TO: Mr. Jim Struhsaker, Mr. John O'Callaghan, NTSB investigation Team LAX08PA259

FROM: Carson Helicopters Party Coordinator, Andy Mills

DATE: 3 November 2010

RE: Response to Hover Study Addendum #2 (dated 28 October 2010)

Carson Helicopters received the Addendum #2 to the Hover Study on 1 November, 2010. We appreciate the opportunity to share our response with the NTSB Team, even with a very short time frame. This addendum contains some conclusions that are based on simulations of the accident takeoff performed by Sikorsky Aircraft Company (SAC) using a GenHel flight simulation program. The data utilized to construct these simulations is fatally flawed and is not useable. The conclusions reached using the GenHel program are factually incorrect and should not be included in the Hover Study.

1. ***The SAC GenHel Program Simulator is utilizing configuration data that is not applicable to this accident aircraft***

The Addendum details results from the SAC GenHel program that utilize data from a flight test done in 2008 for the US Navy with an S61A/NVH-3A helicopter equipped with Carson Composite Main Rotor Blades (CMRB). This is consistently referred to as the SAC/USN data, and is the basis for the GenHel simulation results in the Sikorsky Party Submission and several of the plots in the Addendum #2. This data suggests that the accident helicopter would not have sufficient lift to clear the trees at the site.

The SAC/USN data is based on an aircraft and blade configuration that is significantly different from the accident aircraft or any other Carson CMRB-equipped aircraft. These differences are omitted by SAC and not accounted for in their modeling. Carson delineated those differences in the report referenced in this Addendum from H.C. Curtiss dated 19 October, 2010.

*a.* ***The Composite Blades on the USN aircraft were heavily modified one-off test blades***

The SAC.USN data is based on an NVH-3A short body helicopter equipped with naval sponsons, a small tail rotor set, and a MODIFIED set of Carson Composite Main Rotor Blades (CMRB). In the course of conducting the USN testing, Sikorsky demanded and Carson supplied a set of Carson CMRB blades that were heavily modified with trim tabs added on the outboard portion of the blades, even though the CMRB design does not incorporate trim tabs in any other application, then or now. The trim tabs dramatically increased the vibration level of the blades, and reduced the lift capability of the CMRB. This was a design modification that was requested, tested and eventually rejected by Sikorsky due to the reduced lift, vibration and poor aircraft performance. The trim tabs will have a significant negative effect on any performance modeling, and this is not accounted for in the SAC GenHel program.

Secondarily, during the USN testing one of the blades was fitted with strain gauge wires above and below the entire length of the blade during flight. This dramatically changed the airflow over the blade and more than doubled the vibration level on the blade, as well as negatively affecting flight performance. In other words, the set of CMRB blades on the 3A in the USN testing was **not** a set of Carson/Ducommin blades as FAA certified, and in no way reflects any other set of Carson CMRB. The flight characteristics of this set of CMRB equipped with large trim tabs and strain gauge wires cannot be compared to any other data set of standard Carson CMRB, and certainly not to the accident aircraft. The blades as specified by Sikorsky and flown on the USN S61A aircraft with large trim tabs do not perform up to the same level as the Carson FAA certified CMRB, and there is no correction for this in the simulated data.

*b.* ***The NVH-3A Aircraft Configuration was significantly different***

The NVH-3A used in the SAC/USN testing was equipped with a smaller tail rotor set than those used by commercial S61N aircraft. The smaller tail rotor set requires significantly more horsepower from the engines in order to counteract torque, and typically rob a minimum of 200 lbs. of lift from the main rotor blade disc, and become even more inefficient at high altitudes (*see the Hover Study submitted by CHI by HC Curtiss, Oct 2010*). All of Carson's fleet aircraft and N173U and the accident aircraft were/are equipped with the larger tail rotor set, which is considerably more efficient. There is no mention by SAC of this fact, and no correction in the simulated data for it.

The NVH-3A in the USN study had naval sponsons attached. SAC state they assigned an additional negative factor for the aerodynamic drag of the fixed gear used in the accident aircraft. However, there is no mention of a ***positive*** correction to account for the removal of the vertical lift drag imparted by the much greater surface area of the naval sponsons, which the accident aircraft did not have attached.

Carson is not surprised that the performance of the GenHel USN simulation is less than the FAA certified charts (RFMS 8) or the October 2010 hover test, or the Whipple test. The data used in the SAC/USN simulation is for a completely differently equipped and inferior performing NVH-3A aircraft, and the GenHel program did not take these factors into account. The SAC/USN simulations are not useful for any comparison in this accident and should be removed completely.

