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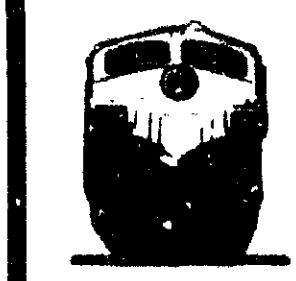

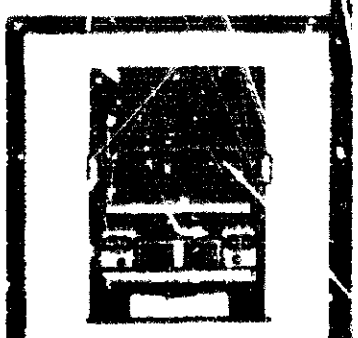

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

WESTERN HELICOPTERS, INC.,
BELL UH-1B, N87701
VALENCIA, CALIFORNIA
JULY 23, 1982

NTSB/AAR-84/14
(SUPERSEDES - - NTSB/AAR-84/02)

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

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15. Supplementary Notes

16. Abstract On July 23, 1982, at 0220 Pacific daylight time, a Bell UH-1B, N87701, registered to Rocky Mountain Helicopter, Provo, Utah, and operated by Western Helicopters, Inc., Rialto, California, crashed during the filming of a movie at Indian Dunes, Valencia, California.

The helicopter was being used in conjunction with the filming of a motion picture scene depicting a village typical of villages in Viet Nam which was under attack from heavy ordnance. The helicopter was used as a camera platform as well as playing an active role in the movie sequence. The helicopter was hovered about 25 feet above the village and nearly directly above the location where special effects explosives were detonated to simulate the heavy ordnance. As the pilot turned his helicopter to the left to provide camera coverage, the helicopter's tail section was engulfed in a fireball created by the detonation of a special effects explosion. The tail rotor assembly separated and the helicopter descended out of control. The helicopter's main rotor blade struck and fatally injured three actors on the ground. The six occupants on the helicopter sustained minor injuries, and the aircraft was damaged substantially.

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On March 6, 1984, the National Transportation Safety Board adopted the report and probable cause of the accident. On March 16, 1984, Mr. John Landis submitted a petition for reconsideration of probable cause of the probable cause that was adopted in the original report. As a result of Mr. Landis' petition, the accident report and the probable cause have been revised.

The National Transportation Safety Board determines that the probable cause of the accident was the detonation of debris-laden high temperature special effects explosions too near to a low flying helicopter, leading to foreign object damage to one rotor blade and delamination due to heat to the other rotor blade, the separation of the helicopter's tail rotor assembly, and the uncontrolled descent of the helicopter. The proximity of the helicopter to the special effects explosions was due to the failure to establish direct communications and coordination between the pilot, who was in command of the helicopter operation, and the film director, who was in charge of the filming operation.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: October 30, 1984

WESTERN HELICOPTERS, INC.
BELL UH-1B HELICOPTER, N87701
VALENCIA, CALIFORNIA
JULY 23, 1982

SYNOPSIS

On July 23, 1982, at 0220 Pacific daylight time, a Bell UH-1B helicopter, N87701, registered to Rocky Mountain Helicopters, Provo, Utah, and operated by Western Helicopters, Inc., Rialto, California, crashed during the filming of a movie at Indian Dunes, Valencia, California.

The helicopter was being used in the filming of a motion picture scene depicting a village typical of villages in Viet Nam which was under attack from heavy ordnance. The helicopter was used as a camera platform as well as in an active role in the movie sequence. The helicopter was hovered about 25 feet above the village and nearly directly above the location where special effects explosives were detonated to simulate the heavy ordnance. As the pilot turned his helicopter to the left to facilitate camera coverage, the helicopter's tail section was engulfed in a fireball created by the detonation of a special effects explosion. The tail rotor assembly separated, and the helicopter descended out of control. The helicopter's main rotor blade struck and fatally injured three actors on the ground. The six occupants on the helicopter sustained minor injuries, and the aircraft was damaged substantially.

The National Transportation Safety Board determines that the probable cause of the accident was the detonation of debris-laden high temperature special effects explosions too near to a low flying helicopter leading to foreign object damage to one rotor blade and delamination due to heat to the other rotor blade, the separation of the helicopter's tail rotor assembly, and the uncontrolled descent of the helicopter. The proximity of the helicopter to the special effects explosions was due to the failure to establish direct communications and coordination between the pilot, who was in command of the helicopter operation, and the film director, who was in charge of the filming operation.

1. FACTUAL INFORMATION

1.1 History of the Flight

On the afternoon and evening of July 22, and the early morning of July 23, 1982, a cast of actors and a movie production crew were filming a segment of a motion picture at Valencia, California. The segment of the movie was a Viet Nam war scene in which a village was under attack by heavy ordnance. The movie set consisted of 11 bamboo huts located along the shore of a shallow manmade river. The scenario included

a Bell UH-1B helicopter, N87701, which served as both a movie prop and a platform from which some of the ground action would be filmed. The movie production required the detonation of special effects explosive devices prepositioned on the ground to simulate the heavy ordnance attack.

The film director was in charge of the filming sequence. He determined the effects that he wanted to create on film and discussed these effects and the placement of explosives to produce them with the special effects coordinator. 1/ The special effects coordinator, in turn, instructed the special effects technicians about the placement of the explosive devices. During the filming sessions, the special effects technicians initiated the detonation of the devices in accordance with cues agreed upon in previous discussions with the special effects coordinator.

Three filming sessions were scheduled at the movie set on July 22 and 23. (See figure 1.) About 2100 P.d.t, 2/ the helicopter departed the takeoff/landing area for the first filming session and proceeded about 600 feet east to the movie set. The helicopter was used as a camera platform during this session, hovering above the set while the ground scene was filmed. The special effects devices were detonated to simulate the ordnance as specified in the script. When the scene was completed, the helicopter returned to the takeoff/landing area.

The helicopter returned to the movie set about 2330 for the second filming session. During this scene, the pilot hovered the helicopter over the set while more special effects explosive devices were detonated. One special effects device had been placed in the water and was detonated while the helicopter was nearly above it. The pilot noted afterward that the water which shot into the air as a result of the explosion was dispersed by the helicopter's rotor system and obscured the pilot's vision through the windscreen for several seconds. Witnesses who were on the ground estimated that the geyser and some of the fireballs which resulted from special effects detonations during this filming session rose as high as the 98-foot cliff behind the village. The two cameramen and one of the stuntmen aboard the helicopter stated during postaccident interviews that they had become concerned about the exposure of the helicopter to the heat generated by the special effects detonations during this filming session.

At the postflight debriefing following the 2330 filming session, the helicopter pilot expressed his aggravation to the director about the unexpected eruption of water, and he further related his concern to the unit production manager (UPM) regarding the potential hazard to the helicopter caused by debris produced by the special effects explosions. The UPM, who had been aboard the helicopter during the second filming session, assured the pilot that he would advise the film director of these concerns. The filming activity was suspended about 2345 for a 1-hour break. The UPM drove to the set and had lunch with the director. When he returned to the helicopter, he assured the pilot that during the third filming session the helicopter was to remain over the water and that there would be nothing to be concerned about.

Preparations for the third filming session resumed after the break. The script to be enacted during this session required that an adult actor carry two children from the village and wade across the river while special effects devices were detonated to simulate the heavy ordnance attack. The helicopter was to hover above the river as a part of the scenario and to make a 180° left hovering turn to provide appropriate camera vantage angles. The scene was to be filmed from cameras both on the ground and in the

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1/ The special effects coordinator was licensed by the State of California as a pyrotechnic operator.

2/ All times herein are Pacific daylight time based upon the 24-hour clock.

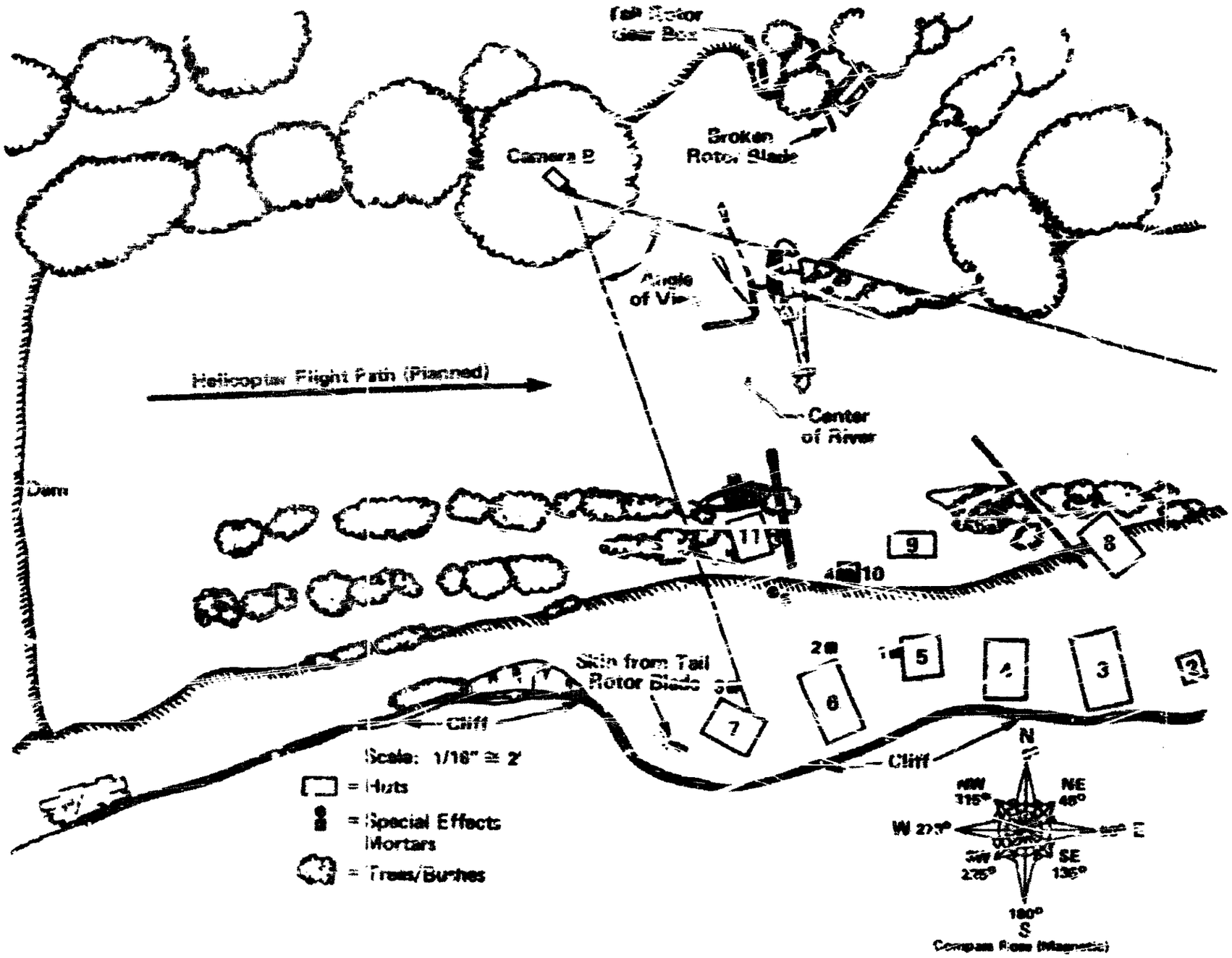

Figure 1.—Accident site.

