

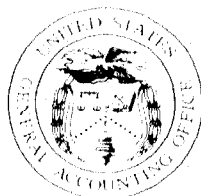
GAO

Report to the Chairman, Subcommittee
on Investigations, Committee on Armed
Services, House of Representatives

September 1991

MILITARY FASTENERS

Changes to Specifications Are Justified



145042

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National Security and
International Affairs Division

B-245447

September 30, 1991

The Honorable Nicholas Mavroules
Chairman, Subcommittee on Investigations
Committee on Armed Services
House of Representatives

Dear Mr. Chairman:

This report responds to your January 11, 1991, request that we review the basis for the Air Force's decision to change military specifications for class 3 threaded fasteners¹ and the scope and methodology of its estimate of the cost to implement the changes.

Background

Currently, three separate sets of standards exist for threaded fasteners manufactured in the United States. These standards include military specifications issued by the Air Force for the Department of Defense and the military services.² Other specifications are federal standards prepared by the Defense Industrial Supply Center (on behalf of the Department of Commerce) and national standards issued by the American National Standards Institute (under sponsorship from the American Society of Mechanical Engineers). The military specifications for class 3 fasteners were issued in 1965 and revised in 1973.

The military specifications describe the thread characteristics (see app. I) and the inspection methods required for verification and acceptance of fasteners and other threaded products by the ordering service. The specifications require certain inspections to be conducted by the manufacturer. Three methods (A, B, and C), which differ in rigorousness, are used for verifying that fasteners meet specifications. These methods are identical to those specified in both the federal and national standards.

¹A class 3 threaded fastener typically refers to nuts and bolts used in aerospace and other high-technology applications, but it also refers to any high-technology threaded product, such as a threaded engine drive shaft. Class 3 fasteners are used in critical applications (those in which thread failure would cause a catastrophic accident) and are manufactured to stringent standards for strength and integrity.

²MIL-S-7742, Screw Threads, Standard, Optimum Selected Series: General Specification for, and MIL-S-8879, Screw Threads, Controlled Radius Root With Increased Minor Diameter: General Specifications for.

Method A inspection is a functional test to determine if the fastener will assemble with a standard thread. Method B inspection includes the functional test required in method A inspection and the measurement of up to four other thread characteristics. Method C inspection includes the measurement of the thread characteristics required by method B inspection and the measurement of six additional thread characteristics. The current specifications prescribe method A inspection for internally threaded fasteners and method B inspection for externally threaded fasteners.³ The proposed specifications include a default⁴ clause that specifies the application category and the thread characteristics to be inspected to ensure thread conformance.

The Air Force is the Department of Defense's executive agent for class 3 threaded fasteners. In 1987 the Air Force changed its own inspection and acceptance policy for class 3 fasteners and in 1988 issued interim specifications, which may be used in acquisition of military hardware. These changes established a safety-critical category of fasteners for which thread failure would result in loss of life, serious injury, or loss of a major weapon system. The changes also eliminated method A inspection.

The proposed specifications would require, as a default, the equivalent of method C inspection for all safety-critical fasteners and method B inspection for all other fasteners. Method B inspection could be conducted on a sample of fasteners from a manufacturing lot. Safety-critical fasteners must receive 100-percent inspection or be produced from a government-approved on-line process control (special measurements taken during the actual production of fasteners to help control manufacturing quality). The thread characteristics detailed in the existing specifications would not change.

During the past several years, the Air Force has been in the process of changing the final specifications, but it has met strong opposition from groups in the fastener and aerospace industries who claim that the changes are unnecessary and will not improve the quality of the product. As we reported earlier,⁵ the Air Force has followed applicable

³Internal threads are used on nuts, and external threads are used on bolts.

⁴A default occurs when the manufacturer does not specify the application category and/or the thread characteristics to be inspected. When this happens, the specifications prescribe what should be done.

⁵DOD Procurement: Changes to Military Specifications for Testing Industrial Fasteners (GAO/NSIAD-91-84, Dec. 21, 1990).

regulations for changing specifications. Each of the other military services has concurred with the technical merits of the changes, and the Air Force prepared an analysis of the cost impact of the proposed changes.

Results in Brief

The Air Force's decision to change the specifications, in our opinion, is reasonable, and the specifications should be implemented. The Air Force had evidence indicating that deficiencies in the specifications contributed to fatal accidents and other incidents that affected the performance of military hardware. The Air Force also had evidence that a substantial number of fasteners in the Department of Defense's inventory did not conform to the requirements of existing specifications. The Air Force attributed this problem to a lack of quality control during manufacture and the inadequacy of inspection methods prescribed by the specifications.

Groups representing the fastener and aerospace industries claimed that poor enforcement of the current specifications by the Department of Defense was the cause of the accidents and the nonconforming inventories. Evidence we examined corroborated that existing inspection specifications are fundamentally flawed. As stated by the Air Force and the National Institute of Standards and Technology, method A inspection accepts products that do not conform to existing specifications and thus have less strength and integrity than products that meet specifications. Moreover, method B inspection provides insufficient information about the adequacy of safety-critical fasteners. The proposed specifications appropriately require more rigorous inspections for safety-critical fasteners.

Although industry groups also claimed that measuring gages needed to perform the proposed inspections were not sufficiently accurate, evidence we examined indicated that measuring gages do exist to perform these inspections with sufficient accuracy and reliability.

The Air Force estimated that government and industry would incur only modest costs in implementing the proposed specification changes. Several industry groups estimated that the costs would be substantially higher than the Air Force predicted. We were unable to determine the most accurate estimate because factors were omitted, inappropriately included, or insufficiently supported in both the Air Force and industry estimates.

Evidence of Need to Change Specifications

The evidence we examined included the accidents and failures cited by the Air Force and the nonconforming threaded products found in the government's inventory. The accidents and failures and the nonconforming inventory are discussed below and in more detail in appendixes II and III, respectively.

Accidents and Failures

The Air Force has repeatedly stated that safety concerns are the motivation for the proposed specifications. The Air Force recently cited two fatal accidents as the primary reason for the proposed specifications. The accidents cited are an Army UH-60A Blackhawk helicopter crash and an Air Force CH-3E helicopter crash, resulting in 9 and 15 fatalities, respectively. In both of these accidents, failure of nonconforming threaded parts caused the helicopters' rotor blades to separate from the main rotor heads. The Blackhawk parts were found acceptable by the manufacturer to existing inspection requirements (method A inspection for internal threads and method B inspection for external threads). Nonconforming supply parts identical to the part that failed on the CH-3E also passed method A inspection.

