Causes for Pilot Mistakes

- Aircraft Controllability - Cockpit Design - Flight Displays - Basic Pilot Training

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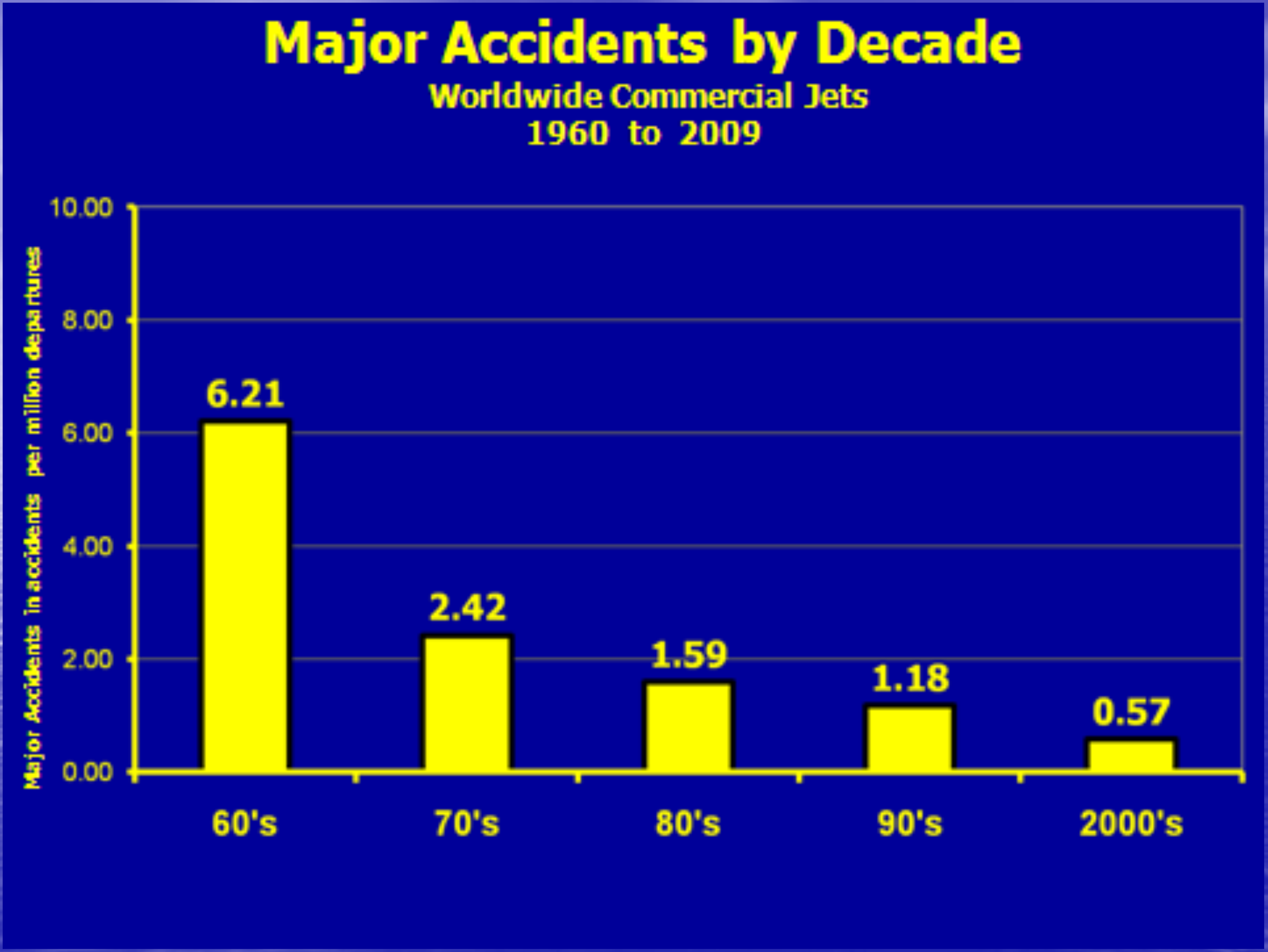
Subject outline:

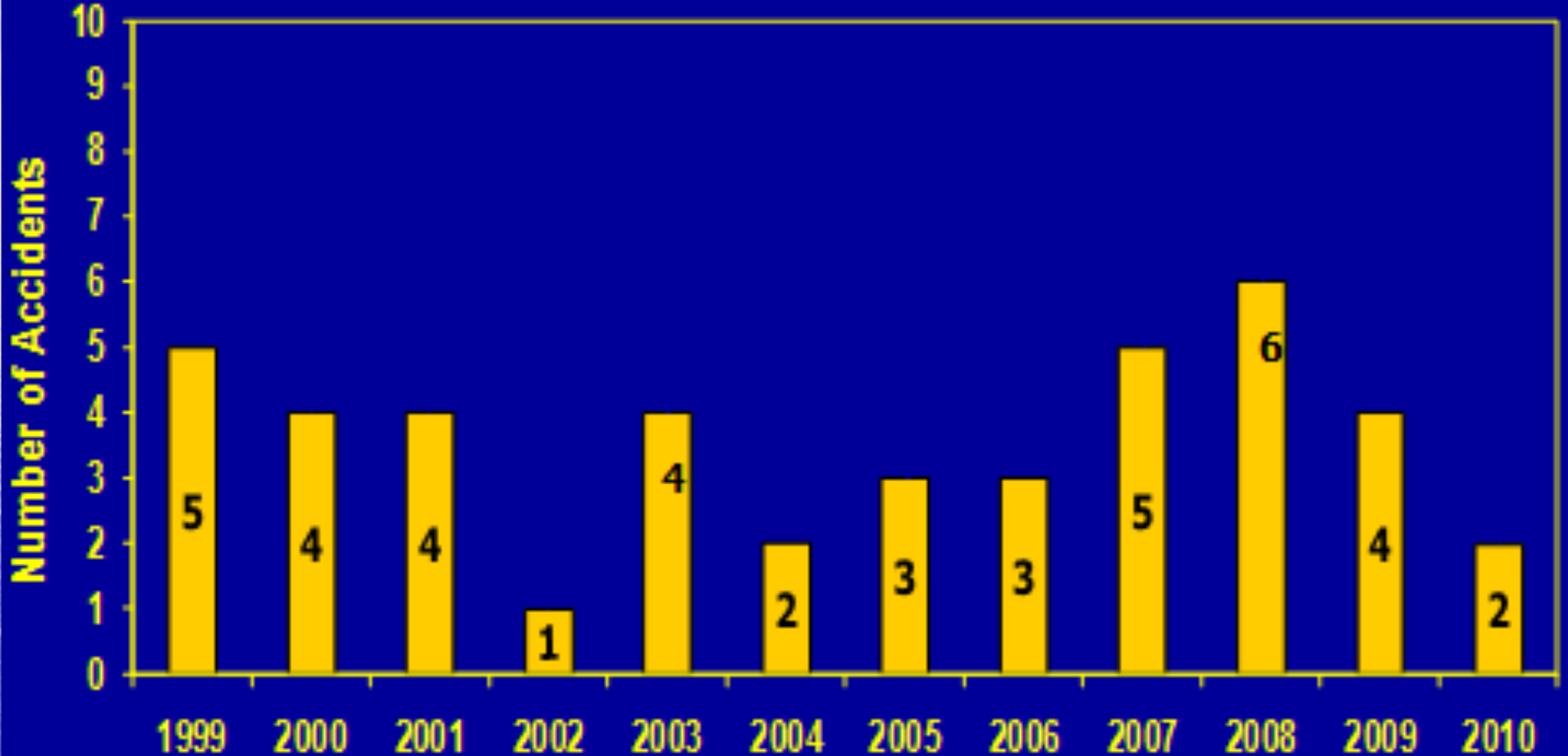
- Review of Aircraft Accidents
- Typical Handling Skills Accidents
- Cause Factors
- Coffin Corner
- Stall
- Deep Stall
- Spin
- Developments in Flight Displays
- Developments in Pilot Education
- Summary

Accident Statistics


Major Accidents by Decade
Worldwide Commercial Jets
1960 to 2009
Major Accidents in accidents per million departures
10.00
8.00
6.00
4.00
2.00
0.00
6.21
2.42
1.59
1.18
0.57
60's
70's
80's
90's
2000's


CFIT
All Commercial Turbojets
CFIT Accidents per Year
10
9
8
7
6
5
4
3
2
1
0
98
99
00
01
02
03
04
05
06
07
08
09
10
11
Year
5 Year Running Average

Loss of Control Major Accidents
Commercial Jets
1999 through 2010



Source: Ascend, Boeing

Some typical LOC accidents and Cause Factors

Stall during high altitude cruise:

- West Carribean MD-82. Venezuela 2005 – high altitude stall (coffin corner) – climbed rapidly from 31,000 ft to 33,000 ft to avoid TS – altitude could not be sustained – on autopilot which gradually lifted the nose to hold altitude until AP disengaged and A/C entered a stall.

  - Contributing cause factors: Let A/S drop to stall speed - improper stall recovery - A/C held with aft stick in deep stall with engine climb power until crashing – limited knowledge.

- Air France A330. South Atlantic 2009 - high altitude stall after loss of IAS (coffin corner) – A/C held with aft stick in a deep stall with engine climb power until it crashed in the sea.

  - Contributing cause factors: Lost A/S – not controlling attitude – allowed the A/C to stall – improper stall recovery – A/C held in deep stall and climb power – limited knowledge.

Stall during Approach:

- Colgan Air DHC-8-Q400. Buffalo USA 2009 – stall during approach – went trough stick shaker and pusher.
  Contributing cause factors: Improper stall recovery - overrode the pusher (by pulling) and entered a fatal spin to the right – limited knowledge.

- Turkish Airlines B737-800. Amsterdam 2009 – stall during final approach on autopilot with one rad alt malfunction – stick shaker at 460 feet.
  Contributing cause factors: Improper stall recovery – too late recovery actions – limited knowledge.

- Commercial Fairchild SA226-T(B) Merlin. Sotra 2008. Skill Test with Candidate, Instructor and CAA Flight Examiner. Practised “approach to stall” with focus on “minimum altitude loss” with Stall Protection System (pusher) deactivated – entered fatal uncontrollable deep stall.
  - Contributing cause factors: Practiced approach to stall with stick pusher deactivated - lack of knowledge.

http://www.aibn.no/Luftfart/Rapporter/2011-40

- Private Cirrus SR20. Sirdal 2010. On AP - flight into clouds with turbulence and icing – AP cut-out – pilot disorientated and lost control - airplane entered spiral dive – pilot deployed BRS parachute successfully.
  - Contributing cause factors: Unable to maintain manual control - lack of knowledge.

http://www.aibn.no/Luftfart/Rapporter/2012-01-eng

Accident Investigations:

Most LOC accidents are labeled «Pilot/Human Error»

Professor Sidney Dekker offers two views on HE, 2006:

The Old View: *«Human error is a cause of trouble» (bad Apple Theory)*

The New View: *«Human error is a symptom of trouble deeper inside a system»*

Professor James Reason, 1997:

«The Organizational model views human error more as a consequence than as a cause. Errors are the symptoms that reveal the presence of latent conditions in the system at large»

