



# **Technical Stuff for Aerobatics Part 1**

## **Basic Flight Mechanics for Aerobatics & How to Break a Decathlon or Pitts**

**David J Pilkington FRAeS**

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# Flying Instructor of the Year 2019 Winner – David Pilkington



30 Sept 95

AVIAT, Inc.  
The Airport - Box 1149  
South Washington Street  
Afton, Wyoming 83110  
Attn: Mr. Malcolm White

Dear Mr. White,

On 29 and 30 September 95, Mr. Lester Berven, an FAA flight test pilot from the Seattle ACO flight test branch reviewed your production flight test acceptance procedures for both the HUSKY A-1, and the Pitts S-2B. Mr. Berven also flew both aircraft, and completed a production flight test pilot standardization check for Messrs. Peter S. Pierpont and David J. Pilkington.

Based on the successful completion of the document review and the flight evaluation, Messrs. Pierpont and Pilkington are hereby authorized to conduct and approve production acceptance flights for both the HUSKY A-1 and the Pitts S-1, and S-2 (all variations).



has this day been admitted to Degree of **Master of Science** in the Faculty of Technology having satisfied the requirements of the Senate in the subject of

AERODYNAMICS

Pilkington gave a masterly exhibition in the stock standard and now very dated ACA Super Decathlon *Little Nell*, including a half upward vertical roll, an elegant slow motion avalanche, and a remarkable knife-edge half-Cuban which he repeated in case his audience, like me, couldn't believe it was possible.

## National Aerobatic Championships Griffith NSW 1985

### Advanced Category

#### FINAL PLACINGS

NAME	SCORE
D. Pilkington	6184.7
W. Farley	5750.1
J. Walker	4623.8
C. Burns	3052.8

*possessing special trust and confidence in the integrity, diligence, and discretion*

DAVID J. PILKINGTON

*has been found to have the necessary knowledge, skill, experience, interest, and impartial judgment to merit special public responsibility, I hereby designate*

DESIGNATED ENGINEERING REPRESENTATIVE

*my authorization to act in accordance with the regulations and procedures of the Federal Aviation Administration relating to this designation.*

**DAVID.PILKINGTON@OZAEROS.COM.AU**

...port of aerobatics for many years:

...st awarded in 1935. Read out a few of the names – anyone recognise them? EG Roberts 1935, PJ Gibbes 1936, JH Hood 1938, CH Cook 1939, CA Morrison 1962, Miss PJ Brown 1967, WF Waterton 1968, JC Fincher 1969, GA Seymour 1971, HV Markby 1975 and RJ Maclean 1977

- RVAC pilots competing at the 1974 National Championships were **Con Simari**, Harry Markby, John Day, John Boag, Dick Maclean, **Ken McKechnie** – that was half the field!
- In 1977, new boy **David Pilkington** had joined them (started aerobatics in 1969 and later some aeros with former RVAC CFI Roy Goon).

## Mr David Pilkington (Australie)

*en reconnaissance des remarquables services rendus à l'aéronautique et aux sports aériens, et plus particulièrement à la voltige aérienne.*

# Why Dinosaurs?

From CASA's Flight Safety  
Magazine December 2017



“Buoyed by the anonymity of the keyboard, these largely fossilised creatures ..... exist in a **cesspit of misinformation, half-baked truths** and misshapen facts .....

and remain cheerful and in good humour—**never resort to personal insult** and mind your manners.”

..a great proportion of them were indeed **white men over the age of sixty ... the human equivalent of t-rex. ....**

# Content



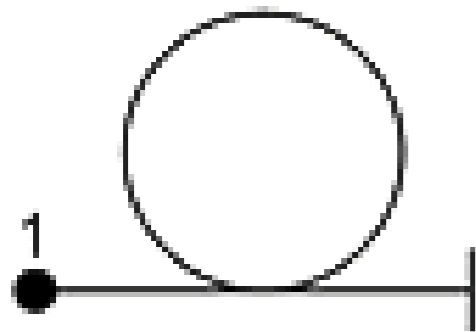
- Physics of a Loop
  - What is a loop?
  - Propeller effects
  - Flight Mechanics
- Hammerhead Flight Mechanics
  - Low & high performance airplanes
- Structural Considerations
  - How to break a Decathlon or Pitts
  - What is  $V_A$  really?



