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Report to the Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives

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ARMY MAINTENANCE

Actions to Reduce the Likelihood of Helicopter Gear Failures

134381

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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 an October 29, 1986, request by your office, we reviewed the Army's actions to address problems with the helical torquemeter gear on OH-6A and OH-58A observation helicopters. This gear is contained in the accessory gearbox of the T63-A-700 engine, which, as of August 1986, was installed in 370 OH-6A and 1,365 OH-58A helicopters. These helicopters are used by both active and reserve forces at U.S. and overseas locations.

The helical torquemeter gear has been identified as the cause of six engine flight failures since 1979. Five of the failures involved OH-58A aircraft, and one involved an OH-6A aircraft. Two of these failures were class A incidents (resulting in destruction of an aircraft or over $500,000 in damage), and four were class C incidents (resulting in less than $100,000 in damage). (See p. 8, app. I, for complete definitions of the classes of incidents.) None involved personal injuries to personnel.

When the gear fails, it causes the engine to fail, and the aircraft crew must take emergency action to land the aircraft. One such action is autorotation, which allows the crew to use the free-spinning engine rotor to lower the aircraft to earth. However, autorotation requires that the aircraft be at a sufficient altitude to accomplish this procedure. Under certain situations, an engine failure at low altitude could result in serious personal injury, loss of equipment, or both.

In at least one of the incidents, the failed gear caused the engine to more or less explode which, in turn, dispersed shrapnel into the engine, crew, and passenger compartments, severed fuel and hydraulic lines, and caused a fire. After the latest failure in June 1986, the Army imposed certain operational restrictions and developed a plan of action that it believes will mitigate the torquemeter gear problem. The operational restrictions included

- not operating the aircraft less than 400 feet above ground (except for takeoffs, landings, and unit training), because the probability for a successful emergency landing decreases as the altitude decreases and
- not allowing passengers in the passenger compartment and ground crew members aft of the crew compartment during engine start-up because of the potential for dispersal of shrapnel if the engine explodes.

As an interim action, the Army plans to replace all used torquemeter gears installed in the aircraft and in stock with new gears of the current design. As of March 16, 1987, the Army had received 662 of these gears and had installed 189. Replacement of used gears is expected to be completed by September 1987 at a cost we estimate to be about $3 million. Ultimately, the Army plans to buy a redesigned version of the gear and install it in all aircraft. This gear is expected to be approved for production in September 1987 with initial deliveries beginning in January 1988. Installation of the newly designed gears is expected to be completed by December 1988. Based on information provided us, we estimate that the total cost of these efforts will be about $4 million.

The following summarizes the results of our review. Additional information, including a chronology of the six gear failures, is included in appendixes I through III.

Timeliness of the Army's Response to the Problem

In February 1980, shortly after the second incident, engineers at the Troop Support and Aviation Materiel Readiness Command suggested that the torquemeter gears be changed in the aircraft and that the engine manufacturer be retained to develop a plan of action to resolve the problem. Although these issues were discussed at the Directorate of Maintenance level, it is not clear whether these concerns were raised to higher management outside the Command.

In April 1984, the Army awarded a contract modification proposal to the engine manufacturer to examine the gear that had caused the second incident, develop a new gear, and formulate inspection criteria for the existing gears. The contractor, in August 1985, responded by recommending development of a new, thicker gear and incorporation of a dampener ring to absorb gear vibrations. The contractor developed and submitted a Component Improvement Program request to the Army in September 1985 for about $400,000 to accomplish these efforts. According to Aviation Systems Command officials, the gear problem was discussed as a safety-of-flight related issue but had not been formally identified as a safety-of-flight item and elevated to the appropriate Command level for a formal determination. Because of various internal administrative problems within the Aviation Systems Command and because the gear had not been determined a safety-of-flight item, Component Improvement Program funds for this effort in fiscal year 1986 were not approved. We were told that if the gear failure had been designated a safety-of-flight issue at that time, funding would have been approved.

The Army's current plans to address the problem are essentially the same as those proposed in 1980 by engineers at what is now the Aviation Systems Command and by the engine manufacturer in 1985. According to Army officials, funding for the Component Improvement Program has been approved because redesign of the gear is now recognized as a safety-of-flight issue.

