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

Airworthiness Group Chairman's Factual Report – Addendum 1

July 6, 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. <u>SUMMARY</u>

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 McCarran 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.

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.

The group met at the Meggitt Control Systems facility in Coventry, United Kingdom from March 27 to March 29, 2012. The group met to examine the four accident servo commande units and the 2 units removed prior to the accident.

The examination and strip down plan was developed and agreed to by the group. The accident servo commande actuators could not be tested due to severe damage to each of the units; therefore, each of the servos was examined and then partially disassembled. The 2 servos removed from the helicopter the day prior to the accident were tested in accordance with the Component Maintenance Manual.

D. <u>DETAILS OF INVESTIGATION</u>

1.0 Further Examination of the Servo Commande Actuators

The group met at the Meggitt Control Systems facility in Coventry, United Kingdom from March 27 to March 29, 2012 to examine and teardown the 4 servo commande actuators removed from the accident wreckage and the 2 servo commande actuators that were removed from the helicopter during maintenance accomplished the day prior to the accident. All of the units had been shipped to Meggitt Control Systems and held in quarantine prior to the arrival of the group.

The part number and serial number of the examined servo units were confirmed as follows:

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

Meggitt Control Systems records indicate that the Fore/Aft servo commande unit had been returned for maintenance, repair, and overhaul at Dunlop Aviation Services (now Meggitt Aircraft Braking Systems) in December, 2000. Meggitt Control Systems had no records of the other 3 accident servo commande units being returned to Meggitt Aircraft Braking Systems.

Each of the Meggitt Control Systems servo actuator units used for this installation – fore/aft, left lateral, right lateral, and tail rotor – consist of a servo valve body attached to the ram body. An extension piece, connected to the ram body, allows for the movement of the piston rod within the piston rod chamber. The units also have an environmental protective cover attached to the servo assembly. The cap protects the area around the control input, with a cutout which allows visual access to the area where the input rod connects to the servo commande unit input.

1.1 Visual Examination of the Accident Servos

Each of the servos were removed from their shipping containers and visually inspected and photographed. The part and serial numbers for each of the servos was confirmed.

The group determined that the damage to each of the 4 accident servos prevented bench testing or performance of the Meggitt Controls Production Acceptance Test protocol. The group decided to strip down each of the servos for further examination. In addition, the group decided to use the preliminary results of the NTSB's computed tomography (CT) scans of the actuators (provided to the group in a Microsoft PowerPoint file) as guidance for the strip down examinations.

1.2 Fore/Aft Servo Strip Down

The fore/aft servo commande actuator differs from the three other servo commande units by the use of a servo control with locking; the servo assembly includes a spring loaded plunger connected to the actuator's lever assembly. If the hydraulic supply to the fore/aft servo fails, the plunger engages into a tapered recess in the lever assembly so the actuator can still be moved by a direct, mechanical linkage. The tail rotor, left lateral, and right lateral servo commande actuators do not have this assembly.

The fore/aft servo commande actuator was heavily sooted and exhibited heat and impact damage. The piston rod and extension piece were bent, and the ram body housing was cracked at the end near the connection to the extension piece. The servo piston was measured 77 mm from the base of the piston housing to the base of the piston rod end.

The servo valve assembly, locking pin and accumulator hardware were removed from the servo assembly. After using considerable manual force to loosen the input linkage, the input linkage could be moved manually. Although the servo valve assembly, locking pin, and accumulator hardware exhibited discoloration due to exposure to heat, no indications of a servo valve jam or other failure were noted.

To inspect the ribbon of material near the piston rod head identified in the CT scans, an endoscopic camera with light source was inserted into an opening in the ram body housing where the housing was cracked and positioned near the piston head. The images from the endoscopic camera indicated that the material appeared to be portions of the glyd ring sleeve on the piston rod head. To inspect the other side of the piston rod head, the piston was manually pulled to create an opening for the endoscopic camera. Once the camera was positioned near the piston rod head, the images confirmed that the ribbon of material was the glyd ring seal. The ring seal had moved from its normal operating position (around the piston rod head, against the ram body inner wall) and was wrapped around the side and top of the piston rod head.

1.3 Left Lateral Servo Strip Down

The servo was heavily sooted and exhibited heat and impact damage. The piston rod and extension piece were bent, and the ram body housing was cracked at the end near the connection to the extension piece.

The left lateral servo was examined for the 4 particles identified in the preliminary CT scan. Particle 1 was noted in the ram body, close to the servo valve area. Particle 2 was noted in the ram body bore. Particle 3 was noted in the servo valve. Particle 4 was noted in a cross-drilled hole in the ram body.

To gain access to the particles in the ram body, the servo assembly was removed. The hydraulic lines inside the housing were examined using an endoscopic camera. The camera was used to find what appeared to be a metallic piece at the bottom of one of the hydraulic passages near the servo spool pin. The particle was identified in preliminary CT scan document as Particle 3.

