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SN 198A
SN 147/34-003A
Alpha Systems' Angle of Attack System for Mitsubishi MU-2 Aircraft

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MU-2

SERVICE NEWS

MITSUBISHI HEAVY INDUSTRIES, LTD.
NAGOYA AEROSPACE SYSTEMS WORKS
10, OYE-CHO, MINATO-KU, NAGOYA, JAPAN

JCAB T.C. : No. 198A
FAA T.C. : No. 147/34-003A

DATE: November 30, 2018

SUBJECT: Alpha Systems' Angle of Attack System for Mitsubishi MU-2 Aircraft

MODELS AFFECTED: All MU-2B Airplanes

As an FAA initiative to prevent and reduce Loss of Control (LOC) general aviation accidents, the FAA issued Memorandum No. AIR100-14-110-PM01 approving non-required Angle of Attack Indicator Systems for general aviation aircraft. Alpha Systems' Angle of Attack (AoA) System is FAA approved for installation on Mitsubishi MU-2B series aircraft of US registered. For non-US registered MU-2, it is the responsibility of the owners to obtain approvals from the local civil aviation authorities. Mitsubishi Heavy Industries America, Inc. (MHIA) assisted DepotStar, Inc., the original manufacturer, to customize Alpha Systems' AoA Eagle Display system in order to function with all flap positions (0, 5, 20, and 40 deg) at takeoff and approach to land phases of flights.

Alpha Systems' AoA System Installation Kits are available for both short-body and long-body airplanes:

1) Dual Eagle Pressurized AoA Installation Kit (Short Body) – Kit No. DSTR-AOA-9600DPK-MU-2-S
2) Dual Eagle Pressurized AoA Installation Kit (Long Body) – Kit No. DSTR-AOA-9600DPK-MU-2-L

Segment 2 "TOO SLOW" | Segment 7 VRef Normal Approach | Segment 10 VRef + 9 | Segment 11 VRef + 12 | Segment 12 VRef +15 ICING

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AoA Systems will improve the way you fly the airplane. An AoA System can aid you in the ability to fly consistent stable "on speed" approaches. This will often result in better landings, especially for the short body pilots. MU-2 AoA indicators mounted above the glare shield are a heads-up reminder of where you are in the airspeed and angle of attack realm.

The primary safety benefit of the AoA System is that it tells you when action is needed:

With an AoA display below the Blue Donut:

- Decrease bank and/or lower nose
- Increase airspeed
- Carefully Increase power as required in a coordinated manner
- Be aware, if the airplane is turning, these actions will result in the turn radius increasing
- If you are in the landing pattern, is the airplane too close to the runway?
- If on approach to a runway you may need to consider a go-around
- Execute a go-around if a stable adequate airspeed or reasonable bank angle cannot be maintained

At voice alert "TOO SLOW"

- Immediately reduce bank angle and/or lower nose and, after accelerating, carefully add power
- If on approach, go-around?

Impending Stall?

- A "TOO SLOW" aural warning will typically sound prior to the stick shaker, so earlier warning of an impending stall is provided

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Angle of Attack (AOA) Systems increase safety by indicating and alerting the pilot when entering a critical phase of flight which might result in LOSS OF CONTROL due to a stall unless immediate and appropriate action is taken. An AOA system does this by increasing pilot awareness of the MARGIN FROM STALL.

The attached articles from past MU-2 Magazines describe the safety and operational benefits of the Alpha Systems' AoA System.

If you have any technical questions on the AoA System, please contact Alpha Systems at the following contact information:

Alpha Systems AOA
DepotStar, Inc.
6180, 140th Ave. NW, Ramsey, MN 55303
Phone: 763-506-9990
Email: aoa@depotstar.com / Website: www.alphasystemsaoa.com

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Why Fly Angle of Attack (AOA)?

by Ron Renz

Angle of Attack (AOA) systems increase safety by indicating and alerting the pilot when entering a critical phase of flight which might result in LOSS OF CONTROL due to a stall or spin unless immediate and appropriate action is taken. An AOA system does this by increasing pilot awareness of the MARGIN FROM STALL.

How does AOA accomplish that? Perhaps a short engineering lesson will help.

The ability of an airplane to fly depends on the lift produced. As the AOA increases approaching stall, airflow begins to detach from the top surface of the wing, losing efficiency, until at some point airflow separates with a corresponding large decrease in lift. This is the critical AOA where the aerodynamic stall occurs (see Figure 1).

