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NWL ADMINISTRATIVE REPORT AR-111/71
February 1971

AD513935

EXPLORATORY DEVELOPMENT PLAN FOR 8" GUIDED PROJECTILES (U)

J. Max Massey, Jr.

U.S. NAVAL WEAPONS LABORATORY
DAHLGREN, VIRGINIA

NWL

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U. S. NAVAL WEAPONS LABORATORY

Dahlgren, Virginia

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NWL Administrative Report
(14) NWL — AR/G-111/71
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EXPLORATORY DEVELOPMENT PLAN
FOR
8 in GUIDED PROJECTILES (U). (8)

[redacted]

by

(10) J. Max Massey, Jr.

Surface Warfare Department
Naval Weapons Laboratory
Dahlgren, Virginia 22448

(11) February 1971 (12) 84p.

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FOREWORD

(U) As a consequence of the First Naval Gunnery Conclave, NWL Dahlgren began, in October 1968, a serious effort to establish a program to develop an extended range, guided projectile for the Navy's eight-inch, Major Caliber Lightweight Gun. Subsequently, the Marine Corps revealed its need for a guided projectile for the eight-inch M110 Howitzer. This document outlines NWL's plan to demonstrate the feasibility of guiding projectiles for these two applications. It covers the work to date and outlines a program leading to advanced development of a guided projectile beginning in FY 1972.

(U) While all the work discussed relates to an 8-inch diameter tube, other, related work is also in progress. For example: system analyses and benefit/cost studies have shown the usefulness of and the need for guided projectiles; design syntheses and gun launched component tests are continuing in sensor/detector systems, anti-radiation seeker systems and control systems applicable to 5-inch and 155 millimeter projectiles. This plan does not attempt to address all areas of this work. Appendix A is provided for reference and contains Research and Technology Work Unit Summaries (DD Forms 1498) covering all the Navy guided projectile effort.

RELEASED BY:

C. Bernard

C. W. BERNARD
Head, Surface Warfare Department
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January 1971

ABSTRACT

(U) An exploratory development plan foı demonstrating the feasibility of a guided projectile has been established. The plan covers work completed from October 1968 through 1 February 1971 and outlines plans leading to Advanced Development of Navy and Marine Corps, eight-inch, guided projectiles in FY 1972. The total cost of the exploratory development program is about $ 5.25 million dollars for FY69, FY70 and FY71.

(C) Most of the guided projectile components have been gun fired and have survived 8000 g's acceleration. The shroud, guidance and control assembly, and telemetry assembly are designed to withstand 8000 g's and have survived 4000 g's. Three gun fired, guided, functional system tests have been conducted. The first two did not guide because of mechanical failures. The third guided toward the target; but, because of aerodynamic incompatabilities it did not maneuver to the target. Subsequent design changes proved aerodynamically sound during an air drop in January 1971. The projectile maneuvered out 2000 feet range error and 700 feet cross range error to impact 36 feet short and 4 feet right of the target. Three more gunfired tests are planned using an eight-inch Navy gun and three from an eight-inch howitzer.

TABLE OF CONTENTS

INTRODUCTION

BACKGROUND

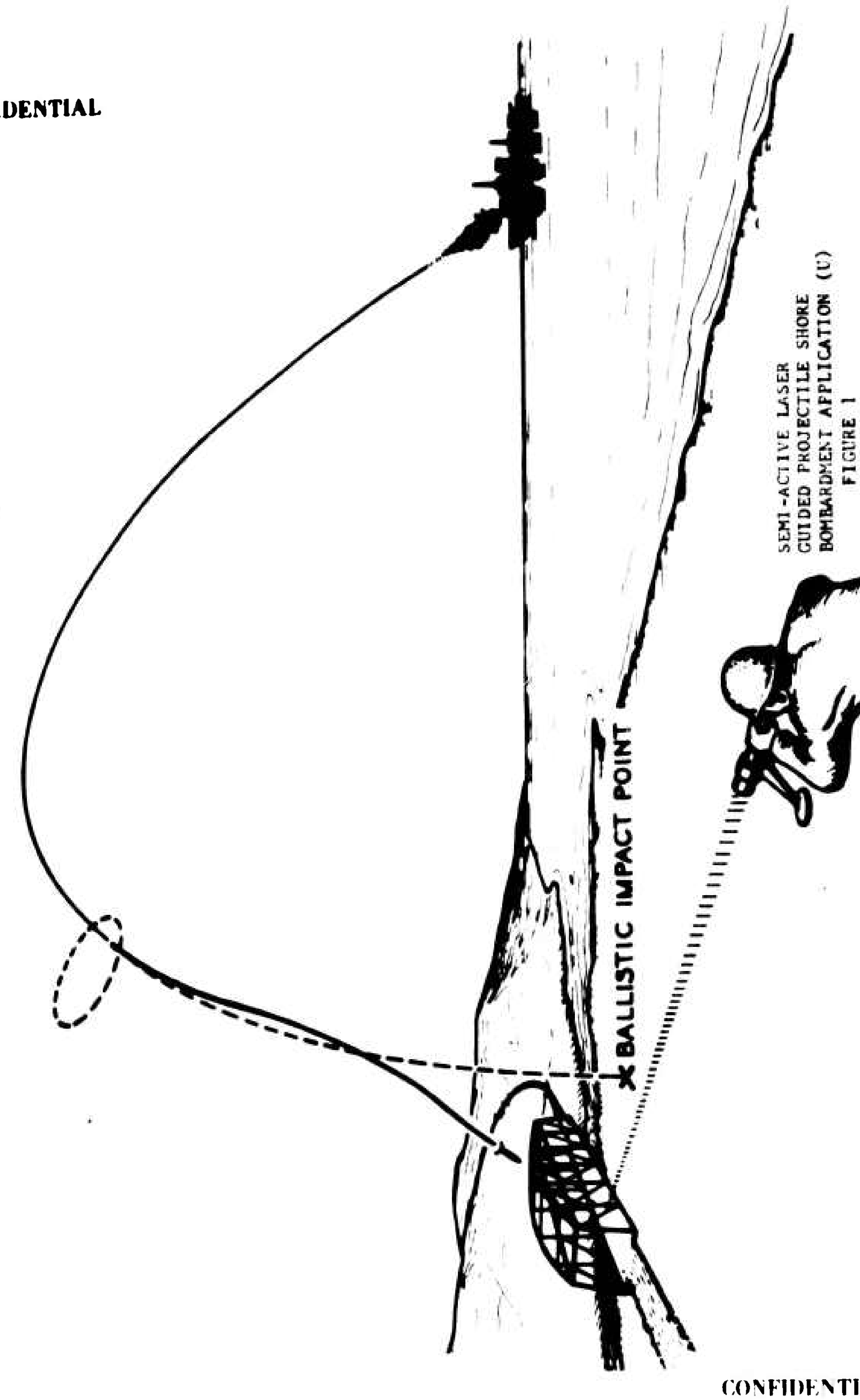
(U) The guided projectile concept is not new. The Angled Arrow project was an attempt to provide a single-shot correction to the trajectory of a projectile during its terminal phase. But the impetus for a truly effective terminal homing, projectile came out of the First Naval Gunnery Conclave. In 1968, Rear Admiral Gralla charged the Gunnery Conclave to "construct a plan for advancing naval gunnery capability, and [to] sift among the technological alternatives for those that are most advantageous in advancing that capability rapidly and economically."

(U) Among other things, the Gunnery Conclave pointed up the requirement for increased accuracy at extended ranges. It also identified the need for a development program for in-flight guidance.

(C) Funds have not been available to embark on the development of a new gun system with a fully integrated systems approach. But, the requirement for increased accuracy at greater ranges led NAVORD to task NWL Dahlgren to develop an extended range, terminally guided projectile. References (a) through (n) cover the effort to date. The conceptual round utilized a semi-active, LASER, guidance system and a forward observer equipped with a portable illuminator. This weapon was intended to be fired from the Navy's eight-inch, Major Caliber, Lightweight Gun primarily for shore bombardment against point and small area targets. (See Figure 1)

(C) During the last quarter of FY 1970, NAVORD tasked NWL, under Reference (g), to demonstrate the feasibility of terminally guiding artillery projectiles. The end product of this effort is expected to lead to Advanced Development of a semi-active LASER guided projectile for the eight-inch M110 and M110E2 Howitzers.

(C) NWL has combined both the Navy and Marine Corps efforts into a unified, Exploratory Development program which is the subject of this plan. The primary effort under this program has been to demonstrate the feasibility of guiding a projectile for both the Major Caliber Lightweight Gun and the eight-inch howitzers. This program is based on the demonstrated capability of the Air Force's



SEMI-ACTIVE LASER
GUIDED PROJECTILE SHORE
BOMBARDMENT APPLICATION (U)
FIGURE 1

semi-active, LASER guided bomb. The terminal phases of the bomb and projectile are sufficiently alike to employ the same guidance techniques. The technical approach of the NWL program is to gun harden the guidance components, repackage the bomb guidance system, and guide gun launched and howitzer launched projectiles to a LASER illuminated target. Over the past year and a half, NWL has gun launched numerous guidance components to prove their survivability. The tests conducted to date are summarized in Appendix C.

PROJECTILE DESCRIPTION

Demonstration Projectiles

(U) The Navy and Marine Corps demonstration vehicles are similar in that they employ the same guidance and control system design; they are both eight inches in diameter; and they may employ similar tail fins and obturation. The howitzer demonstration projectile design has not been finalized; but, to accommodate howitzer loading and ramming requirements, it will probably differ only slightly from the Navy projectile in configuration.

(C) The Navy demonstration vehicle is shown in Figure 2 and consists of a guidance section, a shroud to protect the guidance during gun launch, a body, and a fin stabilization section. It is eight inches in diameter, about six feet long and is fired from an eight inch rifled barrel. The guidance is a true-pursuit, semi-active LASER type with an aerodynamically stabilized seeker and bang-bang canard control. The seeker is gimbal mounted with a ringtail stabilizer which aligns with the velocity vector of the relative wind. Radiation from an illuminated spot on the target is focused onto a four quadrant detector which in turn, through signal conditioning and logic circuits, provides signals to solenoid valves. These valves open and close as required to control hot gases from a gas generator which activates the canards. The projectile does not require roll control. The guidance system deflects the canards in the required direction to close the angle between the target line of sight and the velocity vector. Since the laser is pulsed, the signals to the solenoid valves are updated at the frequency of the laser pulses. A more detailed description of the guidance and control subassemblies is contained in Appendix B.

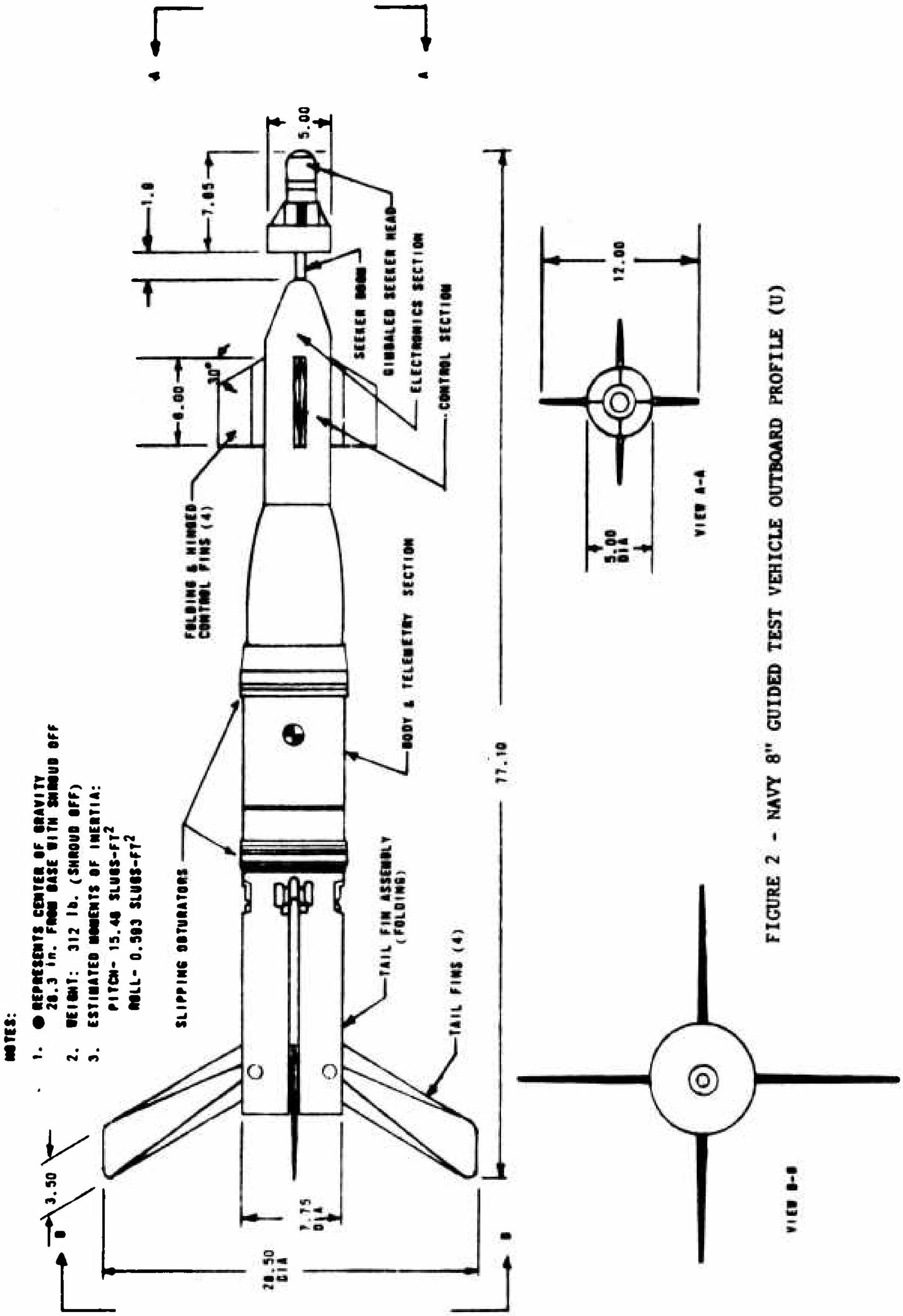


FIGURE 2 - NAVY 8" GUIDED TEST VEHICLE OUTBOARD PROFILE (U)

Navy Operational Projectiles

(C) Design concepts have been developed for two operational projectiles which can be fired from the Navy's eight-inch Major Caliber Lightweight Gun. They are shown in Figures 3 and 4. Both employ semi-active, LASER guidance with bang-bang controls but one is powered by a solid rocket motor and one is unpowered. The maximum range for the powered projectile is about 60 nautical miles; for the unpowered projectile, it is about 11 nautical miles.

Marine Corps Operational Projectile

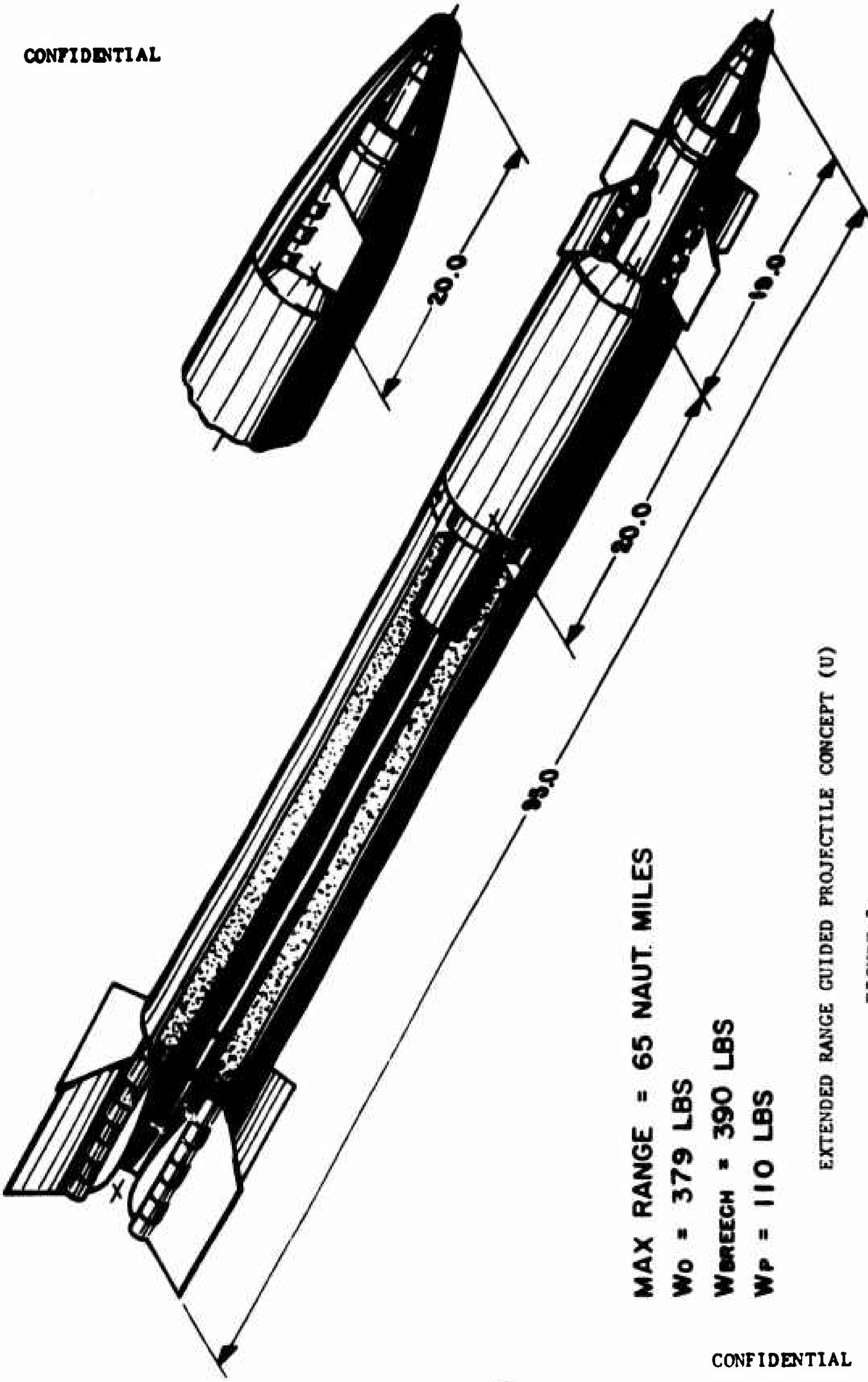
Layouts for a Marine Corps operational projectile are not complete. But an unpowered version should not differ markedly from that shown in Figure 4. Preliminary calculations show that a maximum range of 12,000 meters may be expected when firing from the eight-inch M110 Howitzer.

