# Angle of Attack Technology

for GA

Federal Aviation Administration

**Small Airplane Directorate**

**EASA Brief, Oct 1, 2013**

# Objectives

- Discuss how AOA may help reduce loss-of-control accidents in General Aviation?
- Summarize FAA efforts to promote installation of simple AOA systems

# Overview

- Summary of Situation
- What is AOA?
- What do we have in cockpit?
- Are traditional instruments enough?
- Data on Loss of Control
- Stall warning may not be enough
- Benefits of AOA
- FAA programs
- Summary

# Acroynm List

- AOA — Angle of Attack
- Cl — Coefficient of Lift
- DA — Density Altitude
- eCFI — electronic Certified Flight Instructor
- GA — General Aviation
- GA JSC — GA Joint Steering Committee
- iCAS — Intelligent Collision Avoidance System
- LOC — Loss of Control
- LOCWG — LOC Working Group
- TCRG — Technical Community Research Group

# Executive Summary

- The FAA is convinced simple AOA indicators, which are popular in experimental aircraft, help pilots avoid stall better than traditional stall warnings
- Our largest root-cause of GA accidents is loss-of-control & stall while maneuvering
- Most GA pilots are not aware of dynamic stall
- Simple AOA systems, as a safety enhancing installation, should be acceptable as a minor alteration in most light GA aircraft
- The FAA is clarifying regulations & policy to make installation easier and more affordable

# What is AOA?

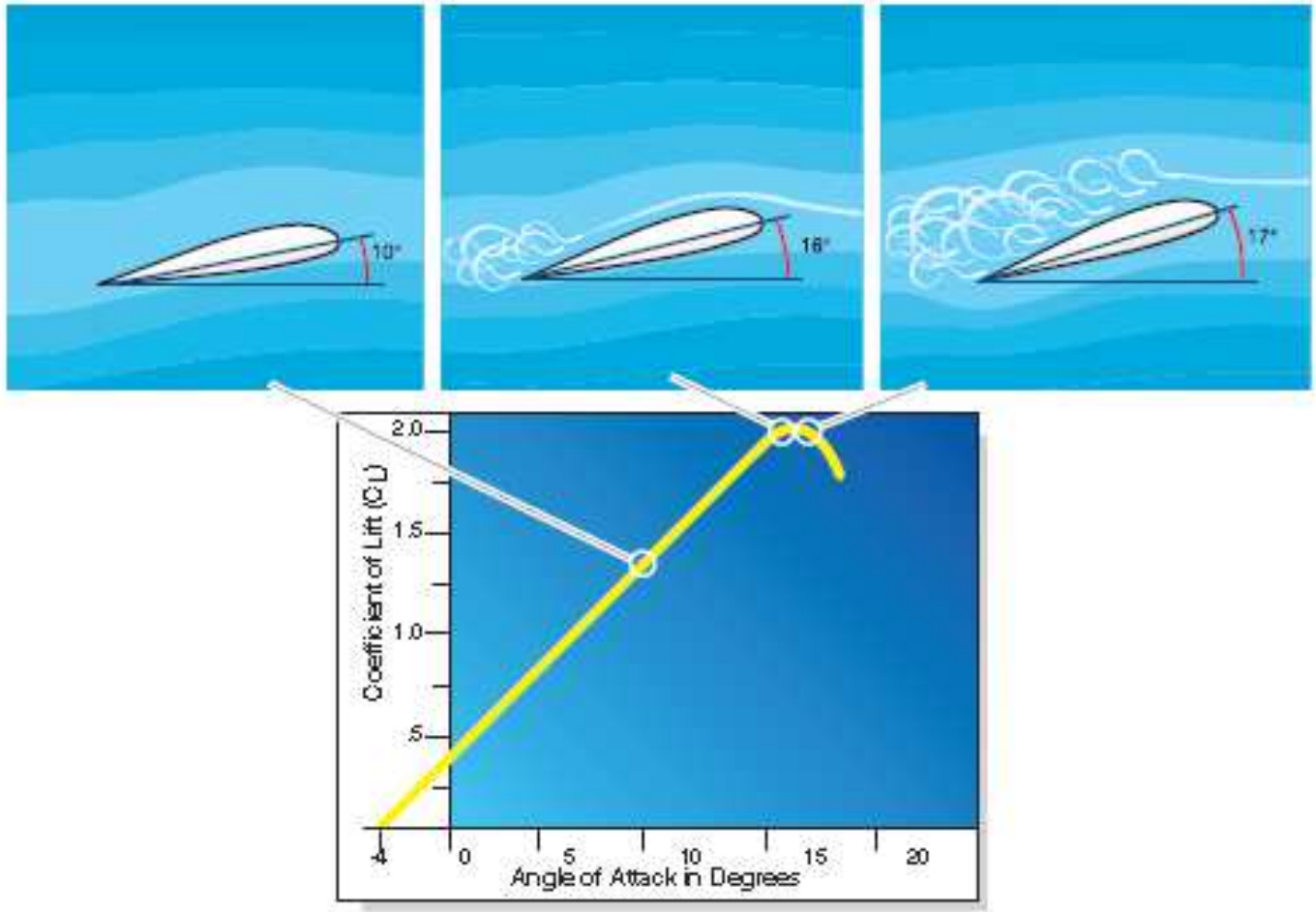



Figure 4-2. Critical angle of attack and stall.

