Flight Test – FINAL REPORT – Revision 3 - (4/10/17)
The EAGLE AOA display with Flap Biasing

in the

Beechcraft King Air 90 Blackhawk

AlphaSystems Angle of Attack Stall Warning System

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This Revision 3 - (3/22/17) report is available at
http://www.ballyshannon.com/air/aoaflighttestkingair90rev3.pdf
This Revision 3 is an update to earlier King Air 90 Flight Tests
Revision 1 - (3/30/11) on the LEGACY AOA display
http://www.ballyshannon.com/air/aoaflighttestkingair90.pdf
Revision 2 - (7/10/14) on the EAGLE AOA display
http://www.ballyshannon.com/air/aoaflighttestkingair90rev2.pdf

This flight test (Rev3) was flown to evaluate the information provided by the Alpha Systems Angle of Attack (AOA) Stall Warning System as displayed on the **Eagle AOA display with newly-introduced flap position sensors** 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**. This flight test (Rev3) focuses entirely on the features of flap-biased AOA software, an advance from earlier non-biased software. This report is otherwise very similar to Revision 2 - (7/10/14).**

TURQUOISE TEXT is used to emphasize the flap-biasing commentary and related data. This report is written to be understood most easily when displayed/printed in full color.

Flap Biasing—How it works

Just as the basic AlphaSystemsAOA calibration technique defines several V-speed set-points to identify important speed/alpha combinations, so does the Flap Biasing calibration. The Flap I/O Module informs the AOA computer whether the aircraft's flaps are deployed, and by how much. Then, additional set points are defined during the Flap Bias calibration procedure and are memorized by the same AOA computer so that the display will illuminate the donut when that configuration is repeated.

Each aircraft will be slightly different and most (Cherokee, Arrow, Lance, Bonanza, etc.) will have a different flap and airfoil design from this King Air C90. The unique set points for those aircraft will be saved in that aircraft's AOA system and that AOA display will illuminate the donut when its pilot has replicated that particular V-speed at that particular flap configuration.

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 Flap Biasing sensing and software offers improved precision and ease of Alpha control when flaps are deployed. The flap biasing makes a difference in an appropriate manner: the pilot can fly "on the donut" in all flap configurations.***
- ***The instrumentation provides clear, un-ambiguous, and easy to comprehend stall proximity information.***
- ***The King Air Flap Position Transducer should be placarded: "Any Adjustment to The Flap Rigging Or Flap Position Transducer Requires Recalibration Of The AOA System." This notice should be logged and added as an "Instruction for Continuous Airworthiness"***

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 4deg. 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 30deg. angle of bank, stall warning occurred at 96 KIAS and again consisted of activation of the stall warning audible horn. Actual stall in the 30deg. 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 30deg. 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.

NOTE: A sharp-eyed reader will notice a few instances herein where we have multiplied V_S or V_{SO} by 1.3, and that we use IAS (not CAS) for the Velocity. For very fine-grained analysis, one must indeed work with CAS values and then use the appropriate graph to change that back to IAS. We do not believe that level of precision is needed for the qualitative (not quantitative) goals of these flight tests "...to determine the usefulness of [this device's AOA guidance] at enhancing safety in the operation of general aviation aircraft". *[Thanks to Tom "Mr. King Air" Clements]*

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

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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

<u>Calibration:</u> 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 X 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 92 KIAS to 99 KIAS. See Table IV.

Optimum Alpha Angle (OAA)	OAA Airspeed Range at 9,800 Lbs.
1.3 V_{so}	92 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 7 KIAS for OAA.

Phase III: Representative weight flights for Alpha Systems AOA Stall Warning system
<u>NO SIGNIFICANT CHANGE from Previous Flight Test Report:</u> 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 (see: Rev2 report) 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.

In early 2017, as plans evolved to add a Flap Bias module to this King Air's currently-installed

AOA system—and being aware of a very minor rigging adjustment to one of the King Air 90 Blackhawk's flaps—it seemed wise to begin with a double-check of the 2½-year-old calibration data. That was accomplished in the three wings-level profiles, hence the turquoise highlights, below.

