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GAO

Briefing Report to the Chairman, Committee on Foreign Affairs, House of Representatives

May 1986

BIGEYE BOMB

An Evaluation of DOD's Chemical and Developmental Tests

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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

PROGRAM EVALUATION
AND
METHODOLOGY DIVISION

May 23, 1986

B-211376

The Honorable Dante Fascell
Chairman, Committee on Foreign Affairs
House of Representatives

Dear Mr. Chairman:

This report responds to your May 10, 1985, letter. You asked that we carry out a detailed examination of the technical and operational issues surrounding the Bigeye bomb. Specifically, you wanted to know if the Bigeye was ready for production. After analyzing the available data on the Bigeye bomb, GAO believes the bomb is not ready for production.

The report deals mainly with the chemical and developmental issues surrounding the Bigeye. Operational data were not available to us at the time the report was written, so our analysis is based on developmental testing. (We are continuing our work on operational testing as you requested.) As you well know, developmental and operational tests serve different purposes. Developmental tests determine if a weapon meets its technical specifications while operational tests determine if a weapon will be useful in combat. From the data we have reviewed, we do not believe the Bigeye has met its technical specifications and should not be undergoing operational tests until these specifications are met. Many of the unresolved critical questions from developmental testing will not and cannot be addressed during the operational tests.

Our principal findings are that the test results to date present major and continuing inconsistencies; that test criteria are ambiguous, shifting, and uncertain; that there is a paucity of test data and analysis to resolve important technical issues; and that "solutions" to technical problems have resulted in operational constraints and uncertainties. We conclude that while more developmental testing may be able to answer some of the unresolved questions, other questions appear to be intractable and not likely to be solved, given the 30-year-old technology being used. We suggest that other technologies and other chemical weapons be examined to accomplish the deterrent and retaliatory mission assigned to Bigeye.

As you requested, copies of the draft briefing report were sent to the Department of Defense for comment. DOD responded that it would not be able to provide comments in 10 days as you requested. It cited as reasons for not providing comments the volume of the report, the nature of the Bigeye issues, the number of components involved in developing the response, and the fact that cognizant DOD staff were busy preparing for hearings. DOD did not request an extension. However, it does plan to provide a "full and complete" response after the report is issued.

To obtain the required security review for a classified document, GAO sent the report to DOD on March 12, requesting this review be completed within 15 days. In a letter dated March 21, DOD reported "the security review of the draft report is currently in process and we anticipate releasing it to you next week." However, we did not receive the classification until April 28, 46 days after the initial request. Although we had no control over the situation, we apologize for this delay.

As we agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution of it until 30 days from the date of the report. At that time, we will send copies to those who are interested and will make copies available to others upon request.

Sincerely,

Eleanor Chelimsky
Director

Contents

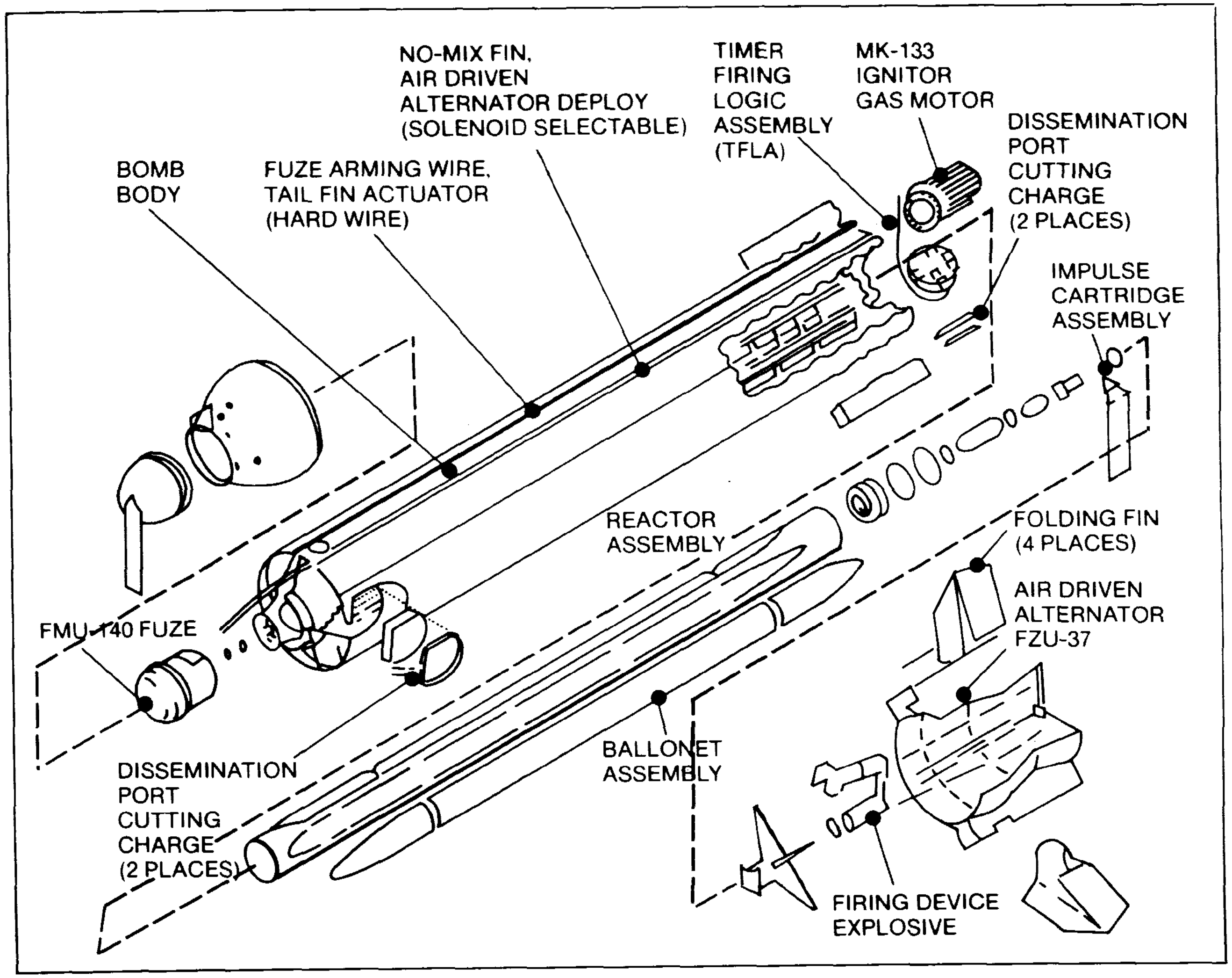
MER	Multiple ejector racks
MNFC	Maximum no-fire current
MK 133	Ignitor electro-explosive device attached to the gas motor
NAVAIR	Naval Air Systems Command
NE	Rhombic sulfur, binary component
OPEVAL	Operational evaluation program
OSM	Off-station mixing
OT&E	Operational Test and Evaluation
QL	Ethyl 2-(diisopropylamino) ethyl methyl - phosphonite, binary component
RF	Radio frequency
ROCKEYE	Navy operational designation for high explosive filled bomb with Bigeye dimensions
r.p.m.	Revolutions per minute
SSTV	Safe separation test vehicle
TECHEVAL	Technical evaluation program
TEMP	Test and evaluation master plan
TIP	Triisopropyl phosphite used in simulant tests
TIPS	Triisopropyl phosphorothionate formed in simulant tests
VX	O - ethyl S - [2(diisopropyl amino) ethyl] methyl phosphonothioate, persistent nerve agent

ABBREVIATIONS

A-4	Attack aircraft
A-6E	Attack aircraft
AV-8B	Attack aircraft
AERO-1D	External fuel tank attached to aircraft
BIGEYE	Navy operational designation for BLU-80/B binary bomb
BIS	Chemical simulant bis - (2 ethyl hexyl) hydrogen phosphite
BLU-80/B	BIGEYE bomb
BLU-80(T-1)/B	BIGEYE bomb test vehicle
BLU-80(T-2)/B	BIGEYE bomb test vehicle with simulant binary components
CATS and TRAPS	Flight operations on an aircraft carrier of catapult launch and arrested landing
CRDC	U.S. Army Chemical Research and Development Center, Aberdeen Proving Ground, Md.
CRDL	U.S. Army Chemical Research and Development Laboratories (now CRDC)
CV	Intermediate precursor which forms VX
DOD	Department of Defense
DT&E	Developmental Test and Evaluation
EED	Electro-explosive device
F-4	Fighter aircraft
F-16	Fighter aircraft
F-111E	Fighter aircraft
FMU-140	Proximity fuze used in Bigeye to initiate the opening of the dissemination ports (see figure 1)
FZU-37	Wind turbine used in Bigeye as an energy source to activate the impulse cartridge and gas agitator motor (see figure 1)
g	Acceleration of gravity
GAO	General Accounting Office
HERO	Hazards of electromagnetic radiation to ordnance
LCL	Lower confidence level used in reliability assessment
LD50	Lethal dose 50 percent kill
mach	A number indicating the ratio of the speed of an object to the speed of sound

1. BACKGROUND

Figure 1: Bigeye Bomb



Research on the Bigeye

1962 The concept of binary VX and air delivery became the Bigeye weapon.

1965 CRDL concluded that sufficient information on VX binary chemistry was available for "weaponization" of the binary technique.

Engineering development and testing

1965 The Bigeye weapon began engineering development at China Lake.

1968 Full-scale weapons were manufactured.

1969 Developmental testing began at China Lake with nontoxic chemical agent simulants to test release procedures and dissemination mechanisms.

Project terminated

Sept. 1969 All chemical warfare programs were terminated by a presidential moratorium.

1976 to present Low-altitude high-speed ingress and egress for tactical fighters to deliver air-to-ground weapons were considered to be the preferred tactics to improve survivability against a medium-to-high air defense threat, because these tactics minimize aircraft exposure to the threat in time and space.

Project restarted

1976 Bigeye program was restarted as a joint Navy and Air Force program with support from the Army.

1977 Major hardware contract was awarded to Marquardt Company.

U.S. POLICY ON CHEMICAL WARFARE

- To deter the use of chemical warfare weapons by other nations.
- To provide the capability to retaliate, if deterrence fails.
- To achieve early termination of chemical warfare at the lowest possible intensity.

DOD'S VIEW OF HOW BIGEYE FITS WITHIN THAT POLICY

- To deter potential adversaries from using lethal chemical weapons against U.S and allied forces.
- To provide a credible and effective retaliatory capability in order to reduce an enemy's incentives to use lethal chemical weapons.
- To generate a persistent nerve agent that can be safely employed and to provide a rapid response where long-duration contamination is required.

THE HISTORY OF THE BIGEYE PROGRAM

Research on binary reaction

1955 The U.S. Army Chemical Research and Development Laboratories (CRDL) initiated research on binary reaction.

1956 CRDL began research on binary VX nerve agent.

Research on weapon concept

1961 The design and exploration of the development of an air-delivered chemical weapon using the binary concept was assigned to the Naval Weapons Center, China Lake, California.

1962 VX purity reached in the large reactor.

1964-65 The major problem for scale-up to a bomb was dissolving one component into the other and mixing. Moisture in combustion gas from injection of the sulfur was recognized as severely reducing VX purity. The contractor developed a central injector system similar to the present system and theoretically solved both the "solution" and contamination problems. Reaction time to form VX was recognized as varying with temperature. However, the variation was judged significant only at temperature extremes. Pressure increase to pounds per square inch during the reaction was expected.

1964-65 Intense flashing (agent burning) occurred during dissemination in 4 of 11 binary and in 2 of 6 static-firing open-air tests.

1966 A contractor's report of studies on the binary reaction concluded that at

The report stressed that mixing at

Sept. 1969 All chemical warfare programs were terminated by a presidential moratorium.

1976 The Bigeye program started again.

1982 Renewed full-scale binary toxic chamber tests uncovered problems with the internal components as well as

1984-85 Various problems such as the disseminating fuze and injector cartridge were identified and addressed.

1979-80 Funding shortfalls caused a restructuring of the program and the postponement of a significant portion of scheduled developmental testing and evaluation.

1980 Renewed interest in the Bigeye prompted a decision to complete development as quickly as possible. The Naval Weapons Center was the development agency charged with updating the 1969 Bigeye design. Significant design modifications were not expected.

Developmental tests

1982 Full-scale binary toxic chamber tests began.

1983 To safely accommodate the pressure buildup, the delivery mode was changed to "off-station mixing" and changes to the hardware and proof-of-concept tests were completed. The lofting concept of delivery was introduced to allow sufficient time for the chemicals to mix and be disseminated.

1984-85 A series of developmental tests called TECHEVAL and additional full-scale toxic chamber tests were conducted.

1985 Toxic chamber tests and developmental tests were completed. The Program Manager determined that the developmental tests had been successfully completed.

Operational tests

1985 Operational tests began.

ITS TECHNICAL HISTORY AND EARLY CONCERNS

1961 A contract was let by the Army to develop a small, test reactor and a large test reactor, similar in dimensions to a

OBJECTIVES, SCOPE, AND METHODOLOGY

- The Chairman, House Committee on Foreign Affairs, requested that GAO provide a detailed report on the technical and operational issues surrounding the Bigeye bomb. Questions to be answered included:

  1. What tests have been performed and what analyses have been done?

  2. What test criteria have been established and have those criteria been met?

  3. Have all issues been resolved to allow for production?

- This report discusses developmental and chemical testing issues. Operational data were not available at the time the report was written and will be addressed in a later report.

- We employed multiple data gathering methods to produce our findings. We obtained documents such as briefing papers, status reports, manuals, memos, and test results and analyses. We reviewed and analyzed these documents to assess the status of the program and to identify information gaps related to testing issues. We also interviewed officials at OSD, the NAVAIR Program Office, the Naval Weapons Center, the Chemical Research and Development Center and the Marquardt Company to verify results and to assure the completeness of our evidence.

TYPES OF TESTING

- There are three major categories of testing--chemical, developmental, and operational. Each serves a different purpose and will be discussed in detail.

