



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

March 4, 2020

HELICOPTER SPECIALIST'S FACTUAL REPORT

NTSB No: WPR19FA109

A. ACCIDENT

Operator: Van Horn Aviation, Phoenix, AZ

Aircraft: N61PH

Location: Fort McDowell, AZ

Date: 16 April, 2019

Time: 0707 PDT

B. GROUP

No group was formed.

LIST OF ACRONYMS

ft	Feet
in	Inches
inHg	Inches of mercury
lbs	Pounds
N1	Gas generator turbine speed
N2	Power/Free turbine speed
PN	Part number
Sta	Station
SN	Serial number
VFR	Visual flight rules

C. SUMMARY

On April 16, 2019, at 0706 mountain standard time, a Bell 206B experimental helicopter, N61PH, impacted an alfalfa field, about 1 mile south of Fort McDowell, Arizona. The commercial pilot and pilot-rated passenger were fatally injured. The helicopter was destroyed. The helicopter was registered to TRE Aviation Corporation and operated by Van Horn Aviation, LLC for research and development flight testing under the provisions of Title 14 *Code of Federal Regulations* Part 91. Visual meteorological conditions prevailed, and a flight plan was not filed. The second leg of the test flight originated from Falcon Field (FFZ), Mesa, Arizona at 0632.

The purpose of the flight was to evaluate developmental main rotor blades that had been installed on the helicopter. According to the operator, the helicopter was fueled for two test flight legs. The helicopter departed at 0545 for the first event and returned at about 0620, parked on the ramp with the engine at idle, and 100 lbs. of ballast was added to the helicopter. Preliminary radar data showed that the helicopter departed at 0632 to continue the second leg of the test flight. The test flight legs consisted of multiple autorotations at maximum gross weight involving a simulated loss of engine power. The accident flight was to be one of the final test flights of the main rotor blades.

D. DETAILS OF THE INVESTIGATION

1.0 HELICOPTER INFORMATION

The Bell 206B is a single-engine helicopter of conventional layout certified for flight in VFR only. It has a teetering main rotor of comparatively high rotational inertia that is controlled through servo actuators. The aircraft is powered by a Rolls-Royce M250-C20B gas turboshaft engine mounted on the fuselage roof behind the main rotor transmission. A freewheel unit, mounted on the front of the engine accessory gearbox, delivers power forward to the main transmission and aft to the tail rotor gearbox.

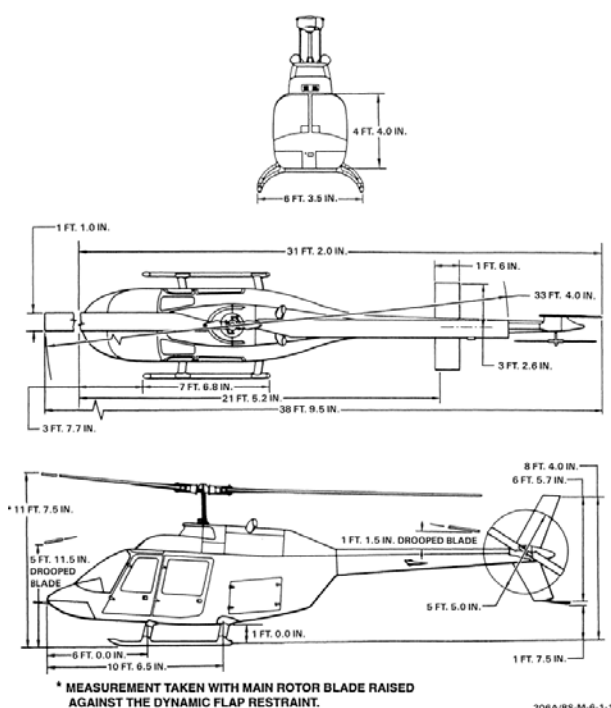


Figure 1: 3-view drawing of a Bell 206B

2.0 WRECKAGE EXAMINATION

The wreckage had been recovered from on-scene and transported to the Air Transport facility in Phoenix, AZ. The wreckage was laid out and a detailed examination conducted.

