Angle of Attack

Common Myths and Misunderstandings

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CHRIS ZAVATSON
WWW.N91CZ.NET
CHRIS.ZAVATSON@YAHOO.COM

Angle of Attack

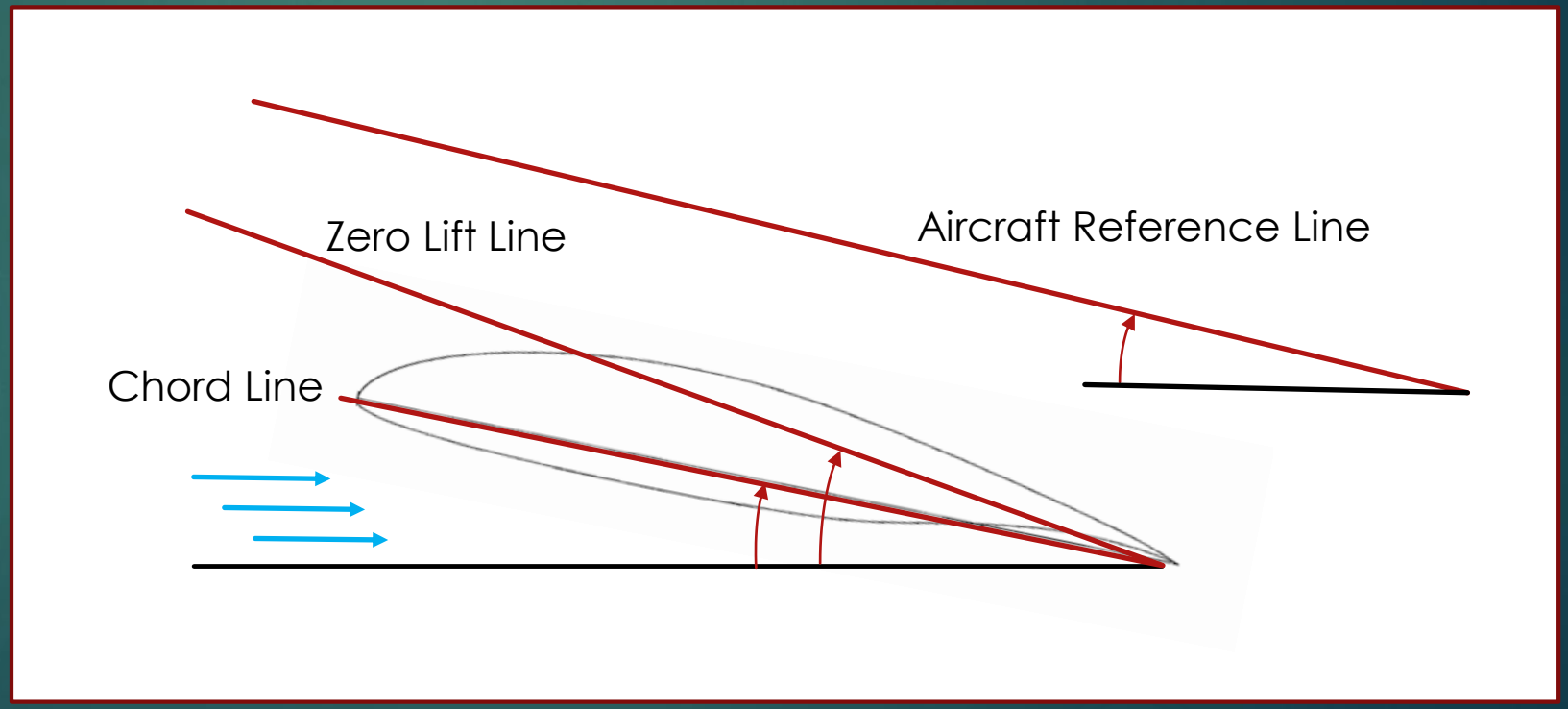
- Misunderstandings about Angle of Attack
  - Factors that that affect stall AoA
  - Characteristics of AoA Measurements
  - AoA and the Navy
- AoA instruments in light GA
- How to stay safe without AoA or other Stall warning device

Angle of Attack
Basic Definitions

Angle of Attack relative to what?

Can be one of several fixed references:

1. Chord Line
2. Zero Lift Line
3. Fixed Reference Line



Angle of Attack

- An often repeated phrase:

"A wing can stall at any airspeed but always stalls at the same angle of attack!"

- Yes/No/Maybe?
  - Several Factors affect the angle of attack at stall – some by a little, some by a lot.

