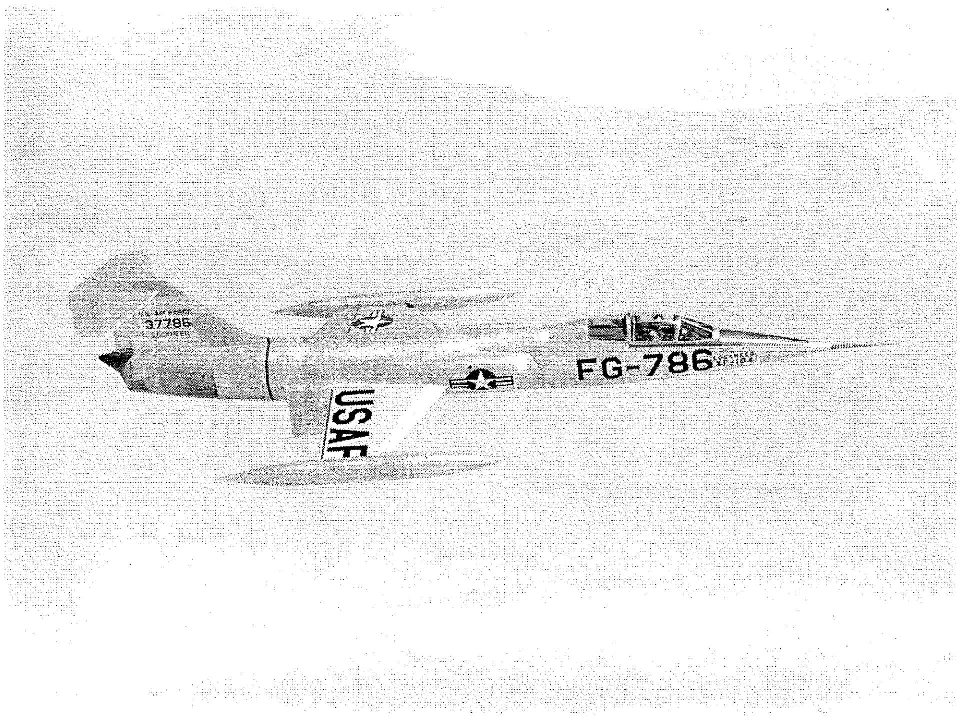
The SURE Project



Lecture – 2/10

STARFIGHTER UTILIZATION RELIABILITY EFFORT

LECTURE 2

INVESTIGATION

OF

F-104

PITCH-UP

AND

SPIN

MODES

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FOREWORD

Throughout the history of the F-104, there has occurred certain maneuvers, the memories of which are permanently etched on the minds of the pilots. The real lucky ones effected recoveries. The plain lucky ones ejected safely. Since I am one of the real lucky ones, I have felt compelled through the years to help prevent any repetitions of pitch-ups and spins in the 104. With the advent of greater numbers of 104's flying in the skies and knowing the spirit of fighter pilots, I am resigned to the prospect of hearing and reading about more recurrences but it is my effort and purpose with this lecture to produce more real lucky jocks. In fact, I hope that this message precludes the necessity of any recoveries from pitch-ups or spins in your flying.

References

1. Lockheed Report No. 12690, "Flight Test of Pitch-up and Spins", Model F-104A.

2. Lockheed Report No. 13321, "Flight Test of Pitch-up and Spins", Model F-104B.

3. Lockheed Report No. 12741, "F-104 Stall Characteristics".

4. USAF Accident Report, "Major Accident F-104A #56-0764, Edwards AFB".

5. Edwards AFB Flight Research Division Publication, "AV-65-1, NF-104A and F-104A Analog Simulation Support" by Capt. Charles D. Zaleski, February, 1965.

6. Lockheed Report 1-14404-1, "F-104G Flight Manual".

7. USAF T.O. 1F-104G-1, "F/RF-104G(MAP) Flight Manual".

8. USAF T.O. 1F-104A-1, "F-104A and F-104B Flight Manual".

9. USAF T.O. 1F-104C-1, "F-104C Flight Manual".

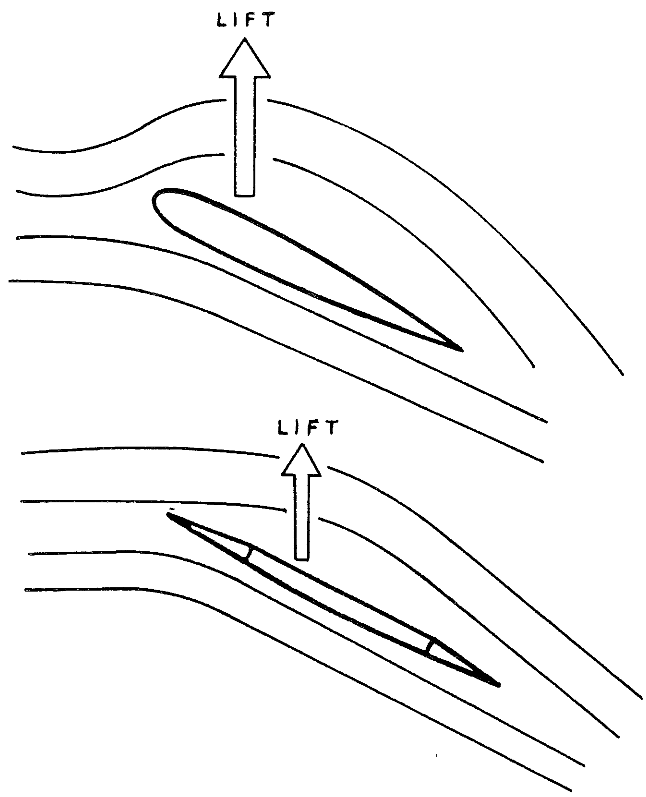
10. Edwards AFB Flight Research Division Publication, "AC-64-5, Some Considerations of Engine Gyroscopic Coupling Effects Upon the Motion of an Aircraft", by W. R. Turley, June, 1964.

