NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

Airworthiness Group Chairman's Factual Report

May 15, 2012

A. ACCIDENT DCA12MA020

Location:	14 Miles East of Las Vegas, Nevada
Date:	December 7, 2011
Time:	1630 Local Time (PST)
Aircraft:	Eurocopter AS350-B2, registration N37SH, Sundance Helicopters flight Landmark 57

B. GROUP

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C. SUMMARY

On December 7, 2011 at 1630 Pacific Standard Time, a Eurocopter AS350-B2, registration N37SH, operated by Sundance Helicopters as flight Landmark 57, crashed in mountainous terrain approximately 14 miles east of Las Vegas, Nevada. The 49 CFR Part 135 flight was a tourist sightseeing flight, which departed from Las Vegas McCarren International Airport (LAS), Las Vegas, NV, intending to fly to the Hoover Dam area and return to LAS, operating under visual flight rules. The helicopter impacted in a ravine in mountainous terrain between the city of Henderson and Lake Mead. The pilot and four passengers were fatally injured, and the helicopter was substantially damaged by impact forces and fire. Access to the accident site was moderately difficult and the investigators were assisted by the National Park Service. There were no installed on-board recording devices. Weather was reported as clear with good visibility and dusk light conditions.

The Airworthiness Group met at the accident site from December 8 to December 12, 2011 to document the relevant helicopter airworthiness systems. Numerous components were removed from the helicopter and retained by the National Transportation Safety Board (NTSB) for further examination. Included in the list of retained components were the helicopter's servo commande actuators:

1. Fore/Aft Servo Commande Actuator:
   Part Number: AC67246
   Serial Number: BX264
   Manufacture Date: November, 1979

2. Left Lateral Servo Commande Actuator:
   Part Number: AC67244
   Serial Number: QG450

Manufacture Date: April, 1992

3. Right Lateral Servo Commande Actuator:
   Part Number: AC67244
   Serial Number: QJ254
   Manufacture Date: May, 1992

4. Tail Rotor Servo Commande Actuator:
   Part Number: AC67032
   Serial Number: DK287
   Manufacture Date: May, 1981

The Airworthiness Group met at the National Transportation Safety Board Materials Laboratory in Washington, D.C. on December 20, 2011 to examine the ~14-inch segment of flight control input linkage and the fore/aft servo. The examination was performed by the NTSB Senior Metallurgist.

From January 25-27, 2012 the four servo commande actuators were examined at Varian Medical Systems in Lincolnshire, Illinois, under direction of the NTSB, to document the internal configuration of the main rotor and tail rotor actuators. Varian Medical Systems conducted computed tomography (CT) scans and digital radiography scans of the 4 servos. The actuators and a rod end of the fore/aft servo commande actuator were documented using a combination of computed tomography (CT) scans and digital radiography.

On March 6th and 7th, 2012, the group met at Air Transport in Phoenix, Arizona to examine the wreckage removed from the accident site. The purpose of the examination was to find connection hardware for the fore/aft input upper rod end attachment and the fore/aft servo. The wreckage was contained in 8 flexible Intermediate Bulk Containers (FIBC bags) with a volume of about 16 cubic feet each of loose pieces and soil from the site and several large pieces of the helicopter placed on a trailer. All of the wreckage was examined; however, none of the connection hardware was positively identified. Multiple washers, bolts, and a cotter pin were removed from the wreckage and retained for further examination. In addition, numerous pieces of melted metal were retained to examine whether the attachment hardware was in any of the pieces.

D. DETAILS OF INVESTIGATION

1.0 Aircraft Structures

1.1 General Description

The Eurocopter AS350-B2 helicopter is equipped with a single three-bladed main rotor system, and a conventional two-bladed tail rotor for anti-torque and heading control. The helicopter has a seating capacity of 6 passengers plus a pilot and has 2 large doors on each side of the helicopter. The fuselage structure is constructed using predominantly aluminum, with composite panels and a skid type landing gear. The helicopter's flight control system is a mechanical flight control system assisted by hydraulic actuators. The system is controlled by a pilot actuated cyclic, collective, and anti-torque pedals. The anti-torque pedals are routed to the tail rotor servo via a flex ball cable. The cyclic and collective controls continue through mechanical linkages to a transmission mounted hydraulic servo control system, which controls lateral, longitudinal, and collective control. All of the right-hand side controls had been removed from the helicopter.