Two other equipment failures were cited by the Air Force to justify the changes. One failure involved engines of Navy F-14 aircraft, and the other involved nuts and bolts used on Navy nuclear submarines. In both of these failures, the inferior threads were found to be acceptable under method A inspection.

Nonconforming Products in Inventory

Several inspections since October 1986 of threaded products accepted in the Department of Defense's inventory have disclosed that over 60 percent did not conform to specifications. The Air Force concluded from the reviews that nonconforming products were being accepted into the inventory because the existing specifications allowed many items to be accepted by method A testing. The National Aeronautics and Space Administration also found high percentages of nonconforming products in the inventory of one of its space centers.

Accuracy of Indicating Gage Measurements

Measuring gages are used to determine if the fastener's threads meet specification requirements. Manufacturers and suppliers frequently use indicating measuring gages when performing method B and C inspections. Indicating gages measure actual dimensions of individual thread characteristics. Industry groups expressed concerns about the proper calibration and the accuracy of these gages (see app. IV). However,

studies conducted by gage users showed that the gages are sufficiently accurate and reliable.

Estimated Costs of Proposed Specifications

The Air Force estimated that the cost to the government of implementing the proposed specification changes would be about \$11 million and the cost to industry would be about \$14 million. Two industry groups polled their member companies, which estimated that their costs would be over \$550 million. These organizations claimed the Air Force had not used all relevant costs (e.g., training personnel, changing engineering drawings, and calibrating gages) when determining the cost impact on industry to implement the proposed changes. Likewise, the Air Force claimed industry inappropriately included factors in reporting costs: for example, capital expenditures for major manufacturing equipment and costs for waste and scrap material were included by some companies. These costs are discussed in more detail in appendix V.

Scope and Methodology

To accomplish our objectives, we spoke with officials from Air Force Headquarters, Washington, D.C.; Aeronautical Systems Division Headquarters and Air Force Logistics Command, Dayton, Ohio; Army Materiel Command's Department Standardization Office, Alexandria, Virginia; Naval Sea Systems Command and Naval Air Systems Command, Washington, D.C.; Defense Logistics Agency, Alexandria, Virginia; National Institute of Standards and Technology, Gaithersburg, Maryland; and National Aeronautics and Space Administration, Washington, D.C. We also spoke with various representatives from the fastener and aerospace industries.

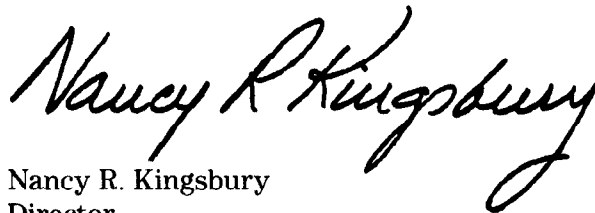
On June 24, 1991, we held a joint government and industry meeting to discuss information obtained during our review. The meeting was facilitated by an Alternative Dispute Resolution Coordinator from the Federal Mediation and Conciliation Service. The agencies and organizations present at the meeting are listed in appendix VI.

We conducted our review from February to August 1991 in accordance with generally accepted government auditing standards, except that we did not independently verify data provided to us by others. As requested, we did not obtain written agency comments on this report. However, we discussed the information in a draft of this report with officials from the Department of Defense and incorporated their comments where appropriate.

We are sending copies of this report to the Chairmen, House and Senate Committees on Armed Services; the Secretaries of Defense, the Army, the Navy, and the Air Force; the Director, Office of Management and Budget; and other interested parties. We will also make copies available to others on request.

Please contact me at (202) 275-4268 if you or your staff have any questions concerning this report. Major contributors to this report are listed in appendix VII.

Sincerely yours,

A handwritten signature in black ink that reads "Nancy R. Kingsbury". The signature is written in a cursive style with a large, sweeping "N" and "K".

Nancy R. Kingsbury
Director
Air Force Issues

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Abbreviations

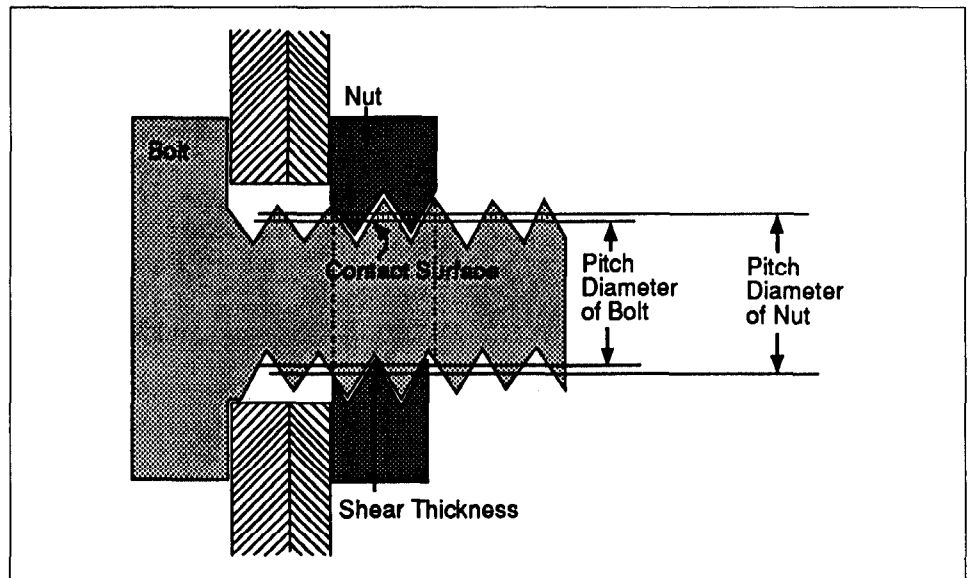
DOD	Department of Defense
NASA	National Aeronautics and Space Administration

Thread Characteristics

Thread characteristics define the size and shape of a thread and determine the strength and integrity of the fastener. Two major thread characteristics are lead and pitch diameter. A thread follows a circular path around a bolt or inside a nut, and the distance the bolt or nut moves during one revolution around the path is called the lead. The lead of the bolt thread must be similar to the lead of the nut thread to allow the two to assemble together correctly. If the leads are not similar, the integrity of the assembly will be substandard.