# Why is AOA important?

- Stall Accidents
- FAA Airplane Flying Handbook States:

*"A stall occurs …when the wing exceeds its critical angle of attack.*

*This can occur at ANY*

- *Airspeed*
- *Attitude*
- *Power*

# What do we currently have in cockpit? (to help manage AOA)

*Most* GA airplanes have:

1) Airspeed Indicator

2) Stall Warning System

3) Attitude Indicator

4) Pilot Brain

# What do we have in cockpit? (to help manage AOA)

## 1. Airspeed Indicator with Markings

$V_{SO}$ – Stall Speed In The Landing Configuration

$V_{S1}$ – Stall Speed In Specified Configuration (Clean)

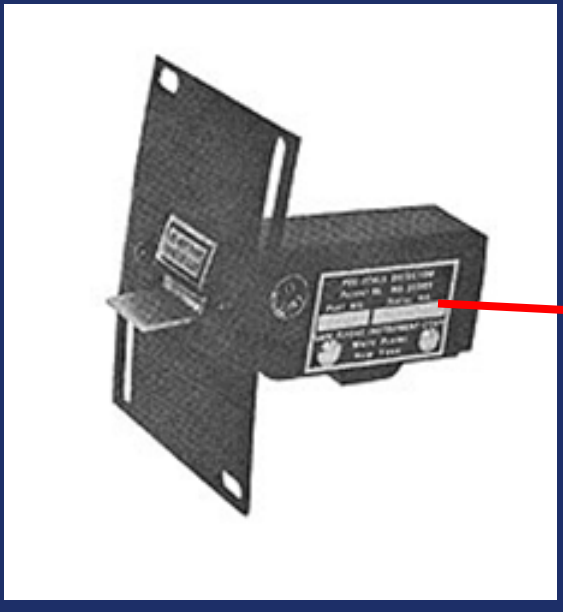
Stall speed is only valid for

- Unaccelerated flight (1g)
- Coordinated flight

# What do we have in cockpit? (to help manage AOA)

## 2. Stall Vane

- Mounts on the leading edge of the wing.
  - Set to actuate at least 5 knots above stall speed.
  - Aural warning (no trend)



