

Flight Test – FINAL REPORT – Revision 2 - (7/10/14)

The EAGLE AOA display

In the

Beechcraft King Air 90 Blackhawk

Alpha Systems Angle of Attack Stall Warning System

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This report is an update to Flight Test – Revision 1 - (3/30/11) on the LEGACY AOA display:

<http://www.ballyshannon.com/air/aoaflighttestkingair90.pdf>

This Flight Test was flown to analyze the information provided by the **Alpha Systems Angle of Attack (AOA) Stall Warning System** as displayed on the **newly introduced Eagle AOA** display in six normal flight configuration and attitude combinations of the Beechcraft King Air 90 Blackhawk aircraft to determine the usefulness of that information at enhancing safety in the operation of **general** aviation aircraft. **The Eagle AOA is substantially identical to the previously-tested LegacyAOA. Accordingly, much of this flight test focuses on the human factors changes from the Legacy display to Eagle.**

EXECUTIVE SUMMARY

NO CHANGE to PREVIOUS CONCLUSION: *The Alpha Systems Angle of Attack (AOA) Stall Warning System offers an accurate, repeatable, and very early warning of impending aerodynamic stall. Such clear stall proximity information mounted prominently in the panel offers enhanced safety in the operation of general aviation aircraft. A display of AOA as a cross check to the primary Airspeed Indicator is particularly useful when operating in steeply banked and/or G-loaded flight conditions because the angle of attack at aerodynamic stall is independent of aircraft weight and/or wing loading.*

Specifically, within the scope of these test flights, the following germane conclusions were reached:

- ***The “Optimum Alpha Angle (OAA) Calibration” technique recommended by the Alpha Systems AOA Stall Warning System Installation Manual is an accurate and repeatable method that can be used to reliably set an AOA target that will be adequately before the aerodynamic stall AOA.***
- ***The target AOA, once calibrated, presents data to the pilot so as to provide early warning of an impending stall, prior to the aircraft stall warning audible system, thereby ensuring a safe margin above stall throughout the entire gross weight envelope.***
- ***The instrumentation provides clear, un-ambiguous, and easy to comprehend stall proximity information.***

Test Procedures and Results

Phase I: Stall Performance Data Verification

NO CHANGE from Previous Flight Test Report: Approach-to-stall, stall warning, and actual stall speed data at representative weights and Center of Gravity locations were tested on the first of two test flights in two configurations, clean and dirty and at two attitudes, wings level and 30 degrees (deg.) angle of bank. Conditions during the stall testing included altitudes between 4,500 ft. MSL and 3,500 ft. MSL and an outside air temperature of 4 deg. Celsius. Deceleration rates to stall warning and actual stall did not exceed one knot (KIAS) per second. All speed references herein are with respect to pilot-side instruments.

In the clean configuration at idle power and wings level with a gross weight of approximately 9,800 pounds (lbs), stall warning occurred at 92 KIAS and consisted of activation of the aircraft stall warning audible horn. Actual stall occurred at 82 KIAS, and was defined as a mild drop in nose attitude. Recovery was immediate as the nose dropped.

In the same clean configuration, weight and idle power, but 30 deg. angle of bank, stall warning occurred at 96 KIAS and again consisted of activation of the stall warning audible horn. Actual stall in the 30 deg. bank attitude occurred at 92 KIAS consisting of a similar mild drop in nose attitude. Recovery was again immediate as the nose dropped.

In the wings-level dirty configuration, with gear down and full flaps at a power setting of 300 Ft-Lbs and the prop at low pitch and weight at approximately 9,700 lbs., stall warning occurred at 75 KIAS with activation of the stall warning audible horn. Actual stall occurred at 72 KIAS and was defined as a mild drop in nose attitude.

In the 30 deg. bank attitude in the dirty configuration, stall warning again consisted of the stall warning horn at 86 KIAS with actual stall occurring at 82 KIAS defined as a mild drop in nose attitude occurred.

Data from these verification tests are presented in Table I below:

Configuration	Bank Angle (Deg.)	Power (Ft-Lbs/Pitch)	Stall Warning (KIAS)	Stall (KIAS)
Clean	0	Idle/Low	92	82
Clean	30	Idle/Low	96	92
Dirty	0	300/Low	75	72
Dirty	30	300/Low	86	82

TABLE I

Verified Stall Speeds

These actual stall speeds were used for the remainder of the flight test.