helicopter. Two stuntmen aboard the helicopter were to fire blank rounds from machine guns on both sides of the craft. The script called for the total destruction of the village by the special effects explosives when the helicopter was over the north shore of the river. A rehearsal of the scene was scheduled before the final filming.

Before the rehearsal, the helicopter pilot walked through the movie set to review the scenario for the scheduled filming session. He personally checked the security of the cardboard and palm frond roofs of the village huts. He was concerned that the helicopter rotor downwash might dislodge these roofs, or portions thereof, and cause them to be swept up into the rotor system. The pilot did not receive, nor did he actively seek, any information from the special effects coordinator or the UPM regarding the sequence, timing, or positioning of the special effects explosions. He stated to the special effects coordinator that "as long as no debris is allowed to enter the rotor system, and nothing is set off under the helicopter, it doesn't matter which structures you have rigged for a firebomb." During interviews conducted by the Safety Board following the accident, the UPM indicated that he had assured the pilot that the helicopter would not be over any special effects explosive devices during the filming sequence.

About 0200, on the 23rd, the helicopter was flown to the movie set to participate in a rehearsal of the scene. The helicopter initially was positioned about 40 feet above the center of the river. There were no special effects devices detonated during the rehearsal. The turbulence generated by the helicopter rotor system during its left turn obscured visibility to the extent that one of the special effects technicians obtained a welder's hood to protect his eyes from the flying dirt. No other difficulties were apparent during the rehearsal.

About 0218, the helicopter took off again for the filming of the scene. In addition to the pilot and the two stuntmen who were to fire the machine guns, the UPM and two cameramen were on board the helicopter. The UPM was sitting in the left front seat to operate a spotlight, one of the cameramen was on the left side of the helicopter, and the two stuntmen with machine guns were positioned by the side doors, one on the left and one on the right. The other cameraman was standing in the passenger compartment. According to the cameraman on the left side, the helicopter initially appeared to follow the same route down the center of the river as it had during the rehearsal flight. (See figure 1.) When the helicopter passed over the dam, he climbed out on the left skid. He then realized that the helicopter was much lower than it had been during the rehearsal and that it was over the village on the south shore rather than near the center of the river. The cameraman on the north shore of the river stated that the helicopter arrived over the sampan area at a height of about 40 feet, and that while hovering there the director shouted commands through a megaphone, including the command for the helicopter to "get lower." The director later stated that he did not recall having given that command. According to the assistant director who had a VHF communications radio and who was standing near the director, the director asked for the helicopter to descend lower. The assistant director could not recall having transmitted the directions to descend to the UPM, and the UPM could not recall having received the directions. The pilot stated that after arriving over the set at 60 to 70 feet, he descended to align his main rotor with a strata line on the adjacent cliff at a height of about 35 feet above the set. He then heard directions over the VHF radio to descend lower. A review of the film from the camera on the north shore of the river showed that after the helicopter descended into view and stabilized in a hover, the special effects charges began to explode.

After three explosions, the helicopter began a level hovering left turn to permit the cameraman on the left skid to film the actors as they waded across the river. A fourth special effects device was detonated, followed less than 0.1 second later by a fifth detonation. As the fifth device was detonated, a column of gasoline/sawdust mixture which it had raised erupted into a fireball which engulfed the tail section of the helicopter.

The helicopter stopped turning to the left and stabilized on a magnetic heading of about 009° for less than 1 second. The helicopter began a right ascending turn until it left the film frame. About 2 seconds later the helicopter reappeared in the film frame in about a 20° tail down attitude, and was still turning to the right, but descending. The tail rotor assembly was missing. The helicopter crashed into the peninsula on the north side of the river in a nosetup 45° left bank attitude, while the helicopter was still turning to the right. The helicopter's main rotor blades continued to turn to the left and struck the adult actor and the two children as they were crossing the river. This entire sequence of events, including the explosions resulting from the detonations of special effects devices and the subsequent crash of the helicopter, was recorded on film by the ground cameras. The accident occurred at night about 0220 hours at latitude 34° 25 feet north and longitude 118° 35 feet west. The elevation of the crash site was 1,000 feet m.s.l.

The special effects coordinator and special effects technicians stated after the accident that radio communication was provided only between the coordinator and the technician who was to detonate the first special effects device. The other technicians had been instructed to begin detonating their explosives when they heard the machine guns aboard the helicopter begin to fire. Although the special effects coordinator stated that each technician was responsible for ensuring that his area was clear before firing his explosives, the technician who detonated the explosives nearest to the helicopter stated that the safety of the helicopter had not been discussed nor had he been apprised of the helicopter's proposed flight pattern. The technician also observed that his vision had been restricted by the welder's hood he was wearing during the filming session.

1.2 Injuries to Persons

Injuries	Helicopter Crew	Ground Personnel	Total
Fatal	0	3	3
Serious	0	0	0
Minor/None	6	40	46
Total	6	43	49

1.3 Damage to Aircraft

The aircraft was destroyed.

1.4 Other Damage

Not applicable.

1.5 Crew Information

The pilot was certificated in accordance with applicable Federal Air Regulations (FAR). He had completed a biennial flight review 2 months before the accident, and

he had conducted six night landings in Bell UH-13 helicopters during the preceding 90 days. According to company and pilot records, he had accumulated 4,514 flight-hours, 4,408 of which were in rotorcraft, and 1,538 of which were in the Bell 204/205/UH-1B. This was the pilot's fourth employment in movie production work, but it was his first experience flying in the vicinity of special effects devices.

The pilot reported for duty about 1830 hours on the evening of July 22. After darkness, he began a series of short flights between the takeoff/landing area and the movie set before the 2100 filming segment. The pilot flew the helicopter for a total of about 20 minutes during the estimated 7 hours 50 minutes he was on duty.

1.6 Aircraft Information

Bell UH-1B helicopter, N87701, serial No. 64-14038, was owned by Rocky Mountain Helicopter, Inc., Provo, Utah, and was operated by Western Helicopters, Inc., Rialto, California. The helicopter was operating under a temporary experimental category airworthiness certificate because it had been modified for use in filming activity. The operating limitations portion of the certificate permitted the pilot to carry passengers for the purposes of film production and to operate at night in VFR conditions. The certificate imposed no altitude operational limits other than those in 14 CFR 91. A review of the maintenance records showed that the helicopter had flown 11 hours since the last annual inspection on April 20, 1982. At the time of the accident, the aircraft had accumulated 5,817 flight-hours. All maintenance inspections prescribed by current regulations had been completed.

1.7 Meteorological Information

The pilot and other witnesses at the scene reported that the skies were clear (moonlight bright), that the visibility was unrestricted, and that the wind was from the east at less than 5 knots. Burbank-Glendale-Pasadena Airport, Burbank, California, located about 23 miles southeast of the accident site, reported the 0145 hours surface weather observation as:

> Scattered clouds at 20,000 feet; visibility--15 miles; temperature --75° F; dewpoint--60° F; wind--calm; altimeter setting--29.92 inches.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

Communications between the helicopter and the ground were conducted by radio. There were no known mechanical difficulties with the communications equipment used to communicate between the helicopter and the ground.

1.10 Aerodrome and Ground Facilities

The helicopter was using an especially constructed takeoff/landing pad located about 600 feet west of the accident site.

1.11 Flight Recorders

Not applicable.

1.12 Wreckage and Impact Information

The helicopter came to rest on its left side on a magnetic heading of 345°. The helicopter's structure, flight controls, and rotating assemblies, except the tail rotor assembly, remained intact. The main rotor mast assembly, including the main rotor blades and their associated components, were heavily damaged as a result of impact. Damage to the main rotor blades was consistent with the damage which would be expected if the blades were rotating at impact. The preimpact integrity of the main rotor flight control system was established; all of the damage to the main rotor flight control system was determined to be the result of impact. There was no evidence of any preexisting malfunction or failure.

The main transmission rotated freely and the free-wheeling unit operated normally. The right-hand rear and fifth mounts had separated from the transmission; the fracture surfaces were clean and typical of overload failure. The left beam was buckled; however, the left link remained attached. The nonrotating flight controls were damaged during impact. The tail boom attachment brackets remained intact and were not damaged. The left synchronized elevator showed evidence of extensive compression buckling. The right synchronized elevator was not damaged. Continuity of the flight control system for both synchronized elevators was established. Continuity of the antitorque control system from the cockpit rudder pedals to the 42° gearbox was established. The Nos. 1, 2, and 3 bearing housing for the tail rotor drive shaft hanger remained intact. The tail rotor drive shaft had separated from the transmission tail rotor drive quill assembly.