  --There are two types of chemical tests: chemical mixing and biotoxicity. Chemical mixing tests are conducted to gain information on the binary chemical reaction. Biotoxicity tests are done to assess the potency of the generated agent (see pages 17, 26).

  --Developmental tests determine whether a weapon meets technical specifications (see page 45).

  --Operational tests determine whether the weapon will be useful in combat (see page 78).

- In terms of the U.S. policy on chemical warfare, testing on the Bigeye should answer five questions:

  1. Will the weapon achieve the specified level of chemical potency and long-duration contamination?

  2. Will it function technically as expected?

  3. Can it be delivered safely?

  4. Does it provide rapid-response capability?

  5. Is it credible and effective overall as a deterrent and as a retaliatory weapon?

INTRODUCTION

- The objective of the chemical mixing tests was to determine the behavior of the Bigeye system over a range of physical and thermal conditions. The goal of the experiments was to gather information to be used in consonance with other data in evaluating overall expected munition performance. According to the U.S. Army Chemical Research and Development Center (CRDC), the single criterion for success was proper acquisition of test data.

- The requirement in the test and evaluation master plan (TEMP) is for lethal-agent generation

- The chemical mixing tests were conducted from August 1978 to April 1985 at the Chemical Research Development Center. Under controlled laboratory conditions, 41 tests were performed, 7 using simulants and 34 actually using QL and sulfur to produce VX. Some tests were performed in a reusable reactor and others in a bomb body over a wide range of temperatures.

- Tests prior to October 1982 were based on the concept of on-station mixing (mixing on the aircraft). After chemical mixing test LB-21 (or laboratory test number 21), using the actual bomb body, the delivery concept was changed to off-station mixing (mixing to begin after the bomb is released from the aircraft). This change precipitated a much shorter requirement for delivery time, changes in the design of the bomb, and the adoption of loft bombing (the aircraft approaches the target from a low altitude ingress and tosses the bomb to a higher altitude to gain standoff for the aircraft and time for the bomb to initiate mixing).

- According to DOD, chemical testing has been completed and no other chemical tests are scheduled.

- The issue of chemical mixing is not limited to the production of VX of a given purity. Many other issues are related to the question of chemical mixing and purity, and they will be discussed in this section of the report.

2. CHEMICAL TESTS

CHEMICAL MIXING TESTS SUMMARY TABLE[a]

Fahrenheit temperature	Total number of tests[b]
	8
	4
	1
	1
Total	14

[a]The table somewhat overstates the problem of the bomb generating agent for the entire critical time since not all tests were sampled during the entire interval.

[b]Our analysis of the chemical mixing tests focused on tests after LB-21, because of changes after this test. Tests prior to LB-21 generally provided the first , which is now the maximum time allowed, and therefore do not provide any information on the early portion of the reaction. We used tests L-22-24, L-27-30, LB-31-34, LB-36-37, and LBE-41 (see appendix I). We did not include tests L-25, L-26, and LB-35 because of problems in sample collection. Tests LB-38, L-39 and L-40 were performed with simulants.

PURITY REQUIREMENT

- DOD's explanation of the purity criterion varied:

  1. At our initial meeting on June 24, 1985, we were told that

  2. A less stringent definition of the criterion was given on July 12, 1985. Based on starting temperature, there is a

  3. Later, on September 3, 1985, we were told that the requirement is that

- The accompanying table summarizes test data using the first and third explanations.

  1. The first explanation is consistent with the requirement for on-station mixing, which required the

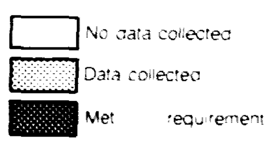
  2. The second explanation is not included in the summary table, because DOD did not provide data to show a time interval corresponding to starting temperature.

  3. The third explanation evokes questions of the validity of the criterion and hence the effectiveness of the bomb.

- DOD officials recognized this variation in explanation. They told us that DOD realizes that . They admitted that the chemical performance is not what they want, but they can design tactics to use it. "Operationally, it's good enough," a spokesperson said.

CHEMICAL TESTS

Figure 2: Test Interval and Purity Reached



INTERVAL TESTED AND PURITY REACHED

- The requirement in the test and evaluation master plan is for lethal agent generation

- The purpose of the chemical mixing tests was to determine "system behaviors over a range of physical and thermal regimes." The goal was to gather information for use with other data in order to evaluate the overall expected munition performance.

- The fact that the TEMP had a requirement for , but that the test purpose was not to see whether this requirement was met but merely to gather information, resulted in a gap in the data regarding agent purity. Thus, it has not been determined whether interval during the tests.

- The 14 tests in the accompanying chart (figure 2) highlight the fact that the critical time interval and the test period are not the same in most cases.

  --Only 4 tests were conducted for the entire interval of

  --Five tests achieved minimum purity over the : 3 tests in (L-22, L-23, L-24), 1 test in (LB-31), and 1 test at the only (LBE-41).

  --Three tests (L-25, L-26, LB-35) experienced problems in sample collection.

--Of the have vented during the critical time period.

GAO Conclusions

o Without data on pressure levels at high temperatures, a pressure-temperature curve cannot be predicted, nor is it known whether the bomb can withstand high pressures. This is especially worrisome because the test evidence (from LB-21) indicates . With off-station mixing, an explosion would not be harmful to the pilot. However,

PRESSURE BUILDUP

Description

- Pressure buildup is one phenomenon of the chemical mixing system. When the initial temperature is high , a significant pressure buildup begins in the first few seconds of mixing.

- This event was reported by a DOD contractor as early as 1966. The contractor stated that the unexpectedly high pressures could cause problems with the on-station mixing concept. This problem was expected to be a design limitation.

- In October 1982, test LB-21 resulted in a bomb blowout, a forceable ejection of internal bomb components. The bomb's initial starting temperature was (pounds per square inch) in approximately , when it blew up.

GAO Observations

- Testing since the 1982 explosion has been done with a pressure relief valve on the bomb, which will not be present in the production model of the Bigeye bomb.

- The relief valve is usually set at . When pressure reaches this point, the valve is opened to allow the pressure to go down to about before the valve is closed again.

- The testers say the reason for venting is to protect the test chamber. Cleanup is costly and time consuming.

- However, because the pressure is artificially relieved, there are no data on how the production model of the bomb will perform without the vent.

  --Of the 14 tests performed after the blowout, 5 have been vented during the

--Laboratory combustion chamber studies have identified complex chemical mechanisms and a large number of interacting variables involved in flashing. In one study, unitary VX vapor air mixtures burned above , and the study's authors added that this might occur "more readily in the unconfined atmosphere of an explosively disseminated agent aerosol cloud than in a combustion chamber." (In five of nine toxic chamber tests in which the initiation temperature was .)

GAO Conclusions

- o GAO believes the likelihood of flashing in Bigeye is speculative, but a very important issue to address. If any appreciable degree of flashing occurs, regardless of other functions, the weapon will be ineffective, because the agent would either burn to form relatively nontoxic products or evaporate and not reach the target at all.

- o Laboratory studies may add useful insights on why, how, when, and at what temperature the Bigeye reaction product may flash.

FLASHING

Description

- Flashing refers to either burning or instant vaporization of VX agent/reaction mixture during dissemination from the Bigeye bomb. DOD officials have stated that the question of whether flashing will occur could not be definitely answered without open-air testing.

GAO Observations

- Burning is a characteristic of VX.

  --VX is flammable; incineration is a recognized method of destroying munitions containing VX.

  --Tests performed in 1966 using unitary VX resulted in agent flashing in 4 of 6 cases.

  --Hydrocarbon gases formed in the Bigeye reaction, especially at high initial mixing temperatures, may enhance VX burning.

- Instant vaporization may be more likely for the binary Bigeye agent because the particle size of droplets may be so reduced as to form a cloud.

  --Simulant data show that an increase in the dissemination temperature reduces particle size. Chemical mixing causes the initial temperature to rise by approximately

  --In a series of dissemination studies using

- o The phenomenon of increased bioequivalent toxicity of binary generated agent was noticed by DOD in 1965. DOD reported that "binary VX is in general slightly more toxic than its normal counterpart; however, the sample population was far too small for any conclusive judgements along those lines."

- o

- o However, DOD officials stated that "the relationship between chemical purity and biotoxicity cannot be considered statistically significant." And DOD chemists at CRDC believe that the . (It seems to be based on impurities generated in the Bigeye reaction. These impurities vary from one reaction to another.)

GAO Observations

- o If we accept the assumption that biotoxicity produces a the stated purity measure, then (see the table on page 19). If, however,

GAO Conclusions

- o Although the , we believe that the use of LD50 as a quantitative test of agent generation is questionable because has been shown. Furthermore, the LD50 test is not precise enough to serve as a standard measurement, although it is a valid screening measurement for determining whether generated agent is potent.

BIOTOXICITY TESTS

Description

- The purpose of the biotoxicity tests was to assess the potency of generated agent. The test used a lethality measure based on the application of agent to the skin of rabbits. The results were reported as "LD50," or the amount of agent required to kill 50 percent of the animals tested. (This amount was statistically derived, using a series of groups of animals, each group given a different amount of agent.)

- There are two limitations to the quantitative use of the LD50 value:

    1. For results to be statistically significant, a certain number of animals must figure in the test.

    2. There is an inherent variation of one animal or group of animals with factors that include age, sex, diet, and disease. This variation affects the precision of comparative LD50 values.

- An assessment of LD50 by the Environmental Protection Agency in its draft regulation guidelines on pesticides states that LD50 is a "relatively coarse measurement" that is useful for classification, labeling, packaging, and expressing the "possible lethal potential of the test substance" following exposure to skin (emphasis added). This implies that LD50 is a more reasonable measure for order-of-magnitude than point estimates.

DOD Results

- DOD performed biotoxicity tests on a few Bigeye-generated samples. LD50 values were determined for 8 samples taken from 4 bomb/reactor full-scale tests (L-8, L-9, LB-33, LB-36). Only 2 samples (from LB-33 and LB-36) represent agent generated from high-temperature starting conditions, and only four data points were generated from these tests.

--In February 1983, DOD stated that "The binary [reactive] simulant used on these trials [dissemination tests] is not acceptable for the measurement of target effects. A different simulant should be used on future trials in which target effects are required." The next series of tests used non-reactive simulants to measure these effects.

- o DOD recognized the limitations of simulants in evaluating the performance of Bigeye.

--In May 1972, it was stated that "Once the static toxic tests are completed, the test plans at Deseret should be reinstated and live flights conducted" (Bigeye Binary Chemical Weapon Development Test and Evaluation Final Report).

--In July 1982, it was stated that "The military effectiveness of Bigeye cannot be demonstrated, beyond a reasonable doubt, without at least two open-air dissemination tests. Since there have been no live agent dissemination tests with large amounts of binary VX material existing under dynamic conditions, there is no baseline against which to compare simulant performance. The binary reaction further complicates simulant development . . ." (Joint Development Plan Revision 2).

--On December 4, 1985, it was stated that "The best simulant is live agent" (CRDC development test coordinator for the Bigeye).

GAO Observations

- o The price of using simulants is continuing uncertainty about how the weapon will function. When open-air testing was halted in 1969, the determination of the particle size of hot VX agent droplets disseminated from a full-scale weapon was identified as a technical problem that was still unresolved.

- o In a March 1985 draft Bigeye Weaponeering Manual, this uncertainty not only remains but is also underscored: "If the hot VX particle size is much different [from the estimated value], certain charts and graphs may need significant revision." Particle size is still unknown, but the charts and graphs referred to in the draft manual continue to serve as the guidance for using the weapon accurately.

CHEMICAL SIMULANTS

Description

o Simulants are relatively nontoxic substances used to test various functions in the Bigeye weapon system. Simulants are necessary because

--Open-air testing of live agents was restricted in 1969 and

--for certain component testing, simulant use is cheaper, less hazardous to workers and the environment, and quick (no cleanup, less administrative review).

o Different simulants have been used in the Bigeye.

--Reactive combinations of liquid (not QL) and sulfur produce a rise in temperature and pressure while generating a nontoxic product. Reactive simulants have been used in in-flight mixing and dissemination tests.

--Nonreactive, nontoxic liquid simulants (chemically similar to the agent) such as alcohol, antifreeze, water, and talc have been used to determine dissemination patterns and particle size and have been used to adjust for the weight of replaced components to test separation from the aircraft and the functioning of the weapon under environmental extremes.

DOD's Observations

o Inadequacies of simulants were noted in various tests.

--In August 1965, DOD stated that "On the basis of the experience gained in the course of this effort (search for a reactive simulant which approximates the binary reaction yet yields a relatively innocuous product) the use of simulants is not recommended except for purely mechanical functioning tests" (Chemical Research and Development Laboratories Special Publication 1-55).

DOD'S REPORTS OF CHEMICAL MIXING TEST RESULTS

- Numerous results of the chemical mixing tests have been reported by DOD. The following table summarizes these reports:

Source	Number of tests	Number of successes
Letter to the Congress from Richard Wagner (Assistant to the Secretary of Defense for Atomic Energy), May 21, 1985	30	26
Letter to the editor of the Washington Post from Thomas Welch (Deputy Assistant to the Secretary of Defense for Chemical Matters), June 24, 1985	8	8
Letter to GAO from Donald Hicks (Undersecretary for Research and Engineering), September 5, 1985	22	19
Briefing given to GAO by DOD December 4, 1985	22	20

- Queried about the inconsistency of these results, a DOD official said they were responding to different questions, as follows:

  --According to the Program Manager, the June 24, 1985, Welch letter referred only to the chemical mixing tests that correspond to TECHEVAL. The 8 tests were conducted between January 1984 and January 1985. (However, we observe that TECHEVAL was conducted from May 1985 to March 1985 and that in the January 1984 to January 1985 period, 10 chemical tests were conducted.)

