The Raisbeck Swept Prop Advances to C90s

The new Raisbeck/Hartzell C90 Swept Blade Turbofan Propeller

the new

SWEPT BLADE TURBOFAN PROPELLER FOR THE ENTIRE KING AIR C90 FAMILY

developed jointly by Raisbeck Engineering and Hartzell Propeller for the C90GTx, C90GTi, C90GT, C90B, C90A, C90 and E90 models

- STUNNING RAMP PRESENCE
- 30º BLADE SWEEP
- LARGER DIAMETER (96″)
- MORE THRUST WITH LESS NOISE
- MEASURABLY IMPROVED FAA-CERTIFIED PERFORMANCE (with the C90 EPIC Performance Package)
- AFFORDABLE ALUMINUM CONSTRUCTION

Raisbeck C90 EPIC* Performance System with NEW SWEP

** EPIC includes 96″ Swept Blade Turbofan Propellers, Dual Aft Body Strakes, 10,500 lb Gross Weight and FAA-Approved Performance*

C90GTx EPIC Performance Comparison*

** C90GTi, C90GT similar*

TAKEOFF (ISA/SL)	Raisbeck EPIC + C90GTx	Factory C90GTx	IMPROVEMENTS
Maximum Takeoff Gross Weight (MTOW)	**10,500 lbs**	10,485 lbs	15 lbs more
Takeoff – Flaps Up	**2,150 ft**	3,000 ft	850 ft less runway
Takeoff – Flaps Approach	EPIC uses flaps up for all takeoffs	2,550 ft	400 ft less runway
Accelerate-Go – Flaps Up	**2,970 ft**	4,380 ft	1,410 ft less runway
Accelerate-Go – Flaps Approach	EPIC uses flaps up for all takeoffs	3,600 ft	630 ft less runway
Accelerate-Stop – Flaps Up	**3,770 ft**	4,200 ft	430 ft less runway
Accelerate-Stop – Flaps Approach	EPIC uses flaps up for all takeoffs	3,770 ft	———
Takeoff Climb Gradient – Flaps Up	**4.7%**	3.9%	20% greater
Takeoff Climb Gradient – Flaps Approach	EPIC uses flaps up for all takeoffs	2.7%	74% greater

CLIMB

Single Engine Rate-of-Climb	**525 fpm**	420 fpm	105 fpm better
Single Engine Service Ceiling (ISA, 10,000 lbs)	**24,200 ft**	18,100 ft	6,100 ft higher

CRUISE

Cruise RPM	**1,750 RPM**	1,900 RPM	150 RPM less

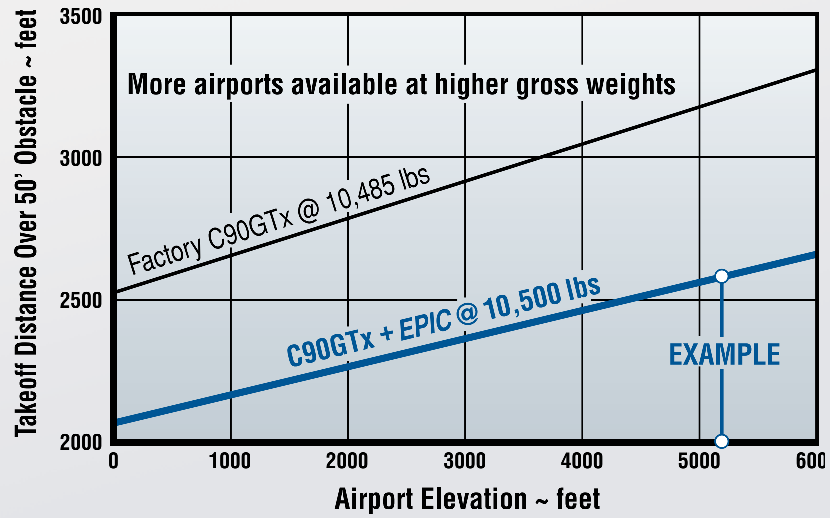
LANDING (Flaps Down)

Landing Distance – No Reverse	**2,120 ft**	2,480 ft	360 ft less runway
Landing Distance – w/ Reverse	**1,580 ft**	2,370 ft	790 ft less runway