STATUS TO DATE

(U) Appendix C summarizes the tests conducted to 1 February 1971. The paragraphs below provide a narrative summary of the program status as reflected in these tests.

(U) Through a series of early firings from a smooth bore, nine-inch gun, critical guidance components were recovered and lab tested. Components found fully operational include the IR dome, lens assembly, filter, detector, preamplifier, and thermal battery.

(C) Dovetailing with the series of smooth bore component tests are rifled bore gun tests. To date, all the major components and many of the major subassemblies of the guidance and control system have survived gun firing at 8000 g's. These have been fired from an eight-inch, rifled gun, recovered and lab tested. The tail fins, body and obturators have also successfully survived rifled gun firing at 8000 g's. All the other major assemblies have survived gun launch at 4000 g's. These include the shroud assembly, the "all-up" guidance and control assembly, and the telemetry assembly. All of these assemblies are currently designed to withstand 8000 g's acceleration and will be qualified at this level as soon as adequate test hardware is available.



EXTENDED RANGE GUIDED PROJECTILE CONCEPT (U)

FIGURE 3

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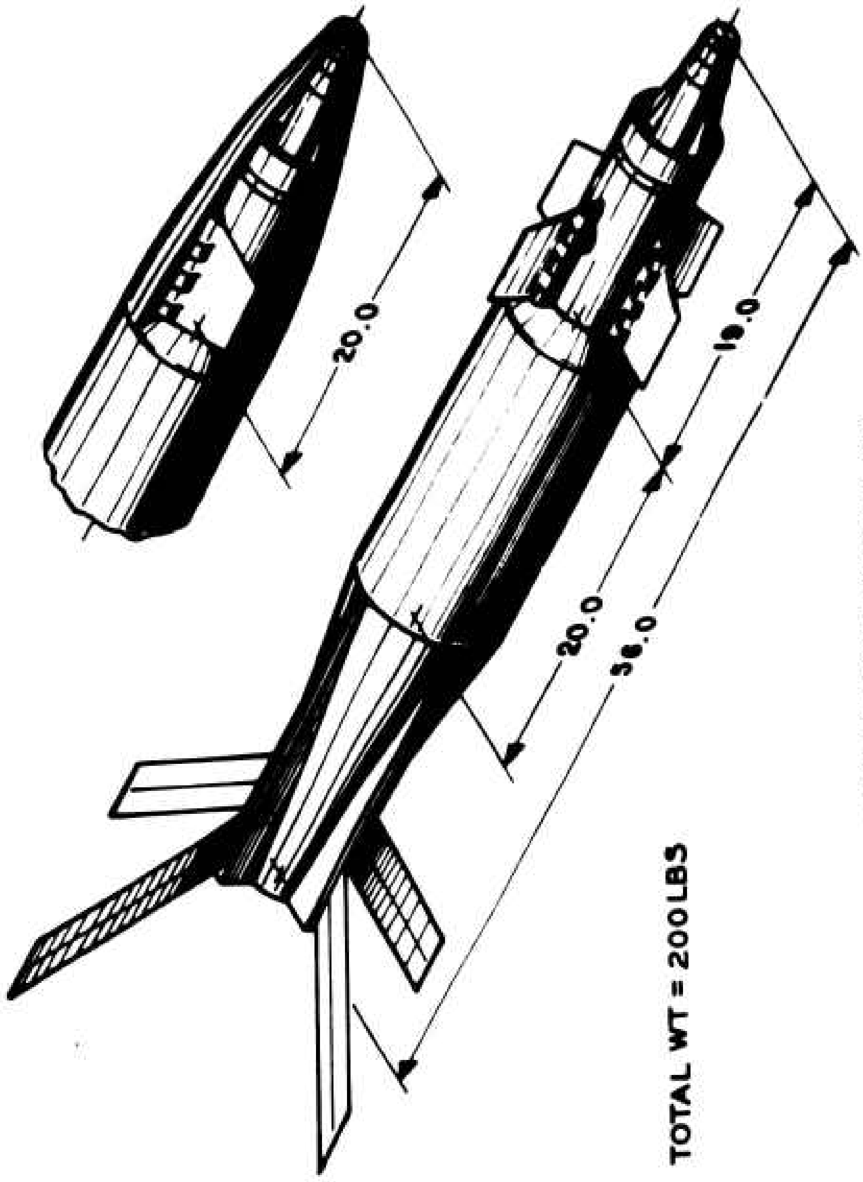

UNPOWERED GUIDED PROJECTILE CONCEPT (U)

FIGURE 4

(C) In support of the actual demonstration firings, a series of wind tunnel tests, air drops, and mathematical simulations of the total vehicle has been conducted. The wind tunnel tests provided aerodynamic coefficients needed for guidance simulation of the basic design. The guidance simulations have resulted in modifications to the design and insure that the vehicle will be both aerodynamically stable and responsive to the control commands. The air drops were designed to prove the electrical and mechanical functions of the guidance and control systems and to verify the static stability, dynamic stability, and the maneuverability of the projectile. These tests were conducted at the White Sands Missile Test Range and NWC, China Lake. The projectiles were air dropped from an A-4 aircraft and critical, on board data were telemetered to a ground station. All the objectives of these tests were met. All the guidance functions performed properly; however, in the first guided drop in March 1970, the projectile was maneuver limited at the drop speed and fell 1200 feet short of the target. The guidance corrected the trajectory 1500 feet in range and 200 feet in cross range. In the second guided drop in January 1971, after design changes had been incorporated in the control system, the body, and the tail, the projectile guided out 2000 feet of range error and 700 feet of cross range error to impact 36 feet short and 4 feet right of the target.

(U) The first attempt at firing an all-up guided projectile occurred in October 1970. The projectile was successfully fired. The slip obturator functioned properly and was discarded after leaving the muzzle. The tail fins properly deployed and the telemetry system functioned. The shroud failed to deploy which prevented target acquisition. As a result, the projectile followed a ballistic trajectory.

(U) A second firing was conducted in November 1970. The projectile was successfully launched with the slip obturator, tail fins, and telemetry again functioning properly. The shroud successfully deployed and the target was acquired as anticipated. The projectile failed to maneuver and was not recovered. Hence the exact cause of failure could not be determined. Analysis of the available data indicates that the gas generator which drives the seeker forward and operated the canards, failed to function.

(U) The third firing was conducted in December 1970 and all elements functioned. After target acquisition the projectile began to maneuver toward the target but experienced progressively larger pitch oscillations, building to peak values in excess of 30 degrees. These unintentionally large pitch oscillations induced drag forces, which caused the projectile to impact short of the target. The projectile was not recovered.

(U) A series of structural design changes to the test vehicle, subsequent to the original wind tunnel tests (0.6 scale) and air drop tests, had adversely affected the vehicle's static stability properties. Previously scheduled wind tunnel tests (full scale) were conducted one week after the firing. The results were substantially different from the results of the original 0.6 scale tests and confirmed that the vehicle lacked sufficient static stability during the guidance phase. Subsequent design changes have resulted in an aerodynamically sound vehicle as evidenced in the January 1971 air drop reported above.

(U) In every instance where the seeker acquired the target, the control surfaces responded correctly to guidance commands, which were in the proper direction for maneuvering toward the target.

GUIDELINES AND PERFORMANCE REQUIREMENTS

(C) Navy and Marine Corps guidelines and requirements as established thus far are listed below Except for accuracy, the Marine Corps requirements are the same as stated by the Army in Reference (ee)

(a) The demonstrations shall be accomplished by firing guided projectiles at a stationary, cooperative target illuminated by approximately a 150 millijoule/pulse LASER Precise geometrical constraints have not been imposed.

(b) The howitzer projectiles shall be compatible with the M110 and M110E2 Howitzers Maximum length is not to exceed 20 calibers; maximum weight is not to exceed 500 lbs

(c) Maximum range for the howitzer projectiles is as follows:

	M110	M110 E2
Required	11K meters	20K meters
Desired	17K meters	30K meters

(d) Required accuracy for the howitzer guided projectiles is 25 feet CEP. Desired accuracy is 15 feet CEP This accuracy is based on the following assumptions: (i) that the system functions, (ii) that the projectile is launched so that the target comes into the field of view of the detector, and (iii) that, given detection, the projectile can maneuver to the vicinity of the target without losing the target from the field of view Requirements must be established for (i), (ii), and (iii).

(e) The Navy guided projectiles shall be compatible with the Navy's eight-inch Major Caliber, Lightweight Gun Maximum length is not to exceed 11.3 calibers. Weight and other handling constraints must be established

(f) Maximum range for the Navy guided projectile has not been established. But a range of about 40 nautical miles (80 kyds) (depending on warhead size) appears feasible for a powered, guided projectile; and a range of about 11 nautical miles (22 kyds) appears feasible for an unpowered, guided projectile.

(g) Accuracy and reliability requirements must be established for the Navy guided projectile.

(h) No requirements or guidelines have been established for either the Navy or howitzer guided projectiles relating to the following:

(i) spotting doctrine
(ii) LASER illuminator
(iii) reliability
(iv) safety
(v) lethality and warhead size
(vi) powder charges
(vii) counter-counter measures
(viii) production costs
(ix) development and production schedules
(x) fuzing
(xi) security

DEVELOPMENT PLANS

OBJECTIVES

(C) Broad objectives for the guided projectile effort are contained in the current Research and Technology Work Unit Summaries (DD Forms 1498) in Appendix A. The specific objectives covered by this plan are as follows:

(a) Demonstrate the feasibility of guiding a projectile compatible with the Navy's eight-inch Major Caliber, Lightweight Gun

(b) Demonstrate the feasibility of guiding a projectile compatible with the Marine Corps eight-inch, M110 and M110E2 Howitzers.

(c) Establish guided projectile advanced development programs for the Navy's Major Caliber, Lightweight Gun and for the eight-inch M110 and M110E2 Howitzers.

(d) Establish data banks of gun hardening techniques, projectile guidance experience, and software guidance simulations applicable to the development of guided projectiles for other calibers such as five-inch and 155 millimeter

APPROACH

(U) The approach to the feasibility demonstrations is through three parallel paths:

(a) smoothbore gun fire tests
(b) rifled bore gun fire tests
(c) air drop tests

(C) In the early phases of component testing, critical guidance components are gun launched at 8000 g's from a nine-inch, smooth bore gun, recovered and lab tested for structural and electrical integrity The components are structurally analyzed as required, redesigned and tested again These tests are conducted without the need to simultaneously tackle the problem of spin decoupling the recovery canisters from the gun tube rifling

(C) Following these component tests from smoothbore guns, major components, subassemblies, and, finally, complete assemblies are gun launched at 8000 g's from an eight-inch rifled barrel to subject the assemblies to service environment. Again, these assemblies are recovered, lab tested, and, as required, structurally analyzed, redesigned, and tested again.

(U) Concurrent with the gun launched tests, wind tunnel and air drop tests of candidate configurations are run to establish aerodynamic requirements and to characterize the static and dynamic properties of the projectile.

(U) In conjunction with the test programs, design trade-off studies, design layouts and performance envelopes are developed for service guided projectiles. The actual feasibility demonstration is accomplished through (a) comparing the results of these trade-off studies, designs and performance calculations with service requirements; (b) conducting ballistic firings of mock-up designs; and (c) conducting a series of gun and howitzer launched, guided projectile firings against LASER illuminated targets.

SCHEDULES AND MILESTONES

(C) Figure 5 is a milestone chart for the eight-inch, guided projectile feasibility program. Table 1 is a listing of these milestones. As can be seen from the chart, emphasis is on hardening critical components to 8000 g's, demonstrating guidance of gun and Howitzer launched projectiles, insuring projectile-mount compatibility and establishing eight-inch, guided projectile advanced development programs.

(U) The program will be executed in several parallel efforts. The efforts are identified by distinct numerical series. Subsequent PERT charts will show event numbers keyed to the milestone series numbers shown on the milestone chart and summarized below:

0000 series - covers component hardening, component redesign and air drop tests

1000 series - covers the eight-inch howitzer projectile design and handling tests