LONG-DURATION CONTAMINATION

- According to DOD, the Bigeye binary weapon is to generate persistent nerve agent VX, which has "long-duration contamination" capability.

- DOD has not performed any studies comparing the persistence, degradation rates or duration of unitary VX with binary VX in the environment. An official from CRDC said, "VX is VX," and could see no reason to conduct such studies.

- We discussed VX with three chemists who have expertise in this area.

  --A recognized expert in organophosphorous pesticide chemistry speculated that the degradation rates of binary (Bigeye-generated) VX would be faster than unitary VX. The types and amounts of impurities trapped in the binary droplet with VX would react to promote degradation of the agent.

  --The other chemists who study the rates of chemical reactions agreed that the degradation rates may be different for binary and unitary VX.

  --All the experts we contacted agreed that testing is necessary to determine the extent of differences in degradation between binary and unitary VX.

- Given that differences in degradation are important to military tactics and strategies, we conclude that studies to determine the durability of binary VX should be conducted.

--The situation is similar with respect to tests L-28, considered successful by DOD and L-29, considered unsuccessful:

<u>L-28</u>	<u>L-29</u>

--Yet DOD considers test L-28 a success and test L-29 (which did not meet the minimum purity criteria) an "apparatus malfunction."

--DOD's standards for "apparatus failure" appear to be arbitrary and inconsistent; it appears that apparatus failure is invoked when the results are unfavorable; the same failure passes unnoticed when the results are what is desired.

o A total of 41 tests were performed:

--34 tests were toxic chemical mixing tests,
--17 tests were conducted after LB-21, when the delivery concept changed to off-station mixing and the design of the bomb changed as well, and
--14 tests experienced no problems with sample collection.

--The three other reports, however, referred to all chemical mixing tests done to date:

1. Mr. Wagner reported 30 chemical mixing tests to date. We cannot account for the 26 successes from the data we have seen, and DOD no longer affirms the 26 successes.

2. The Hicks report (19 successes in 22 tests) is based on the same 30 tests "looked at more closely" the Program Manager said. DOD eliminated 8 tests because of "apparatus malfunction." The 19 successes were based on the criterion

3. At the DOD briefing in December 1985, the Program Manager acknowledged that DOD had reported different answers but said that the number must be changed yet another time, to 20 successes in 22 tests. (This was based on a revised report of test L-30.)

- GAO takes issue with these reports:

--After the December briefing, we contacted CRDC, which issues the chemical mixing reports, to obtain a copy of the revised L-30 report. CRDC said it was not aware of a revised report. Test L-30 was done in March 1984, and CRDC said it knew no reason why a test report so old would be revised. We have not been able to locate the revision and therefore cannot substantiate the claim that test L-30 passed the purity measure.

--Some of the 22 tests DOD considered successful contain the same apparatus failures as the 8 tests eliminated. Tests L-25 and L-26 both had similar problems in collecting the chemical sample. Both generated VX estimates "based on a ," yet test L-25 (which was estimated to have met minimum purity criteria) was considered a valid test and L-26 (which did not meet minimum purity criteria) was not considered a valid test because of "apparatus malfunction."

PROBLEM IDENTIFICATION AND RESOLUTION

Problem: Tabs Failed to Retain Central Injector

On October 7, 1982, in test LB-21 (designed to determine temperature and pressure buildup for one hour or until weapon failure) the into the test because of pressure buildup. The binary VX was explosively released into the chamber, requiring extensive clean-up.

. Rather, modification efforts focused on the delivery mode which was changed to initiate the reaction after the bomb was dropped from the aircraft (off-station mixing), instead of inside the aircraft (on-station mixing) as before. No other tests have been made under the same conditions of LB-21. Subsequent test vessels were modified to control internal pressure (vented). At cold initiation temperatures , very little pressure buildup occurred. Some tests at cold temperatures were run for up to 60 minutes. At mid-range intiation temperature pressure buildup was observed. Here the reactions were vented and/or stopped . At high initiation temperatures , pressure buildups were observed. Reaction times were usually short, but even so, venting was required in 4 of the 8 high temperature cases within the after mixing began.

GAO Comment: Use of the Vent in Toxic Chamber Tests Introduces a Degree of Uncertainty in Assessing VX Production

Although we recognize that the vent is used as a safety feature, we also note it will not be used in the production weapon. During high temperature start tests, the vent allowed the release of volatile or lower molecular weight substances. If not released, these substances could chemically react so as to . Trapped gases could also have an effect on dissemination of the product (similar to opening a hot shaken soda bottle.) Thus, the fact that there exists some relationship between pressure buildup and high

- We belive that the latter 14 tests are the appropriate ones to include in the analysis of chemical mixing. We recognize that some of these tests suffered from structural problems. But because of the current ban on open-air testing, these laboratory tests are the only data on how well the chemistry works, given less-than-ideal laboratory conditions. Eliminating tests L-28 and L-29 because of structural problems reduces the number of applicable tests to 12, which in turn changes the chemical mixing summary table on page 19 and

GAO
Comment: <u>Refinements to the Impulse Cartridge Design Seem Important</u>

GAO found no evidence that the DoD researchers' recommendation was acted upon. As they explained, these refinements should be aimed at both

it appears extremely important to act upon the recommendation.

Problem: <u>Addition and Needed Adjustment of Mixing Manifold</u>

Initially added for test L-23 conducted on June 2, 1983, the mixing manifold (also called a flow diverter) was designed to increase fluid circulation and longitudinal mixing.

initiation temperature is established; however,

. Moreover, because simulants will be used in operational tests, this issue will not be addressed by DOD in subsequent tests and thus remains unresolved.

Problem: <u>Injector Cartridge Propellant Housing Fractured</u>

On January 18, 1984, in the first test (L-28) preconditioned to hot initiation temperature

Problem: <u>Leakage of Binary Agent from the Impulse Cartridge Vent</u>

In the May 17, 1984 (LB-32) test which was preconditioned to

No leaking was observed during this test or subsequent tests.

Problem: <u>Fracture of the Propellant Grain Trap in the Impulse Cartridge</u>

In the March 14, 1984 (L-30) test, preconditioned at

General GAO Conclusion on Chemical Tests:
<u>The Limited Number of Tests Precludes the Statistical Determination of Whether the Bigeye</u>

GAO recognizes the difficulty and complexity in conducting, sampling and analyzing VX full-scale tests. The cost of the tests (about $77,000 each), the availability and the necessary turn around-time limited the number of these tests, according to DOD. In addition, sampling or other test malfunctions resulted in a loss of data from several tests. The consequence of these limitations is that

Problem: Deformation of the Dissemination Port(s)

For the May 17, 1984, test LB-32, the internal control reaction pressure release valve was set to open at

GAO
Comment:

--The relatively thin walls of the Bigeye reactor contain the heat of the reaction, thus making Bigeye the hottest of any binary reaction, according to a CRDC official.

- Mixing

  --Lack of adequate agitation and mixing time can result in

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- Hot Spots

  --Aerodynamics in-flight heating of Bigeye results in

  --During the chemical reaction certain areas are hotter than others.

Because of the great variation in the factors listed above, there are differences from one Bigeye to another.

- Some of these observed differences have been in the chemical portion of the bomb -- e.g., VX purity, temperature, pressure.

- Other differences are in the deviation of the observed dissemination patterns from the calculated patterns and ballistics.

-

FACTORS THAT AFFECT VX PRODUCTION AND THEIR IMPLICATIONS

Factors Affecting VX Production Include:

- Starting Temperature

  --An increase in starting temperature results in an increase in reaction temperature and pressure.

  --Below a starting temperature of

  --At high starting temperatures above

- Purity and the type of contaminants in binary reactants QL and NE (sulfur)

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- Reactor size

  --Down scaling/up scaling can have a critical impact on the hardware component function and chemical reaction product stability. For example, successful mixing in a will work just as well using the same concepts.

SUMMARY OF UNRESOLVED ISSUES

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These unresolved issues from the chemical tests alone mean that the questions about chemical potency, durability and targeting (noted on pages 15 and 31) that affect the credibility and effectiveness of the Bigeye cannot as yet be answered.

- Specifications for QL and NE must be strict and components monitored during storage for degradation/contamination.
- Moisture must be excluded during storage, handling and assembly of the components.

INTRODUCTION

- The objective of this type of test is to determine if a weapon meets technical specifications.

- For the Bigeye, the first phase of developmental testing was conducted between July 1964 - September 1969 (when the program was temporarily halted) and resumed in November 1981.

- The latest phase, known as Technical Evaluation (TECHEVAL), was done between May 1984 and March 1985.

  --The objective was to verify that the design met the technical requirements and that the weapon was ready for operational testing.

  --This section presents the five major subtest programs that were implemented: separation tests (24 tests), dissemination tests (8 tests), carrier suitability tests (number of tests not clear), environmental tests (number of tests not clear), and hazards of electromagnetic radiation to ordnance (HERO) test (tested until successful).

  --Information is also presented on off-station mixing tests, captive carry tests, and system reliability.

- DOD reports that developmental testing has been completed. A certification stating that (1) developmental testing was successfully completed and (2) the program is ready to proceed to operational testing was written by the NAVAIR program office.

3. DEVELOPMENTAL TESTS

DOD Recommendations

- o The BLU-80(T-1)/B MOD 1 be authorized for use on the A-6 aircraft using the noted loadings, configurations and limitations.

- o Further testing be done of the compatibility of the new BLU-80(T-1)/B and its design changes with Navy armament handling equipment.

GAO Observations

- o The angles and g force tested were not the same as the test plan specified.

- o The SSTVs simulated Bigeye's components, e.g. QL, fuze. No internal reaction or mixing and no external dissemination occurred.

- o Some loading incompatibility was observed. For mixed loads (bombs and fuel tanks both carried on racks) certain positions cannot be used because of interference with the landing gear door. Certain loading configurations are acceptable for loft deliveries, but the same configuration is incompatible with dive deliveries.

- o The weapons received for testing had to be reworked. Some components were of inconsistent length and some plates needed redrilling.

- o . We can find no evidence that these additional tests were completed or whether additional data will be developed during operational testing.

SEPARATION TESTS

Objectives

- Verify that Bigeye can be safely released from the A-6E aircraft at speeds up to

- Obtain data suitable to determine store ballistics.

- Obtain data suitable to support flight clearance.

Description

- Twenty-four physical compatibility and separation tests were conducted separating 24 safe separation test vehicles (SSTVs) from the A-6 aircraft during 8 flights. Simulated fuzes were installed in all weapons. Ground based cameras provided coverage of aircraft and store during separation. On board cameras were used to evaluate separation characteristics.

DOD Criterion

- The test vehicles must be separated without contacting other components.

DOD Results

- Twenty-four SSTVs were satisfactorily separated during eight flights. Releases were

  from parent bomb racks and multiple ejector racks.

DOD Conclusions

- Within the scope of this test, Bigeye is satisfactory for tactical employment on the A-6 aircraft using a specified configuration.

DISSEMINATION TESTS

Objective

- Test objectives were numerous and varied with the different source documents. Three objectives were common to most documents. They were (1) gain increased confidence in the ability of the mixing system to mix the binary simulant ingredients, (2) determine dissemination characteristics, and (3) obtain release and fall data to verify weapon ballistics. (A complete list of objectives by document can be found in appendix III).

Description

- Eight dissemination tests were conducted from June 20, 1984 to November 15, 1984, during which time nine weapons were tested (two weapons were released during test 4). The weapons were loaded onto A-6E aircraft and released over the target area with the aid of the aircraft weapons computer. All weapons were filled with a non-reactive simulant (BIS) and the ballonets were empty.

DOD Criteria

- None

DOD Results

- The first test resulted in a "no-test" as the weapon failed to initiate the mixing sequence and the fuze did not function. Proper weapon function was verified for all of the other eight weapons. During the first four tests, the ground impact point was short of the desired location. This was because of an inappropriate correction factor used with the Rockeye software. (Bigeye computer software was not available.)

- o DOD's reporting of data is inconsistent. Consider the following table:

Source	Trials	Successes
May 21, 1985, letter to Congress by Richard Wagner	48	47
June 24, 1985, Washington Post letter by Thomas Welch	35	34
TECHEVAL Summary Report	24	Not given

GAO Conclusions

- o

- o Extensive simulation of Bigeye components may affect the accuracy of ballistic determinations.

- o Reworking of test weapons could indicate quality control problems and the need for quality control production procedures.

- Nine tests were specified in the plan. Eight tests were conducted, with one considered a "no-test" because the fuze failed to function.

- The computer software used was not the Bigeye software which was not yet available. Instead, a modified Rockeye software was used.

- No specific criteria are given. There are numerous objectives for the tests, but no criteria for successful testing exist. On the other hand, DoD has reported various success rates for dissemination testing. Consider the following table which includes all the test results DoD presented, using DoD's categorization.

Source	Type of Dissemination Test Reported by DOD	Trials	Successes
May 21, 1985, letter to Congress from Richard Wagner	Function in disseminating spray	13	12
	Mixing separated components	13	13
	Delivery to ground in predictable pattern	8	8
June 24, 1985, Washington Post letter by Thomas Welch	Dissemination of simulants	8	8
	Mixing simulants in flight	4	4
TECHEVAL Summary Report	Good ground coverage	7	7
	Good data for assessment of densities depositions	7	5
	Good data for ballistics comparisons	7	6
Computer Matching Report	Adequate data for modeling	7	3*

*Resulting in 1 excellent match, 1 good match, and 1 fair match.

DOD Conclusions

- Bigeye can be delivered on target
- Deposition densities and ground coverage are adequate for an effective weapon.
- Computer aided deliveries are viable.

Computer Pattern Matching Analysis

- Naval Weapons Center analysts used a computer model to predict dissemination patterns under various delivery conditions. Results from the TECHEVAL dissemination tests were compared with the model's predictions. Of the 8 tests, 3 were picked as having "adequate data for modeling and enough recovery on the pattern for meaningful comparison." The criterion for adequacy was based on the analyst's experience and judgements of quality of agreement between the two patterns. The results of the three comparisons provided 1 excellent match, 1 good match and 1 fair match.

