

DTIC FILE COPY



# INSENSITIVE MUNITIONS ADVANCED DEVELOPMENT FY 89 PROGRAM PLAN

1

DTIC  
ELECTE  
APR 05 1989  
S D  
D Q

AD-A206 512



**DISTRIBUTION STATEMENT A**  
Approved for public release  
Distribution Unlimited

**DEPARTMENT OF THE NAVY  
NAVAL SEA SYSTEMS COMMAND  
WASHINGTON, D.C. 20362-5101**

89 3 15 001

**INSENSITIVE MUNITIONS  
ADVANCED DEVELOPMENT  
FY 89 PROGRAM PLAN**



**APPROVED BY:**

*Richard E. Bowen*

**RICHARD E. BOWEN**

TABLE OF CONTENTS

SECTION I  
IMAD Program Overview I-1

SECTION II  
High Explosives  
Overview II-1  
Coordination and Technical Direction II-11  
General Purpose Explosives, II-13  
Metal Accelerating Explosives, II-15  
Underwater Explosives, II-18  
Booster Explosives, II-20  
Explosive Processing Techniques, II-22  
Transition Efforts II-24

SECTION III  
Ordnance  
Overview III-1  
Coordination and Technical Direction III-6  
Warhead Design Technology, III-7  
Advanced Mitigation Technology, III-12  
Applied Materials and Shielding, III-15  
Packaging and Container Technology, III-19  
Technology Transition/T&E Support III-21

SECTION IV  
Propellants/Propulsion  
Overview IV-1  
Coordination and Technical Direction IV-11  
Rocket Motors and Large Scale Testing, IV-13  
Propellants, IV-15  
Advanced Cases, IV-19  
Mitigation Systems, IV-21  
Ignition Systems, IV-23

Appendices  
Glossary of Terms A-1  
Telephone Exchanges B-1

Accession For	
NTIS CRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By <i>per ltr.</i>	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

DTIC  
COPY

**SECTION I**  
**IMAD PROGRAM OVERVIEW**

## SECTION I

### IMAD PROGRAM OVERVIEW

Program Manager and Technical Director: Dr. R.E. Bowen; SEA-662,  
Naval Sea Systems Command  
Washington, DC 20362-5101  
Tel: (703) 692-8728/  
AV: 222-8728

*As of 1/1/84*

**INTRODUCTION:** In 1984, the Chief of Naval Operations announced a new Navy policy which states that by 1995 all Navy munitions will be designed to minimize the effects of unplanned stimuli while reliably fulfilling their performance, readiness and operational requirements.

This directive established a management structure (Figure I-1) with the Deputy Chief of Naval Operations (Surface Warfare) being responsible for oversight and coordination of the Navy's Insensitive Munitions Program. He is assisted by the Insensitive Munitions Council (IMC). The IMC is in turn supported in all aspects of program planning and execution by the Insensitive Munitions Coordination Group (IMCG) chaired by the Deputy Commander for Weapons and Combat Systems, Naval Sea Systems Command.

Further, the Naval Sea Systems Command was designated as the lead SYSCOM for explosive material, energetic materials and insensitive munitions. An office was established within NAVSEA (SEA-662) as the action desk to manage and technically direct the Insensitive Munitions Advanced Development (IMAD) Program and to provide technical and administrative support to the IMCG. The IMAD Program, which is the subject of this workplan, is an integral part of the Navy's IM initiative.

**OBJECTIVE:** The objective of the IMAD Program is to develop and demonstrate technology needed to reduce the vulnerability of Fleet munitions by reducing the severity of reactions resulting from fast cook-off, slow cook-off, bullet impact and fragment impact; also, to minimize the probability of sympathetic detonation in storage and in use. The requirements of NAVSEAINST 8010.5, Technical Requirements for Insensitive Munitions, will have to be met while maintaining required munition performance levels.

**MANAGEMENT STRUCTURE:** The management structure of the Navy's Insensitive Munitions Program is depicted in Figure I-1, the structure of the Navy IMAD Program in Figure I-2. Within the Navy IMAD Program there are three projects. They are High Explosives, Ordnance, and Propellants/Propulsion. Technical Coordinators have been assigned for each project. The program

was organized to address the major components of a munition system and still provide for crossovers in technology areas through the NAVSEA Program Manager.

NAVSEA-662 manages and technically directs the 6.3 IMAD Program. This encompasses the solicitation of work plans from the technical coordinators and other public and private agencies, the evaluation of proposals, allocation of IMAD funds, prioritization of work, the establishment and maintenance of channels of communications between Navy Offices of Primary Responsibility (OPRs) and Technical Coordinators, and the overall direction, review and documentation of work.

Navy OPRs have the responsibility to work with SEA-662 and the laboratories to take full advantage of the technology generated under the IMAD Program as the goal of the IMAD Program is to meet the technology needs of these program offices.

The Technical Coordinators are responsible for the identification of IM-related problems as foreseen by the OPRs and various experts in the field of munitions, the generation of proposals, solicitation of proposals from other agencies and the development of an overall action plan to be evaluated by SEA-662.

TECHNICAL APPROACH: Ship survivability can be improved using the following techniques, either individually or in combination: (1) less sensitive energetic materials; (2) mitigation devices or concepts; (3) ordnance container hardening; (4) ship magazine hardening; (5) weapon launcher hardening; and (6) upgraded damage control/fire fighting. Item (1), (2), and (3) are the responsibilities of the NAVSEA IMAD Program.

The development of less sensitive energetic materials will provide improved vulnerability characteristics across a range of threat stimuli. Where this technology cannot satisfy both IM and performance requirements, mitigation concepts or a combination of less sensitive energetic material and mitigation will be developed. Details of problems and approaches within each technical area are discussed in Sections II, III and IV.

The general approach that has been taken by this program has been to develop promising technology and evaluate it using generic hardware. The generic hardware has been designed to provide a low cost test vehicle which takes into account realistic design parameters. In this way, more large scale testing can be done with better statistical significance of the test results. In addition, it provides a baseline for comparing different energetic materials in the same configuration or different configurations using the same energetic material. In these configurations, large scale safety, vulnerability and performance testing is done to evaluate the potential of a

specific technology to meet IM criteria while maintaining performance. In addition, the effects of combined stimuli (i.e. heat and impact) will be investigated, within funding constraints, as part of a realistic threat scenario.

After evaluation in generic hardware, a technology is ready to be transitioned to a specific munition. Often times it is a cooperative effort between the IMAD Program and the OPR. Within these cooperative technology transition efforts, the R&D community adds to the data base and can refine the technology for real applications thereby enhancing producibility for future systems. The OPR takes advantage of the experience of the technical staff and can reduce its risk in applying the technology. Everyone benefits; the IMAD Program, the OPR and future users.

Overall, it is considered critical that this program develop improved large-scale tests, hazard prediction techniques based on small scale testing and theoretical calculations, and improved correlations between hazards and test studies to serve the needs of the OPRs and other technologists.

In order to meet the goals of this program, substantial improvements in the technology of energetics and explosions (detonations) are needed. This will require the exploitation of new 6.1 and 6.2 technology, information exchange between technologists in all areas of energetics and components R&D, as well as coordination with appropriate programs of the DOD, DOE, private industry, universities, and allied nations. The IMAD Program must work with weapon OPRs to identify common munition components and hazard threats (Munitions Data Base), and to meet their needs for improved technology through munitions hazard assessments.

PROGRAM DOCUMENTATION: The documentation requirements for the program are outlined in Figure I-3.

# INSENSITIVE MUNITIONS PROGRAM

## MANAGEMENT STRUCTURE

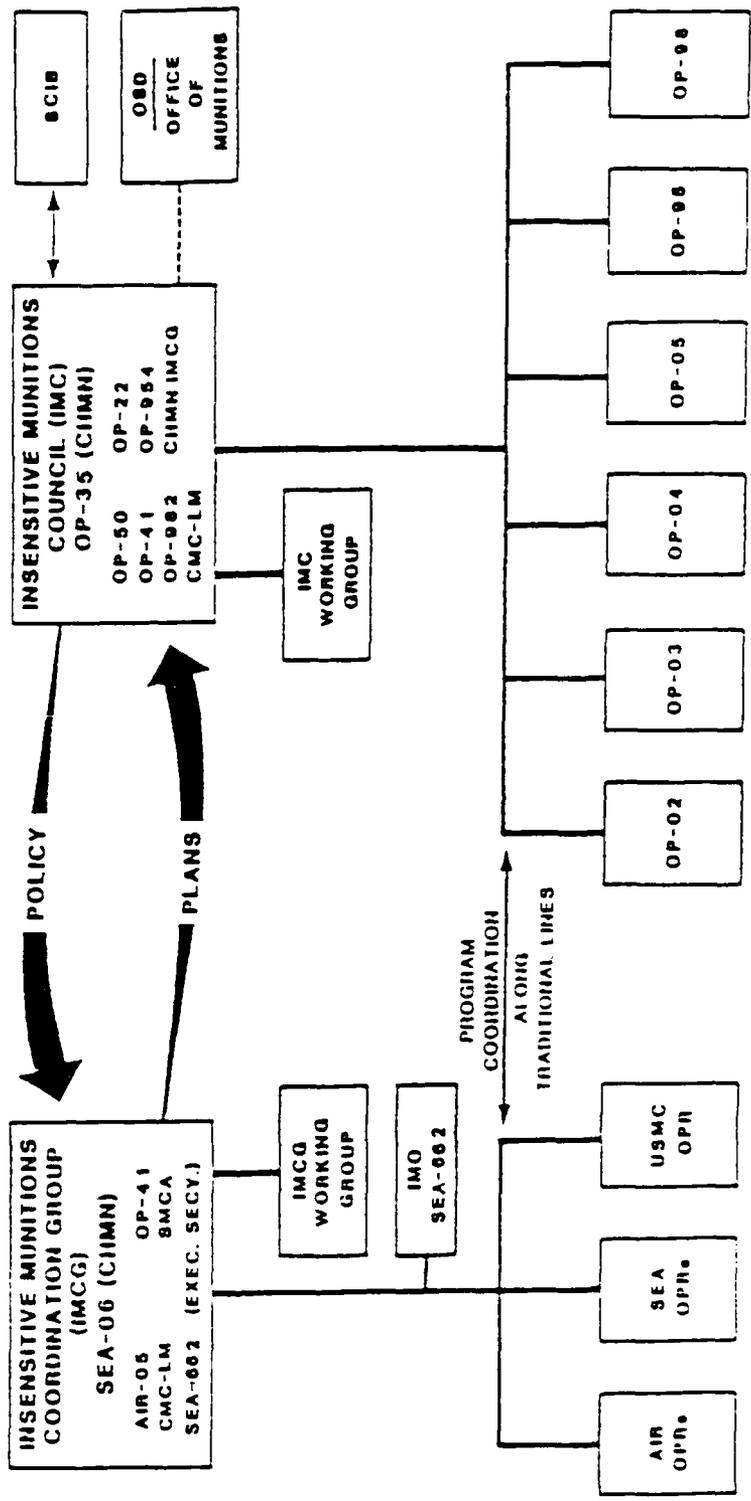


FIGURE 1-1

# INSENSITIVE MUNITIONS ADVANCED DEVELOPMENT PROGRAM ORGANIZATION

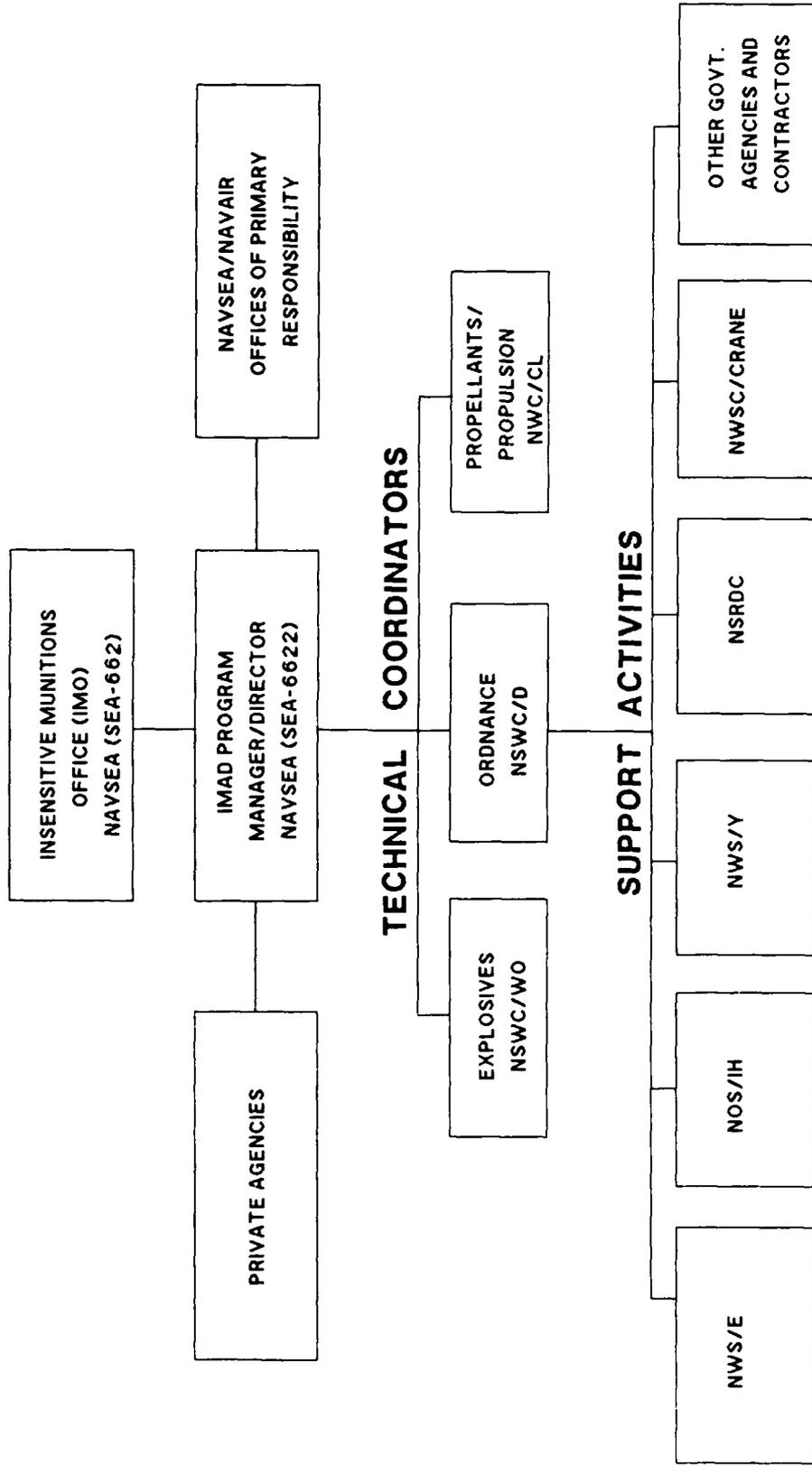


FIGURE I-2



**SECTION II**  
**HIGH EXPLOSIVES**

## SECTION II

PROJECT ELEMENT: HIGH EXPLOSIVES

COORDINATOR: H. S. Haiss, Code R10B  
Naval Surface Warfare Center  
White Oak, Silver Spring, MD 20903-5000  
Tel: (202) 394-2490/AV 290-2490

INTRODUCTION: Navy munitions use conventional high explosives to provide destructive power for offensive and defensive purposes. New weapon systems frequently require explosives with improved performance while minimizing explosive weight and/or volume. Violent, unintentional reaction of high explosives in munitions, as a result of accidental exposure to hazardous environments or enemy attack, has demonstrated the need for explosives that react mildly under these conditions. Special care must therefore be taken to ensure that demands for higher performance do not result in the introduction of unacceptably hazardous materials that will degrade overall Fleet effectiveness.

The U.S. Navy has active 6.1 (basic research) and 6.2 (exploratory development) programs that generate new explosives technology to meet operational requirements. Products include rubbery, plastic bonded explosives (PBXs) that have been found to exhibit good vulnerability behavior, coupled with high performance. The inability of the 6.2 explosives program to adequately support pilot plant scale-up and large-scale testing of new explosives led to the establishment of the 6.3 Explosives Advanced Development (EAD) Program as a "new start" in FY78. This program was necessary to demonstrate that the new technology will provide the expected benefits, that the new materials are producible, and that there will be low risk when the new technology is incorporated into a munitions development program. In FY86, the EAD Program was integrated into the Navy's Insensitive Munitions Advanced Development Program (IMAD).

NAVY MISSION NEEDS: High explosives needed for future munition developments and for munitions upgrade have to display minimum sensitivity to inadvertent stimuli while providing maximum performance. Furthermore, processing techniques and equipment have to be developed which will allow the economical loading of high quality charges. More specifically, in order to reduce munitions vulnerability, explosives with substantially reduced sensitivity to shock stimuli, as encountered in hard target impact, high velocity fragment impact, and sympathetic detonation, and with improved thermal stability, especially under slow cook-off conditions, have to be developed. In addition, explosive formulations have to be chemically stable during storage (particularly primaries).

Increases in performance are especially critical for warheads against "soft" targets (anti-air), where explosive fills with the highest available fragment acceleration capability (~12,000 ft/sec) are required, for underwater munitions, where a substantial increase in performance is necessary, and for shaped charge applications where armor penetration requirements cannot be met with the latest "insensitive" explosives. It is also critical that attention be focused on the production facilities that will have to load munitions with new, improved high explosives which require processing equipment and procedures that are currently not available. For munitions under the cognizance of the Single Manager for Conventional Ammunition (SMCA), these requirements must be defined and provided to the SMCA to develop the necessary support and obtain approvals for equipment installation and construction of facilities.

STATUS OF TECHNOLOGY: During the past 30 years the sensitivity of explosives was substantially improved through the introduction of Plastic Bonded Explosives (PBXs). Their good vulnerability behavior, as compared to TNT based explosives, is attributed to the incorporation of polymeric binders which resulted in nearly voidless, pliant, rubbery materials with fewer discontinuities and hence low energy breakup characteristics and reduced tendency to form hot-spots. An additional feature of some composite PBXs is that fuel and oxidizers are physically separated, making it possible to simultaneously increase chemical energy and decrease sensitivity.

In spite of these developments which resulted in overall improved munitions vulnerability, explosive fills that were selected often will not pass the newly established safety criteria.

Vulnerability characteristics of specific munitions do not solely depend on the specific explosive(s) employed, but are also a function of hardware design (i.e., degree of confinement/protection provided) and charge size. Thus, an explosive may pass slow cook-off in a small warhead under light confinement while it will frequently detonate in larger weapons and/or under heavy confinement. One of the recently developed PBXs, such as PBXN-109, will not sympathetically detonate when tested in 5"/54 warheads (MK 64) but will react violently in a MK 83 GP bomb.