Pitch-Up

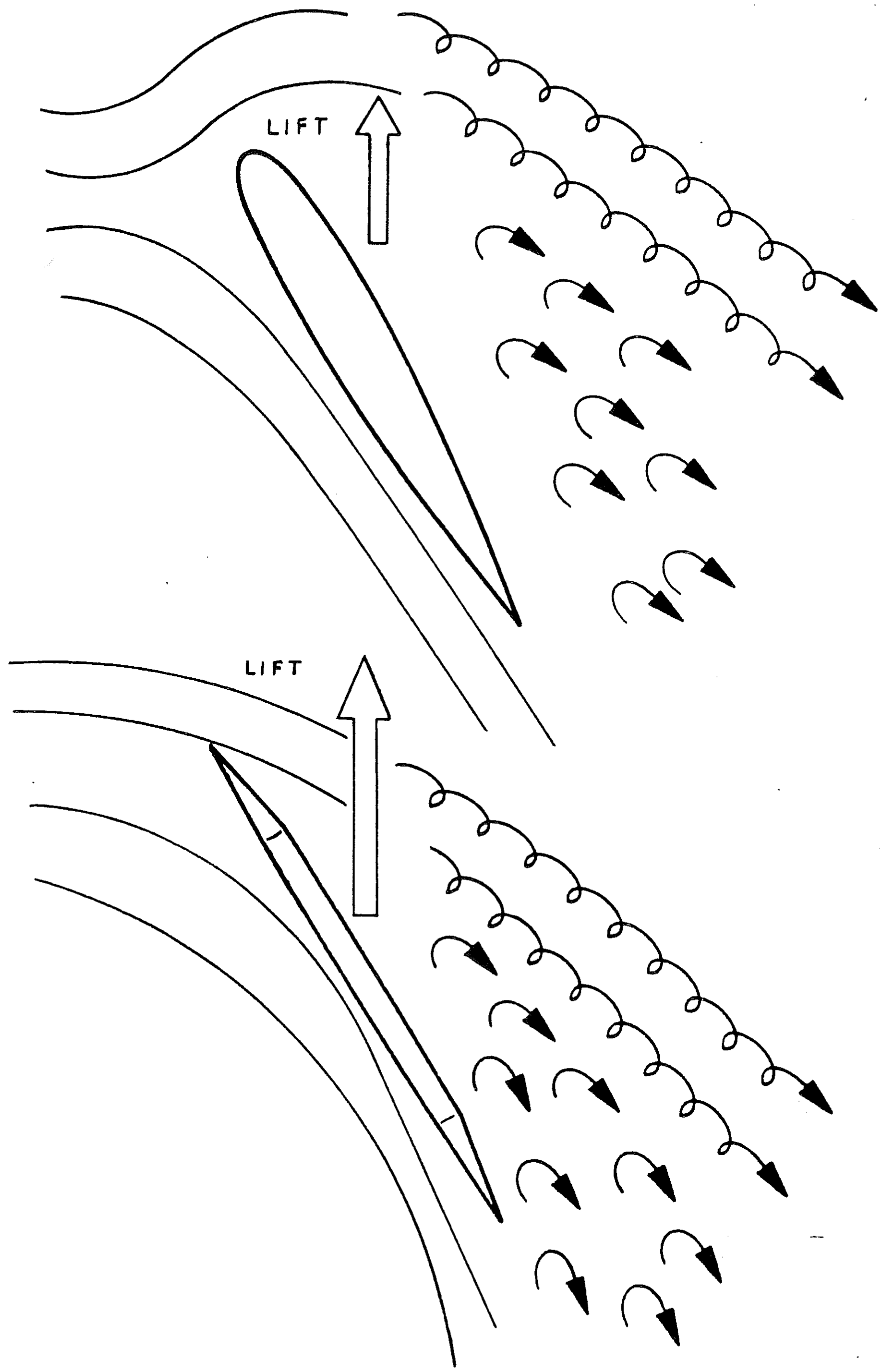
A fully developed pitch-up is best described as a non-repeatable stall maneuver that is inherent in aircraft with high tails. This definition is substantiated by analysis of the Lockheed flight test program which included 50 pitch-ups and 15 neutral stability penetration flights. It is also based on the oscillograph records and pilot's comments -- "No two stalls were exactly the same". Also, it is improbable that an accurate prediction of post pitch-up gyrations can be made. However, we can give you certain trends that develop in the different stall approaches. But to get a solid feel for why the F-104 pitches-up, I would like to explain the design features that give the aircraft this maneuver.

In order to give the F-104 maximum stability, superior control characteristics and minimum drag at subsonic, transonic, and supersonic speeds, many design innovations were adopted. Most important of these are the thin, straight, low aspect ratio wing, the high fineness ratio fuselage, and the large, one-piece horizontal stabilizer positioned high on the vertical fin.

Our wind tunnel evaluation of low aspect ratio wings, disclosed two significant differences between the flight characteristics of the truly supersonic wing and that of the subsonic wing. First, in steady flight, the subsonic wing develops a greater amount of lift than the supersonic wing for any given angle of attack. This sketch shows the comparison.



Second, the supersonic wing continues to provide increasing lift at angles of attack which would result in a stall for the subsonic wing. This sketch now shows the comparison.



Wind tunnel tests showed that this continuing wing lift enables the F-104 to fly at extremely high angles of attack without encountering a definite stall point. Consequently, the F-104 wing will continue to lift at angles of attack that would result in a fully developed stall for a conventional airfoil. Also total lift produced by the F-104 configuration does not decrease as the airplane assumes extremely high angles of attack. Instead, lift continues to increase even though major portions of the outboard wing panel become stalled. The lift forces then become concentrated over the fuselage and inboard wing sections, thereby increasing the downwash behind these areas. In addition, a large turbulent wake is created by airflow separation from the wing and areas of the fuselage. The airflow separation over various parts of the airplane creates instability about the pitch, roll and yaw axes. Depending upon the design of the airplane, one of these instabilities becomes predominant. With the F-104, the pitch instability becomes pronounced as the angle of attack increases. At high angles, the F-104 loses its natural nose down tendencies. This is because with the increased angle of attack, the horizontal stabilizer moves into the wake of turbulent airflow and strong downwash. This combination is responsible for loss of horizontal stabilizer effectiveness and reduced tail lift, thereby preventing longitudinal control of the aircraft. Combined with the nose-up tendency of the long forward fuselage at high angles of attack, this loss of stabilizer effectiveness and tail lift results in pitch-up. When we look at our performance envelope, there are the following types of stalls for us to consider:

1. Subsonic 1 "g" Stall; Approach to pitch-up in this case is characterized by heavy buffet, lateral instability and a dominant tendency for the aircraft to roll off to the right. Large aileron input is required to maintain level flight but sufficient aileron power is available to make the aircraft pitch straight ahead. At the peak angle of attack (70^{o} to 80^{o}), oscillations in roll and yaw are completely uncontrollable and there is no choice but to allow the aircraft to fall and attempt to get the nose down. As a general rule, two or three complete rolls are performed (not necessarily in the same direction) and sideslip oscillations may reach $\pm$ 60 degrees. It is quite unlikely that the vertical acceleration will go beyond the limits of +2 to -1 "g" and it will be oscillatory in nature, i. e., there will be no sustained negative acceleration to hamper engine operation or physically endanger the pilot. Approximately 10 seconds after initial divergence, the angle of attack falls, the airspeed begins to rise, the uncontrolled motions subside and the pilot is able to dive out to recovery. To avoid any possibility of encountering a second pitch-up, recovery should be made smoothly.