The Army's Proposed Plan of Action to Resolve the Problem

After the sixth incident on June 7, 1986, involving a Tennessee Air National Guard aircraft, the Guard unilaterally grounded its OH-6A helicopters. In August 1986, the Aviation Systems Command drafted a safety-of-flight message, which recommended grounding the fleet of OH-6A and OH-58A helicopters, pending resolution of the torquemeter gear problem.

The Aviation Systems Command's recommended course of action was not adopted by a Crisis Action Team comprised of representatives from the Offices of the Deputy Chief of Staff for Logistics and Deputy Chief of Staff for Personnel; the Aviation Systems Command; the Army Safety Center; and the Army Aviation Center. In the Team's opinion, actions other than grounding the fleet could be taken to mitigate safety concerns. In making this decision, the Team determined that grounding would have a negative impact on readiness, probably continuing until about June 1988, the earliest date a new gear could be designed and installed or a later version of the engine installed.

On August 21, 1986, the Army awarded a contract to the engine manufacturer to provide 1,800 new gears of the current design to replace the used gears in the engines and in stock. On the same date, a contract was awarded to this same manufacturer for $400,000 to redesign the gear. The new, thicker gear will include a dampener ring to absorb gear resonance, which is thought to be a factor contributing to metal fatigue and eventual gear failure.

On August 22, 1986, the Team issued a precautionary message outlining operational restrictions to reduce the risk of flying the aircraft.

The Army also contracted, on September 25, 1986, with the engine manufacturer to perform destructive test comparisons between new and used gears of the current design. Although a final test report had not been completed at the time we completed our field work, the preliminary results do not show any significant difference between the strength of new gears (22,000 pounds per square inch) and that of used gears (21,000 pounds per square inch). According to Aviation Systems Command engineers, because of the small margin of safety between maximum gear stress—about 18,000 pounds per square inch—and minimum gear strength—about 22,000 pounds per square inch—the installed gears will be replaced by field maintenance teams as soon as the newly designed gears become available rather than waiting for the next scheduled engine overhaul.

Conclusions

The Army's short-term action to retrofit all aircraft with new gears of the current design—and its long-term solution—to redesign the gear and incorporate a dampener ring—are in essence the same actions that were proposed by the Army engineers in 1980 and the contractor in 1985.

The Army's actions to address the problem seem proper, and funding has been approved because redesign of the gear is now recognized as a safety-of-flight issue. In our opinion, the record does not present a clear picture as to whether a decision that the gear failure was a safety-of-flight issue should have been made in 1985 or earlier.

Objectives, Scope, and Methodology

The objective of our review was to determine whether the Army has taken timely and responsive action to eliminate or reduce the torquemeter gear problem and whether its proposed solution will solve the problem.

Our work was performed between November 1986 and March 1987 in accordance with generally accepted government auditing standards. We held discussions with cognizant Army officials at Army Headquarters; the Aviation Systems Command; the Army Safety Center; and Corpus Christi Army Depot. We obtained the views of engine manufacturing officials on the torquemeter gear problems and proposed solutions. We also reviewed the investigation files for the six aircraft incidents and reviewed and analyzed other documents, studies, and correspondence related to the incidents. A major portion of our effort involved piecing together—through discussions and a review of documents—the various actions that have transpired since 1979. This effort enabled us to obtain what we believe is a relatively complete picture of the events related to each specific incident, as well as the Army's continuing actions in addressing the gear problem.

As requested by your office, we did not obtain official comments from the Department of Defense. However, at various times throughout the review, we discussed the issues in this report with members of the Crisis Action Team, and we have incorporated their comments where appropriate.

We plan no further distribution of this report until 30 days from the date of the report unless you announce its contents earlier. At that time, we will send copies to interested parties and make copies available to others upon request.