OTHER

Propeller	**96″ Raisbeck/Hartzell Swept Blade Turbofans**	90″ Hartzell/Beech 4-Blade	• Exceptional performance • Stunning ramp presence

C90GTx EPIC Takeoff Comparison

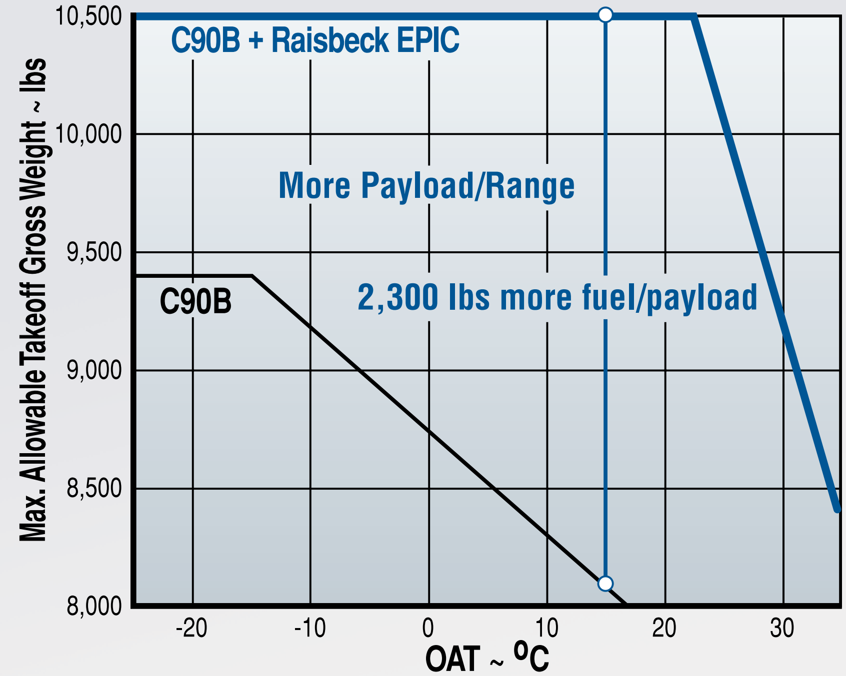


EXAMPLE: An EPIC-equipped C90GTx can operate from mile-high fields as short as 2,600 ft. at its Maximum Gross Weight of 10,500 lbs.

C90B EPIC Performance Comparison

TAKEOFF (ISA/SL)	Raisbeck EPIC + C90B	Factory C90B	IMPROVEMENTS
Maximum Takeoff Gross Weight (MTOW)	**10,500 lbs**	10,100 lbs	**400 lbs more**
Takeoff – Flaps Up	**2,150 ft**	2,710 ft	**560 ft less runway**
Accelerate-Go – Flaps Up	**2,970 ft**	3,650 ft	**680 ft less runway**
Accelerate-Stop – Flaps Up	**3,770 ft**	3,600 ft	**170 ft more runway @ 400 lbs heavier**
Takeoff Climb Gradient – Flaps Up	**4.7% @ 10,500 lbs**	4.8% @ 10,100 lbs	**Virtually the same @ 400 lbs heavier**
CLIMB			
Single Engine Rate-of-Climb	**525 fpm**	495 fpm	**30 fpm better**
Single Engine Service Ceiling (ISA, 10,000 lbs)	**14,500 ft**	13,600 ft	**900 ft higher**
CRUISE			
Cruise RPM	**1,750 RPM**	1,900 RPM	**150 RPM less**
LANDING (Flaps Down)			
Landing Distance – No Reverse	**2,120 ft**	2,290 ft	**170 ft less runway**
Landing Distance – w/ Reverse	**1,580 ft**	2,130 ft	**550 ft less runway**
OTHER			
Propeller	**96˝ Raisbeck/Hartzell Swept Blade Turbofans**	90˝ Hartzell/Beech 4-Blade	**• Exceptional performance • Stunning ramp presence**

C90B EPIC MTOW Comparison



EXAMPLE: Sea Level, 3,000 ft. runway, Accel-Go, Flaps Up

"The biggest benefit of propeller blade sweep for the King Air type of airplane is that it allows for a larger diameter propeller without increasing the sound level in the airplane and on the ground. The larger diameter also provides for more takeoff, climb and cruise thrust."

