NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

December 3, 2013

STRUCTURES

Group Chairman's Factual Report

WPR12MA034

A. ACCIDENT: WPR12MA034

Operator:	Blue Hawaiian Helicopters
Location:	Pukoo, Hawaii
Date:	November 10, 2011
Time:	1214 Hawaii Standard Time
Aircraft:	Eurocopter EC130 B4
Registration Number:	N11QV

B. STRUCTURES GROUP

Chairman: Clinton R. Crookshanks
National Transportation Safety Board
Denver, Colorado

Member: Jean-François Berthier
Bureau d'Enquêtes et d'Analyses
Le Bourget, France

Member: Michel Martin
Eurocopter
Marignane, France

Member: Troy Atkinson
Blue Hawaiian Helicopters
Maui, Hawaii

C. SUMMARY

On November 10, 2011, about 1214 Hawaiian standard time, a Eurocopter EC130 B4 helicopter, N11QV, collided with mountainous terrain near Pukoo (Island of Molokai) Hawaii. The commercial pilot and four passengers were fatally injured. The helicopter was registered to Nevada Helicopters Leasing, Henderson, Nevada, and operated by Helicopter Consultants of Maui, Inc., dba Blue Hawaiian Helicopters, Maui, Hawaii. The flight was operated as a visual flight rules (VFR) sightseeing flight under the provisions of 14 Code of Federal Regulations Part 135. Visual meteorological conditions prevailed at the time of departure and company flight-following procedures were in effect. The flight originated from the Kahului Airport, Kahului, Hawaii, about 1144.

D. DETAILS OF THE INVESTIGATION

1.0 Aircraft

Serial Number: 4909
Total Time: 2439.6 hours (prior to the accident flight)

The EC130 B4 is a single engine, single pilot helicopter that is piloted from the left front seat (Figure 1[1]). The helicopter is approximately 35 feet long, 11 feet in height, and has a rotor diameter of approximately 35 feet. The EC130 features an enclosed tail rotor, known as a Fenestron, for yaw control. The helicopter is powered by a Turbomeca Arriel 2B1 turboshaft engine, and is equipped with skid type landing gear. It has a normal empty weight of 3,036 pounds and a maximum takeoff weight of 5,351 pounds. The accident helicopter was configured from the factory for a single pilot and two passengers in the front row of seats and four passengers in the rear row of seats. Blue Hawaiian reconfigured the helicopter to accommodate the pilot and three passengers in the front row of seats.

The tailboom is a simple stiffened tubular (semi-monocoque) structure that is attached to the fuselage. A drawing of the aft end of the tailboom is shown in Figure 2. The fasteners and horizontal stabilizer have been omitted for clarity. The Fenestron is attached to the aft end of the tail boom by a junction frame (shown in green on the right side of Figure 2) that is riveted to the aluminum tail boom structure and to the composite Fenestron structure. The junction frame has three flanges; the forward flange, aft flange and vertical flange. The forward and vertical flanges are nominally orthogonal around the circumference of the junction frame. The aft flange is oriented at differing angles around the circumference to match the geometry of the Fenestron. There is a ring frame installed forward of the horizontal stabilizer (shown in green on the left side of Figure 2). There are 4 longerons (shown in purple in Figure 2), 2 on each side, installed between the ring frame forward of the horizontal stabilizer and the aft junction frame. The horizontal stabilizer is a single piece unit that is installed through the tail boom and attached to the tailboom by two vertical attachment bolts (shown in red in Figure 2). The upper and lower horizontal stabilizer attach fittings (shown in orange in Figure 2) are attached to the longerons on each side of the tailboom. A shim plate is installed on each stabilizer fitting with two countersunk screws (shown in blue in figure 2). The horizontal stabilizer attachment bolts pass through the shim plates and the horizontal stabilizer spar to attach it to the tailboom. Forward of the ring frame the tailboom is of typical skin/frame/stringer construction. There are 6 internal stringers spaced unevenly around the circumference between the ring frame and the battery door cutout.