Sincerely yours,

Frank C. Conahan

Frank C. Conahan
Assistant Comptroller General

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Abbreviations

AVSCOM	Army Aviation Systems Command
CCAD	Corpus Christi Army Depot
TSARCOM	Troop Support and Aviation Materiel Readiness Command
USASC	U.S. Army Safety Center

Background

When a U.S. Army aircraft incident occurs, several key organizations become involved in the investigation and reporting process. The U.S. Army Safety Center (USASC) at Fort Rucker, Alabama, gathers information on the events surrounding the incident and prepares a report on its findings. If a materiel failure is suspected, the Corpus Christi Army Depot (CCAD) performs various metallurgical and teardown analyses in an effort to determine the cause of the failure. The U.S. Army Aviation Systems Command (AVSCOM)[1] in St. Louis, Missouri, is also a participant in the incident investigation process. Its primary role is to formulate and initiate corrective actions for any materiel problems detected during the investigation.

One of the first actions performed in the investigation process is a determination of the amount of damage incurred. Each incident is classified according to the following criteria:

- Class A incidents are defined as mishaps costing $500,000 or more in combined personnel injuries and property damage or resulting in destruction of the aircraft or a fatality or occupational illness involving permanent total disability.
- Class B incidents are defined as mishaps costing $100,000 or more but less than $500,000 in combined personnel injuries and property damage or resulting in an injury or occupational illness involving permanent partial disability or the hospitalization of five or more personnel.
- Class C incidents are defined as mishaps costing $10,000 or more but less than $100,000 in combined personnel injuries and property damage or resulting in an injury or occupational illness involving the loss of one or more workdays.

These classifications are based upon damage estimates made by the unit or command experiencing the incident. The original classification may be amended later if the initial estimate proves incorrect.

Background on the Helical Torquemeter Gear Problem

The helical torquemeter gear is contained in the accessory gearbox of the T63-A-700 turbine engine. As of August 1986, this engine was installed in 1,365 OH-58A and 370 OH-6A observation helicopters. The helical torquemeter gear has been the cause of aircraft incidents since the mid-1960s. During the 1960s, four OH-6A helicopters experienced engine failures when the torquemeter gear failed while the helicopters

[1] In March 1984, the Troop Support and Aviation Materiel Readiness Command (TSARCOM) became the Aviation Systems Command (AVSCOM).

were in flight. Allison Division of the General Motors Corporation,[2] the engine's manufacturer, performed a gear strength analysis on the torquemeter gears in 1969 and concluded that double shot-peening of the gear teeth and rim would greatly increase the tensile strength of the gear and significantly reduce the chances of fatigue failure. Based on this finding, all torquemeter gears were double shot-peened in 1969. No further fatigue failures were recorded for either the OH-58A or the OH-6A for almost a decade.

However, beginning in 1979, problems with the torquemeter gear reappeared. Since April 1979, there have been six reported incidents of torquemeter gear fatigue failure. All of these incidents occurred while the aircraft were in flight and required the crews to take emergency landing actions. One such action employed is autorotation, which allows the crew to lower the aircraft using lift generated by the free-spinning engine rotor. However, for this maneuver to be successfully accomplished, the aircraft must be at a sufficient altitude. In at least one of the incidents, the failed gear caused the engine to explode and disperse shrapnel into the engine, passenger, and crew compartments. The shrapnel also severed fuel and hydraulic lines and started a fire. None of the incidents has resulted in injury to personnel.

As shown in table I.1, the first five failures involved OH-58A aircraft, and the sixth involved an OH-6A aircraft.

Table I.1: Torquemeter Failures Since 1979

Incident number	Date of incident	Incident class	Aircraft type	Location
1	April 27, 1979	C	OH-58A	Alabama
2	January 10, 1980	A	OH-58A	Germany
3	September 30, 1982	C	OH-58A	Germany
4	October 20, 1983	C	OH-58A	Korea
5	January 24, 1985	A	OH-58A	Germany
6	June 7, 1986	C	OH-6A	Tennessee

As a result of these incidents, various investigations and analyses have been performed by the Army Safety Center, the Corpus Christi Army Depot, the Aviation Systems Command, and the engine's manufacturer, and certain operational restrictions have been imposed to reduce the risk of operating these aircraft until the torquemeter gear problem is resolved.

[2]The Allison Division is now the Allison Gas Turbine Division.

In the following appendixes, we discuss key events and the Army's actions in response to each of the six incidents, its proposed interim action, and its ultimate solution to the gear problem.

Aircraft Incidents Between April 1979 and June 1986

This appendix discusses the actions taken by the Army in response to each of the six helical torquemeter gear incidents, which occurred between April 27, 1979, and June 7, 1986.