# What do we have in cockpit? (to help manage AOA)

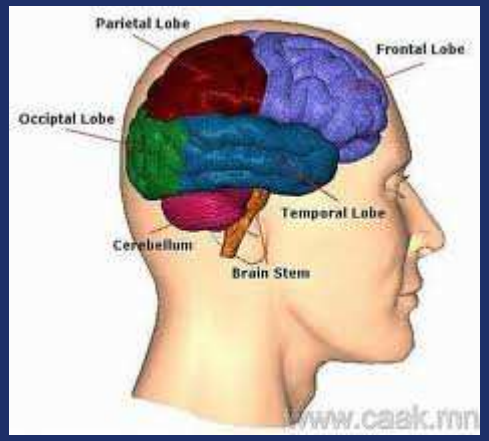
## 3. Attitude Indicator

- Shows Pitch (and Roll) angles
- Typically, does not show AOA

# What do we have in cockpit? (to help manage AOA)

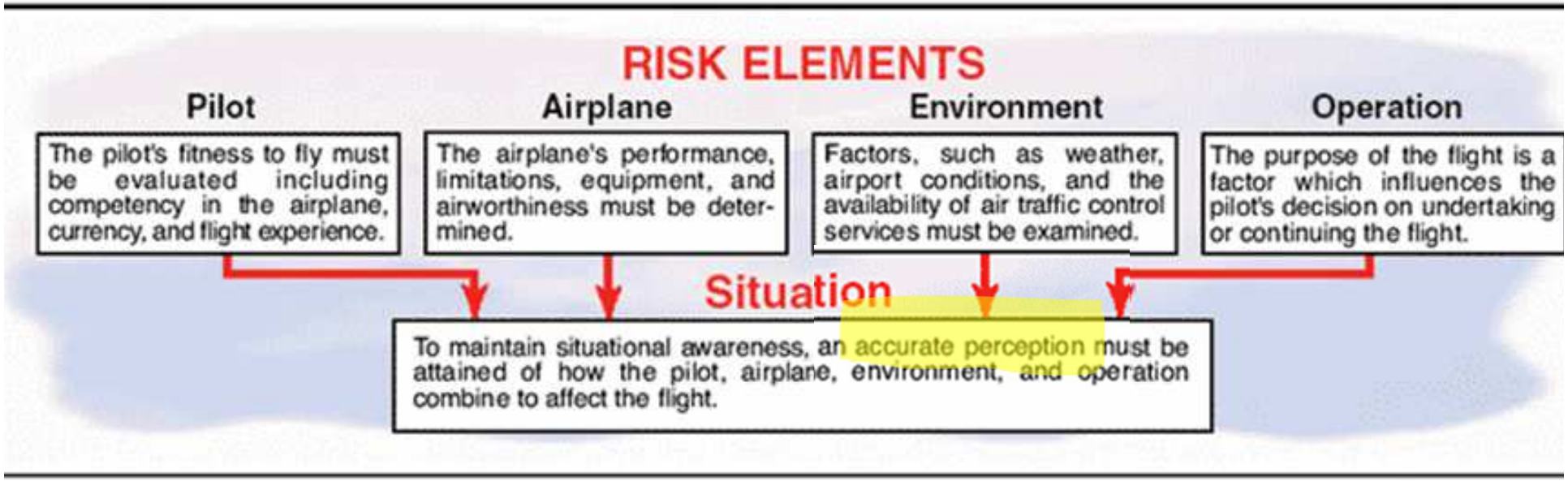
## 4. Pilot Brain

- Visual System
- Vestibular system
- Seat of Pants



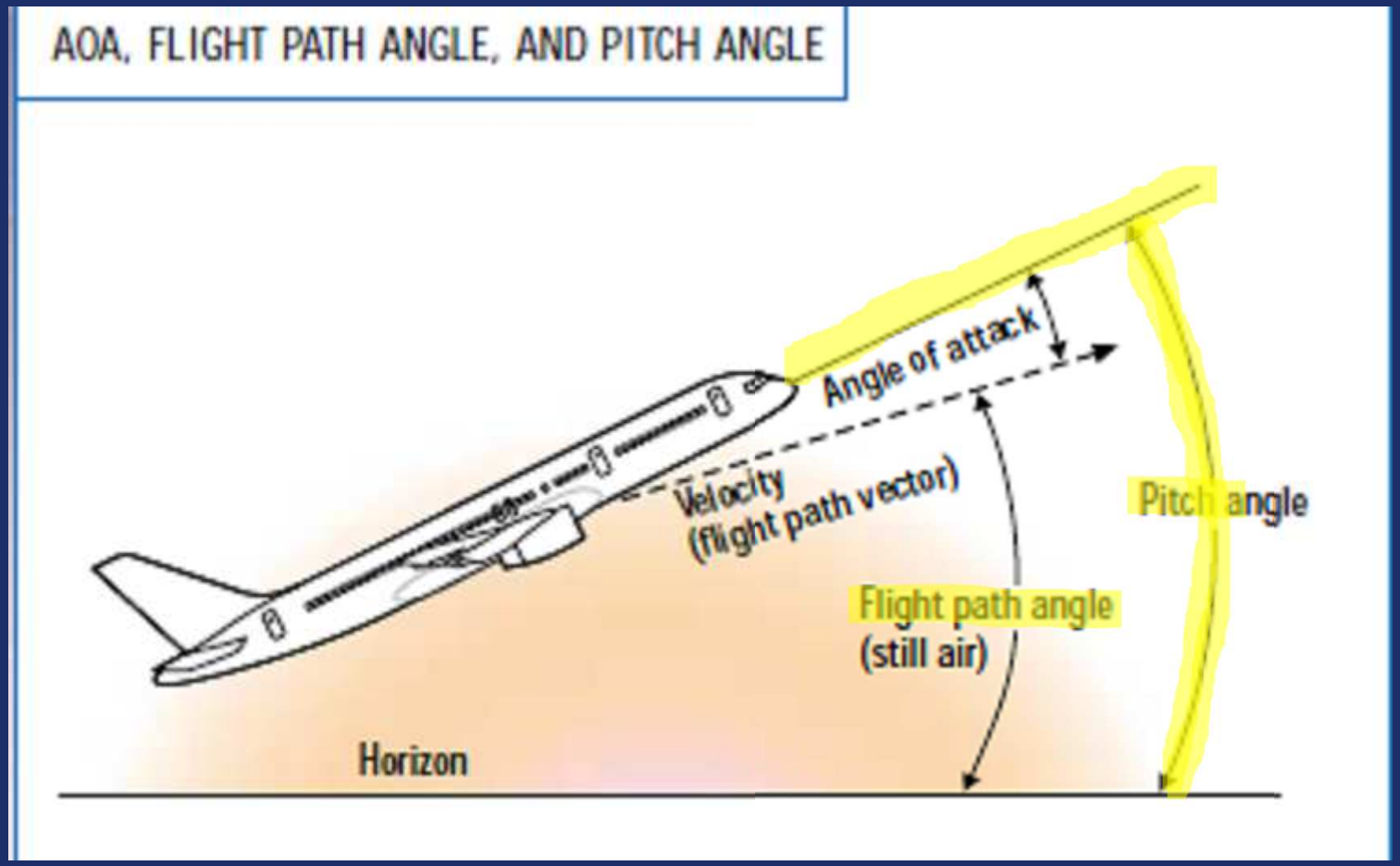

- Perceptions –tie it all together
- Basis for Control Inputs

# Pilot Perception

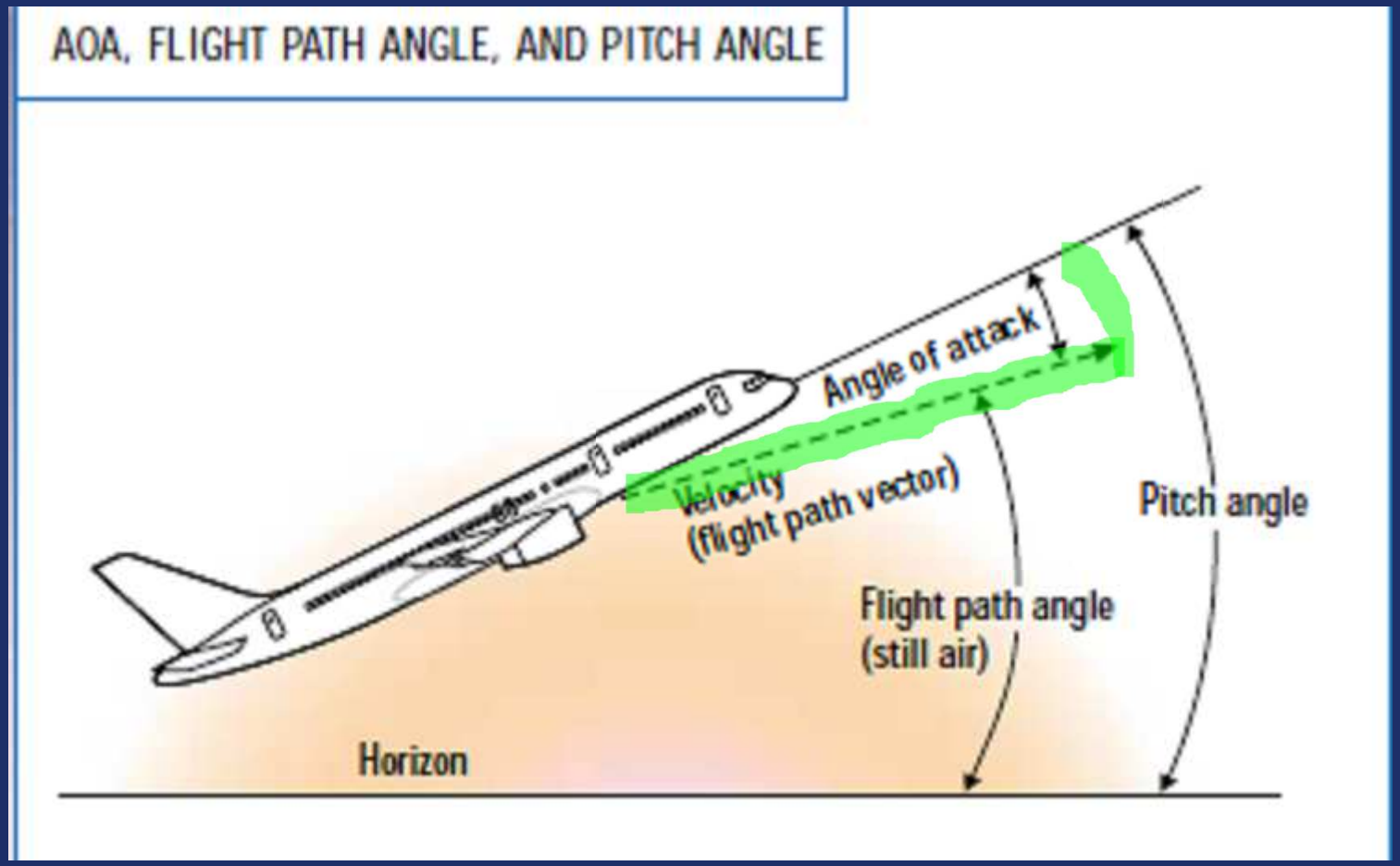