The main fuselage consists of the body rear structure, the bottom structure/cabin floor, and canopy. The main fuselage carries the flight load and landing loads. The main fuselage also supports the main transmission components, landing gear, cabin floor, and rear structure. Finally, it holds the fuel tank. Although the rear structure serves as the baggage compartment, the rear and forward frames of the rear structure support the helicopter engine. In addition, the tail boom is bolted onto the third junction frame. The bottom structure and cabin floor are cantilevered from the body structure by two beams. These two beams, laterally stiffened by cross members, are riveted to the body structure side beams. The beams support the front part of the landing gear.

The tail boom is connected to the rear structure and is a semi-monocoque structure. Plate stiffeners are attached to the top of the tail boom to provide bending rigidity, with the tail rotor drive shaft mounts and tail rotor drive along the length of the tail boom. The tail boom supports the tail gearbox, the tail unit, and the tail cone. The tail unit contains the horizontal stabilizer, an upper (dorsal) fin, and a lower (ventral) fin. The tail cone is attached to the rear of the tail boom

The helicopter canopy structure includes the cabin roof, nose, and 3 windshield uprights that are bolted onto the cabin floor and body structure bulkhead. On each side the cabin has a main cabin door to access the pilot (front) seats and a subdoor to access the rear of the cabin. The canopy also has 2 windshield panels, 2 roof windows (above the pilot seats), and 2 lower windows on the left-hand and right-hand side of the canopy front.

The landing gear assembly consists of two longitudinal skids, connected by front and rear cross tubes. The front cross tube is connected to the bottom structure beams and the rear cross tube is connected to the body structure. The front cross tube also has 2 hydraulic shock absorbers attached to dampen vibration.

According to Eurocopter, the accident helicopter was manufactured as an AS350B in 1989 as serial number 2300. It was subsequently converted to an AS350BA. According to the conversion data plate recovered from the wreckage, the helicopter was converted to an AS350B2 in April, 2008 using Service Bulletin Number 0.00.50 R.3.

1.2 Accident Site Overview

The aircraft was located near the bottom of a ravine that runs East-West surrounded by mountainous terrain that rose above the accident site approximately 150 feet. The aircraft was observed to have extensive post impact fire damage and was substantially destroyed by impact forces. The aircraft impacted the rocky terrain of the north wall of the ravine on an approximate north-easterly heading. The aircraft cockpit area and predominate aircraft structure came to rest on an approximate heading of 260° magnetic. The components required for flight were observed in the immediate area of where the wreckage came to rest.

The aircraft exhibited extensive impact damage and post-impact fire damage. A large amount of the structure forward of the horizontal stabilizer was consumed by post impact fire.

Using a hand-held global positioning system (GPS) receiver, the following latitude and longitude positions of the wreckage were noted:

#	Description	Latitude	Longitude	GPS Altitude (Ft)
1	Rotor Head Vibration Absorber	36° 3.947' N	114° 51.891' W	unavailable
2	Tail Rotor Short shaft	36° 3.948' N	114° 51.905' W	1,826
3	Tail Rotor wreckage	36° 3.954' N	114° 51.901' W	1,847
4	Main rotor hub	36° 3.956' N	114° 51.898' W	1,853
5	Rotor blade pieces 1	36° 3.955' N	114° 51.889' W	2,117
6	Rotor blade pieces 2	36° 3.953' N	114 ° 51.891' W	2,120
7	Rotor blade pieces 3	36° 3.950' N	114° 51.899' W	2,131
8	1st impact - pieces of windscreen	36° 3.954' N	114° 51.908' W	2,133
9	1st Rotor Strike (FAA)	36° 3.960' N	114° 51.914' W	2,060

1.3 Cabin/Cockpit

The aircraft was configured to be flown from the left forward seat. The right forward side was configured to seat two passengers on a bench seat with the right-hand side controls removed. The dual cyclic control cover was observed in the aircraft wreckage and the operator reported that anti-torque and collective covers were installed. The removal of the right-hand side controls and the installation of the bench seat were modifications incorporated under Limited Supplemental Type Approvals (LSTA's) accomplished by the owner in 1997 and not part of the original Eurocopter design.