2. ***The Vertical Drag of the Fire Tank is incorrectly calculated***

The Addendum notes in multiple places that SAC calculates that there is 103 lb. drag from the FireKing Tank. As noted in our previously submitted information to the NTSB on 27 May 2010 and 6 July 2010, this figure was calculated by SAC using incorrect data and is not remotely accurate.

a) The SAC downwash study shows the tank location on the fuselage from station 186 to station 290. This is incorrect. The tank location on the fuselage is from station 213 to station 320, or 30 inches more to the center of the fuselage and the rotor disc than the location in the study. This will necessarily have a very important effect on the strip loading coefficient, and will undoubtedly reduce any downwash loading in the calculation.
b) The Sikorsky drag coefficient utilized from the standard Sikorsky strip diagram is for surfaces at the top deck level of the aircraft directly beneath the rotor. The fire tank is over 10 feet below the rotor, which will significantly reduce the drag coefficient. SAC does not specify this height difference in the calculation.
c) The tank surface is not flat as was assumed by the SAC study. All outside and inside edges of the tank have radiused and rounded smooth edges with surfaces that will spill air and affect perceived downwash quite differently than a solid flat surface.

It is factually wrong to continue to propagate a 103 lb. vertical drag through the NTSB data based on calculations proven to be erroneous that dramatically increase this number. The error in the location of the tank alone will result in an artificially high drag. Carson has supplied empirical flight results to the NTSB that show there is no appreciable lift difference with the fire tank installed on the aircraft.

The serious errors in calculation noted above for the USN GenHel data and vertical drag data are not Carson opinion, they are fact. Any reference to these incorrectly calculated data should be removed from a fact-based Hover Study.

***3. The SAC/GenHel simulations assume HOGE performance figures for the aircraft, but the report and simulations show the aircraft never leaves HIGE conditions***

The report narrative and the plots shown in 9c and 9d for the USN simulation show the aircraft hovering at 20-25 ft., and then accelerating forward in a linear fashion toward the trees. The plots show the aircraft rotor hub never got higher than approximately 50 ft. above ground level and that the rotor struck the tree at 49 feet above ground level. Frankly, it strains common sense that two highly experienced mountain pilots would pick the aircraft up into a hover less than half the height of the trees directly in front of them and then fly the aircraft straight into the trees. If this was the case, there was ample open space in front of the trees to set the aircraft down if they did not have power to clear the trees. The CVR pilot conversations do not support this scenario. However, according to the FAA Rotorcraft Handbook page 8-3, the definition of HOGE (Hovering Out of Ground Effect) is greater than one rotor diameter; on this aircraft, that is 62 feet. On page 8 of the Hover Study Addendum SAC state they conduct out-of-ground effect testing at 100 feet.

By these standards, the helicopter was never in Hover-Out-of-Ground Effect conditions (HOGE). Why is the data throughout the Hover Study Addendum and the GenHel simulation referring to HOGE performance weights? It would be far more correct to utilize Hover-In-Ground-Effect (HIGE) performance weights at these hover heights. According to the IGE/OGE Ground Effect correction chart supplied by Sikorsky to the NTSB in the public docket (as well as the Carson RFMS #6 FAA HIGE load charts), at 20 ft. wheel height the HIGE performance weight shows aircraft performance of over 20,500 lbs. at this density altitude. This is more than 1,500 lbs. of lift performance *greater* than what the NTSB believes the aircraft weighed. The aircraft should have had ample performance to clear the trees along the flight path as it transitioned from HIGE to HOGE. And in fact, figure 9a and 9b of the addendum, which graph the RFMS #8 FAA-certified performance in the GenHel simulation, show this to be exactly true even with HOGE weights; if the aircraft had two engines operating at full power. In order to understand the performance that was truly available to the aircraft at 50 feet or less AGL as presented in the Study, the HIGE performance figures for the aircraft should rightfully be included in this hover study if that was the actual field flight condition of the aircraft. Based on data presented in the report, the aircraft never left HIGE conditions.

***4. The October 2010 CHI/SAC Hover test***

The Hover Addendum report does a good job of pointing out the differences in the way CHI calculates the test data and the way SAC calculates the test data from the hover test conducted by CHI with SAC participation in October 2010. However, a few important points need to be emphasized in the interests of fairness.

CHI utilized the data in calculating performance in exactly the accepted industry practice manner and as authorized and accepted by the FAA for hover performance testing (as noted in the Addendum). The data from this documented hover test validate the FAA authorized RFMS # 6 and #8 CHI CMRB flight charts for the aircraft, and are in line with every other practical and empirical flight test conducted with the CMRB since 2006, both by Carson in several documented tests and the British Royal Navy test branch, QinetiQ. The British Navy conducted 265 hours of flight testing at high altitude in Gunnison, Colorado with the Carson CMRB, and verified the Carson performance charts prior to deploying these blades on commando force helicopters in Afghanistan (*see attached Vertiflight document).*

In order to arrive at the lower performance numbers that SAC utilized in their report, the SAC method used a scheme that more heavily weighted hover data taken in other cardinal points, including directly downwind. That is the only way SAC can make the hover performance numbers remotely resemble the inferior USN data they cite from 2008, which we have already shown to be fatally flawed for this comparison. It must be emphasized that helicopters are not FAA test-certified for hover performance in this fashion, and this method is completely arbitrary by SAC. In fact, when SAC certified the flight performance for the commercial S92 helicopter with the FAA, they did not utilize a weighting scheme based on multiple cardinal point hover tests. They followed the same industry practice that CHI did in this test.

