NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

May 2, 2017

Group Chairman's Factual Report

OPERATIONAL FACTORS

DCA16FA199

Table Of Contents

A. ACCIDENT INFORMATION

Location:	Italy, TX
Date:	July 6, 2016
Time:	1146 CDT[1]
Airplane:	Bell 525, N525TA

B. OPERATIONAL FACTORS GROUP

Van McKenny - Chair
Aviation Engineering Division (AS-40)
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594-2000

Dr. Sathya Silva - Chair
Human Performance Division (AS-60)
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594-2000

Jon Jordan
Rotorcraft Directorate
Federal Aviation Administration
Fort Worth, TX 76177

James Harris
Test & Evaluation IPT Lead
Bell Helicopter
PO Box 482
Fort Worth, TX 76101

Troy Caudill
Lead Experimental Test Pilot, Bell 525
PO Box 482
Fort Worth, TX 76101

C. SUMMARY

On July 6, 2016, about 1148 central daylight time, an experimental Bell 525 helicopter, N525TA, broke up inflight and impacted terrain near Italy, Texas. The two pilots onboard were fatally injured and the helicopter was destroyed. The flight originated from Arlington, Texas, as a developmental flight test and was conducted under the provisions of 14 Code of Federal Regulations Part 91. Visual meteorological conditions prevailed at the time of the accident.

D. DETAILS OF THE INVESTIGATION

On July 8, 2016, the operations group was established during the on-scene phase of the investigation. A review of flight records, schedules, aircrew training, aircrew 72 hour history, and

[1] All times are central daylight time (CDT) based on a 24-hour clock, unless otherwise noted.

weather conditions were conducted. Interviews of all the flight test engineers that were present in the telemetry room and pilots involved in the Bell 525 flight tests were completed.

On July 26, 2016, the Human Performance group chairman was added to the investigation. The Human Performance group chairman and Operations group chairmen formed a joint Operations/Human Performance group.

On August 3 – 4, 2016 the group met at Bell Plant 6, Arlington, TX, to review pilot records, interview Bell test pilots who had flown with the accident crew, observe RASIL[2] simulator tests and shaker table tests.

On November 17, 2016, the group chairmen met at Bell Plant 6 in Arlington, TX, to observe shake testing of Garmin avionics hardware.

On January 17 - 19, 2017, the group chairmen met at Bell Plant 1 and Bell Plant 6 to conduct interviews of design personnel for the Bell 525 and perform familiarization with tactile cueing in the RASIL.

On January 30, 2017, the group chairmen interviewed members of the Bell Control Laws team via teleconference.

On February 6, 2017, the group chairmen met with a team of Bell engineers to discuss the development of biomechanical feedback filters via teleconference.

E. FACTUAL INFORMATION

1.0 History of Flight

The helicopter was an experimental transport category helicopter manufactured by Bell Helicopter, designated as a Bell model 525, registration N525TA, powered by two General Electric CT7-2F1 2,000 shp[3] engines, and was operated by Bell Helicopter. The helicopter was piloted by two Bell employees who each held airline transport pilot certificates. The purpose of the flight was to evaluate engine loads at maximum continuous power (MCP), 2 to 1 simulated engine failures, longitudinal roll oscillations, light on gear dynamic checks, and run on landings in the heavy forward center of gravity (CG) configuration.

On July 6, 2016, about 0630 the flight crew, flight test engineers, and the chase helicopter crew briefed the planned flight. The flight was to be conducted in accordance with visual flight regulations (VFR). Real time telemetry from the helicopter was to be monitored by flight test engineers under the oversight of the designated flight director, who was in direct radio communications with both the test helicopter and the chase helicopter. The helicopter was to proceed to the Arlington Initial Experimental Test Area[4], approximately 30 miles south of the

[2] Relentless Advanced Systems Integration Lab
[3] Shaft horsepower
[4] Refer to the FAA Airworthiness LOA for details

Arlington Airport, to perform the inflight portion of the tests. Two hazards were identified for this flight; rotor speed drops below safe rotor controllability speed and transmission or engine over torque, over speed, or over temp. The mitigation for low rotor speed was to incrementally increase the maneuver entry conditions, autorotation practice in the RASIL[5], and to execute power recovery before rpm drops excessively. The lowest allowable rotor speed limit was identified as 86%. The mitigation for transmission or engine exceedance was to validate the control software functionality on the ground, and both pilots concur before any one-engine-inoperative (OEI) training is selected.