2.0 Accident Aircraft Examination

The helicopter impacted mountainous terrain about 530 feet MSL. The slope was reported to be about 25º - 30º. The wreckage was oriented on about a 260º heading and was inverted. There was a post-crash fire that consumed most of the fuselage. The main wreckage was located at N21º 04.050’, W156º 50.578’. The main wreckage site contained the remains of the fuselage, engine, main rotor system, tail boom, tail rotor drive system, and landing skids. The Fenestron separated from the tail boom and was found in several pieces northwest of the main wreckage. The stinger and stinger mounting plate were separated from the lower ventral fin and were also found northwest of the main wreckage. The Fenestron rotor and gear box were recovered about 81 feet north of the main wreckage and one of the stators was found about 95 feet north of the main wreckage. The first recovered piece in the debris field was a composite main rotor blade trim tab found about 1330 feet northwest of the main wreckage. See the wreckage diagram provided by American Eurocopter in Attachment 1 to this report. The Structures Group did not examine the

[1] All Figures are presented in Appendix A to this report.

accident helicopter on scene. The recovered pieces of the tail boom, Fenestron, and main rotors were shipped to the NTSB Training Center in Ashburn, Virginia, for examination by the group. The information in this report is based on information provided by the on-site team, examination of photographs from on-scene and the subsequent wreckage examinations.

The forward flange of the junction frame fractured circumferentially just forward of the vertical flange causing the Fenestron to separate from the helicopter[2]. The aft portion of the junction frame that included the aft and vertical flanges was recovered about 482 feet northwest of the main wreckage. The junction frame was fractured longitudinally near the 12 o'clock position but was essentially still circular. The junction frame piece had fractured from the Fenestron along the aft edge of the aft flange on the left side and contained a portion of the Fenestron skin on the right side. All junction frame fracture surfaces had features consistent with ductile overstress fracture. The forward flange of the junction frame remained attached to the tail boom.

The Fenestron was separated into multiple pieces. A large portion of the upper Fenestron was recovered about 398 feet northwest of the main wreckage. Two pieces of the lower Fenestron structure were recovered northwest of the main wreckage; one contained the aft portion of the ventral fin and the other contained the forward portion of the ventral fin where the stinger is normally attached. Figure 3 shows the piece containing the forward portion of the ventral fin with the stinger attach bracket positioned where it is normally installed. There was green plant debris and twigs lodged between the ventral fin and Fenestron as indicated by the yellow arrows. The stinger was recovered about 537 feet northwest of the main wreckage and the stinger attach bracket was recovered about 864 feet northwest. The lower forward portion of the Fenestron from the junction frame to the stinger attach point was not conclusively identified but many small pieces of composite structure consistent with the Fenestron structure material were recovered. The Fenestron gearbox with portions of 4 stator blades and 6 rotor blades attached was recovered about 128 feet north of the main wreckage. Many of the separated pieces were recovered and examined in the NTSB Materials Laboratory[3].

The aft portion of the tailboom was found intact from the forward flange of the junction frame forward to the battery door area at the impact site and in an inverted position (Figure 4) with significant damage and deformation. The red arrow in Figure 4 shows the location of the fractured forward flange of the junction frame and the yellow arrow shows the location of the doubler around the battery door. Most of the tail boom forward of the baggage door was consumed by fire and there was moderate to heavy fire damage on the left and upper portions of the remaining portions of the tail boom. There was significant buckling and deformation of the tailboom structure concentrated on the lower and right portions such that the aft portion of the tailboom was displaced to the right. The buckling was evident on the lower surface between the ring frame and junction frame and forward of the ring frame on the right side. The inboard portion of the right horizontal stabilizer exhibited significant mechanical damage and deformation to the remaining structure but most of it was not present at the impact site as outlined in green on Figure 4. There was no evidence of fire damage to the remains of the right stabilizer. The missing portions of the right horizontal stabilizer were not identified in the recovered wreckage. The left horizontal stabilizer was mechanically damaged and fire damaged

[2] See the NTSB Materials Laboratory Factual Report 12-089 for details of the fracture examination.
[3] See the NTSB Materials Laboratory Factual Report 12-128 for the details of the examinations.

as outlined in orange in Figure 5. The left horizontal stabilizer was mostly intact but the center portion was consumed by fire. The outboard portion of the left horizontal stabilizer was intact and remained an airfoil shape. The inboard portion was deformed up and aft and the skin was torn at the leading edge as shown by the red arrow in Figure 6. The center carry-through portion of the horizontal stabilizer was deformed and rotated right-leading-edge forward (counter-clockwise as viewed looking down), as indicated by the yellow dashed line in Figure 6, with respect to the tailboom normal center line, illustrated by the white dashed line in Figure 6. All of the fasteners attaching the steel horizontal stabilizer lower spar strap to the aluminum spar were fractured on both the left and right sides and the strap and spar were deformed.