The reality is that the only performance data set for the CMRB that does not match with all other available empirical data is the SAC weighted, manipulated data and the faulty USN data. All other empirical data support the FAA CMRB flight charts and as the NTSB's own Figure 9 RFMS #8 simulation demonstrates, the aircraft should have had more than enough power to clear the trees with any responsible set of data for this aircraft. The data that are factually erroneous or artificially weighted and averaged should be removed from the report.

5. ***General Notes***

At the bottom of page 12, the report states "The Whipple flight test also documented that when the collective was pulled to its upper limit, the rotor drooped to and stabilized at about 94% Nr, similar to the Nr behavior for the accident takeoff shown in figure 3. "

This is a mischaracterization. In repeated testing in the Whipple report, the aircraft completely stabilized at or above 94% in every flight instance of maximum collective and would not droop any lower without removing power from an engine. In other words, by the time the Nr arrived at 94% in the Whipple tests, Nr loss had already slowed and stopped descending and was essentially flat line from that point onward. The original noise plots from the CVR supplied by the NTSB showed rotor Nr on the accident aircraft drooping in a continuous, steep fashion below 91% when the recording ends. Even on the Figure 3 chart in this report (which is different from the original NTSB CVR chart) the rotor rpm has drooped below 94% and is steadily trending downward when the recording ends. This is not similar behavior to the aircraft response in the Whipple test at all, and it is a mis-characterization to state that it is similar.

This Hover Addendum #2 was constructed with information supplied to the NTSB that is factually erroneous. The result is prejudiced information that is not useful and is not accurate. Note that these errors are not Carson supposition, they are errors in fact. It also does not include the performance represented by in-ground-effect flight conditions, which according to this report was the actual flight attitude of the aircraft at the time. Representing the HIGE figures will aid in showing what the aircraft should actually have been capable of at this density altitude. The report should not be added to the NTSB docket until these items are addressed. If the NTSB chooses not to make changes, we would request that our response be added to this Hover Study.


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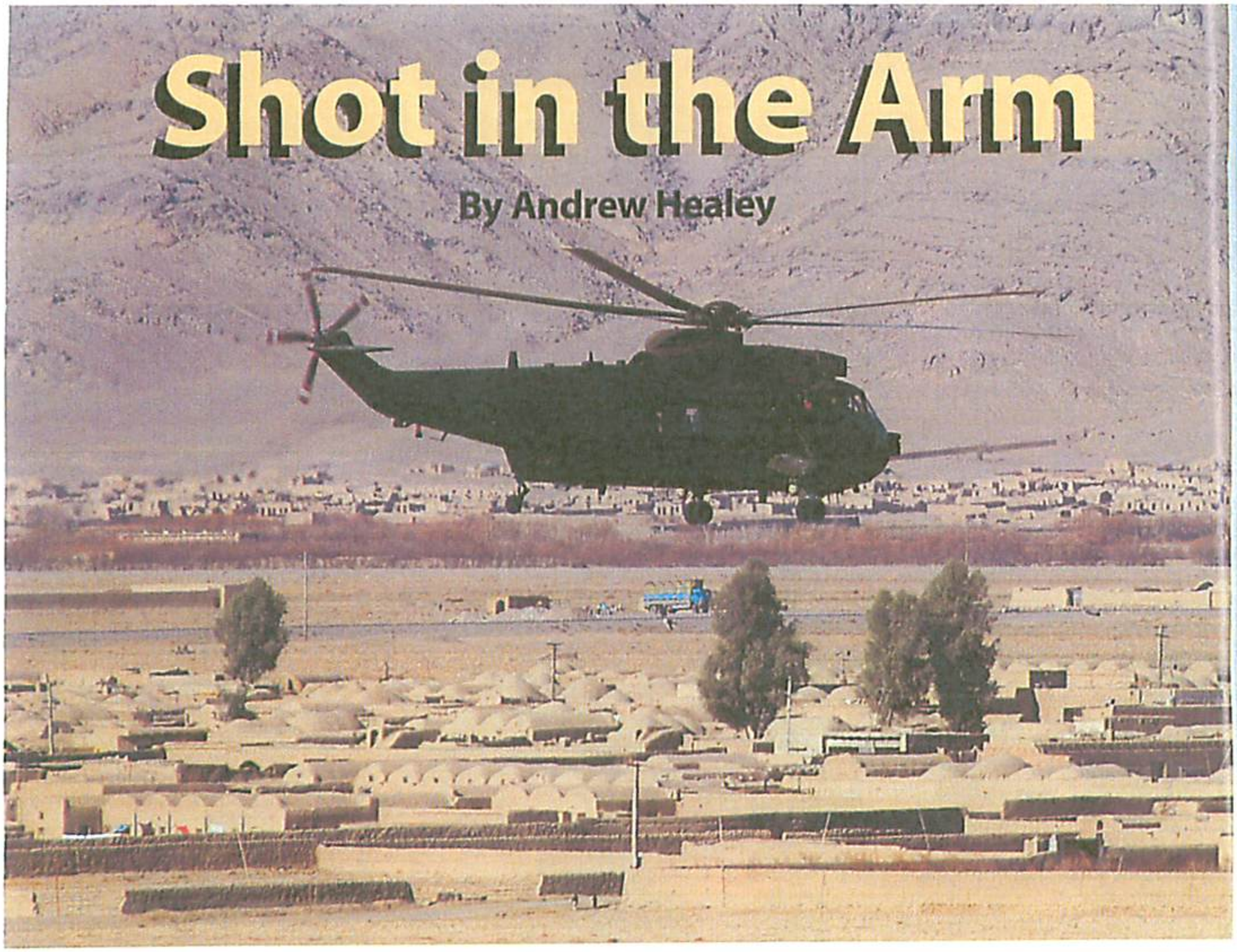