2. Subsonic accelerated stall; For the 1.6 to 2.0 "g" accelerated entry case, pitch-up is preceded by heavy buffet and lateral instability which builds up as angle of attack rises. After the pitch-up angle is reached, divergence becomes quite rapid. A critical point in an accelerated maneuver occurs during this initial divergence when angle of attack and "g" are changing rapidly and the airplane is becoming more unstable laterally. If at this time a disturbance is received which causes a sudden yaw, there is danger of overstressing the fuselage in side bending. This was the condition which led to the highest load experienced in the test program -- a peak value of 99% of limit fuselage side bending.

   A point to be remembered with these increasing nose-up maneuvers is the effect of precession due to the gyroscopic effect of the engine. This force is the dominant tendency for the aircraft to roll off to the right. So in this case of accelerated entry, the trend is a sudden high rate of pitch to approximately 70 degrees angle of attack with the aircraft diverging in right yaw and roll then a pitch-down occurs with the resultant large left yaw and roll. At this point, the aircraft either straightens out to recovery or may begin a rapid roll while going nearly broadside to the flight path.

   The longitudinal moments which reversed originally to cause pitch-up reverse a second time at high angle of attack to bring the aircraft nose down. This phenomenon is attributed to the fact that the wing no longer blankets the stabilizer which enables it to add a large nose down moment. The period of high negative pitch rate is also significant in that as the angle of attack returns to the unstalled region, airspeed is sufficiently high to maintain control power and the aircraft's inherent static stability. The important consideration is whether or not, upon returning to a flyable attitude, the aircraft or its control surfaces or both are oriented so as to cause divergence about other than the pitch axis.

3. Supersonic 1 "g" and accelerated stalls; To attain the low indicated airspeed necessary to stall at a Mach number greater than one, zooms to very high altitude must be made. Zoom angles must be as great as 45° to achieve these low required airspeeds. During the test program, full pitch-ups at supersonic speeds were not done due to the danger of encountering structural failure.

In lieu of supersonic pitch-up, accelerated stall approaches were conducted with the pilot pulling up to as near the stall angle of attack as he thought practical. Even at very high angles of attack, the pilot noted <u>no</u> stall warning but was able to detect a "digging in" of the pitch rate which caused him to terminate the maneuver. Actually, a small amount of stall warning in the form of lateral instability was detectable on the oscillograph but was not noticed by the pilot.

A perusal of the pilot's comments on pitch-up gives us the recommended recovery action. Here we find the following important points:

1. The random roll angle at which pitch-up occurs makes exact duplication of the pitch-up condition impossible.

2. One-half to three-quarters left aileron was necessary to keep the aircraft from rolling right before pitch-up occurred. This was true both with take-off flaps and clean configuration.

3. In the take-off flap configuration the aircraft wants to remain erect or upright after pitch-up, and recovery consists of allowing the nose to descend from the high attitude attained during pitch-up.

4. In the clean configuration, at pitch-up, the aircraft tends to roll right while in a lateral-directional oscillation and as the nose goes up to a high attitude. It then rolls at a very moderate rate from left to right and yaws through large angles as the nose falls. Control movement during recovery consists of moving the stabilizer gently to lower the nose attitude so that the aircraft may gain speed for recovery.

5. The aircraft gyrations occasionally exhibit the characteristics of a classical spin but there is no tendency for the aircraft to stabilize in a spin.

On these precepts, the following conclusions were established:

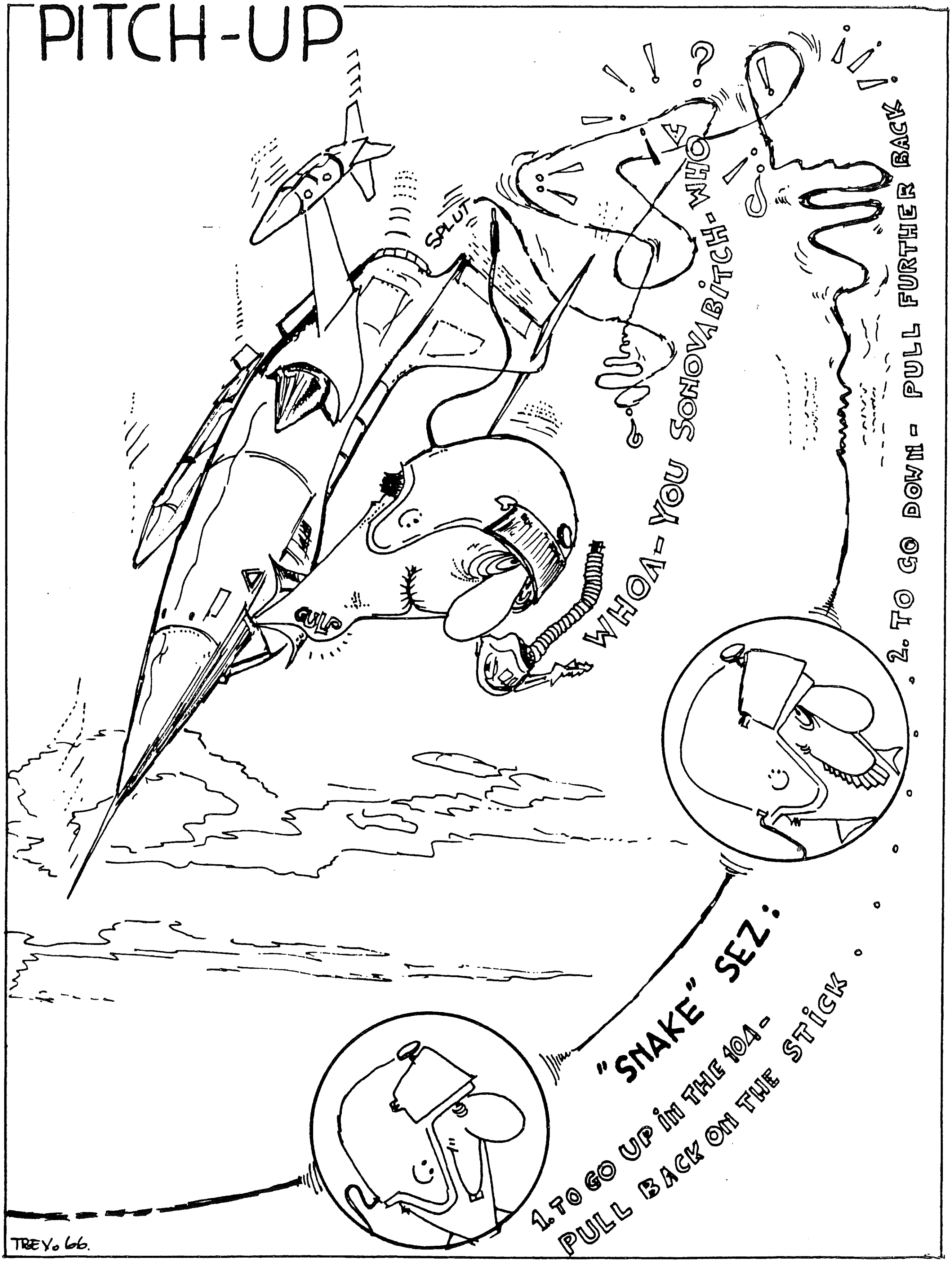
1. Stall warning in the form of airframe buffet and lateral instability is present at subsonic speeds.