Key Events Related to the First Incident

April 27, 1979. A class C incident involving an OH-58A aircraft occurred at the Fort Rucker, Alabama, Aviation Center.

May 2, 1979. The Aviation Center requested that Corpus Christi Army Depot (CCAD) perform a teardown analysis of the failed part.

May 17, 1979. The failed engine was shipped to CCAD.

June 18, 1979. CCAD's Metallurgical Report concluded that the torquemeter gear had failed because of metal fatigue. No other materiel anomalies were noted. The report made no recommendations.

June 21, 1979. CCAD's Teardown Analysis Report contained the same conclusions as its Metallurgical Report. No recommendations were made.

December 11, 1979. The engine's manufacturer advised the Troop Support and Aviation Materiel Readiness Command (TSARCOM) that it could find no reason to question the information contained in the CCAD Report. TSARCOM categorized the incident as an isolated occurrence and concluded that it was not necessary to initiate corrective action.

Key Events Related to the Second Incident

January 10, 1980. A class A incident involving an OH-58A aircraft occurred in Germany.

January 13, 1980. TSARCOM was advised by the unit in Germany that the failed engine was being sent to CCAD for teardown analysis.

February 4, 1980. A TSARCOM engineer in the Maintenance Directorate drafted a memo noting that this was the second gear failure this year and that both failures were identical to those experienced in 1969. He recommended that TSARCOM Maintenance require CCAD to make magnetic particle inspections of the torquemeter gear at each overhaul and that the engine manufacturer be retained to help investigate these failures.

In a February 11 memo, he noted that the two recent failures were similar to those leading to the 1969 fix—double shot peening— and that Maintenance had initiated action requiring magnetic particle inspection at each overhaul. The engineer suggested that the engine manufacturer be retained to identify the cause of the failures and advise TSARCOM of the corrective action necessary.

February 8, 1980. A TSARCOM engineer in the Readiness Office advised his immediate supervisor that the potential for catastrophic failures was very real in view of the second gear failure. He noted that the failure was the same as the failure that had occurred back in the 1960s and that a solution to the problem had been determined to be to incorporate a snap ring (dampener ring) to absorb resonance frequency.

The engineer was unaware that the snap ring (dampener ring) fix had not been incorporated into the T63-A-700 engines in the 1960s. He also noted that fatigue failures of this kind cannot be detected until a crack appears and that the only positive approach was to change the gears. When the engineer became aware that the snap ring had not been incorporated as a fix for the earlier incidents, he suggested modifying the gears to include a snap ring. His supervisor advised him that he was "anticipating a problem." As a result, the engineer wrote a memo for the record (dated February 11) stating that he was no longer pursuing the matter.

February 21, 1980. TSARCOM's Safety of Flight Review Committee's investigation noted that torquemeter gear failure was an old problem that had started recurring. The engine manufacturer was requested to provide input on what should be done.

March 6, 1980. The engine manufacturer met with TSARCOM's Directorate of Maintenance. As a result of the meeting, it was decided that a possible short-term solution was to use a snap ring dampener and a long-term solution was to redesign the gear.

March 20, 1980. TSARCOM's Safety of Flight Review Committee noted that the engine had not changed in 10 years and that it was time to consider moving to the T63-A-720 engine. The Maintenance representative advised the Committee that incorporating the snap ring dampener as an interim solution would be expensive.

March 26, 1980. CCAD's Metallurgical Report identified the cause of gear failure as metal fatigue originating at an inclusion in the metal. No other materiel discrepancies were found that could have contributed to the gear's failure. The report made no recommendations.

April 3, 1980. CCAD's Teardown Analysis Report contained the same conclusions as its Metallurgical Report. The report contained no recommendations.

April 28, 1980. The Army Safety Center report recommended that the Department of the Army's Materiel Development and Readiness Command identify the cause of the gear failure and develop a process to detect onset of the problem.

The report also recommended that the quality control during manufacture of the gear be reviewed. (See June 18, 1980, response from the contractor, p. 13.)

May 15, 1980. TSARCOM replied to the Safety Center's April 28 report, advising that TSARCOM's Safety of Flight Review Committee was studying the matter.