Recent progress in the formulation of general purpose explosives, which are optimized for both blast performance and fragmentation effects, resulted in the qualification of PBXN-109 as the main charge explosive for the MK 83 GP bomb. Although the replacement of H-6 with PBXN-109 will solve most of the IM-related problems, it can only be considered an interim solution since the sympathetic detonation criterion cannot be met.

Development of moderately energetic explosives for fragment accelerating (mainly anti-air) warheads resulted in materials with overall good vulnerability behavior under fast cook-off conditions and for critical fragment impact velocities of 7500-8000 ft/sec. However, new threat weapons develop much higher fragment velocities which will most likely produce explosions or detonations. Explosives with maximum metal accelerating characteristics for shaped charges and submunitions were in the past mainly selected on a performance basis and the present munition fills (i.e., Octol, LX-14) need to be replaced with insensitive explosives of equal performance.

In the area of underwater explosives, the development of PBXN-103 doubled the lethal volume of torpedo warheads with some improvement in explosive sensitivity characteristics. However, neither this explosive fill nor the later developed PBXN-105 and PBXW-115 satisfy all vulnerability criteria cited in NAVSEAINST 8010.5. A needed increase in performance, together with improved vulnerability characteristics, presents a challenging task for the explosives development community.

A reduction in the sensitivity of the main-charge explosive alone will not always solve munition IM problems. Some booster materials and detonation transfer explosives presently incorporated in munitions do not satisfy IM or future mission requirements with respect to thermal stability and/or impact/shock sensitivity and will have to be replaced to achieve total munitions IM status. The development of high output, low sensitivity booster materials for reliable ignition of "shock insensitive" main charge explosives will be a major problem area.

Table II-1 lists explosives which underwent advanced development within the recent past and either have been or are ready to be transitioned into weapon systems.

Difficulties with the loading of PBXs into conventional munitions initially limited the use of those materials to low production rate, high technology weapons. More recent developments, however, have demonstrated that PBXs can be readily loaded into some high volume production munitions (gun projectiles, bombs) at an affordable cost. Present efforts in the area of continuous processing/extrusion should result in even more economical loading of large volume munitions and will, in addition, allow the incorporation of novel binder systems which cannot be processed with conventional mixing/cast/cure techniques. A problem still exists with respect to the high quality loading of new insensitive PBXs into small shaped charges and submunition. Present efforts on an injection loading system shows promise in this area.

APPROACH: New technology emerging from the Navy's 6.2 exploratory development program and, if considered feasible and advantageous to the Navy's effort, from other Services, DOE,

	Status/Availability for Munitions Development	Munitions Application*
<u>Booster Explosives</u>		
PBXN-5	In-Service	SM*/PHOENIX*/SPARROW*/20 MM*
PBXN-6	In-Service	APAM BLU-77*
PBXW-7	Qualified/NOW	QUICKSTRIKE EX-75 S&A*/ PENGUIN*/GP Bomb Fuzing (FMU-139)/SAM-104 Fuze/ MND/AMNE
<u>Initiation Train and Primary Explosives</u>		
PBXN-301	In-Service	Initiation Trains/ Explosives Logic
DXW-1	Qualified/NOW	Lead Azide Replacement Electrical & Stab

---

\*In-Service or Engineering Development/Unmarked - projected application.

private industry, and allied countries will be introduced into advanced development. T&E studies will be conducted in three test phases. First, small scale laboratory studies to improve producibility of the material will be conducted and initial properties data will be generated via small scale experiments (Phase I). Next, the explosives considered promising will be scaled up by the pilot plants (Phase II). This task also includes the development of procedures and processing equipment needed to ensure efficient and economical producibility. In Phase III the scaled-up explosives are subjected to large-scale vulnerability and performance tests in generic munition size hardware, and the test data will be documented, specifications finalized, and data incorporated into an explosives properties document.

The main emphasis within the near future will be placed on the development of a sympathetic detonation-resistant explosive for GP bombs and penetrating warheads (TOMAHAWK, HARPOON). Next in priority are high performance, low sensitivity, metal accelerating explosives for missile warheads (STANDARD MISSILE, PHOENIX, AMRAAM), shaped charge applications (SMAW, DRAGON, HELLFIRE, MK 50) and submunitions (ADVANCED CLUSTER, 16" Projectile). Although underwater explosives with increased bubble performance and reduced sensitivity are high on the Navy's priority list, the transition of candidate explosives from the 6.2 program is not expected until at least FY90. Meanwhile attempts will be made to identify a viable candidate by using industry expertise. To complete this broad approach, candidate fills for small warheads/projectiles, as well as less sensitive booster explosives, have been identified and will be developed.

Additional efforts which are highly important to the overall effort are the development of continuous processing and injection molding techniques which will allow for the safe and economical processing of explosives and the efficient loading of high quality charges.

A vital part of the IMAD-HE Project is the transition of new explosives and processing technology into engineering development. Every possible effort will be made to familiarize munitions offices with available technology and explosive developments in progress. It will also be attempted to establish cooperative programs for explosives in advanced development in order to accelerate the transition of critically needed technology.

PROJECT STRUCTURE: The IMAD High Explosives effort has been organized into seven core tasks as indicated below. The technical tasks are listed in order of priority.

Task NO.	Title
2001	Coordination and Technical Direction
2002	General Purpose Explosives
2003	Metal Accelerating Explosives
2004	Underwater Explosives
2005	Booster Explosives
2006	Explosive Processing Techniques
2007	Transition Efforts

The project work is conducted primarily at three Navy facilities. A point-of-contact (POC) is officially designated at each of these as follows:

Facility	POC
Naval Surface Warfare Center Dahlgren, VA (NSWC/D) and White Oak, MD (NSWC/WO)	B. A. Baudler Code R12
Naval Weapons Center, China Lake , CA (NWC/CL)	G. A. Greene Code 32601
Naval Ordnance Station, Indian Head, MD and Yorktown, VA (NEDED)	J. Chang Code 2730D L.E. Leonard Code 470A

Subprojects, tasks, and schedules are established and coordinated at each Navy facility by the IMAD High-Explosives Project POCS. These in-house technical activities support the High Explosives core tasks.

Principal investigators for the core tasks cited above, as well as task descriptions, are listed in sections to follow.

PROJECT SCHEDULE: Schedules projected for the advanced development and transition of explosives and processing techniques are shown in Figure II-1 (for further details see Task Descriptions). As described above, the T&E on new explosives is conducted in three phases and, in general, five years are allowed for advanced development. The overall timespan may be reduced for high priority items or delays may occur due to processing difficulties or funding shortages. Some of the explosives listed in Figure II-1 may also be dropped from the project if initial evaluation results do not look promising. Similarly, schedules for processing and equipment studies depend largely on the actual funding level. Significant milestones for FY89 and outyears are listed below:

## MAJOR MILESTONES

### FY89

- Transition PBXC-129 into advanced development. 1st QTR
- Complete generic shaped charge performance tests using PBXW-9, PBXC-126, PBXW-113, PBXW-119, PBXW-120, LX-14, and Octol 75/25 as main charge explosives. 1st QTR
- Complete small scale processing studies and testing on PBXW-119 and PBXW-120 and select one formulation for pilot plant scale-up. 1st QTR
- Select main charge explosives for HELLFIRE warhead and APOBS. 1st QTR
- Establish finalized composition for PBXC-18 (low vulnerability booster explosive). 1st QTR
- Complete small scale testing of finalized PBXW-121 (bombfill). 2nd QTR
- Complete small scale formulation of UW explosive candidates at Hercules, Inc. 2nd QTR
- Complete processability studies on PBXN-109 with the 37mm continuous processor/extruder. 2nd QTR
- Complete performance testing on SMAW and DRAGON WHs loaded with PBXW-9/PBXW-113. 2nd QTR
- Start vulnerability and performance testing on APOBS (cooperative effort). 2nd QTR
- Start loading of 16" gun submunition with several PBXs; start performance and vulnerability testing. 2nd QTR
- Process the first live mix with the 2" continuous processor at NOS/IH [NEDED]. 2nd QTR
- Load generic test units (HWP) and MK 82 bombs with PBXW-121 for large scale vulnerability and performance testing. 3rd QTR
- Complete small scale testing of contractor supplied UW explosive candidates. 3rd QTR
- Acquire 100 lbs of B-2188 (French booster explosive) from SNPE and start small scale testing. 3rd QTR

FY 89 (Cont'd)

- Select main charge explosive for SMAW and DRAGON warheads. 3rd QTR
- Complete pilot plant scale-up studies on PBXW-121 (bombfill). 4th QTR
- Start large scale vulnerability studies on PBXW-121 loaded generic units and MK 82 bombs. 4th QTR
- Complete pilot plant scale-up studies on selected high performance explosive (PBXW-119/120). 4th QTR
- Complete scale-up of most promising UW explosive at contractor facility. 4th QTR
- Start loading of generic UW test units with selected explosive. 4th QTR
- Complete small scale processability studies on PBXC-18 and transition it to pilot plant scale-up. 4th QTR
- Complete design and installation of an injection loading system at NWS/Y. 4th QTR
- Provide support to the ADVANCED CLUSTER, QUICKSTRIKE, MK 98 (MND), and AMNE Programs. Cont.
- Establish transition efforts for MK 50, 75mm, and Follow-Through torpedo warhead. Cont.

FY90

- Complete vulnerability testing on generic units loaded with PBXW-121; document test results.
- Start performance tests (blast, fragmentation) with PBXW-121 loaded generic units.
- Load generic test units with high performance explosive (PBXW-119/120) and conduct large scale vulnerability tests.
- Complete pilot plant scale-up studies on PBXC-129 and start S&V testing.
- Start large scale vulnerability and performance tests with selected UW explosive.
- Conduct processability studies on B-2188 (booster explosive).

FY90 (Cont'd)

- Transition B-2188 to the pilot plant for scale-up and loading of generic hardware.
- Scale up PBXC-18 to suitable batch sizes (pilot plant) and evaluate processing and pressing characteristics.
- Request qualification of PBXC-18 as a booster explosive and start S&V testing.
- Continue processing and injection loading studies on new explosives with the small scale laboratory setups (NSWC/NWC).
- Conduct extended run studies with the 2" Readco at NOS/IH [NEDED].
- Develop the injection loading process at NOS/IH [NEDED] using inert simulants and PBX explosives.
- Complete vulnerability testing on HELLFIRE warheads, APOBS, and 16" gun submunition (cooperative programs).
- Support MK 50, 75mm, Follow-Through, ROCKEYE, and ADVANCED CLUSTER programs.
- Establish additional transition efforts.

FY91-92

- Complete performance testing on generic units and MK 82 bombs loaded with PBXW-121; document test results.
- Transition GP-bombfill to weapon developer.
- Start transition (cooperative) efforts with the HARPOON and TOMAHAWK Program Offices.
- Complete advanced development of PBXW-119/120, document test results, and transition explosive to weapon developers.
- Conduct large scale performance and vulnerability tests on generic units loaded with PBXC-129/initiate transition efforts.
- Complete large scale testing of UW explosive developed under contract and document test data; start transition efforts.

FY91-92 (Cont'd)

- Transition high bubble energy UW explosives into advanced development.
- Complete processability study and pilot plant scale-up of high bubble energy UW explosive.
- Conduct large scale cook-off and performance tests on generic booster designs loaded with PBXC-18 (NWC developed), B-2188, and PBXW-7.
- Initiate transitioning of PBXC-18 and/or B-2188 to munition developers.
- Conduct continuous processing studies on melt cast explosives with the 2" Readco at NWS/Y.
- Integrate the NOS/IH [NEDED] injection loading system with the 2" Readco continuous processor.
- Complete transition efforts for SMAW, DRAGON, HELLFIRE, APOBS, and 16" gun submunition.
- Continue to support NAVAIR and NAVSEA in the selection of low vulnerability explosives for IM munition designs.

LONG RANGE PLANS (BEYOND FY92): Long range plans for the IMAD - HE Project depend to a large extent on the technology emerging from the 6.2 Explosives Block Program. This may have to be augmented by soliciting ideas from private industry and/or through adoption and possible modification of explosive candidates and processing techniques developed by other Services, DOE, or allied countries.

New munitions will require explosives that provide higher performance and better vulnerability characteristics than are now available. One way this can be achieved is through new warhead designs, including a variety of directional warheads and use of special multioption, multipoint initiator systems. Such designs will require close cooperation between the IMAD High Explosives effort and munition developers to match explosives properties with those high technology warhead concepts. Specific technology needs are for explosives with substantially higher performance for anti-air missiles, torpedoes and anti-armor munitions, explosives with improved thermal stability for high performance warheads or space applications, deformable explosives, and special purpose binary explosives. New 6.2 development projects are focused on these future Navy requirements and include work on fluorocarbon binder formulations, new metal additives in place of aluminum powder, special charge designs, and reactive case materials.

# TEST AND EVALUATION PHASES\*

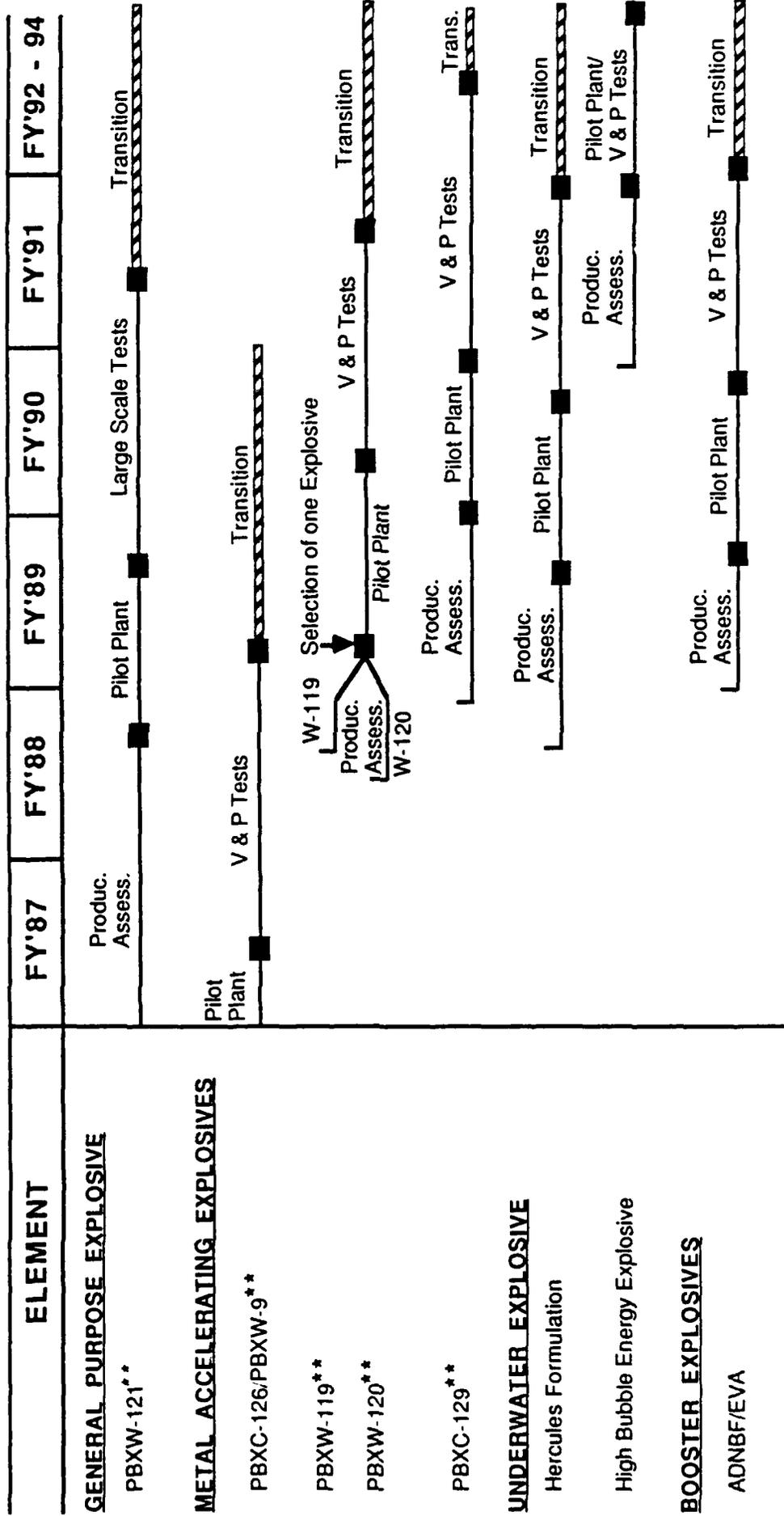
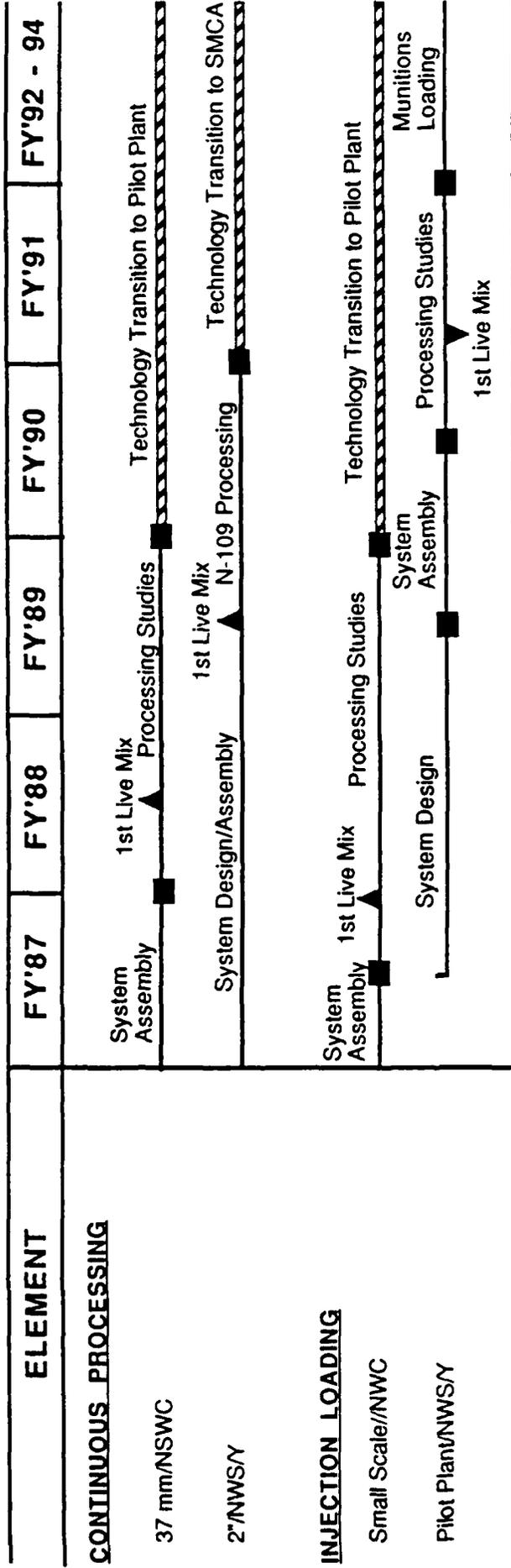


Figure II-1. Project Schedule

# DEVELOPMENT PHASES



\* T & E of explosives is conducted in three major phases: Producibility Assessment/Small Scale Testing, Pilot Plant Scale-Up/Loading of Generic Test Units, and Vulnerability and Performance Testing in generic test units. Upon completion of Advanced Development, explosives are transitioned to weapon developers (cooperative programs).