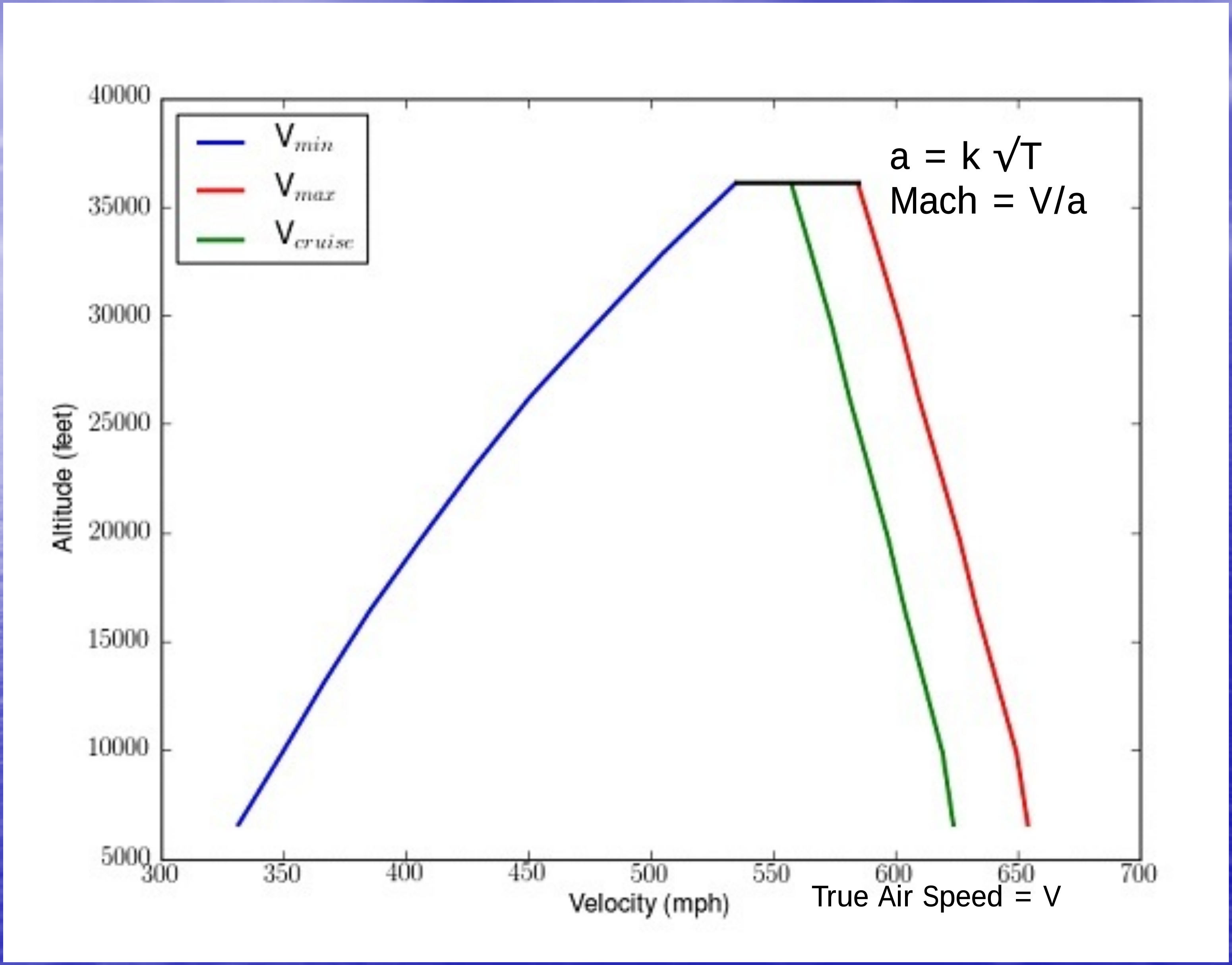
Dr. Simon Bennett, 2012:

"Malfunctions are to be expected in aircraft, by virtue of their interactive complexity, tight coupling and risk-and-error-prone operating environment. In the risk-laden world of aviation the pilot is the last line of defense".

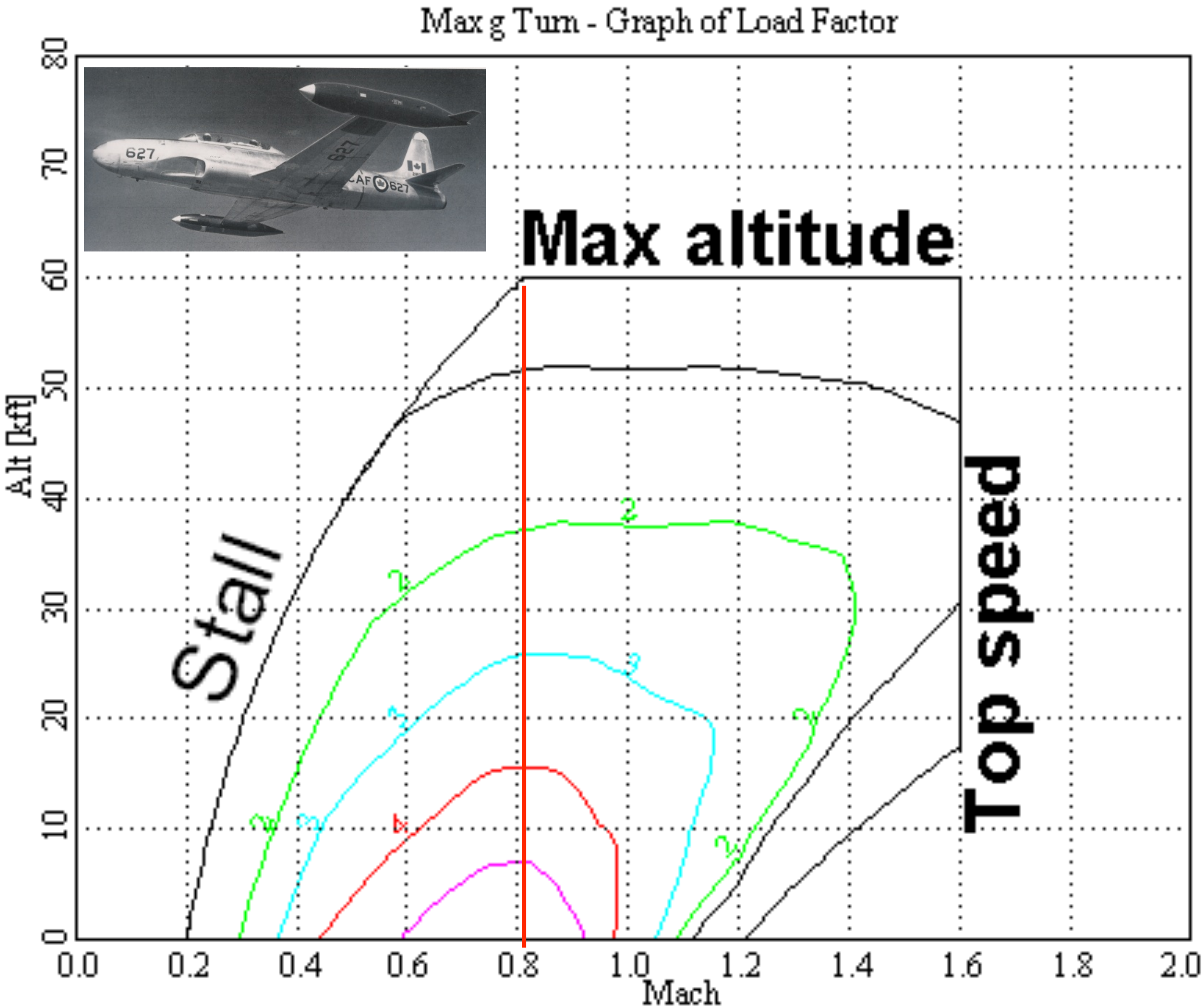
In modern accident investigation theory Human Error is not considered a cause of accident, but a symptom of systemic weakness.

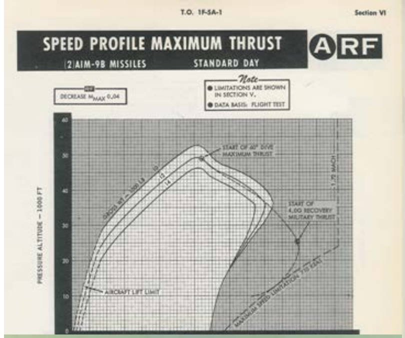
LOC accidents have several underlying cause factors – Organizational Accidents

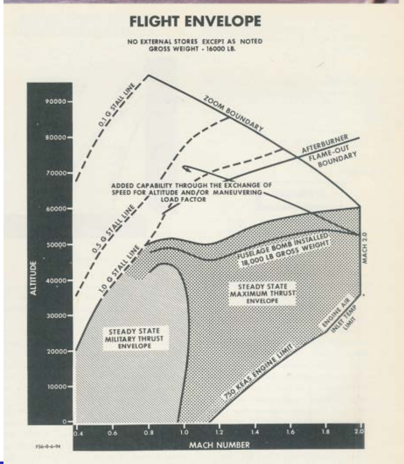
Coffin Corner

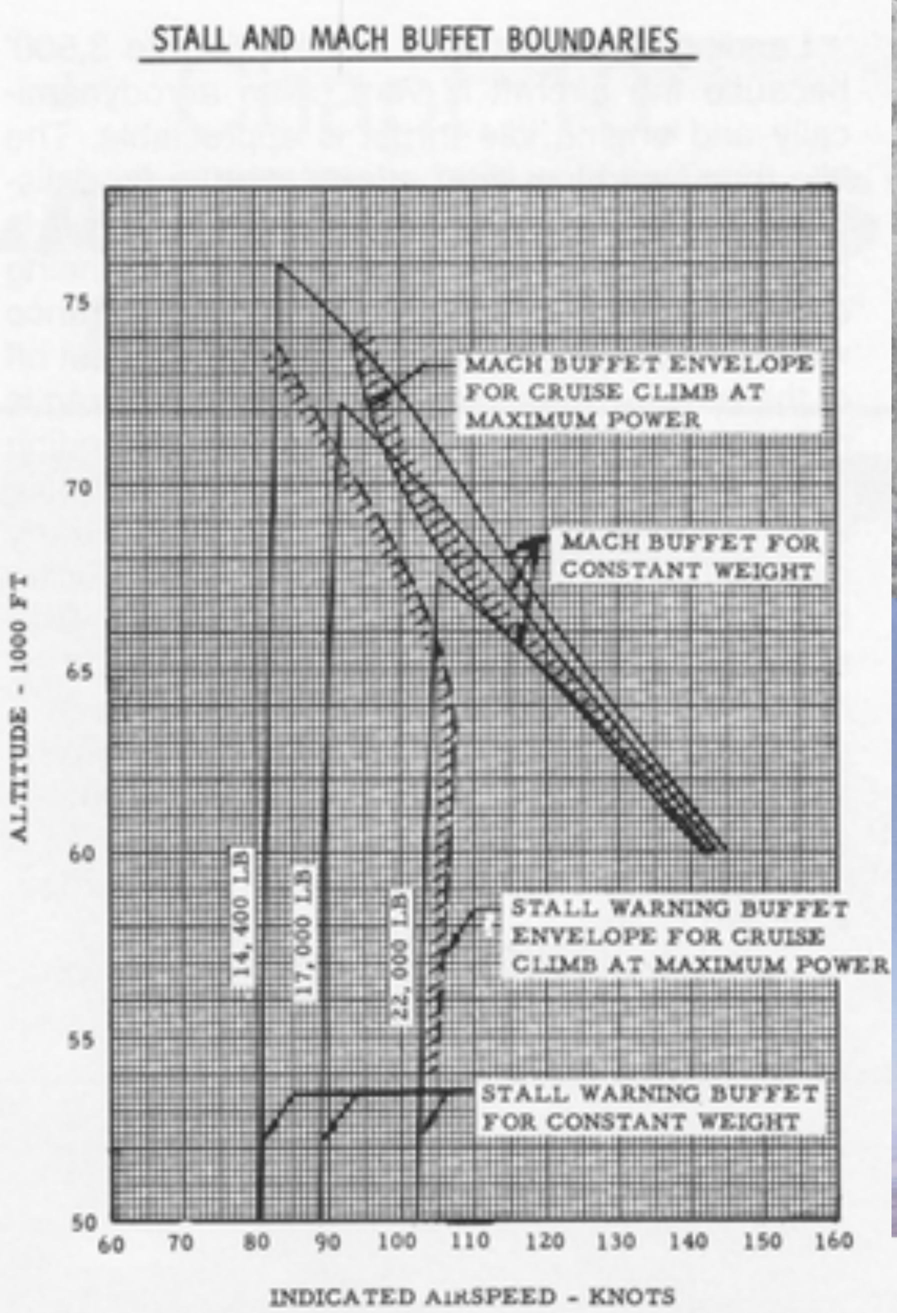


V_{min}
V_{max}
V_{cruise}
$a = k\sqrt{T}$
$Mach = V/a$
40000
35000
30000
25000
20000
15000
10000
5000
Altitude (feet)
300
350
400
450
500
550
600
650
700
Velocity (mph)
True Air Speed = V