Angle of Attack

Six Factors that affect Stall AoA

- 1 - Flap Position
- Cl_{max} increases as Stall AoA decreases

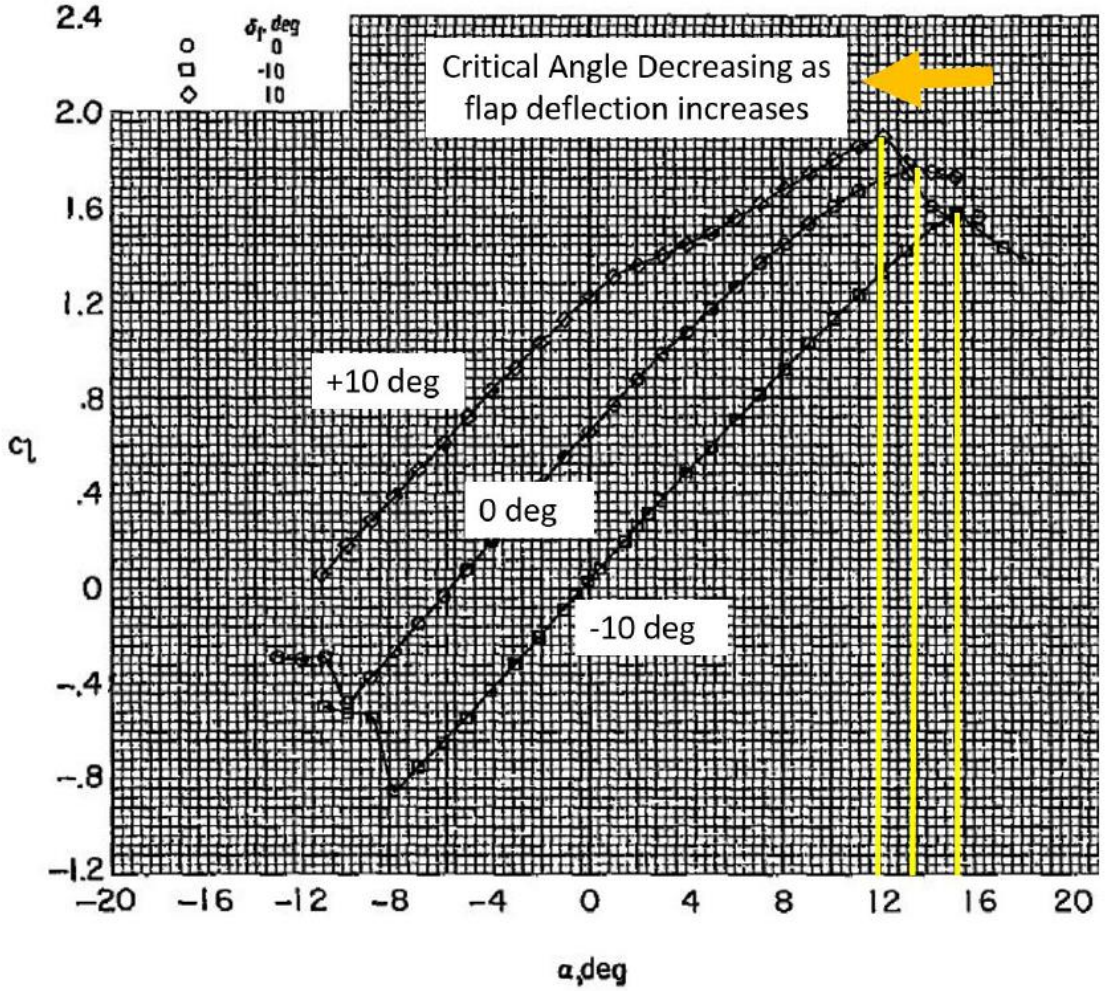


Figure 1, Effect of Flap Deflection on Critical AoA, NASA TP-1865

Angle of Attack

Six Factors that affect Stall AoA

- 1 - Flap Position
- Between -10 and +10 deg flap ➔ 9 degree change in AoA

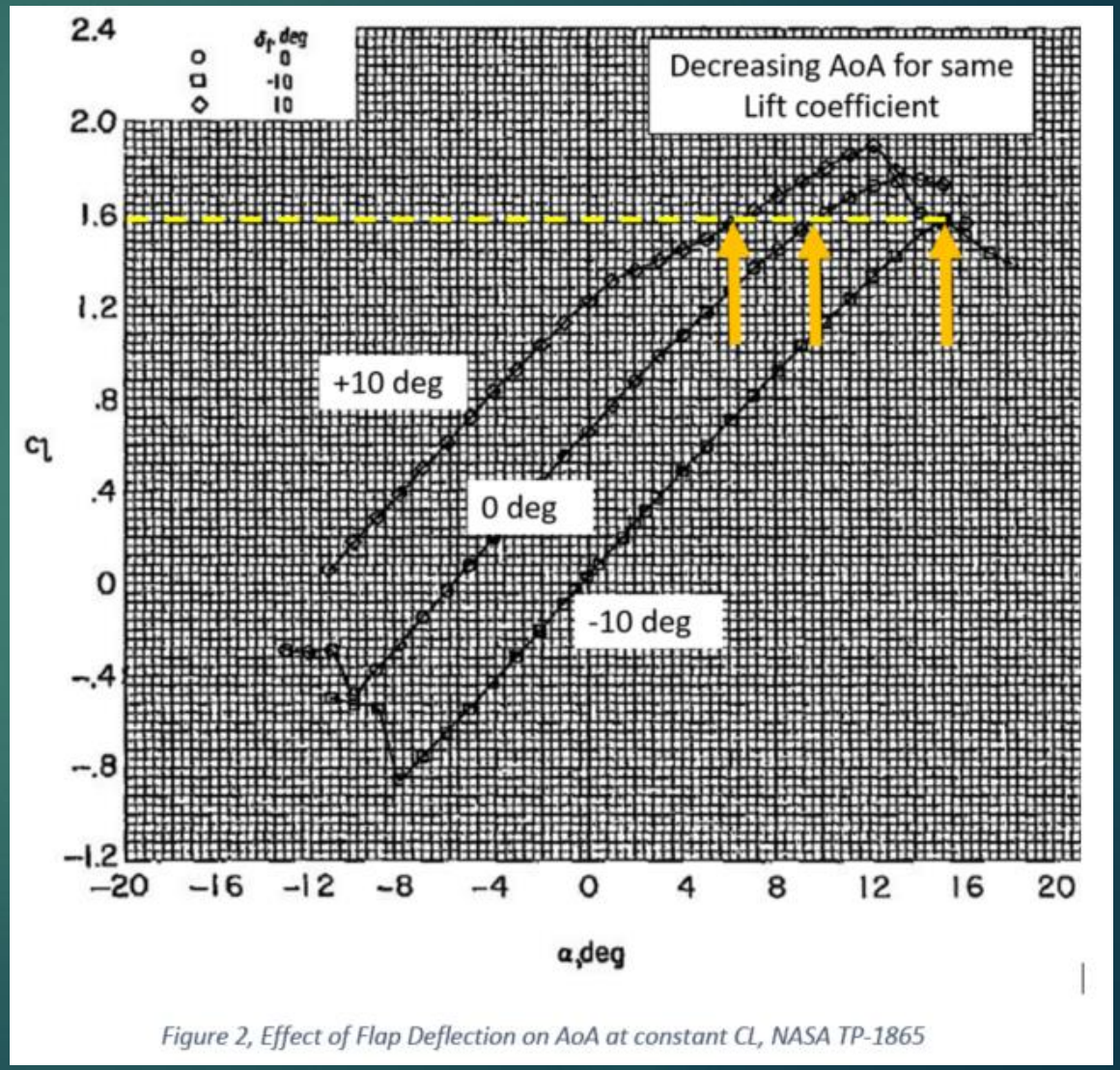
