The F-15 "Streak Eagle" Program

(From Tallyho, Feb 7, 1975,
The Luke AFB Weekly Newsletter)

An Air Force F-15 Eagle, stripped of its paint and 4,200 lbs. of military payload, has assaulted the international record book and unofficially broke all eight existing world "time to climb" records.

The operation, dubbed Project Streak Eagle, was conducted at Grand Forks AFB, North Dakota, from Jan. 16 to Feb. 1, using a production model F-15 which will enter the Tactical Air Command inventory at the 555th (Triple Nickel) Tactical Fighter Training Squadron here.

The first Eagle arrived at Luke on Nov. 14, and the base has the distinction of being the only operational site in the Air Force.

All Streak Eagle fighters were flown by Air Force pilots. Majors Roger J. Smith, Willard R. (Mac) MacFarlane and David W. Peterson.

Three of the eight climb-to-time records were held by the Soviet Union, using a MIG-25 Foxbat interceptor, and five records held by a U.S. Navy F-4H-1 fighter.

Valuable Fighter Data

While breaking the records, which is essentially attempting to reach a certain altitude in the shortest length of time, the flights provided the Air Force with valuable information on the performance of the F-15 at high altitudes and the operation of various aircraft systems under those conditions. The Eagle thus demonstrated its capability to intercept any known fighter threat at extremely high altitudes.

Major Smith, commented on the flight results, said, "The taking of the records proved that the F-15 can operate in the MIG-25 Foxbat environment. This is a capability we have not had in the past."

Records Shattered

Timing for the record flights began when the F-15 started its ground roll on the runway and ended when it passed through the target altitude.

Records broken include 3,000 meters (9,843 ft), 6,000 meters (19,685 ft), 9,000 meters (29,529 ft), 12,000 meters (39,370 ft), 15,000 meters (49,213 ft), 20,000 meters (65,617 ft), 25,000 meters (82,021 ft), and 30,000 meters (98,425 ft).

Five records were established in one day on three flights, each flown by a different pilot.

The 20,000, 25,000 and 30,000 meter records, previously held by the MIG-25, were set in 1973. The 20,000 meter record was borken by more than 25 per cent as the flight time was reduced from 2 min. 50 sec. to 2 min. 3 sec.

The 3, 6, 9, 12 and 15,000 meter records, previously held by the F-4H-1 since 1962, were broken by from 19 per cent to more than 30 per cent.

Lt. Gen. James Stewart, commander of the Air Force Systems Command's Aeronautical Systems Division, said, "The F-15 is meeting our expectations and it has been a winner all the way. The Eagle did not just break the previous records; it shattered them."

The procedure during the lower five altitude records was to lift off, accelerate in level flight and pull up to reach the target altitude.

Flight Profiles

In Major Smith's 3,000 meter record, the thrust to weight ratio at brake release was over 1.6. The Eagle lifted off at 400 feet (about seven aircraft lengths), accelerated to Mach .6 in level flight, then rotated in a 5g pull-up to an 80 degree climb and passed through 9,843 feet at Mach 1 in 27.57 seconds.

On Jan. 16, Major MacFarlane set the 6, 9 and 12,000 meter record times in a flight profile similar to the 3,000 meter run except the max speed was set at Mach .7 before pull-up. The F-15 reached Mach 1 in only 23 seconds after brake release. Precise piloting techniques by Major MacFarlane permitted taking of the three record times in one flight.

On Major Peterson's 15,000 meter and higher flights, full pressure suits were worn by the crew. On lift-off, Major Peterson accelerated at 50 feet above the runway to Mach .65, pulled into a 55 degree flight path angle and reached target altitude of 49,213 feet in 77.02 seconds. This is about 10 seconds quicker to that altitude than the Saturn V rocket boosted the Appollo spacecraft on its way to the moon.