2.1 Fuselage

The fuselage consisted of three main sections: the forward section which extends from cabin nose to bulkhead aft of passenger compartment, intermediate section which extends from the bulkhead aft of passenger compartment to tailboom attach and tailboom section. The forward section utilizes aluminum honeycomb structure and provides the major load-bearing elements of the forward cabin. The forward section provides for pilot and passenger seating, fuel cell enclosure and pylon support. The intermediate section utilizes an aluminum semi monocoque construction and provides a deck for engine installation, a baggage compartment and a compartment under the engine deck for heater and electrical equipment.¹

The fuselage, cockpit, and cabin area had been crushed down on its right side and mostly consumed by fire. Attached to the nose of the helicopter was an orange air-data boom. Landing gear were low skid type. The landing gear had been separated from the airframe by recovery personnel. The cross tubes had buckled. The right skid tube between the forward and aft foot had separated, the heel tube was attached to the rear foot, and the toe tube was separated from the forward foot. The left tube had separated between the fore and aft feet. The toe tube remained attached to the forward foot; the heel tube had separated from the aft foot. Left door hinge pins were in place but separated from the airframe. Door latch was in the closed/latched position. Right door lower hinge pin was present, and hinge attached to airframe. There was an 18-inch long longitudinal rip along the bottom of the door. The door latch was in the closed/latched position. The left side fuselage structure of the cockpit and cabin were completely consumed by fire. The right side of the cabin had extreme heat damage.. Cabin area contained remnants of orange flight test equipment and lead shot ballast bags. The particle separator cowling had separated from the airframe and exhibited no fire damage. The engine compartment exhibited fire damage that removed all paint from the engine cowling and extended on to the tail boom base.

Tail boom remained semi attached to the aft end of the fuselage, with 3 locations that had ripped and separated along its length. First area of damage was immediately after the tail boom attach point aft of station 205.34 that exhibited clockwise torsional deformation, followed by a section that was severed just behind the horizontal stabilizer, followed by a separation between hanger bearings at tail boom stations 109.9 and 136.9, and then severed at the tail rotor gear box fixture forward of station 334.

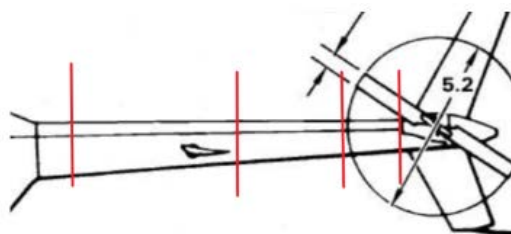


Figure 2: Tail boom separation location marked by red lines.

¹ Fuselage description – BHT-206A/B-Series-MM-5

2.2 Cockpit

Majority of the cockpit was crushed and consumed by fire. Windscreen had fragmented and was distributed along the debris field. Windscreen bow was present and intact. The wire strike protector was in place at the top of the windscreen bow. No witness marks or impact marks were observed on the wire strike cutter. The left and right seat steel frames were present.

Left and right pedals were present and attached to small sections of floor deck. All pedal links were attached to the bell crank. Control tubes under the cockpit floor had been consumed by fire. The right cyclic was present and attached to fragment of support structure, and the control bell crank. Control linkages leading from the cyclic had been consumed by fire. Left cyclic was fragmented. Right collective was attached to a section of the floor deck, but tubes and linkages under the floor had been destroyed. Collective twistgrip button cavity was in the middle of the throttle groove. Left collective was present detached from its support structure.

Instruments:

Altimeter	Needle not present, 98.50 inHg
Airspeed	Needle not present
Engine oil pres	Off scale below 0
Ng/Nr	Needles off gage
Hobbs	0073.8

2.3 Flight Controls

The flight control system consists of push-pull control tubes and bell cranks actuated by conventional helicopter cyclic, collective, and directional controls. The controls are routed beneath the pilot seat aft to the center of the helicopter and up to the cabin roof through the control column which also serves as a primary cabin structure. Cyclic and collective controls are routed to the main rotor blades through the swashplate. The directional controls are routed through the tailboom to the tail rotor. Cyclic and collective control systems incorporate hydraulic servo actuators. The directional control system does not incorporate servo actuators. The servo actuators on the cyclic and collective controls incorporate irreversible valves which prevent control force feedback.²