– James Raisbeck

the Raisbeck/Hartzell Swept Blade Turbofan Propeller
TECHNICAL OVERVIEW

Why Sweep the Propeller blades?

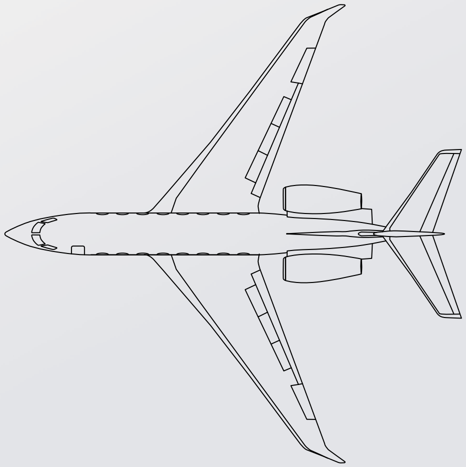
The newer King Air 200s can cruise as fast as .52 Mach (M_{MO}) at 28,000 feet. At a propeller RPM of 1800, the propeller tip Mach number is over .9 at cruise.

The C90s, although slower by a bit than the 200s, turn their propellers at higher RPMs during takeoff, climb and cruise. The resulting propeller C90 tip Mach numbers are right up there with the 200. While the new C90GT-series incorporates an engine which turns slower on takeoff, the climb and cruise RPMs are the same as the earlier versions.

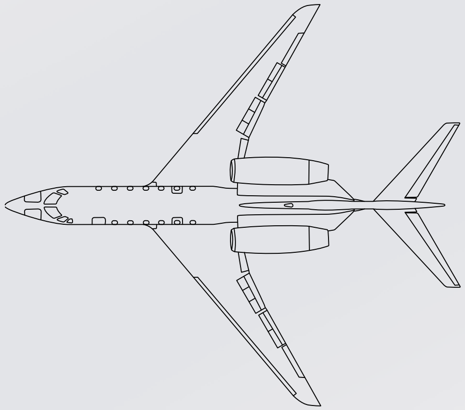
This same high-Mach phenomenon is also very much present during takeoff at low forward airspeeds but higher prop RPM. As an example, at 120 Knots during initial climb at 2000 RPM, the propeller tip Mach is an astonishingly high .8 ; on the C90B at 2200 RPM, it's .88 Mach.

These takeoff, climb and cruise conditions are encountered on almost every King Air in flight, and they push the propeller blades significantly into the transonic drag rise, the same as for airfoils and unswept wings.

As a comparative example, commercial airliners and business jets typically fly around Mach .79 to .82, and some of them are pushing .90 (747) and even as high as .92 (Gulfstream 650 and Cessna Citation Ten). The wing sweep on these airplanes varies from 30 to 40 degrees. All one has to do is look at the top view of any of these aircraft to see how dramatic the sweep is (see figures above right).



Gulfstream 650



Cessna Citation X

Typical commercial airplane quarter-chord sweep angles are the Douglas DC-8 at 32 degrees and the Boeing 737 and 757 with 25 degrees sweep. Boeing's biggest sweep ever built into a Boeing commercial airplane is the 747 with 37½ degrees of quarter chord sweep which cruises over Mach .9 when pushed.

With a jet airplane, its entire wing is at the same freestream Mach number. However, with a propeller blade, the farther out on its diameter, the higher the Mach number. Adding additional diameter to a propeller adds to its tip Mach number, which in turn adds unwanted additional transonic drag and noise. This of course detracts from the other desirable performance increases resulting from such an increase in diameter.

Now, air flowing over an airfoil doesn't know if that airfoil is part of a wing going straight through the air, or a propeller blade being whirled

The new C90 Swept Blade Turbofan Propellers provide unparalleled performance increases across the entire flight envelope for every King Air C90 and E90 ever built. The combination of the Swept Blade Props with the C90 EPIC Performance Package creates the best-equipped C90GTx/C90GTi/C90GT/C90B/C90A/C90/E90, whether built in 1971 or 2014.

around in a circle by its engine. The air reacts the same to increasing Mach number.