Max g Turn - Graph of Load Factor
Max altitude
Stall
Top speed
2
3
Alt [kft]
Mach
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
0
10
20
30
40
50
60
70
80

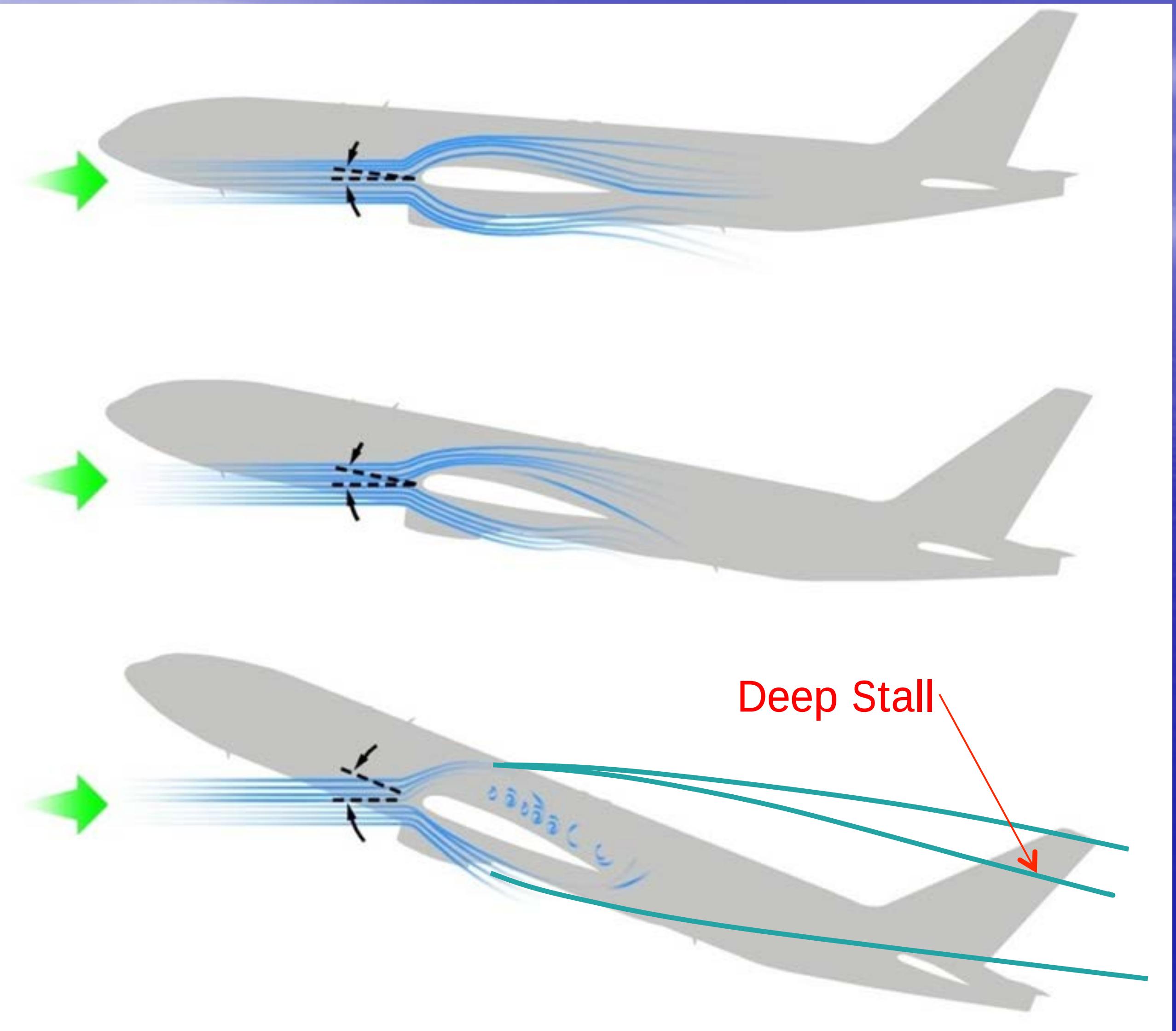

T.O. 1F-5A-1
Section VI
SPEED PROFILE MAXIMUM THRUST
(2) AIM-9B MISSILES
STANDARD DAY
ARF


FLIGHT ENVELOPE
NO EXTERNAL STORES EXCEPT AS NOTED
GROSS WEIGHT - 16000 LB.
ZOOM BOUNDARY
AFTERBURNER FLAME-OUT BOUNDARY
ADDED CAPABILITY THROUGH THE EXCHANGE OF SPEED FOR ALTITUDE AND/OR MANEUVERING LOAD FACTOR
STEADY STATE MAXIMUM THRUST ENVELOPE
STEADY STATE MILITARY THRUST ENVELOPE
MACH NUMBER
ALTITUDE


STALL AND MACH BUFFET BOUNDARIES
MACH BUFFET ENVELOPE FOR CRUISE CLIMB AT MAXIMUM POWER
MACH BUFFET FOR CONSTANT WEIGHT
STALL WARNING BUFFET ENVELOPE FOR CRUISE CLIMB AT MAXIMUM POWER
STALL WARNING BUFFET FOR CONSTANT WEIGHT
14,400 LB
17,000 LB
22,000 LB
ALTITUDE - 1000 FT
50
55
60
65
70
75
60
70
80
90
100
110
120
130
140
150
160
INDICATED AIRSPEED - KNOTS


U.S. AIR FORCE

Stall



Stalls can occur when performing a variety maneuvers

The wing does not know about airplane attitude or airspeed

The deciding factor is the critical/stall angle of attack

The wing stops flying when the stall angle of attack is exceeded

Result = Stall (and possible LOC)

Required = Angle of Attack Indicator

Stall recovery:

JAR 25 CS: « As soon as the aeroplane is stalled, recover by normal recovery technique.»

What is normal recovery technique?

UK CAA: “Simultaneous pitch down and full power”

FAA: “Unstall, smoothly increase power to increase airspeed and minimize loss of altitude”

NTPS: “Unstall, let airspeed increase to at least 1.2Vs before increasing power, recover”

(or, “unstall, delay power for 2 sec and increase power in 2 sec, recover”).

Boeing:

"Emphasis during recovery should be to immediately reduce angle of attack and return the aircraft to a safe flying condition".

"Reducing angle of attack as the first and most important response in the recovery".

Airbus:

"Apply nose down pitch control to reduce AOA".

"Tests show that while applying full thrust at stall warning while maintaining altitude can contribute to reaching full stall conditions".

"Civilian pilots and even turboprop military pilots are not familiar with high Mach buffet".

"Stall recovery training is possible in FFS."

BOTH EMPHEZISING REDUCING AOA – NEITHER IS INSTALLING

Detrimental development over time:

After JAR FCL introduced the concept of *«Approach to stall recovery»* we have seen a gradual tendency to (mal)practise stall recovery from Stall Warning by applying (climb) power and focusing on *«minimum altitude loss»*

This may result in increased AOA and unintentional full stall and LOC

as opposed to traditional

«Stall Recovery» at the Stall/G-break/pitch down/pusher

Some aircraft are equipped with artificial stall warning (shaker) and artificial stall break/nose drop (pusher).

In US NAVY AOA has been in use since the early jet days.

Ex A-4  A-7  etc

In USAF AOA was introduced in some «difficult» A/C types during 1950-ies, ex F-104.

Later A/C has AOA, ex F-16.

During stall training with «pusher» A/C, activation of «pusher» is the artificial «stall» which must trigger recovery action.

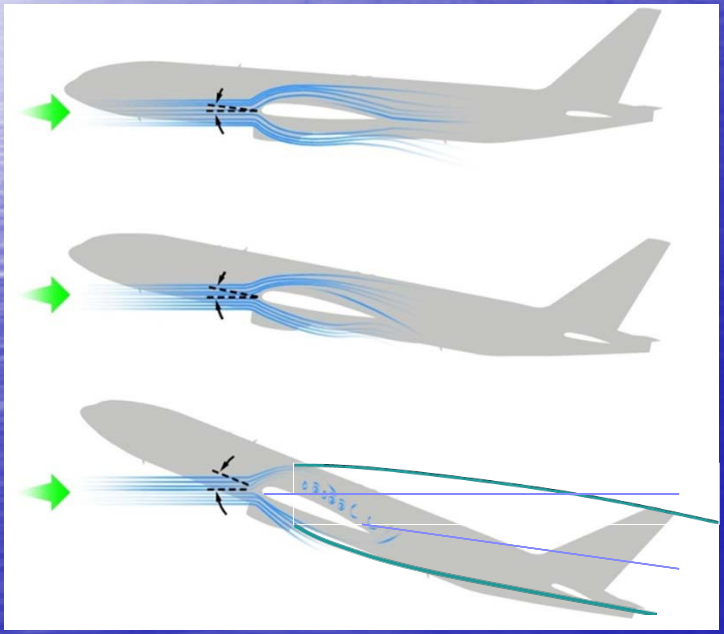
More accurate flying by AOA. We may control A/C by using AOA.

Indicated Airspeed (actually EAS) is just an aerodynamic reference associated with airloads.