The remnants of both left and right cyclic controls were identified during the wreckage examination. Cyclic yoke linkage and pedal linkages under the cockpit had been consumed by fire. The lower cyclic lever assembly was connected to lateral and longitudinal control rods aligned with the hydraulic cylinder support assembly. Collective linkages had been consumed by fire. The lower collective pitch lever assembly had a control tube attached that aligned with the hydraulic cylinder support assembly. Antitorque pedal linkages under the cockpit had been consumed by fire. The lower bell crank had a control tube attached that aligned with the upper deck pedal bell crank. Idler bell crank and walking beam assembly (located on the airframe under the engine bay) both had rod ends attached. Control rods consumed by fire. Antitorque

² Flight control description – BHT-206A/B-Series-MM-8

control rod was traced from the aft fuselage section thru the tail boom to the tail rotor gear box bell crank.

The lateral cyclic servo had not been fire damaged, had separated from the cylinder support assembly. The hydraulic control valve had a rod end attached. Servo bell crank had rod ends attached to each side. The control rod to the stationary swash plate had separated mid length in bending. Longitudinal cyclic servo was separated from the cylinder support assembly. A fractured rod end was attached to the control valve. The control linkages were continuous from the servo bell crank to the stationary swash plate. Collective servo remained attached to the cylinder support assembly, it exhibited heat damage and the control valve rod end had fractured. Control rod from the servo bell crank had fractured. Control rod connecting bell crank to stationary scissors was present with scissors rod end fractured.

2.4 Main Rotor Drive System

The main rotor drive system consists of a transmission, main rotor mast, main driveshaft, freewheel assembly, and oil cooler. The freewheel assembly is mounted on the engine accessory gear case. It connects the engine to the transmission through the main driveshaft on the forward side, and the tail rotor gearbox through related shafting on the aft side, providing simultaneous rotation of main and tail rotors, and permits free rotation of both rotors when the engine is not operating.³

The transmission assembly remained attached to the transmission mounts on each side of the transmission case, and all four deck mounts. Oil filler cap was locked in place. The transmission had a 4x5 inch hole punched into aft facing side. Engine to transmission drive shaft had separated from the kaflex couplings on each end. Rotational witness marks of the transmission side kaflex were observed on the pylon isolation mount cover. Through the rent in the side of the transmission case, the main drive gears were examined. No broken teeth, discoloration, or signs of metal distress were observed. The main rotor mast extended up thru the transmission. The transmission could not be turned by hand. The rotor mast had orange flight test equipment attached to it just below the rotor head. The rotor head had separated from the mast. The fracture exhibited 45° shear planes, grey matte surface appearance. No observation of flat spots or discolorations.

2.5 Main Rotor Head

The main rotor assembly is a two-bladed, semi-rigid, teetering type rotor with underslung mounting.⁴

Modification Incorporated	TB206 91 133
PN: 206-011-100-14X5	SN: A-244EA

The rotor head assembly was intact. The rotor had separated from the mast between 1.5 -2.0 inches below the static stops. The fracture was matte gray in color with 45° shear faces. The section of the mast that remained within the rotor head was bent about 15°. The raised pads on each side of the mast showed paint removed aligned with the static stops consistent with

³ Main rotor drive description – BHT-206A/B-Series-MM-6

⁴ Main rotor description – BHT-206A/B-Series-MM-6

contact.⁵ No gouge marks were identified on the pads. The pitch change horns on each pitch housing was present, with pitch change links attached and separated from the opposite end. The Red blade grip had all blade retention pins in place, and 50 inches of blade extend. The blade fracture end had a carbon fiber boom straw appearance, 45° skin tear. The Red blade had strain gauges placed on the upper and lower surfaces. Orange wire leads were routed on the back side of the blade to the hub. Numerous leading-edge indentations were present. The White/unmarked blade grip had all blade retention pins in place and 48 inches of blade remnants. The blade fracture end had fractured along the chord line in a shear fashion, the carbon fiber bundles had been cut flat & square along the chord line.