# Shot in the Arm

**By Andrew Healey**

***Aging British transport helicopters were ill-suited to the rigors of the Afghan climate. Navy Sea Kings were first to get a performance boost: now Air Force Pumas are benefiting from similar care and attention.***

Although UK forces have been involved in operations in Afghanistan since 2001, their medium-lift helicopters have only just started to deliver the performance that the high-and-hot environment demands. Troop transports such as the Sea King, in service with the Royal Navy since 1970, and the equally elderly Royal Air Force Puma, have been particularly affected, and the light "battlefield taxi" Lynx too; in fact the ubiquitous Chinook is the only utility rotorcraft in the British inventory able to cope with both the Afghani climate and increased op-tempo.

And man, are they flying hard. Since deploying, the annual usage rate has jumped by 50%, from 12,000 hours per year to around 18,000. In an effort to relieve some of the pressure, six RAF Merlins are being deployed this year.

So, in what some term a typical British fudge (an opportunity to order replacements was missed a decade ago) the Puma fleet, only recently released from operations in Iraq, has commenced an upgrade program to install the Turbomeca Makila engines from its civilian offshore cousin. With this and other improvements, the 28 aircraft will get a 30% performance boost and increased range. A glass cockpit is also on the menu.

This $382 million life-extension program – now dubbed Puma Mk2 – is being carried out at Eurocopter facilities in France and Romania.

However another program, to add performance to the Navy Sea King HC4, was developed in southern England, tested in Colorado and is already delivering in theater. Carson replacement main rotor blades – adapted to allow folding while embarked – together with a five-bladed composite tail rotor previously fitted to some export variants, have delivered a massive increase in payload of 2,000 pounds and a full 35 knots of airspeed.

The project was put together to satisfy an Urgent Operational Requirement to deploy the Sea Kings to the Afghan theater, under the control of the Joint Helicopter Command. Interest has since been shown by other non-JHC Sea King users, including RAF/RN Search & Rescue and the RN Airborne Surveillance and Control (AsaC) Mark 7s.

## Chinooks Hold the Fort

Navy Commander Mark (Mario) Carretta leads the Air Warfare Centre's Rotary Wing Test & Evaluation Squadron at Boscombe Down, home to the famous Empire Test Pilots' School. Nowadays the airfield and its facilities are operated on behalf of the UK Ministry of Defence (MoD) by QinetiQ, the defense and technology firm spun off from government research agency DERA: QinetiQ employees now outnumber the military at Boscombe by a factor of 10:1.

Carretta sets the scene. "In 2006 the Chinooks were being heavily worked – both aircraft and crews. Other assets were committed elsewhere or weren't really up to the task. Pumas, Sea Kings, even Merlins, it was thought, would need performance enhancements and at the time they formed the backbone of the UK effort in Iraq."

"Two Naval Air Squadrons of Sea Kings, 845 & 846, were committed to Iraq at the time, but the MoD started looking at ways of helping them cope with the hot-and-high environment of Afghanistan. US logging company Carson Helicopters Inc. (CHI) had been known to us for ages – certainly since I was last at Boscombe in 1998. Frank's outfit claimed his rotor blades would give us 2000 lb of extra lift (equivalent to eight troops) and at least 15 kt of extra speed."