Phase II: Calibration of the Alpha Systems AOA Stall Warning Eagle Electronic Display System

The Alpha Systems AOA Eagle Display provided visual and audible indications as shown in Figure 1 and Table II below. The two triangles are newly added:



Figure 1

**Alpha Systems AOA Stall Warning Eagle Electronic Display
Dual Eagle AOA Indicators in a King Air 90**

Condition	Display Indication
Cruise	Green Bar
Slowing From Cruise	Green Bar and Amber Triangle
Slowing Further From Cruise	Amber Triangle
Slow Flight	Amber Triangle and Amber Chevron
Very Fast (reference the donut)	Amber Chevron
Fast (reference the donut)	Amber Chevron and Lower Half of Blue Donut (Various callouts are available at this indication)
Slightly Fast (reference the donut)	Lower Half of Blue Donut
On Speed (OAA)	Full Round Blue Donut
Slightly Slow (reference the donut)	Upper Half of Blue Donut
Slow (reference the donut)	Upper Half of Blue Donut and Red Chevron
Very Slow (reference the donut)	Red Chevron
Ultra Slow (reference the donut)	Red Triangle

Table II

Alpha Systems AOA Stall Warning Eagle Electronic Display System Indications

Calibration: The Alpha Systems AOA Eagle Display installed on the test aircraft had initially been calibrated at 94 KIAS ($1.3 V_{SO}$) by both A: the Alpha System OAA method and B: by a demonstrated stall (times 1.3). Calibrating to this dirty configuration V_{SO} should provide ample (30%) stall margin in short field operations, but with slightly less stall margin in the clean configuration. Either setting will provide significantly earlier warning than the OEM Stall horn does. See Table III.

Dirty Stall: V_{SO} (KIAS)	$1.3 \times V_{SO}$ (KIAS)	Calibrate OAA (KIAS)
72	93.6	94

Table III
Calibrating the OAA

Calibration of the OAA was accomplished in accordance with the Alpha Systems AOA Eagle Display Installation Manual by first landing to calibrate the system's "zero airflow" point and refuel, and then returning to flight in the dirty (FlapsFull, GearDown) configuration at approximately 9,800 lbs. to calibrate the OAA at 94 KIAS. Once calibrated, the OAA displayed at a range of airspeed from 94 KIAS to 103 KIAS. See Table IV.

Optimum Alpha Angle (OAA)	OAA Airspeed Range at 9,800 Lbs.
$1.3 V_{SO}$	91 KIAS to 99 KIAS

Table IV

Alpha Systems AOA Stall Warning OAA is a Range

With Gear Down/Flaps Full and 300 Ft-Lbs torque set at 94 KIAS, the full blue donut was illuminated. Slowing slightly to 91 KIAS resulted in only the upper (slower airspeed) half of the blue donut remaining illuminated. At 99 KIAS the full blue donut was illuminated, but accelerating slightly to 100 KIAS resulted in just the lower (faster airspeed) half of the blue donut remaining illuminated. This provided a range of 8 KIAS for OAA.

Phase III: Representative weight flights for Alpha Systems AOA Stall Warning system

NO SIGNIFICANT CHANGE from Previous Flight Test Report: Three representative configurations and two bank angle attitudes were flown on the second of two test flights to evaluate the usefulness of the Alpha Systems AOA Eagle Display. The results are presented in Table V below. NOTE: Because this particular upgrade also replaced the sensor probe (because the old probe had been misadjusted by impact), we began by rerunning these Phase III Airspeed vs. Donut Range checks to ensure that the new Eagle system will display at the same ranges as the previous Legacy system did. Our full earlier report is here <http://www.ballyshannon.com/air/aoaflighttestkingair90.pdf>. We are so very close that we do not intend to adjust the probe angle or calibration further.

Configuration	Attitude (Deg. Bank)	Power (Ft-Lbs/Pitch)	Weight (Lbs. approx.)	OAA Airspeed Range (KIAS)
Clean	0	300/Low	9,800	99-107
Clean	30	300/Low	9,780	98-112
Gear Up/Flaps Approach	0	300/Low	9,760	97-108
Gear Up/Flaps Approach	30	300/Low	9,740	99-111
Gear Down/Flaps Full	0	300/Low	9,720	91-99
Gear Down/Flaps Full	30	300/Low	9,700	95-101

Table V

OAA Speeds at Representative Configurations and Attitudes

With the Alpha Systems AOA Eagle Display calibrated to an OAA of 91-99 KIAS at ~9,700 Lbs., holding OAA in the various representative configurations and bank angles in Table V by reference to the Eagle AOA Display (full blue donut) resulted in consistent OAA airspeeds in the 91-112 KIAS range. Accordingly, within the scope of these tests, the Alpha Systems AOA Eagle Display proved to be useful as an additional tool to maintain optimum airspeed (1.3 V_{SO} or its AOA equivalent, when banked) during a variety of normal maneuvering configurations and normal attitudes typical of General Aviation operations.