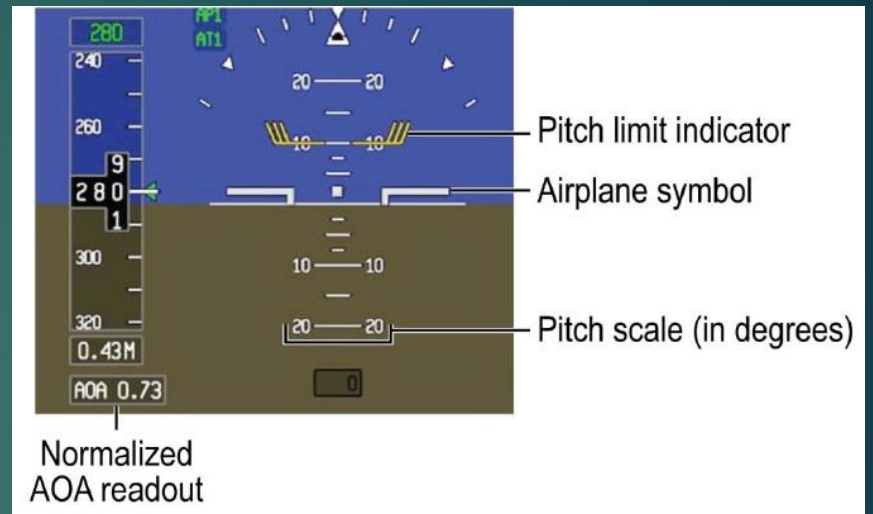


Figure 2, Effect of Flap Deflection on AoA at constant CL, NASA TP-1865

Angle of Attack

Six Factors that affect Stall AoA

- 2 - Ground Effect
- G650 accident
- Incorrect Stall AoA in ground effect programmed into stick shaker and Pitch Limit Indicator



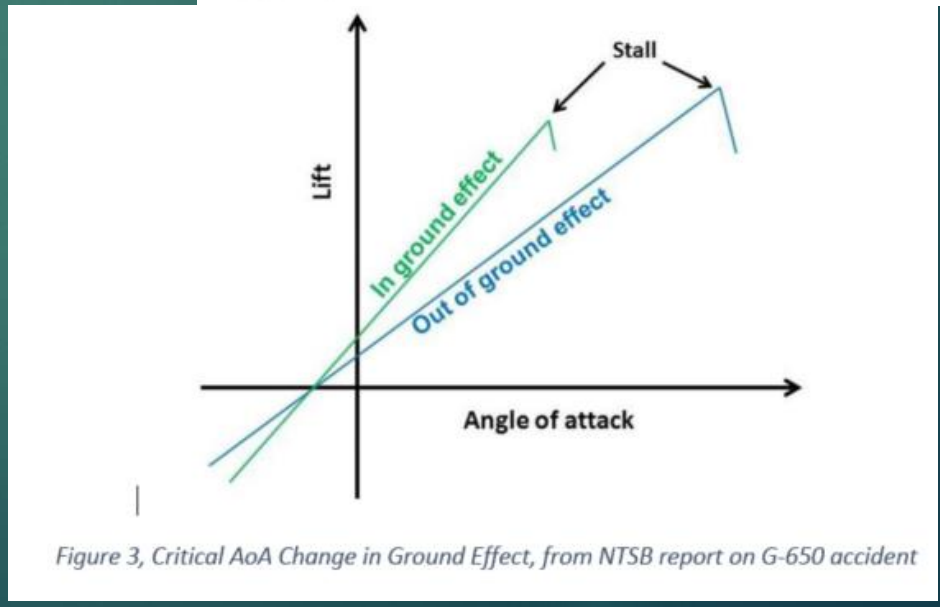


Figure 3, Critical AoA Change in Ground Effect, from NTSB report on G-650 accident

