operation was easily identified. A further verification of proper flywheel performance was obtained by plotting a run-down curve, to ensure that the flywheel would not slow down too rapidly during pod flight, thereby lessening its stabilizing effect.

2.5 ENVIRONMENTAL TEST

2.5.1 Impulsive Load Tests.

To determine the structural capability to withstand the predicted impulse loading, AFSWC contracted Stanford Research Institute (SRI), Menlo Park, California to test Pod E1 to simulate expected loads of the Star Fish event, and Pod E2 for Blue Gill loads.

Since Pod E2 would not be available until a late date, it was decided to proceed with testing of Pod E1, subjecting it to the higher Blue Gill impulsive loads. Four shots were made at

Table 2.6 summarizes these tests.

The lower loads were applied by an oxyacetylene explosive in a gasbag as shown in Figure 2.15. The higher loads, and higher, were applied by EL506D sheet explosive with neoprene foam attenuator to change impulse duration. Figure 2.16 shows the pod with the attenuator and sheet explosive in place. Data was obtained photographically and by strain gages mounted in areas of interest.

The first three tests simulated Star Fish loads and were 10 to 20 microseconds in duration. There was no damage to the aft bulkhead, except for the breaking of the blowoff door bolts. (This was expected.)

The fourth load the Blue Gill load, caused substantial damage to the aft end of the pod and the nose cone. (See Figures 2.17 and 2.18) Post-test analysis revealed the following failures:

1. Brittle fracture of the aft ring on the 15-inch barrel in short transverse bending.
2. Sheer failure of the attachments of the ring on each end of the aft 30-inch barrel.

3. Bond failure of the fiberglass reinforcing ring on the aft end of the heat shield.
4. Shear failure of the bolts holding the heat shield nose cone.

Details of these tests can be found in Reference 1.

The following design changes were incorporated in Pods E2, B1, B3, BS1, BS2, BS3, and all new BS pods:

1. Material in the rings at the aft end of both barrels changed from 7075 aluminum alloy to annealed 321 stainless steel. The latter is more ductile and will bend without fracture.
2. Doubled the strength of the ring-to-barrel attachment at end of the aft 30-inch barrel.
3. Added an aluminum liner inside the aft end of heat shield.
4. Increased the number of nose bolts to obtain five times the original shear value.

Pod E2 was modified as described above and was subjected to the following tests:

1. Impulsive loads of

    on the aft bulkhead.

2. Impulsive loads of

    on the aft bulkhead.

These tests were to demonstrate effectiveness of the design changes, and to show the ability of the recovery system, flywheel, and battery to survive Blue Gill load environment. The pod including recovery system, battery, and flywheel assembly satisfactorily survived both loads with minor damage to the flare and nose cone (Figures 2.19 and 2.20). This damage was not considered significant enough to affect re-entry or recovery capability.

2.5.2 Pod Vibration Tests. Vibration tests were conducted at Wyle Laboratories under supervision of DACO during the period 7 to 13 April 1962. The pod-missile attachment fitting with a 1/4-inch flange thickness failed when vibrated at a booster resonance of about 18 cps. A new fitting was then designed with 5/8-inch flange thickness. Further tests proved that the redesigned flange would withstand expected loads, and it was accepted for flight.

A complete summary of the vibration tests and results is found in Reference 2.

2.5.3 Recovery System Drop Tests. The objective of the drop test program was to insure functional reliability of the recovery system including parachute operation, rate of descent, stability, operation of complete location aid, and water retrieval system.

The first drop, made from a B-66 aircraft at El Centro, California, on 24 March 1962, was an overland drop using the modified T-1 vehicle shown in Figure 2.21. Programming actuator and deployment systems worked satisfactorily. The recovery parachute did not open because of twist in the shroud lines induced by vehicle rotation during deployment. Adverse airflow behind the vehicle possibly had an influence on chute performance. Camera coverage of the drop showed a spin rate of approximately 40 rpm at recovery parachute deployment, caused by instability of the vehicle.

A second drop, to prove that the main parachute would meet design requirements under no-spin conditions, was made with a weight bomb vehicle from the rear door of a C-130 aircraft, on 27 March 1962. A static line deployed the drogue chute, which in turn, immediately deployed the recovery parachute. No damage was sustained by the recovery parachute, which opened satisfactorily.

The third drop was made from a B-66 aircraft at El Centro, on 3 April 1962, from 27,000 feet, and closely simulated the actual aerodynamic conditions of pod recovery. The drop was made using a T-1 vehicle, a modified parachute attachment system incorporating swivels in both drogue and recovery parachute risers (since the pod would rotate), and a revised recovery parachute riser harness configuration (Figure 2.7). To expedite testing, a pyrotechnic rather than nitrogen-actuated system was used.

Objectives of the test were:

1. To assess drogue chute performance at maximum attainable Mach number.
2. To determine drogue and recovery parachute performance with revised attachment configuration.
3. To obtain recovery parachute load and structural integrity data at 10 percent over design dynamic pressure. (This was achieved by weighting the vehicle to 1,300 pounds.)

All systems and components functioned satisfactorily, and the above objectives were achieved.

The next drop was Pod El into the Salton Sea, using a B-66 aircraft, and dropping from 25,000 feet. The test was successful, from a deployment and parachute standpoint. However, at impact the recovery aid balloon system did not eject or inflate. After the pod was retrieved by boat, a study of the system showed that the failure was due to rigging of the balloon release and inflation initiation system.

In the final test, Pod El was dropped from a B-66 aircraft, 6,000 feet, to check new recovery aid balloon system rigging procedures. They were successful in all respects.

Table 2.7 summarizes the recovery system drop tests.

2.5.4 Stabilization Wheel Vibration and High-Altitude Tests. A series of tests was performed on the pod stabilization flywheel assembly. The purpose of these tests was to determine what effects vibration and high altitude had on the flywheel spin rate.

Two high-altitude runs were made with the pod flywheel assembly. In the first run, the flywheel motor was turned off as soon as the chamber door was closed and the vacuum pumps turned on. Consequently, the test started at sea level and reached 175,000 feet in 3 minutes. In the second run, the whole test was conducted at a simulated altitude in excess of 140,000 feet. In the first run the flywheel spin rate decayed 7 percent and in the second run 2 percent in 3 minutes (24 percent was normal decay at sea level). From these tests, it appears that windage or air pressure had a lot to do with flywheel spin rate decay, and because the flywheel was out of the atmosphere during most of the operational flights, the spin rates were faster than originally estimated.

The tests showed that a 10-g vibration in the range of 5 to 500 cycles caused the flywheel to slow down faster than it does normally in air. While being vibrated in the Z-axis, the flywheel spin rate decayed 27 percent of the initial spin rate in 3 minutes. (Normal decay in air was 24 percent.) When the flywheel was vibrated in either the X- or Y-axis, the decay rate increased to 40 percent.

The vibration test indicated that the flywheel rpm could be retarded up to 10 or 15 percent during the first 2 or 3 minutes of flight (powered flight), if the pod was subjected to a heavy horizontal vibration for this total period.

A complete summary of the flywheel high-altitude and vibration tests with results is found in Reference 3.

TABLE 2.1 FREQUENCY ASSIGNMENTS

Pod	Cubic Receive Mc	Cubic Transmit Mc	Sandia Receive Mc	Sandia Transmit Mc	GD/A TLM Mc
C1	310	270	417	235.5	256.2
C2	310	273	417	237.0	
C3	310	279	417	242.0	258.5
B1	310	270			
B2	310	273	417	242.0	
B3	310	279			
S3	310	273	417	242.0	
S1P	310	279			
S2P	310	273			
S3P	310	270	417	242.0	
B1P	310	270			
B2P	310	273			
B3P	310	279	417	242.0	
B1DP	310	270			
B2DP	310	273			
B3DP	310	279	417	242.0	
B1TP	310	270			
B2TP	310	273	417	242.0	
B3TP	310	279			
K1	310	270			
K2	310	273			
K3	310	279	417	242.0	

TABLE 2.2 POD MATERIAL WEIGHT BREAKDOWN

MATERIAL	POUNDS
Fiberglas phenolic (35% resin content)	102
Refrasil phenolic (35% resin content)	149
7075 aluminum alloy	268
2024 aluminum alloy	103
Steel	241
Carbon	33
Epoxy resin	22
Polyurethane foam	33
HT-1 cloth	22
Rubber	3
Copper	24
Instrumentation weight *	150
Total Weight	1,150 *

* Instrument weight varied, and sufficient ballast was added to each pod to bring total weight up to 1,200 ± 25 pounds.

TABLE 2.3 POD FLIGHT CONFIGURATION AND NOMENCLATURE

FLIGHT	POSITION 1	POSITION 2	POSITION 3
Tiger Fish	C1	C2	C3
Blue Gill	B1	B3	B2
Star Fish	R/V*	S2 (S3)	R/V*
Star Fish Prime	S1P (S1)	S2P (S2)	S3P (BS2)
Blue Gill Prime	B1P (BS1)	B2P (BS3)	B3P (B2**)
Blue Gill Double Prime	B1DP (B3**)	B2DP (B1**)	B3DP (C3**)
Blue Gill Triple Prime	B1TP (BS4)	B2TP (BS2**)	B3TP (S2**)
King Fish	K1 (BS5)	K3 (BS7)	K2 (BS6)

C	Certification pod
B	Blue Gill designed pod
S	Star Fish designed pod
BS	Blue Gill or Star Fish designed pod
P	Prime
DP	Double Prime
TP	Triple Prime
*	Project 8C AVCO Re-entry Vehicle
( )	Indicates original Nomenclature
(**)	Indicates refurbished pod

TABLE 2.4 POD RECOVERY SYSTEM CONFIGURATION AND LOCATION

FLIGHT	POSITION 1	POSITION 2	POSITION 3
Tiger Fish	3	None	4
Blue Gill	5	7	6
Star Fish	R/V	11	R/V
Star Fish Prime	9	2[a]	13[b]
Blue Gill Prime	8	10	12
Blue Gill Double Prime	5R	6R[c]	7R
Blue Gill Triple Prime	10R[d]	13R	2[e]
King Fish	9R[f]	4R[g]	10R[h]

R Refurbished Recovery System
a S/N 13 Parachute and Floatation Systems (HT-1)
b S/N 2 Parachute and Floatation Systems (Nylon)
c S/N 10R Floatation System
d S/N 6R Floatation System
e S/N 9R Parachute and Floatation System
f S/N 2R Parachute and Floatation System
g S/N 3 Parachute and Floatation System (new Nylon systems)
h S/N 10R was not refurbished after Blue Gill Triple Prime but just dried out and reused.

TABLE 2.5 POD INSTRUMENTATION AND MEASUREMENTS

Measurement No.	Title and Description	Channel and Sequence [a]
PBF1-1	Pitch Rate: Gyro to measure pod pitch rate in degrees/second. (Maximum of 12.5°/sec.)	10 Cont.
PBF1-2	Yaw Rate: Gyro to measure pod yaw rate in degree/second. (Maximum of 12.5°/sec.)	11 Cont.
PBF1-3	X-Acceleration: Accelerometer to measure acceleration in X-direction during re-entry Transducer No. PAL-5245. Range ± 20 g.	12 Cont.
PBF1-4	Y-Acceleration: Accelerometer to measure acceleration in Y-direction during re-entry. Transducer No. PAL-5245. Range ± 20 g.	13 Cont.
PBF1-5	Z-Acceleration: Accelerometer to measure acceleration in Z-direction during re-entry Transducer No. PAL-5246. Range -10 to 50 g.	14 Cont.
PBF1-6	10° Nose Temp: Thermocouple to measure temperature of nose during re-entry. Chromel/constantan 26/gauge wire cemented in skin 1/10 inch from outer surface. Cement to be same as that used in fabrication of ablative skin. Range 100-1540°F. Commutated at 2.5 rps. STA. -16, X-Axis.	16-1

TABLE 2.5 CONTINUED

Measurement No.	Title and Description	Channel and Sequence
PBF1-7	15° Nose Temp: Same as PBF1-6 except location is STA. 15.7, X-Axis.	16-3
PBF1-8	30° Nose Temp: Same as PBF1-6 except location is STA. 13.8, X-Axis.	16-5
PBF1-9	45° Nose Temp: Same as PBF1-6 except location is STA. -11, X-axis.	16-7
PBF1-10	60° Nose Temp: Same as PBF1-6 except location is STA. -7.5, X-Axis.	16-9
PBF1-11	90° Nose Temp: Same as PBF1-6 except location is STA. 00, X-Axis.	16-11
PBF1-12	Upper Cylinder Temp: Same as PBF1-6 except location is STA. 6, Y-Axis.	16-13
PBF1-13	Middle Cylinder Temp: Same as PBF1-6 except location is STA. 20, Y-Axis	16-15
PBF1-14	Lower Cylinder Temp: Same as PBF1-6 except location is STA. 38, Y-Axis.	16-17
PBF1-15	Upper Flare Temp: Same as PBF1-6 except location is STA. 52, Y-Axis.	16-19
PBF1-16	Middle Flare Temp: Same as PBF1-6 except l ation is STA. 55.5, Y-Axis.	16-21

TABLE 2.5 CONTINUED

Measurement No.	Title and Description	Channel and Sequence
PBF1-17	Lower Flare Temp: Same as PBF1-6 except location as STA. 59, Y-Axis.	16-23
PBF1-18	Outer Back Temp: Back plate temperature. Transducer No. 27-01287-3 cemented to plate. Range 0-400°F commutated at 2.5 rps.	16-25
PBF1-19	Middle Back Temp: Same as PBF1-18 except location.	16-31
PBF1-20	Inner Back Temp: Same as PBF1-18 except location.	16-33
PBF1-21	Reference Temp: Thermocouple junction temperature. Transducer No. 55-01142-1. Range 50-200°F.	16-35
PBF1-22	Pod Environmental Temp: Ambient temperature in forward end of pod. Transducer No. 27-01282-3 cemented to bracket which is insulated from other components and structure. Range 50-200°F.	16-37
PBF1-23	Outer Back Pressure: Pressure on rear of pod near outer side. Transducer No. 27-01386-11 Range 0-30 PSIA.	16-39
PBF1-24	Inner Back Pressure: Same as PBF1-23 except location. Twelve inches from Z-Axis on rear of pod.	16-41

TABLE 2.5 CONTINUED

Measurement No.	Title and Description	Channel and Sequence
PBF1-26	Pod Separation: Microswitch bearing on Thor support structure. Release will activate RF switch so the inboard antenna will radiate.	16-45
PBF1-27	0% Bridge Calibration: Calibrator for bridge circuits.	16-27
PBF1-28	100% Bridge Calibration: Calibration for bridge circuits.	16-29
PBF1-29	28 Volt Monitor: Measure battery voltage.	16-47
PBF1-30	Tape Recorder Start: Time at which power is switched to tape recorder.	16-49
PBF1-31	X-Vibration: Vibrations in X-direction. Uses transducer No. 27-01277-15. Range ± 30 g, frequency 25-2000 cps. (1/8 rps).	E-1-13, 43-55
PBF1-32	Y-Vibration: Vibrations in Y-direction uses transducer No. 27-01277-15. Range ± 30 g, frequency 25-2000 cps. (1/8 rps).	E-15-27, 57-69
PBF1-33	Z-Vibration: Vibrations in Z-direction uses transducer No. 27-01277-15. Range ± 30 g, frequency 25-2000 cps. (1/8 rps).	E-29-41, 71-83

TABLE 2.5 CONTINUED

Measurement No.	Title and Description	Channel and Sequence
PBF1-34	100% Calibration: 2.5 volt transducer power supply signal.	E-87, 90
PBF1-35	0% Calibration: -2.5 volt signal.	E-85
PBF1-36	Decom Signals: -2.5 volt signal.	E-14, 28, 42, 56, 70, 84, 86
PBF1-37	T-0 Time	12 Blip

a Sequence column refers to commutator position.

TABLE 2.6 SUMMARY OF SRI TESTS

Pod	Pod Shot No.	Date	Location	Explosive Type	Explosive Thickness	Attenuator Thickness (inches)	Impulse (dyne-sec/cm^2)
		1962					
Mock-up	1	Jan 30	Rear	EL506D	65 mils	5	
El	1	Feb 26	Rear	Oxyacety-lene	1-1/4 inches	-	
El	2	Feb 27	Rear	Oxyacety-lene	2-1/16 inches	-	
El	3	Feb 27	Rear	E1506D	8.5 mils	1	
El	4	Feb 28	Rear	E1506D	65 mils	5	
E2	1	Apr 28	Side	E1506D	12	5	
			Rear	E1506D	25	7	
E2	2	May 2	Side	E1506D	24	6	
			Rear	E1506D	60	12	

TABLE 2.7 RECOVERY SYSTEM DROP TEST SUMMARY

Test Number		1	2	3	4	5
Date		24 Mar	27 Mar	3 Apr	18 Apr	26 Apr
Location		El Centro	El Centro	El Centro	Salton Sea	Salton Sea
Test Vehicle		T-1 (1)	Weight Bomb	T-1	Pod El	Pod El
Weight		1200	1200	1300	1200	1200
Drop Aircraft		B-66	C-130	B-66	B-66	B-66
Drop Condi-	Alt. (ft)	6,510	6,230	27,010	25,000*	6,000*
tions	Vel. knots	462	145	345	347*	150*
	Mach No.	0.79	N/A	0.89	0.86*	N/A
Drogue	Time (Sec)	1.9	No	0.95	1.0*	No
Chute	Alt. (ft)	6,400	drogue	27,000	25,000*	drogue
De-	Mach No.	1.55	chute	0.83	0.80*	chute
ployed	Dyn. Press.	365	- - -	350	355*	- - -
Re-	Time	11.8	1.6	26.8	31.0*	3.0*
covery	Alt. (ft)	4,750	6,150	20,000	17,000	6,000*
Chute	Vel. ft/sec	290	250	405	360*	250*
Deployed	Dyn. Press.	85	62	105	95*	62*
Impact Velocity ft/sec (2)		240	80	77	80*	80*
Comments		Recovery parachute not inflated			Floatation balloon operation malfunctioned	

(1) T-1 is a Radioplane modified 1,000-lb GFE Bomb.
(2) Corrected from altitude values and for 1200-lb weight.
* These values are nominal, not measured.

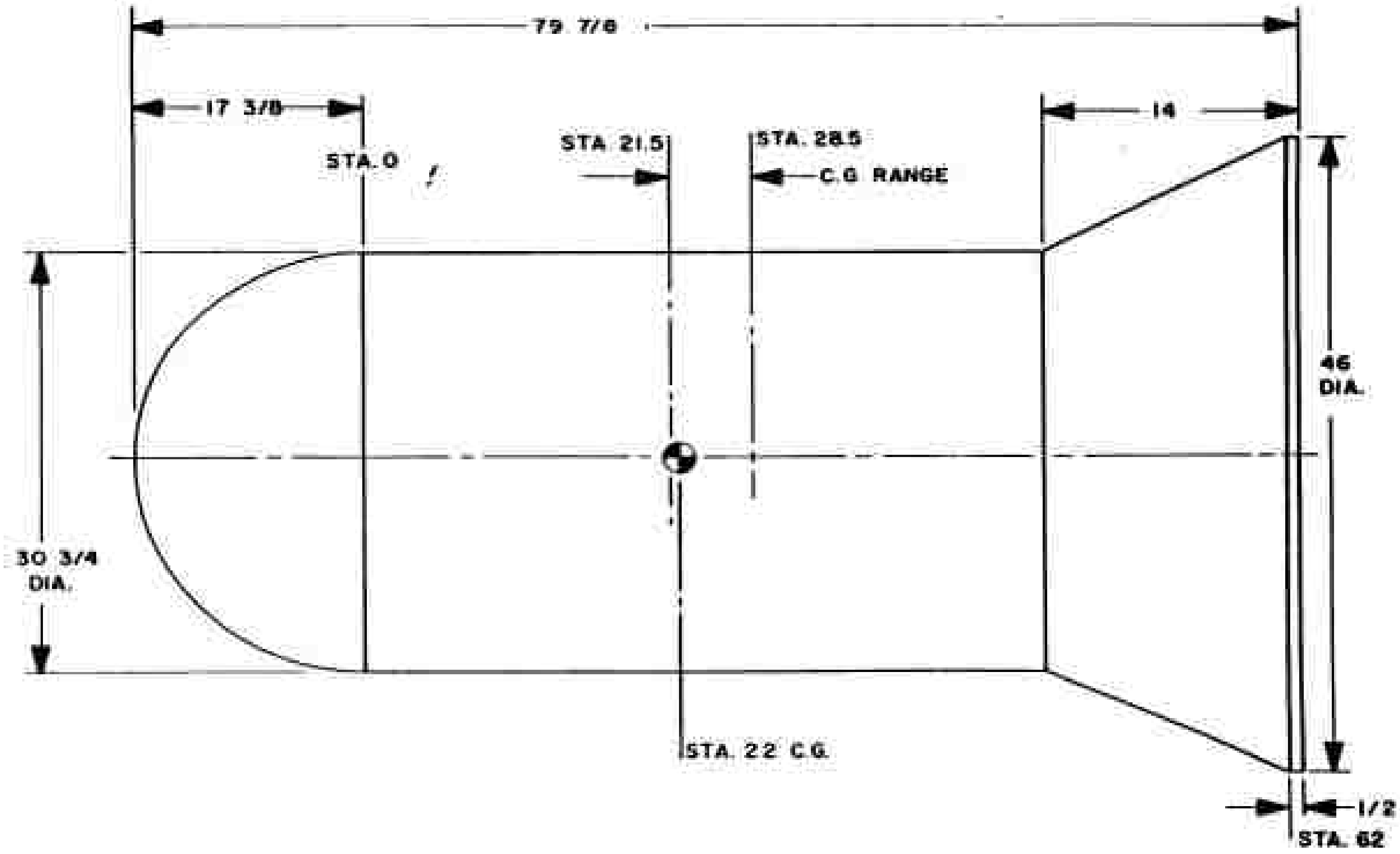


Figure 2.1 Basic pod configuration.

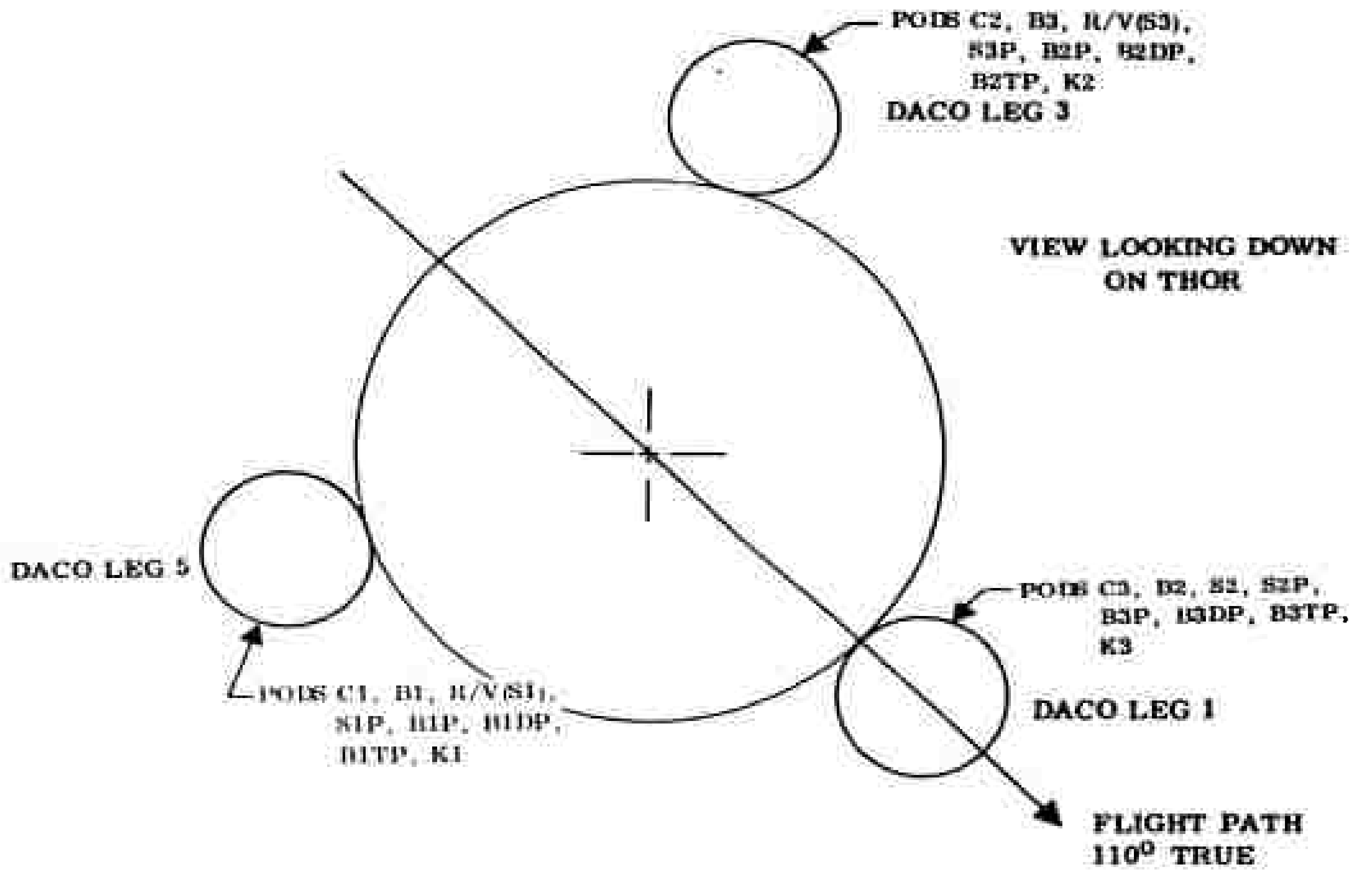


Figure 2.2 Pod locations on booster.