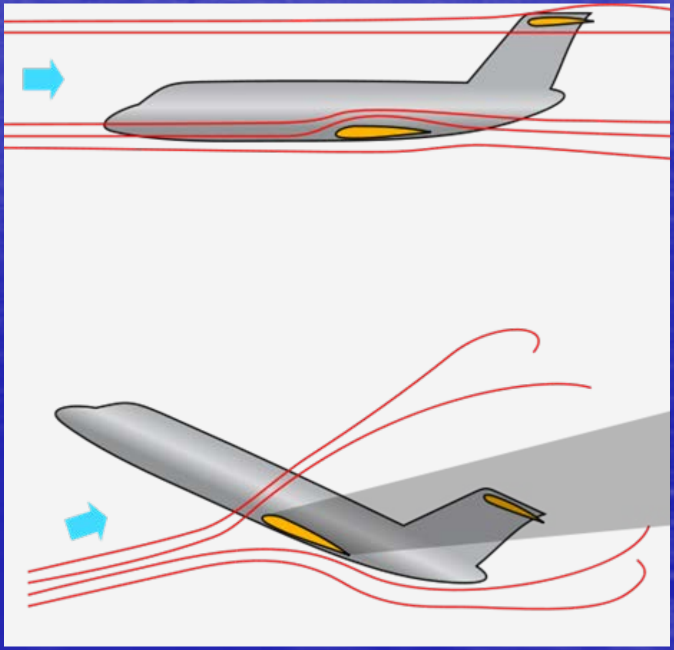
Deep stall

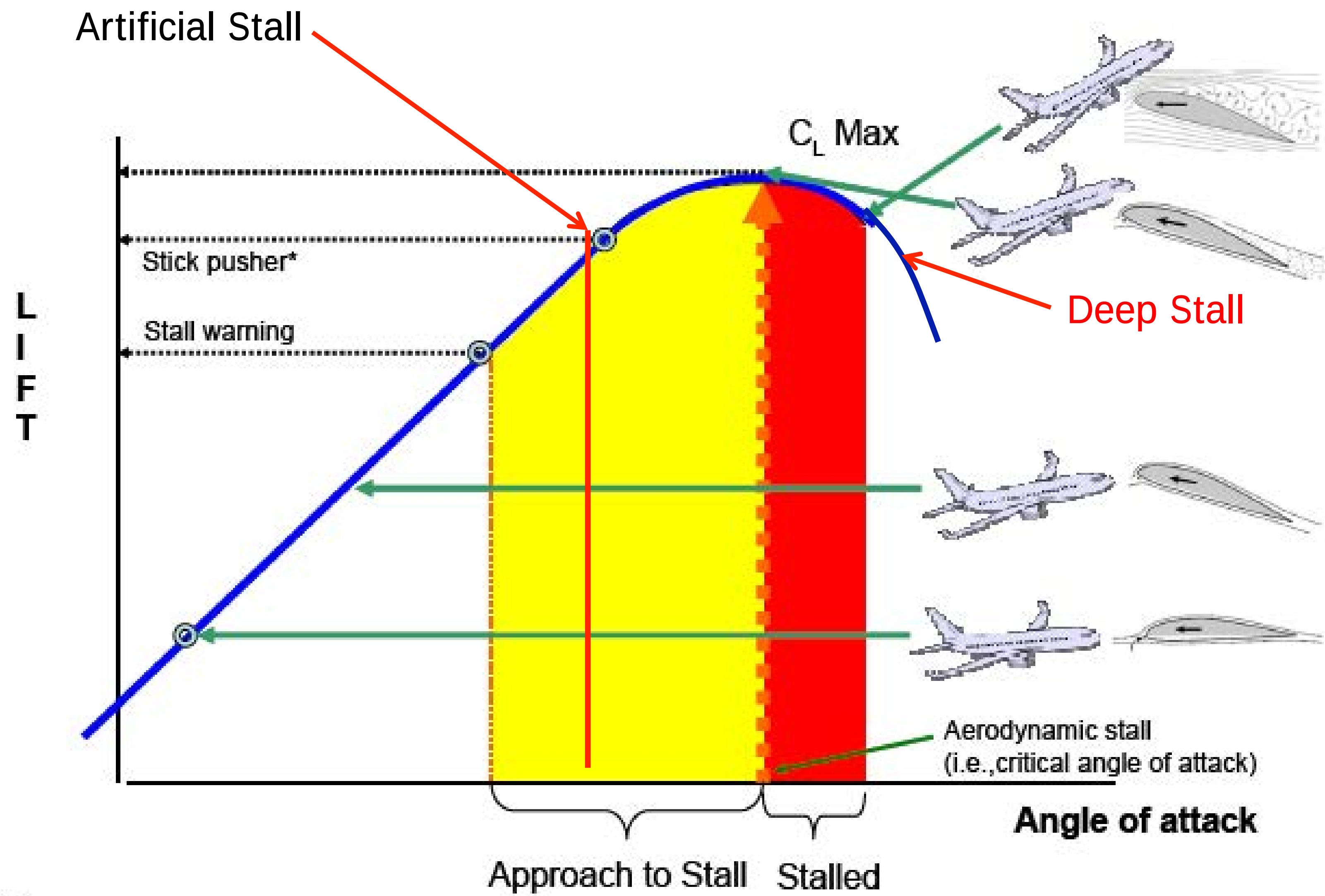
Deep stall

Controllable

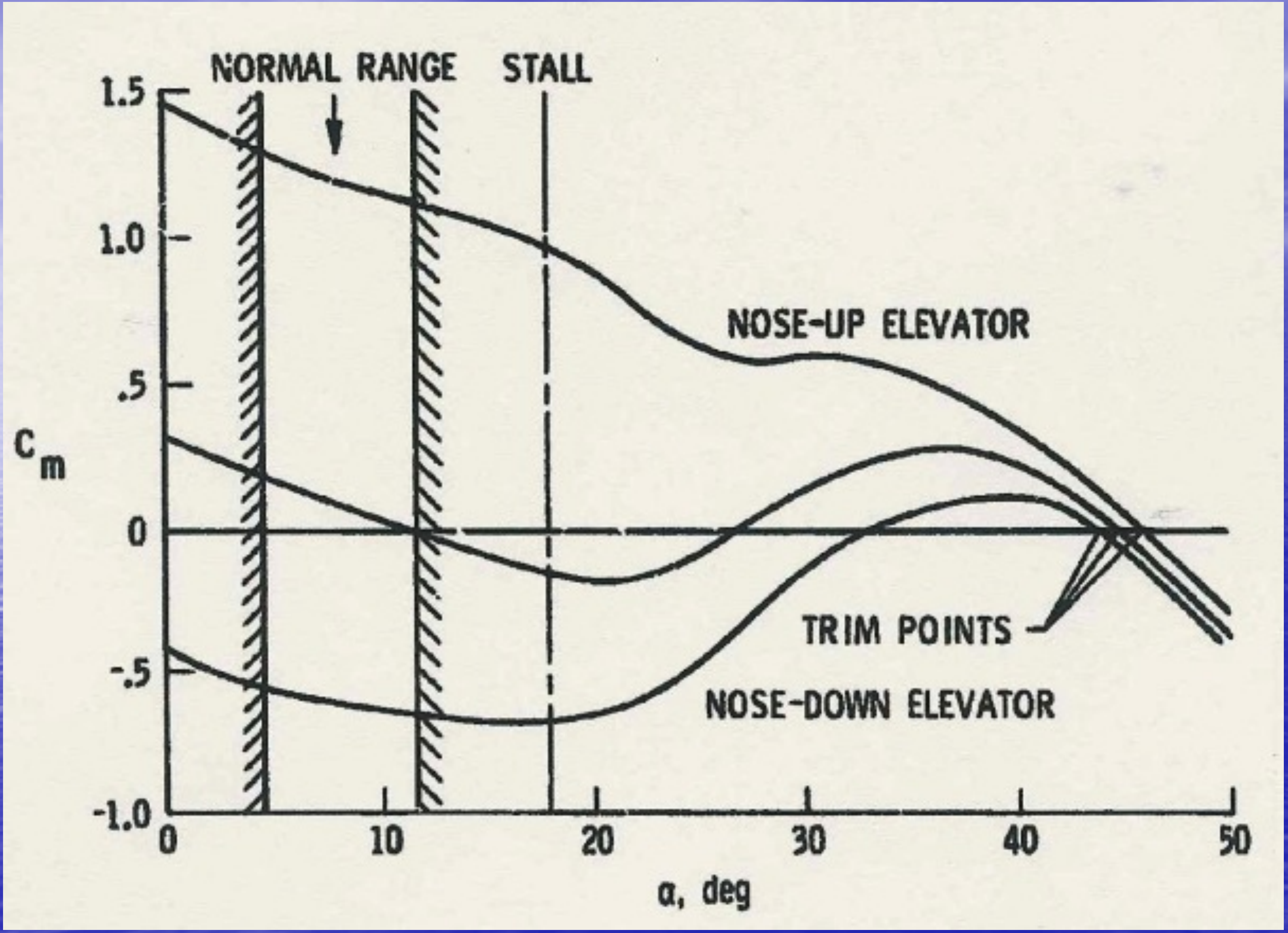


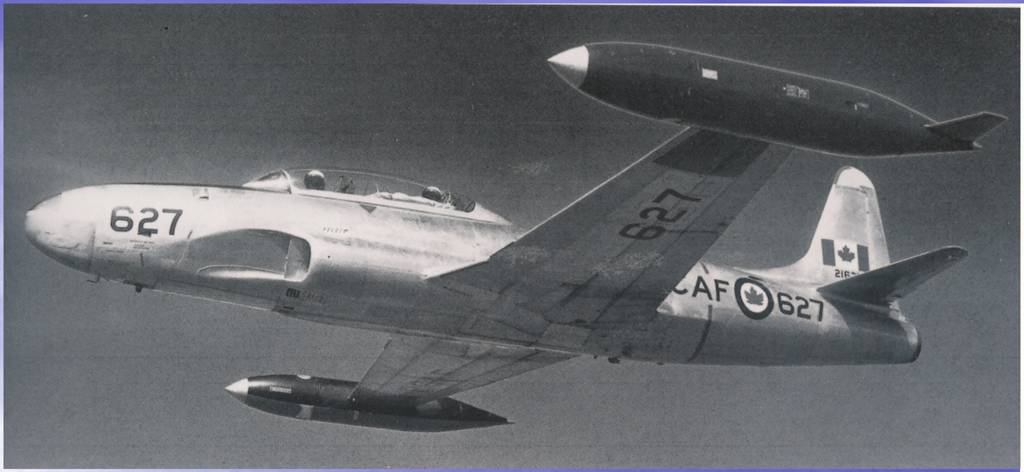
Uncontrollable



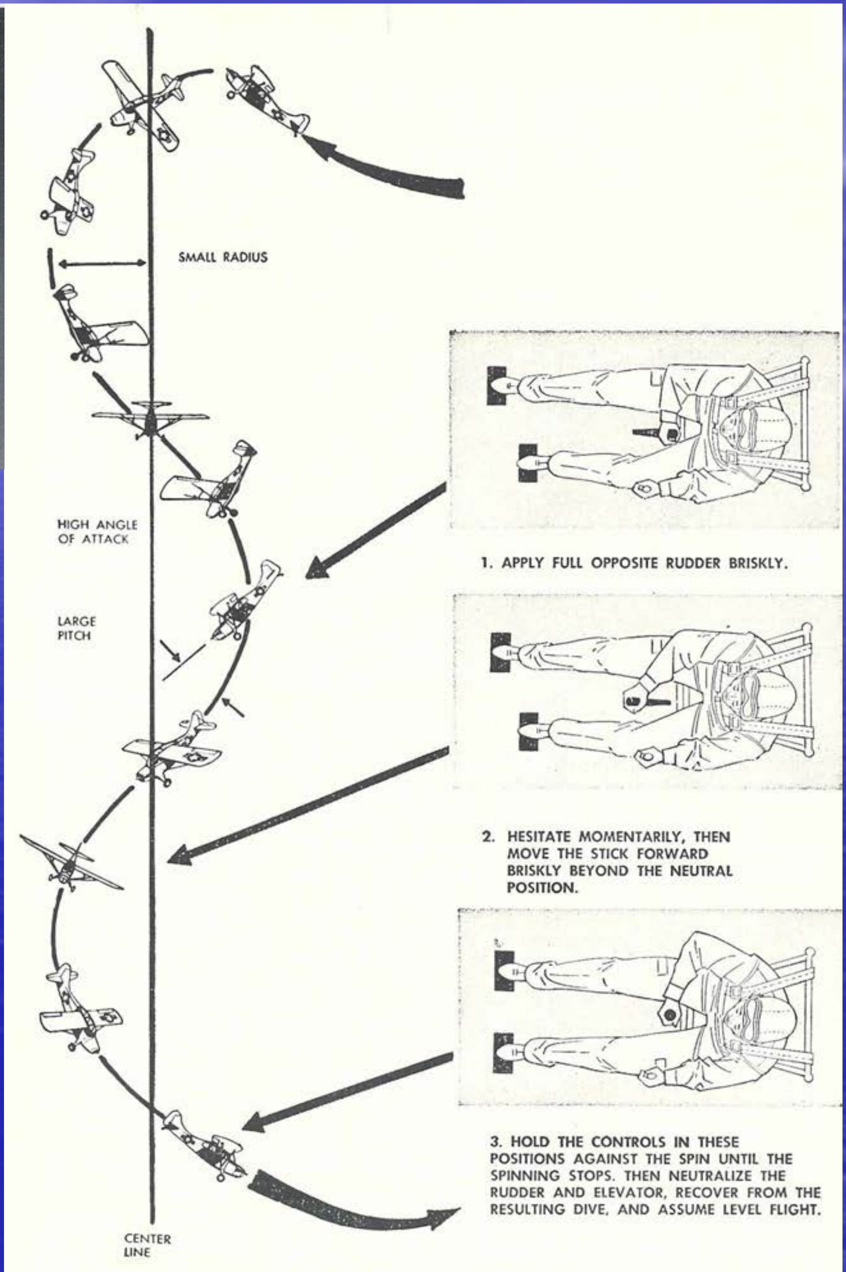


* Stick pusher if installed


NORMAL RANGE
STALL
1.5
1.0
.5
0
-.5
-1.0
C m
NOSE-UP ELEVATOR
TRIM POINTS
NOSE-DOWN ELEVATOR
0
10
20
30
40
50
α, deg



Spin


SMALL RADIUS
HIGH ANGLE OF ATTACK
LARGE PITCH
CENTER LINE
1. APPLY FULL OPPOSITE RUDDER BRISKLY.
2. HESITATE MOMENTARILY, THEN MOVE THE STICK FORWARD BRISKLY BEYOND THE NEUTRAL POSITION.
3. HOLD THE CONTROLS IN THESE POSITIONS AGAINST THE SPIN UNTIL THE SPINNING STOPS. THEN NEUTRALIZE THE RUDDER AND ELEVATOR, RECOVER FROM THE RESULTING DIVE, AND ASSUME LEVEL FLIGHT.