Major Smith's 20,000 meter profile consisted of a giant Immelmann maneuver starting at Mach .65 on the deck and pulling 2.5 gs until the F-15 was over the top at 32,000 feet and an acceleration in the opposite direction from take-off. While passing through 20,000 feet, the Eagle was vertical with a 2.5g load factor and a Mach 1+ rate of climb. At Mach 1.5, Major Smith pulled 4gs into a 55 degree climb to the 65,617-foot target altitude in 122.94 seconds from brake release. Margin over the Foxbat record was 28 per cent.

Major Peterson, in his 25,000 meter record, flew a similar profile. Max speed was achieved at Mach 1.8 just prior to the second pull-up. The 82,021-foot altitude was reached in 161.02 seconds at Mach .6 which beat the Foxbat's time by 17 per cent.

On Major Smith's 30,000 meter run, the 32,000 lb. Eagle lifted off with 500 feet of ground roll, accelerated to Mach .65 and pulled into the 2.5g Immelmann. After rolling 180 degrees at the top, Major Smith accelerated in a slight climb to build up total energy. The F-15 passed through Mach 2 about 21 miles down range. At Mach 2.2, Major Smith pulled up to 4gs and attained a 55 degree climb whereupon the stick was relaxed to maintain a constant altitude. The 98,425 foot target altitude was achieved in 207.8 seconds, bettering the Foxbat by 36 seconds. The Eagle maintained a nearly ballistic path as it went "over the top" at 102,400 feet before descent into a more dense atmosphere. The 18.5 mile high flight took less than 3.5 minutes to reach.

Aircraft Preparations

In preparation for the record attempts, no modifications of special thrust devises were made on the twin Pratt & Whitney F100 engines. Total aircraft weight was lessened by 4,200 lbs. with removal of its military payload, including some electronic systems, fire-control equipment and the M61 cannon. Only enough fuel was carried to fly the predetermined, computer - generated profile and return to base. Fuel weight varied from 3,000 to 6,000 lbs. Takeoff weights varied from 29,000 - 32,000 lbs., giving the Eagle a thrust-to-weight ratio in excess of 1.5.

Air Force claims for the new records must be verified by the Federal Aeronautique International (FAI) in Paris, France, before they become official. The FAI recognizes and honors outstanding contributions to the advancement of aeronautics. The National Aeronautics Association (NAA), the U.S. arm of the FAI, officiated during all Streak Eagle flight and will submit the record data to the FAI on behalf of the Air Force.

Streak Eagle marked the latest phase of a rugged 2½ year flight test program which has verified the basic design performance and reliability of the F-15.

The McDonnell Douglas Company, St. Louis, MO., is the F-15 airframe manufacturer and Pratt and Whitney Co., East Hartford, Conn., makes the 25,000 lb. thrust class F100 turbofan engine.

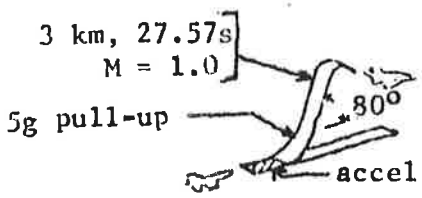
The F-15 Eagle is the first Air Force operational fighter with a thrust-to-weight ratio greater than 1, enabling it to accelerate even while in a vertical climb.

And, that is exactly what Streak Eagle proved to the world.

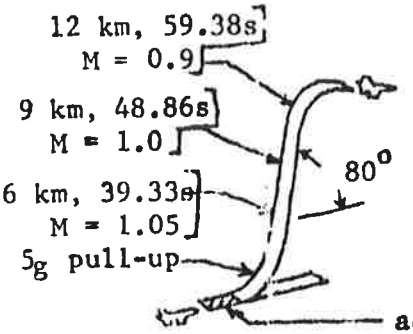
PREVIOUS RECORDS AND THE RESULTS OF THE STREAK EAGLE "TIME-TO-CLIMB" PROJECT ARE SUMMARIZED AS FOLLOWS:

ALTITUDE METERS (Feet)	HELD BY	WHEN	OLD RECORD	NEW RECORD	F-15 PILOT (USAF)
3,000 (9,843)	F-4H-1 Phantom (Cdr. J.W. Young, USN)	2-31-62	34.5 Sec.	27.57 Sec.	Maj. Roger Smith
6,000 (19,685)	F-4H-1 Phantom (Cdr. D.M. Longton, USN)	2-21-62	48.8 Sec.	38.33 Sec.	Maj. Mac MacFarlane
9,000 (29,529	F-4H-1 Phantom (LCol W.G. McGraw, USMC)	3-3-62	61.7 Sec.	48.86 Sec.	Maj. Mac MacFarlane
12,000 (39,370)	F-4H-1kPhantom (LCol W.G. McGraw, USMC)	3-1-62	77.1 Sec.	59.38 Sec.	Maj. Mac MacFarlane
15,000 (49,213)	F-4H-1 Phantom (Lcdr. D.W. Nordberg, USN)	3-3-62	114.5 Sec.	77.02 Sec.	Maj. David Peterson
20,000 (65,617)	MIG-25 Foxbat (B. Orlov, USSR)	6-4-73	169.8 Sec.	122.95 Sec.	Maj. Roger Smith
25,000 (82,021)	MIG-25 Foxbat (P. Ostapenko, USSR)	6-4-73	192.4 Sec.	161.02 Sec.	Maj. David Peterson
30,000 (98,425)	MIG-25 Foxbat (P. Ostapenko, USSR)	6-4-73	243.4 Sec.	207.08 Sec. 36 243	Maj Roger Smith

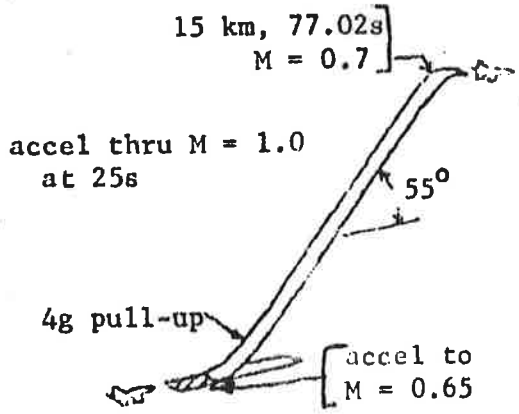
26c



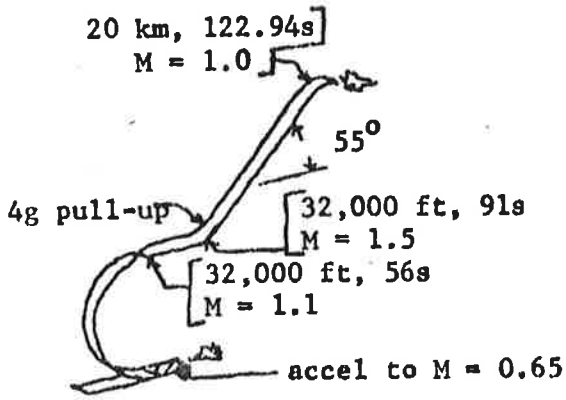
Flight #1 (3 km)
T/w = 1.6+, W_{To} = 27,972 lb



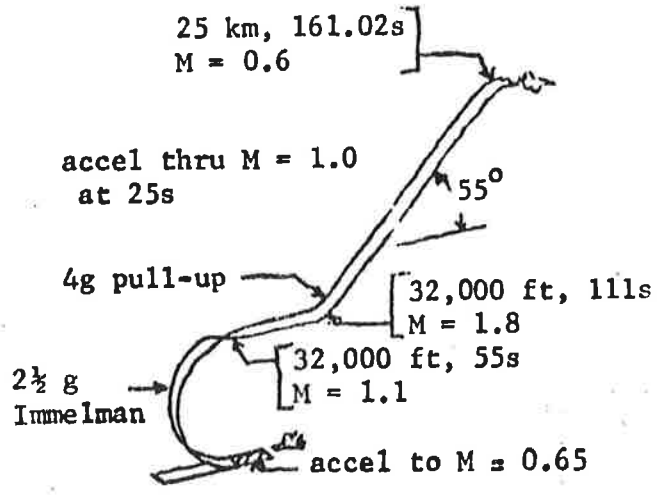
Flight #2 (6,9 & 12 km)
T/w = 1.6+, W_{To} = 28,653 lb