At 0959 weather conditions were determined to be acceptable for the flight. At 1036 the helicopter departed for the test area followed by the chase helicopter. All the maneuvers leading up the accident maneuver were performed around 4,000 feet density altitude (DA), approximately 1,800 feet above ground level (agl). Once in the test area the crew determined the helicopter's maximum level flight airspeed (Vh) to be 148 KCAS[6]. The crew then performed steady heading side slips at 0.7Vh followed by level turns at 0.9Vh, up to 60° angle of bank. The flight crew then prepared for the two-engine to one-engine tests where One-engine Inoperative Training Mode (OEI) software simulates the loss of power from one-engine by reducing the power output of both engines to a preset value based on flight conditions that was representative of the power one-engine would provide. The OEI power value was determined by the flight test engineers and relayed to the pilots. Once OEI training mode is engaged and a loss of power is simulated the pilot monitors rotor speed (Nr) and intentionally delays his response by about 1 second before recovering from the maneuver by lowering the collective (reducing power demanded by the rotor).One critical parameter monitored for this test is the amount of rotor rotational speed decay that occurs between the sudden loss of engine power and the pilot's control inputs to recover. The first 3 data points were performed in level flight at 120 KCAS, 131 KCAS, and 145 KCAS, all of which resulted in rotor RPM decay of 3-7%. The remaining test points required the helicopter to be an a shallow descent in order to achieve the required airspeed and at the target density altitude of 4,000 feet. The following data points were performed 155 KCAS, 159 KCAS, 158 KCAS, 165 KCAS, and 175 KCAS, all which resulted in a rotor decay of 5-10%. The final test point was performed at 1148, at 185 KCAS, where the helicopter experienced an unanticipated vibration which resulted in control inputs that produced a rotor decay below 80% and the catastrophic loss of vehicle and crew.

2.0 Crew Information

2.1 Pilot Duties

The operator describes the duties of their Test Pilots as follows. Test Pilots plan and conduct experimental flight test in helicopters and tilt rotor aircraft, conduct other flight test operations, maintain flight currency, and travel in support of Bell Helicopter flight operations. They are to complete flight analysis, flight evaluations of aircraft, test planning and flight test reports. Their responsibilities include the planning and execution of engineering and experimental test flights of new aircraft and/or systems, evaluation and reporting on data gathered during test flights, and demonstrating safe and efficient test planning and execution. Additionally they interface with the entire project team to ensure successful accomplishment of the test program, and make

[5] RASIL – Relentless Advanced Systems Integration Lab
[6] Knots Calibrated Airspeed

recommendations as to operational effectiveness of systems, aircraft handling qualities and design improvements.

2.2 Pilot

The pilot, age 36, held an Airline Transport Pilot (rotorcraft) certificate, and a commercial pilot certificate with single-engine land and instrument airplane privileges, issued March 18, 2014, and a second-class medical certificate issued on April 8, 2016, with no limitations. Examination of the pilot's military logbooks, civilian logbook, and Bell Helicopter flight records revealed that he had 2,898.9 total flight hours, 2,744.6 rotary wing flight hours, 72.7 hours in the Bell 525, and 40.1 hours flown within the previous 30 days. He held a Letter of Authorization (LOA) from the Federal Aviation Administration dated December 2, 2015, authorizing him to act as pilot-in-command of the Bell Helicopter experimental helicopter designated model 525. His most recent flight review was conducted on October 29, 2015, flown in a twin engine Bell 430 helicopter. He completed Crew Resource Management (CRM) training January 12, 2015. The pilot received his Bachelor of Science degree in electrical engineering from the United States Naval Academy in 2002, and graduated from the United States Naval Test Pilot School (USNTPS) in 2010. After USNTPS he worked on numerous flight test projects involving the AH-1W[7] and UH-1Y[8] helicopters. On September 23, 2013 he was hired in to the Flight Test Department of Bell Helicopter. His primary responsibility was as a pilot on the Bell 525 program.

2.2.1 Pilot's Recent Activities

The pilot's family stated that he spent most of the 4th of July weekend relaxing at home. On Sunday July 3rd he went to bed around 2100. The next day, Monday, July 4, he was up at 0400. His meals consisted of milk and cereal in the morning and afternoon, and a hamburger in the evening. He went to bed around 2200. On Tuesday, July 5, he was up around 0500, ate milk and cereal for breakfast and was at the Bell Plant 6 facility at 0600. He did not fly and left work around 1500. He had a bar-b-que dinner and went to bed around 2200. His spouse stated that he seemed well rested and had not taken any naps. On July 6, he was up around 0430 and was at the Bell Plant 6 facility for the 0600 flight briefing. Family members stated that he did take 61 mg Dexilant once per day, had a history of hay fever symptoms, and had consumed a single beer each of the previous nights.

2.3 Copilot

The copilot, age 43, held an Airline Transport Pilot (rotorcraft) certificate, and a commercial certificate with single-engine land, multi-engine land, and instrument airplane ratings, issued October 15, 2014, and a second-class medical issued on May 31, 2015, with no limitations. Examination of the pilot's military logbooks, civilian logbooks and Bell Helicopter flight records revealed that he had 3,957.5 total flight hours, 2,589.4 rotary wing hours, 84.1 hours in the Bell

[7] Bell AH-1W SuperCobra was twin-engine attack helicopter
[8] Bell UH-1Y Venom aka a Super Huey was a twin engine utility helicopter

525, and 27.4 flight hours within the previous 30 days. He held a Letter of Authorization (LOA) from the Federal Aviation Administration dated December 2, 2015, authorizing him to act as pilot-in-command of the Bell Helicopter experimental helicopter designated model 525. His most recent flight review was conducted on November 6, 2015, flown in a Bell 407. He also completed a flight review in the twin engine Bell 430, October 6, 2015. Crew Resource Management (CRM) training was completed on January 12, 2015. The copilot received a Bachelor of Science degree from Texas Tech University in 1996, and completed US Navy flight training in 2000. In 2006 he graduated from the USNTPS and proceeded to work on numerous AH-1W and UH-1Y test programs. He was hired by the Bell Helicopter Flight Test Department on August 2, 2010. His primary responsibility was as a pilot on the Bell 525 program.