GAO Observations

- Testing was not conducted as the TECHEVAL Test Plan specified.

  --The tests were to be performed using both reactive and non-reactive simulants. Reactive simulant was to be used in tests whose primary objective was to evaluate the mixing system. Non-reactive simulant was primarily to determine dissemination characteristics.

  --None of the tests was performed using reactive simulants.

  --Mixing was verified by visual examination of the weapon carcass, although visual assessments were difficult when the weapon breakup upon impact was extensive. However, in an engineering design test series (done April 1980 - August 1982), weapon functioning and mixing appeared normal until visual examination of the carcass unexpectedly showed the sulfur still in the ballonet.

--Yet in actual use, a sulfur filled ballonet will be used to make VX. And the droplet size is very important. According to the DOD Weaponeering Manual, charts and graphs may need significant revision if droplet size is different from the simulant prediction (see Chemical Simulants, p. 28).

- DOD's reporting of dissemination test results is again (see page 51) inconsistent and problematic.

  --There is no agreement in DOD's reports on the number of disseminating spray tests conducted. The number varies from as few as 7 to as many as 13. We know of only 8 tests (using 9 weapons) performed during TECHEVAL with one considered a "no-test", reducing the number of actual dissemination tests to 7.

  --We know that no liquid and solid component mixing was done during TECHEVAL. Therefore, the tests reported in that category (i.e., 4 tests mixing simulants in flight and 13 mixing separated components, see p. 51) must be based on earlier tests or have been extrapolated from other types of tests (e.g., off-station mixing) or have no grounding in actual fact.

  --Delivery to ground in predictable pattern is again inconsistent. Mr. Wagner claims 8 successful trials. Yet the computer matching report said only 3 tests had good enough data to match with the computer predictions and only 2 of those had matches better than "fair."

- By using Rockeye software, these tests do verify that the bomb can be delivered by computer, but they do not help in the calibration of the Bigeye software.

- The 8 dissemination tests did not address the first test objective at all. By using a non-reactive simulant, no mixing of binary simulant ingredients was done. Even though simulant mixing was specified in test plans, TECHEVAL did not address this issue.

- GAO cannot comment on the success or failure of these tests since there are no stated criteria against which to compare. Without stated criteria, it is difficult, if not impossible, to determine the system reliability of the component. And system reliability is one measure that is used to determine if the weapon is ready for operational testing and production.

GAO Conclusions

- Testing did not fully address the objectives of the tests.

  --By using empty ballonets, there was no way of knowing how well liquid and solid components mix during flight.

  --The

  . None of the tests was performed in this range. Changing the angle could change ballistics and stability data.

- The test conditions produced a recognized bias of unknown size and consequence in the outcome.

  --Contrary to the test plan, empty ballonets were used in all the tests. A DOD report states "The ballonets installed in the weapon did not contain any sulfur or simulated sulfur. This was done so as not to inject any non-soluble particulate matter into the BIS which could affect the resulting particle size distribution."

  --Prior tests showed that droplet size and area coverage differ for reactive (filled ballonet) versus non-reactive (empty ballonet) simulants. Reactive simulant tests produced a smaller droplet size and covered a smaller area.

DOD Conclusions

- o Bigeye can withstand the loads imposed by catapult launches and arrested landings.
- o Static functioning was a complete success.
- o Within the scope of this test, the Bigeye is satisfactory for carrier operations on the A-4, A-6, A-7, F-4 and F-18 aircraft.

DOD Recommendations

- o The Bigeye weapon be authorized for carrier operations on the A-6 aircraft.
- o
- o

GAO Observations

- o DOD states that static functioning was a complete success although they detail and make recommendations on how those problems should be resolved.
- o Reporting of the carrier suitability (cats and traps) testing by DOD is again inconsistent. Consider the following table:

CARRIER SUITABILITY TESTS

Objective

- The objectives were (1) to demonstrate that Bigeye is structurally capable of withstanding the loads imposed during catapult launch and arrested landing and (2) demonstrate that Bigeye will be functional after experiencing such launches and landings.

Description

- Two prototype weapons were hung on an A-7 aircraft and subjected to 5 catapult launches, 9 arrested landings and 6 bolters (touchdown and take-off). Both weapons were then statically functioned at ambient conditions. We cannot determine exactly how to aggregate the number of tests that were performed. Six bolters are mentioned but not analyzed. The 2 static functioning tests met a different objective than the cats and traps and we question the basis for aggregating the two types of tests.

DOD Criteria

- Criteria were delineated negatively in terms of occurrences that would constitute test failure. These include specifics on leakage, central injector rotation, port opening, central injector functioning, ballonet expansion, liquid containment, chemical degradation and fuze function (see appendix IV).

DOD Results

-

Design concepts are under investigation to rectify the problem.

ENVIRONMENTAL TESTS

Objective

- The objective of the tests is to determine whether Bigeye components and chemicals can withstand exposure to environmental extremes with a reliability of .80 at the 80% lower confidence limit (LCL).

Description

- Environmental tests were conducted in two phases and were designed to simulate anticipated environmental extremes during storage and transport and to determine adverse effects, if any, on the operation of the weapon. During the first phase, Bigeye components were tested in a series of temperature and vibration/shock tests. Ten bomb bodies filled with QL were subjected to the full range of temperature and vibration/shock tests. Ten sulfur filled ballonets were subjected to some of the environmental extreme tests,

  Vibration testing was completed using inert-filled ballonets. In the second phase, the components were combined and the weapon functioned--eight simulant tests were reported under TECHEVAL and two tests were conducted and reported by CRDC, one using simulants (LBE-38) and one using actual chemicals to produce VX (LBE-41).[1]

DOD Criteria

- For Phase I tests, the criteria for success are that the liquid and sulfur will not leak from their respective containers and will not degrade as a result of test stress. For Phase II tests, the criteria were delineated negatively in terms of occurrences that would constitute failure (see appendix V).

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[1] LBE-38 was conducted to "check-out the full-scale bomb test procedures" in anticipation of test LBE-41. LBE-41 is included in the Chemical Tests section.

		DEVELOPMENTAL TESTS	
Source	Type of Test	Trials	Successes
May 21, 1985, letter to Congress by Richard Wagner	Cats and Traps	20	20
June 24, 1985, Washington Post letter by Thomas Welch	Cats and Traps	20	20
TECHEVAL Final Summary Report	Cats and Traps	14	14
	Static Functioning	2	2
NWC Report on Weapon Reliability, November 1985	Cats and Traps	2	1

<u>GAO Conclusions</u>

- o DOD provides no explanation of <u>why</u> the

- o Yet if the and the test will not meet the specified criteria for success.

- o Bypassing the when statically functioning the weapon does not provide a realistic appraisal of the weapon system. Thus, the viability of the is an unresolved question and unresolved as well is the success of static functioning.

DOD Conclusions/Recommendations

- In the Phase I report, DOD testers conclude that the QL filled bombs and fuzes can withstand environmental extremes; however,

- In the Phase II report, DOD stated that all aspects of weapon performance No specifically identified discussion of conclusions/recommendations was included in the brief report.

- In the TECHEVAL Summary Report, DOD concluded that the bomb can withstand exposure to environmental extremes,

GAO Observations

- The TECHEVAL Summary Report omits the following:

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  --There is no calculation of overall system reliability.

  --The discusson of the phase II functioning tests is incomplete. The report omits reference to the toxic chamber test (which was sucessfully conducted) and the proposed dissemination test (which we could not document was conducted).

  --There were no documented retests of failed components. The TECHEVAL Test Plan and Phase I Report recommended retesting of redesigned components which failed testing.

DOD Test Results

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Bomb storage reliability with an 80% confidence level was estimated to be between

o

Ballonet reliability with an 80% confidence level was estimated to be between

o (reliability = 1)

o Phase I overall weapon reliability for environmental storage calculated from the composite reliability of its components is at the lower boundary of the 80% confidence interval (this assumes 100% reliability of the ballonets).

o In phase II, 8 simulant filled weapons were functioned
There was 1 "no test" at the low temperature because an incorrectly formulated simulant froze. Of the remaining 7 tests, the FZU and fuze were bypassed in one cold and one hot test respectively. The minimum mix time according to the Bigeye performance specification

One dissemination test was initially planned. (GAO could not confirm that this test was done.) No phase II reliability was reported.

HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE TESTS

Objective

- The overall objective was to demonstrate that the current Bigeye configuration is HERO safe. Specifically in accordance with Military Standard 1385A, the FMU/B fuze and MK 133 ignitor in the Bigeye off-station mixing system were to be tested, modified, if necessary, and retested until they met the standard's requirements during handling and loading procedures and presence conditions.

Description

- Because communications and radar systems, such as those installed on board Navy vessels, produce high intensity electromagnetic environments that can cause inadvertent ignition of electro-explosive devices, ordnance systems are tested to determine whether they are capable of ignition in these environments. Testing involves simulating handling and loading activities in various electromagnetic environments and measuring corresponding currents generated in the weapon's electro-explosive devices such as fuzes.

DOD Criteria

- The Naval Air Safety Office reviewed the Bigeye weapon system configuration and operations manual and determined that only the fully assembled Bigeye would be subject to high electromagnetic environments during on-deck activities. Furthermore, the office determined that if either the fuze or the ignitor were to inadvertently fire, the weapon would dud. However, safety features built into the system would prevent initiation of mixing or port opening (dissemination).

- o There are inconsistencies in the various summaries and reports of test results.

  --Mr. Wagner's letter stated that the weapon can withstand environmental and handling testing. It noted that the weapons were successful per specification and yet added that the " shipping container failed specifications and is being redesigned." Other problems and reliability were not discussed.

  --Overall weapon reliability is not clear. The lower confidence limit for ballonet reliability is 0. But even if this is fixed to have 100% reliability, the LCL for the rest of the component is

  --Summary statistics provided to GAO by the Bigeye Program Officer are internally inconsistent and miscount the number of tests actually completed. One table shows that of 10 tests there were 9 applicable tests and 9 successful tests. Another table of the same data states that of the 10 tests there were 8 applicable tests and 8 successful tests. As a result, it is unclear how many tests were performed and it is therefore impossible to determine the rate of success.

<u>GAO Conclusions</u>

- o DOD has not demonstrated that the current Bigeye weapon (design and components) as a system can withstand stresses induced by climatic extremes

- Testing criteria were for reliability (≤ 45% MNFC) rather than the more stringent safety (≤ 15% MNFC). It was determined that in the assembled state, accidental detonation would not either cause mixing or allow the liquid to be released (safety concerns); rather the effect would be to dud the bomb (reliability concern). If the safety criterion were used, as would probably be appropriate during assembly, the fuze exceeded 15% MNFC in

- The testers reported that the fuze when used "on" the Bigeye weapon is a "HERO SAFE ORDNANCE." Subsequent summaries (TECHEVAL Summary Report and Wagner letter) broaden the qualification to the entire weapon.

GAO Conclusions

- The "HERO SAFE ORDNANCE" qualification is limited.

  --It does not apply to all components (some were not tested).

  --It applies only to handling procedures on deck.

  --It does not apply to storage and assembly which currently are planned for only RF free environments. However, in an RF environment, on deck or on land outside a building, assembly probably would make the fuze HERO susceptible to premature explosion and injury to surrounding personnel.

  --It applies to the then current design as tested. Any modifications must be reevaluated.

- Because the fuze tested was a prototype which can slightly change during full production (even without formal design changes) the

- The established criteria for acceptance or rejection of naval ordnance systems are based on the percentage of maximum no-fire current (MNFC) measured in the system's electro-explosive devices. If inadvertent ignition could injure personnel or burn, the test criterion would be safety and the measured induced current must be less than or equal to (<) 15% MNFC. If the adverse consequence would be a dud weapon, the test criterion is reliability and the measured induced current must be less than or equal to 45% MNFC. The Bigeye fuze and ignitor were tested for reliability (≤ 45% MNFC).

DOD Results/Conclusions

- In the February 1984 test, the FMU-140/B fuze was evaluated as HERO susceptible; . In the June 1984 test, the modified FMU-140/B DPF (Dispenser Proximity Fuze) when used on the Bigeye weapon was classified as "HERO SAFE ORDNANCE." The highest measured current was . The test report noted that presetting and assembly procedures were not included in the HERO tests and that any further modifications to the design or assembly/handling procedures will require reanalysis or retest of the Bigeye system.

- Mr. Wagner's letter and the TECHEVAL Summary Report note that the Bigeye successfully meets all HERO requirements. No success count is given to this test.

GAO Observations

- Not all components of the mixing system, e.g., the FZU-37A/B wind turbine generator, electronics package and interconnecting cables, were tested as proposed.

- Testing did not include storage and handling (assembly). These were determined to be not applicable because they would be performed below deck in a radio frequency (RF) free environment.

GAO Observations

- o Tests were hastily conducted and incomplete.

  --A quotation in test 4 says "Because of the pressure to get the test off, the decision was made to proceed with the understanding that the range data may be minimal." (Heavy rains had affected the range --roads were washed out, power and communications were down).

  --

- o Aggregation of these tests may be inappropriate because of changing modifications to the test vehicle.

- o GAO cannot verify or reconcile the basis for the various DOD test success determinations. Consider the following table:

Source	Trials	Successes
OSM Test Reports	4 (trial 3 not available)	
June 24, 1985, Washington Post letter by Thomas Welch	4	4
Naval Weapons Center Summary Tables	4	

GAO Conclusions

- o Use of the tests to determine the feasibility of the OSM concept is appropriate. However, the weapon tested is not the present design and testing results should therefore not have been included in summaries such as Mr. Welch's. (FZU and FMU-140 were not used in this design.)

OFF-STATION MIXING TESTS

Objective

- The objectives of off-station mixing (OSM) testing varied with the individual tests. The numerous objectives were to evaluate the feasibility of off-station mixing, to demonstrate clean separation from the aircraft when the fins are not deployed, to determine any impact on dissemination time due to the addition of the mix channel and to obtain injector rotational characteristics.

