LAX08PA259
GE Power Study
April 14, 2010

At the request of the NTSB, GE-Aviation prepared a power study[1] in order to quantify the amount of torque a hypothetical 'bad' engine could lose and still maintain HOGE capability for each of the three takeoffs from H44 with three weight scenarios. A secondary purpose of the study was to use the power check captured on the CVR during the first approach to H36 as a measure of the accuracy of the same three weight scenarios. The three weight scenarios were based on fuel, payload, and the possible empty weights noted below:

1) The 12,408 lbs empty weight that the pilots were using on 8/5/08 from June 2008 Chart C (based on Jan 08 chart B weight + 10 seats).
2) The 13,440 lbs empty weight calculated by Carson Helicopter Services Inc. in 2009.
3) The 13,845 lbs empty weight calculated by the NTSB in 2009, referenced in the Operations Group Chairman's Factual Report.[2]

According to the cockpit voice recorder (CVR) transcript,[3] the flight crew performed a power check at 17:42:30 pacific daylight time (PDT), just before landing at Helispot 36 (H36) for the first time on August 5, 2008.[4] According to the transcript, the copilot stated, "Power check - 32 degrees there's three knots showin' eighty - okay power's good."

The helicopter's altitude during the time of the power check was determined using information from the SkyConnect Tracker AFF system, which is an aircraft tracking system that transmits aircraft position, speed, and direction to select ground stations about every two minutes. The SkyConnect system recorded the helicopter's altitude of 2,037 mean sea level (MSL) on August 5, 2008 at 17:40:37 local, which is about 1 minute and 53 seconds prior to the power check and recorded the helicopter's altitude of 2,057 MSL at 17:42:47 local, which is about 17 seconds after the power check. Therefore, it is assumed that the power check was performed at an altitude of about 2,000 feet MSL. The statement of "three knots" refers to the airspeed during the power check. The statement of "showin' eighty" refers to engine torque, in this case 80% torque with both engines' torque values being matched. There was no readout of main rotor speed (N_R) by the copilot, but 103% N_R is appropriate for a power check, and the speed was confirmed by checking the CVR sound spectrum study,[5] which showed ~104% N_R around the time of the power check. The indicated torque of 80% was adjusted to 82% to account for the 3 knots of airspeed. (Reference S-61N RFM, Figure 3-1) At 103% $N_{R,}$ 82% torque corresponds to 1025 shaft horsepower (SHP) per engine, for a total of 2050 SHP. (Reference RFMS #7, Figure 7-4-13, Indicated Torque vs. SHP) At 2,000 feet and 32° C, engine power of

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1 GE prepared the attached Figures 1, 2, and 3. This description was prepared by the NTSB investigator-in-charge, James F. Struhsaker.

2 Reference *Operations Group Chairman's Factual Report* in the NTSB public docket for this accident.

3 Reference *Cockpit Voice/Flight Data Recorder Group Chairman's Factual Report* in the NTSB public docket for this accident.

4 The helicopter had just previously conducted a reconnaissance at H44 and had flown on to H36 to drop four of its nine helitack crew there. Reference *Operations Group Chairman's Factual Report*.

5 Reference *Sound Spectrum Study Cockpit Voice Recorder* and *Addendum Sound Spectrum Study Cockpit Voice Recorder* in the NTSB Public Docket for this accident.

2050 SHP equates to a HOGE weight of 18,350 pounds. (Reference RFMS #8, Figure 7, Power Required to HOGE)

The first data set, labeled “H36 Power Check” (on the left side Figure 1), compares the three selected helicopter gross weights with the actual twin-engine HOGE weight of 18,350 pounds derived from the power check captured on the CVR during the first approach to H36. The horizontal black line represents the HOGE weight based on this power check. The colored bars represent the estimated gross weight of the helicopter using each of the three empty weight scenarios – blue for 12,408 lbs, red for 13,440 lbs and yellow for 13,845 lbs. The white columns for this power check represent the twin-engine torque deficiencies associated with each calculated gross weight, i.e. a measure of the accuracy of each calculated gross weight. For example, if the helicopter’s empty weight was 12,408 pounds then both engines would have been at 74% torque rather than 82% (i.e. 8% lower). The calculations, logic and references for this power check can be found in Figure 2.