2.3.1 CoPilot's Recent Activities

The copilot's family stated that he spent most of the 4th of July weekend at home. On Sunday, July 3rd, he slept late, getting up around 0900. He helped clean up the house and took his children swimming next door. His spouse reported that emotionally he was tired but glad to be home. Monday, July 4th, he got up at an unknown time, ate a good amount throughout the day, shot off fireworks in the evening, and went to bed around 2300. On Tuesday, July 5, he was up around 0500, ate a breakfast bar, was and at the Bell Plant 6 facility by 0600. He did not fly, and left work around 1500. His spouse stated that he was tired after work and took a nap before he went to the gym. He had a sandwich for dinner and went to bed around 2130. On Wednesday, July 6, he was up around 0500, ate a breakfast bar, and was at Bell Plant 6 for the 0600 flight brief. Family members reported that he took no medications other than ibuprofen, and that he had not had any alcohol in the previous 72 hours.

3.0 Flight Test

3.1 Flight Test Schedule

The Bell 525 flight test log that documented the helicopter's operational history, recorded the test events, number of engine starts, flight time, ground time, and number of landings was reviewed. The Test Log indicated that flight test event number 1 occurred on May 15, 2015, with zero flight hours on the airframe. Between May 15, 2015, and the date of the accident, July 6, 2016, 184 flight test events had been completed. Within the previous 60 days prior to the accident, 32 test events were completed, involving approximately 47 flights, totaling 43.6 flight hours. Within the previous 30 days, 16 test events were completed, involving approximately 30 flights, totaling 26.1 flight hours.

Bell provided records showing that the Model 525 had been flown out to maximum allowable airspeed (Vne[9]) a number of times prior to the accident. A similar flight test to the accident flight was flown on June 15, 2016, involving simulated engine failures in the light-aft[10] CG configuration

[9] Vne – Maximum allowable airspeed, never exceed airspeed

[10] Gross weight: 14,794 lbs, Long CG 298.5 in

had been performed up to Vne, at 8,000 feet and 12,000 feet density altitude. During these test points rotor droop never dropped below 93%.

3.2 Flight Test Operations

The flight test monitoring was conducted through a dedicated telemetry room (TM) located at Bell Plant 6, Arlington, Texas. This room received the telemetry data from the helicopter and distributed that data in real time to nine flight test engineer stations using IADS (Interactive Analysis & Display System). The telemetry data is processed and saved using Bell Helicopter's CAFTA (Computer Aided Flight Test Analysis) system. The nine flight test engineer stations were as follows: Test Director, Rotor Dynamics, Control Laws (CLAWs), IADS manager, Structural Dynamics, Handling Qualities, Data Operations, and the Telemetry Room Operator. A large screen was positioned in the front of the room to display selected data. The Test Director is the only flight test engineer that communicates with the helicopter via voice radio communications. All flight test engineers can communicate with each other through a voice loop system internal to the telemetry room. The Test Director's duties are to supervise and direct the conduct of the test being performed.

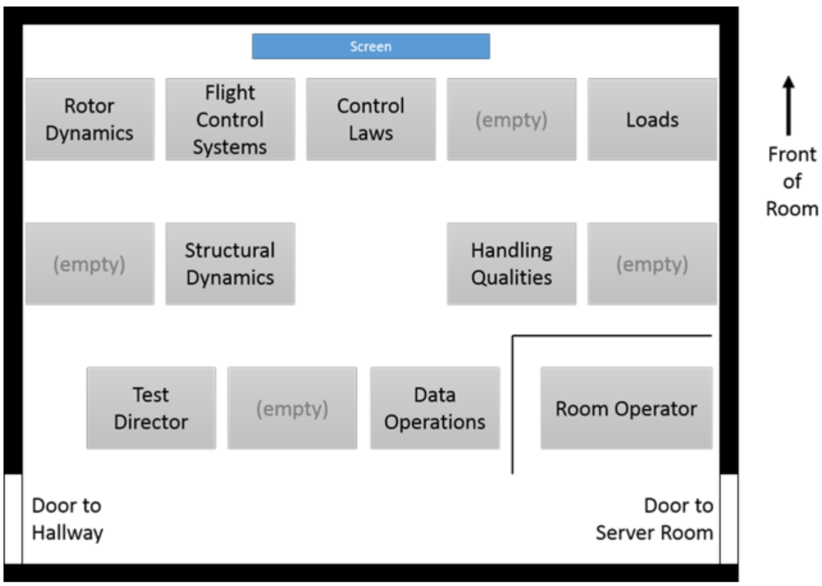

Figure 1- Telemetry Room Configuration

Figure 2- Telemetry Room (TM) viewed from the Test Director's position. (NTSB photo)

The purpose of Test 184 was to accomplish four items in the Bell 525 Development and Envelope Expansion Test Plan.

