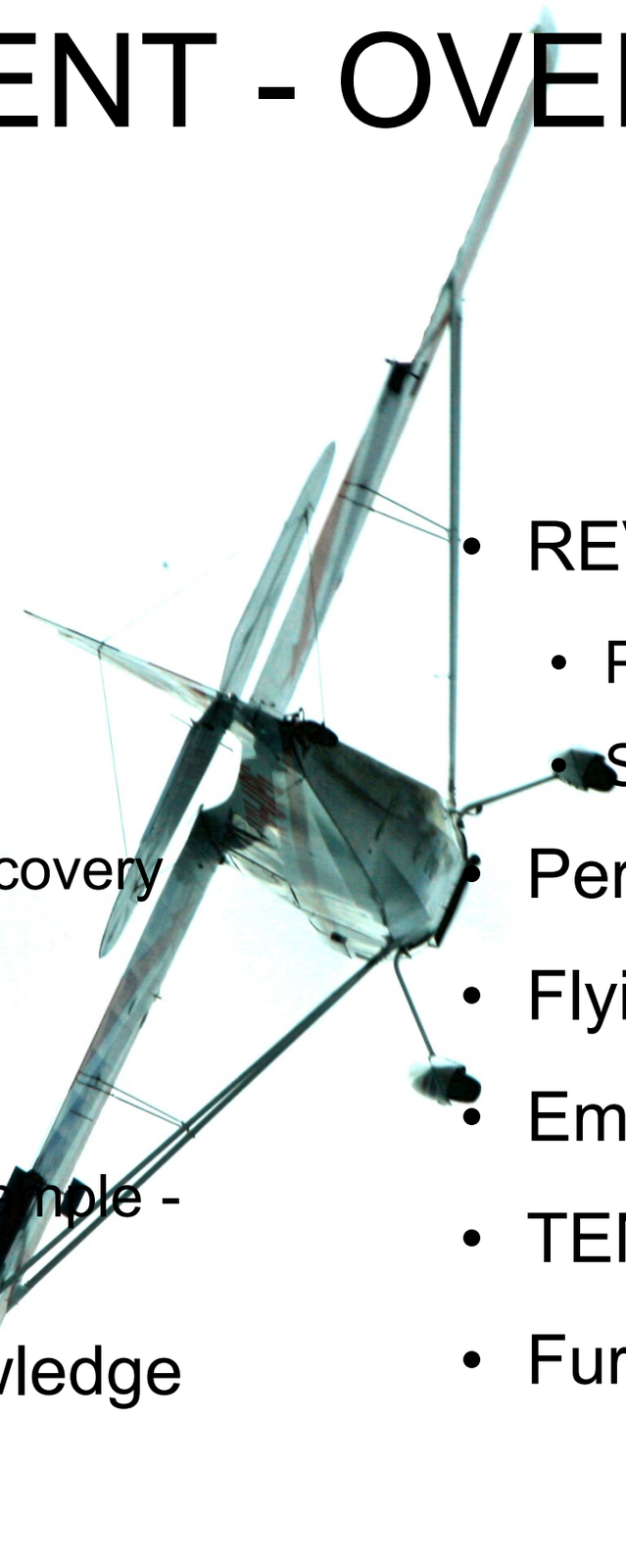
BASIC AEROBATICS (3000 FT)

REFRESHER

David Pilkington FRAeS

CONTENT - OVERVIEW



- Loss of Control In-Flight
  - Decathlon Accidents
  - Stall training
  - Stall and incipient spin recovery
- Basic Aerobatics
  - Current rules
  - Part 61 competencies example - What is a loop?
- Spin Underpinning Knowledge
- REVISION
  - Physiological Considerations
  - Structural Considerations
- Performance & Handling
- Flying the Manoeuvres
- Emergency Procedures
- TEM
- Further Reading

Decathlon Accident History

Stall Revision

Part 61 syllabus (revised Jan 2021):

- straight and level flight; climbing flight; descending flight; approach to land configuration; turning flight
- recognise wing drop at the stall; from balanced flight, recover from stall in the attitudes and configurations most likely to cause a wing drop; perform recovery where the aeroplane exhibits a tendency to drop a wing at the stall

Refer AC 61-16 Spin avoidance and stall recovery training

Stall Revision

From the FAA's Airplane Flying Handbook Chapter 4

Maintaining Aircraft Control: Upset Prevention and Recovery Training

Stall Recovery Template	
1. Wing leveler or autopilot	1. Disconnect
2. a) Pitch nose-down b) Trim nose-down pitch	2. a) Apply until impending stall indications are eliminated b) As needed
3. Bank	3. Wings Level
4. Thrust/Power	4. As needed
5. Speed brakes/spoilers	5. Retract
6. Return to the desired flight path	

Figure 4-6. *Stall recovery template.*

Incipient Spin Recovery

An inadvertent stall/spin entry requires immediate action to unstall the wing and to remove the aggravating control deflections. Move the stick forward and get rid of aileron and rudder input. In other words:

Centralise the controls.

Close the throttle.

It works for both upright and inverted spin entries.

NB: only for types approved for intentional spins and must be done without delay.

BASIC AEROBATICS

Spinning (spin endorsement)

Loop

Roll

Hammerhead

Unusual Attitude Recovery

Manoeuvres	Parameter	Tolerances
Looping manoeuvres	Nominated line feature	±10°
	Nominated airspeed	±10 kts
	Entry and recovery heights	±100 ft
Rolling manoeuvres	Nominated airspeed	±10 kts
	Direction	±10°
	Altitude	±100 ft
Stall turn-hammerhead	Nominated air speed	±10 kts
	Nominated line feature 180°	±15°

Additional training in complex figures:

- **Reverse Cuban Eight**
- **Quarter roll down**
- **Hesitation roll**
- **Snap roll**

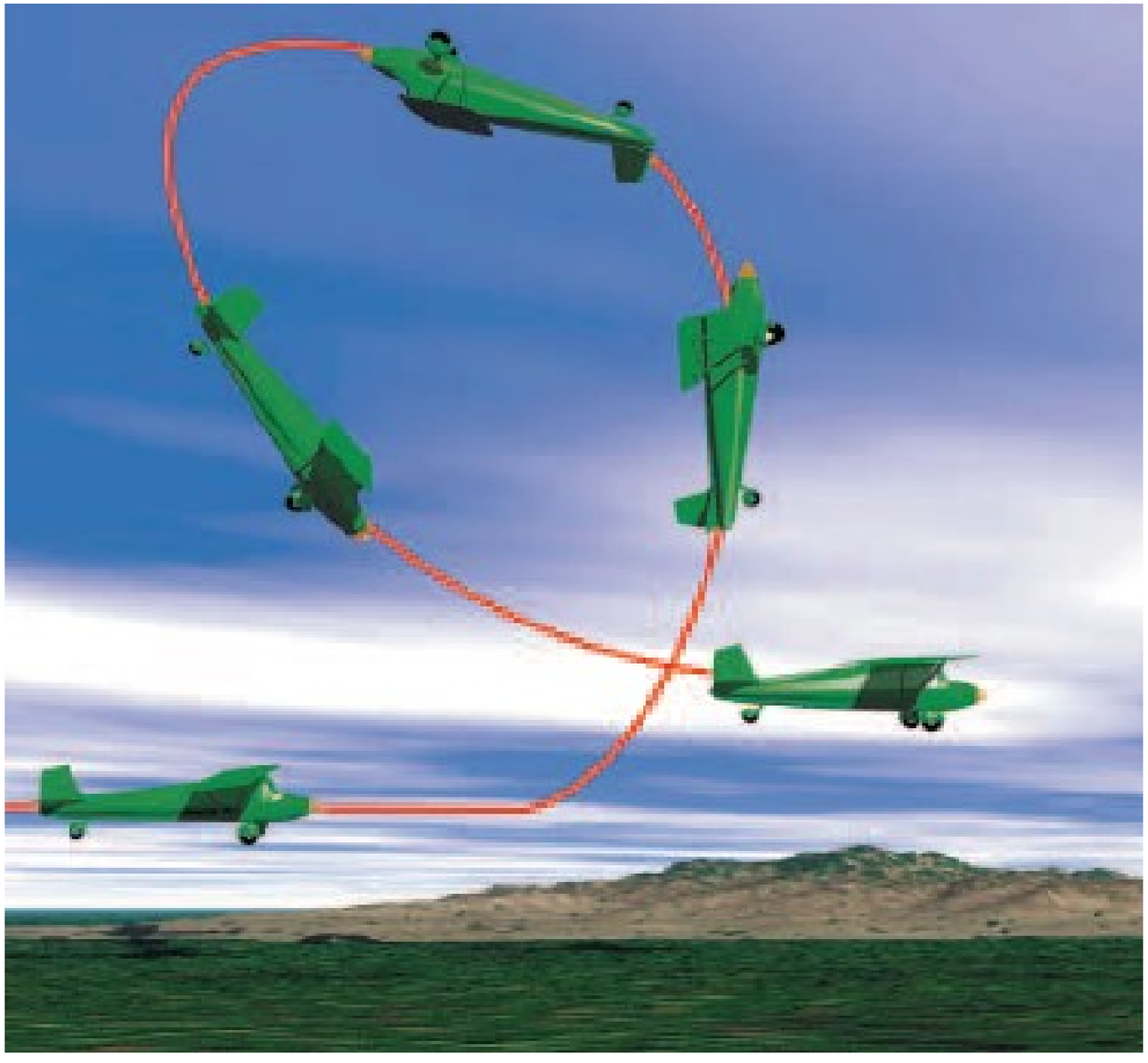
PART 61 COMPETENCY STANDARDS

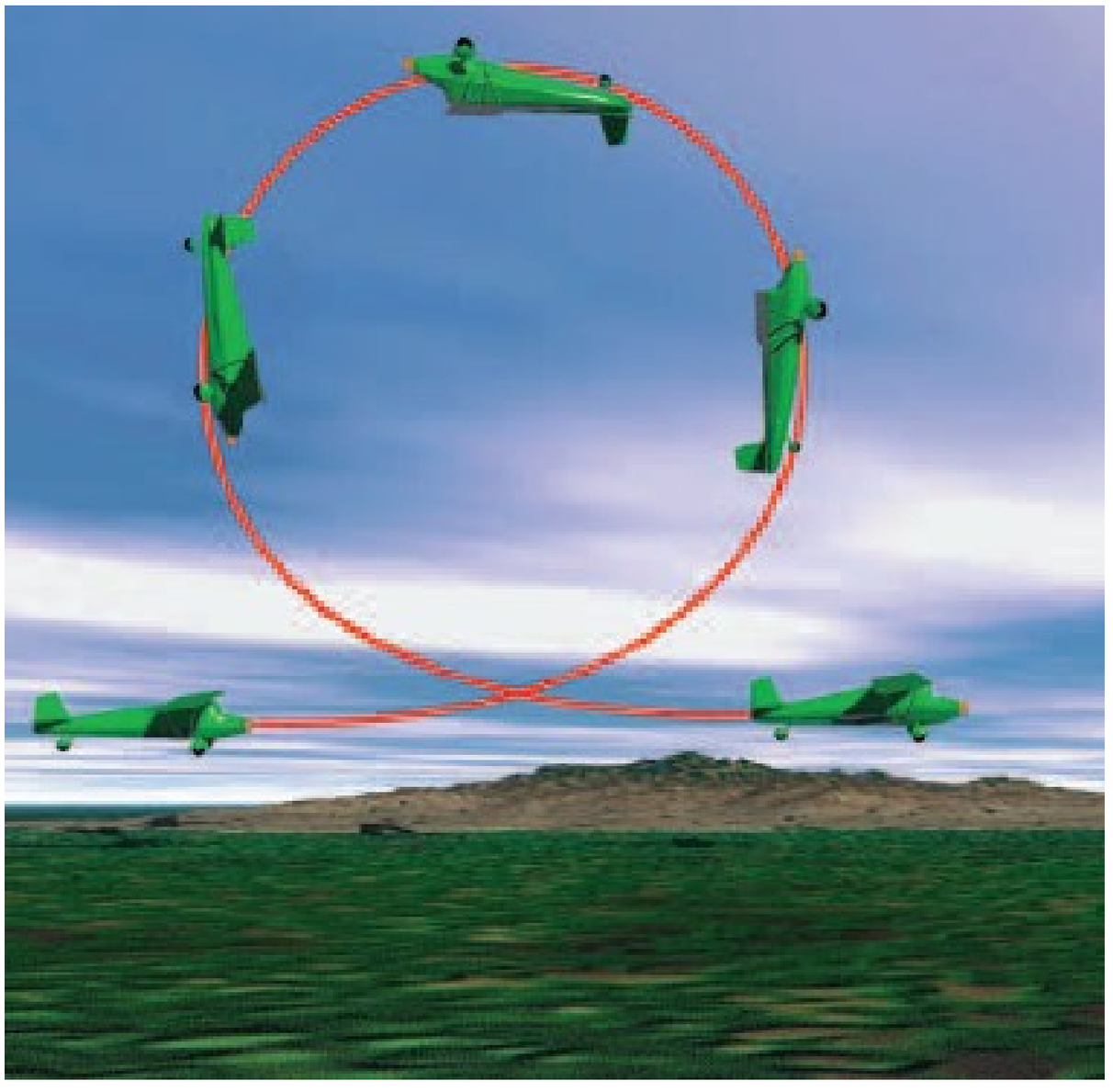
FAE-1.2 – Perform looping manoeuvre

(a) pitch the aircraft vertically at a continuous rate through 360° in balanced flight, maintaining wings parallel to the Earth's horizon, positive 'g', without stalling and maintaining alignment with a nominated line feature from a nominated airspeed that will ensure completion of a loop;

ARE THESE LOOPS?

Per Peter Bythrow
JOHNS HOPKINS APL TECHNICAL
DIGEST, VOLUME 18, NUMBER 1 (1997)





WHAT IS A LOOP?