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Six Factors that affect Stall AoA

- 3 - Reynolds Number Reynolds Number fcn(velocity, chord length, viscosity)
  - Chord length is fixed
  - Viscosity is fixed
  - Velocity changes Stall AoA
- 4 – Mach Number
  - Stall AoA lowers as Mach number increases

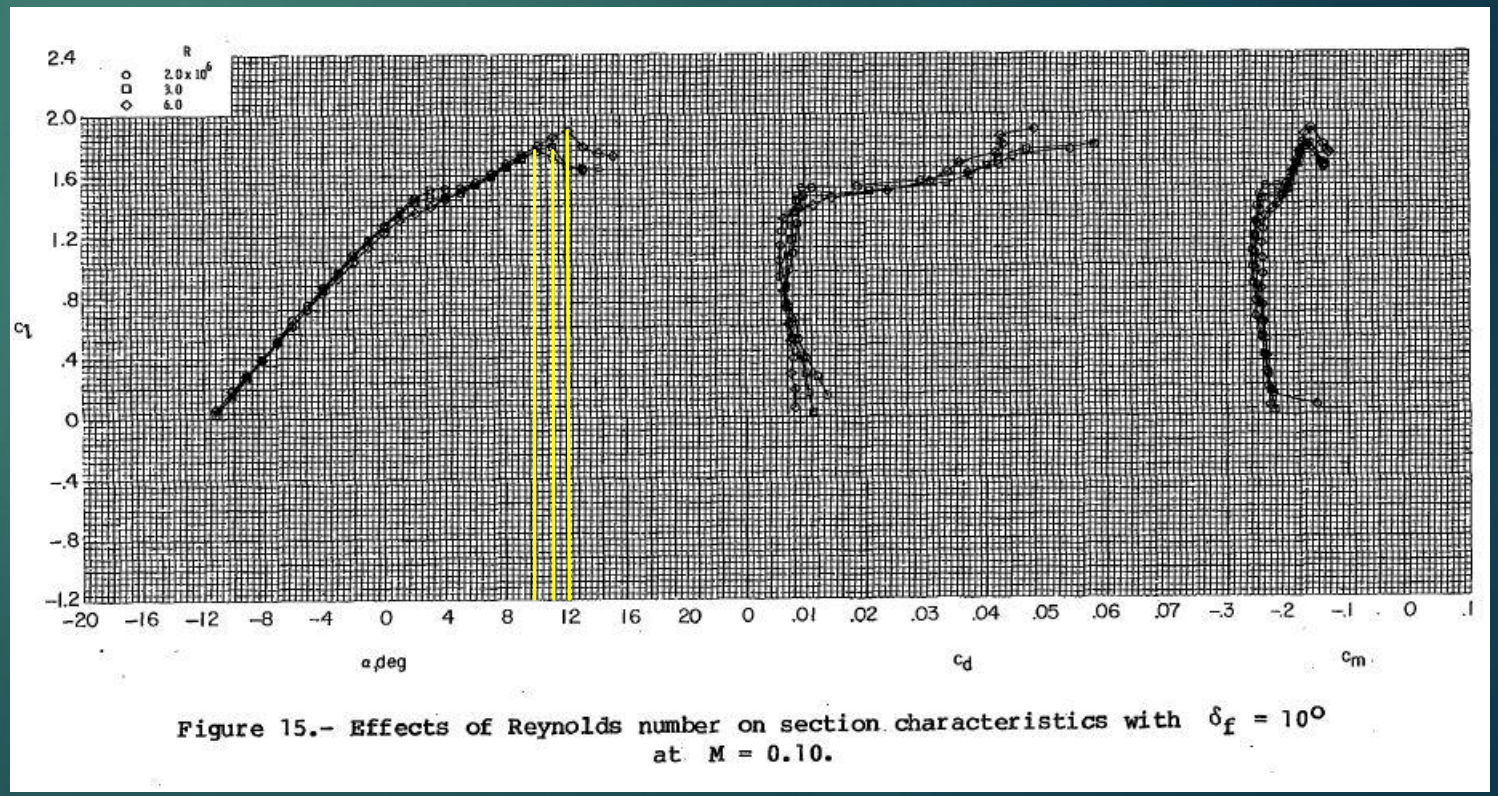

Figure 15.- Effects of Reynolds number on section characteristics with $\delta_f = 10^o$ at M = 0.10.