1. Heavy forward center of gravity (CG) GE (General Electric) engine loads and vibrations at 100% maximum continuous power evaluation.
2. Heavy forward CG longitudinal roll spot-check
3. 2-to-1 Simulated Engine Failures
4. Run-on landings up to 60 knots

According to interviews conducted with the involved flight test engineers, the Test Director's test card notes, and the post-accident notes (created by each engineer immediately after the accident), the decision to conduct the test flight was made at 0959 based on improving weather conditions to acceptable levels. The helicopter's APU (auxiliary power unit) was started at 1024, the helicopter lifted into a hover at 1036, and departed for the designated test area at 1038. While en-route, the aircrew reported that the air quality[11] was "moderate at best." Approximately 1048 the aircrew established the Vh (maximum level flight airspeed) at 4,000 feet density altitude as 148 knots calibrated airspeed (KCAS). About 1053 the aircrew executed a series of steady heading side slips using maximum left or right pedal input, at 0.9 Vh (133 KCAS) at 4,000 feet. Following the steady heading side slips the crew performed a series of level turns at 0.9 Vh utilizing angle of bank between 45° and 60°. During these maneuvers, some of the flight test engineers telemetry screens

[11] Air quality -Air quality refers to the stability of the air the helicopter is flying in. Within the Bell flight test culture air quality is rated good, fair, poor. A subjective grading scale that attempts to convey the amount of turbulence the aircraft is experiencing in level flight. "Moderate at best" would be interpreted as somewhere on the low side of fair

showed “Warning[12]” and “Alert Limit[13]” notifications for some of the monitored data channels. Warning notifications were analyzed to determine if enough margin existed between the reported value and the actual limit to permit the crew to continue on to the next test point. In the case of Alert Limit notifications, flight can be continued if the exceedances are due to anomalous instrumentation, signal drop outs, or, in certain cases, allowable transient exceedances. With the level turn test points completed the aircrew moved on to the 2-to-1 simulated engine failures.

Utilizing GE engine control software and a dedicated test panel installed in the cockpit of the helicopter, the aircrew was able to simulate the loss of engine power from one-engine while keeping both engines operating. This was done by reducing the power output of both engines to represent the maximum power that can be produced by one-engine. This capability function is referred to as Special One-engine Inoperative (OEI) Training Mode. Approximately 1108 the aircrew established Vy airspeed (best rate of climb air speed) and set OEI training engine power to maximum allowable single engine power as determined by the flight test engineers. The aircrew and flight test engineers had determined that the lowest rotor speed (Nr in percent rpm) that was allowable during any aspect of the test was 86%. Any time Nr went below 86% the test would be halted and a “knock-it-off” call made. The following test points were conducted at 4,000 feet density altitude. For airspeeds higher than what could be obtained in level flight at maximum continuous power (MCP) a shallow descent was utilized to obtain the require airspeed for the test.

Record #	**A/S**	**Condition**	**Initial % Nr Droop**	**Time to reach 103% Nr**
41	102 KCAS (0.7Vh)	Level flight, 4,000 ft DA	97%	3.4 sec
42	131 KCAS (0.9Vh)	Level flight, 4,000 ft DA	95%	14.8 sec
43	145 KCAS (Vh)	Level flight, 4,000 ft DA	86.9%	6.2 sec
44	155 KTAS	Descending flt, 4,000 ft DA	94.5%	5.2 sec
46	159 KTAS	Descending flt, 4,000 ft DA	93.6%	8.2 sec
47	158 KTAS	Descending flt, 4,000 ft DA	89.9%	8.5 sec
48[14]	165 KTAS	Descending flt, 4,000 ft DA	89.9%	10.0 sec
50	175 KTAS	Descending flt, 4,000 ft DA	90.3%	13.0 sec
51	185 KTAS	Descending flt, 4,000 ft DA	90%	N/A

[12] Warning is considered less critical than an alert, and is usually set about 20% below the Alert value. Warnings are put in place to alert the TM engineers of data that is trending towards an Alert Limit.
[13] Alert Limit is the maximum allowed value being measured for a given parameter. If exceeded, it requires a halt of the test condition being conducted and potential termination of the test pending further data review and inspection of the affected component.
[14] Record no. 49 - courtesy record was not recorded - aircrew did not execute test point due to turbulence

During the build up to record 51, 185 KTAS OEI test, the flight test engineers received Warning and Alert notifications. The majority of these were related to main rotor and tail rotor pitch link loads, pylon loads, and tail boom loads. These Alerts and Warnings were expected as the airspeed increased, hence, increasing the dynamic loads on the rotor system and airframe. After each test record, the data was reviewed and the engineers calculated the margin that was available between the current loading and the Alert levels. None of the engineers expressed concern about proceeding on to the Vne OEI test (record 51). During the majority of the OEI transitions the pilot responded with the appropriate response of lowering the collective between 1 and 2 seconds after the simulated loss of engine power. However, with each increase in airspeed, the time the pilot took to recover Nr to the target value of 103% was longer. For example, for the 145 KCAS test point, 6 seconds elapsed to regain Nr to 103% and by the time the helicopter was being tested at 175 KCAS, the recovery time was 13.0 seconds to attain 103% Nr. Bell interpreted this trend as the tendency of the pilot to be more judicious while applying collective at the higher airspeed to avoid recovering too fast and over speeding the rotor or damaging the transmission. [15]. A similar tendency was observed by Bell when it was testing the Bell 429[16].