April 29, 1980. TSARCOM's Safety of Flight Review Committee met and reported that an interim solution was being delayed because the engine manufacturer was performing additional analysis.

June 18, 1980. The engine manufacturer advised TSARCOM that a scanning electron microscope examination had disclosed that the origin of fatigue was subsurface and associated with an inclusion. No other discrepancies were observed. The manufacturer also reviewed the processing and inspection criteria for this gear and determined them to be adequate. The failure of the torquemeter gear was considered an isolated incident.

June 26, 1980. TSARCOM's Safety of Flight Review Committee considered the engine manufacturer's report as consistent with CCAD's Teardown Analysis Report. The Committee recommended closing the case.

July 9, 1980. The engine manufacturer's Technical Data Report concluded that the origin of fatigue was a subsurface inclusion of aluminum oxide. The report also stated that the gearshaft material conformed to the requirements of the engineering drawing.

Key Events Related to the Third Incident

September 30, 1982. A class C incident involving an OH-58A aircraft occurred in Germany.

October 1982. The failed engine was shipped to CCAD for teardown analysis.

The technical report prepared by the accident investigation board recommended that the Army Safety Center disseminate the facts and circumstances contributing to the incident in a bulletin and that CCAD perform a teardown analysis to determine the cause of engine failure.

January 24, 1983. CCAD's Teardown Analysis Report concluded that the torquemeter gear failure was due to metal fatigue. The report made no recommendations.

Key Events Related to the Fourth Incident

October 20, 1983. A class C incident involving an OH-58A aircraft occurred in Korea.

January 10, 1984. The incident investigation board recommended that the engine be sent to CCAD for analysis and that, after determining the cause, CCAD should disseminate its findings. The Safety Center endorsed the recommendation.

January 31, 1984. CCAD's Metallurgical Report concluded that the gear had failed due to metal fatigue. No other metallurgical anomalies were noted, and the report contained no recommendations.

February 13, 1984. CCAD's Teardown Analysis Report concluded that the gear had failed due to metal fatigue. The report noted that this was the third known failure of the gear with an "E" part number suffix. (See response dated June 25, 1985, p. 15.) CCAD recommended an engineering study to determine if an improved gear should be developed.

April 10, 1984. The engine manufacturer was asked by AVSCOM to correct the gear problem at no cost to the government. The engine manufacturer declined on the basis that the gear problem was an Army problem.

April 12, 1984. A modification to an existing engineering service contract was issued to the engine manufacturer to (1) examine the failed gear from the second incident, (2) develop a new gear, and (3) develop inspection criteria for existing gears. (See response dated August 15, 1985, p. 15.)

April 18, 1984. The engine manufacturer's Technical Data Report on the fourth incident concluded that the gear failure had been due to metal fatigue that originated at an aluminum-rich inclusion. The report contained no recommendations.

Key Events Related to the Fifth Incident

January 24, 1985. A class A incident involving an OH-58A aircraft occurred in Germany.

March 20, 1985. CCAD's Metallurgical Report concluded that the torquemeter gear had failed due to metal fatigue.

April 9, 1985. CCAD's Teardown Analysis Report contained the same conclusions as its Metallurgical Report. The report also noted that this was the fifth known failure of the torquemeter gear with a suffix "E" part number. CCAD recommended that all gears with a suffix "E" part number be replaced at the next overhaul.

April 19, 1985. The above report was sent to AVSCOM and the Army Safety Center.

May 16, 1985. The Army Safety Center's report noted that there had been four other incidents where suffix "E" gears had failed and that suffix "E" gears might not have been manufactured with the same standards as had the other gears in the system. The report recommended removal of suffix "E" gears from stock and replacement of these gears with a later version of the gear during the next overhaul. This report was sent to the Army Materiel Command[1] on May 22.

June 25, 1985. An AVSCOM engineer noted that about 90 percent of the torquemeter gears in the Army supply system are suffix "E" gears and that the suffix "E" has nothing to do with the gear failures.

August 15, 1985. In response to its April 12, 1984, contract modification, the engine manufacturer advised AVSCOM that (1) gear failures that occur at the rim or web are due to gear vibration and (2) the effect of incorporating a dampener ring in the existing gear greatly reduces the responsiveness of vibratory modes in the gear without adversely affecting mode frequencies or stress distribution in the gear. The recommended solution was to incorporate a dampener ring and increase gear rim and

[1]Formerly the Department of Army Materiel Readiness and Development Command.

web thickness. These actions would require development of a new torquemeter gear.