The aft portion of the tailboom with attached remnants of the horizontal stabilizer was cut from the wreckage for further examination. The upper portion of the tailboom exhibited buckling damage to the structure just forward of the ring frame as outlined in red in Figure 7. The location was immediately forward of where the 4 longerons attach to the ring frame and extended clockwise from about 10 o'clock to about 2 o'clock as viewed looking forward. There was also buckling damage from about 2 o'clock to about 6 o'clock as viewed looking forward that corresponded to the location where the right horizontal stabilizer was displaced forward. The deformation of the left (yellow dashed line) and right (red dashed line) sides of the horizontal stabilizer with respect to the center line (white dashed line) is also shown in Figure 7. The two horizontal stabilizer attach bolts were disassembled and removed and the stabilizer was extracted from the tailboom as shown in Figure 8. The upper steel spar straps remained fastened to the spar on both the left and right sides. The left spar and skin structure was deformed aft and exhibited moderate to heavy fire damage. The right spar was intact from the attach point out to the production end about 20 inches outboard of the attach point. There was dirt and wood debris embedded in the space between the spar and the spar strap on the aft side at the location indicated by the yellow arrow in Figure 8 and shown in Figure 9. The spar strap was buckled away from the spar in this area (Figure 9). The outboard end of the right spar was deformed aft and twisted leading edge down as shown in Figure 10. The right horizontal stabilizer leading edge structure remained attached to the spar from the attach point to about 15 inches outboard. It was deformed up and aft between about 6 inches and 11 inches outboard of the attach point and was crushed against the spar between about 11 inches and 15 inches outboard of the attach point. There were some small pieces of the upper and lower trailing edge skins attached to the inboard 14 inches of spar. The remaining trailing edge of the right stabilizer exhibited bucking damage from the centerline outboard to the attach point. The remaining right horizontal stabilizer structure was separated and not found in the recovered wreckage.

The left, upper horizontal stabilizer attach fitting, stabilizer attach bolt, shim, and shim screws were all intact and installed (Figure 11).

The left, lower horizontal stabilizer attach fitting was intact and installed on the lower longeron. The two shim screws were fractured with the tails and nuts separated and not recovered (Figure 12). The heads of the shim screws remained trapped, but loose, in the shim countersinks, and the fracture faces showed features consistent with shear overstress fracture. The shim and fitting were aligned but the horizontal stabilizer attach area was rotated clockwise with respect to the fitting and shim as looking up at the attach point. The fitting was disassembled and a small area of impact damage was noted on the upper, aft edge of the cutout for the stabilizer attach bolt as identified by the yellow arrows in Figures 13 and 14. The left stabilizer attach bolt had no obvious damage or deformation as shown in Figure 15.

The right, upper horizontal stabilizer attach fitting was intact and installed on the upper longeron. The two shim screws were fractured and the tails with the nuts installed were still in the fitting (Figure 16). The heads of the shim screws remained in the shim countersinks, and the fracture faces showed features consistent with shear overstress fracture. The stabilizer attach bolt was intact and installed through the shim and stabilizer. The shim was aligned with the stabilizer but the shim and stabilizer attach point were displaced forward and outboard and rotated counter-clockwise with respect to the fitting as viewed looking down on the attach point. There was wood debris lodged in the area between the aft side of the shim and stabilizer as identified with the yellow arrow in Figure 16.