- \*\* PBXW-121 – NTO/HTPB based bombfill
- PBXC-126 – GAP/Nitrate plasticizer/HMX
- PBXW-9 – Hycar/DOA/HMX
- PBXW-119 – Fluoro-nitro-polyortho carbonate/Fluoronitro plasticizer/HMX
- PBXW-120 – Fluoropolymer/Fluoronitro plasticizer/HMX
- PBXC-129 – Laurel methacrylate/DOA/HMX

Figure II-1. Project Schedule (Cont'd.)

Task Title: Coordination and Technical Direction  
Task Number: 2001  
Principal Investigators: H. Haiss, NSWC/WO, Code R10B, X2490  
B. Baudler, NSWC/WO, Code R12, X1787  
G. Greene, NWC/CL, Code 32601, X7502  
J. Chang, NOS/IH, Code 2730D, X4453  
L. Leonard, NOS/IH [NEDED]/Y, Code  
470A, X4716

OBJECTIVE: Provide coordination and technical direction of the IMAD HE project. Coordinate with related work being undertaken by the other Services, by private industry, and by other nations. Interact with the 6.2 Explosives Exploratory Development Program and with weapon program offices (OPRs) to expedite transition of all weapons to insensitive status. Attend necessary meetings and conferences, prepare/present plans and reports and respond to various requests by the Sponsor.

BACKGROUND: The original EAD Program was set up to provide a bridge for transitioning technology from the 6.2 technology base into 6.4 munitions development. It was also intended to reduce the overall cost of introducing new technology into Fleet weapons. To do this effectively, it is necessary to coordinate high explosives efforts closely with the technology base 6.1 and 6.2 energetic materials programs and with munition development offices. It is also important to coordinate with related technical activities in this and in other countries to uncover the most promising new technology, to direct efforts into the most fruitful areas, and to avoid duplication of work.

APPROACH: Technical direction and coordination are the responsibilities of the IMAD High Explosives Technical Coordinator (TC) and the Points-of-Contact (POCs) at the three funded Navy facilities, NSWC/D and WO, NWC/CL, and NOS/IH. Active contacts are maintained with the other Services, the SMCA, DOE, private industry, and other countries. Work at the two pilot plants and the R&D Centers is woven into a single, coordinated activity. New explosives are initially assessed at either NSWC/WO or NWC/CL. They are then turned over to NOS/IH for pilot plant scale-up, and later to be loaded into generic test units. Large-scale vulnerability and performance tests and laboratory characterization is divided between NSWC and NWC/CL. Efforts to transition new technology into munition development programs are usually initiated and conducted by either NSWC or NWC. Work priorities and schedules are established by the Technical Coordinator following discussions with sponsor and POCs. Technical data on explosives are obtained and evaluated by teams of project workers from the different laboratories.

Personal interactions, participation in working groups, and presentations at technical meetings are used to exchange information and to coordinate with other related technical

activities. The technical direction of the Navy's 6.1, 6.2, and 6.3 explosives R&D programs is the responsibility of NSWC/WO Energetic Materials Division (Code R10) staff personnel. These technical coordinators interact frequently. Additional coordination of the high explosives development effort is accomplished through the exchange of data and discussions in many meetings, including NAVSEA technical reviews, the Working Party for Explosives (WPE) under the Joint Ordnance Commanders Group, Data Exchange Agreements (DEAs) with various European allies, the Technical Cooperation Panel (TTCP WP-1; USA, UK, Canada, Australia, and New Zealand), the NATO AC/310 Sub-group 1 on Explosives, and meetings sponsored by professional groups (such as the American Defense Preparedness Association).

PROGRESS (FY88): Following substantial funding reductions during FY88, the IMAD-HE program plan, priorities, and milestones were revised. Several subtasks in the areas of data base computerization, revision of test manuals, test/assessment methodology, processing technology, and predictive efforts were terminated. Large scale testing and transition efforts were substantially reduced and the formulation of underwater explosives under contract with private industry was largely shifted to FY89. The funding of the highest priority task (GP bombfill), however, was maintained at the originally planned level.

Navy IM requirements, technology developments, and available technology options were presented to NAVSEA/NAVAIR PMs, Army and Air Force personnel, and representatives of private industry and allied nations. IMAD-HE Project personnel participated in NSWC Explosives Selection Committee meetings and attended 6.2 Explosive Block Program meetings in order to keep up with emerging technology.

PLANS (FY89-FY92): Plans under this task are aimed towards development of explosives and processing technologies for the most critical munition fills, either through in-house efforts or contracts with private industry. The transition of new technology to weapon programs will be actively pursued and communication with 6.2 community, other IMAD projects, DOE, other Services, and representatives of allied countries will be continued.

Task Title: General Purpose Explosives  
Task Number: 2002  
Principal Investigators: J. Leahy, NSWC/WO, Code R11, X4859  
T. Atienza Moore, NWC/CL, Code 3264,  
7530  
J. Chang, NOS/IH, Code 2730D, X4453  
M. R. Senn, NOS/IH [NEDED]/Y, Code  
470H, X4717

OBJECTIVE: Development of a sympathetic detonation resistant main charge explosive fill for GP bombs and heavy-wall penetrators.

BACKGROUND: Recent progress in the formulation of general purpose explosives, which are optimized for both blast and fragmentation effects, resulted in the qualification of PBXN-109 as a main charge fill for the MK 83 GP bomb. Although the replacement of the present H-6 bombfill with PBXN-109 will solve most IM related problems, it can only be considered an interim solution since the sympathetic detonation criterion could not be met. Similarly, several heavy wall penetrators, such as the HARPOON and TOMAHAWK warheads, would greatly benefit from the development of an explosive with substantially reduced sensitivity to thermal, impact, and shock stimuli.

APPROACH: The key to the formulation of a sympathetic detonation resistant bombfill appears to be the elimination or, at least, substantial reduction of the RDX content, as the most shock sensitive component of present GP explosives. Since performance should be kept at or near the level of H-6 and PBXN-109, only a limited number of oxidizers are available if the cost of the fill is to be kept at an affordable level. After considering feasible candidates, such as Nitroguanidine (NQ), Nitrotriazolone (NTO), and Amino-dinitrobenzo-furoxan (ADNBF), NTO was selected. This decision was primarily based on data generated on this ingredient at the DOE and by French scientists. In order to accommodate large volume production, a melt-cast binder system based on a thermoplastic elastomer (TPE) was selected for initial formulation efforts. Intentions are to develop a sympathetic detonation and cook-off resistant explosive based mainly on NTO as oxidizer and aluminum as metallic fuel. In order to meet or approach the performance of H-6/PBXN-109 and to ensure reliable initiation, it is anticipated that the solids loading will have to be maximized and that a low percentage of nitramine (RDX) will have to be incorporated. Following small scale producibility studies and testing, the resulting formulation will be transitioned to a Pilot Plant for scale-up and loading of generic hardware and MK 82 bombs. Subsequently, large scale performance and vulnerability tests will be conducted and cooperative efforts with weapon programs will be initiated.

PROGRESS: While FY87 formulation efforts concentrated on a melt-cast bombfill with solids loads ranging from 80-84%, it became

obvious during the 4th quarter that the thixotropic character of TPE based mixes would not allow any further increase in solids, which seemed a prerequisite to approaching PBXN-109 performance while maintaining a relatively low percentage of nitramine (RDX). Therefore, a cast-cure binder system based on plastician (IDP) and hydroxyterminated polybutadiene (HTPB) was selected for further mixing studies. This change resulted in the successful processing of an 88% solids, low nitramine content explosive which can be reliably initiated to yield high order detonations in 4-5" diameter unconfined charges. This formulation, which has been designated PBXW-121, has been successfully mixed and cast in batches of up to 22 pounds. Firings of 3-5" diameter (16" long) cylinders, both confined and unconfined, showed a critical diameter of 3-4" for this low nitramine (5-10%) composition and detonation velocities similar to PBXN-109. Attempts to initiate an all-NTO (0% RDX), unconfined 5" diameter charge failed, while the identical charge under heavy steel confinement detonated with a rather low average velocity (5700 m/sec). For the remainder of FY88, fine tuning of the basic composition and determination of the critical initiation pressure, as well as preliminary performance tests (arena test/cylinder test) and a sympathetic detonation test, all using 8" diameter charges under heavy confinement, are planned.

PLANS (FY89-FY92): Plans and major milestones for the task by fiscal year are as follows:

FY89

- Complete small scale testing of finalized PBXW-121 formulation.
- Complete Pilot Plant scale-up studies.
- Procure 3000 lbs of NTO under contract.
- Request Qualification of PBXW-121 as a main charge explosive.
- Load generic hardware and several MK 82 bombs for large scale testing.
- Start large scale vulnerability tests using heavily confined charges.

FY90

- Complete vulnerability testing on generic units and MK 82 bombs loaded with PBXW-121.
- Document vulnerability test results.
- Start performance tests (blast, fragmentation) using generic test hardware and MK 82 bombs.

FY91-92

- Complete performance testing and documentation.
- Transition explosive to weapon developer.

Task Title: Metal Accelerating Explosives Task  
Task Number: 2003  
Principal Investigators: T. Spivak, NSWC/WO, Code R12, X1184  
T. Atienza Moore, NWC/CL, Code 3264,  
X7530  
L. Newman, NOS/IH, Code 2730A, X4635  
M. R. Senn, NOS/IH [NEDED]/Y, Code  
470H, X4717

**OBJECTIVE:** Advanced development of high-performance explosives for anti-air warheads, shaped charge designs, and submunitions.

**BACKGROUND:** In the past, explosives with optimized metal accelerating capability for high-performance anti-air warheads and shaped charge designs were primarily selected on a performance basis, disregarding vulnerability characteristics. Presently employed explosives such as Octol, LX-14, A-5, and A-3 need to be replaced with explosives of equal performance and reduced vulnerability. The development of castable, moderately energetic explosives such as PBXN-106, PBXN-107, and PBX(AF)-108 for fragment accelerating (mainly anti-air) warheads resulted in materials with overall satisfactory vulnerability behavior under fast cook-off conditions and for fragment impact velocities of 7500-8000 ft/sec. The criterion for slow cook-off, however, could not be met and sympathetic detonation behavior depends on the size and confinement of the warhead. The later developed PBXW-113 and PBXW-114 display similar vulnerability behavior with improved performance. Further increases in performance with, if possible, simultaneous reduction in sensitivity are highly desirable.

**APPROACH:** During FY85 two new high-performance explosives - the castable PBXC-126 (formulated with an energetic binder system) and the pressable PBXW-9 (based on a Hycar/DOA binder) - were transitioned into the 6.3 Advanced Development Project. These explosives are expected to show improved vulnerability behavior and performance as compared to PBXW-113 and to approach the performance of Octol 85/15 and LX-14. The latter are presently being considered for new shape charge designs based on their exceptional performance characteristics only. Small-scale producibility studies and preliminary sensitivity and performance tests will be conducted on both PBXW-9 and PBXC-126. They will be followed by pilot plant scale-up, loading of generic hardware, and large-scale safety and vulnerability testing in generic hardware such as heavy wall penetrator units, naturally fragmenting test units, and generic shaped charge designs. Performance tests conducted within the IMAD-HE Project will concentrate on shaped charge penetration testing. It is expected that these explosives will be ready for transitioning to weapon programs by the end of FY88.

In order to satisfy demands for even higher performance, low vulnerability explosives, promising new candidates emerging from the 6.2 Exploratory Development Program will be transitioned to 6.3 Advanced Development during the FY88-89 timeframe.

PROGRESS: Large scale vulnerability tests on PBXW-9 and PBXC-126 were completed. Both explosives reacted mildly under various confinements when exposed to fast cook-off. Slow cook-off condition resulted in detonations for PBXC-126 loaded generic test units while PBXW-9 showed only burning reactions, even under heavy confinement. Multiple bullet impact caused a mixture of deflagration and burning reactions. As to be expected for high performance explosives, Multiple Fragment Impact (MFI) led to detonations at fragment velocities above 7000-7500 ft/sec and both explosives sympathetically detonated in MK 64 configuration at PD<sub>50s</sub> of 3-4 inches.

Preliminary performance tests (FY87) with both explosives in SMAW warheads led to penetration depths which fell approximately 5-10% short of results obtained with Octol 85/15. Since consistent processing problems were encountered at this stage with both formulations (inhomogeneities and voids), it is hoped that these results can be improved upon. During FY88 processing difficulties were solved and PBXW-9 was scaled up to a 3000 pound batch by Holston AAP with excellent results. Performance tests with generic 3.2" shaped charges filled with PBXC-126 and PBXW-9 will therefore be conducted during the remainder of FY88 and the results compared with those obtained on LX-14 and Octol loaded generic test units.

Processing studies on PBXW-119 (energetic polymer/nitroplasticizer) and PBXW-120 (fluorocarbon polymer/energetic plasticizer) are in progress. It is expected that both of these high-performance explosives will also be tested in the generic shaped charge configuration during the remainder of FY88. One of these formulations will be selected for Pilot Plant scale-up during the first quarter of FY89.

PLANS: Plans and milestones for the task by fiscal year are as follows:

FY89

- Transition PBXC-129 (moderate to high performance, low vulnerability explosive) into advanced development, qualify finalized composition and transition to Pilot Plant.
- Complete generic shaped charge performance tests on units loaded with LX-14, Octol 75/25, W-9, C-126, W-113, W-119, and W-120.
- Complete vulnerability tests on generic shaped charges loaded with W-9 and C-126.

FY89 (Cont'd)

- Complete small scale processing studies and testing on PBXW-119 and PBXW-120 and select one formulation for Pilot Plant scale-up.
- Complete Pilot Plant scale-up studies on selected high performance explosive (PBXW-119/120).

FY90

- Load generic test units with PBXW-119 (120) and conduct large scale vulnerability and performance tests.
- Complete Pilot Plant scale-up studies on PBXC-129 and start S&V testing.

FY91-92

- Complete advanced development of PBXW-119 (120) and document test results.
- Complete S&V testing of PBXC-129; conduct performance tests and initiate transition efforts.

Task Title: Underwater Explosives  
Task Number: 2004  
Principal Investigator: Joel Gaspin, NSWC/WO, Code R14, X2204

OBJECTIVE: Advanced development of a low vulnerability, high performance explosive for underwater applications.

BACKGROUND: In the area of underwater explosives, the development of PBXN-103 doubled the lethal volume of torpedo warheads with some improvement in explosive sensitivity characteristics. However, neither PBXN-103 nor the later developed PBXN-105 which displays performance similar to PBXN-103 or PBXW-115 with somewhat lower performance and marginally improved vulnerability, satisfy the IM criteria cited in NAVSEAINST 8010.5. In addition to improved vulnerability, improvements in performance, specifically in bubble energy, are needed. Since the transitioning of a promising candidate explosive from the Navy's 6.2 program is not expected until 1991, an attempt is being made to identify a viable candidate using the expertise of private industry.

APPROACH: Proposals on the formulation and scale-up of high performance, low vulnerability underwater explosives will be solicited from private industry. Following the evaluation of proposed efforts, one or more contractors will be selected for the formulation of preliminary candidate explosives. While the actual process development will be done by industry, IMAD personnel will assist in initial formulation efforts and will evaluate the resulting explosives in-house by conducting small scale sensitivity and performance tests. It is expected that, following compositional adjustments, one promising explosive will be selected for scale-up and loading of generic hardware by the contractor. Generic test units will be supplied by the IMAD-HE Program and large scale tests will be conducted in-house.

Should a high bubble energy underwater explosive with substantially improved performance and vulnerability characteristics evolve from the in-house 6.2 Exploratory Development Program during the FY90-92 timeframe, it will be transitioned to the 6.3 phase for advanced development.

PROGRESS: Toward the end of FY87, a contract was awarded to MEGABAR Corporation to start the development of emulsion type explosives for underwater applications. However, during the first quarter of FY88, MEGABAR became involved in a litigation process with IRECO Corporation regarding the ownership of microcellular technology, which ultimately resulted in the closing of MEGABAR.

During the third quarter of FY88, a contract was awarded to Hercules, Inc. For the remainder of this fiscal year this incrementally funded project is expected to concentrate on a literature search specific to underwater explosives, consultation

with Navy and DOE experts, and formulation and testing of a high strain, urethane based energetic binder system.

PLANS (FY89-FY92): Plans and major milestones for this task by fiscal year are as follows:

FY89

- Complete small scale formulation of several UW explosive candidates at Hercules, Inc.
- Complete small scale testing of contractor supplied formulations at NSWC.
- Complete scale up of most promising candidate.
- Load generic hardware for large scale vulnerability and performance testing.

FY90

- Start large scale vulnerability and performance tests in generic hardware.

FY91-92

- Complete large scale testing and document test data.
- Start transition to underwater weapon systems.
- Introduce high bubble energy UW explosive into 6.3 advanced development.
- Complete processability studies and scale-up of high bubble UW explosive.

Task Title: Booster Explosives  
Task Number: 2005  
Principal Investigators: T. Atienza Moore, NWC/CL, Code 3264,  
X7530  
R. Moffett, NSWC/WO, Code R12, X1788

OBJECTIVE: Development of new booster materials with improved vulnerability characteristics.

BACKGROUND: The booster materials currently qualified for use in Navy weapon development programs do not fully achieve desired vulnerability characteristics, particularly in the cook-off environment. ADNBF-based explosive has demonstrated unusually benign reactions, even in a severely confined cook-off environment, while providing output energy and sensitivity levels suitable for use in a booster material. A formulation, designated PBXC-18, has been developed under the Exploratory Research (6.2) Program using ADNBF explosive with an inert binder based on an ethylene-vinyl acetate copolymer which appears to provide a significant improvement in vulnerability characteristics. This material has been evaluated to a point where it is ready to be developed by the IMAD-HE Program.

As part of their program to develop less sensitive munitions, the French have formulated an inexpensive, castable, cook-off resistant, plastic bonded (PBX) booster explosive. The formulation, designated B-2188, is described as having overall good vulnerability behavior, initiation characteristics, and boosting power. Based on this information, the IMAD-HE Program will evaluate B-2188 and assess its value and potential to solve some of the Navy's IM problems.

