



# Aviation Investigation Final Report

<b>Location:</b>	Camp Dwyer, Afghanistan	<b>Accident Number:</b>	DCA20LA100
<b>Date &amp; Time:</b>	April 20, 2020, 08:00 Local	<b>Registration:</b>	N908CH
<b>Aircraft:</b>	Sikorsky S61	<b>Aircraft Damage:</b>	Substantial
<b>Defining Event:</b>	Flight control sys malf/fail	<b>Injuries:</b>	3 Serious
<b>Flight Conducted Under:</b>	Part 135: Air taxi & commuter - Non-scheduled		

## Analysis

During the approach to the airfield at Camp Dwyer, the helicopter entered an uncommanded left yaw while approaching its destination. During the subsequent emergency landing, the helicopter impacted the ground and rolled on its right side, resulting in serious injuries to the three occupants and substantial damage to the helicopter. Investigation found there was no evidence of a preimpact structural failure, nor a main or tail rotor system failure, nor a malfunction of either engine.

The image recorder installed in the helicopter showed that, about 9 seconds before the end of the recorded data, the left seat pilot's left pedal suddenly moved to the fully forward position without pilot input, which caused the helicopter's left yaw. The left pedal remained in its fully forward position, and the helicopter continued to yaw to the left for the remainder of the recording.

Examination of the auxiliary servo cylinder assembly (part of the helicopter's directional flight control system) found fatigue cracks on the housing of the yaw channel pedal damper check valve and the housing bolts. These fatigue cracks initiated before the accident flight and propagated until one of the bolts failed in overload, which unseated the check valve housing, allowed pressurized hydraulic fluid to escape from the upper side of the pedal damper piston (as evidence by the extruded O-ring at the check valve housing and the small pool of hydraulic fluid on the airframe structure next to the auxiliary servo cylinder yaw channel), and caused the piston to move upward. This upward movement resulted in the uncommanded full left pedal movement in the cockpit and a resultant increase in tail rotor thrust, causing the helicopter to yaw left.

Although the investigation was unable to determine if the flight crew attempted to press the right pedal after the onset of the left yaw, crew movement of the right pedal would likely have

been difficult due to the presence of residual hydraulic pressure within the pedal damper piston, which led to the uncommanded full left pedal movement. Thus, the pilots had limited available options to slow the left yaw.

After the onset of the left yaw, the right seat pilot set the speed selector levers (engine throttles) to idle, which reduced engine power to the rotor system, reduced main rotor torque, and substantially increased the left yaw rate (as observed in the image recorder data). The emergency procedures for a tail rotor malfunction called for the speed selector levers to be set to idle assuming that the malfunction was causing a right yaw, which would be experienced during typical tail rotor malfunctions, such as a loss of tail rotor drive.

The accident pilots recalled that they heard a bang and felt a shudder. The helicopter initially yawed left with a slight roll to the right, and soon after the left seated pilot stated, "let's get this down on the ground". The pilots stated they started emergency autorotation procedures and had no pedal or cyclic authority, and recalled the helicopter subsequently spinning to the right. However, the cockpit image recorder and data showed no change in the direction of the helicopter's yaw to the left; however recorded data showed an increase in right roll as the helicopter descended.

The pilots' action to initiate autorotation led them to reduce engine power, but this action exacerbated the left yaw, which continued until ground impact. After the initial loss of yaw control, the helicopter also experienced large excursions in the pitch and roll axes. The excursions in pitch and roll, as evident in the recorded angular data and acceleration data, could have affected the pilots identification of the yaw direction after the emergency autorotation procedures were initiated. The helicopter's high left yaw rate, high nose up pitch attitude, and right roll angle resulted in an uncontrolled ground impact.

The pedal damper check valve conformed to drawing requirements except that the edge where the fatigue crack initiated, which had a radius of about 0.003 inches, did not conform to the drawing requirement for all sharp edges to have a radius between 0.005 and 0.015 inches. The nonconforming edge break was likely a factor in the initiation of the fatigue crack on the pedal damper check valve housing bolt lug. However, given the large area of stable fatigue crack growth on the pedal damper check valve housing, the loads on the pedal damper check valve housing bolt lug were likely low. Thus, the nonconforming edge break was likely not the only factor that led to the initiation of the fatigue crack.

Before this accident, Sikorsky was aware of five events involving cracks and fractures of the pedal damper check valve housing and its bolts. Each of these events resulted in an uncommanded yaw from which the flight crews were able to recover. Sikorsky's investigation of these events determined that improper torque of the pedal damper check valve housing bolts was the primary factor that led to these events. As a result, this investigation considered whether the pedal damper check valve housing bolts were improperly torqued during the last overhaul of the auxiliary servo cylinder, which occurred about 2.5 years and 1,270 hours before the accident. However, examination of the bolts found no evidence indicating that they had been over- or under-torqued.

The investigation could not determine, from the available records, when the accident check valve housing was installed onto the auxiliary servo cylinder assembly. As a result, the total accumulated time of the pedal damper check valve housing was not known. The pedal damper check valve housing had no life limit and was not replaced during the last overhaul of the auxiliary servo cylinder. During the last overhaul, a fluorescent penetrant inspection was performed to detect fatigue cracks initiating at the surface of the housing. No cracks or fractures were found; thus, the fatigue crack on the pedal damper check valve housing and its bolts initiated after the last overhaul of the auxiliary servo cylinder assembly. Nevertheless, the addition of a life limit for the pedal damper check valve housing could reduce the possibility of fatigue crack initiation during operation.