# CASA's Definition of a Loop

## FAE-1.2 – Perform looping manoeuvre

- (a) pitch the aircraft vertically at a continuous rate through  $360^\circ$  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;



Aresti symbol  
Cat No. 7.4.1.1  
Erect positive loop

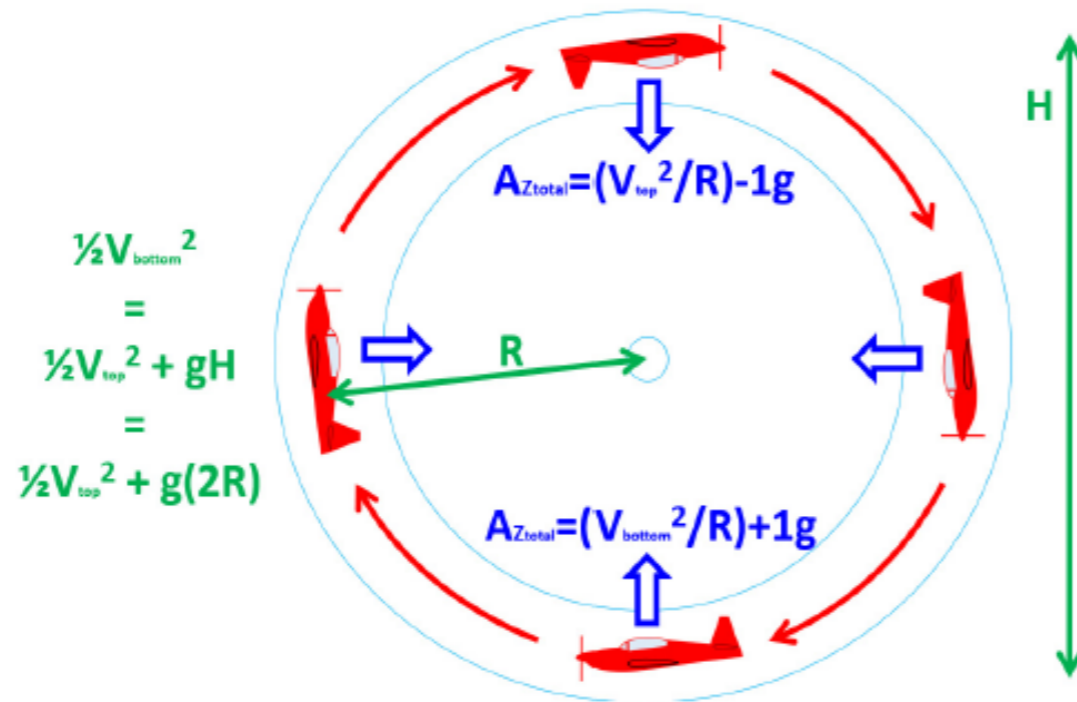


*Full and part loops  
are all judged on CGT  
and the shape must be  
wind corrected, ie. all  
looping elements  
are ROUND!*



# PHYSICS OF A LOOP

- $mgH = \frac{1}{2}mV^2$ , which correlates how much kinetic energy is converted to potential energy (i.e. how much speed is lost) when a body increases its altitude by H, and...
- $A_{centripetal} = V^2/R$ , which gives us the centripetal acceleration as a function of speed and radius.



**Dive to gain speed from 105 to 120 kts  $\approx$  150 ft**

**Approx 10 ft per kt at 100 kts**

**A Super Decathlon loses energy in a loop so, starting at 120, it exits at 110 kts**

$$R = (V_{kts} * 1.69)^2 / (N-1) / 32.2 \text{ \& at the top } R = (V_{kts} * 1.69)^2 / (N+1) / 32.2$$

Loop entry speed: 120 kts & 3.5 G, radius R = 500 ft

So, for a height gain, H, of 1,000 ft for a circular loop – what is the energy and power required?