Criteria for entering Spin

1. $\alpha > \alpha_{stall}$ (angle of attack is higher than stall angle of attack)

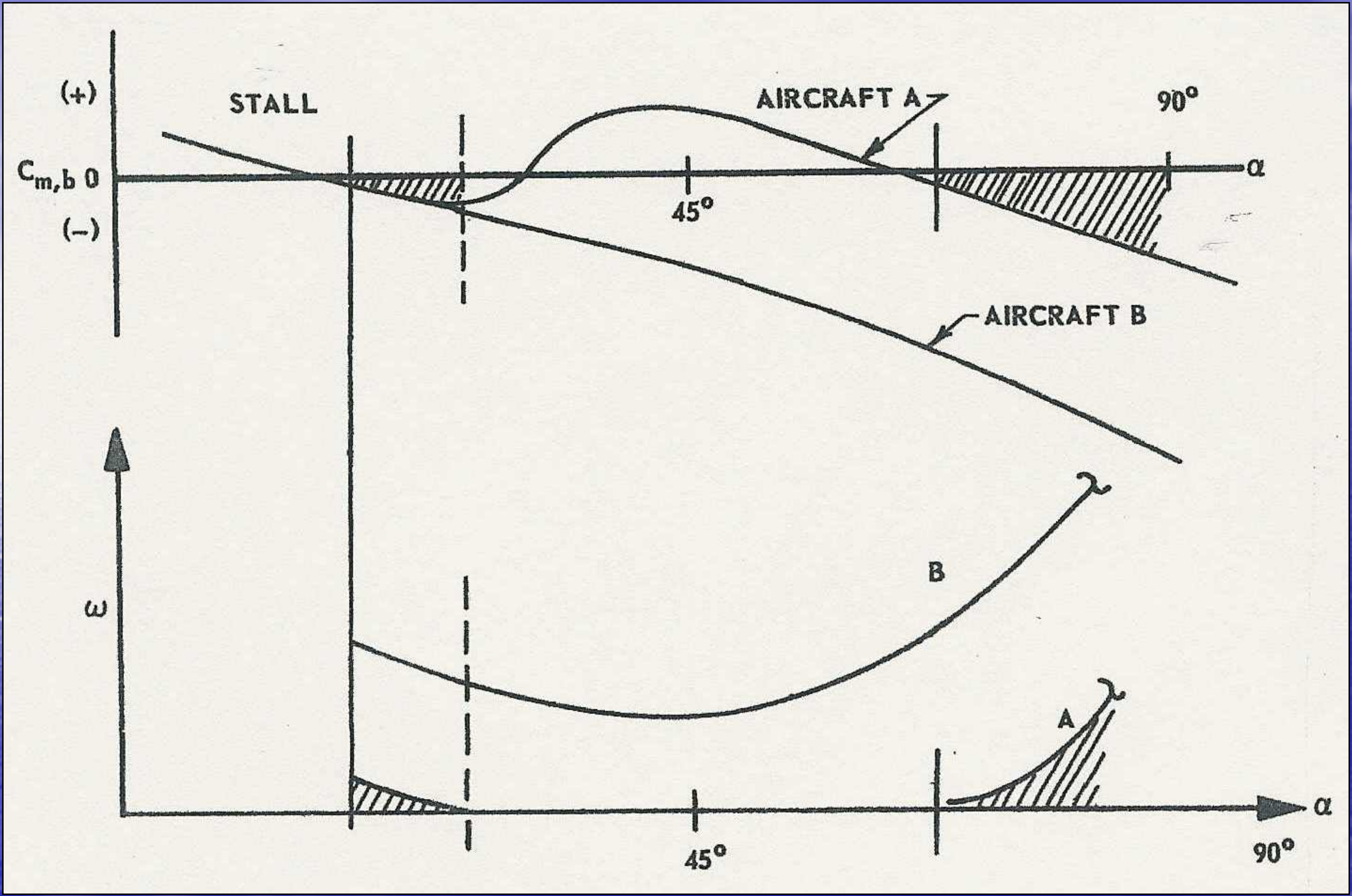
2. $C_n > 0$ (yaw input – uncoordinated flight)

Criteria for stabilized Spin

1. $\alpha > \alpha_{stall}$ (angle of attack is higher than stall angle of attack)

2. Cm < 0 (stabilizing pithing moment)

3. $Cm_{\alpha} < 0$ (negativ pitching courve)