At the time of the accident, there was no specific inspection for the pedal damper check valve housing and its bolts after the installation of the auxiliary servo cylinder onto the helicopter. The required safety inspection, occurring every 15 hours, and the required phase V inspection, occurring every 150 hours, both comprised a general visual inspection of the rotor flight controls. The pedal damper check valve would not be readily visible during these generalized visual inspections due to the installed position of the auxiliary servo cylinder assembly. Further, the check valve housing bolts would likely appear to be installed properly unless the auxiliary servo cylinder was removed from the helicopter and the bolts were checked using a torque wrench. Thus, the inspection guidance at the time of the accident would not likely readily identify fatigue cracks on the pedal damper check valve housing and its bolts. Inspections specifically tailored to the pedal damper check valve housing would most likely increase the probability of finding fatigue cracks.

On October 17, 2022, Sikorsky released an alert service bulletin that addressed the inspection of the auxiliary servo cylinder pedal damper check valve housing. In addition, Sikorsky implemented a daily inspection of the check valve housing and a 30,000-hour life limit for the check valve housing

## **Probable Cause and Findings**

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

Fatigue cracking of the auxiliary servo cylinder's pedal damper check valve housing and its bolts, which caused the sudden and uncommanded movement of the helicopter's left pedal and a subsequent left yaw that continued until ground impact. Contributing to the accident were (1) the nonconforming edge of the pedal damper check valve housing during manufacture and (2) Sikorsky's lack of a specific inspection for the pedal damper check valve housing.

## Findings

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<b>Aircraft</b>	Hydraulic, auxiliary system - Failure
<b>Aircraft</b>	Hydraulic, auxiliary system - Design
<b>Aircraft</b>	Hydraulic, auxiliary system - Inadequate inspection

## Factual Information

### History of Flight

<b>Maneuvering-low-alt flying</b>	Flight control sys malf/fail (Defining event)
<b>Landing</b>	Collision with terr/obj (non-CFIT)

On April 20, 2020, about 0802 local time, a Sikorsky S-61N, N908CH, entered an uncommanded left yaw while approaching Camp Dwyer, Afghanistan. The flight crew made an emergency landing, during which the helicopter impacted the ground and rolled on its right side. The two pilots and the crew chief aboard the helicopter were seriously injured, and the helicopter sustained substantial damage. The flight was operated by Construction Helicopters Incorporated, doing business as CHI Aviation, under the provisions of Title 14 *Code of Federal Regulations* Part 135 and a contract with the US Department of Defense. In accordance with Annex 13 to the International Civil Aviation Organization, the National Transportation Safety Board (NTSB) accepted delegation of this accident investigation from the Afghanistan Civil Aviation Authority.

The purpose of the flight was to transport cargo from Camp Bastion (also in Afghanistan) to Camp Dwyer. The helicopter was installed with a cockpit voice recorder (CVR), which showed that, at 0746:13, the right seat pilot called, "Dwyer's in sight," which the left seat pilot acknowledged.

The helicopter was also equipped with an Appareo Vision 1000 image recorder, which was installed on the ceiling of the cockpit. The image recorder was forward looking with a full view of the instrument panel, a partial view of the left and right seat cockpit controls, and a partial view of the outside via the lower portion of the windscreen. The accident recording consisted of parametric data, still images, and audio. The image recorder transcription began at 0751:44; at that time, all engine and transmission cockpit instruments appeared normal. The auxiliary hydraulic pressure gauge indicator in the cockpit showed about 1,500 pounds per square inch (psi), which indicated normal operation.

According to the CVR, at 0758:37, the flight crew received clearance to land. At 0801:57, the CVR recorded an unintelligible word from either the left or right seat pilot. The image recorder showed that, at that time, the helicopter descended to an altitude of 2,600 ft mean sea level and that the auxiliary hydraulic pressure decreased to about 1,300 psi, which was near the bottom of the normal operating range. Also, the left seat pilot's left and right feet had been resting on the pedals, but the left pedal began to move forward without pilot input. Within the next second, the left seat pilot's left pedal moved uncommanded to the fully forward position, and the pilot's foot lost contact with the pedal after the sudden movement.

At 0801:59, the image recording showed that both pilots were jostled in their seats and that the left seat pilot placed his left foot on the left pedal again and made a momentary forward cyclic input. (The cyclic grip and the left seat pilot's hand were then out of the camera's view.) The right seat pilot's left foot was not on the left pedal for that position. The heading indicator showed a left yaw that continued until ground impact along with pitch and roll excursions. The engine and transmission cockpit indications remained within normal limits for the rest of the flight.

At 0802:00, the CVR and image recording showed that the left seat pilot stated, "do you have the controls?" At that time, both pilots' feet were visible on their respective pedals. The helicopter had rotated about 90 degrees from the previous heading and was pitched down approximately 20 degrees. Three seconds later, the left seat pilot stated, "let's get this/us down on the ground," and the right seat pilot's arm was near the speed selector levers (engine throttles). Afterward, the left yaw rate substantially increased from an average of about 20° per second to about 80° per second.