The set up and entry for the 185 KTAS OEI test profile (record 51) was the same as the previous test points. OEI was engaged, the Nr drooped to 91% within 1.5 seconds, and the Nr decay was arrested by the pilot's reduction of collective, rotor rpm began to recover trending towards 93%. About 7 seconds after arresting the Nr decay (12 seconds into the test record), the Structural Dynamics engineer noticed increased engine vibrations, at which point he called "knock-it-off." The Test Director radioed to the crew to "knock-it-off," while other engineers in the TM were receiving Warnings and Alerts, and reinforcing the 'knock-it-off" call. Approximately 21 seconds into the test record, the tail boom was severed by the main rotor and the TM signal was lost. The chase helicopter crew radioed that there had been a major mishap with the test helicopter.

3.3 Chase Aircrew

Two pilots from the Flight Test group were scheduled as the chase aircrew flying a Bell 429 helicopter. They attended the preflight briefing and manned their aircraft when the weather improved, around 1000. The duties of the chase helicopter includes monitoring the test area for other aircraft, monitoring the flight for safety issues, observing and monitoring the test helicopter as it executes the test card. The chase helicopter was in radio communications with the test helicopter and the Test Director. After a few circuits of the traffic pattern, the chase helicopter positioned it's self behind the test helicopter and they departed to the test area as a flight of two. Once in the test area, the test helicopter executed the test card as planned and nothing unusual occurred up through the OEI test procedure. At the higher test airspeeds the Bell 429 would fall further behind the test helicopter because of its airspeed limitations, but would rejoin the test helicopter as it slowed and recovered from the maneuver. During the final OEI test, the chase helicopter was positioned on the right side about 3-4 rotor diameters away and 100 feet above the test helicopter. The chase aircrew heard the Test Director call "knock-it-off", about the same time

[15] Flight Test Risk Analysis Worksheets -OEI Training Validation Testing (overtorque/overtemp/overspeed), mitigation best practice.
[16] See Human Performance Factual Report

they observed the rotor blades flying high, and the rotor looked wobbly and slow. The chase aircraft radioed "Hey, you're flapping[17] pretty good," but the test helicopter never responded over the radio. The chase crew then observed the helicopter's tail and fuselage jack-knife, and pieces of the helicopter separated from the helicopter. The chase helicopter then radioed to the Test Director, 'We've had a major accident." The chase helicopter landed close by to the wreckage to attempt some sort of assistance.

4.0 Aircraft Information

Figure 3- Bell 525, N525TA (Photo courtesy of Bell Helicopter)

The accident helicopter was a Bell Helicopter Model 525, registration N525TA, serial number 62001, manufactured in 2015, and was a conventional main rotor and tail rotor design. It was powered by two General Electric (GE) CT7-2F1 turboshaft engines, each capable of producing 2,000 shp. The registered owner was Bell Helicopter Textron Inc, and issued an Experimental – Research & Development airworthiness certificate on April 25, 2016. The helicopter was a manufacturing prototype being developed for certification as a transport category helicopter, in compliance with Title 14, Code of Federal Regulations, Part 29.

The Federal Aviation Administration (FAA) issued an Operating Limitations document as part of the airworthiness certificate which was dated April 25, 2016. The Operating Limitations specify that pilots operating this helicopter must hold a temporary Letter of Authorization (LOA) issued by a FAA Flight Standards Operations Inspector to act as pilot-in-command (PIC). The LOA also stipulates that the helicopter be maintained by a FAA-approved inspection program, day VFR flight operations are authorized, and all flights must be conducted with in the designed geographic

[17] Blade Flapping – the upward or downward movement of the rotor blades during rotation (FAA-H-8083-21 Rotorcraft Flying Handbook)

area south of the Arlington Municipal Airport[18], designated as the Arlington Initial Experimental Test Area.