Figure 1: Wing Flow Separation at Stall

Aircraft stall speed varies with weight, load factor (i.e. G's), bank angle, power and density altitude. There are other factors that affect stall speed but these are the big ones. Angle of attack is defined as the angle between the relative wind acting on the wing and the wing chord line. This is depicted in Figure 2. During testing,

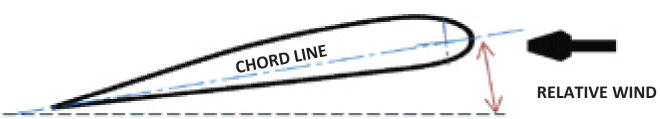

Figure 2: Define Angle of Attack

engineers measure lift and convert it into a dimensionless term called Lift Coefficient (C_L). Generally we represent the lift characteristics of the airplane using a graph of Lift Coefficient (C_L) vs Angle of Attack (for AOA, we typically use the term Alpha or use the Greek symbol α).

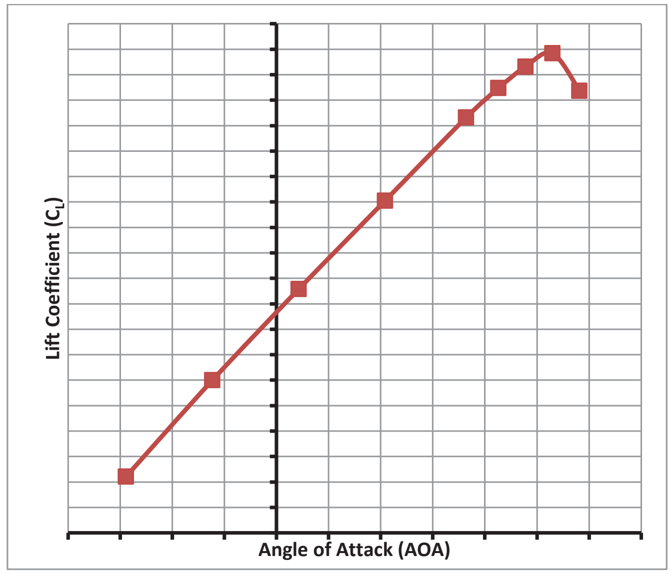

Figure 3: Typical Lift Curve Slope

Figure 3 presents a typical C_L vs α curve. Note the slope of the curve is approximately 0.1 C_L per degree of AOA. The beauty of this depiction is that C_L is a dimensionless quantity that includes lift (i.e. weight or G's) and airspeed in its calculation and allows engineers to analyze the airplane lift in any situation regardless of weight, wing loading (i.e. as it changes due to bank angle), etc. The stall of the wing is well defined by this curve as it occurs at the peak that is shown at the highest C_L. This is where the flow separates from the top of the wing, and the wing stalls aerodynamically. **THE WING WILL ALWAYS STALL AT THE SAME ANGLE OF ATTACK**, regardless of the airspeed, wing loading etc. All pilots should be familiar with the stall Speed vs Bank angle chart that appears in all Airplane Flight Manuals. Figure 4 presents the chart for the MU-2B-60 (Marquise). What this graph shows is how the airspeed changes as the load factor increases (i.e. increasing C_L) in level flight due to bank angle. Note that load factor can be increased not only by turning in level flight, but