- Pilot perceives interaction of airplane with environment through his senses and instruments
- How does the pilot perceive and control AOA?

# Pilot Perception of Pitch



# Invisible AOA



# Summary of typical cockpit systems

1) Airspeed Indicator

2) Stall Warning System

3) Attitude Indicator

4) Pilot Brain

--- PERCEPTIONS

# Are Existing Stall Strategies Working?

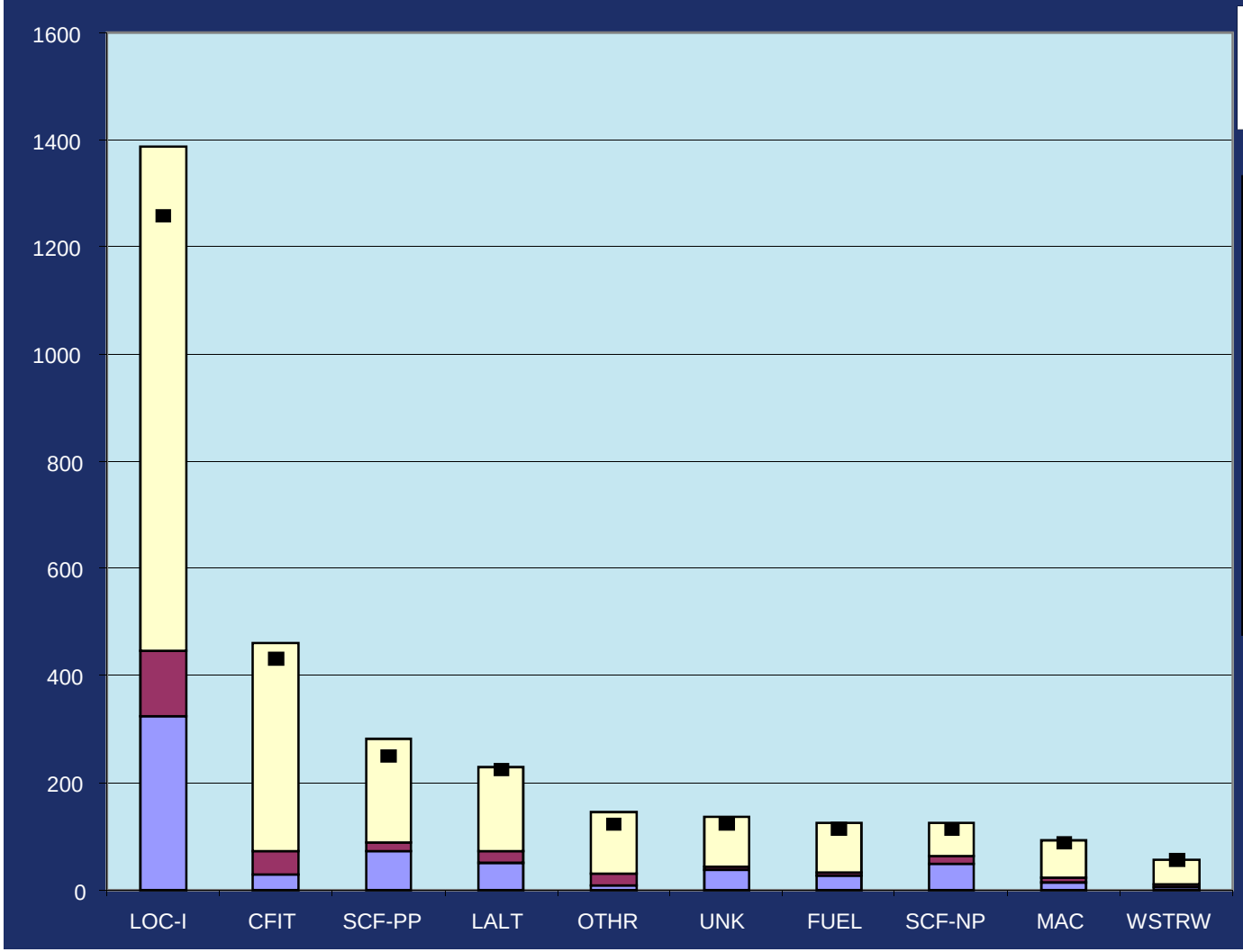
- **No!**

- **Nearly 1400 fatal accidents in 10 years**
  - Stall/Spin or Loss of Control (LOC)
  - GA alone
  - 1 fatal accident every 2-3 days