Phase IV: Operational scenario flights to determine usefulness of Alpha Systems AOA Stall Warning Eagle Electronic Display System

During the second of two test flights maneuvering flight in clean configuration; terminal area flight in gear-up, approach flaps configuration; and landing pattern flight in gear-down full flaps configuration was conducted to qualitatively evaluate the use of the Alpha Systems AOA Eagle Display as a secondary stall avoidance tool when used in conjunction with the installed airspeed indicator. Maneuvers were conducted in turns up to 30 deg. angle of bank and climbs up to a positive 10 deg. pitch attitude. In all configurations and attitudes tested, the Alpha Systems AOA Eagle Display consistently provided adequate, and early, indications of approach to stall.

The Eagle Display proved easy to learn and intuitive. It was clear in its information, unambiguous and easy to comprehend. The arrangement of the donut, the new triangles, and chevrons in the display provided distinct information on proximity to stall and directive information that proved helpful at avoiding a near-stall condition, considerably before the aircraft's OEM audible stall warning system became effective. The newly-added Amber Triangle is a relatively large segment and when it comes alive, it draws a pilot's attention to the AoA instrument. That is very nice.

Audio. Tones and Voice callouts. Like the Enhanced Legacy, the Eagle has a user-selectable choice of audio alerts. For example: when slowing from cruise, we heard a female voice "Getting Slow" and we soon learned to acknowledge this "Pilot Not Flying" by saying "Roger. Slowing". Similarly, deep into the stall regimes we'd hear a repeating "Too Slow...Too Slow...Too Slow". **Without exception, the test pilots agreed that the voice callouts may be the single best feature of the device. Why? Because the voice callout can effectively—and immediately—bring a distracted aviator back into the instrument scan.**

There were no deficiencies noted with the AOA Stall Warning Eagle System (Software Rev A).

Phase V: Free flight and unusual attitudes

NO CHANGE from Previous Flight Test Report: Flight Maneuvering—in attitudes considerably exceeding those experienced in routine general aviation operations—was investigated to determine the usefulness of the Alpha Systems AOA Eagle Display as a secondary stall margin indicator when used in conjunction with other aircraft instruments.

Relatively level steep turns to 59 deg. angle of bank were flown with deceleration to OAA (Blue Donut) on the AOA Stall Warning Eagle Display with airspeed reading well over 120 KIAS but with adequate stall margin remaining with no aircraft stall warning horn. Steep turns were followed by steep climbs to 20 deg. positive pitch angles with wings level decelerating to OAA again with adequate stall margin remaining and no stall warning horn. Finally, pitch and bank were combined to 59 deg. bank angle and positive 15 deg. pitch decelerating to OAA at which point the aircraft stall warning horn still remained silent. The aircraft was allowed to decelerate further to the very slow AOA indication (Table II) and yet the OEM stall warning horn still remained silent. At that point, the nose of the aircraft was raised slightly further to trigger the stall horn, but without causing an aerodynamic stall, thereby proving that adequate stall margin still existed at OAA in this "very unusual attitude" for a King Air operation.

Qualitative Conclusions:

From the Marine Aviator, a former instructor in the Navy Training Command and the senior fixed-wing test pilot instructor at NAS Patuxent River: "As I flew the approach to several landings with this same system in both a Beech King Air and a Beech S-35 Bonanza, I realized that I was "instinctively" flying based on the AOA display. Now remember, although I was experienced with AOA in the Marines, I haven't flown AOA since 1986...that's 24 years. Since leaving the F-18 Hornet in El Toro, CA, I've been an airspeed indicator pilot both privately in my own Bonanza and commercially at American Airlines. In our commercial operation, we had a little booklet where each page was a different weight condition and we would reference that page as we set up for approach and landing to set our V- speeds including V_{ref} for

final-flaps approach. In spite of the many years away from AOA flying, this Alpha Systems AOA Stall Warning is so intuitive that I subconsciously and immediately reverted back to my much younger habit of flying AOA on my approaches. I think that says a lot for the usability of the Legacy—and now the Eagle—system. However, it is important to remember that Airspeed must always be the primary reference. I'm not sure of the value of the Eagle's two additional triangular segments, but the color of the donut is really irrelevant. Our F-4 Phantoms and many other aircraft all had monochrome indexers—all three segments: slow chevron, donut, and fast chevron were red—and these worked fine. In the Hornet, I focused more on the AOA bracket in the HUD and very little on our separate AOA indexer. If the FAA prefers blue for the donut, then that is acceptable to me."