At the top of the loop,  $V \approx 35$  kts at  $\approx 0$  G, the radius is 110 ft.

***How to make it closer to a circle?***

# PHYSICS OF A LOOP cont

For constant radius:

140 kts at 6 G, R = 360 ft

Top 65 kts at 0 G, R = 360 ft

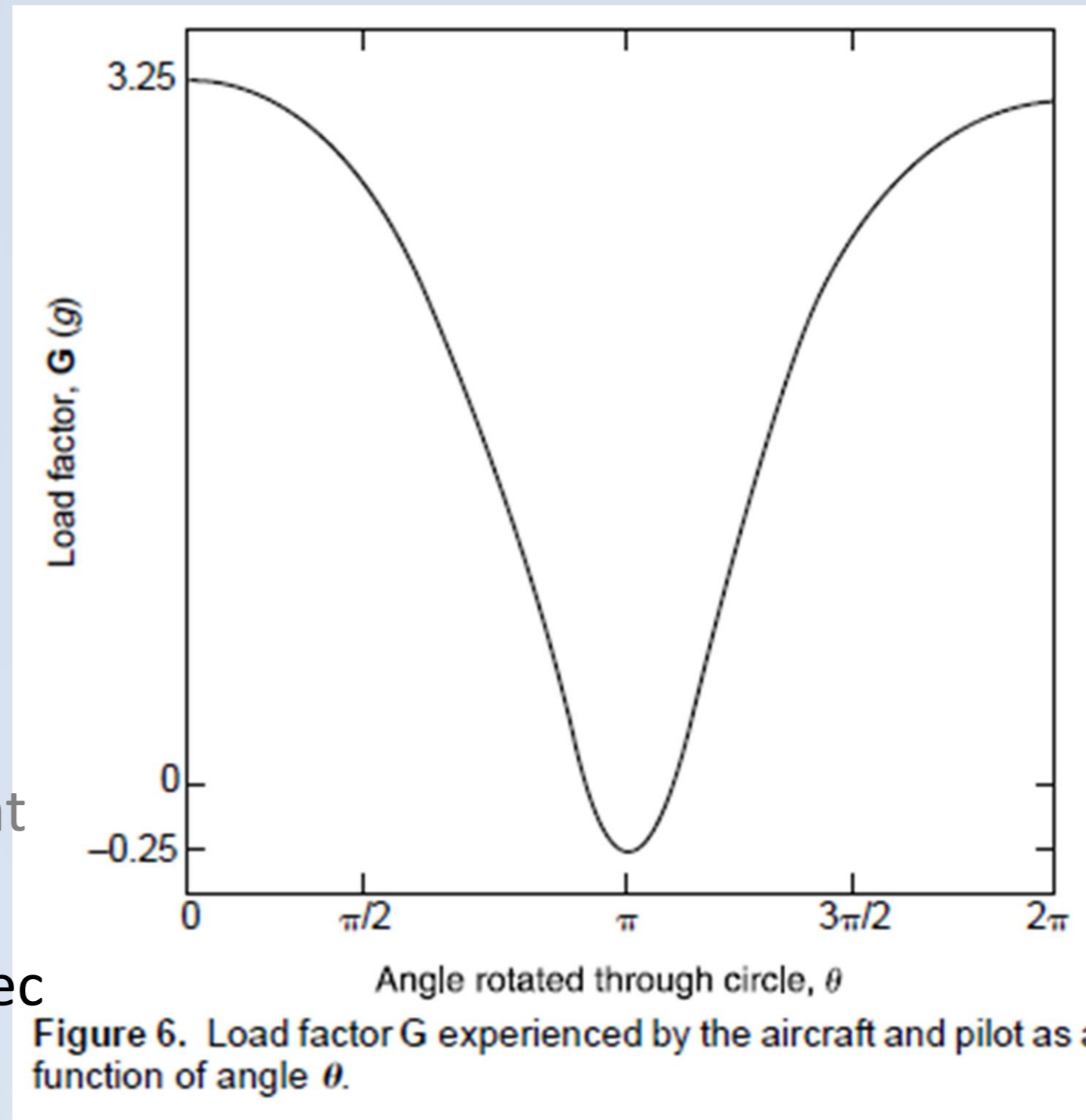
## Considerations?