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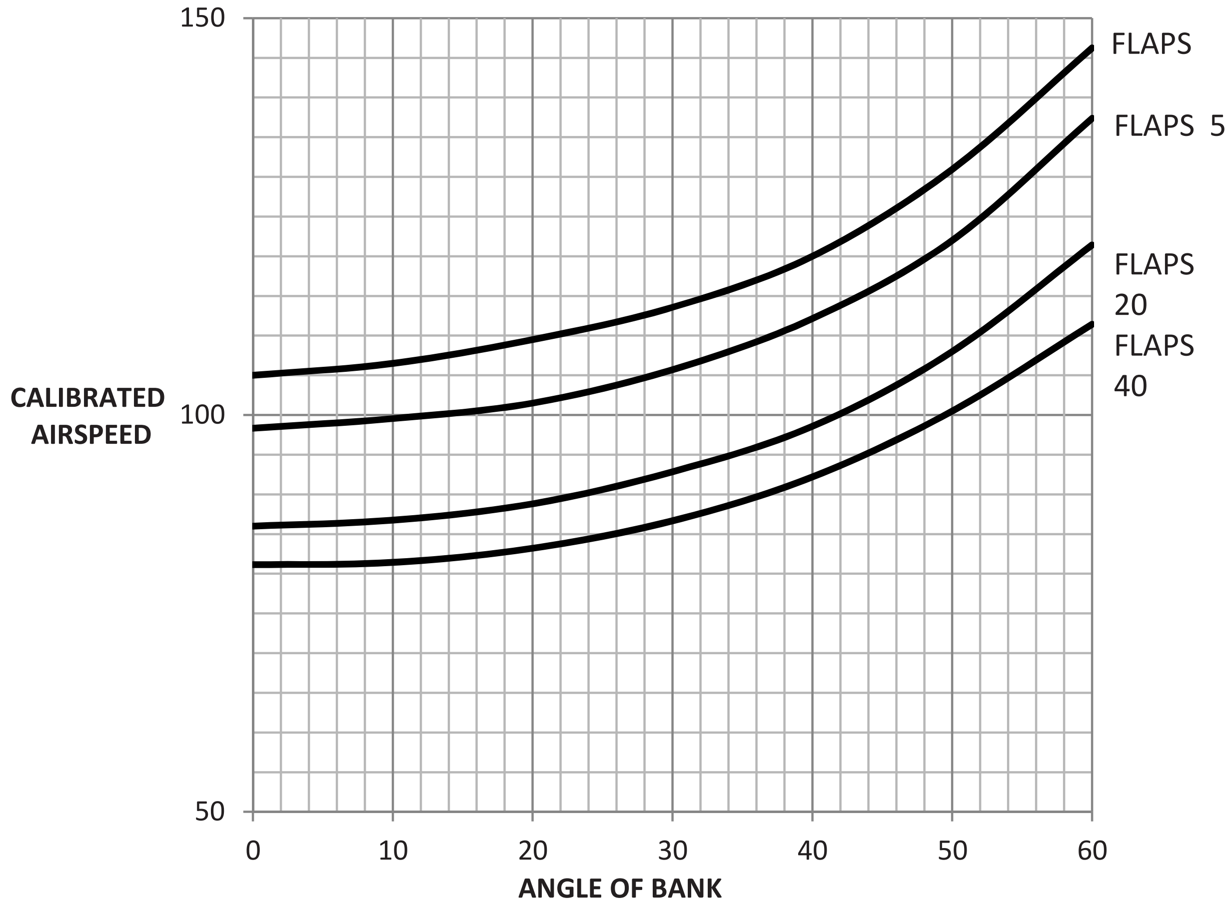


Figure 4: Stall Speed vs Angle of Bank MU-2B-60

also by pulling back on the yoke in any attitude, including wings level, so long as the airfoil has not reached the critical AOA. Incidentally, aerobatic pilots know they can fly an airplane at very low speeds, even zero airspeed, as long as there is no wing loading, and use that knowledge to perform various very slow speed maneuvers under full control.

Why have we not had Angle of Attack Systems before?

Actually, all certified airplanes have some means to measure angle of attack. These have traditionally been used to trigger the stall warning system. On the MU-2B airplane this Angle of Attack Sensor is a stall vane located on the leading edge of the right wing, and it triggers the stick shaker. So even though you may not have been aware of it, pilots have been flying with an angle of attack warning system since they started flying airplanes. For many decades, Navy pilots have been using angle of attack as the primary indicator to fly approaches to aircraft carriers. Many commercial airplanes have had angle of attack indication systems installed to aid the pilot, although some of these earlier AOA systems were quite costly.

Recent technology advances have allowed production of Angle of Attack Systems that accurately measure and display angle of attack information to the pilot at a low cost. An example of the system in the final approval process for the MU-2B is shown in Figure 5. A probe

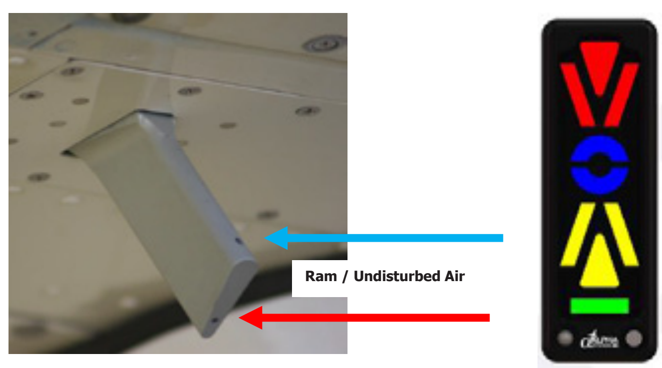


Figure 5: Alpha Systems Angle of Attack Indicator and Under Wing Probe

with no moving parts is used to sense the angle of attack. Pressure differential between the 2 ports on the probe is directly proportional to the angle of the air flowing across the probe, and thus AOA across the wing. This pressure difference is measured and the angle of the air flow is presented on a cockpit display that shows the AOA as 14 unique steps. How these relate to the