Merely adding propeller diameter doesn't necessarily add proportionate performance improvement, and it can be measurably noisier because of high Mach effects at the outer parts of the blades. As a matter of fact, air flowing over the convex lifting blade surfaces will frequently be supersonic.

Introducing blade sweep to the blades can largely overcome these drawbacks. One can never get rid of noise, but sweep does allow an increased propeller diameter for greater performance without paying the normal noise and drag penalties.

Brief History of Wing and Blade Sweep

The next question is, if the swept wing has been around since Willy Messerschmitt put it on the ME 163 in 1943, and that work was discovered by George Schiarer from Boeing after the War in 1945 and was first employed in 1947 on the B-47 swept-wing bomber, why hasn't anybody designed swept propeller blades until now?

Actually, there have been some successful attempts to design and build true swept propellers. The European A400M cargo plane has swept wings and swept propellers (above right). It is designed to fly at Mach .72 and airspeeds to 421 knots. The propeller has 8 blades and is very costly for general aviation consideration.

There are other examples such as the C130J (above right), but they are all very expensive and usually on military airplanes. As such, they inherently don't qualify for markets such as the King Air.

But to the layman, it is not intuitively obvious that sweeping the blades of a propeller installed on a King Air that incorporates no wing sweep

Airbus A400M

Lockheed C130J

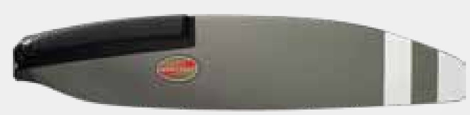
itself and flies at cruise Mach numbers well below the transonic drag rise, makes any sense.

And since no one has gone there in propeller design for airplanes like the King Air, no market has ever been developed. Market is what drives research, technology and their results—new products which satisfy a new market need.

The team of Hartzell Propeller and Raisbeck Engineering have combined for the last three decades to push back the dual boundaries of technology and market. The latest of these efforts is the Raisbeck Swept Blade Turbofan Propeller System (SBTP).

Application of Wing Sweep to the King Air Propeller

Surveying a number of recent general aviation airplane propellers, they at first appear to have swept blades. But they don't. Several examples exist like the Hartzell Scimitar propeller (below).



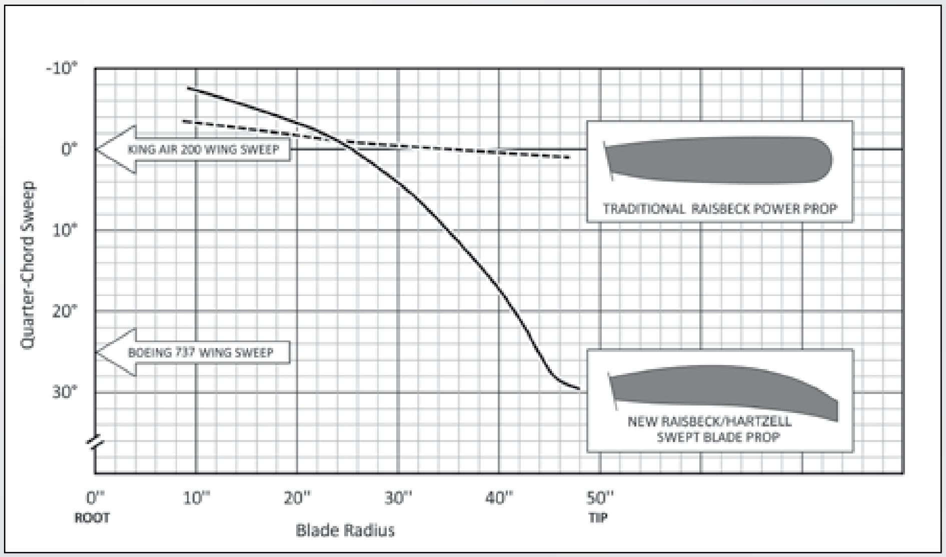
Hartzell Unswept Scimitar Propeller


787

One of the latest of these is the Composite Scimitar Propeller for the King Air 250.

The blades on these propellers have cut-back leading edges, but the trailing edges remain unswept. Quarter chord sweep (the sweep of the 25% chord) is what the air responds to and calibrates well with drag rise at higher Mach. Practical structural constraints, such as bird strikes, limit the aft sweep of composite blades, and thus their ability to achieve the positive effects of true blade sweep.