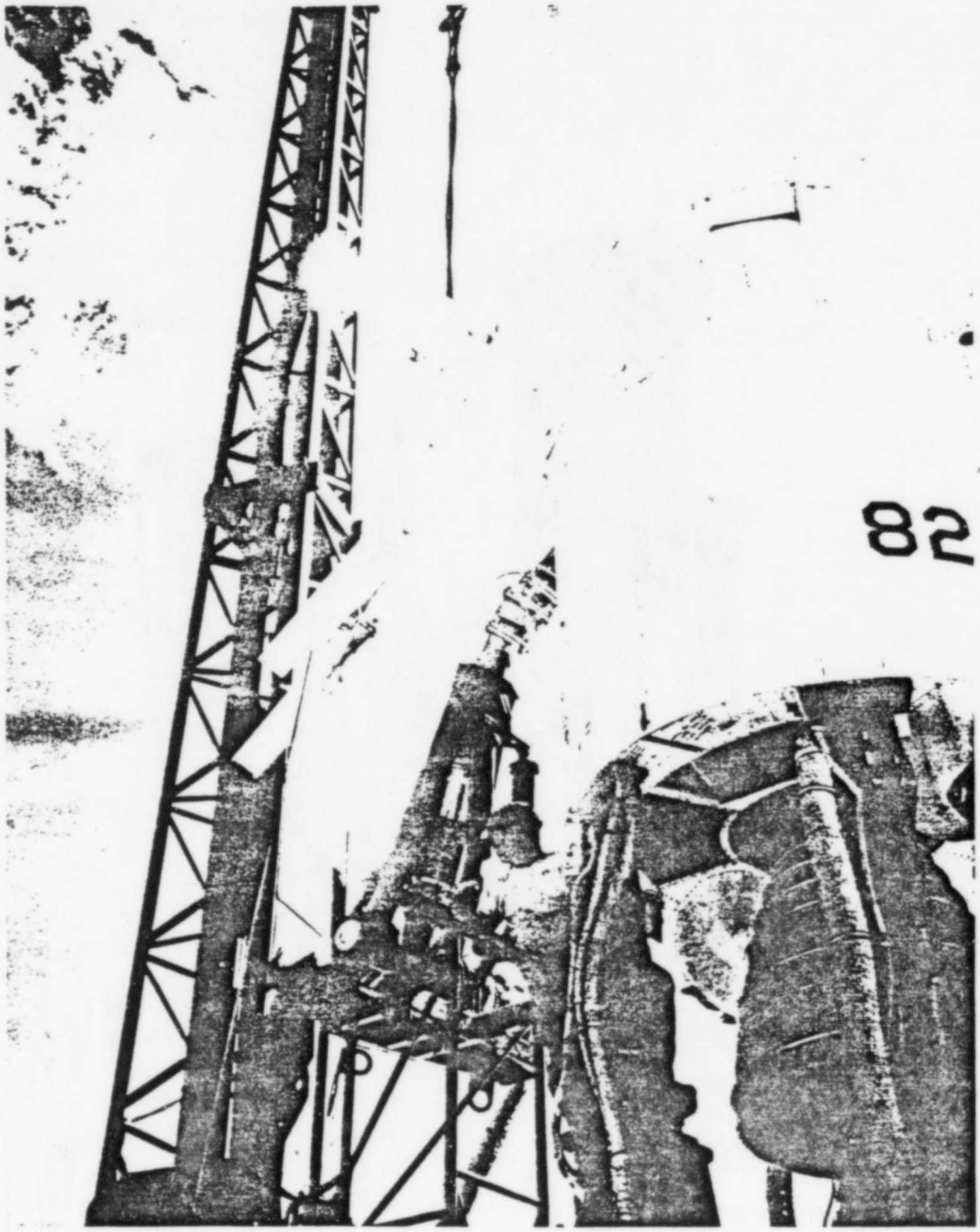


Figure 2.3 Pod fairing installation on Thor. (DASA 26-5624-62)

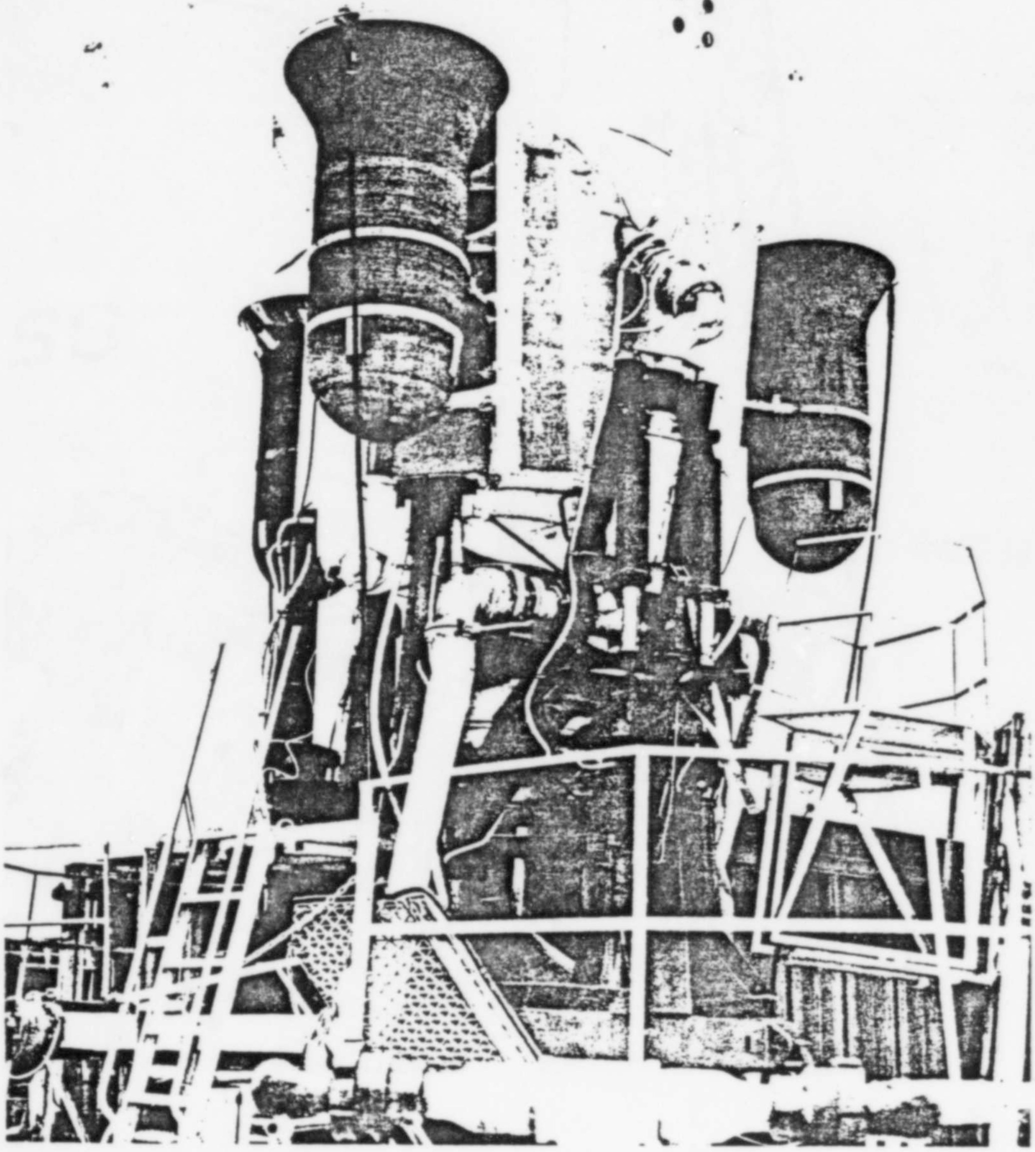
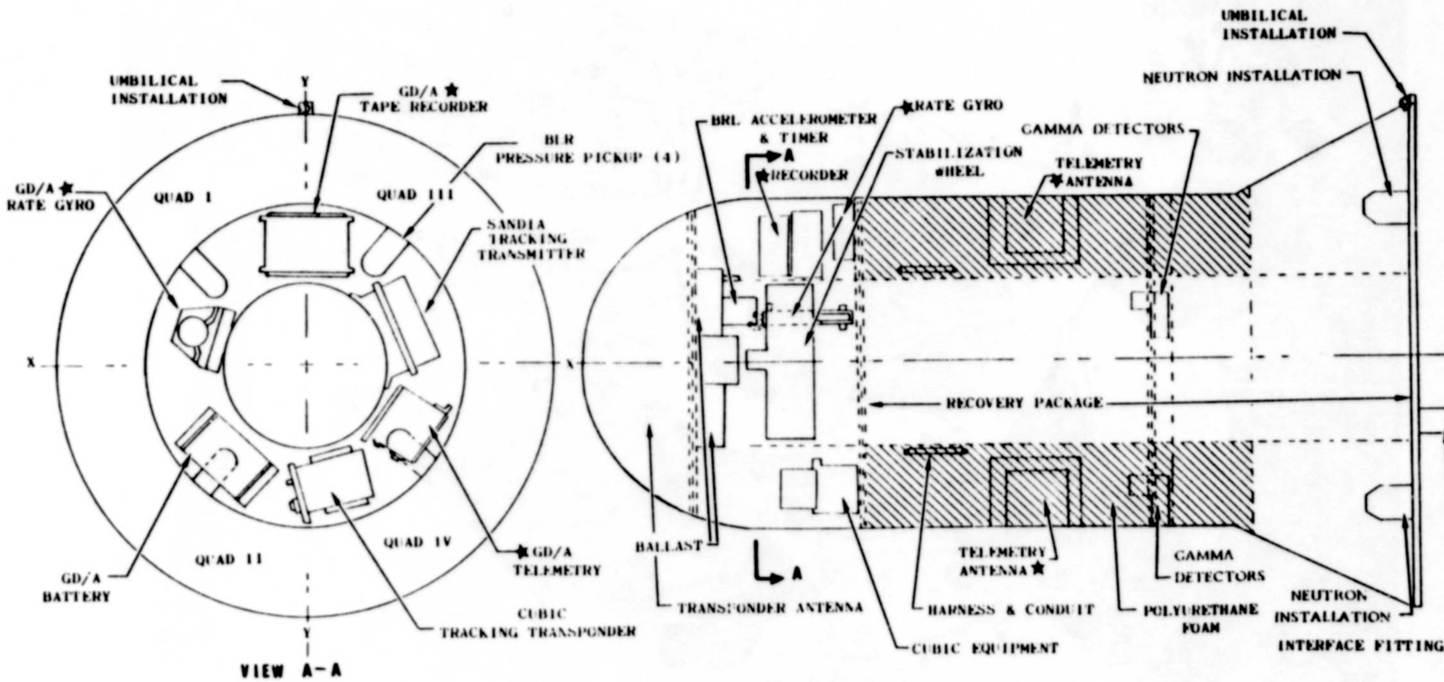


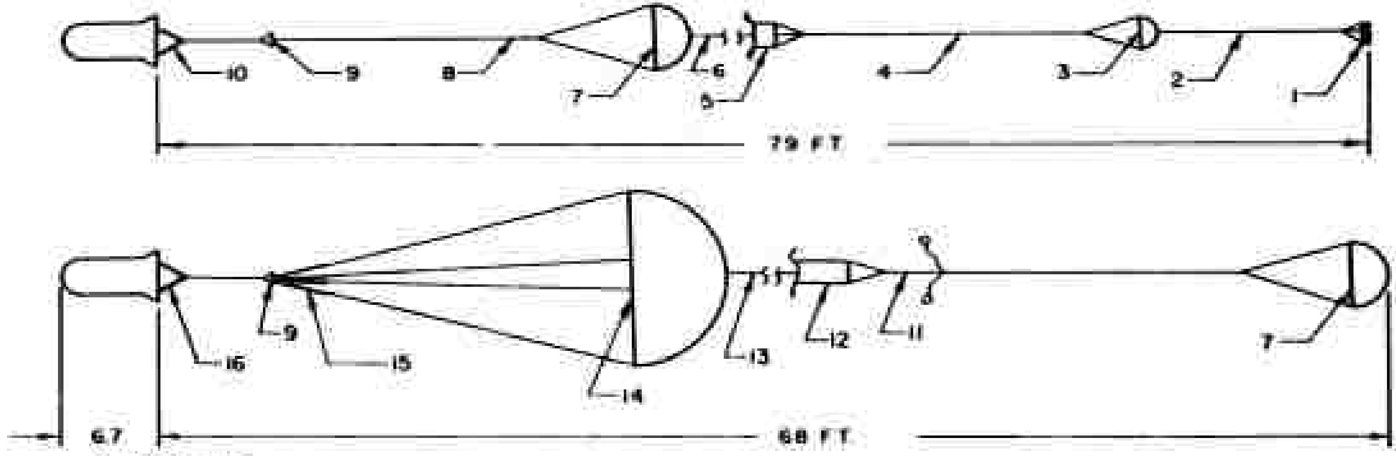
Figure 2.4 Pod installation on Thor. (DASA 26-6267-62)



★ DENOTES EQUIPMENT USED ON THE "TIGER FISH" POD ONLY.

Figure 2.5 Pod subassembly location.

Figure 2.6 Recovery unit installation. (DASA 26-5660-62)



ITEM	RADIOPLANE DRAWING NO	DESCRIPTION	LENGTH (FT.)
1	R5405	VEHICLE COVER	—
2	R5417	P/C TO COVER BRIDLE	15.0
3	R5417	2.25 FT. DIA. SOLID FLAT PILOT CHUTE	3.0
4	R5417	PILOT CHUTE BRIDLE	26.0
5	R5429	DROGUE CHUTE DEPLOYMENT BAG	1.5
6	—	BREAKCORD 1 PLY OF HT-1 90 LB. RIBBON	2.0
7	R5430	4.5 FT. DIA. CONICAL RIBBON DROGUE CHUTE	6.0
8	R5430	DROGUE CHUTE RISER	15.5
9	—	SWIVEL CONNECTOR	—
10	R5430	2 LEG RISER TO VEHICLE	—
11	R5430	JUMP RISER TO MAIN CHUTE DEPLOYMENT BAG	5.0
12	R5415	MAIN CHUTE DEPLOYMENT BAG	2.0
13	—	BREAKCORD 1 PLY OF HT-1 5 CORD	2.0
14	R5401	20 FT. DIA. CONICAL RIBBON MAIN CHUTE	23.0
15	R5401	4 LEG RISER TO SWIVEL CONNECTOR	—
16	R5401	2 LEG RISER TO VEHICLE	—

Figure 2.7 Schematic of deployed recovery system.

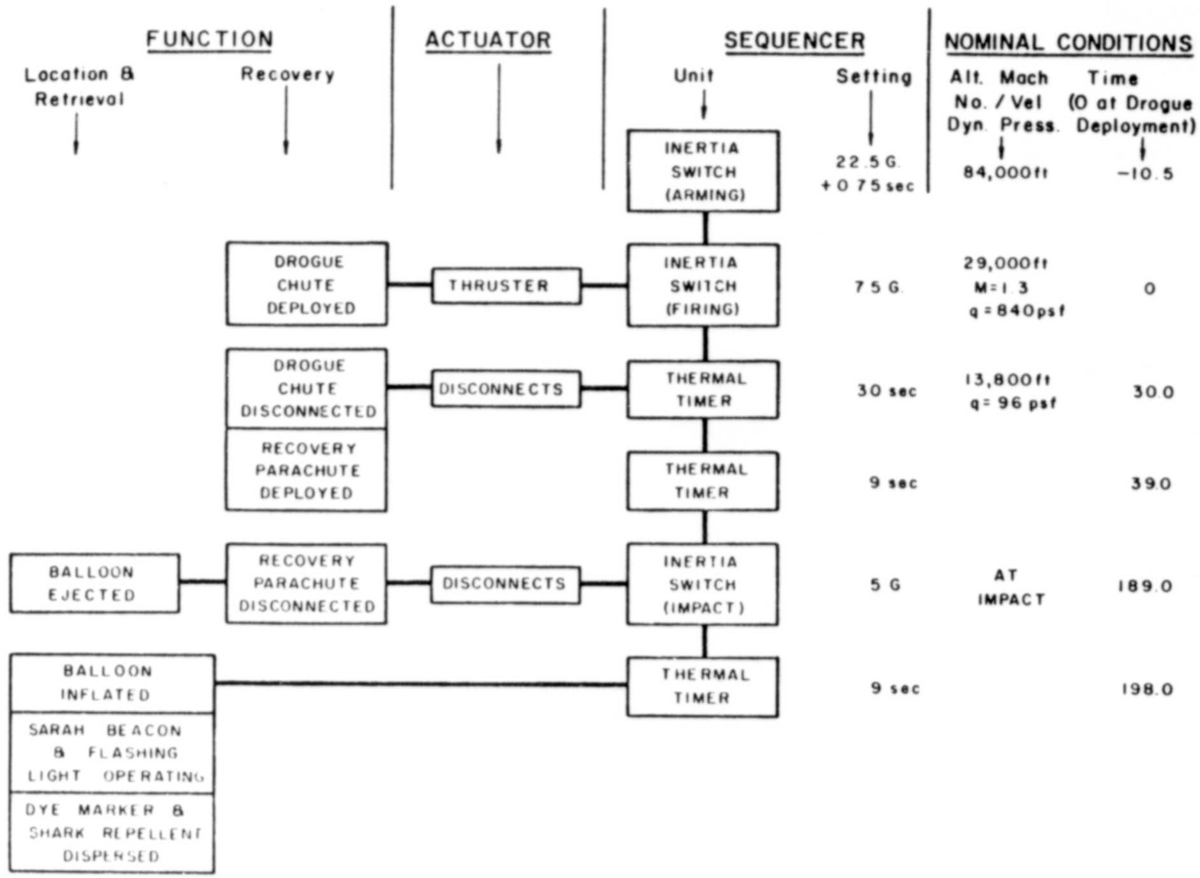


Figure 2.8 Block diagram of recovery system functional schematic.

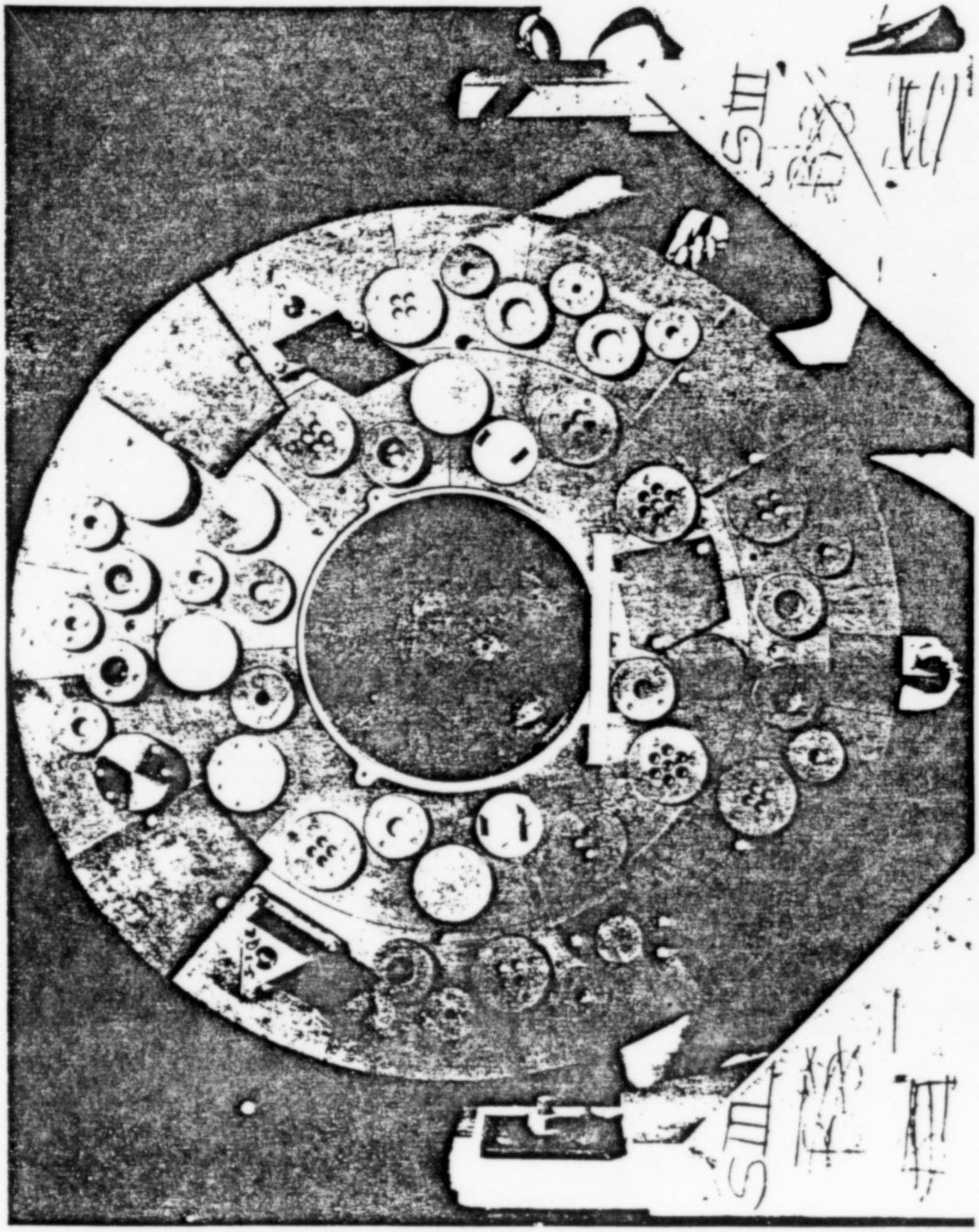


Figure 2.9 Project 8B instrumentation, Star Fish. (DASA 26-6131-62)

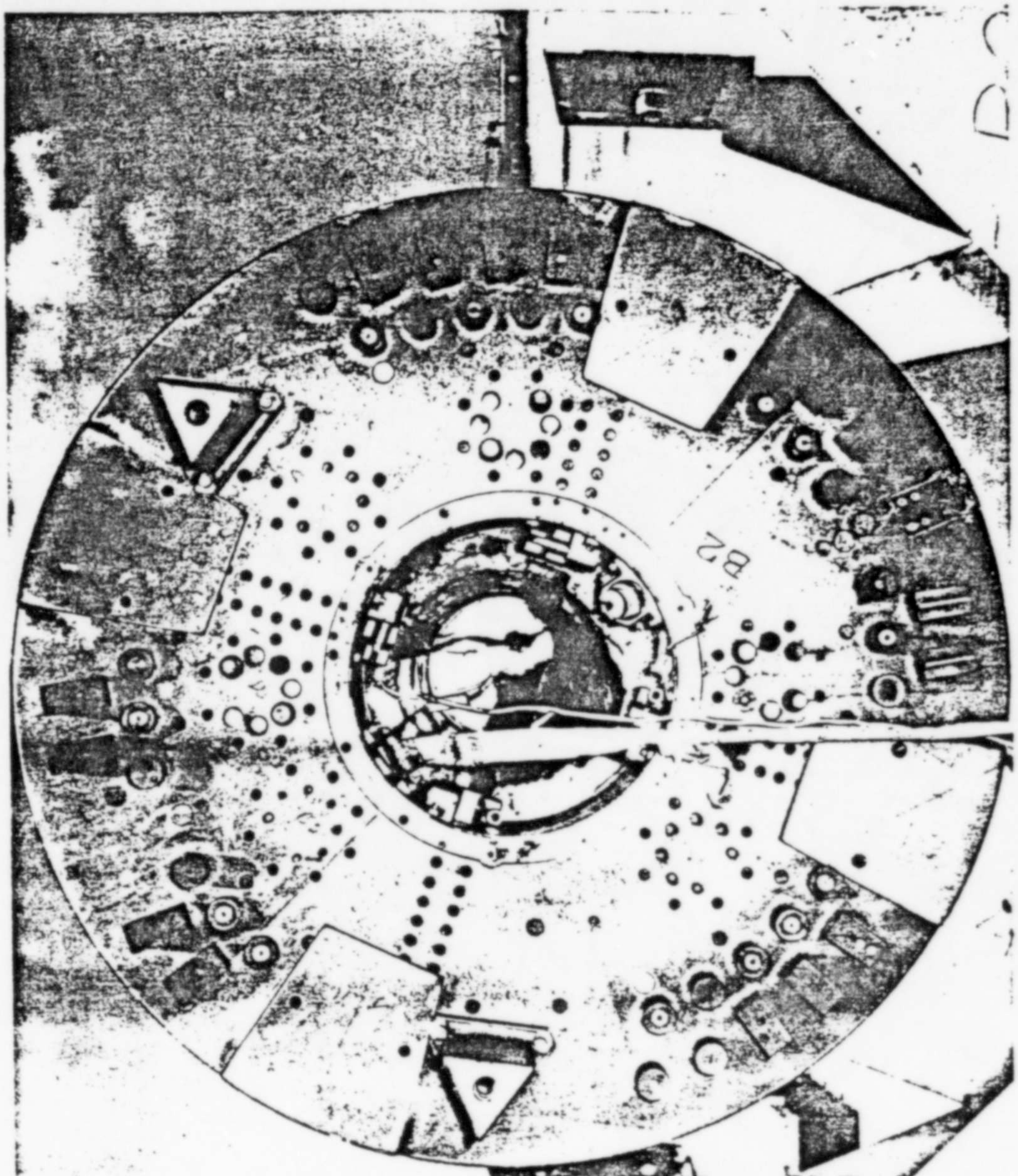


Figure 2.10 Project 8A.3 instrumentation, Blue Gill. (DASA 26-5986-62)