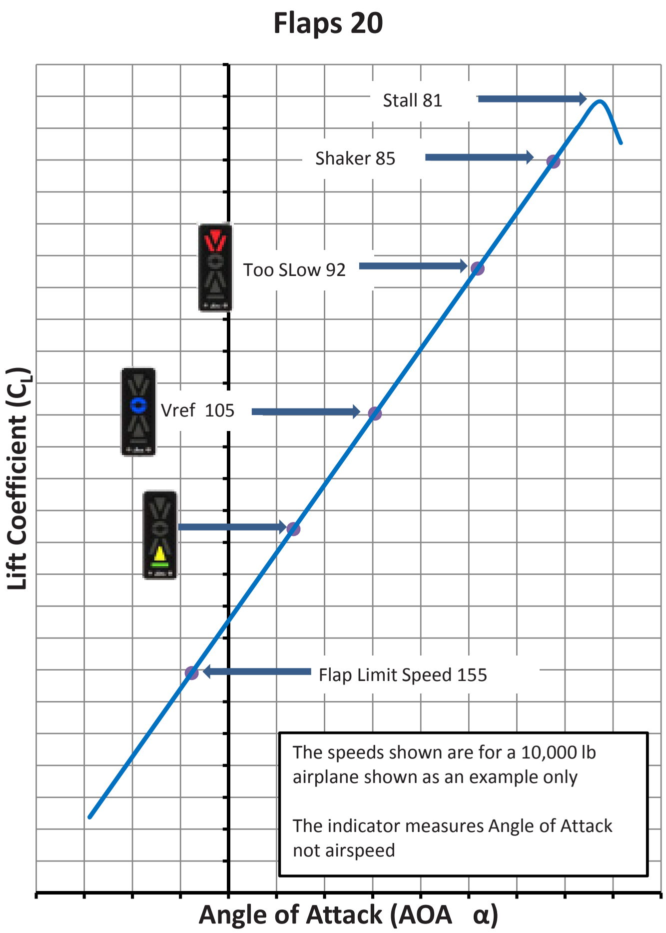


Figure 6: Lift Curve Slope and Angle of Attack Indication

lift curve slope is shown in Figure 6. The important understanding from this Figure 6 is that; **AS YOUR ANGLE OF ATTACK INCREASES, YOUR MARGIN OF AVAILABLE LIFT PRIOR TO STALL DECREASES**, which is displayed to the pilot in an easy to understand method.

Displaying Angle of Attack to the Pilot

This AOA system for the MU-2B uses an intuitive design to indicate to the pilot the relative angle of attack of the airplane and assist in establishing the appropriate approach speed. As the pilot slows the airplane, the angle of attack increases, the display steps thru the various segments as shown in Figure 7, where green is high speed, yellow is slowing toward approach speed, blue indicates normal approach speed, and red indicates **TOO SLOW** (or too high a G load). The red indications are coupled with a voice alert through the headset stating "TOO SLOW" prior to stick shaker. The basic premise used in the display logic is that the RED chevrons intuitively point down advising the pilot to lower the nose. BLUE is the appropriate approach speed, a circle, and yellow is GOOD, with the chevrons pointing up advising the pilot to raise the nose to achieve the appropriate approach speed.