At 0802:05, an expletive was heard on the image recording. The helicopter had pitched up to 36 degrees nose up, had completed one full rotation from the cruise heading, and had increased right roll to 36 degrees. One second later, the auxiliary hydraulic pressure caution lights illuminated on the master warning panel; the auxiliary hydraulic pressure gauge was not visible at this time and for the remainder of the recording. As the helicopter continued to rotate to the left, the roll reached a maximum value of 73 degrees right roll by 0802:06.7, and had pitched up to a maximum of 75 degrees nose up about one second later. The image recording ended at 0802:08, about 9 seconds after the left pedal moved to the fully forward position. The CVR recording ended at 0802:10.

According to the operator, during a postaccident interview, the accident pilots recalled that after a loud bang the helicopter initially yawed to the left with a slight roll to the right. The accident pilots also recalled that the right seat pilot had moved both speed selector levers to the off position during the uncommand yaw to start the autorotation procedure. Both pilots stated they had no pedal or cyclic authority, and the aircraft started a right spin. The cockpit image recorder and data showed that the helicopter did not change yaw direction during the event, and the recorded data showed the helicopter experienced several excursions of pitch, roll, and of acceleration magnitude and direction.

## Pilot Information

<b>Certificate:</b>	Airline transport	<b>Age:</b>	50, Male
<b>Airplane Rating(s):</b>	Single-engine land	<b>Seat Occupied:</b>	Left
<b>Other Aircraft Rating(s):</b>	Helicopter	<b>Restraint Used:</b>	4-point
<b>Instrument Rating(s):</b>	Helicopter	<b>Second Pilot Present:</b>	Yes
<b>Instructor Rating(s):</b>	Instrument helicopter	<b>Toxicology Performed:</b>	No
<b>Medical Certification:</b>	Class 1 With waivers/limitations	<b>Last FAA Medical Exam:</b>	September 20, 2019
<b>Occupational Pilot:</b>	Yes	<b>Last Flight Review or Equivalent:</b>	February 15, 2020
<b>Flight Time:</b>	9100 hours (Total, all aircraft), 1200 hours (Total, this make and model), 6900 hours (Pilot In Command, all aircraft), 181 hours (Last 90 days, all aircraft), 111 hours (Last 30 days, all aircraft), 5 hours (Last 24 hours, all aircraft)		

## Co-pilot Information

<b>Certificate:</b>	Commercial	<b>Age:</b>	34, Male
<b>Airplane Rating(s):</b>	None	<b>Seat Occupied:</b>	Right
<b>Other Aircraft Rating(s):</b>	Helicopter	<b>Restraint Used:</b>	4-point
<b>Instrument Rating(s):</b>	Helicopter	<b>Second Pilot Present:</b>	Yes
<b>Instructor Rating(s):</b>	None	<b>Toxicology Performed:</b>	No
<b>Medical Certification:</b>	Class 2 Without waivers/limitations	<b>Last FAA Medical Exam:</b>	June 29, 2019
<b>Occupational Pilot:</b>	Yes	<b>Last Flight Review or Equivalent:</b>	
<b>Flight Time:</b>	2364 hours (Total, all aircraft), 79 hours (Total, this make and model), 1627 hours (Pilot In Command, all aircraft), 167 hours (Last 90 days, all aircraft), 108 hours (Last 30 days, all aircraft), 5 hours (Last 24 hours, all aircraft)		

## Aircraft and Owner/Operator Information

<b>Aircraft Make:</b>	Sikorsky	<b>Registration:</b>	N908CH
<b>Model/Series:</b>	S61 N	<b>Aircraft Category:</b>	Helicopter
<b>Year of Manufacture:</b>	1977	<b>Amateur Built:</b>	
<b>Airworthiness Certificate:</b>	Transport	<b>Serial Number:</b>	61776
<b>Landing Gear Type:</b>	Tailwheel	<b>Seats:</b>	20
<b>Date/Type of Last Inspection:</b>	April 18, 2020 Continuous airworthiness	<b>Certified Max Gross Wt.:</b>	20500 lbs
<b>Time Since Last Inspection:</b>		<b>Engines:</b>	Turbo shaft
<b>Airframe Total Time:</b>	38495.2 Hrs as of last inspection	<b>Engine Manufacturer:</b>	GE
<b>ELT:</b>	C126 installed, not activated	<b>Engine Model/Series:</b>	CT58-140-2
<b>Registered Owner:</b>	Heligroup Fire Llc	<b>Rated Power:</b>	1250 Horsepower
<b>Operator:</b>	CHI Aviation	<b>Operating Certificate(s) Held:</b>	Rotorcraft external load (133), Commuter air carrier (135), Agricultural aircraft (137)
<b>Operator Does Business As:</b>		<b>Operator Designator Code:</b>	JTAA

### Directional Flight Control System

Inputs from the cockpit cyclic control, collective control, and pedals are transmitted to the auxiliary servo cylinder assembly via control tubes. The auxiliary servo cylinder is mechanically connected to the directional (tail rotor) control system and is the system's only source of hydraulic assistance.

