EXPERT REPORT OF JOHN BLOOMFIELD

1. My name is John Bloomfield. I am over 21 years of age and am legally competent and expressly qualified to author this Report. All of the opinions in this report are stated to a reasonable degree of professional and engineering certainty.

2. I have been retained as an expert by Plaintiffs' counsel in this action, which arises from the crash of a Bell 407 helicopter, N31VA, on August 12, 2017 and was operated by the Virginia State Police. The helicopter impacted trees and terrain resulting in a post crash fire that destroyed much of the main cabin compartment. The two officers onboard were fatally injured.

I. QUALIFICATIONS AND EXPERIENCE

3. I am an expert in avionics, aircraft electrical systems, electrical generation, aircraft electrical distribution, avionics integration, trim systems, autopilot systems, auto-throttle systems, Global Positioning Systems, (GPS), Cockpit Voice Recorders (CVR), Full Authority Digital Engine Control, (FADEC), Flight Data Recorders (FDR), and Traffic Collision Avoidance Systems, (TCAS). I am also an expert in electro/mechanical systems and hydro/mechanical systems electric/pneumatic systems and sub-systems. Additionally, I am an expert in product design, complex component integration, materials specification, product safety analysis, man/machine interface, failure analysis, accident reconstruction, technical manuals and systems development.

4. As listed in my Curriculum Vitae, which is attached hereto as Appendix A, I graduated from the Georgia Institute of Technology, Industrial and Systems Engineering School in 1976. In 1982, I was selected as one of twenty of the most

innovative engineers in the history of Georgia Tech. I was also the youngest member of the Georgia Tech's "Living History" program.

5. I am the President and owner of Bloomfield Research and Development and am the holder of twelve United States patents in the disciplines of electronics, robotics, avionics, medical electronics, ultrasonics, precision spread spectrum radio ranging, battlefield communications, cellular digital software, and electronic toys. Bloomfield Research and Development invents, develops, designs, builds prototypes, patents, and licenses leading edge technology products and systems, some notable examples of which are listed in the attached Curriculum Vitae.

6. I have been involved in investigation of hundreds of aircraft accidents, vehicle accidents, electrocutions, equipment fires and explosions focusing on forensic electronic and electrical distribution problems, electro/mechanical systems and hydro/mechanical systems that caused or contributed to the accidents. Additionally, I have been the lead expert in appliance fires, electrocution accidents involving utility vehicles, hospital bed fires, surgical robotics, marine explosions, appliance electrocutions, appliance fires, patent disputes, automobile safety systems and personal mobile transporters.

7. I have further investigated several helicopter accidents involving the type of engine and electrical control system which equipped the accident helicopter.

II. INFORMATION AND DOCUMENTS REVIEWED

8. A comprehensive listing of the documents I reviewed to prepare this report are contained in Appendix B. Additionally, I personally inspected the wreckage at Anglin Aircraft Recovery in Clayton Delaware. I also had the opportunity to

examine certain harvested components that had been recovered from the wreckage at Micron, Inc. in Wilmington, Delaware.

9. I further conducted an inspection of an exemplar Bell 407 aircraft and witnessed and participated in flight demonstrations done with that aircraft.

III. FADEC DESCRIPTION

10. FADEC is an acronym for Full Authority Digital Engine Control. The FADEC system consists of 3 major components; the Electronic Control Unit, “ECU”, the Hydraulic Mechanical Unit, “HMU” and the electrical harness that electrically and electronically mates the ECU and HMU together. The FADEC system is intended to reduce pilot workload by constantly adjusting fuel flow into the engine to maintain certain flight parameters and demands.

11. The HMU is bolted to the engine casing and is comprised of a plurality of valves, solenoids, stepper motor and fuel metering mechanisms. The HMU is also mechanically connected to the pilot’s power lever. The HMU contains a metering valve that is driven by electric stepper motor that also drives a potentiometer whose value is sent back the ECU so that the ECU “knows” the position of the valve.

