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Report to the Honorable John D. Dingell, Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives

March 1988

QUALITY ASSURANCE

Concerns About Four Navy Missile Systems

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The Honorable John D. Dingell
Chairman, Subcommittee on Oversight
and Investigations
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

In response to your October 9, 1986, request, we reviewed quality assurance issues on four missile systems—the Phoenix AIM-54C, the High-Speed Anti-Radiation Missile (HARM) AGM-88A, the Harpoon AGM/RGM/UGM-84A, and the Sparrow AIM/RIM-7M—for which the Navy has management responsibility. Our review focused on the quality of missiles accepted by the Navy during 1986 and early 1987. Where quality problems were identified, we obtained information on the causes and potential effects of the problems. Details on the results of our review are in appendixes II through VI.

All of the missile systems we examined had defects—that is, they failed in one respect or another to conform with contract specifications. Some defects occurred because of inadequate manufacturing processes at the prime contractor, while several of the more significant problems were caused by poor manufacturing and inadequate quality oversight at subcontractors. The long-term effect of other defects, such as items not meeting the Navy's soldering specification, is not clear. This aspect of quality—compliance with the soldering specification—has been a point of debate within the Navy and industry for years and will probably not be resolved in the near future.

The problems we noted, based on our review of Navy and contractor reports and interviews with Navy and contractor officials, included the following:

- The Phoenix AIM-54C's safety and arming device has design and workmanship defects that have delayed its production. This, in turn, has delayed deliveries of over 500 Phoenix missiles to the fleet.
- HARM pressure transducers may not have been tested as required before being put into missiles. The transducer is used in activating the missile's target seeking device. In recent testing of a sample of 30 of 1,300 suspect transducers, 20 percent did not meet contractual requirements due

to defects. Additional testing is being conducted to determine the extent of the problem and its impact on missile reliability.

- Harpoon altimeters are being accepted under a contract deviation that permits a certain type of soldering-related condition in the printed wiring assemblies of 720 units. This condition is indicative of production problems and could affect missile reliability, particularly after several years of deployment in the fleet.
- Detonators that unknowingly were manufactured without sufficient explosive compound to activate the missile's warhead were installed in the safety and arming devices in Sparrow and other missile warheads, some of which were placed in missiles and shipped to the fleet. This has required the screening of up to 10,000 of these devices to determine whether they have been affected.

Evaluating Missile Quality

The Department of Defense (DOD) does not define a quality product as one that meets each and every contract specification. Instead, DOD regulations state that a product is a quality product if the composite of all its various characteristics, including performance, satisfies the user's needs.

The contracts for each of these missile systems establish specific reliability measures that must be met. Reliability is measured in two ways: mean-time-between-failure in a simulated testing environment and mean-time-between-failure based on captive carry data. (Captive carry means that the missiles are attached to operational aircraft with some of their circuitry periodically functioning.) The mean-time-between-failure for three of the missiles—HARM, Sparrow, and Harpoon—surpassed the contract requirements. Because most of the Phoenix AIM-54C missiles are unusable, data available from the fleet are not sufficient to be conclusive about its reliability.

While mean-time-between-failure data indicate that reliability requirements are being met, it should be noted that before a missile undergoes its initial captive carry test, its circuitry is tested to determine if it is receiving and transmitting data with the aircraft. Missiles failing this test are not reported as part of the captive carry results. Information was not available to determine the extent of such failures, but not counting them increases the reported reliability rates.

Prime Contractor Oversight of Subcontractors and Suppliers

Each instance we identified where quality defects were not detected until large numbers of missiles or missile components were affected involved subcontracted parts. The prime contractor is responsible for the quality of material and parts provided by its subcontractors and suppliers. Government plant representative offices within the prime contractor plants are responsible for verifying that contractors are exercising adequate control over their vendors.

Vendors, both large and small, have a major role in the production of each of the four missiles. For example, about 72 percent of the contract cost for the Harpoon missile is for parts and material furnished to the prime contractor by subcontractors and suppliers.

Most of the problems at the subcontractor level, which led to the defects, involved insufficient production process controls. One common problem was that changes were made in manufacturing processes which were unknown to the prime contractor but affected the quality of the product. Defense Logistics Agency reviews in 1985 and 1986 disclosed a general pattern of inadequate prime contractor control of subcontractors.

Some Navy officials believe that it is probably impossible to adequately police this problem. They contend that to do so would require prime contractors to have "an army of people" at all their vendors' plants and that this would not be cost effective.

Guidance provided in DOD's Transition From Development to Production Manual of September 1985 and in the Navy's follow-on Best Practices manual of March 1986 include guidelines to avoid or minimize the risk of subcontractor quality assurance problems. The manuals emphasize the importance of good communications among the government, prime contractor, and subcontractor. Practices recommended include conducting design reviews and joint government/prime contractor vendor conferences and having the prime contractor assign an individual within its organization to be responsible for each subcontractor.

Soldering

Many of the missile manufacturing defects being reported by inspectors are related to soldering. Some contractors and government officials believe that certain requirements in the Navy's soldering specification are more stringent than necessary to have a reliable missile. They cite high reliability rates and the successful use of missiles that deviate from

the soldering specifications as evidence that the Navy's soldering specification may be too stringent.

DOD and Navy quality assurance officials believe that compliance with the soldering specification is important to ensure that the missiles are reliable and will perform effectively throughout their lives. They emphasize the importance of the missiles to the U.S. defense posture and the need for the missiles to withstand the adverse conditions of the fleet environment. They state that even minor soldering defects, which may not affect missile reliability, need to be reported and addressed to ensure that production processes meet high quality standards. Contributing to the controversy is a shortage of data on the effects of the fleet environment on certain soldering nonconformances, particularly after several years of deployment. The Navy is doing research and tests to obtain more of this type data.

Conclusions

Missiles are complex systems with numerous components and parts required in their assemblies. Each requires demanding production processes and many thousands of individuals, using an array of production and testing equipment, to manufacture and deliver a quality product. The opportunities for defects to occur are immense and just one defect can render a missile ineffective.

DOD's in-plant quality assurance program is intended to assure that weapons producers comply with contract quality requirements, but this review and other studies by DOD show that contractors do not always adequately control quality and produce hardware that conforms with contract requirements. Each missile system we reviewed had some type of problem.

Navy, DOD, and contractor officials continue to disagree about the need for some of the requirements in the Navy's soldering specification. This disagreement continues because of the lack of convincing empirical data on whether certain soldering conditions, now classified as defects, affect the long-term reliability and performance of the missile. Consequently, the Navy's research and testing to evaluate soldering requirements need to be continued. The results of such efforts should help resolve some of the controversy surrounding the quality of these missiles and other weapon systems.

An important area of quality that needs to be continually stressed and evaluated is prime contractor oversight of subcontractors and suppliers.

Subcontractors, particularly those with little or no experience with military specifications, need to be better informed of the technical and "boilerplate" requirements of a contract. Tight controls by the subcontractors over critical production process steps need to be stressed. Changes in manufacturing processes need to be reported and evaluated closely before being implemented to ensure that the quality of the product is not compromised. Also, the prime contractors need to provide closer inspection and testing of items delivered by subcontractors.

We believe the guidance provided on subcontractor control in the recently issued DOD and Navy manuals on transitioning from development to production, when implemented, should improve controls and help minimize the likelihood of the types of problems we found. Because of the clear need for improvements in this area of the acquisition process, it is important that the Office of the Secretary of Defense and the heads of DOD components ensure successful implementation of that guidance.

Agency Comments

DOD reviewed a draft of this report and partially concurred with our findings and conclusions. (See app. VII.) We made changes to the report, where appropriate, to incorporate DOD's comments. DOD acknowledged that a number of problems have been experienced during production of the missiles, but said that in no case has the Navy knowingly accepted missiles suspected of containing defects that could affect the performance of the missiles. It said missiles are accepted with certain nonconformances but only after review and analysis confirm that performance is not affected.

We found that the Navy's review and analysis of nonconforming missiles did not always confirm that the defects would not affect missile performance. For example, four separate teardown inspections during 1986 and 1987 of representative Sparrow missiles detected defects that, according to criteria in a 1987 Navy teardown guide, would likely affect the reliability of the missile. On two of the four sample missiles the contractor did additional testing subsequent to the teardown that indicated that the defects would not affect reliability. However, such additional testing was not performed on the other two sample missiles or on any of the hundreds of other Sparrow missiles produced at the same time as the four missiles and suspected of having similar defects. (See app. VI.)

In the case of the soldering-related condition in 720 Harpoon missile altimeters, DOD said none of the units accepted under the contract deviation were sufficiently flawed to affect reliability. However, we found that DOD's conclusion was based on a defect analysis of two units selected by the contractor and that the analysis was not designed to assess relative risk. Furthermore, DOD's conclusion is not universally shared by Navy soldering and quality assurance experts. (See app. V.)

Contractor Comments

We provided pertinent sections of our draft report to each contractor involved for review and comment. Changes were made to the report in response to their comments and copies of their comments are attached in appendixes VIII through XVII.

McDonnell Douglas Astronautics Company disagreed that the soldering related condition in the Harpoon altimeters could affect missile reliability. It said the printed wire board industry considers the type of condition in question to be "cosmetic," not affecting the reliability of the product, and cited a 1971 industry study to support this position. Our review, however, disclosed that such a condition can and apparently has affected the reliability of some products. This is discussed more fully in appendix V.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 15 days from its date. At that time we will send copies to the Secretaries of Defense and the Navy and to other interested parties.

Sincerely yours,

for Frank C. Conahan
Assistant Comptroller General

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Abbreviations

DCAS	Defense Contract Administration Services
DOD	Department of Defense
HARM	High-Speed Anti-Radiation Missile
MDAC	McDonnell Douglas Astronautics Company
MTBF	Mean-time-between-failure
NAVAIR	Naval Air Systems Command
TDD	Target Detecting Device

Objectives, Scope, and Methodology

At the request of the Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, we reviewed quality assurance issues on four Navy missiles systems—the Phoenix AIM-54C, the High-Speed Anti-Radiation Missile (HARM) AGM-88A, the Harpoon AGM/RGM/UGM-84A, and the Sparrow AIM/RIM-7M. The Chairman was concerned with (1) the extent and seriousness of quality problems in the production of missiles, (2) the causes of the quality problems, (3) the effect of these problems on missile performance and cost, and (4) the structure of the DOD and contractor quality assurance organizations. Another concern was whether the contractors were being paid while delivering poor quality missiles.

Our review was performed from October 1986 to September 1987 and was limited to new production missiles that the government had accepted during calendar years 1986 and early 1987. It was performed primarily at the Naval Air Systems Command (NAVAIR), which has management responsibility for the four missile programs, and at the prime contractor plants where the guidance and control sections are produced. Two prime contractors produce the Sparrow missile—Raytheon Company and General Dynamics. As agreed with the Subcommittee, we performed work only at the Raytheon plant, although some information obtained about the Sparrow program also would apply to General Dynamics-produced missiles.

Information on the quality of the other two major segments of the missiles—the propulsion and warhead sections—was obtained through review of reports and other documents, discussions with government and contractor representatives, and visits to the production facilities, where necessary.

We reviewed (1) DOD and Navy directives and instructions that establish the quality assurance policies and procedures for weapon system programs and (2) numerous government and contractor reports that provided data on the quality of the missiles, including their reliability, effectiveness, and conformance with contract specifications. We did not validate the accuracy of the data in these reports. Also, we examined contracts and contract modifications, including waivers and deviations[1] granted by the government. In identifying quality problem areas, we

[1] A waiver is a written authorization to accept an item that during production or after having been submitted for inspection is found to depart from specified requirements but nevertheless is considered suitable for use "as is" or after rework by an approved method. A deviation is a written authorization granted before the manufacture of an item to depart from a particular contract requirement or specification for a specific number of units or specific period of time.

also used information from a central Navy quality deficiency reporting system, the Airborne Weapons Corrective Action Program.

To obtain the user's perspective, we met with Atlantic Fleet representatives, including pilots and ordnance crews from three aircraft wings and officers and crew of a destroyer. Also, we observed two Sparrow missile teardown inspections[2] and attended the briefings on the inspections' results.

Organizations Contacted During Our Review

We contacted the following government and contractor organizations and facilities during our review.

United States Government

Office of the Secretary of Defense, Washington, D.C.
Office of the Assistant Secretary of the Navy for Shipbuilding and Logistics, Office of the Directorate of Reliability, Maintainability and Quality Assurance, Washington, D.C.
Office of the Chief of Naval Operations, Washington, D.C.
Naval Air Systems Command, Washington, D.C.
Naval Inspector General, Washington, D. C.
Naval Sea Systems Command, Washington, D.C.
Naval Weapons Engineering Support Activity, Washington, D.C.
Naval Weapons Center, China Lake, California
Naval Weapons Support Center, Crane, Indiana
Naval Material Quality Assurance Office, Portsmouth, New Hampshire
Naval Weapons Station, Yorktown, Virginia
Naval Weapons Station, Fallbrook Annex, Seal Beach, California
Naval Weapons Station, Concord, California
Fleet Analysis Center, Corona, California
Pacific Missile Test Center, Point Mugu, California
Commander-in-Chief, U.S. Atlantic Fleet, Norfolk, Virginia
Commander, Naval Air Force, U.S. Atlantic Fleet, Norfolk, Virginia
Commander, Naval Surface Force, U.S. Atlantic Fleet, Norfolk, Virginia
Commander, Operational Test and Evaluation Force, Norfolk, Virginia
Commander, Fighter Wing One, Naval Air Station, Oceana, Virginia

[2]A teardown inspection is a nondestructive disassembly and visual examination of selected components or subassemblies contained within a sample missile. It is used to assess the quality of workmanship, production processes, and quality assurance procedures of the producer and provides a source of feedback to the contractor.

Beach, Virginia
Commander, Light Attack Wing One, Naval Air Station, Cecil Field, Florida
Commander, Medium Attack Wing One, Naval Air Station, Oceana, Virginia Beach, Virginia
Commanding Officer, U.S.S. Conolly (DDG-979), U.S. Atlantic Fleet, Norfolk, Virginia
Contracting Officer's Technical Representative, Lewisville, Texas
Naval Technical Representative Office, Tucson, Arizona
Naval Weapons Industrial Reserve Plant, McGregor, Texas
Naval Plant Representative Office, St. Louis, Missouri
Defense Contract Audit Agency, St. Louis, Missouri
Air Force Plant Representative Office, Tucson, Arizona
U.S. Army Missile Command, Huntsville, Alabama
Federal Bureau of Investigation, Ventura, California
Defense Logistics Agency, Headquarters, Cameron Station, Alexandria, Virginia
Defense Logistics Agency, Defense Contract Administration Services offices at

- Brea, California
- Burlington, Massachusetts
- Dallas, Texas
- Dayton, Ohio
- Hollister, California
- Lewisville, Texas
- Los Angeles, California
- Lowell, Massachusetts
- McGregor, Texas
- Piqua, Ohio
- San Francisco, California

Contractors

Caelus Devices, Inc., Hollister, California
General Dynamics Corporation, Camden Operations, East Camden, Arkansas
Hercules Incorporated, Aerospace Products Group, Rocket Center, West Virginia
Hughes Aircraft Company, Missile Systems Group, Tucson, Arizona
International Business Machines, Federal Systems Division, Owego, New York
Marvin Engineering Co., Inc., Inglewood, California
McDonnell Douglas Astronautics Company, St. Louis, Missouri

Micronics International, Inc., Brea, California
Motorola, Inc., Phoenix, Arizona
Piqua Engineering, Incorporated, Piqua, Ohio
Raytheon Company, Missile Systems Division, Lowell, Massachusetts
Texas Instruments Incorporated, Lewisville and Dallas, Texas

Quality and Its Role in the Production of Four Navy Missile Systems

The objective of DOD's weapon system acquisition process is to provide the Armed Forces with quality products that meet their needs. According to DOD, the quality of a weapon system is the composite of all attributes or characteristics, including performance, that satisfy a user's needs. Quality is the responsibility of every person involved in the manufacture and acquisition of the weapon system. Achieving the desired level of quality is dependent on the equipment, tools, workmanship, and supervision involved in producing the product. In the end, the quality of a product can be measured by the contractor's success in complying with contract specifications related to both production process and techniques and by product reliability and performance.

Quality Responsibilities

Prime contractors are responsible for providing quality products to the government; however, DOD is responsible for ensuring that the products purchased meet the contract specifications, are operationally effective, and satisfy the users' needs. It does this by ensuring that (1) minimum quality, technical, and related requirements are specified in the contract and are achievable and (2) contractor inspections and other quality assurance procedures are reliable and working.

NAVAIR's Quality Program

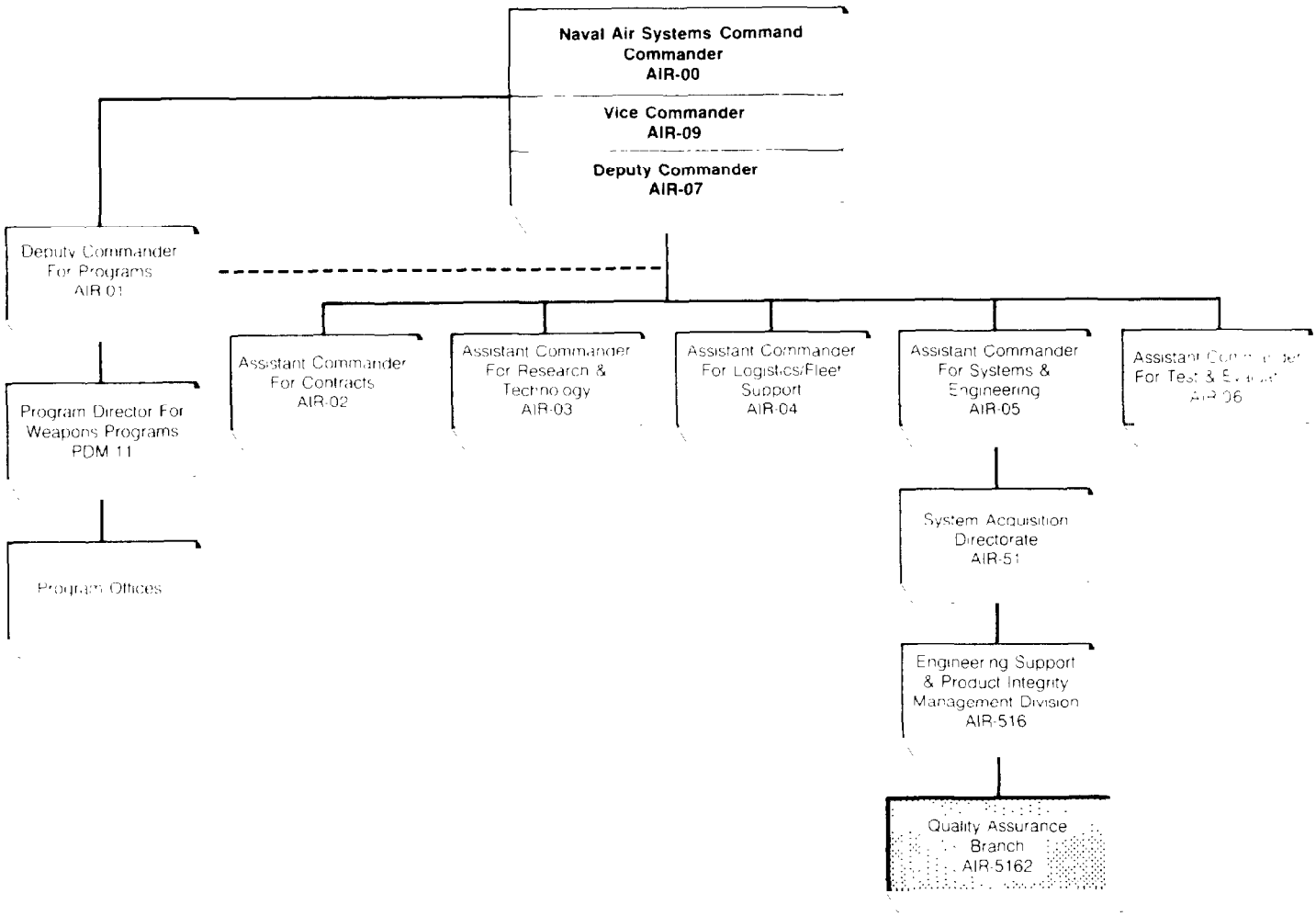
Each of the four missile programs we reviewed has a program office in NAVAIR and a program manager who ensures that products acquired from prime contractors are in compliance with the contract requirements. The program manager also is accountable for all other aspects of the program, including cost and schedule requirements.

The NAVAIR Quality Assurance Branch provides the program manager with advisory and technical support on quality matters, including reviewing proposed contracts to ensure that they contain the appropriate quality assurance provisions. However, the Quality Assurance Branch has no direct line authority over the program. As shown in figure II.1, staff of this office and the program managers report through a separate chain of command to the Commander, NAVAIR. This office provides general oversight of NAVAIR's quality program (e.g., the promulgation of quality policies and procedures) but has no direct link or authority over quality assurance at the contractors' plants.

In the past 2 to 3 years, NAVAIR has attempted to strengthen the authority and staffing of this office, but, relative to program managers, the office remains at a low organizational level within headquarters. (See fig. II.1.) The NAVAIR Commander, the Director of Systems Acquisition,

and the Branch Head of the Quality Assurance Branch told us they believe this office is effectively located in the engineering organization for execution of the NAVAIR quality program and is organizationally independent from the weapon system programs it supports. They did state, however, that the office is new and its current limitation is the maturity of the staff in performing their responsibilities, not the office's size.

Figure II.1: Organizational Location of the NAVAIR Quality Assurance Branch



The Quality Assurance Branch is separately funded but must rely on program offices to fund and support quality efforts, such as teardown inspections. If, however, the office believes the level of support is not

adequate, it can have this issue raised to the Commander, NAVAIR, but officials in this office said they have never found it necessary to do so.

Program managers obtain additional technical and engineering support for quality efforts from various Navy field activities, particularly the Naval Weapons Center, China Lake, California, and the Pacific Missile Test Center, Point Mugu, California. These field activities perform quality assurance functions that are funded by the cognizant program office, and thus their level of program support is determined by the program manager.

The China Lake Naval Weapons Center, as lead development agency for air-launched missiles and other airborne weapons, provides quality support in all phases of weapon system development and production. This support includes performing engineering investigations of quality problems, participating in missile teardown inspections, and providing guidance and support in the implementation of soldering requirements.

The Pacific Missile Test Center's involvement begins late in the development process and continues through the production and life of the weapon system. Program support includes conducting production lot acceptance tests, reviewing contractor manufacturing operations to monitor contract compliance, participating in missile teardown inspections, and administering a program that monitors airborne weapon system problems.

Plant Representative Offices

To ensure that contractors comply with contract quality requirements, DOD has an in-plant quality assurance program that is administered by Plant Representative Offices of the Army, Navy, Air Force and by the Defense Logistics Agency's Defense Contract Administration Services (DCAS). The primary mission of these offices is to support the system program offices by administering contracts awarded to the prime contractor.

These offices are responsible for verifying that contractors' products conform to contract quality requirements and for taking appropriate action to "discourage" continued production of nonconforming products. These actions include rejecting products offered for acceptance and documenting the contractor's performance record. The offices accomplish their quality assurance responsibilities through actions such as (1) reviewing a contractor's quality procedures, (2) conducting audits to determine the adequacy of the management and product assurance

aspects of the contractor's quality control system, (3) inspecting the products being produced to see if they are in conformance with specifications, and (4) collecting and evaluating quality data for purposes such as identifying recurring deficiencies and ensuring that the contractor is taking adequate corrective actions.

The Plant Representative Office can refuse to accept a product because it has defects that affect the product's performance, durability, or reliability or that have other such serious effects; however, the final acceptance decision is to be made by the procuring contracting officer based on information provided by this office and the contractor. If the defects are of a more minor nature, this office can accept the product, except when this authority has been withheld by the procuring contracting officer. The procuring contracting officers for the Phoenix, HARM, Harpoon, and Sparrow report to the NAVAIR Assistant Commander for Contracts, not to the program manager.

On November 3, 1986, we issued a report[1] that cited a number of factors that were hampering Plant Representative Offices' oversight activities and increasing DOD's risk of accepting defective products. We reported that these offices were delegating some of their inspection responsibilities to the contractors and were not performing all mandatory inspections. We also reported that their efforts to discourage repeated tender of nonconforming products were hampered by the lack of data needed to readily identify recurring contractor deficiencies.

Assessing Quality

DOD defines quality as the composite of all attributes or characteristics, including performance, of a product to satisfy a user's needs. Thus, to have a quality product, the design must reflect the user's needs and the product should conform to the design. The extent and type of nonconformances or defects[2] that occur during production affect the degree to which a user's needs are satisfied.