September 20, 1985. The engine manufacturer submitted a proposal for a Component Improvement Program to address the gear problem. The estimated cost was $400,000.

September 25, 1985. The Army Materiel Command responded to the Army Safety Center's report, dated May 16, by agreeing with the report's recommendations, contingent upon the availability of a newly designed gear planned as part of the fiscal year 1986 Component Improvement Program.

October 1985 to May 1986. Various internal delays[2] at AVSCOM resulted in a lack of action in response to the Component Improvement Program proposal.

May 12, 1986. Component Improvement Program funds for the T63-A-700 engine ($1 million) for fiscal 1986 were eliminated.

Key Events Related to the Sixth Incident

June 7, 1986. A class C incident involving an OH-6A aircraft occurred in Tennessee.

June 7, 1986. Tennessee National Guard grounded its OH-6A aircraft fleet.

July 28, 1986. CCAD's Metallurgical Report concluded that the torquemeter gear had failed due to metal fatigue. A crack had developed at a surface pit near the edge of the rim. The gear had also failed to meet carburized case depth requirements and was of marginal hardness. The report recommended (1) changing gear material from aircraft quality to aircraft premium quality, (2) increasing gear web thickness, and (3) improving quality control procedures for the carburizing process.

September 22, 1986. CCAD's Analytical Investigation Report concluded that the gear had failed due to fatigue. The report recommended removing all part number 6871218 gears from service and, if operating time on the gears could be determined, establishing an operating time requirement for changing the gears.

January 1987. Tennessee National Guard lifted the fleet grounding.

[2]See app. III, p. 22, for more details on the types of delays.

Corrective Actions Taken Since Last Incident

The Tennessee National Guard unilaterally grounded its OH-6A fleet after the June 7, 1986, incident. On July 28, 1986, Corpus Christi Army Depot (CCAD) reported to Army Aviation Systems Command (AVSCOM) that this was the sixth incident involving T63-A-700 torquemeter gear failure attributable to metal fatigue. Shortly thereafter, AVSCOM drafted a message recommending that all OH-58A and OH-6A helicopters that use this engine be grounded. After consideration by higher Army levels, the Army decided not to ground the fleets, but instead to impose operating restrictions while additional investigations into risk and cause were conducted.

Grounding the OH-58A/OH-6A Fleet Considered

On August 4, 1986, AVSCOM's Directorate of Engineering recommended grounding all OH-58A/OH-6A helicopters with engines that had more than 2,000 hours of operating time until an improved gear could be designed, procured, and installed. AVSCOM's Deputy Commanding General, after reviewing the recommended action, decided that since it would ground about 90 percent of the fleet and the actual age of gears in the remaining 10 percent of the aircraft was unknown, the entire fleet should be grounded. A draft grounding message was distributed on August 6, 1986, to various Army levels for comment and concurrence. U.S. Army Safety Center's (USASC's) Safety Officer for T63-A-700 engines concurred in this action by telephone on August 7, 1986. On August 8, 1986, a Crisis Action Team comprised of key officials from the Offices of the Deputy Chiefs of Staff for Logistics and Personnel, the Army Materiel Command, AVSCOM, and USASC held a telephone conference to consider the grounding message.

The team concluded that there was insufficient information to make a prudent decision to ground the aircraft at that time. It noted that perceived potential fixes to correct the problem were expected to take nearly 2 years and would affect 1,735 aircraft; that the extent of risk, estimated at less than one failure per year, was low and had not been sufficiently analyzed; and that the causes of the failures had not been sufficiently determined. Rather than ground the fleet, the team decided to issue a precautionary message with flight operating restrictions to reduce risk while flying the aircraft, pending the outcome of further investigation and analysis.

Extent of Risk

AVSCOM's Directorate for Systems and Cost Analysis performed a statistical analysis of the six failures on August 8, 1986. It concluded that the failures were random, were not related to the age of the gear, and did not appear to be increasing. Further, it projected that there would be only about one failure per year.