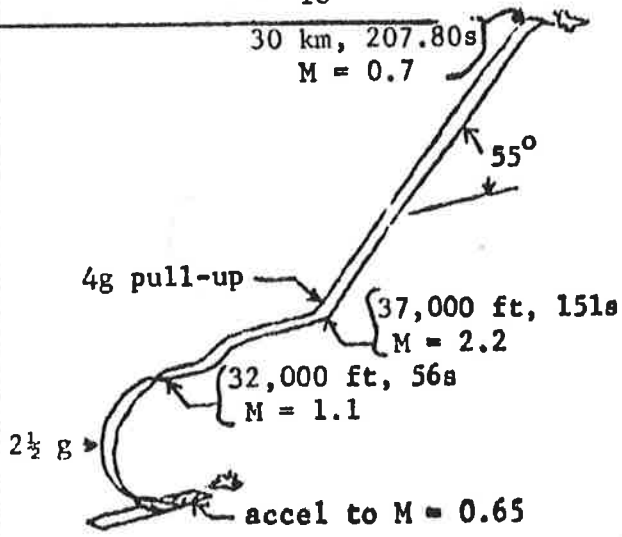
Flight #3 (15 km)
T/w = 1.6+, W_{To} = 28,894 lb



Flight #4 (20 km)
T/w = 1.5+, W_{To} = 29,877 lb

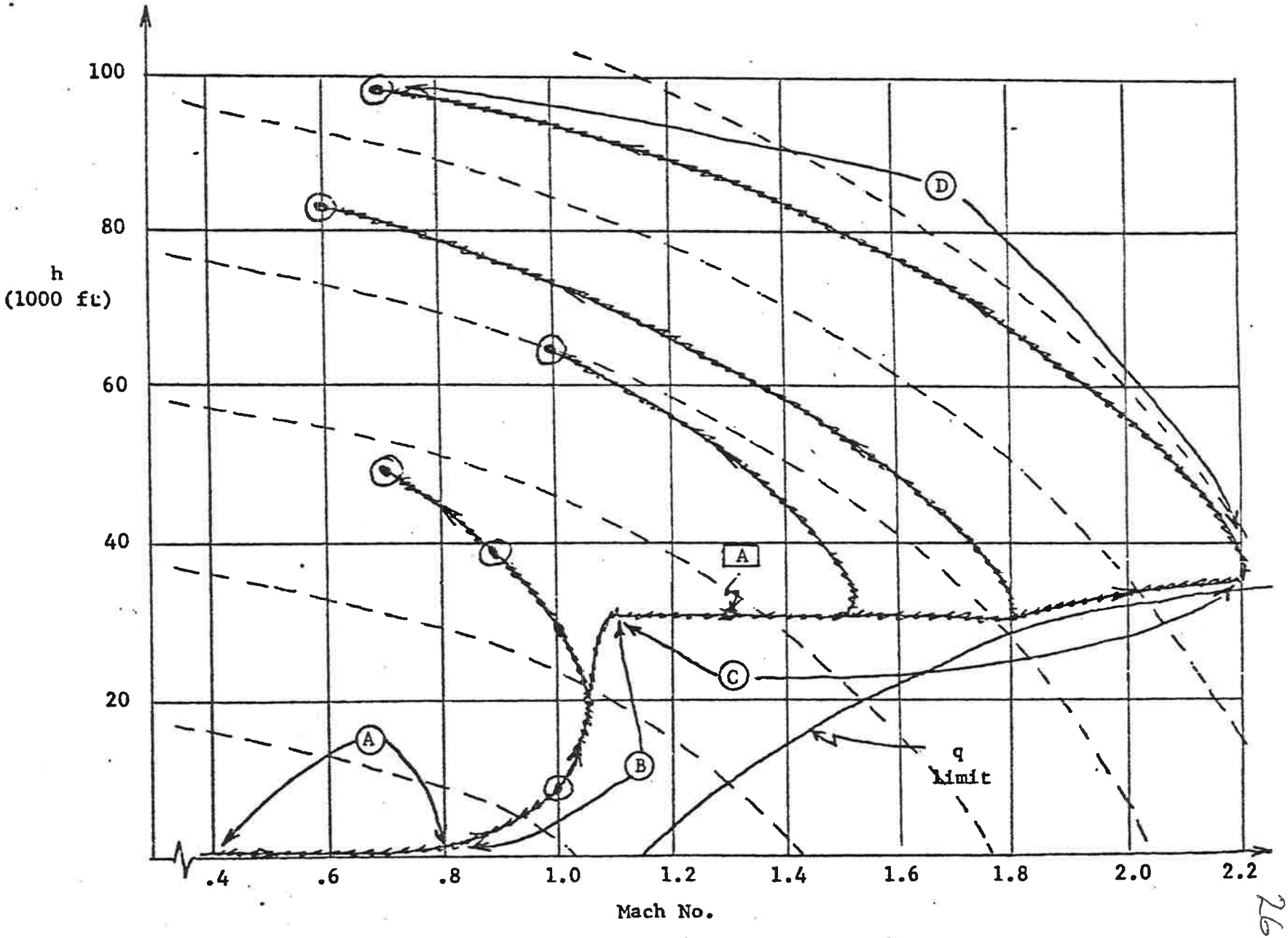


Flight #5 (25 km)
T/w = 1.5+, W_{To} = 30,562 lb



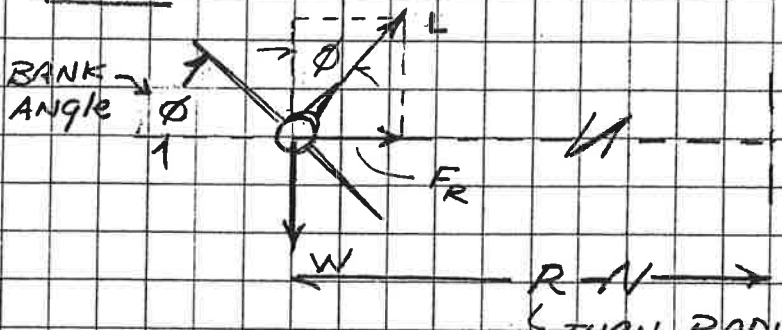
Flight #6 (30 km)
T/w = 1.4+, W_{To} = 31,908 lb

STREAK EAGLE FLIGHT PROFILES


100
80
h
(1000 ft)
60
40
20
A
D
C
A
B
q
limit
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
Mach No.

TURN PERFORMANCE

Level CONSTANT SPEED TURNS



EQUATIONS

$$\Sigma F_y = L\cos\phi - W = 0$$

$$\Sigma F_R = \underbrace{L\sin\phi}_{F_R} = m a_R$$

$$\Rightarrow \quad L = \frac{W}{\cos\phi} \quad \text{OR} \quad \frac{L}{W} = \frac{1}{\cos\phi}$$

$\left\{ \frac{L}{W} \equiv n \text{ "Load Factor"} \right.$

$$L\sin\phi = m a_R = \frac{W}{g}\frac{V_\infty^2}{R}$$

$$\Rightarrow R = \frac{\frac{W}{g}\frac{V_\infty^2}{L\sin\phi}}{} = \frac{\frac{W}{g}\frac{V_\infty^2}{L\sqrt{1-\cos^2\phi}}}{}$$