2.6 Rotors

Van Horn Aviation's 20635000-501 main rotor blade is an aftermarket replacement main rotor blade for Bell model 206B helicopter. The blade is constructed using carbon fiber/epoxy pre-preg woven fabric and unidirectional tape. The blade interfaces with the existing Bell main rotor hub using two titanium grip plates. The grip plates are bolted to the composite sub-assembly. The blade incorporates a NASA developed laminar flow airfoil. The tip is tapered in both chord and thickness directions. No modifications are required to the helicopter to install the blades. The two rotor blades installed on the helicopter were developmental prototype blades that were being used to collect data for certification requirements.

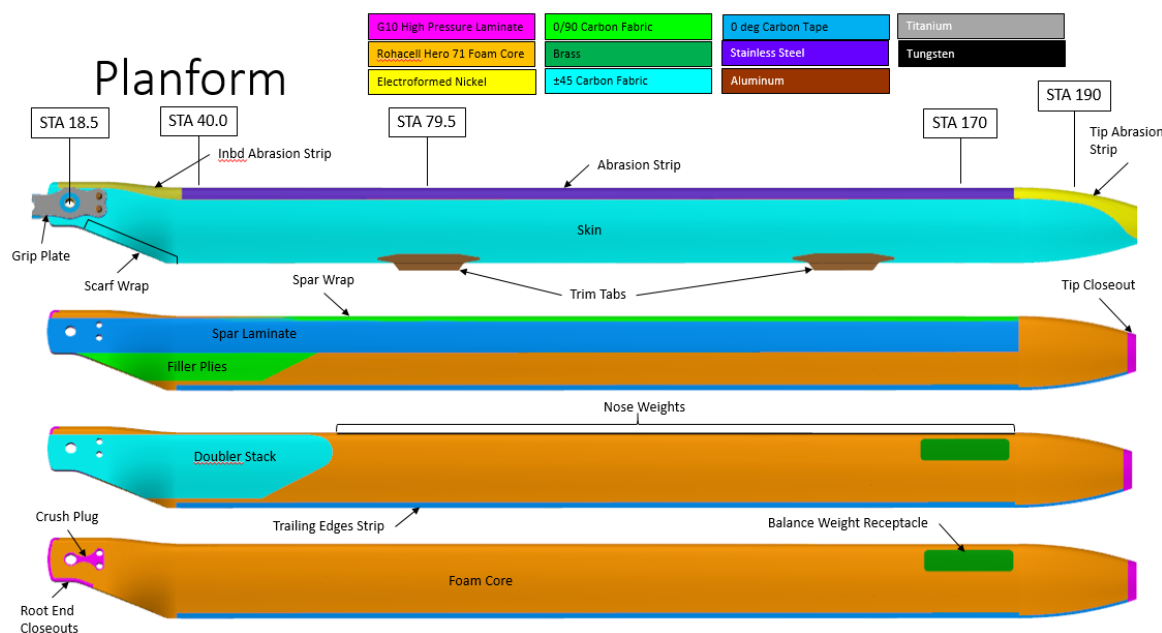


Figure 3: Plan form drawing of main rotor blade construction.

⁵ See NTSB Material Lab Factual Report for details regarding the rotor mast bending and fracture.

2.6.1 Red Rotor Blade

Van Horn Aviation	PN: 2063500-501	SN: A002
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The rotor blade was colored alternating orange and white on the top surface and gloss black on the bottom surface. The leading edge was protected by stainless steel and nickel alloy erosion strips. The length of the upper and lower surface of the blade was instrumented with strain gauges. The rotor blade had separated from the hub. The remaining blade length was 134 inches. A 23-inch section of blade tip had separated from the blade body. The entire length of the blade was split along the trailing edge, white foam after body filler had been liberated. The entire trailing edge carbon fiber strip had separated cleanly from the blade skins. Blade weights were located along the entire interior length of the leading edge. A mid span witness mark matched the curve of the deformed left horizontal stabilizer spar.



