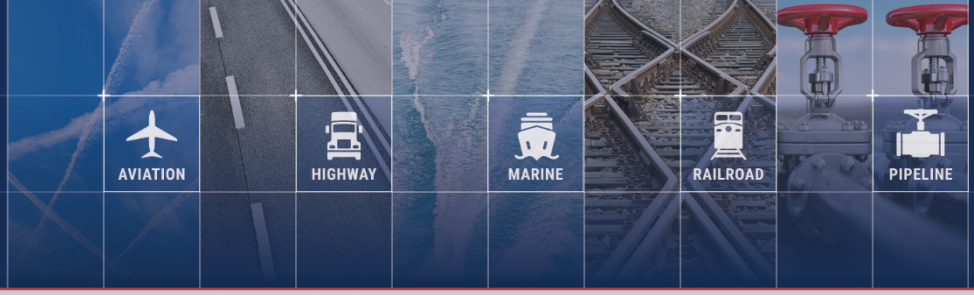

Aviation Investigation Final Report

Location:	Jupiter, Florida	**Accident Number:**	ERA17LA263
Date & Time:	August 2, 2017, 07:20 Local	**Registration:**	N971SK
Aircraft:	Sikorsky S-97A	**Aircraft Damage:**	Substantial
Defining Event:	Flight control sys malf/fail	**Injuries:**	2 Minor
Flight Conducted Under:	Part 91: General aviation - Flight test		

Analysis

The airline transport pilot of the experimental, fly-by-wire-equipped helicopter was taxiing to the runway for a test flight. During the taxi, he had commanded a high collective pitch and a slight forward cyclic pitch stick, and the helicopter was light on its wheels; as a result, the flight control computer transitioned from ground mode to flight mode. The slight forward pitch stick in combination with flight control mode resulted in a nose down pitch rate. The pilot took corrective action, inputting aft cyclic stick. The initial pitch axis correction led to a small initial left roll. The pilot countered the small left roll rate with an appropriate magnitude right stick input. In conjunction with the right stick input, the pilot raised the collective to increase the helicopter's altitude. The helicopter's right roll response to the right stick input was larger than expected, and the pilot countered with a large left stick input. The helicopter's left roll response was also larger than expected. The helicopter bank angles quickly increased, and the pilot rapidly lowered the collective to land the helicopter. The rapid left and right rolls resulted in upper and lower rotor contact, which damaged all rotor blades. The investigation determined that the larger-than-expected roll response to the pilot's cyclic stick input was the unintended result of a flight control system design change that resulted in an increase in cyclic stick sensitivity in the roll axis during the transition from ground control mode to flight mode.

Probable Cause and Findings

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

A design change in the helicopter's fly-by-wire control system that resulted in an increase in the sensitivity of the cyclic stick while transitioning from ground to flight mode, magnifying the pilot's control inputs, which resulted

in unintentional over control in the roll axis, upper and lower main rotor contact, and damage to the rotor blades.

Findings

Aircraft	(general) - Design
Organizational issues	Equipment design - Manufacturer

Factual Information

History of Flight

Takeoff-rejected takeoff	Flight control sys malf/fail (Defining event)
Landing	Hard landing

HISTORY OF FLIGHT

On August 2, 2017, about 0720, eastern daylight time, an experimental Sikorsky S-97, N971SK, experienced a hard landing while hovering at the William P Gwinn Airport (06FA), Jupiter, Florida. Both airline transport pilots were not injured. The test flight was conducted under the provisions of Title 14 Code of Federal Regulations Part 91. Visual meteorological conditions prevailed and no flight plan was filed for the local flight. The aircraft sustained substantial damage.