The second data set shown on the right side of Figure 1 comprises all three H44 takeoffs. It compares the three calculated gross weights for each takeoff with the twin-engine HOGE weight based on engine performance. The horizontal black lines represent this HOGE weight based on the CVR sound spectrum data, which showed both engines operating steady at their topping speeds and powers; credit was given for positive engine torque margins (above min spec) of 1.5% (Number 1 engine) and 4.5% (Number 2 engine) as determined from the topping check conducted on August 4, 2008. The colored bars again represent the estimated gross weight of the helicopter using each of the three empty weight scenarios. The white columns for these three takeoffs represent the engine torque split for a hypothetical case where one 'good' engine is running at its topping speed and topping power, but the other engine is 'bad' and running at its topping speed but not producing topping power. For this hypothetical case, the white columns represent the single-engine delta torques, 'good' engine versus 'bad' engine, associated with each calculated gross weight, i.e. a measure of the cockpit gage torque needle split that would have been observed if one engine had been 'bad'.[6] For example, for the first takeoff from H44 at the blue weight, the ‘bad’ engine could produce 25% less torque than the good engine, and the helicopter would still be capable of HOGE. This would be displayed to the pilots as a torque needle split of 25%. The calculations, logic and references for these 3 H44 takeoffs can be found in Figure 3.

[6] For another hypothetical case where both engines are equally 'bad' (neither running at topping power), these white torque columns would be equally split between the two 'bad' engines, such that the twin-engine torque deficiency for each engine would be half of the total column torque shown on the chart.