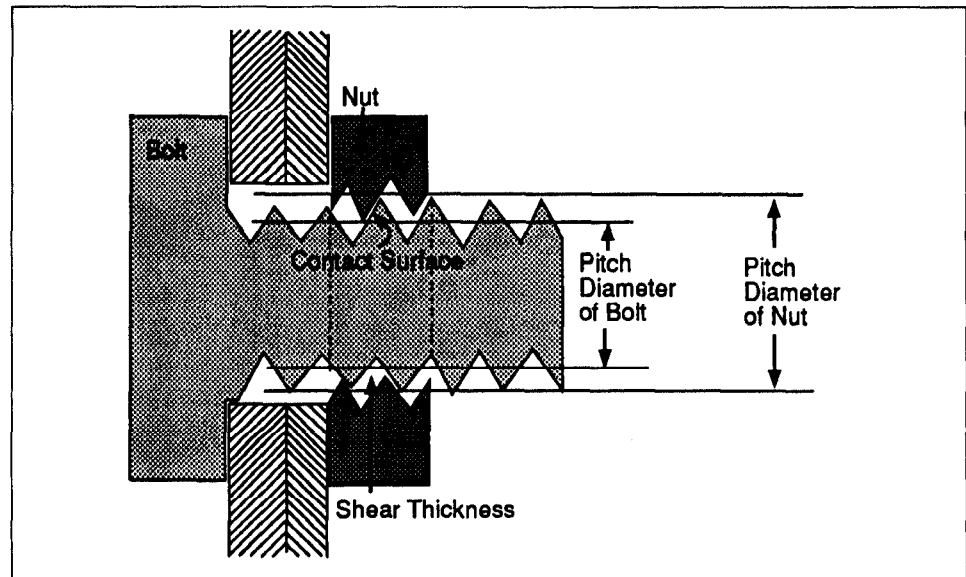
Pitch diameter is a measure of size of the threads. It is defined as the diameter of the fastener where the thickness of the thread and the width of the groove between threads are equal. For a nut to assemble onto a bolt, the pitch diameter of the nut must be greater than the pitch diameter of the bolt. Figure I.1 shows a cross section of a threaded assembly using a nut with a correctly sized⁶ pitch diameter, and figure I.2 shows a cross section of a threaded assembly using a nut with an oversized pitch diameter. The oversized nut has less contact surface with the bolt and less shear thickness (the thickness across the width of the thread) than the correctly sized nut.

Figure I.1: Cross Section of a Threaded Assembly With a Correctly Sized Nut



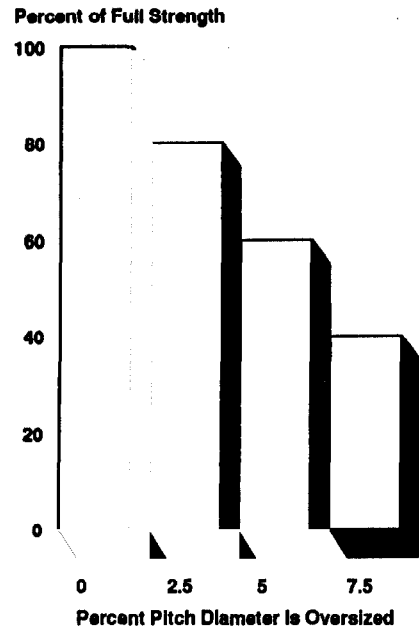
⁶A correctly sized pitch diameter is within the tolerances, or limits, allowed by the specifications.

Figure I.2: Cross Section of a Threaded Assembly With an Oversized Nut



Pitch diameter sizes of the nut and bolt are used to calculate the strength of a threaded assembly. The strongest assembly occurs when the pitch diameter of the nut is slightly larger than the pitch diameter of the bolt. As the pitch diameter of the nut increases, or the pitch diameter of the bolt decreases, the strength of the joint decreases. For example, a 5/8-inch nut oversized by 5 percent will have only 60 percent of the strength of a correctly sized nut. Figure I.3 shows how rapidly strength decreases when pitch diameter deviates from the correct size.

Figure I.3: Thread Strength as Pitch Diameter of Nut Increases



Note: These figures were calculated for a 5/8-inch nut with 18 threads per inch and a pitch diameter of 0.5889 inch using the equations in the American National Standards Institute/American Society of Mechanical Engineers publication, Unified Inch Screw Threads.

Functional size is a measure of the pitch diameter plus the cumulative effects of any errors in the lead and other thread characteristics. If no errors in the lead and other characteristics exist, the functional size will equal the pitch diameter. Correct functional size ensures that nuts and bolts will fit together. However, it does not ensure the strength of the threads because of the cumulative effects of errors in the lead and other characteristics. A nut or bolt may have a correct functional size and an oversized or undersized pitch diameter.

Accidents and Failures

UH-60A Blackhawk Accident

The UH-60A Blackhawk helicopter accident occurred on April 15, 1985. The Army Safety Center reported that the spindle (see fig. II.1) on one of the helicopter's main rotor blades failed. The spindle secures the rotor blade to the main rotor (see fig. II.2). The failure was due to a fatigue crack that originated near the root of the first complete thread (see fig. II.3). Spindles are normally replaced every 6,700 hours; however, this spindle failed after only 1,080 hours of use.