The vertical pylon drive shaft, located between the 42° gearbox and the 90° gearbox, had separated. The shaft was found near the wreckage in the center of the river. The spline teeth, male and female, showed no signs of damage. An impact mark was found on the right side of the vertical pylon drive shaft cover.

The tail rotor 90° gearbox, with one intact blade and the butt portion of the other blade attached to the hub assembly, was found about 41 feet north of the main wreckage. Tail rotor blades, serial No. A3-84197, had separated 19 1/4 inches outboard of its butt end. The outboard portion of the blade was found about 21 feet southwest of the tail rotor 90° gearbox. The broken tail rotor blade exhibited a semicircular indentation about 3 1/2 inches deep on its trailing edge; the indentation spanned the fracture line in the blade. (See figure 2.) The left side of the blade had two rectangular punctures just aft of its leading edge. Foreign particles were found on both fracture surfaces of the blade. Tail rotor blade serial No. A3-84184 remained attached to the hub assembly. About 33 1/4 inches of the blade skin was missing; the skin was found behind hut No. 7. (See figure 1.) Visual examination of the skin disclosed extensive curling at the butt end and extensive heat damage. Also, particles of a rubbery substance with wood embedded were found on the right side of the skin.

The engine was operated by use of its starter. There was no evidence that the rotating components had bound, and the engine rotated freely. After the engine was operated, the particle separator was removed; no foreign contaminates were found in the separator.

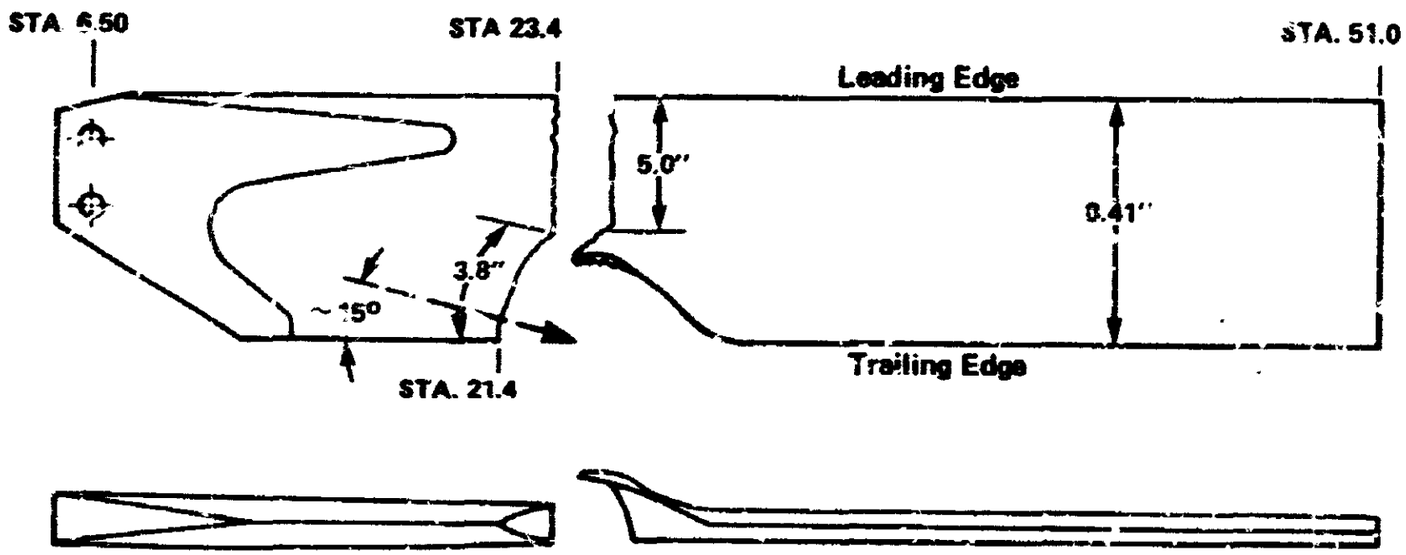

Figure 2.—Blade damage.

1.13 Fire

The helicopter did not catch fire either before or after impact.

1.14 Medical and Pathological Information

Postmortem examinations on the three actors were performed by the Los Angeles County Medical Examiner-Coroner's Office. The postmortem examination of the adult actor and male child actor disclosed that their deaths were attributed to injuries to the head, neck, and shoulder of each actor, inflicted by the main rotor blades of the helicopter. The cause of death to the female child actress was attributed to multiple traumatic injuries and blunt force trauma. Toxicological examinations were performed on the adult actor, and no evidence of drugs and/or alcohol was found. Toxicological examinations were not performed on the children.

The pilot and three of the other five occupants of the helicopter were treated at Henry Mayo Memorial Hospital, Newhall, California, for minor injuries and were released. There was no evidence of any preimpact incapacitation or pre-existing physiological conditions which would have affected the pilot's judgment or performance. Toxicological examinations were not performed, because they were deemed not warranted. Since this aircraft was operating on an experimental airworthiness certificate, crashworthiness was not considered pertinent to this mishap.

1.15 Tests and Research

1.15.1 Film Examination

At the Safety Board's request, the Federal Bureau of Investigation (FBI) examined the film recorded during the accident sequence by one of the movie production cameras located on the north shore of the river and about 12 feet above the elevation of the ground to the rear of hut No. 11. (See figure 1.) The purpose of the examination was to determine the position and movement of the helicopter relative to the special effects devices when they were detonated. The examination included 228 frames of the film taken during an elapsed time of 9.5 seconds, beginning with the first of the five special effects explosions and terminating when the helicopter disappeared from the camera's view immediately before the helicopter crashed.

Table 1 shows the helicopter's height (measured above the camera), heading, rotational rate, and forward speed. Examination revealed that the helicopter's position at the instant of the fourth special effects explosion placed the center of the tail rotor about 34 feet above and 19 feet laterally displaced west-northwest from the source of the explosion. The helicopter's position at the time of the fifth special effects explosion placed the center of the tail rotor about 34 feet above and 13 feet laterally displaced west-northwest from the source of the explosion. (The center of the tail rotor is 10 feet, 4 inches above the skids.)

Table 1.--Helicopter Movements.

Time 1/ (Seconds)	Height of skid above camera (ft)	Heading (°)	Average yaw rate and direction (°/sec)	Forward speed (mph)
0	12	078	None	None
4	12	073	None	None
6 (4th explosion 6.0938 (5th explosion)	12	033	23° left	3.6
7	13	008	None	3.8
7.5	16	008	None	5.6
9.025	19	046	25° right	Leaving frame

1/ The times are seconds elapsed from the first special effects explosion.

1.15.2 **FBI Explosive Tests**

The FBI laboratory also assisted the Safety Board in the investigation by examining the characteristics of the explosions created by the detonation of devices such as those reportedly used by the special effects personnel at the time of the accident. The FBI conducted tests at the accident site and at its own test facilities.

To produce the illusion of a heavy ordnance attack on the movie set, the special effects personnel stated that they had detonated mortars (steel pots) of various shapes and sizes which contained black powder explosive charges and gasoline/sawdust mixtures. The primary black powder charge, which reportedly was 6, 8 or 12 ounces, was placed in the bottom of the mortar with the gasoline/sawdust mixture in the middle and a smaller 2-ounce black powder charge on top.

The purpose of the FBI tests at the accident site, which were performed on September 23, 1982, was to record the sounds of the detonation of different shaped mortars charged with various amounts of black powder. The same recording equipment used at the time of the accident was used to record these sounds. The frequency spectrum of the sounds recorded during the tests were compared with the frequency spectrum of the sounds of explosion recorded at the time of the accident.

The FBI tests disclosed that each mortar configuration produced a unique sound frequency spectrum which did not vary regardless of the amount of the charge. The test sound spectra of the detonation of charges in two of the special effects mortar configurations were similar in frequency content to the sounds of the two explosions which were recorded immediately before the accident. The amplitude of the recorded sounds can, under identical recording conditions, indicate the level of the black powder charge in the mortars. Although a determination of the amount of a charge through a comparison of the amplitude of sound recorded was precluded by the automatic gain control feature of the recorder, it was possible to conclude from these tests that special effects explosions were produced by black powder charges.

The purpose of the tests at the FBI's test facility was to measure the velocity imparted to several objects by the special effects explosions. Mortar charges identical to those used by the special effects technicians were detonated, and the speed of objects

propelled upward was measured about 20 feet above the ground. The tests showed that an object having a mass and geometry similar to the pieces of bamboo used to construct the village huts would reach vertical speeds of 200- to 300-feet per second. Portions of mortar casings were projected to heights of 50 feet and more. There was no attempt during these tests to replicate the placement of the mortar charges or the structures which surrounded them when the accident occurred.

1.15.3 Tail Rotor Sound Spectrum Study

The frequency spectra of the sounds recorded during the filming sequence in which the helicopter crashed were also studied by the Los Angeles County Sheriff's Department. The purpose of the study was to identify the discrete sound of the tail rotor and to relate the changes in sound frequency to tail rotor transient movements and rotational speed changes.

The frequency spectrum study disclosed that before the last two explosions, and just before the accident, the helicopter's tail rotor began to move in a counterclockwise direction away from the recording microphone. About 0.5 seconds after the last explosion began, the sound frequency change correlated with a reversal of the tail rotor's movement toward the recording microphone. About 1.7 seconds later, a frequency change occurred which correlated with a deceleration in the tail rotor's rotational speed.

1.15.4 Examination of the Tail Rotor Component and Other Materials

At the Safety Board's request and under its direction, the helicopter's tail rotor assembly was examined by the helicopter manufacturer and an independent laboratory.

The metallurgical examination by the helicopter manufacturer was conducted using a transmission electron microscope and plastic replication techniques to determine the characteristics of the fracture of the tail rotor blade, serial No. A3-84197. The examination indicated that the tail rotor blade skin had fractured from combined shear loading and tearing and that the fracture progressed from the trailing edge to the leading edge of the blade. The helicopter manufacturer concluded that:

> A foreign object impacted the tail rotor blade trailing edge approximately 18.25 to 22.3 inches (463.55 - 566.42 mm) from the butt end. The impact of the foreign object deformed the aft 4 inches of the tail rotor blade trailing edge at station 25. This deformation created an out-of-track condition of the tail rotor blade that may have resulted in the separation of the 90° gearbox and blades from the aircraft.