The rear cabin was configured with the standard four seats. None of the seat structure was observed. The pilot's seat track and four point restraint buckle exhibited severe fire damage and other seat buckles were found latched/secured. The passenger seats' restraint buckles were located and were observed as latched/secured; however, the items exhibited extensive fire damage.

The instrument panel was severely damaged and the instruments were observed to exhibit damage consistent with a nose down impact angle. The caution warning panel was observed with several light bulbs still present, but thermally damaged.

The helicopter wreckage was confined to the immediate impact and wreckage location. Except for the recovered items, the components were identified and documented at the wreckage site, and removed by the recovery company.

A list of the helicopter components removed from the accident site and retained by the NTSB for possible further examination was included to this report in Attachment 1. In addition, during the wreckage examination in Phoenix, several pounds of melted metal was recovered and shipped to the NTSB Materials Laboratory in Washington, D.C.

2.0 Aircraft Systems

The group identified and documented the relevant systems of the helicopter. The group documented the following categories:

2.1 Flight Controls

2.1.1 Flight Deck Controls

The pilot's cyclic and collective controls were observed to be bent in a forward, downward direction, within ~1" of the pedestal base. The collective remained attached to its base. The cyclic grip was broken off from the cyclic but was still connected, via the unbroken, internal wires, to the cyclic. The fuel flow control lever (FFCL), rotor brake, and fuel cut-off levers were present and exhibited extensive impact and thermal damage.

The anti-torque pedals were located in the wreckage. The anti-torque pedals were observed in a neutral position and not deformed. The pedals were found connected to each other through the linking tube at the bottom of the pedals. The connection pins were present for both pedals.

The linkages between the flight deck cyclic and collective are rigid rods interconnected by bellcranks and levers. Each control linkage eventually leads to the main rotor swashplate through a hydraulic servo commande actuator. The servo commande actuators provide the hydraulic power to exert the necessary control forces. The control linkages run under the main cabin aft to the mixing unit, which is the interface for the cyclic and collective controls. The movement of the collective and cyclic is compensated through the mixing unit and transferred to the servo actuators and main rotor swashplate.

2.1.2 Main Rotor Servo Commande Actuators

The components of the mechanical flight control systems (collective, cyclic, and anti-torque) were examined. The majority of mechanical flight control tubes exhibited impact and thermal damage. Many alloy tubes were consumed by post-crash fire.

All three main rotor hydraulic servo commande actuators were attached to the main transmission (lower) and non-rotating swashplate (upper) attachment points. The piston rods of all three main rotor servos were deformed; the piston sleeves of both lateral servos (left and right) were separated consistent with impact damage and displacement by the deformed piston rods. The servo input control clevis for both lateral servos (left and right) were observed attached to the servos and exhibited thermal damage; however, the input control rod upper rod end and hardware was not present on the fore/aft servo; the servo input attachment holes did not exhibit any visible elongation. All three main rotor servos and the majority of the remaining mechanical cyclic control system were removed and retained for further examination.

Figure 1 - Fore/Aft Servo Commande Unit, as found in wreckage, noted with connection to swash plate (green arrow), main transmission (black arrow), and input linkage connection (red arrow).

An approximate 14” section of a control rod with a similar appearance and dimensions as the fore/aft main rotor servo input upper rod end was observed without attachment hardware (bolt, nut, and cotter pin). No visible elongation of the bolt hole was observed. The approximate 3” lower section of the fore/aft main rotor servo input rod remained attached to the transmission deck bell crank from the mixing unit. The separation points on both sections were consistent with overload/impact damage.

To confirm the identity of the control rod section, the group visited the Sundance Helicopters Maintenance facility in Las Vegas. The group compared the control rod section to various input control rods on another AS350 helicopter. The best comparison was to the fore/aft main rotor servo input upper rod.