(KSHD AWOS: 1237Z Wind 3007, Visibility 10+, Ceiling 4200 OVC, T-3/D-12 A3019 Crew: Scott, Harris)

Configuration	Attitude (Deg. Bank)	Power (Ft-Lbs/Pitch)	**Weight (Lbs. approx.)**	**OAA/DONUT Airspeed Range (KIAS)**
Clean	0	300/Low Re-flown → →	9,800 just prior to FlapBias	99-107 92-105
Clean	30	300/Low	9,780	98-112
Gear Up/Flaps Approach	0	300/Low Re-flown → →	9,760 just prior to FlapBias	97-108 90-101
Gear Up/Flaps Approach	30	300/Low	9,740	99-111
Gear Down/Flaps Full	0	300/Low Re-flown → →	9,720 just prior to FlapBias	92-99 89-100
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 92-112 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 Vso or its AOA equivalent, when banked) during a variety of normal maneuvering configurations and normal attitudes typical of General Aviation operations.

Phase IV: To begin the flight evaluation of the newly-created Flap-Biasing software, we first re-verified the aircraft's speeds/alphas at THREE configurations (all were at Idle Power, GEAR Up or Down, FLAPS at Approach or Full, and wings level) and then re-flew the three turquoise-highlighted routines (in Table V, above) to confirm that no significant shift in calibration had occurred:

DIRTY Stall: V_S (KIAS)	**1.3 X V_S (KIAS)**	**Calibrate OAA (KIAS)**
72 Just prior to FlapBias 69	87 Just prior to FlapBias 89.7	94 Just prior to FlapBias 90

Table VI

RECONFIRMING - Calibrating the OAA

Calibration of the OAA was originally 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 configuration (at idle power, GEAR DOWN, FLAPS FULL, and wings level) at approximately 9,800 lbs. to calibrate the OAA at 94KIAS. Once calibrated, the OAA displayed at a range of airspeed from 92KIAS to 99KIAS. Two and a half years later, the system remains stable. See Table VII.

Optimum Alpha Angle (OAA)	**OAA Airspeed Range at 9,800 Lbs.**
1.3 V_{so}	92 KIAS to 99 KIAS
	↓↑... very similar ...↑↓
Several Years later, it's still at → →	**90 KIAS to 100 KIAS**

Table VII

Alpha Systems AOA Stall Warning OAA is a Range

Calibration of Flap Bias Set-Points:
Taking considerable comfort in the stability of this 2½-year-old setup, the testing team then activated the Flap Biasing—calibrated exactly as the manufacturer suggests—EXCEPT THAT this particular aircraft already had a fully-calibrated AOA system. The initial AOA set-point calibration steps were not needed so Flap Bias became a retrofit executed by installation of a Flap Module I/O device and calibration of later-version AlphaSystemAOA software to this particular aircraft. Each aircraft installation is unique and must be individually calibrated.

The Flap Bias calibration flight routine requires very smooth air and precise speed control to define additional flap-related V-speed set-points in four conditions:

- GearUp/FlapsApproach flown at 1.3V_{so}, then at
- GearDown/FlapsFull flown at 1.3V_{so}, followed by a second pass at
- GearUp/FlapsApproach flown at 1.1V_{so}, then at
- GearDown/FlapsFull flown at 1.1V_{so}

Calibration of AlphaSystemsAOA Flaps Bias software occurred on Saturday March 18, 2017.

The aircraft was then landed and refueled. Then, with the Flap Bias now fully calibrated, the aircraft was flown on the SAME PROFILES in the SAME ORDER as shown in Table V, above. Fuel burn was 181 pounds, so the aircraft weights almost-perfectly replicated the earlier weights in Table V. The day was warming as the First Flight with Bias concluded in late morning; light turbulence occurred occasionally.

On March 21, 2017 two more flights were accomplished.

That data is reported in Table VIII, below

After three identical-profile test flights with Flap Bias, we have high confidence in the Table VIII data.