2. Abnormally high angles of attack may be achieved at all speeds without pitch-up occurring provided low pitch rates are used.

3. Recovery from full 1 "g" pitch-up at subsonic speeds is best accomplished by neutralizing all controls until the nose falls through and then pull out as speed permits.

4. Accelerated pitch-ups at subsonic speeds are best recovered from by applying neutral controls as soon as the stalled condition is recognized.

5. At supersonic speeds, there is <u>no</u> aerodynamic stall warning to the pilot and he must fly by artificial warning parameters.


PITCH-UP
SPLUT
GULP
WHOA-YOU SONOVABITCH-WHO
"SNAKE" SEZ:
1. TO GO UP IN THE 104-
PULL BACK ON THE STICK
2. TO GO DOWN - PULL FURTHER BACK
TREY. 66.

NORMAL SPIN MODE

After the pitch-up investigation, it was necessary to thoroughly research the spin modes of the F-104. Accordingly, there were 25 fully developed spins flown and data was gathered to make an analysis of the normal spin mode. Since all of the spin entries were from a pitch-up, it was again difficult to predict the exact entry conditions. Therefore, when the first spin was accomplished, these control positions were utilized thereafter and known as pro-spin controls. The anticipated anti-spin controls were adequate in all recoveries without the use of the spin-recovery chute.

Rather than investigate all 25 spin records, I shall describe for you what the typical normal spin consists of and the recommended recovery procedure. This description will be for the single-place F-104, and then I will note the difference with the two-place model.

1. Single-place F-104 spins: The F-104 has a moment of inertia in pitch (Iy) about 17 times its moment of inertia in roll (Ix). No great change in this inertia ratio was made during the spin tests. Analysis of the spin parameters shows that pitch-up precedes the spin entry in each case. This creates a yawing motion to the right, or precession, produced by the gyroscopic inertia moment of the engine's rotating mass. The magnitude of this yawing moment (M) is approximately 9,432 ft.-lbs. at 95% RPM engine speed. As the airplane stall becomes fully matured, the aerodynamic pitching moment becomes positive (or nose up). Thus, the aerodynamic pitching moment and the gyroscopic inertia moment becomes additive and the summation of these forces results in a substantial build up of yaw rate to the right. To further supplement this moment, full right rudder and full left aileron must be applied, as pro-spin controls, from a 1 "g" stall to achieve autorotation to the right.

   The spin motion is characterized by one complete oscillation in pitch and two oscillations in roll per turn coincident with an amplitude of oscillation in side-slip that is more sizeable to the right throughout the spin proper. The peak pitch angle, however, recedes in each turn steadily producing more amplitude in the nose down than in the nose up direction. As a result, the right yaw rate diminishes. This is effected as the engine gyroscopic inertia moment declines from a pro-spin driving force to an opposing force due to the predominate nose down pitch oscillation.

The high angle of attack breaks at this time, the autorotation reduces to roll, and recovery occurs as the stabilizer becomes fully effective.

For a better grasp of the spin motion, let's stop the action at key points and isolate the forces so we can see how each contributes to the spin.

Going back to the entry as we are approaching a high angle of attack, lateral instability is encountered and left aileron is increased to hold the wings level as the gyroscopic effect induces right yaw. At the moment that the aerodynamic nose-up pitch rate "roots-in", full right rudder is now added to the gyroscopic inertia moment and the aircraft yaws off to the right in the spin. A check of our control positions at this time is full aft stick, full left aileron and full right rudder. Following the motion of the pitch attitude, we see that the nose progresses to a low point around the 180° turn and rises again to an apex that is not as high as the original attitude. In succeeding turns then, the nose attitude becomes progressively nose down throughout the turn.

Again, let's go back to the entry of the spin and examine the aerodynamic yaw force effects. As the aircraft breaks to the right, the yaw angle builds to a point where the yaw force overcomes the gyroscopic inertia moment and yaws the aircraft back to the left to a point where again the gyroscopic inertia force breaks the aircraft back to the right. However, since the pitch attitude becomes progressively nose down, the gyroscopic inertia moment is diminishing and the aerodynamic yaw stability force becomes predominate, until the rotation stops and the angle of attack breaks. By now introducing the anti-spin controls of full rudder <u>against</u> and full nose <u>down</u>, we straighten out the flight path and dive into a recovery pull-out.

Our final spin motion to consider -- that of the roll oscillations -- is readily explained as being a result of the dihedral effect during yaw which induces the rolling oscillation during the excursions in yaw.

This completes our analysis of the spin motion for the single-place F-104.