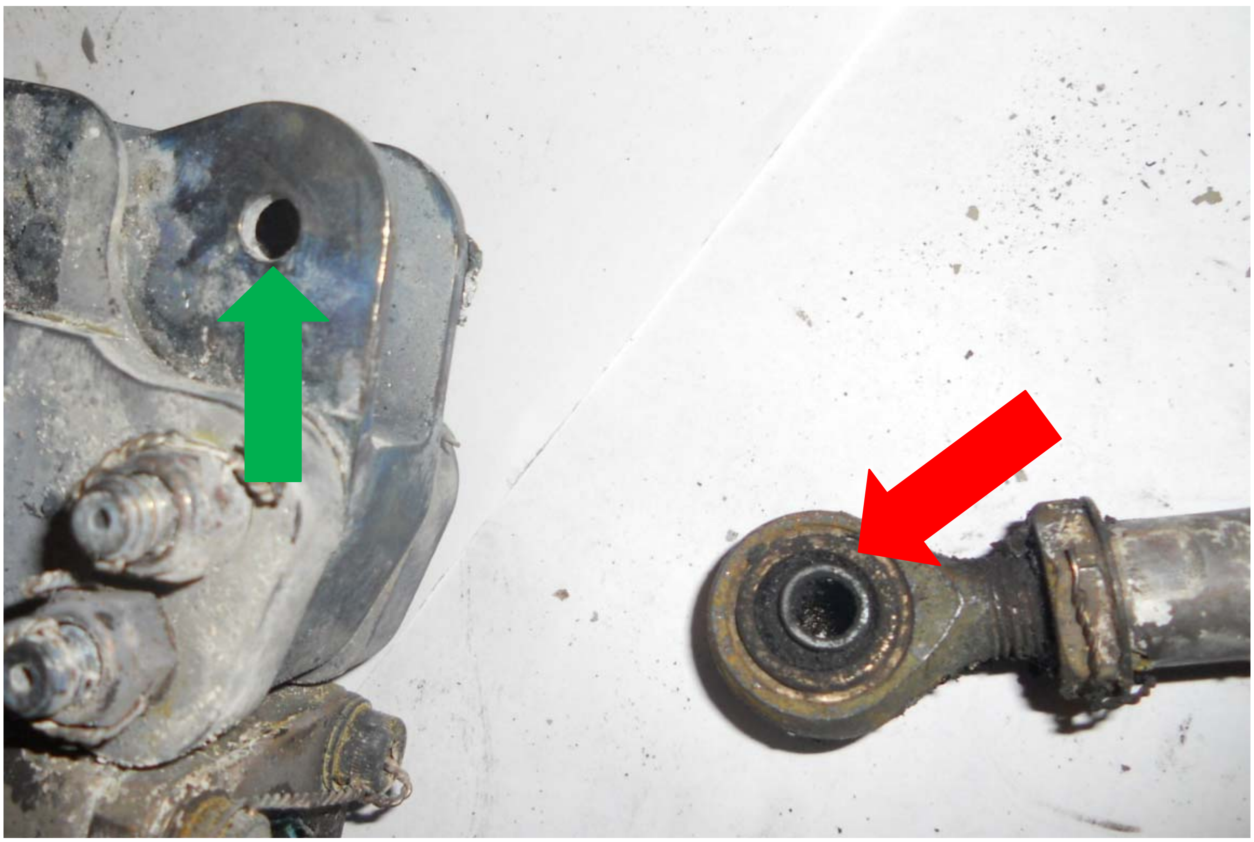

Figure 2 - The Fore/Aft Servo Commande Unit (Left) and the Fore/Aft Servo Input Upper Rod End (Right), with areas of attachment on the Servo Commande Unit (green arrow) and rod end ball bearing (red arrow).

The fore/aft servo commande unit and the fore/aft servo input upper rod end were examined at the NTSB Materials Laboratory in Washington, D.C. by an NTSB Senior Metallurgist. The area around the fore/aft servo commande unit input linkage connection and the area around the rod end ball bearing of the fore/aft servo input upper rod end were examined under microscope. Melted metallic materials that blocked the left control rod attachment hole on the fore/aft servo were removed for further analysis. Melted plastic material covering and blocking the fore/aft input upper rod end attachment hole was removed from the rod for further analysis. Not all of the melted plastic material was removed at this time.