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Six Factors that affect Stall AoA

- 5 – Stall Entry Rate
- Faster entry = high stall AoA
- Slower entry = lower stall AoA
- Certification of stall requires a prescribed entry rate of 1 kt/sec to keep results consistent and comparable

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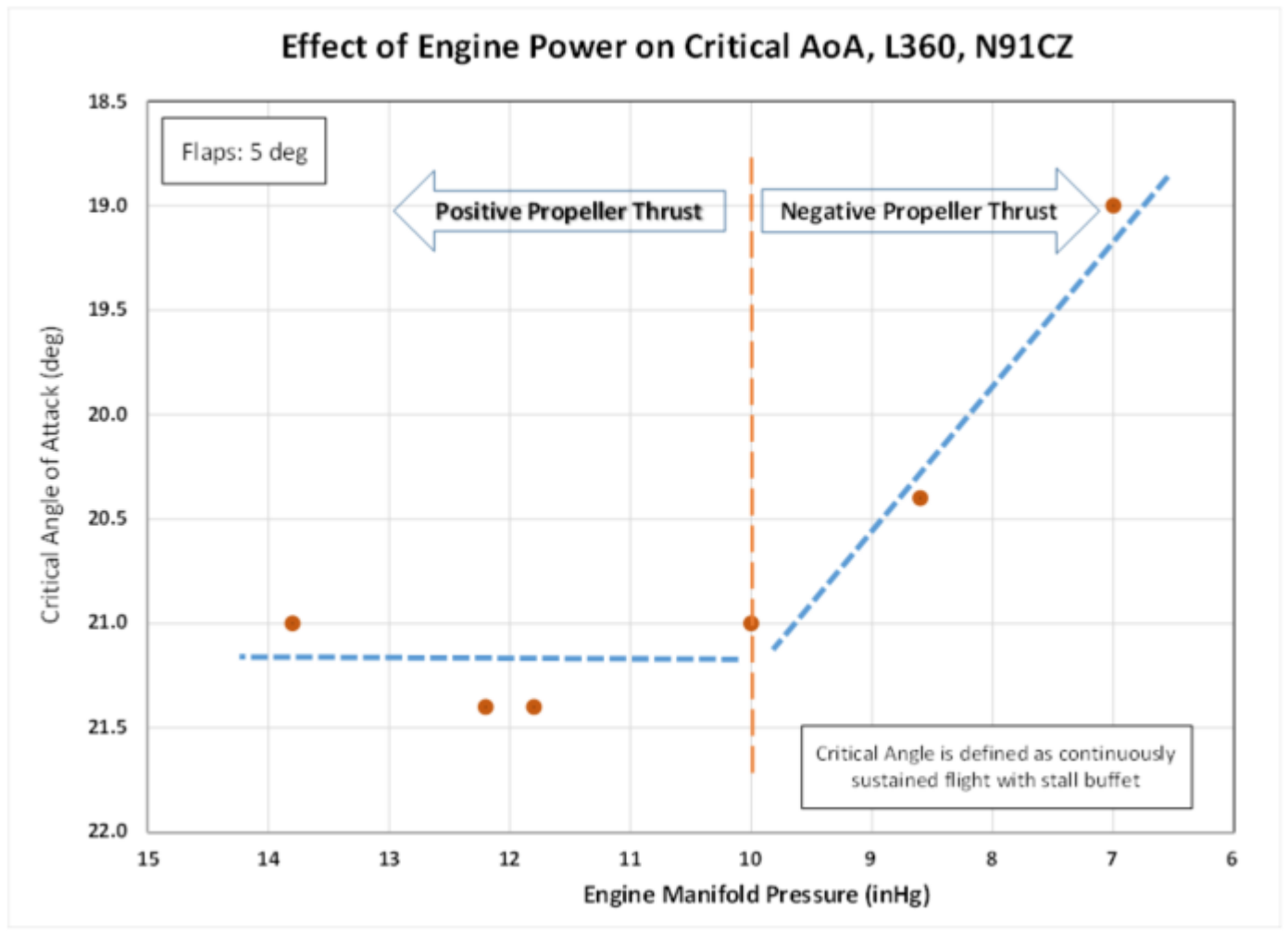
Six Factors that affect Stall AoA

- 6 – Propeller
- Positive vs Negative Thrust

Positive thrust will accelerate and energize the air over the wing behind the propeller.

Negative thrust will extract energy and slow down the air over the wing behind the propeller



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Six Factors that affect Stall AoA

- 6 – Propeller
- Positive vs Negative Thrust

Even just slight positive thrust results in higher stall angle and lower stall speed.