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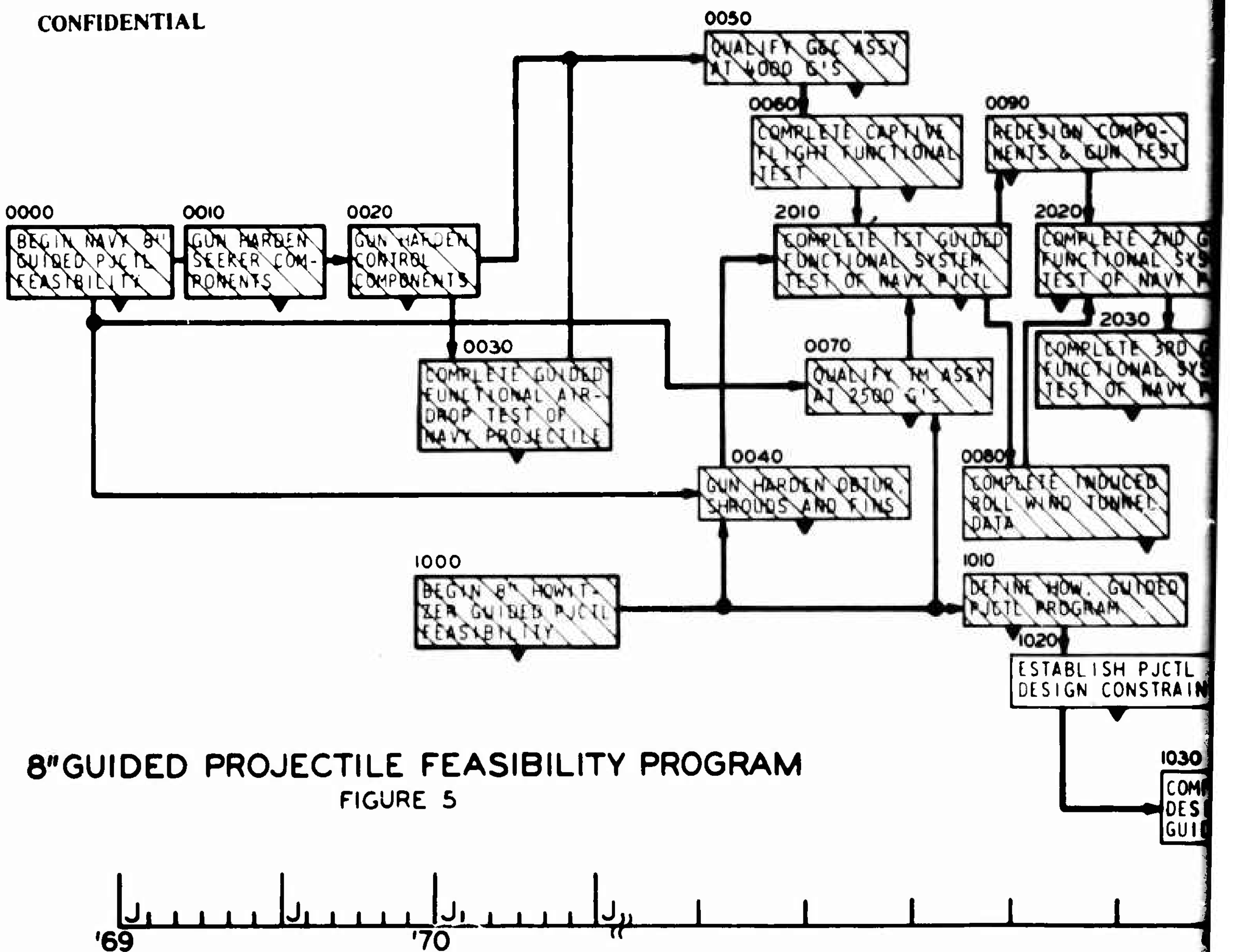
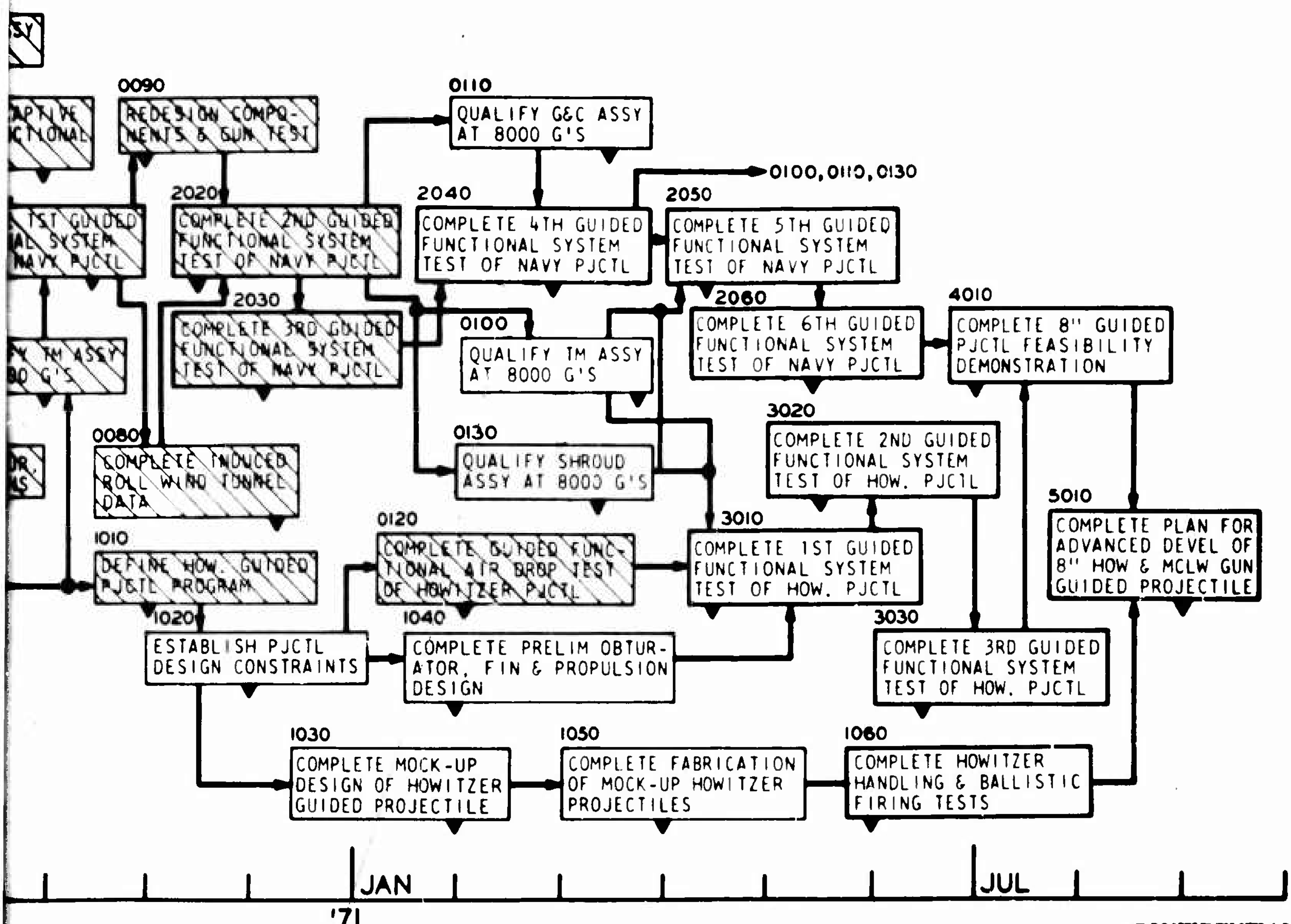


8" GUIDED PROJECTILE FEASIBILITY PROGRAM

FIGURE 5


0090
REDESIGN COMPONENTS & GUN TEST
0110
QUALIFY G&C ASSY AT 8000 G'S
0100, 0110, 0130
2020
COMPLETE 2ND GUIDED FUNCTIONAL SYSTEM TEST OF NAVY PJCTL
2040
COMPLETE 4TH GUIDED FUNCTIONAL SYSTEM TEST OF NAVY PJCTL
2050
COMPLETE 5TH GUIDED FUNCTIONAL SYSTEM TEST OF NAVY PJCTL
2030
COMPLETE 3RD GUIDED FUNCTIONAL SYSTEM TEST OF NAVY PJCTL
0100
QUALIFY TM ASSY AT 8000 G'S
2060
COMPLETE 6TH GUIDED FUNCTIONAL SYSTEM TEST OF NAVY PJCTL
4010
COMPLETE 8" GUIDED PJCTL FEASIBILITY DEMONSTRATION
3020
COMPLETE 2ND GUIDED FUNCTIONAL SYSTEM TEST OF HOW. PJCTL
0080
COMPLETE INDUCED ROLL WIND TUNNEL DATA
0130
QUALIFY SHROUD ASSY AT 8000 G'S
1010
DEFINE HOW. GUIDED PJCTL PROGRAM
0120
COMPLETE GUIDED FUNCTIONAL AIR DROP TEST OF HOWITZER PJCTL
3010
COMPLETE 1ST GUIDED FUNCTIONAL SYSTEM TEST OF HOW. PJCTL
5010
COMPLETE PLAN FOR ADVANCED DEVEL OF 8" HOW & MCLW GUN GUIDED PROJECTILE
1020
ESTABLISH PJCTL DESIGN CONSTRAINTS
1040
COMPLETE PRELIM OBTURATOR, FIN & PROPULSION DESIGN
3030
COMPLETE 3RD GUIDED FUNCTIONAL SYSTEM TEST OF HOW. PJCTL
1030
COMPLETE MOCK-UP DESIGN OF HOWITZER GUIDED PROJECTILE
1050
COMPLETE FABRICATION OF MOCK-UP HOWITZER PROJECTILES
1060
COMPLETE HOWITZER HANDLING & BALLISTIC FIRING TESTS
JAN
'71
JUL

2

2000 series - covers the Navy, guided, functional, system tests

3000 series - covers the howitzer, guided functional, system tests

4000 series - covers summation of results and documentation of all firings constituting the eight-inch, guided projectile feasibility demonstration

5000 series - covers the plans for advanced development of eight-inch guided projectiles for howitzers and the Major Caliber Lightweight gun.

(U) The work under the 0000, 2000 and 3000 series will be a joint NWL/contractor effort. NWL will direct the effort, participate in the hardware development and hardening and conduct all the test firings. The contractor, Texas Instruments, will fabricate the hardware, design the electronics and participate in the system tests at NWL Dahlgren. References (o) through (v) cover the contracts with Texas Instruments. Under Reference (v), Texas Instruments will deliver to NWL 10 guidance and control systems. Six of these will be used for the Navy system tests, three for the howitzer system tests, and one for an air drop system test. This contract also requires component and ballistic tests. The previous contracts with Texas Instruments, References (o) through (u), only required either hardware or component and air drop tests under the 0000 series.

(U) The work under the 1000, 4000 and 5000 series will have no major contract support. Based on requirements established by the Navy and Marine Corps. NWL will design eight-inch projectile mock-ups and prepare the required documentation leading to advanced development of projectiles for the Navy's Major Caliber Lightweight gun and for the M110 and M110E2 eight-inch Howitzers.

TABLE 1

NAVY AND MARINE CORPS GUIDED PROJECTILE MILESTONES

EVENT NO.	MILESTONE	SCHEDULED COMPLETION DATE	STATUS
0000	Begin 8" Guided Projectile Feasibility Program	Jan 69	Complete
0010	Gun Harden Seeker Components (8000 g's)	Jul 69	Complete
0020	Gun Harden Control Components (8000 g's)	Dec 69	Complete
0030	Guided, Functional Air Drop Test of Navy Projectile	Mar 70	Complete
1000	Begin 8" Howitzer Guided Projectile Feasibility Program	Apr 70	Complete
0040	Gun Harden Obturator (8000 g's), Shroud (4000 g's) Fins (8000 g's)	Sep 70	Complete
0050	Qualify G&C Assembly (4000 g's)	Sep 70	Complete
0060	Captive Flight, System, Functional Test	Sep 70	Complete
0070	Qualify TM Assembly (2500 g's)	Sep 70	Complete
2010	First Guided, Functional, System Test of Navy Projectile	Oct 70	Complete
0090	Gun Test Modified Components	Oct 70	Complete

EVENT NO.	MILESTONE	SCHEDULED COMPLETION DATE	STATUS
1010	Define Howitzer Guided Projectile Feasibility Program	Nov 70	Complete
2020	Second Guided, Functional System Test of Navy Projectile	Nov 70	Complete
0080	Induced Roll Wind Tunnel Test	Dec 70	Complete
1020	Establish Howitzer Projectile Design Constraints	Dec 70	Complete
2030	Third Guided Functional System Test of Navy Projectile	Dec 70	Complete
0120	Guided, Functional, Air Drop Test of Howitzer Projectile	Jan 71	Complete
1030	Mock-up design of Howitzer Guided Projectile	Feb 71	
1040	Complete Preliminary Obturator, Fin and Propulsion Design	Feb 71	
2040	Forth Guided, Functional, System Test of Navy Projectile	Feb 71	
0100	Qualify TM at 8000 g's (Subject to successful test, Event No. 2040)	Mar 71	
0110	Qualify G&C Assembly at 8000 g's (Subject to successful test, Event No. 2040)	Mar 71	
0130	Qualify Shroud Assembly at 8000 g's (Subject to successful test, Event No. 2040)	Mar 71	
1050	Fabricate Mock-Up Howitzer Projectiles	Apr 71	

EVENT NO.	MILESTONE	SCHEDULED COMPLETION DATE	STATUS
3010	First Guided, Functional, System Test of Howitzer Projectile	Apr 71	
2050	Fifth Guided, Functional, System Test of Navy Projectile	Apr 71	
3020	Second Guided, Functional, System Test of Howitzer Projectile	May 71	
2060	Sixth Guided, Functional, System Test of Navy Projectile	May 71	
1060	Howitzer Handling and Ballistic Test of Mock-Up Projectiles	Jun 71	
3030	Third Guided, Functional, System Test of Howitzer Projectile	Jun 71	
4010	Complete Eight-Inch, Guided Projectile Feasibility Demonstration	Jun 71	
5010	Plan for Advanced Development of 8" Howitzer and MCLW Gun Guided Projectiles	Sep 71	

HARDWARE REQUIREMENTS

(U) To meet the requirement to handle and fire mock-up guided projectiles from an eight-inch howitzer and to guide projectiles launched from an eight-inch howitzer, NWL will require a cannon, M2A1E1 or equivalent, complete with a gun howitzer mount, M158, or equivalent, rammer and loader assembly and a firing mechanism, M35, or equivalent. Preferably, the cannon will be mounted on a tracked vehicle.

(U) To meet the schedule for the first guided, functional system test of a howitzer launched projectile (Milestone 3010) in March or April, the above equipment is required at NWL on or before 1 February 1971.

DOCUMENTATION AND REPORTS

(U) Progress and milestone achievements are documented in a number of formats including

Memorandums
Technical Notes
Letter Reports
Quarterly Progress Reports
Technical Reports
Contractor Reports
Administrative Reports

Distribution of these documents will vary according to content and need But, generally, Memorandums and Technical Notes will be restricted to "on-station" distribution while the Reports will be given the same distribution as listed in Appexdix D

(U) The following documents will be published routinely.

(a) Memorandums documenting the major results of each Guided, Functional, System Test

(b) Letter Reports issued quarterly documenting technical status, progress, major results, tests conducted and fiscal status

(c) Technical Reports documenting major technical results of the program.

(d) Contractor Reports documenting major technical results of each contract

(e) Administrative Reports documenting general status and future plans.

(U) Table 2 lists the documents published to 1 February 1970.

TABLE 2

Confidential NWL Technical Report TR-2531 (in review) *Acquisition Ranges for Semi-Active LASER System (U)*, Thomas S. Hahn

Confidential Memorandum, *Computer Study of a Compensated Body Fixed Seeker for Terminal Guidance (U)*, R. T. Ramsey

Confidential NWL Technical Note, TN/F-32/69, *Suitability of the MK 86 Gun Fire Control System for the Long Range Gun Project (U)*, Walter P. Warner

Confidential NWL Technical Note, TN/F-61/70, *Airborne Sensor Platform (U)*, Richard W. Dorsey

Confidential Memorandum, *Control Effects (U)*, H. R. Scheibe

Confidential Memorandum, *Infrared Guidance for Ordnance (U)*, John Spencer

Confidential Memorandum, *Gyroscopes for Guided Projectiles (U)*, John Spencer

Confidential Memorandum, *Test and Evaluation of a Magnetic Particle Clutch for the Guided Projectile (U)*, P. S. Laybourne

Confidential Memorandum, *Long Range Gun System Anti-Radiation Seeker Development (U)*, H. C. Oliver

Confidential NWL Technical Note TN/F-41/70, *Estimation of Miss Distance for Body Fixed Seekers Against Surface Targets*, W. R. Chadwick et al.

Confidential NWL Technical Note TN/F-68/70, *RF Seeker Design (U)*, Robert O. Gilmore

Confidential Memorandum, *Anti-Radiation Guidance Computer (U)*, H. E. Pitzer

Confidential Technical Report TR-2427, *A Study of Batteries for Long Range Guided Projectiles (U)*, P. S. Laybourne

Confidential Technical Note TN/F-81/70, *Spurious Emission Seeker for Ordnance (U)*, Robert O Gilmore

Confidential NWL Memorandum, *Proposed Guidance and Control Section for a 5-Inch Projectile (U)*, H. C Oliver et al

Confidential Memorandum, *Reaction Control System for Guided Projectiles (U)*, R. T. Ramsey

Confidential Contrators Report, *Final Repor. MK 25 Projectile Guidance System Gun Firing Tests (U)*, Vols I and II 923-14-045 dtd 25 Sep 1970, Texas Instruments

Confidential Contractors Report, *Contract N00178-69-C-0142 Submission of Final Technical Report (U)*, dtd 29 Jul 1969, Texas Instruments

Confidential Contractors Report, *MK 25 Projectile Guidance System Air Drop Flight Tests (U)*, 923-14-044 dtd 25 Sep 1970, Texas Instruments

Confidential Final Technical Report, *Guided Artillery Projectile Subsystem Test Firings*, 92303/20-17 dtd 27 Feb 1970, Texas Instruments

Unclassified Report HB9GP70 - *Shop Maintenance Test Set LASER Guided Artillery Projectiles*, dtd 16 Mar 1970, Texas Instruments, Vols I and II

NWL Memorandum GL JMM:bsr dtd 16 Oct 1970, *First Guided Projectile, Functional, System Test*

NWL Memorandum GL JMM:bsr dtd 9 Nov 1970, *Second Guided Projectile Functional System Test*

NWL Memorandum GL JMM:bsr dtd 7 Dec 1970, *Third Guided Projectile Functional System Test*

FISCAL SUMMARY

(U) The following tables summarize approximate costs for FY1969, FY1970 and FY1971.

FY1969

Labor -	$367.3K	
Materials -	$10.0K	
Contracts -	$629.7K	
Travel -	$12.0K	
	$1019.0K	TOTAL

FY1970

Labor -	$1731.0K	
Materials -	$142.8K	
Contracts -	$1505.0K	
Travel -	$20.0K	
	$3398.8K	TOTAL

FY1971

Labor -	$1170.0K	
Materials -	$144.0K	
Contracts -	$500.0K	
Travel -	$16.0K	
	$1830.0K	TOTAL

(U) The FY1971 costs are subdivided among the major categories of the program as follows:

8" Guided Projectile Developmental Design & Testing	-	$1150K
8" Gun Guided Projectile Design and Feasibility Demonstration	-	$200K
Wind Tunnel Tests, Air Drop Tests and Aerodynamic Engr. Support	-	$130K
8" Howitzer Guided Projectile Design & Feasibility Demonstration	-	$200K
Alternate Guidance and Control Systems for Guided Projectile Development	-	$150K
	TOTAL	$1830K

MANAGEMENT PLAN

(U) A program manager located in the Surface Warfare Department, Naval Weapons Laboratory will be responsible for overall management and coordination of the technical planning, budgeting, scheduling and evaluating of all aspects of the development program. He will insure coordination of the efforts of the various responsible NWL Divisions, assisting field activities and contractors associated with the design, development and fleet introduction. Figure 6 shows the current Organizational and Staffing Chart. This chart will be expanded to cover other areas as the need presents itself and as the program nears the Advanced Development stage.

(U) In order to insure that all facets of the program are adequately considered, a work breakdown structure has been prepared and is shown in Figure 7. Each of the major areas shown on this work breakdown structure has been assigned to specific individuals.