Several measures are available to assess the quality of the missiles being delivered to the Navy. The most prominent are (1) degree of conformance with government specifications, partially provided by teardowns and other inspections before the missiles are delivered to the fleet and

[1]Quality Assurance: Efforts to Strengthen DOD's Program (GAO/NSIAD-87-33, Nov. 3, 1986)

[2]DOD defines a nonconformance as a failure of a unit or product to conform to requirements for any quality characteristic. A defect is defined as any nonconformance to a requirement. Thus defect and nonconformance have been used interchangeably within DOD.

(2) reliability of the missiles, which is measured through various tests before and after the missiles have been accepted by the government. In addition, fleet firings of the missiles are conducted to assess performance of the entire missile system, including its interface with the pilot and the aircraft.

Compliance With Specifications

Our review of contractor documentation on nonconformances, contract waivers and deviations, and teardown inspection and other reports and discussions with government and contractor personnel disclosed that the four missile systems had numerous nonconformances or defects. Most of these were judged by the government and contractors to be minor, having no effect on missile performance, and thus the missiles were accepted. A common type of minor nonconformance was the use of alternative, but acceptable, material or production processes. For example, an alternative microcircuit was installed in some Sparrow missiles when the supplier discontinued production of the microcircuit stipulated in the specification.

Groups of missiles, however, were accepted that were suspected of having defects that, according to criteria in NAVAIR teardown guidance, could affect the performance of some of the missiles. In a few instances, these defects were known to exist during the production process, but the contractor requested and was granted a waiver or deviation from the specification by the Navy.

Some waivers, deviations or contract modifications were granted because requiring compliance with the contract specifications would have increased production costs or caused schedule delays. Navy officials said that another reason for granting waivers was that to rework or repair certain types of defects could cause further quality problems.

In other instances, defects were detected during teardown inspections of sample missiles, but the Navy accepted all the missiles of that lot as they were rather than have the contractor open each suspect missile. Again, the concern was that additional defects could be caused during the repair or rework process. In some instances, additional testing was performed on the sample teardown missile or components, which provided some assurance that the defects would not affect missile reliability. Also, in some cases, the Navy received extended contractor warranties to cover the cost of repairing any failures caused by these defects.

Some defects in the missiles delivered during 1986 and 1987 were not discovered until after the missiles had been delivered to the fleet. While these defects often were detected in only one or two missiles, others were found in groups of missiles; in a few instances, hundreds or thousands of missiles may have been affected. These quality "escapes," which were detected and corrected in most every instance before the missiles or components were widely dispersed to the fleet and other users, are discussed in appendixes IV through VI.

In commenting on a draft of this report, DOD said that in no case did the Navy knowingly accept missiles that were suspected of containing defects that could affect the performance of the missiles. It said all defects detected during teardown inspections were analyzed and/or tested to confirm there was no affect on missile performance. When the defects were judged to affect performance, the contractor was required to rework the missiles. Where waivers, deviations, or other contract modifications were granted to allow certain defects in the missiles, DOD said careful engineering review and analysis, including testing, was conducted to ensure that there was no performance or reliability impact.

We found that the review and analysis of these defects, in some instances, was quite limited and did not always ensure that the defects would not affect the missiles. Teardown inspections of Sparrow missiles produced by Raytheon Company during 1986 and 1987 identified defects in the four missiles inspected that could affect missile reliability, according to Navy teardown criteria. However, on only two of the four missiles was additional testing done to assess the potential effect on reliability. Also, none of the hundreds of other Sparrows produced at the time and suspected of having similar defects were inspected or tested beyond what was required in the contract. (See app. VI.) In the case of the Harpoon missile, a deviation allowing a certain soldering-related condition in 720 missiles, which could affect the reliability of some of these missiles, was approved, although no risk analysis was performed. (See app. V.)

Missile Reliability

The Pacific Missile Test Center conducts production acceptance tests on the four missile systems before they are sent to the fleet to determine whether they meet contract specifications. These tests consist of taking a sample of missiles from each production lot; subjecting them to vibration, temperature, and humidity conditions; and examining some, but not all, missile functions for malfunctions. These tests, which for the Phoenix were supplemented by data gathered during captive carry tests,

provide mean-time-between-failure (MTBF) data that give a continuing assessment of production quality. While some failures occurred during this testing, data provided to us by the Navy on the results of production lot acceptance tests from January 1, 1986, through June 30, 1987, indicated that all four missile systems were meeting the contract MTBF requirements. (See table II.1.)

Table II.1: Comparison of Contract MTBF, Production Lot Acceptance Test MTBF, and Fleet Captive Carry MTBF

Figures in hours

	Contractually required MTBF	Production lot acceptance test MTBF[a]	Captive carry MTBF[b]
Phoenix AIM-54C	505	542	
HARM AGM-88A	125	2,226	1,092 7
Harpoon 84A	250	1,883	363 9
Sparrow 7M	550	700	2,130 7

[a]Production lot acceptance test data for the period January 1, 1986, through June 30, 1987

[b]Captive carry data for the HARM, Harpoon, and Sparrow are for the period October 1, 1982, through June 30, 1987. Phoenix MTBF data are from October 1, 1984, through June 30, 1987; there were no captive carry flights of the Phoenix AIM-54C during fiscal year 1986

[c]Because of the limited availability of the Phoenix AIM-54C in the fleet, only a few captive carry flights took place. As of June 30, 1987, the Phoenix had a minimum MTBF of 346.9 captive carry hours because there have been no captive carry failures; no MTBF has been established for the missile. If results from operational test and evaluation are considered, the MTBF is 572 hours at a 75-percent confidence level.

To assess the reliability of missiles after they are in the fleet, the Navy performs captive carry testing. While the aircraft is in flight, various functions of the guidance and control sections of the missile are tested, but the missile is not fired. Because of the long duration of the flights and the environmental conditions to which the missile is exposed, the Pacific Missile Test Center's reliability reports state that the MTBF from captive carry operations is the best measure of missile reliability. Data on captive flight hours failures are submitted by the fleet air squadrons to the Navy's Fleet Analysis Center, Corona, California, which compiles the data into an overall average missile MTBF. Despite the Pacific Missile Test Center's statement about the MTBF from captive carry operations being the best measure of reliability, DOD, in commenting on our report, stated that the Navy's position is that fleet firing data is the best measure.

As shown in table II.I, fleet captive carry data also indicated that the HARM, Harpoon, and Sparrow missile systems were meeting the MTBF reliability criteria. Because there had been no fleet captive carry failures

for the Phoenix AIM-54C, a fleet captive carry MTBF had not been established as of June 30, 1987. Fleet data do not include operational test data which, if added, results in an MTBF of 572 hours at a 75-percent confidence level.

Before a missile undergoes a captive carry test for the first time, preflight tests are conducted. If a missile failure occurs during these tests, this information is to be reported by the fleet, but not as part of the captive carry data. We attempted to obtain data on these failures but were told such data are not readily available. We were told the data are not reliably reported by the fleet and thus may be inaccurate. Exclusion of these failures increases the reported reliability rates.

Captive carry testing, while intended to measure reliability, does not detect failures in the propulsion and warhead sections of the missiles. The Navy has separate screening procedures for those sections.

The Navy also has a program for evaluating the quality of its stockpiled missiles. The program includes bringing the guidance and control sections into laboratories for a comprehensive material analysis to see if quality has degraded. At the time of our review, no such analyses had been done on these sections of the four missiles. According to Navy officials, this had not been done because the Phoenix AIM-54C and Sparrow AIM/RIM-7M missiles had not been deployed for a sufficient period of time under the program's guidelines, and the HARM and Harpoon were in short supply and could not be taken out of inventory for such analyses.

In commenting on a draft of this report, DOD said the HARM and the Harpoon had been evaluated under this program. We obtained a listing of the evaluations referred to in DOD's official comments and found that the evaluations were not comprehensive laboratory evaluations of the guidance and control sections, but rather more limited analyses of propulsion and warhead components and parts such as batteries and screws. DOD also said that the Air Force has data that indicate Sparrow missiles significantly exceed their storage requirements; however, it acknowledged that there are no unique Sparrow AIM-7M guidance and control section reports available at this time.

Fleet Firings

As part of the Navy's evaluation of the performance and reliability of air-launched weapons, the Fleet Analysis Center conducts a missile firing program in conjunction with the fleet. However, as with captive carry, fleet firing data also present an incomplete picture of missile reliability because pre-flight test failures are not counted in measuring fleet firing results. Furthermore, fleet firing tests are not part of the contractual performance parameters.

Under the Center's firing program, a telemetry package is installed in place of the missile's warhead before a firing. This package provides data that the Center uses to analyze the performance of the entire weapon system, including the missile and the launch platform. If the Center decides the firing is a failure, it determines whether the failure is attributable to the missile, the aircraft, the aircrew, or the environment. Since the missiles are not recovered, the degree to which a failure is attributable to material or workmanship defects cannot be determined.

In addition, the Center receives reports on warhead firings but does not use them in its performance analysis because, with the absence of a telemetry package, data are not available for the analysis. Center personnel told us that the success or failure of warhead firings is determined by the pilot's visual observations as to whether the target was hit.

The conditions under which telemetry firings occur are dictated by the Navy's Operational Test and Evaluation Force. Officials from the Fleet Analysis Center and the Operational Test and Evaluation Force told us that the firings are often conducted "at the edge of the missile's performance envelope" to test the missile's capabilities. Every missile to be fired in a telemetry test is tested before the aircraft becomes airborne. A missile that fails is replaced with another. The pre-flight failure, however, is not recorded in the telemetry test data. As is the case with missiles that fail before their first captive carry flight, NAVAIR logistics personnel said this information is not readily available or reliably reported.

In commenting on this report, DOD said that the Navy's Maintenance Data Collection System analyzes all pre-flight test data as part of all maintenance data. However, DOD acknowledged that the telemetry test data contains only the actual missile flight and firing data, not pre-flight test results.

Of the four missile systems we examined, the Sparrow AIM-7M has had the most fleet telemetry firings. Between January 1986 and July 1987, 49 fleet telemetry firings were made of the Sparrow and 22 were made of the Harpoon AGM/RGM/UGM-84A. The HARM was fired 27 times by the fleet between January 1986 and July 1987, all of which were warhead firings. (This does not include those fired in the Libyan operation in 1986.) Because there were no telemetry packages available for fleet firings, the only telemetry firings providing scientific data on HARM were nine performed by the China Lake Naval Weapons Center for research and development purposes. Navy logistics personnel said that only three HARM telemetry packages are available for future tests and that these are also for research and development purposes, not for fleet firings. A June 12, 1987, NAVAIR memorandum discussing the fleet requirement for HARM telemetry packages stated that the shortages are expected to continue through 1989.

In commenting on a draft of this report, DOD said telemetry packages have not been used for HARM fleet firings because the telemetry shots destroy both the targets and the missile, whereas for other missiles the targets are intended to be recoverable. We contacted NAVAIR to resolve the apparent inconsistency between the DOD statement and the June 12, 1987, memorandum concerning fleet requirements for telemetry packages; however, we were unable to obtain an explanation.

Since only a few Phoenix AIM-54C missiles have been deployed to the fleet, the only firing data available are those obtained during the missile's operational test and evaluation, which was conducted from March 1983 to August 1984, and a follow-on test and evaluation, which was conducted from May to December 1985. Results from the 1983 and 1984 tests indicated that the Phoenix AIM-54C generally met its operational effectiveness requirements. The 1985 test results indicated the missile met most, but not all, of its effectiveness requirements.

The Phoenix AIM-54C is undergoing additional follow-on test and evaluation, which began in the Spring 1987, to validate software and other changes that had been made since the 1985 testing. In early September 1987, during the first of three or four scheduled firings, the warhead failed to detonate and the missile fell into the ocean. The Navy's testing agency initially attributed the failure to the Phoenix's FSU-lOA safety and arming device. The Phoenix NAVAIR program office told us that further investigation found that the personnel at the Pacific Missile Test Center, who had prepared the missile for testing, failed to configure it

for the warhead to detonate. Program officials told us that since the missile's rocket motor worked and the missile tracked to the target, the firing was not considered a failure; however, they could not say whether the firing would ultimately be considered a success or a "no-test."

User Satisfaction

We met with fleet pilots and ordnance crews and with the commanding officer and crew of a destroyer who use these missiles to discuss their experiences with the missiles during captive carry tests and fleet firings. While they were not in a position to judge the quality of workmanship, they were satisfied with the missiles' performance and capabilities and cited no particular problems.

Quality of Subcontractor Material

Subcontractors play a major role in the production of each of the four missiles. For example, in producing the HARM, the prime contractor, Texas Instruments, uses over 2,000 suppliers of which about 600 provide parts or products unique to the missile. For the Harpoon, about 72 percent of the contract cost is for subcontracted material. The Federal Acquisition Regulation and the contracts for the four missiles place responsibility on the prime contractor for assuring that the quality of the material and the parts provided by its subcontractors conform to contract requirements. The Plant Representative Office at the prime contractor plant is responsible for verifying that the prime contractor has adequate control over subcontractor material and for recommending corrective action when such control is lacking.

Subcontracted parts were involved in every instance we identified where a quality problem was not discovered until after defective or potentially defective missiles or missile components had been accepted by the government. This includes potentially defective transducers and undersized launch lug slots on the HARM (see app. IV) and faulty detonators, wings, and bracket springs on the Sparrow (see app. VI).

Air Force and Defense Logistics Agency reviews from 1984 through 1986 indicated that prime contractor control of vendor material has been a widespread problem in DOD. Some of the most common problems were inadequate vendor selection procedures, failures to include quality requirements in contracts and purchase orders, and insufficient receiving inspection procedures. Defense Logistics Agency follow-on reviews in 1987 concluded that most of the prime contractors with unacceptable controls had taken adequate corrective action.

The Navy's Executive Director for Reliability, Maintainability, and Quality Assurance acknowledged that subcontractor control is a problem. The director said there is often much inconsistency between what the contract requires for vendor control and what the contractor actually does. He believes many contractors are not aware that they have vendor control problems. The director also said it would be too costly for the Navy to pay prime contractors to provide thorough oversight of all vendors' plants. Instead, the amount of control is generally dictated by the worth of the item and its criticality to the end product. Thus, less significant items may get little scrutiny, although they too can affect missile performance and fleet readiness.

DOD Manual 4245.7-M, Transition From Development to Production, effective September 1985, cited the need for more emphasis by industry and the government on prime contractor management of subcontractors because of the impact of subcontractors on final product quality, cost, and delivery. The manual includes guidelines that are to be used by DOD components and that are expected to reduce the risk of encountering subcontractor control problems.

In its Best Practices manual of March 1986, which supplements the DOD manual, the Navy's Reliability, Maintainability, and Quality Assurance Directorate points to poor communication among the Navy, prime contractors, and subcontractors as one of the primary causes of subcontractor problems. The manual describes proven, best practices for the material acquisition process and identifies several practices to ensure effective subcontractor control. Examples include

- evaluating a subcontractor's capabilities before a contract is awarded to avoid performance problems;
- conducting design reviews with subcontractors to determine technical progress;
- using a dedicated specification team to ensure completeness and consistency of specifications, procurement packages, technical interfaces, and flow down requirements to ensure that subcontractors thoroughly understand technical product requirements;
- conducting joint government/prime contractor vendor conferences with subcontractors to establish a team approach; and
- assigning an individual in the prime contractor organization responsibility for each subcontractor to enhance control of the subcontractor's products.

Soldering and Teardown Inspections

Two controversial subjects concerning the quality of missiles have been soldering and teardown inspections. While these are separate issues, many of the defects cited during the teardowns have been soldering related.

Soldering

Soldering[3] electrical connections is a critical production function on these missile systems. For example, the HARM and Phoenix missiles have, respectively, about 42,500 and 60,000 solder joints. Soldering defects can and have lead to missile failures, although many defects have no effect on missile reliability. Large numbers of them, however, indicate that the soldering process may be lacking control and may need adjustment.

While there has been agreement that adherence to soldering standards is important in producing a reliable missile, there also has been considerable controversy about the appropriateness of certain soldering requirements provided in the Navy's WS-6536 specification. This specification has been revised several times since it was originally issued in 1966, and various versions are now in the production contracts for the four missile systems. The specification contains essential design and manufacturing fundamentals and is often referred to as a "how to" specification because it gives very specific requirements and procedures. According to Navy and contractor officials, the specification is considerably more rigid and exacting than normal industry standards and also more rigorous than the standards applied by the other military services. Until 1984, the specification was not required for all Navy equipment but was primarily used by missile programs with the specification modified to meet individual program requirements.

Conflicts have arisen over implementation of the specification because most contractors' soldering processes do not meet all its requirements. Examples of problem areas include requirements related to mounting components on printed wire boards, bubbles in the coating on printed wire boards, and electrostatic discharge. Until 1984, Navy program offices granted contractors numerous waivers and deviations to the specification; but in July 1984, the Navy began requiring (1) use of the WS-6536 specification on all Navy equipment procurements and (2) approval of all major waiver and deviation requests by the Commander of the cognizant Naval Systems Command. The effect was to bring the

[3]Soldering is the process of joining metallic surfaces with solder without the melting of the base material.

Navy and its contractors together to clarify the specification's requirements and to modify them where appropriate.

A troublesome point with regard to the need for such a strict soldering specification is the continuing shortage of age-related data and analysis on how environmental conditions affect soldering over the long term. A Navy project team, after assessing soldered electronic assemblies in various fleet systems, stated in its February 1987 report that the fleet was experiencing equipment failures that could be directly attributable to defects that occurred during the manufacturer's soldering process. However, the study concluded that most of the defects were the result of poor quality workmanship rather than the application of a specific soldering specification. Thus, the study did not resolve questions of whether specific soldering standards are more stringent than necessary to ensure long-term system reliability. It did, however, emphasize that Navy and DOD standards need to be consistently applied in controlling the soldering process.

The Navy is evaluating specific WS-6536 requirements to determine whether they are more stringent than necessary to meet weapon system performance requirements. This evaluation includes researching the rationale behind the initial establishment of the requirements and conducting experiments, when necessary, to develop new data.

Although this issue has not been resolved, the Navy has begun to phase out the use of the WS-6536 specification in favor of a recently issued DOD soldering specification (DOD-STD-2000). The new specification is intended to standardize soldering requirements by reducing the number of solder specifications used in defense system production and is to be used by all DOD components. According to the Director of the Quality Assurance Division in the Navy's Directorate of Reliability, Maintainability and Quality Assurance, the Navy is encouraging its contracting officers to incorporate the new specification into contracts for new systems or when major modifications are made to existing systems. While some of the points of controversy between the Navy and industry over the WS-6536 specification are likely not to occur under DOD-STD-2000. Texas Instruments commented that many of the same problems with requirements will continue to exist.

Teardown Inspections

The Navy has performed teardown inspections on guidance and control sections of all four missiles systems we reviewed. The results of many of these teardowns were controversial and are discussed in more detail in

appendixes III through VI. Much of the controversy centered around the (1) criteria used to assess the quality levels of the missiles and (2) reporting of the results of the teardowns.

Teardowns are an important element of NAVAIR's quality program. A teardown is an analysis of a weapon system or component (such as a guidance section) and is accomplished by taking it apart and inspecting it. Teardowns are used by the Navy in determining the quality level of hardware being procured from the contractor. Such evaluations detect nonconformances with manufacturing specifications, which are then traced back to problems with the manufacturing process, process controls, design weaknesses, and/or poor workmanship. Thus, the results of teardowns can be a valuable tool to the contractor in identifying deficiencies in the production process and in implementing corrective actions.

The Sparrow contracts specify that two annual teardowns will be made for each contractor. Contracts for the other three missile systems do not specifically call for teardown inspections, but NAVAIR's Quality Assurance Branch anticipates approximately one every year for every missile. However, a Harpoon has not been torn down since January 1985, and a teardown is not scheduled.

Two sources of controversy about teardown inspections have been (1) inconsistencies in the criteria applied and (2) the manner in which the results are reported. To reduce the controversy, the NAVAIR Quality Assurance Branch issued a teardown guide in March 1987 to provide consistent criteria for evaluating hardware and a uniform format for reporting results. This guide established three standard risk categories for assessing nonconformances—high risk (likely to adversely affect the short-term reliability of the missile), moderate risk (has potential to affect long-term reliability of the missile), and low risk (not likely to adversely affect missile reliability but is a departure from established standards). It also states that the teardown report should provide a summary of the types of nonconformances cited, as well as a risk assessment.

Quality Assurance Branch officials told us that under the new guidance only the number of high risk nonconformances will be reported. According to these officials, the number of moderate and low risk nonconformances will not be reported because people unfamiliar with the teardowns tend to focus on the total number of nonconformances, and this could be misleading. Many nonconformances cited in teardowns are

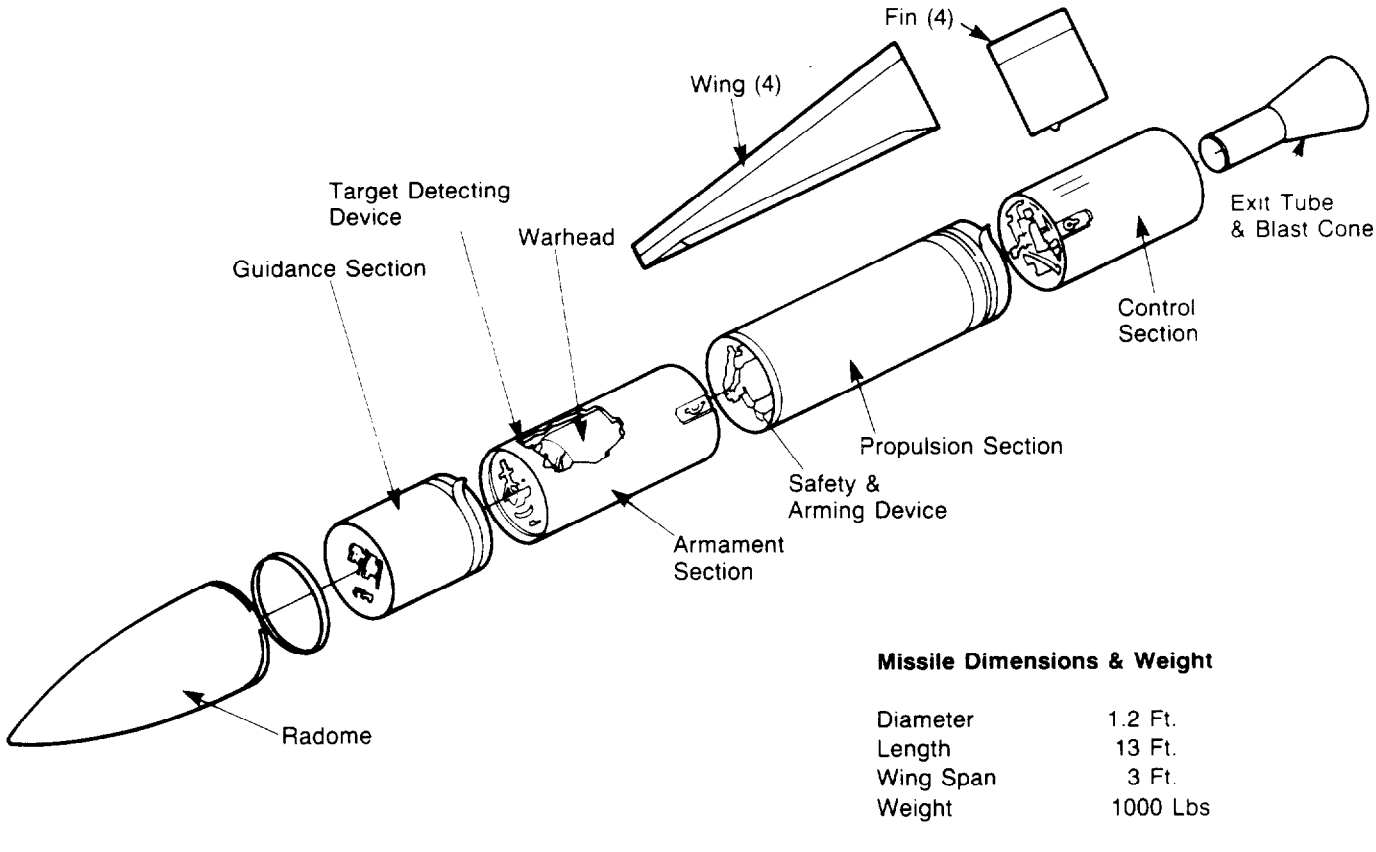
deviations from the specifications that the government and contractors believe are not likely to affect missile performance or reliability.