- High G so fatigue damage
- No margin from limit load factor so risk of major damage
- Less than 0 G at the top for bigger radius.
- Energy loss

**130 – 140 kts & 4 – 4.5 G**

Note that pitch rate  $q = (N-1) g / V$  at bottom &  $(N+1) g / V$  at the top.

25 deg/sec at bottom and 20 deg/sec at the top for this recommended technique.



# PROPELLER EFFECTS



# LOOP FLIGHT MECHANICS

“Ensure that the instrument coaming is level as it passes through the horizon on the way up.”

“The airspeed is reducing quite rapidly now, so you’ll need to increase right rudder pressure ”

In a loop the pitch up results in right yaw from gyroscopics.

Try a part outside loop to demonstrate. Propeller effects are more important at low airspeed and more power.

It depends on the aeroplane:

- Decathlon – keep the rudder fixed
- Pitts S-1 – I found it so hard to do a loop – move up a category!



# HAMMERHEAD FLIGHT MECHANICS

At very low airspeeds on the vertical up, the propeller effects require lot of aileron and rudder just to keep it straight

Hit the rudder when the needle is at the "h" at "mph" on the ASI

OR when the woollen yarn flutters

OR when the aileron is half deflected

Hit the rudder and apply right aileron because the airspeed is decreasing rapidly and aileron is not very effective

Left yaw results in a pitch up so apply forward stick



If you hit the rudder too early and do that – inverted flap spin!

# HAMMERHEAD continue

In a Decathlon:

- Count to 3 to apply rudder?
- Super D AFM states 35 kts
- Std D AFM states 44 kts

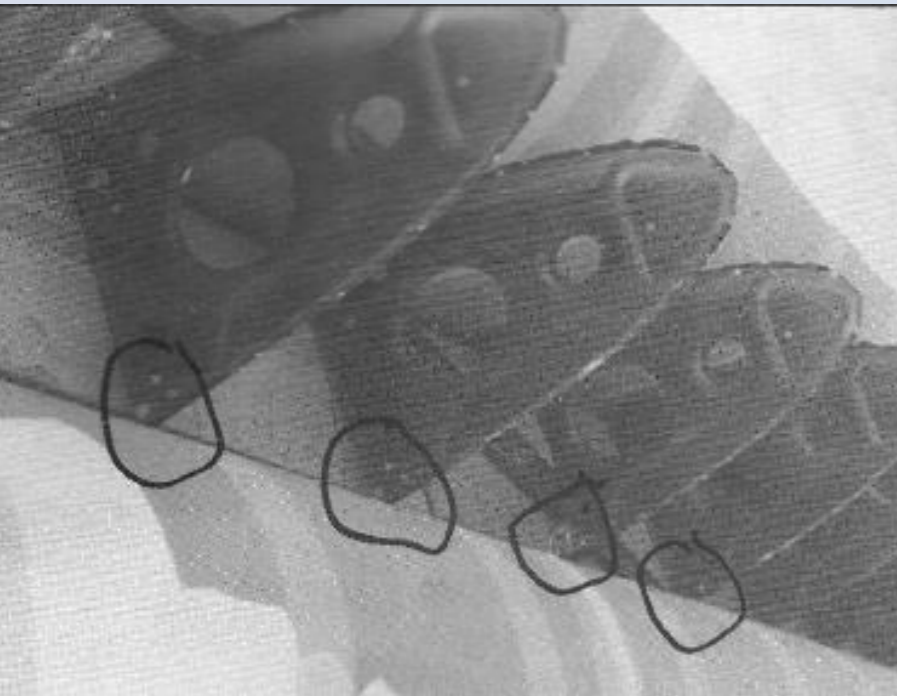
Now we have a higher airspeed and less power so the controls are more effective plus the propeller effects are much less.

Hit the rudder and ?