2. Two-place F-104 spins: During the spin program with the F-104B, it was discovered that the aircraft would spin either left or right depending on the control inputs and the lateral-directional oscillations at pitch-up. This was different from the single-place aircraft which yielded only right spins. The spinning motion and control positions, though, were the same.

There were many factors that were the same for both aircraft and they are:

1. The aircraft does not display an inherent tendency to spin out of 1 "g" stalls except for aft c.g. locations.

2. Spin recovery was possible using aircraft controls only.

3. No spins were obtained from accelerated stalls, vertical attitude stalls, or stalls from constant climb attitudes greater than 30 degrees during the program.

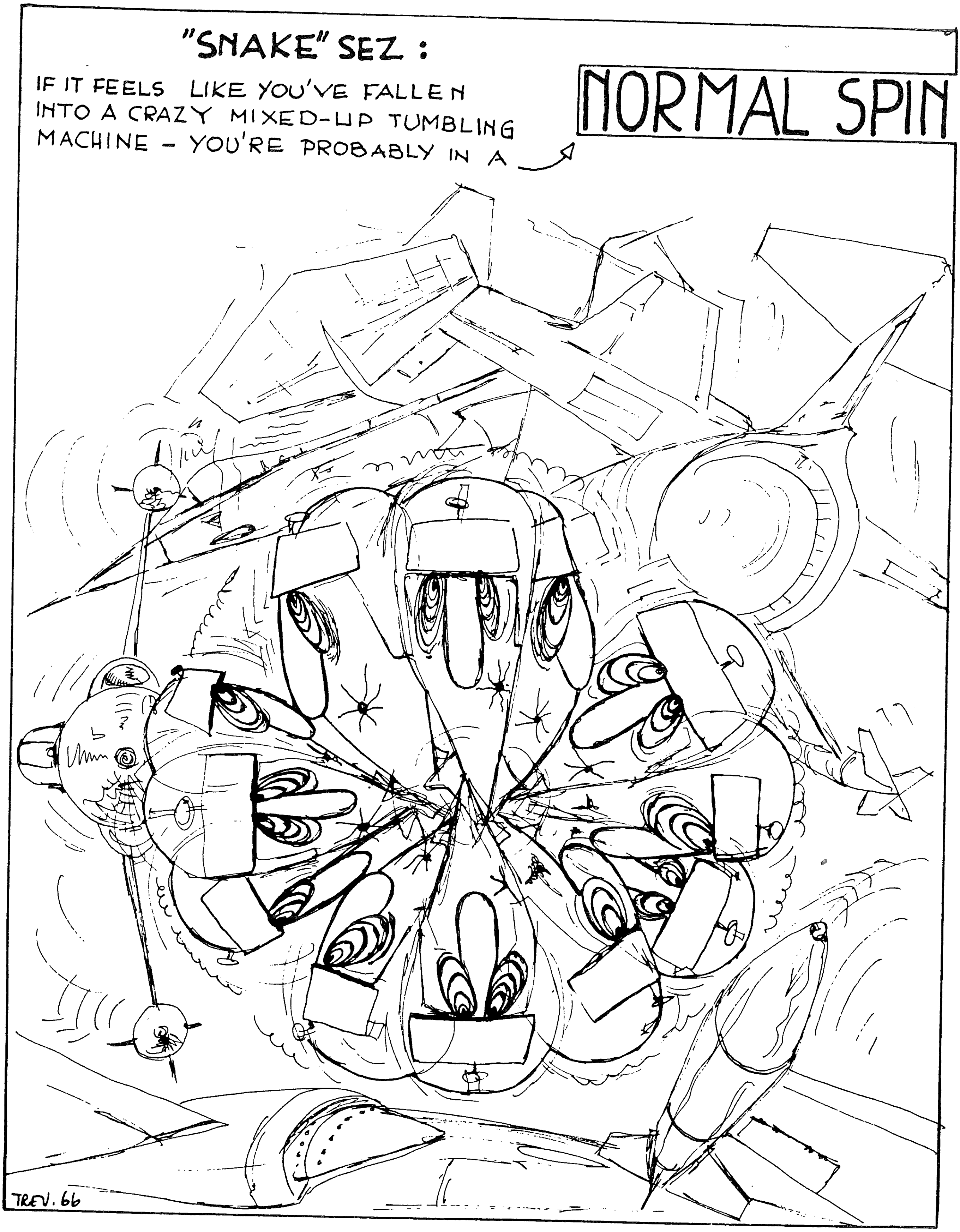
4. Pro-spin controls were: full rudder with rotation, aileron against rotation and full aft stick.

5. Recovery controls were: full rudder against rotation, aileron with rotation and full forward stick.

6. Altitude loss was approximately 1800 feet per turn with a turn period of 6 seconds per turn.

7. All spins were conducted with the engine operating between 93 to 98% RPM, except for one spin made at a flight idle RPM of 77%.

From the operational history of the F-104 up to late 1961, it appeared that our test programs on pitch-ups and spins were complete and adequate. Until 1962, not one aircraft was lost due to pitch-up, and until late 1961, not one aircraft had been lost due to non-recovery from a spin. However, since late 1961, there has been a CF-104, an NF-104 and F-104A -- all lost due to non-recovery from spins. The explanation of these losses comes from the discovery of a unique mode of spin -- the power-off, flat-spin.


"SNAKE" SEZ :
IF IT FEELS LIKE YOU'VE FALLEN INTO A CRAZY MIXED-UP TUMBLING MACHINE - YOU'RE PROBABLY IN A
NORMAL SPIN
TREV. 66

Flat-Spin Mode

The first reported flat-spin was the loss of a CF-104 on a test flight from the factory of Canadair, Ltd. The test pilot reported that on a 1 "g" stall approach, the aircraft pitched-up violently, flamed-out and digressed into a flat-spin to the left from which the pilot was unable to recover. The next reported (and filmed) flat-spin was the loss of an NF-104A on a zoom flight to maximum altitude. The pilot reported the aircraft pitched-up above 100,000 feet and digressed into a flat-spin (both left and right) from which the pilot was unable to recover. And then a pilot in an F-104A reported that on a zoom above 80,000 feet, the aircraft yawed violently at the apex of the zoom, and then digressed into a flat-spin to the right from which the pilot was unable to recover.

In all three of these losses are the nauseating words "from which the pilot was unable to recover". In all three cases, the pilot ejected safely. In order to prevent any more losses, this part of my lecture is to fully brief you on the following:

- How to prevent flat-spins.
- How to recognize a flat-spin.
- How to affect a possible recovery.