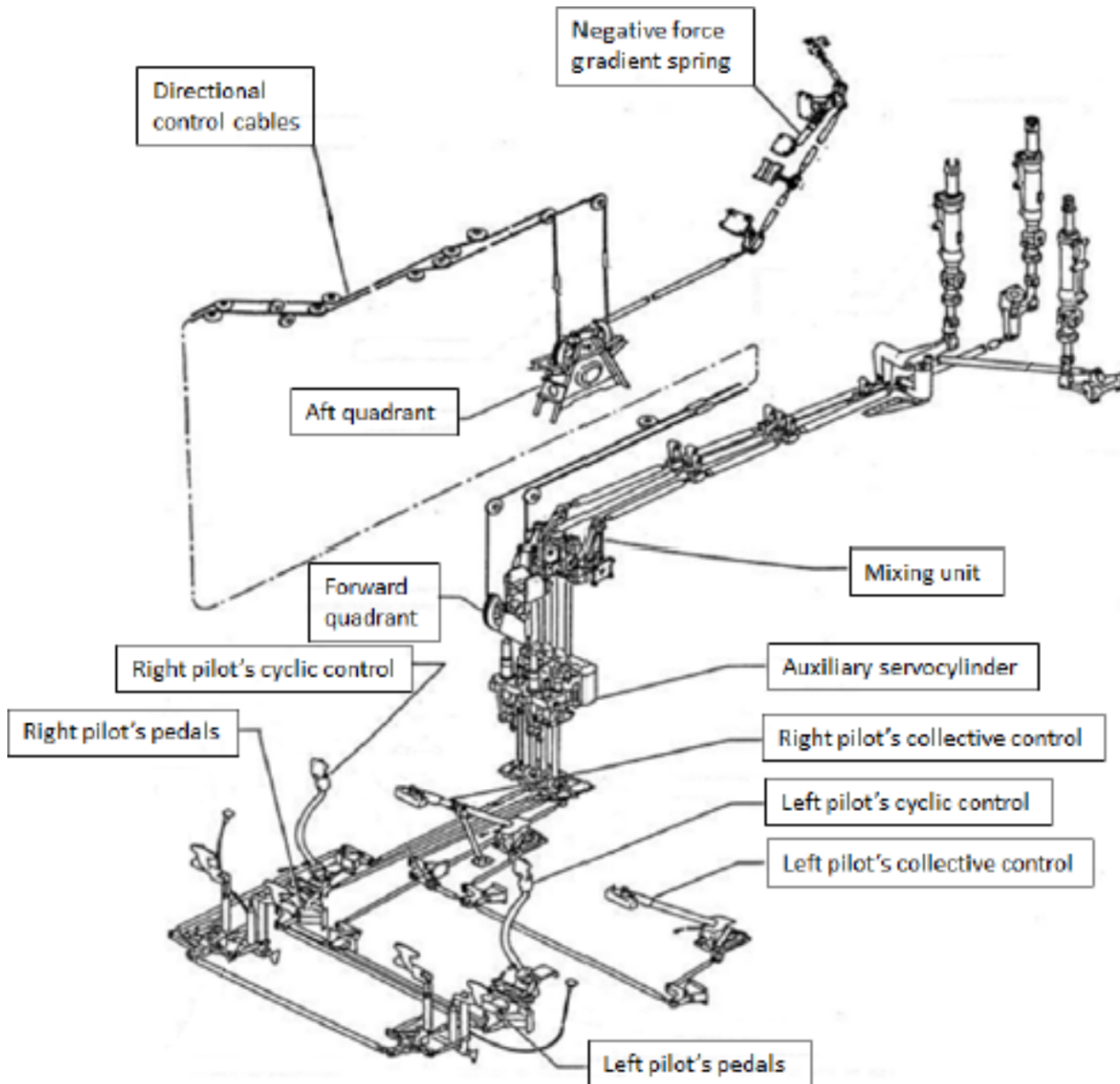


Figure 1. S-61N Flight control system showing the major components of the cockpit flight controls and the directional control system (Image courtesy of Sikorsky and edited by the NTSB)

Within the auxiliary servo cylinder yaw channel, pressurized hydraulic fluid ports are located in the bypass valve, pedal damper, and the input valve. A hydraulic fluid return port is located between the input valve and power piston. The piston pushes hydraulic fluid from one side of the piston to the other side through a restrictor, and an internal spring allows for limited movement without hydraulic dampening. This pedal damper design was intended to prevent sudden, large-displacement pedal movements by pilots.

Movement of the input linkage via the pedals results in movement of the input valve, porting pressurized hydraulic fluid to one side of the power piston and exposing the return port to the other side of the power piston. As a result, the power piston hydraulically actuates the control

cables and control tubes of the directional control system to change the pitch of the tail rotor blades for directional control of the helicopter.

#### Helicopter Maintenance

The operator's S-61 continuous airworthiness maintenance program (which was approved by the Federal Aviation Administration) required a safety inspection at 15-hour intervals. The safety inspection comprised general visual inspections of components and fluid levels throughout the helicopter, including an inspection of the auxiliary servo cylinder. According to the helicopter's daily flight log, a recurrent 15-hour safety inspection was last performed on April 18, 2020, 2 days before the accident.

The continuous airworthiness maintenance program also included five phased inspections performed at 30-hour intervals. Each phased inspection (identified as phases I through V) addressed one or more specific areas of the helicopter. During the phase V inspection (performed every 150 hours), the directional control cables, pulleys, rods and rod ends, and control quadrants and their supports were inspected for security, damage, and wear. The hydraulic accessories, lines, and fittings were inspected for leaks and damage, and their general condition was assessed. The phase V inspection was last performed on April 11, 2020, 9 days before the accident.