The helicopter manufacturer observed that it was not possible to assess accurately the impact force required to produce the observed damage without the support of tests. However, based on certain assumptions, the manufacturer estimated that the required force would be at least 7,800 pounds.

The helicopter manufacturer's examination of the tail rotor blade which remained attached to the hub, serial No. A3-84164, showed that the aluminum skin had separated at the bonding surface as a result of exposure to excessively high temperatures. Tests of the adhesive qualities of the bonded areas with respect to temperature increases disclosed that the adhesive coefficient of the bond area diminished at increased

temperatures; e.g., at 300° F, the average peel strength of the bonded area was about 23 pounds per square inch (psi), which is about 2 percent of the average peel strength at room temperature (1,109 psi).

The tests conducted by the independent laboratory consisted of a visual examination of all the separated components of the helicopter's tail rotor assembly and an energy dispersive x-ray (EDX) microprobe-type chemical analysis of several samples from the tail rotor section, fuels, materials used in the special effects devices and movie set, and debris which was recovered from the vicinity of the explosions and crash.

The independent laboratory tests disclosed that elements typical of the fire fuel used to create the special effects were deposited on the large indentation on the trailing edge of both parts of the separated tail rotor blade and on the two rectangular indentations on the right side of the separated portion of the blade. A green substance found on the separated tail rotor blade skin was chemically similar to a green substance found on a special effects device mortar casing; a black tar-like substance found near the leading edge of the fractured tail rotor blade was foreign to the blade and appeared to have originated from the bombing debris.

A lid from a 5-gallon glue pot, typical of several which were found at the accident site, was examined. The lid was made of steel and had several sharp tangs around its circumference. Two tangs were found to match the size and shape of the rectangular indentations found on the left side of the outboard portion of the separated tail rotor blade.

Red and turquoise substances found in the indentations on the right side of the vertical pylon drive shaft cover were similar to paint found on the fractured tail rotor blade. Also, the shape of the indentation on the drive shaft cover matched the leading edge of the outboard portion of the fractured tail rotor blade.

The independent laboratory's report concluded that debris from a special effects explosion on the ground struck the helicopter tail rotor blade during flight, that the blade fractured, and that this ultimately caused the separation of the tail rotor assembly and the crash.

Additional tests were conducted by a technical consultant engaged by the film director. The tests included analysis of substances deposited on the trailing edge of both parts of the broken tail rotor blade. The consultant used EDX, wave length dispersive spectroscopy, infrared analysis, and atomic absorption tests. Based on all of these tests, the consultant concluded that the substances were olive drab (strip) paint of the same type used to paint the helicopter.

1.15.3 Engineering Evaluation

The Safety Board provided the reports of the studies conducted by the FBI, the helicopter manufacturer, and the independent laboratory to a professor from the University of California School of Engineering for further evaluation.

Upon examination of these documents, the professor concluded that the confinement of the special effects device beneath the floor of a hut might cause debris to accelerate to higher velocities than were evident in the detonating tests conducted by the FBI. He calculated that, under some conditions, projectiles might reach heights of between 800 and 1,500 feet. He also observed that an off-center impulse force to a bamboo stick, typical of those used in the floors of the movie set huts, would cause the

stick to rotate and that the rotating tips would attain velocities higher than those at the center of gravity of the projectile.

The professor's report indicated that he believed it likely that a blow from a piece of the fire-fuel-coated bamboo floor caused the indentation at the trailing edge of the tail rotor blade and that the bent or fractured blade caused aerodynamic and dynamic imbalance which created forces great enough to separate the tail rotor gearbox.

1.18 Additional Information

1.18.1 Director's Responsibilities

Testimony given at a California Assembly Labor and Employment Committee and California Senate Industrial Relations Committee Joint Hearing held in Los Angeles, California, on October 8, 1982, by the Directors Guild representative was to the effect that the director has the final word on production; that is, he has the authority to overrule the stunt coordinator if he is so inclined. However, more often than not, he accepts the advice of the stunt coordinator with respect to safety. Further, safety on the set is the director's responsibility.

The Directors Guild representative further testified, in part, with respect to handling a stunt or special effect, ". . .when one is in a picture, we as directors, discuss and plan it with the assistant director, who is the man in charge of the set, with the production manager, who is in charge of the overall production, with the camera operator, the art director, and the special effects man—all the various people. . . ."

1.18.2 Federal Regulations

According to the flight rules of the FAR (14 CFR 91.79) helicopters can be operated below the minimum altitudes prescribed for aircraft without an express waiver ". . .if the operation is conducted without hazard to persons or property on the surface." Aircraft other than helicopters must be operated at or above the minimum altitudes specified in the regulations in the absence of an express FAA waiver of the minimum altitudes. Since March 1982, operators of aircraft, other than helicopters, to be operated below the minimum specified altitudes as camera platforms or stunt vehicles in motion picture and television film productions have had to obtain FAA approval of a Motion Picture and Television Flight Operations Manual in accordance with Chapter 14, Section 5, of FAA Order 8440.5A, General Aviation Operations Inspector's Handbook, dated March 19, 1975, as amended.

2. ANALYSIS

General

The Safety Board's investigation of this accident concentrated on those aspects of the accident which directly related to the loss of control of the helicopter and its subsequent crash. The Safety Board's analysis also is limited to this issue. The Safety Board believes that comprehensive review and analysis of the practices of the motion picture industry and the safety considerations given to the filming of stunts or other hazardous activities on a movie set are beyond the Board's investigative purview. The Safety Board's investigation of the accident was necessary to ascertain whether the circumstances which led to the accident might have broader application to the safety of U.S. civil aviation transportation, such as inadequate pilot qualifications, regulatory deficiencies, or airworthiness problems with the helicopter.

The helicopter was properly certificated and maintained in accordance with the existing regulations and approved procedures. There was no evidence of preexisting deficiencies, malfunctions, or failures of the helicopter's systems or components which could have led to the crash.

The pilot was certificated and qualified in accordance with applicable regulations. While he had been employed before in film activity, he had not flown previously in proximity to special effects explosions. He was obligated to fly the helicopter in conformity with the operating limitations specified in the helicopter's experimental airworthiness certificate which was issued by the FAA specifically to permit the rigging of the helicopter as required for the film production. The movie production persons who were in the helicopter were not involved in the direct control of the aircraft but were on board to perform their duties in the making of the movie. Since helicopters may operate below the minimum safe altitudes specified by regulation without an express waiver, it has not been the practice to seek waivers in connection with motion picture production activity. Moreover, there was no requirement enforced by the FAA that Western Helicopters, Inc., prepare for FAA approval a Motion Picture and Television Flight Operations Manual. However, the pilot was constrained by regulation to operate the helicopter "without hazard to persons or property on the surface."

The investigation of this accident revealed clear evidence that control of the helicopter was lost following separation of its tail rotor assembly. The time of separation of the assembly was evident in the sound frequency spectrum analysis of the audio tape which had been recorded during the accident sequence. The sound frequency spectrum analysis distinctly showed a speed decay of the tail rotor rpm about 1.7 seconds after reversal of the helicopter's rotational left turn. This speed decay can be associated only with separation of the tail rotor assembly because there was no concurrent decay in main rotor rpm or engine rpm. Further, examination of the production film from the camera that was located on the north shore of the river revealed that the tail rotor assembly was engulfed in a fireball from the fifth special effects explosion while the helicopter was in a left hovering turn. Following the explosion, the helicopter stopped turning to the left, began a right ascending turn, and moved out of the film frame. About 2 seconds later, the helicopter reappeared in the film in a tail low attitude and in a right descending turn, and its tail rotor assembly was missing. The helicopter continued turning right and crashed into the peninsula on the north side of the river.

The camera film showed that the helicopter was under control throughout the left hovering turn until shortly after detonation of the fifth special effects device. During a level hover, the helicopter tail rotor blades produce an essentially horizontal thrust vector to offset the rotational torque from the main rotor system which tends to rotate the helicopter to the right. The tail rotor blade must be structurally and aerodynamically sound to produce the thrust needed to prevent the helicopter from rotating to the right in response to the torque, and to produce the even higher thrust required to execute a hovering left turn. A disruption of the aerodynamic integrity of the tail rotor blade was evidenced by the helicopter's abrupt reversal from a left turn to a right turn. Therefore, the Safety Board concludes that the damage to the tail rotor blades occurred suddenly and was related to the fourth and fifth special effects explosions; the former preceded the latter by less than 0.1 second and originated beneath the bamboo floor of the No. 10 hut. The fifth special effects device was placed on the shore about 14 feet west of the No. 10 hut.

Damage to or separation of a portion of a tail rotor blade creates severe control problems for a helicopter pilot. If tail rotor damage occurs at a high enough altitude, the pilot may be able to enter an autorotative descent (engine no longer driving the rotor system). This flight condition minimizes the tail rotor thrust requirement, may allow the opportunity to reduce significantly the dynamic and aerodynamic imbalance in the tail rotor and prevent separation of the tail rotor system, and allows the pilot to land upright with some measure of control. However, in this accident, the pilot had neither the time nor the altitude to establish an autorotative descent. Consequently, when the tail rotor assembly separated, the helicopter was not controllable, and the crash was inevitable.

The tail rotor assembly completely separated from the helicopter when the casing on the tail rotor's 90° gearbox mounting flange fractured from overload forces. The fracture resulted from the excessive forces applied through the structure from the aerodynamic and dynamic imbalance of the tail rotor. The Safety Board concludes that the imbalance of the tail rotor system could have occurred from either of two sources but most likely occurred from the nearly simultaneous effect of the two sources: (1) damage from a foreign object to the trailing edge of the fractured blade and (2) the delamination and separation of a major piece of the skin on the other blade.