On August 18, 1986, the Army Material Systems Analysis Agency, at AVSCOM's request, submitted its analysis using more advanced statistical methodology. The analysis concluded that failures were increasing with time and were related to the age of the gear. Further, it projected that 1.8 failures could be expected in the next 12 months. In August 1986 the engine manufacturer also estimated that 2.4 gear failures could be expected in the next 12 months.

The Crisis Action Team decided that the risk of an incident was low and that any risk to the aircraft crew would be significantly reduced by imposing operational restrictions through the issuance of a safety-of-flight message. After numerous drafts and coordination with USASC and others, this message was issued on August 22, 1986. It imposed the following operational limitations (subject to waiver by local commanders) on the use of OH-58A and OH-6 aircraft.

- In order to provide sufficient altitude for emergency landing (i.e., autorotation) flight altitudes should be restricted to a minimum of 400 feet above ground level except when taking off and landing, when required for instructional periods, or when required for tactical unit training.
- No passengers should be allowed to ride in the back seat (which is near the engine) as shrapnel had penetrated this area when the failed gear caused the engine to explode.
- To preclude injury from shrapnel, fire guards should stand forward of crew stations during engine starts. (A similar message was issued on December 2, 1986, to include maintenance personnel working on or around the engine.)

Investigations and Corrective Actions

The Army's short-term solution to resolve the torquemeter gear problem is to replace all existing used gears of the current design with new gears of the same design. Its long-term solutions are to replace all gears with gears of a new design and, over the next 7 years, replace all T63-A-700 engines with T63-A-720 engines. Replacement of the engines is intended to resolve more than just the torquemeter gear problem.

Replacement of Used Gears With New Gears of the Current Design

AVSCOM decided that the most immediate corrective action would be to procure new gears of the current design to replace the used, installed and in-stock gears of the same design, pending development of a newly designed gear under the then-contemplated fiscal year 1986 Component Improvement Program. This action was predicated on the assumption that operating hours on a gear were the same as the operating hours of the engine[1] it was installed in.

On August 21, 1986, AVSCOM contracted with the engine manufacturer to provide 1,800 new gears of the current design to be used to replace all used gears in the Army system. In conjunction with this, AVSCOM recognized that the operating time of each gear should be tracked and that a limit should be placed on operating hours. As of August 7, 1986, gear hours must be recorded, and a gear must be replaced after 2,000 operating hours.

Because finite life for the new gears being installed had not been determined, AVSCOM contracted with the engine manufacturer on September 25, 1986, to measure the relative fatigue strengths of used and new gears in order to determine if the new gears would minimize failure. This action was also intended to validate the previously measured fatigue strength in the manufacturer's 1969 study. Although it was not a contractual objective, the Army hoped that it would provide more confidence in its estimate of the 2,000-hour life of the gear or provide a more precise life expectancy.

Although the test reports have not been completed, results as of March 1987 indicate that there is very little difference in the fatigue strength of used and new gears. The 1969 study determined the maximum stress would be about 18,000 pounds per square inch, as compared to a minimum strength of about 56,000 pounds per square inch. The current study estimates the minimum strength of new gears to be about 22,000 pounds per square inch and that of the used gears to be about 21,000 pounds per square inch. Thus, the difference between the peak stress and minimum strength is significantly less than was computed in the 1969 tests. These test results have changed the Army's plan for installing the newly designed gears. Initially, the plan was to change gears at the next scheduled engine overhaul or 2,000 hours. However, the plan is now to install the newly designed gears as soon as they

[1]This assumption may not be valid because the operating hours on torquemeter gears has not been tracked. During overhaul, a torquemeter gear with more or fewer operating hours than the gear that is removed may be installed in the engine.

become available. In addition, reevaluation of 1969 test measurement data indicated a failure rate of 6 gears in 2,000 rather than 1 failure in 4 billion as previously concluded in the 1969 study.

Based on information AVSCOM provided to us, we estimate the cost of replacing the used gears with new gears of the current design at about $3.0 million. Breakdown of these costs is shown in table III.1.