In addition to compliance with contractual requirements, the new guide also allows for evaluating the missiles for "best design and workmanship practices." Including such practices in the inspection's criteria permits the identification and reporting of nonconformances with specifications that have been allowed through an approved waiver, deviation, or other contract modification. Such reporting will provide data not only for assessing overall missile quality and quality trends but also for indicating the effects of waivers, deviations, and contract modifications on the quality of the missiles.

Phoenix Missile

The Phoenix (see fig. III.1) is an air-to-air missile that has been manufactured by the Hughes Aircraft Company, Tucson, Arizona, since 1971. The first contract for production of the Phoenix AIM-54C missile was awarded in 1979, and in 1983 a contract was awarded for an improved version of this missile. The missile's guidance and control sections, manufactured by Hughes, are integrated by Hughes with Navy-provided propulsion and armament sections. The missiles are tested by Hughes before being delivered to the government. DOD's in-plant quality assurance program at Hughes is administered by an Air Force Plant Representative Office.

Figure III.1: Phoenix AIM-54C Sections/Components



Source: U S Navy

The Navy plans to procure 7,204 Phoenix AIM-54C missiles at an average unit procurement cost of $922,000. The total program cost is estimated to be $6.8 billion. Operational evaluation of the missile was completed in 1984 with follow-on evaluations in 1985 and 1987. The monthly rate of production was expected to increase from 24 to 38 by February 1988.

A few of the AIM-54Cs are at naval weapon stations and aboard ships, but those now being accepted by the government are being immediately placed into storage awaiting resolution of problems with the Safety and Arming Device (FSU-l0/A). The Target Detecting Device (TDD), which along with the FSU-10A is government-furnished equipment, has also experienced problems, but solutions to these problems appear to have been identified and are now being implemented.

Waivers and Deviations

The Navy granted Hughes 3 major and 13 minor waivers on the missiles that we reviewed. The major waivers related to an industrywide alert put out in 1984 regarding a testing deficiency by three suppliers on thousands of semiconductor devices used in many defense products. Both Navy and industry representatives told us that the deficiency was determined to be inconsequential after the affected semiconductors were tested. Most of the 13 minor waivers related to nonconformances in testing and to the use of a marking ink that was not contractually specified for use in marking parts.

The Navy also granted Hughes 1 major and 92 minor deviations on these missiles. The major deviation was to allow Hughes to deliver missiles without the Safety and Arming Device (FSU-l0/A) provided by the government as government-furnished equipment. We reviewed 27 of the minor deviations and found that about one half were to allow the use of technically acceptable alternative component parts and materials. For example, nickel and gold-plated material with thicknesses that differed from the specification were allowed in the production of certain components. Ten of the other minor deviations related to the WS-6536D soldering specification and were granted after the 1986 teardown. According to the Navy, Hughes officials said they needed this relief so that the missiles could be produced without incurring additional rework expense and delivery delays. The contracting officer told us that it is unlikely these soldering deviations will result in monetary consideration to the Navy because the Navy sees no reduction in missile quality and because

the deviations were granted so that the contractor could meet production schedules. In commenting on our draft report, the Navy said an extended warranty has since been obtained.

According to the Navy's contracting officer, all waivers and deviations are reviewed for possible monetary adjustment, but at the time of our review there had been none on the Phoenix program. However, nonmonetary benefits have been obtained including (1) improved missile warranties at no additional cost to the government and (2) additional assembly work to install a temporary plug, in place of the FSU-10/A, in the missile until problems with the device are resolved.

In commenting on this report, DOD disagreed with the Navy's contracting officer and said that monetary adjustments have been obtained. It said that although no specific contract modification has been exclusively issued for such actions, the final prices established for subsequent production contracts took into account the waivers and deviations. DOD said that this was explicitly acknowledged by the government and the contractor, but the consideration amounts were merged during the negotiation process with other amounts and therefore cannot be specifically identified.

Teardowns

On June 6 and 7, 1984, in preparation for a decision to go from limited to full-scale production of the Phoenix AIM-54C, the Navy performed its first teardown inspection of the missile. The teardown team found many defects that violated both contractual requirements and acceptable manufacturing practices. Problems included damaged parts, defective solder joints, and unacceptable levels of cleanliness. Many problems were attributed to the difficulty of assembling the missile as designed, but poor quality workmanship was a major concern. The Executive Director of the Navy's Reliability, Maintainability, and Quality Assurance Directorate also told us the workmanship exhibited both poor management and a lack of work ethics on the part of the labor force at the Hughes plant.

On June 22, 1984, the Navy stopped accepting Phoenix missiles. Two additional missiles were disassembled and inspected by the government from June 26 to June 28, 1984, and much the same types of problems were found. The need was evident for Hughes to improve quality by identifying and rooting out the systemic causes of the problems. The teardown report identified the Phoenix's design, Hughes' control of its

soldering processes, and its oversight of subcontractors as three of many areas requiring corrective action.

In August 1984, after the Air Force Plant Representative Office issued a letter of intent to disapprove Hughes' quality assurance system, Hughes shut down the entire Tucson operation. During this shutdown, which lasted for 5 months, Hughes developed an extensive quality assurance improvement plan as required by the Air Force Plant Representative Office. As part of its improvement effort, Hughes invested about $160 million to upgrade the Tucson facility, including installation of new soldering machinery and a computerized quality assurance system. The Navy modified its contracts to require Hughes to rework, reinspect, and redeliver 84 Phoenix AIM-54C missiles that had been previously delivered. The modifications also set forth a plan to teardown a Phoenix missile or component approximately every 6 months during the 2-year period following resumption of missile deliveries. However, only two teardowns have taken place—one in June 1986 and the other in February 1988.

1986 Teardown

Although the 1984 teardown did not list the total number of defects, the June 1986 teardown did—2,694. Hughes, Navy quality assurance and program officials, and Air Force Plant Representative Office officials classified the majority of the defects as either "cosmetic" or the result of using inappropriate inspection criteria. However, the teardown team identified what appeared to be 38 "significant findings"—defects that could potentially affect the long-term reliability of the missile. The categorization of the 2,694 reported defects is shown in table III.I.

Table III.1: Classification of Defects by Type Identified During 1986 Phoenix Teardown

Type of defect		Number
Inappropriate inspection criteria[a]		943
Primarily cosmetic[b]		1,713
Potential long-term reliability impact		
Damaged wire insulation	3	
Foreign materials	5	
Solder splashes/splatter	4	
Wrong size screw	1	
Partially torqued jack screws on connector assembly	8	
Fractured solder joints	17	
Subtotal	**38**	38
Total		**2,694**

[a]The missile torn down was produced under a derivative of Military Standard 454, Standard General Requirements for Electronic Equipment, but, according to the teardown criteria, was inspected against weapon specification, WS-6536D. These defects would not have been defects under the derivative of Military Standard 454.

[b]Appearance does not meet the specification, however, component reliability was not questioned.

After the teardown, Hughes tested and analyzed the 38 significant findings in an effort to assess the long-term effect and concluded that they would not affect reliability. Navy quality assurance and program officials and the Air Force plant representative agreed with the analysis. The Navy, after observing Hughes' testing, reviewing its analysis, and performing some additional analysis, agreed with Hughes.

After the 1986 teardown, the Air Force Plant Representative Office increased its oversight of the production program, and Hughes unilaterally halted delivery of the missiles for 2 months while it strengthened its quality assurance program. Some of the actions Hughes took included improving the inspection and automatic soldering processes and providing additional training to employees.

1988 Teardown

The Navy's most recent teardown of the Phoenix was in early February 1988. This inspection was delayed several times as the Navy waited for a missile that reflected most of the changes made in the production process after the June 1986 teardown. The report on this teardown was not available when we completed this report.

The total number of defects identified in this teardown will be reported differently than in the 1986 teardown. The 1986 report listed the total number of all defects individually and identified as significant those

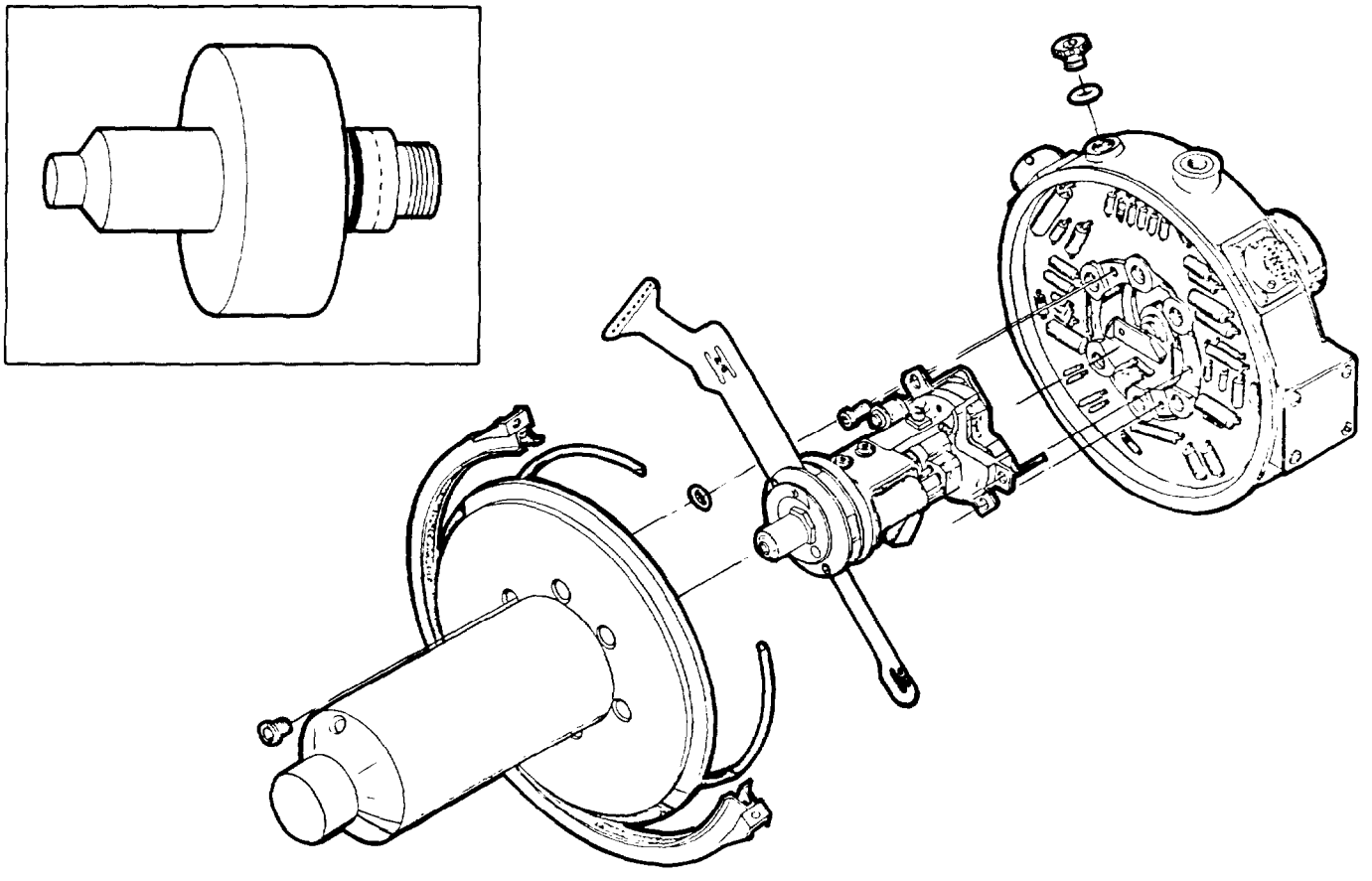
that could potentially affect missile reliability. The plan for the 1988 teardown does not include reporting individual defects that are not significant; instead it requires reporting the same type of defect as either "one" if there is one, "several" if there are two to six, and "numerous" if there are seven or more. Defects are to be categorized into areas needing improvement, which could include such areas as general workmanship, missile cleanliness, and soldering.

Although the March 1987 NAVAIR teardown guide calls for classifying nonconformances as high, moderate, or low risk, the plan for the 1988 teardown originally did not call for using these risk categories. According to the teardown team leader, the plan was prepared before the new guide was published. A NAVAIR Quality Assurance Branch official advised us that the plan was revised to coincide with the teardown guide.

Safety and Arming Device

The FSU-10/A Safety and Arming Device (see fig. III.2) provides the ignition and safe-arming function for both the propulsion and warhead sections of the Phoenix AIM-54C missile. FSU-10/A development started in 1977 as part of the Phoenix AIM-54C upgrade. Originally conceived and proposed by the China Lake Naval Weapons Center, the FSU-10/A became a joint effort between the Center and the manufacturer—Micronics International, Brea, California. Under a study contract with the Center, Micronics became responsible for the majority of the design and development work.

Figure III.2: Drawing of the Safety and Arming Device (FSU-10/A) **Assembly**



Source: Micronics International Incorporated

The FSU-10/A is provided to Hercules, Incorporated, as government-furnished equipment for assembly into the propulsion section. The FSU 10/A, which was first procured under a fiscal year 1982 contract, is installed in missiles manufactured under the fiscal year 1983 and subse quent year contracts. Before fiscal year 1983, Phoenix missiles used the igniter safety mechanism.

Current Status

Reliability problems with the FSU-10/A were discovered during enviror mental testing. Without the device, Hughes cannot provide an operable Phoenix missile. However, since the FSU-10/A is government-furnished

equipment and no alternative component is available, the Navy is accepting delivery and paying for missiles without the device and is then storing these missiles pending resolution of the FSU-10/A reliability question.

As of February 9, 1988, 512 Phoenix AIM-54C missiles, valued at about $472 million, were being stored at Tucson or elsewhere awaiting a usable safety and arming device. Because the number of stored missiles will continue to grow until an improved FSU-10/A is available and storage space at Tucson was exhausted at the end of September 1987, the Navy started shipping missiles to the Crane Army Activity, Crane, Indiana, for storage. From there the missiles will be shipped to the Seal Beach Naval Weapons Station, Fallbrook Annex, Fallbrook, California, where integration with the completed propulsion sections received from Hercules will occur.

Erosion and Interference Problems

Post firing inspections of propulsion sections in April 1986, coupled with FSU-10/A ground tests, revealed significant flame erosion of the units, which was caused by hot gas leakage between the units. In addition, physical interference between the igniter housing insert and the rocket motor liner was identified. The Navy believed these problems were design and/or data package related. Design changes were proposed, which the Navy believed corrected these problems, and a corrective action program that the Navy estimated would cost $1.14 million was initiated. This covered the cost of both rework and new production units. By about April 1987, 139 FSU-10/A devices, manufactured under a fiscal year 1982 contract, had been reworked at a cost of $0.2 million. The Navy paid for the rework because, according to the Navy, Micronics had complied fully with its contract (a firm-fixed price production contract), including numerous changes issued by the Navy.

Current Problems

In April 1987, during environmental testing of the redesigned units, other problems were uncovered when FSU-10/A devices experienced test failures. All testing was stopped and a new investigation that included hardware failure analysis, a design assessment study, and a producibility assessment study was initiated. According to the Navy, the investigation identified four problem areas involving both design and workmanship issues. The NAVAIR Phoenix program office said all fiscal year 1983 and subsequent FSU-10/As would be reconfigured to eliminate any potential problems.

Although the time needed to identify and implement corrective actions is unknown, the program office said in September 1987 it believed the design and production problems would be resolved by January 1988. FSU-10/As were scheduled to be available for assembly into new production Phoenix missiles in January or February 1988, and soon thereafter devices were to be installed in missiles in storage. A program official acknowledged at the time that this schedule was very "success-oriented" and dependent upon encountering no further problems.

In February 1988, the program official advised us that some delays have been encountered. The official said design changes have been implemented and Micronics has commenced low-rate production; however, additional testing remains, including environmental tests. It is these tests that have disclosed problems in the past, and thus the risk of further problems and delays remains. Full-rate production is scheduled to begin in April 1988, and the program office anticipates deliveries of FSU-10/A equipped Phoenix missiles to the fleet in late May or June 1988. If testing discloses the need for further design changes to the FSU-10/A, disassembly of production units may be necessary and further delays and increased cost could be encountered.

Cause of Problems

According to the Navy program office, Micronics did not provide adequate quality assurance and the China Lake Naval Weapons Center did not provide the necessary oversight of Micronics' quality assurance program. Under both the development and production contracts, the Center did not insist on strict adherence to contract requirements. For example, Micronics was not held to the quality assurance data collection specifications. The resulting lack of quality assurance data made it more difficult to determine the cause of the second series of problems.

According to a Naval Weapons Center official, the Center failed to adequately monitor the FSU-10/A contract quality assurance program because it "wanted the hardware out the door." The official also said that the design and development effort did not follow the Center's normal in-house development program for two reasons. First, a lack of Center personnel led to Micronics being given a study contract under which Micronics was to generate concepts and select a development concept for the FSU-10/A—tasks normally performed by the Center. Second, because of a possible compromise of the Phoenix following the fall of the Shah of Iran, the Navy believed an upgraded version of the missile was needed immediately. The upgraded missile included the design and development of the FSU-10/A within a compressed time frame.

To address the FSU-10/A problem, the NAVAIR Phoenix program office transferred responsibility for overseeing the program from the fuze department to the technical management office at the Naval Weapons Center. In addition, Micronics instituted production process changes, including establishing a dedicated production line for the FSU-10/A. The NAVAIR Phoenix program manager expects that the Micronics changes may increase the FSU-10/A unit cost about $2,000, from roughly $4,500 to $6,500.

In providing oral comments on this report, the President of Micronics said he was unaware of any information that indicates that workmanship problems contributed to the problems experienced with the FSU-10/A. He believes they were strictly design related. However, Navy officials said workmanship problems were involved.

Target Detecting Device

The TDD performs target proximity initiation for detonating the Phoenix warhead. The TDD, a Naval Weapons Center design, is manufactured by Motorola, Inc., Phoenix, Arizona, and is provided as government-furnished equipment to Hughes for assembly into the Phoenix, along with other government- and contractor-furnished equipment.

TDD failures were first observed in March 1985 during missile testing at Hughes. As a trend became apparent, failure analyses were conducted, and in November 1985 these failures were determined to be caused by a microscopic crystalline tin growth ("tin whiskers") on the chassis walls of the TDD Radio Frequency Assembly. The tin whiskers, which resulted from using pure tin plating within the assembly rather than a more commonly use tin alloy plating, could potentially cause internal shorting of the assembly. Beginning with fiscal year 1986 production, the Navy imposed a tin alloy plating as a design requirement.

The type of interior plating of the Radio Frequency Assembly was not specified by the Motorola contract. Instead, the contract specified performance requirements, allowing Motorola to provide design details, including the plating composition. In December 1985 Motorola proposed a parylene conformal coating[1] of the affected area and the Navy accepted this proposal as corrective action. Although initial TDD failures were from the fiscal year 1981 and 1982 production, research of production records and a physical examination of fiscal year 1983 hardware indicated that all TDDs were susceptible to the tin whiskers. As a result

[1] A conformal coating is an insulating protective coating applied to the completed board assembly.

of this problem, 526 TDDs are being reworked to incorporate the parylene coating.

Cost Implications

On February 21, 1986, the Navy notified Motorola that the problem was considered to be a latent defect[2] and directed the company to take corrective action. Pursuant to contract terms, Motorola is taking the corrective action. The Navy believes financial responsibility rests with Motorola. However, before accepting financial responsibility for correcting the defect, Motorola is reviewing its legal position regarding a potential claim against the government.

The status is as follows:

- Financial responsibility for reworking fiscal years 1982 to 1984 units has not been resolved between Motorola and the Navy. Motorola estimated rework costs to be $2.6 million.
- The Navy issued a contract modification to Motorola for rework of fiscal years 1980 and 1981 units. Motorola estimates the total costs at completion will be about $650,000. Navy officials said that because of the cost reimbursement nature of the contract for these units, the Navy will pay for the rework.
- The Navy negotiated a $1.3 million contract with Hughes for removing and exchanging TDDs in missiles with new or reworked units.
- The parylene application is now a requirement for production under the fiscal year 1985 contract at no additional costs.

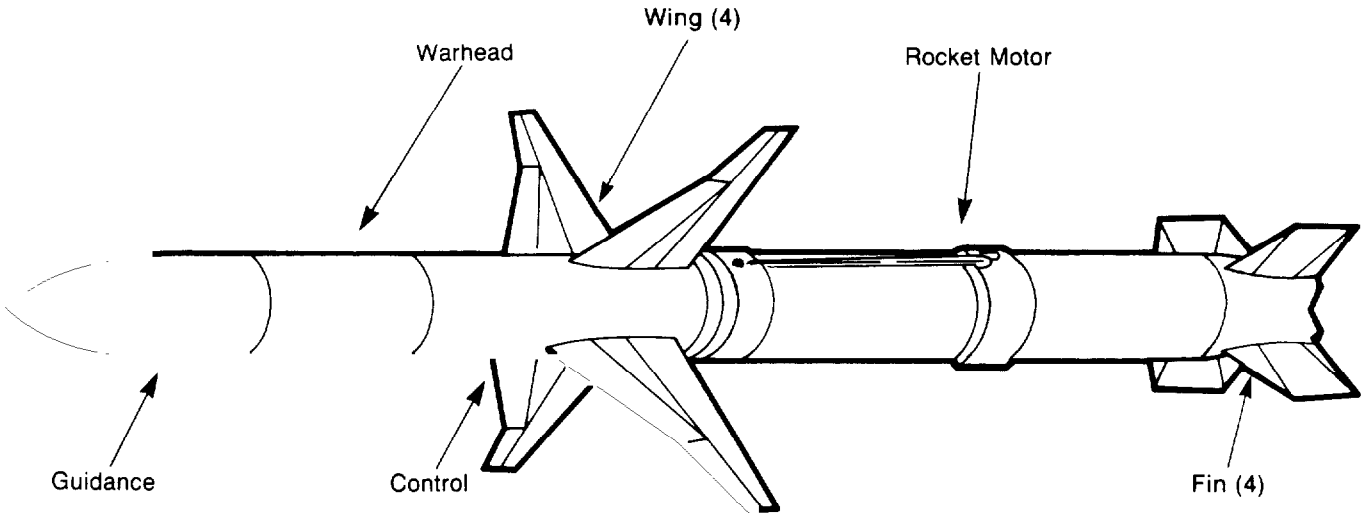
In commenting on a draft of this report, Motorola said the Navy exercised close scrutiny over the development and initial production contracts for the TDD, including the Radio Frequency Assembly. It said that the Navy was at all times aware of the method of plating the assembly and that in January 1985 the Navy formalized concurrence with its use through drawing approval. Regarding the use of the parylene coating, Motorola said this process emerged from technical discussions with the Navy. According to Motorola, the Navy asked Motorola to investigate the effectiveness of the process and, after evaluating Motorola data, directed its use.

[2]A latent defect is a hidden defect that a normal inspection would not have discovered.

High-Speed Anti-Radiation Missile

The Navy, in a joint procurement program with the Air Force, is purchasing the High-Speed Anti-Radiation Missile (HARM), AGM-88A, (see fig. IV.1) from Texas Instruments Incorporated, under annual firm fixed-price contracts. The HARM is an air-launched, surface attack missile for use against land- and sea-based enemy defense radars. Initial production began in 1982 and deliveries through June 30, 1987, totaled 2,319 missiles. The program plan is for the Navy to procure 7,505 at an estimated average unit procurement cost of about $303,000. The Air Force also plans to procure 7,114 missiles. Texas Instruments is producing HARM missiles at the rate of about 150 per month and is in the process of increasing that rate to 211 per month.

Figure IV.1: High-Speed Anti-Radiation Missile AGM-88A (HARM) **Sections**



Missile Dimensions & Weight

Diameter	10 In.
Length	13.7 Ft.
Wing Span	44 In.
Weight	800 Lbs.

Source Texas Instrument Incorporated

The HARM is composed of four sections: the guidance and control sections, which are produced by Texas Instruments, and the warhead and rocket motor sections, which are furnished by Morton Thiokol, Incorporated, and Hercules, Inc., subcontractors of Texas Instruments. (The government will furnish the rocket motor section to the contractor beginning with the fiscal year 1987 contract.) The four sections are assembled and integrated at Morton Thiokol in Brigham City, Utah, and at the Naval Weapons Industrial Reserve Plant operated by Hercules in McGregor, Texas. The complete missile is tested at the two integration sites before being sent to naval weapons stations. DOD's in-plant quality assurance program at Texas Instruments is administered by DCAS.

In July 1986 a contract modification was implemented to permit certain soldering defects in the missiles. Regarding subcontractor-produced items, there are potential problems with the pressure transducer in about 1,300 missiles, and there was a problem with launch lugs on 30 rocket motor cases.

Modification of Defect Criteria

The Navy performed a teardown of a HARM in February 1986 and, as a result of this teardown and other information, a modification in defect criteria was made to the fiscal year 1985 contract. The modification allows certain soldering defects in the missile within established defect control limits and establishes measures intended to improve quality levels.