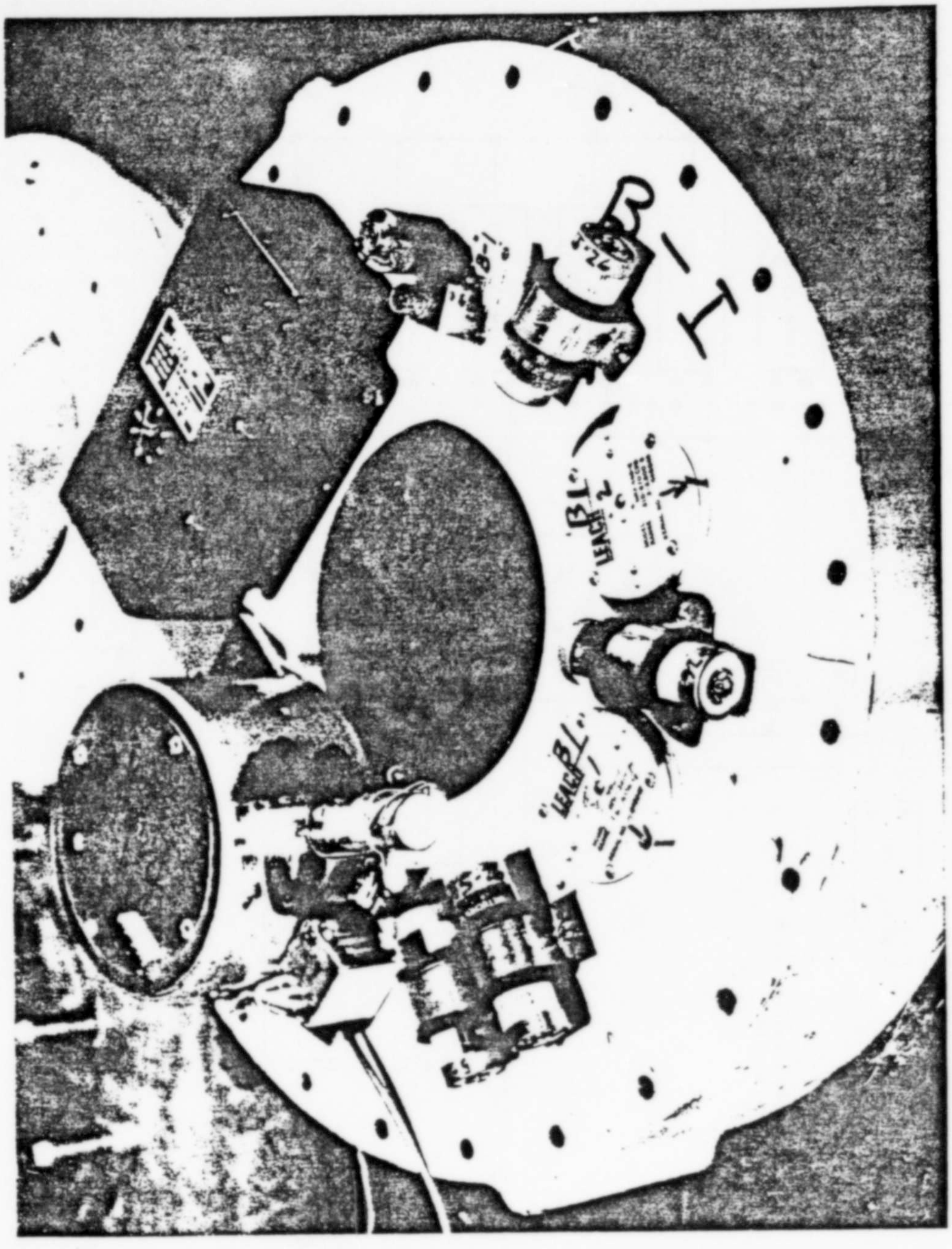


Figure 2.11 Project 1.1 instrumentation, Blue Gill. (DASA 26-5911-62)

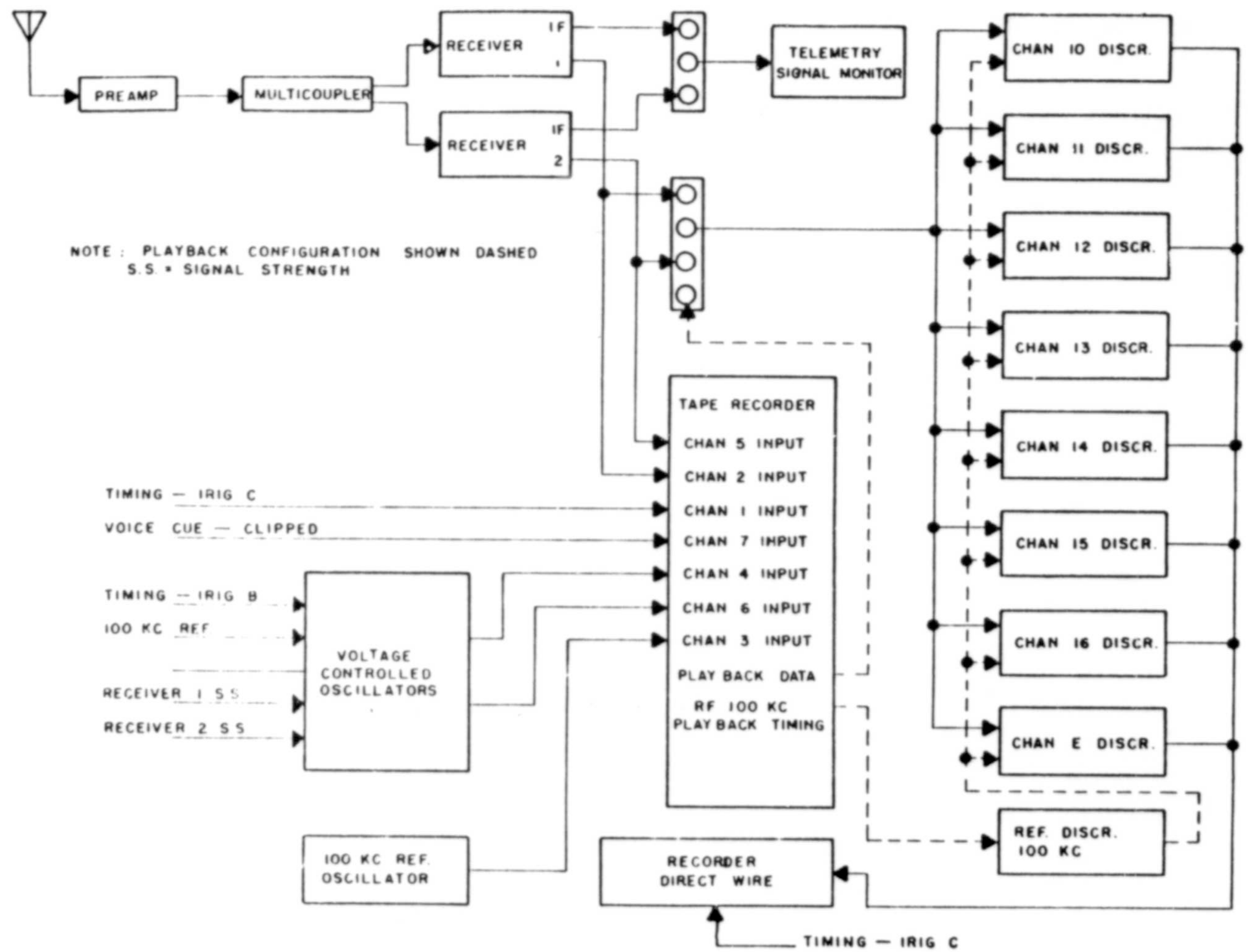


Figure 2.12 Block diagram of receiving station.

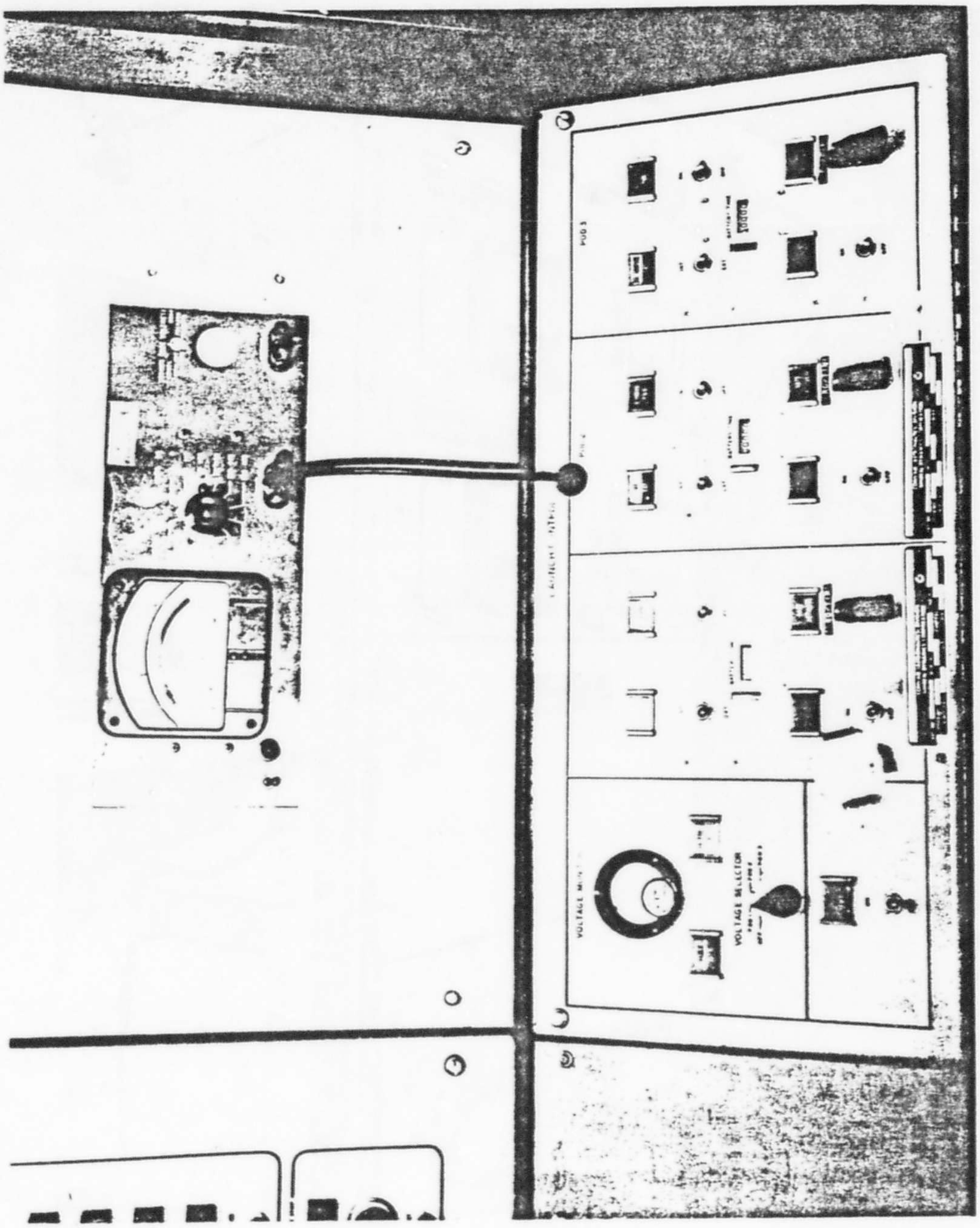


Figure 2.13 Launch control monitor panel. (DASA 26-6445-62)

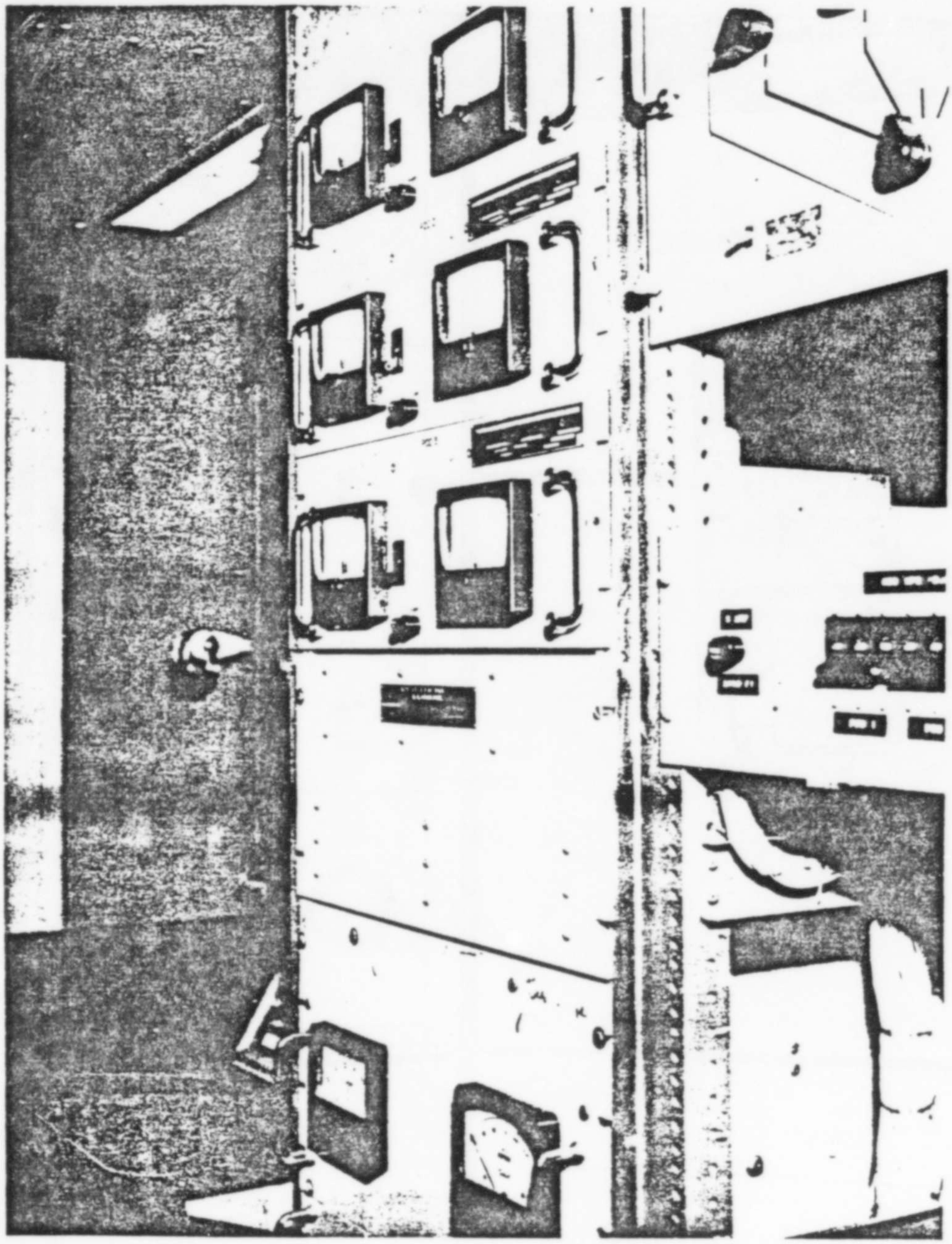


Figure 2.14 Pod control relay racks in missile checkout trailer. (DASA 26-6446-62)

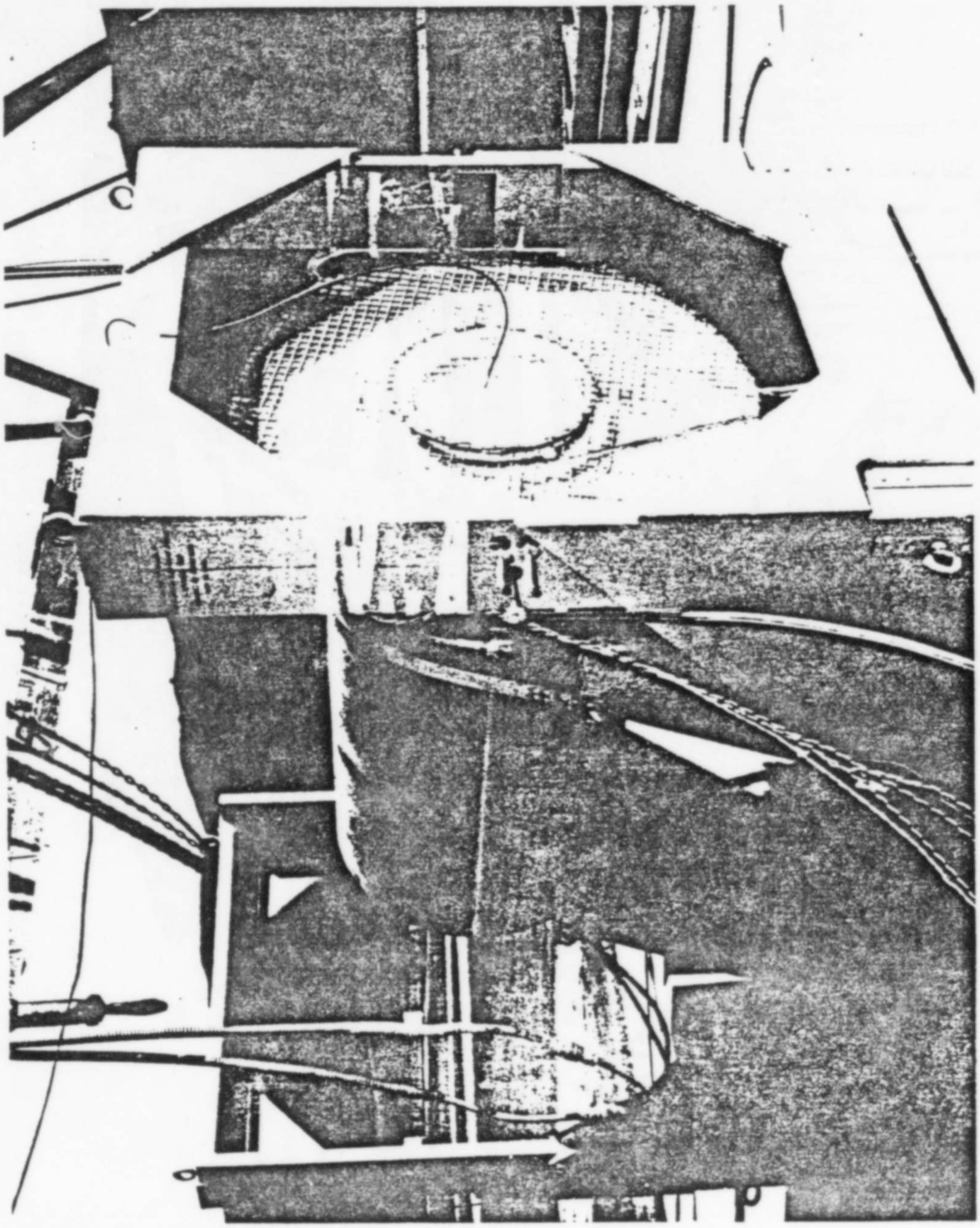


Figure 2.15 Gasbag test setup. (GD/A photo)

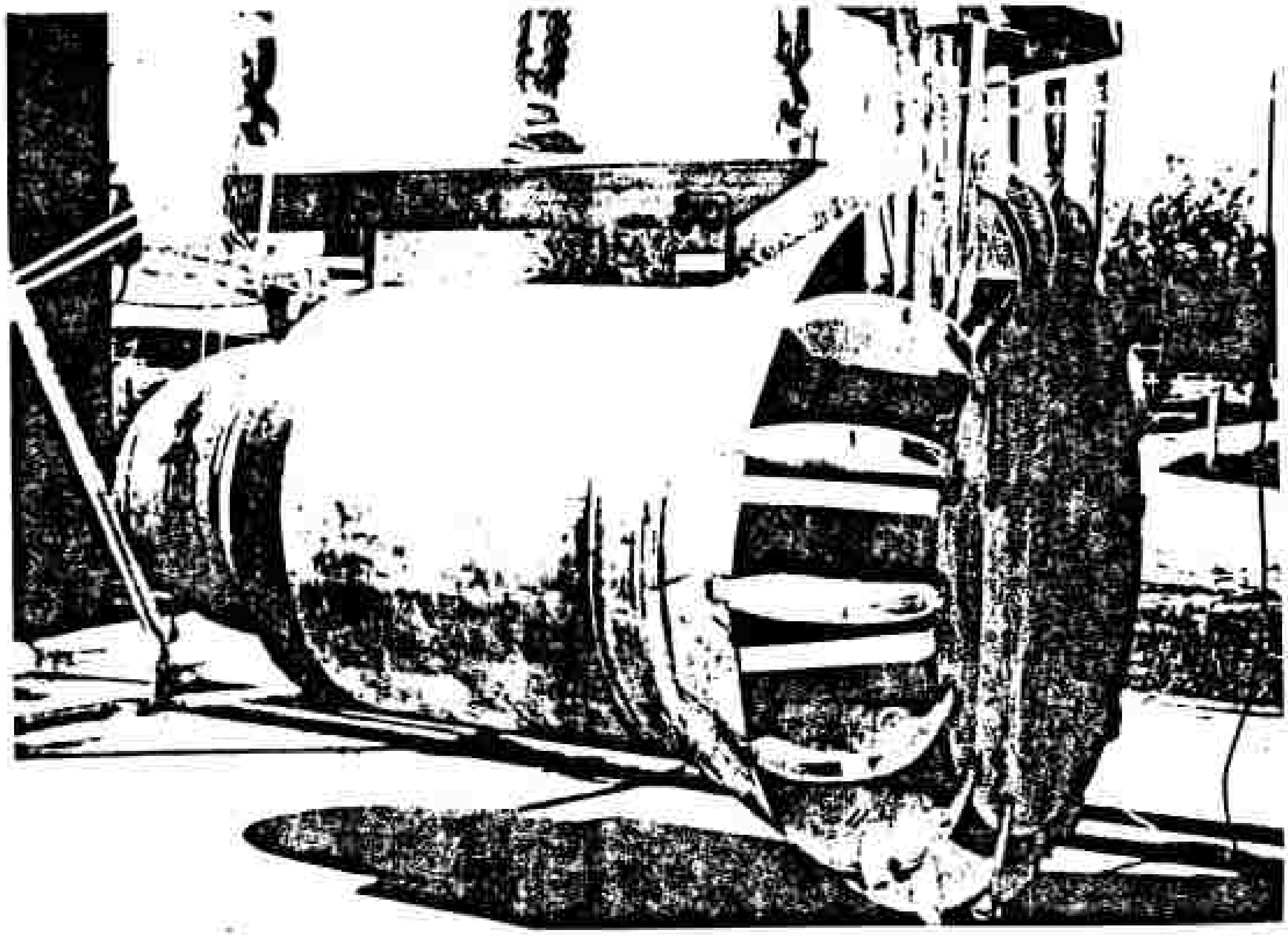


Figure 2.16 EL506D explosive test setup, Pod E2. (GD/A photo)

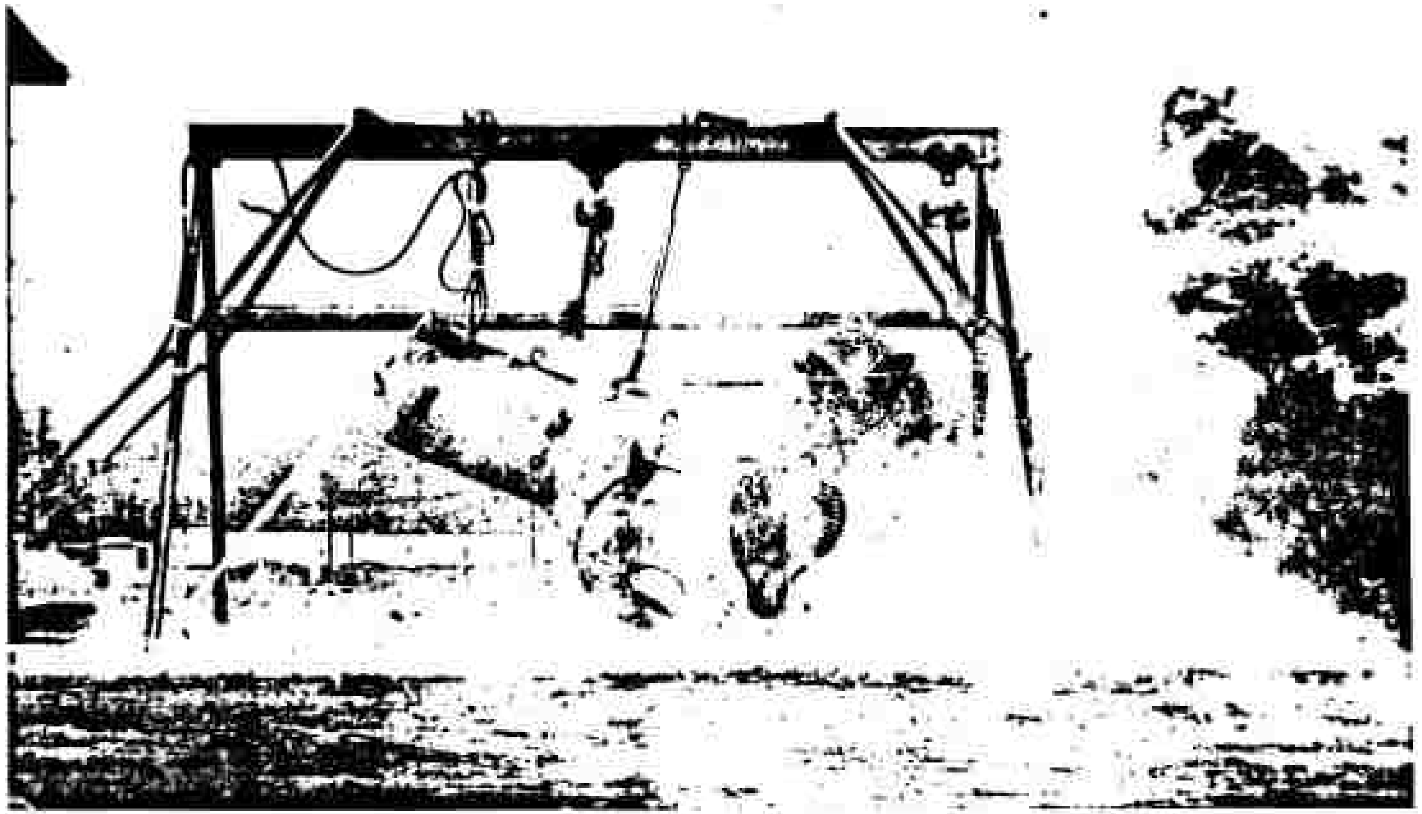


Figure 2.17 test, Pod E1. (GD/A photo)