According to the operator's continuous airworthiness maintenance program manual, the auxiliary servo cylinder assembly had a 2,500-hour interval for overhaul. The accident auxiliary servo cylinder assembly was last overhauled from May to September 2017; at that time, the auxiliary servo cylinder assembly had a time since new of 34,184 hours. The overhaul included a fluorescent penetrant inspection of the pedal damper check valve housing, which found no evidence of cracks or fractures. On the day before the accident (April 19, 2020), the auxiliary servo cylinder assembly had a time since new of 35,455 hours and a time since overhaul of 1,270 hours.

The available overhaul records for the auxiliary servo cylinder assembly did not show if the pedal damper check valve housing had been replaced and, if it had, the date of the last replacement and the hours of service that the housing had accumulated at that time. According to a representative of the overhaul facility, when the facility performed overhauls of the auxiliary servo cylinder assembly, no cracks were found in the pedal damper check valve housing, and the housing was not replaced. In addition, the representative stated that the bolts for the pedal damper check valve housing were "always" replaced with new bolts per the manufacturer's overhaul manual.

At the time of the accident, there was no specific inspection for the pedal damper check valve housing and its bolts after installation of the auxiliary servo cylinder onto the helicopter. Also at the time of the accident, the pedal damper check valve housing had no service life limit. On October 17, 2022, Sikorsky released Alert Service Bulletin ASB 61B65-25, which provided instructions for a one-time fluorescent penetrant inspection of the auxiliary servo unit for cracks. In addition, Sikorsky implemented a daily visual inspection of the yaw pedal damper check valve housing and a 30,000-hour life limit for the check valve housing.

## Meteorological Information and Flight Plan

<b>Conditions at Accident Site:</b>	Visual (VMC)	<b>Condition of Light:</b>	Day
<b>Observation Facility, Elevation:</b>	OAKN	<b>Distance from Accident Site:</b>	96 Nautical Miles
<b>Observation Time:</b>		<b>Direction from Accident Site:</b>	360°
<b>Lowest Cloud Condition:</b>	Clear	<b>Visibility</b>	10 miles
<b>Lowest Ceiling:</b>		<b>Visibility (RVR):</b>	
<b>Wind Speed/Gusts:</b>	9 knots /	<b>Turbulence Type Forecast/Actual:</b>	/
<b>Wind Direction:</b>	230°	<b>Turbulence Severity Forecast/Actual:</b>	/
<b>Altimeter Setting:</b>	29.94 inches Hg	<b>Temperature/Dew Point:</b>	20°C / 6°C
<b>Precipitation and Obscuration:</b>			
<b>Departure Point:</b>	Camp Bastion, OF (OAZI)	<b>Type of Flight Plan Filed:</b>	Company VFR
<b>Destination:</b>	Camp Dwyer, OF (OADY)	<b>Type of Clearance:</b>	VFR
<b>Departure Time:</b>	07:31 Local	<b>Type of Airspace:</b>	Class D

## Airport Information

<b>Airport:</b>	Dwyer Airbase OADY	<b>Runway Surface Type:</b>	Concrete
<b>Airport Elevation:</b>	2380 ft msl	<b>Runway Surface Condition:</b>	Dry
<b>Runway Used:</b>	23	<b>IFR Approach:</b>	None
<b>Runway Length/Width:</b>	8000 ft / 150 ft	<b>VFR Approach/Landing:</b>	Straight-in

## Wreckage and Impact Information

<b>Crew Injuries:</b>	3 Serious	<b>Aircraft Damage:</b>	Substantial
<b>Passenger Injuries:</b>		<b>Aircraft Fire:</b>	None
<b>Ground Injuries:</b>		<b>Aircraft Explosion:</b>	None
<b>Total Injuries:</b>	3 Serious	<b>Latitude, Longitude:</b>	30.115554,64.071388

The helicopter came to rest on its right side on a magnetic heading of about 74°. The main fuselage had partially collapsed from impact, and the tailboom was twisted farther to the right than the main fuselage. The main rotor gearbox remained attached to the airframe, and the main rotor head remained installed. All five main rotor blade cuffs remained attached to the main rotor head. The inboard sections of four main rotor blades remained attached to their respective cuffs, and the outboard sections of the blades were found near the main wreckage.

The fifth main rotor blade had separated from its cuff but was found near the main wreckage. All five main rotor blades exhibited significant fragmentation on their outboard ends, and the inboard ends exhibited distinctive fractures in a generally chordwise direction. The main rotor blade weights and blade fragments were generally found to the right of the main wreckage at various distances. All main rotor rotating controls (from the rotating swashplate to the pitch change links) were present.



Figure 2. Accident helicopter (Image courtesy of CHI Aviation)

The No. 1 tail rotor drive shaft (TRDS) remained attached to the tail takeoff flange. The No. 2 TRDS remained connected to the No. 1 TRDS, but the flanges and flexible coupling at the connection point were axially deformed. The forward section of the No. 3 TRDS was found near the main wreckage. The aft end of this section was fractured, and the shaft exhibited curling deformation. The remainder of the No. 3 TRDS (installed on the tailboom) was connected to the intermediate gearbox. The flexible coupling at the intermediate gearbox connection was slightly deformed with a wavy appearance. The No.4 TRDS remained installed between the intermediate and tail gearboxes and had no significant damage.

The tail rotor gearbox remained installed on the vertical stabilizer. The tail rotor remained attached to the tail gearbox. All five tail rotor blades remained attached, and three of the blades exhibited chordwise bending. All tail rotor rotating controls were present. The tail rotor control cables exhibited fractures resulting from overstress failure.