Per Peter Bythrow

JOHNS HOPKINS APL TECHNICAL DIGEST, VOLUME 18, NUMBER 1 (1997)

$$\dot{V}_\theta = \frac{T}{m} - \frac{C_d \rho S}{2m} V_\theta^2 - g \sin\theta,$$

$$\dot{V}_R = \frac{V_\theta^2}{R} + g\cos\theta - \frac{L}{m},$$

$$\dot{\theta} = \frac{V_\theta}{R},$$

where

C_d = coefficient of drag,

ρ = air density,

S = surface area of the airfoil,

L = lift force supplied by the wing,

T = thrust provided by the engine,

m = mass of the aircraft, and

$G = L/m$.

The $(\cdot)$ denotes the derivative with respect to time.

Unfortunately, since θ must vary from 0 to 2π, the small angle approximation of $\theta = \sin\theta$ cannot be used,

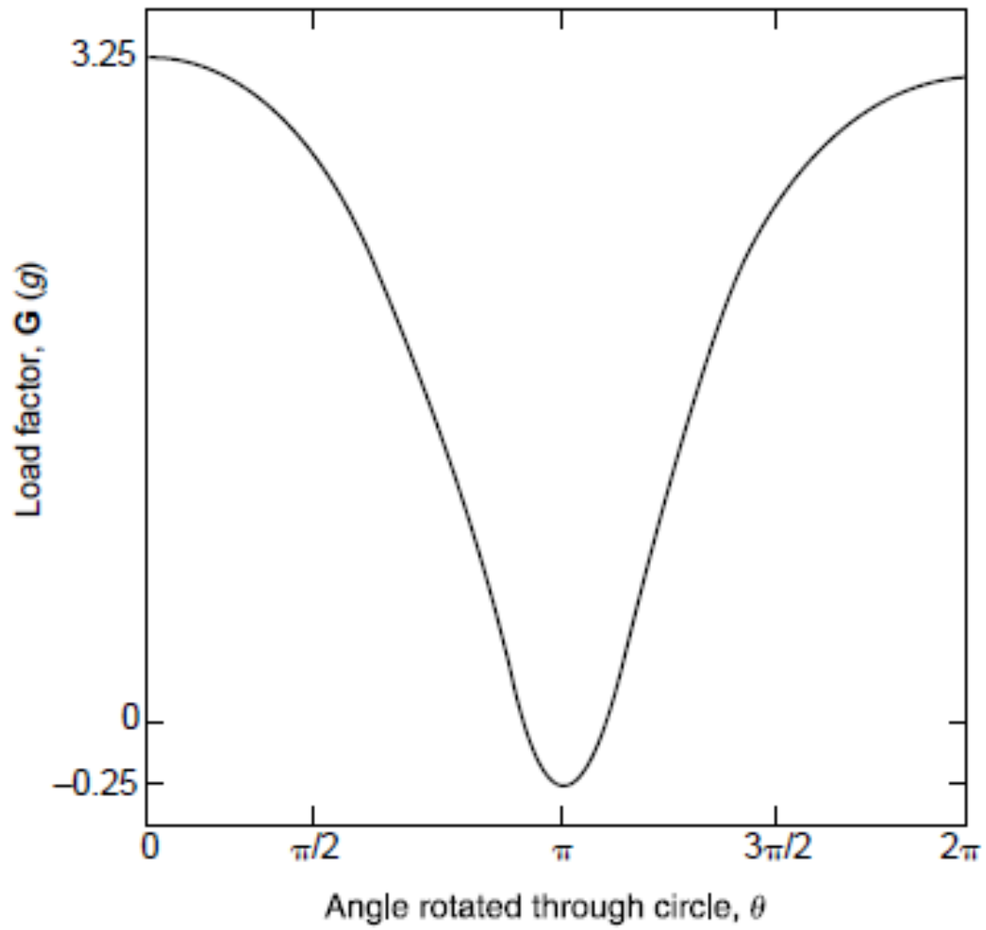
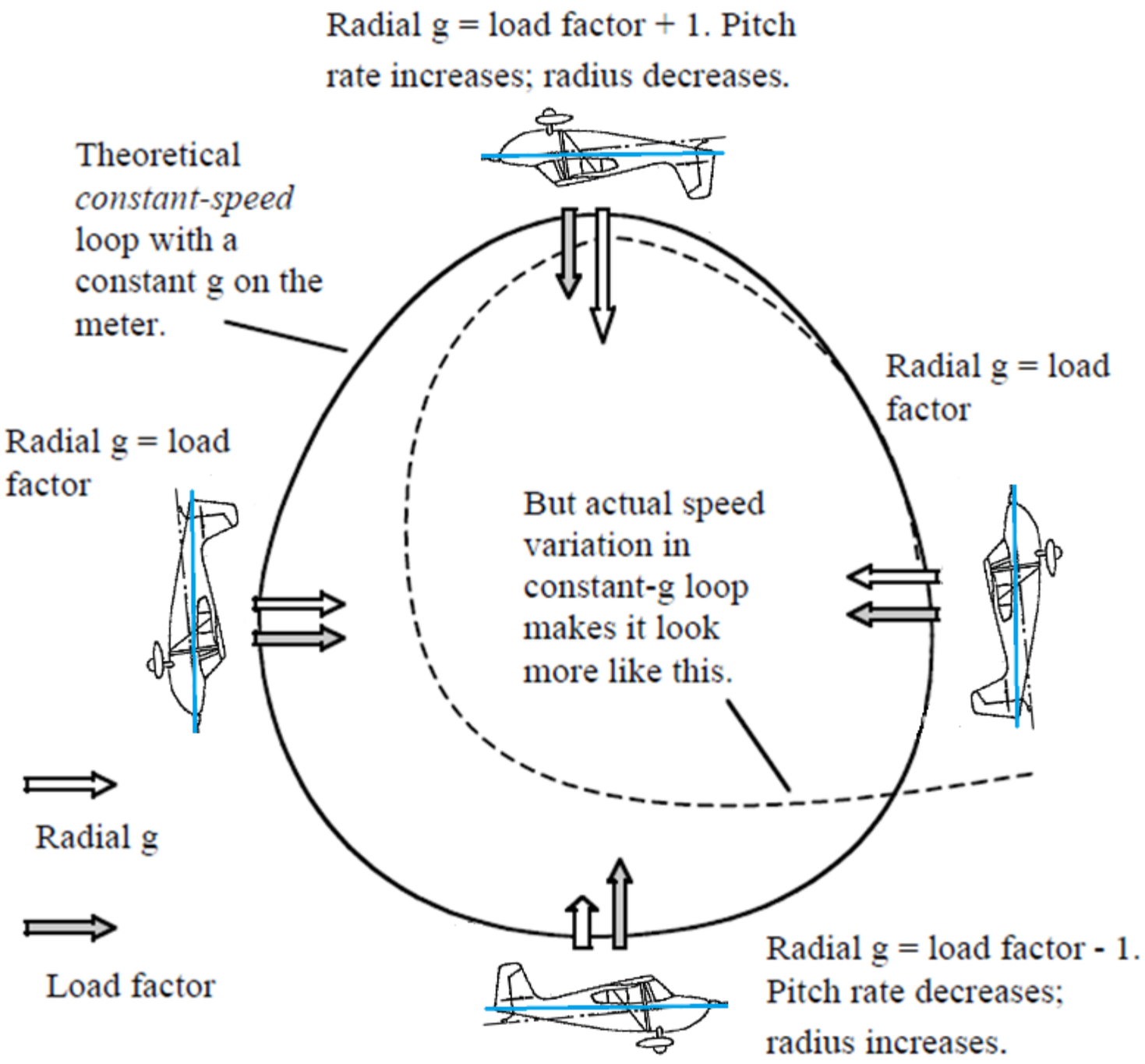
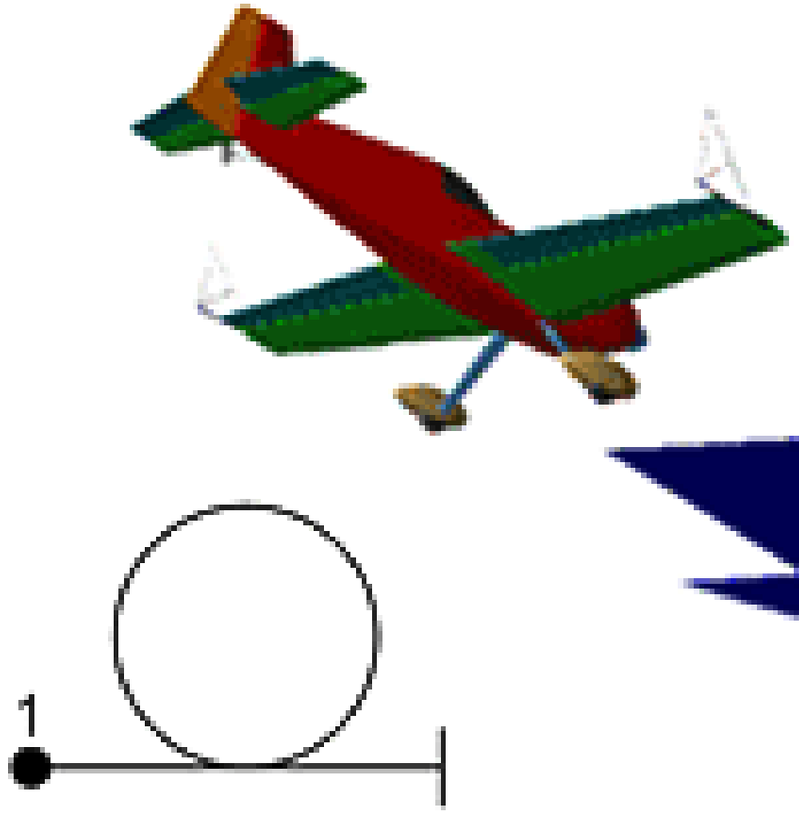


Figure 6. Load factor G experienced by the aircraft and pilot as a function of angle θ.

Shape of a Loop





Aresti symbol
Cat No. 7.4.1.1
Erect positive loop

CGT

Full and part loops are all judged on CGT and the shape must be wind corrected, ie. all looping elements are ROUND!

CGT

CGT

SPINNING

SPIN UNDERPINNING KNOWLEDGE

(a) actions required to recover from an incipient spin (wing drop at point of stall);

(b) what control inputs, with an aeroplane in any attitude, at the point of stall, are likely to cause a spin;

(c) blanketing effects the elevator can have on the rudder during spin recovery;

(d) significance of stick and control wheel position with respect to spin recovery;

(e) aerodynamic causes of a spin;

(f) what aerodynamic factor determines the direction of a spin;

(g) how to recognise a stable spin;

(h) difference between a stable spin and an unstable spin;

(i) effects of C of G position on spin performance and acceleration;

SPIN UNDERPINNING KNOWLEDGE

(j) difference between a spin and spiral dive;

(k) factors which may lead to a flat spin;

(l) difference between an upright and an inverted spin;

(m) visual indications used to determine the direction of a spin;

(n) instrument indications used confirm the direction of a spin;

(o) standard spin entry and recovery techniques for the aircraft being flown;

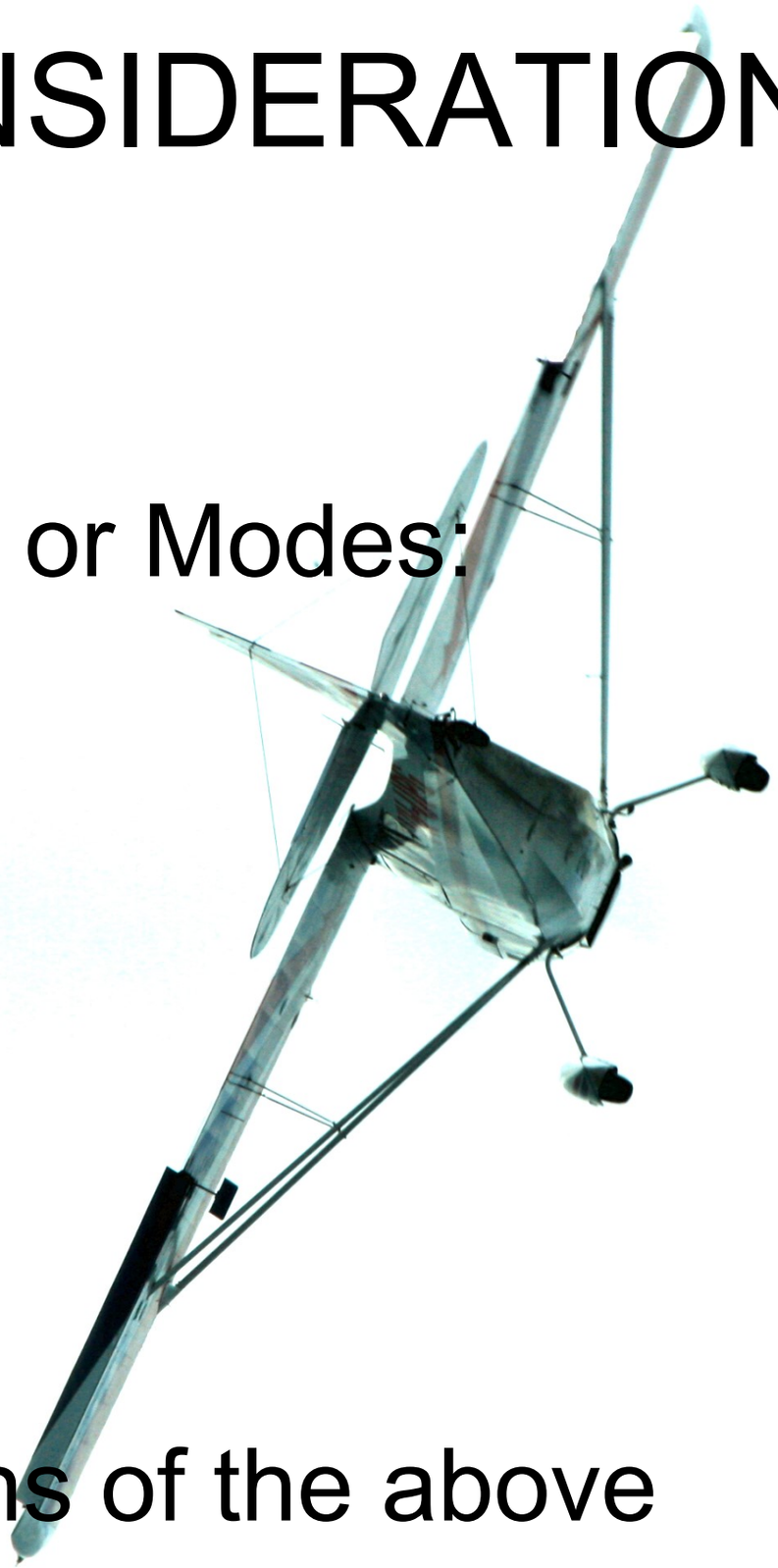
(p) number of turns normally required for spin recovery in the aeroplane type;

(q) height normally required entering and recovering from a stable spin;

(r) Mueller-Beggs spin recovery action and limitations on its application;

(s) 'g' and any other limitations applicable to spinning for the aeroplane type.