Description

- Five OSM tests, referred to as Mixmaster, were conducted from May 1983 to September 1983. (This analysis is based on tests 1, 2, 4 and 5. Test 3 is not included as DOD has not been able to locate a copy of that test report.) Test vehicles were separated from aircraft and the mixing process was then monitored. A reactive simulant (TIP-BIS) was used in all tests and all used an internal battery energy source and time fuze (not current design). Tests 4 and 5 added a mix channel, which is the current design.

DOD Criteria

- None specifically mentioned.

DOD Results

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CAPTIVE-CARRY TESTS

Objective

- To obtain environmental aerodynamic heating responses of the reactor tank and the liquid QL for a tactical no-mix weapon.

Description

- Two low-altitude, high speed (mach 0.85 to 0.90) captive-carry tests were performed in November 1983 and August 1984. Instrumental no-mix weapons were carried by F/A-18 and F-111E aircraft respectively.

DOD Results

	Initial Liquid Temperature Before Flight	Maximum Liquid Temperature Achieved During Flight
Test 1		
Test 2		

- Specifically, the environmental aerodynamic heating responses obtained during the F-111E captive flight test recorded a maximum skin temperature of . Furthermore, the liquid QL reached an equilibrium (i.e., stable) temperature after a time period of about of high speed flight.

2Ambient temperature of 88°F based on atmospheric data at 3000 ft. means sea level; surface air temperature of 97°F.

- It is true that these tests have little continuing technical significance for the Bigeye performance. They do have important significance for judgements on Bigeye decisionmaking since it appears that decisions such as that of proceeding to the next phase of testing was based on data such as these.

- Because this was the only flight testing using reactive simulants, data such as dissemination time and port functioning must now be obtained from operational tests. This violates the testing concept that the weapon's technical specification is determined from developmental testing and validated in operational testing.

GAO Conclusion

- These two tests were performed to provide relevant data on the initial mixing temperature of QL. However, this information was not used in conducting subsequent chemical mixing tests. Therefore, there is a critical gap in the data regarding agent generation over this most likely range of temperatures.

- DOD also performed analyses which indicated that the pre-mix liquid temperature could be heated up to or higher, depending upon (1) the initial temperatures, (2) the atmospheric profile, and (3) the aircraft flight profile.

GAO Observations

- DOD's captive-carry tests and analysis confirmed the phenomenon of environmental aerodynamic heating where the Bigeye bomb develops high pre-mixed QL liquid temperature when carried by an aircraft flying low-altitude high-speed passes.

  This also underscores the importance of testing chemical mixing at the high temperature range to obtain data on both the chemistry of VX production and the mechanics of initiating the mixing system (see pages 35 and 43).

- The maximum liquid temperature achieved during flight corresponds to the initial mixing temperature of the chemical mixing tests. However, GAO notes that no chemical mixing tests were made in the temperature band of

  (see page 19).

- Program officials provided a solution to the

- DOD has completed these two tests and has no plans for further captive-carry tests.

a. Failure of the central injector to rotate at 450 r.p.m. (minimum) for 15 seconds (minimum).

b. Failure of any port to open.

c. Failure of the tail fins to deploy and lock.

d. Failure of the central injector to open after ballonet function.

e. Failure of the ballonet to expand.

f. Failure of the reactor to contain the liquid prior to port opening.

<u>TECHEVAL Reliability Assessment</u>

- In a handwritten November 1985 update of the April 1985 reliability assessment, a Navy reliability engineer stated that the TECHEVAL reliability goal based on the agreed upon "shoot for score" series of the environmental weapons was met. The actual score was 8 of 8 with 2 "no tests" (10 tests overall) for a TECHEVAL reliability of approximately at the 80% lower confidence level. Having reviewed the summary tables updated in November 1985, the April 1985 reliability assessment, the TECHEVAL Summary Report and the various individual test reports, we could not determine which tests were included in summaries, or how tests were determined to be successful. Consider the following excerpts:

--

SYSTEM RELIABILITY

Definition

- Reliability is a measure of the confidence that a system will perform according to standards (specifications) and, in a more general sense, will perform as expected. Reliability, expressed as a probability, is computed from data obtained by testing a system and its components.

Reliability Requirement

- The Testing and Evaluation Master Plan dated May 1985 specified the DT&E and OT&E criterion for weapon system reliability to be
The TEMP adds the following condition:

  --Given that the bomb rack arming unit functions properly and that release occurs, the probability that VX agent is generated, tail fins deploy, forward and rear ports open such that VX agent can be disseminated is

  --Furthermore as noted in a report on the April 1985 reliability assessment of the Bigeye weapon, the demonstrated weapon reliability upon completion of TECHEVAL and OPEVAL is to be at least respectively (determined at the 80% lower confidence limit).

Performance Criteria

- As stated in the April 1985 assessment, the reliability requirement only addresses the mechanical function of the weapon, leaving VX purity as a partial function of the mechanical performance. The success/failure criteria for the Bigeye performance characteristics are based on earlier toxic chamber purity studies conducted at the Chemical Systems Laboratory during the 1960's. The performance characteristics basically state the following: During visual examination, any detected leakage shall constitute a failure. During bomb functional tests, any of the following shall constitute a failure:

Reliability Data Summaries

- The following are summary tables of reliability data provided to us in November 1985 by the Bigeye Program Office in China Lake. These tables illustrate how the tests are grouped. Table A displays those tests in TECHEVAL and a lot acceptance series in which the entire weapon was functioned. (Simulants were used except for one toxic chamber test.) Table B summarizes and groups test results by the subsystem which was tested. Presumably in some tests, such as the static function tests, all subsystems were activated in a single test.

Table A
Phase II Weapon OSM Configuration

Test	No. tests	Applicable tests	Successes	Point estimate	Binomial at 80% LCL
Dissemination	9 (9)*	8 (8)	8 (8)	1.0	
Lot Acceptance	3 (3)	3 (3)	2 (2)	0.67	
Cats and traps	2 (2)	2 (2)	1 (1)	0.50	
Environmental	10 (8)	8 (7)	8 (6)	1.0	
(OSM proof of concept)*	(5)	(4)			
Total	24 (27)	21 (24)			

*Subcategory and numbers in parentheses are as reported in the April 1985 reliability assessment.

- Yet, in the summary tables, November 1985 update, and TECHEVAL Summary for environmental tests, there are no reported failures. (If one also considers the performance criterion "a" (page 71), then there are other failures as well.

- Official Bigeye documents are inconsistent concerning the determination of overall mission reliability. The TEMP states that reliability will be assessed during TECHEVAL and throughout the test program. However, the Joint Development Plan (Revision No. 2) Bigeye Binary Chemical Weapon [BLU-80/B] July 1982 stated that:

  "The overall mission reliability will be determined during operational testing. Due to funding limitations, component reliability will be used to the extent possible in assessing the overall weapon reliability."

- During a December 4, 1985 briefing, the Navy Air Program coordinator dismissed the issue by stating that these test results lacked statistical significance because limited funds resulted in too few tests. A China Lake engineer pointed out that he could "gin up" any kind of numbers.

--Quite apart from the design problem, however, it is questionable whether the Bigeye weapon system actually met the TECHEVAL reliability requirement. The April 1985 reliability assessment notes a phenomenal reliability improvement compared to the old weapon. However, it concludes that the TECHEVAL reliability requirement had not been met (see Table A parenthetical data overall reliability of 80% LCL). Nevertheless, we note as is characteristic of reporting results in this program, that the handwritten November 1985 update to the reliability assessment gives an overall reliability of about @ 80% LCL based on the "shoot for score" series of environmental weapons -- 10 overall tests, 2 no tests and 8 successes out of 8 applicable tests and Table A arrives at a total (presumably system reliability) of @ 80% LCL. (Note in Table A that the November data omitted the OSM Proof of Concept subcategory, noted one more applicable environmental test than the April data did, and upgraded one environmental test failure to a success.) Again, we see inconsistency in data reporting, no documentation as to why tests are dropped from or added to the count and why they are subsequently changed from failures to successes.

--Considering overall reliability from all developmental tests, as reported by DOD in Table B, GAO estimates a reliability of @ 80% LCL. This value is below the .80 @ 80% requirement and does not take into account the of VX generation, a fact which would render overall weapon reliability even lower. We note the of this subsystem thus compounding our concern stated in the first comment. This again leaves DoD with a major unresolved issue as developmental testing concludes that cannot be well addressed at the operational stage. This is because operational testing--

Table B
Combined Reliability Data Base

Subsystem	No. Tests	Successes	Point Estimate	Binomial At 80% LCL
Structural	57	57	1.00	
Central Injector	83	67	.81	
Dissemination	85	77	.91	
Tail Fin	95	94	.99	

GAO Comments

o We could not document which tests were included in the summaries and how or why certain tests were grouped under types of tests or subsystem headings. Therefore, we cannot verify the results or determine the overall system reliability. However, because reliability considerations are at the heart of our concerns about the Bigeye weapon system developmental testing and evaluation, the following comments are emphasized:

--

As we have shown earlier in this report,

Furthermore, to assert that testing of the Bigeye chemical system in the 1960's established success/failure criteria "leaving VX purity as a partial function of the mechanical performance" is meaningless. Neither temperature nor pressure concerns are solely related to mechanical performance. (Note VX purity test results in appendix I, especially those tests run at the same starting temperature). The 1960's tests also did not focus on high initial mixing temperatures and did not predict the rapid high pressure buildup which led to the blowout of LB-21 and the change to off-station mixing delivery. Without VX purity tests developed both for reliability purposes and assessed in context of the other Bigeye weapon system subcomponents, we are left with an evaluation design that does not evaluate the system. Indeed, it would be perfectly possible, using that design,

4. OPERATIONAL TESTS

SUMMARY OF UNRESOLVED ISSUES

- Can the weapon be safely separated at operationally expected angles and gravitational pull (e.g.,)?
- Does chemical mixing occur adequately in flight?
- Is the area covered by agent during dissemination sufficient? (Reports give varied results and no quantitative criteria can be found.)
- Can the weapon withstand catapult launch and arrested landing? (No explanation of problems seen in these tests is given; no actions are planned to address them.)
- Can the weapon withstand environmental extremes? (Serious problems occurred during the test, yet there is no evidence of corrections or retesting.)
- Is the minimum mix time specification important and realistic?
- Are untested components (e.g., FZU, electronics package) HERO safe?
- How well will the weapon function if components are not "bypassed"?
- What is the reliability of the weapon after developmental testing? Why are tests included and excluded at will? How should reliability be calculated?

These unresolved developmental issues pose unrelenting problems with regard to the Bigeye's technical credibility as a weapon. When the unresolved chemical issues (see page 43) are considered as well, uncertainties are added about chemical potency and targeting. This raises questions about the wisdom of the decision taken to move to operational testing, especially since most of the questions on which critical information is needed do not lend themselves well to operational test and evaluation.

CRITICAL ISSUES THAT DOD WILL ADDRESS

- The following are critical issues DOD has identified for resolution/partial resolution during operational testing.

  --Effectiveness Issues

  - Delivery Accuracy: Will Bigeye provide adequate delivery accuracy to support mission requirements?
  - Deposition Density: Will Bigeye provide desired deposition densities when delivered with operationally realistic delivery maneuvers?
  - Operating Environment: Will Bigeye be successfully employed under all conditions encountered during mission operations?
  - Vulnerability: Will the delivery maneuvers required result in unacceptable increases in aircraft vulnerability?

  --Suitability Issues

  - Reliability/Availability: Will Bigeye reliability/availability be adequate to support mission requirements?
  - Maintainability: Is the time required for breakout, assembly, and loading in the operational environment excessive? Does protective clothing, when required to be worn, inhibit or preclude the performance of any required operations?
  - Logistic Supportability: Can the weapon system be adequately supported within existing logistics systems?
  - Compatibility: Will the weapon be compatible with its intended physical, functional and electromagnetic operational environments, both ashore and afloat?

INTRODUCTION

- The objective of operational tests is to determine if a weapon will be useful in combat.
- In the case of the Bigeye, live agent cannot be used in the operational tests because of the ban on open air testing. Simulants will be used instead (see page 28).
- Both the Navy and Air Force are conducting operational tests. Both have completed Phase I testing. Phase II testing (OPEVAL) initiation is dependent upon the problems discovered in Phase I testing and the time it takes to rectify these problems. OPEVAL is expected to begin in the spring of 1986.
- Although operational testing has not been completed and final reports issued, we have some observations on the critical issues that will be addressed by DOD, the critical issues that will not be addressed by DOD, and aircraft software used for Bigeye delivery.

CRITICAL ISSUES THAT DOD WILL NOT ADDRESS

Following is a list of unresolved questions that have been mentioned elsewhere in this report. The following unresolved issues will not be addressed in operational testing, despite their relationship to the efficient functioning and usefulness in combat of the Bigeye bomb.

- A DOD spokesman has said that minimum purity interval and adjustments must be made operationally. . But how does the pilot know when to drop the bomb?

  --DOD developed a series of charts for the Weaponeering Manual that predict starting mix temperature based on initial temperature and flight path.

  - How can the pilot know the initial temperature of the liquid? There are no temperature probes.

  - Even if he knew the initial temperature, how could he make operational adjustments when his flight pattern has changed? Based on projected starting mix temperature, the pilot has a preset mix time, which cannot be changed. How can he adjust if the mix temperature is different from his expectation?

- All chemical mixing tests were done under controlled laboratory conditions. How will the chemical mixing and resultant VX product be affected by operational conditions?

  --The lab tests were conducted with a homogeneous temperature throughout the bomb. Since the bomb body and ballonet will be stored separately and mated right before take-off, it is possible the components will be at different temperatures. Does this affect the reaction?

  --All tests were performed with an artificially low dew point and liquid nitrogen backfill to guard against moisture. A non-acqueous cleaning solution was developed. What happens to the purity of VX when the components are exposed to moisture?