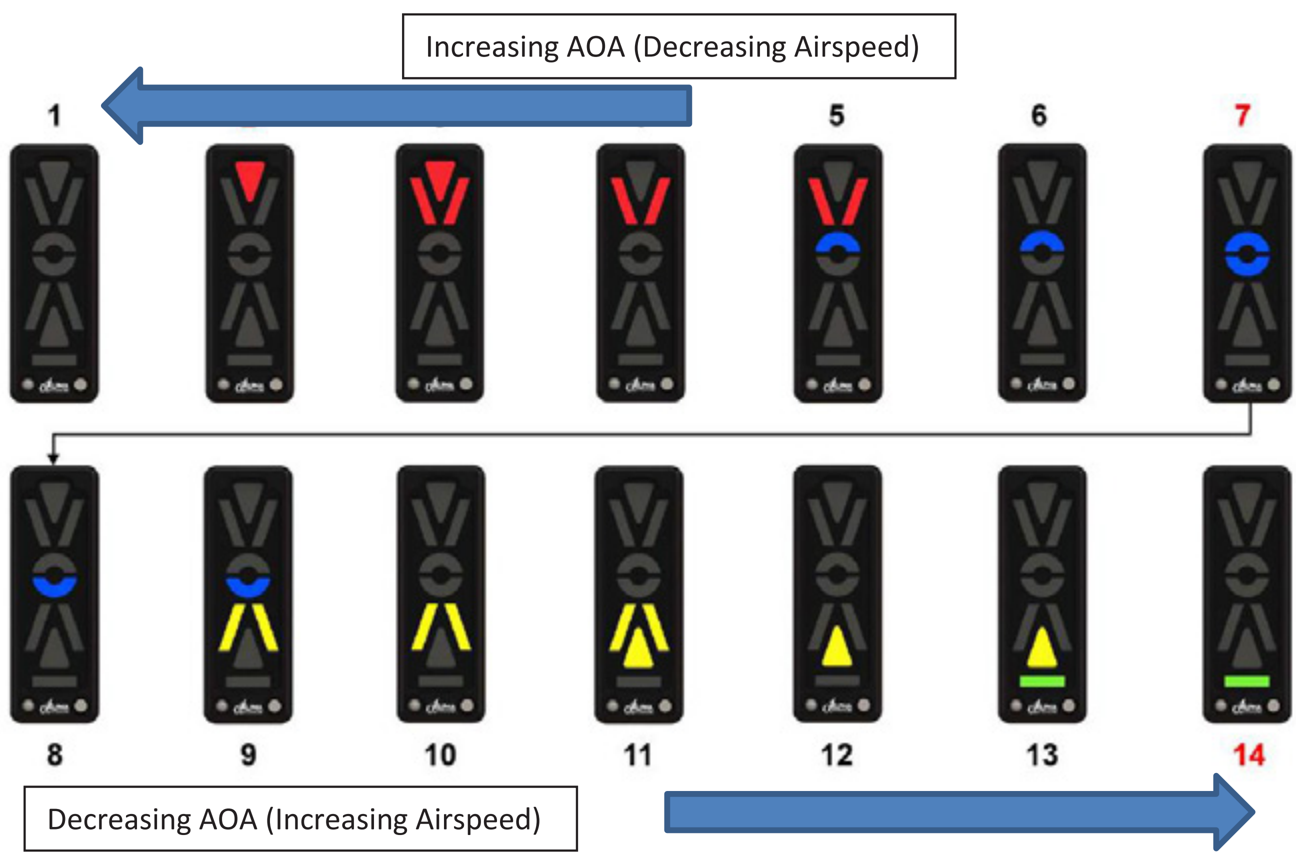


Figure 7: AOA Display Progression

How AOA improves safety.

When the military began installing angle of attack indicting systems in their airplanes, they reduced fatalities significantly. The FAA has determined that a very large portion of approach accident fatalities in general aviation airplanes occur on the base to final turn, in slow flight, or in accelerated stalls. The MU-2B AOA system provides visual and aural warnings as these flight conditions deteriorate. To be most effective, AOA indicators must at a minimum always be in the pilot's peripheral vision, so that when the pilot's focus is outside of the cockpit an indexer or display is **INSTANTANIOUSLY RECOGNIZABLE**. An ideal location is on the windshield center post of the MU-2B. With an AOA indicator in his peripheral vision as it changes from yellow to blue to red and then a "TOO SLOW" voice sounds in his ear, it will draw attention back into the airplane to the instruments, making the pilot aware of the deteriorating flight condition. The AOA system directly provides the pilot **AN INCREASED AWARENESS OF THE MARGIN FROM STALL** and intuitively indicates the action to take by pointing in the direction towards which the nose should be moved.

Angle of Attack is not just about identifying STALL.

AOA can be used to help pilots fly consistent and stabilized approaches. On the system developed for the MU-2B the AOA indicator blue donut is set to match the MU-2B V_{Ref} speeds at all flap settings (0, 5, 20 and 40). Flying the blue donut will automatically place the aircraft at the proper weight-adjusted AFM threshold speeds, providing a safe margin above stall. Other benefits of flying precise approaches are reduced tire and brake wear, and less float on flare and landing.

In a follow on article I plan to discuss how pilots can use an AOA system to help fly more precisely and get the most out of the airplane and the AOA system.

HOW TO USE ANGLE OF ATTACK (AOA)

A follow up to the article "Why Fly Angle of Attack?" that appeared in the January 2016 issue of MU-2 Magazine.

by Ron Renz

THE IMPORTANT PREMISE FROM MY LAST ARTICLE ON AOA BEARS REPEATING...

Angle of Attack (AOA) systems increase safety by indicating and alerting the pilot when entering a critical phase of flight which might result in LOSS OF CONTROL due to a stall or spin unless immediate and appropriate action is taken. An AOA system does this by increasing pilot awareness of the MARGIN FROM STALL.