$(\text{i.e., } \sin^2\phi + \cos^2\phi = 1)$

ϕ since $\cos\phi = \frac{W}{L}$

$$\Rightarrow R = \frac{\frac{W}{g}\frac{V_\infty^2}{L\sqrt{1-\left(\frac{W}{L}\right)^2}}}{} = \frac{\frac{1}{g}\frac{V_\infty^2}{\frac{L}{W}\cdot\frac{W}{L}\sqrt{\left(\frac{L}{W}\right)^2-1}}}{}$$

[TURN RADIUS] $\Rightarrow$

$$\boxed{R = \frac{V_\infty^2}{g\sqrt{n^2-1}}}$$

Level turn Radius $= f(V_\infty, n)$

$\frac{1}{\text{(Load Factor)}}$

ASIDES: (1) STRUCTURAL Load Limit

(2) Very high $V_\infty \Rightarrow$ Large R (SR71)

(3) $n = \frac{L}{W} = \frac{1}{\cos\phi}$ so a "2g turn" $\phi = 60°$ bank

[TURN RATE]

$$\omega = \frac{V_\infty}{R} = \frac{V_\infty}{\left(V_\infty^2/g\sqrt{n^2-1}\right)}$$

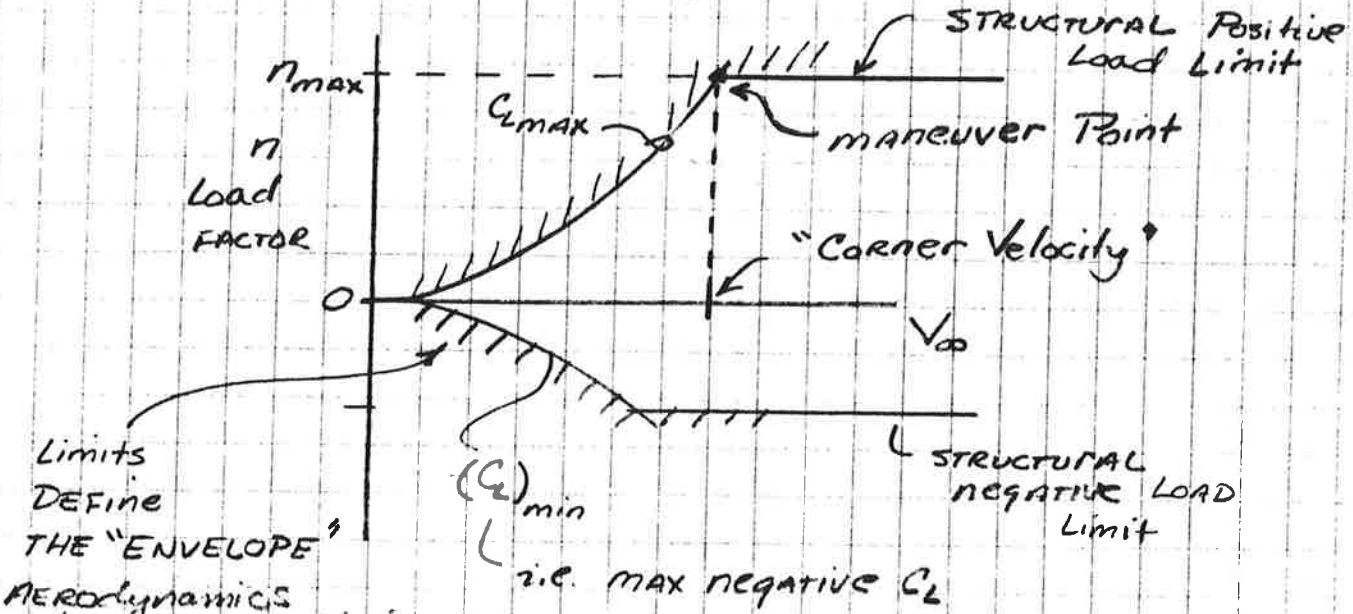
$$\Rightarrow \boxed{\omega = \frac{g\sqrt{n^2-1}}{V_\infty}}$$