The right, lower horizontal stabilizer attach fitting was intact and installed on the lower longeron. The two shim screws were fractured and tails and nuts were separated and not recovered (Figure 17). The heads of the shim screws remained in the shim countersinks, and the fracture faces showed features consistent with shear overstress fracture. The shim and stabilizer attach point were displaced up and forward and the shim was rotated clockwise with respect to the fitting as viewed looking up at the attach point. There was wood debris lodged in the area between the forward side of the shim and the stabilizer as identified with the yellow arrow in Figure 17 and illustrated in Figure 18. The fitting was disassembled for further examination. The forward tang of the shim was deformed upward toward the stabilizer as shown in Figure 18. The right, upper stabilizer fitting had areas of impact damage on both the lower, forward and lower, aft edges as identified by yellow arrows in Figure 19. The shim screw fracture faces in the fitting displayed rearward shear features indicated by the red arrows in Figure 19. The impact damage to the aft, lower edge had a three-sided impression that was found to match the hexagonal head of the stabilizer attach bolt (Figure 20). There was a ridge of displaced material on the aft side of the hexagonal impression as indicated by the yellow arrow in Figure 20. The impact damage to the forward, lower edge had a stepped appearance consistent with more than one impact (Figure 21). The right, lower stabilizer fitting had areas of impact damage on the upper, forward and upper, aft edges as identified by yellow arrows in Figure 22. The damage to the upper, aft edge extended into the recess and rearward along the upper surface to the shim screw hole (Figure 23). The damage to the upper, forward edge was contained mostly in the recess and had a stepped appearance consistent with more than one impact (Figure 24). The right stabilizer attach bolt was slightly bent about 5/8 inch from the lower, threaded end as shown in Figure 25.

The aft end of the tailboom at the junction frame fracture was crushed and deformed such that it was no longer circular (Figure 26). None of the 4 longerons were fractured but all were deformed. The aft end of the tailboom was cut at the horizontal stabilizer trailing edge to facilitate transport and examination. The ring frame at the forward end of the longerons was mostly circular although there was buckling evident on the inner flange (Figures 27 and 28). The ring frame was fractured forward of the right horizontal stabilizer leading edge where the leading edge impacted the frame as indicated by the red arrow in Figure 28. The forward ring frame was crushed and deformed between the right, lower longeron attachment and the lower centerline as indicated by the yellow arrow in Figure 28. The longerons all remained attached at their forward ends to the web of the ring frame. There was no deformation of the forward portions of the 4 longerons between the forward ends of the stabilizer fittings and the ring frame. All of the deformation occurred in the long aft sections of the longerons from the stabilizer fittings to the junction frame. The left, upper longeron was deformed slightly upward aft of the upper stabilizer fitting (Figure 29). The right, upper longeron was deformed inboard, down, and twisted counter-clockwise and there were several areas of buckling in the upper and lower flanges aft of the stabilizer fitting(Figure 30). The right, lower longeron was deformed a small amount up and inboard with areas of buckling in the upper and lower flanges aft of the stabilizer fitting (Figure 31). The left, lower longeron was deformed inboard, up, and twisted counter-clockwise with areas of buckling in the upper and lower flanges aft of the stabilizer fitting (Figure 32).

3.0 Maintenance Records

On June 14, 2011, Eurocopter released Emergency Alert Service Bulletin (EASB) 53A019[4] that required operators to inspect the tailboom/Fenestron junction frame for cracks. The EASB outlined an interior and exterior inspection of the right side of the junction frame within 10 hours of the receipt of the bulletin. Further, within 110 hours of the receipt of the bulletin, operators were instructed to strip the paint from a specified area on the right, exterior side of the junction frame area, re-inspect the area, and apply primer and clear varnish to facilitate periodic inspection. The EASB then required a periodic inspection of the specified area at an interval not to exceed 100 hours. On July 6, 2011, the European Aviation Safety Agency issued Airworthiness Directive (AD) 2011-0116 (effective July 20, 2011) to require that all European operators perform inspections that were the same as those outlined in the EASB. Subsequent to the accident, on February 7, 2012, the Federal Aviation Administration issued AD 2012-02-13 (effective February 22, 2012) mandating that all American operators inspect the junction frame in accordance with the EASB.

Examination of the wreckage revealed that the paint had been removed from the specified area on the right side of the junction frame in accordance with the EASB and documented in the NTSB Materials Lab reports. The last 100-hour inspection on the accident helicopter was performed on November 8, 2011, at an aircraft total time of 2431.4 hours. During this inspection, the EASB inspection was performed as item 9.10 in the Approved Aircraft Inspection Program, 100-hour inspection[5].