- **LOC is #1 root cause of GA fatalities**

# GAJSC Pareto CY2001-CY2011

**Source: NTSB Aviation Accident/Incident Database.**




RECIPROCATING NON-HOMEBUILT
TURBINE
HOMEBUILT
2010 PARETO TOTAL

*LOC-I* – Loss of Control Inflight
*CFIT* – Controlled Flight Into Terrain
*SCF-PP* – System Component Failure-Powerplant
*LALT* – Low Altitude Operations
*UNK* – Unknown or Undetermined
*OTHR* – Other
*FUEL* – Fuel Related
*SCF-NP* – System Component Failure-Non-Powerplant
*MAC* – Midair Collisions
*WSTRW* – Windshear or Thunderstorm

# Why do these accidents occur?

- Large Percentage of accidents
  - Highly trained and experienced pilots
  - Flying advanced modern aircraft (SR-22)
    - And classic stable aircraft (C-172)
  - Distraction during critical phase of flight
- Many accidents in Maneuvering flight
  - especially landing (base to final)
- Angle of Attack is “Invisible”
  - How can the pilot manage AOA if it’s not displayed

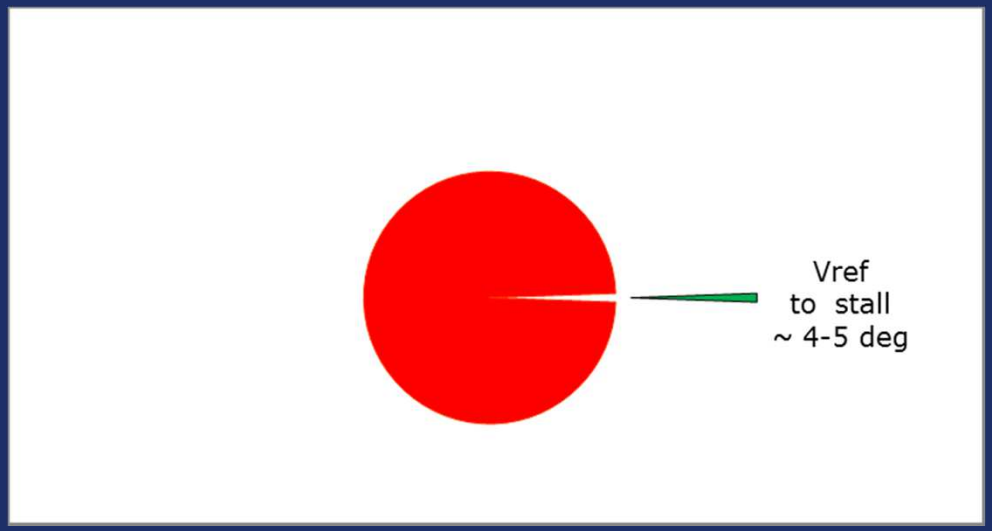
--------- Perceptions

# Accelerated Stall Accident

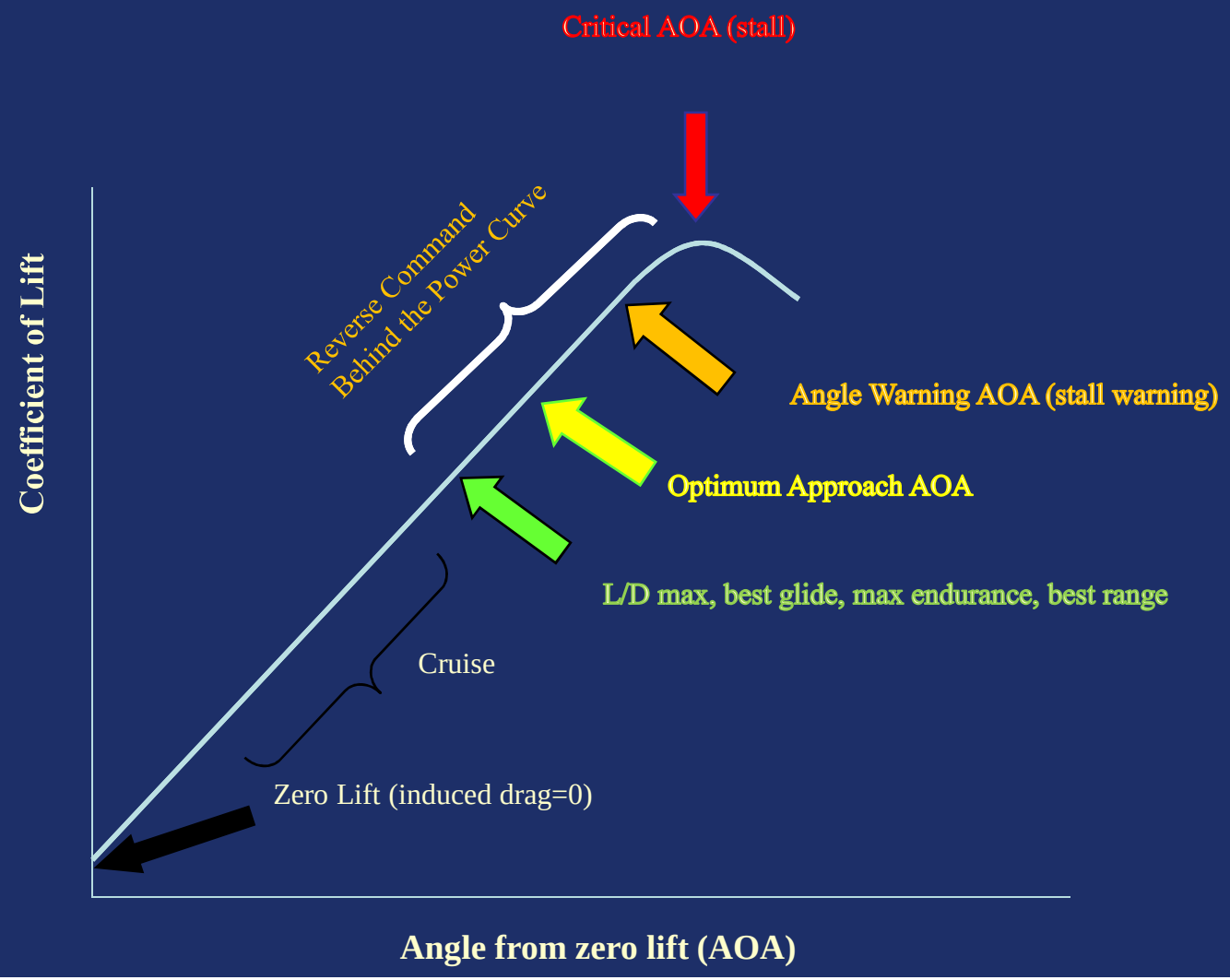
- Cessna L-19 / O-1 Bird Dog
- Attempted Turn Around in Mountainous Terrain
- Listen -- Stall Warning Horn
  - What is Margin?