Photo 1: Upper and lower surfaces annotating the horizontal stabilizer spar witness mark and blade tip separation

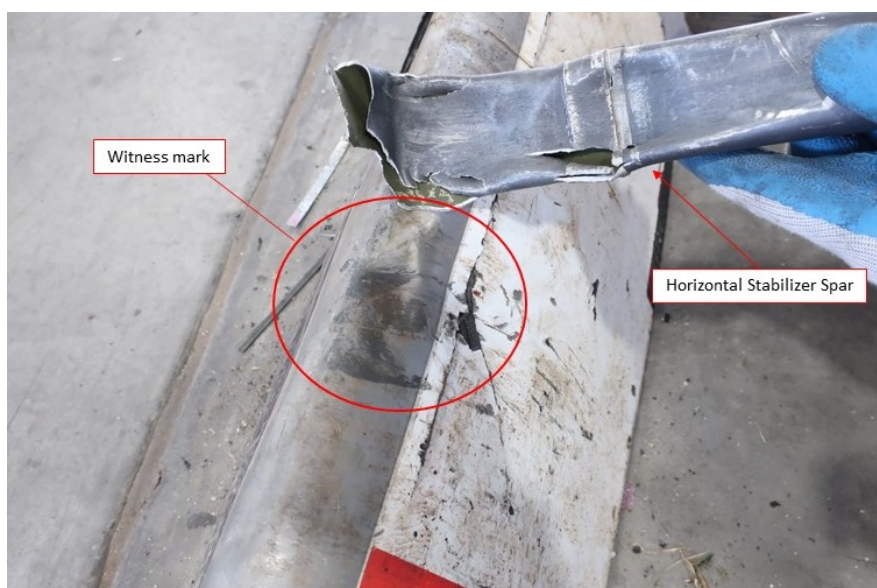


Photo 2: Close up of horizontal stabilizer spar witness mark.

2.6.2 Unmarked/White Rotor Blade

Van Horn Aviation	PN: 20635000-501	SN: A001
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The rotor blade was colored alternating orange and white on the top surface and gloss black on the bottom surface. The leading edge was protected by stainless steel and nickel alloy erosion strips. This blade was not instrumented. The rotor blade had separated from 49 inches from the hub. The remaining blade length was 134 inches. A 22-inch section of rotor tip had separated from the blade. The rotor tip leading edge erosion strip had a lengthwise witness mark consistent with tail rotor leading edge contact.

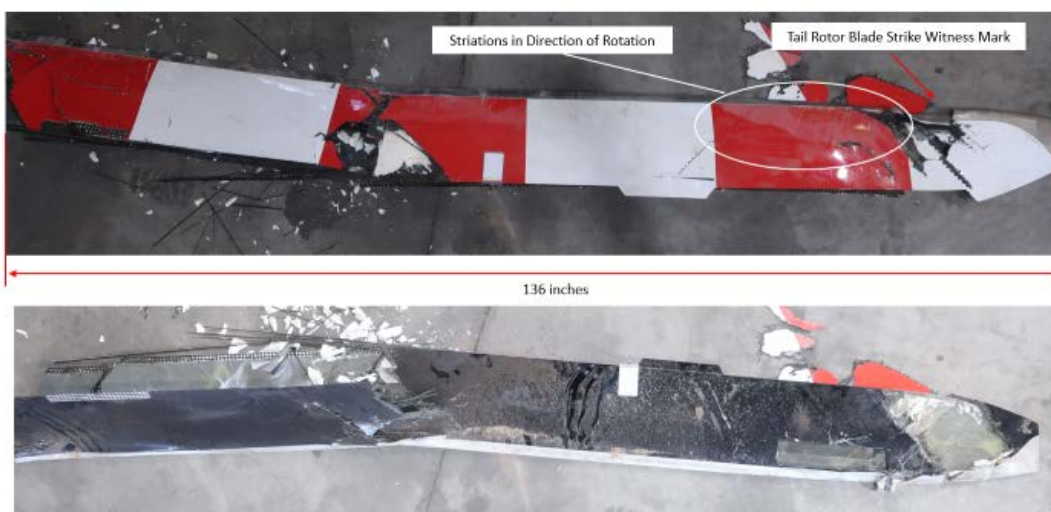


Photo 3: Upper and lower surfaces of unmarked rotor blade.



Photo 4: Tail rotor blade leading edge aligned next to main rotor blade tip.

2.7 Tail Rotor Drive System

The tail rotor drive system includes the following components: tail rotor driveshaft, oil cooler blower, and tail rotor gearbox.⁶

⁶ Tail rotor drive description – BHT-206A/B-Series-MM-7

Tail rotor drive shaft had disconnected from the engine at the squirrel cage blower. Tail rotor drive shaft continuity from the engine to the tail rotor gear box was established through multiple overload and torsional fractures. The forward section of the no. 3 drive shaft was not located. The tail rotor gear box was sheared from the mounting fixtures at the four attach bolts. The gear box turned freely by hand and had a small amount of oil in it. The oil filler cap was locked in place.