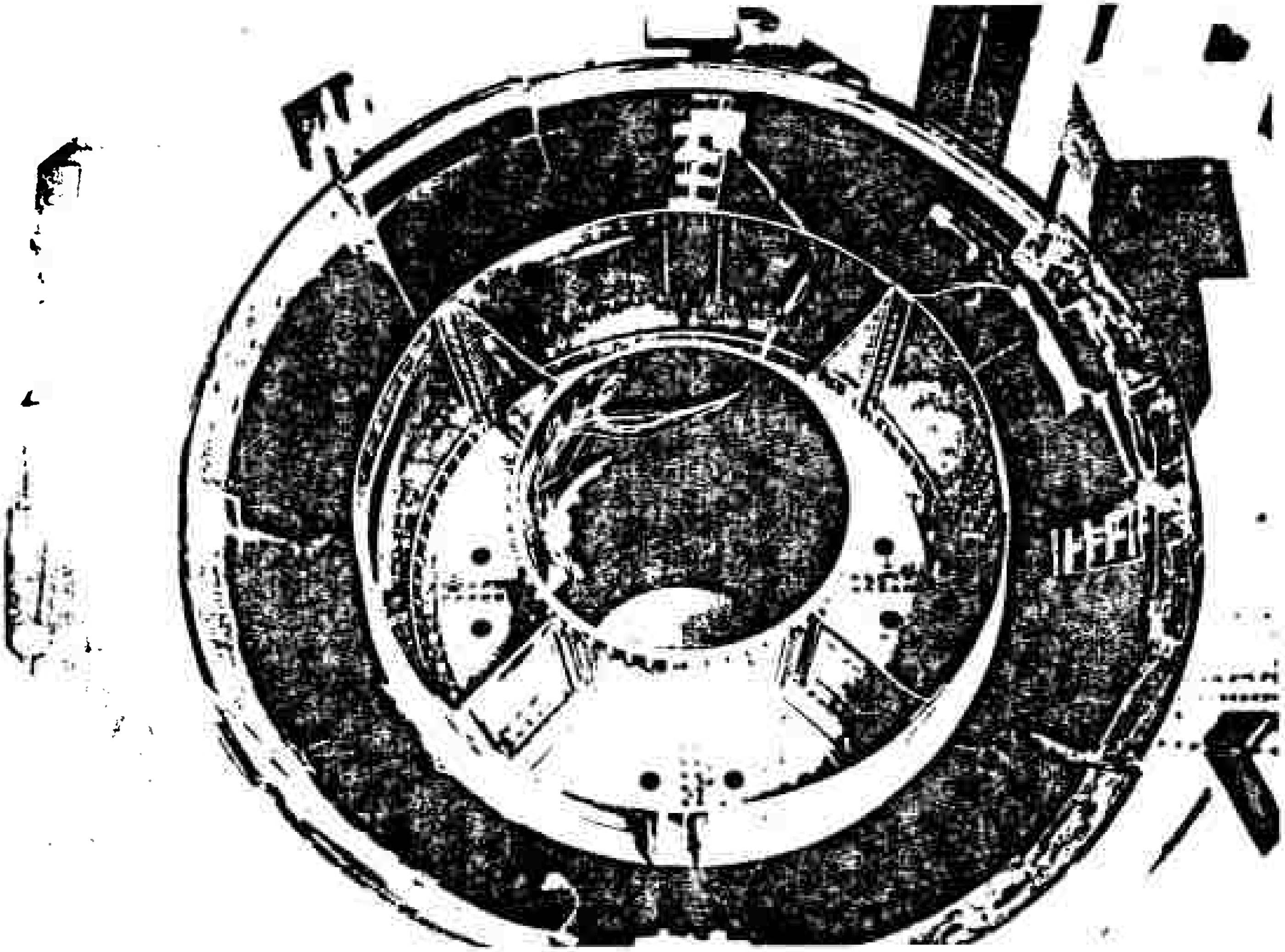


Figure 2.18 37,500 dyne-sec/cm^2 damage, Pod E1. (GD/A photo)

Figure 2.19 Flare damage, P(E2. (DASA 26-6460-62)

Figure 2.20 Nose damage, Pod E2. (DASA 26-6444-62)

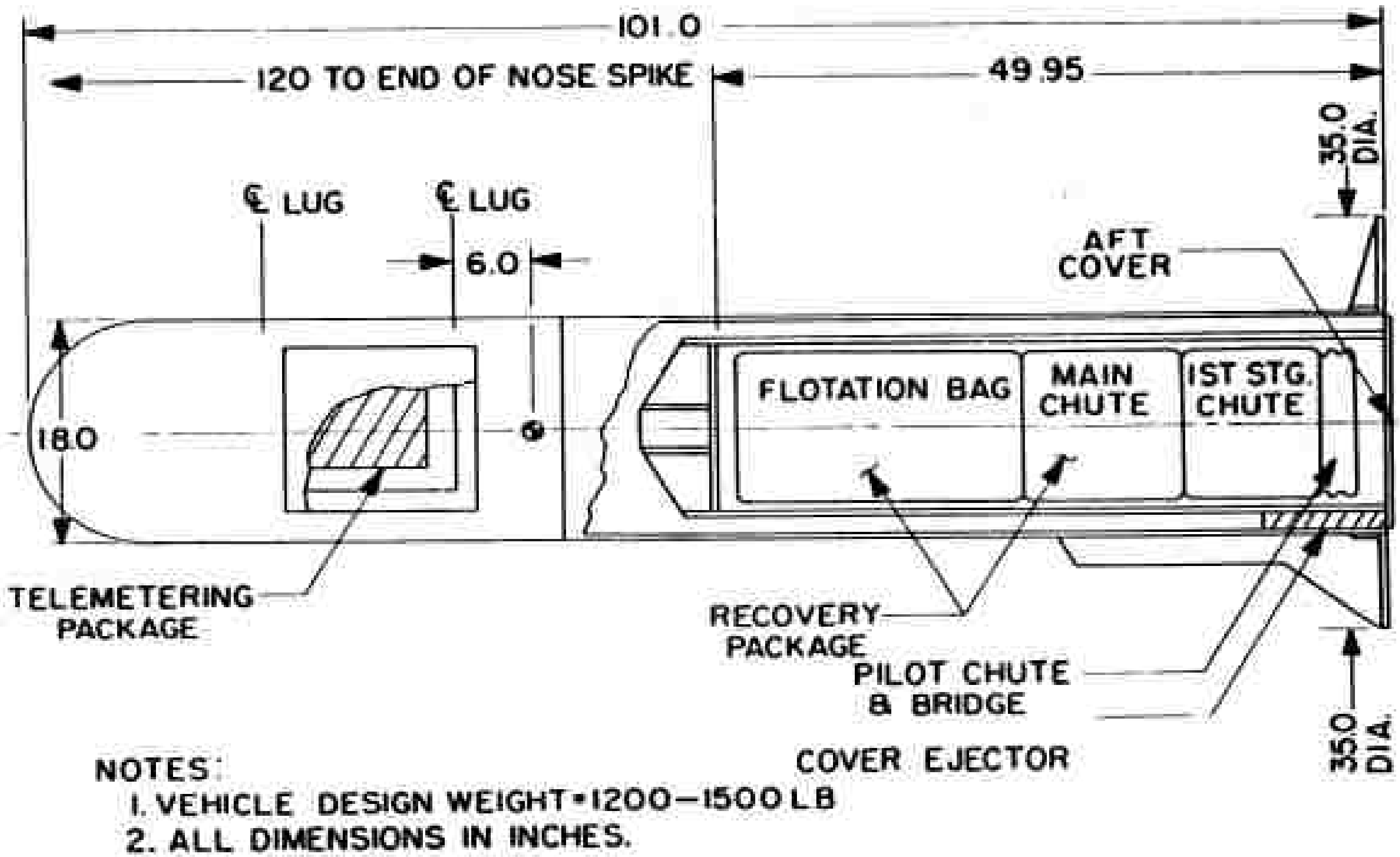


Figure 2.21 Modified T-1 test vehicle.

Chapter 3
RESULTS

3.1 TIGER FISH

From the project viewpoint the primary purpose of Tiger Fish was to prove that pods could be satisfactorily flown and positioned using the Thor IRBM as the carrier. Secondary objectives included proper functioning of the pods and a systems check of the ground support equipment. The GD/A telemetry system was programmed to record such items as stability, re-entry heating, velocity and acceleration profiles, and other data listed under pod instrumentation in Table 2.5.

Tiger Fish used two fully instrumented pods, C1 and C3, and one uninstrumented pod, C2. Pods C1 and C3 contained GD/A telemetry equipment and recovery systems. All three pods contained Sandia Corporation and Cubic Corporation transponder tracking equipment. Pod C2 carried steel ballast in place of instrumentation and a recovery system.

Pods C1 and C2 were programmed for release so that the placement simulated Blue Gill B1 and B3 positions. Pod C3 simulated Star Fish S3 pod position. Thus, the three C pods tested the Blue Gill and Star Fish pod placements relative to burst in one test flight. The pod-to-burst distances that were required by the experimental project agencies are listed in Table 3.1.

During the pre-flight countdown, the 28-volt dc motors on the C1 and C2 flywheel stabilization systems burned out. These dc motors were known to be marginal from previous run-up tests. The motor on C1 was replaced. Because of time limitations, only one other motor could be changed. It was decided to change the motor on C3 to improve its chance of success rather than replace the motor on C2, which had no instrumentation. During the final countdown, the motor in Pod C1 burned out again.

Tiger Fish launch occurred at 1245 W on 2 May 1962, from Johnston Island. Event times occurred as programmed during the flight. Table 3.2 presents predicted flight events. Pod C3 was released at an altitude of 417,028 feet, and Pods C1 and C2 were released approximately 16 seconds later at an altitude of 598,718 feet. All pods attained an approximate altitude of 2,300,000 feet at apogee as expected. Table 3.3 presents a summary of pod-to-burst distances.

Telemetry reception from Pod C3 was excellent with good data available from lift-off to impact. Pod C1 reception was good until re-entry, at which time a temporary blackout occurred due to tumbling and inverted pod re-entry. Motion pictures taken from Pod C1 reveal that the pod was in a position to be impinged upon by the blast from the Thor special retrorockets used to move the Thor away laterally from the pods. When the forward retrorockets were fired 2 seconds after pod separation, the missile was retarded, and the rocket blast hit the aft portion of Pod C1, causing it to tumble.

Drogue chute arming and triggering functioned properly on Pod C3, and both drogue and main chutes were deployed. Arming and triggering did not function on Pod C1, possibly due to the fact that pod attitude at re-entry was reversed.

Evaluation of pod temperature data indicated that no unexpected damage was sustained by the external structure due to re-entry heating. On Pod C3, the umbilical flange burned off, and a slight amount of heat shield charring was sustained as expected. Pods C1 and C2 sustained structural damage as well as charring, but most damage on C1 and C2 was due to unretarded water impact.

All three pods were recovered as planned after impacting in the ocean near Johnston Island. Pods C1 and C3 were equipped with recovery aids consisting of Sarah beacons, dye markers, and flotation balloons. All C3 recovery aids functioned, but those of C1, with the exception of the dye marker, failed to operate. The dye marker on C2 (only recovery aid provided) functioned.

Within 5 minutes after H-hour (burst time) two P2V aircraft engaged in search, located the pods, first by dye markers and then by the C3 Sarah beacon. The pods were in a straight line approximately 1,000 yards in length and about 1/2 mile off target.

Helicopters were airborne from the carrier within 5 minutes after H-hour and arrived at Pod C3 at H plus 13 minutes. The recovery aid balloon was floating near the pod, still attached to the 6-foot electrical umbilical. This connection was broken by the helicopter backwash, and the flotation balloon was blown to the end of the 40-foot line. This operation required the helicopter to approach within a few feet of the pod, which would be unsatisfactory during an operational flight because of the radiation levels.

Pickup of C3 was accomplished by H plus 19 minutes, and the helicopter proceeded toward Johnston Island. Approximately 7 miles from the island, the helicopter developed engine trouble and was forced to return the pod to the water. A second pickup attempt was made but also was unsuccessful when the helicopter's shepherd's hook broke. As the balloon fell back into the water, it was ripped away from the 40-foot line, making it impossible to make another attempt by helicopter. The pod was then netted by the Navy tug USS Matako, which had previously picked up Pods C1 and C2 by this alternate recovery method (Figure 3.1). The tug then proceeded to Johnston Island with the pods.

Pod C3 was recovered with no damage sustained due to impact. Pods C1 (with recovery system) and C2 (with no parachutes) did sustain damage, since neither was retarded by parachutes, but were recovered substantially intact. That the damage did occur at impact rather than re-entry is evidenced by the fact that surface fractures on these pods extended beneath the charred layer sustained at re-entry.

It is significant to note that all three pods remained intact and did float as planned despite the damage sustained at impact by Pods C1 and C2.

Instrumentation was removed from the pods during the night of 2 May 1962. C1 and C2, telemetry tapes, film, and other data were returned to San Diego, California, by special airlift on 3 May. The results of this data and a more complete description of the pods are given in Reference 4.

3.2 BLUE GILL

Checkout and calibration of pod equipment was accomplished on site without difficulty. The new 400-cycle, 208-volt, 3-phase alternating current ground support equipment for the pod stabilization system was installed by DACO personnel. The new 400-cycle flywheel motor was installed in all pods subsequent to Tiger Fish. On Dress Rehearsal Day or Full Power Full Frequency Day (FPFF) minus one, the Blue Gill pod stabilization systems were successfully calibrated on the launch pad. Figure 3.2 presents the typical calibration curve.

The full dress rehearsal was conducted on D-7 and D-6 days with all pod systems operating normally.

Launch occurred at 2344 W on 3 June. Lift-off was normal, and range safety radar indicated nominal tracking through main engine cutoff (MECO). Flight data indicated MECO at 154.27 seconds and vernier engine cutoff (VECO) at 160.87 seconds, which were well within nominal flight criteria. Predicted Blue Gill flight events are listed in Table 3.2. Due to difficulties incurred in the range safety system after MECO, the warhead was destroyed 180 seconds prior to burst time.

Pods B1, B2, and B3 were programmed to release at 174.8 seconds from lift-off. Due to failure of a missile relay, Pods B1 and B3 did not receive the release signal. Pod B2 was released as programmed, since it was on a different relay which operated properly.

Tracking reception from Sandia Corporation and Cubic Corporation was good throughout the flight on Pod B2. Sandia terminated track at warhead destruction but extrapolated to burst time to check pod positioning. Table 3.3 contains a summary of positioning data. Cubic tracking signal strength records definitely confirmed that Pods B1 and B3 were still attached to the Thor until re-entry. At re-entry, the B1 signal became stable, indicating it had broken free. The B3 signal kept fluctuating, indicating it was still attached to the Thor, but the signal strength dropped rapidly at this time, and release time of the pod could not be determined.

All three pods had a normal re-entry, which indicates that B3 did finally release from the Thor. All three recovery systems operated. Pod B1 main parachute failed to release at impact, and the drogue chute was entangled in the main chute.

The balloon system was not released from the canister on B1, due to failure of the main parachute to release at water impact. The balloon systems on B2 and B3 actuated but ruptured in the mouth of the canister, due to weak ejection springs. The strobe lights and Sarah beacons on B2 and B3 did not operate, because the wiring was broken when the balloons burst. All dye markers functioned.

The pods were located at dawn, and pickup drums were attached to the pods by ships. This was necessary because of the ruptured flotation balloons. The helicopters then picked the pods up and returned them to Johnston Island (Figure 3.3).

Pod B2 rear bulkhead showed no abnormal heating. Rear bulkheads of B1 and B3 were burned extensively. Figure 3.4 shows the unusual heating pattern on B1. Pod B3 experienced heat damage over the entire rear bulkhead.

3.3 STAR FISH

One DASA pod was flown on Star Fish with two AVCO re-entry vehicles (R/V's) (Figure 3.5). The S3 pod was to be placed at 10-km separation from the burst. Checkout, calibration, and instrumentation were routine. The Thor was launched 19 July at 2246 hours local time. The lift-off and flight appeared normal until approximately 30,000 feet, where the missile and warhead destruct system were deliberately actuated. A large number of pieces, including Pod S3 and one AVCO R/V, fell back on Johnston Island. Figures 3.6 and 3.7 show the damage to the pod. The parachutes from the recovery system were salvaged for use on a later flight. There were also a few scientific instruments salvaged.

3.4 STAR FISH PRIME

On the D–5 day, full-power full-frequency run, the Pod S2P flywheel failed to operate properly, and the motor burned out. It was removed, and a backup flywheel was installed and checked out. The remainder of the checkout and instrumentation tasks were routine.

This event was scheduled for 4 July at 2300 hours local time. Weather holds delayed the launch until 8 July. During these holds a leak in the actuator nitrogen system of Recovery Unit 10 in Pod S2P grew progressively worse. The unit was removed and recharged after the first 24-hour hold. With the additional holds, the unit was finally replaced with a spare unit on 7 July.

During final flywheel run-up at H–20 minutes (6 minutes prior to lift-off), Pod S1P flywheel malfunctioned. After attaining 2,000 rpm, acceleration practically ceased, and a final speed of 3,600 rpm was achieved at lift-off.

The Thor flight was nominal, and all three pods were released. Thor telemetry indicates events occurring at the following times. T indicates time of lift-off.

Lift-off	2246:28.066 local
MECO	T+157.113 seconds
S3P release	T+157.360 seconds
S2P release	T+157.900 seconds
S1P release	T+158.553 seconds
VECO	T+163.985 seconds
R/V release	T+175.328 seconds
Retro Set 1	T+177.975 seconds
Retro Set 2	T+179.080 seconds

Pod release times listed are the times when the explosive bolt umbilical plug between the pods and the missile separated. The separation requires 0.2-inch motion of the pod relative to the missile. Consequently, actual release times are earlier than those listed. Calculations by DACO indicate Pod S3P was released earlier than programmed while the missile was under full thrust.

Tracking from the Cubic system was marginal on Pod S1P, because of tumbling. Pod S2P signal strength records indicate that it was wobbling. Pod S3P tracking on the Cubic and Sandia tracking systems was good. Tracking continued through re-entry after a momentary blackout at burst time.

Pod positioning data from Cubic and Sandia tracking data is included in Table 3.3. This data indicates that Pods S1P and S2P were within the required ± 20-percent placement accuracy and that Pod S3P was low. Pod S3P tracking confirms DACO's preliminary report of an early release. Pod S1P tumbled at release, due to release and flame impingement perturbations.

From the X-ray shadow effects on the bulkheads of S2P and S3P, Project 8B determined that the longitudinal axes were at angles of 43° and 41° relative to the burst. Pod S1P was almost nose-on to the burst. The large angle of precession cannot be easily explained, since there was no instrumentation on the pods to indicate flywheel speed or disturbances during release. The early release of Pod S3P was probably a contributing factor to the large precession. It is believed that the problem was related to perturbations to the pod during release and passage through the main engine flame.

All parachute systems operated successfully. The balloons and location aids in S1P and S3P operated normally. The recovery aid balloon in S2P burst in the well because of weak ejection springs. Stronger springs were used on subsequent flights (Figure 3.8). The P2V search aircraft located the pods within 20 minutes after starting search. The S1P and S3P Sarah beacon signals were picked up about 20 nautical miles from the pods. The flashing lights were spotted from an altitude of 1,000 feet, about 2,000 yards out. Reports indicated that three lights were spotted on some passes, and it seems likely that Pod S2P strobe light was flashing initially just below the water surface. On subsequent passes to drop marker flares, only two lights were positively identified and marked. Initial pickup of S1P and S3P was made by ship with transfer of S3P to helicopter at dawn. Pod S2P was located, picked up, and returned to Johnston Island by helicopter at dawn.

The condition of Pods S2P and S3P was normal except for shadows left by X-ray impingement. The heat shield suffered no damage during the burst. Pod S1P suffered a circumferential crack in the flare about 3 inches forward of the rear bulkhead. The crack extended around the flare for about 120°. A deep gouge in the edge of the rear bulkhead was noted near the center of the crack, indicating contact with some heavy object. A neutron gage retaining plate located at the point of the gouge was sheared off, and the neutron gage was missing. Examination of the char depth in the crack in the heat shield indicated that it was made after re-entry heating. It is most probable that the damage was caused by impact against the ship during retrieval operations. No other damage was noted in S1P.

3.5 BLUE GILL PRIME

Due to missile malfunction, the Thor burned on the launch pad. Some parts were salvaged and used on later flights.

3.6 BLUE GILL DOUBLE PRIME

Before the Blue Gill Double Prime flight, the flywheel was improved by installing a direct motor/flywheel coupling and a stronger flywheel case.

3.6.1 Checkout. A run-up and a run-down calibration test was performed on all three pods. Plots of motor current versus time and flywheel rpm versus time were made on the run-up tests. A similar plot of flywheel rpm versus time was made on the run-down calibration. Figure 3.2 shows typical flywheel curves. All flywheels performed normally.

Cubic transponders were installed in all three pods. The pods were then taken to the surveyed point of known distance from the transmitter and an RF check made with the Cubic DME Ground Station. All transponders operated satisfactorily. Later a Sandia transponder was installed in Pod B3 and an RF check run with the Sandia Ground Stations. This transponder also performed properly.

On D minus 6 days the pods were hung on the Thor for a fit check and a full-power full-frequency (FPFF) test. The pod fit was good. The flywheels were not turned on during this test but were tested later during the FPFF on D minus 1 day. During the D minus 6 FPFF the Cubic Ground Station had considerable trouble in receiving signals from the transponders in Pods B1 and B3. A later test at the surveyed point proved that the problem was only RF multipath around the pad area. It was learned that Cubic's transmitting antenna is normally fixed but can be changed manually. In a normal operation the antenna is pointed vertically. On all subsequent FPFF tests or flight operations with the pods the antenna was pointed at the launch pad until the Thor and pods were airborne. This seemed to reduce the RF multipath problems considerably.

On D minus 2 days, the pods were assembled, weighed, and readied for flight. The recovery systems had been previously checked out and were then installed. The two pneumatic systems in each of the recovery units had pressures in excess of 3,300 psi (2,900 and 2,500 minimum) with no leaks. The system battery voltages were above 30 volts (28 volts minimum). All Sarah beacons and flashing lights were working. (There was no Sarah beacon available for Pod B3.)

On D minus 1 day, the pods were again installed on the Thor. A pod launch control electrical checkout proved that the launch system was operating properly. Another FPFF was performed. The flywheels were tested and checked satisfactorily. The transponders were rechecked and were reported good.

<u>3.6.2 Flight</u>. After a 24-hour delay due to bad weather, the terminal countdown was picked up at about 2040 W on 15 October 1962. The countdown went smoothly to lift off at 2114 : 3850. All transponders and flywheels were operating normally at lift-off. Telemetry information indicated that all Thor engines went hard over, causing the missile to tumble

while under full power. A destruct signal was transmitted to both missile and warhead at about lift-off + 94 seconds.

3.6.3 Recovery and Examination. All three pods were spotted by helicopter after sunrise on 16 October. Pod B1 and Pod B3 were returned to the hot cell area by helicopter for examining. Pod B2 was considered too dangerous for helicopter recovery because of an unactivated recovery system and was later returned to Johnston Island by boat.

Pod B1 received the most impact damage. Two-thirds of the hardened flare had been broken off. One edge of the rear bulkhead behind the flare was bent over and partially broken off. The nose was dented to a depth of 5 inches on the same side as the rear bulkhead damage (Figure 3.9). On the rear bulkhead, most of the piston-type instruments were bent over. A number of surface-mounted instruments had been sheared off. One DACO Thor mounting fitting was sheared off about 1 inch from the bulkhead (Figure 3.10). The recovery system actuator had blown the door off and deployed the drogue parachute, the drogue chute had released and deployed the main parachute, but the main parachute had not released nor had the flotation bag deployed (Figure 3.11). Over 2,800-psi pressure was still in the release system after recovery. The main parachute had two splits when recovered. One was relatively small, but the other was from skirt to crown.

Pod B2 was severely charred over all of the heat shield, however, no heat damage was apparent on the rear bulkhead. The area normally covered with the saddle and saddle band, which holds the cylindrical body of the pod when it is mounted to the Thor (Figure 2.4), was not charred (Figure 3.12). The rear bulkhead had light damage due to a shear force. A few piston instruments were bent and a number of surface mounted instruments broken. A mounting bracket from the Thor supporting structure was still attached to the pod when recovered (Figure 3.13). The recovery system was not activated during this flight. When checked after recovery, the system pressures were 2,700 (actuator) and 3,400 psi (release). The actuator system developed a leak during flight and was about 200 psi below safe level when recovered.

Because the parachute system on Pod B3 worked properly, the pod received no water impact damage. The flotation bag was deployed but did not inflate. Broken wires prevented the inflation of the bag and the operation of the flashing light. The heat shield was lightly charred and the nose speckled with white spots, probably melted aluminum from the burning missile (Figure 3.14). The rear bulkhead was damaged by a shear force as was Pod B1. This bent most of the piston-type instruments, damaged a large number of surface-mounted instruments, and broke off one of the DACO mounting fittings. The refrasil covering was also scraped off the four Nuclear Defense Laboratory (NDL) back cover plates (Figure 3.15). The recovery system actuator fired the door and deployed the drogue parachute. The drogue released and deployed the main chute.

3.7 BLUE GILL TRIPLE PRIME

3.7.1 Checkout. All pod flywheels were tested and the run-up and run-down characteristics plotted. All curves were normal. A fit check of the three pods was made with the Thor on D minus 10 days. All pods fit properly. A Cubic transponder was installed in each pod, as well as one Sandia transponder in Pod B2. Checks were made with the Cubic and Sandia Ground Stations, and all transponders were reported good. The experimenters started installing their instrumentation on D minus 9 days. The pods were closed, weighed, and readied for flight on D minus 3 days. All battery voltages in the pod recovery systems were 30 volts or more. The pneumatic system pressures were over 3,150 psi in all units except the actuator system in Pod B3 which had 3,070 psi. There were no leaks in any of the pressure systems. All three recovery systems had operating flashing lights and Sarah Beacons. The pods were installed on the missile for the event on D minus 1 day. On the same evening, a FPFF was held. During this test, two systems malfunctioned. The flywheel in Pod B1 would not run up to speed, and the Cubic transponder in Pod B3 did not check out with the ground station. It was later discovered that the flywheel was actuating a 400-cycle circuit-breaker in the missile checkout trailer, which in turn stopped the power to the flywheel. The circuit breaker was first believed to be bad but later checked good. The trouble turned out to be an internal short (inside pod) between one phase of the 400-cycle power and ground. Since the flywheel motor was delta wound (ground wire not used), the problem was corrected by disconnecting the ground wire from the 400-cycle power unit. The Cubic Ground Station reported that the modulation amplitude or modulation index was much lower on the B3 transponder than the other two transponders. Since the modulation problem is a function of gain in the transponder and not related to signal level received at either transponder or ground station, the transponder was removed and a substitute installed.