Also repeated here is the most important graphic from that article. The Lift Coefficient vs AOA graph (Figure 1) provides important details about the airplane flight characteristics which an AOA indication system provides to the pilot.

So how does one make the best use of that information? Comments made in this article are general in nature, but the details refer directly to the AOA system that has been developed for the MU-2B.

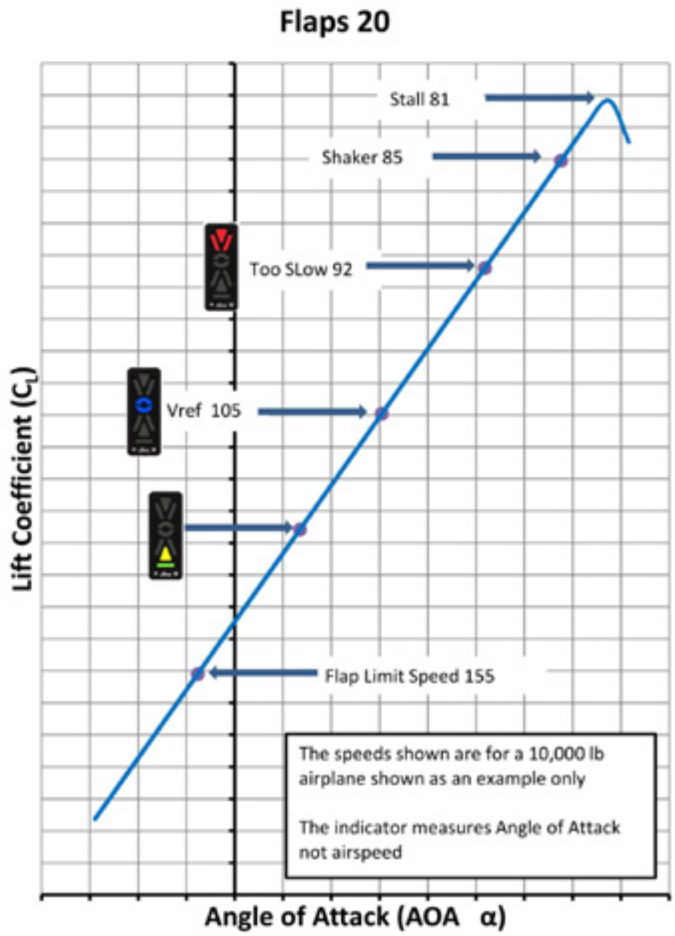
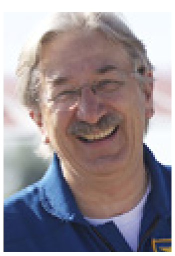


Figure 1 Lift Coefficient vs AOA



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Normal Operations:

Let's start with normal operations. Use the AOA indicator's blue donut to verify V_{Ref}, i.e. use it as a cross check for the Checklist-specified speed. (V_{Ref} will be used in this article to describe the recommended threshold crossing speed from the FAA Accepted Checklist tabular data.) If a large difference exists between AOA indication and the checklist V_{Ref}, verify the gross weight and recheck your V_{Ref} calculation from the checklist. If the weight/V_{Ref} calculation is not causing the discrepancy, then you must disregard the AOA indicator, because the FAA has determined that the AOA system is a secondary instrument only and the airspeed indicator is primary. As always, for gusty crosswind conditions, add ½ the steady stated wind plus all of the gust, but not to exceed 10 knots to your V_{Ref} airspeed. This is about 3 to 4 AOA segments. Therefore, in the worst case crosswind adjustment, fly the segments shown as V_{Ref} + 9 or V_{Ref} +12 knots (Figure 2.)

Now, fly the speed just verified with the AOA indictor using the airspeed indicator as the primary reference, especially during IFR approaches, since the Glideslope and Localizer indications are on the instrument panel near the airspeed indicator. The big benefit here is that the pilot now knows the margin from stall at the current weight and configuration. Refer to Figure 1, the Lift Coefficient vs AOA graph. This shows that at V_{Ref}, there is a comfortable margin from stall. This knowledge provides confidence in the numbers rather than arbitrarily adding 5 knots for the wife, 5 knots for the kids, and 5 knots just for good measure. At minimums, begin the transition outside; keep AOA in your peripheral vision with the goal that by 50 feet above touchdown, you will be at the target speed and AOA. At 50 feet, start a normal deceleration and be aware that, at touch down or just before touchdown, you may hear the "TOO SLOW" message. If you train yourself to fly this way, you will automatically become a more precise pilot, become much more in tune with the airplane, and enhance your ability to fly according to the numbers. This will help reduce wear and tear on the airplane, tires and brakes, and provide comfort that landing distances will be achieved reliably.