(Flight One: KSHD AWOS 1506Z: Winds Calm, Visibility 10+, Clear below 12000, T9/D6, A3004 Crew Scott, Turner).
(Flight Two: KHSD AWOS 1108Z Wind Calm, Visibility 7, Ceiling 3400 BKN T6/D6 A2995, Crew: Scott, Kiser)
(Flight Three: KSHD AWOS 1231Z Wind 0903, Visibility 10, Ceiling 3400 OVC T7/D6 A2995, Crew: Scott, Kiser)

A COMPARISON of **OAA/DONUT Airspeed Ranges – Four Flights**

BEFORE Flap Bias and AFTER Flap Bias

Configuration **To investigate**	Attitude (Deg. Bank)	Power (Ft-Lbs/Pitch)	**Weight (Lbs. approx.)**	**OAA/DONUT Airspeed Range (KIAS)**	**Stall Shudder (KIAS)**
Clean 1.3 $V_{S\ Clean}$	0	300/Low	9,800	**92-107**	**N/R**
			Bias Flight One →	**97-112**	**N/R**
			Flight Two →	**96-110**	**81**
			Flight Three →	**98-112**	**81**
Clean 1.3 $V_{S\ Clean}$	30	300/Low	9,780	**98-112**	**N/R**
			Bias Flight One →	**98-114**	**N/R**
			Flight Two →	**97-110**	**89**
			Flight Three →	**99-114**	**89**
Gear Up/Flaps Approach 1.3 $V_{SO\ Approach}$	0	300/Low	9,760	**97-108**	**N/R**
			Bias Flight One →	**97-110**	**N/R**
			Flight Two →	**96-109**	**73**
			Flight Three →	**97-109**	**75**
Gear Up/Flaps Approach 1.3 $V_{SO\ Approach}$	30	300/Low	9,740	**99-111**	**N/R**
			Bias Flight One →	**96-110**	**N/R**
			Flight Two →	**97-110**	**82**
			Flight Three →	**97-110**	**84**
Gear Down/Flaps Full 1.3 $V_{SO\ Landing}$	0	300/Low	9,720	**92-99**	**N/R**
			Bias Flight One →	**89-98**	**N/R**
			Flight Two →	**90-98**	**65**
			Flight Three →	**89-98**	**66**
Gear Down/Flaps Full 1.3 $V_{SO\ Landing}$	30	300/Low	9,700	**95-101**	**N/R**
			Bias Flight One →	**88-98**	**N/R**
			Flight Two →	**89-99**	**75**
			Flight Three →	**89-100**	**74**

Table VIII (this is an update/edit of Table V)

A COMPARISON of Flaps-Biased OAA/DONUT Speeds
at Representative Configurations and Attitudes

STALL SPEEDS - ZERO THRUST

NOTES:
1. MAXIMUM ALTITUDE LOSS DURING STALL RECOVERY IS APPROXIMATELY 850 FEET.
2. POWER FOR ZERO THRUST (APPROXIMATELY 150 FT-LBS TORQUE AND 1750 PROPELLER RPM).
3. POWER-OFF STALL SPEEDS ARE APPROXIMATELY 4 KNOTS HIGHER THAN THOSE WITH ZERO THRUST.

EXAMPLE:

WEIGHT	9,650 LBS
POWER	ZERO THRUST
GEAR	DOWN
FLAPS	35%
ANGLE OF BANK	30 DEGREES
STALL SPEED	86 KCAS

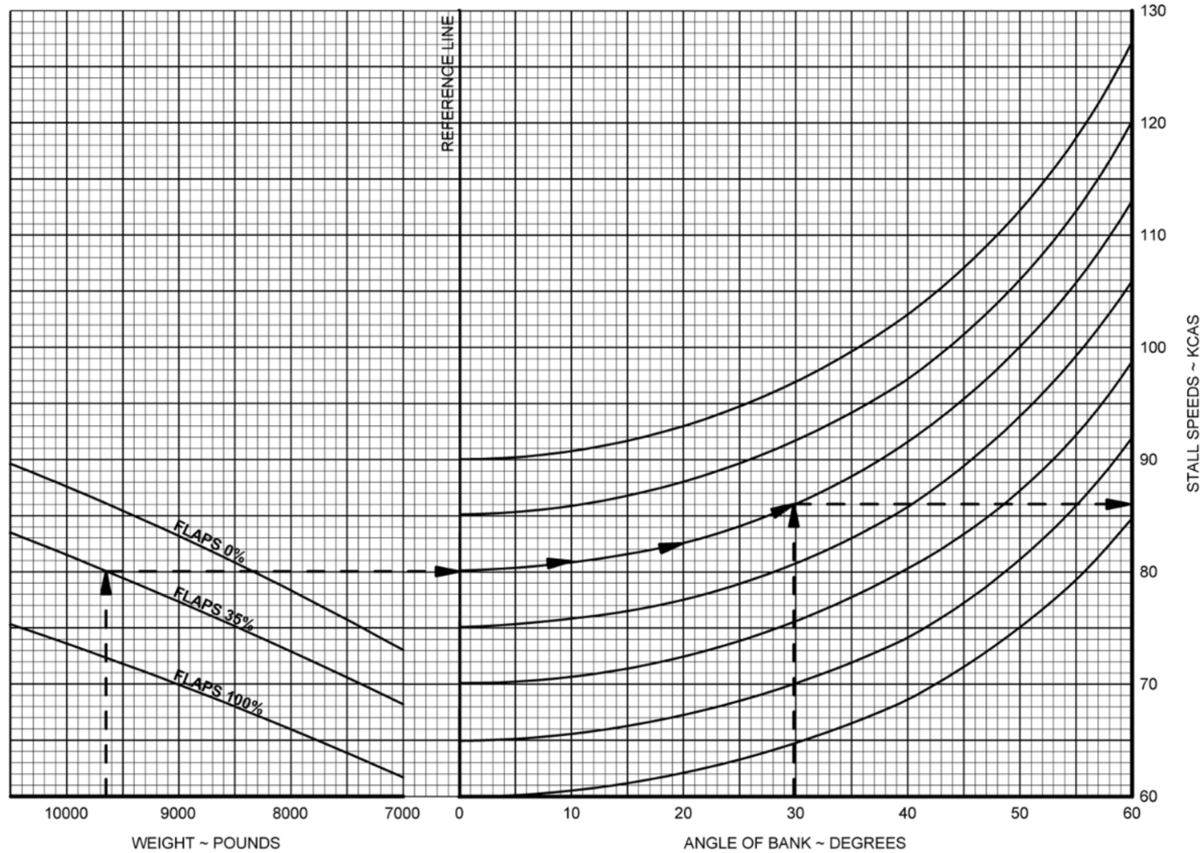

Table IX (for the Raisbeck EPIC C90 Blackhawk)

DISCUSSION:

1: The flight test King Air C90 Blackhawk is substantially identical to the Raisbeck EPIC C90 with the Blackhawk engines. From this Stall Speed vs. Weight graph, we can compare our Table VIII flight test data to Raisbeck's Table IX flight-tested data to see whether the flap bias input is accurate. Using the Table IX graph (while recognizing that our flights' power was set a bit higher at ~300 Ft-Lbs), we determined:

In the Landing configuration at 9,720 lbs., we find a wings-level $V_{SO\ Landing}$ stall speed of 73 KIAS which would suggest an Optimum (Donut) AOA speed at 1.3 $V_{SO\ Landing}$ of 95 KIAS. That compares quite nicely with our flight test data for that configuration both with and without flap biasing … which is what one would expect.

In the Clean configuration at 9,800 lbs., we find the $V_{S\ Clean}$ stall speed of 87 KIAS which would suggest an Optimum (Donut) AOA speed at 1.3 $V_{S\ Clean}$ of 113 KIAS. That airspeed again compares favorably with our flight test data results for the flap-biased Clean configuration. It's only 1.7 KIAS higher than our averaged "high end of range" data for our three test runs.