1986 Teardown

A teardown of HARM guidance and control sections was conducted in early 1986 by a team from the Pacific Missile Test Center. Using the WS-6536D soldering specification as the criterion, the inspectors identified 936 defects, of which 28 were described as major, potentially affecting long-term reliability. The primary conclusion was that Texas Instruments was producing a missile with some defects, none of which would likely result in a malfunction during near-term service life

The inspectors used the WS-6536D soldering specification rather than the modified HARM version of the specification so that they could maintain teardown consistency between various missile programs and contractors. Texas Instruments objected to the inspection findings because the contractual soldering specification requirements—WS-6536D HARM with approved HARM drawings—were not used as the standard for evaluating the missile's workmanship and material. It also objected to counting certain manufacturing processes, such as the method of mounting

particular components on the printed wiring boards, as nonconformances. These processes were specifically allowed in the Texas Instruments contract but were cited as nonconformances because they conflicted with WS-6536D specified procedures. In commenting on a draft of this report, DOD said it believes Texas Instruments' objections were valid.

Contract Modification

Following the teardown, a series of inspections of HARM guidance and control sections, and subsequent DCAS nonacceptance of guidance and control sections, the Navy negotiated a modification—P00030— to the fiscal year 1985 HARM contract. The modification (initiated prior to the teardown, according to the Navy), which took effect in July 1986, significantly reduced the number of soldering defects for which Texas Instruments must take corrective action and introduced a process control approach for monitoring the manufacturing process. Two government organizations involved in the HARM program expressed opposition to it.

Group I Soldering Defects

Repeated discovery in 1985 and early 1986 of Group I soldering defects—defined as defects requiring rework or repair[1] before the article or material can be accepted—precipitated the contract modification. The specification requires that Group I defects be reworked or repaired when found at any stage of the production process. In February 1986 DCAS, believing that there was a high probability that Group I defects existed in missiles being produced and in those ready for acceptance, stopped accepting HARM missiles for about 10 days. DCAS said that it would no longer accept HARM missiles because Group I defects continued to be detected during internal and Navy audits and because the contractor had failed to provide acceptable corrective action.

To address the findings of the 1986 teardown and DCAS's concerns, Texas Instruments agreed to (1) an extended 3-year workmanship and material warranty[2] of all HARM guidance and control sections suspected of containing Group I defects and (2) reliability and engineering tests of sample groups of the affected missiles as conditional terms for resuming acceptance. A sample of missiles successfully completed the reliability

[1]A reworkable defect is one that can be reprocessed to make the article or material conform to the drawings, specification, or contract. A repairable defect cannot be returned to conformance but can be made usable after special repairs.

[2]Texas Instruments' workmanship and material warranty on HARM guidance and control sections is normally a year.

tests conducted at the Pacific Missile Test Center. Failures were reported on two missiles; however, both failures were in the missile's gyro and were believed by the test manager to be attributable to a design problem in the missile test set, not to Group I soldering defects. The test manager recommended that the missiles be returned to Texas Instruments to verify that failures were not missile related. However, the NAVAIR HARM program manager believed there was insufficient reason to return the two missiles to Texas Instruments and thus directed that the missiles be sent to the fleet. Texas Instruments, in its comments on our draft report, said one of these missiles subsequently failed an inventory test and was returned to Texas Instruments for repair at government expense.

The engineering assessment tests of Group I defects, which Texas Instruments made to determine possible failure modes and their potential impact on operational use of the missiles, showed that components with these defects could withstand environmental stress and remain functional. Pacific Missile Test Center representatives who observed the tests agreed with the findings. In commenting on a draft of this report, DOD said that these tests demonstrated that the 28 major defects identified in the February 1986 teardown would not affect missile performance and reliability. However, the scientific consultant to the Reliability Evaluation Division at the Pacific Missile Test Center told us that the aging tests could not be used to project the long-term impact of the defects on the missiles.

Agreement Reached

After the DCAS' nonacceptance decision, the Navy and Texas Instruments agreed to a modification of the fiscal year 1985 HARM contract. The modification reduced by 32 (from 44 to 12) the number of unacceptable Group I defects requiring rework, when these defects were identified after initial inspection. The 32 defects (e.g., insufficient solder, nicked or cut wires, and certain types of residue) would be considered acceptable in completed guidance and control sections because the NAVAIR quality assurance personnel believed they were unlikely to cause long-term reliability problems.

The modification also introduced the use of process controls during production for monitoring and reducing the number of undesirable soldering conditions. Under the process control approach, contractual thresholds of acceptance have been established for acceptable Group I soldering defects. These thresholds become tighter as the contract progresses. As long as the number of defects remains within an acceptable

range, the production process is assumed to be under control. However, an increasing number of defects would indicate a process is getting out of control and may require the contractor to take appropriate corrective action.

Impact

By modifying the contract, the Navy, in effect, authorized the acceptance of certain Group I defects in HARM missiles and changed the soldering criteria DCAS uses to monitor contractor performance. Navy and Texas Instruments officials said the modification was necessary because it would have been difficult and costly for the contractor to comply with certain requirements in the Navy's soldering specification, considering the HARM's design and Texas Instruments' soldering processes. However, Texas Instruments did not provide an estimate of the cost for producing the HARM without the contract modification.

In its comments on this report, Texas Instruments said the prime difference in quality requirements before and after the February 1986 teardown was a sudden shift by the government on the acceptability of noncritical Group I defects in the hardware subsequent to 100 percent visual inspection by Texas Instruments. It said that visual inspection is not 100 percent effective but when coupled with an effective test and environmental stress screening program, it is adequate to screen out critical defects. Thus, according to Texas Instruments, the modification will not adversely affect the integrity of the missile.

Navy program officials and senior quality assurance personnel believe the Navy benefited by modifying the contract because rework and scrap were reduced and production yields were improved without degrading missile reliability. In contrast, personnel at the Naval Weapons Center objected to the modification because it relaxed what they considered to be important soldering specification requirements. DCAS also objected for several reasons, including the (1) appropriateness of reclassifying some Group I defects to a lower criticality, (2) effect on any meaningful comparison of future teardown results with prior teardowns due to the change in criteria, (3) message the revisions may send to the contractor concerning inspection and overall quality control, and (4) precedent that may be set in future contracts that incorporate the WS-6536 soldering specification. Senior Navy quality assurance personnel disagreed with some elements of the positions of the Naval Weapons Center and DCAS but did not specify which elements.

While the modification enabled Texas Instruments to avoid the cost of complying with contract specifications, the government did not receive any monetary consideration from Texas Instruments for the modification. The Navy said that while the specification requirements were changed, Texas Instruments also had to change its process controls and inspections. Navy officials said that they believed the changes were a "wash" from a cost viewpoint. Navy officials said the government did receive nonmonetary consideration in the form of an extended 3-year workmanship and material warranty on suspect guidance and control sections. Navy program officials further said the modification may allow for production of future HARM missiles at a lower cost by reducing rework and scrap and by increasing production yields.

Texas Instruments officials said that despite the modification, the company still incurred some costs. Although the modification avoided costs that strict contract interpretation would require, Texas Instruments maintains that additional inspection hours and statistical analysis costs and other paperwork costs will be incurred.

In its comments on this report, DOD said that the missiles produced under the new process controls have shown significant improvements in quality and production efficiency. The Navy provided us with Texas Instruments' data that indicated the number of acceptable Group I defects had dropped and was within the acceptable range under the modification. A DCAS Plant Representative Office official at Texas Instruments confirmed the accuracy of the Texas Instruments data based on reviews and analyses his office had performed.

Transducer Problems

The pressure transducer, a critical component of the HARM control section, electrically measures atmospheric pressure. The pressure reading is used in estimating the position and altitude of the missile in flight. These estimates are then used in activating the missile's target seeking device.

The Federal Bureau of Investigation is investigating an allegation that Genisco Technology Corporation, Simi Valley, California (one of two suppliers of the transducer) falsified test data on its transducers between 1980 and 1987. Contractual provisions require Genisco to test the transducer at specified cold, ambient, and hot temperature levels. However, Genisco allegedly used computer simulations of the hot and cold temperature tests rather than actual tests to accumulate the test

data. The Navy and Texas Instruments were notified of the investigation in March 1987.

Both Texas Instruments and DCAS had conducted, at one time, source inspections of Genisco transducers for the HARM. However, in about 1985, DCAS stopped its inspections after (1) deciding that Texas Instruments' source inspection procedures were adequate, (2) finding no evidence of past transducer problems at Texas Instruments, and (3) determining the component's failure rate to be low.

Neither Texas Instruments nor the Navy has determined the extent to which the transducer problem may affect HARM reliability or performance; however, Texas Instruments believes about 1,300 transducers may be affected. Most of these are in HARM missiles that have already been accepted by the government.

In July 1987, Texas Instruments officials told us they believe that HARM performance will not be appreciably degraded by the Genisco transducer. Data from preliminary tests using computer simulations indicated a small increase in "flyers" (missiles that miss the target by more than a specified distance), but still within contractual requirements. Other test results had indicated that only high temperatures may pose a problem. Texas Instruments believed its product acceptance test flow process, which tests the pressure transducer in various temperature and pressure combinations during production assembly, was sufficient to detect any component failures that would degrade HARM performance. In August 1987, a Navy official told us that recent testing of 30 transducers from fiscal year 1985 production revealed that 20 percent did not conform with contractual performance requirements and that the problem was not design related.

In its November 1987 comments on this report, Texas Instruments said that when the transducer is integrated into the missile the impact of the nonconformance on missile performance decreases significantly. It said, however, that a small unspecified number of fiscal year 1985 transducers installed in missiles sold to the government will have to be replaced. Texas Instruments also said results from its tests on 30 transducers from the fiscal year 1984 production lot were not yet available. It expected to complete testing and analysis on a sample of 30 from fiscal year 1983 in January 1988 after which final recommendations for corrective action would be made.

Texas Instruments is accumulating cost data for evaluating and resolving the transducer problem and plans to recover the costs from Genisco. Until the transducer evaluation is completed, a second source of pressure transducers is meeting production needs and an additional source is being developed. DOD, in commenting on this report, said that under the terms of the contract, Texas Instruments will be responsible for repair costs on any and all missiles that the government determines need repair due to faulty transducers.

Defective Launch Lugs

The launch lugs on the HARM rocket motor case attach the missile to the aircraft missile launcher and are used in conjunction with a handling fixture in the missile assembly process. Three companies produce the rocket motor cases for Morton Thiokol which, as a subcontractor of Texas Instruments, loads propellant into the cases and provides the rocket motors to Texas Instruments.

In November 1986, during final rocket motor assembly, Morton Thiokol discovered a launch lug that would not fit a handling fixture. Measurement revealed the lug slot was under the allowed drawing tolerance size. After evaluating the problem, Morton Thiokol determined that the undersized lug slot resulted from the supplier using a new, faster cutting tool in its production process, which increased the stress in the lug. The supplier, Lucas Aerospace of Lancashire, England, used an inspection procedure that required inspecting the dimension of the slot after it was machined with the cutting tool, but not after the heat treatment process that relieves stress caused by the cutting operation. It was at this point that the slot defect would have been detectable. Morton Thiokol representatives at Lucas inspected the lug's dimension after the heat process on a sample basis but did not detect any problem.

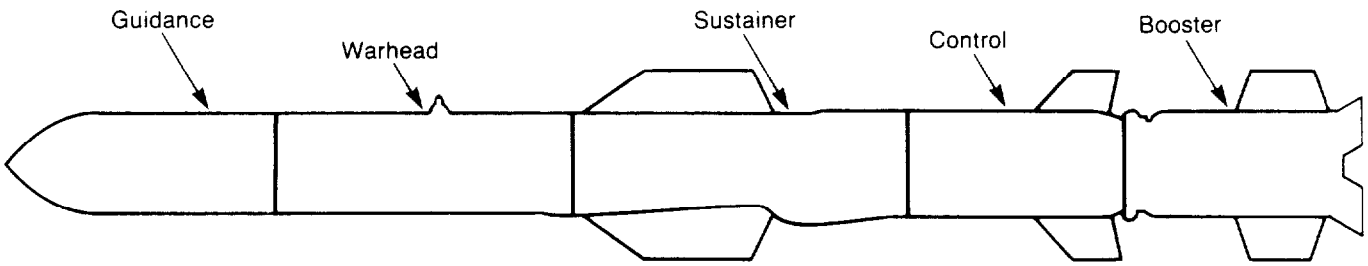
Further investigation by Morton Thiokol indicated that of the 111 rocket motor cases with launch lugs that had been produced using the new cutting tool, 30 had undersized lug slots that needed to be repaired by Morton Thiokol. Five of those had been shipped to Navy and Air Force installations and had to be recalled.

To prevent recurrence of this problem, the three rocket motor case suppliers are required to inspect all lugs after the heat process and before delivery to Morton Thiokol. Also, Morton Thiokol inspects the lug dimensions on all rocket motor cases upon arrival. In commenting on this report, Morton Thiokol said that since the lug problem was warranty related it absorbed the cost of repairing the discrepant parts.

Harpoon Missile

The Harpoon AGM/RGM/UGM-84 (see fig. V.1) is an antiship missile designed to destroy surface ships. It can be launched from aircraft, surface ships, and submarines and is used by the Navy, the Air Force, and 16 other countries. It is built by McDonnell Douglas Astronautics Company (MDAC), St. Louis, Missouri, and has been in production since 1975.

Figure V.1: Harpoon AGM/RGM/UGM-84A Missile Sections



Missile Dimensions & Weights

Diameter	13.5 In.	Weight	
Wing Span	36.0 In.	Airlaunch	1144.9 Lbs.
Length		Ship/Sublaunch	1503.3 Lbs.
Airlaunch	151.5 In.		
Ship/Sublaunch	182.5 In.		

Source McDonnell Douglas Corporation

While MDAC has overall responsibility for the quality and performance of the missile, the company actually makes only a small portion of it. MDAC's role is to integrate and assemble subcontracted components and assemblies.

The program calls for procurement of 3,971 Harpoons at an average procurement unit cost for air, surface, and submarine-launched missiles of about $854,000. Production averages between 40 and 45 missiles a month, with about 30 per month being delivered to the Navy. A Navy Plant Representative Office is responsible for DOD's in-plant quality assurance program.

Several waivers and deviations have been granted on these missiles; one deviation allows a certain type of soldering condition in a critical component—the altimeter—and could lead to reliability problems in some of the missiles. Two teardown inspections were performed in early 1985, and the overall workmanship was reported to be very good, but there was room for improvement.

MDAC has had problems controlling some of its subcontractors and getting them to take corrective actions to address production problems that could affect the missile. There was also one instance in 1986 where 10 missiles were recalled, at no expense to the government, when a potential problem was discovered with crystals in those missiles.

Altimeter Deviation

All the waivers and deviations that related to missile quality were classified as minor by the Navy Plant Representative. However, one deviation, involving the soldering acceptance criteria on the altimeter's printed wiring assemblies, could affect the reliability of some missiles. The altimeter is part of the missile's guidance section.

Deviation Request

Kollsman Instrument Company, located at Merrimac, New Hampshire, was awarded a contract in 1978 to produce an altimeter for the Harpoon with inherent electronic counter countermeasures capabilities. Kollsman encountered numerous problems, including design and soldering, that delayed deliveries to MDAC. Missile deliveries were delayed further in 1985 as a result of production problems that caused measling[1] in the altimeter's printed wiring assemblies. A combination of high humidity and extreme heat in the processing of printed wiring assemblies at Kollsman has been causing the measling.

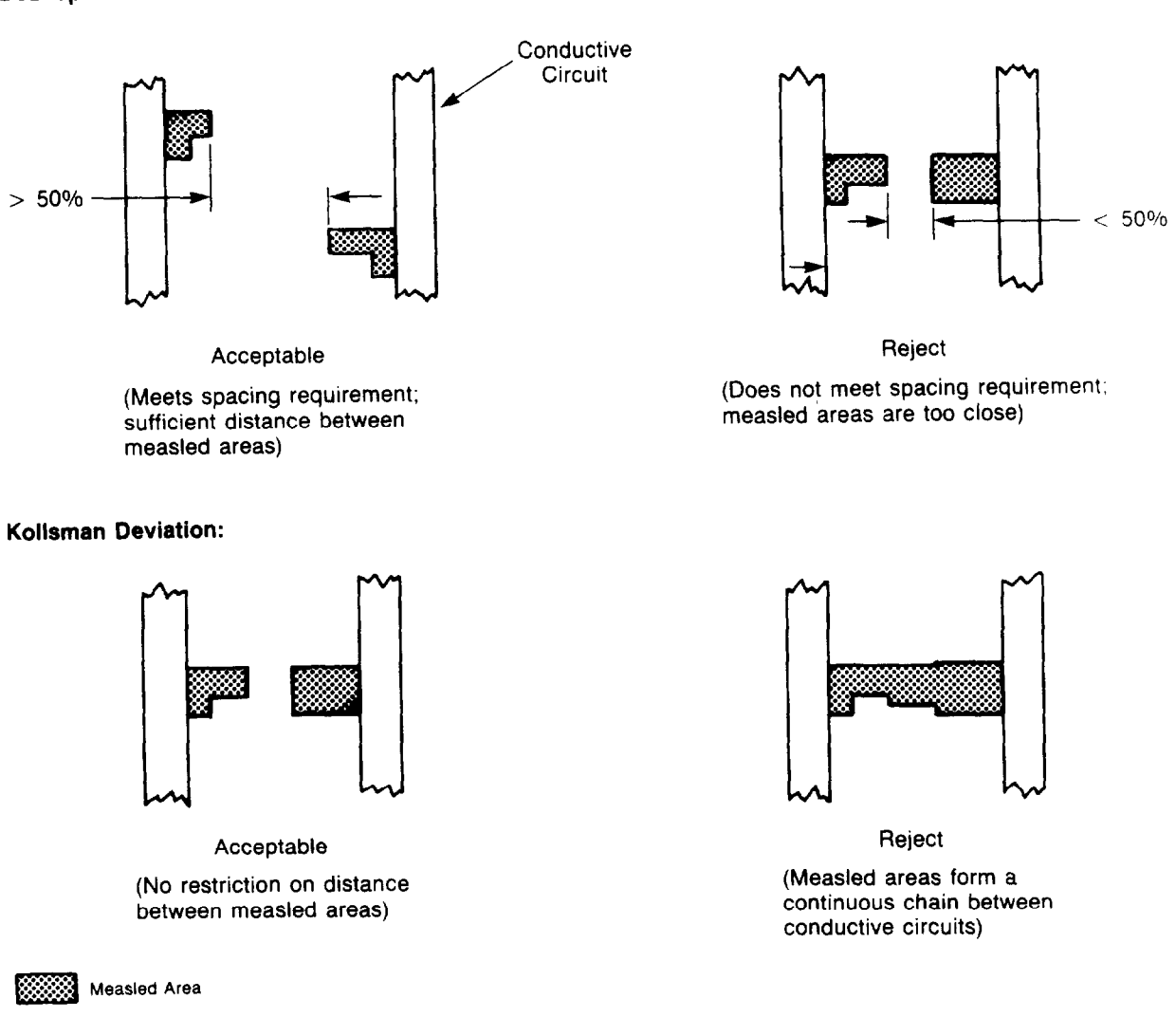
[1]A condition existing in the base material of printed wiring boards and assemblies in which the glass fibers are separated from the resin at the weave intersection. This condition manifests itself in the form of discrete spots below the surface of the base material.

In October 1985, after months of high rejection rates of measled printed wiring assemblies, MDAC submitted a deviation request to the Navy Plant Representative Office for approval. The proposed deviation established inspection criterion that Kollsman had developed. MDAC, anticipating that the request would be approved and with approval from the Plant Representative Office, authorized Kollsman to deliver 14 altimeters that contained measled printed wiring assemblies.

The China Lake Naval Weapons Center, however, recommended disapproval of the deviation, contending that Kollsman should use the criterion in the Navy's soldering specification, WS-6536E, which had just been released. Both the Naval Weapons Center and the Pacific Missile Test Center expressed concern that the measling was an indication of workmanship problems at Kollsman.

A temporary 90-day deviation that allowed more measles than authorized under the soldering specification, as long as they did not form a continuous chain between conductive circuits, was approved in April 1986. The restriction in the soldering specification on distance between measles was not included in the deviation. The Navy Plant Representative Office, with NAVAIR's approval, was authorized to accept missiles with the Kollsman altimeters. (Figure V.2 illustrates the difference in the spacing criteria between the DOD specification and the deviation.)

Figure V.2: Harpoon Altimeter Measling Criteria



Improvements were made by Kollsman in its processing of printed wiring assemblies, and in August 1986 the temporary deviation was revised and approved to include the WS-6536E spacing criterion. This revised deviation applied to 420 altimeters in the existing purchase order, but it

did not apply to the 133 altimeters already delivered or to the printed wiring assemblies in Kollsman's inventory.

Change to the Revised Deviation

Through October 1986, Kollsman experienced few rejections. After October, however, rejection rates rose again with measling being part of the problem. MDAC advised the Navy Plant Representative Office that Kollsman needed relief from the revised deviation and submitted a change to the revised deviation. The plant representative approved the change in January 1987, adopting the Kollsman criteria in the original deviation that included less stringent requirements regarding spacing of the measling between conductive paths. The newly revised deviation applied to 720 altimeters procured on one purchase order.

Acceptance Criteria in January 1987 Deviation

In commenting on this report, DOD said none of the Kollsman units accepted under the deviation were sufficiently flawed to be of concern relative to long-term reliability. It said measling is indicative of poor production process control but that the Naval Weapons Center had conducted an analysis of worse case measled assemblies from Kollsman and concluded that the risk of using them was minimal. Thus, NAVAIR recommended the Plant Representative Office approve the deviation. We found, however, that there was no analysis to support such a conclusion.

We examined various documents concerning the Naval Weapon Center's analysis, including the Center's laboratory report on its evaluation, and discussed the analysis with the Center's soldering specialist involved with the review. The purpose of the analysis was to determine the effect of the measling on the hardware and this was to be done by examining assemblies that represented examples of "worst case conditions." We found that the analysis, which occurred in January 1987, involved only two assemblies and that these had been selected by MDAC and Kollsman representatives. The Center's soldering specialist said the two assemblies were not representative of the worst assemblies at Kollsman—there were many others that were much worse.

Our review of the Weapon Center's laboratory report and discussions with the soldering specialist at the Center disclosed that the analysis of the assemblies by the Center's Failure Analysis Laboratory did not assess risk or the potential impact of the measling on missile reliability. The Center, however, concluded, based on the limited analysis, that the risk of using measled assemblies of the type analyzed was minimal and

provided NAVAIR with a report and pictures to be used as "not to exceed" criteria. However, the recommended acceptance criteria were not used in the deviation. The criteria adopted were less stringent, according to the Center's soldering specialist, than that represented in the Center's report and pictures.

Impact of Measles on Missile Reliability

There is disagreement over the potential impact of measling on equipment reliability. MDAC, in its comments on this report, said "one fact is very clear, there is absolutely no evidence of a hardware failure, field or otherwise, that was caused by the phenomenon known as measling." It added that the printed wire board industry considers it to be a cosmetic defect and cited a 1971 industry study that concluded the effect of measles on the functional characteristics of finished products was "at worst minimal and in most cases insignificant." DOD, in its response to this report, said that in extreme cases measling can be a potential source of future reliability problems.

We contacted the Director of the Quality Assurance Division in the Navy's Reliability, Maintainability, and Quality Assurance Directorate; one of the Navy's three top soldering examiners; and the Director of the Failure Analysis Laboratory at the Naval Weapons Center to discuss the impact of measling on reliability. We were told the measling requirements in the Navy's soldering specification were established to ensure that the dielectric (nonconductive) characteristics designed into printed wire board assemblies are not degraded by measling. Measled sites provide a place for entrapment of moisture. This becomes more of a factor when the measled assembly, which is not waterproof, is deployed in the fleet where it can be subject to humidity and temperature fluctuations for extended periods of time. These small pockets of moisture, which become conductors of electricity, can degrade the dielectric characteristics of the assembly and result in electrical current leakage, possibly affecting the reliability of the product.

The Director of the Quality Assurance Division and the soldering examiner told us equipment failures have been attributed to measling. Thus, it is important that waivers and deviations from the measling requirements in the specification be carefully analyzed for impact on reliability before being approved. This apparently was not done on the Kollsman altimeter deviation.

According to both the Navy Procuring Contracting Officer and an MDAC official, MDAC verbally agreed that if measling is determined to be the

cause of failures, MDAC will pay for repairs; but in commenting on this report, DOD said contractor liability will be established through the latent defect clause in the production contract.