Secondary effect of rudder?



# How to Break a Decathlon



With the fabric removed to expose the first rib we could see deeper into the wing than the inspection holes permit. We initially saw evidence of additional structural failures. So rib- by-rib (and tear-by-tear) the fabric of my beautiful wings was peeled back exposing even more troublesome failures. We found numerous failed rivets in critical areas, cracks in every fuel tank support bracket, and one previously undetected leaky fuel tank. So much for my assumption that this plane could be flown within its limits without failure. The wing root failure was a blessing in disguise. Without that obvious failure, we would not have detected the seven adjacent failed rivets holding the right 3<sup>rd</sup> rib to the leading edge or the leaking left fuel tank. I suspect, a catastrophic failure could have ensued flying the plane as I do (to, but not exceeding its limits). My mechanic and I



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  $\pm 4g$ .* Excursions beyond  $\pm 4g$  may occur but should not be routine.

# How to Break a Pitts


## Analysis

The pilot was conducting aerobatic maneuvers. The pilot stated, that during a maneuver, '...As I pulled out of the maneuver (a 4 to 5 G pull) I heard a very loud 'shot gun' type noise and simultaneously experienced a hard jolt and a release of pressure on the stick as the plane's nose pitched downward....The throttle lever jammed at approximately the half closed position. The plane was descending; in order to stabilize the airspeed for a forced landing, I had to hold full back stick pressure.' Examination of the aircraft revealed the upper left and right longeron tubes from the fuselage were fractured. The fracture of the longerons restricted movement of the cables for the throttle and mixture control. Metallurgical examination of the longeron fractures revealed evidence of fatigue cracking.

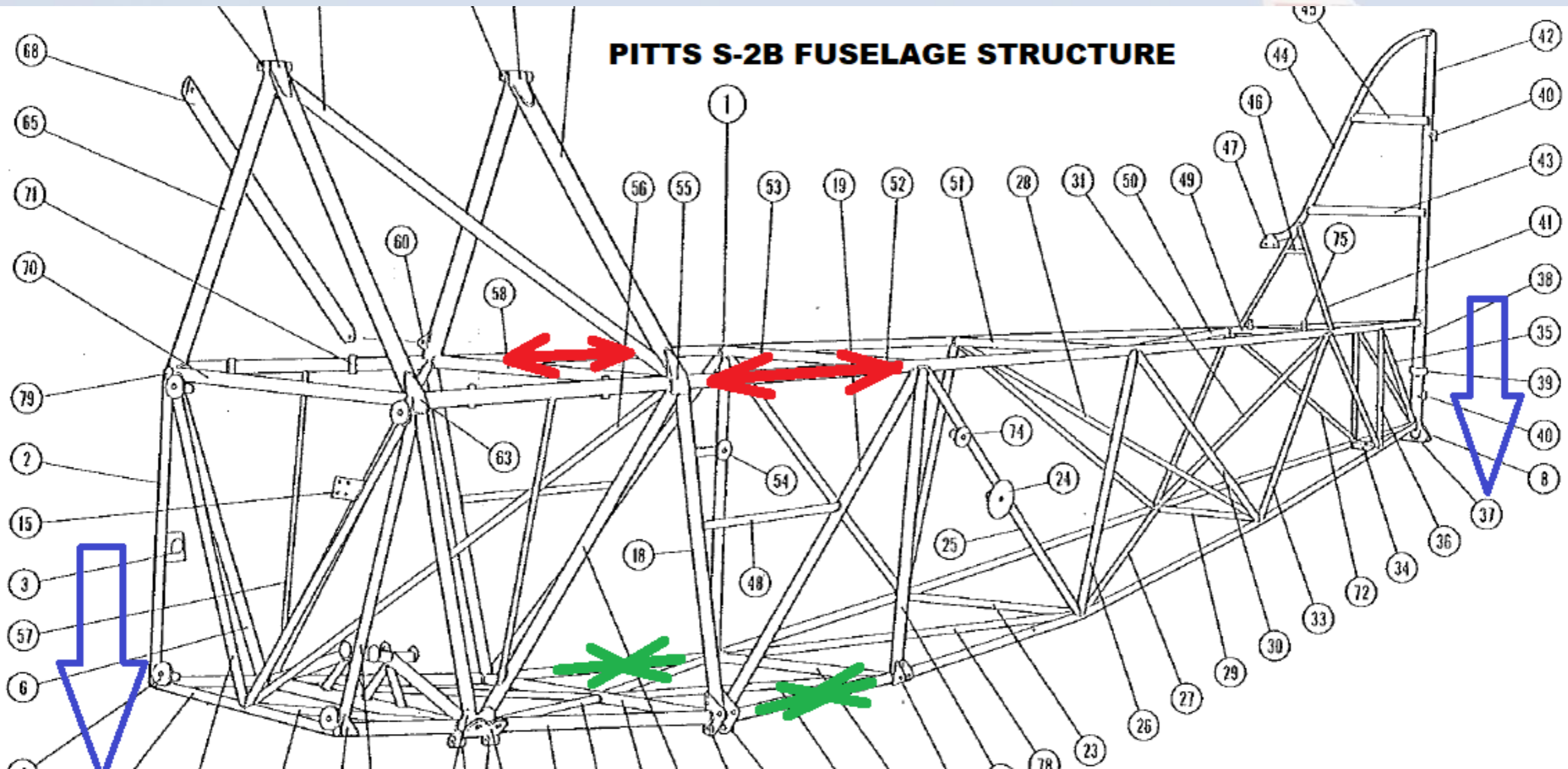
## Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be: failure of the fuselage longeron tubes due to fatigue, which resulted in partial separation (distortion) of the fuselage, partial loss of aircraft control, and a partial loss of engine power.