(+)
STALL
AIRCRAFT A
90°
$C_{m,b}$ 0
α
45°
(–)
AIRCRAFT B
ω
B
A
α
45°
90°

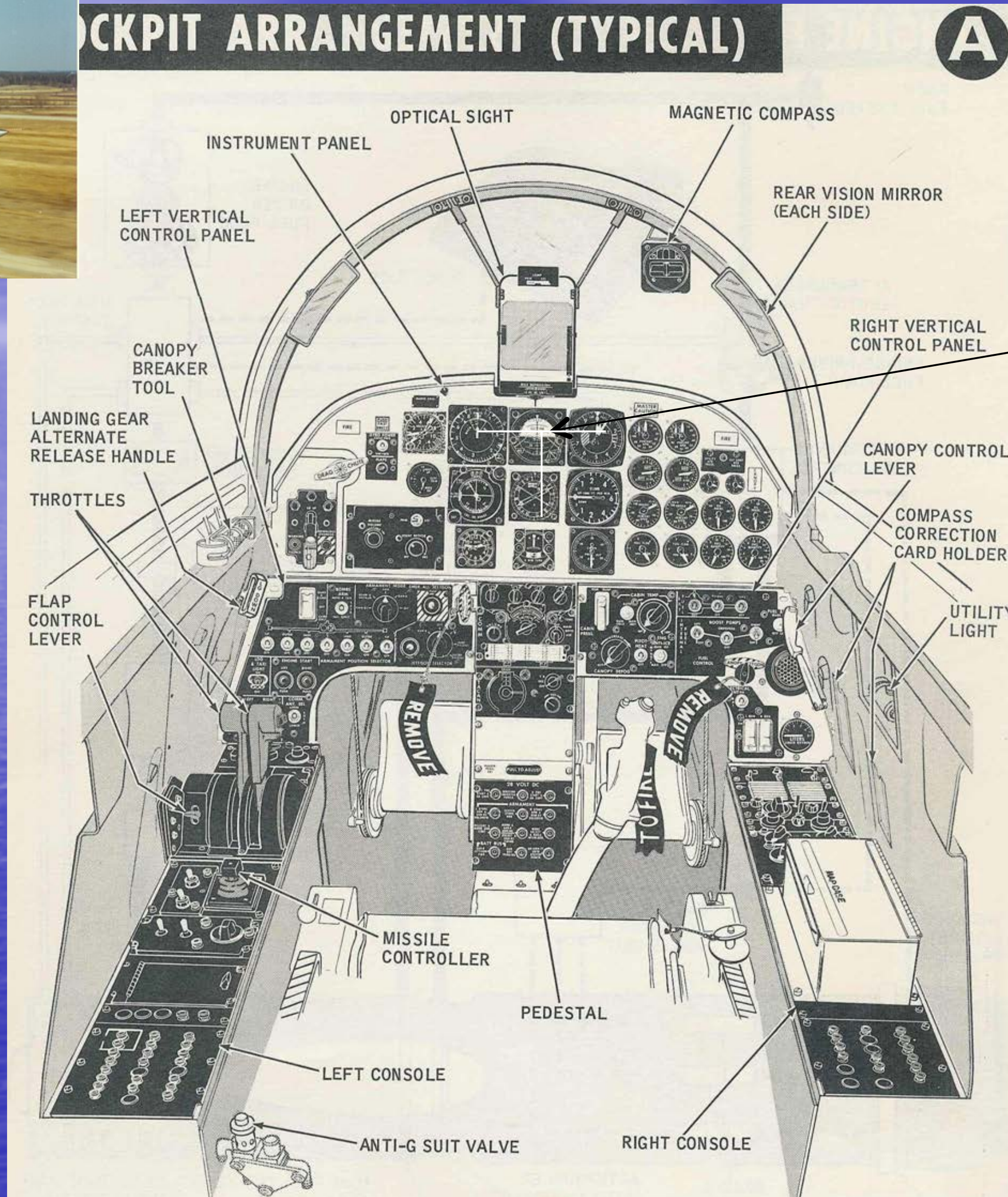
Developments in Flight Displays


AZ-E


FIRE
OVERHEAT
LAND GEAR
CANOPY LOCK
D.C. ELEC

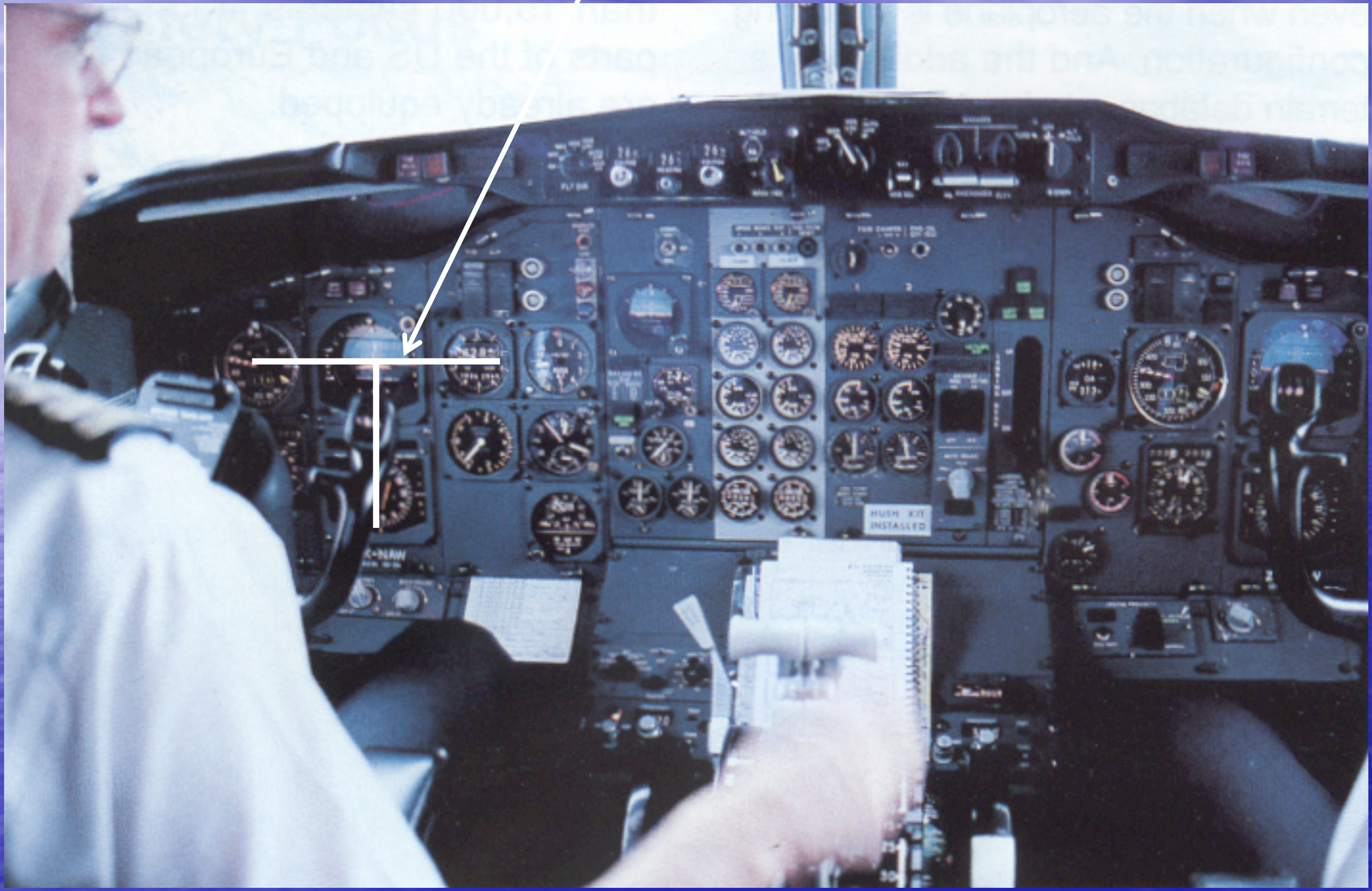

DP-W


AZ-E

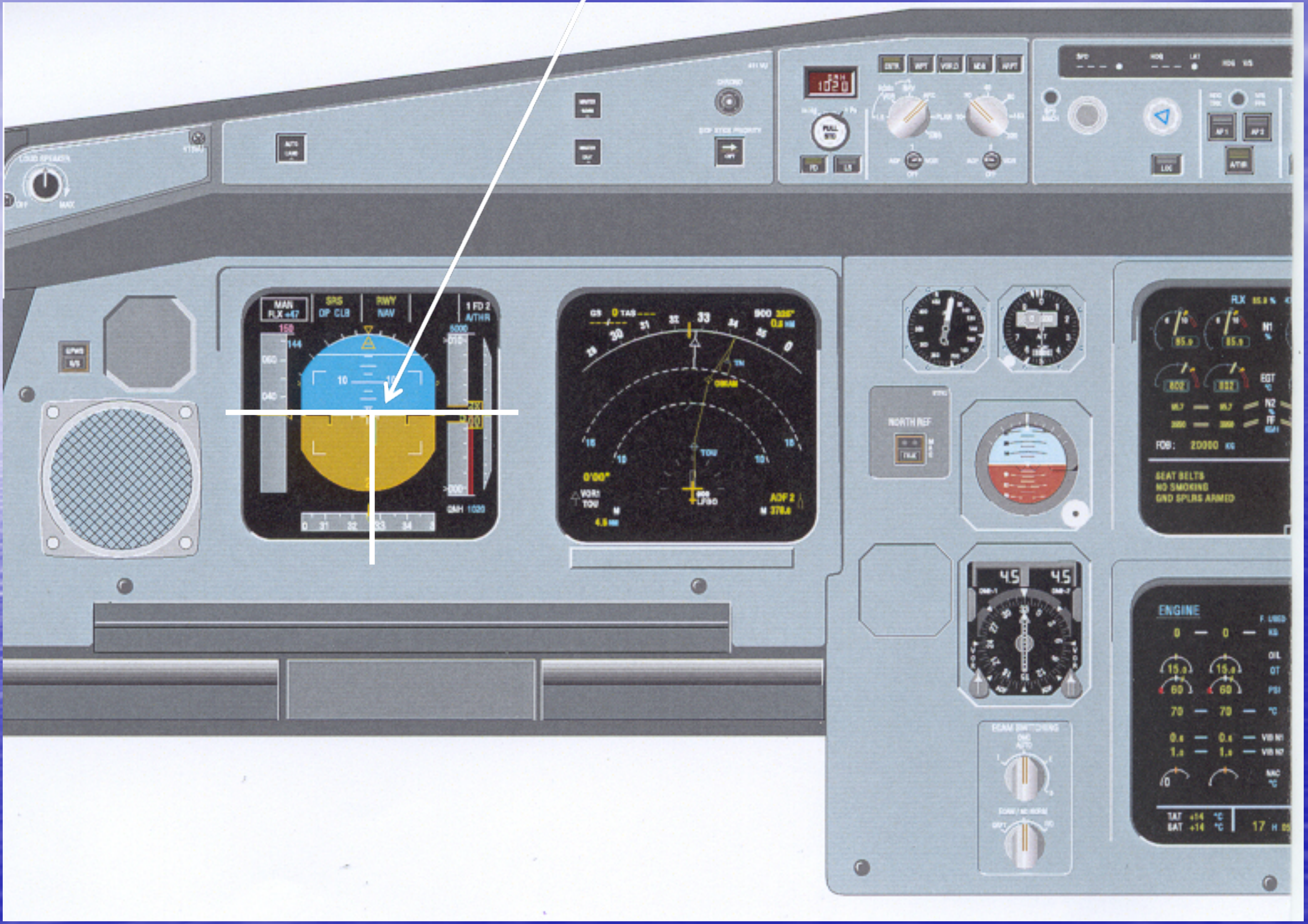

CKPIT ARRANGEMENT (TYPICAL)
A
OPTICAL SIGHT
MAGNETIC COMPASS
INSTRUMENT PANEL
REAR VISION MIRROR
(EACH SIDE)
LEFT VERTICAL
CONTROL PANEL
RIGHT VERTICAL
CONTROL PANEL
CANOPY
BREAKER
TOOL
LANDING GEAR
ALTERNATE
RELEASE HANDLE
CANOPY CONTROL
LEVER
THROTTLES
COMPASS
CORRECTION
CARD HOLDERS
UTILITY
LIGHT
FLAP
CONTROL
LEVER
REMOVE
REMOVE
MISSILE
CONTROLLER
PEDESTAL
LEFT CONSOLE
ANTI-G SUIT VALVE
RIGHT CONSOLE