Figure II.1: Helicopter Spindle

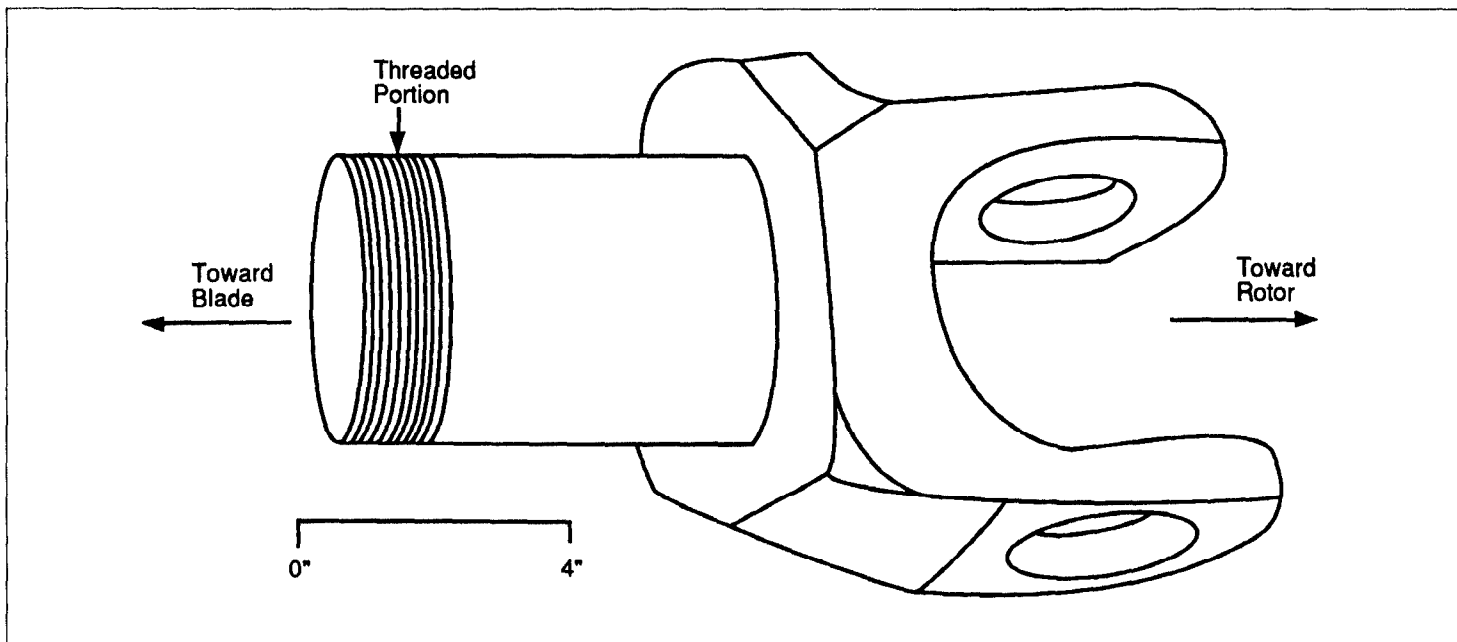
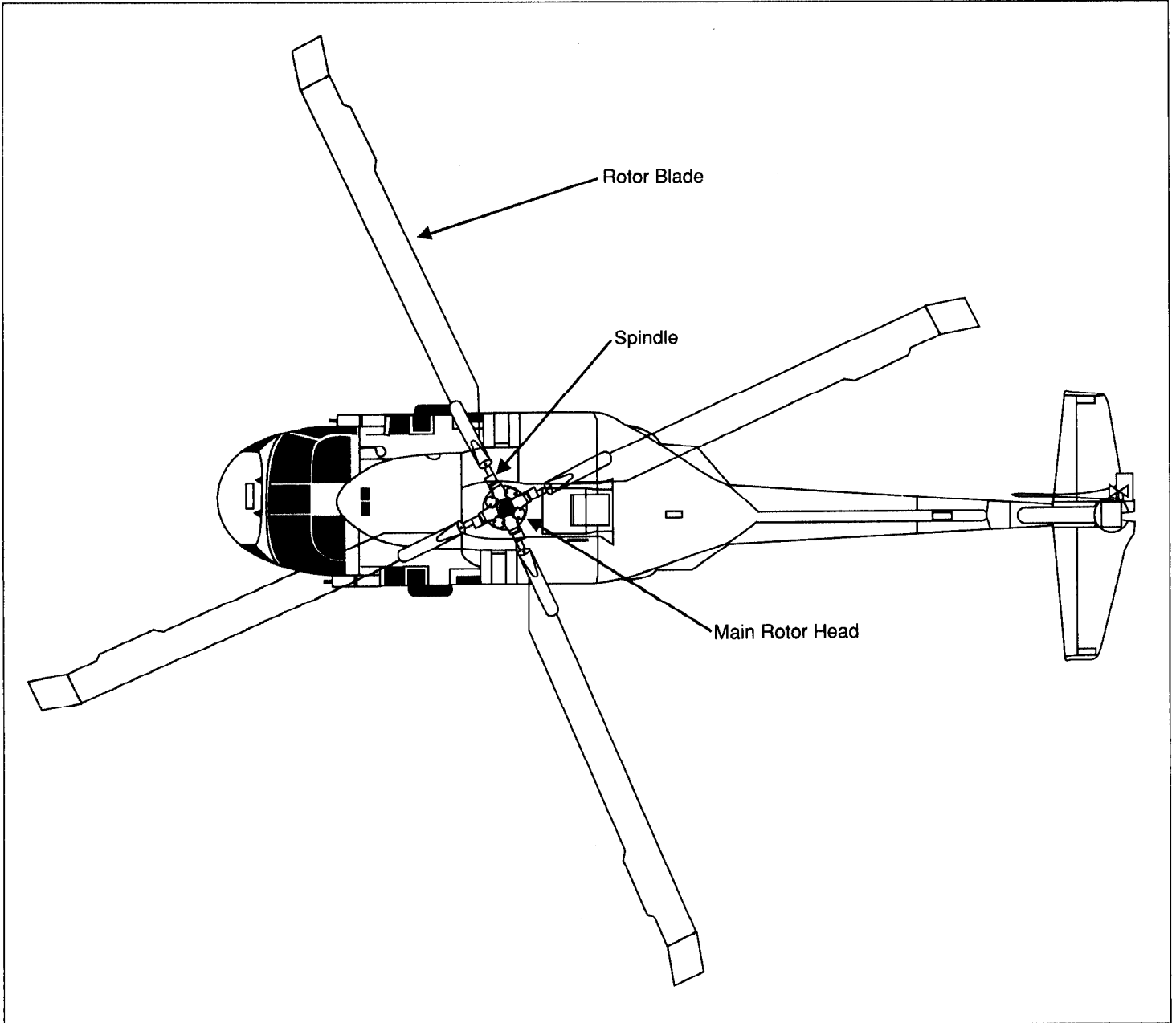
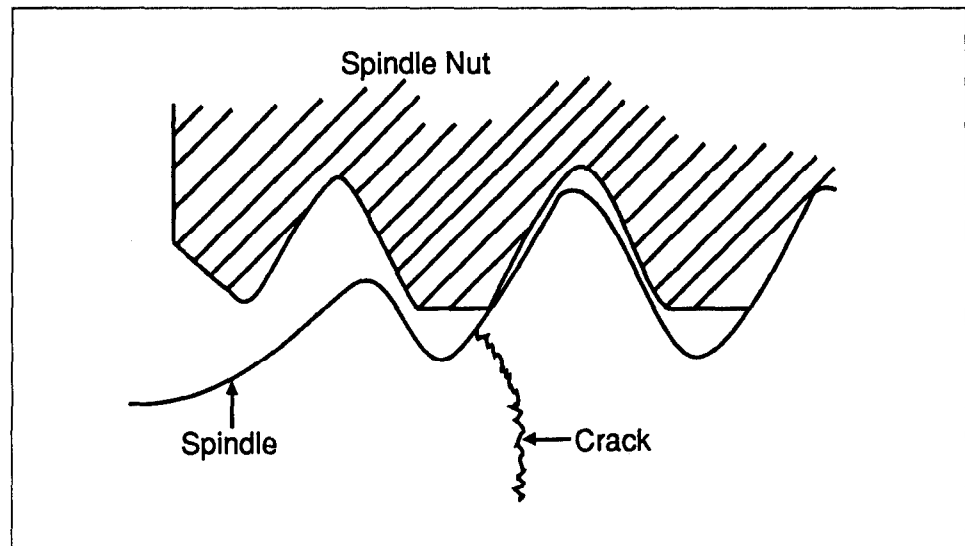