APPROACH: PBXC-18 will be further developed and evaluated within the IMAD-HE Program and, as soon as appropriate, it will be transitioned to the pilot plant and qualified for larger scale testing in generic and weapon system hardware. Initial activities will center on validating the composition and conducting small scale sensitivity, performance, and safety tests to more fully characterize the material. A draft specification will be prepared, and a report will be written, covering the development of PBXC-18 and such other information as may be necessary to transition this material to the pilot plant. Sufficient ADNBF explosive will be produced to provide a supply for this program and some other formulation development programs currently underway.

Through the existing DEA-A-77-F-1221 with France, contacts will be established with SNPE in order to obtain more information on the sensitivity, performance characteristics, and producibility of B-2188 and 200 pounds of this formulation will be purchased for preliminary evaluation and possibly qualification testing. If the generated data are favorable, the explosive will be

transitioned to advanced development and compared to in-house developed formulations (PBXW-7, PBXC-18) via large scale vulnerability and performance testing in generic hardware.

PROGRESS: This is a new start.

PLANS (FY89-FY92): Plans and major milestones for this task by fiscal year are as follows:

FY89

- Establish finalized composition for PBXC-18.
- Complete small scale processability study and testing.
- Transition PBXC-18 to the pilot plant for scale-up.
- Acquire 200 lbs of B-2188 from SNPE and conduct small scale vulnerability and performance tests.
- Qualify B-2188, if test data look promising, and negotiate with French Government to transfer technology to the U.S.

FY90

- Scale up PBXC-18 to suitable batch sizes (pilot plant) and evaluate processing and pressing characteristics.
- Request qualification of PBXC-18 as a booster explosive and start S&V testing.
- Conduct processability study on B-2188.
- Transition B-2188 to the pilot plant for scale-up and loading of generic hardware.

FY91-92

- Conduct large scale vulnerability and performance tests of PBXC-18, B-2188, and PBXW-7 in generic hardware and compare test data.
- Depending on outcome of large scale test series, initiate transition of PBXC-18 and/or B-2188 to various weapon programs.

Task Title: Explosive Processing Techniques  
Task Number: 2006  
Principal Investigators: F. Gallant, NSWC/WO, Code R11, X2861  
T. Mahoney, NWC/CL, Code 3262, X7567  
K. Newman, NOS/IH [NEDED]/Y, Code  
470F, X4718

**OBJECTIVE:** Develop new processing techniques to load high quality insensitive PBXs economically.

**BACKGROUND:** Difficulties with the processing and loading of PBXs into conventional munitions initially limited the use of those materials to low production rate, high technology weapons. More recent developments have demonstrated that PBXs can be readily loaded into some high volume production munitions (i.e., MK 83 GP bomb) at an affordable cost. Problems, however, still exist with respect to the high quality loading of relatively high viscosity PBXs into small shaped charges and submunitions and with the processing of novel binder systems, using conventional mixing/cast/cure techniques. Present efforts in the areas of continuous processing/extrusion and injection loading are aimed towards correcting these shortcomings.

**APPROACH:** Equipment that needs to be investigated and adapted to the processing of PBXs includes continuous processors and processor/extruders which are commercially available, and injection loading systems which are presently used by private industry for the processing of various plastic materials and by Kansas AAP for the loading of small munitions with low viscosity explosives (i.e., Octols). Both techniques will be developed and studied on a small scale at the laboratories, followed by processing demonstrations in larger setups at the pilot plants. Ultimately it is intended to transition the continuous processing technology to the SMCA for large scale production loading. Submunitions, shaped charges, and small missile warheads will be loaded with PBXs at a Navy production facility using the injection loading technique.

**PROGRESS:** Following the successful processing of PBXN-106 and PBXN-109 in a 37mm Werner Pfleiderer continuous mixer/extruder under contract (ICT/FRG) within the FY86/87 timeframe, the installation of a similar setup was completed at NSWC and the first live mix (PBXN-106) was processed during the second quarter of FY88. Installation of the modified 2" Teledyne Readco continuous processing system at NOS/IH [NEDED] was also completed. Trial runs with inert PBX simulants will be conducted during the remainder of this fiscal year.

A manually operated, small scale injection loading system at NWC/CL was first tested with live explosive near the end of FY87 by loading Rockeye bomblets with PBXC-126. Since then the conversion to an automated control and data acquisition system

has been accomplished and a vacuum shroud large enough to accommodate warheads up to the size of a DRAGON has been added. The design of a larger scale injection loading system to be installed at NOS/IH [NEDED] was continued. NEDED intends to adopt a modification of the Kansas AAP injection loader which was originally designed for the processing of low viscosity explosives. During FY88, Kansas AAP completed modifications and conducted trial runs with inert PBX simulants.

PLANS (FY89-FY92): Plans and major milestones for this task by fiscal year are as follows:

FY89

- Conduct processability studies on various explosives with the 37mm continuous mixer/extruder at NSWC.
- Process several explosives with the small scale injection loader at NWC/CL and load submunitions.
- Develop processing and data acquisition parameters for the continuous processing of PBXN-109 in the 2" continuous processor at NEDED.
- Develop an in-line composition analysis system for the 2" processor.
- Complete the design and installation of an injection loading system at NEDED.

FY90

- Continue processing and injection loading studies on new explosives with small scale laboratory setups (NSWC/NWC).
- Continue process development for the 2" continuous processor and develop a loading system NEDED.
- Conduct extended run studies to prove-out the process (2" Readco).
- Develop the injection loading process at NEDED using inert simulants and PBX explosives.

FY91-92

- Conduct continuous processing studies on melt-cast explosives (2" Readco).
- Continue testing of injection loading system at NEDED.
- Integrate the NEDED injection loading system with the continuous processor.

Task Title: Transition Efforts  
Task Number: 2007  
Principal Investigators: L. Montesi, NSWC/WO, Code R12, X2039  
T. Atienza Moore, NWC/CL, Code 3264,  
X7530  
L. Newman, NOS/IH, Code 2730A, X4453  
L. Leonard, NOS/IH [NEDED]/Y, Code  
470A, X4718

OBJECTIVE: Establish efforts with weapon development offices and other technology/program offices to facilitate the transition of new explosives technology into munition development programs.

BACKGROUND: The transfer of new explosives technology into munitions development is sometimes impeded by inadequate communication between the explosives developing community and the munitions developing community. In addition, there often exists a lack of confidence on the part of the munition developer in new technology. Yet, many instances will arise when both the IMAD-HE Project and the Weapons Program can mutually benefit from combining efforts. The new technology must be developed to the point that it is considered to be state-of-the-art and must be demonstrated to be relatively low-risk for munitions development. The efficient coupling of new high explosives technology with new fuze and warhead technologies provides the mechanism for developing the best technical and most economic munition designs.

APPROACH: Dialogs are established between the IMAD-HE Project and munition development offices to determine the developer's needs and to describe available technology. Where new high explosives technology is available to meet the defined requirements, either the technology will be transitioned directly, or if there is a concern regarding its readiness, a program will be negotiated to share costs for demonstrating the new technology. Typical IMAD Program contributions will include provision of technical data and recommendations, generation of draft material/processing documentation, assistance with the loading of initial test units, testing, and test evaluation.

PROGRESS: Transition efforts during FY88 included the recommendation and testing of less sensitive explosives for SMAW, DRAGON, HELLFIRE, APOBS, MK 82 fuze (FMU-139), M-42/M-77 submunition, and ADVANCED CLUSTER Submunition (BLU-97), as well as production loading support for the MK 83 bomb (PBXN-109) and qualification testing of two DOE explosives (LX-07/LX-14). Most of these projects were continuations of efforts initiated during the FY86/87 timeframe. During FY88, penetration requirements were met for SMAW (PBXC-126, two of three attempts), DRAGON (PBXW-113), and HELLFIRE (PBXW-113). Work on the M-77 grenade (ZUNI) was discontinued and the effort shifted to the virtually identical M-223/M-42 submunition used in the 16" projectile. Performance and SD tests on units loaded with PBXC-126 showed

excellent results. A series of vulnerability tests on BLU-97 (ADVANCED CLUSTER) bomblets proved that PBXs (i.e., C-126, AF-108, W-113, N-106, N-107) are superior in their SD behavior to the standard Cyclotol load, and fast cook-off tests resulted in burning reactions only. During the remainder of FY88, additional penetration tests will be conducted with HELLFIRE (W-113, C-126, W-9) and DRAGON warheads (W-113). In addition the performance of PBXW-9, PBXC-13, AND PBXW-7 in the M-42 submunition will be evaluated.

PLANS (FY88-FY92): Plans and major milestones for this task by fiscal year are as follows:

FY89

- Complete performance tests on SMAW, DRAGON, and HELLFIRE warheads loaded with PBXW-9, PBXC-126, and PBXW-113.
- Select main charge explosives for SMAW, DRAGON, HELLFIRE, and APOBS.
- Load 16" gun submunition with several PBXs and start performance and vulnerability testing.
- Provide support to the ADVANCED CLUSTER Munitions Program.
- Support the QUICKSTRIKE, MK 98 (MND), and AMNE programs in the area of Fuze/S&A development (PBXW-7).

FY90

- Complete vulnerability testing on HELLFIRE warheads, APOBS, and 16" gun submunition (cooperative programs).
- Support MK 50, 75mm, Follow-Through, ROCKEYE, and ADVANCED CLUSTER programs.
- Establish additional transition efforts.

FY91-92

- Transition PBXW-121 to GP-bomb (ABF) program.
- Initiate transition efforts with the HARPOON and TOMAHAWK program offices.
- Continue support under previously established cooperative efforts.
- Initiate transition efforts for new high performance (PBXW-119/120) and booster (PBXC-18/B-2188) explosives.

**SECTION III**  
**ORDNANCE**

### SECTION III

PROJECT ELEMENT: ORDNANCE

COORDINATOR: Thomas E. Swierk, Code G22  
Naval Surface Warfare Center  
Dahlgren, VA 22448  
Phone: (703) 663-8716/AV 249-8716

INTRODUCTION: While new policies and technical requirements related to insensitive munitions place much emphasis on incorporation of less sensitive energetic materials, that change alone does not always result in satisfying insensitive munitions requirements. Emerging technologies and mechanical design approaches, which can be incorporated into warhead case and fuze configurations, have been identified as candidates for investigation for providing improvements in insensitivity of munitions that cannot be achieved solely through changes in explosives. This project provides for a broad demonstration of these emerging technologies and design approaches to support surface and underwater ordnance systems which require IM fixes.

NAVY MISSION NEEDS: To successfully fulfill its mission, the Navy requires munitions that meet or exceed operational performance requirements while at the same time are not vulnerable to unplanned stimuli such as heat, shock or radiation.

STATUS OF TECHNOLOGY: Increasing emphasis has been placed on safety related issues in ordnance design work in recent years. In addition to the newer, less vulnerable PBX explosive formulations, concepts such as vented warhead cases and fuze boosters have been incorporated into some of our newer weapons. New materials technology has been applied in all aspects of ordnance design including materials that offer increased protection from hazardous weapon performance is an ever present development objective which often becomes an opposing objective to those safety issues such as insensitive munitions.

The development and adaptation of analytical models as efficient, easy-to-use design tools to assist the developer in the assessment of their components with respect to the insensitive munition requirement has long since been evolving. More work will continue in this area to particularly address the hazards unique to insensitive munitions. The use of new materials and material combinations has been and will continue to be exploited in ordnance design. Materials applications will focus both directly on the ordnance component and indirectly in the application to shielding and/or container areas. Technology relative to initiation components has matured enough in recent years to provide for many near term fixes for most weapon systems. However, far term solutions will be more challenging to develop as new weapon systems emerge.

APPROACH: Technology areas investigated under this task element will demonstrate new technology concepts in a wide range of generic hardware configurations and will also exploit the direct application of these concepts by demonstrating feasibility in weapon specific hardware. Generally, newer explosives with improved characteristics will be utilized. Explosive selection for each technology and/or weapon demonstration application will be based on recommendations from the IMAD HE task element. Large scale testing will be centered on demonstrating compliance with the specific IM requirements such as fast/slow cook-off, bullet/ fragment impact and sympathetic detonation. Additionally, performance testing will be conducted as needed to assess any performance impact of the new design concepts.

The ultimate goal envisioned by the exploitation of the new technologies is to transition these new concepts into the Navy's weapon systems. When the Navy's IM program was formulated in 1984, fifty-three munition groups were prioritized by the CNO Executive Board. This prioritization was updated in 1987. Technology will be aimed at providing solutions for ordnance-related IM demonstrations and ultimately transition opportunities for deficiencies of these prioritized weapons. Several applications directly related to many of these weapon systems have been identified for the various products identified for this task element and are summarized in Figure 1. An example of a technology transition schedule applicable to warhead concept investigations is shown in Figure 2.

To accomplish the objectives of the IMAD program, the ordnance task element will:

- a) Pursue warhead design concepts that depart from conventional warhead design methodology by emphasizing IM-related technology. Primary emphasis will be placed on incorporating alternate materials or material combinations to demonstrate improvements in shock and thermal characteristics without degradation in the performance characteristics.
- b) Demonstrate the potential of advanced initiation concepts for the use of extremely insensitive main charge explosives to solve the sympathetic detonation problems, especially for large warheads and bombs.
- c) Utilize the broad technology base for armor and lightweight, high strength materials to identify optimum materials for weapons systems applications including packaging and container applications.
- d) Demonstrate advanced fuze/initiation systems which will improve upon munition insensitivity.

# APPLIED IM TECHNOLOGY for NAVY ORDNANCE

<u>Products</u>	<u>Applications</u>	<u>Weapon Systems</u>
Dual-Explosive Warheads	<ul style="list-style-type: none"> <li>• Missile warheads</li> <li>• Torpedo warheads</li> </ul>	<ul style="list-style-type: none"> <li>• SM (MK 115 &amp; EX 125), Phoenix</li> <li>• MK 48</li> </ul>
Armor Warheads	<ul style="list-style-type: none"> <li>• Missile warheads</li> <li>• Torpedoes &amp; mines</li> </ul>	<ul style="list-style-type: none"> <li>• Tomahawk, Harpoon</li> <li>• MK 46 &amp; MK 48, Quickstrike</li> </ul>
Composite Warheads	<ul style="list-style-type: none"> <li>• Missile warheads</li> <li>• Torpedoes &amp; mines</li> </ul>	<ul style="list-style-type: none"> <li>• SM &amp; several AL missiles</li> <li>• SMAW, Dragon, mortars</li> <li>• MK 50, ASM, SLMM</li> </ul>
Reactive Warheads	<ul style="list-style-type: none"> <li>• Missile warheads &amp; Bombs</li> <li>• Torpedo warheads</li> </ul>	<ul style="list-style-type: none"> <li>• Tomahawk, Harpoon, GP Bombs</li> <li>• MK 50</li> </ul>
Liners & Venting Techniques	<ul style="list-style-type: none"> <li>• Missile warheads &amp; Bombs</li> <li>• Torpedo warheads</li> </ul>	<ul style="list-style-type: none"> <li>• GP Bombs, Harpoon, Tomahawk</li> <li>• MK 50</li> </ul>
Armor Materials	<ul style="list-style-type: none"> <li>• AUR containers &amp; magazines</li> </ul>	<ul style="list-style-type: none"> <li>• All VLS containers &amp; numerous missile applications</li> </ul>
Advance Initiation Concepts	<ul style="list-style-type: none"> <li>• Missile warheads &amp; Bombs</li> <li>• Torpedoes &amp; mines</li> </ul>	<ul style="list-style-type: none"> <li>• GP Bombs, Harpoon, Tomahawk</li> <li>• MK 50, ASM, SLMM</li> </ul>

FIGURE 1

# Warhead Technology Transition Schedule

Concept	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93
Composite Warheads	F/SCO	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
	B/FI	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
	SD	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
Reactive Case Warheads	F/SCO	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
	B/FI	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
	SD	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
Armor Protected Warheads	F/SCO	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
	B/FI	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
	SD	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
Dual-Explosive Warheads	F/SCO	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
	B/FI	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
	SD	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
Liners & Venting Techniques	F/SCO	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
	B/FI	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal
	SD	Diagonal	Diagonal	Diagonal	Diagonal	Diagonal

**Legend:**

- F/SCO - Fast / Slow Cook-Off
  - B/FI - Bullet / Fragment Impact
  - SD - Sympathetic Detonation
- 
- Technology available for any applicable weapons
  - Technology available for some applicable weapons
  - No Technology available for applicable weapons

Figure 2

e) Establish and maintain a dialog with weapon offices to facilitate the transition of new technology to specific applications.

PROJECT ELEMENT STRUCTURE: The project element has been organized into six primary task areas. Several subtasks have been identified for these task areas in which work may be pursued independently or in conjunction with companion subtasks. A list of task areas and subtasks and the performing activities for this project element is shown below:

- 3001        Program Coordination (NSWC)
- 3002        Warhead Design Technology
  - A.    Reactive Case Warheads (NSWC)
  - B.    Dual-explosive Warheads (NSWC)
  - C.    Armor-protected Warheads (NSWC)
  - D.    Composite Underwater Warheads (NSWC)
  - E.    Warhead Venting Concepts (NSWC)
  - F.    Stress Riser Concepts (NWC)
  - G.    Explosive Cook-off Pressure Confinement Evaluation (NWC)
- 3003        Advanced Initiation Technology
  - A.    Radial Booster Concepts (NWC)
  - B.    Flyer Plate Concepts (NWC)
  - C.    Plane Wave & Bimodal Explosive Concepts (NSWC)
- 3004        Applied Materials & Shielding Technology
  - A.    Materials Research & Field Testing (NSWC)
  - B.    Fragment Hazard Methodology & Shielding Concepts (NWC)
  - C.    Sympathetic Detonation Fragment Characterization (NWC)
- 3005        Packaging & Container Technology
  - A.    Container Design & Fabrication (NWC/E)
  - B.    Container T&E (NSWC)
- 3006        Technology Transition / T&E Support
  - A.    NSWC Weapon Program Support
  - B.    NWC Weapon Program Support

PROJECT ELEMENT SCHEDULE: Detailed milestones associated with the individual task areas are included in the sections that follow, however, significant milestones associated with the overall project element are listed below:

FY89 - Conduct full scale testing of IMAD warhead designs and cooperatively demonstrate technology with weapon-specific hardware.

Continue to investigate shock and thermal response potential of various reactive materials. Select explosives for the dual-explosive warhead concept, formulate warhead designs and screen candidates based on a performance comparison (test and analysis) against conventional single explosive warheads. Conduct large scale tests (bullet/fragment impact) of select dual-explosive warheads. Formulate design options for passive armor protected warheads and screen candidates based on a performance comparison (test and analysis) against conventionally designed warheads.

Composite case structures of varying material types and sizes will be fabricated with an integral honeycomb design and configured similar to existing underwater ordnance items. Hazard testing will be conducted to demonstrate improved vulnerability characteristics. Cook-off mitigation techniques which specifically address venting mechanisms that utilize eutectic materials will be investigated. Determine the minimum pressure that insensitive PBX explosives can be contained at during cook-off without undergoing a transition to detonation.