Given the comparison with this stall speed graph, we can draw two conclusions:

- The Optimum (Donut) AOA is a relatively linear progression from 1.3 $V_{SO\ Landing}$ to 1.3 $V_{S\ Clean}$
- The Flap Bias calibration procedure allows for accurate replication of the Beechcraft King Air 90 Blackhawk's 18 KIAS difference between 1.3 $V_{SO\ Landing}$ and 1.3 $V_{S\ Clean}$ airspeeds or the 14 KIAS difference between the graph-provided $V_{SO\ Landing}$ and $V_{S\ Clean}$ stall speeds

Another thing we can take away from Table VIII: In the $V_{S\ Clean}$ configuration, it seems we were right all along in that flap biasing in an AOA system makes little difference—in the case of a "Plain", "Split" or "Slotted" flap system. That's surely not true of a "Fowler" flap system.

In the case of the King Air C-90, there's only 4 KIAS difference. Yet that 4 KIAS difference likely indicates a minor shift in AOA with the King Air's slotted flaps as suggested by the graph in **"Aerodynamics for Naval Aviators"**. To dig deeper into this subject, please review our test pilot Marine Colonel Aitken's more-extended analysis:
http://www.ballyshannon.com/aoahowtoflyalpha.abs.2015.html#flapbias

The effect of Flap Bias is to allow the pilot to **"FLY THE DONUT"** through the entire range of this AOA display, regardless of aircraft configuration. That is a nice outcome and is an improvement to the design. It remains true, however, that the non-biased AOA could be flown in much the same manner in this same aircraft. But a different (off-donut) segment of the AOA display would be illuminated (and must be memorized) when flaps are deployed.

A REMINDER: Our purpose throughout these AOA flight tests has been to determine if the AOA system provides ample, early, and appropriately continuous warning of stall approach regardless of bank angle, weight or G-loading…and we believe these cumulative test results clearly show that it does. Our purpose has never been to determine the level of AOA sensing and indication precision provided by the system.

2: The Gear Down/Flaps Full configuration data leads us to another point. When airborne, it was immediately apparent that—when deep into VERY slow flight, the Speed/Alpha instrumentation was significantly improved. The Pilot Flying is very familiar with this aircraft and its non-biased donut setting; he immediately recognized that the low-speed donut had shifted slightly (as it should have) to suggest a slower target airspeed, at a higher Alpha—one far more likely to be accurate in the GearDown/FlapsFull configuration.

An example: the test aircraft was cut off its Final Approach by a much slower aircraft. The test crew took advantage of the opportunity to evaluate if a close-follow was feasible. The close-follow (at near-Idle with GearDown/FlapsFull) was "comfortable" and completely under control as the King Air delayed its touchdown (until halfway between KSHD Rwy23 Taxiway F and G) so as to allow the slower aircraft to exit the runway. The test flight then landed and was fully stopped in about 900 ft. and also exited easily at Taxiway F. Throughout, there was always a conservatively safe distance behind the much slower aircraft.

3: The Flap Bias calibration procedures specify set-points at both A: the conventional $1.3V_{so}$ setting and B: another at $1.1V_{so}$ with a smaller margin above stall. The crew was curious which of the two was being displayed as the donut when any flaps are deployed. The manufacturer explained that the DONUT displays at $1.3V_{so}$ (a comfortable margin above stall) and the RED TRIANGLE (imminent stall) illuminates at $1.1V_{so}$. That calibration logic should offer more precision in Alpha guidance at the very edge of imminent stall. At $1.1V_{so}$, the software is designed to illuminate the red triangle only. We report that it appears to do so. Further verification would be wise. Our testing has been qualitative, not quantitative.