Basic T

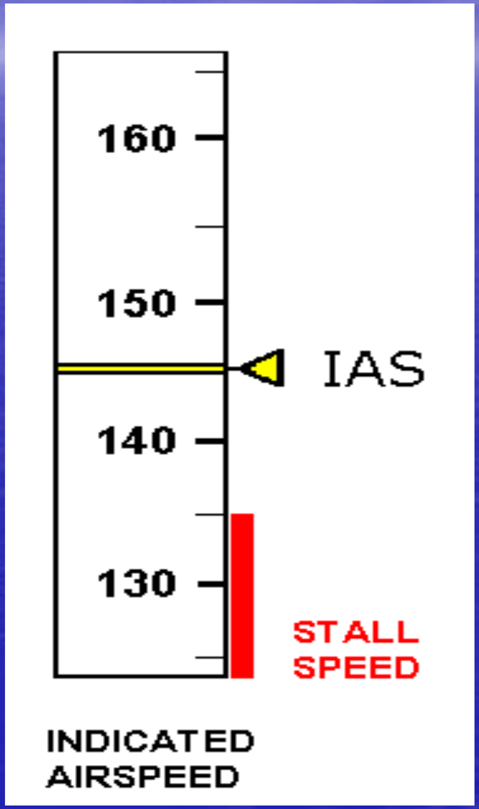
Basic T



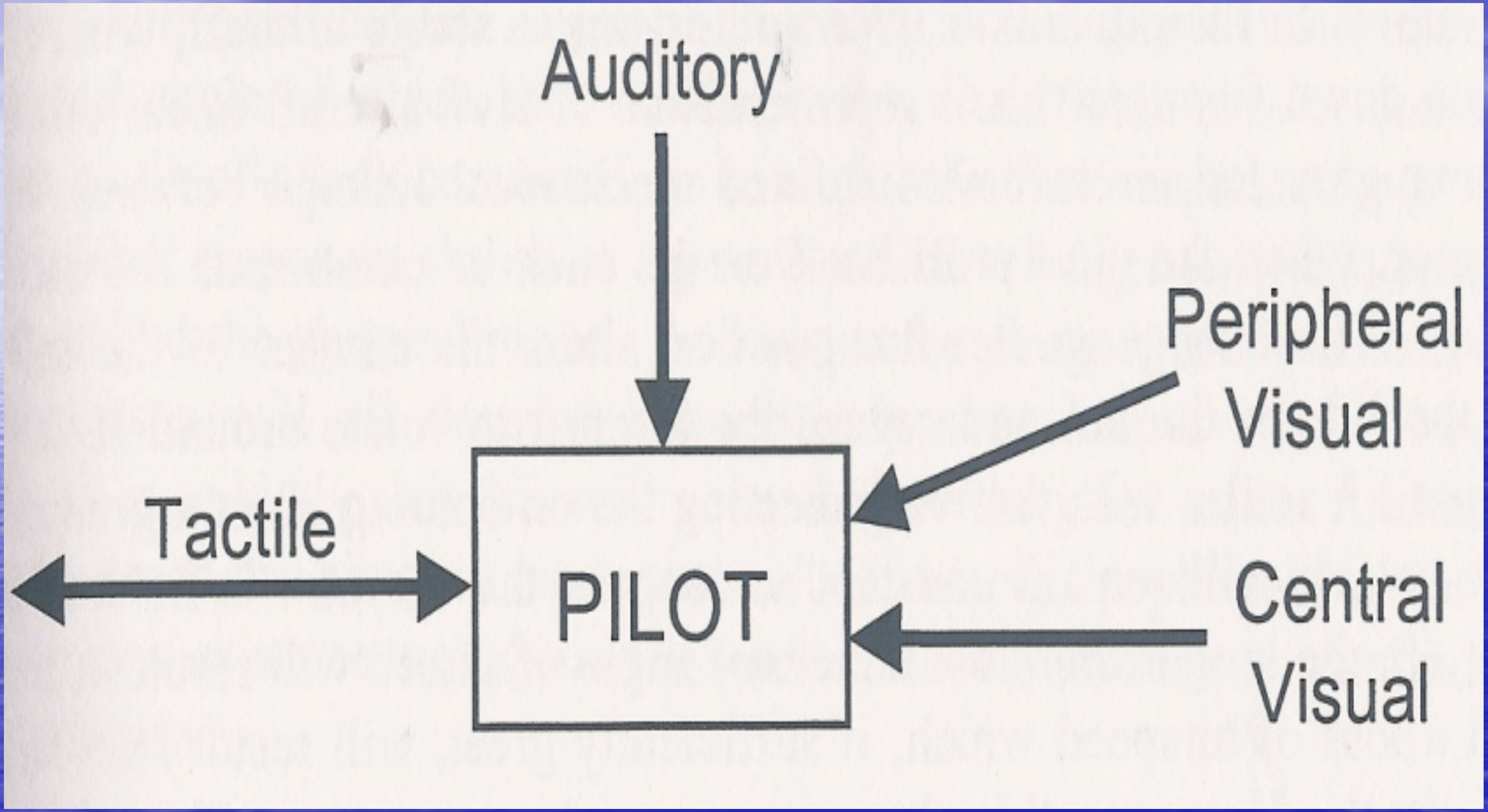
Basic T



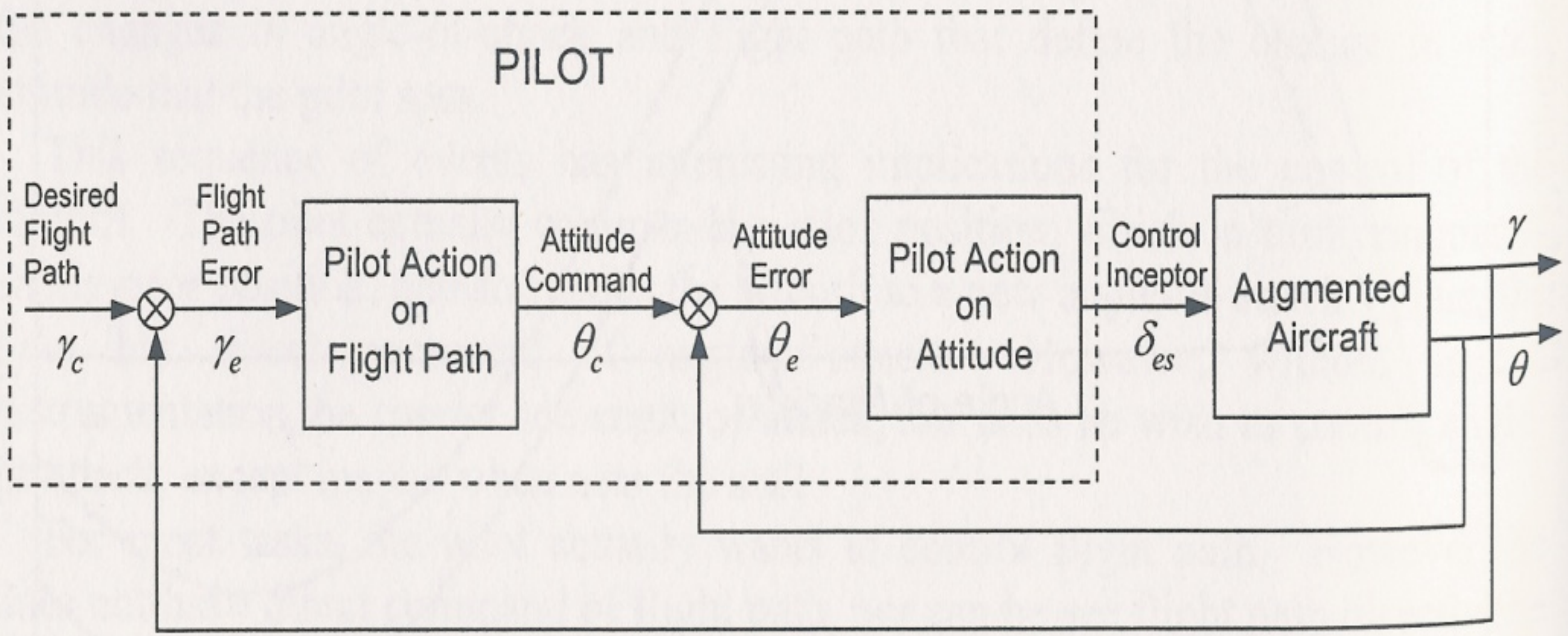

240
40
220
60
200
80
180
100
160
140
120


160
150
IAS
140
130
STALL
SPEED
INDICATED
AIRSPEED

Pilot information cueing channels

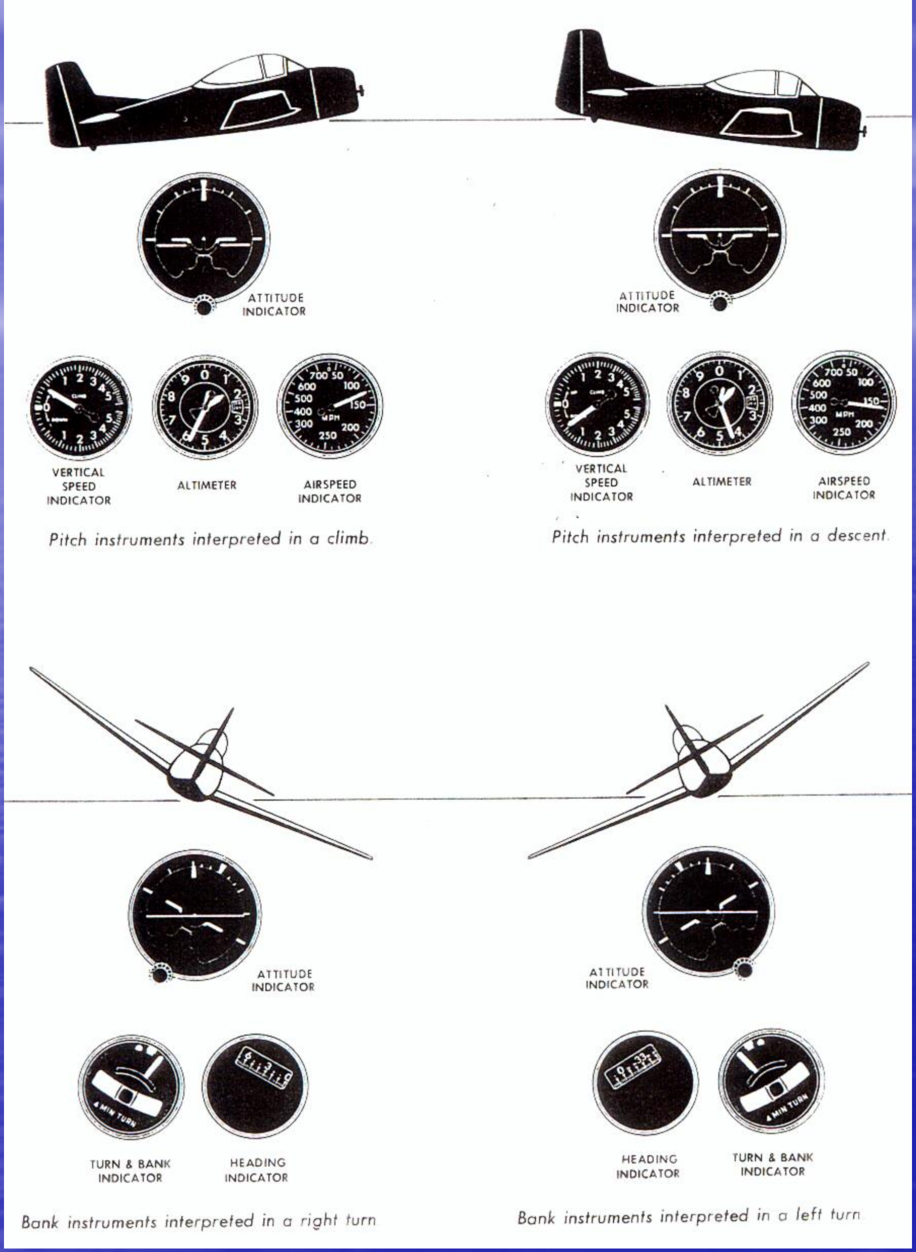


The series pilot model




CIRRUS PERSPECTIVE
BY GARMIN

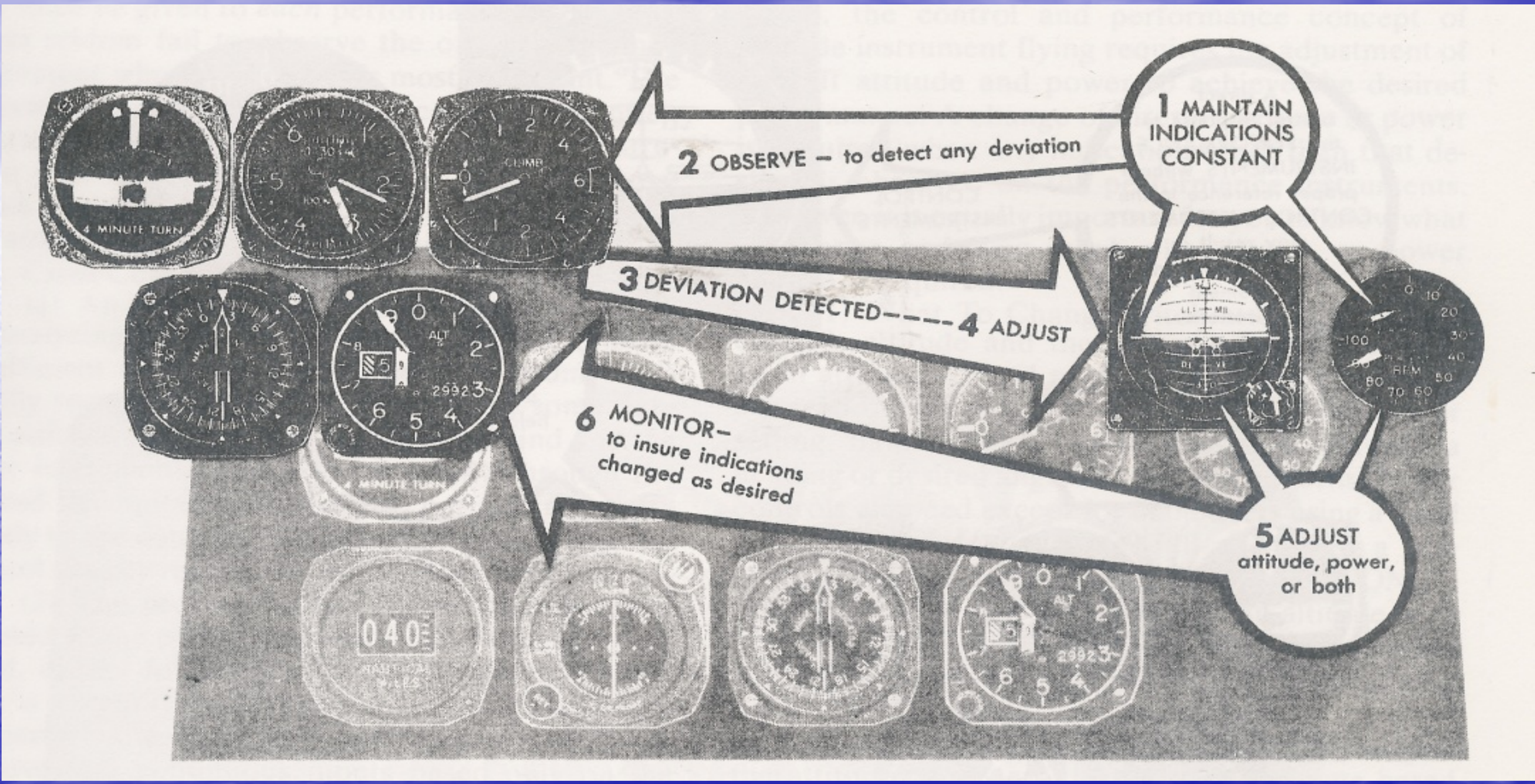
Developments in Pilot Education


ATTITUDE INDICATOR
VERTICAL SPEED INDICATOR
ALTIMETER
AIRSPEED INDICATOR
Pitch instruments interpreted in a climb.
ATTITUDE INDICATOR
VERTICAL SPEED INDICATOR
ALTIMETER
AIRSPEED INDICATOR
Pitch instruments interpreted in a descent.
ATTITUDE INDICATOR
TURN & BANK INDICATOR
HEADING INDICATOR
Bank instruments interpreted in a right turn
ATTITUDE INDICATOR
HEADING INDICATOR
TURN & BANK INDICATOR
Bank instruments interpreted in a left turn