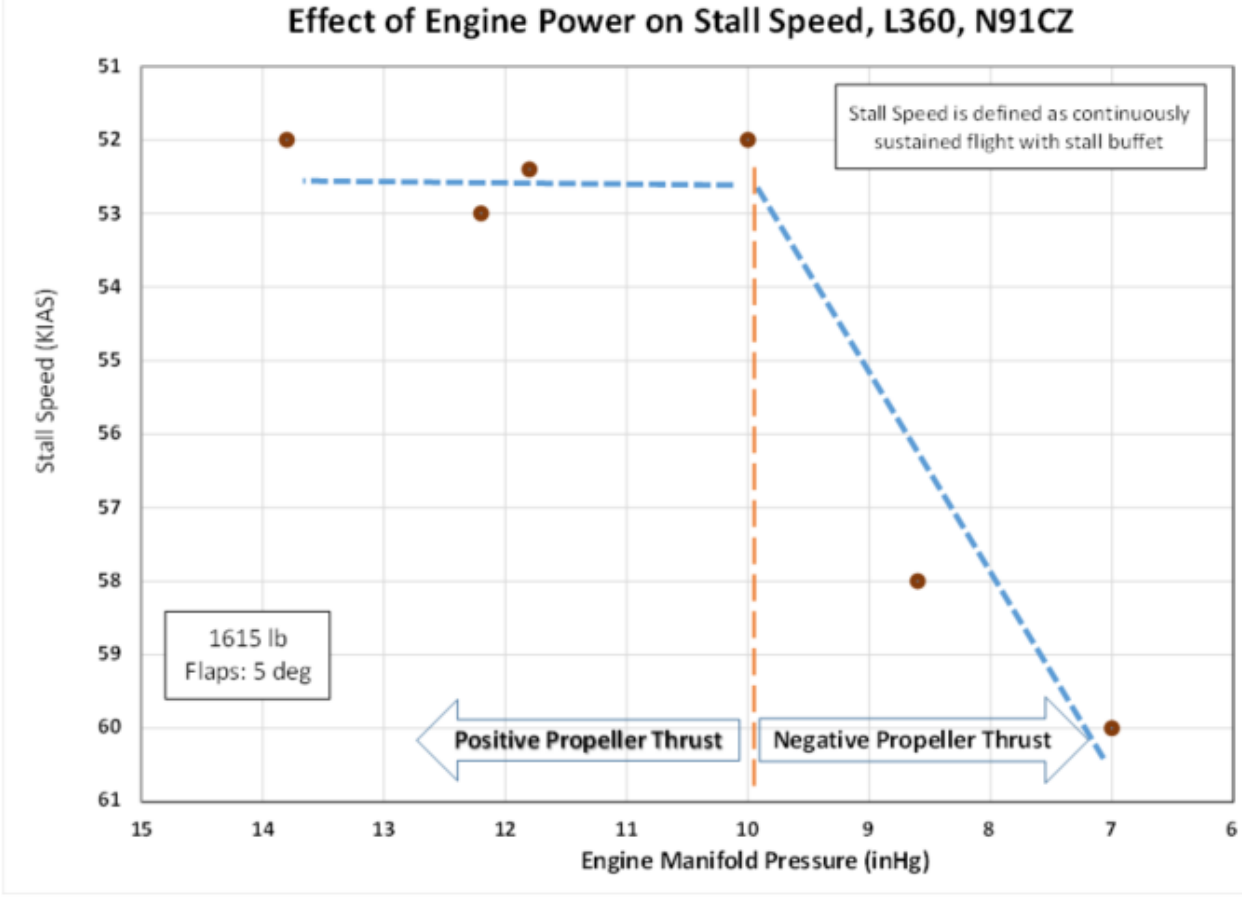
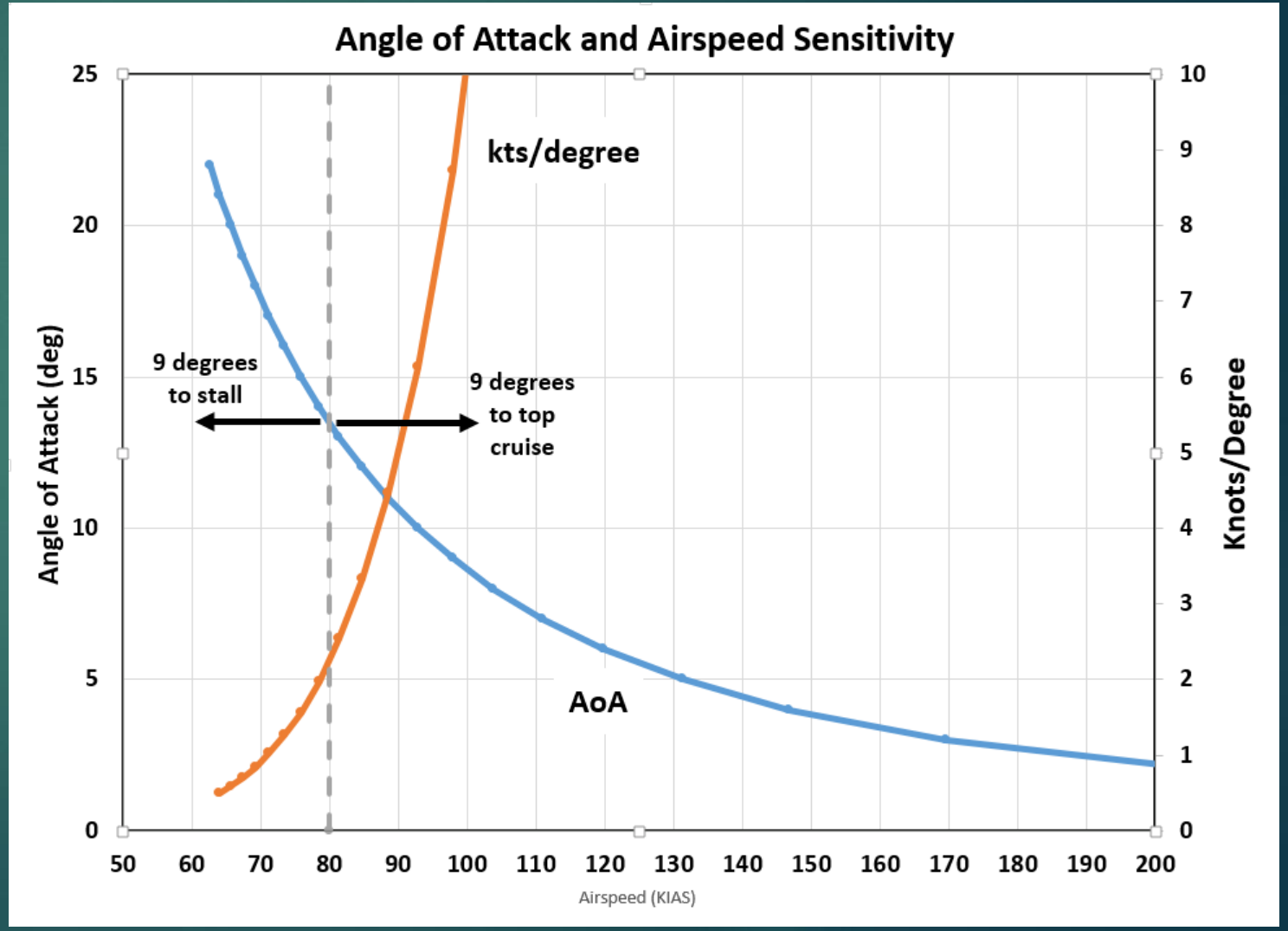