"TURN PERFORMANCE"

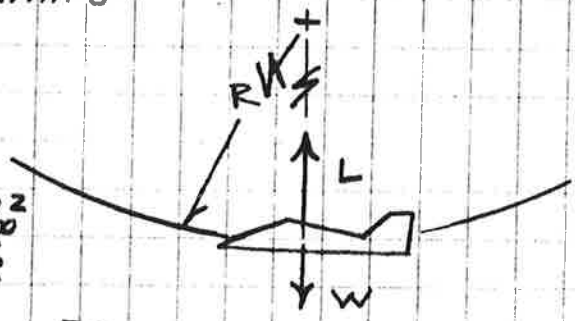
minimum turn RADIUS at MAXIMUM Load FACTOR and minimum SPEED ($V_{\infty_{min}}$) also $\Rightarrow$ max turn RATE

RECALL that $L = Wn = C_L \frac{1}{2} \rho_\infty V_\infty^2 S$

so min V_∞ is at $C_{L_{MAX}}$



PULL UPS



$\Sigma F_R = L - W = m\frac{V_\infty^2}{R}$

$\Sigma F_\theta = T - D = 0$ $\quad \boxed{T = D}$

$\Sigma F_\phi = 0$ i.e. $\phi = 0$

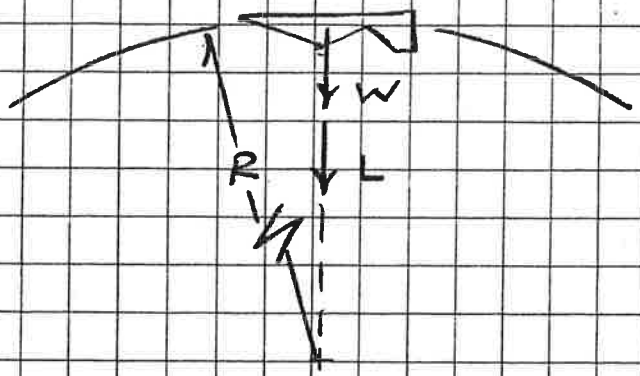
$$W\left(\frac{L}{W} - 1\right) = \frac{W}{g}\frac{V_\infty^2}{R} \Rightarrow (n-1) = \frac{1}{g}\frac{V_\infty^2}{R}$$

($\frac{L}{W} = n$)

$$\Rightarrow \boxed{R = \frac{V_\infty^2}{g(n-1)}} \quad \& \quad \omega = \frac{V_\infty}{R} \Rightarrow \boxed{\omega = \frac{g(n-1)}{V_\infty}}$$

PULL UPS

PULL OVER



EQUATIONS

$$\Sigma F_R = L + W = m\frac{V_\infty^2}{R}$$

$$\Sigma F_\theta = T - D = 0$$

$$\Sigma F_\phi = 0 \quad \text{i.e. } \phi = 0$$

$$T = D$$

$$\Rightarrow \quad L + W = W\left(\frac{L}{W} + 1\right) = \frac{W}{g}\frac{V_\infty^2}{R}$$

$$\Rightarrow \quad (n+1) = \frac{1}{g}\frac{V_\infty^2}{R}$$

$$\Rightarrow \quad \boxed{R = \frac{V_\infty^2}{g(n+1)}} \qquad \omega = \frac{V_\infty}{R} \Rightarrow \boxed{\omega = \frac{g(n+1)}{V_\infty}}$$