UNCLASSIFIED

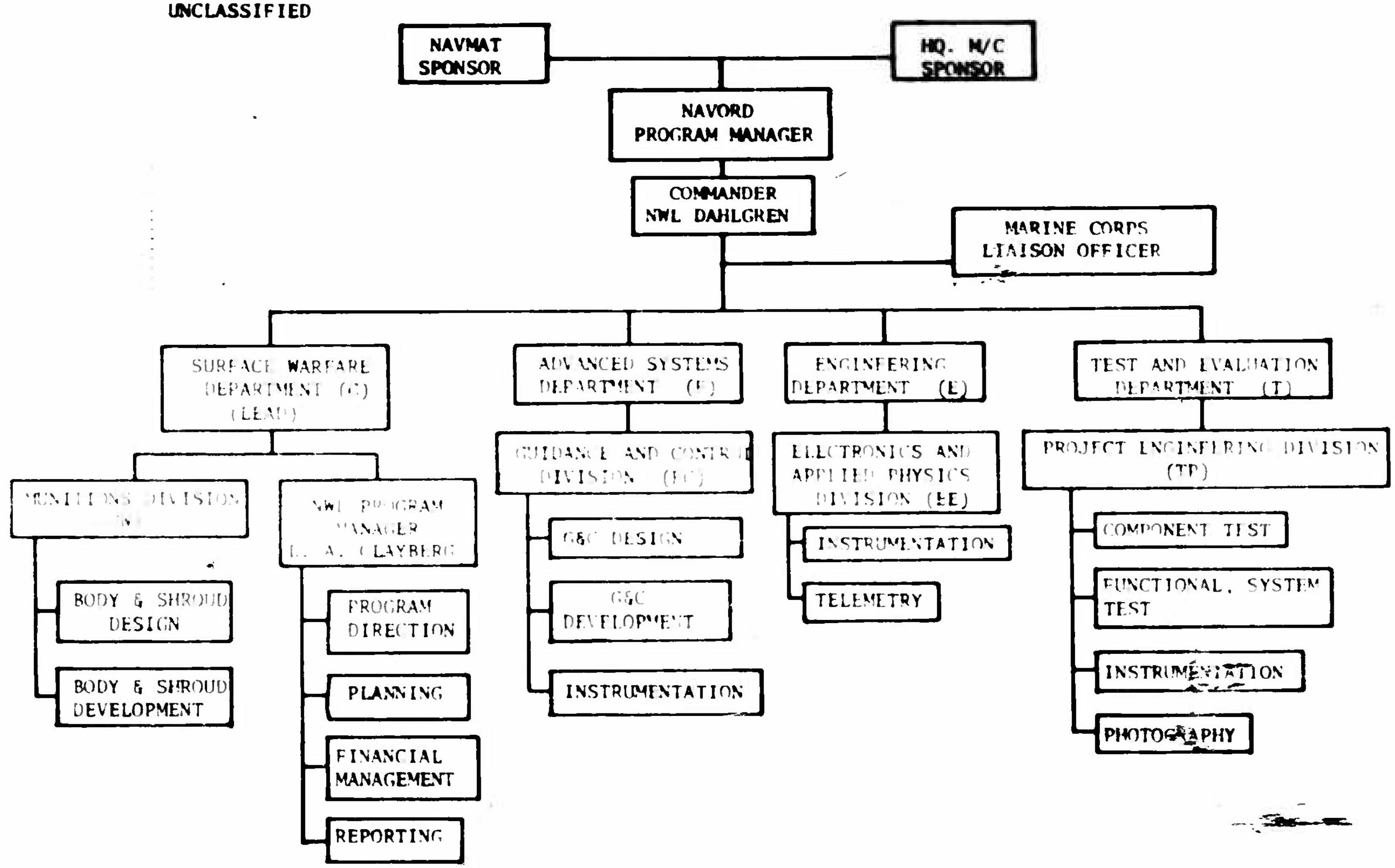
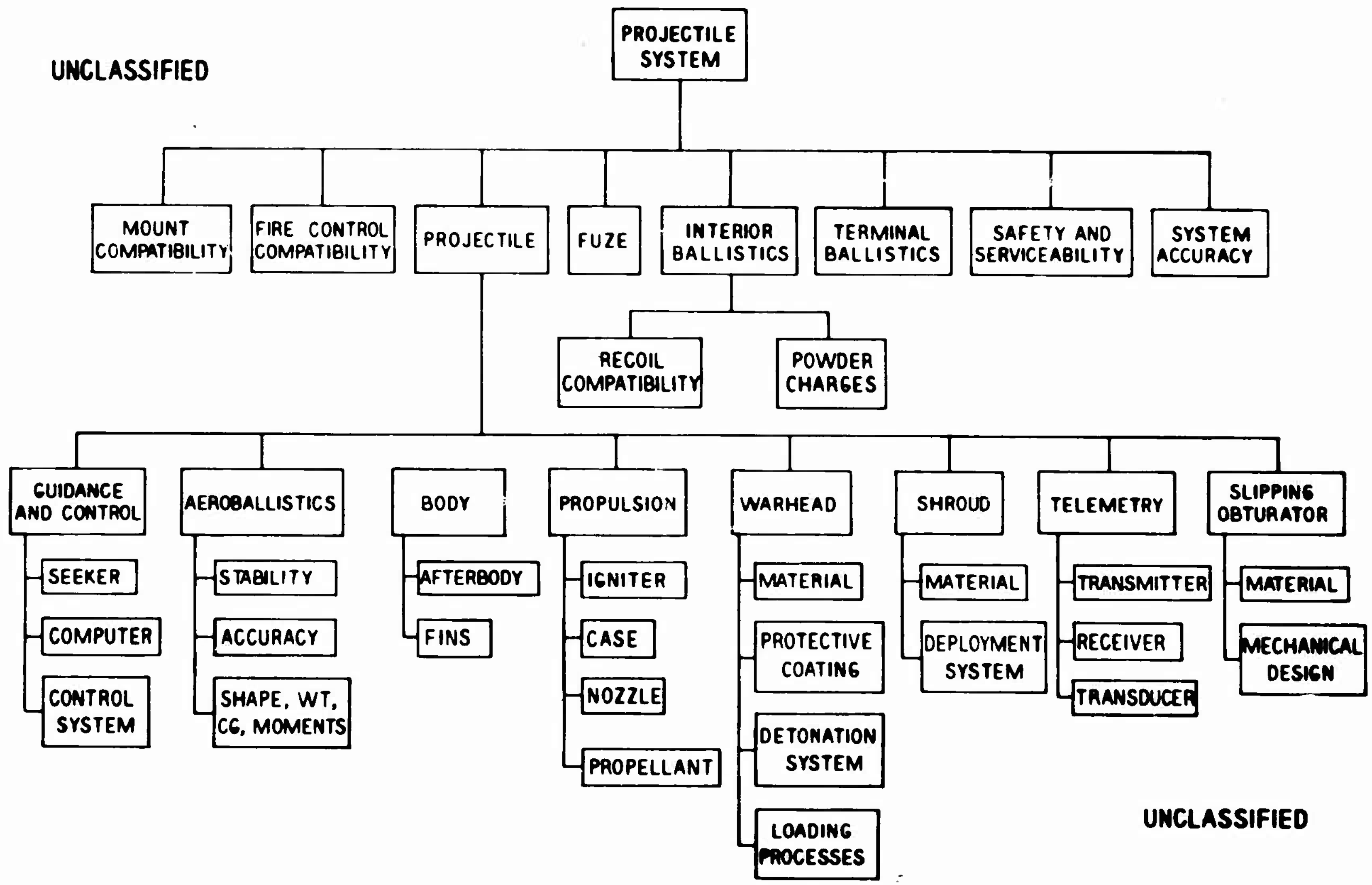


FIGURE 6. ORGANIZATION & STAFFING CHART

UNCLASSIFIED

UNCLASSIFIED



UNCLASSIFIED

FIGURE 7 8" GUIDED PROJECTILE WORK BREAKDOWN STRUCTURE

REFERENCES

(a) Major Caliber Lightweight Gun Ammunition Research Work Request #WR-0-5426 ORDTASK # 08B-116-090-1 UF-17-313-209 (1 Jul 1969)

(b) Close-In Point Defense Gun System (Proj Propulsion) Work Request #WR 0-5383, ORDTASK # 08B-113/090-1 UF-17-313-209 (1 Jul 1969)

(c) Polygon Application to Guided Projectile/Research Work Request # WR-9-6289, ORDTASK # 08B 116-090-1 UF-17-313 209

(d) Gun Accuracy Investigations Work Request # WR-0-5424, ORDTASK # 08B-116-090-1 UF-17-313-209 (1 Jul 1969)

(e) Long Range Bombardment Ammunition Work Request # WR-0-5427, ORDTASK # 08B-116-090-1 UF-17-313-209 (1 Jul 1969)

(f) Gun/Rocket Suits, Major Ships Work Request # WR-0-5383, ORDTASK # 08B-002/090-1 UF-17-313-216 (1 Jul 1969)

(g) Laser Homing Ordnance Interior Ballistics Project Order 0-0026, ORDTASK UR 50-343-501 (4 Jun 1970) (Marine Corps)

(h) Long Range Gun Systems Investigations Work Request # WR-1-5321, ORDTASK # 08B-194-090-1 UF-17-311-209 (24 Jul 1970)

(i) Long Range Projectile Effectiveness Investigation Work Request # WR-1-5321, ORDTASK # 08B-197/090-1 UF-17-311-209 (24 Jul 1970)

(j) Passive Projectile Guidance Investigation Work Request # WR-1-5321, ORDTASK # 32E-001/090-1 UF-20-311-212 (24 Jul 1970)

(k) Projectile Guidance/Advanced Sensor System Work Request # WR-1-5321, ORDTASK # 08B-198-090-1 UF-17-311-209 (24 Jul 1970)

(l) Polygon Warhead Application Work Request # WR-1-5624, ORDTASK # 08B-194-090-1 F 17-311-209 and # 08B-116-090-1 F 17-313-209 (3 Aug 1970)

(m) Major Caliber Lightweight Gun Mount, Work Request # WR-1-5852, ORDTASK #

(n) Terminally Guided Artillery Projectiles, Work Request # WR-1-5891, ORDTASK # 35D-001/090-1 UF 50-343-501 (18 Sep 1970)

(o) Contract Number N00178-69-C-0142, Texas Instruments, dtd 21 Feb 1969

(p) Contract Number N00178-69-C-0196, Texas Instruments, dtd 30 Apr 1969

(q) Contract Number N00178-69-0238, Texas Instruments, dtd 7 May 1969

(r) Contract Number N00178-69-C-0285, Texas Instruments, dtd 11 Jun 1969

(s) Contract Number N00178-70-C-0062, Texas Instruments, dtd 11 Sep 1969

(t) Contract Number N00178-70-C-0063, Texas Instruments, dtd 15 Sep 1969

(u) Contract Number N00178-70-C-0060, Texas Instruments, dtd 15 Sep 1969

(v) Contract Number N00178-71-C-0182, Texas Instruments, dtd 21 May 1970

(w) Contract Number N00178-70-C-0059, Space Research Corporation, dtd 19 Sep 1969

(x) Contract Number N00178-69-C-0280, Space Research Corporation, dtd 11 Jun 1969

(y) Contract Number N00178-69-C-0266, Space Research Corporation, dtd 30 May 1969

(z) Contract Number N00178-69-C-0172, Space Research Corporation dtd 28 Feb 1969

(aa) Contract Number N00178-69-C-0309, University of Virginia, dtd 27 Jun 1969

(bb) Contract Number N00178-69-C-0306, Lockheed Propulsion Company, dtd 17 Jun 1969

(cc) Contract Number N00178-69-C-0290, Lockheed Propulsion Company, dtd 11 Jun 1969

(dd) Contract Number N00178-71-C-0002, Space Research Corporation, dtd 17 Jul 1970

(ee) Rock Island conf ltr AMSWE-REV-SPA dtd 10-16-70. Howitzer Data for Guided Projectiles

APPENDIX A

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARIES (U)

(DD Forms 1498)

CLASSIFICATION CONFIDENTIAL DD FORM 1498

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	CN	1 Feb 71	

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
NA	A. New	C	C	3	NA	☐ YES ☐ NO	A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	0	35D001/090-1	UF50343501	NWL/G-21401, 21402
b. CONTRIBUT.				[redacted]
c. CONTRIBUT.				

11. TITLE (Precede with Security Classification Code)

(U) Terminally Guided Artillery Projectile Investigation for USMC

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

001600 Ammunition, 006100 Ballistics, explosives

13. START DATE	14. EST. COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
Jun 70	Cont.		C. In-house

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUMULATIVE:

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 70	0.0	0.0
	CURRENT 71	8.0	925.0

19. RESPONSIBLE DOD ORGANIZATION

NAME: Naval Ordnance Systems Command

ADDRESS: Washington, D. C. 20360

RESPONSIBLE INDIVIDUAL

NAME: (Code:)

TELEPHONE:

20. PERFORMING ORGANIZATION

NAME: NAVAL WEAPONS LABORATORY

ADDRESS: DAHLGREN, VIRGINIA 22448

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Inst.)

NAME: L. A. Clayberg (Code: GL)

TELEPHONE: 703-663/8831

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS:

NAME:

NAME:

21. GENERAL USE

NA

22. KEYWORDS (Precede EACH with Security CLASSIFICATION Code)

(U) AMMUNITION, (U) BALLISTICS, (U) EXPLOSIVES

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (C) TECHNICAL OBJECTIVES. To develop terminal guidance for artillery projectiles, to provide accurate fire support against stationary or moving targets.

24. (C) APPROACH. Demonstrate feasibility of terminally guiding artillery projectiles by designing, testing and firing prototype guidance and control systems from in-service cannons. The system shall be compatible with existing Howitzer mounts and cannons with minimum modifications. The exploratory development shall be directed toward demonstration of techniques for homing on inherent or induced target signatures. Initial efforts complement the Navy program and are aimed to demonstrate semi-active, LASER guided projectiles fired from 8" Howitzer. Demonstration of alternate guidance systems such as IR, RF or other electronic optical devices follows.

25. (C) PROGRESS. Feasibility flight vehicles have been designed, fabricated, and gun fired. A series of component and subassemblies were developed and have withstood gun launch up to 8000 g's. Complete fin assemblies, guidance and control assemblies, TM packages and the protective shroud have been qualified to 4000 g's. A complete assembly was dropped from an aircraft on 21 January 1971 to determine aerodynamic characteristics. The projectile acquired the target and corrected its flight path by 2000 feet in range, by 700 feet in cross range to achieve an actual miss distance of 36 feet short, 4 feet right. The next gun fired functional guided projectile is scheduled for firing during the month of February.

*AVAILABLE TO CONTRACTOR'S UPON ORIGINATOR'S APPROVAL.

WORK UNIT NO. G-21401, 21402	NAVY WORK UNIT CONTINUATION SHEET DATA FORM
26. PRIOR IDENT: NA	27. TECH AGENT: NA

28. MANPOWER AND COST ESTIMATES	CFY-1 1970	CFY 1971	CFY+1 1972	CFY+2 1973
a. PROFESSIONAL MAN-YEARS	0.0	8.0	8.0	8.0
b. TOTAL DIRECT LABOR MAN-YEARS	0.0	11.3	17.5	17.5
c. TOTAL LABOR AND OVERHEAD ($K)	0.0	225.0	350.0	350.0
d. MATERIALS AND TRAVEL ($K)	0.0	125.0	150.0	150.0
e. MAJOR PROC/CONTRACTS ($K)	0.0	575.0	500.0	500.0
f. PLANNING E ATE ($K)		925.0	1000.0	1000.0
g. FUNDS AVAILABLE ($K)	0.0	820.0	0.0	0.0
h.				
h.				

29. BACKGROUND, 30. PLANS AND MILESTONES, 31. REFERENCES, 32. MAJOR PROCUREMENTS AND CONTRACTS, 33. SPECIAL REQUIREMENTS *(Furnish individual paragraphs identified by number. Precede each with Security Classification Code).*

29. (C) BACKGROUND. The Guidance and Control package chosen for the first feasibility firing of a guided projectile proven and operational components. The seeker is a semi-active laser system employed currently by the Air Force Bolt Bomb. The Computer and Control secti-ns are modified SHRIKE systems.

30. (C) PLANS AND MILESTONES.

(1) Complete subassembly qualification at 4000 g's - October 1970
(2) Initiate gun firing of complete guided projectiles - October 1970

Continue through one air drop and nine firings terminating with three launches from an 8" Howitzer (M110) during the 4th quarter of FY 71.

31. (U) REFERENCES.

(a) NAVORD ltr GW:BLM:reb dtd 11 Jun 1970 to Distribution, Subj: "Semi-Active Laser Guided Projectile; Security guidelines for"

32. (U) MAJOR PROCUREMENTS AND CONTRACTS. CPFF Contract to Texas Instruments, Inc. Dallas, Texas. Incremental funding, N00178-70-C-0182, estimated cost $1,027,661.00 effective 21 May 1970.

33. (U) SPECIAL REQUIREMENTS. None

DD FORM 1498

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DN	1 Feb 71	

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8. DISB'N INSTR'N	9. SPECIFIC DATA-CONTRACTOR ACCESS	10. LEVEL OF SUM
NA	A. New	C	C	3		☐ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	62312N	08B198/090-1	UF17311209	NWL/ G-19601 & 18801
b. CONTRIBUT.	62312N	32E001/090-1	UF20311212	[redacted]
c. CONTRIBUT.				