The separated portion of one tail rotor blade was found 21 feet away from the tail rotor gearbox to which the blade hub with the mating fracture surface was still attached. A matching semicircular indentation existed on the trailing edges of both portions of the fractured tail rotor blade. The matching indentations are conclusive evidence that the blade was struck by an object before the blade fractured, and that the fracture may have been precipitated by the damage inflicted by the object or by vibrational forces caused by the resulting imbalance in the tail rotor system.

The large piece of skin from the other tail rotor blade was found behind the No. 7 hut on the south side of the river. Tests showed that the skin had separated at the bonding surface (delamination) because of exposure to excessively high temperatures. Since the only source of high temperatures was the special effects explosions, the Safety Board concludes that the delamination resulted from the blade's exposure to the heat of the fifth special effects explosion which engulfed the tail rotor assembly. The delamination and high speed rotation of the blade would have caused the skin to flap as it separated from the blade structure. The consequent disruption of the blade's aerodynamic shape and the creation of a dynamic imbalance due to the loss of the skin could have resulted in forces sufficient to fracture the tail rotor gearbox flange and could have caused the tail rotor assembly to separate.

Sources of Tail Rotor Damage

The Safety Board concludes that the two rectangular punctures found on the separated portion of the tail rotor blade near its leading edge were not significant to the fracture of the blade. These punctures matched closely the tangs on the steel lids of the 5-gallon glue pots found in the vicinity of the crash. Since the punctures were not elongated and the surrounding damage was limited, the Safety Board concludes that the blade was not operating at high rotational speeds when the damage was inflicted. Consequently, the Safety Board concludes that the lid struck the blade after the tail rotor assembly had separated from the helicopter.

The Safety Board cannot identify with any degree of certainty the specific object which struck the tail rotor blade and caused the semicircular identation at the point of fracture. The deformation of the fracture in the outboard portion of the blade

tends to indicate that the blade was struck from the right side and from the trailing edge. However, the Safety Board believes that any of the objects propelled upward by the special effects explosions would not have had sufficient mass and speed to inflict the evident damage if they had struck the blade from behind in its direction of rotation. It is more likely that an object traveling essentially perpendicular to the tail rotor blade's plane of rotation and striking the blade just forward of its trailing edge would have produced the necessary force to deform the blade. Under such conditions, the impulse force related to such an impact would have been very high because of the rotational speed of the blade. In these circumstances, the damage could have been inflicted by an object of relatively low mass. Furthermore, such an impact would have been consistent with the pressure differential across the blade (deflected to produce a left turn) and the movement of debris through the blade's rotational plane. The peculiar deformation of the fracture surface of the outboard portion of the blade could be explained by the twisting of the blade by the aerodynamic and dynamic forces which caused its fracture and by the impact of the blade against the drive shaft cover of the vertical pylon.

The Safety Board considered the possibility that the object which damaged the helicopter's tail rotor blade may have been ejected from the helicopter instead of projected upward from the ground. The object specifically considered was a 0.30 caliber blank casing, such as those from the blanks being fired from the machine guns on each side of the helicopter. Normally, objects from a hovering helicopter would descend rapidly as a result of the downwash force generated by the main rotor system. Although the downwash forces from the helicopter's main rotor might have been offset for an instant by the upward force generated by the explosion, the Safety Board believes that the evidence does not support this possibility because the near 1/2-inch-diameter size of the 0.30 caliber blank casing is not consistent with the approximate 3 1/2-inch-diameter size of the semicircular indentation on the trailing edge of the fractured tail rotor blade.

The circumstantial evidence and some physical evidence indicates that the object that struck the blade probably was propelled upward by the special effects explosions, but the Safety Board cannot exclude the possibility that the fracture occurred after rather than before the separation of the tail rotor assembly, i.e., the broken blade did strike and dent the right side of the drive shaft cover on the vertical plyon which supports the tail rotor assembly. Moreover, the blade may have contacted another part of the helicopter forcefully causing the fracture of the weakened blade. This possibility is supported by the identification of the substances found on the trailing edge of the blade as olive drab paint. However, because the dynamics of the conditions surrounding the separation of the tail rotor assembly are extremely complex, and because the separation of the rotor assembly was completely obscured by the fireball from the fifth special effects explosion, the Safety Board cannot conclude with certainty that the damage to the blade occurred before it separated from the helicopter as part of the tail rotor assembly. However, the Safety Board believes that if the blade had been damaged by debris while the tail rotor assembly was under the aerodynamically loaded condition consistent with a hovering left turn, the resultant aerodynamic and dynamic imbalance would have been sufficient to have fractured the tail rotor gearbox flange.

A review of 13 years of U.S. Army UH-1 accident/incident data revealed no accidents or incidents caused by skin delamination of tail rotor blades. Similarly, Safety Board accident/incident data for the Bell 204 and 205 models helicopters (civil version of UH-1) disclosed no accident or incident caused by delamination of a tail rotor blade. Further, these data disclosed no instance in which a tail rotor assembly was separated from the helicopter because of delamination of skin from a tail rotor blade. Notwithstanding the lack of accidents or incidents related to the delamination of a tail rotor blade, the Safety Board concludes that in the circumstances of this accident

delamination could have occurred and that such a condition could have caused the loss of the tail rotor assembly. The posterash position of the piece of delaminated skin from the unbroken tail rotor blade tends to indicate that the skin was torn from the blade while the blade was turning at a relatively high speed and that the piece of skin, after striking the face of the cliff to the rear of the helicopter, fell to the ground behind the No. 7 hut. Consequently, the piece of skin probably tore from the blade before separation of the tail rotor assembly. Also, the delamination occurred while the helicopter was in a high performance maneuver — a left hovering turn. Under those conditions, the helicopter would have been under the influence of high rotational torque which would have required near maximum deflection of the tail rotor blades to counter and produce the left turn. Consequently, the aerodynamic loads on the tail rotor blades would have been near maximum so that the loss of a large piece of skin from one blade could have produced sufficient aerodynamic and dynamic imbalance to have fractured the tail rotor gearbox flange.

Regardless of the specific damage to the tail rotor blades which caused the loss of the tail rotor assembly, the Safety Board finds the evidence clear and convincing that there was damage as the direct consequence of the helicopter's close proximity to the detonation of special effects explosions propelling debris at high temperature, specifically the detonation of the fourth and fifth special effects devices and that the damage caused the separation of the tail rotor assembly. Therefore, the Board concludes that the cause of the accident encompasses those conditions and circumstances that placed the helicopter in a position of vulnerability to the damage it sustained to the tail rotor system.

Safety of the Operation

Although the Safety Board considers the safety precautions taken by the motion picture industry during the filming of stunts, combat scenes, or other dangerous activities beyond its investigative purview, it is concerned by the events which led to the exposure of the helicopter to the hazards of the special effects explosions because of the frequent use of aircraft in film production. The concerns expressed by the pilot and other personnel following the filming of the second sequence in which special effects were detonated and following the rehearsal verified that the hazards of the operation were recognized by the pilot as well as by some of the film production personnel. It must be recognized that the pilot in command is ultimately responsible for the safety of flight. Since none of the personnel involved except the pilot had knowledge of helicopters and their vulnerability to damage from debris and heat from special effects explosions, this recognition should have prompted the pilot, who was responsible for the operation of the helicopter in a manner that would not pose a hazard to persons or property on the surface, to initiate the measures necessary to insure that the helicopter would be separated safely from the prepositioned special effects mortars when the mortars were detonated. These measures should have included, at a minimum, an insistence on a joint briefing among the director, the pilot, and the special effects technicians as to the exact maneuver the helicopter was to perform, the timing of the maneuver, and a keying of the detonation of the hits to the helicopter's completing the left turn and moving across the river. Further, as an added precaution, the pilot should have insisted on direct radio communication with the technicians to keep them apprised of his progress in the maneuver and to warn them in the event that alterations of the intended maneuver became necessary. In this case, however, no specific measures were agreed upon. Instead, the pilot relied on assurances from the UPM and special effects coordinator that nothing would be exploded beneath the helicopter. Additionally, apparently in response to commands from the director, he modified the maneuver and flew lower over the surface of the river and closer to the huts than had been intended originally, as established by the observations of the cameraman on

the left skid and the cameramen on the north shore of the river. Consequently, it is evident that the operation lacked the precise planning and coordination needed to conduct it safely, particularly if changes in the scenario were made.

On the other hand, the Safety Board also recognizes that in the motion picture and television film industry, the director has full responsibility for safety on the set of a filming operation. Consequently, it is incumbent upon the director to take cognizance of visible and reported hazards and to take the measures needed to either eliminate the hazards or to cope with the hazards in a manner that will insure the safety of the personnel involved. In this accident, the director did not conduct preproduction meetings with the principals concerned—the pilot, the UPM, the assistant director, and the special effects coordinator—regarding the hazards related to operation of the helicopter in proximity to the special effects explosions. Further, after conclusion of the 2330 filming session, when apprised of the hazards by the UPM and the pilot, the director took no positive measures to insure the precise coordination needed among all concerned to eliminate the hazards. Consequently, the Safety Board concludes that the director failed to fulfill his responsibility of insuring safety on the film set.

The FAA has recognized that significant precautions must be taken to assure safety of persons and property when civil airplanes are used in the production of movie and television films. Since March 1982, operators of airplanes (but not helicopters) used in film productions have been required to prepare a Flight Operations Manual detailing the safety precautions that must be taken before the operators are permitted to fly the aircraft at altitudes below minimum safe altitudes established by regulations. The Safety Board recognizes that the flight rules for helicopters allow pilot-initiated deviations from the minimum safe altitudes prescribed by regulation and that practically speaking requiring an express waiver for each operator would degrade the utility and value of the helicopter, which is its ability to hover and fly slowly at very low altitudes above the surface. Film production helicopter operators have not been required to obtain a specific waiver of the flight rules to operate at very low altitudes and have not been required to prepare a Motion Picture and Television Flight Operations Manual. However, the Safety Board believes that the facts, conditions, and circumstances of this accident amply demonstrate the need for a requirement that helicopter operators prepare such a manual and carry out its provisions as a prerequisite to the use of a helicopter in movie and television film production. At a minimum, the manuals should contain provisions for pilot qualifications, including any special qualifications, mandatory briefings of film production personnel on the risks involved, the safeguards needed during operations, emergency procedures, a communications plan for all participating personnel, and a provision confirming the pilot-in-command's ultimate authority to control all flight regimes relative to this type of operation.