In late 2006, as part of a feasibility study looking at extending the life of the Sea King, QinetiQ was tasked to fit a set of Carson's blades to one of three Sea Kings at Boscombe for 20 hours of evaluation test flights. After the blades had been adapted to accommodate the folding head, in-flight testing suggested he was right about the payload and an increase in speed also "looked likely."

Based on these findings, QinetiQ suggested to the MoD that Sea kings fitted with the new blades could offer a solution to the lift problem in Afghanistan. The MoD concluded that the matter was worth pursuing and issued an Urgent Operational Requirement notice. In early 2007, the Sea King test bed was subjected to a highly technical instrumentation process – one of the most complicated ever undertaken by QinetiQ – to investigate the stresses on the new blade and establish safe operating limits for the other improvements.

These included a five-bladed composite tail rotor from AgustaWestland. Over its years in service, the Sea King's original five-bladed metal rotor had been replaced by a six-bladed component. Now by reverting to five, originally manufactured for the export version, they had the opportunity to further increase tail rotor authority and reduce the power requirement. It was calculated that this system alone would deliver a 200 to 400 pound increase in lift to the main rotor. The composite blades were still available from Westland but the hub, a long-lead item, had to be re-manufactured in the US. Gearing, by the way, was not affected and in fact a prime consideration was to minimize downstream disruption.

"In May 2007 flight trials commenced and it was at this point that I became involved," Carretta continues. "I was then commanding 846 NAS, one of the units earmarked for Afghanistan. So because of my test-flying background I was sent to participate in the hot-and-high portion of the trials to take place that summer in the mountains of Colorado, with the task of finding out how the modified aircraft performed in hot and high conditions."

These commenced in July. A measure of how smoothly the new components bedded in and the efficiency of the test program, is that within two months, in September 2007, the squadron was flying the first two modified airframes in the Troodos mountains of Cyprus – during work up training prior to deployment. Carretta and his crews had immediate cause for optimism; veterans of Operation Telic in Iraq could recall that, when working up their old Sea King Mk.4s in the same area, they couldn't even get to the mountain tops at 6,500 feet.

"We were operational by the end of October."

## Huge Speed Increase

Once the squadron was in theatre, the true nature of the upgrade's effectiveness became apparent. Kandahar is about 3,500 feet above mean sea level and a typical summer temperature is around 35°C (95°F), so the British crews were flying at density altitudes of around 7,700 feet. They soon confirmed the payload improvement but were astounded by the speed increase. "We were expecting a fifteen knot premium but found that, in those conditions, the cruise had increased from 86 knots to a full 120 – nearly 35 knots more."

New engines were also fitted. When the RN originally deployed to Iraq in 2003, they found that the Rolls-Royce Gnome 1400-1T engines fitted to the Navy Sea Kings of their Egyptian comrades offered a more accurate way of measuring power output – a vital parameter in the desert heat. While the British -1 Gnomes measure power turbine inlet temperature, the -1T calculates a more accurate relationship with the critical turbine entry temperature. Explains Carretta, "with the old engines you had to incorporate a safety margin to take this into account. Now when you're at max contingency, you know that you're getting the absolute most out of your engines."

The two lead aircraft were deployed with the squadron in October with a limited clearance to their speed, all-up-weight and so on. By Christmas the whole squadron detachment was operational. They found that, instead of a crew and ten minutes fuel, they could now carry a "useful load" of Royal Marines or troops over a useful distance.

They also scored a tiny but satisfying point. "It was a great moment," Carretta recalls, "when one day a Lynx asked me to slow down."

The other Sea King variant now operating in Afghanistan, the ASaC Mk.7, is deployed in the overland search role, having completed its trials with the new rotor systems.

Looking back, Carretta says that fitting the blades was the easy bit: the main challenge was the complexity of the instrumentation carried out at Boscombe Down. As well as feeding the telemetry from affected components to the flight test engineers (FTEs) in the rear cabin, many of the performance parameters were duplicated in the cockpit. Several extra screens were installed to enable the pilots to ease the FTEs workload. "The section here did a cracking job."

## Better Late Than Never

Carretta's next visit to Colorado is to flight test a "bifilar," a star-shaped self-tuning frequency absorber fitted to the rotor head that self-tunes out a great deal of airframe vibration – to the extent that it can even lead to significant life extensions to airframe and components. "I flew in the back of a Carson S-61 and the effect is impressive. It is next to impossible to write legibly in the back of a standard Sea King: with a bifilar fitted, it's like flying in an airliner. Absolutely amazing."