4: The Flap Position Transmitter should have a placard to warn the maintaining crews and a parallel Instruction for Continuing Airworthiness*. It will be far too easy for a technician to adjust the transmitter or flap rigging while being unaware that the aircraft has a AOA that's dependent on its rigged position. **[Our thanks to Paul Sneden]*

So, we installed a placard to serve as an example → → → → → →

5: The Flap Bias Calibration Instructions are very complex and difficult to follow. Yet, they must be executed precisely and perfectly while airborne. The manual text intermixes instructions for digital and analog systems as if they were one system. This was all very confusing, requiring several calls back to the factory. Throughout, the senior leaders at AlphaSystemsAOA were very accessible and helpful. Even so, and after very careful pre-flight briefings, the crew still managed to press a CAL or SET button at the wrong time! Two attempts were required calibrate the Flap Bias correctly. Simpler and clearer instructions would help a lot.

6: While it was not a part of this evaluation, the crew noticed that the voice callouts—at the "Boing! Getting Slow" alpha point—had gone silent as the aircraft was being maneuvered into and out of the donut speed range. As it turns out, this recent version of software mutes the annunciation after repeated callouts, to eliminate nuisance calls. It re-sets after the aircraft has accelerated to a faster regime. The muting was a good idea and has been very nicely implemented. It functions like this:

- SLOWING FROM CRUISE: The "Too Slow" and "Boing! Getting Slow" audio callouts are first armed when the AOA display comes alive as the aircraft slows from cruise speed. The arming is auto-enabled at the (Yellow Chevron + Green Bar).
- SLOWING TO APPROACH SPEEDS: The "Boing! Getting Slow" audio will call out one time only when the aircraft slows to the (Fast-Half Blue Arc) from the (Fast-Half Blue Arc + Yellow Chevron).
- Then—if the aircraft has speeded back up—the "Boing! Getting Slow" audio will be re-armed at the (Fast-Half Blue Arc + Yellow Chevron) transition point. There is no limit on the number of these re-arms.
- IN NEAR-STALL REGIMES: The "Too Slow" audio will play three "Too Slow" callouts when the aircraft slows to the (Red Chevron + Red Triangle). Then—if the aircraft has speeded back up to the Blue Donut—the "Too Slow" audio will be rearmed to play three "Too Slow" callouts when next at the (Red Chevron + Red Triangle). There is no limit on the number of these re-arms.
- DEEP INTO THE STALL: The "Too Slow" and "Boing! Getting Slow" audio is disabled when the (Red Triangle) is illuminated. The aircraft is now very slow: quite likely rolling on the runway.

Phase V: 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 30deg. angle of bank and climbs up to a positive 10deg. 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 VI: 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 59deg. 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 20deg. 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 59deg. bank angle and positive 15deg. 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:

<u>From the Marine Aviator</u>, 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 <u>Airspeed</u> 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."

As for the Flap Biasing…the Flap I/O Module is a clever addition; it simply tells the AOA computer whether the aircraft's flaps are deployed, and by how much. The additional set points flown/defined in the Flap Bias calibration procedure (see Phase IV above) are memorized by the AOA computer so that the display can illuminate the donut when that configuration is repeated. Each aircraft will be slightly different and most (Cherokee, Arrow, Lance, Bonanza, etc.) will have a different flap and airfoil design from this King Air. The unique set points for those aircraft will be saved in that AOA system and that AOA display will illuminate the donut when its pilot has replicated that particular V-speed at that particular flap configuration.

<u>From the Civilian Aviator</u>: 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 as well. That's nice. However, I see no real purpose for the Red Triangle. [Correction in 2017: Yes, I do. We now know that "…at 1.1Vso, the audio callouts will annunciate just before the red triangle is illuminated and go silent when the red triangle is alone illuminated." I was seeing product evolution-planning that, in hindsight, makes sense.]

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." The recent addition of the Flap-Biasing module could not have been simpler: we identified a variable Flap Position Indicating voltage and used it as the signal. We also agree (with Paul Sneden who first suggested) that the Flap Position transmitter be placarded and an "Instruction for Continuous Airworthiness" be included in the Maintenance documents. 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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IN HONOR OF

David Ingalls Brown and **Robert H. Baldwin**

TWA Captain Ray Rotge and **TWA Captain Mack Johnston**