The primary hydraulic pressure gauge remained installed on the instrument panel and the indicator was slightly above the 9:00 position. (That position indicates normal hydraulic

system pressure.) The auxiliary hydraulic pressure gauge also remained installed on the instrument panel, and the indicator was slightly above the 3:00 position, which corresponded to 0 pounds per square inch (psi) on the gauge. Both engine speed selector levers were in the shutoff position.

The cyclic, collective, and pedals for the pilot in the left seat remained installed. The left pedal was displaced fully forward, and the right pedal was displaced fully aft. The collective-mounted hydraulic switch was found in the "AUX OFF" position. (That position is used to cut off hydraulic pressure to the auxiliary servo cylinder assembly.)

The cyclic control for the pilot in the right seat remained attached to its base, but its upper portion, including the grip, was not present. The collective head was fractured but remained connected via wiring to the collective control. The hydraulic switch was found in the center position. The left pedal position could not be determined because of crushing damage. The right pedal appeared to be aft of its neutral position.

The auxiliary servo cylinder remained installed, and its surrounding structure had partially collapsed to the right. The input control tubes to the auxiliary servo cylinder remained connected at their rod ends, and the tubes were fractured at various locations. The output control tubes from the auxiliary servo cylinder remained connected at their rod ends, and there was no evidence of a disconnection of the control tubes leading up to the position of the mixing unit. The hydraulic lines to the auxiliary servo cylinder remained attached, and the plastic shield was intact. A small pool of hydraulic fluid was observed on the airframe to the right of the auxiliary servo cylinder.



Figure 3. Red arrow denotes small pool of hydraulic fluid visible to the right of the auxiliary servo cylinder. (Image courtesy of CHI Aviation)

Further examination of the auxiliary servo cylinder assembly found that, on the yaw channel pedal damper check valve housing, the forward right bolt was fractured, but its bolt head remained attached to the safety wiring, which remained attached to the forward left bolt on the pedal damper check valve housing. An extruded piece of an O-ring near the fractured bolt was found at the interface between the pedal damper check valve and the pedal damper body. A crack was visible on the pedal damper check valve housing near the forward left bolt.

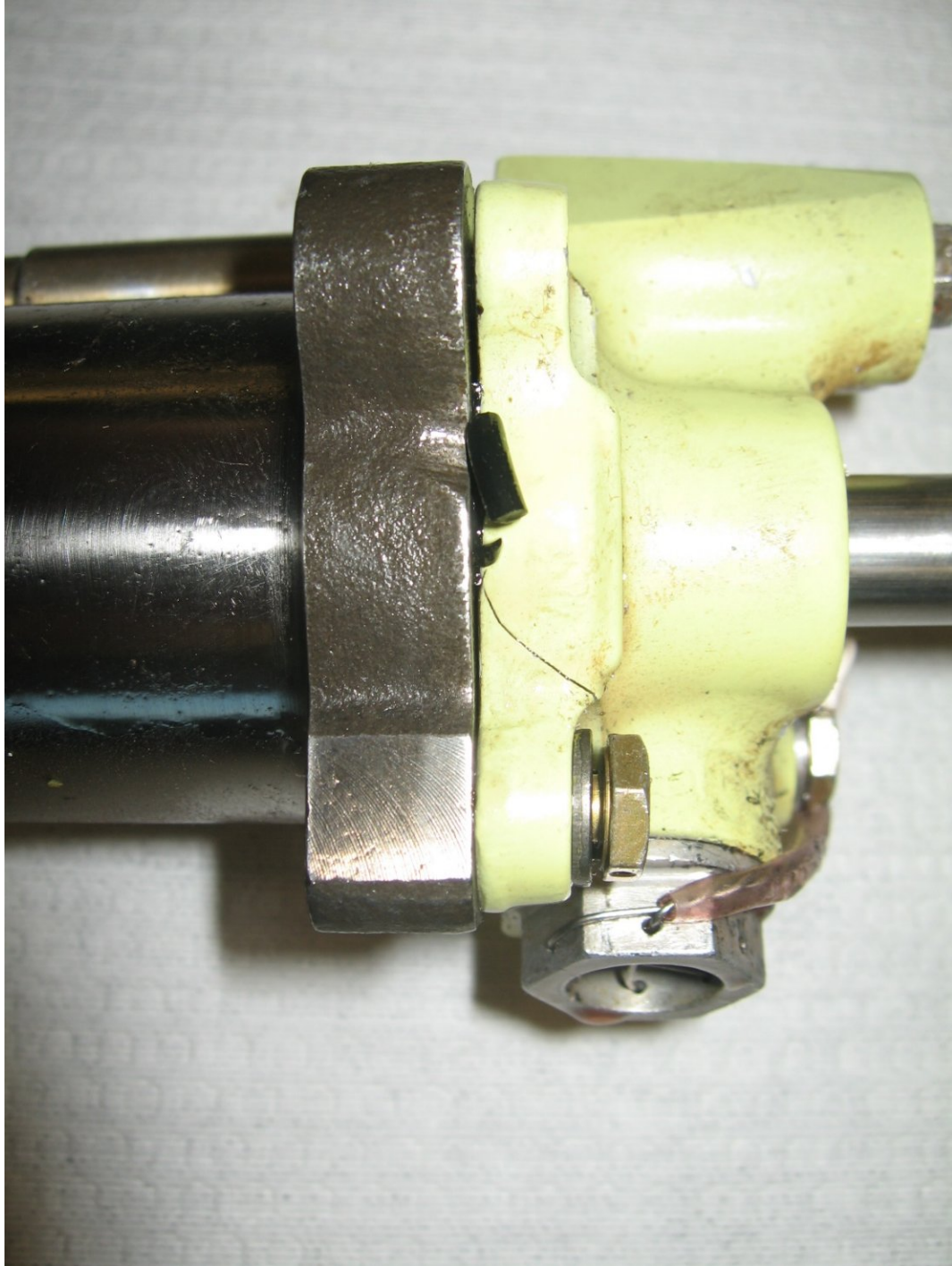


Figure 4. Pedal damper check valve housing installed on the pedal damper. (image courtesy of Sikorsky)