The bifilar is nothing new to Sikorsky, or indeed the US Navy who have flown with it for many years. "Frank Carson recommended we fit a bifilar at the start of our relationship, but we didn't have the time to test that as well. There is a weight penalty, but it is more than compensated for by the advantages. It will be especially useful in protecting the avionics in the Mk.7, and in reducing crew fatigue: If the evaluation goes well then I think that, eventually, we might see it across the whole Sea King fleet."

## Out of Life, Power and Spares

The Anglo-French Puma is the mainstay of the RAF's medium-lift fleet and its unsuitability for the Afghan theatre is not only keenly felt, but puts a barely tolerable strain on the Chinook squadrons. Without the prospect of a replacement, something had to be done to maintain this capability in service beyond 2012.

Rich Pillans, a Puma Mk.2 Test Pilot within QinetiQ, explains how the Puma Life Extension Plan was hatched. "Its 1970s-vintage Turmo gas turbines were running out of life, power and spare parts, but it was clear it would be a relatively simple process to replace them with the Makila 1A1 from the AS322L Super Puma." With the engine would come a digital anticipator, an engine control aid not only to gladden the heart of every old Puma pilot in the RAF, but an absolute must-have for the Afghan theater."

An anticipator helps the pilot deal with unexpected engine power requirements during the approach to a landing site. Says Pillans, "In any other helicopter, if you need a prompt increase in power and have to adjust, then the aircraft will look after you. Not so the Puma Mk1: if you pull the collective up too sharply, the rotor speed will droop out of range before the engines can respond, and you run the risk of a heavy landing. Crews have been living with this in various environments for decades. In Afghanistan though, the workload required would just be too high."

The Makilas will enable its full load of troops to be carried at altitude. It will also get a new cockpit and digital automatic flight control system: Eurocopter having been briefed to source, where possible, avionics elements from other Puma variants that could be fitted without too many issues.

In early 2010, the first RAF airframe to be upgraded to Mark 2 status had been stripped back at the Eurocopter facility near Marseilles, France, and new wiring looms fitted. From April 2011, a combined flight test team will plan and manage the flight test program in France. In October that year, the whole activity, including the first three or four aircraft, will transfer to England for further testing and to fit the UK-secret modifications.

As the test flying progresses during 2012, the RAF will want to amend its operations and tactics manuals to take into account the Mk2's new capabilities. New handling and maintenance equipment may be required. Final completion and acceptance will take place at Eurocopter UK and the first aircraft is slated to enter service, with pilots and engineers ready to go, later that year. A year on from then, the process should be complete.

Unfortunately, the Life Extension Plan solution will last for just over ten years – the Puma airframe holding all these improvements together can only last for so long. These programs may be a testament to the skill and dedication of teams at Boscombe Down, JHC, MoD and elsewhere, but is also something of an indictment of their political masters who failed to react to the growing problem with transport helicopters as the last decade unfolded. At least there is some confidence within the civil and military teams that, next time, they may be listened to.

## About the Author

Andrew Healey is a freelance writer and marketing consultant. He is a former Royal Navy and commercial helicopter pilot who has been writing about the rotorcraft industry for the past 25 years. His book Leading from the Front. Bristow Helicopters, the First 50 Years is published by Tempus and available on Amazon.com.

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Sikorsky
A United Technologies Company

08 November 2010

Mr. Thomas Haueter
Chief, Major Investigations Division
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594

PSL-104-10

Re: **Investigation LAX08PA259**
**Sikorsky S-61N; near Weaverville, CA; 05 August 2008**

Dear Mr. Haueter:

Enclosed, please find Sikorsky Aircraft Corporation's response to Carson's response to Addendum #2 of the Hover Performance Study as part of NTSB's investigation LAX08PA259; Sikorsky S-61N aircraft, near Weaverville, CA; 05 August 2008.

Sikorsky Aircraft appreciates the opportunity to present our analysis of the subject issues.

For any further correspondence on this matter, feel free to contact me at 203-386-4240 or [redacted]

Very truly yours,

SIKORSKY AIRCRAFT CORPORATION

[redacted]
Christopher Lowenstein
Chief - Aircraft Safety Investigation

Sikorsky Aircraft responds to Carson Helicopter's "Response to Hover Study Addendum #2 (dated 28 October 2010)" as follows:

1. Carson **1. a)** alleges that the trim tabs and instrumentation on the NVH-3A blades had a negative effect on the blade's performance. Sikorsky disagrees. The correlation of the hover performance prediction (based on a model derived from NVH-3A flight test data with blades with trim tabs and one instrumented blade) with the S-61A hover 'spot check' data (acquired with blades without trim tabs or instrumentation) verifies that the trim tabs and instrumentation have a negligible impact on hover performance.

   It should be noted that Sikorsky hover prediction model for the S-61A, although based on the model for the NVA-3A, was analytically corrected to account for hover performance applicable configuration differences (specifically the reduction of vertical drag associated with the removal of the tail cone strake, and the adjustment of vertical drag associated with the replacement of the sponson main gear with the land type main gear; as well certain mission equipment and antennae) The conclusion is that the presence of trim tabs and instrumentation wiring does not measurably affect the hover performance.