3.7.2 Flight. The operation was delayed 24 hours because of bad weather, but the terminal count started about 2040 W on 25 October 1962. Lift-off took place at 2344 : 0564 W. All transponders and flywheels were operating properly at lift-off. The engine cut-off time and pod separation times were as follows:

Main engine cut-off	T + 156.940 seconds
Vernier engine cut-off	T + 165.579 seconds

Pod B1 separation	T + 175.702 seconds
Pod B2 separation	T + 175.622 seconds
Pod B3 separation	T + 175.612 seconds

All times are given with respect to lift-off time.

3.7.3 Recovery and Examination. The flashing light on Pod B1 was sighted by P2V aircraft shortly after impact. A recovery ship picked up the pod about 0230 W on 26 October. The pod arrived in the hot cell area on Johnston Island by about 0600 W. The pod was in very good condition. It had the normal amount of charring due to re-entry. Examination of the rear bulkhead shadowing indicated the look angle (angle between the axis of the pod and line to the burst point) at the time of burst was good. Later metallurgical examination showed this angle to be 11 degrees ± 2 degrees.

The instrumentation was in excellent condition. The recovery system worked very well. The only item that did not function as expected was the Sarah beacon antenna. The refurbished Sarah beacon had a cracked antenna which deployed horizontally from the flotation bag instead of vertically. Because of this, the beacon was not received by any stations.

Pod B2 was found and returned to the hot cell area by helicopter. The first sighting took place about 0900 on 26 October. This pod had quite a bit of impact damage. The rear flare section was completely broken off and missing. Most of the bulkhead, however, was in good condition. There was also a slight dent in the nose section. Pod B2 was refurbished using fiberglass instead of refrasil for building up the nose. Because of the fiberglass, the ablation showed a different pattern from the normal refrasil ablation. Metallurgic examination revealed a look angle of 7 degrees ± 2 degrees. The recovery system was only partially successful. The actuator fired the door and deployed the drogue parachute. The drogue chute released and deployed the main chute. The main chute did not release, but the flotation bag was out. The risers on the main parachute were cut between the pod and the cross or point where the risers come together below the swivel. The cut was not clean but consisted of a number of short cuts or frictional cuts. The rubber flotation bag fell out of its reinforcing tape when picked up by helicopter. It was concluded that the flotation bag deployed while still airborne, and the flashing light and Sarah beacon were damaged at this time.

Pod B3 was recovered by helicopter at 0900 on 26 October. It was in excellent condition. The level of re-entry ablation was similar to Pod B2. (This also had fiberglass on the nose.) All instruments were in good condition. Rear bulkhead shadowing showed that the pod orientation was about the same as Pods B1 and B2 (11 degrees or less). The recovery system was successful except for the final phase. The actuator fired the door and deployed the drogue chute. The drogue released and deployed the main chute. The main, however, did not release nor did the flotation bag deploy.

3.8 KING FISH

3.8.1 Checkout. The King Fish Event used three new pods. The flywheels were tested and the results plotted. The graphs show that these pods had the best run-down characteristics of any of the pods flown. On D minus 7 days, the pods were installed on the Thor for a fit check. All pods fit properly, but the experimenters wanted a minimum of one thirty-second of an inch clearance between the edge of the rear bulkhead and the Douglas structure ring (the Douglas ring encloses the pod backplate to prevent charring). This was necessary so as not to damage the carbon on the rear bulkhead during pod separation. Certain portions of the rear bulkhead circumference were ground to obtain the proper clearance. A Cubic transponder was installed in each pod and a Sandia transponder installed in Pod K3. All transponders were reported good after running tests with the respective ground stations. On D minus 1 day final weighing and flight readiness functions were performed. Of the recovery units left for this event, the three best systems consisted of one unit that checked out in all respects and was placed on the most important pod, K2; one unit that had a 100-psi leak in 24 hours (the maximum acceptable) which was installed on the second most important pod, K1; and one system that had a 300-psi leak in 24 hours was to go on Pod K3. However, on the night of D minus 2 days a burst-valve exploded and damaged, beyond field repair, the recovery system designated for Pod K3. The used recovery systems in Pods B1 and B3 from Blue Gill Triple Prime were removed and tested. Neither system passed all tests. The unit that was finally used for K3 was good pneumatically (no pressure leaks), but the delay switch which operates after the main chute deploys and which prevents early release of the main chute was never observed to operate with a time more than 2 seconds, where 9 seconds is normal. The pressures in the pneumatic systems in all recovery units were in excess of 3,200 psi when installed. All primary batteries in the units had over 30 volts. Pods K1 and K2 had flashing lights but none had Sarah beacons. The recovery units were installed and the pods hung on the Thor, on D minus 1 day. An FPFF that evening verified that all transponders and flywheels were working properly.

3.8.2 Flight. The preliminary countdown began about 2000 W on 31 October 1962. Lift-off occurred at 0154 ; 47.6 W on 1 November. All transponders and flywheels were operating properly. Engine cut-off times, pod separation times and retrorocket firing times are as follows:

Main engine cut-off	T + 157.783 seconds
Pod K2 separation	T + 164.550 seconds
Pod K3 separation	T + 165.378 seconds
Pod K1 separation	T + 165.809 seconds
Vernier engine cut-off	T + 166.579 seconds
R/V separation	T + 177.678 seconds
First retro firing	T + 180.593 seconds
Second retro firing	T + 181.701 seconds

All times given above are in "T" time, that is referenced to lift-off.

3.8.3 Recovery and Examination. Pod K1 was discovered and returned to the hot cell area on Johnston Island by helicopter. The pod was found at about 0900 W on 1 November. Pod K1 was in very good condition. Only normal re-entry charring had occurred. Nothing seemed to be damaged on the rear bulkhead (Figure 3.16). X-ray shadows indicates a look angle of 5 degrees ± 2 degrees. The recovery system on Pod K1 worked properly in almost all phases. The actuator fired the door and deployed the drogue. The drogue chute released and deployed the main chute. The main parachute released upon impact and deployed the flotation bag. However, the flashing light did not operate.

TABLE 3.1 EXPERIMENTAL AGENCY POD-TO-BURST SEPARATION REQUIREMENTS

EVENT		POD SEPARATION TO BURST	BURST ALTITUDE km
Tiger Fish	C1	2,500 feet	
	C2	6,000 feet	
	C3	14 km	
Star Fish	S1 (or R/V), S1P	7.5 km	400
	S2 S2P	10 km	400
	S3 (or R/V), S3P	14 km	400
Blue Gill	B1, B1P, B1DP, B1TP	2,500 feet	
	B3, B2P, B2DP, B2TP	4,000 feet	
	B2, B3P, B3DP, B3TP	6,000 feet	
King Fish	K1	1.9 km	
	K3 *	2.4 km	
	K2 *	3.3 km	

* Pods 2 and 3 were installed on the Thor so that Pods 2 and 3 were released in reverse order.

TABLE 3.2 PREDICTED FLIGHT EVENTS

Based on Reference 3.

EVENT	TIME (SEC)	VELOCITY (FT/SEC)	ALTITUDE (KM)	SURFACE RANGE (KM)
MECO [a]	156.9	10,375	126.5	3.1
Pod C3 and Star Fish Pod release	157.1	10,423	127.1	3.1
Pods K1, K2, K3 release	164.1			
VECO [b] (except King Fish)	164.9	10,239	151.7	3.5
VECO (King Fish)	165.8			
Pods C1 and C2 and Blue Gill pod release	174.9	9,937	182.5	4.0
R/V Separation	176.4	9,892	187.0	4.1
Apogee	538.9	195	719.2	16.5
400-km event	821.1	7,540	400.0	29.5
Impact	1012.0	438	0.0	35.3

a MECO, Main Engine Cutoff

b VECO, Vernier Engine Cutoff

TABLE 3.3 SUMMARY OF POSITIONING DATA

EVENT	POD	PROGRAMMED SEPARATION	MEASURED SEPARATION	PERCENT DIFFERENCE
Tiger Fish	C1	2,500 feet	2,300 feet	8
	C2	6,000 feet	5,700 feet	5
	C3	14 km	15.5 km	11
Star Fish	S2	10 km	Thor blew up prior to pod release	
Star Fish Prime	S1P	7.5 km	8.7 km	16
	S2P	10 km	12.2 km	22
	S3P	14 km	23.4 km	67
Blue Gill	B1	2,500 feet	- - -	
	B3	4,000 feet	- - -	
	B2	6,000 feet	3,800 feet	37
Blue Gill Prime	B1P	2,500 feet	Thor blew up on launch pad.	
	B2P	4,000 feet		
	B3P	6,000 feet		
Blue Gill Double Prime	B1DP	2,500 feet	Thor destroyed prior to pod release.	
	B2DP	4,000 feet		
	B3DP	6,000 feet		
Blue Gill Triple Prime	B1TP	2,500 feet	3,280 feet	31
	B2TP	4,000 feet	4,603 feet	15
	B3TP	6,000 feet	6,760 feet	13
King Fish	K1	1.9 km	2.4 km	26
	K3 *	2.4 km	2.9 km	21
	K2 *	3.3 km	3.8 km	15

* Pods 2 and 3 were installed on the Thor so that Pods 2 and 3 were released in reverse order.

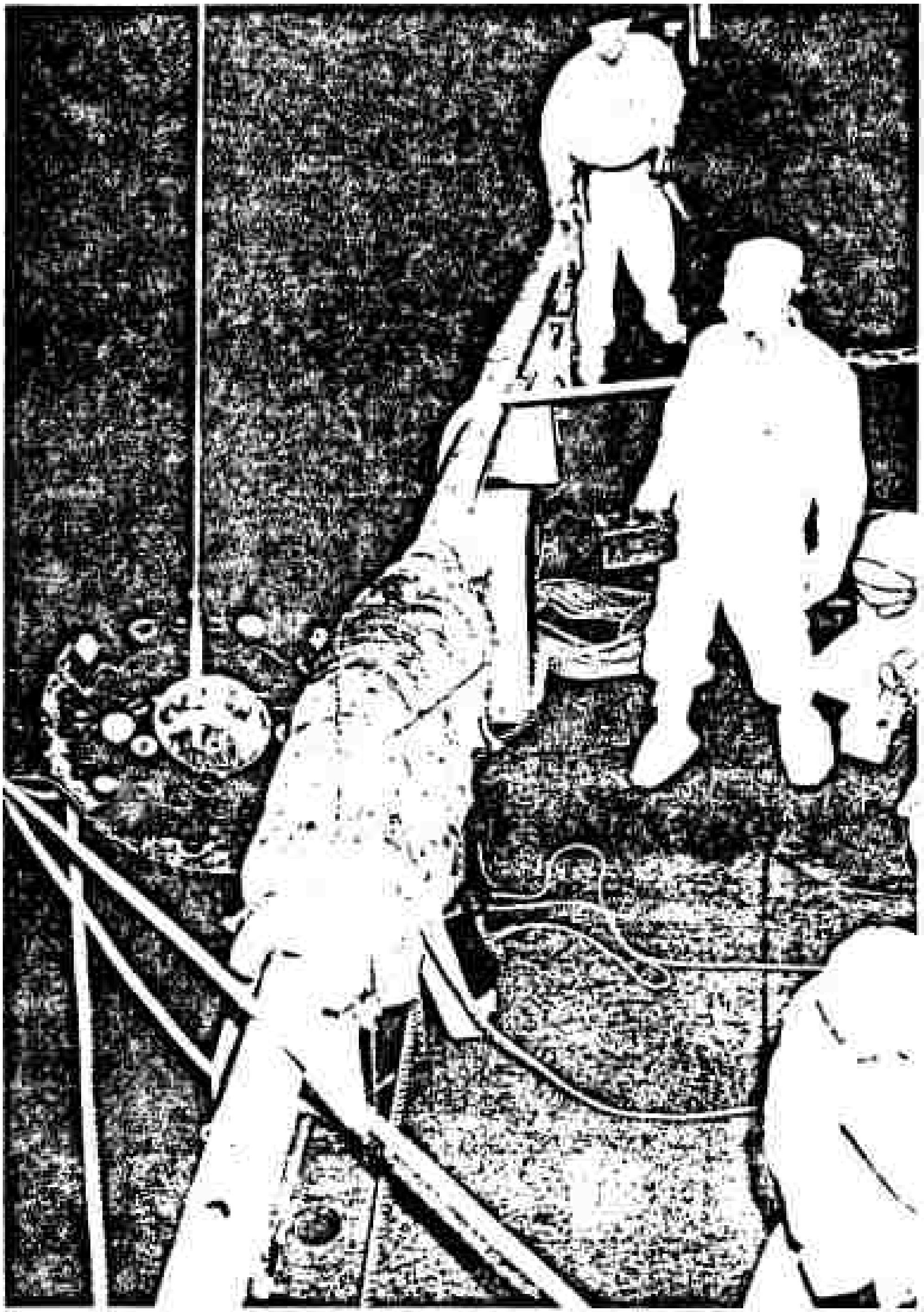


Figure 3.1 Pod recovery by ship. (DASA 26-6297-62)

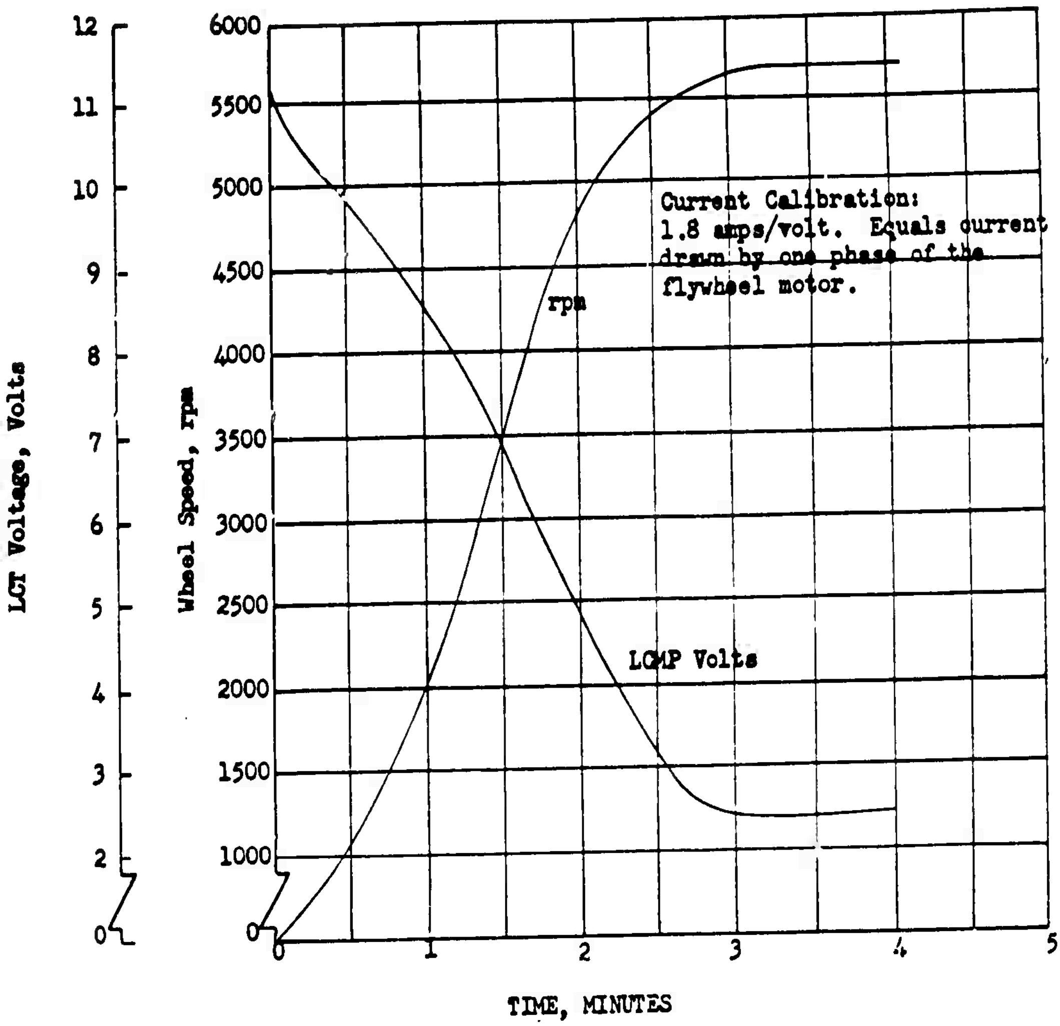


Figure 3.2 Flywheel calibration curves.

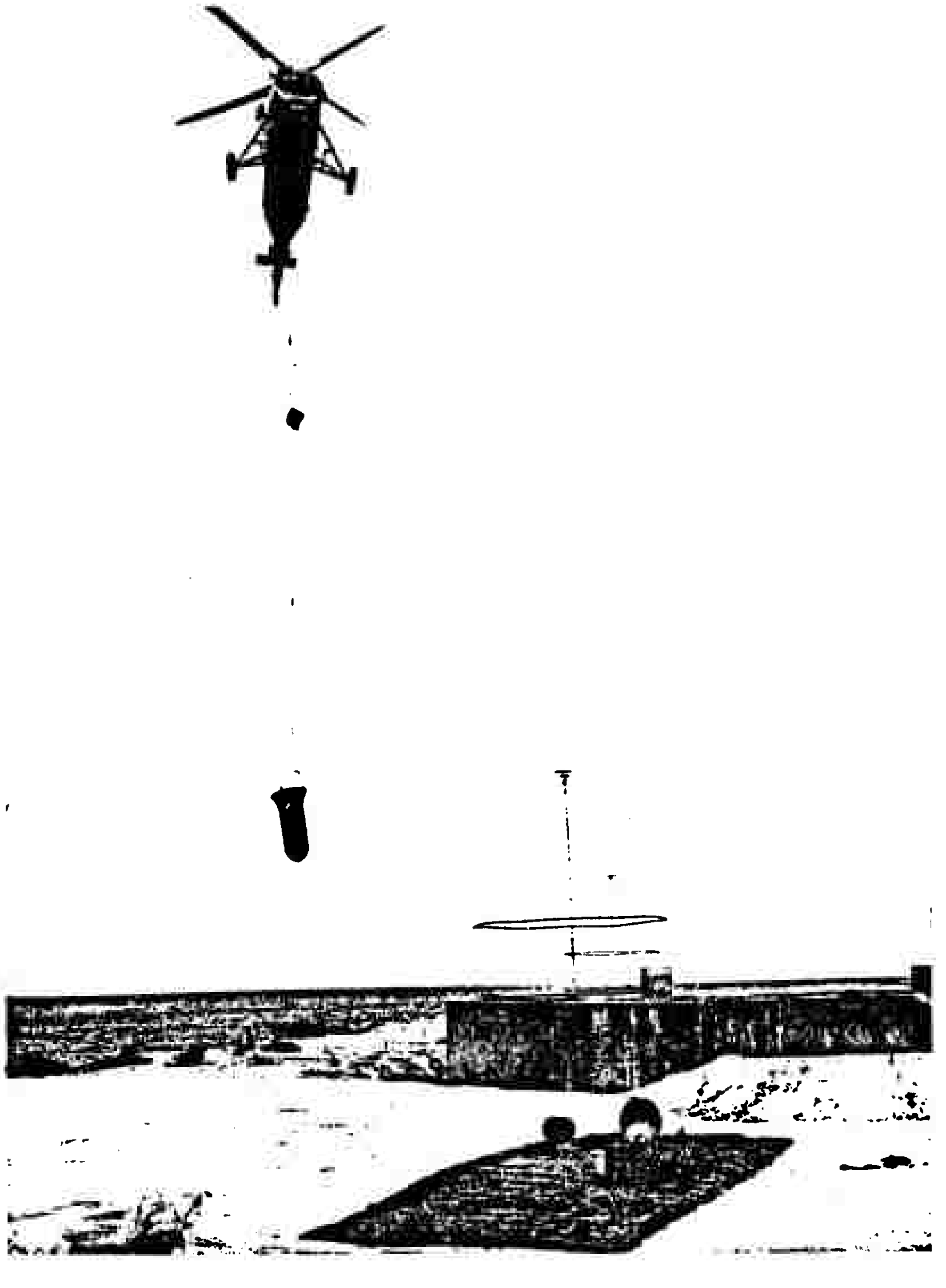


Figure 3.3 Pod recovery by helicopter. (DASA 26-6279-62)

Figure 3.4 Bulkhead heating pattern, Pod B1. (DASA 26-5984-62)

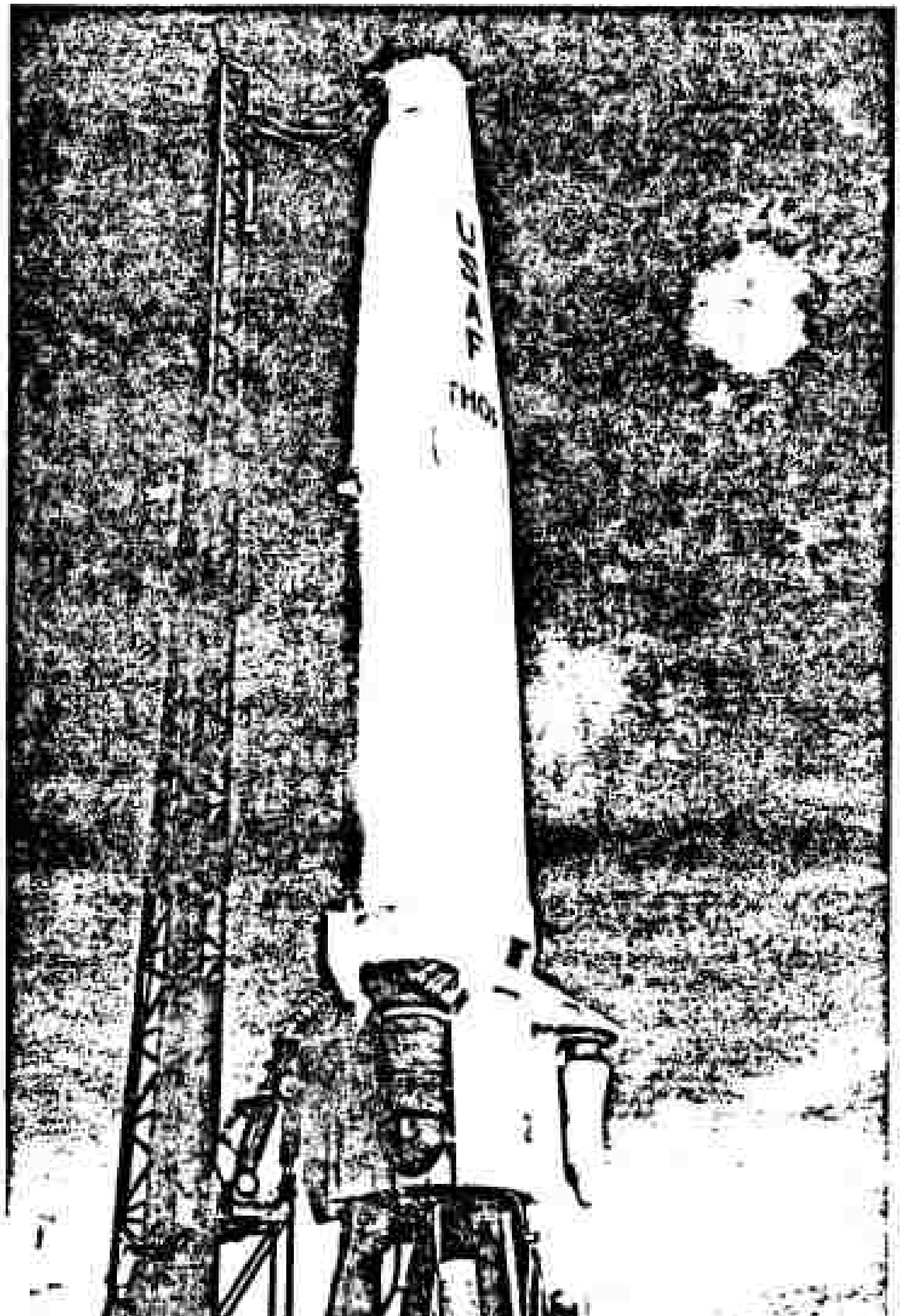


Figure 3.5 Star Fish Pod S2 and AVCO re-entry vehicles. (DASA 26-6045-62)

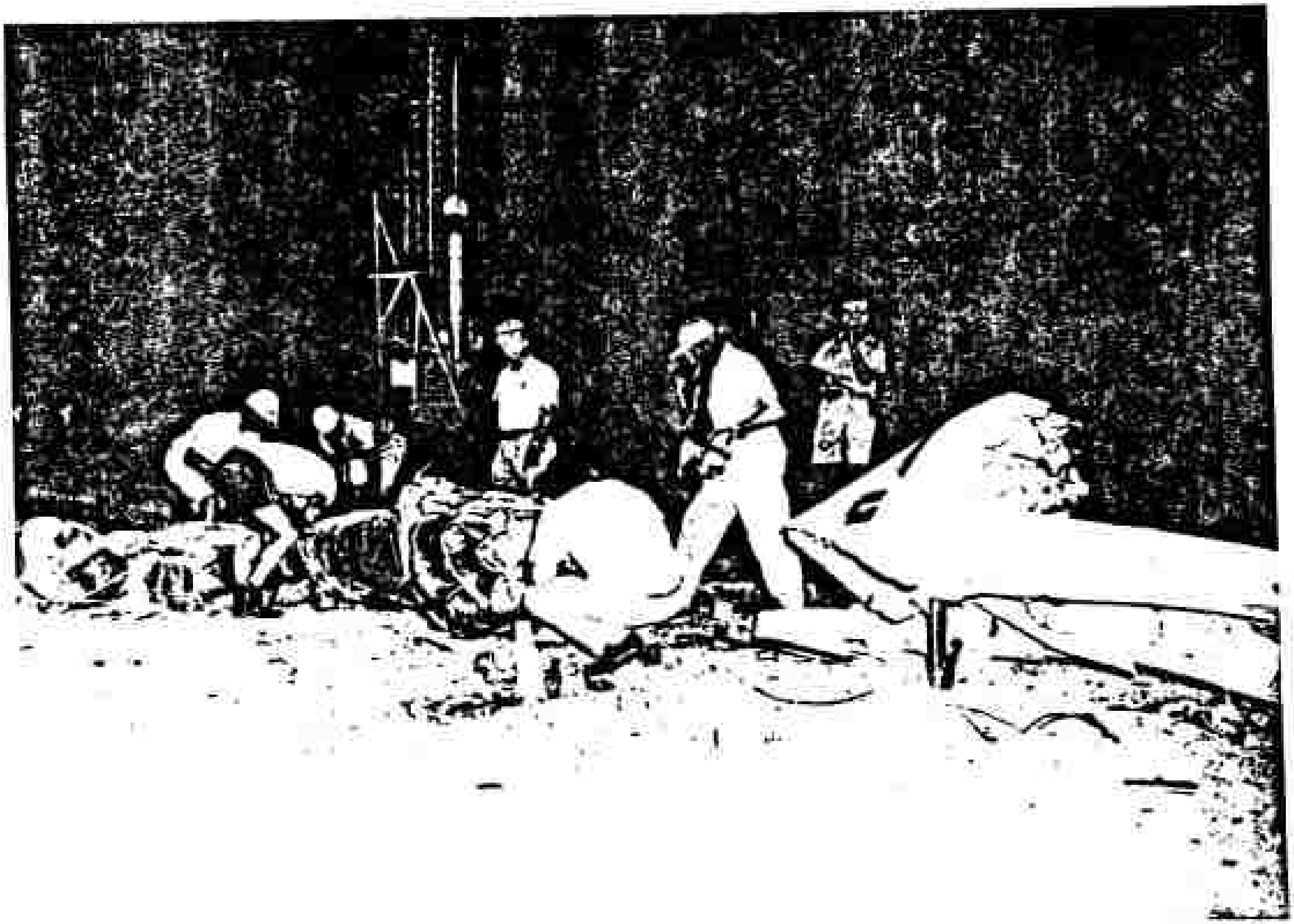


Figure 3.6 Pod S2 after impact on Johnston Island. (DASA 26-9538-62)