← PULL OVERS

In Fighters n_{MAX} is Large so AT LARGE n NOTICE THAT

$$n \cong n+1 \cong n-1$$

AT high n R & W Approx same at any ϕ & θ i.e. out of plan turns

Level turns	$R = \frac{V_\infty^2}{g\sqrt{n^2-1}}$	$\xrightarrow{\text{Large } n}$	$\frac{V_\infty^2}{gn}$ & $\omega \longrightarrow \frac{gn}{V_\infty}$
Pull ups	$R = \frac{V_\infty^2}{g(n-1)}$	$\xrightarrow{\text{Large } n}$	$\frac{V_\infty^2}{gn}$ & $\omega \longrightarrow \frac{gn}{V_\infty}$
Pull overs	$R = \frac{V_\infty^2}{g(n+1)}$	$\xrightarrow{\text{Large } n}$	$\frac{V_\infty^2}{gn}$ & $\omega \longrightarrow \frac{gn}{V_\infty}$

Using these APPROXIMATIONS

$$L = C_L \tfrac{1}{2}\rho_\infty V_\infty^2 S \Rightarrow V_\infty^2 = \frac{2L}{\rho_\infty S C_L} \Rightarrow \begin{cases} R = \dfrac{V_\infty^2}{gn} = \dfrac{2L}{g\left(\frac{L}{W}\right)\rho_\infty S C_L} \\ \boxed{R = \dfrac{2}{\rho_\infty C_L g}\left(\dfrac{W}{S}\right)} \\ \& \quad \boxed{\omega = g\sqrt{\dfrac{\rho_\infty C_L n}{2\left(\frac{W}{S}\right)}}} \end{cases}$$

Notice the importance of wing Loading $\left(\frac{W}{S}\right)$

$$R_{min} = \frac{2}{\rho_\infty g C_{L_{MAX}}}\left(\frac{W}{S}\right)$$

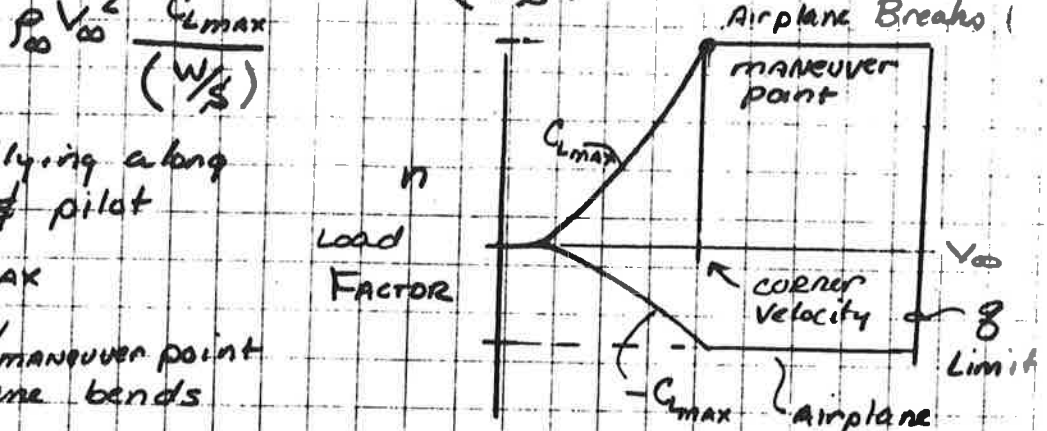
R_{min} goes up with altitude

$$n = \frac{L}{W} = \frac{C_L \frac{1}{2}\rho_\infty V_\infty^2 S}{W} = \frac{C_L \frac{1}{2}\rho_\infty V_\infty^2}{(W/S)}$$

$$n_{MAX} = \frac{1}{2}\rho_\infty V_\infty^2 \frac{C_{L_{MAX}}}{(W/S)}$$

Plane flying along at V_∞ & pilot pulls $C_{L_{MAX}}$

if $V_\infty > V_{maneuver\ point}$ plane bends



V-n Diagram