Figure 1 - Carson S-61N N612AZ - Comparison of HOGE Powers and Weights

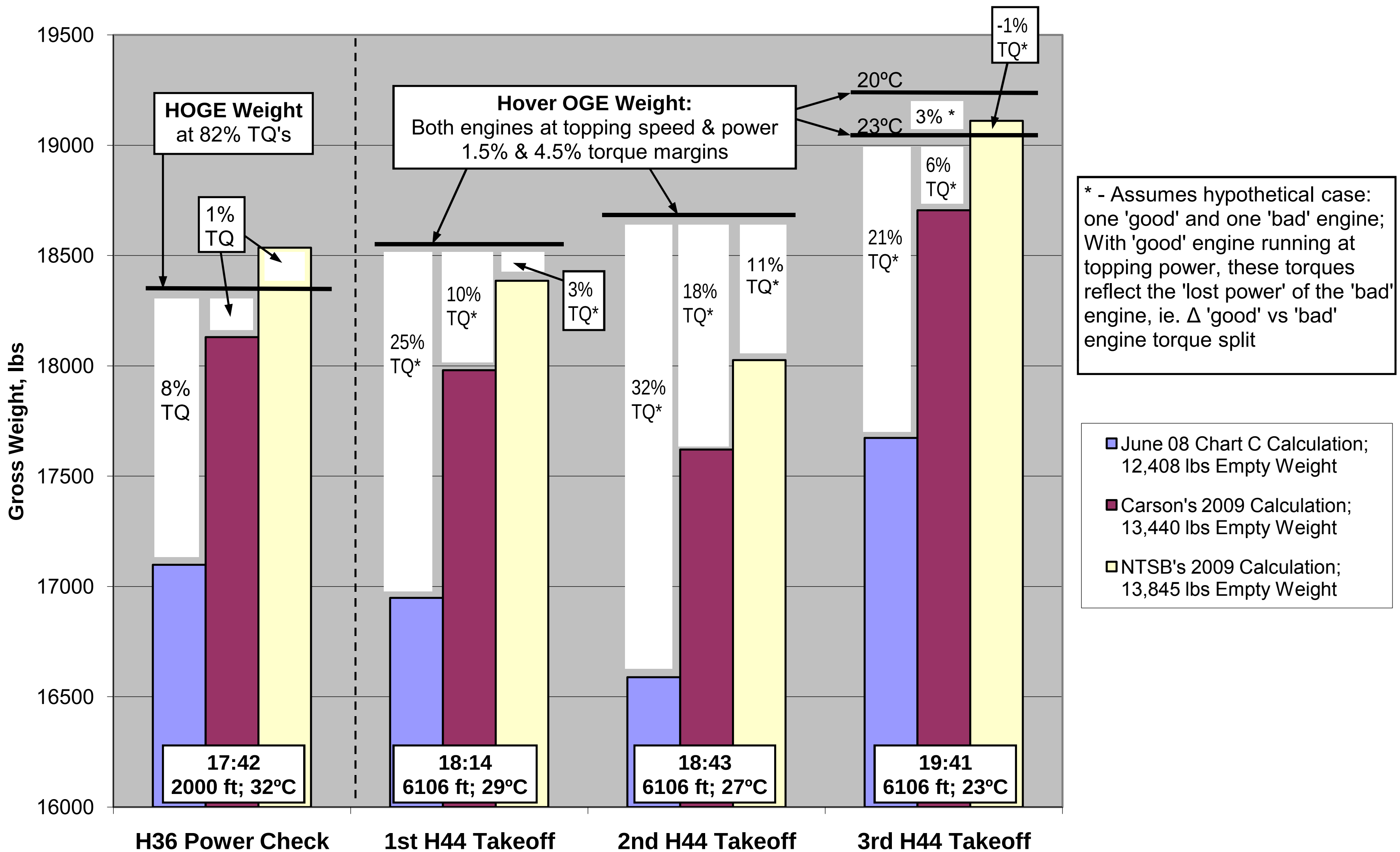

Figure 2 - Carson S-61N Accident: H36 Power Check on CVR

N612AZ; 8/5/08	Power Check on CVR	References/Comments
Time:	17:42	CVR sound spectrum; 104% rotor speed
Pressure Altitude:	2,000 ft	SkyConnect data
OAT:	32ºC	"32 degrees" on CVR transcript
Engine Power Available:		
Engine Torques (assumed matched):	80%	"showin 80" on CVR transcript
Estimated Torques for HOGE:	82%	corr for "3 knots" airspeed on CVR; S-61N RFM, Fig 3-1
Power per Engine:	1025 SHP	RFMS #7 Torque vs SHP at 103% NF
Total Engine Power, SHP:	2050 SHP	Power per engine x 2
Twin-Engine HOGE Weight:	18,350 lbs	Carson RFMS #8, composite blades, 103% Nr
Carson/USFS Documented Weights:		
W1) Flight Crew (3 pilots):	650 lbs	Ref 1, page 27, Figure 8 & Page 29
W2) Payload (Manifest, PAX + Cargo):	2,250 lbs	9 Helitac crew + tools, ref. USFS email 9/22/09
W3) Estimated Fuel Load:	1,790 lbs	Est burn rate of 17 ppm in flight, 5 ppm on ground
1st Scenario: Assumes Empty Weight per June 08 Chart C (Pilot's Load Calcs):		
1) Empty Weight:	12,408 lbs	Ref 1, pages 25, 36 & Fig 14
2) Estimated Gross Weight:	17,098 lbs	Empty Weight + W1 + W2 + W3
3) Power Required to Hover OGE:	1860 SHP	Carson RFMS #8, composite blades, 103% Nr
4) Power per Engine:	930 SHP	3) divided by 2
5) Torque per Engine:	74%	RFMS #7 Torque vs SHP at 103% NF
6) Delta Torque:	**8%**	
2nd Scenario: Assumes Empty Weight per Carson's 2009 Calculations:		
1) Empty Weight:	13,440 lbs	Ref. NTSB Progress Meeting, 7/30/09
2) Estimated Gross Weight:	18,130 lbs	Empty Weight + W1 + W2 + W3
3) Power Required to Hover OGE:	2,020 SHP	Carson RFMS #8, composite blades, 103% Nr
4) Power per Engine:	1,010 SHP	3) divided by 2
5) Torque per Engine:	81%	RFMS #7 Torque vs SHP at 103% NF
6) Delta Torque:	**1%**	
3rd Scenario: Assumes Empty Weight per NTSB's 2009 Calculations:		
1) Empty Weight:	13,845 lbs	Ref 1, Pages 38, 39, 40; Figures 15 & 17
2) Estimated Gross Weight:	18,535 lbs	Empty Weight + W1 + W2 + W3
3) Power Required to Hover OGE:	2,070 SHP	Carson RFMS #8, composite blades, 103% Nr
4) Power per Engine:	1,035 SHP	3) divided by 2
5) Torque per Engine:	83%	RFMS #7 Torque vs SHP at 103% NF
6) Delta Torque:	**-1%**	