In the pattern, keep the AOA indicator in the scan. AOA will help in maintaining proper stall margin, especially when turning. In a turn, the load the wing must carry increases, and in order to maintain altitude, AOA must increase and the margin above stall must decrease. However, even with stall margins slightly decreased during level, circling turns, margins should still be more than adequate, and above the blue donut, if proper profile airspeeds are maintained. Of course, anticipate adding small amounts of power during level turns to maintain proper airspeed as per the SFAR profiles. Use the AOA indicator as a guide to help determine how much power to add during the turn. Note that airspeeds called for in the SFAR 108 profiles

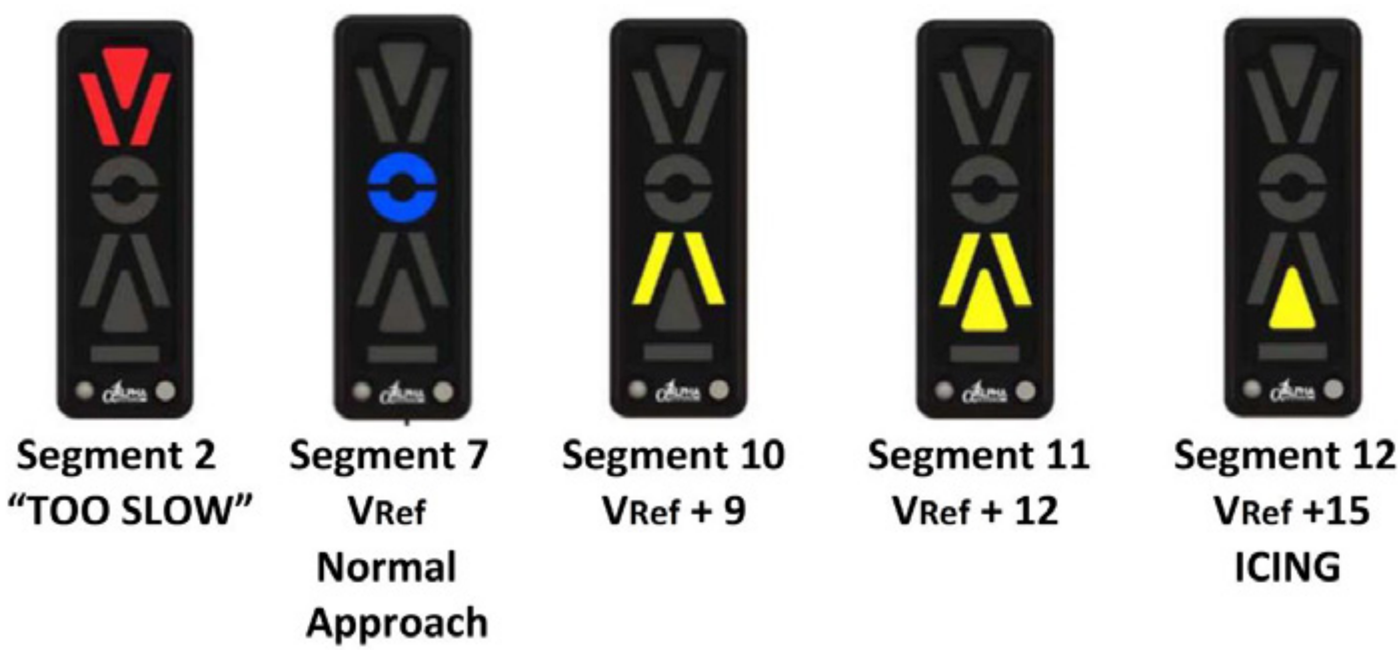

Figure 2 Selected AOA Segments

provide adequate margins above stall as long as bank angles do not exceed 30 degrees.

On descent to landing, AOA can help fly a precise glide path. Use AOA to help control the pitch angle and airspeed, and use power to control descent rate. Remember the pneumonic that your instructor used during IFR training? “Pitch controls airspeed, power controls rate of descent.” This really means pitch controls AOA, and now you know why this is important. As you learn to use AOA, remember to point the nose in the direction the AOA arrow indicates. For example, when slow, the shapes of the AOA indications point in a downward direction. Therefore, proper response is to push the nose down. Conversely, when fast, the AOA arrows point up, telling you to raise your nose. AOA is an intuitive indicator.

As the airplane accelerates on takeoff, keep the AOA indicator in your peripheral vision and plan to accelerate past the Blue Donut into the yellow range as the airplane climbs away from the runway.