Teardowns

There were no teardowns of a Harpoon missile during the period of our review and one is not scheduled. However, teardown inspections were performed in early 1985 on one missile, which was new production, and on a 5-year-old missile that had been returned from the fleet. The inspections evaluated all workmanship using the latest soldering specification, WS-6536D, which differed from that used in the design and manufacture of the missiles; WS-6536D was used because the teardown team members were not familiar with the Harpoon's specific contract requirements.

Although the teardown report described the overall workmanship quality as "very good," some problems were disclosed and recommendations were made. While the report did not individually classify them or list the total number—which was 191 on the new production missile and 208 on the fleet return missile—it did conclude they were minor.

We asked Naval Weapons Center and Pacific Missile Test Center representatives who had participated in these teardowns to assign risks to each defect using WS-6536C, the specification used to manufacture the missiles. These assessments were performed based on the descriptive words in the report and did not include reviewing the photographs of the defects. These representatives said that about 80 defects that had been classified as minor would have been considered serious based on the criteria in WS-6536C. Defects included fractured or disturbed solder joints, joints with insufficient soldering, and flux residue. According to the specification, parts with these defects are to be reworked or repaired.

The results of the teardowns were published by the Naval Weapons Center but were not widely disseminated. According to MDAC, the Navy Plant Representative Office, and the teardown team members we contacted, they had not seen the report until we provided them copies. In our opinion, such reports should be disseminated because they contain information that contractors can use in identifying and eliminating defects. In commenting on a draft this report, DOD said that since there were no major defects and no recommendations, the teardown report was not generally released. All team members, including MDAC and plant representative office personnel, were given exit debriefs.

Subcontractor Control

According to MDAC cost data, about 72 percent of the cost of the Harpoon is for subcontracts and material. Thus, the quality of the missile is heavily dependent upon the quality control at subcontractor facilities and MDAC's control of the quality of its subcontractors and suppliers. However, our review of quality assurance audit reports prepared by MDAC and various government agencies indicated that MDAC was not always able to get its subcontractors to take effective corrective action. The most common problems were adherence to procedures and to soldering specifications, inadequate records and work instructions, and inappropriate material disposition.

Subcontractor quality assurance requirements are not always implemented as intended. MDAC representatives told us MDAC is hesitant to force compliance or to seek adequate corrective action for contractual and/or procedural requirements. This, they said, stems from the fact that many of MDAC's subcontractors are major prime contractors (e.g., Texas Instruments and IBM) and are considered to be expert in their fields, providing unique items that usually cannot be obtained from other sources.

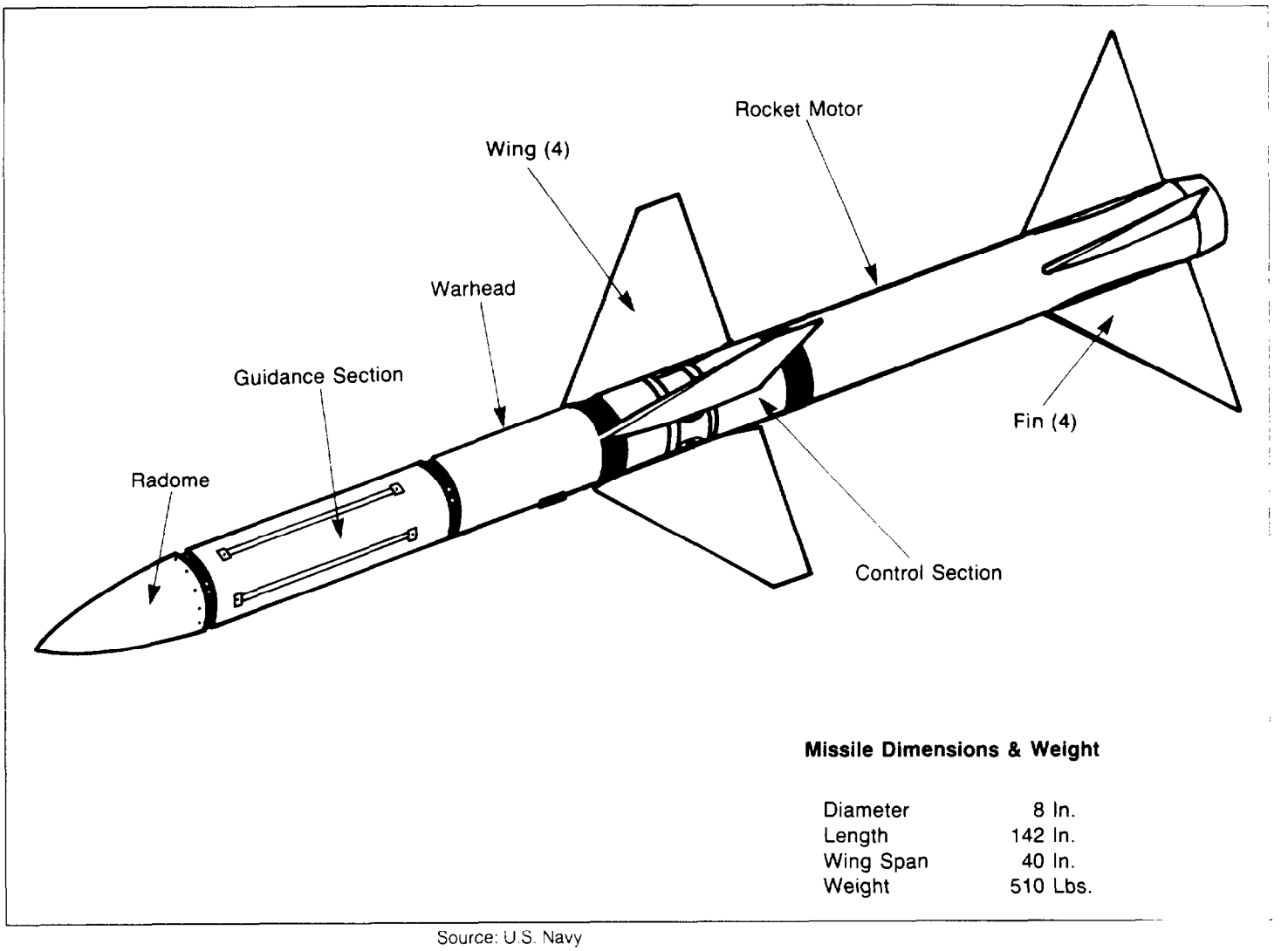
In commenting on this report, MDAC said that although it was lax in its follow-up of quality assurance audits, the problems cited above represent noncritical matters and its follow-up system has been improved. It added that although it recognizes and uses the expertise of major suppliers, all Harpoon requirements are rigidly enforced.

Our conclusions concerning MDAC's control of subcontractors is based on our extensive review and analysis of 782 quality assurance audit findings. We found that 383 of the findings related to subcontractors and about 25 percent of those could affect the form, fit, or function of the missile based on definitions contained in Military Standard 105, Sampling Procedures and Tables for Inspection by Attributes. Our analysis of the actions taken to correct the 91 most serious subcontractor findings disclosed that in 29 instances either action was not taken or action taken did not address or correct the problem.

Sparrow Missile

The Sparrow (see fig. VI.1) is a medium-range air-to-air (AIM) and surface-to-air (RIM) missile used by the Navy, the Air Force, and several foreign countries. The AIM/RIM-7M, the latest version of the missile, was first delivered to the fleet in January 1983. Current plans are to procure 7,944 missiles at an estimated average unit procurement cost of $183,000.

Figure VI.1: Sparrow AIM/RIM-7M Missile Sections



Source: U.S. Navy

The two prime contractors producing the guidance and control sections under firm fixed-price contracts are the Raytheon Company, Lowell

Massachusetts, and General Dynamics Corporation, East Camden, Arkansas. The missile's rocket motor is procured from Hercules, Incorporated, Rocket Center, West Virginia, and the safety and arming device for the warhead is procured from Piqua Engineering, Inc., Piqua, Ohio, and Micronics International Inc., Brea, California. The guidance, control, propulsion, and warhead sections are assembled into complete rounds at naval weapons stations. The government's in-plant quality assurance programs at Raytheon and General Dynamics are administered by DCAS.

We reviewed reports and other documents on the quality of the guidance and control sections produced by Raytheon, the original prime contractor. Teardowns of four samples of those sections during 1986 and 1987 disclosed continuing quality problems. The government accepted hundreds of missiles during this time that were suspected of having defects that could affect missile reliability according to Navy teardown criteria. In two instances, additional testing of the teardown missiles by Raytheon indicated that the defects would not affect reliability. Other suspect missiles were not further tested or inspected beyond requirements in the contract but, for some, additional warranties were obtained. Additionally, problems with three missile components/parts (the detonators, the wings, and antenna bracket springs), each involving subcontractors, were not detected until thousands of missiles or missile components were potentially affected.

Teardowns

As required by the Navy's contracts with Raytheon and General Dynamics, two teardowns of the guidance and control sections are performed yearly under each contract. Seven teardowns took place during the period covered by our review, four of them on Raytheon missiles.

April 1986 Teardown

An April 1986 teardown of a Raytheon missile disclosed 603 defects, of which 10 were described as major, requiring repair. Of these, eight were soldering defects such as a fractured solder joint, insufficient solder, and solder fragments; one was a problem with the missile's gyro; and one was a damaged resistor. Defects of a similar nature on other Sparrow missiles also were being detected and reported by DCAS during production, thus raising concern about the missiles being produced at that time. Accordingly, Raytheon strengthened its production and process controls and DCAS set up special inspection points at four areas of the plant where teardown results had indicated major problems existed.

September to October 1986 Teardown

During the September to October 1986 teardown of a Raytheon missile, defects were categorized as high, moderate, or low risk rather than as major or minor. The number of defects reported dropped from 603 in April 1986 to 146, of which 9 were identified as high risk (i.e., likely to affect the short-term reliability of the missile). These included conductive material contamination, insufficient solder, and solder fragments. A DCAS representative who participated in the teardowns said the quality of the missile torn down was about the same as the one in April 1986.

June and August 1987 Teardowns

A June 1987 teardown of a Raytheon missile showed 127 reported defects, of which 12 were reported as high risk. These high risk defects included five instances of solder fragments, three conductive material contaminations, three nicked leads or wire cuts, and one extensive measling problem. (See discussion of altimeter problem in app. V for information on measling.) The teardown team noted some improvements in quality but also said they were concerned about the type and number of defects.

In a July 15, 1987, letter to Raytheon, the NAVAIR Sparrow program manager described the teardown results as disappointing and directed the China Lake Naval Weapons Center, the Pacific Missile Test Center, and the DCAS Plant Representative Office to conduct a detailed review of Raytheon production procedures. The review, conducted in August 1987, focused on the two areas where most of the defects were occurring—rework and soldering operations—and included a teardown Raytheon performed with government representatives as observers. Risk assessments were not assigned to the defects identified; however, the results were described by government representatives as being essentially the same as those from the previous two teardowns. A written report was not prepared, but the need for certain changes was identified and agreed to verbally by Raytheon officials.

Raytheon officials said that, in their opinion, the problems detected in the teardowns were more cosmetic than substantive. They said that before a missile is subjected to a teardown inspection, it has usually undergone about 200 hours of simulated flight without a failure. Additionally, in commenting on this report, Raytheon said there is no correlation between the types of faults found in the missile teardowns and reliability as verified through testing. It cited high reliability figures experienced in various tests of the missile and additional testing of the

April 1986 and June 1987 teardown missiles. Raytheon said both missiles were re-assembled and rerun for additional failure free hours—350 hours on the April 1986 missile and 184 hours on the June 1987 missile.

DOD, in commenting on this report, said each of the major and high risk defects was carefully reviewed and determined to have no affect on missile performance and reliability. However, the only additional testing and analysis we found to support such a determination was the testing done by Raytheon on the April 1986 and June 1987 teardown missiles. Neither of the other two teardown missiles was tested beyond what was required in the contract nor were any of the other Sparrow missiles which the four sample missiles represented.

Warranty Controversy

For some Sparrow guidance and control sections delivered in 1986 and 1987, the Navy took two actions that affected warranties and responsibilities for repair costs on a limited number of the Sparrow missiles delivered by Raytheon. One action resulted in the Navy and Raytheon disagreeing about who will pay for the repair of certain failures.

NAVAIR, concerned about the number and type of defects (primarily soldering defects) discovered in the April 1986 teardown and revealed during DCAS inspections, negotiated a special agreement with Raytheon in which a conditional acceptance would be attached to 512 missiles. Under the agreement, Raytheon is to repair failures caused by soldering workmanship and material defects during the next 3 years and to be responsible for the repair costs.

As of February 12, 1988, 28 failures of these missiles had been reported in tests after they left Raytheon, and the missiles were returned for repair. Nineteen returns were because the missile had failed incoming electrical tests either at weapons stations or at depots and 9 because of test failures at other locations such as the Pacific Missile Test Center.

Raytheon officials said that Raytheon does not believe it is liable for repair costs on any of these missiles because the Sparrow has not gone below the 95-percent acceptance quality level specified in the contracts.[1] According to Raytheon officials, missiles that fail incoming electrical tests at weapons stations come under the acceptance quality level clause

[1]Under an acceptance quality level clause in its contracts, if the missiles do not meet a cumulative acceptance level of 95 percent or more during incoming electrical tests, Raytheon is responsible for the repair costs. Raytheon's acceptance quality level for the 1985 contract was over 97 percent as of April 1987, and the cumulative level has been about 97 to 98 percent since 1981

in the contract, not the special warranty agreement. These officials believe the special warranty relates only to failures experienced after the missiles have passed these incoming tests.

NAVAIR officials disagree with the Raytheon officials. They believe that missiles that fail during these incoming tests as a result of soldering workmanship or material defects are covered under the special agreement and should be repaired at Raytheon's expense.

Raytheon, in its November 1987 comments on our report, stated:

"Notwithstanding our firm belief that we have no contractual obligation to do so, Raytheon, without prejudice on a nonprecedent basis, will bear the costs of repairing the nineteen GCS's [guidance-control sections] in question which have failed the first electrical test, to the extent repairs are required."

Defective Detonators

Navy testing and analysis of Sparrow safety and arming devices in late 1986 and early 1987 revealed that some MK 71 detonators in these devices were defective because they lacked some of the explosive compound (lead azide) required by the detonator specifications. The detonators are produced by Caelus Devices, Incorporated, Hollister, California, a subcontractor to Micronics International and Piqua Engineering, which manufacture the Sparrow's safety and arming device.

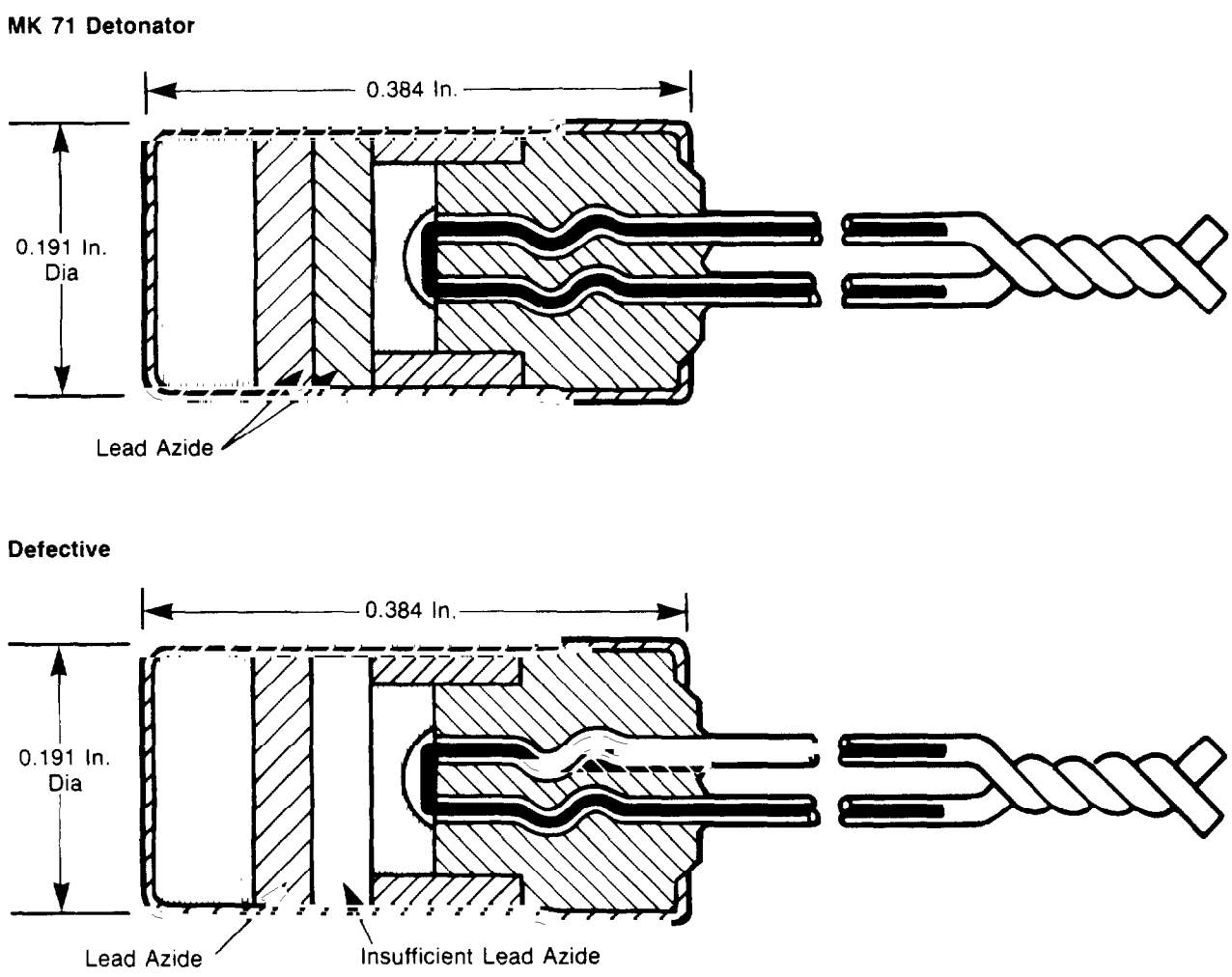
The Navy and the contractors involved began attempting to determine the extent of the problem (i.e., how many detonators were suspect and which devices contained these suspect detonators) in October 1986. However, this has been complicated by the possible intermingling of detonator lots and by the uncertainty of the effect of having one bad and one good detonator in a safety and arming device. (Each Sparrow missile safety and arming device has two detonators.) Testing and analysis were ongoing at the completion of our review.

Extent of Problem

In March 1987 the Navy estimated that there were eight lots of Sparrow safety and arming devices containing 3,950 suspect detonators. Of these eight lots, four were placed in warheads that were shipped to weapons stations where some of the warheads were installed in missiles sent to the fleet. The Navy later revised its estimate to about 8,000 suspect Sparrow detonators.

As of July 1987, 3,611 Sparrow safety and arming devices, containing 7,222 of the suspect detonators, had been screened. Of those screened, 225 devices failed because they contained at least one bad detonator. Figure VI.2 illustrates the difference between a detonator with the missing explosive compound (lead azide) and one with all the lead azide.

Figure VI.2: Illustration of Normal and Defective Sparrow Detonators



Source U S Navy

By September 1987 the Navy had decided to screen additional missile safety and arming devices. This decision was based on the results of tests performed in late August 1987 at the China Lake Naval Weapons

Center. The tests involved detonating 50 good and 50 defective detonators in simulated safety and arming devices to determine whether one good and one bad detonator was sufficient to detonate a missile's warhead. A Sparrow program official said the results indicated that this combination is sufficient to detonate the missile's warhead about 72 percent of the time. Navy officials said that two defective detonators probably will not set off the warhead.

The only way to ensure that missiles do not contain bad detonators is to x-ray or screen all devices that could contain potentially defective detonators. According to a Sparrow program office representative, this will involve screening devices in up to 400 additional Sparrow warheads.

Safety and arming devices for the Navy's Sidewinder and Standard missiles and the Army's Chaparral missile also received some of the suspect detonators. Considering all Navy, Army, and Air Force missiles, we estimate that up to 10,000 of these safety devices will have to be screened to determine whether they have been affected. As of June 29, 1987, screening of 7,127 devices had identified 297 with at least one bad detonator.

In its January 1988 comments on this report, DOD said all but 402 Sparrow safety and arming devices had been screened and these are being recalled. According to the Navy, based on statistical experience to date, four of these are potentially defective.

Cause of Problem

A NAVAIR Sparrow program official and Naval Weapons Center officials said the problem occurred because Caelus did not use sound manufacturing techniques. According to Caelus officials, certain second shift workers did not follow prescribed production procedures that resulted in insufficient explosive compound being placed in detonators produced over a 1-month period. The Caelus officials indicated that the production and inspection processes lent themselves to inefficient quality control When this problem was discovered, several corrective actions were taken. However, these actions were insufficient to detect all defective units processed.

The former DCAS representative responsible for performing government source inspections at Caelus did not report any problem. The former inspector told us at a meeting in June 1987 that he "probably" did not perform the required reviews, even though he had signed and affixed the DCAS stamp on the respective shipping documents. He said that

because of the workload and number of sites he had to cover, his primary concern was to oversee prime contracts, not small subcontracts.

In commenting on this report, Caelus said the inspector probably did not inspect for the problem because it was not required. To verify our information, we contacted the current DCAS representative for Caelus who told us that the letter of delegation from the DCAS at Piqua required that a test be done to verify the presence of lead azide. Documentation on file indicated only one such test had been performed by the former DCAS representative, and it was of an insufficient sample. Caelus also suggested in its comments that we may have misquoted the inspector when we said his primary concern was prime contracts, although Caelus officials were not present when we interviewed the former DCAS inspector.

Micronics and Piqua, as contractors for the safety and arming devices, are responsible for the quality of materials provided by their subcontractors, including Caelus. The Vice President of Micronics acknowledged to us that they have this responsibility but added that the government may also be partially at fault for this problem. In his opinion, the request of the DCAS at Micronics to the DCAS at Caelus to perform government source inspection at Caelus and the DCAS stamp affixed to the Caelus shipping documents indicate government quality assurance review and acceptance of the detonators.

Piqua's quality assurance surveys at Caelus did not note potential problems with Caelus' production process. In commenting on this report, Piqua acknowledged that it is responsible for the quality of material supplied by its subcontractors, but said it believes the government must bear part of the responsibility for the defective detonators. It said all shipments were source inspected at Caelus by the government, which indicated specified tests were run and procedures were followed. According to Piqua, it could not have caught Caelus deviating from the procedures without having an inspector in the plant at the time the deviation occurred.

DOD did not comment on why the DCAS inspector approved acceptance of the Caelus detonators without performing the proper inspections or on the extent to which the government may be responsible for the defective detonators. DOD did remark that the records at Caelus were exceptionally poor, making the screening process difficult.

Cost Implications

In September 1987 a Sparrow program office official said that at the present time, the Navy and the Air Force are paying for the screening program. The official also said that Piqua and Micronics agreed to pay for replacing defective detonators and reinspecting the safety and arming devices and for some related shipping costs. Piqua estimates it will cost about $300 to repair each device. However, until the number of devices with defective detonators is determined, the cost of correcting the problem will not be known. The program office estimates that the Navy and the Air Force's cost to screen both Sparrow and Sidewinder missiles will not exceed $220,000 and said the Navy may seek some reimbursement from Piqua and Micronics.

According to a NAVAIR Sparrow program official, Piqua and Micronics agreed to x-ray detonators under current Sparrow contracts at no additional cost to the government. Although not required by the specification, Piqua and Micronics officials said that it would be impossible to detect a void without x-raying the detonators.

RIM-7M Wings

Sparrow RIM-7M folding wings, manufactured by Marvin Engineering Co., Inc., Inglewood, California, under subcontracts with Raytheon and General Dynamics, were not cut sufficiently during production to permit some of the wings to fold enough to allow the missile to be placed correctly in launching tubes aboard ships. Marvin Engineering started repairing the wings in February 1987 at no cost to the government, and Marvin Engineering officials believe that all wings have now been repaired.

Problem Identified

The Navy first learned of the problem with Sparrow folding wings when the Hellenic Navy (Greece) reported the problem to NAVAIR in September 1986. The wings were returned to the Yorktown Naval Weapons Station for investigation, and Raytheon notified Marvin Engineering of the problem.

In November 1986 representatives from NAVAIR, North Atlantic Treaty Organization, Yorktown Naval Weapons Station, China Lake Naval Weapons Center, Raytheon, and General Dynamics met at Yorktown to examine wings that had been returned from Greece. The wings were evaluated as "bad" because they would not accept the launcher clip and, therefore, would not fit into the launcher tube.