CONSIDERATIONS cont



Types of Spins or Modes:

- Steep
- Flat
- Accelerated
- Inverted
- Transition
- Combinations of the above

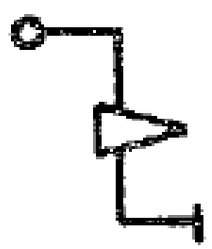
CONSIDERATIONS cont

CAUTION – Spins can be aggravated (i.e. flattened and/or accelerated) by incorrect use of power and controls leading to prolonged or impossible recovery.

Engine power was then heard to decrease and the aircraft entered a spin, probably to the left although one of several witnesses believed it was to the right. As the spin progressed, the nose attitude appeared to steepen to the near vertical. After making four complete turns, and after the fifth turn commenced, the aircraft struck the ground some 600 metres south-east of the aerodrome terminal building. There was no fire.

AIR EXERCISE - cont

NORMAL SPINS



Enter from normal stall, power off with full aft stick and full rudder in desired direction of spin. Maintain spin with full pro spin control until 1/4 to 1/2 spin prior to recovery heading. Recover with positive movement of stick to neutral position and full opposite rudder: Hold pro recovery control until rotation stops and positive control and flying speed is restored. Then neutralize rudder and smoothly recover from the dive* to level flight. Free release of controls is <u>not</u> adequate for spin recovery. Positive movement of the controls by the pilot is required.

AIR EXERCISE - RECOVERY FROM A FULLY DEVELOPED SPIN

P – **P**ower check OFF

A – **A**ilerons NEUTRAL

(identify direction of yaw)

R – **R**udder FULL OPPOSITE the direction of yaw **and then**

E – **E**levator briskly FORWARD towards neutral to unstall the wings

Hold recovery controls, the spin should stop immediately but may take up to one complete rotation.

S - When the rotation **S**tops – centralise the rudder.

Ease out of dive. Power on when nose is above the horizon.

AIR EXERCISE - cont

- These notes apply specifically to the Decathlon and Super Decathlon.
- Other aircraft types may have different spin characteristics and require a different recovery method – talk to your instructor before spinning a different type.

Instructor training

The pilot's flight instructor taught and used a method for Chipmunk spin recovery that was reasonably effective in the early stages of a spin, but would become less effective as the spin developed. It was different to the standard method of spin recovery recommended by the Civil Aviation Safety Authority, and to the Chipmunk-specific method recommended by the type design organisation. The flying school's training materials did not include Chipmunk-specific spin recovery methods, and did not clearly emphasise the forward control stick movement necessary for some aircraft.

EMERGENCY PROCEDURES

- **PARES**

Apply the correct recovery actions - if spin does not stop within one turn – check recovery actions.

- **FLAT SPINS**

Some aircraft require a special recovery technique from a flat spin. Some aircraft which are not approved for spinning, DO NOT recover from a flat spin – regardless of CG.

- **BEGGS-MUELLER**

Apply if known to be applicable to your type.

INVERTED SPIN

PHYSIOLOGICAL CONSIDERATIONS

(h) physiological effects of positive and negative 'g';

(i) the 'g' figure that a normal person may experience 'g' induced loss of consciousness (G-LOC);

(j) differences between grey out, black out, and G-LOC;

(k) conditions under which G-LOC is likely to occur;

(l) time period that disorientation may occur for after recovery from G-LOC;

(m) factors that can reduce G-LOC tolerances;

(n) physiological effects of sustained and rapid changes of 'g' loading;

(o) relationship between tunnel vision and loss of consciousness;

(p) hazards and consequences of performing aerobatics with blocked eustachian tubes;

(q) physiological factors that can reduce 'g' tolerance;

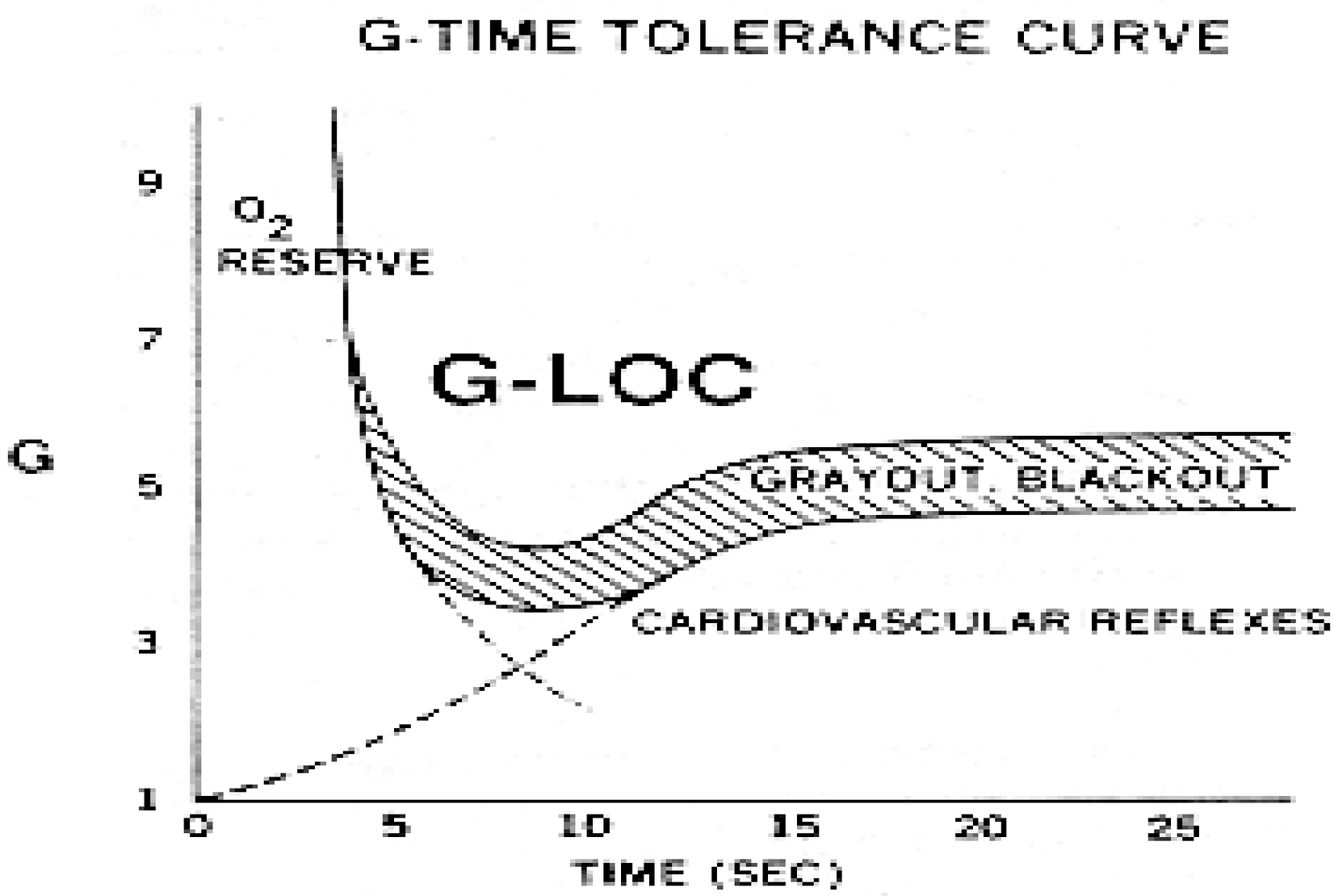
(r) physical actions that may increase 'g' tolerance;

PHYSIOLOGICAL CONSIDERATIONS

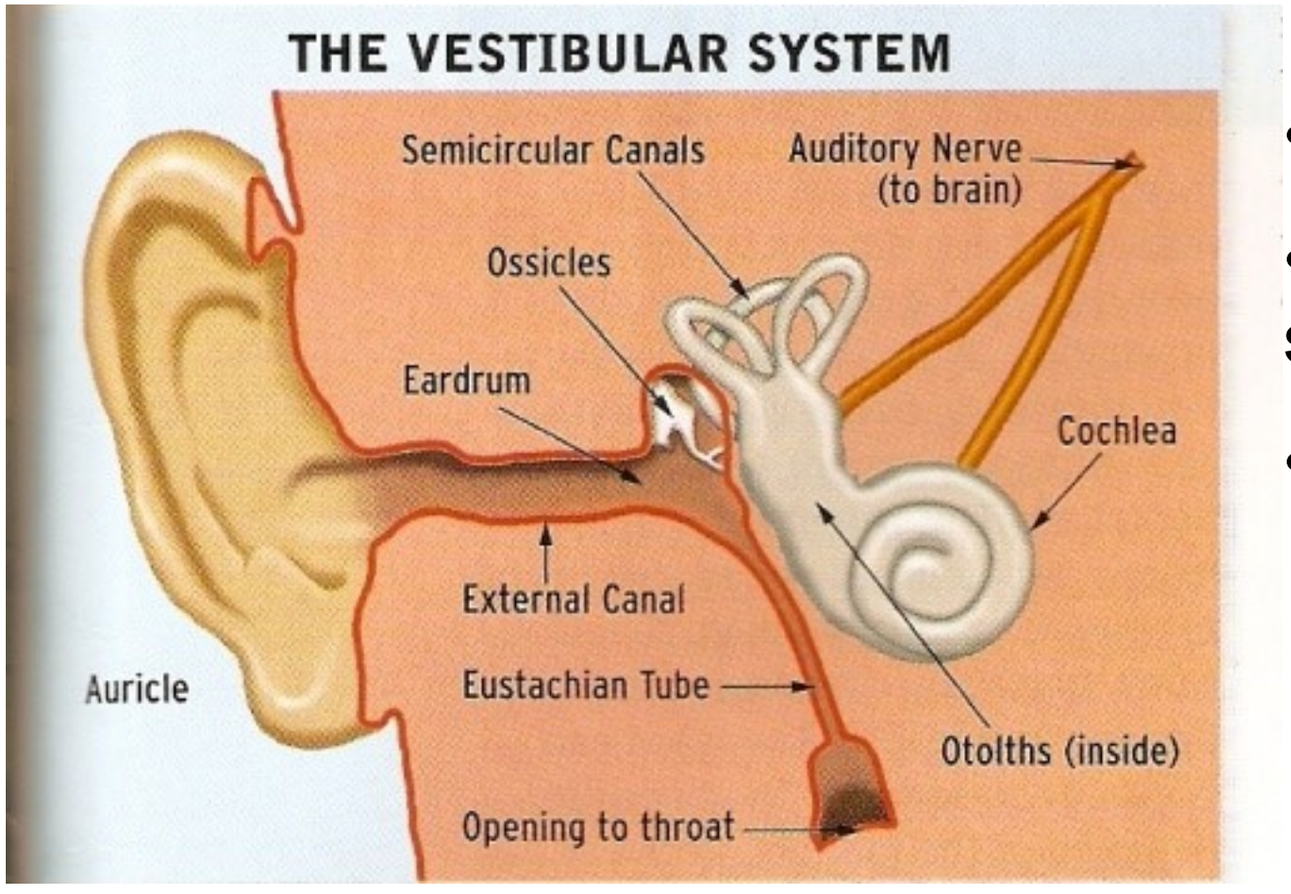
(za) recovery from manoeuvre-induced disorientation;

(zb) how to assess personal fitness for aerobatic flight;

STOHL CURVE


G-TIME TOLERANCE CURVE
9
7
5
3
1
G
O_2
RESERVE
G-LOC
GRAYOUT, BLACKOUT
CARDIOVASCULAR REFLEXES
0
5
10
15
20
25
TIME (SEC)

Eustachian Tube



- Normally equal pressures
- Descents – pressure pushes – swallow etc
- Blocked due cold etc :
  - Pain
  - Dizziness

STRUCTURAL CONSIDERATIONS

(a) meaning of the terms positive and negative 'g';

(b) symmetrical positive and negative 'g' limits for the aircraft flown;

(c) meaning of the term rolling 'g';

(d) rolling 'g' limits for the aircraft flown;

(e) how to calculate the rolling 'g' limitation of an aircraft;

(g) engine RPM limitations for the aircraft flown;