According to the pilot-in-command, he was in the right seat and manipulating the controls at the time of the accident. He stated that he applied collective to get the helicopter light on the wheels and then applied forward cyclic to initiate a roll forward. He ground taxied to the runway just as he had done on other flights. He intended to hold short of the runway and wait to be notified that the SAR (search and rescue) aircraft was on station. As the helicopter approached the runway, a slight left roll developed. The pilot decided to lift the helicopter into a 5 ft hover and stabilize. As he applied collective and got airborne the helicopter rolled quickly left and then right, continuing with 2-3 roll reversals of increasing roll attitudes eventually exceeding an estimated 60° angle of bank. The pilot applied counter roll control inputs, but roll rates experienced were excessive. After 2-3 roll reversals and after a large right angle of bank roll, as the helicopter reversed its roll, the pilot lowered the collective to full down to execute a landing. After the landing, he shut the engine down, and completed the emergency shutdown procedure. He and the copilot exited the helicopter normally. An examination of the helicopter revealed a collapsed landing gear, structural cabin damage and rotor blade tip separation of all 8 rotor blades.

AIRCRAFT INFORMATION

The helicopter's main rotor consists of two four-bladed coaxial rotors with counter-rotating blades. The rotor head consists of an upper and lower hub, incorporates blade retention, and stationary and rotating controls. The upper and lower rotor blades are similar with the exception of some mounting differences to account for the different rotation directions. The diameter of the rotor is 34-ft. Both the upper and lower rotor heads appeared visually undamaged. The helicopter is also equipped with a composite six bladed propeller, which is utilized as a thrusting device, and is geared directly to the main gearbox.

The helicopter's flight control system is a full authority fly-by-wire system with redundant sensors and processors suitable to a full authority system. Three flight control computers process inputs to manage the flight control system. The flight control system has three modes or paths, which are referred to as the feed forward command paths. These three paths are: fully on ground path, fully in air path, and in transition path. While the helicopter is on the ground, as detected by any one of three weight-on-wheels

switches, it is in the fully on ground path. When all three weight-on-wheels switches are disengaged for more than 3 seconds, the helicopter utilizes the fully in air path. These two modes are blended during the transition from air-to-ground, or ground-to-air, creating a temporary third mode. During the 3 seconds after the last weight-on-wheel switch is disengaged, or 0.5 seconds after a weight-on-wheels is first engaged, the flight controls are in the in-transition path.

Control law changes were introduced in late 2015 to improve ground to air transitions. An unintended byproduct of these changes was an increase of the cyclic stick sensitivity by 2.5 times while operating in the in-transition path.

WRECKAGE EXAMINATION

The helicopter was resting upright on the south side of the runway at the intersection of taxiway A and runway 9/27. The two main landing gear and the tail wheel had collapsed outward, with the helicopter resting on its belly. The helicopter is configured with two 4-bladed counter rotating rotors, with the rotor stacked vertically one over the other. All 8 rotor blades remained attached to their respective hubs and all rotor blade ends had been separated from each blade at approximately the same location along the length of each blade. The tail has a horizontal stabilizer with rudders attached at each end of the stabilizer in a H-configuration. The vertical stabilizers and attached rudders had fractured at the attach points on the horizontal stabilizer as a result of ground impact. A 6-bladed composite variable pitch pusher propeller was positioned at the end of the tail section. All six blade tips exhibited leading edge damage and upward bending as a result of ground contact. The tail wheel fractured at the strut mount and was displaced to the left of the central vertical tail fin.

The propeller gear box remained attached to the tail pylon, no external damage was observed. The propeller drive shaft appeared to be completely intact with no external damage observed. All 6 propeller blades remained attached but exhibited damage from ground contact, with blade tips curled 90° toward the blade back (cambered side).

ADDITIONAL INFORMATION

Based on telemetry data provided by the airframe manufacturer, the accident sequence began as the helicopter was taxiing to the runway and the pilot pushed forward on the cyclic pitch control while also commanding a high collective pitch setting. The following events occurred over the next 4.4 seconds.