The existing modified MK 28 flying plate leads will first be tested to determine plate velocities and plate break-up characteristics as functions of plate material, plate curvature, and driving explosive. Efforts will be initiated to optimize the interfaces between insensitive boosters and main charge explosives and on flying plate axial boosters.

Several initiation techniques will be compared for their ability to properly initiate explosives that are insensitive formulations with relatively large failure diameters.

Emphasis will be placed on providing specific recommendations for barriers/shields/containers and documenting recommended manufacturing procedures to convert the materials into hardware items.

Evaluate DYNA2D, EPIC2, and MESA2D for handling modeling of sympathetic detonation and fragment impact response.

Identify opportunities for technology transition, coordinating cooperative demonstration programs with weapon program offices.

FY90-92 - Conduct full scale testing of technology concepts and conduct demonstrations of weapon ordnance items to support technology transitions. Identify opportunities for technology transition and coordinate cooperative demonstration programs with weapon program offices.

LONG RANGE PLANS (FY92-FY95): Since the IMAD program objectives are geared toward complete transition to insensitive munitions by FY95, the near-term plans are directed toward having technologies demonstrated by FY92 so they can be qualified into weapon systems by FY95. Completion of demonstrations prior to FY90 represents only initial demonstrations. Long range plans include follow-on investigations, development, and demonstrations of alternate materials and design concepts under the investigations currently planned. Lower cost improvements will be demonstrated and user support will be provided. In addition, promising new approaches, yet to be identified, which can be engineered into systems that are to enter the fleet after FY95, will be investigated.

Task Title: Coordination and Technical Direction  
Task Number: 3001  
Principal Investigator: Thomas E. Swierk, NSWC/D, Code G22, x8716

OBJECTIVE: Provide for sponsor liaison and overall coordination of the objectives of the Ordnance Task Element and coordinate with the other IMAD project elements.

BACKGROUND: The organization of the IMAD program by NAVSEA identified NSWC to coordinate the element of the effort that focuses on IM technologies for all ordnance items (warheads and fuzes). Identification of this broad investigative area as a major project element of the IMAD program necessitates having a task responsible for the management of a support organization and for the coordination of and liaison with external activities. This task establishes a program office to provide for that support.

APPROACH: Establish and maintain an administrative staff, technical support and program structure that will result in timely development and demonstration of promising technologies to meet the IM requirements. Attend necessary meetings/conferences, coordinate technology exchange meetings/workshops, ensure the transitions of new technology to weapon developers, prepare/present plans and/or reports and provide for other inputs required by the sponsoring agencies.

PROGRESS: The task has resulted in coordination with NAVSEA, other DoD activities, contractors, and NSWC personnel through many informal meetings to support the objectives of the project element. Personnel were identified and committed to support all of the planned tasks of the project element. The annual budget was closely monitored to ensure the timely execution of program tasks. The execution of this task also provided for program plan updates, progress reports and other planning/ reporting documents as required by NAVSEA. Restructuring of the IMAD program in FY 88 required that this task element be reorganized, resources identified and a new program plan written.

PLANS (FY89-FY91): Plans and major milestones of the task are directed toward having IM technologies developed and demonstrated through the supporting investigative tasks in time to provide for engineering of these technologies into munitions in the FY91-95 timeframe.

LONG RANGE PLANS (FY92-FY95): Long range plans include providing transition of demonstrated technologies into qualified munition configurations to satisfy the FY95 goals. In addition, more advanced IM technologies will be identified. Demonstrations of these advanced technologies will be completed for use in development of ordnance items for fleet introduction beyond FY95.

Task Title: Warhead Design Technology  
Task Number: 3002  
Principal Investigators: Paul E. Bolt, NSWC/D, Code G22, x8716  
David R. Crisp, NSWC/D, Code G22, x8716  
Katherine M. Ruben, NSWC/WO, Code U11, x1861  
Thomas J. Gill, NWC/CL, Code 3261, x7282  
Jack M. Pakulak, Jr., NWC/CL, Code 3262, x7262

OBJECTIVE: This task is subdivided into several subtasks which address new and/or alternate warhead design concepts that could lessen the susceptibility of various types of warheads to the wide range of IM threats which include fast/slow cook-off, bullet/fragment impact, and sympathetic detonation events.

BACKGROUND: The foundation of traditional warhead design has been to offer the maximum lethality possible for weapon effectiveness without sacrificing weapon system safety. IM initiatives have added new dimensions to weapon system safety, thereby making the opposing performance and safety design criteria that much more difficult to reconcile. Many of the established warhead design techniques may not be good enough to permit compliance with the IM requirements in the future. Novel ideas and concepts must be examined as a means of achieving IM compliance without sacrificing performance (i.e., overall weapon system effectiveness). When exploited judiciously, these new technologies may even yield both enhanced performance and safety characteristics.

APPROACH: Warhead design concepts that depart from conventional warhead design methodology by emphasizing IM-related technology will be pursued. Primary emphasis will be placed on incorporating alternate materials or material combinations to demonstrate improvements in shock and thermal characteristics without degradation in the performance characteristics when compared to conventional warhead designs. The basic approach for the individual subtasks include the following:

- A. Reactive Case Warheads - Warheads which use reactive materials as energy absorbing materials to help mitigate the effects of shock-induced stimuli. Porous aluminum and other low density compositions will be evaluated as reactive/energy-absorbing components.
- B. Dual-explosive Warheads - Warheads which utilize two explosives (layered) with significantly different output and vulnerability characteristics.
- C. Armor-protected Warheads - Warheads utilizing an outer layer of an armor composite material, typically a ceramic with a high strength, non-metallic encasement.

D. Composite Underwater Warheads - Warheads which utilize a composite/honeycomb case structure of varying thickness and material composition.

E. Warhead Venting Concepts - Techniques to vent the warhead products of combustion during cook-off events utilizing various temperature sensitive materials within prefabricated vent ports.

F. Stress Riser Concepts - Techniques to vent the warhead products of combustion utilizing longitudinal stress risers to facilitate substantial case opening. Data will be obtained on the failure mode and related contributing factors to the functioning of stress risers in generic warheads. Evaluation of the predicted failures and actual tested failures will lead to the development of guidelines by which stress risers may be designed.

G. Explosive Cook-off Pressure Confinement Evaluation - Techniques to determine the critical confinement pressures of insensitive explosives especially in the slow cook-off environment.

PROGRESS: Initial work with composite warhead designs was conducted in FY86-87. These warheads consisted of a filament-wound inner cylinder overlaid with a mat of preformed fragment cubes and an outer cylinder which was also filament-wound. The basic configuration was that of the NFTU. Three types of high strength filaments (KRP, carbon, and S2 glass) and several bonding techniques were chosen as the design variables. Limited testing demonstrated that warhead performance would not be compromised by employing this type of design approach. Testing was conducted which also demonstrated that this type of warhead was not vulnerable to the fragment impact threat. Other prior efforts pertinent to the planned subtasks include the following:

A. Reactive Case Warheads - Material source investigations and design support efforts were initiated and initial warhead design concept studies were completed in FY 88. Generic test hardware (8-inch) was fabricated and large scale testing (fragment/bullet impact) was conducted with improved vulnerability characteristics demonstrated. Concerns with scaling effects indicate a need to establish a better understanding of the theoretical base (shock response of the reactive materials). Sponsoring agencies and weapon offices responsible for potential applications such as Harpoon and Tomahawk were briefed on the potential IM benefits of this warhead concept.

B. Dual-explosive Warheads - Selection of an initial warhead design (explosive combination and quantities) was made and hardware was fabricated and loaded in FY 88.

Testing to be completed by the end of FY 88 included a performance assessment with 8-inch warheads and vulnerability tests (fragment impact) with 11-inch warheads.

C. Armor-protected Warheads - Several preliminary designs have been completed. No hardware has been fabricated but heavy wall penetrator test units are available for modification if needed for future testing.

D. Composite Underwater Warheads - None, prior task efforts did not address composite case structures for underwater applications.

E. Warhead Venting Concepts - None, new subtask.

F. Stress Riser Concepts - None, new subtask.

G. Explosive Cook-off Pressure Confinement Evaluation - None, new subtask.

PLANS (FY89-FY91): Plans and major milestones of the task by fiscal year are as follows:

FY89

A. Reactive Case Warheads - Continue to investigate shock and thermal response potential of various materials in the expanded materials data base. Conduct velocity prediction verification testing of advanced materials. Document results of prior large scale testing. Continue fragment size and multiple fragment effects studies.

B. Dual-explosive Warheads - Select explosives for the dual-explosive warhead concept, formulate warhead designs and screen candidates based on a performance comparison (test and analysis) against conventional single explosive warheads; conduct large scale tests (bullet/fragment impact) of select dual-explosive warheads.

C. Armor-protected Warheads - Formulate design options for passive armor-protected warheads and screen candidates based on a performance comparison (test and analysis) against conventionally designed warheads.

D. Composite Underwater Warheads - Screening tests will be performed on composite sandwich structures (panels or cylinders). Composite case structures of varying material types and sizes will be fabricated with an integral honeycomb design and configured similar to existing underwater ordnance items. Hazard testing will be conducted to demonstrate improved vulnerability characteristics for shock and thermal stimuli.

E. Warhead Venting Concepts - Cook-off mitigation techniques which specifically address venting mechanisms that utilize eutectic materials will be investigated. Various types of materials, material quantities and vent port sizes will be considered. The generic underwater test unit will be used as the test vehicle.

F. Stress Riser Concepts - A small scale generic warhead will be designed/fabricated and used as a test model. These warheads will be fabricated using two different materials - a ductile steel and a relatively hard steel. Stress risers of various sizes and configurations will be cut into the test items. A rupture due to internal pressure will be predicted by standard equations and numerical methods. The accuracy of the predictions will be determined by pressurizing the test items until failure occurs. From these data, guidelines for sizing and placement of stress risers will be developed. The final part of this work will be to determine the effects of stress risers on warhead performance.

G. Explosive Cook-off Pressure Confinement Evaluation - This task will determine the minimum pressure that insensitive PBX explosives, such as PBXN-109, can be contained at during cook-off without undergoing a transition to detonation. During FY88, a standard slow cook-off bomb was modified so that it would burst at any desired pressure. Selected PBX explosives will be cast into these bombs and tested through a range of burst pressures. The maximum safe pressure for each of the explosives in slow cook-off will thus be determined. For those explosives which exhibit violent reactions at unacceptably low levels of pressure confinement, a follow-on effort will be initiated to attempt to identify liners and/or liner additives which can increase the safe pressure confinement levels. Additionally, the effects of outgassing agents in liners will be tested since these materials have been demonstrated to aid in the controlled rupture of warhead cases using stress risers.

#### FY90-91

A. Reactive Case Warheads - Complete fragment size and multiple fragment effects studies and start design applications of advanced reactive case warhead concepts. Conduct additional vulnerability testing as necessary to demonstrate concept suitability.

B. Dual-explosive Warheads - Complete all testing on the first two dual-explosive candidate configurations. Based on the results of this test series, two to four additional configurations will be formulated. Fabrication, loading, and a complete test series of at least one or two new configurations is planned.

C. Armor-protected Warheads - Complete all tests of the first two configurations. Generate up to three additional compromise configurations. Conduct complete IM testing on the new candidate configurations. Complete specific design for a warhead application.

D. Composite Underwater Warheads - Several composite sandwich structures representative of underwater warhead cases will be built. Hazard tests to determine the degree of improvement will continue. The standard for comparison will be existing data on current weapon systems. Analysis of test results may lead to design changes to improve weapon vulnerability characteristics. Additional hardware incorporating similar features for tactical warheads may be fabricated and tested.

E. Warhead Venting Concepts - Several warhead cases will be built utilizing the various types of temperature sensitive venting systems. Cook-off tests to determine the degree of improvement will continue. The standard for comparison will be existing data on current weapon systems. Additional hardware incorporating similar features for tactical warheads may be fabricated and tested.

F. Stress Riser Concepts - Technology investigations begun in FY89 will continue to completion as the merits of this concept should be demonstrated and available for transition to specific weapon applications.

G. Explosive Cook-off Pressure Confinement Evaluation - Technology investigations begun in FY89 will continue to completion as the merits of this concept should be demonstrated and available for transition to specific weapon applications.

LONG RANGE PLANS (FY92-FY95): Long range plans include providing support to expedite the transition of innovative technology into the Navy's warheads for fleet munitions. In addition, new and more advanced warhead concepts will be investigated for demonstrations, as appropriate, for munitions planned for introduction beyond FY95.

Task Title: Advanced Initiation Technology  
Task Number: 3003  
Principal Investigators: Dr. C.D. Lind, NWC/CL, Code 3262, x7528  
Joseph Etoch, NWC/CL, Code 3356, x7611  
Robert Moffett, NSWC/WO, Code R12, x2029

OBJECTIVE: This task is divided into four subtasks with the following objectives:

A. Radial Booster Concepts - Develop, demonstrate, and optimize radial output booster technology for application to all new fuze designs with possible application to current fuzes with marginal reliability or for boosters which must use more insensitive materials.

B. Flyer Plate Concepts - Develop, demonstrate, and optimize flying plate lead technology for application to all new fuze designs with possible application to current fuzes with marginal reliability or for boosters which must use more insensitive materials.

C. Plane Wave & Bimodal Explosive Concepts - Evaluate various boosting techniques to determine the most efficient method to initiate insensitive explosives. Initial emphasis will be centered on plane wave and bimodal explosive techniques and slapper initiation technology. Other technology areas such as multi-point initiation systems and implosion techniques will also be pursued.

BACKGROUND: IM technology is being developed to reduce the susceptibility of ordnance to fast/slow cook-off, bullet/fragment impact and sympathetic detonation. Advanced initiation concepts will be required for the use of extremely insensitive main charge explosives to solve the sympathetic detonation problems, especially for large warheads and bombs. Radial output boosters have particular application to Phoenix, Sparrow, Shrike, and Standard Missile. Flying plate boosters would be especially useful for AMRAAM, Harpoon, Tomahawk, Maverick, and GP Bombs. Other initiation concepts will also have widespread application to a variety of weapon systems.

APPROACH:

A. Radial Booster Concepts - Initial efforts will concentrate on radial output booster designs. Units will be fabricated, loaded and tested against main charge explosives which are especially difficult to reliably initiate. The boosters will be designed to be compatible with the flying plate leads being developed under a companion subtask. Testing will be conducted to complete the evaluation of MK 28 flying plate leads.

B. Flyer Plate Concepts - Candidate designs will be optimized through a series of tests to evaluate the major design parameters of plate material, thickness, radius of curvature, diameter and type of explosive.

C. Plane Wave & Bimodal Explosive Concepts - Evaluate the ability of various boosting techniques to properly initiate current and representations of future insensitive explosives. Computationally compare the ability of the best boosting techniques to optimize design variables.

PROGRESS:

A. Radial Booster Concepts - Modified MK 28 flying plate leads were obtained. The modifications included using stainless steel in place of aluminum and testing three different plate curvatures. These leads were loaded with PBXW-7, HNS, and CH-6 explosives. A preliminary design was made for a radial output booster.

B. Flyer Plate Concepts - Initial efforts concentrated on the MK 8 size lead because it would fit within a bomb fuze booster. Five flying plate materials were tested against several booster explosives using vented booster hardware. These tests were unsuccessful because the MK 8 lead proved to be too small to reliably function.

C. Plane Wave & Bimodal Explosive Concepts - None, new subtask.

PLANS (FY89-FY91): Plans and major milestones of the task by fiscal year are as follows:

FY89

A. Radial Booster Concepts - The existing modified MK 28 flying plate leads will first be tested to determine plate velocities and plate break-up characteristics as functions of plate material, plate curvature, and driving explosive. The best combinations will then be tested using actual boosters. This work will be coordinated with other subtasks and with the GP Bomb program to develop insensitive fuze boosters. Efforts will be initiated to optimize the interfaces between insensitive boosters and main charge explosives and on flying plate axial boosters.

B. Flyer Plate Concepts - Hardware will be fabricated and tested using high speed photography and other instrumentation to evaluate performance of the leads as functions of several parameters. The best design(s) will then be tested to determine their ability to reliably initiate a variety of insensitive booster explosives. This work will be coordinated with the GP Bomb program to develop insensitive fuze boosters.

C. Plane Wave & Bimodal Explosive Concepts - To develop the required data, several initiation techniques will be compared for their ability to properly initiate explosives such as PBXN-103, PBXW-115, and PBXW-121. The selected explosives are current, insensitive formulations with relatively large failure diameters which are representative of future (developmental) insensitive explosives. In addition to the experimental tests, computational methods will be used to help optimize the boosting techniques, especially those that show the most promise.

FY90-91

A. Radial Booster Concepts - Technology investigations begun in FY89 will continue to completion as the merits of this initiation concept should be demonstrated and available for transition to specific weapon applications.

B. Flyer Plate Concepts - Technology investigations begun in FY89 will continue to completion as the merits of this initiation concept should be demonstrated and available for transition to specific weapon applications.

C. Plane Wave & Bimodal Explosive Concepts - Technology investigations begun in FY89 will continue to completion as the merits of these various concepts should be demonstrated and available for transition to specific weapon applications.

LONG RANGE PLANS (FY92-FY95): Long range plans include providing support to expedite the transition of advanced fuze and/or initiation technologies into fleet munitions. In addition, new and more advanced IM initiation technologies will be investigated for demonstrations, as appropriate, for munitions planned for introduction beyond FY95.

Task Title: Applied Materials & Shielding Technology  
Task Number: 3004  
Principal Investigators: Dr. Benjamin D. Smith, NSWC/D, Code R35, x8901  
Martha Wagenhals, NWC/CL, Code 3894, x2206  
Eric Lundstrom, NWC/CL, Code 3894, x2206

OBJECTIVE: This task is divided into three subtasks with the following objectives:

A. Materials Research & Field Testing - Incorporate advanced materials into the design of weapon system components, including but not limited to warheads, warhead shrouds and/or protective shields, and shipping/stowage containers for the purpose of minimizing thermal and shock responses in events such as cook-offs and fragment/bullet impacts, while maintaining high levels of operational performance.

B. Fragment Hazard Methodology & Shielding Concepts - Develop a methodology which can be used by the design community to estimate which portion of the fragment hazard spectrum and associated shock hazard to which their weapon is vulnerable, compare the areas of vulnerability with their anticipated fragment/shock environment to determine if they need additional protection to prevent inadvertent initiation of their weapon, and to provide a means of estimating the degree of protection required.

C. Sympathetic Detonation Fragment Characterization - Develop a design methodology for specifying energetic material sensitivity requirements to enable munitions to survive the hazards associated with the sympathetic detonation environment.