STRUCTURAL CONSIDERATIONS

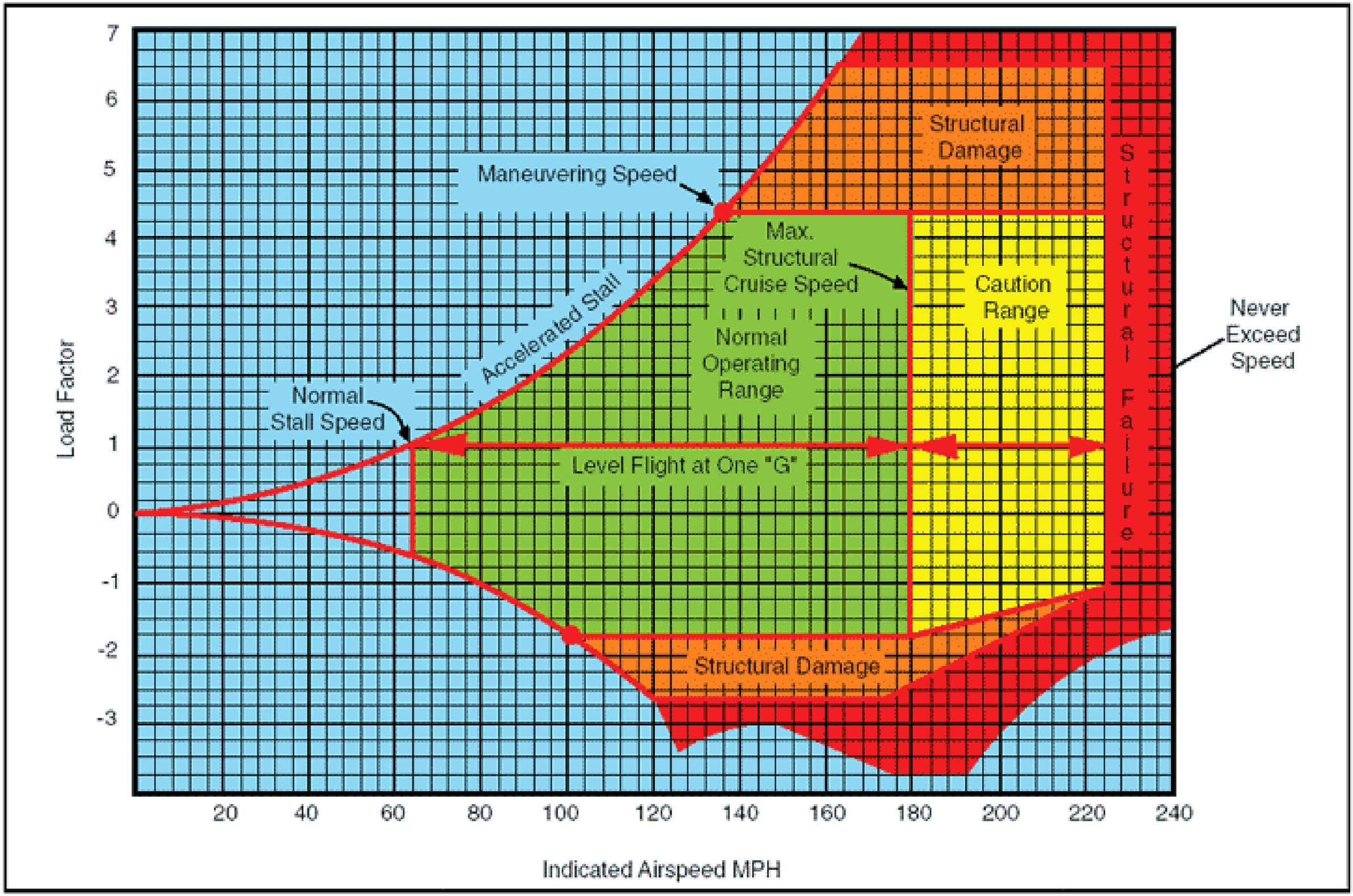
(v) structural irregularities that indicate an aircraft has been overstressed;

(x) airspeed limitations;

(y) V_A, V_{NE} and V_{NO};

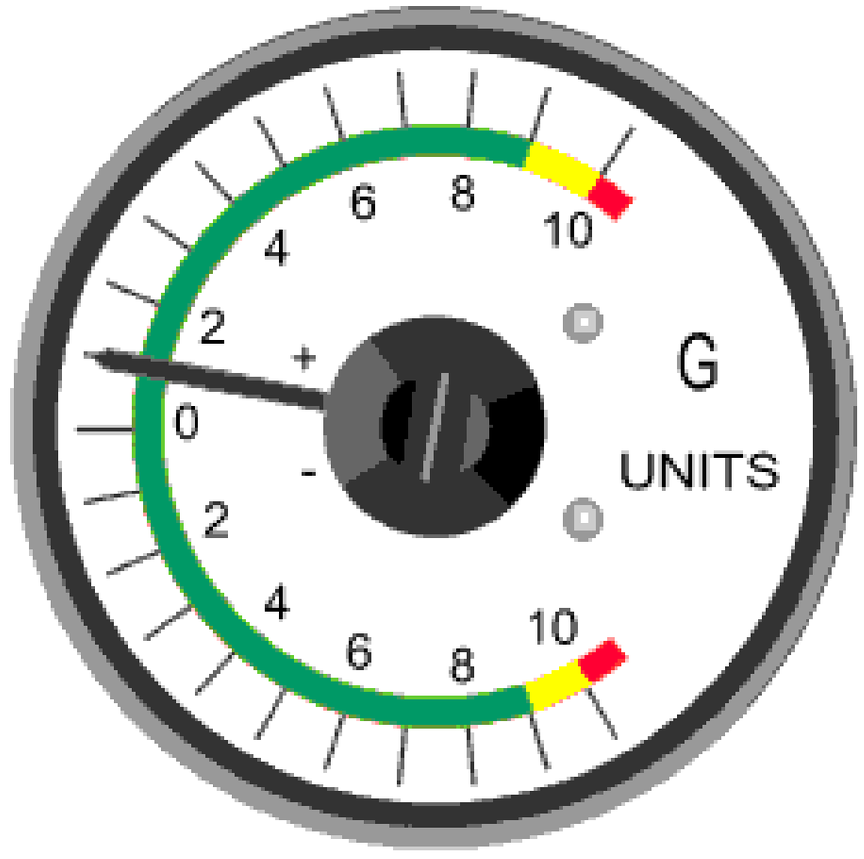
(z) effect of aircraft weight on VA and what precautions must be taken;

FLIGHT ENVELOPE (example only)



MANOEUVRE SPEED

Manoeuvre load factors +6/-5 g (8KCAB only)



V_A 115 KIAS – reduce by 6 kts per 100 kg

One control only at max deflection at V_A

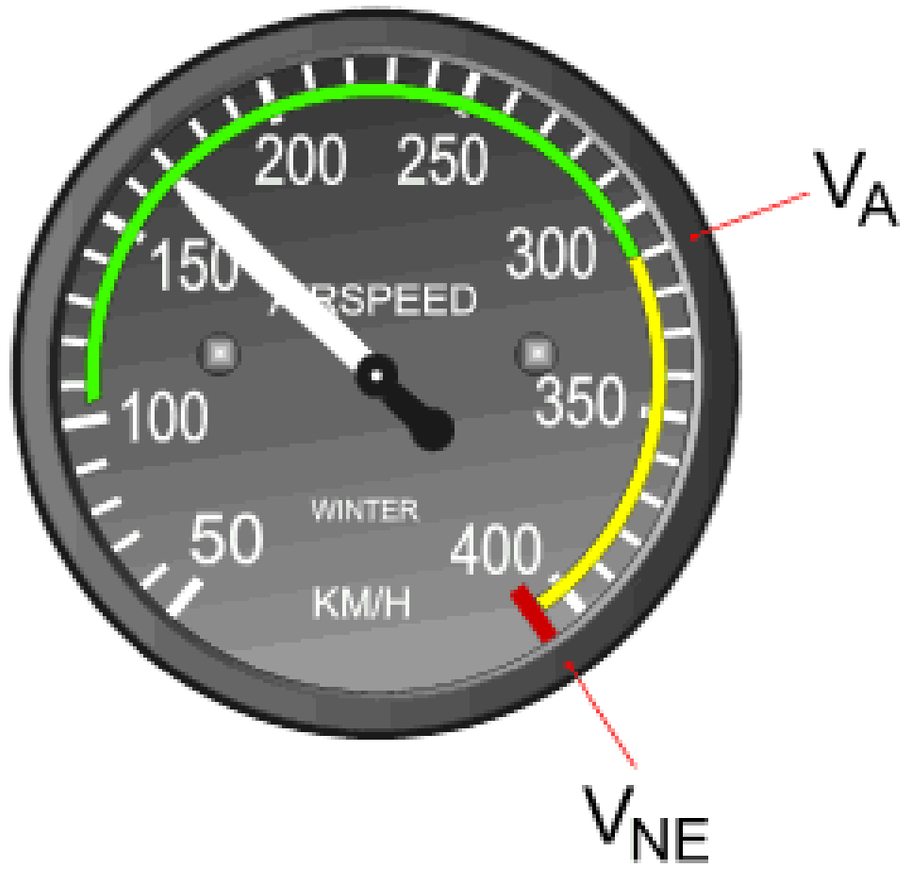
MANOEUVRE SPEED cont

What's wrong with the diagram?

Elevator – full & abrupt up to VA –

beyond that –

remain within limit load factors



MANOEUVRE SPEED cont

From SL445: limit Gs to 4!

The AFM and/or POH provide the following information:

- *Never Exceed Speed - 200 CAS (mph) - Do not exceed this speed in any operation*
- *Acrobatic Category Maneuvering Speed - 132 CAS (mph) - Do not make full or abrupt control movements above this speed*
- *Acrobatic Category limit load factors are +6g and -5g*
- *Maneuver Limits - Typical Entry and Exit Speeds of 140 IAS (mph) and acceleration of ±4g are listed*
- *Slow or Barrel Roll - Entry Speed 130 IAS (mph) - Use Smooth Application of Controls, No Full or Abrupt Control Movements Above Maneuvering Speed*

The limit load factors of +6g and -5g are the maximum loads anticipated on the airplane during its lifetime of service. Early AFMs provided maneuver entry speeds; later AFMs provided both entry speeds and accelerations. While operation to the limit load factors is not restricted by the AFM - it is not considered a routine operating condition and will decrease airframe life. Pilots should make every effort to operate the airplane as described in the maneuver limits, *typically* ±*4g*. Excursions beyond ±*4g* may occur but should not be routine.

MANOEUVRE SPEED cont

From the AFM: Ailerons: full up to V_A at +4g – beyond that – same roll rate as at V_A

From SL 445:

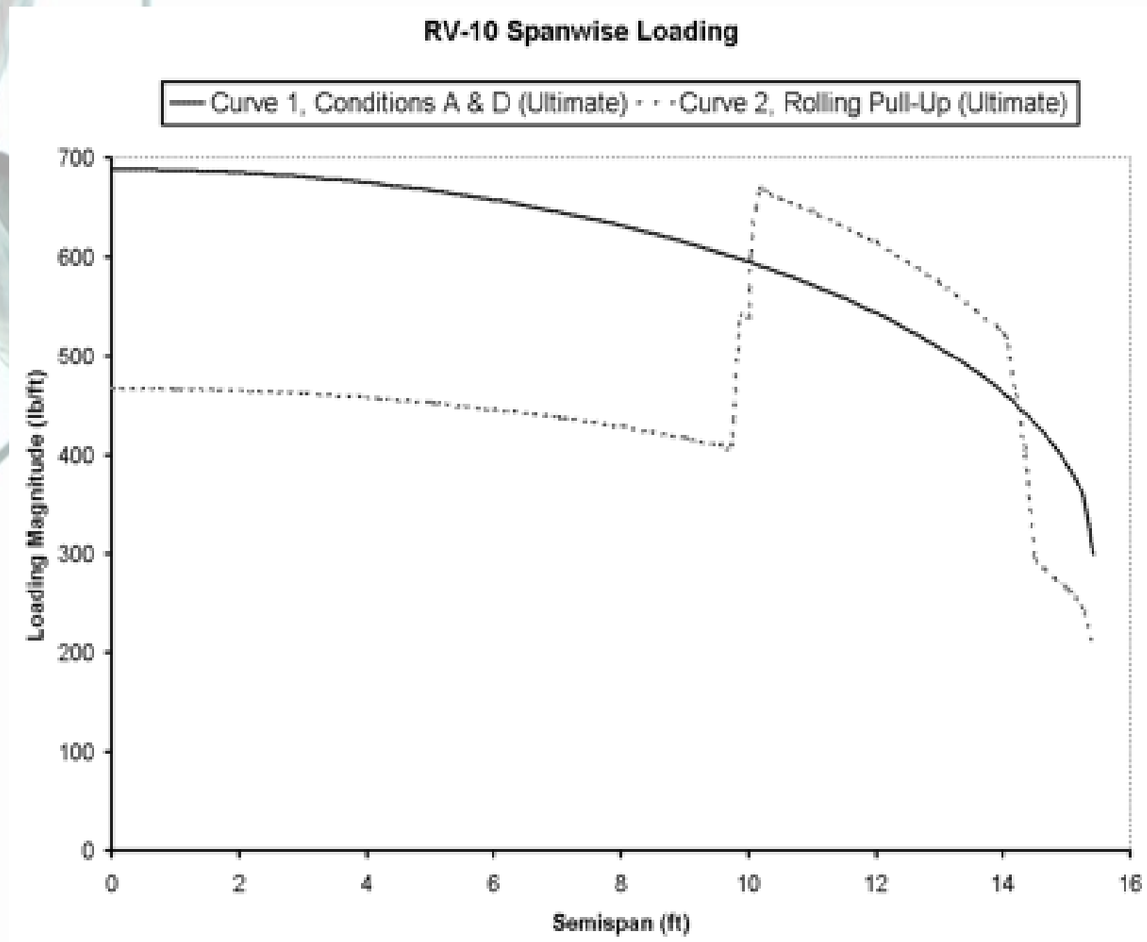
Table I: Aileron Design Speeds and Deflection

Speed	CAS (mph)	Deflection
Aerobatic Maneuvering, V_A	132	Full
Maximum Structural Cruising, V_{NO}	160	3/4
Never Exceed, V_{NE}	200	1/2

Pilots should again operate the airplane as described in the maneuver limits with regard to rolling maneuvers, *Entry Speed 130 IAS (mph), Smooth Application of Controls, No Full or Abrupt Control Movements Above Maneuvering Speed.* In effect - do not exceed the effort required to roll the airplane at V_A.