- o Interoperability: Will Bigeye adequately interface with the racks, flight envelopes and weapons control systems of the A-4, A-6, F/A-18 AV-8B, F-4, F-16 and F-111 aircraft?

- o Training: Will the Training Plan adequately support personnel training requirements?

- o Safety: Can all aspects of transportation, handling, loading and delivery be accomplished safely without requiring that personnel involved in any of these activities wear chemical protective clothing? Can the weapon be jettisoned safely, without producing significant amounts of lethal agent?

o Numerous sorties are planned to deliver test vehicles from four types of aircraft using as many combinations of delivery aircraft and tactical maneuvers as practicable. Weapons will be filled with either mix simulant or dissemination simulant. Scenarios will simulate the operational environment to the greatest degree possible.

o Detailed test plans are not available for OPEVAL so GAO cannot determine specifically what the testing will cover.

AIRCRAFT SOFTWARE FOR DELIVERY

Purpose

- o The computer software is used to aid the pilot in the automatic delivery of Bigeye weapons.

Description

- o Pre-planning is very important for the mission. Height of burst, flight altitude and mix time determine the envelope of time during which the bomb should be delivered. (Mix time is based on the temperature of the components as mixing begins.)

- o The planner tries to select the combination allowing the greatest amount of time for delivery (the simulation we saw gave the pilot to release the bomb to hit the target.) Inflight changes can change the envelope of delivery. Because the best alternative was selected during pre-planning, the time for delivery will generally be shorter.

- o After boarding but before take-off, the following information is entered into the computer:

  --Latitude, longitude and altitude of target
  --Density factor
  --Height of burst (altitude)
  --Minimum mix time
  --Expected target wind direction and velocity (actual wind direction and velocity as determined by aircraft may be used instead).

(U)o Actual air speed and altitude of aircraft are calculated by the aircraft and used by the software package.

o Retesting was recommended, but it was not done. How will affect the integrity of the bomb components, the ability to properly mix and the generation of lethal agent?

o

o Testing was done in a horizontal position. How well will mixing occur in a non-horizontal position?

o Will flashing occur, burning up all the agent before it hits the ground?

o Will binary VX provide the long-duration contamination that is required?

o What is the droplet size of VX? The Weaponeering Manual bases its charts and graphs on a particular size. But the two different types of simulant (reactive and non-reactive) generate different size droplets. Which is more representative of the binary reaction?

o What is the actual reliability of the bomb? Chemical purity was not included in DOD's estimate as the requirement only addresses the "mechanical function of the weapon." Ballonet reliability was calculated as , yet 1.0 was used in the reliability computation since "failure mode correction should raise the reliability to 1.00." What would the reliability be if (1) all components of the bomb were included and (2) reliability was calculated based on actual performance and not assumed corrections?

- The mix time input only has a minimum value.

  --The mix time input to the software is the minimum mixing time needed to generate agent. There is no provision for maximum mixing time, and the computer allows up to to mix.

  --At high temperatures where agent degrades rapidly, o As the pilot flies and approaches the target, the "symbology" on the screen directs his movements and bomb delivery. The screen presents a "pathway" in the sky and if the pilot follows this path as it moves above the horizon, it automatically guides him to do a loft maneuver. The screen tells the pilot when he is "in-range" and the pilot then presses a release button, although the computer actually releases the bomb(s) at the optimal time.

o The pilot generally arms the bombs after take-off but before close approach to the target. The arming control unit allows the pilot to select the number of bombs to release in each pass.

o

o The computer software has been written and tested for the A-6 aircraft. Information on how to use the software and guidance on how to determine inputs (e.g., mix time) are in the Weaponeering Manual, now in draft form.

GAO Observations of Potential Problems

o The pilot cannot change several inputs after takeoff.

PRINCIPAL FINDINGS

- The Bigeye chemical and developmental test program presents major and continuing inconsistencies.

  --There are gaps between weapon requirements and test purposes (see page 20).

  --There are incongruities between test plans and actual tests (see pages 46, 50). In some cases, tests were even conducted under conditions which would produce an acknowledged bias in the results (see pages 52).

  --DOD has provided conflicting test results and analyses (see pages 31, 48, 51, 56, 60, 65, 73).

- Test criteria are ambiguous, shifting and uncertain.

  --The chemical mixing tests were subjected to sequentially different interpretations of one criterion. No justification was given for the changes (see page 18).

  --Some tests were performed with no stated criteria at all (e.g. dissemination, off-station mixing). Yet success/failure rates were given for those tests (see pages 49, 64).

  --Other tests were conducted with vague and general criteria. Test objectives were often confused with or substituted for specific criteria (see pages 49, 64). This allowed non-functioning components to be bypassed during testing (see pages 56, 58).

  --Because of vague or nonexistent criteria, tests could be, and were, added to and dropped from reporting of results, at the discretion of the reporter. Tests were moved from failure to success categories without explanation (see pages 31, 48, 56, 60, 65, 73).

- There is a paucity of test data and analysis to resolve important technical issues.

5. PRINCIPAL FINDINGS AND CONCLUSIONS

--The calculation of weapon system reliability does not include chemical mixing tests/VX generation.

--The program office has not provided us with certain documents on which consequential actions were based. Revised test L-30 and OSM test number 3 are examples (see pages 32, 64).

o "Solutions" to technical problems result in operational constraints and uncertainties.

--The excessive pressure buildup problem resulting in a bomb blowout was "solved" by going to the off-station mixing concept. However, to allow the bomb enough time to mix before dissemination, the primary delivery mode was changed to lofting. The pilot is thus limited in his freedom to manuever (see page 17). Aircraft vulnerability is a concern as well and the draft Weaponeering Manual states that a loft of more than

--Since the bomb cannot generate pure agent over the entire critical time interval (according to DOD), the onus is now on the pilot to deliver the bomb during a shorter time period (which is based on the initial liquid temperature of the bomb) (see page 18).

--With the advent of off-station mixing, leakage is no longer considered a concern by the project office because leaks could not harm the pilot. However, it is uncertain if a leaking bomb would deliver an effective payload (see pages 23, 36).

--The excessive pressure buildup problem was "solved" by going to the off-station mixing concept. Subsequent to OSM, laboratory tests artificially released pressure above . Since a pressure-release valve is not part of the design of the bomb, it is uncertain how chemical mixing or the structural integrity of the bomb will be affected--the bomb could explode prematurely and be rendered useless (see pages 22-23).

--Chemical mixing tests were done under controlled laboratory conditions and provided no information on how well the chemistry works under more realistic conditions. This problem will not be resolved during operational testing (see pages 22, 81-82).

--Tests to evaluate the mixing system were conducted with a simulant that did not require mixing. These tests should have been conducted during developmental testing (where performance specification is determined) and not pushed forward into operational testing (where weapon usefulness is determined) (see pages 52-53).

--Because of lack of test data, numerous issues (e.g., pressure buildup, flashing, droplet size, durability of binary VX) remain unresolved (see pages 22-25, 29, 30).

--The paucity of biotoxicity test data makes it impossible to determine the relationship between chemical purity and biotoxicity (see page 27).

--Because of the discrepancies between test plans and actual testing, there are gaps in data. For example, separation testing provides no information on angles steeper than are expected and were specified in the plan (see page 46).

--In some areas (e.g., transportation), testers made recommendations for corrections, improvements and retesting to increase available knowledge. These recommendations were not acted upon (see pages 55, 60).

--Analysis was often lacking or deficient. For example, problems were noted in carrier suitability testing. There was no explanation of why the problems occurred, but the analysis went on to state that it was not a result of the test itself (see page 56).

--Reliability data analysis is of especially dubious quality. Numerous tables on reliability exist, yet there is no documentation on why tests are included or excluded, why certain subsystems are included or not. No reasonable analysis on weapon reliability calculation seems to exist (see pages 70-75).

CONCLUSIONS

- Testing to date has not been able to demonstrate the feasibility and effectiveness of the Bigeye.
- Operational testing will not address many of the unresolved critical questions which remain.
- More developmental testing may be able to answer some of these questions, if the testing is well designed, implemented and reported.
- Other problems, however, are intractable (e.g., the proposed tactic which exposes the aircraft to enemy defenses (flying at high altitude) versus the need to control the temperature of the bomb).
- The Bigeye bomb is not ready for production.
- Given that the deterrent and retaliatory mission assigned to Bigeye remain, and given that the binary concept and technology are not new (over 30 years old), the potential of other technologies and other chemical weapons for accomplishing those missions should be examined.

- Moving from one set of tests to another (e.g., developmental tests to operational tests) is not an insignificant thing to do. Test names have more than nominal significance--they are categorized for a purpose. Developmental tests determine if a weapon meets its technical specifications; operational tests determine if a weapon will be useful in combat. If testing is moved from one category to another before unresolved issues are solved, those issues often become lost and forgotten with the emergence and resolution of new problems and are never addressed.

Test number	LB-34	LB-33	LB-32	LB-31
Test date	9/84	6/84	5/84	4/84
Initial temperature				
Preconditioning (moisture control)	Yes	Yes	Yes	Yes
Venting occurs within critical time				
Structural problems				
Purity analysis				

CHEMICAL MIXING TESTS DATA

Test number	LBE-41	LB-37	LB-36	LB-35
Test date	4/85	1/85	12/84	10/84
Initial temperature				
Preconditioning (moisture control)	Yes	Yes	Yes	Yes
Venting occurs within critical time				
Structural problems				
Purity analysis				[a]Chamber malfunction: samples not collected for 3 days.

Test number	L-26	L-25	L-24	L-23	LB-22
Test date	10/83	9/83	8/83	6/83	4/83
Initial temperature					
Precondi- tioning (moisture control)	Yes	Yes	Yes	Unclear	Unclear
Venting occurs within critical time					
Structural problems					
Purity analysis	[a]No samples collected. Estimate only	[b]No samples collected. Estimate only			

Test number	L-30	L-29	L-28	L-27
Test date	3/84	2/84	1/84	11/83
Initial temperature				
Preconditioning (moisture control)	Yes	Yes	Yes	Yes
Venting occurs within critical time				
Structural problems				
Purity analysis				

SCOPE OF TESTING

TECHEVAL Test Plan Appendix C January 1984	TECHEVAL Test Plan Text March 1984	Naval Air Test Center Interim Report January 1985	Naval Air Test Center Final Report September 1985	TECHEVAL Final Summary Report
Initial testing done with 4-SSTVs during 4 flights totaling approximately 2 hours Subsequent testing to require 36 SSTVs for approximately 30 flights totaling 22 hours Practice runs to be conducted as required to establish proper operation of test equipment, familiarize aircrew and ground support personnel with desired test point Detailed post flight inspection of airplane to be conducted to detect evidence of store-to-airplane contact Film data to be reviewed for separation characteristics and weapon clearance Photographic computer analysis to be used to analyze various tests	40 SSTVs to conduct testing SSTV is chemically inert with a QL simulant, simulated central injector and adjustable ballonet to simulate the gas generator, hot gas motor--only explosive present is tail fin cartridge	To date: 8 separation flights conducted releasing 24 SSTVs from the A-6 aircraft	Physical compatibility and separation tests conducted with 8 flights separating 24 SSTVs Ground based cameras provided coverage of aircraft and store during separation Onboard cameras used to evaluate separation characteristics Simulated fuzes installed in all weapons QL simulant simulated injector SSTV Modifications -new arming lanyards manufactured because of inconsistent length (4" for fuze, 6" for tail fins) -some fuze mounting plates required redrilling Type of test -Fit test -Armament handling equipment compatibility -Ground ejection -Flight test for separation characteristics from parent racks, multiple ejector racks, mixed loads	24 SSTVs released from an A-6E aircraft from a variety of flight conditions

SEPARATION TESTS DATA

OBJECTIVES

TECHEVAL Test Plan Appendix C January 1984	TECHEVAL Test Plan Text March 1984	Naval Air Test Center Interim Report January 1985	Naval Air Test Center Final Report September 1985	TECHEVAL Final Summary Report
Evaluate loft separation characteristics from the A-6E airplane	Obtain data for determining store ballistics Verify Bigeye can be safely released from A-6E aircraft at speeds up to Obtain data suitable to support a flight clearance from NAVAIRSYCOM	Evaluate the improved BLU-80/B with the A-6 aircraft	Evaluate separation characteristics of BLU-80/B MOD 1 weapon configured with FMU-140 fuze from the A-6E airplane	Obtain data for determining store ballistics Verify Bigeye can be safely released from A-6E aircraft at speeds up to Obtain data suitable to support a flight clearance from NAVAIRSYSCOM

CRITERIA FOR OBJECTIVES

Release points will be considered accurate if the deviations from planned release parameters are less than the following values: (a) Release altitude (b) Release airspeed (c) Release acceleration (d) Dive angle Safe separation criteria require released stores not to contact other stores or suspension equipment	Not mentioned	No store to tank contact on release	NAVAIRSYCOM msg dtg 291506 NATCINST 8600.1 "Standardized Armament Test Manual," July 1, 1976	Not mentioned

DISSEMINATION TESTS DATA

OBJECTIVES

TECHEVAL Test Plan Appendix E August 1983	TECHEVAL Test Plan Text March 1984	Test Results Write-Up Dugway Proving Ground March 1985	Test Results Write-Up Naval Weapons Center February 1985	TECHEVAL Final Summary Report
Gain increased confidence in mixing system to mix simulant ingredients Determine dissemination characteristics Obtain release and fall data to verify weapon ballistics Determine droplet spectra, by means of printflex card samplers, for reactive or nonreactive simulant product mixture Qualitatively estimate area coverage of reactive simulant product for deposition densities of military significance, using printflex card samplers	Gain increased confidence in mixing system to mix simulant ingredients Determine dissemination characteristics Obtain release and fall data to verify weapon ballistics Evaluate weapon delivery technique	Gain increased confidence in the ability of the mixing system to mix simulant ingredients Determine dissemination characteristics Obtain release and fall data to verify weapon ballistics	Determine area coverage for various release conditions Provide data to validate area coverage models Evaluate weapon reliability	Obtain release and fall data to verify weapon ballistics Determine dissemination characteristics Evaluate weapon delivery techniques

RESULTS		
Naval Air Test Center Interim Report January 1985	**Naval Air Test Center Final Report September 1985**	**TECHEVAL Final Summary Report**
One additional separation flight was satisfactory Release of MER station 3 on aircraft station 5 in a 4g loft at 550 KIS Previously 7 separation flights released 23 SSTVs.		
CONCLUSIONS		
Specific OPEVAL separation limitations loadings given, noting a BLU-80/B's should be equipped with 6" tail fin arming lanyards and 4" fuze arming lanyards	Within scope of this test, BLU-80 (T-1)/B MOD 1 is satisfactory for tactical employment on A-6 aircraft using noted configurations	Bigeye can be safely released at speeds up to
RECOMMENDATIONS		
NATC reommended specific load-out configurations	Recommend further testing of compatability of new BLU-80 (T-1)/B and its design changes with Navy armament handling equipment Recommend that BLU-80 (T-1)/B mod 1 weapon be authorized for use on A-6 aircraft using the noted loadings, configurations and . limitations	None.