# Pilot Task: Landing

- 1) The AOA margin from Vref to stall is small
  - Typically only a few degrees



# AOA vs. Cl


Critical AOA (stall)
Reverse Command
Behind the Power Curve
Coefficient of Lift
Angle Warning AOA (stall warning)
Optimum Approach AOA
L/D max, best glide, max endurance, best range
Cruise
Zero Lift (induced drag=0)
Angle from zero lift (AOA)

# Why display AOA?

- The Wing always stalls at critical AOA
  - Regardless of weight, speed, G
- Used as *a Supplement* to Airspeed
- AOA gives Trend + is Instantaneous
- Many Military, NASA, + Transport Planes
- The Accident Record for Loss of Control

# AOA Equipment

Probe

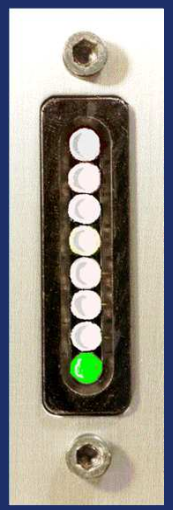
Computer - AOA

Multi-Segment LED Display

Military Style AOA Display

# Typical AOA Display

**Cruise**

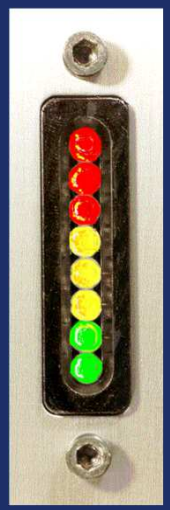


**Best L/D**

Optimum approach

Angle advisory

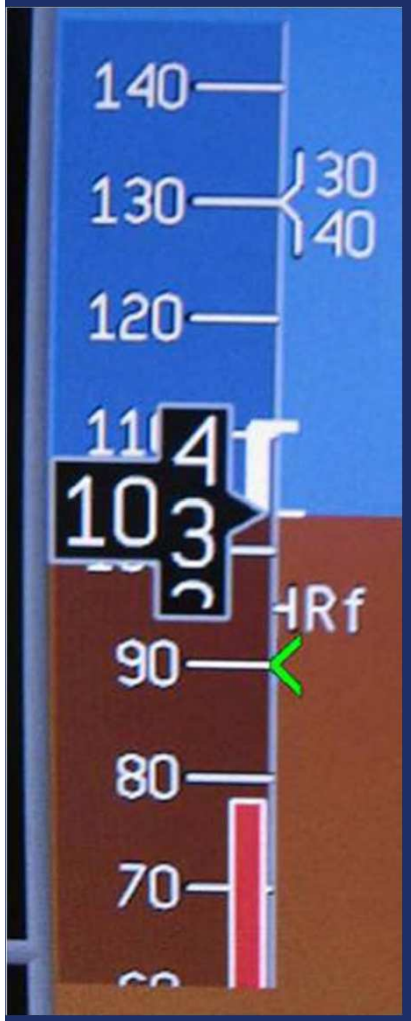
**Critical AOA**



# AOA and speed

- Vs, Vx, Vy, $V_{REF}$, Best Engine out Glide and Max Endurance
- Most critical performance is function of AOA
- When you fly airspeed numbers, these are derived from AOA (Configuration, Weight)
- AOA is instantaneous, speed lags