This problem had not been reported by U.S. Navy fleet units. NAVAIR officials offered two possible explanations for this: the wings provided to the Navy were not as far out of tolerance and could fit into the launchers, or U.S. sailors were able to force the wings closed to install the launcher clip and fit the missile into the launchers.

Extent of Problem

In January 1987 an urgent bulletin was issued that, based on serial numbers involved, identified as many as 5,721 defective wings. According to Marvin Engineering, because of a break in the manufacturing serial number sequences only 5,036 suspect wings were produced, not 5,721. In February 1987 Marvin Engineering began correcting defective wings at Yorktown. As of September 1987, a Marvin Engineering official told us the company had repaired 4,841 wings and believed that all defective wings had been repaired.

Most of the defective wings were identified and repaired before being put aboard ships. The Navy, however, has no system for tracking these missile wings and therefore could only estimate the number of suspect wings placed aboard ships. The Sparrow program office believed as many as 936 might have been aboard ships in January 1987.

DOD, in commenting on this report, said that it has two systems for tracking and controlling suspect or defective minor components of missiles and weapons and that these were used to locate the defective wings. We found, however, that the wings were not tracked by serial number, and thus the exact locations of the wings in question were not known.

Impact of Problem

The Sparrow program manager said the wing problem has not affected readiness or missile performance as it was possible to force the wings to close, put a clip on them, and insert the missile into the launcher tube. The acting supervisor of the wing and fin repair shop at the Yorktown Naval Weapons Station and other Navy officials told us, however, that some of the defective wings would not fold sufficiently, even when forced, to allow missile placement within launcher tubes.

In commenting on this report, DOD said the wing problem has had absolutely no effect on missile performance and the effect on readiness is considered very small. It said that only 20 wings could not be folded, and these were easily replaced in the fleet. We found, however, that the

number of wings that could not be folded is not known. When the problem was discovered and the serial numbers of the wings in question were identified, repairs were initiated by Marvin Engineering. Many of the wings were repaired without being inspected to see if they could be folded sufficiently to permit attachment of the wing clip. Thus, the number of wings flawed to the point of affecting use was never established. Figure VI.3 shows Sparrow wings with the clip attached, and figure VI.4 shows two defective wings folded on a missile.

Figure VI.3: Folded Non-Defective Sparrow RIM-7M Wings

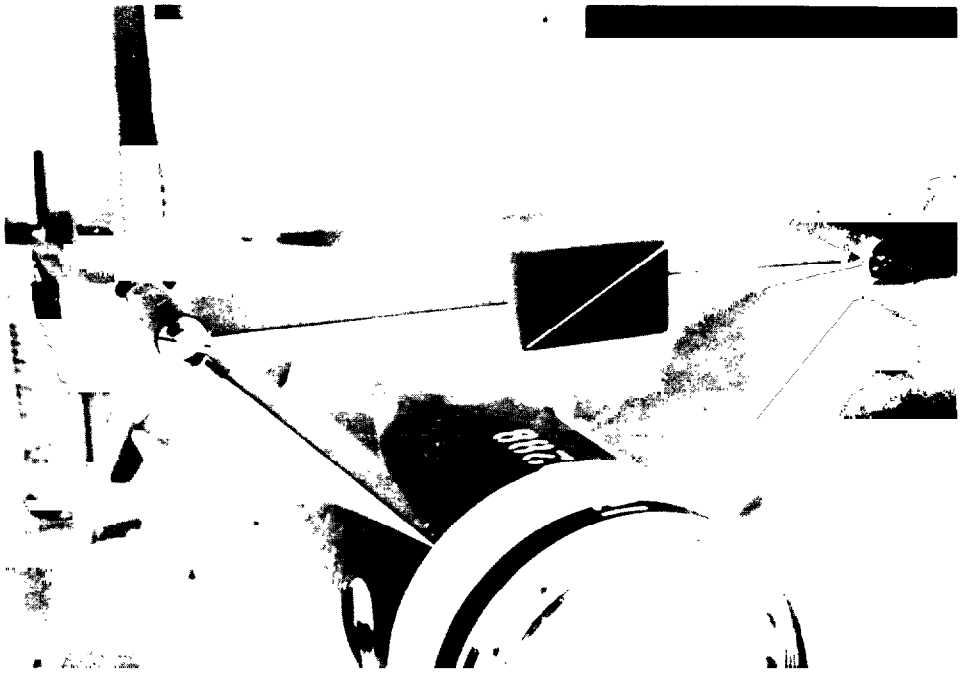


Figure VI.4: Folded Defective Sparrow RIM-7M Wings

Quality Control Breakdown

In December 1986 a review team, consisting of representatives from Raytheon, General Dynamics, and the China Lake Naval Weapons Center, visited Marvin Engineering to investigate the problem. They found that the problem started in June 1985, when Marvin Engineering changed its manufacturing method by using different machinery that did not cut the wings to the acceptable angle. A Marvin Engineering official said the company did not notify either prime contractor because the change was not a production process change that would have required such a notification.

A Marvin Engineering official said that the problem is a vague note on the drawing, not one of quality. Also, a drawing or specification requirement for folding the wings to any specific degree, which would verify they were properly cut, did not exist. In commenting on this report, the company added that there was no specific requirement for a fold angle. Thus, Marvin Engineering does not believe it made any errors in machining the wings to the drawings as they existed at that time. The prime contractors and NAVAIR officials claim that if the contractor had followed the specification, the wings would have been properly produced.

Neither the DCAS quality assurance representatives at Marvin Engineering nor the General Dynamics and Raytheon inspectors detected the problem. A Raytheon official said that the inspection checklist the Raytheon inspectors used did not require folding the wings to a specific angle because the drawing did not specify this requirement. Such an inspection of the end item part would have been the only way to detect the problem in a completed wing. Additionally, Raytheon said that an interface gauge to assure proper assembly should have been designed and made available by the government for Plant Representative Office and contractor use. Finally, Yorktown Naval Weapons Station personnel did not detect the problem because, according to a Yorktown official, wings received at the station are categorized as ready for issue and the fold angle is not checked.

Actions were taken to prevent future problems. The China Lake Naval Weapons Center assigned General Dynamics the task of reviewing, clarifying, and updating the folding wing drawing package. Marvin Engineering added new machining and inspection operations to its work process and tightened its in-process quality inspection requirements. Raytheon revised its inspection acceptance forms to require that the wings be folded to the minimum fold angle and that a check be made of the hinge radius area on unassembled parts. Raytheon officials told us that the DCAS at the Raytheon-Lowell facility requested the DCAS at Marvin Engineering to perform government source inspection of the wing hinge.

Cost Impact

The President of Marvin Engineering stated the company is repairing the wings at no cost to the government. However, the Navy stated in a May 1987 letter that it had paid about $29,000 to uncrate and recrate suspect wings. An official of NAVAIR told us that the Navy requested Raytheon and General Dynamics to pay for these costs and that discussions are in process with the contractors.

Antenna Bracket Springs

In March 1986 operational units in Germany discovered that the antenna bracket spring, a small part externally attached to the rocket motor of the Sparrow, was cracking and/or breaking in a number of deployed missiles. Although a defective spring would not affect the performance of the missile, there is a remote chance that the broken spring could fall from a missile, perhaps onto the flight deck of an aircraft carrier, and be drawn into the engine of an aircraft, causing serious damage.

The affected missiles and rocket motors were identified and the springs replaced as soon as possible. Hercules, Inc., the prime contractor for the rocket motor, replaced 2,728 springs, and the Navy performed the labor at an estimated cost of $85,000. NAVAIR does not intend to seek reimbursement for this expense as the Navy's technical data package for the spring was deficient and contributed to the problem.

The problem occurred as a result of a Hercules subcontractor heat treating the springs to a higher tensile strength than necessary to meet minimum requirements. This caused the springs to become excessively hard and to crack and/or break when placed under pressure in the missiles. It was never determined why the supplier started heat treating the springs to a higher tensile strength. At the time, the Navy's drawings stated a minimum tensile strength but did not specify a maximum. However, the specification has been changed to specify a maximum tensile strength. A Hercules representative told us that the company has stopped purchasing springs from this supplier because of quality and delivery schedule problems.

According to the Hercules representative, the company paid for the replacement springs because it is responsible for ensuring the quality of the parts in the rocket motor. He said that while Hercules does perform receiving inspection on all components, the degree of inspection performed is relative to the complexity of the part. He added that subcontractors cause quality problems for Hercules when they (1) do not adhere to quality assurance procedures and (2) do not fully understand that government specifications are usually tighter than commercial specifications.

Comments From the Department of Defense

ASSISTANT SECRETARY OF DEFENSE
WASHINGTON D C 20301 8000

PRODUCTION AND
LOGISTICS
(PS/IPQ)

19 JAN 1988

Mr. Frank C. Conahan
Assistant Comptroller General
National Security and
International Affairs Division
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Conahan:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) Draft Report, "QUALITY ASSURANCE: Concerns About Four Navy Missile Systems," dated October 29, 1987 (GAO Code 394186), OSD Case 7451.

The DoD partially concurs with the report. The DoD acknowledges that a number of problems have been experienced during the production of the Navy missiles. There are established procedures to identify defects and potential problems at the earliest time in production and to expedite corrective actions necessary to provide quality missiles to the fleet. Contrary to the GAO implication, in no case has the Navy knowingly accepted missiles suspected of containing defects that could affect the performance of the missile. In any case where the defects were determined to affect performance, the contractor was required to take the necessary corrective action.

Further comments on each of the GAO findings are enclosed. In addition, a number of technical corrections have been separately provided to members of your staff.

The DoD appreciates the opportunity to comment on the draft report.

Sincerely,

Jack Katzen
Deputy Assistant Secretary of Defense
(Systems)

Enclosure

GAO DRAFT REPORT DATED OCTOBER 29, 1987
(GAO CODE 394186) OSD CASE 7451

"QUALITY ASSURANCE: CONCERNS ABOUT FOUR NAVY MISSILE SYSTEMS"

DEPARTMENT OF DEFENSE COMMENTS

* * * * *

FINDINGS

- **FINDING A: Assessing the Quality of Navy Missiles: Conformance With Specifications.** The GAO reported that one measure to assess the quality of missiles being delivered to the Navy is how well the missiles conform with specifications. The GAO found that the four missiles it reviewed had numerous instances of nonconformance or defects. The GAO reported that, while most of these instances were judged to be minor, groups of missiles were accepted that were suspected of having defects that could effect performance. According to the GAO, in a few instances, the defects were known to exist during production, but the Navy granted a waiver or deviation. The GAO reported that in other instances, however, the defects were detected during teardown inspections, and the Navy opted to accept the missiles as they were. In addition, the GAO reported that some of the defects in the missiles delivered during 1986 and 1987 were not discovered until after the missiles had been delivered to the fleet, effecting anywhere from one or two to hundreds or thousands of missiles. (pp. 24-26/GAO Draft Report)

Now on pp. 6 and 20-21

DoD Response: Nonconcur. The report indicates that the Navy knowingly accepted missiles that were suspected to contain defects that could effect the performance of the missiles. In no case did the Navy knowingly accept missiles suspected of containing defects that could effect the performance of the missile.

In the case of defects detected during teardown inspections, all were analyzed and/or tested to confirm there was no effect on the performance of the missile. When the defects were judged to effect the performance of the missile, the contractor was required to rework the missiles. The report cites examples of actions taken by the Navy to have the contractor correct such defects in missiles known to have defects effecting performance.

In some cases, missiles are accepted with certain specification nonconformances after careful engineering review and analysis, including testing, to ensure that there is no performance or reliability impact. Such nonconformances do not render the product defective. This is a formal, contractually authorized and well documented process. Rework of minor cosmetic nonconformances often has a higher potential for reducing missile reliability than the original problem, and unnecessarily adds to program cost. Also, by definition, minor deviations or waivers to

1

not effect cost or performance. If a major deviation or waiver is granted, consideration is obtained from the contractor.

The report also states that a number of problems were discovered after delivery to the fleet. The report does not, however, give adequate credit to the fact that the in-place quality assurance system at contractors and Navy activities was responsible for detecting almost all cited problems. More importantly, the Navy took quick and decisive actions to resolve problems detected by the in-place quality assurance systems. In any large and complex manufacturing process, "escapes" are bound to happen. The important point is that the Navy is not complacent about such escapes, and has actively and aggressively obtained corrective actions from responsible contractors and seeks to introduce process disciplines that will reduce the future likelihood of such escapes. Such efforts as teardown inspections are ample evidence of the continued importance the Navy places upon quality.

o **FINDING B: Assessing the Quality of Navy Missiles: Missile Reliability.** The GAO reported that a second measure of quality is the reliability of the missiles. The GAO reported that, to assess reliability, various tests are performed after the missiles are delivered to the Government. The GAO, discussed two such tests, as follows:

- production acceptance tests, performed before the missiles are sent to the fleet; and

- captive carry tests, after they are sent to the fleet.

The GAO assessed the mean-time-between-failure (MTBF) for both types of tests performed for the four missiles it reviewed and found that the missiles are generally meeting the MTBF contract requirements. The GAO noted that there was insufficient data to assess captive carry results of the PHOENIX AIM-54C. The GAO pointed out that captive carry testing does not detect failures in the propulsion or warhead sections of the missiles, but that such problems have impacted missile effectiveness. In addition, the GAO noted that the Navy has a program to evaluate the quality of stockpiled missiles, but found that no such analyses had been performed on the missiles it reviewed. (pp. 3-4 p. 24, pp. 27-30/GAO Draft Report)

Now on pp. 2 and 21-23

DoD Response: Partially concur. While the DoD agrees with the general description of tests and their results, the DoD does not agree that "there was insufficient data to assess captive carry results for the PHOENIX AIM-54C." Table II.1 of Appendix II of the GAO draft report indicated PHOENIX captive carry MTBF to be 346.9 hours. Also, the report ignores all operational test experience on the AIM-54C. Considering all flights through Operational Test IIIA, the AIM-54C MTBF is 572 hours at a 75 percent confidence level.

With regard to the GAO statement that captive carry testing does not detect failures in the propulsion or warhead sections of the missiles, and that such problems have impacted missile effectiveness, the first phrase was factual, but the follow on phrase is not relevant. It appears that the GAO intent was to define a need for testing that goes beyond the guidance and control section. Any test of those components, however, would result in their destruction. The Navy specifies stringent test and acceptance quality levels on lots of each of the aft (warhead and propulsion) components. In addition, these "single shot" devices are sample tested (destructive evaluation) at the sub-contractor level to verify lot integrity and provide quality/reliability confidence.

Contrary to the GAO finding, the Navy program for the quality evaluation of all of its in-service or stockpile missiles and weapons has included the four missiles reviewed by the GAO. This program addresses the quality of produced missiles and weapons after fleet deployment or storage (time). This program brings all of the components or sections of the missiles into laboratories not just the guidance and control sections. Complete all-up-round weapons or sections are evaluated on a cyclic schedule based upon in-service age, environmental usage, similarity to other systems, chemical/ physical make-up, as-built configuration, etc. During FY 1986 and FY 1987, for example, six PHOENIX evaluation reports, 15 SPARROW reports, six HARM reports, and 14 HARPOON reports were prepared.

The PHOENIX (AIM-54C) guidance and control sections have not been evaluated by this program as the units have not experienced sufficient fleet deployment time to allow for a scientific or statistically significant evaluation. It should be noted that the AIM-54C only represents 10 percent of the active PHOENIX missile inventory (AIM-54A and C).

The SPARROW (AIM-7M) guidance and control sections have been included in the overall SPARROW (AIM-7E, F, M and RIM-7H) weapon systems evaluation process. The evaluation process is, however, a long one since the program is designed to evaluate for long-term fleet exposure related degradation. Accordingly, while there are several SPARROW system evaluation reports available, there are no unique AIM-7M guidance and control section reports available at this time. The GAO draft report also did not recognize that there is also an ongoing Air Force program, with significant data, that addresses the issue of evaluating the quality of stockpile missiles. The Air Force data indicate that SPARROW missiles significantly exceed their storage requirements.

The HARM and HARPOON missile systems are currently being and have been evaluated by this program. These missiles are constantly undergoing evaluation (depending on their specific evaluation cycle). The evaluation process is not unduly

restricted by the inventory status of the individual weapon system. As necessary, the missiles or missile sections are removed from the inventory for evaluation. If the evaluation is nondestructive, sections are returned to the inventory.

- **FINDING C: Assessing the Quality of Navy Missiles: Fleet Firings.** The GAO reported that a third means to assess missile quality is the missile firing program conducted by the Fleet Analysis Center. The GAO reported that, between January 1986 and July 1987, 49 fleet telemetry firings were made of the SPARROW and 22 of the HARPOON. According to the GAO, the High-Speed Anti-Radiation Missile (HARM) was fired 27 times by the fleet during this period, but the only telemetry firings were nine performed by the China Lake Naval Weapons Center. With regard to the PHOENIX, the GAO found that the only firing data available were those obtained during earlier testing. The GAO noted that the PHOENIX is currently undergoing additional testing, with the first firing taking place in September 1987. The GAO reported that it could find no criteria to evaluate the overall results of the fleet firings. The GAO further reported that users it contacted were satisfied with the performance and capabilities of the missiles. (p. 24, pp. 30-34/GAO Draft Report)

Now on pp. 23-25

DoD Response: Partially concur. The purpose of the fleet firings of a missile is two fold -- (1) to provide an opportunity for the evaluation of the actual performance of the missile and (2) to provide an opportunity for pilot training. The Navy attempts to provide telemetry packages for all of its fleet firings. Of the four missile systems under discussion, over 95 percent of the PHOENIX and SPARROW fleet firings are conducted with a telemetry package and over 70 percent of the HARPOON firings are configured with telemetry packages installed.

The HARM missile has not utilized telemetry packages for its fleet firings since the basic firing is destructive to both the missile and its intended target; whereas, the targets for the other missiles are intended to be recoverable. A large number of these HARM firings were conducted at the Navy Weapons Center, China Lake, which utilizes an instrumented range to track and analyze the firings.

The Navy tests each missile before its planned fleet firing, whether or not the missile contains a telemetry recording device. A planned fleet firing is a very expensive undertaking, in that ranges, aircraft, targets, weapons, support personnel, and telemetry recording devices (both in the missile and on the ground) are employed. This also ensures range safety. Each missile is tested using an intermediate maintenance level test set before it is provided to the fleet unit that will conduct the live firing. As with any intermediate level test, the data from this test is provided to the Navy Maintenance Data Collection System (MDCS) and is analyzed as part of all maintenance data. Also, each missile is tested on the individual aircraft just as it would

be in the actual fleet environment. The data from this test is reported in the same manner as the testing of all fleet missiles. These test results are reported through the standard Navy maintenance data reporting systems. The telemetry test data contains only the actual missile flight and firing telemetry data and is not intended to contain preflight data. Both the telemetry data and the missile maintenance data is readily available, and is analyzed for trends and failures.

With regard to the GAO statement that it could find no criteria to evaluate the overall results of the fleet firings, the Test and Evaluation Master Plan (TEMP) provides baseline criteria for fleet evaluation. The missile capability is evaluated through a fleet conducted follow-on test and evaluation program. Additionally, the Navy uses missile specific criteria to evaluate each fleet firing. These are used in individual/unique component engineering performance criteria -- i. e., the same criteria used to evaluate performance during test or production of the missile. These individual parameters are recorded by telemetry and are analyzed to determine whether or not the missile would have been successful if it had contained a live warhead. This evaluation takes into account the speed of the missile, the kill radius of the warhead, the timing sequence of the target detecting device and the fuze train, the size and speed of the target, and various other factors that effect kill performance.

o **FINDING D: Quality of Subcontractor Material.** The GAO found that subcontractors play a major role in the production of each of the four missiles it reviewed. The GAO reported that regulations place responsibility on the prime contractor for assuring that the quality of the material and parts provided by its subcontractors conform to contract requirements, while the Government plant representative office verifies the adequacy of subcontractors controls. The GAO found that subcontracted parts were involved in every instance where a quality problem was not discovered until after defective or potentially defective missiles had been accepted by the Government. The GAO also pointed out that both Air Force and Defense Logistics Agency (DLA) reviews, from 1984 to 1986, indicated that prime contractor control of vendor material has been a widespread problem in the DoD. In addition, the GAO reported that a Navy official acknowledged that subcontractor control is a problem, and stated that many contractors are not aware they have vendor control problems. The GAO also cited both DoD and Navy manuals as recognizing that more attention is needed to address subcontractor control problems. (pp. 34-37/GAO Draft Report)

Now on pp. 3 and 26-27

DoD Response: Concur. Subcontractor controls need to be continually stressed. The Naval Air System Command has, and will continue, to place emphasis in this area and totally supports the efforts of other involved DoD activities.

Creation of a system to provide absolute control of every

subcontractor manufacturing operation is not affordable, nor is it cost effective. It is noted that Government surveillance relies largely on the integrity of individuals and contractors. Quality problems that emanate from fraudulent activities, such as the HARM transducer problem (see finding L), are extremely difficult to detect and would involve an enormous expense to provide absolute assurance of product quality.

- **FINDING E: The Impact of Soldering on Missile Quality.** The GAO reported that much controversy has surrounded the issue of soldering requirements. According to the GAO, there has been general agreement that adherence to soldering standards is important to producing a reliable missile, but there has been much debate about the appropriateness of requirements contained in the Navy specification WS-6536. The GAO reported that the conflicts have arisen because most contractor soldering processes do not meet the requirements and there is a feeling the specification is overly restrictive. According to the GAO, a 1987 Navy project team report attributed problems being experienced in the fleet to poor workmanship, rather than the soldering specifications, thus leaving the question unanswered. The GAO also reported, however, that both DoD and Navy quality assurance officials believe compliance with the soldering specification is important to ensure that the missiles are of high quality. The GAO noted that the Navy is presently doing research and tests to determine how certain soldering nonconformances may effect performance and reliability. In addition, the GAO reported that the Navy is currently evaluating the WS-6536 requirements and has begun to phase out its use in favor of a new DoD soldering specification DoD-STD-2000. The GAO concluded that the Navy should continue these efforts, which should help resolve some of the controversy surrounding missile quality. (pp. 6-8, pp. 38-40/GAO Draft Report)

Now on pp. 3-4, 27-29

DoD Response: Concur. The DoD acknowledges that some soldering defects could lead to missile failures. It should also be recognized, however, that many soldering non-conformances will not lead to missile failures. Their presence in large numbers is an indicator of a process that may need adjustment. Such an observation by the Navy leads to required corrective action by the contractor (if not already underway due to the contractor's own quality system). There is no known fleet problem on these programs as a result of a failed solder joint. This is supported by the absence of fleet failures as a result of the type of soldering nonconformances that are typically identified and evaluated as being nonintrusive into missile performance or reliability.

As some specifications have been applied more broadly in recent years, DoD experience has shown a need to tailor some of the requirements to accommodate specific hardware design characteristics or contractor equipment and facilities. For each program, the DoD intent is to retain essential product

characteristics and process discipline, consistent with requirements for performance, reliability and economic production. In fact, the DoD is continually working with industry to clarify or redefine specification provisions that commonly require interpretation or tailoring and make other sensible adjustments, rather than continue peculiar modifications on a case-by-case basis. The application of the DoD-STD-2000 should ease this process.

- **FINDING F: Results of Teardown Inspections on Assessing Missile Quality.** The GAO found that much controversy has surrounded the teardown inspections the Navy has performed on the guidance and control sections, centering on the methodology and criteria used and the reporting of the results. In this regard, the GAO reported that there have been inconsistencies in how the teardown inspection criteria have been applied, and the results reported. The GAO found that to address this problem, in March 1987, the Navy issued a guide to provide consistent evaluation criteria and a uniform reporting format. The GAO pointed out that the new guide allows not only for an assessment of compliance with contractual requirements, but also for evaluating the missiles for "best design and workmanship practices." According to the GAO, this will permit the identification and reporting of nonconformances resulting from contract waivers, deviation or modifications. The GAO concluded that such reporting will provide data to assess overall missile quality and provide an indication of the effects of waivers, deviations and modifications on quality. (pp. 41-43/GAO Draft Report)

Now on pp. 29-31

DoD Response: Concur.