Figure 3 - Carson S-61N Accident: Comparison of H44 Takeoff Powers

N612AZ; 8/5/08	H44 1st Takeoff	H44 2nd Takeoff	H44 3rd Takeoff	H44 3rd Takeoff	References / Comments
Time:	18:14	18:43	19:41	19:41	USFS SkyConnect Data
Pressure Altitude:	6,106 ft	6,106 ft	6,106 ft	6,106 ft	Ref 1, Figure 20
OAT:	29ºC	27ºC	23ºC	20ºC (Carson)	Ref 1, Figure 20
Engine Power Available:					
E1) Ng (GG Speed), #1 / #2:	102.0 / 101.4%	101.8 / 101.4%	102.1 / 101.5%	102.1 / 101.5%	Ref 2, Charts 5, 7 & 11; both at topping speed
E2) SHP (based on Ng), #1 / #2:	1,115 / 1,115	1,125 / 1,125	1,145 / 1,155	1,155 / 1,170	Ref 3 and Ref 4, Fig 3b, Table 2; topping powers
E3) Total Engine Power, SHP:	2,230	2,250	2,300	2,325	SHP#1 + SHP#2 = Total Power
E4) Twin-Engine HOGE Weight:	18,550 lbs	18,700 lbs	19,050 lbs	19,250 lbs	Carson RFMS #8, composite blades, 103% Nr
Carson/USFS Documented Weights:					
W1) Flight Crew (3 pilots):	650 lbs	650 lbs	650 lbs	650 lbs	Ref 1, Page 27, Figure 8 & Page 29
W2) Payload (Manifest, PAX + Cargo):	2,430 lbs	2,450 lbs	2,355 lbs	2,355 lbs	Ref 1, Page 27, Figure 7
W3) Estimated Fuel Load:	1,460 lbs	1,080 lbs	2,260 lbs	2,260 lbs	Est: burn rate of 17 ppm inflight, 5 ppm onground
1st Scenario: Assumes Empty Weight per June 08 Chart C (Pilot's Load Calcs) and One Low Power ('Bad') Engine:					
1) Empty Weight:	12,408 lbs	12,408 lbs	12,408 lbs	12,408 lbs	Ref 1, Pages 25, 36 & Fig 14
2) Estimated Gross Weight:	16,948 lbs	16,588 lbs	17,673 lbs	17,673 lbs	Empty Weight + W1 + W2 + W3
3) Power Required to Hover OGE:	1,920	1,860	2,040	2,030	Carson RFMS #8, composite blades, 103% Nr
4) 'Good' Engine at Topping Power:	1,115	1,125	1,150	1,160	Average power of #1 & #2 engines from E2) above
5) 'Bad' Engine at Lower Power:	805	735	890	870	3) minus 4); 4) + 5) = 3) total power for HOGE
6) 'Good' vs 'Bad' Engine Torques:	92% vs 67%	93% vs 61%	95% vs 74%	96% vs 72%	Carson RFMS #7, TQ vs SHP at 100% Nf
7) Delta Torque:	**25%**	**32%**	**21%**	**24%**	Large torque splits
2nd Scenario: Assumes Empty Weight per Carson's 2009 Calculations and One Low Power ('Bad') Engine:					
1) Empty Weight:	13,440 lbs	13,440 lbs	13,440 lbs	13,440 lbs	Ref. NTSB Progress Meeting, 7/30/09
2) Estimated Gross Weight:	17,980 lbs	17,620 lbs	18,705 lbs	18,705 lbs	Empty Weight + W1 + W2 + W3
3) Power Required to Hover OGE:	2,115	2,040	2,230	2,220	Carson RFMS #8, composite blades, 103% Nr
4) 'Good' Engine at Topping Power:	1,115	1,125	1,150	1,160	Average power of #1 & #2 engines from E2) above
5) 'Bad' Engine at Lower Power:	1000	915	1,080	1,060	3) minus 4); 4) + 5) = 3) total power for HOGE
6) 'Good' vs 'Bad' Engine Torques:	92% vs 82%	93% vs 75%	95% vs 89%	96% vs 87%	Carson RFMS #7, TQ vs SHP at 100% Nf
7) Delta Torque:	**10%**	**18%**	**6%**	**9%**	Noticeable torque splits
3rd Scenario: Assumes Empty Weight per NTSB's 2009 Calculations and One Low Power ('Bad') Engine:					
1) Empty Weight:	13, 845 lbs	13,845 lbs	13,845 lbs	13,845 lbs	Ref 1, Pages 38, 39, 40; Figures 15 & 17
2) Estimated Gross Weight:	18,385 lbs	18,025 lbs	19,110 lbs	19,110 lbs	Empty Weight + W1 + W2 + W3
3) Power Required to Hover OGE:	2,190	2,120	2,310	2,300	Carson RFMS #8, composite blades, 103% Nr
4) 'Good' Engine at Topping Power:	1,115	1,125	1,150	1,160	Average power of #1 & #2 engines from E2) above
5) 'Bad' Engine at Lower Power:	1,075	995	1,160	1,140	3) minus 4); 4) + 5) = 3) total power for HOGE
6) 'Good' vs 'Bad' Engine Torques:	92% vs 89%	93% vs 82%	95% vs 96%	96% vs 94%	Carson RFMS #7, TQ vs SHP at 100% Nf
7) Delta Torque:	**3%**	**11%**	**-1%**	**2%**	Small torque splits

Ref 1: NTSB Operations Factual Report by Zoe Keliher
Ref 2: NTSB CVR Sound Spectrum Study by Jim Cash; shows both engines at topping speed
Ref 3: GE CT58-140 Cycle Deck (#75029), SHP vs Ng, Estimated Installed Performance:
> with ~3% installation losses; +1.5% & + 4.5% torque margin engines (Ref 1, page 23)
> 0 knots airspeed; no horsepower or bleed extraction
Ref 4: NTSB Hover Study by John O'Callaghan