The graph below compares the quarter-chord sweeps of the blades on our Raisbeck Turbofan Power Prop (introduced in 1985) with our new Swept Blade Turbofan Propeller.

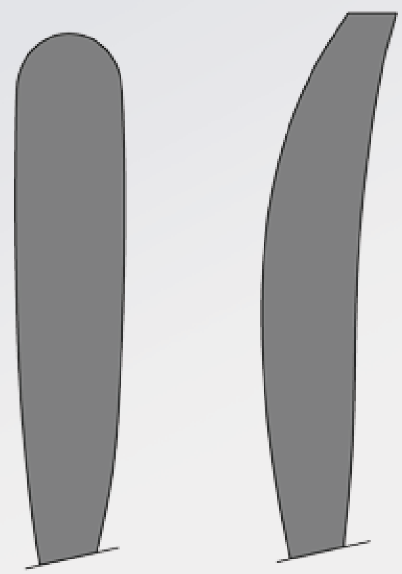


When viewed side by side (see at right), the visual effect of the blade sweep stands out in a crowd.

Development and FAA certification Flight Testing — King Air 200 Swept Blade Props

First conforming propellers with the new blades were delivered to Raisbeck's flight-test facilities In June 2012, following 2½ years of CFD analyses and resulting studies and trade-offs. Configuration had been frozen in February 2012, and Hartzell had then begun manufacture of the pre-production blades.

During development flight testing, three different propellers were evaluated on a fully instrumented King Air B200; the current Hartzell OEM propeller for the B200GT (93″ diameter); the current Raisbeck Turbofan Power Prop (94″ diameter); and the new Swept Blade Turbofan Prop (96″ diameter). Incremental increases in performance between these three were documented, and fell roughly as expected, with performance following increased diameter in each case.



Traditional Raisbeck Power Prop ***New Raisbeck Swept Blade Prop***

With performance well documented in-house, Raisbeck's engineers went forward with full FAA certification. FAA flight testing was completed in August, and all submittals were made except the new Airplane Flight Manual Supplements containing the performance. These were submitted two months later and accepted shortly thereafter.

BB-1723, the first installation of Swept Blade Turbofan Propellers in March 2013.

The propeller itself was separately Type-certificated by Hartzell to add to their Type Certification Data Sheet, a necessary step toward Raisbeck certification. Details of the certified King Air performance comparisons are available in separate documents at www.raisbeck.com, Raisbeck Engineering's website.

C90 Swept Blade Prop test airplane lands at Boeing Field

Manufacturing Considerations

The large sweep on the new propeller in turn required new aluminum forgings for quantity production. New forgings cost money; they are provided to Hartzell by Alcoa in this case. Long lead times for new forgings are typical.

As a result, the blades used for flight testing and FAA certification were machined from large aluminum blocks. Three complete propellers were required; two for performance, stability and control, governor pressure, takeoff, landing and taxi characteristics; the third Swept Blade Propeller was fully instrumented and put on one side only, to document stress, strain, loads, vibration and dynamic response.

Second Generation Swept Blade Propellers for the King Air C90 Family

With success of the Swept Blade Turbofan Propeller program for the King Air 200-family assured, Raisbeck engineers turned to the King Air C90, still in continuous production since 1971.

Preliminary design studies revealed that further blade sweep could result in quieter sound levels for FAA and European (EASA) noise certification. Increased sweep also allowed for a propeller diameter increase of a full 6 inches over the OEM propeller, from 90″ to 96″.

With newly-earned experience and the availability of Swept Blade aluminum forgings, the C90-family program went considerably faster. A King Air E90 was used for development and certification since the PT6A-28 engine is certified for both 2200 RPM and 1900 RPM takeoff settings in one airplane. Certification flight tests were conducted during the early summer of 2013, and successfully completed on August 14th. C90 Swept Blade Turbofan Propeller production is under way at Hartzell Propeller.

— Written by James D. Raisbeck

What’s Next?

The engineers and marketers at Raisbeck are looking at where the new technology should be applied next, and on what model aircraft. In keeping with Raisbeck Engineering’s long-standing policy of proving our new technology before talking about it and offering it for sale, any discussion of what tomorrow brings will have to wait until tomorrow.

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