BACKGROUND: The insensitivity of munitions can be improved by the use of new, lightweight, high strength, thermal and shock resistant materials. These materials may serve many purposes in weapon design. Weapon systems will often incorporate several different materials in varying thickness and configurations. The optimum selection of each material type, thickness and configuration for a variety of applications as well as identifying material sources and fabrication/assembly methodology are all critical considerations and will be incorporated into weapon design guidelines. The large number of warheads will require a variety of materials and configurations to address both the IM and performance characteristics. A combination of judicious material selection and munition/container design is required to fully demonstrate the potential for IM improvements in armored and lightweight munition design. An integrated systems engineering approach is required.

APPROACH:

A. Materials Research & Field Testing - The broad technology base for lightweight, high strength materials forms a sound foundation for the application of these materials to numerous weapon systems. Material characterizations coupled with laboratory and field testing are designed to develop a material data base from which the best material of construction and/or protective materials (i.e., barriers, shields) can be integrated into specific designs. This subtask provides the material characteristics data, the level of protection that can be achieved against the various threats, and acceptable manufacturing procedures to weapon system designers and manufacturers.

B. Fragment Hazard Methodology & Shielding Concepts - The framework for the materials/shielding methodology exists. There are four parts to the methodology and include:

- 1) producing a fragment environment definition by developing a "threat map" for each specific fragment source;
- 2) determining the detonation sensitivity of each component of the weapon to predict vulnerable regimes which involve developing hazard plots for each weapon component containing an energetic material;
- 3) quantifying the predictions by determining the probability of being hit by detonation causing fragments;
- and 4) establishing a data base of shielding material properties to analytically estimate which material and material thickness, or combination of materials, is required to slow down and break up the hazardous fragments, and to provide an estimate of the degree of risk associated with each suggested level of protection. This requires characterization of armor materials to provide equation-of-state data. Ballistic characterization tests and computer modeling of results is needed on an iterative basis to develop the model for the materials and a similar test/model scenario is needed for developing an improved model for the penetration mechanics of armor materials and their ability to degrade the effects of the hazardous fragments.

C. Sympathetic Detonation Fragment Characterization - Determine the shapes and sizes of fragments at the close-to-origin distances occurring during sympathetic detonation events.

PROGRESS:

A. Materials Research & Field Testing - Efforts during FY 86-88 identified a variety of structural materials and armor materials. A number of tests were conducted to more fully characterize these materials with respect to aiding in the compliance with the IM requirement. A systems approach was

initiated to fully integrate these materials into warhead case design concepts and protective hardware such as shipping containers, barriers and shrouds. Specific accomplishments include identifying fabrication procedures, conducting gas gun tests, fragment simulator projectile tests, fragment impact tests (FI), and sympathetic detonation tests. A number of specific weapon system applications have been investigated. A major effort has been to interface with other weapon system project offices to apply the materials technology to all weapon systems currently in the fleet or planned to be deployed in the near future.

B. Fragment Hazard Methodology & Shielding Concepts - All elements of the hazard methodology are in place but require substantial amplification and validation. Characterization data on nine munitions are in the computer data base. The basic elements for preparing threat maps and hazard plots are in place. Several different penetration/response computer programs are being used and evaluated for their applicability to this methodology. Methods to account for various real world factors have been investigated and partially implemented. Sympathetic detonation analyses are being conducted for weapon program offices based on this methodology.

C. Sympathetic Detonation Fragment Characterization- None, new subtask.

PLANS (FY89-FY91): Plans and major milestones of this task by fiscal year are as follows:

FY89

A. Materials Research & Field Testing - Emphasis will be placed on providing specific recommendations for barriers/shields/containers and documenting recommended manufacturing procedures to convert the materials into hardware items. Specific areas will include: a) improving the performance of ceramics used as curved-surface tiles by selecting base materials of higher purity, packing density and hardness; b) fabrication of cylindrical-shaped KRP or S-2 glass GRP to serve as the inner protective barrier (nearest the explosive); c) incorporation of other non-metallic shock-absorbing materials and documentation of the fabrication procedures using sheet and granular forms; 4) provide support to warhead design related subtasks as requested.

B. Fragment Hazard Methodology & Shielding Concepts - Add other warhead characterizations to the data base and automate the preparation of threat maps basing them on fragment data bases. Set up the methodology for generation of hazard plots and document. Evaluate DYNA2D, EPIC2, and

MESA2D for handling modeling of sympathetic detonation and fragment impact response. Establish test procedures, conduct tests and model the results. Develop fragment/warhead scale models for testing of energetic material response to fragment impact for proof-of-concept testing. Conduct scale model proof-of-shielding-concept sympathetic detonation tests. Model/verify small scale test results and complete computer methodologies.

C. Sympathetic Detonation Fragment Characterization - Generic naturally fragmenting and/or heavy wall penetrator warheads will be statically detonated; and specially modified x-ray techniques used to observe fragment formation, shapes, sizes, velocities, and orientations. If it is determined that the fragments at typical warhead-to-warhead stowage separation distances are significantly different (physically) than at the longer characterized distances, then work will be proposed to model and test the effects these near field fragments have on the sympathetic detonation of warheads and bombs.

FY90-91

A. Materials Research & Field Testing - Continue prior efforts with emphasis on the evaluation of thermoplastic materials in combination with the established armor materials. It is anticipated that better performing ceramics will become available either because of improved fabrication procedures or a blending of ingredients to improve the material properties.

B. Fragment Hazard Methodology & Shielding Concepts - Validate the methodology and selected shielding concepts for full scale (in containers) sympathetic detonation testing and document results.

C. Sympathetic Detonation Fragment Characterization - None.

LONG RANGE PLANS (FY92-FY95): Long range plans include providing for any support necessary to expedite the transition of high-strength, lightweight structural and armor materials into Navy munitions designs or shielding concepts. In addition, new and more advanced materials and their associated fabrication methodology will be investigated for demonstration, as appropriate, for munitions planned for introduction beyond FY95.

Task Title: Packaging & Container Technology  
Task Number: 3005  
Principal Investigators: S. Petoia, NWS/E, Code 8021, x2840  
C. Han, NWC/E, Code 8021, x2843  
D. MacLeod, NWS/E, Code 8021, x2841

OBJECTIVE: Investigate and provide packaging and/or container alternatives which will reduce the vulnerability of Navy munitions when subjected to unplanned stimuli resulting from fire, shock, fragment or bullet impact, electrostatic discharge or electromagnetic radiation.

BACKGROUND: For a number of munitions it will be difficult, if not impossible, to fully comply with the IM requirements through incorporation of less sensitive explosives, mitigation devices, or redesign within the specified timeframe (especially for the fragment impact and sympathetic detonation threats). The redesign of packaging and/or container items may solve or alleviate some of the remaining problems.

APPROACH: Investigate the effectiveness of current packaging to protect munitions from unplanned stimuli by conducting performance testing and evaluating the results. Where shortfalls exist, develop and validate alternatives that provide the required degree of protection. Recommendations will be provided to the weapon program managers.

PROGRESS: This task has been narrowed to the investigation of protection against the bullet impact, fragment impact and sympathetic detonation threats without adverse effects to the transportation, handling and storage functions. The munitions with known problems have been prioritized and efforts have begun to address these weapons. A generic container has been designed for testing new concepts in munition protection. Mathematical modeling is planned for the evaluation of protective materials for these new containers.

Additionally, the following items have been accomplished: prioritized weapons into appropriate categories based on the level of vulnerability against the broad IM threat spectrum, met with industry representatives to explore new barrier/dunnage materials, provided extruded sidewall specimens to NSWC for testing to establish baseline bullet/fragment impact data on materials used for container designs, conducted limited slow cook-off testing on a typical steel container to establish baseline thermal data, coordinated a thermal study at NSWC to simulate fast cook-off of a containerized weapon, and assisted in the preparation of proposals for the development of new containers which improve the resistance against the IM threats.

PLANS (FY89-FY92): Plans and major milestones of this task by fiscal year are as follows:

FY89

Review and evaluate new/improved barrier and dunnage materials for packaging, design and fabricated generic containers for demonstration tests, prepare IM test plans/procedures for container evaluations/demonstrations, conduct field tests at NSWC to demonstrate IM improvements with respect to containers/container materials, continue work on the needs addressed in the prioritization of munitions for this task, coordinate with program managers on specific IM container requirements, monitor IM hazard tests of containerized weapons, and provide assistance to weapon managers in the preparation of IM proposals/POAMs for containers and/ or packaging.

FY90-92

Continue work on the needs addressed in the prioritization of munition containers for the packaging/container task and incorporate "lessons learned" into Navy packaging/container design requirements such as a MIL-SPEC/STD document.

Task Title: Technology Transition/T&E Support  
Task Number: 3006  
Principal Investigators: William H. Grigsby, NSWC/D, Code G22, x8716  
John Fontenot, NWC/CL, Code 3208, x7234

OBJECTIVE: Exploit opportunities to transition new IM technologies as appropriate to Navy weapons. Additionally, provide support to principal investigators, as needed, for their T&E programs.

BACKGROUND: Many instances will arise when both the IMAD and weapon programs can mutually benefit from joint test programs. Typical instances will include performing demonstration of IMAD concepts in weapon system ordnance sections and assisting weapon offices in planning technology transitions. It may also be desirable to have one program or the other collect additional or specialized data in tests planned for other purposes.

APPROACH: Establish and maintain a dialog with weapon offices to facilitate the transition of a new technology to specific applications. Assist potential customers (weapon developers/program offices) in planning cooperative programs to demonstrate IM technology advancements that would apply to specific weapons. These efforts would often be mutually beneficial - significant technical data would be obtained for the IMAD program and IM solutions would be identified/demonstrated for the weapon system to solve an IM deficiency. This task will also provide support to other principal investigators by coordinating hardware fabrication, explosive loading and test scheduling, as requested.

PROGRESS: The technology transition efforts have continued at both NSWC and NWC with initial contacts made with personnel associated with the following programs: Standard Missile, Vertical Launch System, SMAW, Advanced Sea Mine, Mine Neutralization System, 16"/50 gun ammunition, Harpoon, Tomahawk, HARM, Sparrow, Phoenix, AMRAAM, GP bombs, Maverick, Smokeye, Walleye and the Advanced Cluster Munition. It is anticipated that many other programs will share in this technology program in the future. Technical advances put forth by the above task elements should materialize into transition demonstrations or programs coordinated through this task element.

PLANS (FY89-FY92): Future plans of this task include continuing efforts to identify opportunities for technology transition and to coordinate cooperative demonstration programs with weapon program offices.

LONG RANGE PLANS (FY93-FY95): Long range plans include providing transition of demonstrated technologies into qualified munition configurations to satisfy the FY95 goals. In addition, more advanced IM technologies will be identified. Demonstrations of these advanced technologies will be completed for use in development of ordnance items for fleet introduction beyond FY95.

**SECTION IV**  
**PROPELLANTS/PROPULSION**

## SECTION IV

PROJECT ELEMENT: PROPELLANTS/PROPULSION

COORDINATOR: Andrew C. Victor, Code 32051  
Naval Weapons Center, China Lake, CA  
TEL: (619) 939-7391/AV 437-7391

INTRODUCTION: The propellant in missile rocket motors and in gun ammunition constitutes up to 80% of the explosive material in the munition. To meet the Navy's requirements for insensitive munitions (IM), we must ensure that safety hazards of the propulsion units of our munitions are reduced to levels compatible with NAVSEAINST 8010.5A, Technical Requirements for Insensitive Munitions. Because the requirements of this instruction were not a major factor in the design and development of propulsion units until 1985, there is no mature technology base from which to draw the improvements required.

The past focus of exploratory development programs in tactical rocket propulsion has tended to be oriented toward improved performance rather than toward reduced sensitivity. One exception to this has been the de facto requirement that propellants used in Navy rocket motors, particularly air-launched rocket motors, meet requirements for Class 1.3 explosives. Other notable exceptions have been the Navy's and the Army's work on Low Vulnerability Ammunition (LOVA) propellants for gun propulsion and the Navy's 6.2 and 6.3A programs on reducing the output violence of munitions in response to fast cook-off.

The past focus of research programs in propulsion, while also oriented toward improved performance, has had to consider sensitivity as a result of more and more energetic ingredients involved. As a result of that work, some promising new ingredients for advanced propellants are available.

Through the Navy's work on strategic propellants and explosives, we have considerable techniques and expertise that can be applied to the sensitivity problems of tactical propulsion. However, we have learned through the IMAD program that tactical propellants present additional unique sensitivity problems.

NAVY MISSION NEEDS: The propulsion units needed to meet Navy missions are defined in terms of threats (targets), major capital assets (ships and aircraft), and the performance capabilities of other parts of the munition delivery system (warhead, guidance, etc.). Propulsion units are required to deliver the munition within a certain distance of the target, within a certain time, and sometimes, with reduced detectability, and by trajectory and velocity selected to maximize survival of the munition and

capital assets. Meeting these mission needs has required all the energy that modern chemical science and engineering can package into the limited volume available in modern propulsion units.

Even though care has generally (especially recently) been taken to avoid propellants that are obviously detonable in munitions, unacceptably violent reactions by rocket motors have been observed in response to many of the IM stimuli.

Meeting the Navy's mission needs will require propulsion units capable of current performance levels now, and improved performance levels in the future. At the same time, these units must meet the requirements for insensitive munitions. To meet these needs, this project addresses all Navy tactical rocket, missile, and gun propellant systems.

STATUS OF TECHNOLOGY: The success of rocket propulsion technology in meeting its key objectives has resulted in it frequently being called "a mature technology." This appellation, however, should be qualified by a careful look at the limited requirements that have been put on that technology, and at the many uncertain factors added by the requirement for insensitive munitions. First of all, whenever fuel and oxidizer are packaged together, as they are in a rocket or gun propellant, you have an explosive. While the terms "propellant" and "explosive," are used synonymously in the following text, it should be understood that we are always referring to propellants, but emphasizing one or the other aspect of their behavior.

All propellants (explosives) have some degree of sensitivity. When initiated, all propellants (explosives) react with some level of violence. That is always true. The Insensitive Munitions Program sets a practical target level for minimizing the sensitivity and reaction violence of the propellants used. Propulsion performance is maximized by maximizing the energy delivered by the propellant. Fortunately, sensitivity and explosive violence are not strictly monotonic functions of the propellant energy. However, for some of the propellants studied most recently in research and exploratory development, the hazard behavior is, unfortunately, directly related to energy content. Under exploratory development programs recently started by the Navy, and also some ongoing abroad, other approaches to achieving high delivered propellant energy with reduced sensitivity and reaction violence are being tried.

The other side of sensitivity and reaction violence involves pressure buildup in a reacting explosive. If an explosive is confined, internal pressure can increase without relief. A chain of events may progress that ultimately leads to a very violent explosion or detonation. The time required for this progression and its ultimate violence depend on the stimulus, the explosive, and the degree of confinement.

Successful reduction of the violence of munition reactions in fuel fires (fast cook-off) demonstrated by NAVAIR's Weapon Fast Cook-off Program (which has subsequently become the NAVAIR IM Technology Transition Program) has depended on reducing confinement (venting of the case) of the explosive prior to ignition. In this way it has been possible to modify warheads and rocket motors that exploded or detonated in fast cook-off so that the maximum reaction was only burning. A number of concepts for actively reducing case confinement have been demonstrated by the NAVAIR program. More recently many additional concepts have been demonstrated by the IMAD program. We have recently demonstrated that slow cook-off reaction violence can also be decreased by venting in some systems. More active intervention for slow cook-off relief, if needed for some explosives, may require ignition of the explosive after venting but prior to exponential self-heating. The IMAD Propulsion Project has completed feasibility and proof-of-concept tests on a multihazard mitigation system which successfully vented rocket motor cases in fast cook-off, slow cook-off, and bullet impact tests. IMAD efforts on active mitigation systems for rocket motors has terminated at this point. It is not feasible to develop a generic mitigation system since such systems must be tailored to the specific motor they are designed to be used on. It makes more sense to work with a specific weapon system, if an active mitigation system is needed. We believe that such a system, since it is intrusive to a rocket motor's primary function should be incorporated only as a last resort.

There is a regime of heating between the current fast cook-off and slow cook-off test conditions which is quite likely to occur in hazard scenarios. This intermediate cook-off regime, which causes extreme reaction violence similar to that experienced in slow cook-off, is now being studied in the IMAD program to determine its range of applicability, its effect on reaction violence, and methods for mitigating its effects. Tests of rocket motor reaction violence at a 75°/hr (intermediate) heating rate have been performed to compare the results with those obtained at a 6 hr heating rate for rocket motors that detonated at the slower heating rate. The results indicate that reaction violence is greatly reduced at the higher heating rate.

One category of propulsion technology available derives its insensitivity from separation of fuel and oxidizer. On the IMAD Program we refer to such technology as "Alternate Propulsion Systems." Bipropellant gels, liquids, solids, and hybrids as well as airbreathing systems (ramjets, ducted rockets, and turbojets) comprise this category. The IMAD Program is studying the potential of alternate propulsion technology to meet Navy missile propulsion performance requirements. We are also engaged in testing that technology available from previous exploratory development. A bipropellant gel system developed by the Army (MICOM), TRW, and Talley was readied for IM large-scale hazard tests during FY88.

Preliminary work on several new rocket motor case concepts (strip laminate, composites, and hybrids) shows promise for passive venting in response to hazardous stimuli. Some designs of these cases vent well and quickly in fires and in response to bullet and fragment impact, and some have the potential to relieve the violence of response to intermediate and even slow cook-off situations as well.

IM vulnerability testing of low vulnerability ammunition (LOVA) propellants for Navy 76 mm and 5"/54 guns was completed during FY87. Final reports of all the tests were completed in FY88. Effort to develop insensitive primers, started in FY87, had to be stopped during FY88 because of a major budget cut. These insensitive primers are needed to get the full benefit of the improved insensitivity provided by LOVA propellants.

At this stage in the IMAD Program, it is not absolutely clear what the relationships between stimulus, explosive, and confinement are for the wide range of these three variables in our existing rocket motors. Clarification of this relationship, while at the same time developing satisfactory technology for hazard reduction, are critical goals of this project. As a result of data obtained from large scale tests on generic motors and small scale tests on propellants during the past year we have identified prioritized goals for insensitive propellants for Navy missiles and have prepared test procedures for testing those propellants prior to scale-up of these formulations and loading of generic motors.

The ultimate goal for exploitation of the new technologies is to transform these new concepts into the Navy's weapon systems. Several applications directly related to many of these weapon systems have been identified for the various products identified for this task element and are summarized in Figure IV-1.

APPROACH: The work of this project is focused on reducing the sensitivity and hazardous output of rocket motors and gun propulsion systems in the Fleet. Collection of available hazard data on rocket motors currently in the Fleet has been started. However, not all necessary data exist, and because existing data are not adequate, we must assemble a data base of the responses of current rocket motors to the thermal and shock stimuli specified in the Navy's technical requirements for insensitive munitions. To establish a consistent data base (baseline) we are performing large scale hazard tests of conventional (in use) propellants in generic rocket motors.