Figure 3.7 Pod S2 impact damage. (DASA 26-9521-62)

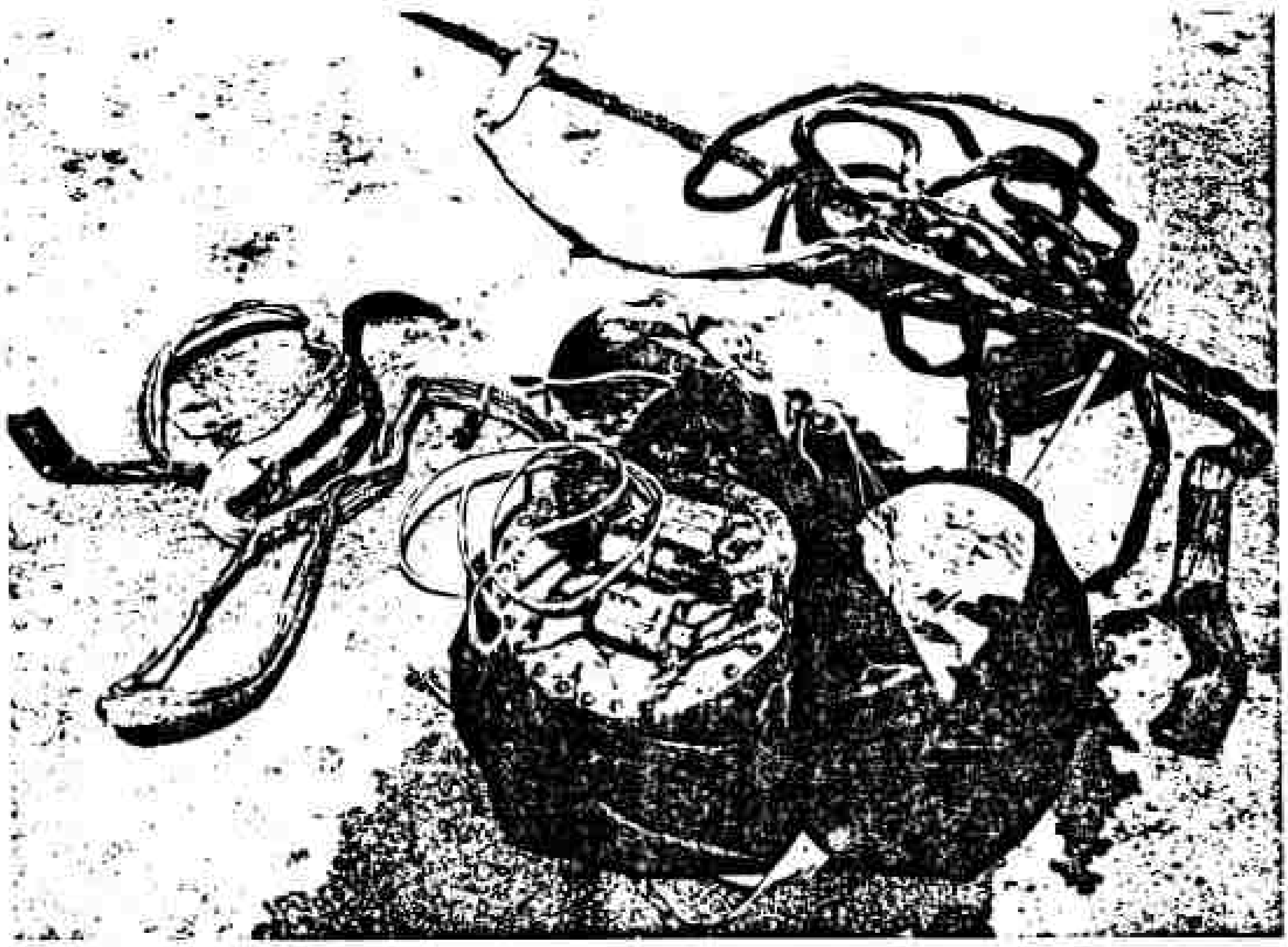


Figure 3.8 Ruptured recovery aid balloon. (DASA 26-6005-62)

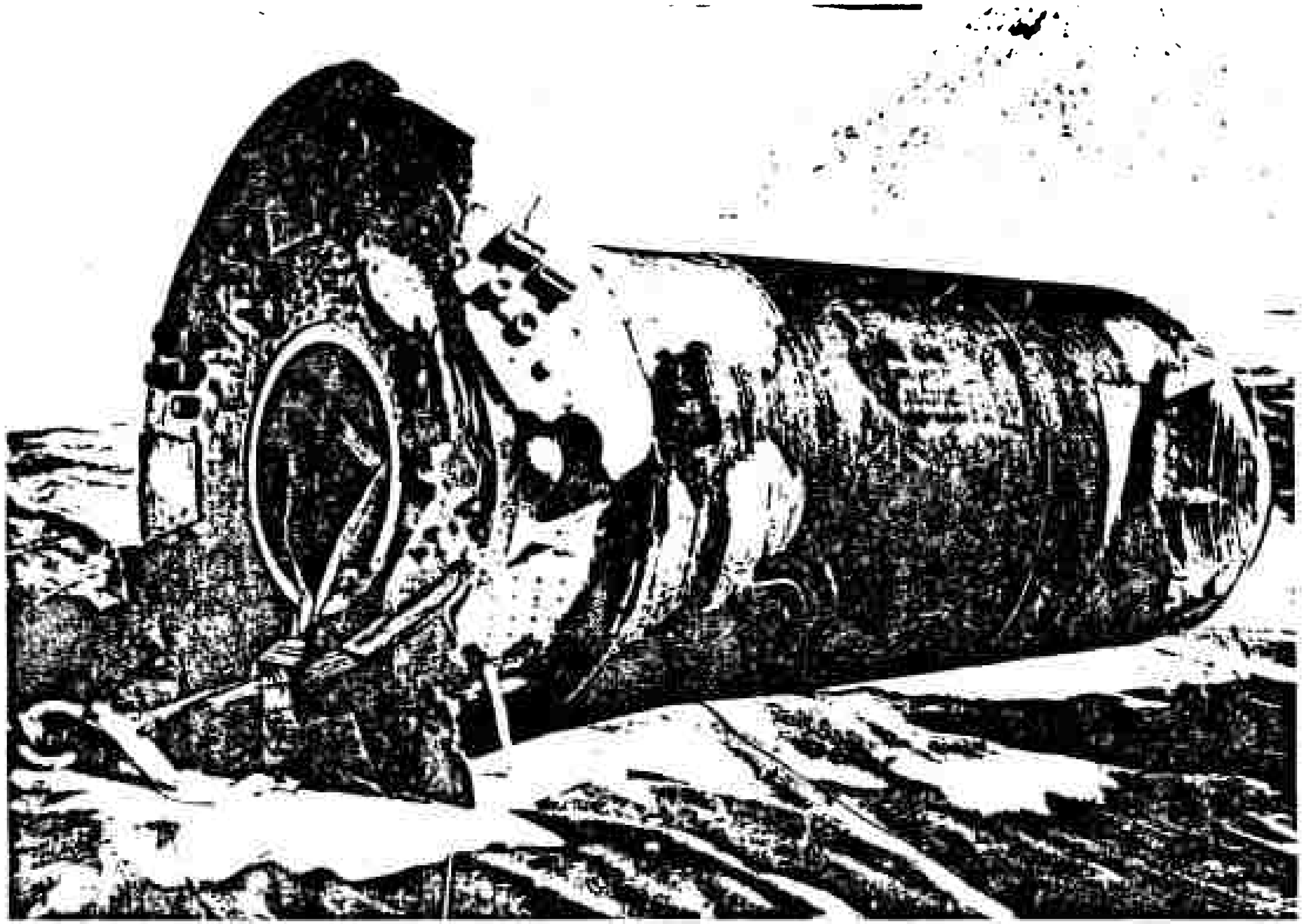


Figure 3.9 Pod B1DP impact damage. (DASA 26-6723-62)

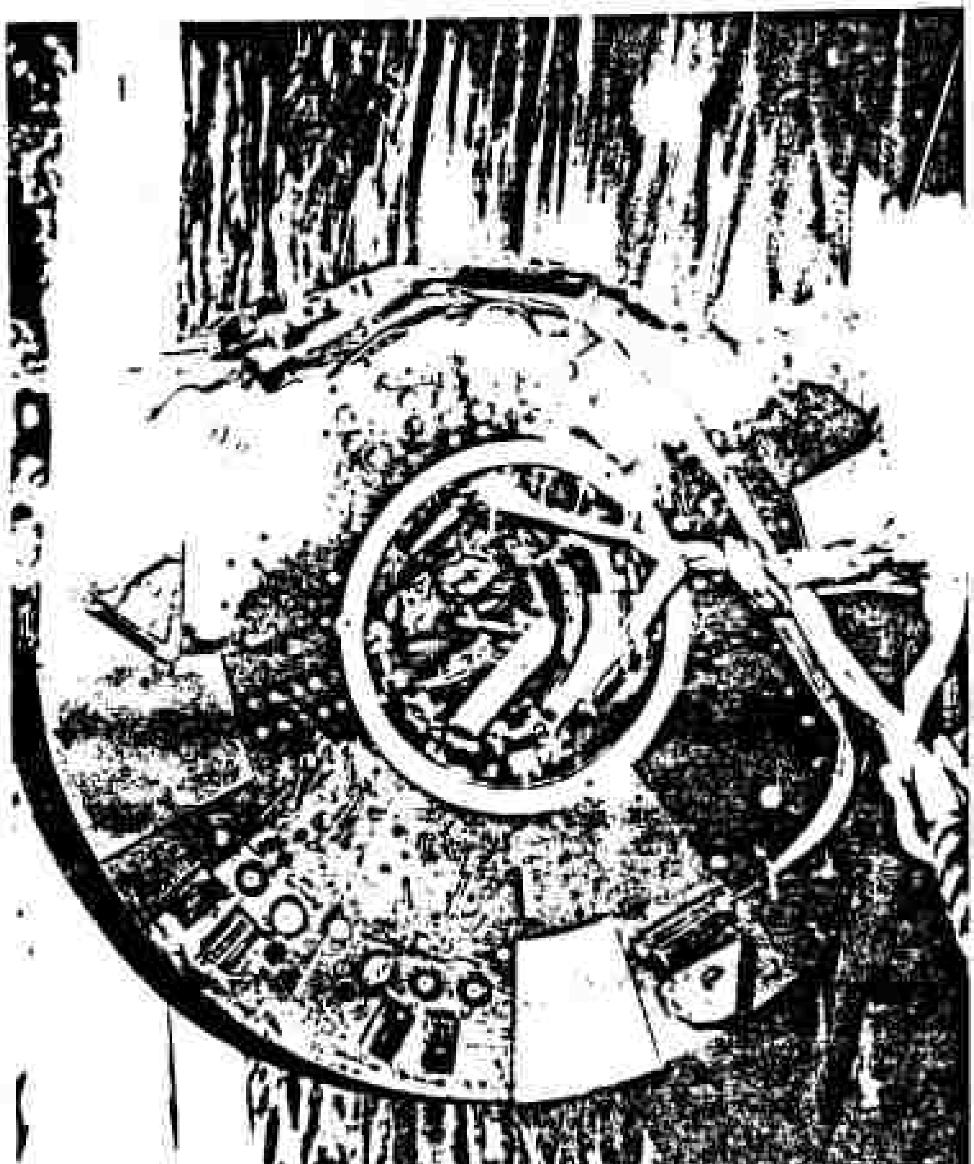


Figure 3.10 Pod B1DP bulkhead damage. (DASA 26-6726-62)

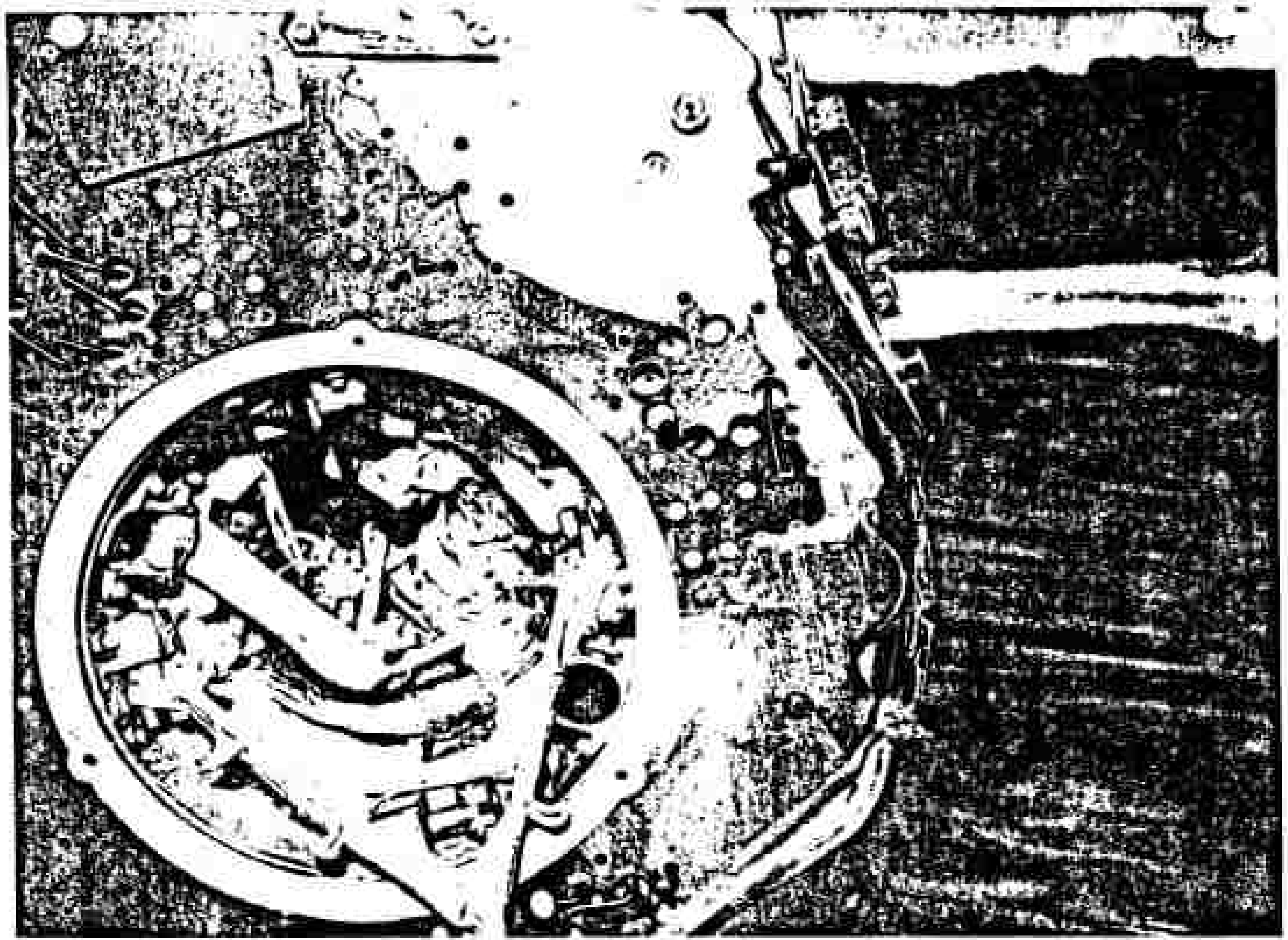


Figure 3.11 Pod B1DP recovery system. (DASA 26-6725-62)

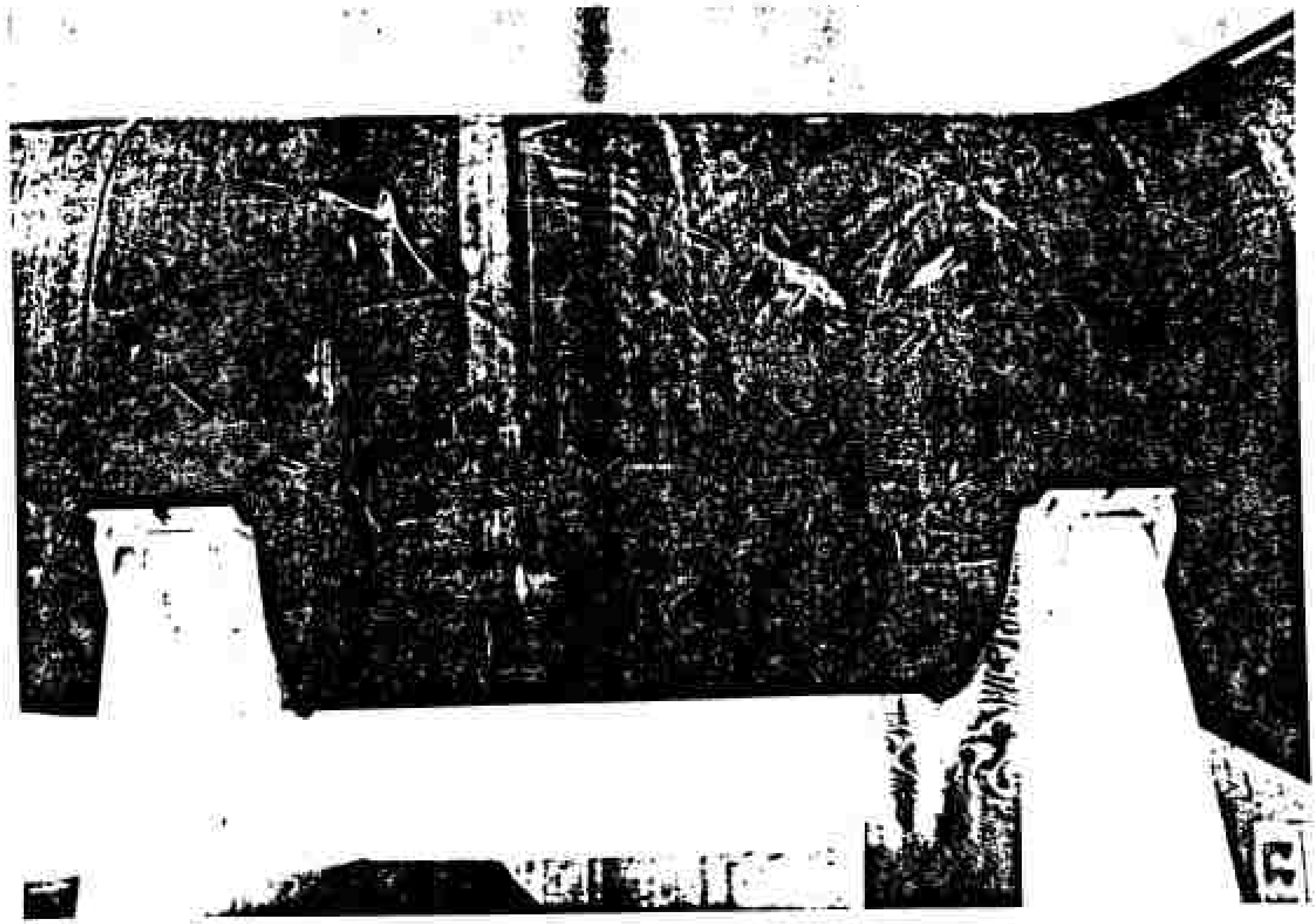


Figure 3.12 Pod B2DP heat shield charring. (DASA 62-6736-62)

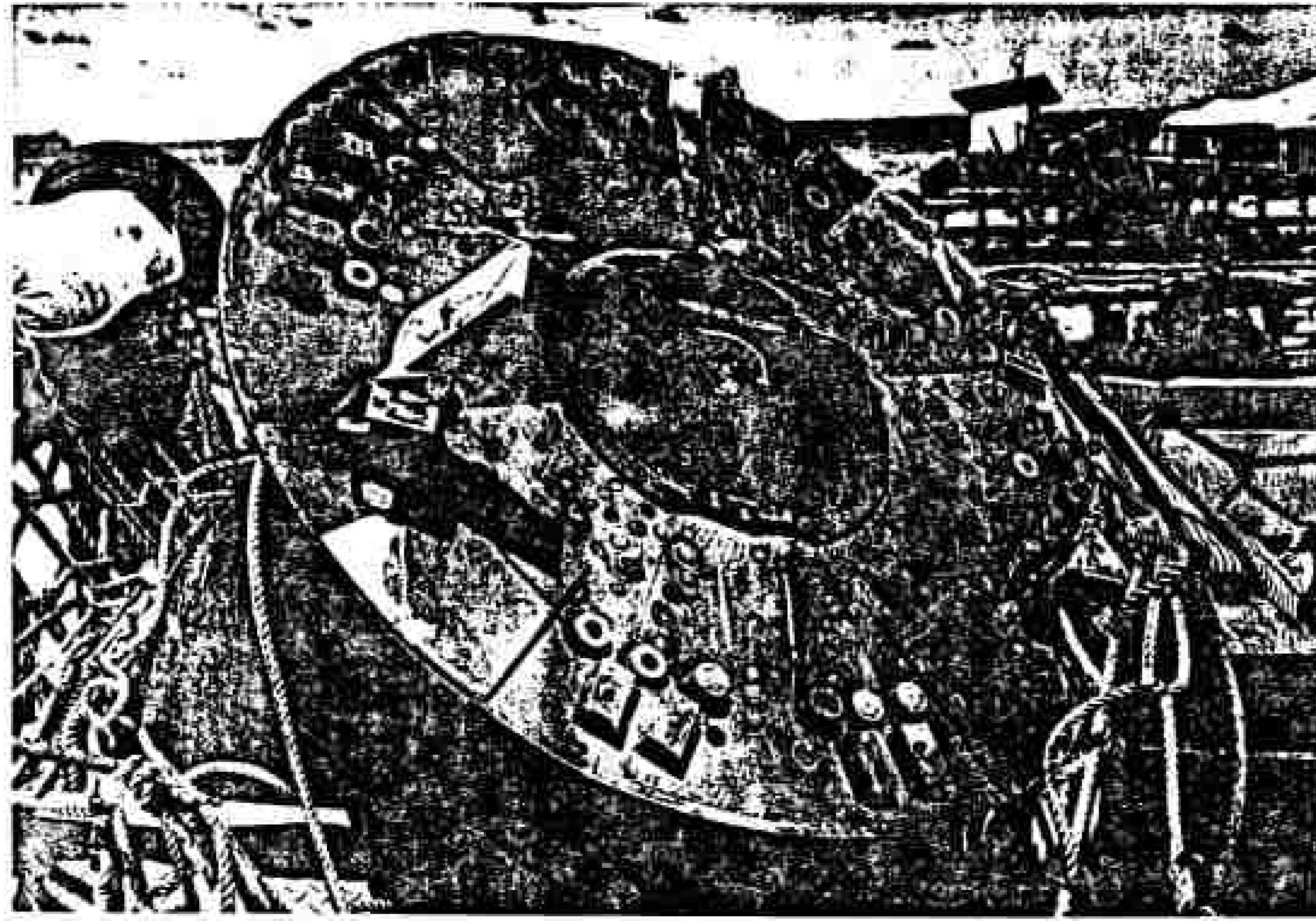


Figure 3.13 Pod B2DP bulkhead damage. (DASA 26-6739-62)