- Elapsed time (sec) - Event description
- 54.8 - Taxi (ground mode) Helicopter is light on wheels, forward pitch stick, high collective setting.
- 55.7 - Weight on wheels switch disengages. Transition mode initiates.
- 56.2 - Forward pitch stick commands nose down.
- 56.6 - Pilot inputs aft stick pitch correction. A negligible left roll input is introduced.
- 56.9 - Pilot counters small left roll with small right stick input. Pilot adds collective to increase altitude. Helicopter responds with a disproportionately large right roll.
- 57.4 - Pilot counters large right roll rate with large left stick input. Helicopter's left roll is disproportionally large.

- 57.6 - Left main landing gear contacts ground and transition to ground mode is momentarily initiated. Left main landing gear raises off the ground, resetting transition to flight mode. Helicopter continues to rapidly roll to the right.
- 59.2 - Blades contact each other due to gyroscopic moments generated by the high roll rate.

Pilot Information

Certificate:	Airline transport	**Age:**	52,Male
Airplane Rating(s):	Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane; Helicopter	**Second Pilot Present:**	Yes
Instructor Rating(s):	Helicopter	**Toxicology Performed:**	No
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	August 10, 2017
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	March 29, 2017
Flight Time:	(Estimated) 6679 hours (Total, all aircraft), 19 hours (Total, this make and model), 33 hours (Last 90 days, all aircraft), 14 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

Pilot Information

Certificate:	Airline transport	**Age:**	52,Male
Airplane Rating(s):	Multi-engine sea	**Seat Occupied:**	Left
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane; Helicopter	**Second Pilot Present:**	Yes
Instructor Rating(s):	Helicopter; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	August 1, 2017
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	June 4, 2017
Flight Time:	5714 hours (Total, all aircraft), 10 hours (Total, this make and model), 28 hours (Last 90 days, all aircraft), 16 hours (Last 30 days, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Sikorsky	**Registration:**	N971SK
Model/Series:	S-97A NO SERIES	**Aircraft Category:**	Helicopter
Year of Manufacture:	2014	**Amateur Built:**	
Airworthiness Certificate:	Experimental (Special)	**Serial Number:**	0001
Landing Gear Type:	Retractable - Tricycle	**Seats:**	2
Date/Type of Last Inspection:	August 2, 2017 Condition	**Certified Max Gross Wt.:**	11400 lbs
Time Since Last Inspection:		**Engines:**	Turbo shaft
Airframe Total Time:	104 Hrs at time of accident	**Engine Manufacturer:**	General Electric
ELT:	C126 installed, not activated	**Engine Model/Series:**	YT706-GE-700R
Registered Owner:	On file	**Rated Power:**	2514 Horsepower
Operator:	On file	**Operating Certificate(s) Held:**	Commercial space transp. experimental permit

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Dawn
Observation Facility, Elevation:	SUA,16 ft msl	**Distance from Accident Site:**	18 Nautical Miles
Observation Time:	07:47 Local	**Direction from Accident Site:**	19°
Lowest Cloud Condition:	Clear	**Visibility**	7 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	/	**Turbulence Type Forecast/Actual:**	/
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.11 inches Hg	**Temperature/Dew Point:**	27°C / 25°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Jupiter, FL (06FA)	**Type of Flight Plan Filed:**	Company VFR
Destination:	Jupiter, FL (06FA)	**Type of Clearance:**	VFR
Departure Time:	07:20 Local	**Type of Airspace:**	Class D

Airport Information

Airport:	William P. Gwynn 06FA	**Runway Surface Type:**	Asphalt
Airport Elevation:	22 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	09	**IFR Approach:**	None
Runway Length/Width:	7003 ft / 150 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	2 Minor	**Aircraft Damage:**	Substantial
Passenger Injuries:		**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	2 Minor	**Latitude, Longitude:**	26.908056,-80.32833(est)

Administrative Information

Investigator In Charge (IIC):	Alleyne, Eric
Additional Participating Persons:	Javier Casanova; Sikorsky Aircraft Corporation; Jupiter, FL Jill Browning; Sikorsky Aircraft Corporation; Jupiter, FL
Original Publish Date:	July 8, 2019
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=95726