Figure II.2: Overhead View of UH-60A Helicopter



Source: Jane's Defence Weekly

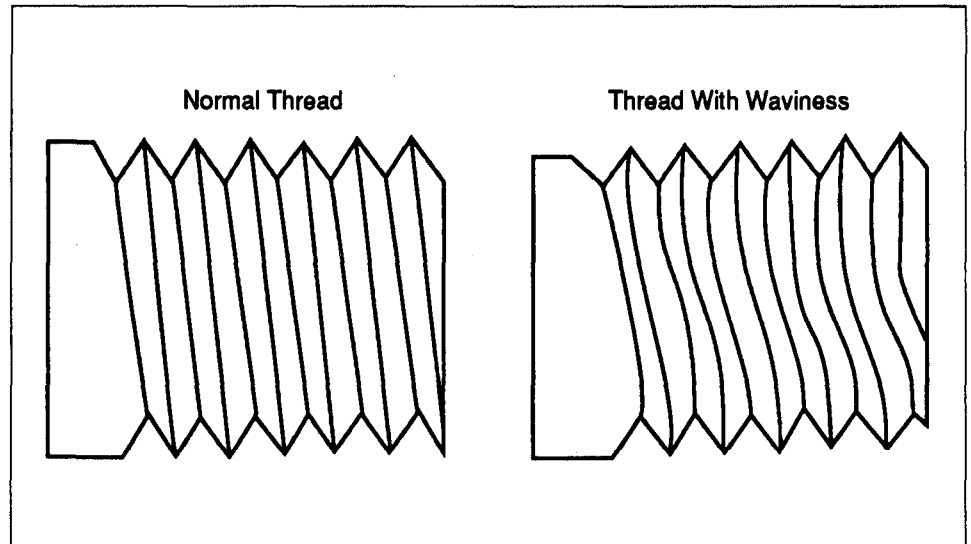
Figure II.3: Origin of Fatigue Crack on UH-60A Helicopter Spindle



Source: Army Safety Center

The manufacturer of the helicopter examined the spindle and nut assembly for the Army Safety Center. This examination revealed that the threads of the spindle did not meet specifications because of thread waviness (see fig. II.4). This waviness caused the threads of the spindle to come in contact with the mating threads of the spindle nut only in certain areas. This uneven contact pattern compromised the strength of the threaded connection. The manufacturer found no other abnormalities in the spindle.

Figure II.4: Normal and Wavy Thread Forms



Although a group representing the fastener industry claimed that the spindle threads would not have passed the less rigorous method A inspection, the helicopter's manufacturer determined that the spindle was acceptable to the more rigorous method B inspection at the time of manufacture. The group did not have the results of the manufacturer's examination when the claim was made.

CH-3E Accident

The CH-3E helicopter accident occurred on March 12, 1989. The Air Force's Accident Investigation Board reported that one of the aircraft's rotor blades separated from the main rotor. The separated blade's spindle remained attached to the main rotor.

The Materials Engineering Laboratory at Pensacola Naval Air Station, Florida, analyzed the nut that attached the separated blade to the spindle and found that its threads clearly did not conform to specifications and were considered substandard. The laboratory also sampled 11 nuts from supply and found that 4 were oversized in pitch diameter by at least 0.0350 inch, corresponding to a strength loss of approximately 35 percent.

Other Failures

Other failures have occurred that were partly or completely due to inadequate inspection methods. In both of the following failures, nonconforming internal threads passed method A inspection.

The Naval Air Rework Facility at Norfolk, Virginia, determined that excess vibration on many TF-30 engines it tested was due to nonconforming pitch diameters of the internal threads on the engine's sealing tubes. The TF-30 engines, used to power Navy F-14 aircraft, were rejected after overhaul because of excess vibration.

The engine manufacturer attributed the nonconforming threads to the fact that fixed limit gages (see app. IV) cannot properly and consistently identify all thread element nonconformances. Subsequently, the Navy incorporated an inspection program using indicating gages on all overhauled TF-30 engine sealing tubes. This inspection program lowered the engine rejection rate due to vibration from 13.5 to 5.8 percent, representing a \$290,000 estimated savings for the first year. The engine's manufacturer now requires that suppliers of the sealing tubes conduct inspections using indicating gages.

In another example, corrosion-resistant nuts and bolts used on nuclear submarines failed on installation. The Norfolk Naval Shipyard examined a sample of the failed nuts and found that all had nonconforming threads with pitch diameters outside the allowable specification limits. All of the nuts passed method A inspection. A shipyard official told us that although the absence of lubrication in the threaded assembly was the primary cause of the failures, the oversized condition of the nuts exacerbated the failures. To help prevent further failures, the shipyard alerted other submarine shipyards using these nuts to measure the pitch diameter of internal threads in critical applications.

Nonconforming Products in the Government's Inventory

Since October 1986 inspections by the Air Force and the Department of Defense (DOD) Inspector General's Office have disclosed that over 60 percent of DOD's inventory of class 3 fasteners did not conform to specifications. On the basis of these reviews, the Air Force concluded that nonconforming products were being accepted into DOD's inventory because the existing specifications allowed many items to be accepted by method A testing, which only determines whether a fastener will assemble with a standard thread. The National Aeronautics and Space Administration (NASA) also identified nonconforming products in the inventory of one of its space centers during a 1989 inspection.