11. TITLE (Precede with Security Classification Code)*

(U) Advanced Sensor Systems for Projectile Guidance

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 019000 Control Analysis and Theory

011900 Optical Detection; 008200 IR and IV Detection; 013700 Radar Detection

13. START DATE	14. EST. COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
Jul 70	Cont.		C. In-house

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUMULATIVE:

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 70	0.0	0.0
	CURRENT 71	2.0	74.0

19. RESPONSIBLE DOD ORGANIZATION

NAME:* Naval Ordnance Systems Command

ADDRESS:* Washington, D. C. 20360

RESPONSIBLE INDIVIDUAL

NAME: Kirschke (Code: 08B)

TELEPHONE: (202) OX-6-2097

21. GENERAL USE

20. PERFORMING ORGANIZATION

NAME:* NAVAL WEAPONS LABORATORY

ADDRESS:* DAHLGREN, VIRGINIA 22448

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Inst.)

NAME:* Pitzer, H. E. (Code: FGR)

TELEPHONE: 703-663-8781

SOCIAL SECURITY ACCOUNT NUMBER: 232-62-1281

ASSOCIATE INVESTIGATORS:

NAME: Gilmore, R. O.

NAME: Fontenot, L. J.

22. KEYWORDS (Precede EACH with Security CLASSIFICATION Code)

(U) Projectile; (U) Guidance; (U) Sensor

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (C) TECHNICAL OBJECTIVE. To increase gun system effectiveness against a wide spectrum of targets by developing a family of guidance sensors which will control the terminal flight of projectiles.

24. (U) APPROACH. Search for, originate, develop and prove feasibility of sensor concepts and hardware for application in terminally guiding gun launched projectiles against targets. Existing and proposed guided missile seekers will serve as the information base for this effort in its first few years. Constraints unique to the gun launch scenario, such as the high launch accelerations, small volume and necessarily low production costs dictate departures from the usual guided missile seeker systems. These departures will be developed and should be applicable to guiding other ordnance such as bombs and small rockets.

25. (C) PROGRESS. A laser semi-active seeker has been gun hardened and is being used on a guided projectile for a feasibility demonstration. An anti-radar seeker for gun launching exists in breadboard form. Anti-air IR seekers are being designed for gun launching.

*AVAILABLE TO CONTRACTOR'S UPON ORIGINATOR'S APPROVAL.

WORK UNIT NO.	NAVY WORK UNIT
19601, 18801	CONTINUATION SHEET DATA FORM
26. PRIOR IDENT: NA	27. TECH AGENT: NA

28. MANPOWER AND COST ESTIMATES	CFY-1 19 70	CFY 19 71	CFY+1 19 72	CFY+2 19 73
a. PROFESSIONAL MAN-YEARS	0.0	3.0	5.0	5.0
b. TOTAL DIRECT LABOR MAN-YEARS	0.0	4.0	7.0	8.0
c. TOTAL LABOR AND OVERHEAD ($K)	0.0	100.0	170.0	190.0
d. MATERIALS AND TRAVEL ($K)	0.0	31.5	25.0	40.0
e. MAJOR PROC/CONTRACTS ($K)	0.0	0.0	50.0	50.0
f. PLANNING ESTIMATE ($K)		131.5	245.0	280.0
g. FUNDS AVAILABLE ($K)	0.0	131.5	0.0	0.0
h.				
h.				

29. BACKGROUND, 30. PLANS AND MILESTONES, 31. REFERENCES, 32. MAJOR PROCUREMENTS AND CONTRACTS, 33. SPECIAL REQUIREMENTS *(Furnish individual paragraphs identified by number. Precede each with Security Classification Code).*

29. (C) BACKGROUND. During FY 70 NWL Dahlgren has had a program underway to prove the feasibility of gun launching a guided projectile against a target. A laser semi-active guidance scheme such as that employed in the BOLT bomb system was chosen for the feasibility model. A laser semi-active projectile guidance system has one serious operational limitation, that is the requirement of having an observer illuminating the target with a lser. Effort is now underway at NWL to design and develop an anti-radar seeker for gun launched projectiles. Infrared target signatures are being collected as a first step toward the design and development of an IR target seeker system for gun launched projectiles.

30. (C) PLANS.

(1) (C) Design and develop IR seekers for gun launched projectiles against air and ship targets.

(2) (C) Continue searching for and developing new and/or refined seekers and seeker concepts for use with gun launched munitions. Such seekers include (but are not limited to) spurious RF emissions, acoustic, active radar, active laser and image correlation, in addition to those previously mentioned. Initiate development of such seekers when feasibility is indicated.

MILESTONES:

(a) (C) Complete initial anti-air IR seeker design concepts. 1 July 1971.
(b) (C) Design and gun harden critical IR seeker components. 1 July 1971
(c) (U) Continue study to identify additional seekers feasible for projectile guidance. FY71, 72.

31. (U) REFERENCES:

NWL/FGR Training Report (U) Laser Semi-Active Guidance Bibliography, Clarence C. Andressen, 30 June 1970 (Confidential)

NWL Tech. Note TN-F-66/70 July 1970 (U) Computer Study of a Compensated Body Fixed Seeker for Terminal Guidance, R. T. Ramsey (Confidential)

NWL Tech. Report TR-2427 June 1970 (U) A Study of Batteries for Long Range Guided Projectiles, P. S. Laybourne (Confidential)

NWL Tech. Note F-10/69 April 1969 (U) Terminal Guidance for a Long Range Projectile - A Computer Simulation, K. L. McCloud and R. T. Ramsey (Confidential)

NWL Tech. Report TR-2425 June 1970 (U) Acquisition Ranges for a Laser Semi-Active Guidance System, T. S. Hahn (Confidential)

NWL Tech. Note (Being published) June 1970 (U) RF Seeker Design, R. O. Gilmore (Confidential)

NWL Tech. Note TN-F-41/70 February 1970 (U) Estimation of Miss Distance for Body Fixed Seekers Against Surface Targets, W. R. Chadwick, R. T. Ramsey, J. H. Spencer (Unclassified)

32. (U) MAJOR PROCUREMENTS AND CONTRACTS:

FY 72 Procure industry fabricated RF seeker for gun launch
FY 73 Procure industry fabricated RF seeker for gun launch

33. (U) SPECIAL REQUIREMENTS: None

CLASSIFICATION CONFIDENTIAL

DD FORM 1498

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DN035503	1 Feb 71	

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8. DISB'N INSTR'N	9. SPECIFIC DATA-CONTRACTOR ACCESS	LEVEL OF SUM
29 Dec 69	D. Change	C	S	3	NA	☐ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	64605N	08B116/090-1	U1210	NWL G-19801,02;27901-02;28001-5
b. CONTRIBUT.			UF17313209	[redacted]
c. CONTRIBUT.				

11. TITLE (Precede with Security Classification Code)*

(U) Long Range Gun System Research Development

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 001600 Ammunition, explosives and pyrotechnics; 019900 Guidance and navigation; 01980 Control design

13. START DATE	14. EST. COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
May 1968	Cont.		C. In-house

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUMULATIVE:

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 70	0.0	3398.8
	CURRENT 71	7.0	700.0

19. RESPONSIBLE DOD ORGANIZATION

NAME:* Naval Ordnance Systems Command

ADDRESS:* Washington, D. C. 20360

RESPONSIBLE INDIVIDUAL

NAME: Kitterman, W.P. LCOL (Code: 08B)

TELEPHONE: 202-OX-6-5513

20. PERFORMING ORGANIZATION

NAME:* NAVAL WEAPONS LABORATORY

ADDRESS:* DAHLGREN, VIRGINIA 22448

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Inst.)

NAME:* L. A. Clayberg (Code: GL)

TELEPHONE: 703-663-8831

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS:

NAME:

NAME:

21. GENERAL USE

NA

22. KEYWORDS (Precede EACH with Security CLASSIFICATION Code)

(U) CONTROL DESIGN, (U) GUIDANCE

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (C) OBJECTIVE. To provide a lightweight gun system to the fleet which will have the capability of: (1) Shore bombardment for area neutralization out to approximately 25 nautical miles; (2) Landing force fire support out to approximately 50 nautical miles; (3) Long Range ship-to-shore weapon support to the landing force out to ranges of approximately 100 miles. Accuracy at these ranges will be provided through the use of terminal guidance in conjunction with the inherent gun launch accuracies.

24. (C) APPROACH. Define the specific performance and physical characteristics of the system and subsystems to provide a cost-effective weapon for fleet use. Because of the high risk associated with guided, gun-launched projectiles, first establish requirements for and conduct Advanced Development to prove technical feasibility and military usefulness of guided projectiles.

25. (C) PROGRESS. Project studies and system definition were initiated in October 1968. The Concept Formulation Plan was published in April 1969. The TSOR and answering PTA have been compared and submitted in draft form. Preliminary to the Advanced Development of a guided projectile all the components and subassemblies of a semi-active laser guidance system have been hardened to withstand gun launch and tested satisfactorily at 8000 g's. Shroud, tail fins, and complete guidance and control assemblies have been successfully gun launched and qualified at 4000g's. A complete assembly was dropped from an aircraft on 21 January 1971 to determine aerodynamic characteristics. The projectile acquired the target and corrected its flight path by 2000 feet in range, by 700 feet in cross range to achieve an actual miss distance of 36 feet short, 4 feet right. The next gun fired functional guided projectile is scheduled for firing during the month of February.

*AVAILABLE TO CONTRACTOR'S UPON ORIGINATOR'S APPROVAL.

WORK UNIT NO.	NAVY WORK UNIT
19801,02;27901,02; 28001-5	CONTINUATION SHEET DATA FORM
26. PRIOR IDENT: NA	27. TECH AGENT: NA

28. MANPOWER AND COST ESTIMATES	CFY-1 19 70	CFY 19 71	CFY+1 19 72	CFY+2 19 73
a. PROFESSIONAL MAN-YEARS	0.0	7.0	15.0	14.0
b. TOTAL DIRECT LABOR MAN-YEARS	64.7	20.0	100.0	150.0
c. TOTAL LABOR AND OVERHEAD ($K)	1530.4	400.0	2000.0	3000.0
d. MATERIALS AND TRAVEL ($K)	184.3	150.0	200.0	300.0
e. MAJOR PROC/CONTRACTS ($K)	1684.1	150.0	1800.0	4700.0
f. PLANNING ESTIMATE ($K)		700.0	4000.0	8000.0
g. FUNDS AVAILABLE ($K)	3398.8	551.0	0.0	0.0
h.				
h.				

29. BACKGROUND, 30. PLANS AND MILESTONES, 31. REFERENCES, 32. MAJOR PROCUREMENTS AND CONTRACTS, 33. SPECIAL REQUIREMENTS *(Furnish individual paragraphs identified by number. Precede each with Security Classification Code).*

29. (U) BACKGROUND. The need for a long range shore and inland bombardment capability has been emphasized by the limited conflict situations in the Near and Far East. This system will provide support for amphibious assaults, vertical assaults, independent shore bombardment, interdiction of supply and communication lines, and anti-ship capability at ranges far in excess of any gun system in existence.

30. (U) PLANS AND MILESTONES

(1) Complete guided projectile feasibility demonstration in 8" size - July 1971
(2) Develop recovery system to cover complete rocket motors subsequent to gun launch - March 1971
(3) Begin gun launch tests of rocket motors. Static fire motors subsequent to gun launching to evaluate motor survivability - July 1971
(4) Initiate feasibility of RF and IR passive seeker systems for guided projectiles - July 1971
(5) Complete guided projectile advanced development - July 1973
(6) Complete gun system advanced development - July 1975

#L. (U) REFERENCES.

(a) Concept Formulation Plan, "Long Range Gun System (U)", April 1969, GOR-12, GOR-14
(b) NAVORD ltr GW:BLM:reb dtd 11 Jun 1970 to Distribution, Subj: "Semi-Active Laser Guided Projectile; Security guidelines for"

32. (U) MAJOR PROCUREMENTS AND CONTRACTS.

ITEM	$K SERVICES	CONTRACTOR	FY	ESTIMATED DELIVERY DATE
Guidance and control subassemblies for feasibility program - N00178-70-C-0182	150.0	Texas Instruments	71	July 1971
Guided projectile advanced development designs and hardware	180.0	Unknown	72	July 1973
Gun system advanced development	4700.0	Unknown	73	July 1975

33. (U) SPECIAL REQUIREMENTS. None

APPENDIX B

DESCRIPTION OF GUIDANCE AND CONTROL SUBASSEMBLIES (U)

DESCRIPTION OF GUIDANCE AND CONTROL SUBASSEMBLIES

INTRODUCTION

(C) This appendix covers the theory of operation of the laser Guidance and Control System for the guided projectile demonstration programs. The discussion includes a functional description of the system and block diagrams of the guidance and gas-operated control sections. Figure 8 shows an inboard profile of the guided projectile.

THEORY OF OPERATION

(C) The guidance and control system steers the projectile toward a target which has been illuminated by the laser energy. A laser beam from an airborne or a ground observed designates the desired target. After reflection from the target, the energy of the laser beam appears to be radiating fróm a point source. The laser semi-active guidance system is designed to detect such a target illuminated by 1.06 micron energy. The system contains electronic circuitry to derive appropriate commands from the quadrant detector, amplify these signals to levels suitable for further processing, and apply these commands to movable surfaces to affect changes in source. In addition, the control logic includes an interpulse blanking circuit to reduce the susceptibility of the system to jamming by an enemy illuminator and a signal dropout detector which allows the control surfaces to move into a neutral "trail" position prior to acquisition, during signal loss after initial signal acquisition, and while tracking on boresight. The system, Figure 9, may be divided into the following main components: the LASER illumination detector (Unit 1), the guidance computer (Unit 2) and the guided projectile control unit (Unit 3).

LASER ILLUMINATION DETECTOR (UNIT 1)

(C) The detector is contained in a cylindrical housing, gimbal-mounted by means of a ball joint assembly to a support boom. The detector is maintained in alignment with the projectile velocity vector by a ring-tail stabilizer. The detector consists of an IR dome; an optical bandpass filter; a lens; a quadrant detector; and electronics containing detector bias network, signal mixer and preamplifiers. The