Figure 5, Effect of Propeller Thrust on Stall Speed

Angle of Attack

Characteristics of AoA Measurements

- Best sensitivity right at stall
  - 0.5 kts/deg
- Sensitivity drops quickly as Airspeed increases
- Worst sensitivity in cruise i.e. 300 kts/deg



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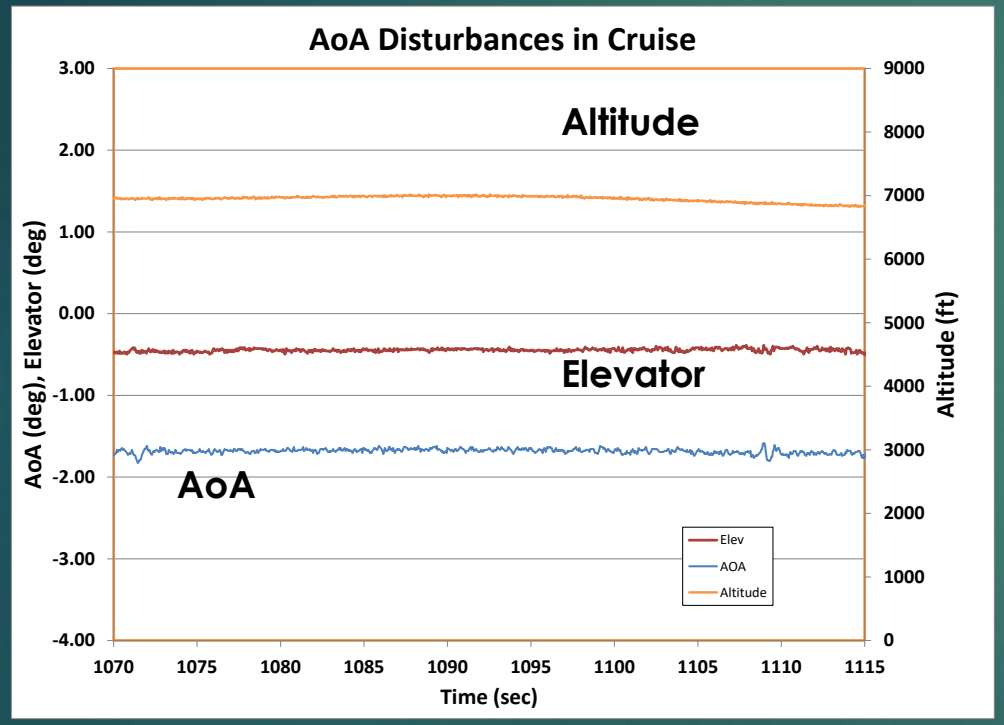
Characteristics of AoA measurements

- Fluctuations in AoA
  - AoA measures a very narrow slice in the flow field
  - Natural disturbances near the ground result in significant fluctuation in local AoA readings – requires damping or averaging
- Flying solely by AoA can result in PIO – chasing the AoA reading
- Flying solely by AoA can also result in a Phugoid – which is a constant AoA maneuver
- Video of GA AoA unit on approach – Note the erratic fluctuations