The endoscopic camera was used to locate particle 2 in the ram body bore. Although particle 2 could not be positively identified, a piece of fibrous material was removed for further analysis. In addition, pieces of extruded glyd ring sleeve were noted near the piston rod.

The group decided to remove 2 of the Lee pin plugs from the servo body to gain access to particles 1 and 4. However, during removal of the first Lee pin plug it was determined by the group that the process to remove the plug produced additional particles which fell into the area of interest. The attempt to remove the second Lee pin plug was aborted when it was determined that it was necessary to drill out the plug and that the effort would introduce additional particles into the area of interest. Further, when an endoscopic camera was probed into the areas noted by the CT scan, no particles were found. The group concluded that the particles in the CT scans were probably loose and subject to movement and decided not continue the examination for the particles.

Meggitt Control personnel indicated that, based on the positioning of the 4 particles noted in the preliminary CT scans, that none of the 4 particles were noted in a position that would indicate a servo jam or servo malfunction. In addition, although the servo valve assembly, locking pin, and accumulator hardware exhibited discoloration due to exposure to heat, no indications of a servo valve jam or other failure were noted.

The particles identified as particle 2 and 3 were provided to the Meggitt Materials Laboratory for identification. A scanning electron microscope was used to analyze the elemental make up of the 2 particles. The Meggitt Materials Laboratory provided a report on the composition, included in Attachment 1.

<u>Particle 2 - Determined to be a cluster of particles, identified in report as "Debris 1, 2, and 3:</u>

- Included: a long strand of Aluminum (Debris 1 and 2)
- Particles of Nickel (Debris 3)

<u>Particle 3 – Noted in Report as "Debris 4"</u>

- 69% Tin
- 13% Nickel

1.4 <u>Right Lateral Servo Strip Down</u>

The servo was heavily sooted and exhibited heat and impact damage. The piston rod and extension piece were bent, and the ram body housing was cracked at the end near the connection to the extension piece. The entire extension piece was broken off from ram body housing.

The servo was examined to confirm the preliminary results of the CT scans, which indicated the filter screen (strainer) assembly was missing. The electro-hydraulic manifold was removed to allow examination of the supply pressure port area for the filter screen assembly. None was found. For comparison, the left lateral servo was opened and the filter screen assembly found in the supply pressure port area.

In addition, although the servo valve assembly, locking pin, and accumulator hardware exhibited discoloration due to exposure to heat, no indications of a servo valve jam or other failure were noted.

1.5 <u>Tail Rotor Servo Strip Down</u>

The servo was heavily sooted and exhibited heat and impact damage. The piston rod was bent and the extension piece was broken and separated approximately 5 inches from the ram body housing.

The servo input lever/linkage connection with input rod were still attached and examined. The installed pin noted on the attachment hardware (see Figure 1) was larger than the split pin used on the other servo commande units. Rather than a split (cotter) pin, the installed pin was a larger safety pin (p/n 23340AK1020LE). Eurocopter indicated that, since the accident helicopter was a former AS350-BA which had been upgraded in to an AS350-B2, which, for this variant, the larger safety pin was an accepted part. The version of AS350 could use either a split pin (cotter pin) or a safety pin. Other AS350 variants do not allow the use of the larger safety pin.

Figure 1 - Safety Pin on Tail Rotor Servo Input Linkage

Figure 2 - Safety Pin on Tail Rotor Servo Connection

In summary, although the servo valve assembly, locking pin, and accumulator hardware exhibited discoloration due to exposure to heat, no indications of a servo valve jam or other failure were noted.

2.0 Examination of the Previously Removed Servos

2.1 Visual Examination

The Fore/Aft Servo (S/N RX187) and Tail Rotor Servo (S/N FE212) were removed from their shipping containers and visually inspected and photographed. The part and serial numbers for each of the servos was confirmed.

2.2 Part Acceptance Test Procedure for Removed Servos

The Fore/Aft Servo and Tail Rotor Servo were placed onto the Meggitt Control Systems Hydraulic Test Rig 7 and were tested in accordance with portions of the Component Maintenance Manual, Sections 65-40-02 (Fore/Aft Servo) and 65-40-01 (Tail Rotor Servo) respectively. The portions of the tests were accomplished to demonstrate the operation of the removed in-service units to the group members; the portions completed were short term, dynamic tests.

The resultant test sheets for the 2 operable units were included in Attachment 2

Following the examinations, all of the servos were placed back into their shipping containers and returned to the NTSB.

3.0 Examination of the Helicopter Wreckage in Phoenix, Arizona

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 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.

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 American Eurocopter and Sundance Helicopters group members provided exemplar connection hardware as comparison.

The group looked through the entire wreckage contents. Each bag was dumped out onto large tarpaulins for the examination. The larger non-pertinent pieces were set aside. The tarpaulin was then placed onto a table and the remaining smaller pieces examined by hand. Sifters and a large magnet were used to separate the pieces for better identification.

Larger sections of wreckage, including the engine and star arms, were examined for pieces that might have fallen inside the sections.