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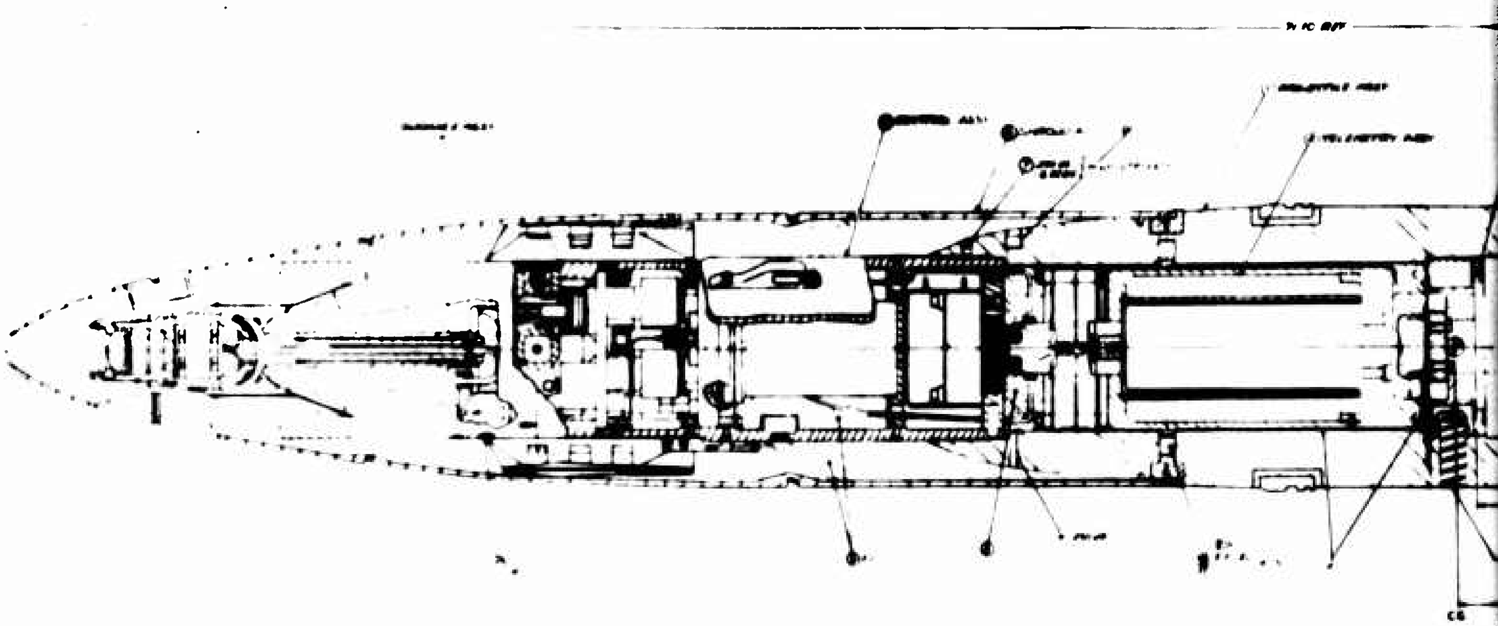
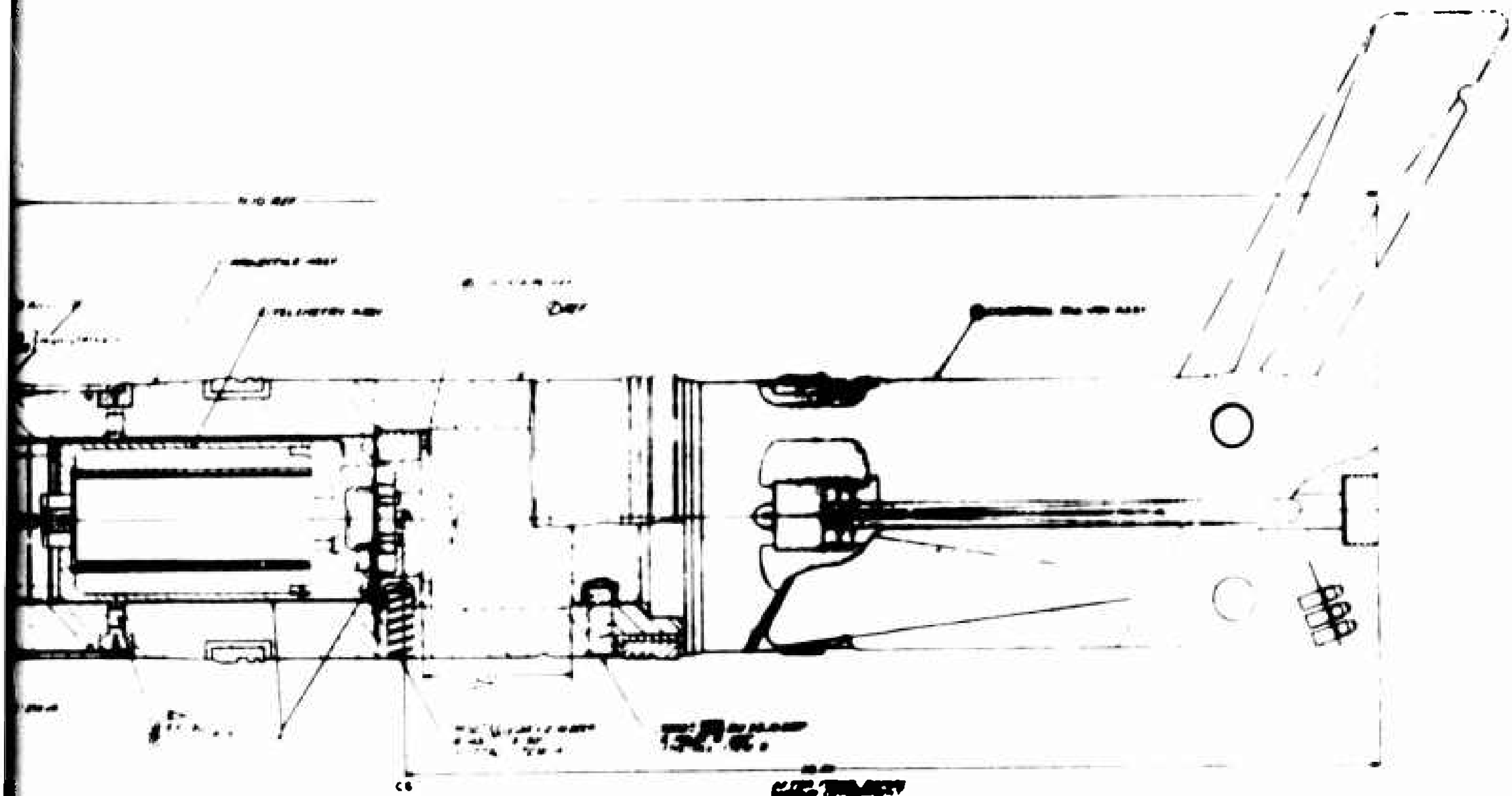


FIGURE 8 - GUIDANCE AND CONTROL INBOARD PROFILE (U)

1



CONTROL INBOARD PROFILE (U)

2

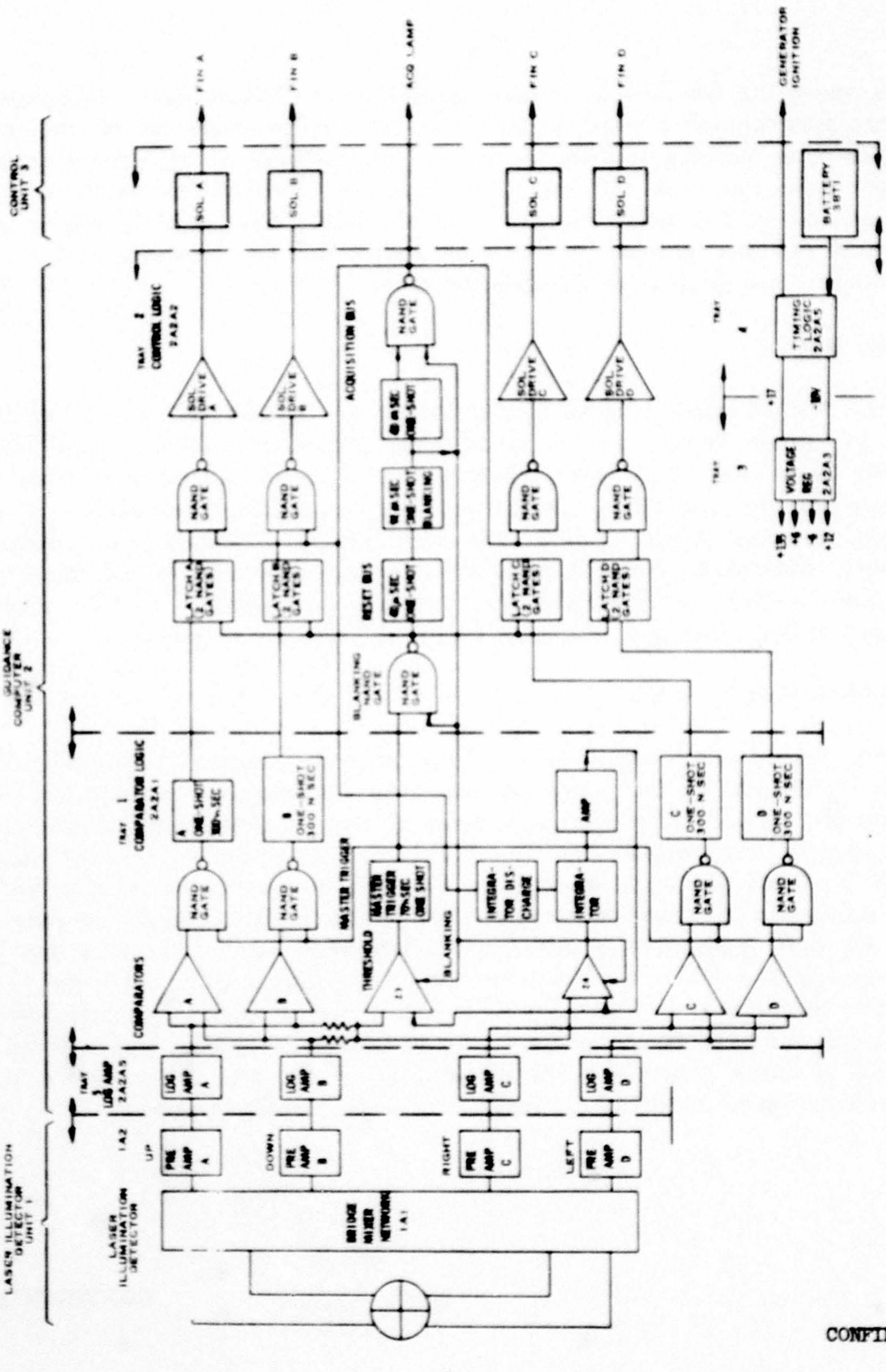


Figure 9 - Projectile Guidance System Block Diagram (U)

four-quadrant infrared detector receives LASER energy which has a wavelength in the near-infrared spectrum and is not visible. This energy passes through the optical bandpass filter lens and falls on one of the four quadrants of the infrared detector. Energy failing on one of the four quadrants generates an electrical signal corresponding to that sector. In some cases, the energy may appear on one or more quadrants and thus generate two or more signals simultaneously due to the finite size of the circle of focus on the detector surface.

IR Dome

(C) The IR dome is epoxy-bonded to the lens retainer and as such serves as both an optical window and an aerodynamic surface. The curved frontal surface provides lower drag and better stability. The IR dome is fabricated from fine annealed infrared transmitting glass. This glass has excellent transmission at 1.06 microns, uniform optical quality and high thermal, chemical and mechanical durability. Both sides of the IR dome are anti-reflectance coated in accordance with procedures outlines in JAN-F675 for maximum transmittance at 1.06 microns. Measured transmittance after coating is slightly in excess of 98 percent.

Optical Bandpass Filter

(C) The optical bandpass filter is used to restrict incident illumination to a narrow bandwidth in the region of the laser illumination wavelength. A basic characteristic of such multilayer interference filters is a shift in the wavelength of peak response with increasing angle of incidence. Since the direction of shift is uniformly toward shorter wavelengths, it is possible to compensate partially for the shift and increase the transmission at the field-of-view angular limits by designing the filter for peak response at a wavelength slightly above that of the laser line. The shift characteristic also dictates that the filter be placed as close as possilbe to the IR dome (rather than the detector) for optimum optical efficiency; if placed at the focal plane, the filter would cause excessive attenuation of incident rays refracted by the lens at angles greater than 15 degrees. Optical bandpass filters used in flight hardware have peak transmittances typically between 71 and 75 percent.

Focusing Lens

(C) Determination of the lens diameter to be used in the system involved a compromise between maximizing the detector acquisition range and minimizing the overall size of the LASER illumination detector in order to maintain aerodynamic stability. Calculations indicated that an f/1 optical system with a 1-inch aperture would allow the laser illumination detector dimensions to remain within suitable bounds and would provide adequate acquisition range for guidance. Bausch and Lomb Lens No. 35-58-90-029 provides computed overall optical speed of f/1.09 with a flat optical window and f/1.19 with the IR dome described above. The Bausch and Lomb Lens No. 31-58-90-029, with the IR dome, has blue circle diameters (3σ values of 0.032 inch and 0.058 inch on axis and at 12 degrees off axis, respectively). The effective aperture of the lens is 1.08 inches. The design value of the optical field of view is 12 degrees, conic half-angle. Both surfaces of the lens are anti-reflectance coated per JAN-F675 to achieve transmittances at 1.06 microns of approximately 96 percent.

Quadrant Detector

(C) This detector has an active area which measures 0 inch in diameter. Ideally, the detectors should have their peak spectral response at the illuminator line wavelength, 1.06 microns and should have quantum efficiencies as high as possible. To respond properly to the very short pulse, the detector should have a capacitance in the order of 10 picofarads per quadrant; this requirement is based on the assumption that shot noise and thermal noise are equal under worst case (100 percent reflectance) background environments. In addition, the leakage (dark) current of the detector should be less than two microamperes per quadrant to avoid contributions to the overall nose level from this source. These detectors are multidiffused junction detectors fabricated from high-resistivity silicon wafers. These devices have quantum efficiencies in the order of 45 percent at 1.06 microns and a design maximum capacitance of 13.4 picofarads per quadrant at 130-volt dc bias. Detectors supplied have typically measured 10 to 20 picofarads per quadrant. Achievement of extremely low leakage currents is primarily due to the use of a guard ring diffused around the quadrant area; this permits leakage currents around the edges of the detector waver to return to the bias supply through a separate circuit isolated from the signal circuits. The detector-optics assembly is hermetically sealed to prevent moisture condensation on the detector.

Electronics

(C) The quadrants of the detector are applied to the bridge-mixer network circuitry. The primary function of the preamplifiers is to amplify the low-level signals from the mixer network and to provide impedance matching for driving the coax cables which apply the signals to the guidance computer. Both the mixer network and preamplifier circuitry are contained in an enclosure immediately behind the detector bulkhead to minimize lead capacitance and reduce the potential for extraneous noise pickup. It is important to note that an input to the detector, striking only on one quadrant, will generate pitch and yaw commands at the output of the mixer network and preamplifiers.

GUIDANCE COMPUTER (UNIT 2)

(C) The guidance computer receives signals from the laser illumination detector through a cable, and processes these signals to provide control commands to operate the control fins. The guidance computer contains the following: log amplifier, comparator logic, control logic, voltage regulator and timing logic. The following subparagraphs consider each individually in the order of signal flow.

Log Amplifier

(C) The log amplifier receives signals from the laser illumination detector preamplifiers IA2. Since the received signal amplitude increased as the square of reciprocal range, it is apparent that linear signal processing techniques are not applicable to a system such as the laser guided projectile. Acquisition is desired at slant ranges up to 15,000 feet, and the log amplifier video processing circuits must operate without saturation until the projectile is closer than the slant range at which improper maneuver can no longer have a significant effect on the impact point; if the latter range is taken as 100 feet (a fairly conservative change in the impact point), the required dynamic range of logarithmic video amplification is approximately 85 db. The log amplifiers have the function of compressing the dynamic range of the output signals. They do this by amplifying relatively weak signals and attenuating strong ones in proportion to the strength of the signals. Thus, input signals having a range of 110 db (equivalent to a voltage range of 350,000 to 1) are compressed into a voltage range of 0.2 volts to 3.0 volts (a voltage range of 15 to 1). This operation makes it possible to detect both weak and very strong signals in the same system without the problem of overloading in the case of large signals or noise masking weak ones.

Comparator Logic

(C) The comparator logic of the guidance computer contains the comparator portion of the error processing circuitry. The comparators have the function of comparing pairs of outs from the log amplifiers (left-hand and up-down) and making decisions as to the direction for correction. The gates block the outputs of the comparators until the incoming signal reaches a sufficient level to overcome the master trigger threshold. The master trigger threshold consists of a fixed and a variable (tracking) threshold. No steering decisions can be made until the master trigger one shot multivibrator is fired. This prevents noise (false alarms) from entering the guidance channels. Additionally, the signal that fires the master trigger 70-nanosecond one-show multivibrator is fed to an integrator through comparator Z4 where the video signal is peak detected. This produces a dc bias level which is used as a variable threshold setting. The level of this variable threshold signal is such that it will follow 10 db below the peak signal level so that signals below this level will not trigger the master trigger one-shot multivibration. In the event that the received signal is lost, the acquisition signal will discharge the integrator so that the threshold setting will return to maximum sensitivity setting. Briefly, then, the sequence is as follows: as signals are received, the summed output of log amplifiers A and B will first exceed the fixed threshold established by comparator Z3, firing the master trigger 70-nanosecond one-shot multivibrator. As signal intensity increases beyond the preset tracking offset, the comparator Z4, driving the integrator produces a pulse output. This pulse charges a capacitor in the integrator which holds the dc bias level between pulses. The output after amplification is fed back to Z4 closing the loop. Thus, the circuit functions as a peak detector which charges the integrator whenever a pulse input exceeds the sum of the tracking offset bias plus the feedback voltage on Z4. The feedback voltage is also applied to comparator Z3 so that the input signal must have an amplitude to overcome the variable threshold and the fixed threshold in order to initiate the master trigger. During the interval of the pulse period, the 94-millisecond one shot blanking gate disables comparators Z3 and Z4, thereby preventing extraneous noise pulses from influencing the guidance channels. After the NAND gates, the 300-nanosecond one-shot multivibrators convert the analog information of the comparators to digital form by standardizing the pulse length and height. The master trigger one-shot multivibrator determines the minimum length of time that the gates will be open. Note, finally, that the up-down section and the right-left section of the comparator tray are identical.

Control Logic

(C) The control logic contains circuitry for converting the error commands from the comparator logic to solenoid drive signals. It performs "last pulse" logic functions, interpulse blanking and signal dropout commands for resetting the fins to a trail position. Five signal lines leave the comparator logic tray and pass to the control logic tray. These signals are up, down, rifht, left and threshold. The sequence of operations in the control logic are as follows. First, the output of the 94-millisecond one-shot multivibrator blanking gate must be high (i.e., logic "1"). This condition occurs approximately 94 milliseconds after the receipt of the previous trigger pulse. The onset of a new cycle is triggered when the threshold one-shot multivibrator in the comparator is activated. The output is a positive-going pulse driving the blanking NAND gate. The combination of a "1" from the 94-millisecond one-shot multivibrator blanking and the positive output from the master trigger 70-nanosecond one-shot multivibrator generates a negative "0" serving as a reset to the latches and activating the 40-microsecond one-shot multivibrator. By resetting all latches, they are armed to receive new input information. Two of the latches, latch A or B and latch C or D, will be activated by input signals from the comparator one-shot multivibrator. If the activation is caused by a spurious reflection and a later one occurs, the earlier latch condition will be canceled when the threshold pulse resets, and the second (or third, etc.) will be registered in the latch. At the end of the 40-microsecond timing pulse, a 94-millisecond one-shot blanking is initiated which holds the blanking gate low (i.e., logic "0"), thus inhibiting any further threshold triggers from entering to reset the latches. The latches, thus, retain the last condition fed into them before the onset of the blanking impulse. This condition is fed through the following gates, inverters and solenoid drivers to actuate the proper solenoid valves causing the fins to move and thus steer the projectile. The last circuit in the control logic tray is the 40-millisecond one-shot and gate which serves to place the steering commands in a trail position if, in any cycle, no input is strong enough to exceed the threshold; i.e., the guidance signal is lost.