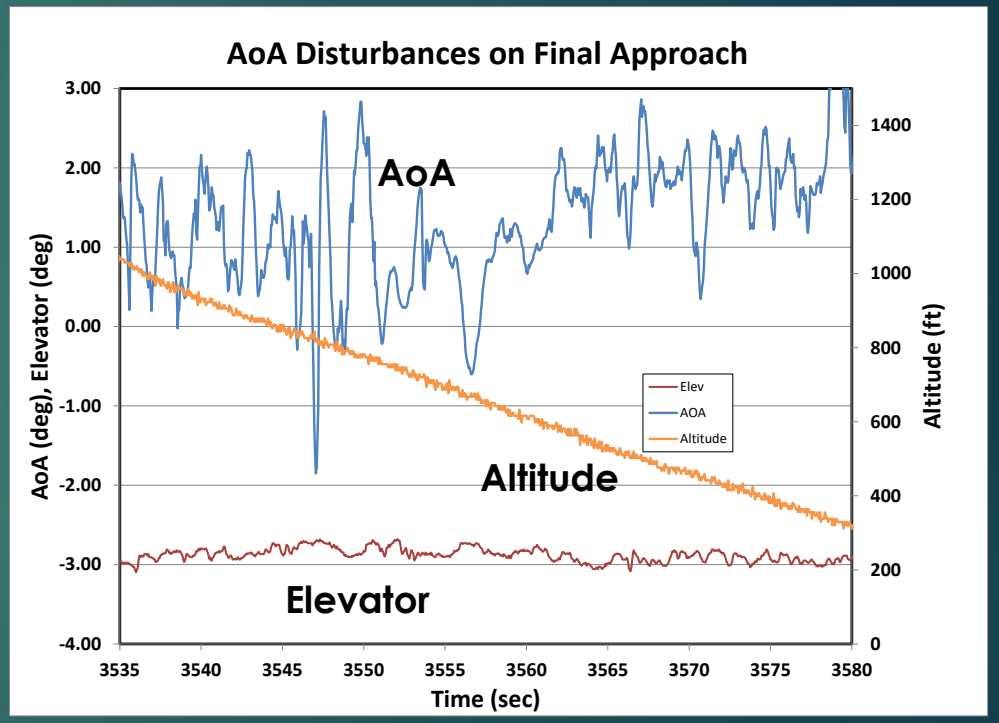
Angle of Attack

Characteristics of AoA Measurements

- AoA readings only look at a narrow slice of oncoming air
- Without averaging AoA is not usable – averaging unfortunately adds lag



Transition between two test points at altitude
AoA is very calm



Final approach at low altitude.
AoA is very active despite smooth descent
and very little elevator movement

Angle of Attack

Navy use of AoA

- Places Aircraft in proper orientation for hook engagement with cable
  - AoA too high ➔ hook grabs cable with aircraft still airborne, slam nose gear onto the deck
  - AoA too low ➔ Tires can depress cable, hook misses cable

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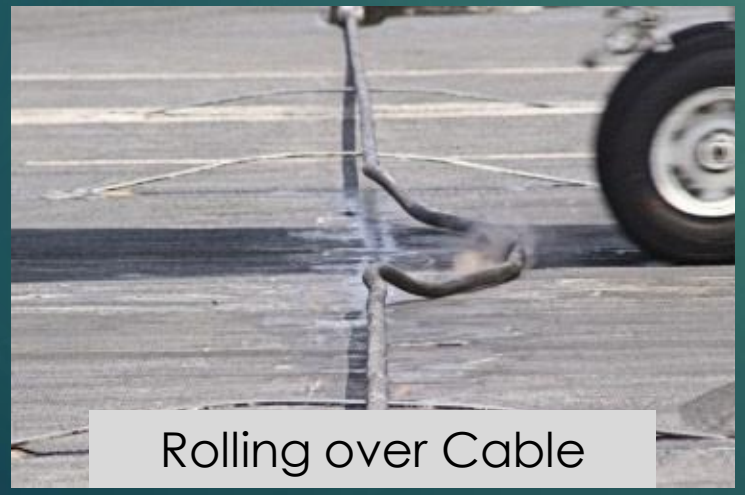
Navy and AoA

Pitch down on rollout



Rolling over Cable

Pitch down while still airborne

Angle of Attack
AoA Instruments in light GA

- FAA Intent
  - Reduce stall/spin accidents turning base to final
  - Stall Warning
  - Education
- Restrictions imposed by FAA
  - Not be used as primary instrument. Supplemental information only
  - Existing certified stall warning system must remain operational
- Uses and capabilities uses are being a bit exaggerated on YouTube in promo videos

Angle of Attack
AoA in General Aviation

- FAA made installation of non-certified AoA indicator very easy via memorandum: "Approval on non-required Angle of Attack (AoA) indicators", AIR100-14-110-PM01
- Must meet ASTM F3011-13
  - A very short and simple specification. Nothing close to the requirements standards of certified or military equipment

Angle of Attack

How to stay safe with AoA/stall warning

- Root cause of LOC – got too slow for maneuver being flown
  - Know the lower limits for maneuvering
  - Lower altitude/speed should lead to greater focus on and more frequent scan of airspeed

Minimum safe maneuvering speed should be well understood and heeded to avoid LOC.

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How to stay safe with AoA/stall warning

- Adjusting stall/approach speeds as weight changes
  - new speed = old speed x sqrt(new weight/old weight)
  - Example:
    - Stall Speed @1700lb is 60KIAS. What is Stall Speed at 2000lb
    - 60 KIAS x sqrt(2000/1700) = 65 KIAS

No need to calculate on the fly. Predetermine most commonly flown configurations.

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How to stay safe with AoA/stall warning

- Rule of thumb to avoid LOC in the pattern
  - Maintain 1.5 x V_{so} for maneuvering in the pattern
  - Provides 2+g capability (i.e. 60 degree bank turn capability)
- Example
  - 60 KIAS x 1.5 ➔ $(90/60)^2 = 2.25$ g

Slow Flight 2G video