3. CONCLUSIONS

3.1 Findings

1. The aircraft was properly maintained in accordance with existing regulations, and there was no evidence of pre-existing malfunction or failure of the helicopter's systems or components that could have led to the crash.

2. The pilot was certificated and qualified for the flight in accordance with the existing regulations, and he was obligated to fly the helicopter in accordance with the operating limitations of its experimental airworthiness certificate.

3. The helicopter pilot was ultimately responsible for operation of the helicopter in a manner that did not pose a hazard to occupants of the helicopter and to persons or property on the surface.

4. The helicopter pilot and film production personnel were aware that the flight involved operating in very hazardous conditions.

5. There was no direct discussion among the director, the helicopter pilot, and the special effects personnel to insure that there was a common understanding of the intended positioning of the helicopter throughout the left hovering turn and to insure that the special effects charges would not be detonated prematurely.

6. No provision was made for direct radio communication between the pilot and the special effects technicians to insure that the technicians did not detonate the special effects charges in such a manner as to endanger the helicopter operation.

7. The helicopter flight, including the left hovering turn maneuver, was not conducted at a sufficient height above the river or at a sufficient distance from the huts to insure that the helicopter would not be struck by debris or affected by heat from special effects devices detonated under or near the helicopter.

8. Personnel involved in the filming operation other than the pilot did not have knowledge regarding the vulnerability of the helicopter to high temperatures and debris.

9. The director of the filming operation did not conduct a preproduction meeting of the principals involved in a known hazardous operation to insure the safety of the personnel on the film set.

10. The pilot was assured by the unit production manager that explosives would not be detonated beneath his helicopter.

11. Either the indentation in the one blade caused by an object propelled upward by the special effects explosions or the delamination of skin from the other blade caused by heat from the explosions, or a combination of these two conditions, created a dynamic and aerodynamic imbalance in the tail rotor system which generated sufficient loads to separate the 90° tail rotor gearbox and the tail rotor assembly.

12. The object which hit the blade probably was not ejected from the helicopter.

13. The helicopter was not controllable after loss of its tail rotor assembly.

14. There was no requirement enforced by the FAA that the helicopter operator submit a Motion Picture and Television Flight Operations Manual to the FAA for approval as a prerequisite to use of the helicopter in the film production.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the detonation of debris-laden high temperature special effects explosions too near to a low flying helicopter leading to foreign object damage to one rotor blade and delamination due to heat to the other rotor blade, the separation of the helicopter's tail rotor assembly, and the uncontrolled descent of the helicopter. The proximity of the helicopter to the special effects explosions was due to the failure to establish direct communications and coordination between the pilot, who was in command of the helicopter operation, and the film director, who was in charge of the filming operation.

4. RECOMMENDATION

As a result of this accident, the National Transportation Safety Board recommended that the Federal Aviation Administration:

> Extend the terms of FAA Order 8440.5A Section 5, Waiver of Section 91.79(a) and (c), Motion Picture and Television Flight Operations Manual, to require an FAA-approved flight operations manual for all types of aircraft. (Class III, Longer Term Action) (A-84-16)

REVISED REPORT ADOPTED

BY THE NATIONAL TRANSPORTATION SAFETY BOARD*

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G. H. PATRICK BURSLEY
Member

*The original report was adopted on March 6, 1984, by the following members of the National Transportation Safety Board: Jim Burnett, Chairman; Patricia A. Goldman, Vice Chairman, and G. H. Patrick Bursley and Donald D. Engen, Members. Vernon L. Grose, Member, did not participate.

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety Board's Los Angeles Field Office was notified of the accident about 0300 on July 23, 1982, by the FAA Western Region Duty Officer. An investigator was dispatched to Valencia, California, from the Los Angeles Field Office and arrived at the scene of the accident about 0530 July 23, 1982.

Parties to the investigation were the Federal Aviation Administration, Western Helicopters, Inc., Los Angeles County Fire Department, The Screen Actors Guild, Bell Helicopters, California State Fire Marshalls, and Burbank Studios. Representatives of these parties assisted in the investigation.

2. Public Hearing

No public hearing was held and no depositions were taken.

Testimony of 34 witnesses was recorded and transcribed, one of which was taken under oath at the request of the witness.

APPENDIX B

CREW INFORMATION

Pilot Dorsey A. Wingo

Pilot Wingo, 35, held commercial certificate No. 2032217 with a rotorcraft rating. He also possessed a certificate for private priviledges in single engine land airpianes. He completed a biennial flight review in a Bell 206 helicopter 2 montns prior to the date of this accident. Pilot Wingo held a valid second class medical issued in March of 1982, with no waivers or limitations.

According to company and pilot records, pilot Wingo had a total of 4,514 hours. Of this time 4,408 hours was rotorcraft time and 1,538 hours were in the Bell 204/205/UH-1B type aircraft. He had flown 60 hours in the last 90 days. Six of those hours were in the Bell 204/205/UH-1B type aircraft. During the 30 days preceding the accident he accumulated 42 flight-hours. During the 24-hour period prior to the accident, he had about 2 hours of flight time. Pilot Wingo received his flight training in the U.S. Army and served as a rotorwing pilot in Viet Nam. His military experience totaled about 1,200 hours of flying time. Of that time, about 900 hours was in helicopters similar to the one used in the movie filming. This was the pilot's fourth experience in movie work but this was the first film production in which he had flown near special effects explosions.

APPENDIX C

AIRCRAFT INFORMATION

The aircraft, a Bell UH-1B, serial No. 64-14038, was acquired by Rocky Mountain Helicopter, Inc., from Southern Helicopters, Inc., Sarasota, Florida, on September 2, 1980. On March 4, 1980, the aircraft received a restricted category airworthiness certificate. Prior to receiving the airworthiness certificate, the aircraft was operated by the U.S. Army, the Department of Health, Education and Welfare, and the Maryland State Police. These public agencies are exempt from obtaining an appropriate airworthiness certificate. On August 10, 1981, Rocky Mountain Helicopter, Inc., relinquished operational control of the subject aircraft to its subsidiary, Western Helicopters, Inc.

On July 21, 1982, the FAA General Aviation District Office, Riverside, California, issued a temporary experimental airworthiness certificate for the helicopter at the operator's request. The helicopter's gross takeoff weight was 6,205 pounds; the maximum authorized takeoff weight was 8,500 pounds. The helicopter was fueled with 600 pounds of jet-A fuel. The helicopter's center of gravity was well within prescribed limits. The maintenance records examination disclosed that the last annual/100-hour inspection was performed on April 20, 1982. The aircraft had accumulated 5,806 flight-hours at the time of the inspection.

APPENDIX D

PETITION FOR RECONSIDERATION OF PROBABLE CAUSE

CABLE "WOOLKERN"
TELEX NO. 66-6244

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CABLE "TEXAIRLAW"
TELEX NO. 79-2977

March 16, 1984

National Transportation Safety Board
Bureau of Accident Investigation
Washington, D. C. 20594

Re: Report No. NTSB/AAR-84/02
Western Helicopters Bell UH-1B, N87701
Valencia, California
July 23, 1982

TO THE MEMBERS OF THE BOARD:

This firm represents John Landis. Request is hereby made on behalf of Mr. Landis that the Board reconsider its report on the above referenced accident pursuant to 49 CFR Sections 845.41 and 845.51.

This request for reconsideration and modification is based on the fact that evidence which was available but not presented to, and thus not considered by, the Board proves as follows:

1. The accident directly resulted from a heat delamination of the tail rotor blade skin of the helicopter.

2. The delamination was caused by a failure of the adhesive which bonds the skin to the tail rotor blade. The adhesive used on the model UH-1B loses its effective strength when exposed to temperatures as low as 180 degrees Fahrenheit.

3. The failure of the adhesive was precipitated by the detonation of a defective special effects explosion which engulfed the tail rotor and exposed it to temperatures in excess of 600 degrees.

4. The special effect was detonated by an expert pyrotechnics operator, licensed by the State of California and exercising sole control over, and with sole responsibility for, the detonation sequence.

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5. No physical evidence exists to support a view that the tail rotor of the helicopter was struck by debris generated by a special effects explosion.

Research by experts into accident investigation records, as well as the uncontroverted testimony under oath of numerous experts, discloses that there is no prior instance of heat delamination of a tail rotor on a UH-1 helicopter.

Board consideration of this new evidence and modification of its findings and recommendations are significant: failure to do so will create a substantial risk that another accident of this nature may occur.

SUMMARY OF THE NEW EVIDENCE

The evidence summarized in this request is contained in transcripts of the Preliminary Hearing held in the Municipal Court of Los Angeles Judicial District during January/February, 1984. A full transcript of this proceeding has been available since mid-February and has been provided to interested parties upon request, including the media. We have been informed by the Board's counsel that the transcripts, in which the evidence is presented, were not provided to the Board by its staff. Portions of the transcript are enclosed with this request. We are prepared to make a full transcript of the Preliminary Hearing available to the Board without charge.

[The citations which follow refer to Volume and page number of the transcripts.]

In its report, the Board found that debris propelled by a special effects explosion struck the trailing edge of the tail rotor blade and caused the helicopter to crash. This finding parallels that contained in the previous draft reports of Abdon D. Llorente, chief investigator for the Board on this accident. Those reports were furnished to us by Mr. Llorente.

Mr. Llorente based his view upon the tests and conclusions contained in the report of Dr. Arum Kumar. In fact, Dr. Kumar's report served not only as the basis for Mr. Llorente's view, but also for the views of others retained by Mr. Llorente and appears to have set the tenor and focus of the Board's investigation.

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A pivotal statement in Mr. Kumar's report was erroneous. Dr. Kumar agreed in his testimony that his statement was subject to question (and in fact was proved to be erroneous). Dr. Kumar's key testimony was not presented to the Board, nor was the contrary evidence and findings.