SCOPE OF TESTING

TECHEVAL Test Plan Appendix E August 1983	TECHEVAL Test Plan Text March 1984	Test Results Write-Up Dugway Proving Ground March 1985	Test Results Write-Up Naval Weapons Center February 1985	TECHEVAL Final Summary Report
9 tests 5 tests with reactive simulant (TIP/BIS and ballonet with sulphur/ talc), used primarily to evaluate weapon mixing system 4 tests with non-reactive simulant (BIS and no ballonet fill), used primarily to determine dissemination characteristics Aircraft to fly practice runs until all participants are satisfied with altitude, delivery mode, speed and countdown, and to ensure pilot familiarity with target terrain. Flight line for each trial to be clearly marked with radar reflectors, smoke and/or panels.	9 tests Simulant fill is BIS Ballonets loaded with sulfur/ talc mixture	8 tests (First resulted in a no-test since weapon failed to initiate mixing sequence and fuze did not function) All tests done with non-reactive simulant (BIS and no ballonet fill) used primarily to determine dissemination characteristics Aircraft flew practice runs until all participants were satisfied with altitude, delivery mode, speed and countdown, and to ensure pilot familiarity with target terrain Flight line for each trial was clearly marked with radar reflectors, smoke and panels Flight line was selected based on predicted wind direction	8 tests First resulted in a no-test since weapon failed to initiate mixing sequence and fuze did not function) All tests done with non-reactive simulant (BIS and no ballonet fill) used primarily to determine dissemination characteristics	First trial was a no-test Seven different flight conditions used

OBJECTIVES (Continued)

TECHEVAL Test Plan Appendix E August 1983	TECHEVAL Test Plan Text March 1984	Test Results Write-Up Dugway Proving Ground March 1985	Test Results Write-Up Naval Weapons Center February 1985	TECHEVAL Final Summary Repcrt
Determine area coverage for deposition densities of military significance, using printflex card and filter paper samplers, for nonreactive simulant product mixture dispersed by single and multiple BIGEYE DTVs				
Obtain release, fall, and source parameter measurements from photographs				
Confirm reaction of TIP/NE by examining contents of liquid collector samplers for TIPS				
Evaluate adequacy of mathematical models used to define target effects				

CRITERIA FOR OBJECTIVES

None	Not mentioned	None	Not mentioned	Not mentioned

CONCLUSIONS

Test Results Write-Up Dugway Providng Ground March 1985	Test Results Write-Up Naval Weapons Center February 1985	TECHEVAL Final Summary Report
Off-station mix design functions reliably in dynamic flight		"Bigeye could be delivered on target
Bombs can be released and payload dispersed on target as designed		"Computer aided deliveries are viable"
Mass median diameter (mmd) of binary simulant compares closely with mmd obtained on previous tests using nonreactive simulant		Deposition densities and ground coverage are adequate for an effective weapon
Area results for these binary simulant trials were greater than those obtained from previous binary simulant tests		
Mass of binary simulant recovered was similar to amounts recovered on previous tests using nonreactive simulant		

RESULTS

Test Results Write-Up Dugway Providng Ground March 1985	Test Results Write-Up Naval Weapons Center February 1985	TECHEVAL Final Summary Report
Trials 2-8 produced droplet size ranging from Recovery of simulant varies from Raw data graphs and charts for the following: --Three-dimensional graphs showing flight characteristics for trials 1-7 --Contour diagrams of filter paper data for trials 3-8 --Horizontal chemical filter paper data for trials 3-8 --Contour diagrams of printflex card data for trials 2-8 --Horizontal deposition of mass median diameter data for trials 2-8 --Droplet spectra data for trials 2-8	"During initial several tests, ground impact point was short of desired location" because of inappropriate correction factor used with the Rockeye software (Bigeye computer software not available) "Proper weapon function was verified for all of the last eight weapons" (trials 2-8) Onboard cameras recorded weapon release Fuze fuction monitored by optical telemetry and radar output Visual examination of weapon carcass to determine FZU, electronics module, gas generator and ballonet impulse cartridge function and both port openings.	"Good ground coverage obtained on all tests" "Good data for assessment of desposition densities was obtained for 5 trials" Data suitable for ballistics comparisons good on 6 trials

CARRIER SUITABILITY TESTS DATA

TECHEVAL Test Plan Appendix C January 1984	TECHEVAL Test Plan Text March 1984	Test Results Write-Up Naval Air Center Message, January 1985	Test Results Write-Up Naval Weapons Center March 1985	TECHEVAL Final Summary Report
OBJECTIVES				
	Demonstrate Bigeye is structurally capable of withstanding loads imposed during catapult launch and arrested landing Demonstrate Bigeye will be functional after experiencing catapult launch and arrested landings			
CRITERIA FOR OBJECTIVES				
(Criteria for static functioning tests found in Appendix B) During visual examinations, any detected leakage of simulant shall constitute a failure During bomb functional tests any of the following shall constitute failure: --Failure of central injector to rotate at 450 rpm for 15 sec minimum	Not mentioned	Not mentioned	Not specified, made reference to criteria contained in TECHEVAL test plan	Not mentioned

Comparison of Dissemination Patterns to Computer Models

Naval Weapons Center analysts compared dissemination patterns with predicted patterns from computer models

Data: Three tests (trials 3, 6, and 7) from the TECHEVAL dissemination tests

Of the 8 trials, 3 were picked as having "adequate data for modeling and enough recovery on the pattern for meaningful comparison"

Criteria: Quality of agreement based on the analyst's experience and judgment--there are no quantitative measures of "goodness of fit"

Results: Trial 3 - Good Agreement

Trial 6 - Fair Agreement

Trial 7 - Excellent Agreement

The model over predicted light depositions and under predicted heavy depositions (for BIS simulant)

APPENDIX IV

SCOPE OF TESTING

TECHEVAL Test Plan Appendix C January 1984	TECHEVAL Test Plan Text March 1984	Test Results Write-Up Naval Air Center Message, January 1985	Test Results Write-Up Naval Weapons Center March 1985	TECHEVAL Final Summary Report
Two production type inert weapons to be used Testing to be conducted on A-7 airplane 6 catapult launches and 14 arrested landings to be performed One weapon (with simulant) to be ground actuated to verify proper functioning Both stores to undergo further engineering analysis.	Testing to be conducted on A-7 airplane Weapons to undergo static functioning after testing	5 catapult launches, 6 bolters and 9 arrested landings conducted Bomb was strucutrally checked by NATC project engineer and NWC representative after each test event	Static functioning of the two weapons used in cats and traps tests	2 Phase II prototype weapons were hung on an A-7 aircraft and subjected to 5 catapult launches and 9 arrested landings Both weapons were then statically functioned at ambient conditions

RESULTS

		No deficiencies were noted during testing		

CRITERIA FOR OBJECTIVES
(Continued)

TECHEVAL Test Plan Appendix C January 1984	TECHEVAL Test Plan Text March 1984	Test Results Write-Up Naval Air Center Message, January 1985	Test Results Write-Up Naval Weapons Center March 1985	TECHEVAL Final Summary Report
--Failure of fore or aft ports to open --Failure of tail fins to deploy and lock --Failure of central injector to open after ballonet function --Failure of ballonet to expand --Failure of reactor to contain the liquid after ballonet function and before port opening				
During analysis of the sulfur, failure to meet the acceptable criteria for moisture, acidity, and angle of response as specified in MIL-B-85252				
During evaluation of fuze, failure to meet the performance criteria as specified in N287-0021-DT-IIB				
During analysis of QL, degradation of purity to a point where minimum agent purity would not be achieved				

ENVIRONMENTAL TESTS DATA

OBJECTIVES

TECHEVAL Test Plan Appendix B	TECHEVAL Test Plan Text	CRDC Test Write Up on Phase I	NWC Test Write Up on Phase II	TECHEVAL Final Summary Report
Qualify bomb and components to environments which can realistically be expected in logistics flow and tactical cycle	Qualify BLU-80/B design to withstand exposure to anticipated environmental extremes Determine whether QL is adversely affected while stored in a bomb which has experienced exposure to environmental extremes Demonstrate a reliability of 0.80 at 80% lower confidence	Provide information on: Qualification of ballonet shipping container Qualification of BLU-80/B design to withstand exposure to anticipated environmental extremes Demonstrated storage reliability of 0.80 at an 80% lower confidence limit		Qualify BLU-80/B design to withstand exposure to anticipated environmental extremes Determine whether QL is adversely affected while stored in a bomb which has experienced exposure to environmental extremes Demonstrate a functional reliability of .80 at 80% lower confidence

CONCLUSIONS

TECHEVAL Test Plan Appendix C January 1984	TECHEVAL Test Plan Text March 1984	Test Results Write-Up Naval Air Center Message, January 1985	Test Results Write-Up Naval Weapons Center March 1985	TECHEVAL Final Summary Report
		Within scope of this test, Bigeye is satisfactory for carrier operations on A-4, A-6, A-7, F-4, and F-18 aircraft	Static functioning was a complete success All aspects of success/failure criteria specified in TECHEVAL test plan were met Electrical performance of FZU was monitored upon deployment and met performance requirements	Bigeye with ballonet installed can withstand loads imposed by catapult launches and arrested landings Functional performance of Bigeye is not adversely affected by exposure to catapult and arrested landing loads

RECOMMENDATIONS

		Bigeye weapon be authorized for carrier operations on A-6 aircraft		

CRITERIA FOR OBJECTIVES
(Continued)

TECHEVAL Test Plan Appendix B	TECHEVAL Test Plan Text	CRDC Test Write Up on Phase I	NWC Test Write Up on Phase II	TECHEVAL Final Summary Report
Failure of reactor to contain liquid after ballonet function and before port opening				
During analysis of sulfur, failure to meet acceptable criteria for moisture, acidity, and angle of response as specified in MILB-85252 shall constitute a failure				
During evaluation of fuze, failure to meet performance criteria as specified in N287-0021-DT-IIB shall constitute a failure				
During analysis of QL, degradation of purity of QL to a point where minimum agent purity would not be achieved shall consitute a failure				

APPENDIX V

CRITERIA FOR OBJECTIVES

TECHEVAL Test Plan Appendix B	TECHEVAL Test Plan Text	CRDC Test Write Up on Phase I	NWC Test Write Up on Phase II	TECHEVAL Final Summary Report
During visual examinations, any detected leakage of simulant shall constitute a failure During bomb functional tests any of following shall constitute failure: Failure of central injector to rotate at 450 rpm for 15 sec minimum Failure of fore or aft ports to open Failure of tail fins to deploy and lock Failure of central injector to open after ballonet function Failure of the ballonet to expand		QL-filled bombs will not show signs of leakage during or after stresses Bomb components will not suffer physical degradation as a result of stresses Ballonets will not leak sulfur after exposure to extreme conditions Vapor bag integrity will not be degraded by exposure to stresses Shipping container will not be affected by storage stresses	Referred to TECHEVAL TEST PLAN	Referred to Techeval Test Plan Appendix and Phase I Test Write Up

APPENDIX V

RESULTS

CRDC Test Write Up on Phase I — Summary Table (as reported by Army Testers)	NWC Test Write Up on Phase II		TECHEVAL Final Summary Report	
			Environmental Problem/Failure	Comment
Numerous recurring and non-recurring problems/failures and corrective actions needed listed	Of 8 static function tests, 7 were completed with 1 no test (simulant froze)			
Recurring problems include:	Problem Noted	Comment		
--Fuze radome cracked --Turnbuckles loosened or came off; hinge pins also --H- frames loosened or came off --Bomb cradles, pins came off or loosened --Fins deployed under random vibration - not acutated by fuze Recurring failures include: --Vapor barrier bag penetrated, around initiator cartridge end --Support blocks (foam) deformed inelastically, on initiator end and lower/upper transverse supports --Ballonets leaked sulfur during vibration tests. Insufficient support on ballonets allowed for oscillation --Impulse cartridges loosened under vibration stresses				
	No reliability calculations			