Air Force Inspections

During October 1986 through February 1987, the Air Force conducted method B inspections of threaded fastener products at four of its air logistics centers and two Defense Logistics Agency depots. The lots sampled at each facility included different thread sizes for both internal and external threads that were tested for dimensional conformance. Although the overall average rejection rate was 60 percent for internal threads and 40 percent for external threads, four of the six facilities had overall rejection rates for both types of threads that exceeded 65 percent. The inspections also found that internal threads of sampled products exceeded specified pitch diameter tolerances but were within the functional size tolerance (i.e., the products assembled correctly). According to the Air Force, the pitch diameter problem cannot be detected by method A inspection. Also, external threads of some sampled products exceeded allowable tolerances for functional size. Most of the sample would not pass method A inspection because the threads would not fit into the maximum limit side of a fixed limit gage.

DOD Inspections

In April 1989 and September 1990, the DOD Inspector General reported on its reviews of nonconforming products at the Warner Robins Air Logistics Center and the Defense Industrial Supply Center, respectively. The results of both studies, which addressed major nonconformances of threaded fasteners, were basically the same. At Warner Robins, all 20 fastener parts tested did not conform to specifications. The quality of the products tested at the Supply Center was also poor.

The DOD report did not specifically address threaded fasteners at the Supply Center; rather, it addressed the Center's quality assurance program. The report stated that the quality assurance program did not work adequately to minimize acceptance of nonconforming products that were received in 1986 and 1987. The Center stated that the report's

finding was based on contracts awarded before it took corrective actions once it discovered fastener fraud and nonconformances in its inventory. The corrective actions the Center took included

- installing thread measurement equipment (indicating gages) at depots receiving class 3 fasteners;
- incorporating a traceability requirement using manufacturing insignias or logos;
- instituting product verification testing before acceptance and shipment to depots;
- incorporating a certificate of quality compliance, which requires actual test and inspection data to support certification that a product meets requirements; and
- pursuing legal action against manufacturers and individuals.

The Center reported that, as a result of its corrective actions, the non-conformance rate for class 3 fasteners has decreased from 45 to 3.5 percent, approximately \$2.9 million has been recovered, and 19 individuals have been convicted of fraud and 45 companies or individuals have been disbarred.

NASA Inspections

In May 1989 NASA, with the support of its contractors, inspected 11 different sizes of flight-critical class 3 fasteners at the Kennedy Space Center for thread compliance. NASA inspected 1,077 external fasteners and 655 internal fasteners. The inspection revealed that approximately 72 percent of the external fasteners and 66 percent of the internal fasteners did not conform to specifications. NASA contractors reinspected 180 of the fasteners and found that 27.5 percent still did not conform to specifications. As a result of these inspections, the Center's Director of Safety, Reliability, and Quality Assurance issued an interim policy that all class 3 threaded fasteners with flight-critical applications be inspected.

Accuracy of Indicating Gages

The two types of measuring gages used by most of industry are fixed limit gages and indicating gages. These gages determine if the measured thread characteristic meets specifications.

Fixed limit gages measure threads by checking to determine if the thread characteristic is within the limits prescribed by the specifications. These gages are only used for inspecting the functional size, the measurement specified by method A inspection.

Indicating gages give an actual reading of the thread characteristic measured. These can be used to measure almost all the thread characteristics required by the current and proposed specifications. Indicating gages have been used by industry since 1973, when method B inspection was used for external threads.

Industry groups have expressed concerns about the accuracy of indicating gages that measure internal threads. These gages are manufactured to the same tolerances as indicating gages that measure external threads. However, since indicating gages that measure internal threads are required to measure inside a nut, they are usually more fragile and more difficult to use than indicating gages that measure external threads.

Indicating gages that measure internal threads have been shown to have sufficient accuracy to measure pitch diameter reliably. Seven gage studies conducted over the last year by two gage users showed measurement variation, used to determine the accuracy of a gage, to be from about 7 to 27 percent of the product tolerance. According to one of the gage users, variation of 25 percent or less is acceptable. The results of the gage studies are shown in table IV.1.

Table IV.1: Results of Studies on Measuring Internal Pitch Diameter With Indicating Gages

Company	Product tolerance ^a	Measurement variation
SPS Technologies	0.0037	27
SPS Technologies	0.0032	25
SPS Technologies	0.0037	24
SPS Technologies	0.0032	23
Ford Motor Company	0.0044	11
Ford Motor Company	0.0045	7
Ford Motor Company	0.0051	7

^aProduct tolerance varies depending on the size of the fastener measured.

Industry was also concerned that indicating gages could not be calibrated accurately. Calibration of indicating gages is conducted by first measuring a threaded rod (external thread) or ring (internal thread) with a highly accurate thread setting gage. The threaded rod or ring and the measurement obtained by the setting gage are then used to calibrate the indicating gage.

Industry was concerned that the measurements obtained using different setting gages would vary greatly. However, experiments conducted by the American Society of Mechanical Engineers Screw Thread Committee in which threaded rings were measured by setting gages from five different organizations produced measurements that were within, or close to, the range required.

Estimated Costs of Proposed Specifications

DOD regulations require that, before changing specifications, (1) an initial justification for change be prepared; (2) industry comments be solicited; (3) a project control number be assigned; and (4) the cost impact be evaluated, when appropriate. As we reported in December 1990, the Air Force followed DOD regulations for changing the testing specifications of class 3 fasteners but did not initially perform a cost impact analysis. According to an Air Force official, the Air Force did not perceive a need to evaluate the cost impact of the proposed changes on the basis of its experience with previous specification changes. Another official could not remember performing a cost analysis for any specification change.

As a result of concerns about costs expressed by representatives from the aerospace and fastener industries, the Army, and the Subcommittee on Investigations of the House Committee on Armed Services, DOD requested that the Air Force study the cost impact of its proposed changes. Industry representatives stated that cost increases would result if the proposed changes were implemented because they would need to acquire and calibrate gaging equipment, spend more time on inspection, and train personnel. In response to these concerns, the Army temporarily withdrew its support of the proposed changes while it studied the associated costs. In July 1990 the Army completed its cost study and concluded that the cost impacts would be minimal. The Army submitted its report to the Investigations Subcommittee with a conclusion that the possibility of far-reaching cost and other economic implications were hard to envision.

In February 1991 the Air Force completed its cost analysis, concluding that cost impacts would be minimal, and the Army restated its concurrence with the proposed specifications. Subsequently, several industry groups polled their members and reported that the cost impacts would be substantially greater than those concluded by the Air Force.