12. The ECU electronically controls the FADEC system and contains a microprocessor, power supplies, input/output electronics, electronic circuitry, buffers, filters and memory. The ECU is a computer and can be programed as a computer to tailor and configure the FADEC system for a variety of aircraft with respect to that particular aircraft’s desired needs and uses. The ECU is constantly monitoring a plurality of inputs. For the microprocessor (computer) to determine the proper amount a fuel delivery it takes into consideration inlet temperature, the

power lever angle, the collective pitch angle, torque pressure, NG, (gas compressor speed), NP, (turbine speed) and other parameters. The values of all these inputs are exercised through various algorithms and configurations to derive an output to the HMU that best fits the fuel delivery requirements for that instant. The ECU constantly monitors these parameters and therefore is constantly adjusting the fuel delivery and is able to actually anticipate engine requirements by monitoring the rate of change of the combination of input parameters.

13. The FADEC system in Auto Mode constantly monitors and constantly meters the proper amount of fuel to the engine. In the Manual Mode the pilot is in control of the amount of fuel delivered to the engine. Should the system, with internal checks and self-monitoring detect a failure in the system it will annunciate to the pilot the failure with a "FADEC Fail" and reverts into the "Fail-Fixed Mode". When that condition occurs the stepper motor that drives the fuel metering mechanisms is de-energized and essentially "freezes" the fuel delivery flow at that last value. The FADEC system is now no longer controlling the engine and the pilot through the "Direct Reversion to Manual Mode", now has full authority over the engine.

14. The FADEC system also utilizes a feature to prevent the engine from "overspeeding." If the power turbine reaches a speed of 118.5% the system will severely limit the fuel to the engine. The mechanism to achieve that action is called the "overspeed solenoid valve." That overspeed solenoid valve is normally electrically de-energized. When an overspeed condition is recognized by the ECU, the ECU electrically energizes the overspeed solenoid valve and the fuel is then

limited to around 40 pounds per hour. That fuel rate will not generate enough engine power to support flight.

IV. ACCIDENT SEQUENCE

15. The FADEC ECU records several engine parameters when certain events trigger a "capture" for later analysis. Those parameter are, rotor rpm (Nr), compressor speed (%Np), gas generator speed (%Ng), fuel flow (Wf), torque (%Q), power lever angle (PLA) and collective position (%CP). The following Figure 1 represents approximately the last 18 seconds of flight. The X axis is time directly from the ECU clock and not local time of the accident.