While looking at the fore/aft servo attachment area under microscopic power, the Senior Metallurgist indicated that he did not observe any marks indicative of hardware being installed at impact. In addition he did not observe any visible elongation or deformation of the attachment holes in either the fore/aft servo commande unit input linkage connection and the area around the rod end ball bearing of the fore/aft servo input upper rod end.

For more information, please see the Materials Laboratory Factual Report regarding this matter.

2.2 Main Transmission

The main transmission exhibited extensive impact and thermal damage. The modules separated from one another due to impact and fire, and a majority of the magnesium case was consumed by post crash fire. All gears were present and exhibited no evidence of pre-impact abnormality. The main transmission input pinion separated from the transmission with the rotor brake and transmission input shaft assembly. The engine power output shaft sheared in torsion near the freewheel unit and everything from that point through the main transmission input pinion remained attached as an assembly but was heavily damaged, consistent with a powered impact.

2.3 Main Rotor System

The main rotor provides the lift for the helicopter and controls the direction of flight. The main rotor consists of the three rotor blades, the rotor hub, and the main rotor mast. The main rotor mast is secured to the main gearbox. It drives the main rotor hub and transmits the rotor lift to the airframe. The hub is attached to the rotor shaft and supports the blades. The blades convert the mechanical engine power into lift.

The main rotor system consists of a main rotor hub with 3 identical rotor (or star) arms spaced evenly about the rotor (separated by 120°). Each rotor arm (or blade) is identified by a different color – yellow, blue, or red. Each rotor blade is approximately 4,677 mm in length and is comprised of a composite material with a stainless steel cover attached to the leading edge. The rotor blade has static and dynamic balance weights placed near the end of each blade. Each blade is connected to the main rotor star. The blades are flexible to “flap” as well as rotate in the pitch direction and in the drag direction, and provide the centrifugal loads into the center of the star.

The main rotor mast consists of the main rotor driven by the main gearbox, the swashplate (which is comprised of a rotating star and a non-rotating star), and the casing assembly which houses the connection between the mast and the main gear box.

The main rotor hub vibration absorber is mounted on the top of the main rotor assembly. The absorber is comprised of a large weight with 3 springs that counteract the periodic cyclic loads on the rotor hub.

The main rotor Starflex arms and sleeves were broken and/or deformed consistent with a powered impact. The red star arm was fractured at a 45 degree angle with evidence of tension on the leading edge and compression on the trailing edge.

Figure 3 - Main Rotor "Starflex" Hub with letters to indicate each of the star arms (Yellow, Blue, or Red).

All three main rotor blade roots remained attached to their respective sleeves. All three main rotor blades exhibited impact damage consistent with a powered impact. Fragments of main rotor blade foam and skin were found surrounding the accident site. The red blade exhibited the most severe damage with broom-strawed segments of the spar found around the wreckage site. The majority of the spars from all three blades were found, and all tip weights were located within the immediate vicinity of the accident site.

Figure 4 - Main Rotor Blades after removal from the main rotor mast

The main rotor hub and rotor head vibration absorber separated from the mast and was observed outside of the fire zone and did not exhibit thermal damage, but did exhibit impact damage.

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Figure 5 - Main rotor head vibration absorber

2.5 Tailboom

The tailboom forward of the horizontal stabilizer was consumed by the post impact fire. The separation of the horizontal stabilizer from the tailboom was consistent with fire and impact damage.

Figure 6 - Aft Tailboom

2.4 Tail Rotor System

The tail rotor system controls the helicopter about its yaw axis. The tail rotor counteracts the main rotors torque with tail rotor thrust. The tail rotor has two flexible composite blades with a “see-saw “mounting that allows the rotor to balance every half revolution. This helps counteract dissymmetry of lift due to the advancing and retreating blade.

Rotational power is provided to the tail rotor from the rear engine power output, a forward drive shaft, rear drive shaft, and the tail gearbox. The shafts are connected to the engine, the tail rotor gearbox, and each other by use of 3 flexible couplings. The tail rotor gearbox is a spiral, beveled gear. The gearbox is designed to absorb the radial loads and axial thrust.