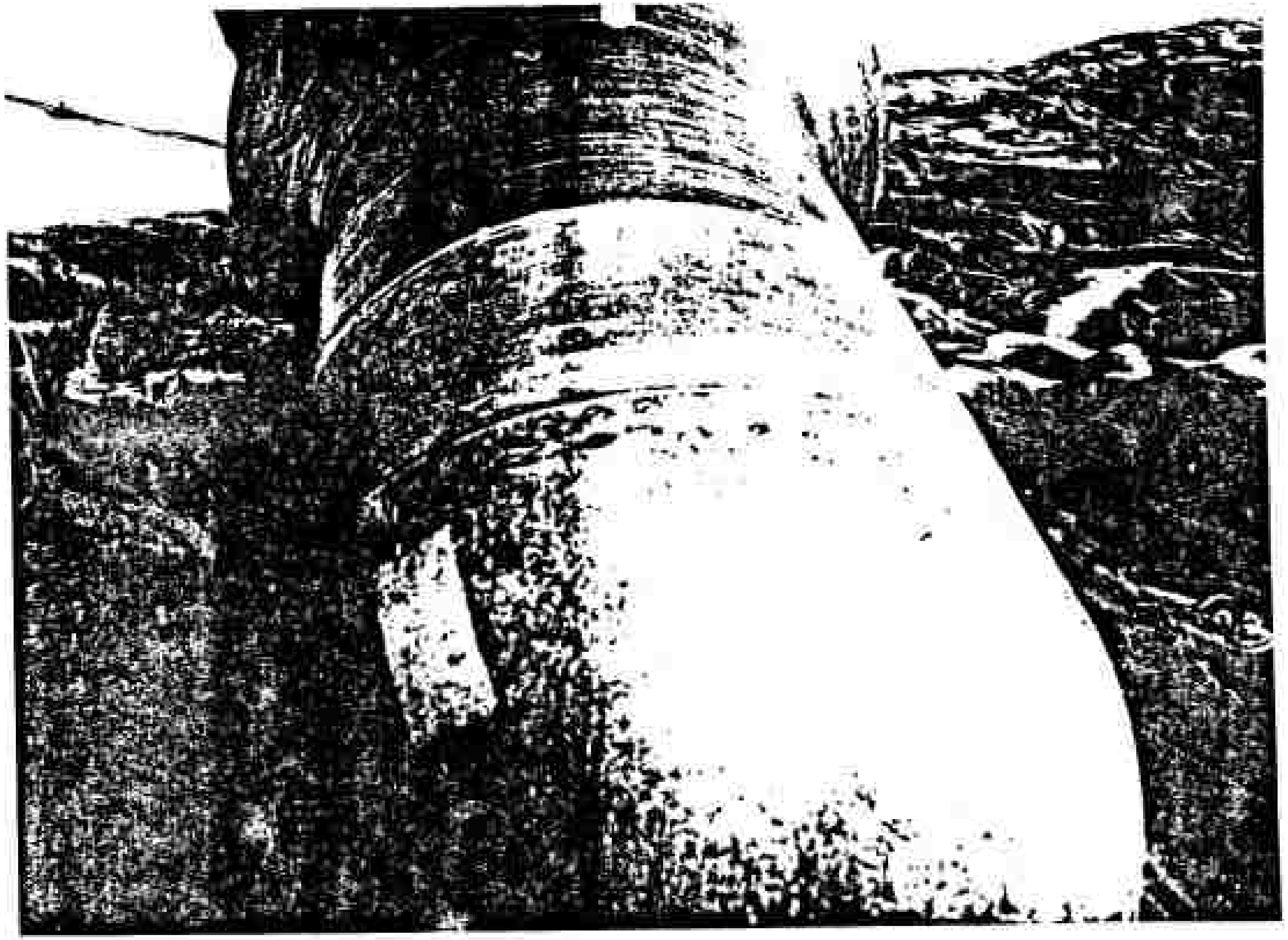


Figure 3.14 Pod B3DP heat shield charring. (DASA 26-6728-62)

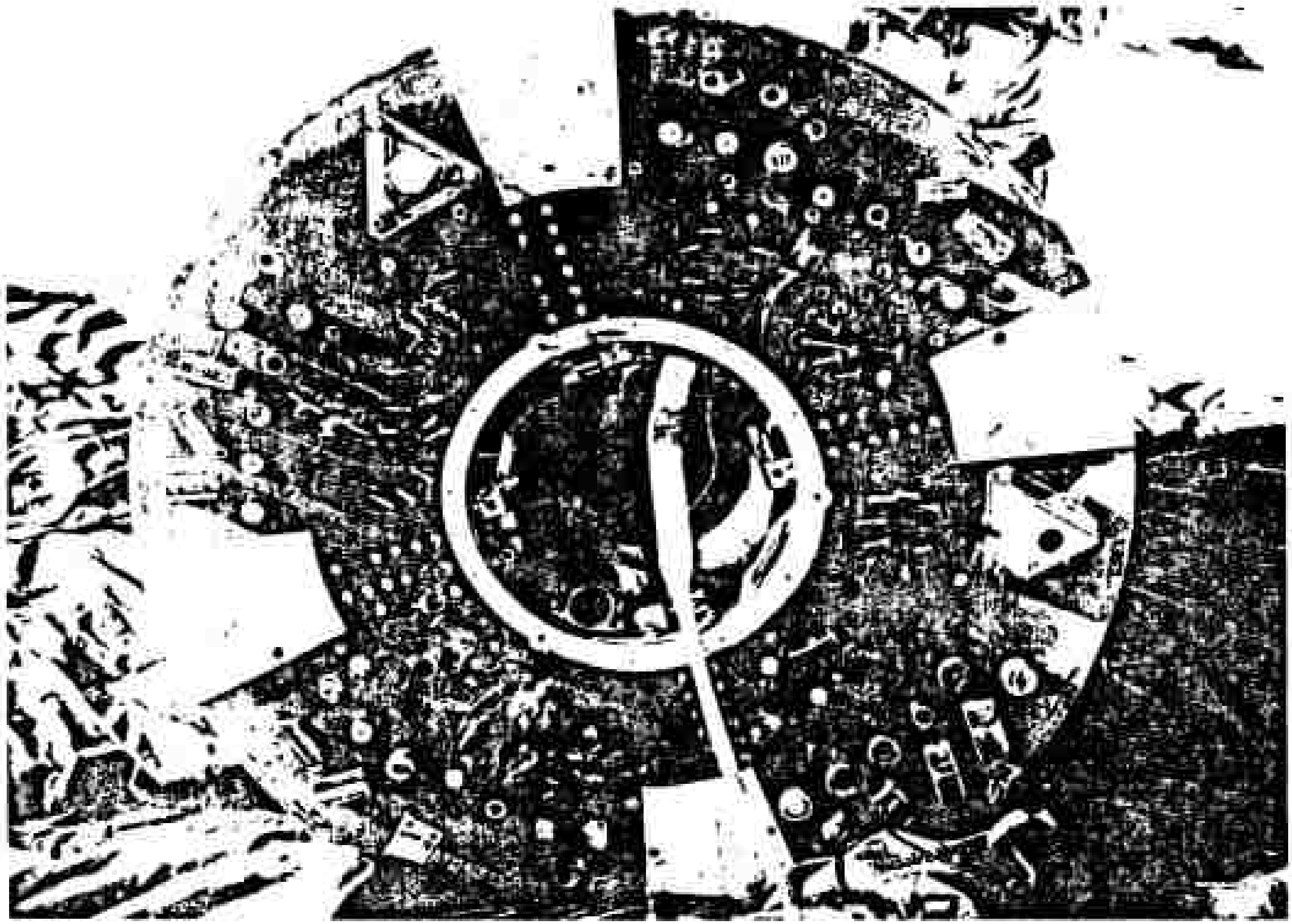


Figure 3.15 Pod B3DP bulkhead damage. (DASA 26-6719-62)

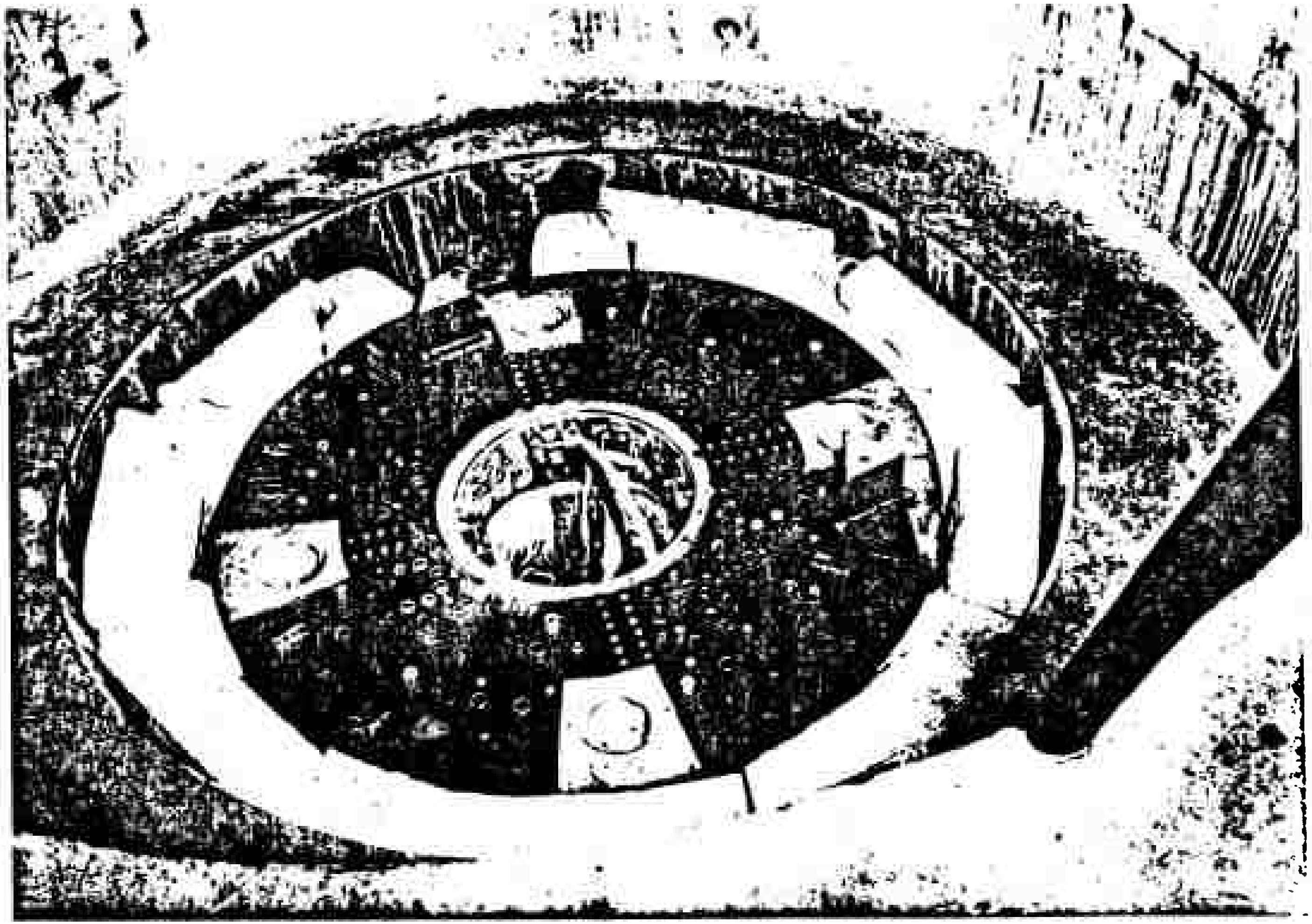


Figure 3.16 Pod K1 bulkhead. (DASA 26-6872-62)

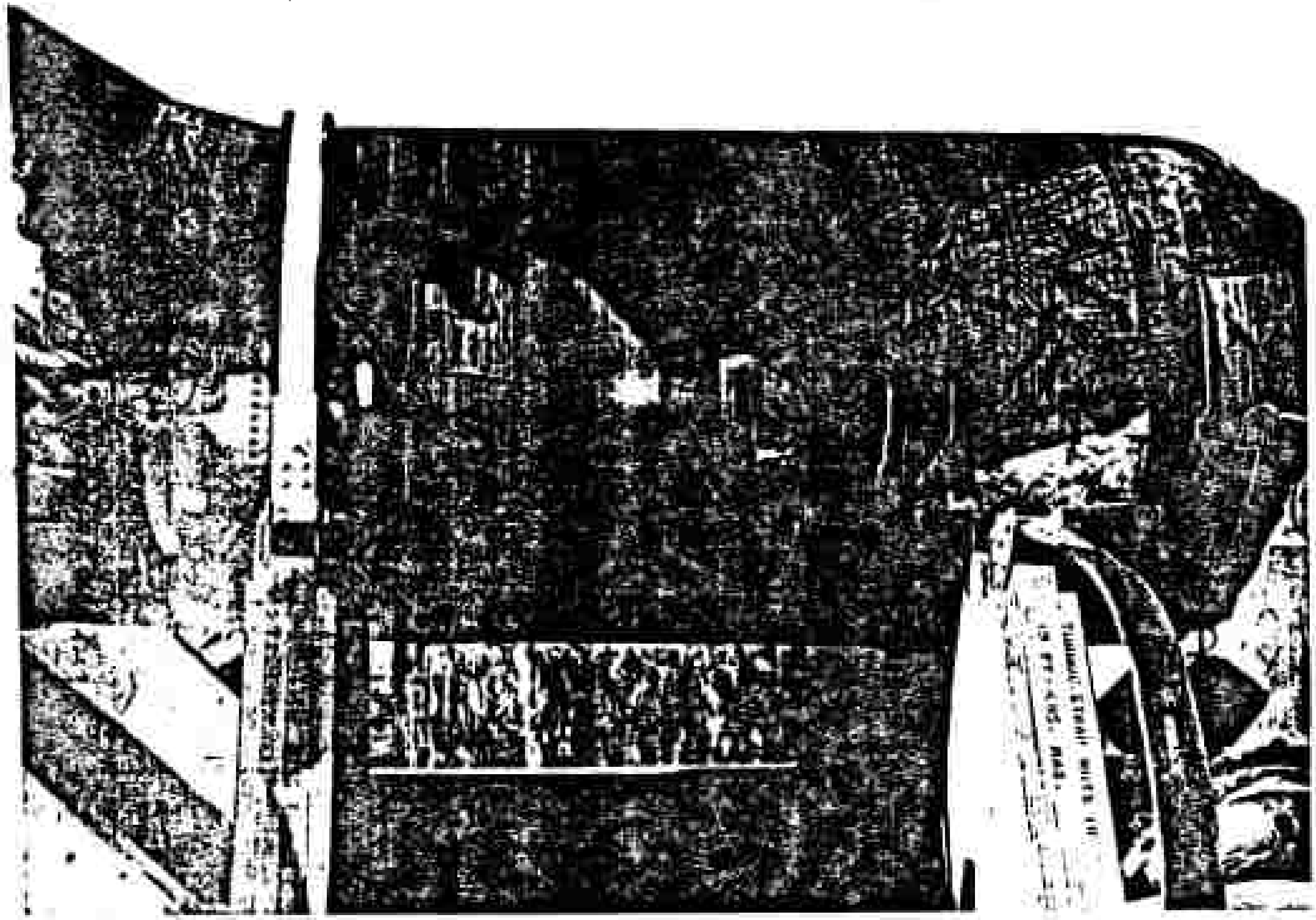


Figure 3.17 Pod K2 impact damage, heat shield. (DASA 26-6869-62)

Figure 3.18 Pod K2 impact damage, rear bulkhead. (DASA 26-6870-62)

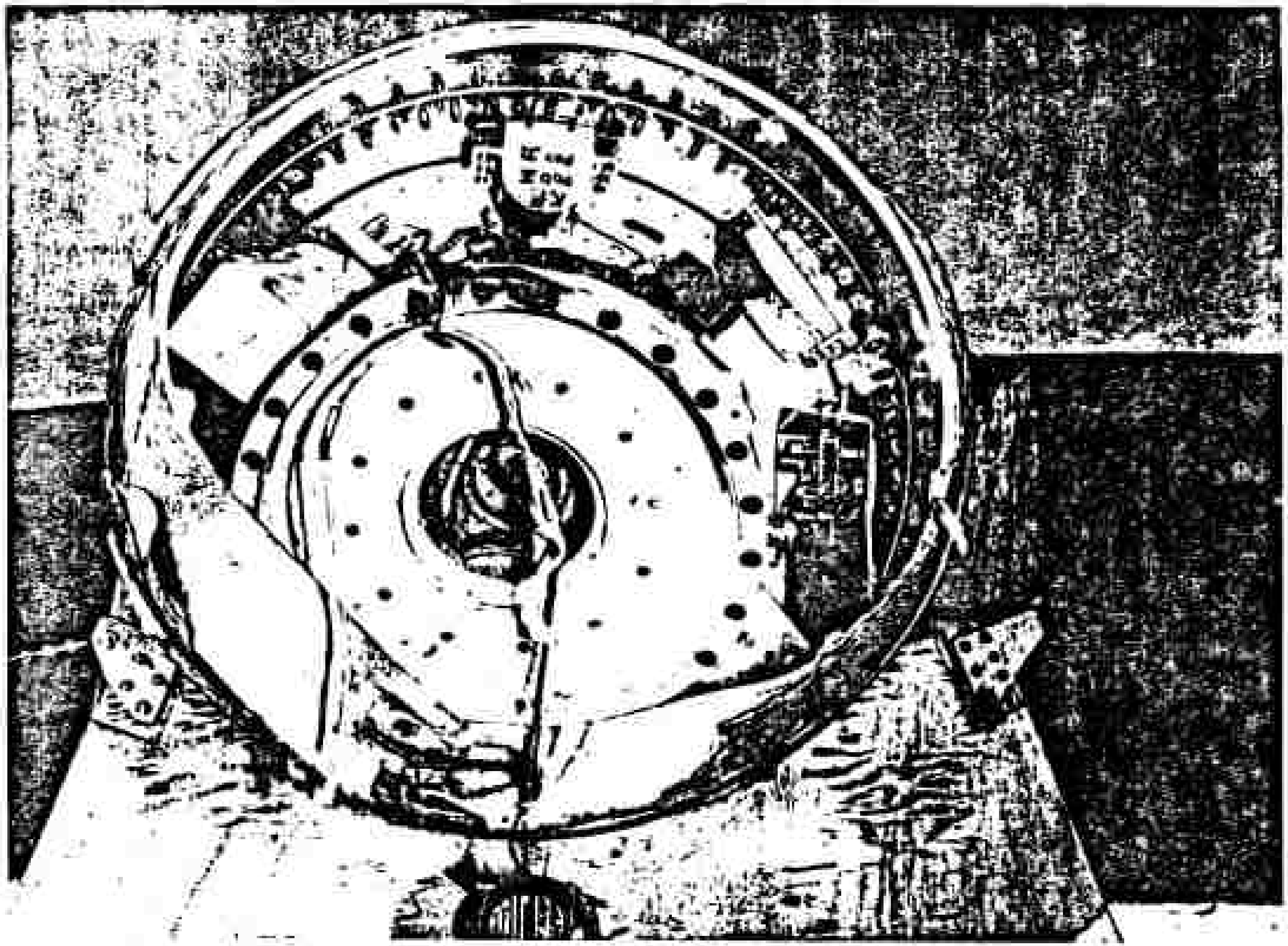


Figure 3.19 Pod K2 impact damage, mounts. (DASA 26-6871-62)

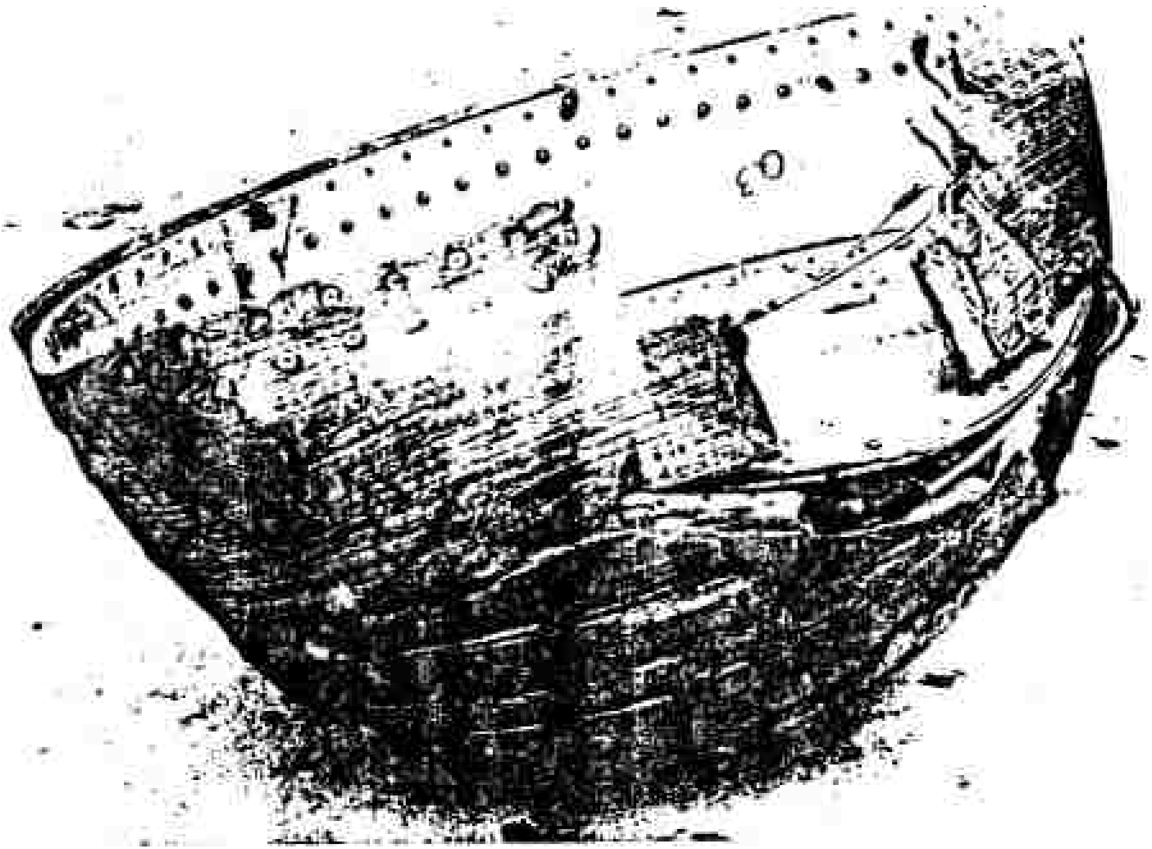


Figure 3.20 Pod K3 nose impact damage, side view. (DASA 26-6883-62)

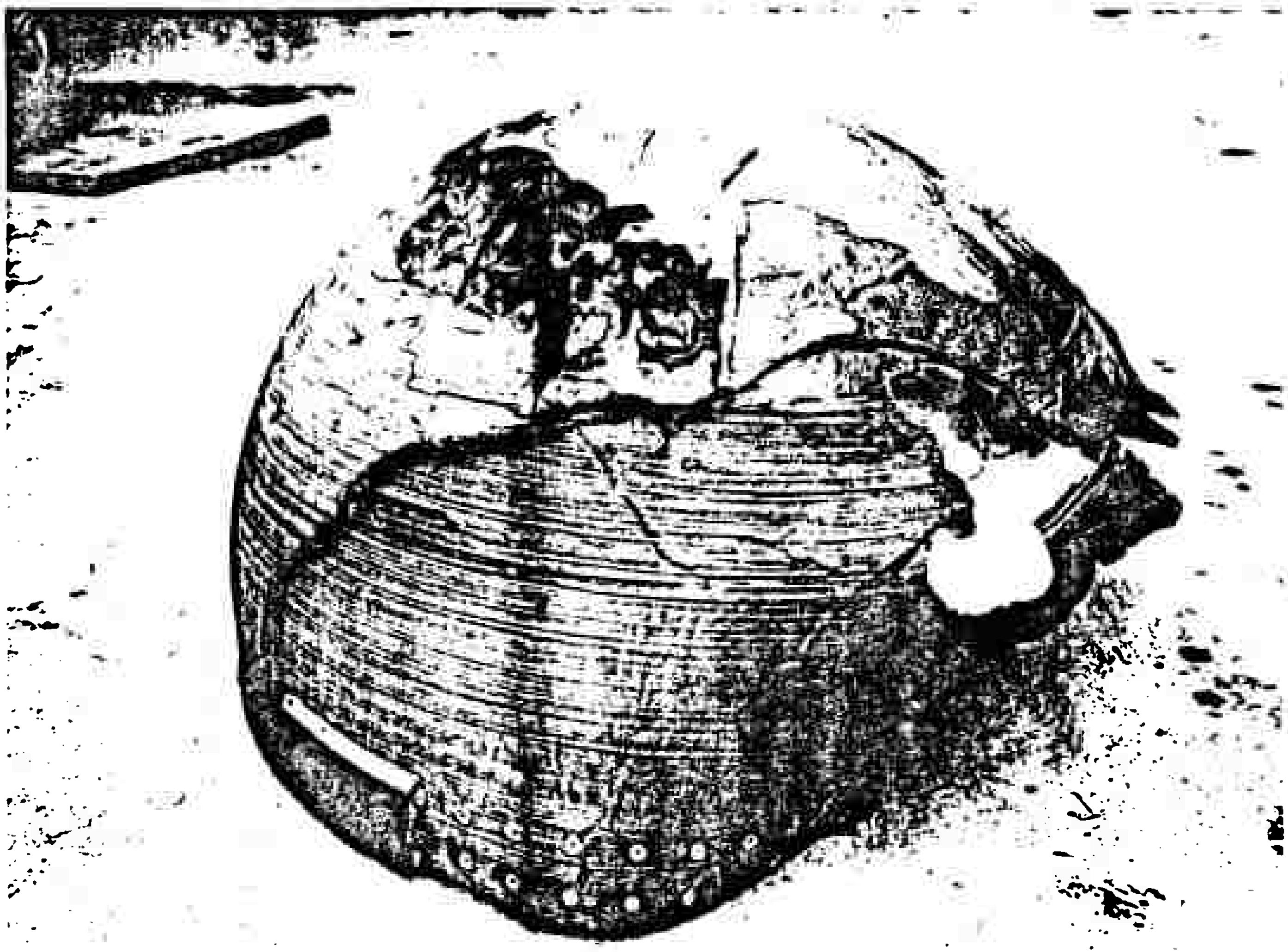


Figure 3.21 Pod K3 nose impact damage, top view. (DASA 26-6882-62)

Chapter 4
DISCUSSION

4.1 TIGER FISH

Flight of Pods C1, C2, and C3 verified the capability of the missile to carry pods and properly position them at burst time, along with the capability of the pods to return instrumentation for post-flight examination.

Analysis of rate gyro data from Pods C1 and C3 indicated significantly higher disturbing moments during release than were originally estimated by DACO. Pod C1 and presumably Pod C2 were submitted to a large overturning force 4 seconds after release. The time of the disturbance corresponded with the time of the second Thor retrorocket firing and apparently was due to this cause. Both C1 and C2 were in a position to be struck by flame impingement from the second retrorocket package as it pushed the booster sideways from the pods.

In addition, the motion-picture camera (looking out the rear of Pod C1) showed that the pod support fairing almost struck the rear of the pod as the Thor backed away from the warhead. Rate gyro data indicated that the fairing did not strike the pods.