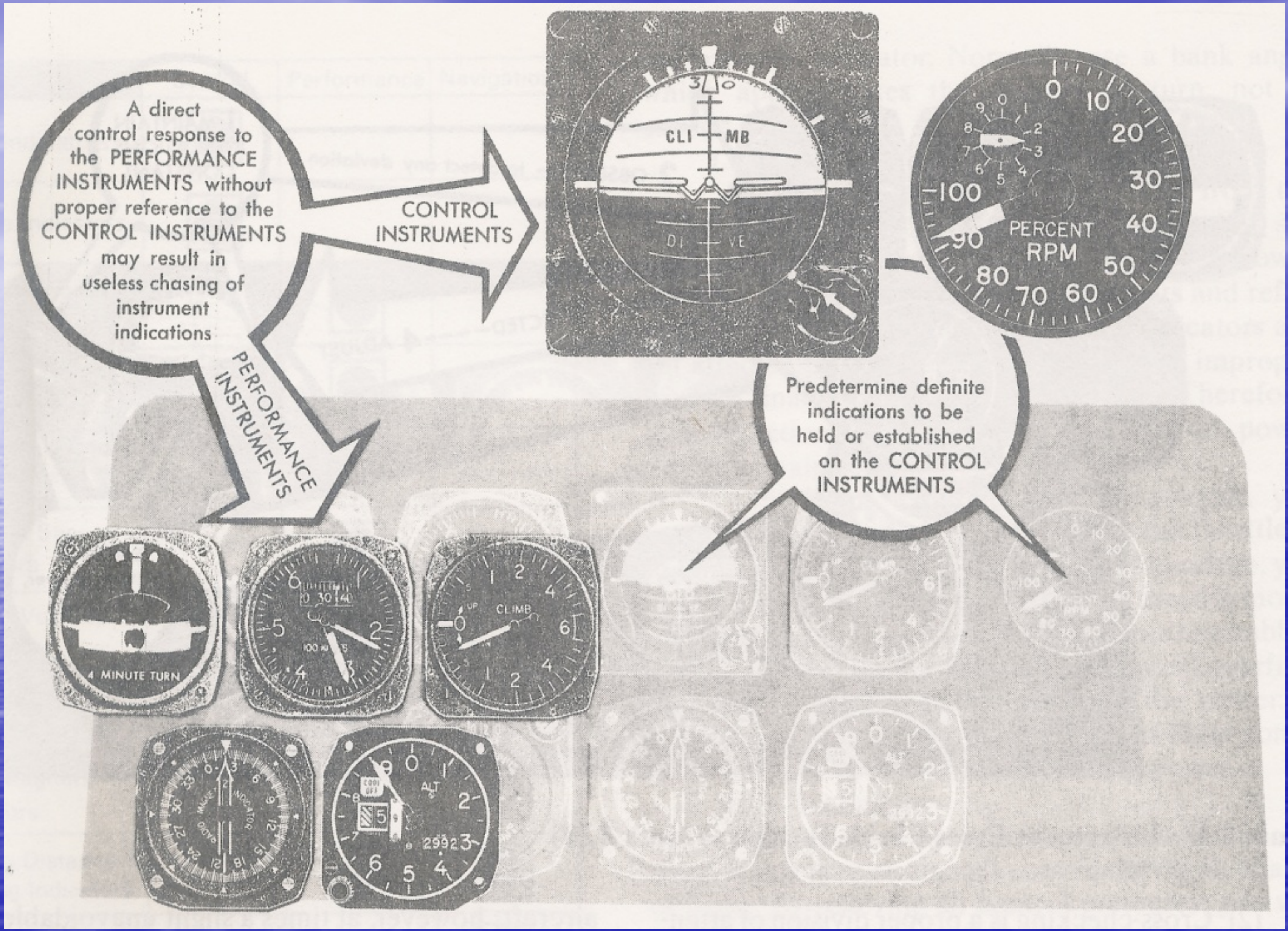
INSTRUMENT CATEGORIES

Instruments can be divided into three general categories.

Figure 7-2.
Instrument Categories:
Control-Performance-Navigation

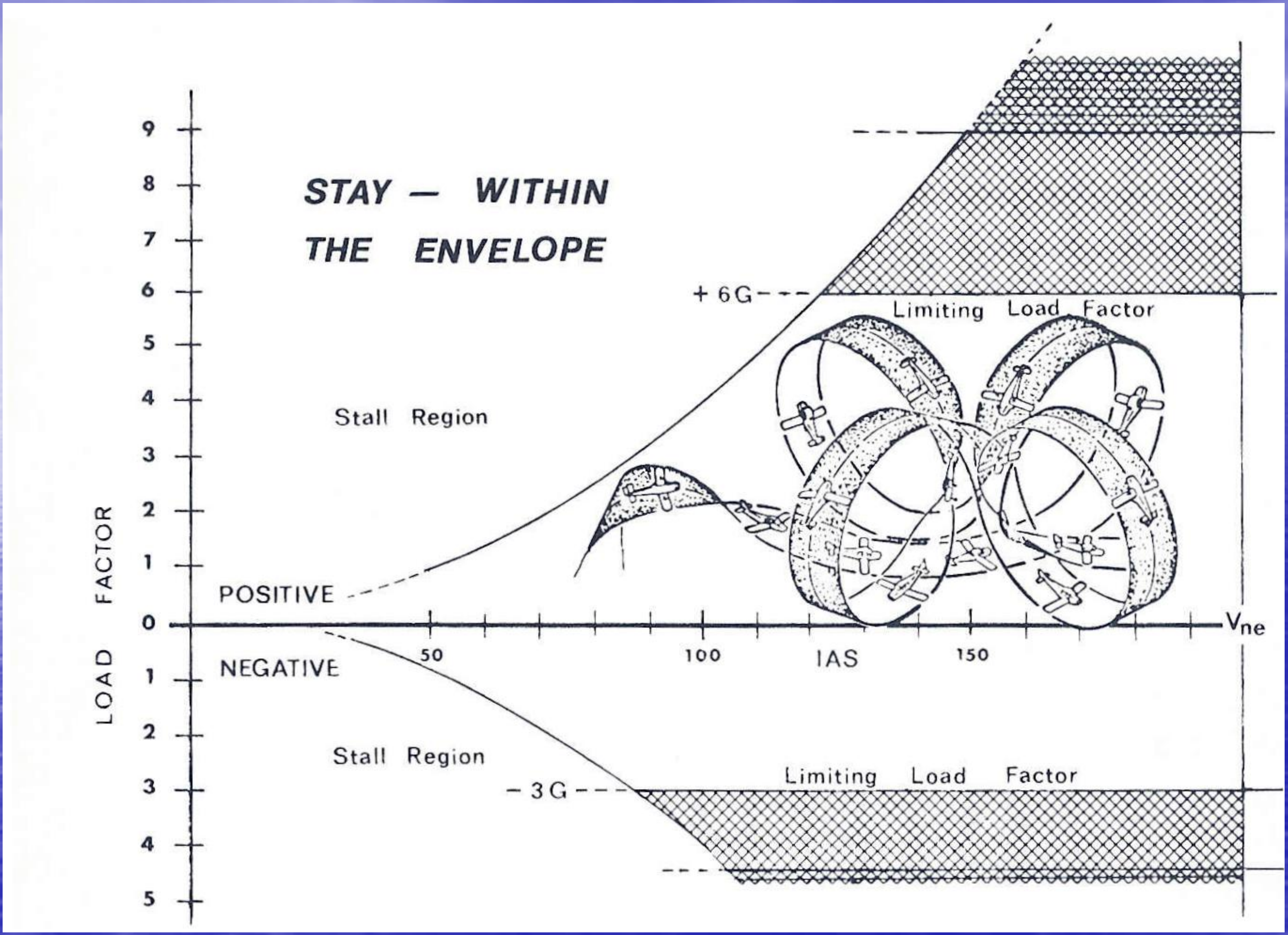


1 MAINTAIN INDICATIONS CONSTANT
2 OBSERVE – to detect any deviation
3 DEVIATION DETECTED----4 ADJUST
5 ADJUST attitude, power, or both
6 MONITOR– to insure indications changed as desired
4 MINUTE TURN
CLIMB
ALT
2992
RPM
040


A direct control response to the PERFORMANCE INSTRUMENTS without proper reference to the CONTROL INSTRUMENTS may result in useless chasing of instrument indications
CONTROL INSTRUMENTS
PERFORMANCE INSTRUMENTS
Predetermine definite indications to be held or established on the CONTROL INSTRUMENTS
CLIMB
DIVE
PERCENT RPM
4 MINUTE TURN
CLIMB
ALT

Developments in Pilot Education

Stall and Aerobatic Training

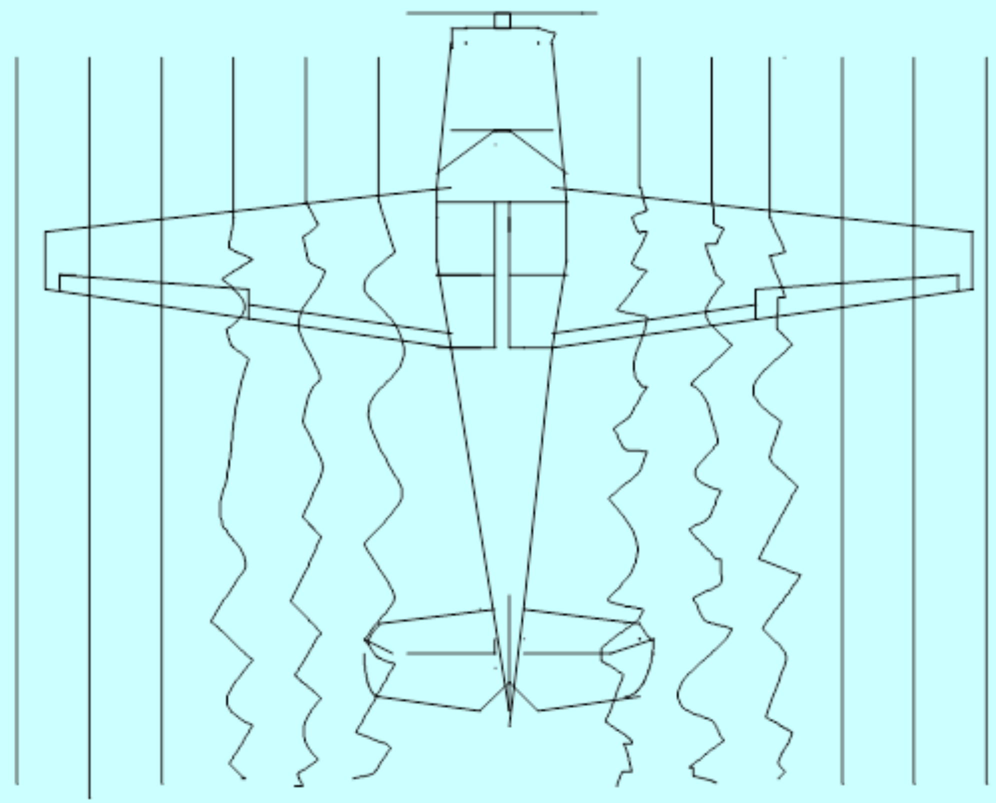


STAY — WITHIN
THE ENVELOPE
LOAD FACTOR
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
+ 6G
Limiting Load Factor
Stall Region
POSITIVE
NEGATIVE
50
100
IAS
150
V_{ne}
Stall Region
– 3G
Limiting Load Factor


AY


333


LN-SAP



Deepstall

Stall training in Safir (and other aerobatic A/C):

- Clean stall recovery
- Landing config stall recovery
- Final turn stall recovery
- Deep stall control and recovery

Summary

- Flight safety is increased to a very high level, but may still be improved.
- The improvements are mainly a result from improved flight displays and technology (Navigation Displays).
- The technology on the other hand, has reduced pilots ability to manually control the aircraft in unusual attitudes (Flight Displays/Controls).
- The basic pilot education seems to have declined over time (Academics/Full Stall Recovery Training).
- Further improvements in flight safety requires improvements in basic pilot education and training.

Thank you for your attention

Questions?