4.0 Tests & Research

Tailboom skin samples were removed from four locations (labeled W, X, Y, and Z) to test the material thickness and alloy as shown in Figure 33. The paint was chemically stripped from the skin samples and the thickness was measured with a digital micrometer. The skin material was determined using an X-ray fluorescence (XRF) spectrometer. The results for the four samples are presented in Table 1. The part number of the skin sections and the required thickness and material from the drawings are also presented.

---

[4] See Attachment 2 to this report for a copy of the EASB.
[5] See Attachment 3 to this report for the pertinent inspection records.

SAMPLE	THICKNESS (in/mm)	XRF	PART NUMBER	DRAWING THICKNESS (mm)	DRAWING MATERIAL
W	0.0467/1.18	2024	350A23-4288-20	1.2	2024
X	0.0394/1.00	2024	350A23-4287-20	1.0	2024
Y	0.0483/1.23	2024	350A23-4219-20	1.2	2024
Z	0.0475/1.20	2024	350A23-4238-20	1.2	2024

Table 1 – Skin sample information

A section of the tailboom skin and stringer structure was also removed from the area forward of the forward ring frame to measure the material thickness and determine the material of the 6 stringers as shown in Figure 34. The paint was chemically stripped from the stringers and the thickness was measured with calipers. The results for the 6 samples are presented in Table 2. The part number of the stringers and the required thickness and material from the drawing are also presented.

SAMPLE	THICKNESS (in/mm)	XRF	PART NUMBER	DRAWING THICKNESS (mm)	DRAWING MATERIAL
S1	0.0485/1.23	2024	350A23-4260-20	1.2	2024
S2	0.0314/0.80	2024	350A23-4260-20	0.8	2024
S3	0.0314/0.80	2024	350A23-4260-20	0.8	2024
S4	0.0316/0.80	2024	350A23-4260-20	0.8	2024
S5	0.0320/0.81	2024	350A23-4260-20	0.8	2024
S6	0.0315/0.80	2024	350A23-4260-20	0.8	2024

Table 2 – Stringer sample information

The EASB mentioned previously was the result of in-service cracking of the aft flange of the junction frame on the right side of the Fenestron. Eurocopter was aware of 15 instances of frame cracking and examined 3 of the cracked junction frames. The original design of the joint utilized a double row of countersunk rivets to attach the Fenestron skin to the aft flange of the junction frame. The Eurocopter investigation into the root cause of the cracking revealed that the countersink in the aft flange was too deep and produced a knife edge condition in the flange. This condition initiated fatigue cracking in the flange that propagated at a constant rate under normal loading conditions. The largest crack observed was about 200 mm (7.9 inches) long. Residual strength calculations showed that the frame could withstand cracks up to 300 mm (11.8 inches) at limit load and up to 170 mm (6.7 inches) at ultimate load. The aft flange of the junction frame on the right side was sized by a certification load case with a 10º sideslip at an airspeed of 140 knots and with an aft center of gravity (CG). Based on the results of their investigation, the EASB was developed for inspection and the design of the joint was changed to utilize a double row of button head rivets. There have been no reported cases of cracking on the new design.

In order to understand the loads at the junction frame, the group examined design limit load information, frame strength, ground test results, and correlated flight test results. There are 8 load inputs that govern the load in the junction frame.

1. Aerodynamic loads on the vertical fin portion of the Fenestron
2. Inertia loads from the ballast installed in the Fenestron

3. Aerodynamic loads on the exterior shroud area around the rotor
4. Aerodynamic and stator loads on the interior shroud area
5. Thrust, transmission, and torque loads from the rotor
6. Inertia loads from the rotor
7. Aerodynamic and impact loads on the keel (ventral fin)
8. Impact loads on the tail skid