SCOPE OF TESTING

TECHEVAL Test Plan Appendix B	TECHEVAL Test Plan Text	CRDC Test Write Up on Phase I	NWC Test Write Up on Phase II	TECHEVAL Final Summary Report
10 test items tested to qualify bomb and components to environments which can realistically be expected PhaseI: high/low and temperature shock, transportation vibration, handling shock, humidity, lauch shock, random vibration, QL evaluation Phase II: 4 bombs (simulant filled) functioned at 1 bomb functioned in full-scale toxic test, 1 bomb dissemination test Failure Reports, Analysis and Corrective Actions. "Failures which occur during test sequence will cause the entire test sequence to be repeated upon completion of corrective action unless otherwise determined by joint decision of testors and Bigeye Technical Management Office"	Testing to be conducted using 10 prototype weapons Phase I: temperature extremes/vibration: reactor cavity of each of 10 BLU-80/B's to be filled with QL, ballonets to be loaded with talc with 10 additional sulfur filled ballonets Phase II: Bomb functioned--8 simulant filled at temperature extremes, 1 toxic chamber test, 1 simulant filled dissemination trial	Test items were challenged with environmental extremes, drops, transportation vibration, catapult launch and random vibration. Environmental test sequence selected to provide increasing amounts of stress on component tested Vibration test sequence selected to demonstrate stresses imposed on Bigeye hardware and chemical fill from magazine storage to delivery on target by attack aircraft	2 test reports from CRDC static functioning of components previously subjected to the environmental test sequence LBE-38 simulant filled LBE-41 QL and sulfur filled toxic chamber test	10 QL filled weapons and 10 sulfur filled ballonets subjected to environmental test sequence which simulated anticipated exposure during life cycle QL purity was determined after environmental testing 8 weapons filled with simulant were static functioned at temperature extremes of

	CRDC Test Write Up on Phase I	NWC Test Write Up on Phase II	TECHEVAL Final Summary Report
CONCLUSIONS		Not specifically discussed	Mix duration for hot static functions is adequate
RECOMMENDATIONS		None	Proceed with operational testing with current weapon configurations Increase strength of tail fin shear rivets on future weapon procurements Revise success/failure criteria in the Bomb Top specification for mix duration to reflect temperature effects

APPENDIX V

RESULTS
(Continued)

CRDC Test Write Up on Phase I — Reliability Determinations (Storage Conditions)			NWC Test Write Up on Phase II	TECHEVAL Final Summary Report	
Component/System Composite	Point Estimate	Lower Limit of the 80% Confidence		Environmental Problem/Failure	Comment
Fuze	1.0				Criteria do not consider starting temperature--performance was more than adequate for a higher temperature mix time
Bomb (without ballonet)	.9				
Ballonet (as tested)	.1				
Ballonet (ASSUMES FAILURE MODE IS CORRECTED)	1.0				
Weapon system composite-- R(Bomb) R(Fuze) R(Ballonet-corrected)	.9			Bomb can withstand exposure to environmental extremes	
QL and NE Purity Levels QL--slight decrease in purity (may be within analytical accuracy) NE--post test purity greater than 100% indicating absorbed moisture				Design is satisfactory for likely flight environments encountered during operatonal testing	

SCOPE OF TESTING

TECHEVAL Test Plan Appendix D	TECHEVAL Test Plan Text	Test Write Up	TECHEVAL Final Summary Report
For simulated EMI levels present in aircraft carrier environments, evaluate: 1) safety and reliability effects on FMU-140/B DPF 2) survivability of OSM, EED and HERO resistance to OSM initiation system: FZU-37A1B wind turbine Electronics package MK133 ignitor interconnecting cables Test vehicle BLU-80/B dispenser, fully assembled and mounted above a ground plane Ignitor and fuze are inert	One inert Bigeye and three explosively inert ignitors planned for testing according to the standard	Inert fuze (FMU 140/B DPF) and ignitor (MK 133) tested in Bigeye body for reliability, not safety (Naval Air Safety Office determined reliability is appropriate HERO concern) Four test series using 12 frequency ranges conducted	Two areas of Bigeye were tested--the fuze (FMU-140/B) and mix initiation subsystem (electronics assembly module and gas generator ignitor)

HERO TEST DATA

	TECHEVAL Test Plan Appendix D	TECHEVAL Test Plan Text	Test Write Up	TECHEVAL Final Summary Report
OBJECTIVES	Verify safety and operability of electro-explosive devices (EED) used in FMU-140/B (fuze) and BLU-80/B off-station mixing (OSM) system upon exposure to electromagnetic interference (EMI) levels which fuze may encouter during storage, handling and aircraft carrier flight deck operations	Demonstrate current Bigeye configuration is HERO safe in accordance with military standard MIL-STD-1385	Determine if Bigeye weapon with the FMU-140/B fuze (as modified) met requirements of MIL-STD-1385A during handling and loading procedures and presence conditions	Demonstrated current Bigeye configuration is HERO Safe in accordance with MIL-STD-1385
CRITERIA FOR OBJECTIVES	MIL-STD-1385 (tested, modified and retested until in compliance with standard)	MIL-STD-1385	MIL-STD-1385 Reliability $\leq$ 45% maximum no fire current MNFC (Safety $\leq$ 15% MNFC)	MIL-STD-1385

PROGRAM COSTS (in Millions of Dollars)[a]

Fiscal year	Current dollars	Constant dollars 1985
Prior to 1968[b]	$ 4.2	$14.1
1968	1.0	2.9
1969	1.3	3.6
1970	0.1	0.3
1971 - 1975[c]	0.0	0.0
1976	1.6	2.8
1977	1.5	2.5
1978	2.0	3.1
1979	1.9	2.7
1980	2.5	3.2
1981	1.6	1.9
1982	9.2	10.3
1983	9.6	10.4
1984	11.0	11.4
1985	5.1	5.1
Total		$74.3

[a]Total program cost to date appears in above table. All costs are for research, development, testing and evaluation.

[b]Breakout by year not available.

[c]Program suspended.

APPENDIX VI

RESULTS

TECHEVAL Test Plan Appendix D	TECHEVAL Test Plan Text	Test Write Up	TECHEVAL Final Summary Report

CONCLUSIONS/RECOMMENDATIONS

TECHEVAL Test Plan Appendix D	TECHEVAL Test Plan Text	Test Write Up	TECHEVAL Final Summary Report
		Modified FMU-140/B DPF when used on the Bigeye weapon is "HERO SAFE ORDNANCE" Any further modifications to design or assembly/handling procedures will require re-analyses or retest of Bigeye system	Bigeye successfully meets all HERO requirements

<u>Equivalent biotoxicity</u>: A measure of the potency of VX agent generated in the Bigeye system. It is reported as the ratio of the LD50 of laboratory VX to Bigeye generated VX.

<u>Flashing</u>: Burning or instant vaporization of the VX agent/reaction mixture during dissemination of the Bigeye bomb.

<u>Fuze (FMU-140)</u>: The component of the Bigeye weapon that initiates the opening of the dissemination ports.

<u>FZU-37</u>: The component of the Bigeye weapon that is a pop-up wind turbine. It provides an energy source to activate the impulse cartridge and gas generator motor.

<u>Hot spots</u>: The phenomenon observed in Bigeye liquid-reaction mixtures in which certain areas are hotter than other areas. This indicates that the liquid-reaction mixture temperature is not the same throughout.

<u>Impulse cartridge</u>: Part of the Bigeye system that inflates the cylinder in the ballonet and causes injection of the sulfur into the QL.

<u>Injector cartridge propellant housing</u>: A part of the impulse cartridge that contains propellant and is subject to high stress during functioning.

<u>Lethality</u>: The ability of a substance (because of its design, intended use, or composition) to cause death or injury.

<u>Loading</u>: The itemization of the types of stores (e.g., bombs, fuel tanks) and their position on aircraft racks.

<u>Lofting</u>: A delivery tactic for air-delivered free-fall weapons. The tactic requires the delivery aircraft, at a designated point from the target, to begin a quick climb before releasing its weapons. This climb imparts a vertical velocity to the weapon that allows it to continue upward after release, placing it in a trajectory toward the target.

GLOSSARY

Aerodynamic heating: A phenomenon of heat buildup caused by the friction of air against a fast moving object.

Arrested landing: The method of stopping an aircraft during landing on an aircraft carrier.

Ballistic determination: The height, distance and flight profile of a projectile.

Ballonet: One of the two major components of the Bigeye system. It consists of a long tube that contains sulfur and the system for injecting the sulfur into the reactor (see figure 1).

Bigeye bomb: A binary air-delivered munition (BLU-80/B) that produces VX nerve agent through the chemical reaction of solid sulfur with liquid QL.

Bolter: An event in flight operations, especially on an aircraft carrier, when an aircraft touches down and takes off without landing.

Bomb body: One of two major components of the Bigeye system. It consists of the outer air frame and the reactor, which contains the liquid QL.

Catapult launch: The method of propelling an aircraft that assists the aircraft in taking off from an aircraft carrier.

Cats and traps: Catapult launch and arrested landing.

Degradation rate: A chemical measurement of the breakdown of a substance in the environment.

Dissemination ports: Areas in the Bigeye bomb body that are designed to be opened by a cutting charge after the bomb has been activated. Opening the ports allows the contents of the bomb to be disseminated as droplets before the bomb reaches the ground.

Tests:

1. Biotoxicity test (LD50): The process of determining the amount of chemical required to kill 50 percent of the animals tested. (Statistically derived by using a series of groups of animals, each group given a different amount of chemical.)

2. Bypass: The action of circumventing one component during the testing of a system in order to make the remaining components function. To make the Bigeye system function, one component in a chain must be activated and in turn produce an impulse that activates the next component in the chain, until the last component produces the specified effect. When one component is isolated from the chain and the impulse to the next component in the chain is artificially generated, the isolated component is said to have been "bypassed."

3. Captive-carry test: A test performed with the weapon secured under the wing so that the weapon is not released from the aircraft.

4. Carrier suitability tests: A series of tests designed to demonstrate that the Bigeye is structurally capable of withstanding stresses imposed during catapult launch and arrested landings.

5. Chemical mixing tests: Tests conducted with instrumented full-scale reactor/bombs that were statically functioned in a controlled, enclosed, toxic chamber building at Aberdeen Proving Ground, Md. Although some tests used simulants, most were conducted with actual binary chemicals (QL and sulfur) and produced nerve agent (VX).

6. Developmental tests: A series of tests conducted to determine if a weapon meets its technical specifications.

7. Dissemination tests: A series of tests in which simulant-filled Bigeye bombs are dropped from aircraft. The trajectory of the weapon, its operation, and the simulant ground-contamination patterns are analyzed.

Mixing manifold: A part of the Bigeye reactor that directs the liquid flow of the reaction mixture and improves the mixing of QL and sulfur.

MK 133 ignitor: An electro-explosive device in the Bigeye system that mixes the QL and sulfur.

Off-station mixing: The activation of the Bigeye weapon and mixing system after the weapon is released from the aircraft.

On-station mixing: The activation of the Bigeye weapon and mixing system before the weapon is released from the aircraft, with the aircraft carrying live VX agent until the bomb is released.

Preconditioning: The actions taken to assemble the components of the reactor/bomb and to attain the specified starting conditions.

Pull-up: Part of the lofting maneuver, during which the pilot begins a quick climb before releasing the weapon. The maneuver results in gravitational forces on the system.

Purity: A measure of the amount of VX generated by the Bigeye reaction expressed as a percentage of the theoretical 100-percent yield. The measurement is based on a chemical analysis of the reaction mixture.

(tore: Any device carried and mounted on aircraft suspension and release equipment, whether or not the device is intended to be separated in flight from the aircraft. Stores include missiles, rockets, bombs, nuclear weapons, mines, fuel and spray tanks, and torpedoes.

Tail fins: Part of the Bigeye bomb body. During storage and the attachment of the Bigeye to the airplane, the tail fins are collapsed; they become extended when the Bigeye is released and are designed to stabilize the flight of the weapon.

17. Operational tests: A series of tests conducted to determine if a weapon will be useful in combat.

18. Reactive simulant: A combination of liquid (BIS/TIP) and sulfur that simulates the Bigeye reaction by reacting chemically to produce a rise in temperature and pressure while generating a nontoxic product.

19. Reactor: An instrumented reuseable apparatus in which chemical mixing tests are run. The full-scale reactor has approximately the same geometry as the Bigeye bomb body.

20. Reliability: A statistical presentation of data obtained from testing a system and its components. It is a measure of the confidence that a system as tested will perform according to standards or specifications repeatedly in the same way.

21. Separation tests: A series of tests designed to verify that the Bigeye can be safely released from an A-6 aircraft at speeds up to Ballistics and flight clearance data are the basis of the analysis.

22. Simulant: A relatively nontoxic substance used to test various functions in the Bigeye weapon system.

23. Statically functioned: Tests of specific components of the entire Bigeye weapon system conducted on the ground in various harness platforms (control mechanism to hold the bomb).

24. Toxic chamber test: A test using hazardous substances conducted in an environmentally controlled and sealed off enclosure. (See chemical mixing tests.)

Venting: The release of the internal reaction pressure at a predetermined level during the mixing sequence in a chemical mixing test. For example, releasing the pressure at will keep the internal pressure below this level throughout a test.

8. Environmental tests: A series of tests designed to simulate anticipated environmental extremes during storage and transport and to determine adverse effects, if any, on the operation of a weapon.

9. Hazards of electromagnetic radiation to ordnance (HERO) tests: A series of tests designed to determine whether the electro-explosive devices (FMU-140 and MK 133 ignitor) in the Bigeye weapon are susceptible to being inadvertently fired in high-intensity electromagnetic environments such as those on the deck of an aircraft carrier.

10. L test: A chemical mixing test performed in a reactor.

11. LB test: A chemical mixing test performed in an actual bomb body.

12. LBE test: A chemical mixing test performed in a bomb body that has been subjected to environmental testing.

13. Lot acceptance test: A test to determine whether items received from a contractor meet procurement (design and performance) specifications.

14. Maximum no-fire current (MNFC): Used in HERO testing, a statistically determined value for each electro-explosive device component. It represents a 95-percent confidence that the current so determined is the maximum that can be applied to 99.9 percent of the device without detonation.

15. Non-reactive simulant: A simulant used in Bigeye tests that does not react chemically but possesses physical characteristics similar to those of QL and sulfur. Substances such as alcohol, antifreeze, water, sand, and talc have been used in various tests.

16. No-test: The determination that an individual test of a series will not be included in an overall analysis because of some failure not related to the variables being tested (e.g., an apparatus or sampling failure in the chemical mixing tests).

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