- **FINDING G: PHOENIX Waivers and Deviations.** The GAO found that the Navy granted the contractor three major and 13 minor waivers on the PHOENIX missiles it reviewed. The GAO reported that three major waivers related to an industry-wide alert regarding supplies, which was later determined to be inconsequential. The GAO found that most of the 13 minor waiver related to nonconformances in testing and non-certified markings. With regard to deviations, the GAO found that one major and 92 minor deviations were granted. The GAO noted that the major deviation concerned delivery of the missiles without the Safety and Arming Device (also see Finding I). The GAO reported that, of the 27 minor deviations it reviewed, about half were for the use of alternative components and materials and ten related to the WS-6536 soldering specification. The GAO further reported that, according to the Navy contracting official, all waivers and deviations have been reviewed for possible monetary adjustment, but none have been identified. The GAO noted that non-monetary benefits have been identified, however, including improved missile warranties and additional assembly work. [pp. 45-46/GAO Draft Report)

Now on pp. 33-34

DoD Response: Partially concur. Contrary to the GAO finding, monetary adjustments have been achieved, documented, and identified for Government acceptance of the PHOENIX waivers/deviations. Although no specific contract modifications have exclusively been issued for such actions, the definitive prices established under both the FY-1984 and FY-1985/1986 production contracts were explicitly acknowledged by the parties to include consideration for approval of deviations and waivers. The fact that these consideration amounts have been blended together with other matters does not alter the fact that monetary consideration has flowed to the Government in the form of establishing definitive prices that were lower than would have otherwise been achieved.

- FINDING H: PHOENIX Teardown Results and Plans. The GAO reported that the Navy performed the first teardown of the PHOENIX in June 1984, and that many defects were found. According to the GAO, the defects involved various types of problems, including poor workmanship, and prompted the Navy, on June 22, 1984, to stop accepting PHOENIX missiles. Subsequently, the GAO found that the contractor has taken a number of steps to upgrade its facilities and procedures, and the Navy has modified the contracts to require additional efforts to rework, reinspect and redeliver 84 previously delivered PHOENIX missiles. The GAO reported that a second teardown was performed in June 1986, and although 38 apparently major defects were identified, subsequent analysis determined they would not effect missile reliability. Following this teardown, the GAO reported that the DoD representatives increased oversight of the production program and the contractor strengthened its quality assurance program. The GAO reported that a third teardown was planned for late October 1987. The GAO noted that the planned reporting will be different from that done in 1986, inasmuch as the Navy stated it will conform with the Navy teardown guide issued in March 1987. (pp. 47-51/GAO Draft Report)

Now on pp. 34-37

DoD Response: Partially concur. The PHOENIX teardown that was scheduled for late October 1987 has been rescheduled for January 1988. Neither the teardown team nor the teardown report identified 38 "major defects." There were 38 "significant findings." The choice of terms tends to imply much more serious problems than actually existed. Improvements in the areas of process control and workmanship were evident compared to the 1984 teardown, but there were specific corrective actions required to further improve solder process control and to resolve inspection oversights.

- FINDING I: PHOENIX Safety and Arming Device. The GAO reported that the PHOENIX Safety and Arming Device (FSU-10A) is a Government-furnished item jointly developed by the Navy and the manufacturer. The GAO found, however, that reliability problems have effected the availability of the FSU-10A and, in turn, the

ability of the PHOENIX contractor to provide an operable PHOENIX missile. As a result, the GAO reported that the Navy has been accepting delivery, paying for the missiles without the Government furnished FSU-10A, and storing them pending resolution of the problems. The GAO reported that since the FSU-10A problems were first identified, work has continued to rework the units and complete testing. According to the GAO, the latest estimates are that the FSU-10A devices should be available beginning in January or February 1988. The GAO reported that, according to the Navy, the FSU-10A problems are attributable to inadequate quality assurance by the manufacturer and insufficient oversight by the Navy. The GAO reported that both the manufacturer and the Navy have taken actions to address these problems, which the Navy estimates may increase the FSU-10A unit costs by about $2,000. (pp. 51-57/GAO Draft Report)

Now on pp. 37-41

DoD Response: Concur.

- **FINDING J: PHOENIX Target Detecting Device.** The GAO reported the PHOENIX Target Detecting Device (TDD) is another Government-furnished item that has experienced problems. According to the GAO, TDD failures were first observed in March 1985, while the cause of the failures was identified in November 1985. The GAO reported that, in December 1985, a solution to the problem was proposed and accepted, and 526 TDDs are being reworked. The GAO reported that the Navy determined the problem to be a latent defect and the manufacturer is taking corrective action. The GAO noted, however, that the manufacturer is reviewing its legal position before accepting financial responsibility. Thus far, the GAO reported that the Navy and the manufacturer are negotiating the $2.6 million to rework the FY 1982 to FY 1984 units, the Navy has already modified the contract to rework the earlier units, and the Navy has negotiated a contract of $1.3 million with the PHOENIX manufacturer to remove and exchange the TDDs already installed. (pp. 57-59/GAO Draft Report)

Now on pp. 41-42

DoD Response: Partially Concur. No negotiations are underway. The Navy February 21, 1986, determination of a latent defect remains as the current determination that financial responsibility rests with Motorola. The $2.6 million figure is the Motorola pre-rework estimate. Motorola has absorbed all the cost of rework.

- **FINDING K: Modification of Defect Criteria For the HARM.** The GAO reported that, in early 1986, the Navy performed teardown of a HARM and, using the WS-6536 soldering specification as the criterion, identified 936 defects, including 28 described as major. The GAO found, however, that Texas Instruments (the HARM manufacturer) objected, since the contractual soldering requirements differed from the WS-6536 specification. The GAO reported that subsequently, in July 1986, a contract modification was negotiated, significantly reducing the number of soldering

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defects requiring contractor action (Group I defects). According to the GAO, prior to this modification, several hardware inspections substantiated the existence of Group I defects, resulting in the Defense Contract Administration Services (DCAS) action to stop accepting HARM deliveries for 10 days in February 1986. The GAO found that, to address the DCAS concerns, the Navy and the HARM manufacturer agreed to an extended warranty on the effected items and to perform tests on sample groups of the effected missiles. The GAO noted that the missiles subsequently passed most of the tests and the tests showed the effected components could withstand the environmental stress and remain functional. According to the GAO, the contract modification subsequently agreed to, in effect, authorized the acceptance of certain Group I defects and changed the soldering criteria, which caused controversy within both the Navy and the DCAS. The GAO also reported that, while the Government did not receive any monetary consideration for the modification, Navy officials cited other benefits in the form of an extended 3-year warranty and a possible future reduction in rework and scrap and increased production yields. [pp. 62-68/GAO Draft Report)

DoD Response: Nonconcur. The Texas Instruments (TI) concern was valid. The WS-6536D specification had been tailored for the HARM program by mutual agreement of the Government and TI. Inspection to the untailored version by the team did not reflect the actual contractual requirements to which TI was obligated to manufacture the HARM. Contrary to the implication that the extended warranty and the special tests were initiated to address the DCAS concerns, they were actually instituted to address the findings of the February 1986 teardown. As is the case with all teardowns, a focused evaluation, including the special tests, was performed on each of the findings and it was determined that there would not be any effect on missile performance or reliability. The imposition of the extended warranty recognized the existence of certain non-conformance even though the existence of these non-conformances would not effect missile performance or reliability. The further tailoring of the soldering specification actually was initiated prior to the teardown. The contract modification altered the defect criteria, production measurements and inspections in order to enhance the overall production process controls. Under this modification, in no case are defects potentially detrimental to service performance or acceptable reliability. The contract modification was generated by the Naval Air Systems Command quality personnel and was approved by the Commander, Naval Air Systems Command totally independent of HARM program personnel. The comments and recommendations of the two Government organizations, which expressed reservations about the changes -- the Naval Weapons Center, China Lake, and the Defense Contract Administration Services Plant Representative Office, TI -- were considered in the review process. The internal Navy decision process, categorized as debate, ensured that all points of view were considered before a final decision was made. Basically, senior Navy quality personnel have considered all the positions, but disagree with some elements of these positions. It is noted

that the missiles produced under these new controls have shown significant improvements of quality measures, as well as production efficiency.

- **Finding L: HARM Transducer Problems.** The GAO reported that one of the two suppliers for the pressure transducer used in the HARM is presently under investigation for falsifying test data on its transducers. According to the GAO, neither the HARM manufacturer nor the Navy has determined the extent to which the problem may impact HARM reliability or performance, but up to 1,300 transducers may be effected. The GAO reported that, in July 1987, the HARM manufacturer indicated that HARM performance would not be appreciably degraded based on preliminary tests. The GAO further found, however, that according to a Navy official in August 1987, more recent tests indicated that 20 percent from the FY 1985 production did not meet requirements. As a result, the GAO reported that the HARM manufacturer plans to test transducers from FY 1983 and FY 1984 and plans to recover costs from the transducer supplier. The GAO further reported that the second transducer supplier is presently meeting production needs and an additional source is being developed. (pp. 69-71/GAO Draft Report)

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DoD Response: Concur. Testing of missiles with suspect transducers is still underway so no conclusive statements regarding the impact of the problem can be made at this time. Under the terms of the contract, however, TI will be obligated to repair, at no cost, any or all of the missiles that the Government determines are in need of such repair due to faulty transducers.

- **FINDING M: Defective HARM Launch Lugs.** The GAO reported that, in November 1986, the HARM rocket motor manufacturer discovered a problem with the fit of the launch lugs on the rocket motor case. According to the GAO, the problem was traced to one of three suppliers of the motor case, who was using a new cutting tool. The GAO reported that the motor manufacturer found that 30 of 111 effected cases had undersized lugs, which were subsequently repaired by the manufacturer. The GAO pointed out that the motor case suppliers are now required to perform new inspection procedures on the lugs. In addition, the GAO reported that the HARM manufacturer plans to recover costs incurred by it and the Navy to resolve the problem. (pp. 71-72/GAO Draft Report)

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DoD Response: Concur. The discussion is evidence of how well the HARM overall quality control system is working.

- **FINDING N: Altimeter Deviation in the HARPOON Missile.** The GAO reported that, in October 1985, after months of problems involving measled assemblies from the altimeter supplier, the HARPOON manufacturer submitted a deviation request to the Navy. The GAO found that Navy test offices recommended disapproval of

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the deviation and expressed concern over the possibility of workmanship problems. The GAO further found that, notwithstanding this concern, a temporary deviation was approved in April 1986, and later revised, in August 1986, to include the latest criterion included in soldering specification WS-6536B. The GAO noted that the revised deviation applied to the altimeters in the existing purchase order, but not to other altimeters already delivered or in the inventory. According to the GAO, the altimeter supplier experienced few rejections through October 1986, but after that rejection rates rose. As a result, the GAO found that the HARPOON manufacturer submitted a change to the deviation to allow less stringent requirements, and the plant representative approved the change. The GAO pointed out that it could find no documentation authorizing acceptance of the missiles with the effected altimeters, nor any documentation covering a verbal agreement with the HARPOON manufacturer that it would pay for any repairs involving the measled altimeters. The GAO concluded that the altimeter problem could effect the reliability or performance of some effected missiles. (pp. 75-79/GAO Draft Report)

DoD Response: Nonconcur. The "measling" blemish is caused when faults in the "wave soldering" process are corrected by hand soldering, and the circuit board preparation and hand soldering techniques are flawed. In extreme cases these blemishes can be potential sources of future reliability problems. None of the units accepted under waiver from Kollsman, however, were sufficiently flawed to be of concern relative to long-term reliability. The blemish is indicative of poor production process control. The scrutiny provided by the sequential waivers has resulted in improved processes.

It is noted that the Naval Plant Representation Office (NAVPRO) has authority to exercise deviation or waiver approval; however in this case, at the request of the NAVAIR HARPOON Assistant Program Manager for Systems and Engineering (APM/S&E), approval was withheld pending an in-depth review by the NWC, the cognizant testing activity. The NWC conducted a sectioning/ electron microscope analysis of worse case measled boards and concluded that the risk was minimal and indicated that Kollsman was not up to the industry standards and should institute procedures to correct their process problems. At the completion of the NWC review, the HARPOON APM/S&E concurred with the NWC position and recommended that the NAVPRO process the deviation. The NAVPRO documented this acceptance through their normal process.

This action resulted in the acceptance of the existing Kollsman parts, while imposing increasingly stringent process controls. Through this process, the interests of the Government were protected, while the quality of the Kollsman product was improved. At the current time (1) there is no indication that any of the waivers have resulted in failures of Kollsman products in US Foreign Military sales (FMS) services, and (2) the Kollsman Corporation has reduced the blemish rate/severity to an acceptable level.

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Based on the technical review and fleet performance to date, there is no basis to conclude that missile reliability or performance will be effected. Surveillance of fleet missiles that are routinely returned to the Weapons Station will uncover any problem if one were to exist. In that event, contractor liability will be established through the current in-place latent defects clause.

- **FINDING O: HARPOON Teardown Inspections.** The GAO reported that there were no teardowns of the HARPOON during the period of its review, nor are any currently scheduled. The GAO found that two teardown inspections were performed in early 1985, and although some problems classified as minor were found, the overall workmanship was described as very good. The GAO further found, however, that a number of the defects identified involved solder specification problems, which called for the parts to be reworked as required. According to the GAO, the results of the teardowns were not widely disseminated and, in fact, neither the HARPOON manufacturer nor Navy inspection officials had previously seen the report. The GAO concluded that full distribution was important, since the report contained information on defect trends that could have been used by the HARPOON manufacturer and its suppliers to identify and eliminate such trends. (pp. 80-81/GAO Draft Report)

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DoD Response: Concur. As part of the Navy's quality program, the HARPOON APM (S&E) directed a missile teardown of a new production missile and a fleet return missile. These teardowns were accomplished in January and February of 1985. In both teardowns the team findings were all classified as minor defects or cosmetic in nature; no critical or major defects were found. The teardown was done as part of a HARPOON program initiative. In view of this fact and considering that no recommendations were made, the report was not generally released. All team members, including both contractor and Naval Plant Representative Office (NAVPRO) personnel, were given exit debriefs on the minor defects found.

- **FINDING P: HARPOON Subcontractor Control.** The GAO reported that, since about 72 percent of the HARPOON cost is for subcontracts and materials, the missile quality is heavily dependent on contractor and subcontractor quality control procedures. The GAO reported that it reviewed various quality assurance reports and found various problems that could effect quality. The GAO also found, however, that the HARPOON manufacturer apparently was not always able to get corrective actions taken and that quality assurance requirements were not always implemented as intended. The GAO noted that the HARPOON manufacturer was hesitant to force subcontractor compliance in some cases, due to the nature of some of the subcontractors. (pp. 82-83/GAO Draft Report)

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DoD Response: Concur. The GAO report properly noted that the contractor -- McDonnell Douglas Aircraft Corp. (MDAC) -- has a responsibility to "flow down" the quality assurance provisions of their contract with the Navy to subcontractors and suppliers. The GAO also reported, however, that the MDAC shows "reluctance" in applying the required quality control standards to "many of it's subcontractors (which are also) major prime contractors." The examples suggested are Texas Instruments and International Business Machines.

The MDAC executives have reported that they do view major corporations, which have prime contracts with the Navy, as a peers in the industry. In this regard, they recognize that the subcontractor's corporate standards have been judged adequate in other Navy programs. The MDAC officials report that they value the judgment of these subcontractors.

The officials also report, however, that where the requirements of the HARPOON program are more stringent that the subcontractor's other Navy contracts, the requirements of the program are applied. They report that this has led (in some instances) to "bitter disputes" in which MDAC has always prevailed.

Although the control of a large number of suppliers comprising the industrial base for a missile system is a difficult job, the Navy holds prime contractors responsible for the quality of their supplier's products.

- **FINDING Q: Teardown Inspections of The SPARROW.** The GAO reported that contractual requirements require that two teardowns of the guidance and control sections of the SPARROW be performed annually for each of the two manufacturers. The GAO reported that, an April 1986, teardown identified ten major defects, resulting in the contractor strengthening its production and process controls and setting up special plant inspection points. The GAO reported that another teardown, performed in the September to October 1986 time-frame, identified nine high risk defects; while a third teardown in June 1987, resulted in 12 high risk defects being reported. According to the GAO, the 1987 teardown team noted some improvement in quality, but also expressed concern about the number and types of defects found. The GAO reported that the SPARROW manufacturer considered the problems more cosmetic than substantive. The GAO also reported that a follow-up teardown was performed in early August 1987, which found essentially the same conditions. (pp. 86-88/GAO Draft Report)

Now on pp. 60-62

DoD Response: Concur. It should be noted that each of the major and high risk defects have been carefully reviewed and determined to be nonintrusive on missile performance and reliability.

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- **FINDING R: Controversy Over the SPARROW Warranty.** The GAO reported that the Navy took two actions on some of the sections delivered by one of the manufacturers in 1986 and 1987 that effect warranties and responsibility for repair costs. The GAO reported that the Navy negotiated a special agreement with the manufacturer for a conditional acceptance of the missiles, with the contractor to repair the involved failures during the next 3 years. The GAO noted that, as of September 17, 1987, 26 missiles had been returned to the manufacturer under the agreement. The GAO found that controversy has arisen between the Navy and the manufacturer, however, because the manufacturer does not believe it is liable for the repair costs since the quality level is still within the contractual amount. According to the GAO, the Navy and the manufacturer are currently attempting to reach agreement on this point. (pp. 89-90/GAO Draft Report)

  DoD Response: Nonconcur. There is no controversy over the SPARROW warranty provision. By contract, the procurement contracting officer will make the determination as to who is liable to repair missiles under special warranty.

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- **FINDING S: Defective SPARROW Detonators.** The GAO reported that, in late 1986 and early 1987, Navy testing revealed that some of the MK 71 detonators used in the SPARROW safety and arming devices were defective. The GAO found that, as of July 1987, 3,611 Sparrow safety and arming devices, containing 7,222 detonators, had been screened and 225 of the devices were found to contain at least one bad detonator. The GAO noted that, by September 1987, the Navy had decided to screen additional safety and arming devices. The GAO further found that some of the same detonators were also received for the safety and arming devices used for the Navy SIDEWINDER and STANDARD missiles, and the Army CHAPARRAL, which the GAO estimated will require up to 10,000 devices to be tested. The GAO noted that as of July 1987, 7,127 devices had been screened, with 297 found to contain at least one bad detonator. The GAO reported that, according to Navy and company officials, the detonator problem occurred because the manufacturer did not follow prescribed production procedures, but that the procedures have now been revised. The GAO also found that the Navy and the Air Force are paying for the screening program, while the manufacturers are paying for the repair and replacement work. The GAO noted that, according to Navy officials, the Navy may seek some reimbursement of screening costs from the manufacturers. [pp. 91-96/GAO Draft Report)

  DoD Response: Concur. In August 1986, there was a safe and arm (S/A) lot failure at the Naval Weapons Support Center, Crane, Indiana, where the S/As are routinely tested. The ensuing investigation revealed that one detonator subcontractor had not placed an explosive compound in a group of detonators. Records at the sub-vendor were exceptionally poor. An X-ray screen was immediately established at the Naval Weapons Support Center, Crane, in order to (1) purge the inventory of any bad detonators

and (2) bound the problems in the absence of clear records at the contractor. All but 402 SPARROW S/A devices have been screened, and these are being recalled. Statistically, there are only four potentially defective missiles in the fleet.

- **FINDING T: Problems with the SPARROW Wings.** The GAO reported that the SPARROW RIM-7M folding wings were not properly cut during production, causing some not to fold sufficiently to allow correct placement in launching tubes. According to the GAO, the problem was first reported to the Navy in September 1986, and in January 1987, an urgent Airborne Weapons Bulletin was issued identifying as many as 5,721 defective wings. The GAO found that, as of September 1987, the manufacturer stated 4,841 wings had been repaired, representing all the defective wings. The GAO noted that, although the Navy has no system to track the wings, the Navy estimated that in January 1987, as many as 936 may have already been aboard ships. The GAO reported that there is a possibility that some deployed SPARROW missiles cannot be used. According to the GAO, in December 1986, a Navy/contractor review team, found the wing problem started in June 1985, when the supplier changed its manufacturing method without notifying the prime contractors. The GAO also found that none of the Government or contractor quality control inspections detected the problem. Since then, the GAO noted that several actions have been taken to clarify requirements and improve inspection procedures. The GAO further reported that the wing manufacturer is repairing the problem at no cost to the Government, and the Navy is negotiating to recover its costs to uncrate and recrate the suspect wings. (pp. 96-103/GAO Draft Report)

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DoD Response: Partially concur. Contrary to GAO finding, the Navy has a system for tracking and identifying the location of All-Up-Round missiles and major components or sections. This system is the Conventional Ammunition Inventory Management System. The Navy also utilizes two interrelated systems to track and control suspect or defective minor components of missiles and weapons. These systems are the Notice of Ammunition Reclassification (NAR) systems and the Technical Directive (bulletin) system. The NARS and bulletins are used to identify and remove from either the inventory or the fleet suspect or defective items. The defective SPARROW wings were located and reworked through the use of these two systems.

Additionally, it should be recognized that there is no disagreement within the Navy over the effect of the wing problem on SPARROW readiness and performance. This problem has absolutely no effect on performance and the effect on readiness is considered very small, since only 20 wings could not be folded and were easily replaced in the fleet.

Now on pp. 71-72

- **FINDING U: Problem with the SPARROW Antenna Bracket Springs.** The GAO reported that, in March 1986, it was found that a large number of SPARROW antenna bracket springs were cracking and/or breaking. According to the GAO, the problem would not effect missile performance, but could result in other problems on board ship. The GAO found that the problem resulted from the supplier heat-treating the springs at a higher than specified temperature. According to the GAO, the Navy has now changed the specification to specify a maximum temperature. The GAO found that the manufacturer has paid for, and replaced, 2,728 springs, with the Navy performing the labor at an estimated cost of $85,000. The GAO noted that the Navy does not plan to seek reimbursement for this expense, since its technical data package was deficient. (pp. 103-104/GAO Draft Report)

  DoD Response: Concur. While the facts are basically correct, it should be recognized that the potential for shipboard foreign object damage is highly remote.

Now on pp. 3-5 and 26-27

- **FINDING V: Overall Observations on Prime Contractor Oversight of Subcontractors.** The GAO reported that every instance, where quality defects were not detected until large numbers of the missiles were accepted by the Government, involved subcontracted parts. The GAO pointed out that the prime contractor is responsible for the quality of its subcontractor materials and parts, while the Government plant representatives are responsible for verifying that contractors are exercising adequate control over their vendors. The GAO also noted that most of the subcontractor level problems involved insufficient production process controls, the type of problem previously found by the DLA in 1985 and 1986. According to the GAO, some Navy officials believe it may be impossible to adequately police this problem. The GAO also pointed out, however, that recent DoD and Navy manuals have included guidance to avoid or minimize the risk of subcontractor quality assurance problems, and emphasize the importance of good communications. The GAO concluded that contractor oversight of subcontractors is a quality area that needs to be continually stressed, and that closer inspection and testing of subcontractor items needs be done by the prime contractor. The GAO also concluded that the recently issued DoD and Navy guidance on subcontractor control should, when implemented, foster such improved controls and minimize the likelihood of the problems, if found. (pp. 4-6, pp. 8-9/GAO Draft Report)

  DoD Response: Concur. See the DoD response to Finding D.

Comments From Hughes Aircraft Company

HUGHES

MISSILE SYSTEMS GROUP

WILLIAM J. POLON Vice President Product Operations

In reply refer to
87-WJP-265

November 23, 1987

Mr. Frank C. Conahan
Assistant Controller General
United States General Accounting Office
National Security and International Affairs Division
Washington, DC 20548

Dear Mr. Conahan:

I have reviewed your draft report on quality concerns on four Navy missile systems which includes concerns on the Phoenix missile manufactured by the Missile Systems Group of Hughes Aircraft Company (GAO Code 394186).

The draft as related to our hardware is factual when taken as a whole using references, parenthetical expressions, and recognizing contractual agreements. My suggestions for accuracy and clarity follow.

Now on p. 28

1. Page 38, 4th line - Change "35,000" to "70,000"

   Rationale. There are approximately 30,000 solder holes on the Phoenix missile printed wiring assemblies. Each of these holes has two opportunities for solder non-conformances: one on the top side, the second on the bottom side of the assembly board. This addition identifies 60,000 solder non-conformance opportunities. There are approximately 10,000 additional point-to-point solder connections that are individually hand soldered.

PO Box 11337
Tucson, AZ 85734
(602) 295-7744

2. Page 43, last paragraph

This paragraph describes missile evaluation with the recently established "Best Practices." It provides for reporting quality and quality trends against these "Best Practices" to indicate the effects of waivers, deviations, and contract modifications. The paragraph does not give any insight into the design condition of the circuitry nor the producibility of hardware designed many years ago. The specifications and practices that create the "Best Practices" criteria are not described as being inconsistent with the currently approved and contracted for design.

Now on p. 31

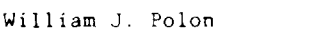
3. Page 46, parts of line 3 and 4 - Add . . . (FSU-10/A) provided by the government as GFE.

I recognize that the parenthetical expression, "(this is discussed below)" is truly an operative statement, however, it seems to me that the lack of a Safety and Arming Device (FSU-10/4) is a well-known reason for Phoenix missiles to be in storage rather than in the fleet. The slight change in wording clarifies the situation immediately without requiring the reader to proceed to page 51 for the clarification that Hughes does not produce the FSU-10/A.