Voltage Regulators

(C) The system voltage regulators regulate the thermal battery voltages of +28, +17 and −10 volts to the system requirements of ±6 volts and +12 volts. These circuits are straightforward series regulators with ripple reduction factors in excess of 65 db. The voltage regulator also contains a dc-to-dc converter for converting +12 volts to +135 volts for detector bias.

Timing Logic

(C) The timing logic board contains devices which, upon activation of the thermal battery, initiates a timing sequence for deploying the shroud and firing the gas generator. Voltage from the thermal battery is applied through a pair of normally closed contacts in a squib relay to the activating coil of the squib relay. The relay fires and guillotines the wire wraps which hold the shroud halves together. After a 0.1 second delay, the guillotines are disconnected from the firing circuit and the battery voltage is applied to the gas generator and the shaped charge; but, since the gas generator has a possibility of shorting out the power supply, a disconnecting switch is set to interrupt the gas generator firing current 8.5 seconds after power is applied. The thermal battery is initiated by a master timer, which is activated by firing setback forces. Figure 10 shows the circuitry for the shroud deployment system.

(C) The following is a listing of the sequence of events that occurred during demonstration gun launches with approximate times.

Time	Event
0	Close of firing key
5 milliseconds	Thermal battery activated and timing sequence initiated
50 milliseconds	Guided projectile muzzle exit and fins deploy
0.5 seconds	Battery delivers full output to telemetry and timer
26 seconds	Twenty-six second timer delay activated and explosive switch connects battery to guillotines

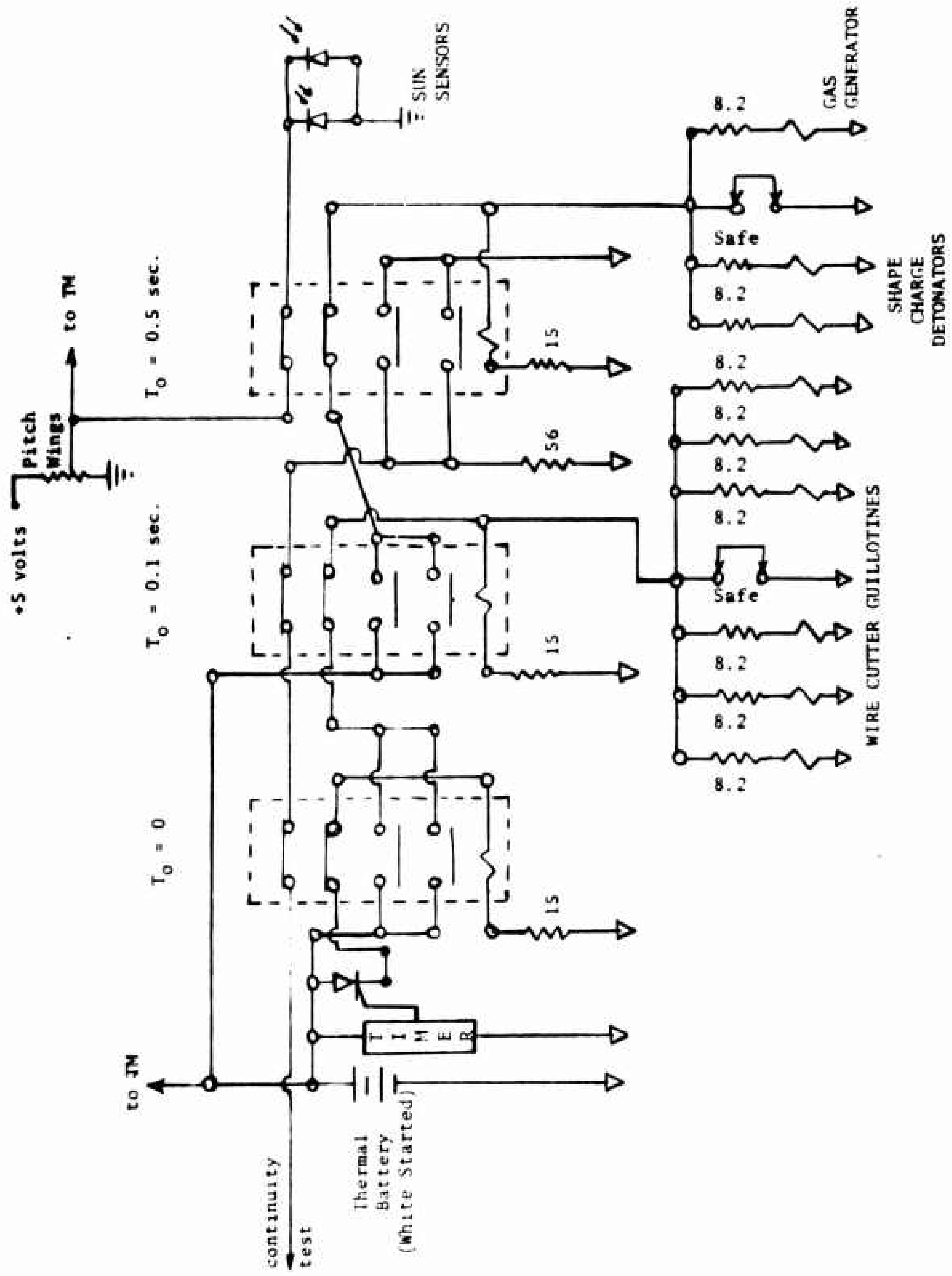


FIGURE 10 SHROUD DEPLOYMENT CIRCUITRY

Time	Event
26.1 seconds	Disconnect guillotine circuit and connect shaped charge and gas generators
26.6 seconds	Disconnect shaped charge and gas generator
29 seconds	Begin guidance
44.6 seconds	Impact

GUIDED PROJECTILE CONTROL UNIT (UNIT 3)

(C) The guided projectile control contains the solenoid valves (four), thermal battery, hot gas generator and four movable fins. It guides the projectile during controlled flight by moving the fins in accordance with the command signals received from the guidance computer. Each pair of fins, sharing a common shaft, is driven in a bang-bang manner to its 10.0 degree stops in one direction or the other. In the absence of command signals to both solenoid valves controlling a given fin shaft, neither piston is operated, and that fin axis is held in a trail position by the airstream and centering springs.

APPENDIX C

SUMMARY OF TESTS CONDUCTED TO 1 JANUARY 1971

8" GUIDED PROJECTILE PROGRAM TESTS

1969	Test No.	
3 Apr	F-1	Seeker Components (6.25)
30 Apr	F-2	Seeker Components
23 May	F-3	Seeker Components
23 May	F-4	Accelerometer
4 Jun	F-5	Seeker Components
12 Jun	F-6	Seeker Components
13 Jun	F-7	Seeker Optics & Electronics
13 Jun	F-8	Gas Generator and Igniter and Parachute Retard System
27 Jun	F-9	Parachute Recovery System and Preamplifier
27 Jun	F-10	Parachute Retard System
27 Jun	F-11	Thermal battery and optical filter
27 Jun	F-12	Control Actuator
7 Jul	F-13	Gas Generator and Igniter
8 July	F-14	Canards and Shaft
21 Jul	F-15	Seeker Subassembly and Parachute Retard System
21 Jul	F-16/17	Control Actuator Assembly (2 tests)
21 Jul	F-18	Gas Generator and Igniter
21 Jul	F-19	Gas Generator and Experimental Igniter
21 Jul	F-20	Slipping Obturator
7 Aug	F-21	Parachute Retard System
7 Aug	F-22	Parachute Retard System and canards with shaft

8" GUIDED PROJECTILE PROGRAM TESTS

1969	Test No.	
7 Aug	F-23	Parachute Retard System
7 Aug	F-24	Parachute Retard System, Seeker Optics and Electronic Subassembly
7 Aug	F-25	Wound Fiberglass Canister
7 Aug	F-26	Actuator Assembly
13 & 15 Aug		0.6 Scale Wind Tunnel Test
19 Aug	F-27	Slipping Obturator
20 Aug	F-28	Parachute Retard System, Seeker Optics Electronics Subassembly and master timer
2 Sep	F-29	Actuator Assembly
4 Sep	F-30	Hollow Boattail and Fins
16 Sep	F-31	Slipping Obturator
19 Sep	F-32	Electronics package
19 Sep	F-33	Electronics and sun sensor

8" GUIDED PROJECTILE PROGRAM TESTS

1969	Test No.	
23 Sep	1	Shroud and solid afterbody
30 Sep	2	Hollow Afterbody and fins
30 Sep	3	Solid afterbody and fins
1 Oct	4	Fiberglass Shroud
1 Oct	5	Fiberglass Shroud
7 Oct	6	Wiring harness, thermal switch
9 Oct	7	Fins with damping device
9 Oct	8	Fiberglass Shroud
16 Oct	9	TM system
17 Oct	10	Fiberglass Shroud
17 Oct	11	Cylindrical tail and fins
23 Oct	12	Cylindrical tail and fins
23 Oct	13	Fiberglass Shroud
23 Oct	14	Obturating bands
23 Oct	15	Balloon recovery system
2 Nov	F-34	Shrike radome, antenna and PC boards
7 Nov	16	Balloon recovery system
7 Nov	17	Shroud (1 pc.) with cylindrical tail and fins
21 Nov	18	TM antenna and connectors
21 Nov	19	TM system
24 Nov	20	Balloon recovery system and thermal battery

8" GUIDED PROJECTILE PROGRAM TESTS

1969	Test No.	
5 Dec	21	TM antenna and thermal battery
5 Dec	22	Control housing wiring
5 Dec	23	Fiberglass shroud
12 Dec	24	G&C system less electronics
12 Dec	25	Recovery system (float)
19 Dec	26	48" Canister with dummy G&C
19 Dec	27	TM antenna and sun sensor
29 Dec	28	48" Canister - dummy weight
1970		
5 Jan	T-1	30" solid shroud
	T-2	48" Canister with floats
	T-3	Shroud
7 Jan	T-4	Computer Electronics
12 Jan	T-5	TM and timer
28 Jan	T-8	Soft recovery system
6 Feb	T-14	Soft recovery system
6 Feb	F-35	Anti-radiation electronics
13 Feb	L-4	Liquid support and fins
16 Feb	T-16	Soft recovery system
20 Feb	T-17	Soft recovery system
5 Mar	T-18	Soft recovery system, setback switchtransistor, connector and antenna
6 Mar	F-36	Amplifier boards, crystals and motor armature

8" GUIDED PROJECTILE PROGRAM TESTS

1970	Test No.	
6 Mar	F-37	Float system with explosive bolt
6 Mar	F-38	Retard plate with nylon shroud lines
17 Mar	T-19	Shroud
17 Mar	T-20	Soft recovery system
25 Mar	T-23	Soft recovery system (2 tests)
31 Mar	G1-1	Ribbon stabilizer
31 Mar	T-24	Shroud
31 Mar	TF-1	Trailing fin projectile
8 Apr	F-39	Thermal battery
8 Apr	F-40	Setback switch, viscous gyro, photo cell and generator
9 Apr	G1-2	Ribbon stabilizer
9 Apr	T-25/1	Soft recovery system
16 Apr	G1-3	Shroud
16 Apr	T-25/2	Soft recovery system
16 Apr	T-26	TM system
20 Apr	G1-4	Ribbon stabilizer
20 Apr	T-27	Soft recovery system
20 Apr	F-41	Vickers Particle clutch
30 Apr	T-21	Soft recovery and dummy G&C
1 May	T-22	G&C #1 recovery
21 May	F-42	Vickers Particle clutch

8" GUIDED PROJECTILE PROGRAM TESTS

1970	Test No.	
28 May	F-43	Accelerometer and solenoid valve
26 Jun	T-26A	TM crystals and solenoid valve
1 Jul	G1-5	Shroud
6 Jul	T-28	Ballistic #1
13 Jul	T-29	Shroud structural
18 Jul	T-30	G&C #2 recovery
16 Jul	T-31	Detonators, TM crystals and thermal battery
31 Jul	T-32	TM system
31 Jul	G1-6	Aluminum Shroud
7 Aug	T-33	Shroud deployment
18 Aug	G-7	Canister recovery system
20 Aug	TF-2	Fins with discarding cover
20 Aug	LPC-2	Liquid support and fins
21 Aug	G-8	Canister recovery system
25 Aug	T-34	Shroud Wind Tunnel Deployment
31 Aug	G-9	Dummy G&C
2 Sep	G-10	Structural G&C
2 Sep	T-36	Canister recovery system
11 Sep	T-38	Canister recovery system
16 Sep	G-11	G&C recovery system
16 Sep	G-12	Structural G&C
16 Sep	T-37	Dummy TM

8" GUIDED PROJECTILE PROGRAM TESTS

1970	Test No.	
18 Sep	G-13	G&C #3 recovery
18 Sep	T-39	Dummy TM
22 Sep	T-40	TM system
23 Sep	NA	Captive flights
29 Sep	T-41	TM system
6 Oct	NA	Ballistic Projectile
8 Oct	NA	G&C #1 Projectile
25 Oct	T-42	Tracking Flare
26 Oct	T-43	TM system
2 Nov	NA	Ballistic Projectile
6 Nov	NA	G&C #2 Projectile
19 Nov	T-45	TM
19 Nov	T-46	Gas Generator
3 Dec	NA	G&C #3 Projectile
14 & 15 Dec		Full Scale Wind Tunnel Test
16 Dec	T-47	Gas Generator Ignitors
16 Dec	T-48	After End Parachute Recovery System, Ultrasonic pingers, and Single Slipping Obturators
22 Dec	T-49	TM
1971		
21 Jan		G&C #4 Air Drop

CANISTER RECOVERY SYSTEM TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL.(g's)	REMARKS
6/13/69	F-7	Parachute Retarding System	9.12	6899	Failed
6/27/69	F-9	Parachute Retarding System	9.12	7342	Parachute deployed and survived
6/27/69	F-10	Aluminum canister with parachute	9.12	6987	Failed
7/21/69	F-15	Parachute Retarding System	9.12	7165	Parachute streamed; lost in river
8/7/69	F-21	Parachute Retarding System	9.12	7342	Failed
8/7/69	F-22	Parachute Retarding System	9.12	7076	Failed
8/7/69	F-23	Parachute Retarding System	9.12	7076	Failed
8/7/69	F-24	Parachute Retarding System	9.12	7342	Failed
8/7/69	F-25	Wound Fiberglass Canister	9.12	6457	Recovered two weeks later; ends damaged
8/20/69	F-28	Parachute Retarding System	9.12	6899	Parachute successful, retarded canister
10/23/69	15	30" canister; six balloons	9.12	6697	One inflated, three deployed
11/7/69	16	30" canister; six balloons	8.0	5524	Wires broke, balloons ripped off
11/24/69	20	30" canister; six balloons	8.0	5815	Retaining nut broke releasing balloons and breaking wires.
12/5/69	22	48" Canister with G&C housing	8.0	3236	Survived
12/12/69	24	48" Canister with G&C	8.0	5519	Recovered 9/9/70
12/12/69	25	48" Canister with float system	8.0	5367	Failed in barrel
12/19/69	26	48" Canister with dummy G&C	8.0	8922	Not recovered
12/29/69	28	48" Canister with dummy G&C	8.0	8162	Recovered intact

CANISTER RECOVERY SYSTEM TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL.(g's)	REMARKS
1/5/70	T-2	48" Canister, floats on front and rear	8.0	8850	Not recovered
1/28/70	T-8	30" Canister, float and parachute	8.0	7985	5" Can broke weld at bore rider
2/6/70	T-14	30" Canister, float and parachute	8.0	7426	Failed in barrel
2/16/70	T-16	30" Canister, float and parachute	8.0	8144	Top can crushed; chute line broke
2/20/70	T-17	30" Canister, float and parachute	8.0	8120	Top release broke
3/5/70	T-18	30" Canister, float and parachute	8.0	8403	Survived; 5" can slightly crushed
3/6/70	F-37	Float, explosive bolt & firing circuit	9.12	7253	Float failed; other components survived
3/6/70	F-38	Retarding plate, nylon ribbon shrouds	9.12	7253	Failed in barrel
3/17/80	T-20	30" Canister; float and parachute	8.0	7980	Float line broke; chute not deployed
3/25/70	T-23AM	30" Canister; float and parachute	8.0	8002	Top did not release
3/25/70	T-23PM	30" Canister; float and parachute	8.0	7849	Cable cutter did not function
3/31/70	GI-1	30" Canister; ribbon stabilizer	8.0	8530	Ribbon torn up in flight
4/9/70	T-25/1	30" Canister; float and parachute with two cutters, one delayed	8.0	7976	Delayed cutter - good primer indentation Non-delayed cutter - poor primer indentation
4/9/70	GI-2	30" Canister; ribbon stabilizer	8.0	8163	Ribbon cut on setback
4/16/70	T-25/2	30" Canister; float and parachute with two cutters, one delayed	8.0	7947	Successful
4/20/70	T-27	30" Canister; float and parachute with two cutters, one delayed	8.0	8348	Successful deployment
4/20/70	GI-4	30" Canister; ribbon stabilizer	8.0	8458	Ribbon torn off in flight