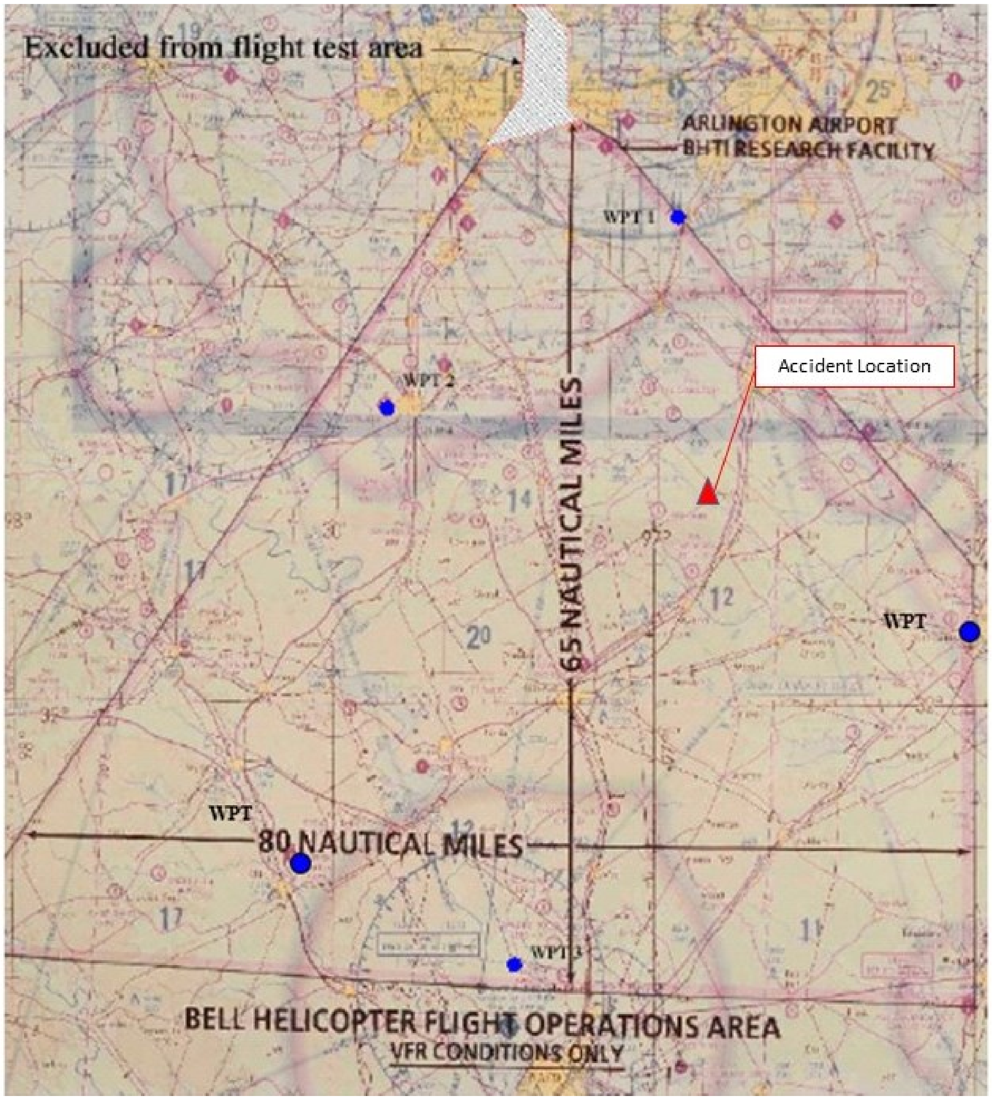

Figure 4 – Arlington Initial Experimental Test Area

[18] See the FAA Operating Limitations for N525TA for the dimensions of the experimental test area

4.1 Cockpit layout

Figure 5 - Cockpit Overview. Photo of the cockpit of ship #2, N525BK (NTSB photo)

The cockpit is configured for two pilots in a side-by-side seated position and a center console between them. Each pilot had a cyclic side stick controller forward of the seat's right armrest and a collective side stick controller immediately forward of the seat's left arm rest. Each pilot has a set of anti-torque pedals forward of their feet. The instrument panel consists of four identical primary flight display/multifunction display panels. The center console consists of two Garmin Touch Control (GTC) panels, landing gear handle, Nav/Com panel, and the Flight Test Switch Panel which includes some controls for the One-Engine-Inoperative (OEI) Special Training software. Directly above the GTC's were the engine control COSIF[19] knobs. Outboard of the instrument panel, each pilot had an additional pilot display unit (PDU) that provided real time flight test instrumentation parameters such as density altitude, boom airspeed, mast airspeed, engine torque, load factor, pitch/yaw/roll rates, slip angle, main rotor and tail rotor flapping angles.

---

[19] COSIF - crank, off, start, idle, fly

Figure 6 – PDU data display (NTSB photo)

Figure 7 – PDU data display (NTSB photo)

4.2 Weight and Balance

The intended weight and center of gravity (CG) location for the accident flight was referred to as a heavy-forward condition. To achieve a heavy forward CG, ballast (steel plates) were placed in designated ballast fixtures within the helicopter. The following weight and balance information was taken from the weight and balance calculation sheet for the test flight, preflight briefing card, and the Test Director's test card notes.

Basic Operating Weight	[redacted]	
Crew Weight	405 lbs	
Ballast	[redacted]	
Initial Fuel Load	[redacted]	
Ramp Weight	[redacted]	
Takeoff Fuel Load	[redacted]	
Takeoff Weight	[redacted]	

Longitudinal CG was at 281.4 inches aft of the datum.
Lateral CG was 1.0 inches left the fuselage station-butt line.