At the time of the loss of the CF-104, Lockheed sent Mr. John Margwarth, Flight Safety Engineer, and myself to Canadair to assist the RCAF in their accident investigation. In assembling the details, there were some very interesting contributing facts:

1. The C. G. of the aircraft at pitch-up (calculated 16.0%) was farther aft than any condition during our test program.

2. During the spin, the flamed-out engine rotation decayed to a very low value -- below 10%.

3. Control inputs by the pilot were reported as completely in-effectual.

4. The spin was reported to be definitely to the left <u>without</u> the associated oscillations about the axes of the aircraft.

5. The indicated airspeed varied from 60 KTS to 140 KTS.

The investigation ended on an incomplete answer as to why the pilot was unable to recover.

Almost two years later, in the NF-104A program, two spins from altitude ocurred but both resulted in recovery. One was with a USAF test pilot and one with a Lockheed test pilot. At the time, both spins appeared to have extenuating circumstances, i.e. the Lockheed pilot did not have full fuel in his tanks for the vernier controls and therefore, this was attributed as the cause for the spin. Unsuspectingly, the program for maximum altitude continued. In an attempt to reach 118,000 feet, the NF-104A pilot rotated to an extreme angle for climb and zoomed. As recorded on film, the aircraft mushed at its peak altitude of 102,000 feet and gyrated through maneuvers until it digressed into a flat spin, to the left. After trying normal spin recovery procedures, the pilot deployed the drag chute which stopped the flat spin and stabilized the aircraft in a vertical nose down attitude. Unfortunately, upon jettisoning the chute, the aircraft immediately pitched-up again into a flat spin to the right. The pilot smartly ejected and the aircraft continued flat-spinning to impact. Again, in assembling the details, there were some very interesting contributing facts:

1. The C. G. of the aircraft at 20.3% MAC at pitch-up was much farther aft than any recorded during the test program.

2. During the spin, the flamed-out engine rotation decayed to a very low value and was 6% by 18,000 feet.

3. Control inputs by the pilot in any direction and in any manner were completely ineffectual.

4. The spin was reported (and filmed) as to the left <u>and</u> right, without the associated oscillations around the aircraft axes.

5. The airspeed did not even register during the spin, but on the instrumented boom, the pitch vanes were practically vertical.

The accident investigation ended with the cause listed as flight into an extremely hazardous regime in which the aircraft entered the spin and from that point on was not recoverable.

Due to the peculiar configuration and special mission of the NF-104A, not much concern was given to the daily zoom flights of the F-104A's in the Aerospace Research Pilot School. After all, over 325 high altitude zooms had been flown by the ARPS students and they were only going to 85 - 90,000 feet.

At this point in time, the accident occurred that instigated the study that put all the pieces of the puzzle on the table. This was the loss of F-104A #56-0764. Since this accident happened on a zoom profile that any standard F-104 can undertake, I want to go into more detail on the facts. First, the pilot's statement:

The flight was a standard high altitude zoom profile with an initial pitch angle of 45° to be attained, since on previous flights, angles of 25°, 30° and 40° had been achieved.

Accordingly, the pilot made the required checks for proper pressure suit operation and began accelerating for the zoom. At 1.9 Mach No. and 37,000 feet, the aircraft was rotated to 45° pitch angle and the zoom was started. At 62,000 feet the afterburner blew-out and at 75,000 feet the engine was shut down to prevent overtemperature. At the peak altitude of 83,000 feet, the pilot felt a stick kick that approximated the APC kicker so he pushed in full forward stick. The nose started down normally but as it went through the horizon, the aircraft started a left yaw so that by the time the nose was fully below the horizon, the aircraft had yawed 135° to the left of the flight path. The aircraft nose then started rising again but was yawing right as it rose to the horizon and it continued to the right in a flat spin. Even though the pilot noted the unusual gyrations of the aircraft, he maintained rudder and ailerons neutral with stick full forward, expecting the nose to drop and the airspeed to increase as in previous zooms. After approximately one turn to the right, the pilot realized he was in a spin and applied proper recovery controls: rudder against, ailerons with the spin, stick forward and trim nose down. The actuation of recovery controls had no apparent effect on spin rate or pitch attitude. The spin characteristics were a rotation rate of approximately one revolution every six seconds, nose approximately 10 degrees below the horizon, wings level or slightly right wing down, and no oscillations about any axis. The recovery controls were held without change until the pilot ejected except for a momentary neutralization and reapplication of full left rudder. At 65,000 feet, the pilot tried the first of several airstarts, all of which were unsuccessful. At 35,000 feet, take-off flaps were selected, but after noting no effect the flap handle was moved back to the up position. At approximately 25,000 feet, the pilot deployed the drag chute with no apparent effect on the spin except that a light momentary deceleration along the longitudinal axis was felt and a slight reduction in yaw rate was noticed.

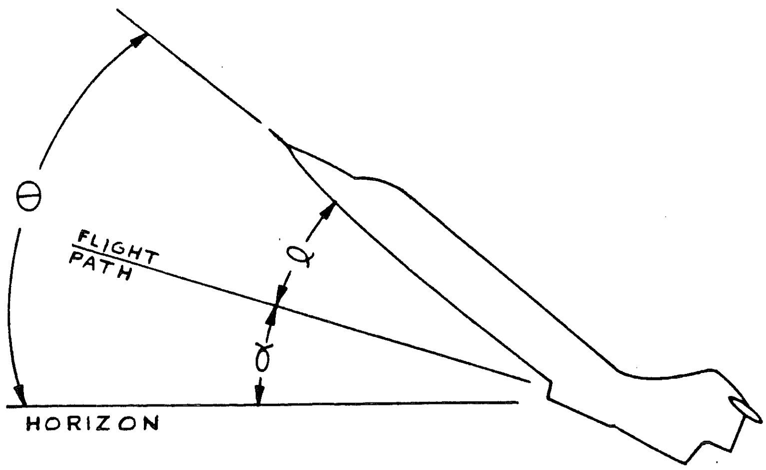
At 4,000 feet, the pilot ejected and the aircraft continued to spin to impact.

The striking coincidence of the two losses now galvanized into action a thorough engineering evaluation of the accidents. In the flight research division at Edwards AFB, there were two problems they were faced with: First, to solve the question of what causes the F-104 to flat spin and second, How to fly maximum altitude profiles without entering flat spins.