Air Force Study

The Air Force studied the cost impacts on the government resulting from the issuance of the proposed specifications. In response to Army's concerns, the Air Force also looked at industry's costs in implementing the changes. The Air Force estimated that the cost to the government to implement the changes would be about \$11 million and the cost to industry would be about \$14 million, as shown in tables V.1 and V.2, respectively.

**Appendix V
Estimated Costs of Proposed Specifications**

Table V.1: Air Force's Estimate of Government Costs

Dollars in millions	
Recurring costs	
Defense Industrial Supply Center	\$3.7
Air Force	1.6
Navy	0.6
Subtotal	5.9
Nonrecurring costs	5.5
Total	\$11.4

Table V.2: Air Force's Estimate of Industry Costs

Dollars in millions	
Initial/nonrecurring costs for safety-critical items	\$3.9
Cost to measure internal pitch diameter	10.6
Total	\$14.5

The Air Force's estimate of government costs was based on estimates provided by the Defense Industrial Supply Center, the Air Force air logistics centers, and the Navy. The estimate provided by the Defense Industrial Supply Center of \$3.7 million was based on (1) increased expense in purchasing class 3 fasteners, particularly safety-critical items, of approximately \$2.7 million annually, and (2) increases in administrative and production lead times of approximately \$950,000 annually, including additional depot costs to maintain larger inventories because of longer lead times. The Air Force costs of \$1.6 million was provided by three of the its five air logistics centers. Two of the five air logistics centers reported that they would not incur any cost as a result of the proposed changes, whereas three reported costs based on estimates of costs they had experienced over 7, 12, and 25 months. The Navy based its cost estimate of \$0.6 million on one additional person per depot with no equipment costs included. (Navy officials stated the one person per depot concept is used in most of its cost estimates. They did not include equipment costs in the estimate because they did not know what equipment would be needed.)

Although the Army performed two studies (July and October 1990) and reached two different conclusions, it did not provide cost estimates for either. The first study concluded that the overall cost impact to the Army would be minimal, and the second study reported three major cost impacts:

- an increased cost in production incurred by the manufacturer and passed on to the government for the inspection of all safety-critical fasteners;
- the obligation of money for longer periods of time and the longer lead time between obligation of money and actual receipt of safety-critical fasteners due to the delay in having all these items inspected; and
- an increased frequency of receiving complaints from contractors, causing an increase in government management of contracts.

The Air Force used information from a telephone survey of eight major aerospace contractors, published cost data of eight gage manufacturers, and discussions with DOD and contractor personnel to develop its estimate of industry costs to implement the changes. The eight aerospace contractors estimated that the cost to update drawings and change internal procedures, on the basis of number items they believed would be designated as safety-critical, would be \$1.2 million (see table V.3). (The Air Force used this figure to determine that the total cost for all 25 aerospace prime contractors would be about \$3.9 million.) The Air Force reported that its overall estimates included the costs to update drawings, manuals, and procurement policies; provide additional training; and purchase additional measuring equipment to meet the changes (see table V.4). However, industry groups claimed the Air Force had not used all relevant factors (e.g., training personnel, engineering drawing changes, and calibration costs) when determining their costs.

Table V.3: Air Force's Estimate of Industry Costs to Implement Safety-Critical Provision of Proposed Specifications

Company	Cost per safety-critical item	Number of safety-critical items	Total cost
Pratt & Whitney	\$1,500	12	\$18,000
General Electric	400	0	0
Sikorsky	875	350	306,300
Hamilton Standard	400	0	0
McDonnell Douglas			
Helicopter	475	6	2,900
St. Louis and Long Beach	5,000	160	800,000
Boeing			
Vertol	650	25	16,300
Seattle	250	200	50,000
Northrop	3,000	10	30,000
Lockheed (Burbank)	500	0	0
Total			\$1,223,500

Note: The cost for each company has been rounded.

Table V.4: Air Force's Estimate of Industry Costs to Acquire Equipment Needed to Meet Changed Specifications

Industrial classification	Number of facilities needing new equipment	Number of devices per facility	Cost per facility at \$4,500 per device	Total cost
Fastener manufacturer	75	1	\$4,500	\$337,500
Distributor	135	1	4,500	607,500
Prime contractor	25	3	13,500	337,500
Original equipment manufacturer subcontractor	85	2	9,000	765,000
Subcontractor	1,900	1	4,500	8,550,000
Total	2,220			\$10,597,500

Industry Cost Estimates

Groups in the aerospace and fastener industries estimated the cost to implement the proposed changes to be more than the Air Force's estimate. The Aerospace Industries Association and the Industrial Fasteners Institute⁷ polled a small number of their member companies to determine the cost to their groups. The Association estimated that the costs would be \$517.8 million, and the Institute reported the costs would be \$33.7 million. The estimates from both groups included the costs of additional measuring equipment for safety-critical items, changes to engineering drawings, training personnel, product assurance, additional inspection time, and manufacturing and material costs.

The Aerospace Industries Association initially reported the costs for eight member companies (see table V.5). However, it later revised its estimates to reflect the costs for 25 prime contractors (see table V.6), the same number of contractors used by the Air Force in its industry cost estimate. The Association also estimated the costs to suppliers in implementing the change to be \$100 million. These cost are not included in table V.6.

⁷The Aerospace Industries Association is a nonprofit trade association that represents over 50 U.S. manufacturers of commercial, military, and business aircraft, helicopters, aircraft engines, missiles, spacecraft, and related components and equipment. The Industrial Fasteners Institute is a nonprofit trade association of North American manufacturers of bolts, nuts, screws, rivets, and all types of special formed parts. It has over 130 member companies (actual fastener producers), which account for about 75 percent of fasteners produced in the United States.

Table V.5: Aerospace Industries Association's Original Cost Estimate for Implementing Proposed Specifications

Dollars in millions		
Company	Nonrecurring/ initial costs	Recurring/ annual costs
Pratt & Whitney	\$61.5	\$0
General Dynamics	5.8	0
Bell Helicopter	6.7	0.8
Martin Marietta	1.7	0.4
Boeing	16.3	29.2
Lockheed	4.7	0
McDonnell Douglas	5.9	2.3
General Electric	30.4	0
Total	\$133.0	\$32.7

Table V.6: Aerospace Industries Association's Revised Estimate of Industry Costs

Dollars in millions	
Nonrecurring costs	\$415.6
Recurring costs	102.2
Total	\$517.8

Note: The original estimate was based on 8 prime contractors; the revised estimate was based on 25 prime contractors.