4.3 One-Engine-Inoperative (OEI) Training Mode

One-Engine-Inoperative (OEI) Training Mode is a specific software driven capability developed by General Electric (engine manufacturer) that executes a reduction in power to simulate the loss of a single engine, without the necessity of actually rolling back or shutting down an engine in flight. When OEI Training Mode is engaged by the flight crew both engines reduce power to represent the power available from a single engine. Depending on the flight conditions, if the power demanded by the rotor exceeds the power available, the rotor rotational speed will droop. In such a flight condition, the pilot must reduce the power demanded by the main rotor by lowering the collective control in a timely manner. OEI Training Mode automatically adjusts the torque/horsepower limits (representing the "remaining good engine") to the computed OEI power available for the sensed ambient temperature and pressure*.

Entry and exit of OEI Training Mode is normally done by using the OEI training page on the Garmin Touch Controller (GTC), where the pilot can select which engine to fail. While in the OEI Training Mode, the pilot's displays (right seat) will show the simulated OEI conditions while the copilot's displays (left seat) will show actual AEO[20] data.

Numerous manual actions and automatic triggers will cause OEI Training Mode to exit, resulting in the return to normal engine operations. These conditions are listed below.

Manual Exit

- COSIF Switch is set to anything other than "Fly"
- Deselect the failed engine on the GTC
- The OEI Training GTC page is exited

Automatic Exit

- Loss of an engine or engine failure
- Torques of the two-engines are *not* within ~30 ft-lb of each other
- There is any fault that would cause local channel degraded on any of the 4 channels.
- If the enable bit for training is set (bit 20) AND both engine request bits are set (bit 21 and 22). To engage training only one-engine request bit can be set.
- Np[21] is 5% below the reference value (having previously been within 1% of the reference while in training) or to a value below 90%*.
- Loss of all aircraft OAT input
- Real Engine Ng[22] is above 106%
- Real Engine MGT[23] is above 1934.3°F/ 1056.8°C
- Real Single Engine Torque is above 521 ft-lb
- Real Engine Oil Temperature is above 148.89°C
- Low oil pressure switch is tripped

4.4 Special OEI Training Mode

A Special OEI Training Mode was developed specifically for flight test purposes only. Special OEI Training Mode is enabled via a software trim file and was active on the N525TA's engines at the time of the event. Similar to OEI Training mode, Special OEI Training Mode does not affect the information presented on either pilot's flight test PDU.

[20] AEO – All engines operating
[21] Np – Power turbine speed (% rpm)
[22] Ng – Gas producer turbine speed (% rpm)
[23] MGT – Measured gas temperature

Special OEI Training Mode incorporates the below features, in addition to those of OEI Training Mode:

- Computed OEI power is now a function of Np, ambient temperature and ambient pressure
- Maximum power can be adjusted via a cockpit beep switch to ±30% of the approximate sea level, standard OEI power at rating. In this case, torque will increase as Np decreases.
- Maximum torque can be adjusted via a cockpit beep switch to ±30% of the aircraft transmission torque limit at each OEI rating.
- Adjustment of the low Np threshold for automatic exit via software trim file.

During flight tests, the low Np value for automatic exit was set to 0% which allowed Nr to droop to whatever level demanded by collective position.

4.5 OEI Training Mode Flight Test Risk Analysis

The following Flight Test Risk Analysis Worksheets documented planned operational risk mitigation for OEI Training.

Test:	OEI Training Validation Testing (overtorque/overtemp/overspeed)
Requestor:	E. Boyce
Date of Request:	March 14, 2016
Date of Approval:	April 1, 2016
Hazard:	Transmission and engine overtorque/overtemp and/or overspeed due to sudden increase in power available.
Probability:	Remote (unlikely to occur)
Severity:	Major (minor injury/minor damage)
Mitigation:	Aircrew familiar with Single/Dual Engine Emergency Procedures; Adherence to Best Practices and Approved Test Procedures; Evaluation of software in RASIL[24] prior to test; Conduct restrained ground run tests before flight to verify software functionality; Build up in airspeed, and entry power levels separately. Verify GE Trim file FADEC[25] channel in brief. Dual concurrence before any channel, OEI training selections

Test:	Autorotation Demonstration During D&EE Test Plan
Requestor:	P. Lindauer
Date of Request:	January 26, 2015
Date of Approval:	June 29, 2015
Hazard:	Rotor speed droops below safe rotor controllability speed.
Probability:	Occasional: Likely to occur sometime
Severity:	Critical: Serious injury or substantial aircraft damage

[24] RASIL – Relentless Advanced Systems Integration Lab.
[25] FADEC – Full Authority Digital Engine Control

Mitigation:	Aircrew familiar with Dual Engine Helicopter Autorotation Testing; Adherence to Best Practices and Approved Test Procedures; Conduct Dual to Single and Single to Auto testing prior to testing Dual to Auto points; Entry conditions will begin in middle of weight and airspeed envelope; Build up in gross weight, airspeed, and entry power levels separately. TM Monitoring. Build up in delay time before pilot response.