The tail rotor control rod bell crank was moved by hand. The rotor head moved in and out in concert with the rotor blades changing pitch. Both pitch links were attached.

Van Horn Aviation	PN: 2062200-301	SN: 0147
Van Horn Aviation	PN: 2062200-301	SN: 0158

The leading edge of both blades had been fractured mid span. Both outboard sections of the blades had separated about midspan.

3.0 ENGINE INFORMATION

The engine consists of a single-stage axial-centrifugal-flow compressor, a single combustion chamber, a two-stage gas producer turbine, and a two-stage power turbine.⁷

Rolls Royce
M250-C20B
SN: CAE-830577
Engine TT: 9337.1 hrs

There was no evidence of pre-impact fire, damage, or malfunction of the engine. The engine displayed significant impact damage along the entire length of the right-hand side. Several accessory drive components showed fracture damage at their gearbox connections. There was evidence of engine and drive train rotation at the time of the event. Continuity was established for the N1 rotor system. The N2 rotor assembly remained locked. Further disassembly of the engine to assess N2 continuity was not accomplished. Control continuity could not be established to either the power turbine governor or fuel control unit due to the severity of impact damage.⁸

4.0 RECENT MAINTENANCE HISTORY

The helicopter was issued an airworthiness certificate on July 27, 2004, with an Experimental classification in the Research and Development category. Examination of the maintenance records revealed the following helicopter and maintenance information.

Aircraft total time (13 April, 2019): 7,115.0 hrs

⁷ Power plant description – BHT-206A/B-Series-MM-9

⁸ Summarized from the Rolls-Royce Engine Investigation Field Notes

Total engine time (13 April, 2019): 9,333.1 hrs

Blade Assembly	PN: 20635000-501	SN: A002	Prototype	Approval date: 26 Mar 2019
Blade Assembly	PN: 20635000-501	SN: A001	Prototype	Approval date: 26 Mar 2019

Significant Maintenance:

Date	Maintenance Action	Aircraft Total Time (hrs)
4.13.2019	Engine chip light – cleaned plug, 30 min ground run.	7,115.0
4.8.2019	Removed & Replaced bell crank 206-001-578-009	7,112.7
4.4.2019	Balanced tail rotor and main rotor.	7,111.0
4.4.2019	Installed tail rotor blades C158 & C147. Installed main rotor blades A001 & A002	7,109.5
1.27.2019	Turbine overtemp during start. Performed overtemp inspection	7,107.9
1.24.2019	Airframe 100 hr, 12-month, 300 hr, & 6-month inspections	7,107.9

4.1 Weight and Balance

The following weight and balance information was contained in the helicopter maintenance records. The most recent weight and balance was dated 18 May, 2017. Max Gross Weight for Takeoff & Landing⁹ is 3,200 lbs

Empty weight: 1769.0 lbs
 Longitudinal arm: 116.9 in
 Lateral arm: 0.3 in

The weight and balance calculation for the accident flight was provided by the operator. Refer to attachment 2 for details of the weight and balance calculations.

Weight and Balance	
Aircraft (including data acquisition system & instrumentation)	2009.0
Pilot	175.0
Flight Test Engineer	185.0
Laptop computer	10.0
Ballast	325.0
Fuel (91 gal) ¹⁰	591.5
Takeoff Weight:	3,295.5
Estimated weight at the time of the accident:	3,199.2

⁹ 206B Flight Manual (BHT-206B-FM-1)

¹⁰ The weight listed does not correspond with 91 gallons of fuel. The 91-gallon figure represents the total capacity of the installed fuel tank.

5.0 FLIGHT DATA FILES

The flight test engineer's lap top computer was recovered at the accident site. The computer contained the recorded flight test data that was being collected by the flight test equipment installed on the helicopter. These files were successfully recovered off the computer by investigative personnel.

Rotor blade serial number A001 was instrumented using strain gages to measure blade loads in flight. Measured loads were flap bending, chord bending, and torsion at several stations along the span of the blade.