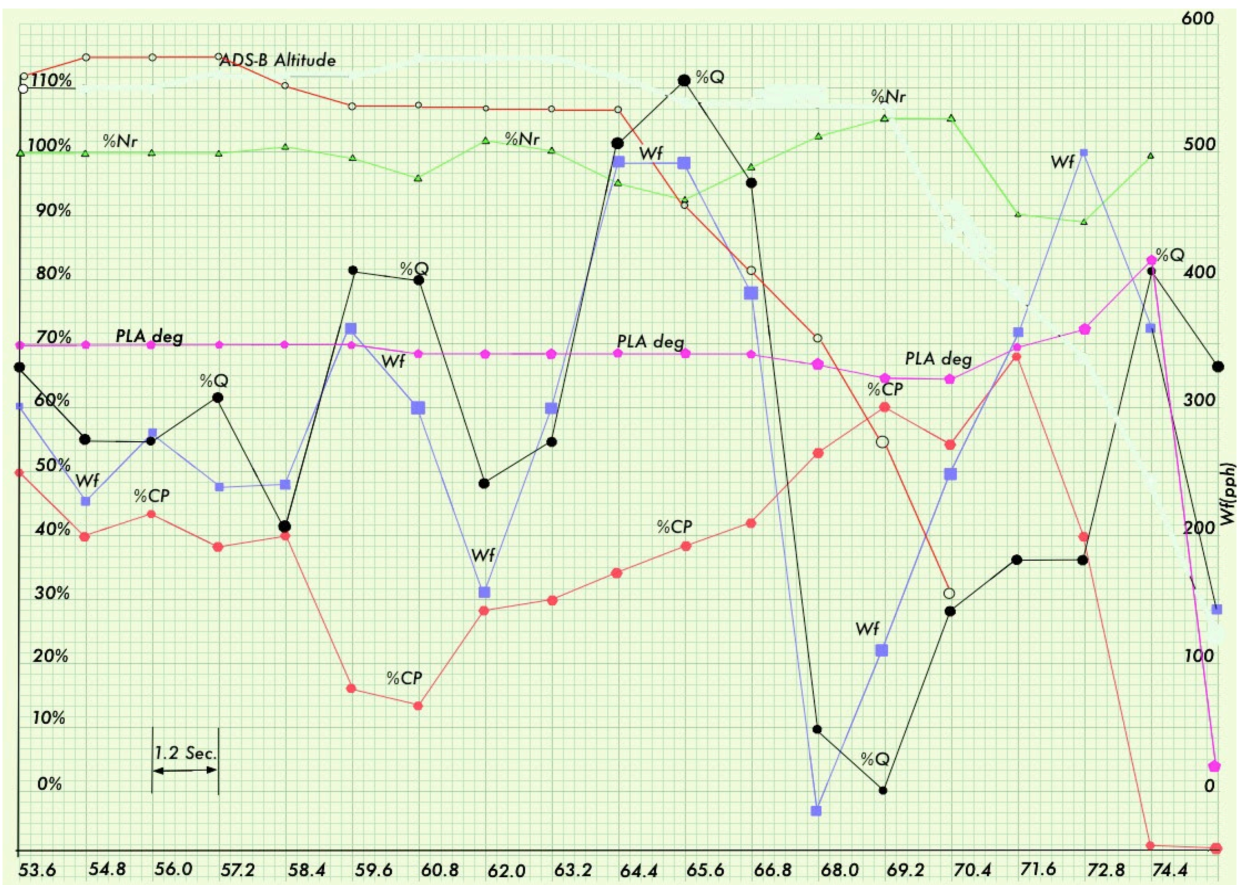

Figure 1.

16. The following Figure 2 is the direct download tabular data.

. IRDATA.eep - Incident Data Page 1 of 5

ECU Version: C-00257-5400 E844 Date Extracted: 09/12/17 17:12:40 UTC
Description: JG&ALK0565 - ACCIDENT INVESTAGATION

Record	Time Stamp HH:MM:SS.mmm	NgInRcrd %Ng	NrInRcrd %Nr	MGTInRcrd Deg F	QInRcrd %Q	NpInRcrd %Np	WfActInRcrd pph	NDOTFilt %Ng/Sec	P1InRcrd psia	Mode	CPInRcrd %CP	ESW Counts	ESW2 Counts	ESW3 Counts	ESW4 Counts	ESW5 Counts	ESW6 Counts	NDOTWRCd	PLAInRcrd Deg PLA
E 1	6572:00:53.640	96	100	1240	66	100	304	0.8	13.32	1	50	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	4	70
E 2	6572:00:54.840	94	100	1180	56	100	224	-5.6	13.29	1	40	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	4	70
E 3	6572:00:56.040	94	100	1180	56	100	268	0.4	13.30	1	44	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	4	70
E 4	6572:00:57.240	95	101	1220	62	101	240	-0.5	13.30	1	38	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	23	70
E 5	6572:00:58.440	90	99	1100	42	99	240	-0.5	13.29	1	40	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	23	70
E 6	6572:00:59.640	99	97	1360	82	97	364	6.9	13.33	1	16	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	4	70
E 7	6572:01:00.840	100	102	1360	80	102	300	-3.1	13.30	1	14	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	23	68
E 8	6572:01:02.040	93	100	1160	48	101	160	-9.2	13.33	1	28	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	23	68
E 9	6572:01:03.240	91	96	1140	54	95	296	3.7	13.43	1	30	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	7	68
E 10	6572:01:04.440	101	93	1420	104	93	488	9.1	13.36	1	34	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	7	68
E 11	6572:01:05.640	105	97	1520	112	97	488	0.7	13.44	1	38	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	6	68
E 12	6572:01:06.840	104	103	1500	96	103	388	-4.9	13.50	1	42	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	23	68
E 13	6572:01:08.040	84	105	1020	10	105	36	-22.5	13.70	1	54	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	1	66
E 14	6572:01:09.240	71	105	840	0	104	116	-1.3	13.75	1	60	0x0024	0x0000	0x0000	0x0000	0x2090	0x8080	24	64
E 15	6572:01:10.440	82	90	1260	28	90	248	10.6	13.78	1	54	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	7	64
E 16	6572:01:11.640	93	90	1360	36	91	360	9.2	13.87	1	68	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	7	68
E 17	6572:01:12.840	103	89	1500	34	89	500	4.8	13.95	1	40	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	24	72
E 18	6572:01:14.040	100	99	1360	82	100	364	1.6	14.04	1	2	0x0024	0x0000	0x0000	0x0000	0x0090	0x8080	4	82
E 19	00:00:00.000	86	0	1260	66	85	140	-11.8	14.19	1	0	0x0004	0x0000	0x0004	0x0000	0x0000	0x0000	0*	0
E 20	00:00:00.000	0	0	0	0	0	0	0.0	0.00	0*	0	0x0000	0x0000	0x0000	0x0000	0x0000	0x0000	0*	0
E 21	00:00:00.000	0	0	0	0	0	0	0.0	0.00	0*	0	0x0000	0x0000	0x0000	0x0000	0x0000	0x0000	0*	0