Now on p. 33

Thank you for the opportunity to review this draft report. I hope our general concurrence and the specific observations provided are helpful to your efforts. Should you need any additional information, please allow me to be of assistance.

HUGHES AIRCRAFT COMPANY



William J. Polon

jmr

Comments From Texas Instruments Incorporated

TEXAS INSTRUMENTS

24 November 1987

United States General Accounting Office
National Security and International Affairs Division
Washington, D C 20548

Attn Frank C Conahan
Assistant Comptroller General

Dear Mr Conahan

The attached response to the GAO report number B-225066 reflects the Texas Instruments Incorporated (GAO Code 394186) analysis of the facts, issues and concerns contained in the subject draft GAO report received in my office on 5 November 1987

Texas Instruments considers this response, shown in the "side-by-side" format for ease of reading, to be a true and accurate reflection of the facts and/or of the circumstances that existed in the time period that the report addresses The original text of the draft report is shown on the left side and the Texas Instruments interpretation, clarification and/or appropriate additional comments are shown immediately to the right of the underlined report text.

In general, Texas Instruments considers the draft GAO report to accurately reflect the facts discussed with the GAO Field Team during the on-site review at the Texas Instruments, Lewisville, Texas facility from 5 January 1987 to 21 August 1987 As pointed out in the report, there were some intragovernment discussions to which TI has only indirect knowledge However, in those cases, comments have been added when TI had information not directly reflected by the report

Texas Instruments believes that these comments, clarifications and/or interpretations relative to the HARM missile will be useful to the GAO in formulating and properly interpretating the final report for the Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce

If you have questions regarding the Texas Instruments comments/analysis, please feel free to contact me at (214)462-4068

Sincerely,

Jim W. Coffer

Jim W. Coffer
Quality and Reliability Assurance Manager
Missile Systems Business Entity
Texas Instruments Incorporated
Defense Systems & Electronics Group

Attachment

TEXAS INSTRUMENTS INCORPORATED • POST OFFICE BOX 405 • LEWISVILLE, TEXAS 75067

[illegible] • [illegible] • [illegible] • 214 462-4 • CABLE TXN

Comments From McDonnell Douglas Astronautics Company

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
ST. LOUIS DIVISION
Bldg 598
Box 516, Saint Louis Missouri 63166

N. J. GOLDING, JR.
VICE PRESIDENT PROGRAM MANAGER
HARPOON

(314) 925-5753

EXM-E007-NJG-6065
24 November 1987

United States General Accounting Office
National Security and International Affairs Division
Attn: Mr. Frank C. Conahan
Washington, DC 20548

Dear Mr. Conahan:

Thank you for the opportunity to review and comment on the draft GAO Quality Assurance Report (GAO Code 394186) as it relates to Harpoon. We have shared the appropriate sections of the draft report with Kollsman and this letter reflects their inputs as well as those of McDonnell Douglas Astronautics Company - St. Louis (MDAC-STL).

We at MDAC-STL and our supplier teammates are very proud of the Harpoon missile system and the performance record it has exhibited over the years in service. It is the most widely deployed missile in the U.S. Navy inventory and the documented track record of fleet deployment is outstanding. Our customers, which include 19 countries as well as the U.S. Navy and the U.S. Air Force, have expressed satisfaction which your report cites as an indicator of quality. We feel we are doing a good job in delivering a quality product and thus disagree with allegations or statements in the report which imply conditions to the contrary. The following comments are offered to establish our position regarding these points.

Our comments are submitted as follows concerning six points contained in the report; cost, "potential defective crystals", "measling", solder specifications, teardowns, and control of suppliers.

Now on p. 52

Cost: The cost cited on Page 74 of Appendix V is incorrect for Air Launched Harpoon. As given to the local GAO auditors, the average cost of an Air Launched Harpoon, for comparison with the other air launched missiles included in the report, is $500,000. Surface and Sub-Surface Launched Harpoons, without their launching systems, are somewhat more expensive because of the required booster and folding aerodynamic surfaces. Possibly, the cost quoted in the draft includes attendant logistics costs and U.S. Navy field activity support.

MCDONNELL DOUGLAS CORPORATION

EXM-E007-NJG-6065
Page 2

"Potential Defective Crystals": On Page 35 of Appendix II and again on page 74 of Appendix V, statements are made about "defective" and "potentially defective" crystals. The crystals in question were not defective or potentially defective. They met all Harpoon requirements. As a result of evaluation by a companion hardware program, the qualification of the brand of crystal was being questioned by the U.S. Navy. It was decided that to avoid any concerns that particular brand of crystal would not be used. However, in the "sweep-up" activity several units which were in transit escaped. Rather than cause any questions, MDAC-STL and the hardware supplier volunteered to replace them and did so. There was never any question of a defective component.

Now on p. 52

"Measling": This subject is alluded to on Page 2 of the report cover letter as well as at considerable length in Appendix V. The subject of measling unfortunately became a very emotional issue. One fact is very clear, there is absolutely no evidence of a hardware failure, field or otherwise, that was caused by the phenomenon known as measling. It is also a fact that the printed wire board industry considers it to be a cosmetic defect. For example, The Institute of Printed Circuits, in its publications IPC-A-600C, revised 1978, and IPC-R-700A, September 1971, state: "It is the position of the special committee on measles following their comprehensive review of available literature and available research and test data, that while measles may be objectionable cosmetically, their effect on functional characteristics of finished products are at worst minimal and in most cases insignificant." Further, despite all the commentary, it was determined by the U.S. Navy that the particular occurrences on the printed wiring boards of the Kollsman altimeter were not detrimental to the operational use of the altimeter and would not cause any degradation in future use. The statement in the third paragraph on Page 77 of Appendix V concerns a hypothetical condition wherein measling bridged conductive paths; a condition not allowed in the waivers approved by the U.S. Navy.

Now on pp. 2, 5-6, and 52-57

"Solder Specifications": This subject was covered at great length in the report but it is felt a comment is necessary. As provided to the local GAO auditors, the U.S. Navy WS-6536 Solder Specifications are a purposeful overkill. Certainly soldering is an important aspect of production, however, implementation of WS-6536 criteria as absolute requirements with no tailoring or modification can cause excessive costs. Some specification tailoring is usually desirable in most applications.

Now on pp. 28-29

EXM-E007-NJG-6065
Page 3

Now on p. 57

Teardown: The two teardowns of Harpoon missile cited on Pages 80 and 81 of Appendix V were a voluntary action by the U.S. Navy. Since MDAC-STL was a participating member of the teardown team, we were very aware of what was found. It was determined that the hardware was satisfactory with possibilities for minor improvements. A re-evaluation of the written word, as indicated in the report, without hardware or photograph observation seems to be open to question and thus inappropriate. There were no recommendations made at completion of teardown and therefore, no corrective action was considered necessary.

Now on p. 58

Subcontractor Control: Based on a survey of MDAC-STL audit reports, the report on Page 82 of Appendix V criticizes MDAC-STL control of its suppliers. Although it is true that there was some laxness in follow-up of audits, the problems cited by the report represented non-critical matters. The follow-up system at MDAC-STL has been improved. There was, and always has been, a direct monitoring by MDAC-STL of supplier quality. This system has proven itself valid through the quality of the end product. Further, although MDAC-STL does recognize and utilize the expertise of major suppliers, such as Texas Instruments and IBM, all Harpoon requirements are rigidly enforced. We never abdicate our responsibility in enforcing requirements.

I hope the above comments are received in the constructive vein that they are given. We on the Harpoon Program feel that we are providing a quality product to a satisfied U.S. Navy customer. Thank you for your consideration.

Yours truly,

J H Bell for

N. J. Golding, Jr.
Vice President Program Manager
Harpoon

EC: Naval Air Systems Command
Attn: CAPT D. Finch, PMA-258
Washington, DC 20361

Naval Plant Representative Office
Attn: CDR D. Smith
St. Louis, MO 63166

Comments From Raytheon Company

Charles I Mullaney
Vice President
Manager Lowell Plant

Raytheon Company
Missile Systems Division
Bedford Street
Lexington, MA 02173

Raytheon

November 23, 1987

United States
General Accounting Office
Washington, D. C. 20548

Attention: Mr. Frank C. Conahan, Assistant Comptroller General

Subject: Draft Government Accounting Office Report, dated October 29, 1987

Enclosure: (1) Sparrow 7M Fact Paper on Reliability

(2) Suggested Revisions to the "Wing" comments on Page 102 of the GAO Report

Dear Mr. Conahan:

Raytheon Company has reviewed the subject Government Accounting Office Report and as requested we would like to provide our comments in the areas of Reliability, RIM-7M Folding Wings and the special warranty.

Now on pp. 61-62

1. Reliability versus Teardown Issue
We are attaching as Enclosure (1) a fact paper on Reliability which presents Raytheon's position that there is no correlation between the types of faults found in the missile teardown and reliability as verified through contractor and Government testing.

Now on p. 71

2. RIM-7M Folding Wings
It is suggested that Page 102 of the General Accounting Office Report be revised to incorporate the changes set forth in Enclosure (2) attached regarding the need for an interface gauge specified on the drawings.

Now on pp. 62-63

3. Special Warranty
The report on Page 90 addresses an open issue concerning the responsibility for repair of missiles which have failed during the Government Incoming Electrical Tests at the Weapon Stations (95% AQL Versus Special Warranty).

United States
General Accounting Office
Page 2
November 23, 1987

Notwithstanding our firm belief that we have no contractual obligation to do so, Raytheon, without prejudice on a nonprecedent basis, will bear the costs of repairing the nineteen GCS's in question which have failed the first electrical test, to the extent repairs are required. Raytheon is submitting a letter to the Sparrow Contracting Officer affirming this decision.

I wish to thank you for the opportunity to submit these comments for your review and incorporation into the final report.

Very truly yours,

RAYTHEON COMPANY

C O Mullaney

Charles I. Mullaney
Vice President

Comments From Motorola, Inc.

MOTOROLA INC.

17 November 1987

In Reply Refer To:
JHC87-527/GAO

Mr. Frank C. Conahan
Assistant Comptroller General
General Accounting Office
Washington, D.C. 20548

Dear Mr. Conahan:

By letter dated 29 October 1987, you forwarded to Motorola, Inc., Government Electronics Group (GEG), two copies of an edited version of a draft report on quality concerns on four Navy missile systems. You requested GEG submit comments about the draft within twenty (20) working days. GEG appreciates the opportunity to comment and will do so in this letter.

Now on pp. 41-42

GEG's comments are directed to Pages 57 thru 59, inclusive, of Appendix III, which deal with certain aspects of the Target Detecting Device (TDD) of the Phoenix missile. In general, GEG found the information concerning the potential for "tin whiskers" growth in the TDD Radio Frequency Assembly (RFA) to be a fair presentation of the events surrounding the development of the TDD, identification of a potential problem with the plating of the chassis of the RFA and the implementation of efforts by GEG to repair or rework TDDs. There are, however, two points which GEG wishes to clarify.

First, GEG does not consider the description in the draft report on Page 58, concerning design responsibility for the plating of the RFA, to be complete. The Navy exercised close scrutiny over the development and initial production contracts for the TDD including the RFA. The Navy was at all times aware of the method of plating of the RFA and in January, 1985, the Navy formalized its concurrence of its use via drawing approval.

Second, GEG believes the description on Page 58 concerning the manner in which the parylene conformal coating corrective action was adopted also should be clarified. The possibility of using parylene coating to prevent tin whiskers-caused problems emerged from technical discussions between GEG and the Navy. The Navy requested GEG investigate the effectiveness of the process, and, after evaluating GEG's data, directed its use.

In conclusion, GEG is proud of its work for the Navy on the Phoenix program. To the extent that any engineering judgments GEG and the Navy made in the development or production of TDDs for the Phoenix program may have proved to have been less than nominal, we have endeavored to remedy such situations as expeditiously as possible. In so doing we believe GEG has lived up to our corporate goal of "Total Customer Satisfaction".

Please contact me if you have any questions about this letter.

Very truly yours,

John H. Cole
Program Manager
Missile Fuzing Office
Tactical Electronics Division

/slb

Motorola Inc. • Government Electronics Group
8220 East Roosevelt St. • P.O. Box 9040 Scottsdale AZ 85252 • Phone (602) 949-3033
A1121B

Comments From Morton Thiokol, Inc.

MORTON THIOKOL, INC.
Tactical Operations
Utah Tactical Division
James W. White
Vice President and General Manager

24 November 1987
A600-FY88-024

GAO
United States General Accounting Office
Washington, D. C. 20548

National Security and International Affairs Division

Attention Frank C. Conahan
Assistant Comptroller General

Subject: GAO Code 394186, HARM Defective Launch Lugs

Morton Thiokol has reviewed the draft report on quality concerns on the HARM program and has provided copies to our subcontractor, Lucas Aerospace, for their comment. Having received Lucas' response, attached, our comments are as follows:

Now on p. 50

- A more accurate description of the situation would be "new cutting methods incorporated to increase production rate had a "push-off" effect over the center section of the lugs."

- Corrective actions as incorporated are more encompassing than those stated in the draft report, and include:

  a) 100% gauge inspection of the aft ring assembly and the subassembly.

  b) 100% gauge inspection of the final assembly after phosphate coating.

  c) Several dimensional checks following heat treat.

1060 North Main, Brigham City UT 84302-0524 801 863-5501

d) Upon receipt at MTI, case/lug dimensions are inspected (100%) to MTI gauges acquired upon identification of this issue.

No discrepancies have been identified since incorporation of the above corrective actions.

As stated in the draft, all discrepant parts were repaired by Morton Thiokol/Lucas. The issue is warranty related and the contract Warranty provision requires the contractor to repair/replace discrepant parts. This has been fully accomplished by Morton Thiokol without cost to Texas Instruments or the Navy. As such, the statement "Texas Instruments plans to recover from Morton Thiokol all costs incurred by it and the Navy in resolving the lug problem" is considered inappropriate and should be deleted in it's entirety.

I trust the foregoing information is of assistance. Should you have further questions or require further data, please so advise.

Very truly yours,

J. W. White

J. W. White

Comments From Piqua Engineering Incorporated

Piqua Engineering Incorporated
Armament Systems Division
234 First Street
Piqua, Ohio 45356
FAX No (513) 773-1525
(513) 773-2464

PEI

November 17, 1987

United States
General Accounting Office
National Security and International
Affairs Division
Washington, D.C. 20548

Attention: Mr. Frank C. Conaham
Assistant Comptroller General

Subject: Draft Report on Navy Missile Systems

Gentlemen:

This letter is in answer to your letter of October 29, 1987 which was received by us on November 2, 1987 in regard to the above subject.

Now on pp. 63-67

Our comments on the draft report refer to pages 91 through 96 of Appendix VI entitled Defective Detonators.

We come under the jurisdiction of DCAS and have two full-time DCAS inspectors stationed at our plant who make sure that we follow all specified procedures and maintain a high quality level.

Caelus made preproduction samples and was approved as a qualified source for the Mk 71 Detonator by the Naval Weapons Center, China Lake, California. Subsequently, the Navy purchased Mk 71 Detonators directly from Caelus on prime contracts. We made a survey of Caelus, as required by regulations, and assured ourselves that Caelus had the proper facilities and procedures to make a quality product. The Navy also did the same thing and arrived at the same conclusions before they issued contracts to Caelus.

Every order placed with Caelus called for Government source inspection by DCAS. All shipments received by us were properly stamped by the DCAS inspector at Caelus. Our procedures are the same as used by Micronics.

Piqua Engineering Incorporated
Armament Systems Division
234 First Street
Piqua Ohio 45356
FAX No (513) 773 1525
(513) 773-2464

PEI

General Accounting Office
Washington, D.C.

November 17, 1987

We acknowledge that we are responsible for the quality of the material supplied by our subcontractors and that is the reason that we have visited Caelus's plant. We feel that the Government must bear part of the responsibility for the defective detonators. All shipments were source inspected at Caelus by DCAS which indicates that all specified tests were run and procedures were followed as determined by a Government inspector. There were no problems with Caelus's written procedures. The problem is they deviated from the procedures. The omission of the lead azide occurred during the transition from the first shift to the second shift. There is no way that this would have been caught without having an inspector in the plant at a change of shift.

We followed all specified requirements and procedures in regard to inspection and sampling of the Mk 71. There is no way to detect a missing part in the Mk 71 with 100% certainty by sampling and destructive tests which is the way the specifications are written. The only way to do this is by x-raying each item. The Government should have recognized this fact and made 100% x-ray as a specification requirement for an item this critical. If that had been done, this problem would not have occurred. In fact this has now been done by the Government as a corrective action.

We will appreciate you incorporating our comments in the final draft of your report. We will also appreciate receiving the final copy.

Yours very truly,

PIQUA ENGINEERING, INC.
Armament Systems Division

John D. Scarbrough, Sr.
President

JDS:jlm

Comments From Caelus Devices, Inc.

CAELUS DEVICES, INC.
P.O. Box 1097 • Hollister CA 95024-1097 • (408) 637-7488 • TLX 172031

November 16, 1987

United States General Accounting Office
Washington, D.C. 20548
Attention: National Security and International Affairs Division
John D'Esopo

Reference: Draft Report, "Quality Assurance Concerns about Four Navy Missile Systems," GAO Code 394186.

Dear Mr. D'Esopo:

We have reviewed the reference report and offer the following proposed changes:

Now on p. 63

1. Page 91, line 12: Change "by the subcontractor" to "by the contractors".

   Reason: A review of Caelus Devices records by GAO and Micronics personnel showed that although one manufacturing lot of 10,000 detonators had more than one shipment lot number, lots were not intermingled at Caelus Devices and were traceable to the original manufacturing lot number. Intermingling of lots could have occurred at the contractor facilities because the detonators are too small to be individually marked with lot numbers, as are many other explosive components.

Now on p. 65

2. Page 94, line 4: Change "certain workers" to "certain second shift workers".

   Reason: Caelus Devices Quality Assurance records show that the problem occurred when evening shift workers were discovered to have taken partially loaded detonator cups and assembled them to ignition elements without first loading loose lead azide. The portion of the lot believed to be affected was X-rayed and discrepant units discard, however, it appears that other units were also faulty.

Now on p. 65

3. Page 94, line 8: Change "cumbersome and unwieldly and lent themselves to inefficient quality control" to "applied in discrete steps to components in various stages of completion rather than in a continuous process. They lent itself to inefficient quality control in that an important step could be omitted without being noticed. When this problem was discovered several corrective steps were taken, to include termination of several

CAELUS DEVICES, INC.
P.O. Box 1097 • Hollister CA 95024-1097 • (408) 637 7488 • TLX 172031

shift production and radiographic screening of suspected detonators. The corrective actions taken at the time were insufficient to detect all of the defective units already processed."

Reason: The manufacturing process included measuring and pressing two small amounts of explosive powder into a tiny metal cup, then measuring a small amount of loose powder and adding it before final assembly. These operations were done one at a time on groups of components in a lot of 10,000 units. Partially completed units were stored in a dry room in various stages of completion before the next step. See also the reason for 2. above.

Now on pp. 65-66

4. Page 94, line 10: Delete "As part of --- inspection processes". Add "In subsequent production, Caelus installed a continuous production line to preclude omitting process steps. It also instituted a 100% radiographic inspection of completed detonators to screen out defective units before shipment to its customers."

Now on pp. 65-66

5. Page 94, paragraph 2, line 3: Delete "told us he --- shipping documents." Add "told us he probably did not inspect for the presence of the loose load because it was not required by the letter of delegation issued by the prime contractor's DCAS representative. He said the DCAS stamp on shipping documents indicates compliance with the letter of delegation which required inspection of finished dimensions and test requirements."

Reason: Clarity.

Now on pp. 65-66

6. Page 94, paragraph 2, last sentence: Delete "contracts, not small subcontracts." Add "contracts and mandatory inspection requirements at the subcontract level."

Reason: Misquote.

Other than the above, we have no other comments on the draft report.

Sincerely,

John B. Fitch
Manager of Contract Administration

JBF:jg

Comments From Marvin Engineering Co., Inc.

MARVIN ENGINEERING CO., INC.

260 WEST BEACH AVE • INGLEWOOD CALIFORNIA 90302 • [illegible]

November 18, 1987

GENERAL ACCOUNTING OFFICE
441 "G" Street, N.W.
Washington, DC 20548

Attention: Marvin Casterline
National Security
and International Affair Division

In reply refer to: WP-FIB-11117.ak

Reference: GAO Letter dated October 29, 1987

Dear Mr. Casterlin:

Thank you for your letter of 10/29/87. Submitted herewith are our comments on the draft report regarding Navy Missile Systems forwarded to us by your office.

Now on p 67

PAGE 96: RIM-7M WINGS

It has been stated that wings "were not properly cut during production." The area in question was properly machined to the blueprint as it existed. This area is a termination of a chamfer at a shoulder and cannot be considered a true radius. There is no dimensional callout; only a pictorial depiction. Our cutter run-out formed the radius. Note 4 of B/P 5020381 does not apply as witnessed by proposed change MM5019.2 Page 1 where the radius called out on Note 4 was deleted and added to the casting portion of the drawing where it belonged. (Copy attached).

Due to the above, some wing assemblies may not fold sufficiently to be placed correctly in launching tubes. Marvin Engineering had no way of knowing how far the wing should fold. There was no specific requirement for a fold angle. (See Pages 2 and 3 of MM5019.1A copy attached). Rather than saying MEC repaired defective wings, a more accurate statement would be MEC altered wings to allow them to fold to an acceptable angle by reducing the cutter run-out radius to match the pictorial depiction.

Rework cost was absorbed by Marvin Engineering Co., Inc. because we value the Folding Wing Program in which we have participated over the last 11 or 12 years with two (2) major customers.

Now on p 67

PAGE 96: PROBLEM IDENTIFIED

China Lake Naval Weapons Center in conjunction with the design activity at General Dynamics started drawing clean-up to clarify many ambiguous and unclear or conflicting dimensions on the various drawings. Several changes are now being considered which will clarify all drawings affected. Excerpts from these changes that affect the folding of the RIM-7M Wing are attached to this correspondence.

Now on pp 70-71

PAGE 101: QUALITY CONTROL BREAKDOWN

The contention that the defects were not detected by anyone assumes there were defects. We do not agree. The area in contention is the termination of a chamfer and is not dimensioned. (See Page 4 of MM5019.2A copy attached).

Wings currently being manufactured are being folded to the proposed change (See Page 3 of MM50191.1A copy attached). The radius in contention is being cut to conform to the proposed change MM5019.2A Page 4 (copy attached).

CONCLUSION

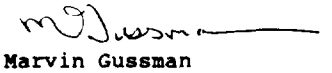
Marvin Engineering does not feel any errors were made in machining wings to the prints as they existed at that time. Note 17, Pages 1 and 4 "need for change" of ECP MM5019 (copy attached) addresses ambiguities and omissions which contribute to the difficulty in installing clips to fold wings in place.

Enclosed are highlighted copies of ECP 5019 and applicable sheets of proposed changes.

Information about the investigation was released to the L.A. Times before the parties involved were notified. As a result Marvin Engineering Co., Inc. received adverse publicity.

Thank you for allowing us to explain our position. If you have any questions or comments, please do not hesitate to call. We would appreciate it if you could incorporate our comments into the draft or have the draft changed to read like our explanation. Please send us a copy of the revised draft.

Very truly yours,



Marvin Gussman
President

MARVIN ENGINEERING CO., INC.

MG:ak

Comments From Hercules Incorporated

Hercules Incorporated
Aerospace Products Group
Allegany Ballistics Laboratory
P O Box 210
Rocket Center WV 26726
(304) 726-5000

December 2, 1987

United States
General Accounting Office
Washington, D.C. 20548

Dear Mr. Conahan:

Now on pp. 71-72

I have received the sections from your draft report on quality problems on four Navy missile systems and offer the following re-write of the paragraphs concerning Antenna Bracket Springs on pages 103 and 104. I feel that this re-write more closely incorporates facts that were transmitted to and discussed with Mr. Marvin Casterline this past summer.

Although not specifically mentioned in the report it is noteworthy that Hercules took immediate action when made aware of the problem. With the cooperation of the manufacturer of the Spring the cause was quickly identified and corrective action taken. A Purchase Order for replacement springs was placed and that purchase order contained special quality assurance provisions to establish a maximum tensile strength requirement. Concurrently, an Engineering Change Proposal was prepared and submitted to the Navy to add that same requirement on the drawing for the part. Although 2728 replacement springs were furnished to the Navy, fewer than 70 springs were actually reported to have broken.

Sincerely yours,

James P Niland

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Quality Assurance Engineer

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(4665V)

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