The project maintains an intimate link with the weapon program officer responsible for fleet missile propulsion. In this way we have been able to directly support specific weapon IM plans and development including Harpoon, Sidewinder, Standard Missile, HARM, Hellfire, Skipper (Shrike), Tomahawk and VLS systems. The

# POTENTIAL IM TECHNOLOGY APPLICATIONS FOR PROPELLANTS AND PROPULSION SYSTEMS

PRODUCTS	APPLICATIONS	WEAPON SYSTEMS
CONVENTIONAL PROPELLANT CHARACTERIZATION	THERMAL RESPONSE (FCO/SCO) SHOCK RESPONSE (BI/FI/SD)	SIDEWINDER, HELLFIRE, STANDARD MISSILE, TOW, ASROC, STINGER, WAM, HARPOON
ALTERNATE PROPULSION CONCEPTS	THERMAL RESPONSE (FCO/SCO) SHOCK RESPONSE (BI/FI/SD)	MISSILE PROPULSION SYSTEMS-PARTICULARLY VERTICAL LAUNCH SYSTEMS
ROCKET MOTOR MITIGATION CONCEPTS	THERMAL RESPONSE (FCO/SCO) SHOCK RESPONSE (BI/FI/SD)	MISSILE PROPULSION SYSTEMS
ADVANCED CASES (COMPOSITE, STRIP LAMINATE, HYBRID)	THERMAL RESPONSE (FCO/SCO) SHOCK RESPONSE (BI/FI/SD)	STANDARD MISSILE, HARM, SIDEWINDER, TOMAHAWK, SEA LANCE, HELLFIRE, TOW STINGER, PENGUIN
INITIATION SYSTEMS	THERMAL RESPONSE (FCO/SCO) SHOCK RESPONSE (BI/FI/SD) EMP RESPONSE	ZUNI, 2.75" FFAR
GUN SYSTEMS	THERMAL RESPONSE (FCO/SCO) SHOCK RESPONSE (BI/FI/SD) EMP RESPONSE	5"/54, 76MM

FIGURE IV - 1

link with the weapon offices feeds back into the IMAD propulsion project and focuses IMAD technology development on to real fleet related problem areas. In the past, rocket motor cases have been designed for performance only. Those case concepts, such as strip laminate and composite cases, which have demonstrated reduced reaction violence in some vulnerability tests, have been a bonus. Other case concepts are being investigated under this project. These include the concept of a case "tuned" to attenuate the shock energy transfer upon fragment impact, while still offering the cook-off and bullet impact advantages of strip laminate and composite cases. Another concept being investigated involves design of composite cases to enhance crack propagation upon bullet or fragment impact while retaining necessary integrity under all other conditions.

The key function of mitigation concepts, as they are envisioned today, is to relieve confinement of energetic material in a munition case. This may be accomplished either passively, as with strip laminate or composite motor cases, or actively, as with linear shaped charge or thermite case penetrator concepts. In either method a three step process occurs: 1) the stimulus is sensed, 2) a signal to vent the case is sent, and 3) the case is vented. With active mitigation concepts, it is necessary to design components to specifically perform each of these three steps. The primary utility of active mitigation concepts, as we have addressed them, is to provide a retrofitable means to enable existing rocket motors to meet IM requirements prior to a time when advanced propellant and case technology can be used in new production. Other key functions and steps for passive mitigation concepts are beginning to emerge from our work. One of these is based on using the mitigation concept to change the stimulus as sensed by the energetic material and thus reduce the sensitivity of the munition as a whole. Development of case opening devices under this project has been completed. Development of sensors has ceased. Mitigation concepts based on shielding in container and stowage space designs are supported by other IMAD projects and will be coupled with propulsion IM requirements as part of the technology transition and weapon system integration efforts.

Propellants, the energetic materials in rocket motors, are ultimately responsible for hazardous behavior. The propellant(s) in any rocket motor must meet both performance requirements and insensitivity requirements for probable scenarios.

Those propellants that meet established insensitivity standards in small scale tests, and offer future improvements in both performance and insensitivity, will be scaled up for production of quantities large enough for motor loading. They will be loaded into generic rocket motor cases for large scale vulnerability testing in accordance with the insensitive munitions technical requirements. Several candidate propellants are currently being developed under this project as well as under

the Navy's 6.2 Propulsion Program. In addition, a considerable amount of new commercial "insensitive" propellant development has recently started to help meet the Navy's requirements. In response to our FY88 Broad Area Announcement in the Commerce Business Daily, we received 12 proposals for insensitive propellant development. As many as possible (after funding cuts) were supported during FY88. We intend to fund additional work in the future.

When the results of the small and large scale tests are correlated, they provide a means for projecting the behavior of munitions from small scale tests results. This is a basis for useful heuristic rules that provide guidance for propellant selection and for the design and development of mitigation concepts. The progress we have already made along these lines is being avidly welcomed by the technical community and incorporated into the work of other services and allied nations.

LOVA propellants, while demonstrated under this program to reduce the sensitivity of gun propelling charges, must be further protected with less sensitive primers and with venting cases. These were the thrusts of the task before being stopped due to funding cuts.

Advanced case technology offers a way to achieve reduced output in response to fast cook-off and bullet impact threats. There is also some potential that slow and intermediate cook-off violence can be reduced by using advanced cases. For example, we have demonstrated reduction of violence for one propellant from detonation to deflagration in slow cook-off by using a composite case. Technology developments will provide cases capable of reducing the shock stimulus to the propellant grain, thus attenuating the fragment impact and sympathetic detonation threat.

PROJECT STRUCTURE: The IMAD propulsion project is organized into the six tasks shown in Table II.

The Naval Weapons Center, China Lake (NWC) is the lead laboratory for this project. The project is implemented by the Navy R&D Centers with expertise in propulsion technology and related hazard behavior. Additional support is obtained from appropriate contractors and other Government laboratories. The project builds upon the results of the Navy's exploratory development (6.2) programs in missile and gun propulsion. Close coupling with other propulsion development programs, including industrial R&D, other service programs, and other national programs is maintained.

PROJECT SCHEDULE: Significant milestones associated with the project are listed below:

FY89

- Continue case development and acquisition.
- Complete large scale vulnerability tests of existing Navy propellants.
- Complete IM hazard tests on bipropellant gel alternate propulsion system.
- Start investigation of other alternate propulsion systems.
- Start small scale tests of other service and industry propellants, new propellants with advanced ingredients, and other propellant advances.
- Load developmental Navy propellants into generic cases and start large scale vulnerability tests.
- Begin loading of viable other service and industry propellants into generic cases for large scale vulnerability tests.
- Continue small scale tests of developmental propellants.
- Continue advanced development (scale-up and test) of selected developmental propellants.
- Continue funding of industrial IM propellant development.
- Expand large scale vulnerability test program to include advanced case concepts.
- Continue to improve prediction methodology.
- Continue development, acquisition, and test of motor cases based on new design methodology.
- Identify critical variables for "IM propellant qualification" from results of this project and adjust test protocol and procedures accordingly.
- Complete intermediate cook-off investigation.
- Start development of alternate propulsion concepts with IM potential.
- Publish and promulgate results of the project in a timely manner.
- Update data base for IM propulsion/propellants.
- Support weapon systems IM programs.
- Evaluate VLS IM threat environment.

FY90

- Support transition of demonstrated technologies to weapons.
- Continue large scale vulnerability tests of developmental propellants.
- Continue small scale tests and evaluation of newly emerging propellants.
- Continue funding of industrial IM propellant development.
- Continue advanced development (scale-up and test) of selected developmental/advanced propellants, including industry.
- Continue test and evaluation of alternate propulsion concepts.
- Qualify propellants and propulsion systems for use in missiles.
- Continue and accelerate acquisition and test of motor cases based on new design methodology.
- Continue to improve prediction methodology.

- Publish and promulgate results of the project in a timely manner.
- Maintain data base for IM propulsion/propellants.
- Support weapon systems IM programs.
- Document results and recommendations based on the program.

FY91

- Support transition of demonstrated technologies to weapons.
- Continue large scale vulnerability tests of developmental propellants.
- Continue small scale tests and evaluation of newly emerging propellants.
- Continue funding of industrial IM propellant development.
- Continue advanced development (scale-up and test) of selected advanced propellants, including industry.
- Complete testing of alternate propulsion concepts and select primary concept for development and performance demonstration.
- Qualify propellants and propulsion systems for use in missiles.
- Support tests of advanced motor cases based on new design methodology in munition configurations.
- Maintain data base for IM propulsion/propellants.
- Support weapon systems IM programs in transition to production modifications.

FY92

- Support transition of demonstrated technologies to weapons.
- Continue large scale vulnerability tests of advanced propellants.
- Continue small scale tests and evaluation of newly emerging propellants.
- Continue advanced development (scale-up and test) of selected advanced propellants, including industry.
- Support tests of advanced motor cases based on new design methodology in munition configurations.
- Qualify propellants and propulsion systems for use in missiles.
- Maintain data base for IM propulsion/propellants.
- Support weapon systems IM programs in transition to production modifications.
- Document results and recommendations based on the program.

LONG-RANGE PLANS (BEYOND FY92): Table I shows predicted progress of technology development and demonstration in this project. The numbers in the table represent fiscal years for transition windows of each indicated technology area into weapons IM fix programs. The years given are for 40%/80% transition readiness. The 40% readiness window represents the situation when the weapons program must do 60% of the technology development to affect the transition. The 80% readiness window represents the situation in which the IMAD program has done 80% of the

technology development and each weapon program only has to do that amount which is very weapon specific (estimated to be about 20%). Major long range effort will focus on transition of hazard reduction technology into Navy weapon systems. Significant effort beyond 1990 will concentrate on demonstrating the hazard reduction provided by advanced propellants in the hardware developed and demonstrated by this project. Additional effort will focus on advanced technology applicable specifically to the new advanced propellants.

FUNDING: Funding required to support this project is summarized by fiscal year and task in Table II.

TABLE I. TECHNOLOGY TRANSITION WINDOWS FOR ROCKET MOTOR IM FIXES  
PRESENT PERFORMANCE LEVELS  
40/80% Readiness in FYs Shown

Fix Technology	Threats					
	SD	FCO	FI	SCO	EMP	BI
Initiating systems			86/90		/90	86/90
Propellants	89/90	86/91	89/92	88/92		88/92
Alternate propulsion	91/95	91/95	91/95	91/95		91/95
Cases						
strip laminate		86/88		89/91		86/89
composite		88/90	90/92	88/91		88/92
hybrid	90/92	90/92	90/92			90/92
Liners	90/92	90/92	90/92			
Coatings		86/89				
Container	90/92	90/92	90/92	90/92	/86	90/92
Storage	86/88					
Mitigation Devices						
retrofit		88/		88/		88/
forward fit		88/		88/		88/

Task Title: Coordination and Technical Direction  
Task Number: 4000  
Principal Investigator: Andrew Victor, NWC/CL, Code 32051, X7391

OBJECTIVE: Provide management and coordination of the entire project. Provide for sponsor liaison, overall coordination of the tasks within the project, administrative support, overall contract support, coordination with other projects of the IMAD program, coordination with Navy weapons programs and with related programs in the other services, industry and allied nations.

BACKGROUND: NAVSEA identified the Naval Weapons Center as the lead laboratory for the propulsion project of the IMAD program. This task provides support for personnel required to perform planning, coordination, administrative support, reporting, and liaison functions for the project.

APPROACH: Establish and maintain the management and administrative staff, technical support, and program structure that will result in timely development and demonstration of propulsion technology to meet the requirements of NAVSEAINST 8010.5. Attend necessary meetings and conferences, prepare and present plans and reports and provide any other inputs or coordination required by the sponsor. Enlist the support of industry and other government agencies toward the IMAD program objectives by preparing papers and presentations for appropriate forums. Provide overall contractor support and funding for joint service IM tasks.

PROGRESS (FY88): Continuing coordination with major propulsion companies was highlighted by a joint government/industry meeting on Insensitive Propellants Requirements at NWC in June 1987. Numerous papers and presentations were promulgated to help define IM requirements and establish proper directions for industrial and government efforts. Coordination activities in JANNAF have led to formation of the new Insensitive Munitions Information Center Subcommittee and a new IM Panel. Coordination activities through TTCF have led to formation of a new WAG (W-Action Group) on propellant and explosive sensitivity. Working under contract to this task, COMARCO completed charts of Production Schedules/IM Plans for all major Navy munitions, worked on the IM data base, supported definition of blast overpressure measurement requirements, and served as an important link for IM technology needs definition for weapon system support. A joint bullet impact study between NWC and MICOM was started. A Small Business Innovative Research (SBIR) project on advanced rocket motor case design was initiated. Support continued for the NATO-FTE project combining rocket propellant and motor case technologies which was defined under this project and transitioned to NAVAIR for support, redefinition, and management. The major focus of the NATO-FTE is IM. International coordination with French, British, and Australian scientists was extremely profitable to the project in terms of new technology made available for U.S. use on the IM problem.

PLANS (FY89-FY92): Plans and major milestones of the task are directed toward having IM technologies developed and demonstrated, through the other tasks in the project, to provide engineering of these technologies into munitions in a timely manner. Refer to the milestones of the other tasks.

FY89

- Continue and expand cooperative programs (ongoing task).
- Institute protocol and procedures for qualifying insensitive propellants.
- Update and maintain data base for IM propulsion/propellants.
- Support transition of demonstrated technologies.

FY90

- Continue and expand cooperative programs (ongoing task).
- Continue to update and maintain data base for IM propulsion/propellants.
- Continue to support transition of newly demonstrated technologies.

FY91/FY92

- Continue to expand cooperative programs (ongoing task).
- Continue to update and maintain data base for IM propulsion/propellants.
- Continue to support transition of newly demonstrated technologies.

Task Title: Rocket Motors and Large-Scale Testing  
Task Number: 4100  
Principal Investigator: James Farmer, NWC/CL, Code 3274, X7504

OBJECTIVE: The objective of this task is to develop and demonstrate IM technology directly applicable to operational rocket motors. This involves acquisition and testing of rocket motors incorporating baseline and advanced cases and propellants, advanced initiation systems, and alternate propulsion concepts. This task coordinates all of the rocket motor work on the project including hazard and performance test management.

BACKGROUND: The existing data base on rocket motor sensitivity is not adequate to support rational design of motors that meet IM requirements. This task will augment that data base and apply it to demonstrate advanced propellants, cases, and alternate propulsion systems that meet IM requirements.

APPROACH: This task has instituted the first systematic test of the propellants in our current advanced performance inventory. The results of these tests provide a baseline for evaluation of current technology in terms of both sensitivity and the ability of small scale tests to predict munition sensitivity. Simultaneous small scale test studies of the baseline propellants are performed in Task 4120. In the out years hazard testing will continue with advanced propellants in the generic rocket motor cases. Improved testing methods and instrumentation are also being investigated under this task. This task provides advanced development applicable to all air and surface launched missiles.

PROGRESS (FY88): Large-scale IM hazard tests of baseline propellants (reduced smoke and high aluminum HTPB composite) in generic monolithic steel, composite, and strip-laminate cases were completed and reported (NWC TP 6840). The maximum performance Class 1.3 propellant was loaded in generic cases for IM testing. Additional large scale hazard tests were run for Hellfire motors and Rapier motor cases containing RDX loaded EMCDB propellant. Tests were also run on several other rocket motors, and test preparation for Alternate Propulsion Systems (bipropellant gel) was started. Intermediate cook-off tests were started.

PLAN (FY89-92): Plans and major milestones of the task area by fiscal year are as follows:

FY89

- Continue large scale hazard tests on generic motors.
- Propulsion performance tests of generic rocket motors with advanced propellants will be run as needed.
- Begin large scale hazard tests of advanced propellants.

- Expand large scale hazard test program to include advanced case concepts.
- Complete intermediate cook-off investigation.
- Continue hazard tests of alternate propulsion systems.

FY90

- Propulsion performance tests of generic rocket motors with advanced propellants will be run as needed.
- Continue large scale hazard tests of advanced propellants and advanced case designs.
- Continue tests of alternate propulsion systems.
- Support special IM test requirements of weapon systems.

FY91/FY92

- Complete tests of alternate propulsion systems.
- Continue hazard tests of advanced propellants and cases.
- Transition IM propulsion technology to weapon systems.

Task Title: Propellants  
Task Number: 4200  
Principal Investigators: E. Panella, NWC/CL, Code 3274, X7305  
J. Kelley, NSWC/IH, Code R10E, X4791

OBJECTIVE: The objective of this task is to provide insensitive propellants that meet the Navy's requirements for performance and IM, and examine alternate propulsion concepts.

BACKGROUND: Propellants that meet performance requirements for high energy delivered at appropriate rates, low signature, and insensitivity are required to satisfy the Navy's IM policy. Some missiles show an urgent need for new propellants to satisfy these requirements. Generic vulnerability tests of propellants must be performed with real rocket motors. Therefore, standard design practice and standard rocket motor fabrication techniques are used to produce the generic units. Small-scale tests are required to characterize propellant insensitivity prior to scale-up and generic motor loading. Immediate applicability of this task to HARPOON, HELLFIRE, ASROC, STANDARD MISSILE, SIDEWINDER, TOMAHAWK, TOW, STINGER, and Wide Area Missile has been identified.

The propulsion work that is described in other task areas is devoted to concepts in which propulsion is provided by a single solid propellant grain in a structural container. Under this task, alternate concepts, such as gelled fuel/oxidizer systems, solid bipropellant systems, and hybrid propulsion systems will be considered. For those examined that show promise, they will be developed and demonstrated. Some have been investigated on prior exploratory development projects by various services (most recently, Army/MICOM work on TRW/Talley bipropellant gels).

APPROACH: This task comprises sensitivity, formulation, and producibility evaluation of advanced propellants. As part of the requirement to provide satisfactory propellants, candidate formulations will first be tested (characterized) on a small scale to select for scale-up only those that are expected to meet requirements for sensitivity and performance. This will require the development and application of small scale test and analytical techniques, the generation of data on a variety of existing formulations, and the correlation of generated and already existing data to predict responses of new propellants to IM stimuli in large scale testing. This task further includes the tailoring of advanced formulations for easy producibility, loading, and grain design, and will be supported in the loading and large scale testing of new formulations in generic cases by Task 4100. In-house and contractor sources will be employed. The actual selection of formulations will be based on technical data generated, as well as on cost and schedule. Within the FY86-FY88 effort five conventional tactical propellants (reduced smoke [SIDEWINDER], minimum smoke [HELLFIRE], conventional

aluminized HTPB [MK-111], high energy advanced composite propellant [MK-104], and a high energy variant of the British-developed elastomer modified cast double base [EMCDB] propellant) have been evaluated. Much generic case loading and large scale IM hazard testing of these propellants was accomplished during FY87/88. In the outyears more advanced propellants will be loaded. Some of these are just emerging from the 6.2 propulsion program now; others are still being developed.