# AOA on PFD




- System such as Honeywell APEX
- Hi AOA Awareness

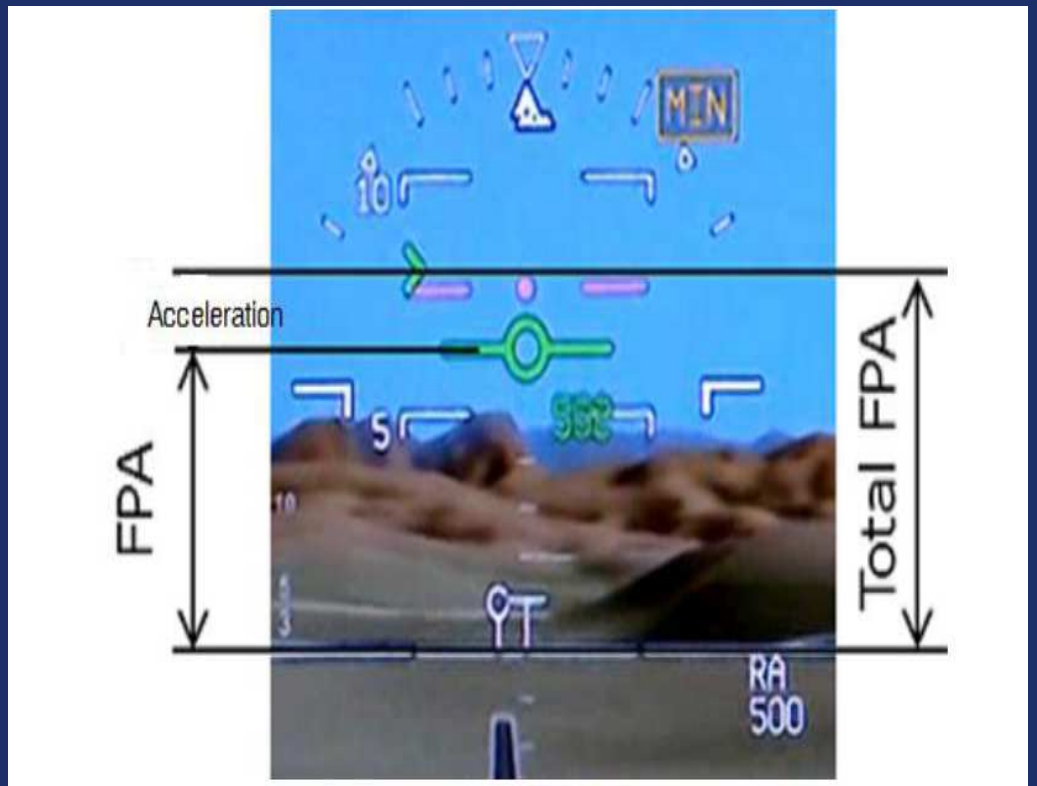



Figure 9-10 21 Acceleration Chevron above FPS: Aircraft accelerates (aircraft is climbing in this example)

# Why AOA

- **Supplements Existing Stall Warning, Does Not Replace it**
- **Trend Awareness**
  - PRIOR to Stall Warning
    - Visual Display (pitch limit)
    - Audio Tones (good and bad)
    - Prescriptive Command (AOA- push)
    - Stick Shaker /Seat Shaker/
    - AOA Limiter
    - Stick Pusher

# AOA – Future Uses

- **eCFI – Electronic Flight Instructor**
- **Refuse to Crash Automation**
- **iCAS – Ground and Air Collision Avoidance**
  - With Maximum Maneuver Performance
- **Enhanced aero Stability**
  - Improve spin resistance

# AOA Benefits beyond Raw Displays

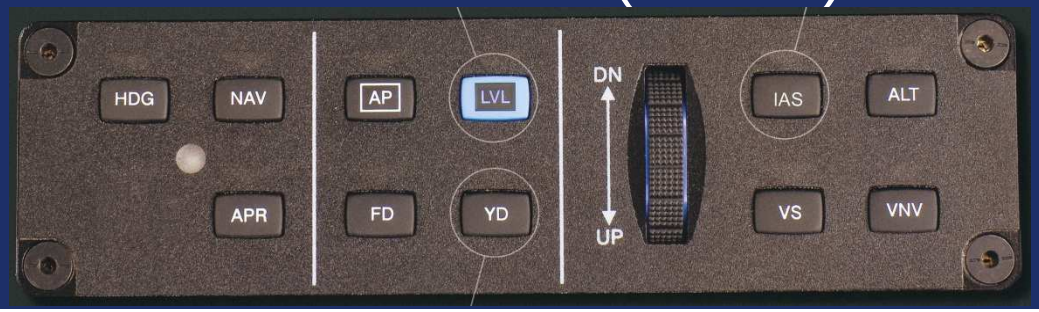
- AOA derived pitch limits
  - Display on Electronic ADI

    (Attitude Director Indicator) -- Show Trends + Margins
- Envelope Protection
- Input to stick shaker
- Haptic Feedback – Stick and or seat
- Stability Augmentation

## Preventing Loss of Control

# Current System: EP

- **Envelope Protection**
  - AVIDYNE and GARMIN
- **Utilize Autopilot and FD**
  - Feedback to Pilot for excessive:
    - Speed (Over and Under) + AOA?
    - Bank Angle
    - Pitch Angle
  - Audio + Visual + (Tactile)



# If AOA is good, Why is it not in GA?

- Equipment Cost ?
- Cultural Environment
  - “I’ve always flown without it”
    - But ask anyone who’s flown with it!
  - Look at accident record
    - Something must change

# What is the FAA doing about it?

- **Small Airplane Directorate Business Plan**
  - ✓ Reduce Regulatory Roadblocks
  - ✓ Part 23 Re-write and ARC
- **Allow Process to install certain equipment**
  - ✓ Non-required Safety-enhancing
  - ✓ No Hazard
  - ✓ No conflict with existing Stall warning
- **ASTM F39 Committee for AOA - Standards**

# What is the FAA doing about it?

- **GA JSC**

  General Aviation Joint Steering Committee

  ✓ Reduce fatal accidents in GA

  ✓ Partnership with

  FAA + NASA + Industry + Academia

- **FAA Small Airplane Directorate Goals**

  ✓ Reduce Accidents by 50%

  ✓ Reduce Cost by 50%

# What is the FAA doing about it?

- **Sponsored Research (TCRG)**
  - ✓ Ways to bring affordable AOA to GA
  - ✓ Utilize readily available sensors
  - ✓ Additional benefits such as stick shaker
  - ✓ Enablers for Retrofit Market
- **FAAST Team**
  - ✓ Education and Outreach
- **Technology Board**
  - ✓ **Meeting Regularly to promote safety enhancements**

# What is the FAA doing about it?

- Encourage Spin Resistant Designs
  - ICON Exemption – Not really a weight issue, but overall performance & safety
- Stall Char. 23.201 and 23.203
  - Wings level and turn (-1kt/sec)
  - Accelerated Stall (-3 kt/sec)