None of the connection hardware pieces were positively identified during the wreckage examination. Approximately 56 pounds of melted pieces of melted metal were removed from the facility and sent to the NTSB headquarters in Washington, D.C. for further examination using x-ray. In addition, numerous washers, bolts, and a cotter pin were retained for further examination.

4.0 Use of X-ray to Examine Melted Pieces of Wreckages

The NTSB's x-ray machine, a General Electric (GE) Sensing & Inspection Technologies GmbH model nanome/x 180, was used to examine the material removed from the wreckage examination in Phoenix, Arizona. To facilitate the examination, the x-ray unit's computer was used to combine hundreds of individual x-ray images into one large, merged, mosaic image. To develop each merged image, pieces of the melted wreckage were arranged directly on the x-ray's imaging plate. The pieces were arranged so that they were not touching, for ease of identification in the merged, x-ray image. The x-ray was then programmed to move the imaging plate in a row and column (X-Y) incremental, manner and take a series of x-rays (at 90-100 micro amp power setting). For each series of pieces on the tray, the x-ray would take approximately 175-190 separate images over the area of the imaging plate.

The x-ray software then merged the individual x-ray images together into a mosaic, overall image of the materials on the imaging plate. The mosaic was then examined by the x-ray operator and the group chairman to identify any items in the x-ray images that appeared to be from the connection hardware for the fore/aft servo commande unit input linkage rod connection. To completely examine all of the materials, 11 sets of x-rays were created. In all cases, none of the connection hardware was found.

Photographs of the arrangement of the pieces on the plate and the resultant mosaic x-ray image were included in Attachment 3.

5.0 Input Linkage Connection for Servo Commande Actuators

While at the accident site, each of the 4 servo commande actuator units were examined for the connecting hardware to the servo input linkage. For the tail rotor, left lateral and right lateral servo commande units, the connecting input rod was present, with the connecting hardware still intact. However, for the fore/aft servo commande unit, the hardware connecting the servo commande unit input linkage to the input rod – bolt, washer, castellated nut, and split (cotter) pin - were not found, and the fore/aft servo commande unit and input rod were found separated at the accident site. See photographs in Attachment 4.

6.0 Recent NTSB Investigations

The NTSB has conducted the following investigations regarding the Eurocopter AS-350:

- ERA10LA118: January 18, 2010 in New York, New York
  Aircraft: EUROCOPTER AS 350 B2
  Registration: N696BH
  Probable Cause: The failure of maintenance personnel to properly secure one tail rotor pitch change link to its respective tail rotor blade resulting in an in-flight separation of the link from the blade. Contributing to the accident was the lack of an adequate post-maintenance inspection procedure.

- WPR10FA371: July 28, 2010 in Tucson, Arizona
  Aircraft: EUROCOPTER LLC AS 350 B3
  Registration: N509AM
  Probable Cause: The repair station technician did not properly install the fuel inlet union during reassembly of the engine; the operator’s maintenance personnel did not adequately inspect the technician's work; and the pilot who performed the post maintenance check flight did not follow the helicopter manufacturer's procedures. Also causal were the lack of requirements by the Federal Aviation Administration, the operator, and the repair station for an independent inspection of the work performed by the technician. A contributing factor was the inadequate oversight of the repair station by the Federal Aviation Administration, which resulted in the repair station performing recurring maintenance at the operator’s facilities without authorization.

- WPR10FA112: January 17, 2010 in Reno, Nevada
  Aircraft: EUROCOPTER AS350 B3

Registration: N904CF

Probable Cause: The improper installation of the engine-to-main gear box flex coupling, which resulted in the failure of the flex coupling and a loss of power to the rotor system during takeoff. Contributing to the accident was the mechanic who removed the engine's failure to follow the operator’s maintenance procedures. Also contributing was the Quality Assurance inspector's failure to follow the operator’s post-maintenance inspection requirements.

7.0 Responses to Questions Submitted to Eurocopter

A series of questions were submitted to Eurocopter regarding the servo commande actuators and the materials used in the units. The responses to questions received from Eurocopter are included in Attachment 5.

8.0 Responses to Questions Submitted to Meggitt Control Systems

The following questions were asked of Meggitt Control Systems with regard to the fore/aft servo commande unit. The answers submitted from Meggitt Control Systems were included below in italics:

1. What is the accurate name for clevis part and part number?

The drawing title states Lever Assembly, which consists of the Lever (ACM28710) and Bush (ACO43220).

2. What is the material and strength for clevis part?

The material is BS S 98 (non corrosion resistant steel). This is an aircraft material which is a 2½ per cent nickel-chromium-molybdenum steel (high carbon) (75/85 tonf/sq in.)

3. What is the shear out or fracture out load for the clevis?

{Note: for this question, the answer from Meggitt Control Systems is provided in Attachment 6.}

4. Is anything in the area of the servo made from nylon 12 – for example, the environmental protective cover?

There is no Nylon 12 material used in the Servo unit. The environmental cover is made from polypropylene.

Tom Jacky

Aerospace Engineer