   Sikorsky has acquired vibration test data on six different occasions (three with trim tabs; and three without trim tabs) and has determined that an elevated 5/rev airframe vibration was noted with both configurations as compared to the original aluminum blades. This appears to be related to an increase in the blade lag stiffness that moved a blade lag mode closer to 4/rev, which is then transmitted to the airframe as a 5/rev vibration. In any case, 5/rev vibration (at the levels measured with composite and aluminum blades) does not affect hover performance.

   Carson's allegation that the instrumented blade's strain gauge wires affected its performance is inaccurate. While Sikorsky prefers to do all performance testing with 'clean' blades; this is not always feasible, and we routinely fly with instrumented blades with little measurable effect on blade performance. Further, it should be noted that the strain gauge wires are mounted well aft of the center of lift of the blade and do not adversely affect performance.

   However, if Carson's assessment of the blade has determined that the blades are actually that sensitive to surface contamination, then the NTSB's investigation would need to further evaluate the effect of the raised rough ash/soot contamination noted at the accident site along the inboard leading edge of the White blade.

2. Carson **1. b)** alleges that the Sikorsky GenHel simulation did not take into account the smaller tail rotor and sponson gear that were fitted on the NVH-3A. This is incorrect. Sikorsky accounted for the tail rotor change, the tail cone strake, the sponson vs. fixed landing gear difference, the antennas and other classified gear, (for comparison to S-61A test aircraft N3173U) and also added the corrections for the difference in fuselage length and the Fire King tank download (for comparison to the S-61N accident aircraft N612AZ). While some of these corrections were fine-tuned during the 12 months of GenHel runs; the basic differences in configuration were always taken into account.

3. Carson **2. a)** corrects the Fire King tank's location to STA 213-320. Sikorsky first included this correction in Revision 2 of the Fire King download study in August 2010. The change in location did NOT decrease the download, because Carson's supplied data indicated that we had under-estimated the tank's exposed download area by 0.94 sq ft. The increase in exposed surface area offset any reduction in download obtained by moving the tank aft to the correct location. All current data uses the correct location and geometry.

4. Carson **2. b)** states that Sikorsky's drag coefficient does not take into account the fact that the tank is 10 feet below the rotor, and thus is overestimated. Sikorsky does not agree. A drag coefficient is by definition a dimensionless number, an inherent characteristic of any shape and is not dependent upon location. If the intent of this comment was to state that the overall drag *load* (not drag *coefficient*) should be lower because the tank is farther away from the rotor, it indicates a lack of understanding of basic rotor aerodynamics.

   According the principles of *conservation of fluid momentum* and *conservation of energy*, the acceleration of a region of air will cause a local reduction in pressure, and an associated constriction of the overall stream tubes, resulting in rotor wake contraction (*vena contracta*) and a far-field velocity that is equal to two times the induced velocity. This means the downwash velocity is substantially HIGHER ten feet below the rotor than it is directly beneath the rotor.

   The *vena contracta* effect is clearly explained by J. Gordon Leishman[1] and is mathematically stated in the equation labeled **(2.10):** $v_i = ½w$**;** [where $v_i$ is the induced velocity in the plane of the rotor and $w$ is the velocity in the *vena contracta*]. Thus the rotor downwash *accelerates* to *two times* the induced velocity as distance from the rotor increases.

   Sikorsky's CCHAP[2] program, which takes into account the Fire King tank's location both vertically and horizontally, calculated an average downwash velocity at the tank edge to be 47 ft/sec, which is substantially higher than the zero ft/sec that Carson predicted. The actual CCHAP analysis was conducted using the Carson CMRB performance and geometry, including cut-out, chord, twist, and airfoil; although the legacy illustrative diagram in the Fire King Download Study showed the original Sikorsky geometry.

5. Carson **2. c)** states that Sikorsky did not account for the tank's rounded edges. Beginning with Revision 2 of the Fire King study (August 2010), Sikorsky has calculated the downwash load using the corrected two inch radius geometry.

   Finally, it also should be noted that Sikorsky's estimate of 103 lbs download is about ½ of 1% of the total rotor lift capability. Sikorsky concurs that pilots would not likely notice the difference. However, during flight operations that are conducted beyond the charted power available limit; any amount of additional vertical drag can become significant. Sikorsky stands by this calculation.

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[1] **Principles of Helicopter Aerodynamics;** J. Gordon Leishman. Cambridge University Press, 2006; pp 58-64.