Non Normal Operations, the Real Safety Benefit:

Where the AOA will most likely have the most marked safety benefit is the circling IFR approach. Imagine you’ve just shot a great minimums approach, and now you need to circle. Where is your attention focused? Often, you’re outside the cockpit keeping the runway environment in sight. Then, out of the corner of your eye the AOA display transitions to the red chevrons. You notice this. If you are circling to the right, AOA will be in your direct vision, and if circling to the left, AOA will still be in your peripheral vision. Red chevrons should bring you back to the cockpit instrument panel and alert you to the threat of low airspeed and possible low altitude, thus providing time for you to correct the situation while there is still plenty of margin from stall. If you don’t notice the display, the next indication will be the voice alert “TOO SLOW” in your headset. Tests conducted on the M-2 show that there is ample margin at the voice alert to correct the situation if prompt action is taken. Abandoning the landing, and executing a missed approach may be the safest action to take.

Let’s assume that an engine failure occurs shortly after liftoff. With runway remaining, the pilot can focus outside and execute an emergency landing, while keeping the AOA indication in his peripheral vision and keeping the airplane flying with adequate stall margin during this critical maneuver. If there is not enough runway remaining, while transitioning to single engine climb, if the speed deteriorates, the AOA indictor can help in several ways. If the airspeed or AOA deteriorates away from best climb toward stall, the red chevrons will be the first indication, alerting the pilot to take action. Lowering the nose to increase airspeed is the appropriate response. If the red chevrons are not noticed, the next indication would be the voice alert “TOO SLOW,” bringing attention to what is now a critical problem. At the “TOO SLOW” alert, the airplane is at or near the minimum control airspeed and well below V_{YSE}, requiring immediate action to rectify the situation. Lower the nose and reduce drag prior to potential loss of control. Feather the engine when time permits. Check gear position and landing lights. Leave flaps in their takeoff position until clear of obstacles, at which point accelerate and retract flaps on schedule. Once rectified, the climb can continue.

During a missed approach or go around, either multi engine or single engine, a potential loss of control is again lurking nearby. AOA can again help alert the pilot if loss of control is imminent. The scenario is virtually identical to the engine failure on takeoff, except that if flaps are at 40 for landing, immediately select 20 and establish a climb attitude.

These are just three potential scenarios where the AOA system may mean the difference between loss of control and a non-event. In each, information is available to alert the pilot of a potential loss of control in the form of a visual indication in his field of view, and, possibly, a voice alert of “TOO SLOW” in his headset. The response is always the same - focus back to the cockpit instruments, lower the nose, reduce drag, add power (as appropriate) and maintain control of the airplane.

Icing:

Icing will change the Lift Coefficient to AOA characteristics. A wing covered with ice will require a higher AOA to provide the same lift, and the stall angle of attack will be reduced compared to a clean wing. The MU-2B Checklist says: “When landing with any ice accumulation on the wing, increase the computed V_{Ref} by 15 knots.” This quantifies what happens to the wing lift characteristics for the MU-2B. Use AOA segment 12 shown in Figure 2 when determining the proper speed to use for the approach. On the MU-2B installation, AOA probe heat is provided whenever the right hand pitot heat is turned on. Like all airplane systems, this needs to be verified functional before relying on it in icing conditions.

Other:

There will be an AOA for best climb, both **V_X** and **V_Y**. Testing conducted for the MU-2B AOA system did not determine these data points. Each pilot can determine the AOA for **V_X** and **V_Y**, but they will be among the higher yellow segments.

Conclusion:

AOA can provide a substantial safety advantage when used by a trained pilot, providing ample warning of deteriorating flight situations. The FAA has determined that adding AOA as a supplemental system can significantly reduce loss of control mishaps.

IMPORTANT POINTS TO REMEMBER:

Keep the AOA indicator in your peripheral vision to monitor lift reserve, especially during head-out-of-cockpit flying.

If below Blue Donut, it is time to do something. Actions to take are:

- Decrease bank and/or lower nose
- Increase airspeed
- Increase power as required in a coordinated manner
- Be aware that if the airplane is turning, all these actions will result in the turn radius increasing. If you are in the landing pattern, is the airplane too close to the runway?
- If on approach to a runway you may need to consider a go around.
- Execute a go around if a stable adequate airspeed or reasonable bank angle cannot be maintained.
- At voice alert "TOO SLOW," immediately reduce bank angle and/or lower nose and, after accelerating, add power.
- If on approach, go around?
- The "TOO SLOW" aural warning will typically sound prior to the stick shaker, so earlier warning of an impending stall is provided.