Pitts S-2B N260AF in 1995

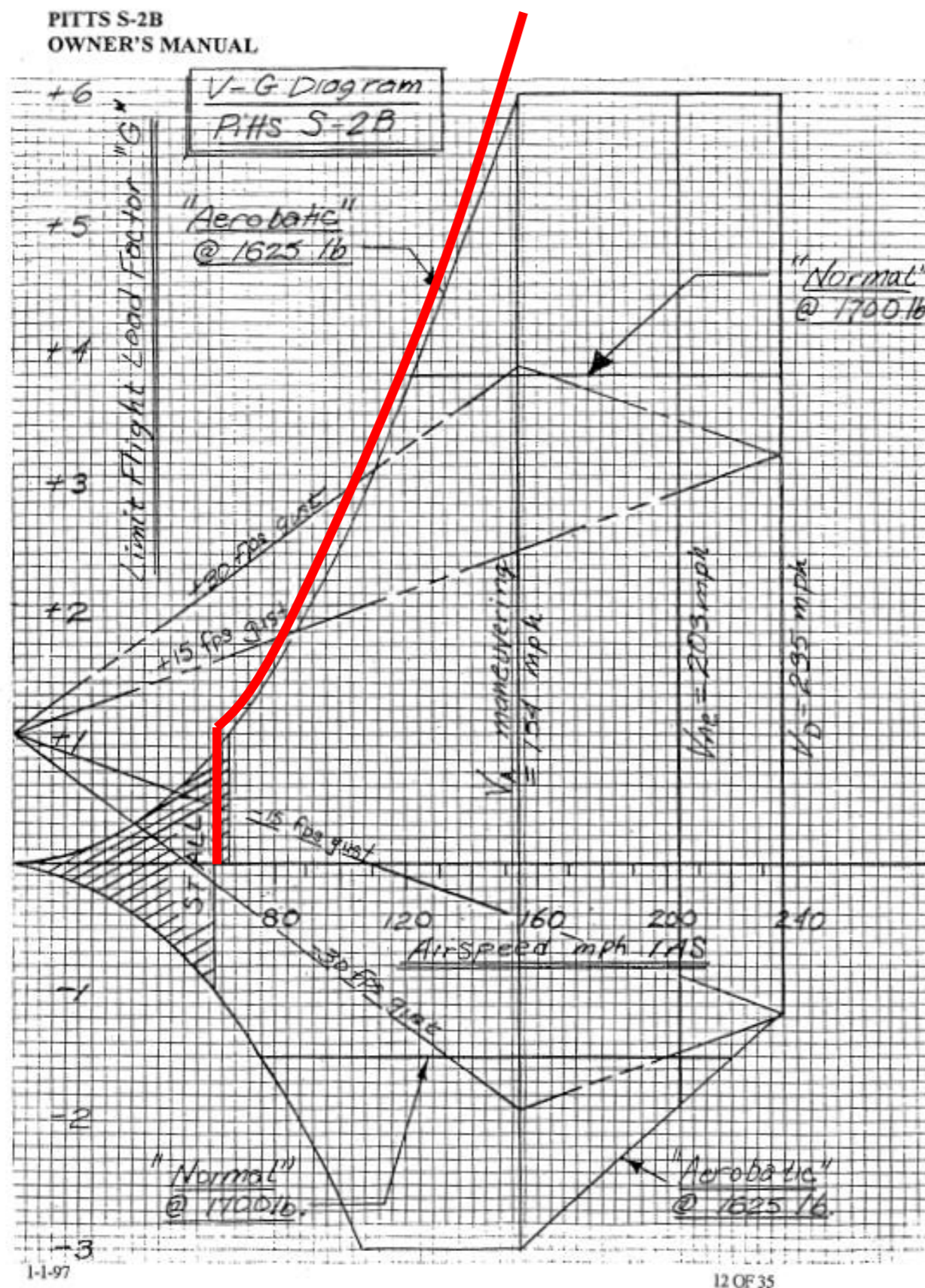


# How to Break a Pitts



**FEA & flight tests with strain gauges and accelerometers**

# Pitts S-2B Design



## Design flight envelope

- $V_A$  154 mph = 134 KCAS
- Stall speed 63 mph = 54.6 KCAS

But when flight tested stall speed  
= 60 mph = 52.1 KCAS

So, the corner speed is 128 KCAS  
and, from simple arithmetic, you  
will get **6.6 G** at  $V_A$  !

but .....

# Simple Pilot Theory vs Real Aerodynamics

## 2.4 SNAPPED MANEUVERS:

CAP 10 POH

Recent wind-tunnel tests have shown that quick variations of the angle of attack can increase substantially the maximum coefficient of lift of airfoils (unsteady flow). For this reason, the full and quick deflection of the elevator at speeds below or equal to the maneuvering speed (146 mph) can cause the overstepping of the limit load factors and could cause breaking.

Pitts S-2B flight testing:

Full elevator at 121 kts resulted in 6 G so, at  $V_A$  of 134 kts, expect **7.4+ G**! The aeroplane will break .... they did!

# What is $V_A$ really?

**48. What is the design maneuvering speed  $V_A$ ?**

FAA AC 23-19

**What is the Operating Maneuvering Speed?**

c. Amendment 23-45 added the operating maneuvering speed,  $V_O$ , in § 23.1507.  $V_O$  is established not greater than  $V_S\sqrt{n}$ , and it is a speed where the airplane will stall in a nose-up pitching maneuver before exceeding the airplane structural limits.

# What is $V_A$ really?

a. The design maneuvering speed is a value chosen by the applicant. It may not be less than  $V_S \sqrt{n}$  and need not be greater than  $V_C$ , but it could be greater if the applicant chose the higher value. The loads resulting from full control surface deflections at  $V_A$  are used to design the empennage and ailerons in part 23, §§ 23.423, 23.441, and 23.455.

b.  $V_A$  should not be interpreted as a speed that would permit the pilot unrestricted flight-control movement without exceeding airplane structural limits, nor should it be interpreted as a gust penetration speed. Only if  $V_A = V_S \sqrt{n}$  will the airplane stall in a nose-up pitching maneuver at, or near, limit load factor. For airplanes where

$V_A > V_S \sqrt{n}$ , the pilot would have to check the maneuver; otherwise the airplane would exceed the limit load factor.

# QUESTIONS?



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