In the flight deck the tail rotor pedals are interconnected by a rocker arm so that when one pedal moves forward the other moves backwards. The command is transferred back to the tail rotor by a series of input rods, bellcranks, and a flexible ball-type sliding control. At the tail rotor servo control the input is transferred through a bellcrank and input rod.

The mechanical anti-torque control system to the tail rotor flex ball cable was damaged by impact and post crash fire. The flex ball cable was present and was traced back to the tail rotor servo input. The servo attach point was consumed by post crash fire. The tail rotor servo was present and retained for further examination.

The tail rotor system was observed with extensive thermal damage. The tail rotor spar was broken and the blades exhibited thermal damage. One of the two blades exhibited some impact damage near the tip. The tail rotor drive system short shaft was observed with impact damage at both ends of the adapters, and flex couplings exhibited splaying consistent with separation during rotation. Four or the five hanger bearings were observed and exhibited extensive thermal damage.

Figure 7 - Tail Rotor Short Shaft

The tail rotor system was observed intact with thermal damage. The tail rotor gearbox rotated and no pre-impact abnormalities were observed with gearbox. One of the two pitch links was deformed. Contact damage was observed between the tail rotor boss weights and the tail rotor shaft consistent with a neutral pitch setting.

The gearbox was noted as follows:

Assembly Number: 3302005

Serial Number: MA1987

Tail rotor drive integrity was confirmed from the tail rotor drive shaft. The tail rotor rotated when the drive shaft was rotated.

2.5 Landing Gear

Sections of both cross tubes and skids were recovered in the wreckage. One of the skids was partially consumed by fire. The landing gear cross tubes separated from the skids near the ankles and rotated aft. The skid toes were damaged consistent with a nose-down impact.

The aft cross tube was still attached to the main helicopter structure at the aft engine compartment bulkhead.

Both skid steps were recovered.

2.6 Hydraulic System

2.7.1 Description

The helicopter is equipped with a hydraulic system which supplies hydraulic power to the servo commande actuators. The system includes a constant-pressure hydraulic system, including a gear pump driven at constant speed by the main drive shaft via a belt and pulley assembly, with a constant discharge flow of 6 liters/minute; a 3-micron filter with a visual clogging indicator; and a regulator valve to keep the pressure at its rated value of 40 bar (~580 psi). The flow is designed to satisfy the demands of the servo commande actuators in all conditions. This results in an excess flow in normal flight conditions. The excess flow is bypassed into the hydraulic reservoir by the regulator valve, which opens when the pressure exceeds 40 bars.

The helicopter can be equipped with servo commande actuators from 2 manufacturers – SAMM (now Goodrich Actuation Systems) and Dunlop (now Meggitt Control Systems). There are 4 servo commande actuators in the system – 3 on the main rotor (fore/aft, left lateral, and right lateral), and 1 for the tail rotor system. The servo commande actuators from the 2 manufacturers are essentially identical in function.

The servo commande actuator installed in the fore/aft position is fitted with an input lever lockout system. This lockout system reduces input lever play while in the manual mode.

Each of the 3 main rotor servo commande actuators have 3 connections – an input linkage directly back to the flight deck input controls, a linkage to the main rotor mast via rod-end bearings, and a connection to the swashplate. The tail rotor servo commande actuator is secured to the airframe via a rod-end bearing and to the output adapter guide, as well as the input rod connection. The piston rod end is secured to the rotor mast casing.

Hydraulic system flight deck controls and indications include the accumulator test pushbutton switch on the control pedestal, hydraulic cut-off guarded switch on the collective lever, a “HYD” light on the Warning-Caution-Advisory Panel which indicates low system pressure (less than 30 bars), and an aural “horn” in case of loss of pressure.

If the hydraulic system fails or otherwise shuts down, the flight controls can be operated with manual reversion, although the flight loads are non-negligible. Each of the main rotor servos have an accumulator backup that provides servos with sufficient hydraulic pressure to allow the pilot to reach a safety speed of 40-60 knots (the speed corresponding to the minimum load to control the aircraft) before switching off the hydraulics via the hydraulic cut-off switch on the collective.