Figure 2.

17. Examination and analysis of both the graphical depiction and tabular data present an extremely radical departure from steady controlled flight. In fact, working in time reverse from the actual videos of the last several seconds of flight, the helicopter was likely out of control by time stamp "58" (Record 5). The ECU controls and meters the fuel into the engine. One of the major attributes of the FADEC system is to anticipate and "smooth" the fuel flow into the engine better than a human pilot could reasonably perform. Reviewing Figure 1, it clearly shows an erratic fuel control and delivery by going from 240 pph (pound per hour) to 364 pph in 1.2 seconds to 160 pph only 2.4 seconds later. The aircraft was

rotating out of control at this time. This erratic fuel flow results in erratic power output of the engine that results in erratic torque (%Q). The limited pedal travel experienced by the pilots can easily cause an aircraft to depart from controlled flight and results in the erratic engine behavior shown by the data.

18. At time "65.6" on the graphical depiction, Figure 1, the fuel flow plunges due to an Overspeed Valve closure. At Record line 14 and Engine Status Word 5 (ESW5) column, a hexadecimal number 0x2090 exists. The immediate Record line 13 above, the ESW5 is 0x0090. This transition means the Overspeed Solenoid Valve has closed, shutting off almost all fuel to the engine leaving minimum fuel (36 pph) to just enough to maintain ignition. Reviewing Figure 1, it depicts the imparted power (in this analysis can be derived into torque) %Q also plummets to 10%. This is not enough power to sustain flight.

19. The "pedal limiter" was found in the activated state meaning it limited the travel of the left pedal and thereby limited the authority range of the system.

20. As long as sufficient fuel was being metered into the engine to maintain altitude the rotating would be very disconcerting, but it would allow the crew some time to try to diagnose the problem with the limited pedal. That precious time was denied to the crew because at time "65.6" on the graphical depiction, Figure 2, the fuel flow plunges due to an Overspeed Valve closure. As soon as the fuel flow was interrupted, the torque goes to "0", helicopter continues to rotate and falls toward terrain uncontrollably. In just 10 seconds from the fuel being shut down to minimum fuel flow, the aircraft crashed.

21. The condition of the tail rotor solenoid confirms engagement at the time of the accident, which should not have been the case based upon the speeds the helicopter was traveling.

22. The solenoid remained activated when it should not have been, and witness marks on the housing confirm it was activated at the time of the crash.

23. Solenoids such as the one which controls the pedal limiter in the model 407 are prone to failure due to overheating or exposure to moisture.

V. CONCLUSIONS AND OPINIONS

24. When the pedal limiter activated improperly, the helicopter became uncontrollable and resulted in the engine reacting as shown in the data, discussed above.

25. The FADEC system that Bell Helicopter chose to control and manage the fuel delivery to the accident helicopter's engine further reacted in such a manner which resulted in fuel being taken away from the engine, furthering the sequence of events in the accident. The FADEC system and engine did not cause the accident.

My work is ongoing and opinions are subject to revision based on new information. Therefore, I reserve the right to supplement this report as new information is provided to, or obtained by, me.

John Bloomfield
February 1, 2022