ROLLING G

- Care must be taken not to exceed G limits while applying high G-loads in a pull up and roll together. Rolling creates increased lift on the up-going wing increasing the loading on that wing. G-meter will only measure G-loading in the pitching plane
- General rule: Rolling G limit is 2/3 of max limit load factor



MANOEUVRE LIMITATIONS

Refer the POM:

- **Lomcevak**
- **Tail-slide**

Plus structural reliability considerations:

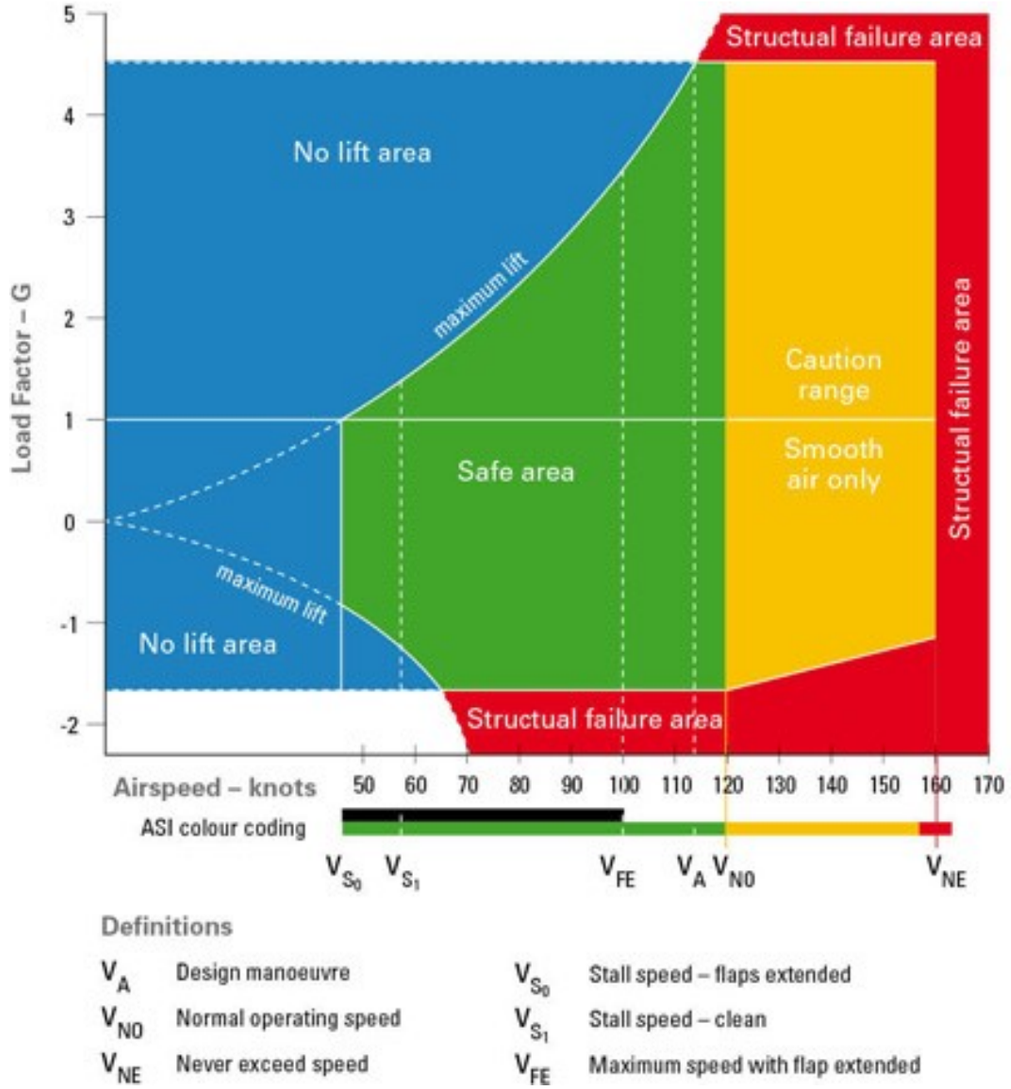
- **No flick (or snap) rolls**

POWERPLANT LIMITATIONS

- Avoid continuous operation: 2000-2250 rpm (Hartzell only).
- Avoid aerobatic operation: 2600–2700 rpm.

FLIGHT ENVELOPE (review)

- Limitations of Va
  - Aileron & rudder?
  - Aft & forward stick (elevator)?
- Limitations of Vmo
  - Aileron & elevator?
- Limitations of Vne
  - Aileron and G?
- Maximum speed to apply full elevator plus full aileron?
  - Elevator plus rudder?



DECATHLON STRUCTURE

STRUCTURE

Wing Spars - aluminium

Wing Ribs - aluminium

Wing Struts:

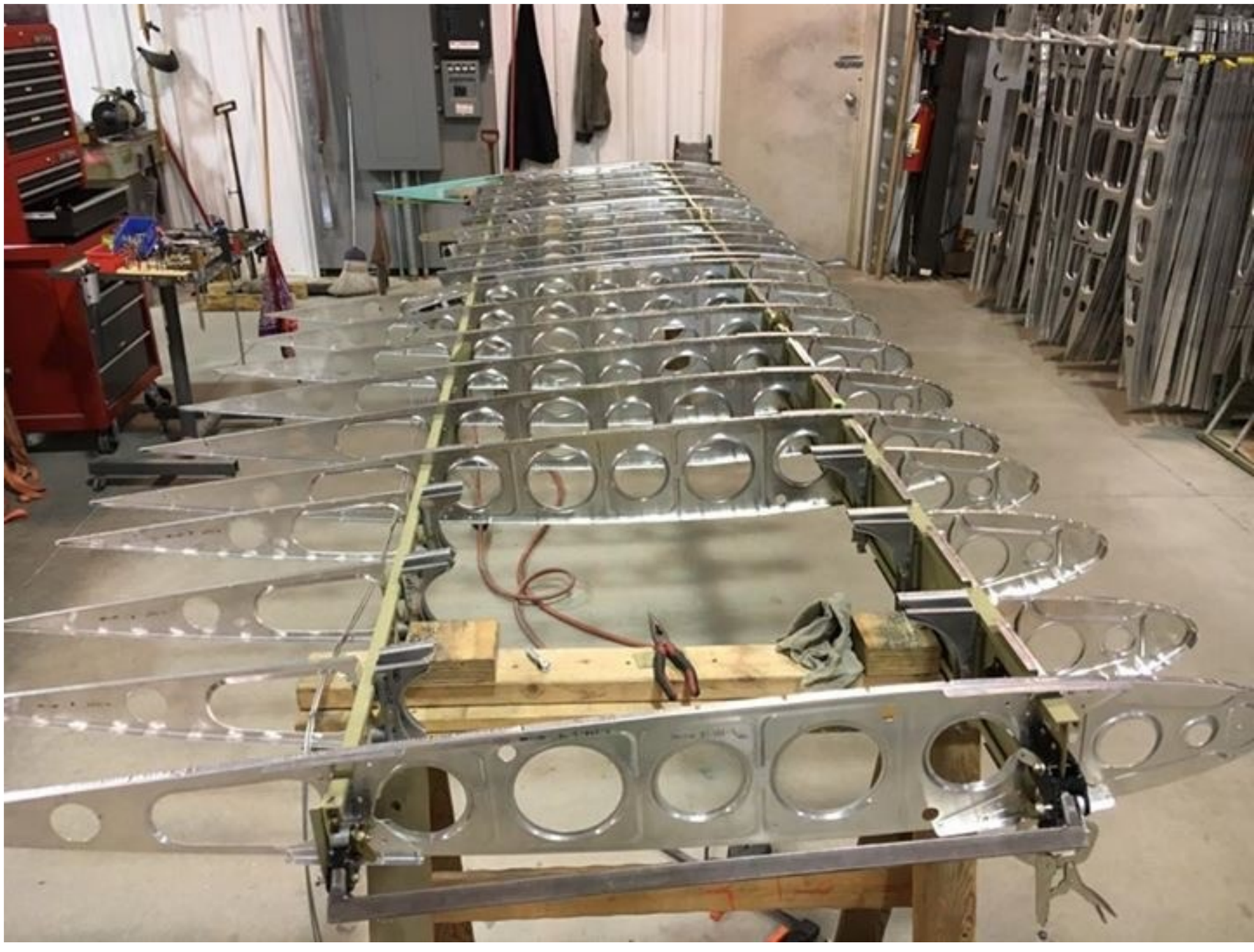
front aluminium extrusion
rear steel tube

COVERING

Fabric: Ceconite

Wing Leading Edge: sheet metal

Forward fuselage: F/G cowl and sheet metal



SNAP ROLLS

americanchampionaircraft.com/faqs

Are snapped rolls an approved maneuver? (Acrobatic Models Only)

Yes, snap rolls are an approved maneuver. To reduce unnecessary wear and tear:
- Respect the aerobatic gross weight (1800 lb for the 8KCAB and 7GCBC, 1750 lb for the other Citabria models)
- Perform snaps at or below the listed entry speeds (90 mph for the 8KCAB, 85 mph for the Citabria models)
- Limit the acrobatic fuel load to half tanks or less

This question is often followed with questions about the wing structure and fuel tanks. Any aircraft used for aerobatics will have increased maintenance requirements; to an extent this should be expected by owners and operators. Where the design has not meet expectations, ACA has made changes to eliminate issues with strut fittings, fuel tanks, butt ribs and gaps skins. The following changes have been made to the 8KCAB wings and tanks:

1996 - The butt rib thickness was increased from .020 to .032 inch, the upper gap skin rivet spacing was doubled and an airworthiness limitation was added to the strut fittings
2002 - Four slosh holes, two welds and a doubler were added to tank center baffle
2004 - The tank beading was changed from rolled to stamped with a deeper draw and the center baffle was changed from 3003-0 to 5052-0
2010 - Revised fuselage fairings to eliminate strain on upper wing gap skin

The changes have made significant improvement, exactly how much is hard to quantify. Some operators still chose to prohibit snaps in an effort to reduce maintenance costs. This is prudent for a flight school where each student is going to snap the aircraft multiple times. For a typical owner snap rolls will not create a maintenance concern.

LIFED PARTS

Front wing strut, attach fittings & bolts

Airworthiness Directive AD/CHA/15

"The hours are those actually spent in aerobatic flight and do not include positioning time."

Sequence of 10 figures takes <0.1 hr

A single figure typically 10 - 20 secs

Typical training sortie may be 0.1 to 0.2 hr of aeros

PERFORMANCE and HANDLING

(f) relationship during rolling manoeuvres between pitch angle required on commencement of a roll and rate of roll;

(s) minimum altitude to perform aerobatic manoeuvres;

(t) relationship between pre-stall buffet and rate of turn or rate of pitch;

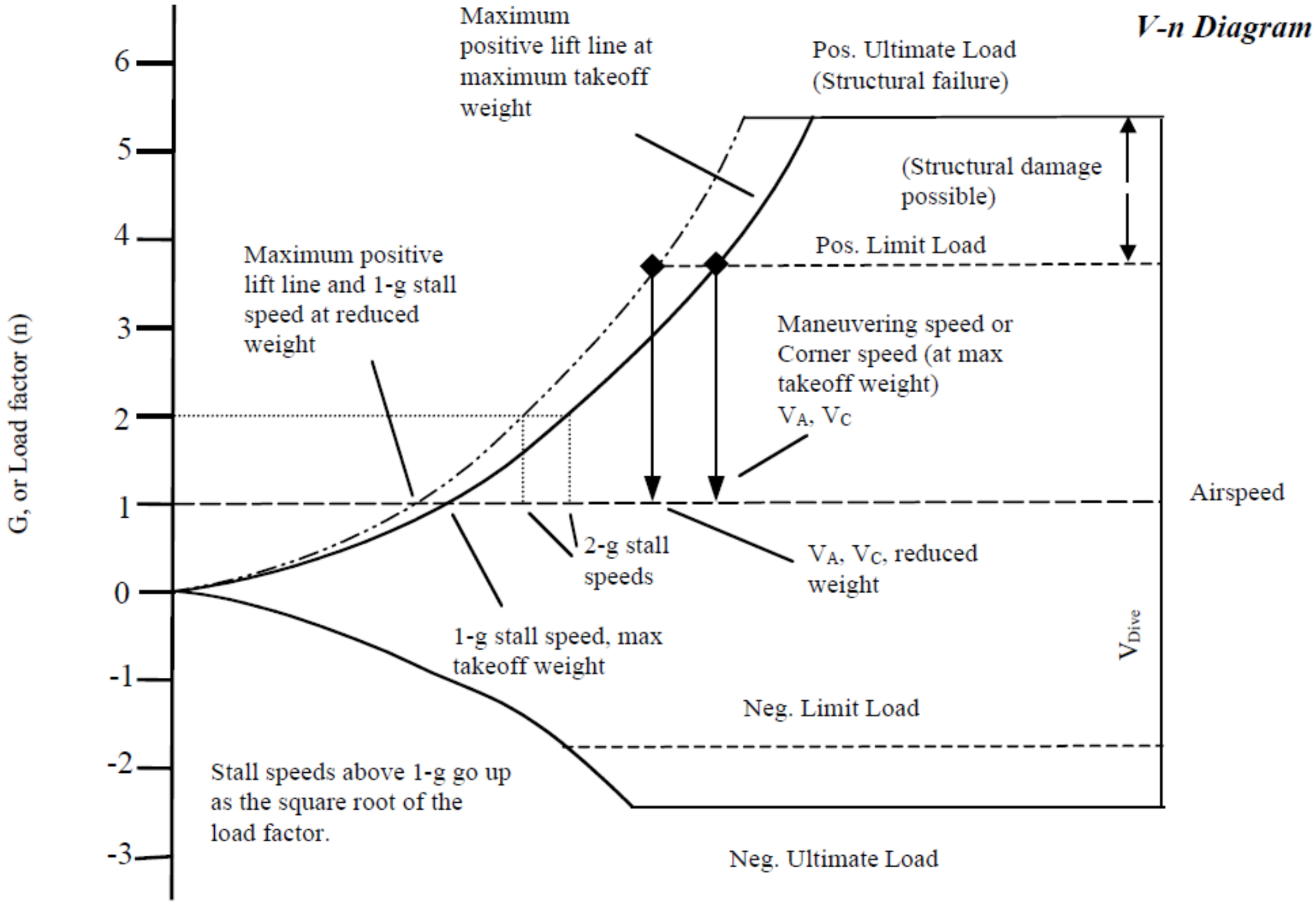
(u) effect of increasing airspeed on stick force;

(w) effect of increased 'g' loading on stall speed;

(zc) maximum rate turn criteria;

(zd) minimum radius criteria.