2.7.2 Accident Site Observations

The hydraulic system lines were consumed by post-crash fire. The hydraulic pump was removed for further examination. The pump rotated freely and fluid exited the pump when rotated. The pump was disassembled at the accident site under group witness, and the coupling splines were noted in good condition and were amply lubricated.

2.7 Fuel System

The fuel tank was destroyed by impact forces and post-crash fire. Small segments of the fuel tank were located in the wreckage site. The fuel lines were consumed by post crash fire.

2.9 Flight Deck Components

The following flight deck components were noted in the wreckage, separated from the front instrument panel unless otherwise noted:

a. Avionic unit with “V55004 Video Sequential Switches” inscribed on the front face. Six (6) small switches on the front were noted. Five of the switches were bent upwards and 1 was broken off. Attached to the unit was a larger unit with a slot for recording medium. No medium was present in the slot.

b. Directional Gyro, found loose
Manufacturer: Mid-Continent Instruments
Part Number: 3300-11
Indication: Instrument face missing, no indication possible.

c. Bank Indicator, found loose.
Manufacturer: Mid-Continent Instruments
Part Number and Serial number unreadable
Indication: Instrument face missing, no indication possible.

d. Portion of unknown temperature indicator, found loose
Manufacturer: Ruegger
Instrument glass face missing, dial indicator moves freely no indication possible.

e. Oil Pressure Instrument, found loose
Manufacturer: Thales
Part number: 64818-010-1
Serial number: 3791

Indication: ~4.3 bars, in green band, instrument glass missing

f. Fuel Pressure Instrument, found loose
   Manufacturer: Thales
   Part number: 64818-303-1
   Serial number: 3732
   Indication: Zero, instrument glass missing

g. Amperage Indicator
   Manufacturer: Thales
   Part Number: 2309-362-80-10
   Serial Number: 1192
   Indication: ~zero, instrument glass intact

h. Attitude Indicator
   Manufacturer: Mid-Continent Instruments
   Part number: 4300-311
   Serial number: H07-10545
   Mod status: 1-3
   Indication: Instrument glass missing.

i. Warning and Caution Panel - Panel has front glass missing and damaged by fire. Several individual items have bulbs remaining inside the panel. No data plate available.

j. Several unknown avionic components.

k. Four small square light components from the center console.

2.10 Doors

The baggage doors are hinged along their top edges and can be held open by a rod, which clips on the inside of the door for stowage. The two front doors are fitted with a jettison system. When operated, a handle on the door jamb pulls out the hinge pins and neutralizes the door closure lock.

ATTACHMENT 1

List of Components Removed From Wreckage for Further Examination

List of Components Removed From Wreckage for Further Examination

1. Fore/Aft Servo Commande
   Part Number: AC67246
   Serial Number: BX264
   Manufacture Date: November, 1979

2. Left Lateral Servo Commande
   Part Number: AC67244
   Serial Number: QG450
   Manufacture Date: April, 1992

3. Right Lateral Servo Commande
   Part Number: AC67244
   Serial Number: QJ254
   Manufacture Date: May, 1992

4. Tail Rotor Servo Commande
   Part Number: AC67032
   Serial Number: DK287
   Manufacture Date: May, 1981

In addition, the following servo units removed from the helicopter on the day prior to the accident:

5. Fore-Aft Servo Commande
   Part Number: AC67246
   Serial Number: RX187

6. Tail Rotor Servo Commande
   Part Number: AC67032
   Serial Number: FE212

7. Fore/Aft Servo Input Control Rod (Upper)

8. Tail Rotor Forward/Aft Shaft Coupling

9. Tail Rotor Short (Front) Shaft

10. Hydraulic Pump

11. Miscellaneous Gauges and Parts

12. Caution Warning Panel

13. Unknown Instrument

14. Attitude Indicator
15. Directional Gyro
16. Star Arm Bushing
17. Passenger Electronics (x3)
18. Right Position Light
19. Miscellaneous Flight Control Pieces
20. Flight Control Mixing Unit
21. Miscellaneous Bellcranks
22. Fore/Aft Control Bellcrank
23. Miscellaneous Parts Not Needed
24. Segment of Aircraft Flight Log