# Ultimate Goal - Improving Safety

- **Paradigm Shift**
- **Education / Outreach**
- **Training**
  - AOA integrated syllabus
  - Upset Recovery
- **Focused Effort**

# Summary

- How AOA may benefit GA
- FAA activities to increase safety
- Need Streamline Certification Processes

- Disclaimers

1. Not an endorsement for any vendor
2. Not the cure all for Loss of Control

# Questions ?

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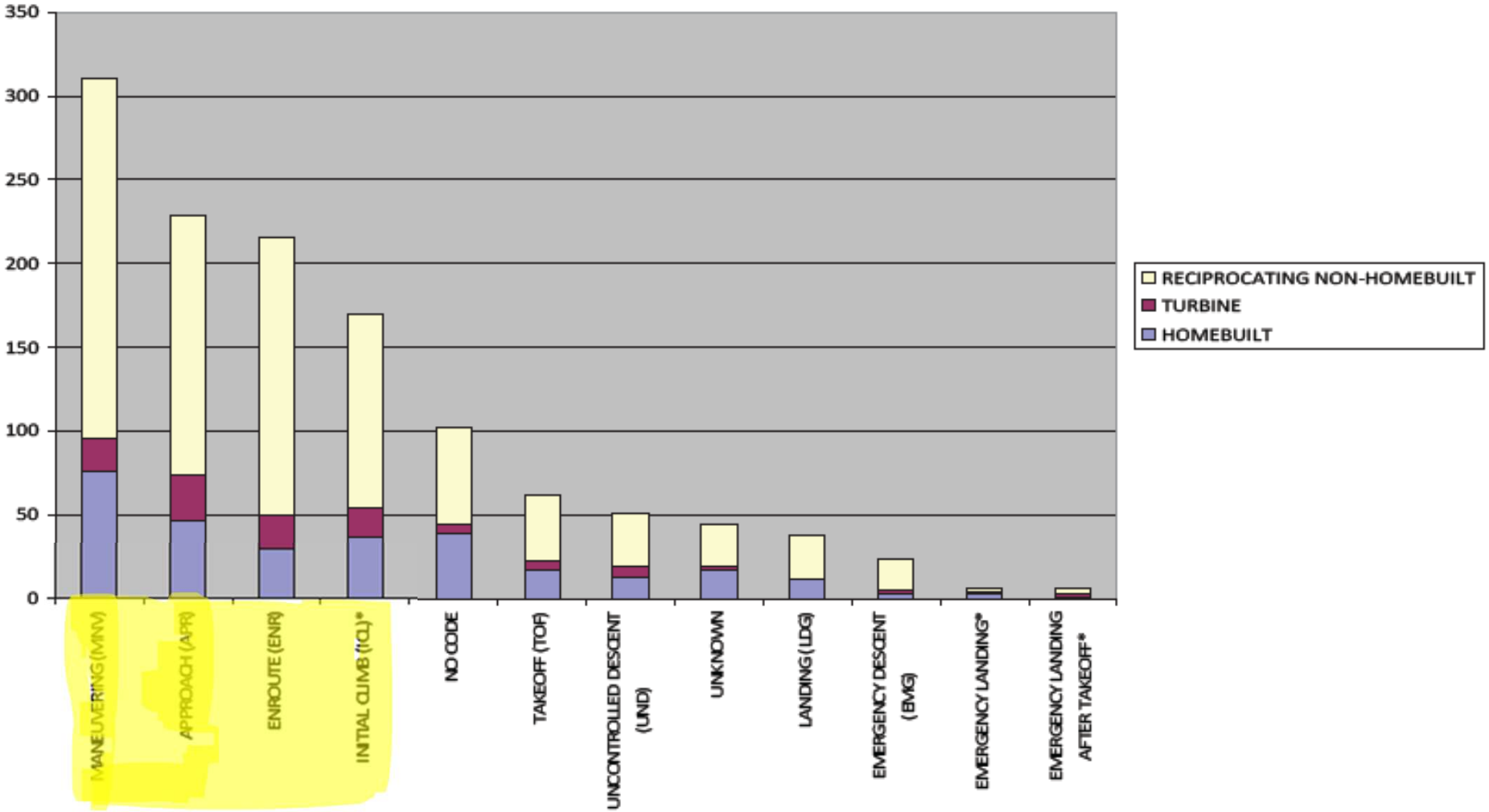
- Installation Boundaries
- Magazine Article
- Example Hardware

# BACK-UP SLIDES

# AOPA 2010 Nall Report

- **Stall / LOC is root cause in GA of:**
  - 76% of all Take-Off Fatalities
    - » Other = DA + rwy condition
  - 67% of Maneuvering Fatalities
    - » Other = hit obstacle + aerobatics
  - 47% of Approach Fatalities
    - » Other = Gust/Wake Turbulence + Loss of Power

# Loss of Control – Inflight (LOC-I) Events by Flight Phase 2001- 2010



# Some COTS AOA - Today

- **Dynon**
  - Probe and a PFD
- **Advanced Flight Systems**
  - Tap into pitot static system
- **SAFE Flight** ** **(Certified system ~$6000)**
  - Vane similar to Stall warning
- **Alpha Systems**
  - Stand Alone Display and probe

Costs: Hardware ~ $500-$1100
Install ~ 4-8 hrs @ $80/hr

# How AOA can Help

- AOA is Simple and Universal
  - All aircraft from LSA to Jets  benefit
  - Ref AOA is independent of weight
    - Vref speed changes with weight

- *Making AOA commonplace in GA*
  - FAA + Industry endorsement
  - Paradigm shift  from 1-G stall speeds
  - Updated training
  - Outreach
  - Reducing Regulatory Roadblocks