To solve the first problem, the use of the analog simulator was utilized to investigate the lateral - directional handling qualities at low dynamic pressure. A check of the performance parameters in the analog simulator perfectly duplicated the radar plot of the profile, so the accuracy was deemed adequate. At the peak altitude, which was the spin entry condition, Mach number, dynamic pressure (q) and altitude were then duplicated so that the handling qualities could be examined. Two significant results were found. First, that the damping became negative as q became very low. This revealed a dynamic lateral-directional instability at low q. Secondly, and more important, it was found that the engine gyroscopic effects which couple pitch rate into yawing moment and yaw rate into pitching moment became significant at low dynamic pressure where aerodynamic restoring forces become low. This explained why the nose down pitch rate produced the left yawing moment. Since q was low, the aerodynamic restoring moment in yaw was not great enough to overcome the gyroscopic yawing moment, and a left yaw rate developed. The development of a large sideslip angle caused an aerodynamic rolling moment, and the aircraft soon became uncontrollable. Both gyroscopic effects and aerodynamic effects were equally significant at the low q encountered, and the aircraft controls were not effective enough to handle both moments.

Duplicating on the simulator the F-104A pilot inputs which occurred prior to the spin entry, resulted in the same uncontrollable maneuvers described by the pilot.

Analysis shows then that the key parameter for the pilot to avoid is an angle of attack greater than the critical angle of attack. The critical angle of attack, of course, being the angle where the aircraft has such low q that the aerodynamic controls become ineffective. Let's define the three important angles and their relationship in a high altitude zoom.



θ (PITCH ANGLE) = γ (FLIGHT PATH ANGLE) + α (ANGLE OF ATTACK)

This apparently simple relationship is all-important in the planning of zoom flights to maximum altitude.

Surprisingly enough, the two losses (NF-104A and F-104A) revealed the two different ways in which the aircraft can encounter an angle of attack greater than the critical angle of attack and then digress into a flat spin. They are:

1. If the pilot holds back stick in an attempt to hold the pitch angle constant, then at the top of the zoom, the flight path angle will decrease and the angle of attack will increase beyond the critical angle of attack.

2. If the pitch angle is varied at a rapid rate at the top of the zoom where the dynamic pressure is low, the engine gyroscopic effects create a yaw-roll motion which gives an angle of attack greater than the critical angle of attack.

Utilizing the radar plot for guidelines as to the parameters approaching the apogee of the zoom, the five-degree of freedom simulator duplicated the aircraft motion completely. The parameter values were:

1. Altitude - 83,000 Ft.

2. True Airspeed - 270 Kts.

3. Dynamic pressure - 8 Lb./Sq. Ft.

4. Angle of Attack - 15° at 82,000 Ft.

Investigation then showed that even for an unwinding engine RPM of 50-60%, a negative pitch rate, caused by a rapid push-over or forward stick action, definitely causes the aircraft to yaw left. This disturbance triggers the inherently unstable mode that results in the flat spin.

Now that the reasons were known as to what causes the F-104 to flat-spin, it was then decided to use the simulator to help define a minimum dynamic pressure to which the F-104 should be zoomed. By investigating the minimum q that the NF-104A should be flown without using the reaction control system (RCS), this would yield a criteria for other F-104 zoom altitudes. Naturally, on the simulator, the criteria established was that the pilot should be capable of recovering from the coupled maneuver, which results when the stick kicker is actuated, by using only aerodynamic controls and no rudder. The simulator showed that the trend toward dynamic instability became noticeable about where q = 15 psf. Flight test verification of this minimum q was made by an incremental approach starting at about 40 psf.

Flight tests verified that the minimum q for satisfactory handling qualities was about 20 psf. It should be pointed out that many flights were safely accomplished at q's around 10 psf because of the smooth technique of the pilot in keeping the body rates very low.

The accident investigation had now solved the two questions of what caused flat spins and how to achieve maximum altitude without getting into flat spins. Also, this should make clear to you how to recognize a flat spin. The steps for you to take to prevent a flat spin involve precise planning <u>before</u> you pull the nose up to a steep angle and bid the cruel world goodbye! The steps we recommend you take are these:

1. Careful calculation of the flight path angle - 45 degrees desired, no more than 50 degrees.

2. Preplan the energy management maneuver to avoid an aft C. G. that contributes to the possibility of a spin.

3. Pullup 2 - 2 1/2 "g"; maximum of 3 "g".

4. Do <u>not</u> trim nose up in pullup or climb. Leave trimmed condition at maximum Mach number and level flight.

5. Rudder limit control circuit breaker - pull.

6. Calculate an airspeed at the apogee of 450-475 knots ground speed. This will guarantee a q of 20 psf or greater.

7. Do not exceed shaker or kicker boundary.

8. For zooms above 80,000 feet, maintain supersonic flight over the top of the zoom. This also assures adequate dynamic pressure.

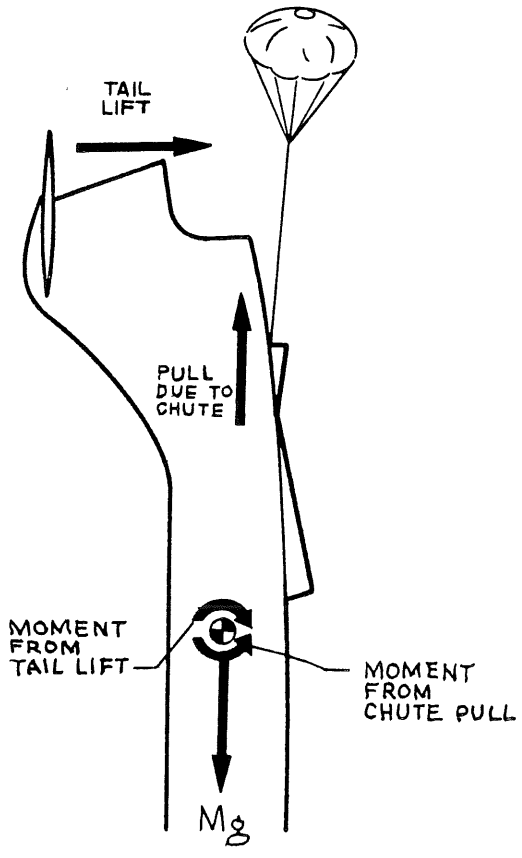
9. Be prepared for loss of complete electrical power, except the battery bus, and the associated control inputs as the dampers become inoperative.