CANISTER RECOVERY SYSTEM TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL.(g's)	REMARKS
4/30/70	T-21	48" Canister; dummy G&C float and parachute	8.0	8212	Successful deployment
5/1/70	T-22	48" Canister; G&C float and parachute	8.0	8821	Not recovered
7/16/70	T-30	48" Canister; F&C float and parachute	8.0	8655	Not recovered
8/18/70	G-7	30" Canister-Scheibe float system	8.0	8400	Float failed
8/21/70	G-8	30" Canister-Scheibe float system	8.0	8607	Successful
8/31/70	G-9	30" Canister-Scheibe float system	8.0	8106	Canister lost; front bore rider and attached float recovered
9/2/70	T-36	30" Canister-Thorsted system	8.0	8135	Failed
9/11/70	T-38	30" Canister-Thorsted system	8.0	7415	Failed
9/16/70	T-37	41" Canister-Thorsted system	8.0	7707	Failed
9/16/70	G-11	30" Canister; Scheibe system	8.0	4646	Successful
9/16/70	G-12	30" Canister; Scheibe system	8.0	5016	Successful
12/16/70	T-48	After-End Parachute System	8.0	7132	Failed
12/16/70	T-48	Three Ultrasonic Pingers	8.0	7132	Two survived oriented longitudinally facing forward. One failed oriented longitudinally facing rearward.
12/22/70	T-49	30" Canister; Scheibe system	8.0	3926	Successful

3

AFTERBODY AND FIN TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL.(g's)	REMARKS
9/4/69	F-30	Aluminum hollow boattail; 0.4" fins	8.0	5934	Failed in barrel
9/23/69	1	Solid aluminum boattail, no fins	8.0	6042	Broke in recovery
9/30/69	2	Aluminum hollow boattail; 0.4" fins	8.0	5774	Failed in barrel
9/30/69	3	Aluminum solid boattail; 0.4" fins	8.0	6270	Two fins survived
10/9/69	7	Solid boattail; damper on fins	8.0	6416	No fins deployed
10/17/69	11	Cylindrical tail; 0.4" fins	8.0	6675	Three fins deployed
10/23/69	12	Cylindrical tail; 0.7" fins with latches	8.0	7260	Four fins deployed; roll 12.5-13 rps
11/7/69	17	Cylindrical tail; 0.7" titan. fins	8.0	4717	Four fins deployed; 9000 yd. range
2/13/70	L-4	Finned Liquid Support System	8.0	--	Failed
3/31/70	TF-1	Finned projectile, discarding cover	8.0	4388	Failed
7/6/70	T-28	Ballistic #1, solid shroud & fins	8.0	2649	13 Kyds; good flight
8/20/70	TF-2	Finned projectile, discarding cover	8.0	--	Failed
8/20/70	LPC-2	Finned Liquid Support System	8.0	5934	Failed
11/2/70	NA	Cylindrical Afterbody with Fins, No Grease	8.0		Successful

SLIPPING OBTURATING BAND TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL. (g's)	REMARKS
7/21/69	F-20	Bands on MK 25 body	8.0	4481	Roll data not sufficient
8/19/69	F-27	Bands on MK 25 body	8.0	5227	Roll rate 12.4 rps
9/16/69	F-31	Bands on MK 25 body	8.0	4891	Roll rate 18 rps
10/23/69	14	Bands on MK 25 body	8.0	8263	Roll rate 12.5 rps
1/26/70	L-1	Bands on MK 25 body	8.0	--	Roll rate 10.6 ± .3 rps
1/26/70	L-2	Bands on MK 25 body	8.0	--	Roll rate 12.1 ± .4 rps
2/13/70	L-3	Bands on MK 25 body	8.0	--	Roll rate 10.7 ± .2 rps
4/16/70	GI-3	Bands and shroud	8.0	7618	Roll rate 9.12 rps
7/1/70	GI-5	Bands and shroud	8.0	7731	Roll rate 12.99 ± 1.93 rps
7/31/70	GI-6	Bands and shroud	8.0	8114	Data not reducible
8/7/70	T-33	Bands and shroud	8.0	3934	Data not reducible
12/16/70	T-48	Rear Obturator Band on Pusher with 30" Canister	8.0	7132	Appeared to be successful in prevention of gas leakage. Roll rate data not obtained.

SHROUD TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL. (g's)	REMARKS
9/23/69	1	2 Pc. fiberglass, shell 828 epoxy	8.0	6042	Failed in barrel
10/1/69	4	2 Pc. fiberglass, shell 815 epoxy	9.12	6745	Failed in barrel
10/1/69	5	2 Pc. fiberglass, shell 828 epoxy	9.12	6793	Survived and recovered
10/9/69	8	2 Pc. fiberglass, shell 828 epoxy partial foam fill	8.0	5367	Failed
10/17/69	10	2 Pc. fiberglass, shell 828 epoxy foam filled	8.0	4968	Failed
10/23/69	13	2 Pc. fiberglass, shell 828 epoxy foam filled	8.0	5465	Failed
11/7/69	17	1 Pc. fiberglass, F161 epoxy	8.0	4714	Survived; good flight to 9K yds.
12/5/69	23	2 Pc. fiberglass, F161 epoxy	8.0	5353	Failed
1/5/70	T-1	Nose section in canister	8.0	2490	Survived, 10" straight charge fired ring charge did not fire
1/5/70	T-3	2 Pc. fiberglass on MK 25 body	8.0	3012	Survived
3/17/70	T-19	2 Pc. fiberglass on MK 25 body	8.0	3658	Wires failed
3/31/70	T-24	2 Pc. shroud on MK 25 body	8.0	3969	Wires failed
4/16/70	G1-3	1 Pc. Aluminum shroud	8.0	7618	Survived
7/1/70	G1-5	1 Pc. fiberglass	8.0	7731	Survived
7/6/70	T-28	2 Pc. fiberglass on finned projectile	8.0	2649	Survived
7/13/70	T-29	2 Pc. fiberglass with seal	8.0	3747	Survived

SHROUD TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL. (g's)	REMARKS
7/31/70	G1-6	1 Pc. aluminum shroud	8.0	8194	Survived
8/7/70	T-33	2 Pc. deployable fiberglass	8.0	3934	Successful
8/25/70	T-34	Wind tunnel deployment	-	--	Successful
11/3/70	I-41	Deployable Fiberglass Shroud	8.0	≈2000	Shroud survived gun launch; Shaped charge functioned but shroud was not recovered

TELEMETRY TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL. (g's)	REMARKS
10/16/69	9	TM System	9.12	6224	TM and signal processor failed; setback battery, timer, thermal battery and coax cable survived
11/21/69	18	Antennas and connectors	9.12	6347	Antenna mounting bolts failed
11/21/69	19	TM xmitter and processor	9.12	5642	Base broke and xmitter lost; processor survived
12/5/69	21	Antennas and connectors	8.0	5923	Survived - antennas detuned
12/19/69	27	Antenna, wiring, sun sensors and wing pets	8.0	8572	Antenna detuned but useful
1/12/70	T-5	TM system and timer	8.0	7649	No TM signal; not recovered
3/5/70	T-18	S-band antenna, connector, transistor 2N1907 and setback switch	8.0	8320	Setback functioned - all items structurally sound
4/16/70	T-26	TM system	8.0	7853	TM failed to function - crystal failed
7/31/70	T-32	TM system	8.0	4188	No signal; canister damaged
9/16/70	T-37	Dummy TM	8.0	7707	Failed
9/18/70	T-39	Dummy TM	8.0	8402	Failed
9/22/70	T-40	TM system	8.0	2281	Econ crystal failed
9/29/70	T-41	TM system	8.0	2166	HDL crystal survived; Econ failed
10/26/70	T-43	TM system	8.0	3991	System survived, used in G&C #2
11/19/70	T-45	TM system	8.0	3885	System survived, used in G&C #3
12/22/70	T-49	TM system	8.0	3926	System survived, to be used in G&C #5

G&C COMPONENT AND SUBASSEMBLY TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL. (g's)	REMARKS
4/3/69	F-1	Seeker components - IR dome, optical filter, lens, detector, pre-amp, mixer assembly	6.25	7176	Destroyed on impact
4/30/69	F-2	Same as F-1	6.25		Destroyed
5/23/69	F-3	Same as F-1	9.12	4809	Lens & filter survived, IR dome chipped on edge; solder loose on detector
5/23/69	F-4	Copper ball accelerometer	9.12	5081	Measured 6500 g's; high frequency accel. to 35000 g's
6/4/69	F-5	Seeker components (F-1)	9.12	6442	Components survived; accelerometer measured 6720 g's with 13000 g's high frequency
6/12/69	F-6	Seeker components	9.12	7165	Lens chipped, other components undamaged
6/13/69	F-7	Seeker optics and electronics	9.12	6889	Survived and met functional specifications
6/13/69	F-8	Gas generator and standard igniter	9.12	7253	Gas generator fired with excessive volume and flamed out. Retest with proper volume satisfactory.
6/27/69	F-9	Pre-Amplifier	9.12	7342	Survived and functioned satisfactorily
6/27/69	F-11	Optical filter and three thermal batteries	9.12	7165	All survived, two batteries slightly deformed
6/27/69	F-12	Control actuator assembly	9.12	7076	Survived
7/7/69	F-13	Gas generator and standard igniter	9.12	6634	Survived and functioned satisfactorily
7/8/69	F-14	Two canards and simplified shaft	9.12	6811	Survived

G&C COMPONENT AND SUBASSEMBLY TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL. (g's)	REMARKS
7/21/69	F-15	Seeker subassembly	9.12	7165	Not recovered
7/21/69	F-16	Control actuator assembly	9.12	6634	Survived
7/21/69	F-17	Control actuator assembly	9.12	6723	Survived
7/21/69	F-18	Gas generator and standard igniter with support screen	9.12	6722	Survived and functioned satisfactorily
7/21/69	F-19	Gas generator and experimental igniter	9.12	6811	Survived and functioned with 519 ms ignition delay
8/7/69	F-22	Two canards and shaft	9.12	7076	Survived
8/7/69	F-24	Seeker optics and electronics subassembly	9.12	7342	Seeker survived but would not extend; lens chipped on edges
8/7/69	F-26	Actuator assembly - four pistons, valves, manifold and release valve	9.12	6987	Survived
8/20/69	F-28	Seeker optics, electronics subassembly and master timer	9.12	6899	Survived
9/2/69	F-29	Actuator assembly	9.12	6191	Survived; gas tested successful
9/19/69	F-32	Electronics package	9.12	6722	
9/19/69	F-33	Electronics and sun sensor	9.12	6722	Pre-amp survived; computer collapsed due to potting voids
10/7/69	6	Wiring harness, thermal switch, Beckman I.C., coax cable and connector	9.12	6529	Beckman I.C. and thermal switch survived
10/23/69	15	NiCd battery, I.C. in T.0-5 can, potentiometer	9.12	6697	Survived

G&C COMPONENT AND SUBASSEMBLY TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL.(g's)	REMARKS
11/7/69	16	Programmer timer	8.0	5524	Survived
11/7/69	F-34	Shrike radome, antenna, and coated PC boards	8.0	6111	Disintegrated in barrel
11/21/69	19	Setback switch, timer and PC boards	8.12	5642	Timer and PC boards survived; setback switch failed
11/24/69	20	Thermal battery and transistor	8.0	5815	Payload destroyed by bolt from float system
12/5/69	21	Thermal battery, antenna and potted connector	8.0	5923	Survived
12/5/69	22	Ribbon wire on control housing	8.0	3236	Survived
1/7/70	T-4	Computer electronics	8.0	8392	Functional test satisfactory
2/6/70	F-35	Assorted electronics applicable to anti-radiation guidance	9.12	6700	All components survived
3/5/70	T-18	Setback switch, transistor, connector and antennas	8.0	8320	Setback switch functioned; all items survived structurally
3/6/70	F-36	Amplifier circuit boards, crystals and motor armature	9.12	7253	Crystal failed, other components survived
4/8/70	F-39	Thermal battery	9.12		Survived
4/8/70	F-40	Setback switches, viscous gyro, PIN-10 photo cell, square wave generator	9.12	6987	All survived, data recorded from generator during travel in tube to 50 ft. outside
4/20/70	F-41	Vickers particle clutch	9.12	7650	Survived
5/21/70	F-42	Vickers particle clutch	8.0	7800	Canister failed - not recovered
5/28/70	F-43	Accelerometer and solenoid vavle	8.0	--	Not recovered

G&C COMPONENT AND SUBASSEMBLY TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL. (g's)	REMARKS
6/26/70	T-26A	TM crystals and solinoid valves	8.0	7742	One valve failed - requires support; one crystal failed
[illegible] 16/70	T-31	Dupont 706 detonators	8.0	4520	3 vertical mounted good, horz failed
		Dupont 790 detonators			All survived
		Holex 2800 cable cutter			All survived
		TM crystals			2 survived, one bad (prior damage)
		Thermal battery - inertial			Appears to have functioned
12/16/70	T-46	Gas Generator	8.0	4200	Survived
12/16/70	T-47	Gas Generator Igniters	8.0	7769	Survived

GUIDANCE AND CONTROL SYSTEM TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL. (g's)	REMARKS
12/12/69	24	Optical and gas operated hardware	8.0	5519	Recovered 9/9/70; some parts damaged
5/1/70	T-22	Operable G&C #1	8.0	8734	Retaining rings failed
7/16/70	T-30	Operable G&C #2	8.0	8655	Not recovered
9/2/70	G-10	Structural G&C	8.0	4767	Not recovered
9/18/70	G-13	Operable G&C #3	8.0	3980	Functional test successful

WIND TUNNEL TESTS

DATE	ITEM	REMARKS
8/13-15/69	0.6 scale model	Tested over Mach range 0.8-2.6; static forces and moments measured
12/14-15/70	Full Scale Model	Tested over Mach range 0.6-1.0; static forces and moments and canard hinge moments and seeker angle measured

AIR DROP TESTS

DATE	ITEM	REMARKS
10/69	Full scale ballistic vehicle	Proved aerodynamically stable and compatible with drop aircraft; drag was measured.
11/14/69	Full scale programmed control system	Programmer malfunctioned which drove the vehicle into resonant circular yawing motions with large amplitude angles
1/23/70	Full scale guided vehicle	Guidance power on switch malfunctioned and the vehicle fell ballistically
3/26/70	Full scale guided vehicle	All guidance and control components functioned properly. The vehicle impacted 1200 feet short and 500 feet left of the target. The ballistic impact point was 3000 feet short and 700 feet left of the target. Thus, the vehicle maneuvered 1800 feet in range and 200 feet in cross range. Undersized canards, sluggish canard response, and canard-induced rolling motion account for the large target miss.
1/21/71	G&C #4, Full Scale Guided vehicle	All guidance and control components functioned properly. The vehicle guided out 2000 feet of range error and 800 feet of cross range error to impact 36 feet short and 4 feet right of the target.

GUIDED AND CONTROLLED PROJECTILE TESTS

DATE	TEST NO.	ITEM	GUN	ACCEL. (g's)	REMARKS
7/6/70	T-28	Ballistic #1	8.0	2000	Good flight, shroud survived; fins deployed 14,763 yds range, 15 yds right, 1811 fps, QE 35°
9/23/70		Captive Flights			Verified acquisition for G&C #1
10/6/70		Ballistic #2	8.0	2000	Good flight, shroud survived; fins deployed 1710 fps to 13,338 yds range; 5 yds left, QE 35°
10/8/70		G&C #1	8.0	2000	Shroud did not deploy - no guidance; TM functioned; QE 31°; 1628 fps; 11,784 yds range; 67 yds left
11/3/70	T-44	Ballistic #3	8.0	2000	Good flight; shroud did not deploy; fins deployed; QE 35°; 1640 fps; 12,594 yds range, 68 yds left
11/6/70		G&C #2	8.0	2000	Shroud deployed; TM functioned; guidance commands transmitted to solenoid valves; but, gas generator failed to ignite; 35° QE; 1685 fps; 13,371 yds range; 94 yds left
12/3/60		G&C #3	8.0	2000	Aerodynamic incompatibilities prevented maneuver to target. Shroud deployed; TM functioned, guidance and control functioned; 32.5° QE; 1624 fps; 12,029 yds range; 211 yds left

APPENDIX D

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

(U) An exploratory development plan for demonstrating the feasibility of a guided projectile has been established. The plan covers work completed from October 1968 through 1 February 1971 and outlines plans leading to Advance Development of Navy and Marine Corps, eight-inch, guided projectiles in FY 1972. The total cost of the exploratory development program is about \$ 5.25 million dollars for FY69, FY70 and FY71.

(C) Most of the guided projectile components have been gun fired and have survived 8000 g's acceleration. The shroud, guidance and control assembly, and telemetry assembly are designed to withstand 8000 g's and have survived 4000 g's. Three gun fired, guided, functional system tests have been conducted. The first two did not guide because of mechanical failures. The third guided toward the target; but, because of aerodynamic incompatabilities it did not maneuver to the target. Subsequent design changes proved aerodynamically sound during an air drop in January 1971. The projectile maneuvered out 2000 feet range error and 700 feet cross range error to impact 36 feet short and 4 feet right of the target. Three more gunfired tests are planned using an eight-inch Navy gun and three from an eight-inch howitzer.