To lessen the probability of actual pod-missile contact, as well as relieve the retrorocket flame impingement, both retrorocket firings were delayed 2 seconds on all Blue Gill flights. This had the effect of allowing Pod B1 to fall approximately 6 feet farther behind the missile, before the first retrorockets backed the booster toward it. Pods B2 and B3 were correspondingly farther away because of their slightly greater separation velocity. Thus, the likelihood of striking the pod was lessened, as well as placing the second retrorockets farther away, thereby lessening their effect on pod overturning.

As discussed in Chapter 2, the 1/7-horsepower flywheel motor was changed to a 1.85-horsepower motor to obtain higher flywheel momentum at pod release and to increase reliability of the system.

4.2 BLUE GILL

4.2.1 Pod Release Failure. The failure of Pods B1 and B3 to release from the missile was attributed to a random malfunction of the pod release enable relay in the Thor missile. During powered flight, the enable signal from the guidance system locked-in two pod release enable relays. One enable relay controlled Pod B2 on the down-range side of the booster, and the second enable relay controlled Pods B1 and B3. Through these relays, the release signal from a programmer actuated the explosive bolts. Thor telemetry indicated that this latter enable relay did not properly function. Thus, when the release signal from missile guidance was sent, only Pod B2 was released.

On all subsequent flights, the enable circuitry was redesigned by DACO to improve reliability. No further trouble was encountered.

4.2.2 Pod Orientation. The effect of the 2-second delay in retro-rocket firing on pod attitude and stability was not determined due to destruction of the warhead. No knowledge of the attitude of Pod B2 after release was gained. Tracking signal strength was steady, however, indicating the pod did not tumble.

4.2.3 Recovery System. The recovery system parachutes functioned sufficiently well to return all pods to the water in an undamaged condition. Cubic tracking data on B3 indicated main chute deployment at 25,000 feet. The improper programming of the main chute can probably be attributed to pod re-entry while still attached to the Thor. This would significantly change the load factor altitude history during re-entry. Arming of the system and initial parachute deployment are dependent upon load factors at the correct altitude and may only be obtained by proper re-entry.

Tracking data indicating parachute deployment of Pods B1 and B2 was not obtained. Both systems apparently deployed parachutes as planned, although Pod B1 was attached to the Thor during re-entry.

The failure of Pod B1 main chute to release was attributed to a malfunction of the impact switch.

None of the balloons functioned properly, thus delaying locating the pods until daylight. The balloon in Pod B1 was recovered intact and was operated successfully after return to Johnston Island. The malfunction was caused by the failure of the main chute to detach after impact and was the indirect result of the impact switch malfunction.

The balloons on Pods B2 and B3 both burst, apparently due to inflation prior to ejection from the parachute canister. Upon rupture, the wiring to the Sarah beacon and flashing light was broken. The probable cause was traced to weak ejection springs. For subsequent flights, stronger springs were ordered and the balloon retaining rigging changed slightly to permit easier deployment. The stronger springs were not available until Blue Gill Prime. Star Fish and Star Fish Prime pods were flown with the strongest of the springs available on site.

4.2.4 Rear Bulkhead Heating. The refrasil coating on the rear bulkhead of Pod B1 showed charring over about two-thirds of its surface. The area left uncharred was near the pod umbilical on the side opposite the Thor. Shadows left by protruding instruments indicated the heat flow was from the side of the pod nearest the Thor.

No particular significance was taken of the burn pattern because of re-entry while attached to the Thor. After recovery of pieces of the Star Fish missile and after determination that the probable cause of failure was the recirculation of hot gases around the AVCO pods, the burn pattern was re-examined. Hot gases passing up the side of the missile behind the pod and exiting between the fairing and the pod rear bulkhead could have caused a char pattern similar to that on the Blue Gill pods. The area near the umbilical would be protected more than other areas by the cantilevered pod support structure which is only 5 inches forward of the rear bulkhead. While the burn pattern cannot definitely be attributed to this cause, it is a more likely explanation than re-entry heating.

4.3 STAR FISH

Pieces of the Star Fish missile were recovered from Johnston Island proper and the lagoon area adjacent to the eastern end of the island. Examination of this wreckage by DACO indicated failure started in the boat-tail region adjoining the AVCO pods. The failure was caused by recirculation of hot gases from the main engine turbine exhaust forward along the side of the missile behind the AVCO pods. This unexpected flow pattern was the result of a disturbance in the normal air flow passing along the aft end of the missile. This formed a low-pressure area behind the pods, causing hot gases from the nearby turbine exhaust to be pulled into this low-pressure area. The missile skin was heated until it could no longer carry loads from the engine, and failure resulted.

It was felt that similar but less severe heating probably occurred on Tiger Fish and Blue Gill. The change in shape from GD/A pods to AVCO R/V's resulted in increased heating and eventual failure. Examination of Pod B1 bulkhead after recovery indicated that such heating may have occurred. Likewise, on Tiger Fish, a recheck of the TLM records on Pods C1 and C3 showed a small heat rise from 40 to 60 seconds after launch, which may have been due to the same cause.

To prevent recurrence of the failure, DACO, on future shots, insulated the entire boattail section aft of the pod support structure. The open portion of skin was insulated with a 0.260-inch layer of cork. The pod support structure was sprayed with a layer of Thermolag. All crevices in the boattail closure bulkhead were covered with a layer of cork compound. A ring was attached to the pod fairing extending aft and sealing the gap between the fairing and the pod rear bulkhead. The pod protruded inside this ring about 3/8 inch with a 0.06-inch clearance around the periphery. All openings that would permit heat to enter beneath the support fairing were sealed. The above fix did not prevent the recirculation of turbine exhaust gases, but insulated the boattail structure from damage caused by such flow.

4.4 STAR FISH PRIME

4.4.1 Flywheel Malfunction. Two flywheel malfunctions occurred prior to Star Fish Prime launch. During the full-power full-frequency (FPFF) test on 29 June, Pod S2P flywheel motor burned out. The burned out flywheel assembly was replaced with a spare unit and was shipped to GD/A for failure analysis. A second malfunction occurred during the countdown on Pod S1P, causing the flywheel to attain a maximum speed of 3,600 rpm instead of the design value of 5,700 rpm.

The first flywheel to malfunction was disassembled at GD/A, San Diego. It was found that a small piece of a broken thread tap was in the flywheel housing and had wedged in between the flywheel and side of the housing. This bound the flywheel, causing the motor to overload and burn out.

Pod S1P flywheel was returned after recovery to GD/A San Diego for checkout. The motor was not usable due to the salt water corrosion, but the windings were checked for continuity and under load, which indicated that the motor did not fail electrically. The flywheel assembly was also found to be in operable condition. A new motor was installed, and the duplication of possible failure conditions was tried. By running the flywheel up to 2,000 rpm and then removing one phase to the motor, the flywheel reached 3,450 rpm in almost 7 minutes. This closely approximates the failure conditions during launch.

Since the original S1P motor checked out, it is suspected that the problem was with either land lines or ground support equipment. These were thoroughly checked after the flight and were found normal. The only item that was not checked was the umbilical which was badly burned and damaged during lift-off. The cause of this failure is unknown.

4.4.2 Pod Orientation. At burst time, Pod S1P was oriented almost nose-first toward the event. Pods S2P and S3P had look angles at the rear bulkhead of 43° and 41°, respectively. The failure of the stabilization system to provide the design look angle of ± 7-1/2 degrees was due to release disturbances greater than those estimated by DACO and the pods' loss of stabilization due to low flywheel momentum plus pod spin. This will be discussed in detail in paragraph 4.9.

4.4.3 Recovery System. The parachutes operated as planned on all three pods. Tracking data ended before re-entry, so parachute deployment altitudes were not available.

The balloons and location aids functioned normally on Pods S1P and S3P. The balloon on S2P was ruptured when recovered, although the flashing light may have functioned for a short time after impact. The probable cause of balloon rupture was inflation while in the parachute cavity.

Stronger balloon ejection springs arrived on site after this launch. Tests run with the new springs showed improved balloon bag ejection.

4.4.4 Rear Bulkhead Heating. There was no evidence on the rear bulkheads which indicated that there had been heating caused by recirculation of the turbine exhaust gases.

4.5 BLUE GILL PRIME

During the countdown prior to lift-off, the flywheel on Pod B1P malfunctioned. Motor current fluctuated between no-load and full-load current. The probable cause was a periodic slippage in the drive clutch connecting the motor to the flywheel. However, just prior to launch time, the motor was running at full speed. Due to contamination of the flywheel assembly, it was impracticable to disassemble and inspect the clutch.

4.6 BLUE GILL DOUBLE PRIME

4.6.1 General. The failure of Blue Gill Double Prime was due to a malfunction of the Thor missile. The trouble was traced to a missile power supply that failed. Since the pods are not connected in any way with the Thor electrical system except by squib (explosive bolt) activation and then only at pod separation, there seems to be no connection between the failure and the pods. Because the shot was terminated early and there was no deliberate separation of the pod, no conclusions can be drawn upon the orientation, stabilization, and placement of the pods.

4.6.2 Pod Damage. There were three separate areas of damage on this shot. The first is the shear damage on the rear bulkhead. This was probably done about the time of destruct when the pods were thrown clear of the Thor. While being thrown clear, the rear bulkhead was scraped by the DACO structure ring, shearing off Douglas fittings, instruments and refrasil coverings.

The second area of damage was the heavy charring of Pod B2. This was either due to the Thor engines, probably when they went hard over, or to the burning of the missile during descent.

The third area of damage was due to hard impact with the water.

4.6.3 Recovery System. Because of the missile tumbling, the pods could have been thrown free of the missile at any attitude. Because of this, plus the lower altitude and flywheel stabilization, the proper orientation and g-forces required for recovery system activation were almost impossible to obtain. However, the recovery system in Pod B1 started to work, but too late. The main chute probably started to open just at impact, and because of the 9-second delay after main chute deployment, the main chute did not release nor did the flotation bag deploy.

The recovery system in Pod B2 did not operate at all. Since there was very little impact damage on this pod, the pod must have been attached to a large part of the missile during re-entry. Because of this, the g-forces and pod orientation were quite different from a normal return. Consequently, the recovery system did not arm.

Pod B3 recovery system did work. Because this pod did not have the hard (reinforced) flare, the center of gravity was farther forward. Because of this, the pod probably reoriented itself into a nose-down position faster than Pod B1. Therefore, the main chute opened in time.

4.7 BLUE GILL TRIPLE PRIME

4.7.1 Pod Placement. The pods were given the proper spacing from the event by the use of different weight springs in the Blue Gill shots. The spring ejection system used on the pods gave them a differential velocity (slowed them down slightly) so that their distance from the event would be proper. The actual results on Blue Gill Triple Prime looked good. Final tracking data shows that spacing from the event to the pods was: for B1, 3,280 feet, 31 percent higher than the 2,500 feet desired; for B2, 4,603 feet, 15 percent higher than the desired 4,000 feet; and for B3, 6,760 feet, 12 percent higher than the desired 6,000 feet.

4.7.2 Recovery System. The recovery system on Pods B1 and B3 worked very well, with a few minor exceptions. The main chute did not release nor the flotation bag deploy on B3. This malfunction was probably due to a faulty impact g-switch.

From transponder signal level recordings made at the Cubic Ground Station, it was determined that the recovery was normal until H + 148 seconds for Pod B2. Up to this time, the recovery systems on Pods B1 and B2 were functioning about the same. At H + 33 seconds, the drogues deployed. At H + 88 seconds, the drogues were released and the main parachutes deployed. At H + 148 seconds, Pod B2 started tumbling and probably lost the main chute. Pod B2 impacted at about H + 210 seconds. When the pod was returned to Johnston Island, the flotation bag was out of the system. The main chute risers had not released from the pod, but the main chute from the swivel up was missing. This indicates that the flotation equipment ejected prematurely, probably right after main chute deployment. The ejection spring lodged in the cross of the main risers and slowly cut through the risers. This was speeded up by the heavy loading placed on the risers.

4.8 KING FISH

4.8.1 Pod Placement. The pods were given their spacing from the event by releasing them at different times during vernier solo which gave them a differential velocity. Based upon DACO information, two pods were inadvertently reversed in position. Pod K3 which should have been on launcher leg No. 3 was actually installed on leg No. 1, and K2 which should have been on leg No. 1 was actually installed on leg No. 3. This resulted in pod release in the order K2, K3, K1. Study of the Sandia tracking data on the re-entry vehicle and on Pod K3, together with Cubic data on Pods K1 and K2 indicate the pods were placed approximately where planned. Pod K1 functioned as intended throughout flight and through recovery to inspection. The extensive damage on Pod K2 and the virtual total loss of K3, together with loss of tracking at an early time on Pod K2, rendered post-flight analysis almost impossible.

4.8.2 Recovery System. The recovery system worked quite well on K1. However, both the K2 and K3 recovery systems were unsuccessful.

The riser below the main chute swivel was broken off on K2. It appeared as if the riser was twisted until the failure occurred. However, even if the swivel jammed, it seems inconceivable that the riser would twist and fail before collapsing the main chute.

There is very little information available on Pod K3. The only possible answer to the failure is that the main chute delay switch did not operate properly. Prior to installation of this recovery system in Pod K3, the delay switch only had a 2-second delay rather than 9 seconds. Therefore, if the main chute opening shock was slightly later than 2 seconds after the main chute started to deploy, the main parachute would release and the flotation bag would deploy. Only the nose and flotation bag were found.

4.9 POD FLYWHEEL STABILITY TESTING AND ANALYSIS

When the pod was first designed for the Fish Bowl series, the flywheel was analyzed assuming a constant flywheel speed throughout the flight. Later, it was decided that the only practical approach was to remove motor power to the flywheel at lift-off and let the flywheel coast during the remainder of the flight. A cursory prediction indicated that wobble due to wheel rundown would be very small. Stability tests of the flywheel, impossible to accomplish in the original time limit, have now been run (Reference 5). These tests show that the pod behaves in the following manner. From lift-off to pod ejection from the Thor Missile, the pod flywheel slows down fairly rapidly due to windage, friction, acceleration, and vibration. After the pod is released from the missile, all the angular momentum lost from the stability wheel is picked up by the pod structure. That is, after pod release, the pod is free to turn and, as the flywheel slows down, this spin is transferred to the pod through the friction of the flywheel bearings. Consequently, the pod starts to turn in the same direction as the flywheel is spinning. This torque is transferred because of bearing friction; loss of momentum by external torques on the pod was not considered. Immediately after separation from the missile, the pod and flywheel system respond like an inertia wheel spinning in space. (The pod is not spinning.) After a long time, nearly all of the angular momentum will be in the pod structure rather than the stability wheel and will approximate that of a vehicle spinning around a minimum axis of inertia, such as a rotating drive shaft. Both of these conditions possess a high degree of rotational stability. However, in progressing from an inertia wheel configuration to a vehicle spinning around a minimum axis of inertia, the pod will, at some time, respond like a sphere spinning in space or in a state where the stabilizing forces of the pod cancel out the forces of the wheel. During this transition period, the spin vector momentum vector is not restricted to any position in the body. This is the region of no-spin stability.

This region of no-spin stability was thoroughly investigated with a full-scale gimbaled pod stability test and then analyzed on an analog computer (Figure 4.1).

These tests showed that the pod/wheel system exhibits no spin stability when the following condition exists:

$$(I_{yy} - I_{xx}) W_p = I_w W_w$$

Where (Figure 4.2):

I_{yy} = Mass moment of inertia of the pod in pitch.

I_{xx} = Mass moment of inertia of the pod in roll.

W_p = Pod angular roll rate.

I_w = Wheel mass moment of inertia in roll.

W_w = Wheel angular roll rate.

This no-spin stability region occurred on the pod/wheel system when the wheel was spinning at 325 to 350 times the pod angular velocity. At this point, the pod would have no stability and would tumble if there was any unbalance in the system. The stability tests also showed that it was almost impossible to balance the pod sufficiently so that it would not tumble in this unstable condition. Even a very slight unbalance of the pod, due to battery fluid, wiring, or parachutes shifting, was enough to tumble the pod. (A slight wobble due to pod ejection from the Thor would have a similar effect.)

On all flights the wheel/pod system was operating very close to the no-spin stability region. On Star Fish Prime, the pods were either in the unstable region during the time of the event or had passed through this region, tumbled, and then restabilized themselves in random attitudes. On the Blue Gill and King Fish events the pods were just approaching the no-spin stability region and consequently have pod orientations equal to or slightly outside the design limit. (The stability improvement in the later events was due to improved flywheels with less friction.)

There are a number of changes that could be made to the present flywheel to give the desired stability. The best solution from a dynamic point of view would be to power the flywheel throughout the flight. With this system the motor would supply enough torque to overcome the flywheel bearing friction, consequently keeping the pod from rotating and also keeping the flywheel up to speed. Some other possible ways of keeping the pod/wheel system out of the no-spin stability region would be to use a wheel with higher rotational inertia, a wheel with higher rpm at lift-off and/or a wheel system in a low-pressure case (low windage loss) so that the wheel speed would be higher at pod separation.

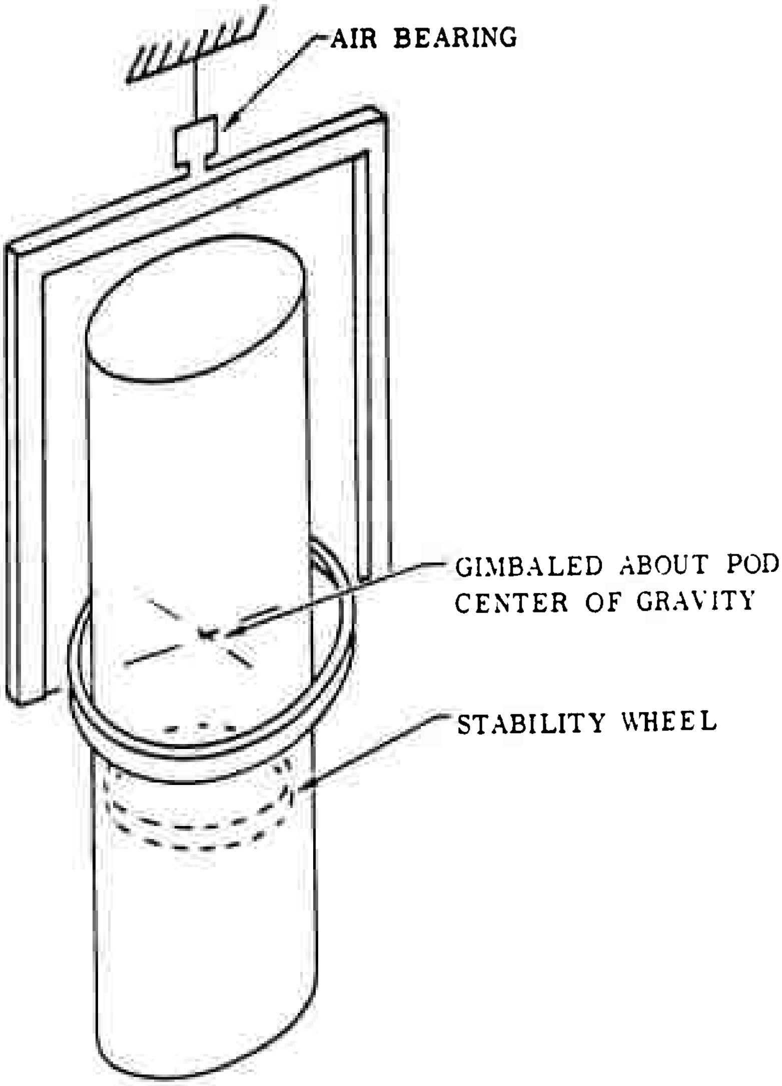
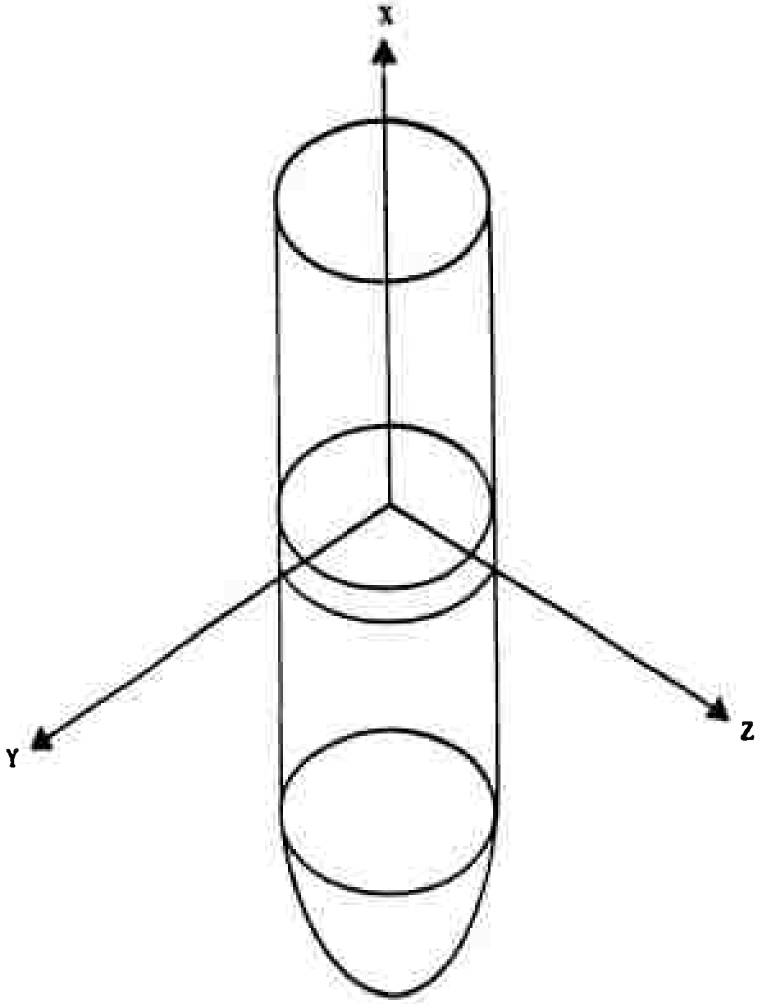


Figure 4.1 DASA pod test configuration.



ω_p = ROLL RATE OF POD

ω_w = ROLL RATE OF WHEEL

I_{yy} = I_{zz} = MASS MOMENT OF INERTIA OF POD IN PITCH

I_{xx} = MASS MOMENT OF INERTIA OF POD IN ROLL

I_w = MASS MOMENT OF INERTIA OF WHEEL IN ROLL

Figure 4.2 Stabilization terminology.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

5.1.1 General. The overall capability of the Thor-pod system for placement, and subsequent recovery, of passive scientific instrumentation in the vicinity of a nuclear high-altitude detonation was found to be marginal. However, it is felt that post-flight analyses of the Fish Bowl events point the way to solutions of the problems encountered.

5.1.2 Pod Structural Design. The pod was designed to withstand, structurally, the impulsive loads expected from the Fish Bowl events. Since the majority of pods flown, (including those pods closest to Blue Gill Triple Prime and King Fish events), re-entered and were recovered, even when the recovery system failed, it is concluded that the pod met and exceeded design objectives.

5.1.3 Pod Placement. Tracking data indicated that pod placement was marginal with five of the nine instrument-carrying pods exceeding the ± 20-percent limits.

The excessive look angle experienced on Star Fish Prime was attributable to excess release and flame impingement perturbations and a region of pod instability due to a pod no-spin stability phenomenon. Paragraph 4.9 explains this no-spin stability in detail.

The Blue Gill Triple Prime pod orientation and stabilization was marginal. The look angle on one pod was within the design requirements. However, one pod exceeded the limit, and no accurate data is available on the third.

Information on pod orientation for King Fish was limited. However, with the information available, the pod stabilization appeared to be marginal to good. The only pod with adequate orientation data available was well within the design limit. The second pod, with limited information, indicated that the look angle was outside the design limit. No data was available on the third pod.

In reducing data for each event, Sandia tracking was used to ascertain location of the burst and of the pod containing the Sandia transducer. To find location of the other two pods (for each event), a correction was applied to Cubic data. Differences in location readings, for the pod containing both Sandia and Cubic transducers, were applied to Cubic readings for the other two pods.

5.1.4 Pod Stabilization. It is concluded that pod stabilization obtained in the Fish Bowl events was marginal. On Star Fish, which contained the unimproved stabilization system, flywheel run-down was excessive, and the angle of pod wobble was not satisfactory. Blue Gill Triple Prime pod orientation did not meet design criteria but did permit achievement of objectives. On King Fish, pod orientation and stabilization were very good.

For future events requiring stabilization, recommended changes appear in paragraph 5.2.1.

5.1.5 Pod Recovery. The recovery system, in the overall program, was less than satisfactory. However, all recovery system failures were with rebuilt equipment. Field maintenance experience indicated that the highly complex system used could not be adequately serviced under field conditions. For example, the recovery unit pressure system could not be pressurized when the unit was installed in the pod. The complexity of the recovery system was reducing its reliability.

5.2 RECOMMENDATIONS

5.2.1 Stabilization and Orientation. It is believed that a highly reliable stabilization system can be obtained from a design embodying the following: (1) A flywheel possessing greater moment of inertia and providing several times as much momentum. (2) An electric motor on the flywheel shaft with continuous access to battery power. This motor would bring the flywheel up to planned speed before launch, and during powered flight. After ejection, the motor would be powered on command from an autopilot system. (3) A high-pressure gas tank and valve system feeding pitch and yaw nozzles on command from the autopilot system. (4) A compact, lightweight autopilot system controlling both the pitch and yaw nozzles, and also the flywheel motor switch. This autopilot system would actuate the nozzles to pitch and yaw the pod (overpowering gyroscopic effect of the wheel) to the desired orientation.

The wheel then would hold the pod in the position reached at nozzle cut-off. The autopilot system would control the motor switch, supplying power in the proper direction to stop rolling.

5.2.2 Recovery. It is believed that a satisfactory recovery can be provided through a design modification. The primary objective of the design would be reliability through simplicity of the system, and through easy field servicing. The parachute system used is considered very successful. (Failures occurred only when chutes were re-used, and telemetry data from Tiger Fish flights indicated that chutes performed as planned.)

It is recommended that the flotation system, as used, be dispensed with. In its place, it is believed, a much simpler system can be provided which will float the pick-up loop, and allow the required separation in pick-up and transportation of the pod.

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Pages 139 and 140 deleted.