10. Avoid any rapid pitch rate, either nose up or nose down, approaching the apogee.

Obviously some of these steps are to assist you in case you do wind up in a flat spin. And if this does occur, the following is our best advice as to affecting a possible recovery.

1. Apply spin recovery controls: observe characteristics of spin to determine if it is normal or flat. If the spin is flat, aerodynamic controls will be ineffective, therefore -

2. Deploy Drag Chute: If chute deployment is successful, allow the aircraft to stabilize in a vertical nose down attitude. Before you release the chute, though, be fully prepared for an abrupt nose up. This is due to the forces acting on the aircraft and can be shown thusly -



2. From our sketch, it is obvious that when the force of the chute is released, the moment caused by the lift on the tail becomes predominate and induces a nose up attitude. The procedure recommended by simulator tests was to set in full forward trim while the chute was deployed and use stick force to fly straight down while accelerating to flying speed. Just prior to chute release, the stick was neutralized. This procedure counteracted the trim change due to drag chute jettison, and the aircraft could be recovered by a normal pullout. Of course, trim will not be available with a flamed-out engine but the recommended procedure of not trimming during the zoom will insure that you do not have a nose-up trimmed condition.

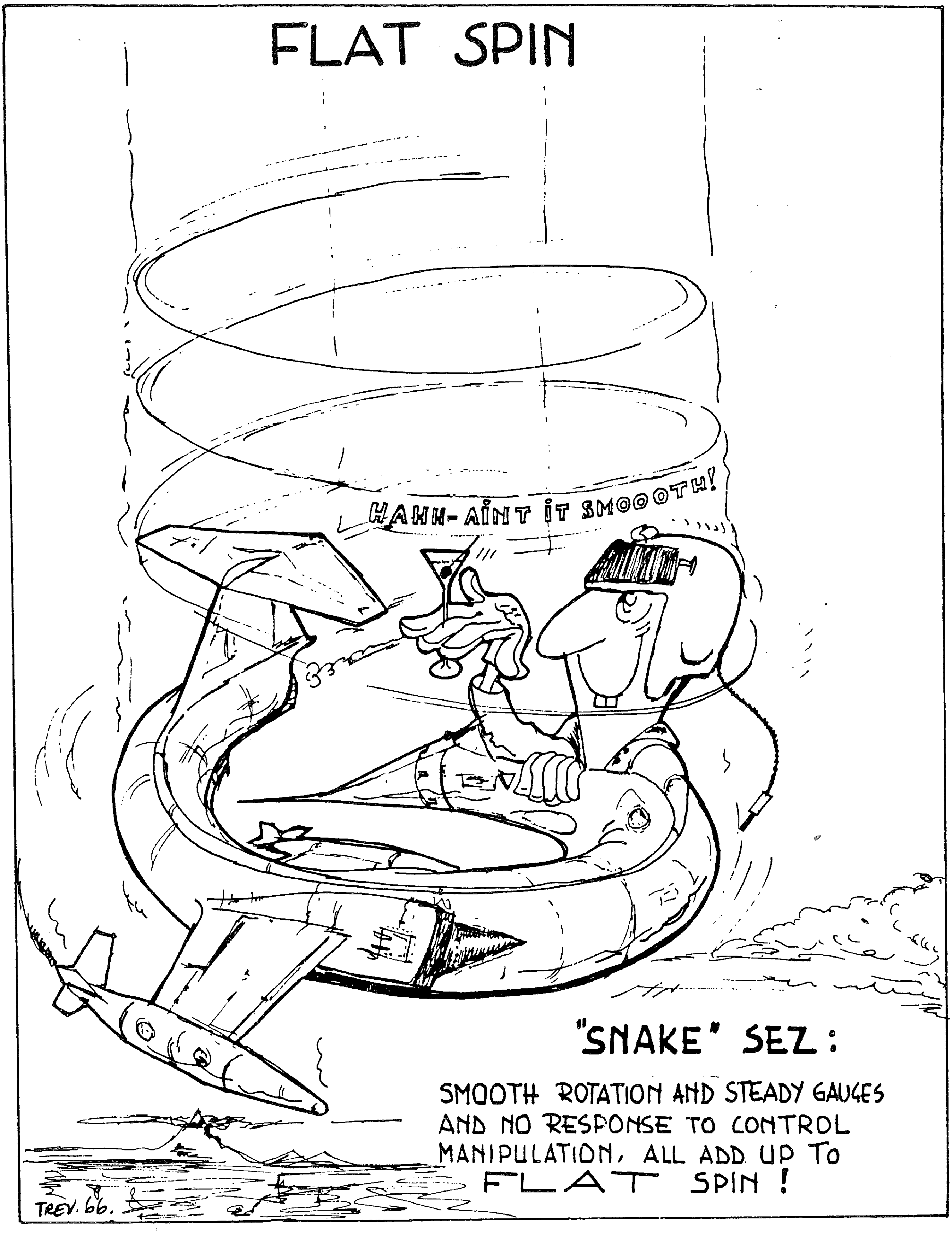
3. Attempt Air Start: Based on calculations by General Electric, an airstart during the flat spin is highly improbable. Assuming zero ram conditions during the spin, these are the fuel/air ratios.

Alt.	RPM	Pamb.	CDP	Fuel Flow	Fuel-Air
65000	40	1.66 in. Hg.	1.1psia	500 Lb/Hr.	.078
50000	30	3.42	2.0	500	.053
40000	20	5.24	3.0	500	.052
30000	10	8.88	4.5	500	.053

This chart shows that you have three to four times the fuel-air ratio above the optimum of .015 to .020.

If you want to attempt an air start while the drag chute is stabilizing the aircraft vertically, our tests have shown that the panels will burn out at RPM's above 90%. Also, the shear link should fail above 225 knots.

4. Make gradual pullout: In the simulator studies, the minimum altitude for normal recovery, starting with drag chute deployment, was 25,000 feet. For minimum altitude loss during the pullout, take-off flaps should be used.


FLAT SPIN
HAHH- AINT IT SMOOOTH!
"SNAKE" SEZ:
SMOOTH ROTATION AND STEADY GAUGES AND NO RESPONSE TO CONTROL MANIPULATION, ALL ADD UP TO
FLAT SPIN!
TREV. 66.