Bench testing of the auxiliary servo cylinder showed that, when hydraulic pressure was just under 200 psi, the yaw channel began to exhibit a leak at the pedal damper check valve housing in the area of the fractured forward right bolt. Disassembly of the auxiliary servo cylinder assembly found that the forward left bolt had a crack on the threaded shank (on the

bolt head end) as well as a slight bend. The crack on the pedal damper check valve housing extended toward the threaded bore for a plug, neither of which exhibited cracks. The extruded O-ring on the check valve housing was separated near its extruded location. Disassembly of the remainder of the pedal damper and its subcomponents showed no anomalies.

The yaw power piston rod end exhibited a slight bend. The pitch, roll, collective, and yaw power piston surfaces had a shiny appearance and typical in-service wear. All O-rings and backup rings on the pistons were in good condition with no cuts or extrusions.

The yaw bypass valve spring showed evidence of contact within its housing, which, according to Sikorsky, was not unusual. The remainder of the yaw bypass valve showed no anomalies. On the servo cylinder assembly housing, the bores for the yaw and collective bypass valves and pitch and roll trim exhibited no anomalies.

Scanning electron microscope examination of the fractured forward right bolt showed signatures consistent with fatigue. Multiple fatigue origins were observed at the root of the first engaged thread. The fracture surface area was about 75% fatigue and about 25% overload. The forward left bolt exhibited multiple cracks in the first three engaged thread roots. Both the forward left and right bolts appeared to conform to the required configuration for grip length, thread length, and thread major and minor diameters. The pedal damper check valve housing bolts also conformed to required specifications and showed no evidence of over-torque (such as yielded material) or under-torque (such as fretting).

The check valve housing crack fracture surface exhibited fatigue on most of the surface. The fatigue fracture surface showed no evidence of damage or contact wear. A red-colored oil consistent with hydraulic fluid was present within the crack. The fatigue origin was located near the radius of the forward left lug. The radius was measured to be about 0.003 inches, which did not conform with drawing requirements for all sharp edges to be from 0.005 to 0.015 inches. (Such edge breaks can be used to reduce stress concentrations, which could otherwise lead to fatigue cracks.) The material composition and hardness conformed to drawing requirements, and the microstructure appeared typical for the material.