From the Civilian Aviator: The reason that the earlier AlphaSystems AOAs have a green donut is because the earliest devices we tested used a blue donut and that particular blue was a very blurry and un-defined presentation. In early test flights, we really disliked that color so we squawked the display and the manufacturer changed it to green, at our request.

In June 2014, we swapped out the dual Legacy indicators for the latest dual EAGLE display. It is identical to the Legacy in functionality and includes two additional triangular display segments. The big difference is that now—at the suggestion of the FAA SAD (Small Aircraft Directorate)—the donut is BLUE again. FAA is now suggesting blue as a REFERENCE color, meaning neither "Good" nor "Bad", meaning neither "Fast" nor "Slow", simply meaning only "you are here"

Which, of course, is exactly what the donut is: a Reference Alpha.

Having now, perhaps 800 hours with the bright green Legacy donut, and given that I am the principal one who raised Cain and got the early, fuzzy indistinct blue changed to the sharp clear green now used in the Legacy AOA, I was certain that I'd just hate the new blue. I do not; the Eagle has a much crisper display than did the earlier Legacy, and the donut is a bright and well-defined blue. On my first landing—this King Air is my personal aircraft—I barely noticed the color switch; the sharply-defined new blue is just fine. In our test flights, we don't notice the (green or blue) color so much as being aware that we have a solid donut that's neither Amber nor Red.

The two additional solid triangles are interesting. At first, I didn't see the purpose in having so many segments. Because I'm a "Keep It Simple" aviator, in some ways I still don't. But the Amber Triangle is a relatively large segment and is useful in drawing a pilot's initial attention to the previously-dark AOA display as it comes alive when slowing from Cruise, and then doubling in size as the adjacent Amber Chevron comes alive, too. That's nice. However I see no real purpose for the Red Triangle.

One huge improvement—unique to the Eagle in the AlphaSystemsAOA product line—is the setup configuration. Using the small hard-mounted Audio/Switch Panel, we are led down the configuration path by clearly understandable voice-responses to our pushbutton taps as we define/set the various Alpha points, voice/tone callouts, illumination, etc. This is a much better method than was used on earlier units, requiring a lot less computer expertise. I'm quite impressed at the new voice-assisted setup routine.

Installation and Calibration - from the owner of the shop that did the install: "From the installation perspective, the new Alpha Systems Eagle Angle of Attack (AOA) and the prior AOA devices are identical...with the exception being the remote audio/calibration selection box that's included with the Eagle AOA system. This additional feature only takes approximately an extra hour to install (depending on mounting location, etc.); but the benefit outweighs the slightly longer installation time, as the calibration procedure is much easier to understand with the voice-directed step-by-step instructions. The new AOA display is much improved, and would look "at home" in any aircraft no matter the age. Connectors and cabling are of the same high quality as used in prior Alpha Systems AOA kits. The Installation Manual has been greatly improved by recent editorial effort; there is more clarity...especially in the section explaining the Calibration/Configuration."

Kyle London, owner, Classic Aviation KSHD

From another Civilian ATP & CFII: "This simple yet effective device has the potential to significantly reduce the number of general aviation incidents attributed to low altitude stall/spin scenarios. The angle of attack indicator has been considered standard equipment in large turbojet equipment for years...and stall/spins in these aircraft are almost unheard of. Alpha Systems has developed an affordable AOA system for the general aviation community. Although my only experience with the Alpha Systems AOA was in the King Air 90, the Legacy display would be just as useful in any light single or twin. To be clear: I have not yet flown the Eagle AOA, which is substantially identical. Enhanced safety would be my primary reason for installing it in my aircraft, but an added benefit is that the AOA simply makes you a better pilot. With a direct indication of angle of attack in the cockpit, my approach is more stable and my landings are more consistent, with less float in the flare."

DISTRIBUTION

The Flight Test Report is placed in the public domain by its authors and will initially be distributed by them to the manufacturer of the Alpha Systems AOA Stall Warning System as well as to the FAA if installation guidance is sought for the Alpha Systems AOA Stall Warning Systems. Any applicant for any FAA Supplemental Type Certificate, PMA certification, or TSO approval, etc. may use this data freely.

This Flight Test Report will also be available to the American Bonanza Society's Air Safety Foundation, to the Aircraft Owners and Pilots Association (AOPA) Air Safety Foundation, and to the Experimental Aircraft Association (EAA) as well as others seeking information on the applicability of AOA Stall Warning Systems on general aviation aircraft. Other than payment for reproduction costs, no charge may be made for use of this research.

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David Ingalls Brown and Robert H. Baldwin

TWA Captain Ray Rotge and TWA Captain Mack Johnston