The Industrial Fasteners Institute based its estimate on the costs reported by five of its member companies (see table V.7). Four of the five companies reported that the cost to purchase measuring equipment would be from \$40,000 to \$2 million. The Institute has argued that major costs associated with the purchase of various measuring equipment will be necessary to implement the proposed changes. The companies used different items and assumptions in estimating their costs. For example, company A's estimate was based on the projected number of safety-critical parts ordered in 1 year. These costs include gage procurements and calibration, engineering training, and production inspection. Companies B, C, and D based their estimates on engineering, product assurance, manufacturing, and increased acquisition cost for material. Company E provided a detailed breakout of safety-critical and other items to be manufactured. Costs include \$27.8 million in manufacturing costs (e.g., inspection, \$2.3 million; tapping labor, \$6.8 million; and waste/scrap/rework, \$5.8 million) and \$5 million in capital expenses (e.g., tapping, \$3 million; gages, \$2 million).

Appendix V
Estimated Costs of Proposed Specifications

**Table V.7: Industrial Fastener Institute's
Cost Estimate for Implementing
Proposed Specifications**

Dollars in millions	
Company	Cost
A	\$0.5
B	0.2
C	0.1
D	0.1
E	32.8
Total	\$33.7

June 1991 Meeting Participants

The following agencies and organizations were present at the joint industry and government meeting held on June 24, 1991, to discuss information obtained during our review:

Department of Defense

- Office of the Secretary of Defense
- Office of the Inspector General
- Defense Logistics Agency
- Defense Industrial Supply Center

Air Force

- Office of the Special Assistant for Reliability and Maintainability
- Structures Division, Directorate of Flight Systems
Engineering, Aeronautical Systems Division

Navy

- Navy Gage and Standards Center
- Naval Sea Systems Command
- Naval Air Systems Command

Army

- Army Materiel Command

Other federal agencies

- National Institute of Standards and Technology
- Federal Mediation and Conciliation Service
- National Aeronautics and Space Administration

Aerospace Industries Association

- Lockheed
- Boeing

Industrial Fasteners Institute

- SPS Technologies

Other industry organizations

- Johnson Gage Company
- Sikorsky Aircraft
- Ford Motor Company
- Specaero Incorporated
- Mercury Gage Company
- ITW Southern Gage
- American Defense Preparedness Association
- Kaynar Manufacturing Division, Microdot Inc.

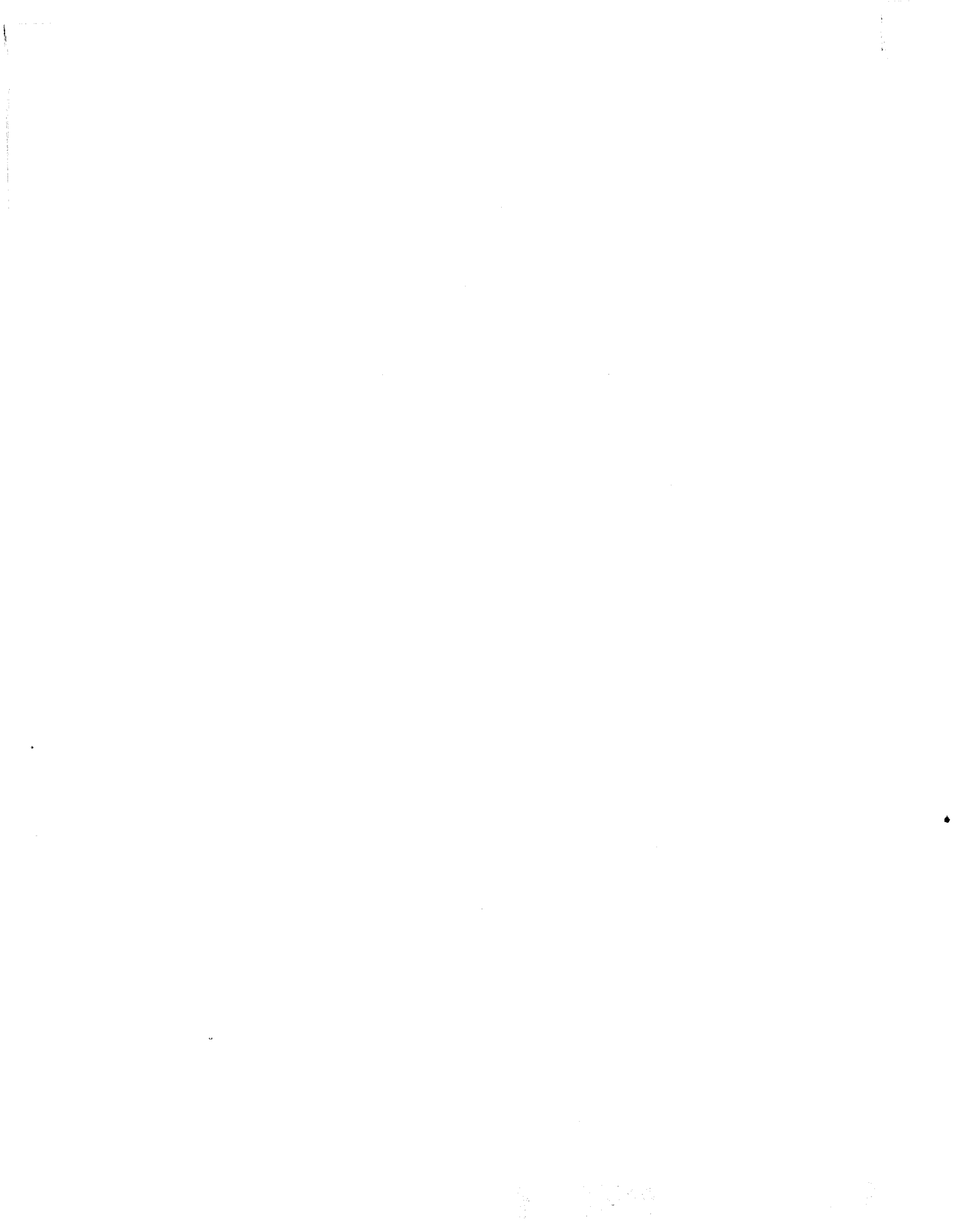
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