In brief, Dr. Kumar performed an EDX test which indicated that a foreign substance found on the trailing edge of the fractured tail rotor (not the rotor which suffered the delamination) contained elements similar to those found in lock bond adhesive. (Lock bond adhesive was used as a fire agent on huts used in the filming.) Without performing additional tests, Dr. Kumar concluded that, based upon this similarity of elements, a piece of bamboo or a glue-pot lid covered with adhesive had been propelled by one of the special effects and struck the trailing edge of the tail rotor blade.

However, at the Preliminary Hearing, Dr. Kumar's own testimony under oath raised serious questions about the scientific basis of his conclusion and, hence, the finding of Mr. Llorente. Dr. Kumar testified that:

1. The EDX test which he performed on the foreign substance found on the trailing edge of the tail rotor can only show a "similarity" of elements and cannot be used to scientifically or positively identify the substance as lock bond adhesive. [V.12, pp. 24-27, 75-77]

2. He orally recommended at least three additional tests, infra-red, atomic absorbtion, and mass spectrometry to Mr. Llorente which he believed as a scientist were essential to positively identify the substance. [V.12, pp. 24-29, 33-34, 56-57]

3. Mr. Llorente never authorized or performed those tests for budgetary reasons. [V.12, pp. 27-28, 58, 77]

[Dr. Kumar's testimony is attached to this request.]

Dr. Gary J. Fowler, a failure analyst and metallurgist who has previously performed services for the Board, performed the tests which Dr. Kumar recommended and analyzed the accident. Dr. Fowler's findings, which were not presented to the Board, conclusively prove that:

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National Transportation Safety Board
March 16, 1984
Page Four

1. The tests which Dr. Kumar recommended to Mr. Llorente positively identified the foreign substance on the trailing edge of the tail rotor as fuselage strip-paint and not lock bond adhesive. [V.17, p.p. 46-54]

2. There is no physical evidence to support a view that debris struck the tail rotor blade caused the crash. [V.17, p.p. 55-56, 67]

3. There is conclusive scientific evidence to support the finding that heat delamination cause the crash.

Using the scientific method of failure analysis, Dr. Fowler described in detail the sequence of events which led to the failure of the tail rotor and the crash. A full transcript of Dr. Fowler's analysis and conclusions is attached to this request. We are also prepared to provide the Board with the complete results of Dr. Fowler's tests. Dr. Fowler is available to appear before the Board.

Dr. Kumar has stated that Dr. Fowler's findings would cause him, as a scientist, to reevaluate his own view. [V.12, p.p. 30-32]

It should be noted that the experts hired by Mr. Llorente used Dr. Kumar's erroneous report as a basis for their own conclusions. Even then, the results did not support Dr. Kumar's admittedly incomplete report.

James C. Ronay, an FBI explosives expert retained by Mr. Llorente, testified that based upon the scientific tests which he conducted, debris propelled by a special effect could not have struck the tail rotor with sufficient force to dent the tail rotor blade, this causing the crash. [V.14, p.p. 70, 82-83, 87, 91-92, 95, 112]

Dr. George Sines, a theoretician retained by Mr. Llorente, testified that he premised his theoretical calculations upon the conclusions of Dr. Kumar. [V.15, p.p. 9-14, 19] Dr. Sines also testified that his hypothetical calculations inexplicably did not take into account the severity of the propwash from the

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helicopter or the "drag effect" caused by the atmosphere. [V.15, pp. 42-43, 60-61]. The hypothetical calculations were never properly made by Dr. Sines.

Other expert witnesses called at the hearing by the District Attorney supported Dr. Fowler's conclusions. Alfred Schwider, an aviation adhesives expert, whose conclusions were not presented to the Board, testified that the adhesive used on the tail rotor of the UH-1B loses its effective strength at temperatures above 180 degrees Fahrenheit. [V.13, pp. 18-19]. Mr. Ralph Lightfoot, a pioneer in helicopter design and engineering as one of Sikorsky Helicopter's original engineers, and an expert whose conclusion was not presented to the Board, testified that the tail rotor suffered a heat delamination after exposure to excessive temperatures and that this delamination was sufficient alone to cause the crash. [V.15, pp. 80-83, 101, 108-110]. Mr. Lightfoot could point to no scientific physical evidence whatever to support a conclusion that the tail rotor was struck by debris from the special effects. [V. 15, pp. 102-105, 111].

Significantly, neither Mr. Lightfoot or Mr. Schwider knew of any prior instance of a helicopter crash resulting from heat delamination of a tail rotor blade. [V.13, pp. 29-30; V.15, pp. 101-102]. Dr. Fowler also researched A.O.P.A. and military records as far back as ten years and could find no instance of any such delamination in either the UH-1 or the 204. [V.17, pp. 28-30].

Therefore, based upon the evidence presented at the preliminary hearing, the helicopter crash was caused by a heat delamination of the tail rotor.

The heat delamination was precipitated by events which were neither within the control nor the expertise of the director. The Board has acknowledged in its findings its inexperience with the motion picture industry. Evidence has been available from the hearing which proves that a director is under not only a customary, but also a statutory, obligation to hire and rely on experts to conduct scenes involving special effects and helicopter flight.

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National Transportation Safety Board
March 16, 1984
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Just as the FAR's regulate the operation of aircraft, special effects are regulated by the California Health and Safety Code and regulations promulgated pursuant to it. [A copy of those regulations is attached to this request.]

Those regulations provide that special effects may only be obtained, prepared and detonated only by a licensed pyrotechnic operator. (California Administrative Code, Title 19, State Fire Marshall Regulations, Article 15, Section 997) They also provide that state safety officials can be required to supervise the use of special effects. (California Administrative Code, Title 19, State Fire Marshall Regulations, Article 15, Section 994, and California Health and Safety Code, Section 12648.)

In fact, four state fire safety officers were required and present during filming. Jack Tice, one of those safety officers, testified that he personally supervised the placement of the special effects and approved the location of the helicopter in relation to them. [V.5, p.p. 40-43]

James Camomile, the licensed pyrotechnics operator who detonated the defective special effect which engulfed the tail rotor of the helicopter, testified that the director has no authority over special effect and only a licensed operator in control of the special effect may make the decision when to detonate a special effect. [V.10, p.9]

Any requirement that a movie director, the artistic leader of the film, have authority with respect to the detonation of special effects and the flight of an aircraft would constitute a requirement that he act in violation of the California and Federal law.

This additional evidence shows that the findings of the Board are in error. Without reconsideration of those findings and a modification of the Board's recommendations, the cause of this accident could remain unknown to the aviation community.

We, therefore, respectfully request that the Board reconsider its report. We will remain prepared to assist the

APPENDIX D

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Board and its investigators upon request.

Sincerely,

KERN and WOOLEY

M. Eugene Wooley
Michael J. Terhar

By Michael J. Terhar
Michael J. Terhar

MJT:eg

Enc.

Reporter's Transcript of Proceedings:

Vol.	5	pp	86 - 89	Mr. Jack Tice
Vol.	10	pp	1 - 29	Mr. James Camomile
Vol.	12	pp	1 - 80	Dr. Arum Kumar
Vol.	14	pp	12 - 60	Mr. Alfred Schwider
Vol.	14	pp	31 - 146	Mr. James Ronay and Dr. George Sines
Vol.	15	pp	1 - 161	Dr. George Sines and Mr. Ralph Lightfoot
Vol.	17	pp	1 - 68	Dr. Gary Fowler
Vol.	18	pp	1 - 57	Dr. Gary Fowler

Health & Safety Code, Section 12648

APPENDIX E

NTSB RESPONSE TO PETITION
FOR RECONSIDERATION OF PROBABLE CAUSE

National Transportation Safety Board

Washington, D.C. 20594

October 30, 1984

Mr. John Landis, Petitioner
Petition of Reconsideration of Probable Cause
Aircraft Accident -- Western Helicopters, Inc., Bell UH-1B,
N87701, Valencia, California, July 23, 1982 (NTSB/AAR-84/02)

RESPONSE TO PETITION FOR RECONSIDERATION

Based on its review of the Petition for Reconsideration and Modification of March 16, 1984, the National Transportation Safety Board has revised portions of the accident report, has revised two findings and deleted one, and has modified the probable cause of the subject accident. The Safety Board has not changed the probable cause as proposed by the Petitioner, and therefore, the Safety Board has granted the Petition only in part.

In accordance with the Safety Board's rules (49 CFR Part 845), the Safety Board has considered a Petition for Reconsideration of its analysis, findings, and probable cause in the aviation accident involving a Western Helicopter, Inc., Bell UH-1B, N87701, Valencia, California, on July 23, 1982.

On March 6, 1984, the Safety Board determined that the accident occurred while the helicopter was being used in the filming of a motion picture scene depicting a village in Viet Nam which was under attack with heavy ordnance. The helicopter was being used as a camera platform and in an active role in the movie sequence. The helicopter was hovered about 25 feet above the village and nearly directly above the location where special effects devices were detonated to simulate the heavy ordnance explosions. As the pilot turned the helicopter to the left to position it for filming operations, the helicopter's tail section was engulfed in a fireball created by the detonation of a special effects device. The tail rotor assembly separated, and the helicopter descended out of control. The helicopter's main rotor blade struck and fatally injured three actors on the ground. The six occupants on the helicopter sustained minor injuries, and the aircraft was damaged substantially.

The Safety Board's investigation and analysis of this accident concentrated on those aspects of the accident which directly related to the loss of control of the helicopter and its subsequent crash. The Safety Board's investigation was necessary to ascertain whether the circumstances which led to the accident might have broader application to the safety of U.S. civil aviation transportation, such as inadequate pilot qualifications, regulatory deficiencies, or airworthiness problems with the helicopter.

The Safety Board's analysis of the evidence indicated that there were no airworthiness deficiencies with the aircraft, and that the pilot was trained and qualified for the flight. The Safety Board determined the aircraft flew too close to a special effects device as it was being detonated to simulate an artillery shell. The explosion, from a distance of about 25 feet, caused a piece of debris to strike a tail rotor blade. An indentation caused by the impact created a dynamic and aerodynamic inbalance in the tail rotor system which generated sufficient loads to cause separation of the 90° tail rotor gearbox and the rotor gearbox. The aircraft was not controllable after the tail rotor assembly separated.