[2] **The Circulation Coupled Hover Analysis Program (CCHAP)** code was created at Sikorsky over 30 years ago to calculate the airloads and downwash velocities under a hovering rotor. The inputs are the rotor geometry (chord, twist, airfoil distribution), rotor speed, the ambient atmospheric conditions, and the desired rotor thrust. The model uses Prandtl lifting line theory to calculate the circulation on the blade elements and the effect of trailing vorticity on the induced velocity. The model iterates on collective pitch to achieve the desire thrust and calculates the downwash velocity field under the rotor as a function of radial location, azimuthal location, and vertical distance below the rotor. All of this assuming an out-of-ground-effect (OGE) hover.

The resulting downwash velocities impinging on airframe and other portions of the aircraft under the rotor are used to calculate the vertical drag of those items with the drag coefficient based on experimental data and accounting for either sub-critical or super critical flow (transition from laminar flow to turbulent flow). The velocities and vertical drags are then provided to the user.

6. Carson **3. a)** states that the aircraft remained in HIGE conditions. Sikorsky disagrees. All of the simulations run in GenHel fully account for the benefits provided by ground effect, including the non-linear taper of ground effect from full HIGE to HOGE conditions. Sikorsky does concur that common sense is strained to explain why two mountain pilots picked the aircraft up into a low hover and flew away, not once, but three times. The fact that they barely succeeded the first two times (exceeding aircraft mandatory redlines – and reaching topping power on both engines) indicates that neither pilot was paying appropriate attention to their use of power well beyond that which was predicted.

7. Carson **4.** states that Sikorsky intentionally skewed the data to the negative. Sikorsky disagrees. Sikorsky equally weighted the data for all relative wind azimuth angles. This is a common sense approach, as it is difficult to accurately measure winds in the extreme low range of 0-3 knots. Sikorsky has no motivation to intentionally skew the blade performance, however, the test results show that using our methodology, the blades simply do not perform as well as predicted by RFMS #6 or #8. Further, for winds that are *truly* below 3 knots; Sikorsky concurs that there should be no measurable effect on rotor performance. A method that includes multiple azimuth angles produces a larger dataset, which offsets various test error, including the effect of any wind measurement errors.

   Carson recently informed Sikorsky Aircraft that ALL of their short-body test data, including RFMS #5, #6 (there are two different Supplements #6) and #9 are incorrect and should not be used. Carson has provided no explanation as to why that data is incorrect. This indicates a flaw in their flight test procedures and analysis. While Sikorsky has certainly made mistakes during flight test, they are rapidly identified and corrected. To date, to Sikorsky's knowledge, Carson has not determined the source of the error, nor have they informed the FAA that the FAA-approved data contained in RFMS #5 is invalid, despite Sikorsky's recommendation to do so made by letter on August 12, 2010.

   Further, in the past, Carson has made claims that the short-body S-61A provides a substantial performance gain (in the marketing of their short-body conversion STC) as compared to a long-body S-61N. However, Carson's RFMS #8 shows the S-61N providing slightly *better* performance than was measured on the CHI/SAC S-61A flight test. Either Carson's earlier claims or RFMS #8 (or both) are incorrect.

8. Carson **5.** states that the $\mathbf{N_R}$ tracking is inconsistent between the Whipple Test and the accident aircraft. As Columbia's submission shows, the general $\mathbf{N_R}$ trend is consistent until late in the sequence, when the aircraft began striking trees, at which point energy is removed from the rotor system, and $\mathbf{N_R}$ would be expected to decrease.

   The Sikorsky simulation data was all run at the request of and under the supervision of the NTSB. The final set of data that is contained in the Addendum was completely determined by the NTSB. It is important to note that if the blades performed as Carson stated in RFMS #8, with the engines operating as recorded on the CVR, the aircraft would have cleared the trees, despite being substantially overweight. Conversely, using the Sikorsky performance modeling experience and data acquired over more than fifty years of professional engineering flight test shows the helicopter will impact the tree. The two different temperatures the NTSB used bracket the actual impact site.

Carson's analysis does not seem to account for the fact that:

1) their pilots planned for 1250 lbs more lift capability than they should have [2½ min vs. 5 min power charts];
2) that the empty aircraft weighed 1042 [Carson estimate] to 1437 lbs [NTSB Ops Group estimate] more than the aircraft logbook indicated;
3) that an oversight on-scene did not account for the 210 lb weight of the USFS inspector pilot;
4) and that Carson's performance data did not account for the 103 lbs of Fire King tank download.

The fact that the aircraft successfully took off twice before the accident take-off when operating at a weight approximately 3000 lbs higher than planned is a testament to the better-than-specification performance provided by both engines. However, it also indicates that the pilots failed to notice that their *substantial* predicted power margin was **negative** on the first two takeoffs; as they exceeded redlines on BOTH engines and reached topping power. Proper planning with accurate power available and weight data indicates that these takeoffs should never have been attempted.