Activity on alternate propulsion concepts started in FY87. For all proposed concepts, performance analyses and small scale tests will be performed early and in conjunction with the 6.2 propulsion program and with related work in the other services, to determine feasibility. In general, if the concepts have the potential to provide the necessary performance, relatively low cost vulnerability tests of propellant containers will be performed before going to the expense of developing functioning propulsion units. Only when adequate insensitivity and performance potential have been demonstrated will propulsion demonstration motors be fabricated and tested.

PROGRESS (FY88): Test samples of the five conventional propellants selected for baseline tests on the project have been evaluated in small and large scale tests. The tests include small scale characterization, sensitivity, and hazard output tests, and large scale IM tests in conventional and advanced motor cases. Several new small scale sensitivity and hazard test methods have been investigated, developed, demonstrated, and documented. The small scale investigations of conventional propellants is well under way. The results of some of these studies have been rather startling; and, as a result, we anticipate major improvements to be forthcoming in widely accepted methods of characterizing propellants for IM in the near future. Priorities for insensitive propellant development were identified and incorporated in both Navy in-house propellant formulation subtasks and industrial development.

Energetic materials with the potential to replace HMX and RDX in high energy propellants have been evaluated by a computer based performance optimization technique. Advanced ingredient scale-up to obtain these and other ingredients for propellant formulations was started in FY87. Resulting reduced sensitivity propellants are in development.

Under development in-house are 1) slow cook-off mitigating propellants, 2) low pressure extinguishing propellants, 3) TPE propellants, 4) high energy/density propellants for volume limited applications, 5) "homogeneous" propellants, and 6) rugged non-detonable minimum signature propellants. These subtasks are in accord with the identified priorities for Navy insensitive propellant development.

Progress (FY88) (Cont'd):

Regular contact with industry has been maintained for their new ideas, their support in obtaining conventional and advanced propellants, and for participation in the JANNAF and TTCP forums on IM.

In response to our publication of a Broad Area Announcement in the Commerce Business Daily for insensitive propellant development, 12 industry proposals were received. These proposals meet the identified priorities for Navy insensitive propellants by a number of different approaches.

Alternate propulsion concepts started in FY87 with acquisition of tankage for containing bipropellant gel materials during IM hazard tests. In FY88 a contract was awarded to manufacture and load gelled fuel and oxidizer. Analyses of the gel propellant performance in Navy missiles were performed.

PLANS (FY89-FY92): Plans and major milestones of this task area by fiscal year are as follows:

FY89

- Initiate additional industrial development contracts for insensitive propellants.
- Complete small scale propellant tests on baseline conventional propellants.
- Perform analytical performance study of newly identified advanced propellants.
- Identify additional candidate Navy developmental propellants for outyear IM advanced development and future scale-up.
- Complete correlation of large scale and small scale test results on baseline conventional propellants; publish the results.
- Perform small scale tests on selected Navy and industry developmental propellants.
- Begin advanced developmental (scale-up and test) of selected Navy developmental propellants.
- Load developmental insensitive propellants into generic motor cases for large scale IM hazard vulnerability testing under Task 5100.
- Begin small scale tests of other service and industry propellants, new propellants with advanced ingredients, and other propellant advances.
- Complete verification of insensitive propellant characterization protocol and procedure.
- Establish prediction methodology on basis of large and small scale test results and scientific principles.
- Continue evaluation of advanced propulsion concepts as IM alternatives.
- IM hazard tests on bipropellant gel alternate propulsion system.

Plans (FY89-FY92) (Cont'd):

FY90

- Continue industry advanced propellant development.
- Continue small scale tests of advanced propellants.
- Identify critical variables for "propellant qualification" from results of this project.
- Load developmental insensitive propellants into generic motorcases for large scale IM hazard vulnerability testing under Task 4100.
- Continue advanced development (scale-up and test) of selected developmental propellants, and add advanced propellants.
- Begin loading of viable other service and industry propellants into generic cases for large scale hazard tests.

FY91/92

- Continue industrial advanced propellant development.
- Continue small scale tests and evaluation of newly emerging propellants.
- Continue to improve prediction methodology.
- Continue advanced development (scale-up and test) of selected advanced propellants.
- Load additional advanced propellants for hazard testing under Task 4100.
- Document results and recommendations based on the program.

Task Title: Advanced Cases  
Task Number: 4300  
Principal Investigator: J. Farmer, NWC/CL, Code 3274, X7504

OBJECTIVE: The objective of this task is to develop and demonstrate advanced rocket motor case concepts that reduce the sensitivity and/or hazardous output of rocket motors subjected to inadvertent stimuli, and to acquire generic rocket motor cases for use in large scale hazard vulnerability testing of propellants and rocket motors.

BACKGROUND: The confinement provided by rocket motor cases is a major factor in the level of response of rocket motors to various unplanned stimuli. In this project, generic rocket motors of various design concepts will be developed for evaluation in various vulnerability tests in Task 4100 in accordance with the requirements of NAVSEAINST 8010.5. Generic motors will be designed to meet specific requirements so the effects of changes in propellants on sensitivity and reaction severity can be evaluated. This task is directly applicable to STANDARD MISSILE, HARM, HARPOON, ASROC, SIDEWINDER, TOMAHAWK, SEA LANCE, HELLFIRE, TOW, STINGER, and PENGUIN.

APPROACH: Cases will include monolithic steel cases of the Skipper (Shrike) design and cases made of alternate materials (strip laminate, graphite/epoxy composite, and various hybrid designs) fabricated to the Skipper performance requirements. Design methods will be developed and evaluated for tailoring cases to mitigate specific hazard threat stimuli. Case concepts designed specifically for their ability to mitigate certain hazards will be acquired for testing. Hazard mitigation systems, where necessary, will be tailored for the specific characteristics of the cases. Supporting design work planned in the Navy's 6.2 propulsion program will address new concepts and design methods and design requirements due to operational stresses in Navy missions. Results of a current SBIR contract on shock attenuating cases (SPARTA, Inc.) will be incorporated.

PROGRESS (FY88): Sixty conventional steel baseline generic cases, 25 composite cases, and 20 strip laminate cases were acquired during FY88. An SBIR contract on "tuned" motor cases was completed (with SPARTA, Inc.) with a recommendation to go to phase II. The concept of a tuned motor case is to tailor the case to specifically attenuate shock pressure into the propellant, and thus reduce the probability of detonation in response to high velocity fragment impacts. Design efforts on hybrid and composite cases were aborted in FY88 due to funding cuts.

PLANS (FY89-FY92): Plans and major milestones of the task are as follows:

FY89

- Continue generic motor case acquisition for advanced propellant IM tests.
- Continue study of advanced case concepts and of design methods for insensitive rocket motor cases with specific emphasis on composite and hybrid cases.
- Fabricate and start tests of first advanced "tuned" cases (if current SPARTA contract is technically successful).

FY90

- Continue generic motor case acquisition for advanced propellant IM tests.
- Complete and document study of advanced case concepts and of design methods for insensitive rocket motor cases.
- Acquire generic motor cases for larger diameter and higher pressure analogs.
- Continue case development and acquisition.
- Start acquisition and test of motor cases based on new design methodologies.

FY91

- Perform IM tests of advanced case concepts with baseline propellants for concept evaluation.
- Continue generic motor case acquisition for advanced propellant IM tests.
- Continue acquisition and test of motor cases based on new design methodology.

FY92

- Transition appropriate advanced case technology to weapon systems.

Task Title: Mitigation Systems  
Task Number: 4400  
Principal Investigator: A. Diede, NWC/CL, Code 3273, X7328

OBJECTIVE: The objective of this task is to provide mechanical and thermal means for mitigating the hazards of rocket motors subjected to the entire range of threat stimuli specified in NAVSEAINST 8010.5A.

BACKGROUND: Under various exploratory and advanced development programs, a number of means of mitigating (that is reducing the severity of) munition responses to hazardous stimuli have been demonstrated. Some of these concepts, like alternate rocket motor cases (strip laminate, composite, hybrid, etc.) have demonstrated mitigation in fast cook-off, slow cook-off, and bullet impact tests. Active mitigation devices, like the TCP and TIVS developed by the NAVAIR IM Technology Transition Program (IMTTP) are designed to work only against the fast cook-off threat. Active mitigation devices for slow cook-off have been devised and demonstrated under this task of the IMAD program. Problems are encountered in devising active mitigation devices for impact threat stimuli because the reaction times must be very short. Even though we have demonstrated successful case venting active mitigation systems for some bullet impact stimuli, it will be necessary to develop passive systems (case designs combined with propellant changes) for general, and completely reliable fixes.

APPROACH: Identify promising active mitigation device concepts, develop new concepts, select those concepts most likely to produce devices suitable for Fleet use. Conduct subscale and full-scale tests to demonstrate feasibility and proof-of-concept and select those concepts which will enter full development. In FY86 this task area concentrated on preliminary design and evaluation of a wide variety of mitigation concepts. Several of these preliminary designs were selected for further advanced development in FY87 and FY88. Close coordination with the NAVAIR IMTTP is maintained.

PROGRESS (FY88): Over one dozen new hazard mitigation systems were conceptualized in FY86. Hardware for several of these was fabricated and feasibility tests were performed. Two designs for scaled up development and demonstration on full size rocket motors were selected as the major foci for FY87. Both approaches focused on retrofitable systems to mitigate fast cook-off. One of the approaches was also designed for applicability to slow cook-off and bullet and fragment impact threats. This involved a "quad-function" mitigation system designed and successfully tested in FY87 and FY88 to mitigate fast and slow cook-off reaction violence and also some bullet impact threats. Work on the concept that focused on a removable mitigating "belt," designed mainly for fast cook-off mitigation on air-launched

missiles, was stopped early in FY88 due to budget cuts. Work on mitigation systems was concluded for this task during FY88 with successful proof-of-concept demonstration of the "quad-function mitigation system" and preparation of a report of the work done (NWC TP 6849).

PLANS (FY89): Plans for FY89 involve minor work in an advisory capacity and presentation of the results of this completed task.

Task Title: Ignition Systems  
Task Number: 4500  
Principal Investigator: TBD

OBJECTIVE: The objective of this task is to reduce the effect of initiation systems on the sensitivity and hazardous output of rocket motors subject to inadvertent stimuli.

BACKGROUND: The initiation system is sometimes the most sensitive part of a rocket motor, resulting in a marked difference in response depending on whether or not the initiation system is directly impacted by hazard stimuli. In some systems (2.75" FFAR and ZUNI) there is no safe-and-arm link in the igniter; such igniters are susceptible to EMP.

APPROACH: Determine, by hazard testing and assessment, the sensitivity and output of different ignition systems and their effects on rocket motor hazard responses. Develop and demonstrate improved ignition systems which reduce the hazard responses of rocket motors.

PROGRESS: Effort on this task has not started.

PLAN (FY89-FY92): Plans and major milestones of this task area by fiscal year are as follows:

FY90

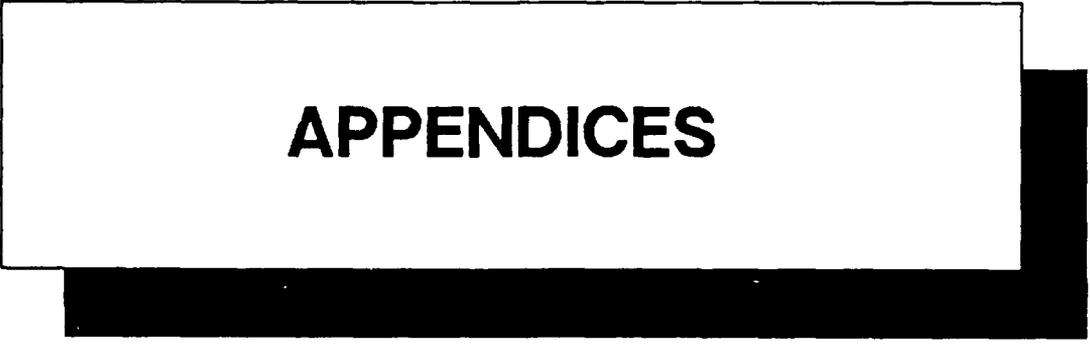
- Appoint task leader and plan approach.
- Perform initial sensitivity tests.
- Start test item acquisition.

FY91

- Install test items in baseline generic motors for hazard testing.
- Perform hazard tests.

FY92

- Assess hazard test results.
- Design improved initiation systems for hazard reduction.
- Test improved initiation systems in generic/munition hardware.
- Transition improved initiation system to weapon systems.



**APPENDICES**

APPENDIX A  
GLOSSARY OF TERMS

<u>ABBREVIATION</u>	<u>TERM</u>
ADP	AUTOMATED DATA PROCESSING
ADPA	AMERICAN DEFENSE PREPAREDNESS ASSOCIATION
AEPS	AIRCREW ESCAPE PROPULSION SYSTEM
BI	BULLET IMPACT
BOD	BOARD OF DIRECTORS
CAD	CARTRIDGE ACTUATED DEVICE
CNO	CHIEF OF NAVAL OPERATIONS
DEA	DATA EXCHANGE AGREEMENT
DOD	DEPARTMENT OF DEFENSE
DOE	DEPARTMENT OF ENERGY
DTA	DIFFERENTIAL THERMAL ANALYSIS
EAD	EXPLOSIVES ADVANCED DEVELOPMENT
EMCDB	ELASTOMER MODIFIED CAST DOUBLE BASE
EMI	ELECTROMAGNETIC IMPULSE
EMP	ELECTROMAGNETIC PULSE
ESD	ELECTROSTATIC DISCHARGE
FCO	FAST COOK-OFF
FI	FRAGMENT IMPACT
FLSC	FLEXIBLE LINER SHAPED CHARGE
GTU	GENERIC TEST UNIT
HE	HIGH EXPLOSIVE
HWPTU	HEAVY WALL PENETRATOR TEST UNIT
IM	INSENSITIVE MUNITIONS
IMAD	INSENSITIVE MUNITIONS ADVANCED DEVELOPMENT
IMC	INSENSITIVE MUNITIONS COUNCIL
IMCG	INSENSITIVE MUNITIONS COORDINATION GROUP
IMIC	INSENSITIVE MUNITIONS INFORMATION CENTER
IMO	INSENSITIVE MUNITIONS OFFICE
IMTIC	INSENSITIVE MUNITIONS TECHNOLOGY INFORMATION CENTER
IMTTP	INSENSITIVE MUNITIONS TECHNOLOGY TRANSITION PROGRAM
JANNAF	JOINT ARMY, NAVY, NASA, AND AIR FORCE
JOCG	JOINT ORDNANCE COMMANDER'S GROUP
LANL	LOS ALAMOS NATIONAL LABORATORY
LLNL	LAWRENCE LIVERMORE NATIONAL LABORATORY
LOVA	LOW VULNERABILITY AMMUNITION
LSGT	LARGE SCALE GAP TEST
MCAAP	MCALESTER ARMY AMMUNITION PLANT
MCX	NON-AQUEOUS SLURRY EXPLOSIVE
MICOM	ARMY MISSILE COMMAND, HUNTSVILLE
NAVAIR	NAVAL AIR SYSTEMS COMMAND
NAVSEA	NAVAL SEA SYSTEMS COMMAND
NAVSEAINST	NAVAL SEA SYSTEMS COMMAND INSTRUCTION
NESIP	NAVAL EXPLOSIVE SAFETY IMPROVEMENT PROGRAM
NFTU	NATURALLY FRAGMENTING TEST UNIT
NOS/IH	NAVAL ORDNANCE STATION, INDIAN HEAD
NSRDC	NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER, CARDEROCK
NSWC/D	NAVAL SURFACE WARFARE CENTER, DAHLGREN
NSWC/WO	NAVAL SURFACE WARFARE CENTER, WHITE OAK

APPENDIX A

<u>ABBREVIATION</u>	<u>TERM</u>
NUSC	NAVAL UNDERWATER SYSTEMS CENTER, NEWPORT
NWC/CL	NAVAL WEAPONS CENTER, CHINA LAKE
NWS/E	NAVAL WEAPONS STATION/EARLE
NWS/Y	NAVAL WEAPONS STATION, YORKTOWN
NWSC, CRANE	NAVAL WEAPONS SUPPORT CENTER, CRANE
OPR	OFFICE OF PRIMARY RESPONSIBILITY
PAD	PROPELLANT ACTUATED DEVICE
PBX	PLASTIC BONDED EXPLOSIVE
PC	PERSONAL COMPUTER
POA&M	PLAN OF ACTION AND MILESTONES
POC	POINT OF CONTACT
R&D	RESEARCH AND DEVELOPMENT
RCT	REACTIVE CASE TECHNOLOGY
RCW	REACTIVE CASE WARHEAD
S&A	SAFE AND ARM
SBIR	SMALL BUSINESS INNOVATIVE RESEARCH
SCO	SLOW COOK-OFF
SD	SYMPATHETIC DETONATION
SMCA	SINGLE MANAGER FOR CONVENTIONAL AMMUNITION
SNL	SANDIA NATIONAL LABORATORY
SYSCOM	SYSTEMS COMMAND
T&E	TEST AND EVALUATION
TAIS	THERMALLY ACTIVATED INTERVENTION SYSTEM
TASAD	THERMALLY ACTIVATED SAFE AND ARM DEVICE
TC	TECHNICAL COORDINATOR
TCP	THERMAL COATED PROTECTION
TIVS	THERMALLY INITIATED VENTING SYSTEM
TTCP	TECHNICAL COOPERATION PANEL
USMC	UNITED STATES MARINE CORPS
UTU	UNDERWATER TEST UNIT
WFCP	WEAPONS FAST COOK-OFF PROGRAM
WPE	WORKING PARTY FOR EXPLOSIVES

APPENDIX B  
TELEPHONE EXCHANGES

The Navy activity, mailing code and telephone extension for each of the principal investigators is given in the text of the program plan. The commercial and Autovon telephone exchanges for each activity are as follows.

<u>Activity</u>	<u>Commercial</u>	<u>Autovon</u>
Naval Sea Systems Command Washington, D.C. 20362-5101	(703) 692-XXXX	222-XXXX
Naval Surface Warfare Center White Oak Laboratory Silver Spring, MD	(202) 394-XXXX	290-XXXX
Naval Surface Warfare Center Dahlgren, VA	(703) 663-XXXX	249-XXXX
Naval Surface Warfare Center Indian Head, MD 20640-5000	(301) 743-XXXX	364-XXXX
Naval Weapons Center China Lake, CA	(619) 939-XXXX	437-XXXX
Naval Ordnance Station Indian Head, MD 20640-5000	(301) 743-XXXX	364-XXXX
Naval Ordnance Station Detachment NEDED Yorktown, VA		
Naval Weapons Station Earle, NJ	(201) 577-XXXX	499-XXXX