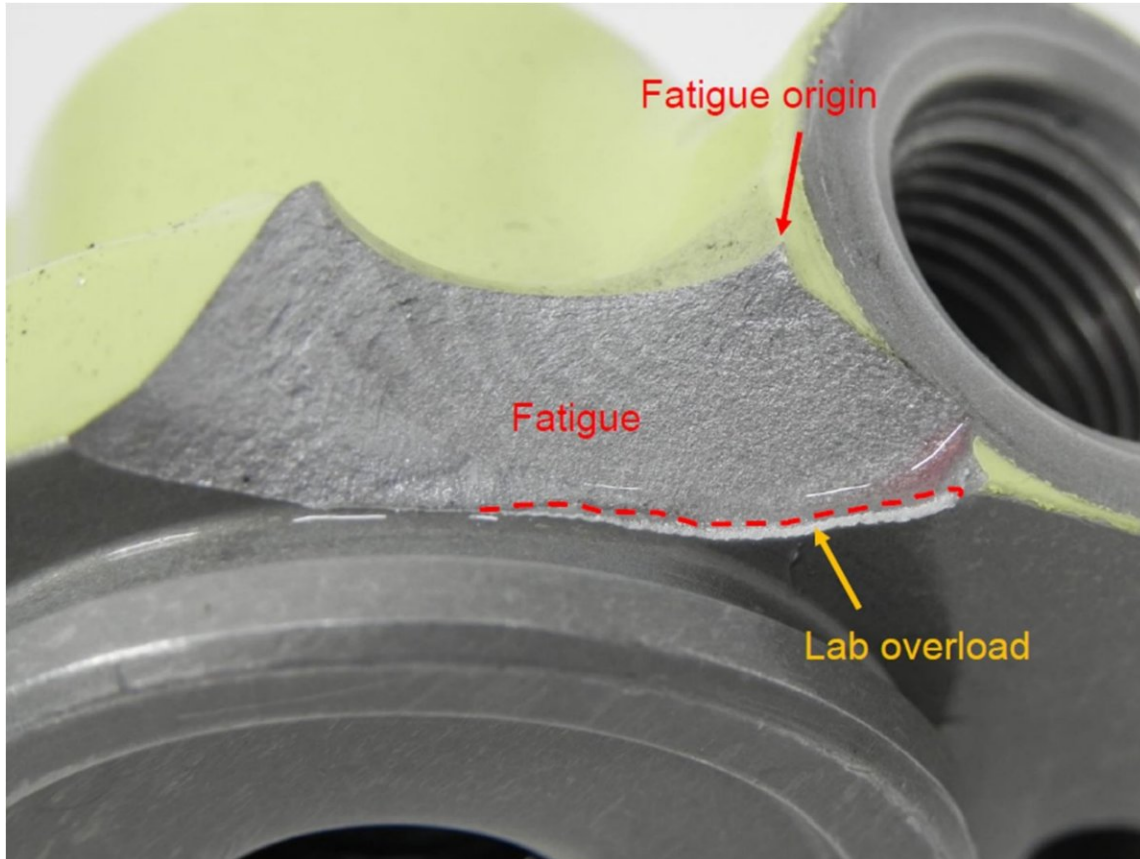


Figure 5. Areas of fatigue cracking identified on the forward-left lug of the pedal damper check valve housing. (Image courtesy of Sikorsky)

Bench testing of the yaw servo valve showed no evidence of external leakages after 1,500 psi of hydraulic pressure was applied. A gain (flow rate vs. current) test was performed, and the results showed that the hydraulic and electric functionality of the unit was within the required performance parameters. The yaw servo valve electric connector exhibited no anomalies. The surface of the servo had a small amount of the grit-like debris. The connector side of the servo showed anomalous wear where the O-ring contacted the servo surface. The input link exhibited typical service wear and no anomalous damage. The two internal filters had grit-like debris on both filters. The two end cap O-rings appeared to be in good condition.

### Additional Information

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According to Sikorsky, in 1978 and 1979, one operator reported three separate instances of a loss of hydraulic pressure to the auxiliary servo system on S-61 helicopters. Two of these events occurred during flight, and one occurred on the ground during a postflight shutdown of the helicopter. In all three instances, the auxiliary hydraulic pressure gauge indicated 0 psi. In two of these instances, a visual inspection found that two pedal damper check valve bolts had fractured, resulting in a loss of hydraulic fluid. In the third instance, the flight crew reported a "violent 45-degree yaw to [the left] and a 5 degree roll to [the right]." A subsequent inspection found that the pedal damper check valve housing had cracked and that two bolts had fractured. All the bolts involved in these events had reportedly failed in fatigue with none exhibiting signatures of excessive torque loading. According to the Sikorsky materials engineering laboratory report that documented these three events, improper operator maintenance when the bolts were installed might have been a factor that led to their failure.

A fourth event, which involved a different operator, occurred in 1991. The operator reported that the helicopter entered an uncommanded yaw to the right and a nose-up pitch with "recovery achieved in 3 to 4 seconds." Two bolts for the pedal damper check valve housing had fractured in fatigue, and fatigue origins were observed at the first engaged thread root. There was reportedly no evidence of pre-existing anomalies at the fatigue origins, and the material composition and hardness met the requirements for the bolt design. Further, there were reportedly no indications of over- or under-torque or improper installation of the bolts. No details were provided regarding the auxiliary hydraulic pressure gauge indication at the time of the uncommanded yaw.

A fifth event, which involved an operator in Greenland, occurred on January 15, 2008. The operator reported that while the helicopter was running on the ground, the helicopter entered an uncommanded yaw to the left. The crew input right pedal to arrest the uncommanded left yaw, by which point the helicopter had yawed about 110 degrees to the left. The Accident Investigation Board of Denmark conducted an investigation of this incident. The investigation found the two bolts securing the pedal damper check valve housing had fractured in fatigue. The bolts conformed to the specifications of AN3H5A with no evidence of material defects. The Accident Investigation Board of Denmark determined the likely cause of fatigue fracture initiation of the pedal damper check valve housing bolts was due to improper installation of those bolts.

Sikorsky issued Safety Advisory No. SSA-S61-08-001, dated February 28, 2008, to notify operators of S-61 helicopters of an event in which a fracture of the pedal damper check valve bolts resulted in a loss of auxiliary hydraulic servo pressure and a subsequent uncommanded yaw of the helicopter. The safety advisory cautioned that the "failure to utilize the correct bolts and to properly torque and safety wire connections may result in failure of these bolts and uncommanded yaw of the aircraft." The advisory also stated that, when installing the bolts, technicians should ensure that "proper torque procedures are adhered to per maintenance manual requirements."

In addition, Sikorsky’s auxiliary servo cylinder overhaul manual required new bolts during the installation of the pedal damper check valve housing (the reuse of bolts was prohibited) as well as a specific torque range for these bolts.

## Administrative Information

<b>Investigator In Charge (IIC):</b>	Bower, Daniel
<b>Additional Participating Persons:</b>	Steve Hiles; CHI Aviation Clayton Carson; Carson Helicopters David Gridley; GE Aviation Todd Gentry; FAA Javier Casanova; Sikorsky
<b>Original Publish Date:</b>	February 1, 2023
<b>Last Revision Date:</b>	
<b>Investigation Class:</b>	<a href="#">Class 3</a>
<b>Note:</b>	The NTSB did not travel to the scene of this accident.
<b>Investigation Docket:</b>	<a href="https://data.nts.gov/Docket?ProjectID=101190">https://data.nts.gov/Docket?ProjectID=101190</a>

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The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, “accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties ... and are not conducted for the purpose of determining the rights or liabilities of any person” (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB’s statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)). A factual report that may be admissible under 49 *United States Code* section 1154(b) is available [here](#).