5.0 Meteorological Information

The Arlington Municipal Airport is located 31 miles NNW of the accident site. A review of the Arlington (KGKY) automated surface observation system (ASOS), elevation 628 feet msl, recorded observation for 1145 was wind from 170° at 15 knots, 10 statute miles visibility, sky was clear of clouds, temperature of 32° C, dew point 23°C, and altimeter of 29.95 inHg[26]

The Hillsboro Municipal Airport is located 15 miles SSW of the accident site. A review of the Hillsboro (KINJ) automated weather observation system (AWOS-3), elevation 686 feet msl, recorded observation for 1136 was wind from 190° at 16 knots with gusts to 22 knots, 10 statute miles visibility, scattered clouds at 3,000 feet, temperature 31°C, dew point 23°C, and altimeter at 29.98 inHg.

6.0 Medical and Pathological Information

6.1 Pilot

The Office of the Medical Examiner for the county of Dallas, Texas, performed an autopsy on the pilot on July 7, 2016. The conclusion of the report stated that the cause of death was thermal and blunt force injuries.

The Federal Aviation Administration (FAA) Forensic Toxicology Research Team, Civil Aerospace Medical Institute (CAMI), performed toxicology on the specimens from the pilot. The specimens were noted as being putrefied, and tests for carbon monoxide and cyanide were not performed, 32 mg/dl of ethanol was detected in muscle, no ethanol was detected in brain, none of the listed drugs were detected in liver specimen.

6.2 Copilot

[26] inHg – inches of mercury

The Office of the Medical Examiner for the county of Dallas, Texas, performed an autopsy on the pilot on July 7, 2016. The conclusion of the report stated that the cause of death was blunt force injuries.

The Federal Aviation Administration (FAA) Forensic Toxicology Research Team, Civil Aerospace Medical Institute (CAMI), performed toxicology on the specimens from the pilot. The specimens were noted as being putrefied, and tests for carbon monoxide and cyanide were not performed, 65 mg/dl of ethanol was detected in muscle, no ethanol was detected in liver, propanol detected in muscle, none of the listed drugs were detected in lung or liver specimens.

7.0 Bell 525 Program Organization

The Chief Engineer for the 525 Program was responsible for all 525 testing, certification activity, structures (drive, rotor, & airframe), and reported to the Vice President for Commercial Programs at the time of the accident. Six discipline areas reported to the Chief Engineer; Airframe Engineering, Systems Engineering & Certification, Rotors Engineering & Component Test, Drive Systems, Flight Technology, and Flight Test/Experimental Test & Evaluation. The 525 Program Flight Test IPT consisted of 12 flight test engineers, and 3 instrumentation engineers. The Experimental Test and Evaluation department consisted of 12 flight test pilots and did not report to the 525program. Six of the 12 pilots were assigned to support the 525 Program.

The Chief Engineer worked closely with the Air Vehicle IPT (integrated product team). The Air Vehicle Director was also a direct report to the Vice President for Commercial Programs. The Air Vehicle Lead was responsible for of all systems not directly under the control of the Chief Engineer, which included flight control system and software, control laws, avionics, electrical system, propulsion, hydraulic system, fuel system, and environmental controls.

7.1 Flight Crew Risk Assessment

In December of 2015 the Flight Test group had put in place a personal risk assessment tool, that each pilot could complete prior to flying. Crews have been encouraged to fill out the risk assessment every day, but it was not mandatory. The mishap aircrew did not have a risk assessment on file for the day of the accident.

7.2 Training

The majority of pilot training consisted of time spent in the RASIL engineering simulator. The RASIL consists of an accurate engineering representation of the cockpit, including control feel, and visual inflight representation projected on a screen that wrapped around the cockpit. Next to the RASIL cockpit was a separate "Rig Room" containing actual flight hardware (hydraulic servos) rigged to apply flight loads into engineering representations of related hardware. When a control was moved in the RASIL cockpit, hardware would actually respond to the command in the Rig Room.

Figure 8- RASIL Cockpit (NTSB photo)

Pilots assigned to the 525 program would routinely operate the RASIL while developing flight procedures, validating software changes, and reviewing fight test plans. While there were no written logs showing when a pilot or flight crew worked in the RASIL the lead test pilot stated that he knew the crew had reviewed the test card for the mishap flight in the RASIL, and the RASIL engineers stated that the crew routinely worked in the RASIL. Typical training flow would involve two RASIL sessions for each test flight. If the pilots had been in the RASIL within two weeks of a test flight, they were considered current.

Additionally, both the pilot and copilot had accumulated 72 and 84 flight hours respectively in the 525, and had accumulated many ground testing hours validating the Special OEI Training Mode in the helicopter.

F. LIST OF REFERENCES

Reference 1: Operations/Human Performance Interview Summaries
Reference 2: FAA Airworthiness LOA

Submitted by:

Captain Van McKenny, NTSB
Operations Group Chairman