Table III.1: Cost to Replace Used Gears With New Gears of the Current Design

Item	Cost
Procurement of 1,800 new gears	$2,262,105
Labor to install 1,700 gears	544,000
Tools, kits, and miscellaneous	220,000
Total estimated cost	**$3,026,105**

As of March 16, 1987, the Army had received 662 of the new gears of the current design and had installed 189 of them. AVSCOM expects delivery of the new gears of the current design to be completed in August 1987 and installation of the gears by September 1987. Once the gear is installed in an OH-58A or OH-6A, that helicopter will no longer be subject to flight operation restrictions.

Replacement of All Gears With Newly Designed Gears

AVSCOM planned to replace the newly installed gears of the current design with newly designed gears at the time of each helicopter's next engine overhaul. The Army requires an overhaul of the T63-A-700 engine every 1,000 operating hours but has been averaging between 600 and 700 hours between overhauls. However, based on stress/strength tests currently being conducted, AVSCOM now plans to replace the gears as soon as the redesigned gears are available rather than waiting until the mandatory engine overhaul or gear replacement times are reached.

In 1970, the engine manufacturer received production approval for its commercial version of the T63-A-720 engine. The commercial version, called the C-20B engine, has a torquemeter gear in it much like the one in the T63-A-700 engine, except that the gear has a snap ring (dampener ring) incorporated into the rim of the gear to reduce vibration stresses. An AVSCOM engineer who was involved in the helicopter program in the late 1960s thought that the dampening ring design had been adopted as the corrective action for the four OH-6A torquemeter gear failures in the mid-1960s. In actuality, the Army had adopted the double shot-peening process as the corrective action, because the shot-peening process only involved reworking the existing inventory of gears rather than buying all new gears.

The C-20B engine is used in Army OH-58C helicopters and is identified as the T63-A-720 engine. AVSCOM officials informed us that the Army has not experienced any incidents of torquemeter gear rim fatigue failures on OH-58C helicopters. Also, the engine manufacturer reports that there have not been any torquemeter gear failures in over 27 million operating hours involving 10,500 C-20B and T63-A-720 engines.

In April 1984, AVSCOM had contracted with the engine manufacturer to rework and fabricate a new design of the existing gear. The manufacturer had reworked some existing gears by incorporating a dampening ring into the gears. However, tests of these gears showed that the gear rim was weakened by incorporating the dampening ring into the existing gear rim. The manufacturer, in August 1985, recommended development of a new gear incorporating a dampener ring and a thicker gear rim and web and in October 1985 submitted a Component Improvement Program proposal to accomplish these efforts. However, as a result of various delays[2] at AVSCOM, funds for the fiscal year 1986 Component Improvement Program were eliminated, and the redesign effort was delayed until the safety-of-flight message was issued in August 1986. On August 21, 1986, AVSCOM contracted with the engine manufacturer to design a new T63-A-700 torquemeter gear, which incorporates a dampener ring assembly. As an added precaution, the newly designed gear will be manufactured from the stronger aircraft premium quality steel rather than aircraft quality steel.

AVSCOM expects that the new gear design will be approved for production in September 1987 and that the first production gears will be delivered beginning in January 1988. Installation of these gears is expected to be completed by December 1988. Because strength tests on the new and used gears of the current design are not showing any significant differences, AVSCOM may not wait for the engines to be overhauled to install the new gear design. Instead, it may send teams to the field to replace the gears.

As shown in table III.2, we estimate that the cost to replace the existing gears with gears of the new design will be $4.0 million.

[2]The delays resulted from a lack of a formal urgency statement, attempts to change from a cost-plus-fixed fee to a fixed price contract, and the need for additional funds necessitated by a price increase because of the proposed change in contract type.

Table III.2: Cost to Replace Gears With Newly Designed Gears

Item	Cost
Cost of design effort	$400,000
Procurement of 1,800 gears of the new design	2,880.000
Labor to install 1,700 gears	544,000
Other	220,000
Total estimated cost	**$4,044,000**

Replacement of All T63-A-700 With T63-A-720 Engines

As early as 1980, AVSCOM considered replacing all T63-A-700 engines with T63-A-720 engines. This action is not driven by the need to resolve the torquemeter gear problem. Instead, it is intended to solve a lack of power problem in the T63-A-700 engine, which has been a long-standing problem. The engine replacement program is planned for fiscal years 1987 through 1993 and is estimated to cost more than $200 million.

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