Rotating data are acquired using an Advanced Telemetry International rotating telemetry system. Data are transmitted from the telemetry system to the Cosworth data logger located in the helicopter's passenger compartment. Data are transmitted via FM radio signal. The data logger continuously acquires data as soon as power is supplied to the system. Data are streamed real time to the flight test engineer's laptop computer. The flight test engineer occupies the left seat of the helicopter. When commanded by the flight test engineer using a "start recording" button, data may be saved to a file on the data logger. When a "stop recording" command is sent, the data are transferred from the data logger to the laptop's hard drive. The files' title is the date and time the file was created.

Flight cards are prepared for each test flight. The cards list the maneuvers that will be performed during the test flight. The maneuver table was taken directly from the flight test folder on VHA's server as written by the flight test engineer. The file is labeled "Flight Card – 20635000-501 Autorotation Maneuvers – High Altitude Optimized". Optimized is interpreted as meaning that the maneuvers were arranged to allow as many maneuvers as possible to be performed during each autorotative descent. While the flight card is labeled as "high altitude", each maneuver calls for the altitude to be 3000 ft.(low altitude). High altitude maneuvers are performed at 9000 ft. Recorded data and radar data confirm that the maneuvers were performed at low altitude. The flight card contained 18 maneuvers.

There were 15 files; 7 Pi Dataset (.pds) files, 7 event log (.txt) files, and one file that contained no data. Each Pi Dataset file had matching text file. These files represented 7 test events recorded by the flight crew. By comparing the flight data to the flight test card 15 of the 18 maneuvers were identified with high confidence of correlation¹¹. There were 3 maneuvers that were not identified:

Cond No.	Maneuver
43	Simulated power failure, 3000 ft. One second delay
51	Autorotation – 3000 ft lateral reversal $\pm 15\%$ at 90% Nr
52	Autorotation – 3000 ft lateral reversal $\pm 15\%$ at 107% Nr

The file containing no data had been modified at time 07.05.26¹², indicating that the *start recording* command had initiated file creation but the stop recording command had not been received that would format and place the data into the file.

¹¹ See Airworthiness Attachment 1 for details of the flight test data.

¹² File name likely represents a time stamp, 07 hours 05 minutes 26 seconds.

The simulated power failure maneuver procedure requires the pilot to initiate the maneuver from level flight at 100 kts. The pilot then reduces the engine power to flight idle by using the collective twist grip, allowing 1 second delay, then lowering the collective, applying right pedal to maintain directional control, and enter an autorotative descent. The purpose of this maneuver is to represent a realistic reaction of a pilot when confronted with a sudden loss of engine power.

The autorotation maneuver procedure requires the pilot to be in level flight at 100 kts. To commence the maneuver the pilot lowers the collective, applies right pedal to maintain directional orientation, and reduces the engine power to flight idle by using the collective twist grip.

6.0 MAST BUMPING

Mast bumping is a phenomenon specific to the 2-bladed teetering or underslung rotor system where the rotor hub flap stops shear the mast. Mast bumping is the result of excessive rotor flapping. The mechanical design of this rotor system dictates downward flapping of the blades have some physical limit. If the flapping exceeds the design value, the static stop will contact the mast. It is the contact between the static stop and the mast during flight that causes mast damage or separation.

In straight and level flight, blade flapping is minimal. Flapping angles increase slightly with high forward speeds, at low rotor rpm, at high density altitudes, at high gross weights, low-g maneuvers, and when encountering turbulence.¹³ The entry into an autorotation following a reduction of collective pitch will produce low rotor thrust and a subsequent low-g condition, making the helicopter susceptible to mast bumping. The rotor tip-path plane will respond to cyclic pitch inputs by tilting and if the tilt goes beyond the design limit, hub to mast contact is likely¹⁴.

7.0 LIST OF ATTACHMENTS

Attachment 1 – Flight Test Data Analysis, Van Horn Aviation LLC

Attachment 2 – 206B, N61PH, Weight & Balance

Van S. McKenny IV
Aerospace Engineer – Helicopters

¹³ Rotorcraft Flying Handbook

¹⁴ Prouty, Ray – Helicopter Aerodynamics (Second Edition), Chapter 42.