The Safety Board concluded that there was no direct discussion among the director, the helicopter pilot, and the special effects personnel to insure that there was a common understanding of the positioning of the helicopter throughout the left hovering turn, and to insure that the special effects devices would not be detonated prematurely. Additionally, no provision was made for direct radio communications between the pilot and the special effects technicians to insure that the technicians did not detonate the special effects devices in such a manner as to endanger the helicopter operation.

When the report was adopted, the Safety Board determined that the probable cause of the accident was "the detonation of a debris-laden special effects explosion too near to a low flying helicopter leading to damage to a rotor blade, the separation of the helicopter's tail rotor assembly, and the uncontrolled descent of the helicopter. The proximity of the helicopter to the special effects explosions was due to the failure to establish direct communications and coordination between the pilot, who was in command of the helicopter operation, and the film director, who was in charge of the filming operation."

The following discussion addresses the evidence the Petitioner submitted to the Safety Board which the Petitioner states supplements the factual evidence developed in the investigation, and provides a foundation to revise the analysis, conclusions, and probable cause. The Petitioner contends that the failure of the tail rotor assembly was caused by the heat delamination of the skin of one of the two tail rotor blades. The Petitioner contends further that the responsibility for the detonation of the special effects device which generated the heat to delaminate the tail rotor blade rested with the licensed pyrotechnics operator on the movie site.

In support of the petition, the Petitioner provided transcripts of testimony at a preliminary hearing in the Municipal Court of Los Angeles Judical District of a technical consultant engaged by the film director, of several expert witnesses, and of persons who were involved with the movie, the movie scene, and the operation of the helicopter.

Petitioners first contention is that the accident was the result of the heat delamination of the aluminum skin from one of the tail rotor blades. The delamination was caused by the failure of the adhesive which bonded the skin to the tail rotor blade. The Petitioner contends that the adhesive failed after the tail rotor blade was exposed to excessive heat which was generated by the explosion of a defective special effects device. In Petitioner's view, the delaminated tail rotor blade subsequently caused the failure of the tail rotor assembly, and the loss of control of the helicopter.

The tail rotor blade which had delaminated skin was examined during the accident investigation at the helicopter manufacturer's facility under the supervision of the Safety Board. The accident report stated that "...the aluminum skin had separated at the bonding surface as a result of exposure to excessively high temperatures. Tests of the

adhesive qualities of the bonded areas with respect to temperature increases disclosed that the adhesive coefficient of the bond area diminished at increased temperatures. . ." However, there was no analysis in the report of the possible consequences of a delaminated tail rotor blade, or of any relation of this event to the cause of the accident. Nevertheless, the report stated that "the skin probably separated after the fracture of the other blade, and therefore, was not a significant factor in the loss of the tail rotor assembly."

The Safety Board's reexamination of the accident data and the evidence provided by the Petitioner indicates that its original assessment of the delaminated blade's possible involvement in the separation of the tail rotor system was not complete. Following reassessment, the Board believes it possible that the delamination of the skin on one blade could have led to an imbalance in the tail rotor system that could have caused the tail rotor gearbox and assembly to separate. Consequently, the Safety Board now concludes on the basis of all the data that the separation of the tail rotor system could have resulted from dynamic and aerodynamic forces caused by the delamination of a 33 1/4- by 1/2-inch piece of skin from one of the tail rotor blades. As noted in the report, the examination of the other blade of the tail rotor assembly by the Safety Board and by independent sources showed that the blade was struck on the trailing edge by an unknown object. The strike either fractured the blade outright, or so distorted and weakened the blade that the ensuing out-of-balance dynamic and aerodynamic forces resulted in the fracture of the blade.

The pictures of the accident scene and the tail rotor sound spectrum study indicate that the tail rotor assembly separated from the helicopter about 2 seconds after the last special effects device was detonated. Additionally, all examinations of the tail rotor gearbox indicated that the gearbox failed instantaneously from an overload failure. As a result, it is not possible to determine which occurred first: the delamination of one blade or the strike of the other blade by an unknown object. However, it is quite possible that since the two events occurred almost simultaneously, the aerodynamic deterioration of one blade contributed to the failure of the other blade and, cumulatively, to the failure of the tail rotor assembly.

Therefore, the Safety Board has accepted the argument of the Petitioner on the delamination issue, and the analysis of the report has been revised to examine and evaluate blade skin delamination as a factor in the accident sequence. The revised analysis to be included in the accident report concludes "that the imbalance of the tail rotor system could have occurred from either of two sources, but most likely occurred from a nearly simultaneous combination of two sources: damage from a foreign object to the trailing edge of the fractured blade and the delamination and separation of a major piece of the skin on the other blade." The findings in the report and the probable cause of the accident will be revised to reflect the Board's acceptance of delamination of a rotor blade as a factor in the accident.

The Petitioner's second major allegation was that there was no physical evidence to prove that a blade of the tail rotor was struck by debris generated by a special effects explosion. The Petitioner further asserted that the foreign substance on the trailing edge of one tail rotor blade was fuselage strip paint and not lock bond adhesive, which was used in the special effects devices.

The Safety Board does not agree with the contention of the Petitioner that there was no physical evidence to prove that a tail rotor blade was struck by debris hurled upward by a special effects explosion. Movie films of the helicopter at the time the tail rotor assembly separated showed clearly that the aft end of the helicopter was engulfed

by the effects of an explosion which involved debris and flame around the tail rotor assembly. Also, two independent examinations of the broken tail rotor blade established that the tail rotor blade fractured after being struck by a foreign object. Consequently, the Safety Board believes that its analysis of this issue, as reflected in the accident report, is correct and does represent a valid explanation of a factor in the failure of the tail rotor gearbox assembly.

At the time of the initial investigation, the Safety Board engaged a technical consultant to test the foreign substances in the indentation on the trailing edge of one tail rotor blade. An energy dispersive X-Ray (EDX) microprobe-type chemical analysis was conducted of the substances. The Safety Board's technical consultant concluded that substances found on the separated tail rotor blade (which was broken at the time of examination) were similar to that found in lock bond adhesive. Subsequently, the accident report cited these findings to support a conclusion that the object that struck the blade was propelled upward from the ground by the detonation of a special effects device. The Petitioner engaged another technical consultant who did three additional tests and found that substances on the broken blade were fuselage strip paint. The report has been revised to include the results of the tests which were conducted by the Petitioner's consultant. However, because the traces of green and black substances found on many areas of the blades may have been deposited on the blades before the accident or during the accident sequence, the source of the substances on the broken blade was not definitively established.

Associated with the Petitioner's second contention was the allegation that any debris hurled upward by the detonation of special effects devices could not have been propelled with sufficient force to dent the tail rotor blade and cause the accident. The Safety Board agrees that the explosion lacked the force to hurl debris at significant velocities and this belief is stated in the accident report. However, the analysis of the encounter between the tail rotor blade and a foreign object established a possible explanation of the impact which might have produced the force needed to dent the blade. That portion of the report has not been revised.

The Petitioner's third contention is that the movie director had no authority under California or Federal law to exercise control over the detonation of special effects devices or the flight of the helicopter. The Petitioner claims that the licensed pyrotechnics operator who detonated the special effects devices exercised sole control over, and had sole responsibility for, the detonation sequence and, therefore, the cause of the accident was the improper detonation of a special effects device solely under the control of the licensed pyrotechnics operator. However, the acceptance of this contention by the Safety Board would require disregarding all the critical conditions and circumstances attendant on the accident and which preceded the accident sequence. As in most aircraft accidents, the cause of the accident is the sum of many related events. This accident was no exception. To contend that the licensed pyrotechnics operator was the only person on the movie set responsible for the safety of the helicopter, its occupants, and persons on the ground beneath and around the helicopter completely overlooks the responsibility of key persons who made decisions that created the conditions and circumstances wherein an accident was likely to occur. The helicopter pilot and the film director had direct responsibility for the safe operation of the helicopter and the safe management of the movie scene, respectively. Consequently, the Safety Board does not accept the contention that these responsibilities were delegated by law or any other means to the person who was in charge of the detonation of the special effects devices. Therefore, the Safety Board believes that portion of the accident report which analyzed

the safety of the whole filming operation properly discussed and evaluated the relationships between the helicopter pilot, the movie director, the unit production manager, and the special effects technicians. The lack of preproduction meetings, coordination, and communications led the Safety Board to conclude that the director failed to fulfill his responsibility of insuring safety on the film set. As a result, the Safety Board does not accept the Petitioner's assertions on this issue.

With regard to the probable cause, the Safety Board has accepted the Petitioner's argument that the delamination of a tail rotor blade may have been a factor in the accident. As a result, the Safety Board concludes that the probable cause as well as the analysis of the report and some findings should be revised.

ACCORDINGLY,

(a) The Petitioner's petition for reconsideration and modification of probable cause and finding of the aircraft accident report on Western Helicopters, Inc., Bell UH-1B, N87701, Valencia, California, July 23, 1982, is hereby granted in part.

(b) The Safety Board's report is revised and a corrected report will be issued which contains a revised analysis section, two revised findings (and deletes one finding), and a revised probable cause.

(c) The probable cause is revised as follows:

The National Transportation Safety Board determines that the probable cause of the accident was the detonation of debris-laden high temperature special effects explosions too near to a low flying helicopter leading to foreign object damage to one rotor blade and delamination due to heat to the other rotor blade, the separation of the helicopter's tail rotor assembly, and the uncontrolled descent of the helicopter. The proximity of the helicopter to the special effects explosions was due to the failure to establish direct communications and coordination between the pilot, who was in command of the helicopter operation, and the film director, who was in charge of the filming operation.

The Safety Board commends the Petitioner for the thorough preparation of the petition, and for his interest in aviation safety.

JIM BURNETT, Chairman, PATRICIA A. GOLDMAN, Vice Chairman, and G. H. PATRICK BURSLEY, Member, concurred in the disposition of this Petition of Reconsideration.

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