ACCELERATED STALLS

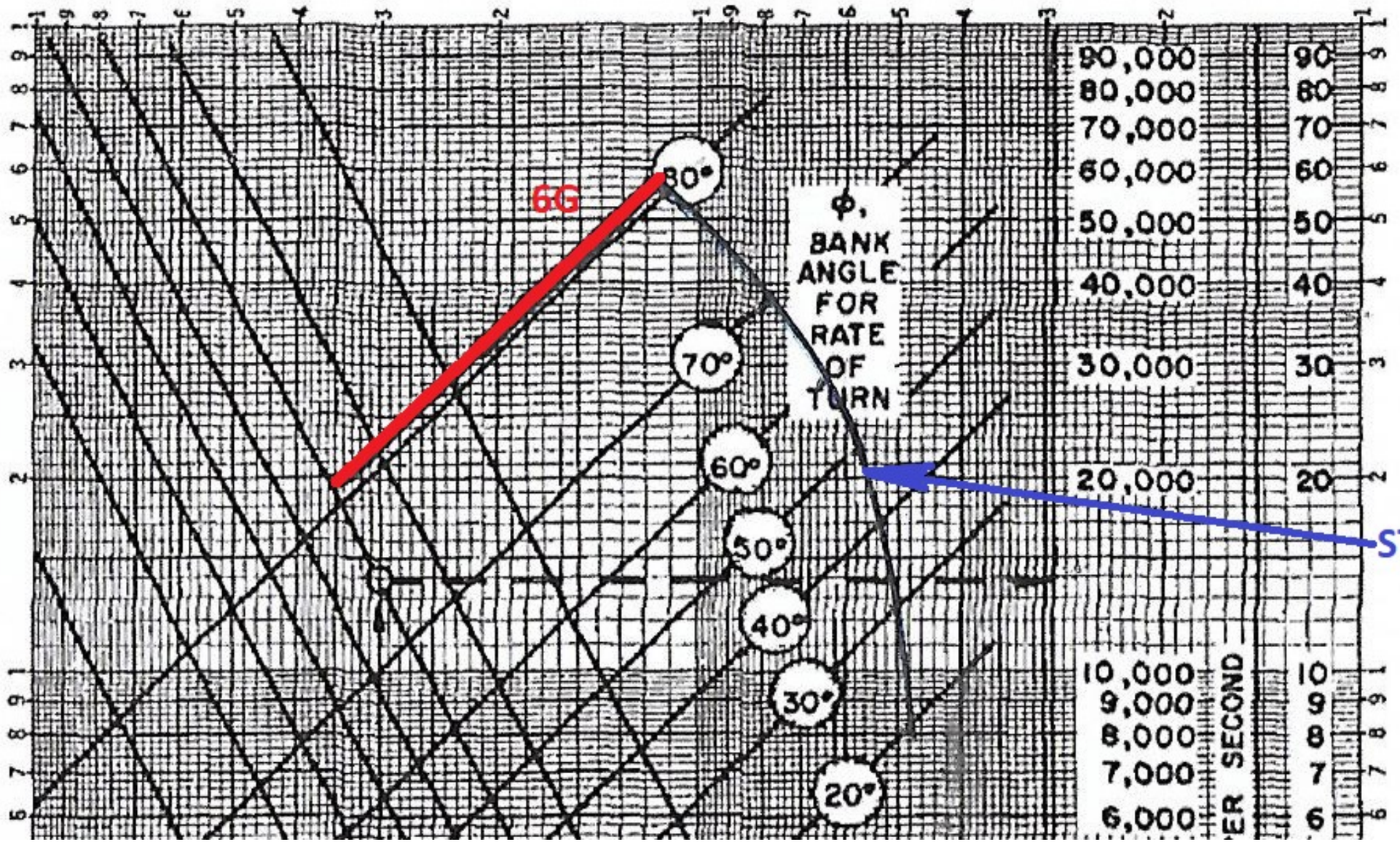


BALANCE BETWEEN ROLL & PITCH

- Application is at commencement of a roll
- Also relevant to a barrel roll
- Main consideration is for aircraft with low performance, slow roll rate and carburetor
- High performance aircraft have a greater range of capability in rolling manoeuvres
- Consider a Tiger Moth vs a Pitts Special

Rate of Turn

8KCAB



Turn Radius

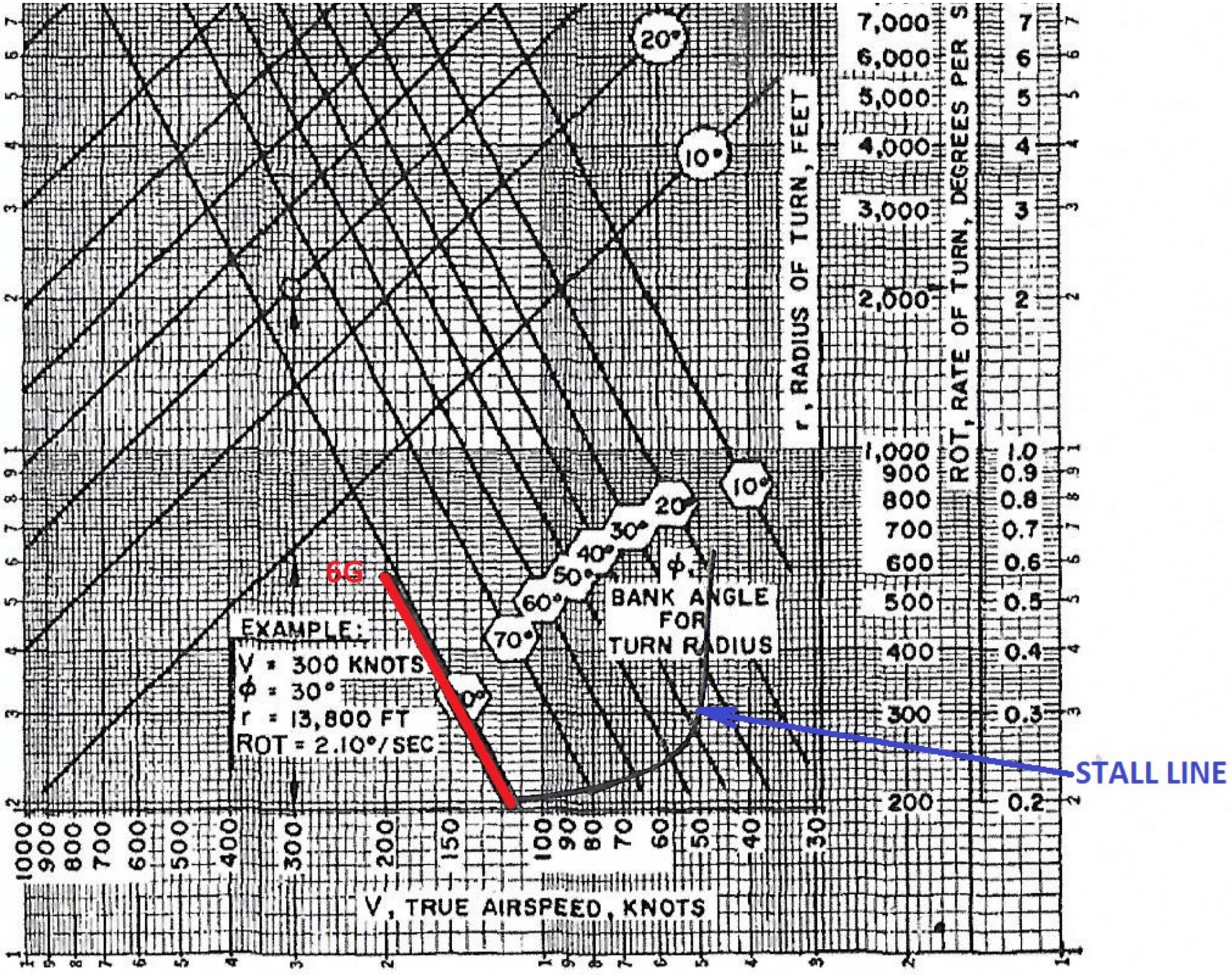


Figure 2.29. General Turning Performance (Constant Altitude, Steady Turn)

Stick Forces

Application:

- A measure of aircraft longitudinal stability
- Control feel to avoid overstressing
- Elevator –
  - Push to dive for speed
  - Pull to increase G
- Aileron – recall V_A limits

Stick Forces

Aileron – refer SL 445.

- Force varied with airspeed squared

Speed	CAS (mph)	Deflection
Aerobatic Maneuvering, V_A	132	Full
Maximum Structural Cruising, V_{NO}	160	3/4
Never Exceed, V_{NE}	200	1/2

Pilots should again operate the airplane as described in the maneuver limits with regard to rolling maneuvers, *Entry Speed 130 IAS (mph), Smooth Application of Controls, No Full or Abrupt Control Movements Above Maneuvering Speed.* In effect - do not exceed the effort required to roll the airplane at V_A.

- Do not exceed effort to roll at V_A!

Stick Forces - cont

Decathlon stick force: 15 lb per G

Longitudinal Stability - Some of the basic longitudinal stability characteristics were documented prior to the aerobatic test program. The stick-fixed neutral point was found to vary from $0.38\bar{c}$ at $C_L = 0.6$ and $V_e = 100$ knots to $0.53\bar{c}$ at $C_L = 1.0$ and $V_e = 70$ knots. The longitudinal stick force gradient was 15 lb/g. Since the pitching maneuverability is appreciably affected by the longitudinal stability characteristics, it should be kept in mind that the center-of-gravity location ($0.23\bar{c}$) used during these tests resulted in a very stable configuration.

Flying the Manoeuvres

in the Super Decathlon

The Loop

ENTRANCE SPEED
140 MPH

KEEP WINGS LEVEL

LOOK AT ROAD - KEEP WINGS LEVEL

LOOK-- PULL

AS AIR SPEED INCREASES, INCREASE BACK PRESSURE

LOOK OUT FRONT WINDOW - CHOP POWER - REDUCE RIGHT RUDDER - AIR SPEED ABOUT 55 - DO NOT PULL OVER ½ G AT THIS POINT

LOOK AT ROAD - KEEP STRAIGHT WITH RUDDERS

THROW HEAD BACK - LOOK OUT TOP GLASS AT ROAD BEHIND YOU

PULL 3G - KEEP RIGHT RUDDER IN AS AIR SPEED SLOWS - KEEPS AIRCRAFT IN STRAIGHT LINE

KEEP WINGS LEVEL

POWER 2200 RPM

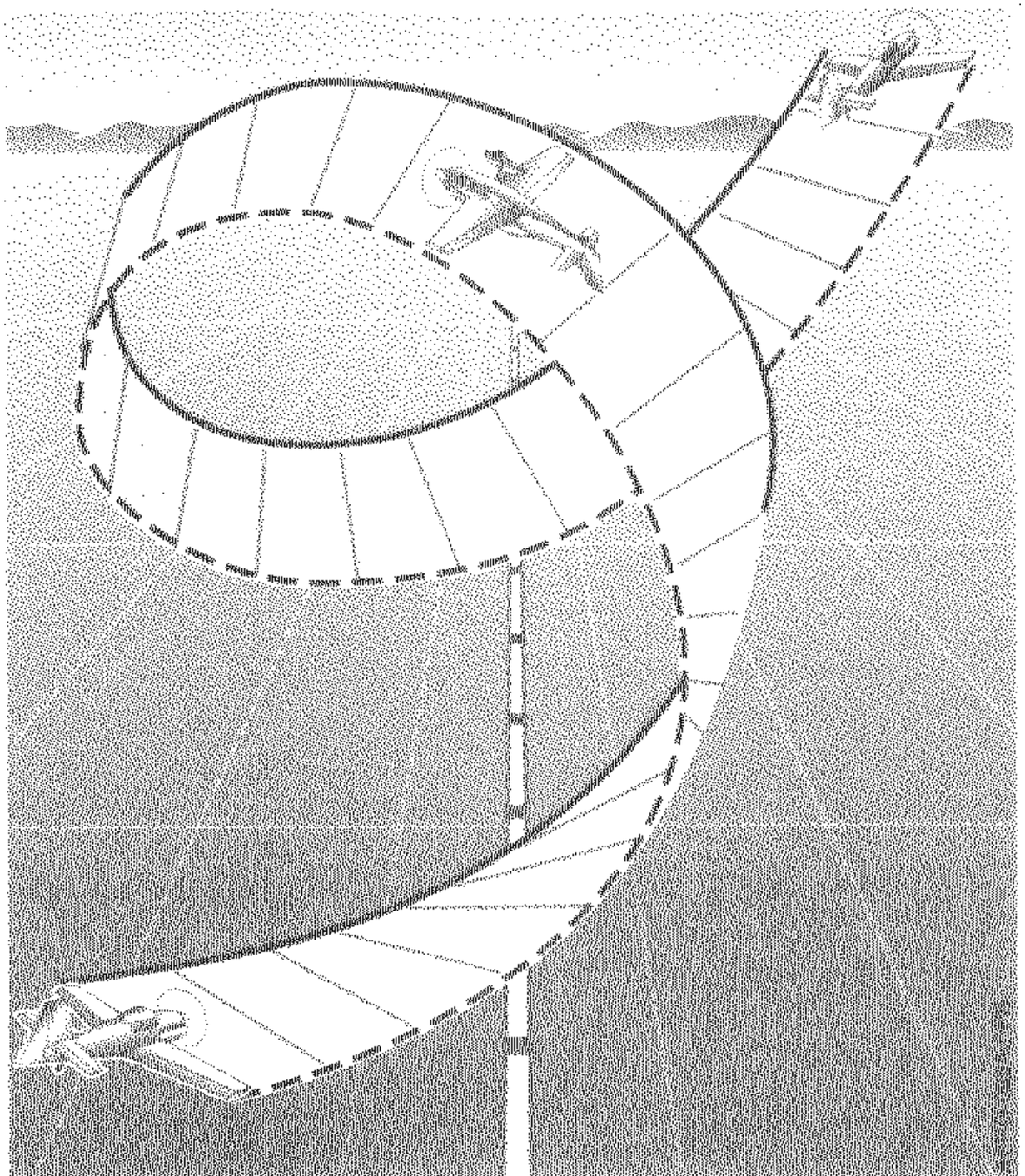
LINE UP ON ROAD 135-140 MPH

FULL POWER - PULL NOSE UP - KEEP WINGS LEVEL

Power notes for FP prop

CS prop: maintain power

BARREL ROLL



Simple brief to get started:

Entry 115 kts

Feet at eye level – approx. 45° up

Aileron to roll

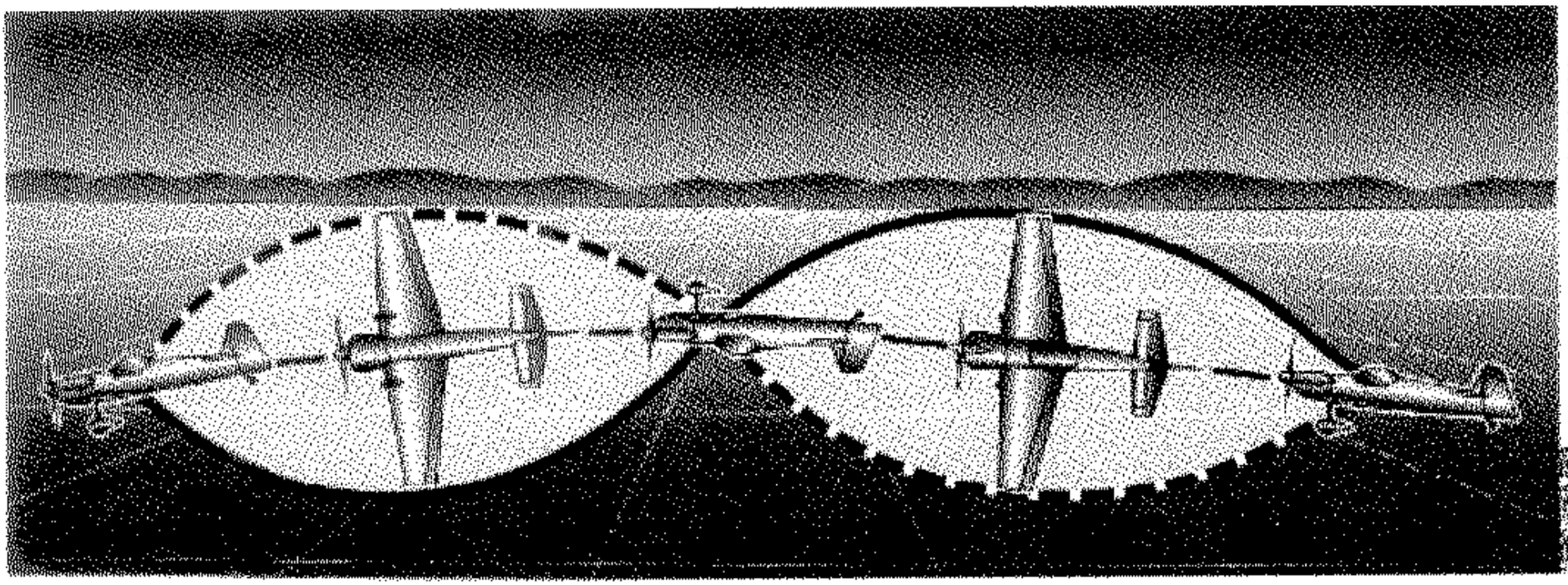
Recover

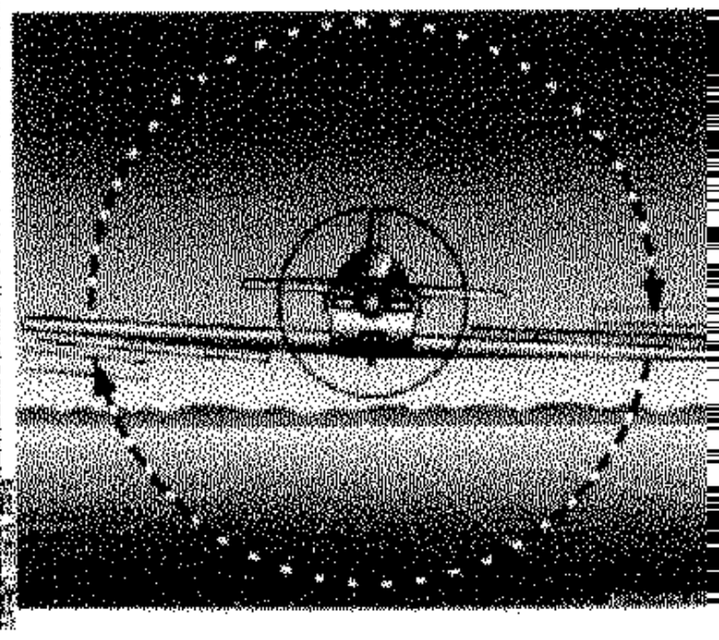
Recall spiral dive recovery

Balance between amount of roll and amount of pitch – choose whether more loop or more roll. Consider other types – Tiger Moth to Pitts

Refine it later: competition rules are 40° off heading at top

AILERON / SLOW ROLL





Entry 110 kts,

Pitch up to landing attitude

Release back pressure

Aileron to roll

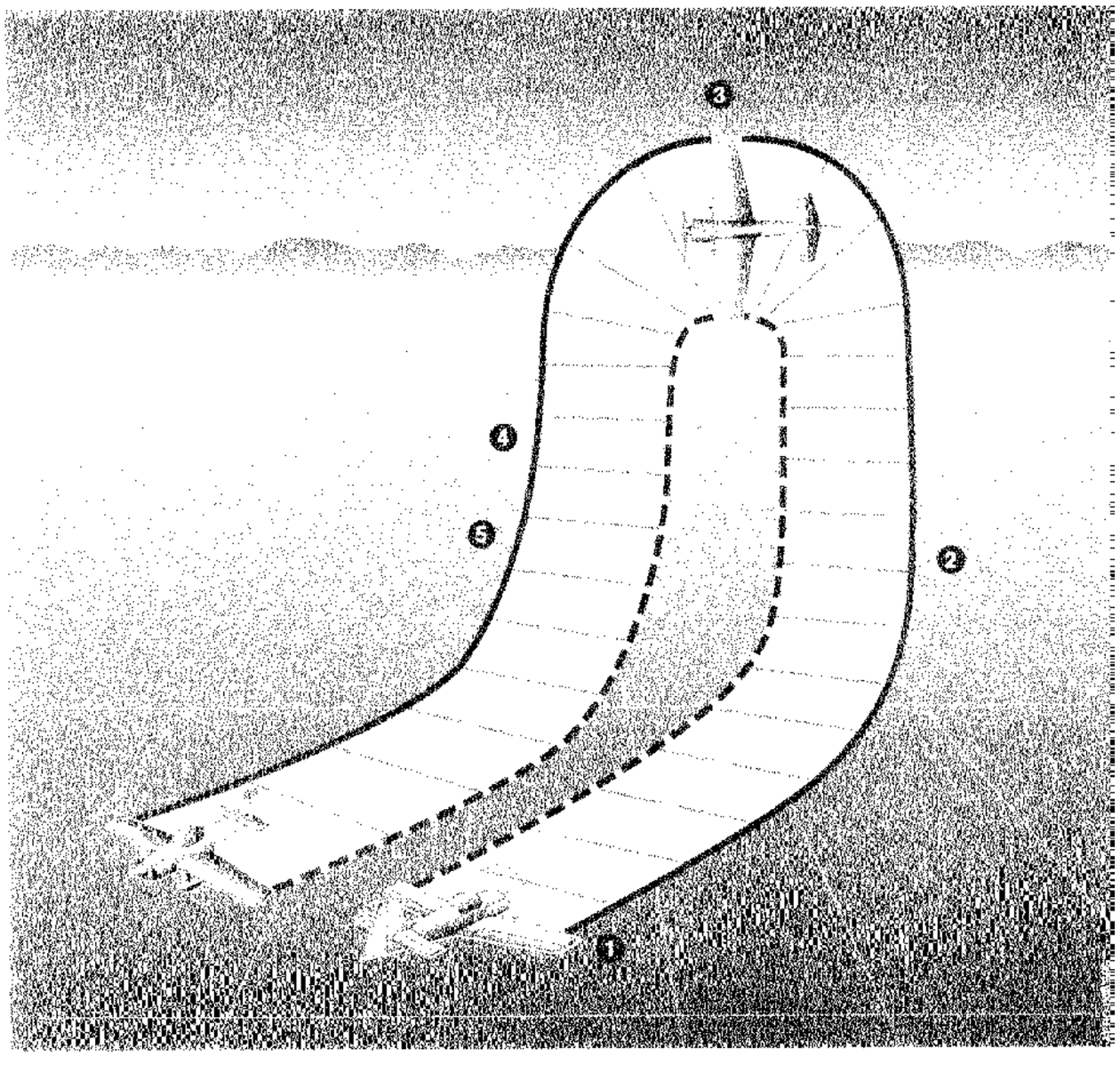
Stick forward through inverted

Exit on heading

Use top rudder to maintain direction & prevent nose slice

IMPORTANT:
Keep rolling
Never pull through

STALL TURN



1. Ground references – road and horizon on the side

2. 120 KTS pull, as for a loop, to vertical

4. Look to side at the reference on the horizon. Maintain vertical plane – forward pressure and slight right rudder.

5. As speed decays through 40 kts, apply full rudder briskly. Apply stick only as necessary to keep straight.

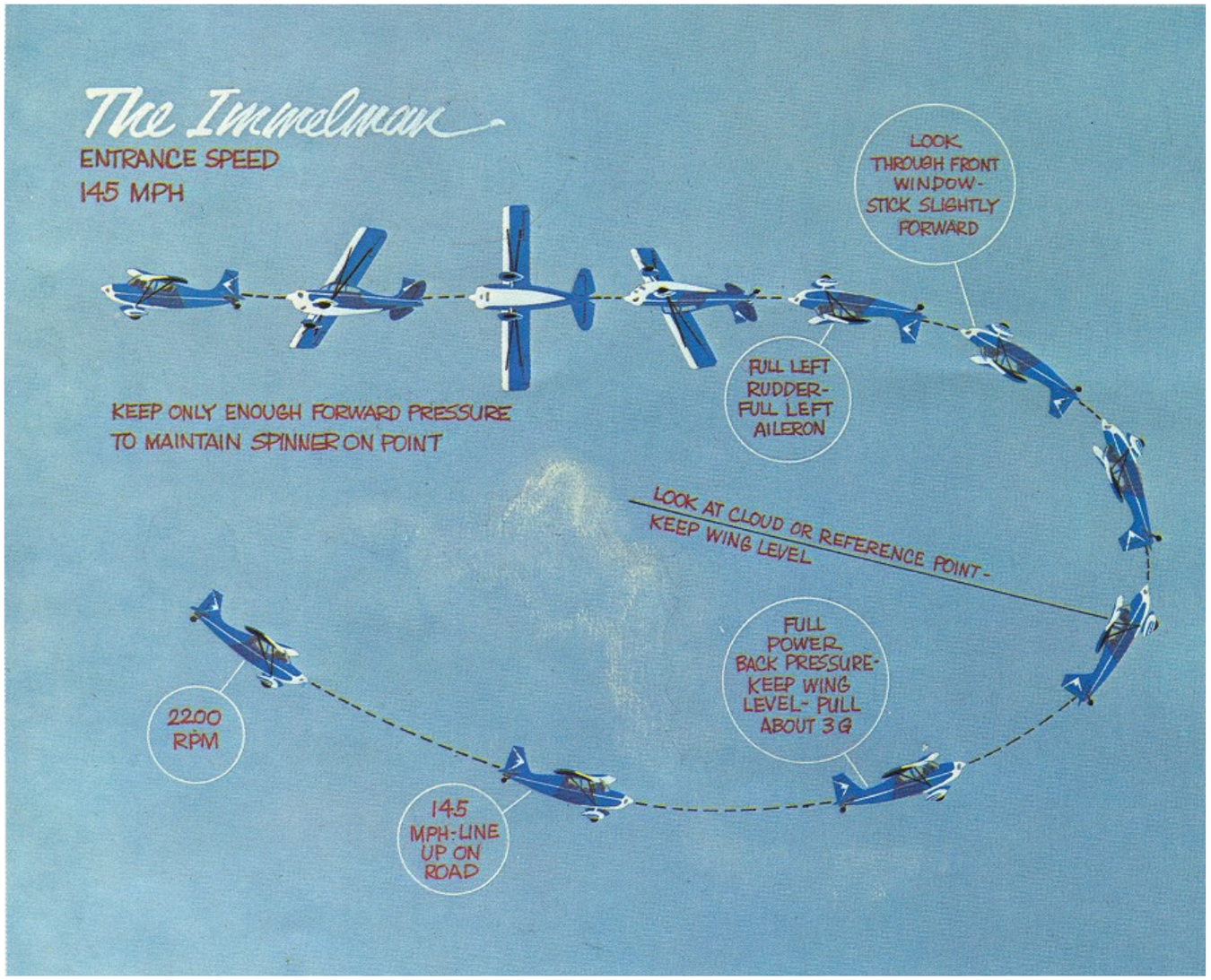
Recall secondary effects of controls.