All these loads combine to produce the forces and moments resolved at the point in space located at the center of the junction frame utilizing the sign convention in Figure 35. For the design of the junction frame the first order moments in the y (My) and z (Mz) directions are the limiting loads. Eurocopter ran over 500 unique load cases, both certification cases and Eurocopter cases, to establish the limit load envelope for the junction frame (Figure 36). In the My direction the upper (negative) limit of almost -200 m·daN (1,480 ft·lbs) is defined by 3 Eurocopter tail skid impact conditions and the lower (positive) limit of about 600 m·daN (4,400 ft·lbs) is defined by a lightweight certification landing condition. In the Mz direction the left side (negative) limit of about -500 m·daN (3,700 ft·lbs) is defined by 2 certification yaw maneuver conditions, and the right side (positive) limit of about 200 m·daN (1,480 ft·lbs) is defined by 2 Eurocopter ground mooring conditions. During flight test, the loads at the junction frame were not measured directly. The skin loads measured on the tail boom skin just aft of the forward frame where the tailboom attaches to the fuselage, the bending loads measured on the horizontal stabilizer, and the bending loads measured on the vertical fin were resolved to the junction frame through the Eurocopter certification finite element model (FEM) of the tailboom. All of the measured and correlated flight test loads were within the limit load envelope.

Eurocopter further analyzed the junction frame strength at the request of the group and identified 5 possible failure locations, shown in Figure 37, including the accident failure location (location 5). At each location they identified the particular failure and the required moment (My or Mz) necessary to produce the failure. Location 1 is a failure of the composite honeycomb Fenestron skin at the location where the honeycomb stops which requires a moment of 1100 m·daN (8,118 ft·lbs). Location 2 is a shear failure of the rivets that join the junction frame to the composite Fenestron skin which requires a moment of 1000 m·daN (7,380 ft·lbs). Location 3 is a shear failure of the rivets joining the junction frame to the tailboom skin which requires a moment of 1000 m·daN (7,380 ft·lbs). Location 4 is a buckling failure of the vertical flange of the junction frame which requires a moment of 3200 m·daN (23,616 ft·lbs). Location 5, the accident failure location, requires a moment of 7500 m·daN (55,350 ft·lbs). All of these values are well above the limit load envelope and above the ultimate load envelope (1.5 x limit). The two lowest strengths at the end of the honeycomb (Location 1) and at the rivets (Locations 2 and 3) provide a safety margin of 8%-10% above the ultimate load values. For the accident failure location the maximum ultimate load is less than $1/10^{th}$ of the required moment for failure.

As part of the certification of the helicopter, Eurocopter also performed several static ground tests to substantiate the design. In tests at limit load, ultimate load, and somewhat beyond ultimate load, no failure of the junction frame was produced.

Based on the design of the EC130 B4 tailboom and Fenestron and various accident or incident load cases, Eurocopter has identified 3 critical areas of the tailboom that have experienced failures. Figure 38 shows the FEM of the tailboom with the critical locations identified as 1, 2, and 3. Locations 4 and 5 represent the load application points for the rotor loads and stinger loads, respectively. Location 1, at the forward ring frame where the tailboom attaches to the fuselage, becomes critical under hard landing conditions. Location 2, at the battery door cutout, becomes critical for hard landings and tail skid impact conditions. Location 3, at the junction frame, becomes critical for horizontal stabilizer impact conditions. Numerous examples of failures at locations 1 and 2 were presented that occurred due to hard/crash landings well in excess of the certification load levels. Eurocopter presented 4 known cases where the Fenestron separated from the tailboom at the junction frame during the accident sequence. Three of these cases involved a failure at the forward flange of the junction frame similar to the accident junction frame and the fourth involved a failure at the aft flange of the junction frame. One case occurred during the in-flight collision with electrical power lines in the area of the horizontal stabilizer. One case occurred during an uncontrolled crash landing in which the right horizontal stabilizer impacted a vehicle prior to ground impact. The third case occurred during controlled flight into terrain in which there was significant impact damage to the right horizontal stabilizer. The case that involved a failure of the aft flange occurred during a hard landing with a significant tail skid impact. As a result of these cases and the accident failure, Eurocopter performed some finite element analyses of the tailboom when subjected to loading at the ends of the horizontal stabilizer. The results indicate that loads can be applied at the end of one of the horizontal stabilizers that are below the stabilizer failure loads which induce a buckling instability in the aft tailboom between the forward ring frame and junction frame and induce stresses in the junction frame necessary to cause failure at location 5 in Figure 37, as observed in the accident.

Submitted by:
Clinton R. Crookshanks
Aerospace Engineer (Structures)