4. Look down at the wingtip to the ground reference.

5. Maintain vertical – centralise rudder or even slight opposite rudder briefly. Apply stick only as necessary to keep straight

6. Recover from dive.

COMBINATIONS



- Oil pressure limitations
- Cuban Eight
- Reverse Cuban Eight
- Hammerhead with ¼ roll down
- Humpty bump with rolls
- NO snap or flick rolls

EMERGENCY PROCEDURES

- Engine Restarts
- Parachutes
- Unusual Attitude Recoveries

UA RECOVERIES

What possible UA's are there?

General recovery technique:

Power

Pitch

Roll – to nearest horizon

Initial post-stall gyration:

- or incipient spin

Spin – upright and inverted

Spiral dive

Two important ones:

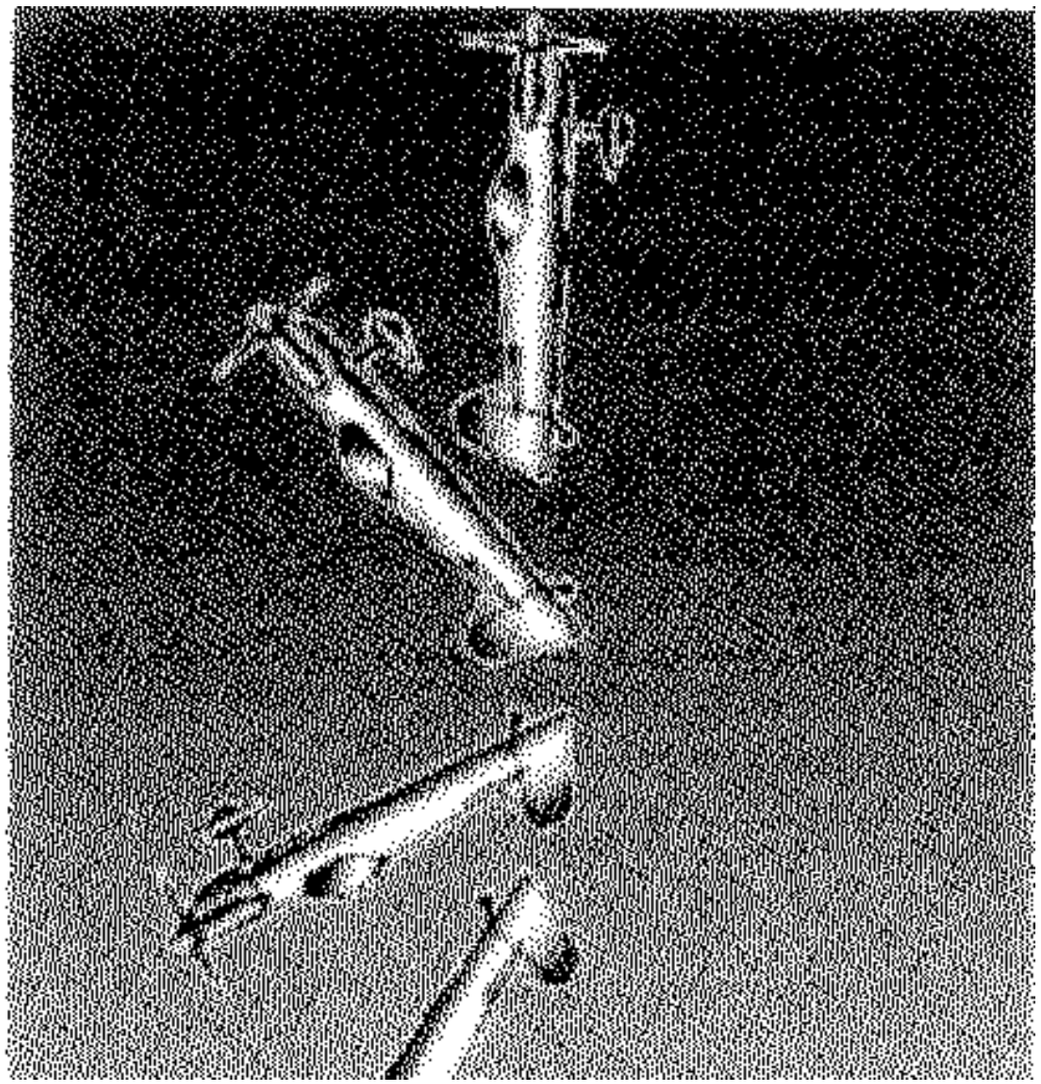
Extreme nose high – risk of a tail-slide from a failed stall turn

Inverted dive – from a failed roll

UPSET RECOVERY

Upset Recovery Template
1. Disconnect the wing leveler or autopilot
2. Apply forward column or stick pressure to unload the airplane
3. Aggressively roll the wings to the nearest horizon
4. Adjust power as necessary by monitoring airspeed
5. Return to level flight

EXTREME NOSE HIGH RECOVERY



Extreme nose high

Power on

Pitch?

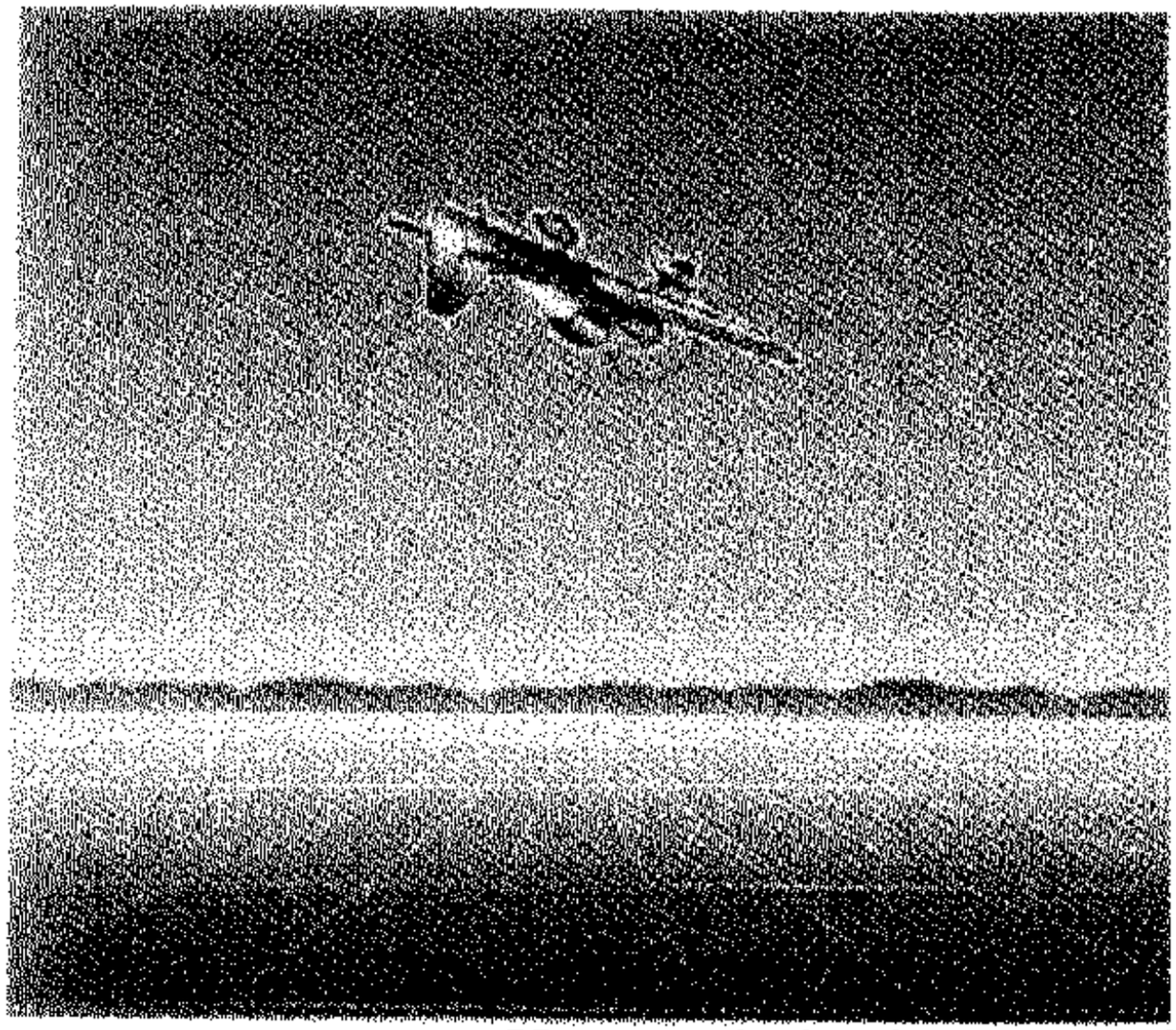
Roll?

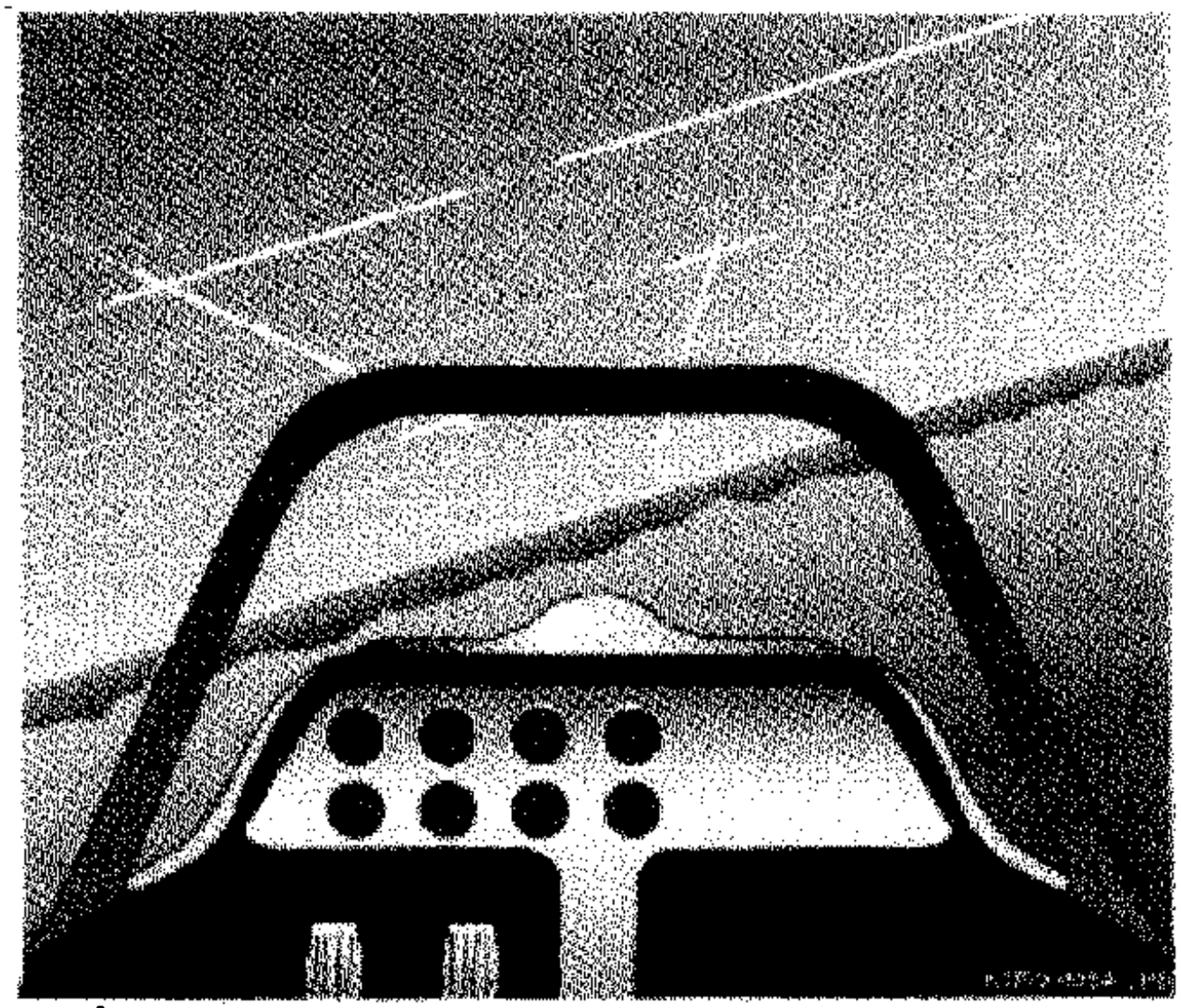
Rudder …. Pitch

Centralise & recover from dive

If tail-slide – centralise controls and hold firmly

INVERTED NOSE LOW RECOVERY





Power - off to minimise acceleration

Pitch – push to prevent nose dropping further

Roll – nearest horizon – which way?

HUMAN FACTORS, TEM and AIRMANSHIP CONSIDERATIONS

THREATS

- Other traffic
- Weather

- ERRORS
  - Stall / spin

- ANY OTHERS?

- DISCUSS: undesirable aircraft states – manage - actions

HUMAN FACTORS, TEM and AIRMANSHIP CONSIDERATIONS cont

AIRMANSHIP

- Pre-takeoff safety brief:
  - Runway 17L departures
  - Intercom failure
- Undesired aircraft state – recognition and early, appropriate action.
- Consider radio call to all traffic in aerobatic area
- Pre-manoeuvre checks – leave loose articles behind
- Speed and manoeuvre limitations not to be exceeded
  - **4 G, V_A, max aileron, half fuel**
- Correct handover / takeover procedure
- Safe height – note ground elevation
- Do not reset G meter.

FURTHER READING

1. Aerobatics Down Under by David Pilkington
2. Aerobatics Principles and Practice by David Robson
3. Tailwheel and Aerobatics Flying by Bob Tait
4. Stalls, Spins and Safety by Sammy Mason

QUESTIONS?